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Technical Memorandum

DATE: July 23, 2013

TO: David Roulston, P.Eng., District of Squamish

FROM: David Roche, M.A.Sc., P.Eng.

RE: **DISTRICT OF SQUAMISH – WEST MAMQUAM BLIND CHANNEL**
Provisional Guidance for Coastal Flood Hazard Management
Our File 463.292-300

1. Introduction

Areas near and around downtown Squamish are subject to coastal flood and erosion hazards from Howe Sound and its estuaries and sloughs. These water bodies experience high tides, storm surges, waves, and sea level rise induced by climate change, and may also experience tsunami effects.

As the local government, the District of Squamish (District) is responsible for managing development in floodplain areas, as well as for providing the community with an adequate level of protection against flood and erosion hazards. In 1994, a comprehensive Flood Hazard Management Plan (FHMP) was commissioned to assist the District in these tasks. Flood protection measures recommended in the 1994 FHMP reflect the standard of the day, particularly in regard to known hazards and technical tools.

Since 1994, numerous and significant advances have occurred in the field of flood hazard management. These changes include nearly two decades of community development, an evolving understanding of climate change, improvements in tools and approaches, and changes in the respective roles of regulatory authorities and the Qualified Professional (QP). As a result of these changes, several key aspects of the 1994 FHMP have become obsolete.

The District's 2009 Official Community Plan (Section 25) highlights the importance of updating the FHMP as well as engaging in active planning for risk management planning. In response, the District is currently planning a comprehensive FHMP update for fiscal year 2015.

While planning for the comprehensive FHMP update is underway, the District has received proposals to redevelop areas along the west side of Mamquam Blind Channel adjacent to downtown Squamish. Redevelopment of this area is a key objective within the District's Official Community Plan (OCP), and it is not realistic for the District to defer all development decisions for several years until the FHMP update is complete.

Kerr Wood Leidal Associates Ltd. (KWL) was retained to provide provisional guidance for flood hazard management along the west side of the Mamquam Blind Channel to guide "interim" development reviews pending the comprehensive FHMP update. This provisional guidance study considers an area approximately bounded by Pemberton Avenue (near the CN Rail bridge) and Vancouver Street (near the north boundary of the Squamish Oceanfront Development Corporation (SODC) lands. The study area is shown in Figure 1, and referred to herein as "West Mamquam Blind Channel" for brevity.

KWL's team of David Sellars and David Roche carried out a site reconnaissance on May 24, 2013 to support preparation of this provisional guidance. KWL was accompanied by Rod MacLeod, David Roulston, and Sarah McJannet of the District.

This memorandum summarizes KWL's assessment and findings, presented with the understanding that its application will be limited to selected developments within the specified geographical area over a maximum three-year period. The memorandum includes commentary for the development proposal and review process as well as specific guidance targets for provisional flood hazard management. Reference is made to numerous standards, guidelines, and technical documents that collectively define the current state of flood hazard management in BC.

The memorandum was prepared by KWL Project Engineer David Roche with technical review by Senior Water Resources Engineer David Sellars. Recognizing the importance of this provisional guideline to the District's ongoing review of development proposals, Senior Water Resources Engineer Mike Currie provided an internal peer review.

2. Vision for Foreshore and Flood Protection

Part 5 of the District's 2009 OCP provides a long-term redevelopment vision for the waterfront along Mamquam Blind Channel. The OCP designates this area as Development Permit Area 4 (DPA-4) and outlines a diverse suite of goals for re-development; however, the discussion does not consider flood and erosion protection issues. Introduction of flood protection measures that meet current standards could have significant impacts on the vision presented in the OCP, especially since the standards have become significantly more stringent in recent years.

The District should consider a detailed review of its DPA-4 objectives to incorporate flood and erosion protection considerations. Such a review could highlight potential areas of opportunity as well as conflict between the various development objectives. A summary of the District's development, recreation, and flood protection objectives, as understood by KWL at the time of this study, is provided below. The development and foreshore recreation goals provide the context for subsequent flood protection recommendations.

2.1 Development Goals

The District's 2009 OCP calls for gradual conversion of the working harbour, transportation corridor and industrial areas to a more urban, mixed-use commercial, recreational, tourist and multiple-family residential neighbourhood. The OCP specifically calls for a water-oriented development with the more narrow property dimensions facing the water, interacting with the water in a variety of ways. The OCP specifically states that "no reduction of the width of the Mamquam Blind Channel will be permitted through the use of filling".

Of particular note, the Marina Estates development at the north end of the study area represents an existing development constraint for the future of the area, particularly with regard to flood hazard management. Some stakeholders may assume that Marina Estates established a template or precedent for further development.

2.2 Foreshore Goals

The 2009 OCP envisions "continuous safe and unrestricted pedestrian access for the public along the water's edge" as an essential part of redevelopment along Mamquam Blind Channel. The OCP specifically states that the public walkway should provide a variety of interfaces with, and varying

proximity to, the water including sea wall, sea wall plus riprap, pier, pier and dock, walkway on pilings, floating walkway/dock, and natural bank.

The minimum clear unobstructed width for the proposed public walkway is stated as 3.5 m, with larger allowances recommended in areas of concentrated use, connections, art installations, street furniture, or safety and security infrastructure.

Based on independent conversations with the District, KWL understands that the District would also like to preserve ease-of-access from nearby Loggers Lane to the public trail at regular intervals, and from the public trail to tidewater at selected locations.

