CITY OF NANAIMO
THE HARBOUR CITY

# SEA LEVEL RISE STUDY

FINAL – DECEMBER 2018

Associated Engineering

CANADA BEST MANAGED COMPANIES
Platinum member

DHI

ASSOCIATED ENGINEERING

QUALITY MANAGEMENT SIGN-OFF

Signature

Date 2018/12/14 (26-18-081)



**The preparation of this study was carried out with assistance from the Government of Canada and the Federation of Canadian Municipalities. Notwithstanding this support, the views expressed are the personal views of the authors, and the Federation of Canadian Municipalities and the Government of Canada accept no responsibility for them.**

# Executive Summary

The City of Nanaimo is preparing for the future impact of climate change through their upcoming Climate Change Resiliency Strategy. The City's long coastline on the Strait of Georgia is very important for the economic, social, and environmental health of the City. Situated along the shore are numerous public parks and infrastructure, important environmental resources and habitat, private residences, major ferry terminals, and large industrial sites. Understanding the potential hazards and increased risk that climate change brings is key to planning and building towards a resilient City.

The purpose of this Sea Level Rise Study is to provide localized information on potential flood levels to facilitate informed planning. The traditional standard, and what has been used in this study, is flood analysis based on the 1-in-200-year event – the event that has 0.5% probability of occurring in any given year. To allow for long term planning and timing of upgrades, we have created maps for scenarios reflecting the years 2018, 2050, and 2100.

The Flood Construction Level (FCL) is useful in establishing the minimum elevation that buildings or infrastructure may be constructed to, to protect them from water levels that are smaller than or equal to the specified flood event. Determining the FCL includes summing the high tide, storm surge, and wind and wave effects. An additional parameter, freeboard, is added on top of this to provide an extra factor of safety. As coastal effects on maximum sea level are highly variable based on bathymetry and exposure, detailed modelling of wave and wind effects was completed to provide FCLs for shorter sections of shoreline with uniform characteristics. Mapping the FCL gives a strategic-level of understanding of areas which may be impacted, now or in the future, by elevated sea levels.

Results from the study show that there are several low-lying areas along the coastline which are vulnerable to sea level rise. Specifically, Departure Bay, Duke Point, Protection Island, and areas of downtown have land that is located below the FCL. Assessing the extent of risk posed in these areas would require further work, but these are the areas the City should focus on to mitigate future loss. The areas that are built up on higher rocky bluffs along the coast, such as the North Slope, have a greater degree of protection to sea level rise.

In addition to sea level rise effects, coastal erosion was investigated to estimate the rate of coastal retreat. Erosion effects were found to be concentrated in isolated locations and are primarily attributed to areas with softer coastlines and high-energy wave/tidal action. Generally, the coast is relatively stable and in agreement with erosion rates in published literature. We recommend that the City continue to monitor areas of concern such as the North Slope.

# Table of Contents

# List of Tables

# List of Figures

# List of Abbreviations

| | |
|---|---|
| AAD | Annual Average Damage |
| AEP | Annual Exceedance Probability |
| CBR | Cost-Benefit Ratio |
| CGVD1928 | Canadian Geodetic Vertical Datum 1928 |
| CGVD2013 | Canadian Geodetic Vertical Datum 2013 |
| DEM | Digital Elevation Model |
| DTM | Digital Terrain Model |
| EC | Environment Canada |
| EVA | Extreme Value Analysis |
| FCL | Flood Construction Level |
| FEMA | Federal Emergency Management Agency |
| GIS | Geographic Information Systems |
| HHWLT | Higher High Water Large Tide |
| LiDAR | Light Detection and Ranging |
| MCA | Multi-Criteria Analysis |
| MFLNRO | Ministry of Forests, Lands and Natural Resource Operations |
| MWD | Mean Wave Direction |
| MWL | Mean Water Level |
| NOAA | National Oceanic and Atmospheric Administration |
| NPV | Net Present Value |
| SLR | Sea Level Rise |
| SLRMP | Sea Level Rise Management Plan |
| SWL | Still Water Level |

