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nhc
northwest hydraulic consultants ltd

NHC Ref. No. 3004524

22 March, 2019

[redacted]

Attention: [redacted]
Via email:

Re: **Flood Hazard Assessment – Final Report**
4358 Ross Crescent, West Vancouver, BC

Dea[redacted]

This letter report summarizes the flood hazard assessment (FHA) study conducted by Northwest Hydraulic Consultants Ltd. (NHC) in support of future building permit for the proposed 4358 Ross Crescent development located within the District of West Vancouver (DWV).

1 INTRODUCTION

A single-family home is being proposed for 4358 Ross Crescent (Lot 7, Block 2, District Lot 582, Group 1, New Westminster District, Plan 4725). The property is located on the north shore of Burrard Inlet within the DWV (**Figure 1**). A number of creeks drain the steep slopes of the coastal North Shore mountains to outlet to Burrard Inlet near the project site; specifically, Claymore Creek, Willow Creek, and Cypress Creeks. The property is potentially at risk to coastal flood hazards from Burrard Inlet as well as riverine flood hazards from the adjacent creeks. NHC has conducted a flood hazard assessment to identify and assess these hazards. This report presents this assessment, the findings, and recommended measures to mitigate the hazard.

The objective of this assessment is to identify and evaluate the flood hazards that may affect the safe development and use of the property with respect to the proposed development and decide if development is possible to an acceptable safety threshold, either without or with mitigation. The currently accepted safety threshold in British Columbia is 0.5% annual exceedance probability (AEP) up to the year 2100. The 0.5% AEP event is often referred to as the 200-year event as such an event is expected, on average, to occur or be exceeded, once every 200 years.

The report has been structured by presenting referenced guidelines, site observations, coastal assessment, riverine assessment, and concluding with findings and recommendations.

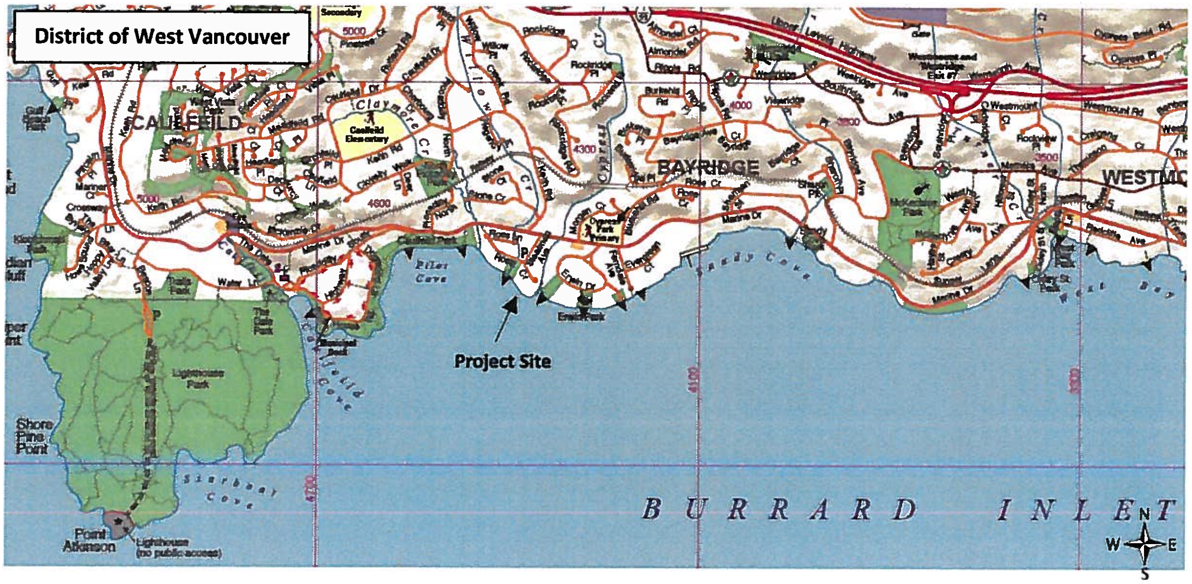

Figure 1. Location map of study site.

1.1 Existing FHA Covenants

DWV requires all applicants applying for a building permit to construct buildings in coastal areas to provide a site specific FHA report, prepared by a qualified professional, that confirms the land may be used safely for the use intended.

The report prepared by a qualified engineer must:

- Be prepared in accordance with the most recent edition of the Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC published by Engineers and Geoscientists of BC (EGBC, 2018);
- Be prepared by a qualified registered engineer;
- Be accompanied by the Flood Hazard and Risk Assurance Statement (Appendix A); and
- Identify all floor areas proposed to be constructed below the 4.5 m GSC (Geodetic Survey of Canada) datum and specify use of these areas.

2 REFERENCED GUIDELINES

The following guidelines and regulations were reviewed as part of our investigation of the possible hydrotechnical hazards that could threaten the study property.

- Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC (EGBC, 2018)
- Flood Hazard Area Land Use Management Guidelines (BCMFLNRD, 2018)

- Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use – Draft Policy Discussion Paper (BC Ministry of Environment, 2011a)
- Coastal Floodplain Mapping – Guidelines and Specifications (BC Ministry of Environment, 2011b)
- Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use – Guidelines for Management of Coastal Flood Hazard Land Use (BC Ministry of Environment, 2011c)

3 SITE DESCRIPTION

A site investigation was conducted on January 25th, 2019, by a geomorphologist and coastal engineers from NHC to examine the foreshore morphology as well as to identify the condition of existing foreshore structures, and surrounding beach materials. The weather throughout the site inspection was mostly sunny and relatively calm. The tide level at Point Atkinson was about -0.9 m Geodetic Datum (GD) during the site inspection, which permitted a reasonable extent of the inter-tidal foreshore to be visually inspected. An additional site investigation was conducted on February 26th, 2019 to examine portions of Cypress Creek, which is located 30 m east of the subject property.

The existing foreshore (**Photo 1**) consists of gravel and cobble beach sloping at a roughly 6.6% slope (15H:1V) followed by a 15 m long flat section. In front of the property, the foreshore transitions to a roughly 5% slope (20H:1V) where large woody debris accumulation **(Photo 2)** was observed on top of boulders placed along the width of the property. A vertical concrete wall with crest elevation at El. 3.17 m GD is located between the dwelling and the foreshore (**Photo 3**). The beach faces towards the south-west but is exposed to waves from the west, south, and east.

The existing foreshore protection areas consist of poorly interlocked rock embedded roughly one-third into the sand beds and no toe structure [redacted] Out of scope - not subject property

From east to west Cypress Creek, Willow Creek, and Claymore Creek flow north to south entering Burrard Inlet east (Cypress) and west (Willow Creek and Claymore Creek) of the property. The Cypress Creek channel draining to Burrard Inlet is located about 30 m east of the property. The channel transitions from roughly 15% grade upstream of the railway crossing (480 m upstream) to 5% at the Marine Drive crossing (200 m upstream), and roughly 2% as it approaches Burrard Inlet. The closest crossing, Marine Drive, is provided by a clear span bridge. A 0.5 m deep and 1 m wide ditch running along the creek was observed between top of the bank and Ross Crescent (El. 3.5 m GD) (**Photo 6**). The channel width of the Cypress Creek between the project site and the Marine Drive crossing is relatively consistent, with the width of 10 m. The channel width gradually widens to about 30 m at its mouth (where the creek meets the ocean) and widens (**Photo 7**). Both channel banks are steep, with an elevation of about 4.4 m GD or 2.1 m above the channel bed (**Photo 8**).

Willow Creek, an order of magnitude smaller than Cypress Creek, is located 90 m west of the subject property. Willow Creek flow is conveyed from upstream of Marine Drive through to Ross Crescent within a 1.2 m diameter concrete culvert; approximately 270 m long. A debris trash rack structure was recently installed at the upstream end of the culvert, replacing the previous structure that performed poorly during recent flooding in June, 2016 when flood flows were diverted down the road system, affecting many homes in the area.

Claymore Creek, the smallest of the three creeks has a relatively small watershed and equally small constructed channel with limited flow capacity. Low lying banks appear easily overtopped. The slope of this creek is more than 5% upstream of Marine Drive and flattens to 3 to 5% just upstream of Ross Crescent, and to about 1% near its outlet at Burrard Inlet.

Photo 1. View towards site from south.

Photo 2. Large woody debris accumulation.

Photo 3. Existing vertical concrete wall.

Out of scope - not subject property

[redacted]

Out of scope - not subject property

[redacted]

Photo 6. Ditch between Cypress Creek and road (looking south).

Photo 7. Cypress Creek channel geometry – looking south.

Photo 8. Cypress Creek right bank.

4 COASTAL FLOOD HAZARD ANALYSIS

Coastal flood hazards are primarily dictated by flood inundation, but can include overflow and spray, shoreline erosion and scour, beach degradation and aggradation, or physical loading from hydraulic forces or wood debris. Flood inundation is the focus of this coastal assessment. Other coastal hazards are of less concern for this assessment based on initial review; that is:

- Overflow and spray can be assessed and addressed through site drainage design follow site design.
- Evidence of shoreline aggradation was identified during the site inspection as a result of woody debris accumulation. No scour was identified along the walls protecting the neighbouring properties.