2.3 Flood Protection Goals

Areas along both sides of Mamquam Blind Channel are currently subject to coastal flood hazards. The intensity of these hazards will increase significantly within the current development planning horizon due to the predicted effects of Sea Level Rise (SLR).

The District of Squamish has a dual responsibility with regard to flood and erosion protection:

- as the local government, the District is responsible for mandating and implementing an appropriate level of flood and erosion protection on behalf of its constituents; and
- as the local diking authority, the District is responsible for operation, maintenance and repair of the community's structural flood and erosion protection works.

The District must therefore balance the goals of development and recreational use along Mamquam Blind Channel with the paramount need to protect public safety, property, and infrastructure from flood and erosion hazards.

Given the nature of the coastal flood hazard, the extent of development in Downtown Squamish, and the value of assets at risk, the District's objectives for flood protection along the west side of Mamquam Blind Channel should include the following:

- a continuous "standard dike" that ties into high ground at either end (and therefore continues well beyond the geographic limits of this study), such that the dike can provide reliable flood protection for both legacy and new development within the downtown peninsula and adjacent low-lying areas;
- continuous erosion protection along both the foreshore and the standard dike;
- implementation of flood and erosion protection works in an environmentally-sensitive and socially-conscious context;
- appropriate setbacks to accommodate natural processes, and to support maintenance and upgrading of the flood and erosion protection works; and
- secondary flood proofing of buildings within the floodplain area.

The District must also consider the potential for flood hazards associated with an upstream dike breach along Squamish River or Mamquam River, wherein a continuous sea dike (as proposed above) could impound water within the downtown peninsula. Similarly, the District's flood protection planning must give appropriate consideration to potential tsunami hazards.

Among the flood protection objectives outlined above, the most significant from a development perspective is the need for a standard dike and its associated setback requirements. The term "standard dike" is used by the provincial Inspector of Dikes (IOD) to describe dikes that meet a suite of provincial standards. The most common considerations include (APEGBC, 2012):

- design and construction to meet applicable flood, seismic, seepage, stability, and geometric criteria;
- design and construction completed under the supervision of a qualified Professional Engineer;
- implementation of a fully-funded operation and maintenance program by a designated local authority; and
- legal access (by rights-of-way or land ownership) for the local authority to maintain the dike.

As a condition of approval for a new dike, the provincial Inspector of Dikes requires that the local government jurisdiction act as local authority and accept responsibility for operation and maintenance.

2.4 Conflicts and Opportunities

Within a community planning context, flood protection and recreation objectives are often compatible; for example, the District has developed an extensive trail system along its existing river dikes. For Mamquam Blind Channel, the minimum 3.5 m wide recreational trail is congruent with the 4 m minimum crest width required for a standard dike structure. Implemented appropriately, the pedestrian route could provide excellent equipment access for inspection, maintenance, and repair of flood protection works.

The most likely source of conflict with recreation objectives arises from the OCP recommendation to provide a "variety of interfaces with, and varying degrees of proximity to the water", including sea wall, riprap slopes, and natural bank. This objective will be difficult to reconcile with the need for standardized and continuous flood and erosion protection works along the length of the redevelopment area. Transitions between various foreshore treatments can create potential weak spots in a flood protection system while increasing operation and maintenance (O&M) costs. Implementing multiple transitions over a short distance solely for aesthetic purposes is unusual and would likely result in additional scrutiny from regulators such as IOD.

Other conflicts between flood protection and recreation objectives can arise during the operational phase when public access is restricted for repairs or upgrades, or where recreation use damages the dike at a nuisance frequency. Both of these potential challenges can be easily mitigated when considered at the design stage.

It is possible to find common ground between development objectives and flood protection objectives; for example, the orientation of buildings with their narrow face to the water (as proposed in the OCP) will maximize access to waterside flood and erosion protection works as well as outflow capacity in the event of an upstream dike breach. However, the potential for conflicts between development proposals and flood protection objectives is more significant, particularly given the constrained lot width available between the natural bank and road / railway allowances at Loggers Lane. The limited space will highlight conflicts between developers' short term interests (minimize construction costs and maximize floor space) and the District's long-term interests (encourage development while minimizing costs for operation, maintenance, repair of flood protection works as well as risk of flood damages).

In some cases the District's flood protection objectives are themselves not straightforward; West Mamquam Blind Channel is an example of this. Section 25-14 of the OCP recommends that building construction and fill within the West Mamquam Blind Channel area be minimized, presumably to allow outflow in the event of an upstream dike breach as per the 1994 FHMP. However, recent guidance on sea level rise (released after the OCP) significantly increases the magnitude and potential consequences of the coastal flood hazard. Construction of a continuous sea dike around downtown to mitigate the coastal flood hazard must be balanced against the need to allow for dike breach outflows. This issue is technically complex; KWL expects that it will be addressed as part of the comprehensive FHMP update.

When balancing conflicts between flood protection, recreation, and redevelopment objectives, it is critical that District staff appreciate the long-term challenges and costs of protecting the community from flood and erosion hazards, including the long-term costs and implications of failing to allow adequate space for future flood and erosion protection works.

3. Approach to Development Review

The recently-released APEGBC document entitled Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC outlines requirements for conducting flood assessments in support of development proposals. Typically the Approving Authority (in this case, the District) would require that a potential developer retain a Qualified Professional (QP) to undertake a flood assessment on the developer's behalf. This flood assessment would evaluate hazard and risk, compare the results to existing standards for "acceptable" risk, and certify that the site is "safe for its intended use". Where the site is not inherently considered "safe for its intended use", the QP may propose a combination of structural works and terms for a restrictive covenant that make it so.