Canadian Hydrographic Service Chart 3495 (**Table 1**) presents the local tides at Point Atkinson, which is 1.8 km west of the study site. The existing top of wall at the study site is at 3.17 m GD. Coastal flood levels due to tide, storm surge, wave effects and long-term changes in global and local sea level are expected to be higher than this elevation which could lead to flood inundation.

Table 1. Tidal heights, extremes, and mean water level at Point Atkinson.

Sea State	Tide Elevation (m Geodetic Datum)
Higher High Water, Large Tide (HHWLT)	2.0
Higher High Water, Mean Tide (HHWMT)	1.3
Mean Water Level (MWL)	0.0
Lower Low Water, Mean Tide (LLWMT)	-2.0
Lower Low Water, Large Tide (LLWLT)	-3.1

4.1 Coastal Flood Level

To reduce the likelihood of damage from coastal flood inundation, the coastal flood level was assessed and used to derive a minimum construction level – the flood construction level (FCL). The FCL provides a level of mitigation to limit the likelihood of flooding for homes located along the coast or rivers and creeks. The FCL is generally based on an event with an AEP of 0.5%, often referred to as the 200-year event; since on average it would be expected to occur or be exceeded once every 200-years. In addition, due to changing conditions (primarily human induced global climate change) future conditions are considered up to the expected life of the project; often considered as the year-2100 (roughly 80 years from present).

The BC Ministry of Environment's published Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use (BC Ministry of Environment, 2011b) and the BC Ministry of Forests, Natural Resource Operations and Rural Development's amendment (BCMFLNRD, 2018) present two approaches for determining the 200-year FCL: 1) combined method and 2) probabilistic method. Parameters that sum up FCL for each method are illustrated in **Figure 2** and **Figure 3**.

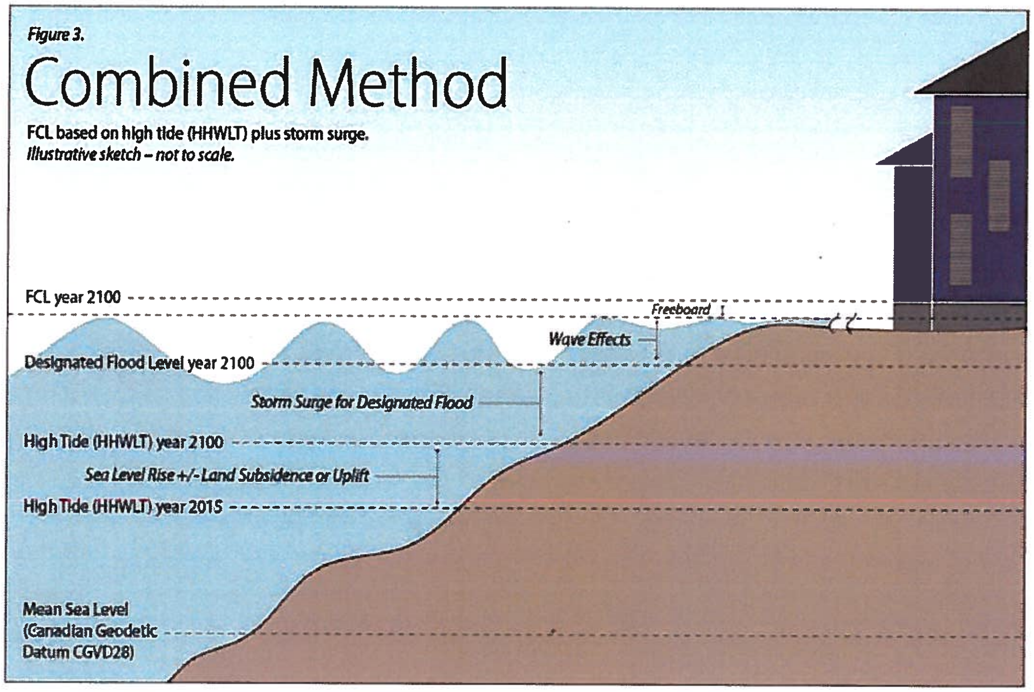

Figure 2. FCL based on combined method (BCMFLNRD, 2018).

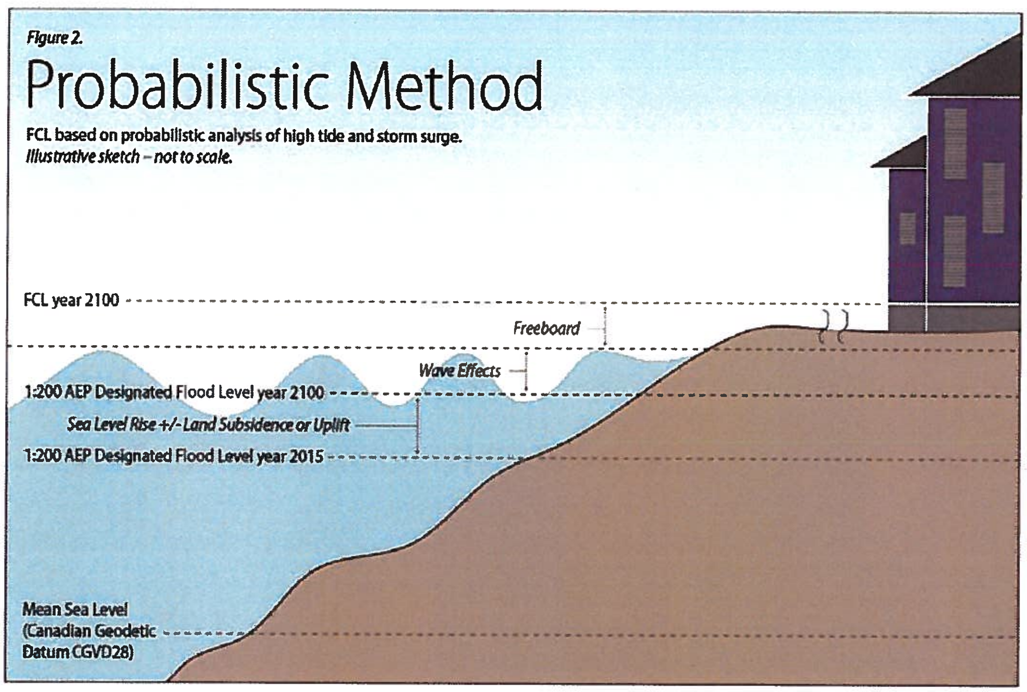

Figure 3. FCL based on probabilistic analysis (BCMFLNRD, 2018).

The combined method is based on the combined effects of HHWLT tide, storm surge, wave run-up, and sea level rise (SLR). This approach generally results in conservative calculation of a design flood level, as it is often applied ignoring the probability of the various design events cooccurring (the probability that a 200-year storm surge co-occurs during HHWLT and 200-year wave event is closer to a 4,000-year event, AEP of 0.025%, instead of 200-year event, AEP of 0.5%). For this assessment the joint probability approach has been applied.

4.2 Coastal Flood Construction Level Assessment

The coastal flood construction level using the probabilistic approach is the sum of:

- 1-in-200 AEP total water level as determined by probabilistic analyses of tides and storm surge;
- Allowances for future SLR to the year 2100;
- Allowance for regional uplift or subsidence to the year 2100;
- Estimated wave effects associated with the designated storm with an 1-in-200 AEP; and
- Freeboard.

Each of these components are described in the following sections.

Predicted changes in storm intensity and frequency over the next 81 years, which could influence storm surge and wave effects, are highly variable and inconclusive. Such influence has not been incorporated in this analysis.

4.2.1 Joint Occurrence of Storm Surge and Tides

Coastal flood levels for the 1-in-200 AEP was developed by applying the Empirical Simulation Technique (EST) on the long term observed data (66 years) at Point Atkinson (NHC, 2008). The EST method is recommended by the Coastal Hydraulics Laboratory (of the US Army Corps of Engineers) and FEMA for frequency related studies. The analysis determined that the 1-in-200 AEP water level is 2.89 m GD.

4.2.2 Sea Level Rise

Global climate change is expected to result in increased sea levels resulting from melting of global ice and increased ocean volume due to rising water temperature. Typically, projects are considered to have a service life of roughly 80-years, resulting in designs often considering projections to the year-2100. The BC Provincial Sea Dike Guidelines (BC Ministry of Environment, 2011c) recommends that SLR associated with global climate change will result in a base water level 1 m above that seen in the year 2000 by the year-2100. The rate of SLR is projected to increase as the climate warms (**Figure 4**). Therefore, any increase incorporated in the past 18 years is expected to be minimal and hence ignored.