The District has the authority to require a flood assessment pursuant to the APEGBC Professional Practice Guidelines, to the extent that they apply. This would include a QP's certification of a proposed suite of measures that will render the land "safe for its intended use". With regard to West Mamquam Blind Channel, this authority is explicitly referenced in Clause 25-5 of the OCP:

> ***"25-5*** *A report prepared by a qualified engineer will be required for all development proposals for land located within an identified natural hazard area. The report shall establish the suitability of the land for development and any required mitigation measures."*

To complete a flood hazard assessment under the APEGBC Flood Hazard Assessment guidelines, the QP must evaluate the proposed design against a level of acceptable risk to conclude whether the development may be considered "safe for its intended use". Guidance provided by the District to the developer (e.g., identifying a target FCL) may therefore be interpreted as assisting the QP with standards-based definition of acceptable risk at both site and community levels.

4. Provisional Guidance for Flood Protection Measures

On a provisional basis, the following discussion outlines a reasonable, prudent, and appropriate suite of guidelines to assist QPs in preparing their flood assessment reports for West Mamquam Blind Channel. In providing this guidance, KWL assumes that a QP will design and certify works in compliance with all applicable standards and guidelines, modified where appropriate by the discussions herein.

4.1 Alignment of Flood Protection

Perhaps the single most important decision for coastal flood protection at West Mamquam Blind Channel is the alignment of the future standard dike. Previous engineering reports (e.g., 1994 FHMP and 1999 design report by Bland Engineering) have assumed a sea dike alignment along the Mamquam Blind Channel foreshore. However, standards have become considerably more stringent in recent years and the Inspector of Dikes (2013) has encouraged the District to explore potential for a setback alignment (e.g., along Loggers Lane).

The advantages of locating the primary dike along the foreshore are immediately evident: all development between Loggers Lane and Mamquam Blind Channel would be protected by the primary sea dike. However, there are significant disadvantages to this approach, including footprint and statutory Right-of-

Way (ROW) requirements, environmental impacts, seismic design and ground stability concerns, and geometric limitations as the dike curvature attempts to follows inflections in the natural bank.

A dike alignment along Loggers Lane would avoid these impacts, and is particularly attractive where the foreshore area outside the dike can be preserved as a public park at its existing elevation. A primary dike alignment along Loggers Lane would also reduce any waterfront flood and erosion protection works to "secondary dike" status, meaning that such works may not have to meet the more stringent design requirements associated with a primary dike.

The existing CN Right-of-Way adjacent to Loggers Lane has historically been a critical grade constraint for any flood protection works. However, District staff advise that the CN Right-of-Way will be decommissioned in the near future. Decommissioning this Right-of-Way removes a significant constraint and could provide additional space for a future dike footprint.

While the Loggers Lane alignment offers notable advantages, it also introduces potential concerns such as phasing, safety, repairs and "raiseability", and connectivity for adjoining roads, businesses, and trails.

The choice of alignment is complex and cannot be assessed effectively in this provisional study. Nonetheless, KWL considers the choice of alignment crucial to the District's redevelopment vision and a key component of the District's overall flood hazard management strategy.

Decisions on development proposals would ideally be deferred until the comprehensive FHMP update is completed. However, KWL understands that deferral may not be realistic given the District's OCP commitment to redeveloping DPA-4.

To avoid prejudicing future flood protection decisions, development proposals submitted prior to the comprehensive FHMP update could provide allowance for the primary sea dike to be constructed to its ultimate height and geometry along either alignment. The alternative (i.e., selecting a dike alignment without appropriate technical review and stakeholder consultation) could result in an imbalance of costs, benefits, and risks between the District, future developers of adjacent properties, and residents and businesses within the downtown community.

Some specific implications for "interim" development proposals are summarized below:

- The developer would be responsible for designing and constructing that part of the foreshore flood and erosion protection works necessary to establish the QP's certification of the development as "safe for its intended use". These works would be regulated by IOD and may or may not become part of a future standard dike;
- The developer would be responsible for constructing all buildings to an FCL that reflects the Loggers Lane dike alignment. Structural, functional, and geotechnical design should provide for all structures to function "outside the primary dike"; and
- The design should accommodate tie-in and interface with Loggers Lane in its current configuration, but also allow for a future road raise to the ultimate dike crest elevation.

KWL recognizes that these measures are likely to be more stringent than what will be required by the updated FHMP. The District may wish to give developers the option to "park" their development (without prejudice) until the comprehensive FHMP update is completed.

4.2 Coastal Flood Hazard Water Levels

In 2012, KWL provided flood hazard management recommendations for the Squamish Oceanfront Development Corporation (SODC) site at the mouth of Mamquam Blind Channel. Some of these

previous recommendations are relevant for West Mamquam Blind Channel, and bear consideration herein as part of a consistent approach to flood protection.

As part of the SODC study, site-specific estimates for design water levels and wave analysis were completed by EBA Engineering Consultants (EBA) and summarized in a series of design memos; the latest dated November 30, 2010. The values used to design the shoreline erosion protection for SODC are summarized in Table 4-1 (EBA, 2010).

Table 4-1: Design Water level Components (EBA, 2010 and Ausenco Sandwell, 2011)

Design Water Level Component	EBA (2010)	Ausenco Sandwell (2011b)
Tide	2.65[a]	2.05[b]
Storm Surge		1.3[c]
Wind Set Up	0.023[d]	
Sea Level Rise	0.10[e]	1.0[f]
Wave Effect	1.93[g]	0.65[h]
Freeboard	0.6	0.6
Design Water Level (m GD)	**5.30**	**5.60**

Notes:
a. Estimated 200-year return period water level from analysis of recorded water levels at Point Atkinson (1914-2002): combined effect of tide and storm surge.
b. Higher High Water Large Tide: the average of the highest high waters, one from each of 19 years of predictions.
c. Estimated 500-year return period storm surge plus allowance for local wind set-up. Return period based on consideration of extensive foreshore development in downtown Squamish, industrial development and high ecological values (Ausenco Sandwell, 2011a).
d. Estimated 200-year return period wind setup.
e. Assumes 2 mm annual sea level rise for 50 year design life.
f. Recommended allowance for global sea level rise to 2100 time horizon. Regional adjustment = 0 m.
g. Maximum of estimated 2% exceedance wave run-up from site-specific wave and shoreline analysis (Zone 5: riprap shoreline).
h. Allowance for wave run-up on natural gravel – pebble beach shoreline.

Shortly after the EBA analysis was completed, new guidance was released by the BC Ministry of Environment for incorporating climate change and sea level rise in managing coastal flood hazards and land use (Ausenco Sandwell, 2011a and 2011b). Ausenco Sandwell (2011b) includes preliminary design water levels and flood construction levels for the Squamish River Delta incorporating sea level rise (year 2100 time horizon). These values are provided for comparison in Table 4-1.

The estimates in Table 4-1 are not directly comparable since the values provided by EBA are based on a detailed wave analysis and modelling study of the project site while the values provided in Ausenco Sandwell (2011b) are not intended to be site-specific. In general, a site-specific assessment is required to properly assess wave effects (KWL, 2011).

In addition to differences in wave analysis, EBA's storm surge estimate is for a 200-year return period event while the storm surge allowance suggested by Ausenco Sandwell represents a 500-year return period scenario.

The main components estimated by EBA (2010) that differ from the recommendations in KWL's 2011 report "Coastal Floodplain Mapping – Guidelines and Specifications" (KWL, 2011) are summarized in the following sections.

4.2.1 Tide and Storm Surge

EBA prepared a frequency analysis of water levels to estimate a combined 200-year return period water level resulting from combined tide and storm surge (EBA, 2010). In contrast, the Guidelines report recommends that the Higher High Water Large Tide water level be independently added to the estimated return-period storm surge (KWL, 2011).

EBA (2010) also includes an analysis of separate tide and storm surge effects. The estimated 200-year return period storm surge is 1.09 m.

Ausenco Sandwell (2011a) notes that the level of development at Squamish may warrant the selection of the 500-year return period storm surge. The 500-year return period storm surge is not provided in EBA (2010), but may be on the order of 1.3 m, as per the combined storm surge and wind set-up value estimated by Ausenco Sandwell (2011b) as shown in Table 4-1.

4.2.2 Sea Level Rise

The EBA (2010) sea level rise allowance assumes a 2 mm/year increase over a 50-year design life based on a 1997 study by Thomson and Crawford. In contrast, Ausenco Sandwell (2011b) considers a more recent review of sea level rise projections and research and recommends an allowance of 1 m for global sea level rise for the year 2100 time horizon. This global allowance is typically adjusted for regional ground movement (i.e., uplift or subsidence). Squamish appears to be neutral and therefore has a regional adjustment of 0 m.

Sea level rise is predicted to exceed 1 m beyond year 2100 (Ausenco Sandwell, 2011b). These allowances are based on the latest climate projections and are considered realistic estimates; conservative estimates are significantly higher.

Given the long-range planning horizons associated with redevelopment of West Mamquam Blind Channel, the full 1 m provision for Sea Level Rise to year 2100 should be considered as a minimum value for planning purposes.

4.2.3 Wave Effect

EBA (2010) performed a site-specific assessment of the proposed SODC development shoreline to estimate wave run-up. The SODC shoreline was sub-divided into eight zones to represent different materials and shore gradients. The resulting wave run-up for the 200-year return period storm varies from about 1.9 m at the exposed headland to approximately 0.4 m for the sheet pile frontage at the upstream end of SODC on Mamquam Blind Channel.

The EBA model indicates that wave heights will continue to decrease moving up Mamquam Blind Channel. However, EBA did not explicitly consider wake effects for vessel traffic, which may govern above SODC as waves from Howe Sound are diffused and refracted. In addition, wave run-up can vary somewhat with the shoreline angle and surface treatment. In the absence of specific foreshore designs and additional analysis for DPA-4, EBA's calculated run-up of 0.4 m at the upstream end of SODC is considered the best available information for the study area.

EBA's 0.4 m wave run-up is validated by a similar finding of 0.4 m by Golder Associates in a more qualitative site assessment prepared for a 2008 development proposal.

The Ausenco Sandwell (2011b) estimate of 0.65 m for wave run-up on a natural gravel-pebble beach shoreline is very similar to the wave run-up estimated by EBA (2010) for the two sandy beaches at the SODC development. Ausenco Sandwell did not consider different shoreline types or site-specific conditions.

According to Ausenco Sandwell (2011b), for coastal flooding hazard management the required allowance for wave effect can be approximated by taking one-half of the calculated run-up.