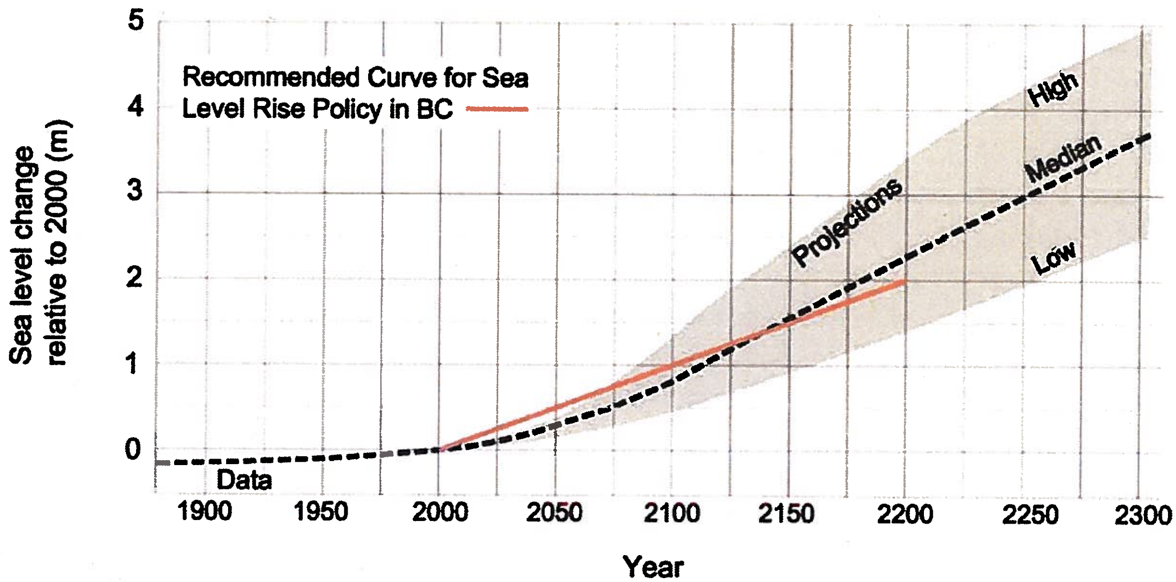

Figure 4. Projected climate change (BC Ministry of Environment, 2011c).

Note that the recommended SLR for planning and design in BC was based on a 2008 study by Fisheries and Oceans Canada (Thomson et al., 2008) and MOE (Bornhold, 2008). The authors of those works acknowledge the design SLR for BC is greater than the global mean SLR projected by the IPCC AR4 (2007) for the year 2100 (roughly 40 cm greater). However, more recent studies, such as IPCC AR5 (2014), suggests global mean SLR of up to 1 m or more by the year 2100. These values were based on the Paris Accord being adopted and adhered to, which appears not to be the case.

Other studies have investigated the potential effect of a collapse of the Antarctic ice sheet and have shown that such an event would result in far greater SLR, with estimates that are orders of magnitude larger than the 1 m to 2 m projected over then next 80-180 years. Recent changes in estimates of global mean SLR to the year 2100 or 2200 have not yet been addressed in the context of coastal BC, but based on recent conversations with FLNRORD, the province is amidst a study of SLR to update the 2011 design values. This study is not expected to be complete until April 2019.Despite the 1 m adopted by this flood hazard assessment, residents along the coast should therefore be aware that SLR could be substantially greater over the next 80-years, which may require raising, reconstruction, or relocation.

4.2.3 Local Subsidence

In addition to a rising sea, downward movement of the ground (subsidence) or upward movement (uplift) will influence the local relative sea level. Provincial guidelines (BC Ministry of Environment, 2011c) for local uplift are based on regional estimates and are less applicable than a more site-specific data source (Mazzotti et al., 2009), which suggests that subsidence for this location is on the order of -1 ± 0.5 mm/yr (**Figure 5**). To the year 2100, this translates to a lowering of 0.12 m.

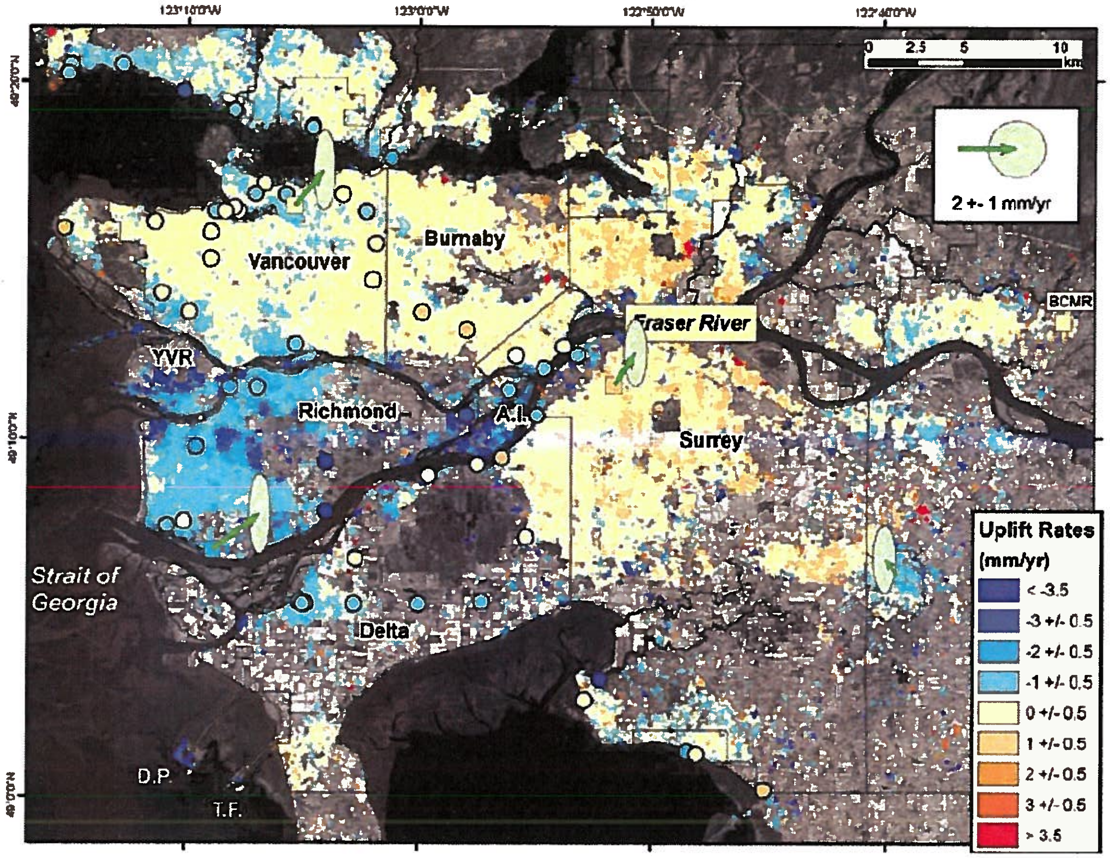

Figure 5. Local subsidence, shown as rate of uplift (Mazzotti et al., 2009) .

4.2.4 Wind Analysis

There is one Meteorological Service of Canada (MSC) station in the vicinity of the study area that has a long-term record suitable for wind analysis: Point Atkinson. Twenty years of hourly wind data was used for the study, as summarized in **Table 2**.

Table 2. Point Atkinson station information.

Station	Station ID	Station Location	Period
Point Atkinson	1106200	480768 E 5464953 N	1997–2018

*No data is available for the period between 1959 and 1961.

The local wind climate can be visualized using a wind rose plot, utilizing arrows at the cardinal and inter-cardinal compass points to show the direction from which the winds blow and the magnitude and frequency for a given period. A wind rose showing the direction and magnitude of the winds at Point Atkinson is shown in **Figure 6.**

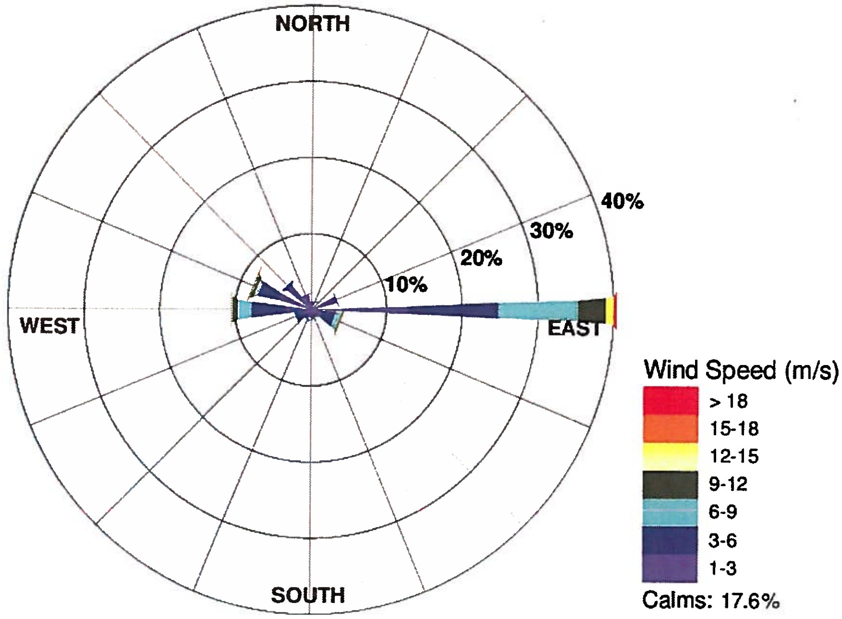

Figure 6. Wind rose based on data from Point Atkinson.