KWL understands that the District has not historically considered tsunami hazards as a component of their community flood protection strategy, although this may be introduced as part of the comprehensive FHMP update. In the interim, it will be the responsibility of the QP to consider the potential implications of tsunami hazard in preparing their Flood Assessment report, as required by the 2004 Flood Hazard Area Land Use Management Guidelines.

4.2.4 Ultimate Flood Construction Level

Following the KWL 2011 Guidelines report, and combining the EBA (2010) and Ausenco Sandwell (2011b) values as summarized in the table below yields an ultimate Flood Construction Level (FCL) of 5.0 m for the year 2100 time horizon. Mitigation of the coastal flood hazard beyond the year 2100 time horizon is discussed separately in the next section.

Table 4-2: Proposed Ultimate Flood Construction Level

Design Water Level Component	(m)	Note
Tide	2.05	Higher High Water Large Tide.
Storm Surge	1.09	From EBA (2010). 200-year RP.
Wind Set Up	0.02	From EBA (2010). 200-year RP.
Sea Level Rise	1.00	Year 2100 time horizon.
Wave Effect	0.21	50% of the 2% exceedance wave run-up, 200-year RP for Zone 1: sheet piles, from EBA (2010).
Freeboard	0.60	Provincial Standard
Provisional Ultimate Flood Construction Level (m), rounded	**5.0**	

The provisional FCL sets the elevation for habitable space as well as corresponding crest elevations for primary structural flood mitigation works. A lower elevation can be applied to undeveloped areas (e.g. parks), roads or parking areas.

The provisional FCL presented in the above table is less than the reference value provided for Squamish by Ausenco Sandwell (2011b) primary due to the site-specific allowance for wave effect and the adoption of a 200-year storm surge.

The 200-year storm surge has been adopted on a provisional basis to provide a standard of protection that is nominally equivalent to that applied for upstream river dikes. Adopting a higher standard of protection (e.g., 500-year storm surge as recommended by Ausenco Sandwell 2011b) may be appropriate; however, such decisions can involve transfer of risk and are beyond the scope of this provisional guidance. The selection of an appropriate return period for coastal flood defences should be revisited in the comprehensive FHMP update.

The provisional ultimate FCL provided herein is intended to allow time-critical development proposals to proceed while the comprehensive FHMP update is underway. It is assumed that the provisional ultimate FCL will be superceded or confirmed as part of the larger FHMP update, which is expected to balance coastal flood hazard protection against the risks of inundation from an upstream dike breach (not addressed in this memorandum).

4.2.5 Mitigation of Future Coastal Flood Hazard

Site FCLs presented above are tied to the year 2100 sea level rise planning horizon. However, global sea level rise is projected to continue into the future, and is likely to accelerate.

The current recommended allowance for sea level rise to year 2100 is 1.0 m. The current recommendation (Ausenco Sandwell, 2011b) for sea level rise to year 2200 is 2 m (i.e., an additional metre above the year 2100 allowance). More conservative estimates suggest that year 2200 sea level rise could be as high as 3.4 m above present day.

In some cases, development within the West Mamquam Blind Channel area could have a lifespan that extends beyond year 2100. In other cases, the development could establish a form or precedent that would preclude future raising or expansion of structural flood protection works. In such cases, it would be appropriate for the District to make allowance for mitigation of coastal flood hazard *beyond* the year 2100 time horizon.

Future coastal flood hazard (beyond the year 2100) may be mitigated by raising an existing dike or sea wall, provided sufficient land has been set aside for this purpose and the underlying works have been designed appropriately.

4.2.6 Within-Site Variation of Ultimate FCL

In coastal areas, it is not uncommon for FCLs within dike-protected areas to include a reduced wave allowance (relative to foreshore areas exposed to direct wave attack). For the purposes of this provisional guidance, it is assumed that the FCL will be maintained at 5.0 m for all developments within the West Mamquam Blind Channel area.

This assumption reflects the uncertainty surrounding the alignment of the community's primary sea dike, since a setback alignment along Loggers Lane would leave some buildings outside the primary dike and potentially exposed to some wave action.

In general, elevations for roads, walkways, parks, and parking areas can be lower than the FCL. These decisions should be reviewed on a case-by-case basis.

4.2.7 Consideration for River Dike Breach

While KWL has selected a provisional ultimate FCL based solely on the coastal flood hazard, we note that an FCL equal to or exceeding the dike crest may be necessary to accommodate outflow overtopping of the sea dike during an upstream river dike breach scenario. Detailed consideration of river dike breach scenarios are beyond the scope of this provisional assessment and should be considered as part of the comprehensive FHMP update.

4.2.8 Interim Dike Crest Elevation

The District will be responsible for determining the extent of flood protection works that must be constructed as part of any new development, and to what extent future flood protection works may be deferred. This decision is largely independent of the dike alignment, since some degree of flood and erosion protection will be required along the waterfront even if the dike is constructed along Loggers Lane. On a case-by-case basis, the District may consider a QP's recommendation for an "interim" dike crest elevation that must be achieved at initial construction, with provisions for construction to the ultimate FCL at a later date. An example of this approach is provided in a September 2008 design report prepared by Golder Associates for BCR Properties and provided by the District for KWL's review (Golder, 2008b).

Potential advantages of an "interim" dike crest elevation would include reduced costs (for the developer) and less abrupt grade changes along a developing foreshore trail. The primary disadvantage is that the District (as the local diking authority) would likely have to accept responsibility for implementing any future upgrades.

Engineering studies in 1994 and 1999 recommend a design elevation of 3.3 m for the Squamish Sea Dike. KWL notes that a combination of updated estimates for HHWLT, storm surge and wave allowance exceed this value (i.e., without making any allowance for climate change or freeboard). The previous recommendation of 3.3 m is therefore no longer considered a realistic interim dike crest elevation.

It may be reasonable for the QP to consider a reduced storm surge allowance if buildings, landscaping, and appurtenant works are designed to accept infrequent inundation. In addition, sea level rise is a continuous process over time and the required allowance could be reduced significantly where provision is made to accommodate future raising and where the District agrees to accept responsibility for completing such work. The QP may wish to explore a risk-based analysis that considers increasing sea levels over the expected design life of the structure.

Assuming the elevation of the existing waterfront pathway at Marina Estates is about 3.3 m, a visual assessment suggests that it may be feasible to raise the pathway to an elevation of about 4.3 m with relatively minor impacts to the adjacent development. For illustration purposes only, an example of a corresponding risk-based calculation is outlined in the table below.

Table 4-3: Example Calculation for an Interim Dike Crest Elevation

Design Water Level Component	(m)	Note
Tide	2.05	Higher High Water Large Tide.
Additional Allowance for Storm Surge	0.93	From EBA (2010) based on 10-year RP combined tide + surge.
Wind Set Up	0.01	From EBA (2010). 50% of 200-yr RP.
Sea Level Rise	0.50	Year 2050 time horizon.
Wave Effect	0.21	50% of the 2% exceedance wave run-up, 200-year RP for Zone 1: sheet piles, from EBA (2010).
Freeboard	0.60	Provincial Standard
Revised Interim Dike Crest Elevation (m), rounded	**4.3**	

To successfully evaluate the suitability of an "interim" dike crest elevation, the District would need to understand the costs of future upgrading commitments as well as appropriate timelines and triggers for implementation. It is expected that these factors would be discussed in the QP's flood assessment report.

4.3 Building Setbacks

The minimum engineering building setback required for any development should be the greater of:

- setback required to protect against waves and erosion; and
- setback to allow implementation of the ultimate structural flood mitigation works.

Additional setback considerations for environmental purposes may also apply.

Appropriate setbacks would normally be confirmed on a site-specific basis by the QP responsible for the Flood Hazard Assessment. However, the presence of a public trail and the role of the District as operation and maintenance authority for any flood and erosion protection works suggest that a minimum allowance should be specified to guide the QP in preparing development applications.

The two classes of setback allowance are discussed individually below.

4.3.1 Wave and Erosion Setback

The 2004 Flood Hazard Area Land Use Management Guidelines prepared by the BC Ministry of Water, Land and Air Protection (now Ministry of Forests, Lands and Natural Resource Operations) include the following statement for coastal flood hazard areas within the Strait of Georgia region:

> *"Buildings should be setback 15 metres from the natural boundary of the sea."*

Allowing for sea level rise impacts, the future estimated natural boundary of the sea is estimated to be defined by the intersection of the ultimate FCL less the freeboard with the ground surface.

According to Ausenco Sandwell (2011b), all new buildings that fall within the "sea level rise planning area" for a given time horizon such as the year 2100 should be provided with a building setback. Ausenco Sandwell recommends building setback to protect from:

- wave and splash-related impacts; and
- erosion of the shoreline.

The building setback for wave and erosion protection recommended by Ausenco Sandwell (2011b) is:

> *"[…] the greater of 15 m from the future Estimated Natural Boundary or a distance to where the native land elevation equals the Flood Construction Level."*

Ausenco Sandwell (2011b) does not offer guidance on setbacks for sites in which the shoreline will see major modifications as part of development. For West Mamquam Blind Channel, KWL assumes that the entire site will be modified and raised, that building FCLs will consider the year 2100 sea level rise planning horizon, and that the shoreline will be protected to minimize the risk of shoreline erosion.

For the purposes of this project, KWL interprets building setbacks as being measured from the engineered top of bank (i.e., the waterside crest of fill not including erosion protection or slope retaining measures). The setback would ideally be measured to the property line (i.e., the building would itself be set back some additional distance from the property line).

It is reasonable for the QP to consider a reduced building setback along the Mamquam Blind Channel given the modest size of expected waves, and provided the QP explicitly confirms that the shoreline protection is "safe for its intended use" (i.e., the improved shoreline may be considered non-erodible). The reduced setback must allow adequate space for the waterfront pathway, for wave and splash impacts, and for access to repair and maintain the erosion protection works.

KWL recommended a reduced setback of 10 m for the inner end of the SODC development along Mamquam Blind Channel. This is considered a realistic minimum precedent for "interim" development proposals along West Mamquam Blind Channel.

4.3.2 Dike Setback

The 2004 Flood Hazard Area Land Use Management Guidelines include the following statement for areas protected by standard dikes:

> *"Buildings should be located a minimum of 7.5 metres away from any structure for flood protection or seepage control or any dike right-of-way used for protection works. In addition, fill for floodproofing should not be placed within 7.5 metres of the inboard side of any dike right-of-way used for flood protection works."*

The standard 7.5 m setback is reflected in the 1994 FHMP, the 2003 BC Dike Design Guidelines and the 2012 APEGBC Professional Practice Guidelines for Legislated Flood Assessments.

The BC Inspector of Dikes typically defines the inboard toe of a dike as the location where a standard dike backslope would intersect the native ground.