The wind rose shows that wind experienced at Point Atkinson is most frequently from the east and secondly from the west. Frequency analysis was conducted on the Point Atkinson data to obtain the wind speed for the design easterly and westerly storm events. The results are summarized in **Table 3** with the westerly winds being slightly faster than from the east for the same return frequency.

Table 3. Design wind speeds – Point Atkinson.

Event	Easterly		Westerly	
	Speed (m/s)	Speed (km/hr)	Speed (m/s)	Speed (km/hr)
1-in-5 year	20.4	73	21.0	76
1-in-10 year	20.9	75	22.3	80
1-in-50 year	22.2	80	25.2	91

The provincial guideline suggests that the wave effect is to be based on the 0.5% AEP storm event. However, NHC considers that establishing the FCL based on the 0.5% AEP storm event co-occurring with the 0.5% AEP water level (tide and surge) to be overly conservative. For this study, the 50-year (2% AEP) storm events were used to for the flood hazard assessment instead of the 200-year (0.5% AEP) storms.

4.2.5 Nearshore Wave Modelling Analysis

A nearshore wave model (Simulating Waves Nearshore or SWAN) of the Strait of Georgia and Burrard Inlet was developed to model wave generation and propagation from deep water into coastal areas and shorelines. SWAN incorporates physical processes such as wave propagation, wave generation by wind, white-capping, shoaling, wave breaking, bottom friction, sub-sea obstacles, wave setup and wave-wave interactions in its computations (Booij, N. et al., 2004). SWAN version 41.20 was used for this study.

Two model grid resolutions were used for the analysis: a fine grid model of the approaches at Burrard Inlet was nested in a coarse grid model of the Strait of Georgia. The coarse grid measures about 113 km southwest to northeast, and 253 km northwest to southeast, with each grid cell measuring 500 m by 500 m. The fine grid measures about 9 km east to west, and 8 km north to south, with each grid cell measuring 50 m by 50 m. The model's bathymetric grids were generated from digitized Canadian Hydrographic Charts and NOAA 3 arc-second resolution data.

The 50-year event (2% AEP) for each design wind directions (westerly and easterly) were used to drive the SWAN model. For each event, a spatially varying Strait of Georgia wind field was developed and applied to both the coarse and fine grid models. The regional wind stations used to generate the spatially varying wind field are presented in **Table 4**.

Model results showing the 50-year waves from the west and east are presented in **Figure 7**, **Figure 8**, and **Table 5**. Wave height is shown by colour shading, wave direction and relative heights are shown by vectors. The largest waves to reach the project site are from the east. The design significant wave height and mean wave period at the study area are from the east at 1.70 m and 4.64 seconds respectively.

Table 4. Regional wind data sources.

Station	Station ID	Period	Location
Entrance Island	EC ID 1022689	1994 – 2018 (Present)	49°12'31.195" N 123°48'38.001" W
Ballenas Island	EC ID 1020590	1994 – 2018 (Present)	49°21'01.000" N 124°09'37.000" W
Nanaimo Airport	EC ID 1025370	1954 – 2013	49°03'16.000" N 123°52'12.000" W
Nanaimo Airport	EC ID 1025365	2014 – 2018 (Present)	49°03'16.000" N 123°52'12.000" W
Sandheads CS	EC ID 1107010	1994 – 2018 (Present)	49°06'21.225" N 123°18'12.123" W
Saturna Island CS	EC ID 1017101	1994 – 2018 (Present)	48°47'02.067" N 123°02'41.082" W
Sisters Island	EC ID 2027403	1995 – 2018 (Present)	49°29'11.800" N 124°26'05.800" W
Victoria Int'l Airport	EC ID 1018620	1953 – 2013	48°38'50.010" N 123°25'33.000" W
Victoria Int'l Airport	EC ID 1018621	2013 – 2018 (Present)	48°38'50.000" N 123°25'33.000" W
Kelp Reefs	EC ID 1013998	1997 – 2018 (Present)	48°32'51.700" N 123°14'13.320" W
Halibut Bank	C46146	1992 – 2018 (Present)	49°20'24.000" N 123°43'48.000" W
Sentry Shoal	C46131	1992 – 2018 (Present)	49°54'36.000" N 124°59'24.000" W
Pat Bay	C46134	2001 – 2016	48°38'60.000" N 123°30'00.000" W

Table 5. Simulation results of design waves near project site

Event	Easterly Event		Westerly Event	
	Hs (m)	T (s)	Hs (m)	T (s)
1-in-50 year	1.70	4.64	1.41	5.37

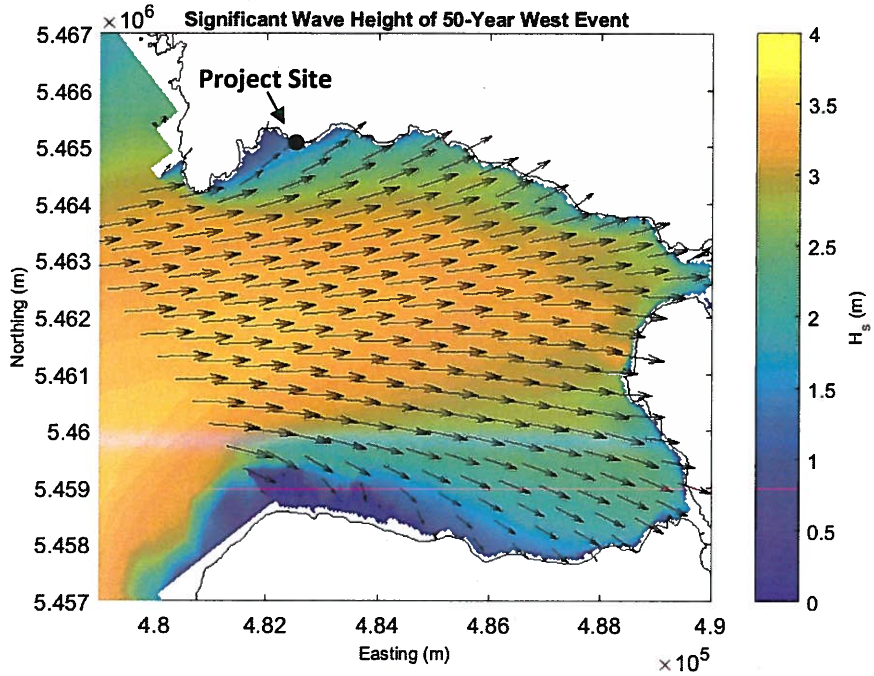

Figure 7. Significant wave height (Hs) and direction for simulated 50-year westerly event.

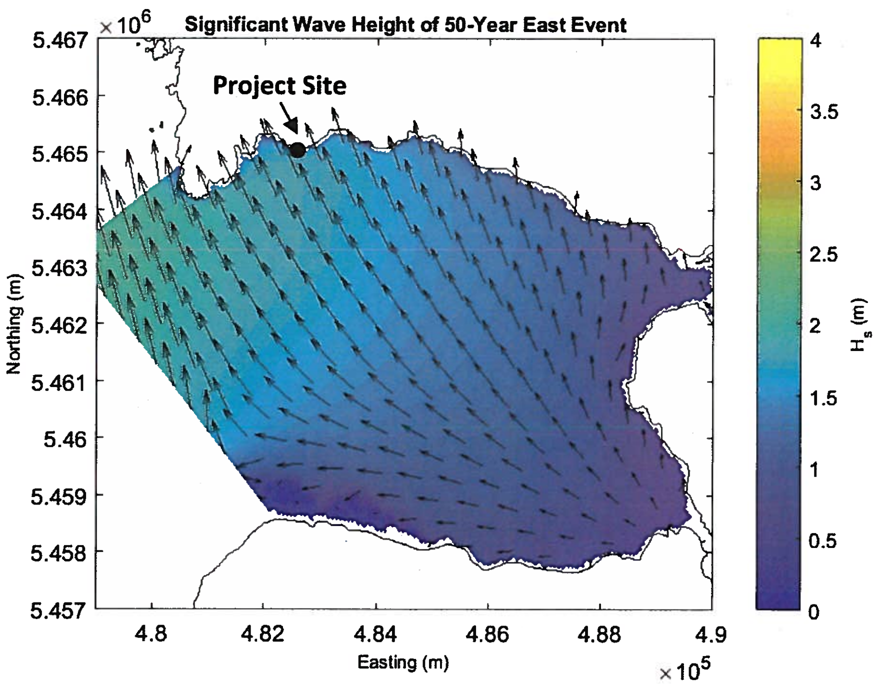

Figure 8. Significant wave height (Hs) and direction for simulated 50-year easterly event.

4.2.6 Wave runup and Wave Effect Assessment

Wave runup at the shoreline determines the extent over which waves act. Wave runup is therefore an important parameter to determine flood inundation extents from coastal storms. To determine the maximum wave runup, a Simulating Waves till Shore (SWASH) numerical model was developed to simulate the wave transformation, breaking and overflow on the shoreline (The SWASH team, 2018). For this study, SWASH version 5.01 was used.

To illustrate the effectiveness of the model to this type of application, **Figure 9** shows an example of the SWASH model results against the observed nearshore process during the December 20th, 2018 storm event in West Vancouver. A 20-second long model simulation video can be viewed at https://www.youtube.com/watch?v=qXIFPvBgelI.

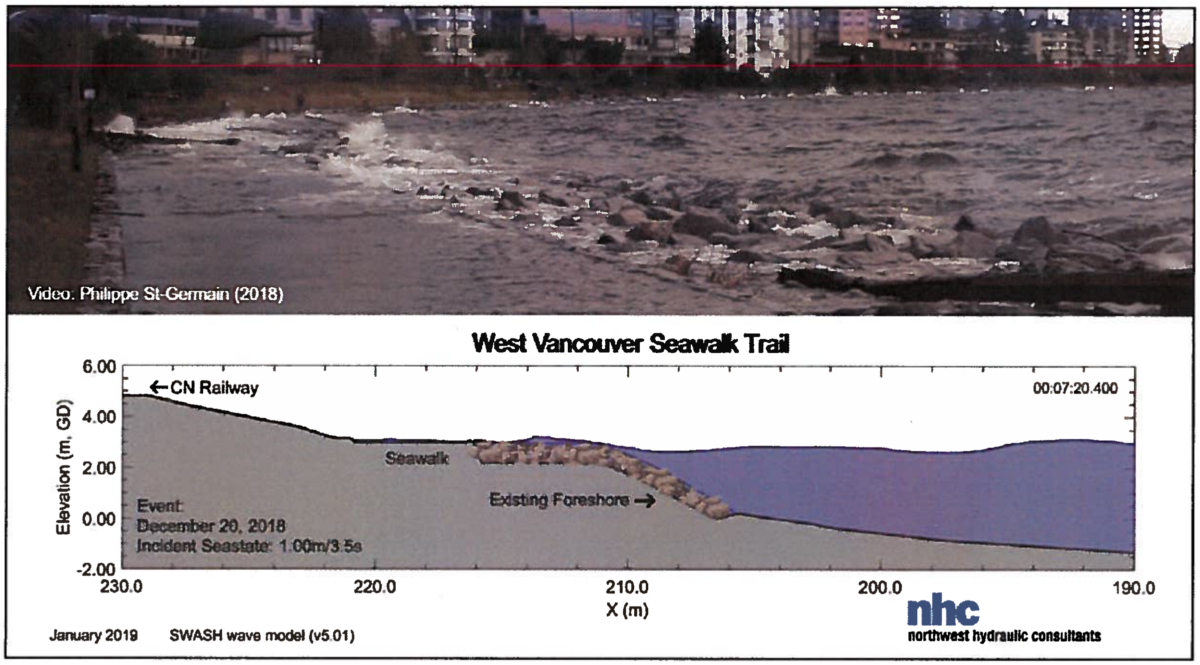

Figure 9. Numerical simulations of wave propagation and overtopping - December 20, 2018 storm event in West Vancouver.

Several simulations were performed as part of the wave runup analysis. A general profile of the study site was created using the architectural drawings provided by the client (**Appendix B**), the foreshore survey data collected during the site visit, and the bathymetry used in the SWAN model. Limited information with respect to the length of certain structural components was provided and therefore some assumptions have had to be made. From the south end of the building, an outdoor dining area was modelled, extending roughly 7 m towards the beach, at an elevation of 5.5 m GD. The outdoor area, is followed by a lawn area at an elevation of 4.78 m GD, transitioning into a beach garden (3.7 m GD) extending until the property limits.

Figure 10 shows a snapshot of the SWASH model output for the proposed design under the future design water level conditions. The result shows that the wave runups were calculated to be 0.9 m and

1.2 m under the current and future design water levels, respectively. The different wave runup values correspond to different DWL and foreshore geometry.

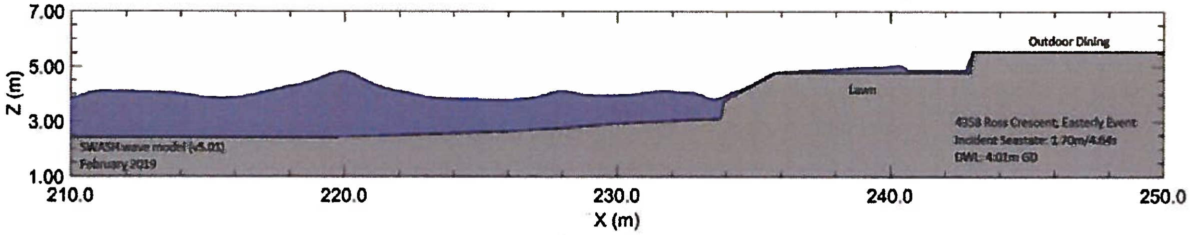

Figure 10. SWASH wave overtopping sample results - proposed design conditions.

Various configurations of soft engineering solutions and 'hard' engineering elements (e.g. concrete walls) were tested to determine if the wave runup component of the CFL could be mitigated. Given the low elevation of the lawn and beach garden proposed, a soft engineering solution is expected to have a limited effect on wave runup. Following discussions with the project architect, options for installing a concrete wall to reduce wave runup potential was not pursued.

4.2.7 Freeboard

The freeboard is applied to account for temporal and spatial variances in wave climate and surge, as well as precision of the calculation overall. Freeboard for infrastructure according to the amendment to the Flood Hazard Area Land Use Management Guidelines (BCMFLNRD, 2018) is 0.6 m when using the probabilistic approach.

4.2.8 Coastal Flood Construction Level

Table 6 summarizes the resulting FCL for the current condition and that predicted for the year 2100.

Table 6. Coastal flood construction levels.

FCL Input	Year 2019 Elevation (m)	Year 2100 Elevation (m) Proposed Design
Tide + storm surge (joint probability)	2.89	2.89
+ wave effect	0.86	1.19
+ Design sea level rise (to year 2100)	0	1.0
+ Subsidence (to year 2100)	0	0.12
Coastal flood level	3.75	5.20
+ Freeboard (m)	0.6	0.6
Flood construction level	**4.35**	**5.80**

Notes:
[1]CFL based on the ground elevation behind the wall.

4.3 Tsunami Hazard

In addition to wave and storm events, high water and coastal property inundation could potentially occur from a tsunami event. Previously denoted as tidal waves, the Japanese term tsunami, is now used to denote long period waves (5 to 60 minutes) that radiate out from the rapid displacement of a large volume of water. The initial displacement can result from an earthquake, landslide, volcanic eruption, glacier calving, or impact from a meteorite. However, major tsunami events generally are a result of earthquakes that produce substantial vertical movement of the sea floor in sufficiently shallow water.

Assessment of tsunami hazards are beyond the scope of this project, however previous studies suggest that the tsunami wave height reaching Vancouver Harbour would be roughly 10% of the tsunami wave height observed at Tofino on the west coast of Vancouver Island (Spaeth and Berkman, 1967) and that run up from a tsunami is expected to be less than 2 m on the North Shore from a tsunamis originating from the Pacific Ocean (Clague et al., 2005). Such an event would be extremely large on the west coast of Vancouver Island assuming the attenuation through the strait is roughly 10%.

The expected maximum tsunami run-up of less than 2 m would be for events far less frequent than the 200-year event, and when added to mean water high high tide (MWHHT), sea level rise, and subsidence, is still below the coastal derived FCL minus freeboard (El. 4.42 m versus El. 5.2 m).

5 RIVERINE FLOOD HAZARD ASSESSMENT

This riverine assessment considers flood hazards from Willow Creek, Claymore Creek and Cypress Creek. Historical flooding has been reported for the area resulting from Willow Creek and Claymore Creek (Vancouver Sun, 2016) and possibly also Cypress Creek (North Shore News, 2016). The Pacific Stream Keepers Federation also reported the occurrence of flooding in 1975 and 1983. Recently, the District of West Vancouver updated the inlet of the Willow Creek at Keith Road by adding a new trash rack to intercept debris prior to culvert blockage. All three creeks are not expected to impose substantial hydrotechnical hazards on the site other than flood inundation. That is, avulsion, channel migration, scour, and erosion risk has not been further investigated. Exposed soils or steep slopes towards Burrard Inlet could suffer erosion during a riverine flood event, but such conditions are not expected for this site.