While 7.5 m setback from the dike toe is a well-established convention, there are numerous examples of situations where the developer, local authority, and provincial Inspector of Dikes have worked together to provide a site-specific exemption. A recent example of this is the Rivendale development in Squamish, where KWL understands that District and IOD accepted a reduced minimum setback of 2.7 m from the interpreted dike toe.

It would be reasonable for the District to waive the setback provisions regarding floodproofing fill where the floodproofing fill is provided as part of the initial design and construction, where the floodproofing fill is compatible with the abutting dike fill, and where the composite earthfill structure has been assessed as part of the QP's flood assessment report. However, the presence of floodproofing fill should not be considered to reduce the footprint of the standard dike cross-section that would be constructed in the absence of any floodproofing fill. In such cases, for the purposes of determining setback, an inboard dike toe should be implied using the approach defined by IOD.

If a proposed development includes a foundation below the existing grade, the inboard dike toe should be defined as the location where a standard dike backslope would intersect the grade of the subsurface foundation. A reduced setback could be considered in such cases; however, KWL does not recommend allowing any structure to encroach into the hypothetical dike cross-section.

4.3.3 Rights of Way

It is assumed that the District would acquire legal access to operate, maintain, and repair and flood or erosion protection works as a condition of development approval under a Statutory Right-Of-Way (SROW) agreement. It would be appropriate for the SROW limits to incorporate the minimum setbacks defined above.

Because the SROW agreement will be established concurrently with design of flood protection works to at least year 2100, an additional setback from the edge of the established Right-of-Way may not be required.

IOD may ask to be a signatory to a SROW agreement to ensure they have the opportunity to consult on any future changes.

4.4 Restrictive Covenants

In addition to establishing FCLs, building setbacks, and SROW, it is appropriate to require covenants be established on the title of all West Mamquam Blind Channel properties for purpose of implementing floodproofing measures in perpetuity and further mitigating the District's risk. Covenants can be used to:

- document and acknowledge flood hazard(s) affecting the property;
- incorporate flood assessment reports prepared by a QP (where applicable);
- specify the year 2100 FCL (and/or 2200 FCL, if appropriate) established for the property;
- document any restrictions on infrastructure or construction below the FCL;

- provide notice of any allowances and restrictions on land and structure use;
- provide notice that the property may be located outside the future sea dike (where appropriate);
- clarify that future FCL levels may vary depending on future sea level rise projections; and
- specifically indemnify the District against any responsibility for flood-induced damages.

Section 25-6 of the OCP requires "save harmless" restrictive covenants pursuant to Section 219 of the *Land Title* Act prior to any subdivision, rezoning or building permit approval. The District may wish to have legal counsel prepare a covenant template as the basis for discussions with developers and QPs.

4.5 Design Issues

The District may wish to offer the QP some guidance on a number of specific design issues as discussed below.

4.5.1 Seepage Analysis

The QP is responsible for evaluating seepage through a proposed dike as part of their flood assessment report. In situations where relief drains are required to mitigate foundation pressures or high exit gradients, this should include evaluation of environmental impacts of any saltwater interception, since this would be delivered to the stormwater system.

Minimum exit gradients should consider the findings of the 2008 dike assessment report prepared for the District by Thurber Engineering.

4.5.2 Seismic Performance

IOD (2013) has confirmed that they will apply the most recent seismic guidelines to any new sea dike constructed by or on behalf of the District. Developers should be advised of this, and should be encouraged to contact IOD for the latest information and revisions.

IOD has also indicated that some flexibility in regard to seismic performance of foreshore flood protection works may be considered if a primary dike alignment is provided along Loggers Lane.

4.5.3 Off-site Works

To avoid a transfer of risk scenario, the QP's flood assessment report should confirm that a seamless, geometrically-acceptable, equitable, and technically-sound transition of flood and erosion protection works can be achieved between the proposed development property and any adjacent property, under both existing (i.e., initial construction) and future (i.e., ultimate) conditions.

4.5.4 Vegetation

Landscaping should be appropriate for a flood protection context. The developer's QP should have knowledge of, and access to, appropriate guidelines such as the 1999 Vegetation Management Guidelines published by the then-Ministry of Environment, Lands and Parks.

4.6 Operation and Maintenance Considerations

As part of design, the QP should prepare an O&M manual for all flood and erosion protection works. The District may wish to provide the QP with a copy of the District's existing O&M manual to facilitate this task; alternatively a new O&M manual may be prepared based on templates available from IOD.

Consideration of O&M needs can affect design choices; for example, a paved surface may be ideal for a public trail but could be damaged by tracked equipment carrying out maintenance activities.

Cost estimates for operation, maintenance, and periodic repair of the proposed works should be included as part of the operation and maintenance manual.

4.7 Regulatory Considerations

Flood and erosion protection works constructed along foreshores or within the riparian area will require approval from regulatory agencies or organizations including Transport Canada (Navigable Waters), Fisheries and Oceans Canada (DFO), Ministry of Forests, Lands and Natural Resource Operations, and the Squamish Estuary Review Committee (SERC). Environmental limitations may influence the location or configuration of flood and erosion protection works and their associated setbacks; environmental and engineering needs are best evaluated concurrently in any development review.

Development proposals submitted prior to the comprehensive FHMP update will be among the first approvals for the West Mamquam Blind Channel area, and as such may establish precedent for future flood and erosion protection works. To proactively manage future challenges, the District may request that regulators consider potential cumulative impacts of a precedent-setting development decision. Developers should be advised accordingly, particularly in situations where the District has already explored and/or taken action on cumulative impacts issues.