5.1 Riverine Flood Inundation

5.1.1 Hydrology

The Cypress Creek watershed is gauged; Willow Creek and Claymore Creek are not gauged and have no record of water level or discharge. Cypress Creek gauge data is available for only six years, which is not adequate for performing a reliable peak flow analysis. Therefore, flow was estimated using a regional analysis based on the long term data record from McKay Creek (WSC 08GA061, 1970-2012) and through use of the Rational method. Results from the regional analysis were transposed between sites using the equation $Q_1/Q_2 = (A_1/A_2)^n$; where *Q* is discharge, *A* is contributing watershed area, and *n* is a scaling factor estimated as 0.75 as per Eaton et al (2002). Results of the analysis are shown in the following table (**Table 7**).

To account for climate change, changes to rainfall intensity were investigated using an IDF-CC tool (intensity-duration-frequency climate-change). This suggests an increase in precipitation intensity of 13% to 30% for the 200-year event to the year 2100. The impact to flow may be variable due to changes in snow-pack, timing of events, and ground cover. However, adoption of 30% increase was assumed for this analysis to remain conservative.

Table 7. Design flood flows.

Variable	McKay	Claymore	Willow	Cypress
Watershed area (km^2)	3.6	0.6	0.9	11.8
2-year flow (m^3/s)	5.6	1.5	2.0	13.6
5-year flow (m^3/s)	8.0	2.1	2.8	19.5
10-year flow (m^3/s)	9.9	2.6	3.5	24.2
20-year flow (m^3/s)	11.9	3.1	4.2	29.0
50-year flow (m^3/s)	15.4	4.0	5.4	37.4
100-year flow (m^3/s)	17.7	4.6	6.3	43.2
200-year flow (m^3/s)	20.3	5.3	7.2	49.4
Year 2100, 200-year flow	26.4	6.9	9.3	64.2

5.1.2 Hydraulic Analysis

Since Cypress Creek is located about 30 m east of the property and its 200-year flood flow is roughly eight times larger compared to the other creeks located further from the site, the riverine flood hazard analysis was conducted only for Cypress Creek. To predict flood levels resulting from 200-year flood flows (0.5% AEP) with allowance for climate change, a one-dimensional hydraulic model was constructed using the US Army Corps of Engineers' HEC-RAS software based on Cypress Creek sections and channel slope information collected in the field. To be conservative, it is assumed that the 200-year flood flow (64 m^3/s) coincides with the future 200-year tide level of 4.01 m GD. Manning's roughness value of 0.07, which is the maximum value for channel bed consisting of cobbles with large boulders, was applied.

The model results suggest the flow will overtop the existing bank (elevation at 4.4 m GD) and flood the neighbouring area. The predicted flood depth is about 1.0 m with maximum velocity of 2 m/s. The current road elevation is at 3.5 m. With consideration of 0.6 m freeboard, the riverine FCL value is **5.1 m**. Overland velocities could be high enough to induce erosion and scour if ground cover is not maintained. The riverine FCL is below the coastal FCL, which is considered to govern for the main residence facing the ocean. The garage/studio that is proposed to be constructed at the back of the property (portion of the lot facing Ross Crescent) would not be exposed to elevated flood hazard resulting from wave runup and so the riverine FCL is considered to govern at this location.

6 SUMMARY AND RECOMMENDATIONS

A hydrotechnical flood hazard assessment was conducted for the subject property at 4358 Ross Crescent. It has been found that flooding originating from Burrard Inlet is the governing hazard. From this study, the following recommendations are made for safe use of the property:

1) The calculated riverine flood depth is less than that calculated for coastal flooding, therefore the coastal FCL should be adopted for the main residence while the riverine FCL should be adopted for the garage/studio located near Ross Crescent.

2) The 2100-year design coastal FCL for the project site was found to be 5.8 m GD for the proposed development, including the main residence.

3) The riverine design FCL for the garage/studio structure located at the back of the property adjacent to Ross Crescent was found to be 5.1 m GD.

4) Building entrances and windows to habitable space should be at or above the applicable FCL.

5) The underside of any wooden floor system, or the top of any concrete floor system used for habitation should be above the applicable FCL. An exception to this recommendation for wooden floor systems can be made if the underside of the wooden floor system is inset inside and below the top of concrete foundation, in which case the top of concrete foundation should be above the applicable FCL.

6) No enclosed space to be used for habitation or storage of goods that can be damaged by floodwaters should be below the FCL. An exception to this recommendation can be made if suitable provisions are made to design the space below the FCL such that flood waters cannot enter the space; for instance, a 'floodproof' basement is designed and certified by a qualified engineer.

7) All main electrical and mechanical infrastructure are to be above the applicable FCL. Any electrical supply below the FCL (i.e. outlets or lighting) should be protected by GFCI (ground fault circuit interruption) located above the FCL. . Mechanical infrastructure may be located within a floodproof enclosed space below the FCL if the provisions of Recommendation #4 (above) are met.

8) The residence is set back from the edge of water a minimum of 15 m. Additional set back improves options to address further increases in SLR that may occur as well as shoreline erosion if it becomes a problem in the future.

9) If the site is landscaped with isolated low lying ground between the properties boundary with Burrard Inlet and the proposed residence, than stormwater drainage is designed to accommodate potential spray and overtopping.

10) Any ingress or egress routes existing above the applicable FCL are adequate for evacuation during a flood with loss of electrical power.

11) From all areas below the applicable FCL (i.e. underground parking) an unobstructed means of pedestrian ingress and egress is provided above the FCL, suitable for use under loss of electrical power.

12) Final building plans should be reviewed by qualified registered engineer to ensure they meet the recommendations presented within this FHA.

In addition, it is recommended that the property owner monitor and inspect their property for erosion and beach degradation twice a year to allow further investigation and mitigation if either become a problem in the future.

This flood hazard assessment was conducted following EGBC 2018 Class 1 flood hazard assessment guidelines. A summary of the EGBC criteria for such an assessment is presented in **Table 8.** Hazards other than flood hazards from the Burrard Inlet and the adjacent creeks, such as geotechnical, fire, and wildlife hazards have not been assessed as part of this assessment. Stormwater and sediment management has not been designed or assessed through this study and may also impose hazards if not adequately addressed.

Table 8. Summary of EGBC typical Class 1 flood hazard assessment methods and deliverables

EGBC Flood Hazard Assessment Component	Notes
Typical hazard assessment methods and climate/environmental change considerations	
Site inspection and qualitative assessment of flood hazard	Completed by NHC 2019
Identify any very low hazard surfaces in the consultation area (i.e., river terraces)	Completed by NHC 2019
Estimate erosion rates along river banks	River erosion not applicable to site. Coastal erosion not evident.
1-D or possibly 2-D modelling, modelling of fluvial regime and future trends in river bed changes, erosion hazard maps, possibly paleoflood analysis	2-D coastal and 1-D riverine completed by NHC 2019
Identify upstream or downstream mass movement processes that could change flood levels (e.g., landslides leading to partial channel blockages, diverting water into opposite banks)	Potential blockage of culvert or sediment deposition in the channel considered possible mechanism of the flood scenario
Conduct simple time series analysis of runoff data, review climate change predictions for study region, include in assessment if considered appropriate	Completed by NHC 2019 including allowance for climate change as recommended by MWLAP (2004)
Quantify erosion rates by comparative air photograph analysis	N/A – erosion risk deemed low
Typical deliverables	
Letter report or memorandum with at least water levels and consideration of scour and bank erosion	Completed
Cross-sections with water levels, flow velocity and qualitative description of recorded historic events, estimation of scour and erosion rates where appropriate with maps showing erosion over time	Flow descriptions completed. Erosion risk deemed low

EGBC Flood Hazard Assessment Component	Notes
Maps with area inundated at different return period, flow velocity, flow depth, delineation of areas prone to erosion and river bed elevation changes, estimates of erosion rates	Areas and elevations inundated during the 200-year return period design event described

7 CLOSURE

We hope this work and report meets your current needs. If you have any questions don't hesitate to contact Derek Ray or Edwin Wang by phone **604-980-6011** or email (dray@nhcweb.com | ewang@nhcweb.com).

Sincerely,

Northwest Hydraulic Consultants Ltd.

Prepared by:

s. 22(1) [redacted] 22 March 2019

Adrian Simpalean, MASc.
Hydrotechnical Analyst

Reviewed by:

s. 22(1) [redacted] PROFESSIONAL PROVINCE OF D. A. RAY #26680 BRITISH COLUMBIA SCIENTIST 22 Mar, 2019

Derek Ray, P.Geo.,
Principal Coastal Geomorphologist

PROFESSIONAL PROVINCE OF E. C. WANG # 29366 BRITISH COLUMBIA ENGIN Mar 22, 2019 s. 22(1) [redacted]

Edwin Wang, [redacted]
Hydrotechnical Engineer

DISCLAIMER

This document has been prepared by **Northwest Hydraulic Consultants Ltd.** for the benefit of s. 22(1) [redacted] s. 22(1) [redacted] for specific application to the **Flood Hazard Assessment at 4358 Ross Crescent, West Vancouver.** The information and data contained herein represent **Northwest Hydraulic Consultants Ltd.** best professional judgment in light of the knowledge and information available to **Northwest Hydraulic**

Consultants Ltd. at the time of preparation, and was prepared in accordance with generally accepted engineering practices.