For example, the 1999 Squamish Estuary Management Plan states that:

> *"[I]t is intended that habitat losses, or HADDs, as a result of projects within and/or adjacent to the Industrial/Commercial area that impact habitat within this designation area will be pre-compensated through this Plan, by the protection of the conservation areas and the completion of the habitat improvement projects illustrated in Figure 9. Therefore, no further compensation will be required for projects within the Industrial/Commercial Area including, for example, along the western edge of the Mamquam Channel in downtown Squamish."*

This implies that existing District initiatives may provide some "pre-compensation" for projects implemented along the West Mamquam Blind Channel foreshore in accordance with the OCP and previous work through SERC. Some limitations would likely apply to works offset by pre-compensation, particularly where the proposed works conflict with objectives outlined in the OCP (e.g., significant infilling of the existing Mamquam Blind Channel). Draft SERC Guidelines from 2006 (SERC, 2006) highlight channelization of Mamquam Blind Channel as an outstanding concern.

5. Recommendations

The preceding discussion outlines the basis for provisional guidance regarding flood and erosion protection to support development within the West Mamquam Blind Channel area. Pending completion of the comprehensive FHMP update, KWL recommends that the District adopt the following key elements as the core of a provisional flood and erosion protection strategy for West Mamquam Blind Channel:

1. Update the OCP to incorporate flood and erosion protection considerations into guidelines for specific Development Permit Areas.
2. Complete the comprehensive FHMP update as soon as possible, and allow developers the option to "park" development proposals until the update is completed.

3. Require that all "interim" development proposals (i.e., those reviewed prior to or during the FHMP update) provide a flood assessment pursuant to the APEGBC Professional Practice Guidelines and Section 25-5 of the OCP, concluding that the land is "safe for its intended use".
4. Defer a final decision on the primary dike alignment (i.e., foreshore or Loggers Lane) pending recommendations from the comprehensive FHMP update, and require that all "interim" development proposals make allowance for both primary sea dike alignments.
5. Adopt SLR forecasts of 1 m by 2100 and 2 m by 2200 on a provisional basis for planning and flood protection purposes.
6. Adopt a provisional ultimate FCL of 5.0 m to allow time-critical development reviews to continue while the comprehensive FHMP update is underway.
7. Increase the provisional ultimate FCL in cases where development has a design life extending beyond year 2100, or where development could establish a form or precedent that would preclude future raising or expansion of structural flood protection works.
8. Consider interim dike crest elevations based on a QP's recommendation in situations where the advantages outweigh the District's projected costs of future upgrades to meet the provisional ultimate FCL.
9. Adopt a wave and erosion setback of 15 m from engineered top of bank, with a reduction to 10 m permitted where environmental and local development (e.g., recreational) objectives permit, and where engineering justification and sign-off is provided by the QP.
10. Require dike setbacks in accordance with the 7.5 m minimum standard from inboard toe of any flood protection structure, except where a lesser setback is recommended in a QP's flood assessment report and can meet the District's flood protection needs in perpetuity.
11. Waive requirements for setback of floodproofing fill from a flood protection structure where the floodproofing fill and flood protection structure will be constructed concurrently under the QP's design and supervision.
12. Waive requirements for setback from a SROW where the SROW is established concurrently with development approvals and where SROW can accommodate future works plus appropriate setback.
13. Implement appropriate restrictive covenants as outlined in Section 25-6 of the OCP.
14. Assist QPs by identifying relevant design targets established through, or applied to, previous District projects, including seepage exit gradients, provincial seismic performance standards, geometric and technical transitions, vegetation requirements for flood protection works, and potential regulatory issues such as cumulative impacts assessment or pre-compensation.
15. Consult with all relevant stakeholders (e.g., environmental, engineering, and planning) early in the review of any development proposal to minimize design iterations.
16. Require an O&M manual (or modifications / additions to the existing District O&M manual) for any new flood protection works, including estimates of future maintenance and repair costs.

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Revision History

Revision #	Date	Status	Revision	Author
0	June 12, 2013	Draft	-	DR
1	July 10, 2013	Draft	Incorporated comments from District of Squamish	DR
2	July 18, 2013	Final	Removed draft marks & Tsunami header at District request	DR

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District of Squamish
West Mamquam Blind Channel
Provisional Guidance for Coastal Flood Hazard Management

Legend

District of Squamish Cadastral Information

Study Area

Squamish Oceanfront Development Corporation (SODC) Lands

Hwy 99 to Whistler

Hwy 99 to Vancouver

Howe Sound

Crescent Slough

Cattermole Slough

Mamquam Blind Channel

CN Rail Mainline

Bailey St

Buckley Ave

Hunter Pl

Cleveland Ave

Loggers Lane

Pemberton Ave

Winnipeg St

Victoria St

Main St

Vancouver St

1st Ave

2nd Ave

3rd Ave

4th Ave

5th Ave

6th Ave

Smoke Bluff Rd

Vista Cres

Plateau Dr

View Pl

Northridge Dr

Hospital Pl

Harbour View Pl

Clarke Dr

Behrner Dr

Maple Dr

Chestnut Ave

Cedar Dr

Hemlock Ave

Alder Pl

Garden Pl

Guilford Dr

Magnolia Cres

Westview Ave

Highway 99

Valley Dr

Stawamus Rd

Loggers Lane

KERR WOOD LEIDAL
consulting engineers

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Project No.	Date
463-292	July 2013

Study Area

Figure 1