Except as required by law, this report and the information and data contained herein are to be treated as confidential and may be used and relied upon only by [redacted] its officers and employees. **Northwest Hydraulic Consultants Ltd.** denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents.

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Appendix A

Flood Hazard and Risk Assurance Statement

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: 2019-03-22

Planning, Permit, and Properties, District of North Vancouver

4358 Ross Crescent, West Vancouver, BC V7V 3A7

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:

Lot A, Block 7, District Lot 582, Group 1, New Westminster District, Plan 6662

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

---

(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.

8. Where the *Approving Authority* has **not** adopted a level of *flood risk* or *flood hazard* tolerance I have:

NA 8.1 described the method of *flood hazard* analysis or *flood risk analysis* used

NA 8.2 referred to an appropriate and identified provincial or national guideline for level of *flood hazard* or *flood risk*

NA 8.3 compared this guideline with the findings of my investigation

NA 8.4 made a finding on the level of *flood hazard* of *flood risk* tolerance on the Property based on the comparison

NA 8.5 made recommendations to reduce *flood risks*

NA 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 <u>subdivision approval</u>, 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 <u>development permit</u>, 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 <u>building permit</u>, 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".

Derek Ray

Name [redacted]

Signa[redacted]

2019-03-22

Date

Address

30 Gostick Place, North Vancouver, BC V7M 3G3

604-980-6011

Telephone

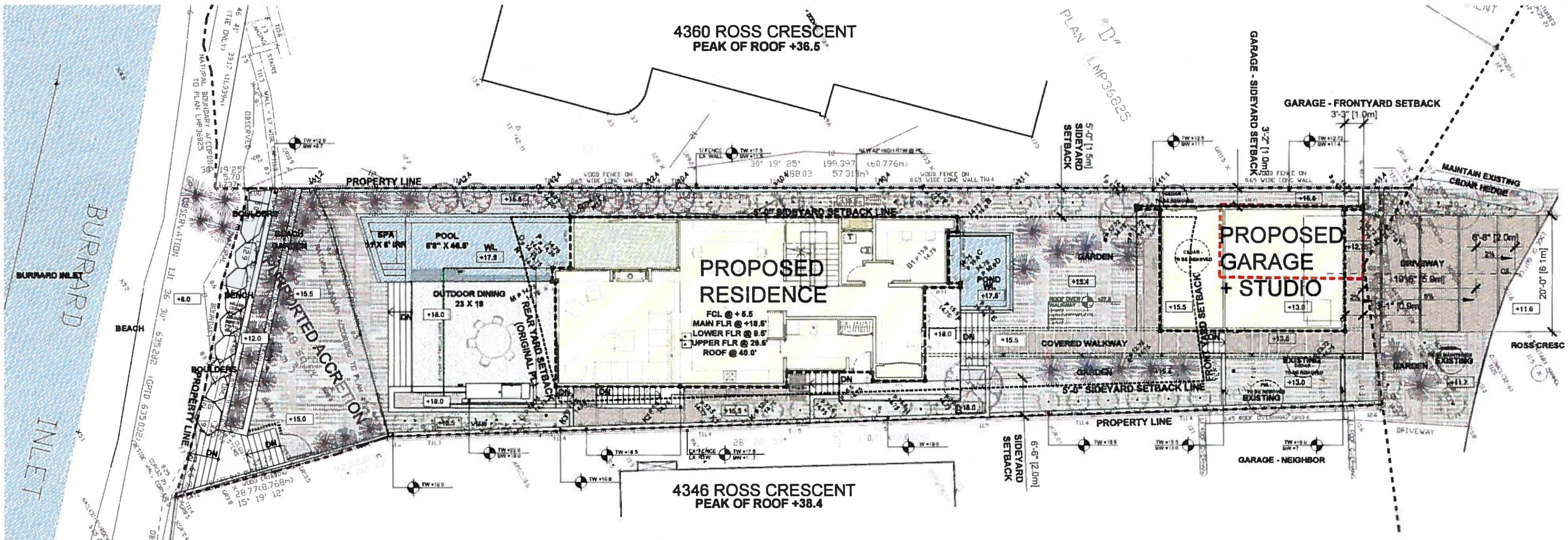
(Affix Professional seal here)

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

I am a member of the firm Northwest Hydraulic Consultants Ltd. (NHC)
and I sign this letter on behalf of the firm. (Print name of firm)

Appendix B

Received Design Drawings



PROJECT STATISTICS

LOT ADDRESS
4358 ROSS CRESCENT WEST VANCOUVER, BC

LEGAL DESCRIPTION:
LOT 7 BLOCK 2 DISTRICT LOT 582, GROUP 1 NEW WESTMINSTER DISTRICT PLAN 4726, P.I.D. 011-374-270

	EXISTING	RE-ZONED	COMMENT
ZONING	RS-4		
LOT AREA	7,676 SF 657.3 m2	8,223 SF 764 m2	REQUIRES RE-ZONING APPROVAL BASED ON ACCRETION

SITE COVERAGE	ALLOWED	PROPOSED	COMMENT
LOT AREA - [illegible]	2,880.2 SF 266.0 m2	2,716.8 SF 251.6 m2	ALLOWED BASED ON RE-ZONING MAIN HOUSE + OVERHANG OVER 4 = 2050 SQ FT GARAGE + COACH HOUSE = [illegible] SQ FT TOTAL = 2716 SQ FT < 2863 SQ FT = CONFORMS

FLOOR AREA RATIO			
8,223 * 0.35 =	2,878.0 SF 267.4 m2	2,877.0 SF 267.3 m2	BASED ON RE-ZONING

ELEV.	AREA CALCULATIONS	ACTUAL	EXEMPT	COUNTABLE	NOTES
+14.75	MAIN FLOOR	1500	0.0	1500	
+25.75	UPPER FLOOR	1100	0.0	1100	
	TOTAL LIVING AREA	2877			
	STUDIO	240	240	0	
	BASEMENT	1587	100%	0	
	GARAGE	440	440	0	* BASED ON FINISHED GRADE + FCL - CONFORMS
	TOTAL AREA	5344		2877	

BUILDING + GARAGE SETBACKS

SETBACKS	CURRENT	BYLAW	PROPOSED	BASED ON ACCRETION	VARIANCE REQUIRED	NOTES
FRONT YARD HOUSE	71.375'	30'	70.83'	N/A	NO	
REAR YARD HOUSE	41'	30'	30'	17'	NO	
SIDEYARD EAST	3.45'	5'	5'	N/A	NO	
SIDEYARD WEST	4.3'	5'	5'	N/A	NO	
COMBINED SIDEYARD	7.75'	15'	11.5'	N/A	YES	
FRONT YARD GARAGE	0.17'	30'	3.2'	N/A	YES	This will also trigger roof setback.
SIDEYARD WEST GARAGE	2.75'	5'	3.2'	N/A	YES	This will also trigger roof setback.

TO BE UPDATED

VARIANCE REQUIRED

FRONT YARD PAVED AREA

AREA WITHIN FRONT YARD SETBACK (30'-0") = 1,172.0 SF
PAVED AREA PERMITTED (50%) = 586 SF
[illegible]

NOTES: SEE OPTION 3 DIAGRAMME VARIANCE REQUIRED

BUILDING HEIGHT 25'-8" (7.82 m) 24.29 (7.2 m) PROPOSED GRADE GOVERNS

BUILDING HEIGHT BASED ON FLOOD CONTROL LEVEL (14.75') = 22.85'
BUILDING HEIGHT BASED ON EXISTING (8.5') = 28.6'

PROPOSED AVERAGE GRADE AT PERIMETER

	A	B	(A+B)/2	LENGTH	PRODUCT
A-B	12.50	15.00	13.75	2.50	34.38
B-B1	[illegible]	[illegible]	[illegible]	1.50	22.50
B1-C	15.00	18.00	[illegible]	[illegible]	127.50
C-D	[illegible]	15.00	[illegible]	2.00	30.00
D-E	[illegible]	[illegible]	15.00	[illegible]	18.00
E-F	[illegible]	15.50	15.25	[illegible]	91.50
F-G	[illegible]	[illegible]	[illegible]	15.00	248.00
G-H	[illegible]	[illegible]	15.50	[illegible]	139.50
H-I	[illegible]	[illegible]	15.50	1.50	23.25
I-J	15.50	12.50	14.00	[illegible]	126.00
J-K	12.50	12.50	[illegible]	[illegible]	31.25
K-K1	12.60	12.60	[illegible]	[illegible]	225.13
K1-K2	12.50	6.50	[illegible]	[illegible]	0.00
K2-K3	6.50	12.50	[illegible]	[illegible]	120.26
K3-L	12.50	14.75	13.63	7.00	95.38
L-M	14.75	[illegible]	14.75	[illegible]	268.45
M-N	14.75	[illegible]	14.50	[illegible]	10.10
N-O	[illegible]	[illegible]	14.25	2.25	32.06
O-P	[illegible]	[illegible]	14.25	3.20	45.60
P-Q	[illegible]	14.25	14.25	[illegible]	124.69
Q-Q1	14.20	12.50	13.30	[illegible]	0.00
Q1-A	12.50	[illegible]	[illegible]	[illegible]	828.75
TOTAL PERIMETER				[illegible]	
TOTAL PRODUCT					2846.63
AVERAGE PROPOSED GRADE					13.36
MEAN HOUSE HEIGHT ELEVATION					37.60
HOUSE HEIGHT ABOVE PROPOSED GRADE					24.24

TO BE UPDATED

GARAGE/STUDIO HEIGHT 12'-0" (3.7 m) 12.00 (3.7 m) PROPOSED GRADE GOVERNS

BUILDING HEIGHT BASED ON FLOOD CONTROL LEVEL (14.75') = 9.97'
BUILDING HEIGHT BASED ON EXISTING (8.5') = 16.72'

GARAGE/STUDIO - HEFFEL RESIDENCE
PROPOSED AVERAGE GRADE AT PERIMETER

	A	B	(A+B)/2	LENGTH	PRODUCT
a-a1	12.72	12.72	12.72	0.50	6.36
a1-a2	[illegible]	12.72	12.72	3.00	38.16
a2-b	[illegible]	12.72	[illegible]	20.75	263.94
b-c	[illegible]	12.72	[illegible]	31.75	403.86
c-d	[illegible]	12.72	[illegible]	20.75	263.94
d-e	[illegible]	[illegible]	12.72	4.00	50.88
e-f	12.72	[illegible]	12.72	0.50	6.36
f-a	[illegible]	[illegible]	12.72	33.00	420.94
TOTAL PERIMETER				115.00	
TOTAL PRODUCT					1463.44
AVERAGE PROPOSED GRADE					12.72
MEAN GARAGE/STUDIO ELEVATION					24.72
HOUSE HEIGHT ABOVE PROPOSED GRADE					12.00

TO BE UPDATED

NORTH

1	PREPARED FOR DVP SUBMISSION	[illegible]	[illegible]

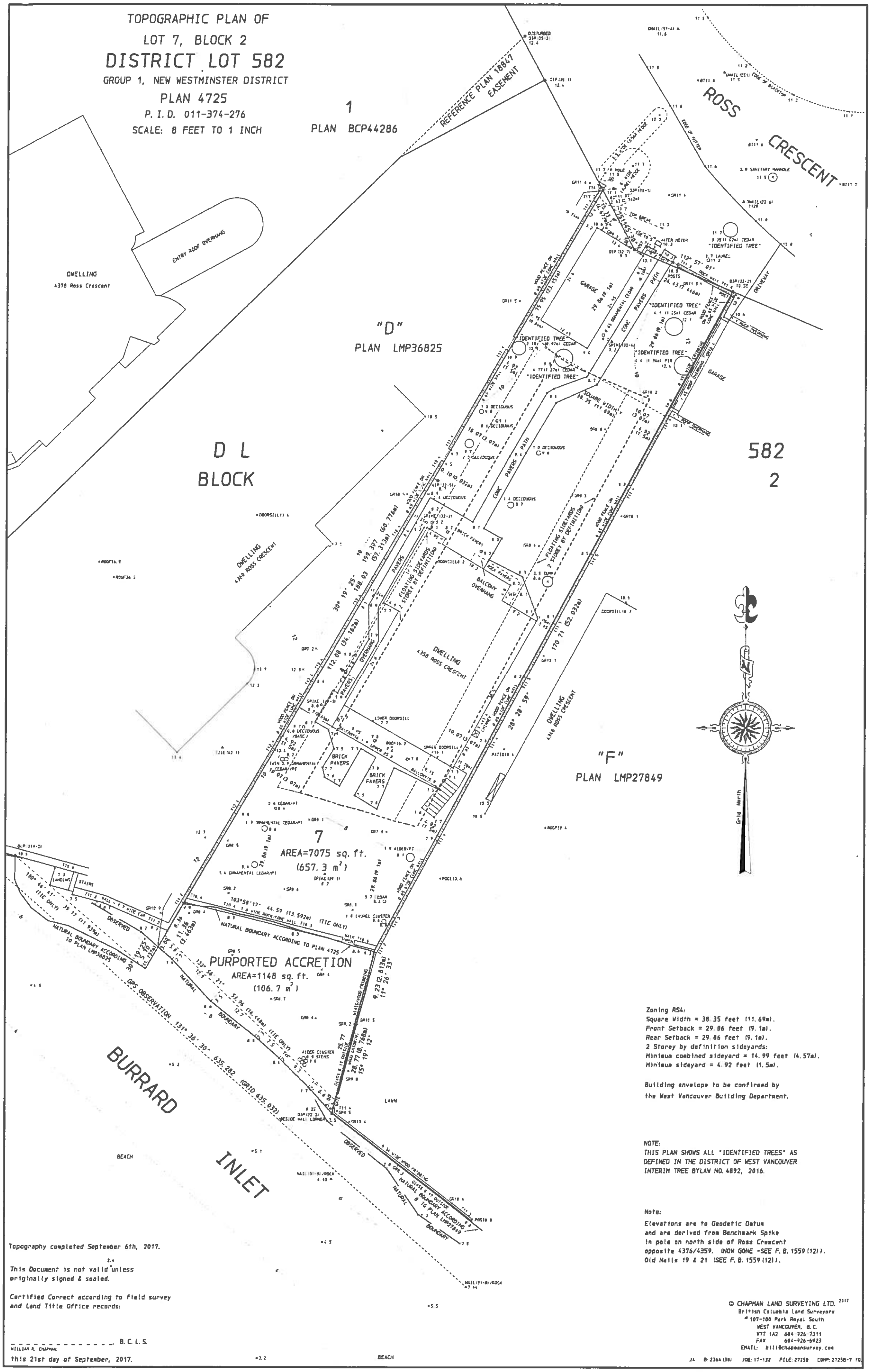
HDA
HLYNSKY + DAVIS ARCHITECTS INC.

[redacted] s. 22(1)
4358 ROSS CRESC
W VAN, BC

SITE PLAN

SCALE: 1/8" = 1'-0"

A1.2


TOPOGRAPHIC PLAN OF
LOT 7, BLOCK 2
DISTRICT LOT 582
GROUP 1, NEW WESTMINSTER DISTRICT
PLAN 4725
P. I. D. 011-374-276
SCALE: 8 FEET TO 1 INCH
1
PLAN BCP44286
REFERENCE PLAN 18847
EASEMENT
ROSS CRESCENT
DWELLING
4378 Ross Crescent
ENTRY ROOF OVERHANG
"D"
PLAN LMP36825
D L
BLOCK
582
2
DWELLING
4360 ROSS CRESCENT
GARAGE
"IDENTIFIED TREE"
DWELLING
4356 ROSS CRESCENT
BALCONY OVERHANG
BRICK PAVERS
"F"
PLAN LMP27849
DWELLING
4348 ROSS CRESCENT
7
AREA=7075 sq. ft.
(657.3 m²)
PURPORTED ACCRETION
AREA=1148 sq. ft.
(106.7 m²)
NATURAL BOUNDARY ACCORDING TO PLAN 4725
GPS OBSERVATION 131° 36' 30" 635.282 (GRID 635.032)
BURRARD
INLET
BEACH
LAWN
Grid North
Zoning RS4:
Square Width = 38.35 feet (11.69m).
Front Setback = 29.86 feet (9.1m).
Rear Setback = 29.86 feet (9.1m).
2 Storey by definition sideyards:
Minimum combined sideyard = 14.99 feet (4.57m).
Minimum sideyard = 4.92 feet (1.5m).
Building envelope to be confirmed by
the West Vancouver Building Department.
NOTE:
THIS PLAN SHOWS ALL "IDENTIFIED TREES" AS
DEFINED IN THE DISTRICT OF WEST VANCOUVER
INTERIM TREE BYLAW NO. 4892, 2016.
Note:
Elevations are to Geodetic Datum
and are derived from Benchmark Spike
in pole on north side of Ross Crescent
opposite 4376/4359. (NOW GONE -SEE F.B. 1559 (12)).
Old Nails 19 & 21 (SEE F.B. 1559 (12)).
Topography completed September 6th, 2017.
This Document is not valid unless
originally signed & sealed.
Certified Correct according to field survey
and Land Title Office records:
_______________, B.C.L.S.
WILLIAM R. CHAPMAN
this 21st day of September, 2017.
© CHAPMAN LAND SURVEYING LTD. 2017
British Columbia Land Surveyors
#107-100 Park Royal South
WEST VANCOUVER, B.C.
V7T 1A2 604-926-7311
FAX 604-926-6923
EMAIL: bill@chapmansurvey.com
J4 B: 2364 (38) JOB: 17-132 FILE: 27258 COMP: 27258-7 FO