# 1 Introduction

## 1.1 PROJECT BACKGROUND

The City of Nanaimo ("CoN", "the City") is currently producing a Climate Change Resilience Strategy (CCRS) as part of its preparation for climate change. Other documents, including the Official Community Plan (2008), Community Sustainability Action Plan (2012) and the City of Nanaimo Strategic Plan Update (2016-2019), will combine with the CCRS to inform the City's climate change adaptation. A major component of preparing for climate change is the understanding of sea level rise and how it may impact the coastal areas of Nanaimo. Sea level rise (SLR) denotes the increase in mean sea levels as a result of global warming driving thermal expansion of seawater and melting terrestrial ice-sheets and glaciers.

To support the City's Climate Change Resilience Strategy, Associated Engineering (AE) and our team of subconsultants, DHI Water & Environment, Inc. (DHI) and Westmar Advisors Inc. have been retained to complete a Sea Level Rise Study; which will help inform the upcoming CCRS. The objective of the Sea Level Rise Study has been to identify coastal areas of Nanaimo that are vulnerable to sea level rise and storm surge for years **2050** and **2100**. The **present-day** (2018) conditions were also analysed to establish a study benchmark. Specifically, the intent is to develop maps showing the 200-year FCL (Flood Construction Level) for the specified years.

FCLs are used to keep living spaces and areas used for storage of goods above flood levels. The 200-year FCL is the traditional standard in BC for floodplain mapping and represents the expected water level for the 200-year event plus an additional allowance in height defined as freeboard. Specific to coastal mapping, the development of the FCL takes account of the effects of relative sea level rise (SLR), an adjustment to the SLR accounting primarily for uplift or subsidence of the land surface, tide, storm surge (regional and local), wave setup and wave runup, along with a nominal allowance for freeboard. A 200-year event refers to the flood level that has a 1 in 200 chance (0.5%) of being equalled or exceeded in any given year.

In addition to the development of the FCL for the three time-horizons in question, the potential rate of coastal retreat (i.e. coastal erosion) has also been estimated in this study.

Project work began upon appointment in mid-June 2018, with review of various sources of background data, described in Section 1.5. During the project period, team members attended an internal CoN stakeholder meeting that helped define the scope of works and potential deliverables. We also conducted a boat survey of the coastline in early September 2018, the goal of which was to photograph substantial swathes of coastline in support of the erosion analysis.

We subsequently completed coastal and erosion analyses, as per the methodologies presented in Sections 2 and 3. These results were then used to inform a strategic-level risk assessment and produce finalised **Flood Construction Level Mapping** for the three time-horizons mentioned above.

## 1.2 PROJECT LOCATION

The City of Nanaimo is located on the eastern side of Vancouver Island, as shown in Figure 1-1. The City has a land area of approximately 91 $km^2$ and a coastline, as shown in Figure 1-2, along the Salish Sea that will be vulnerable to sea level rise. Elevations in the study area range from sea-level in lowland coastal areas, to 340 m (geodetic datum) in Westwood Lake Park, to the west. Much of the coastline through the main urban centre is elevated and protected by way of rock armour revetments. The coastline is well developed with numerous private residences, tourist amenities, commercial industries and transportation facilities.

The study area also includes Newcastle and Protection Islands. Newcastle Island is a marine provincial park, approximately 3.3 $km^2$ in area. There is limited infrastructure on the island, with no risk receptors located on its coastline. Protection Island is an inhabited island, approximately 0.71 $km^2$ in area. The island is densely developed, with numerous properties and transportation infrastructure being potentially vulnerable to extreme changes in coastal processes.

Gabriola Island, though not a focus of this study, does exert influence of the coastal processes in Nanaimo Harbour, being located immediately to the east. Gabriola Island is shown in Figure 1-1, directly underneath the inset map.

The study area covers a range of coastal settings, including high rocky bluffs, developed and undeveloped shoreline with varied exposures and beach composition (shingle, gravel, sand and silt), estuaries and lagoons, coves, to name a few. The study area is affected by coastal processes originating from within the Strait of Georgia. These processes include large tidal variations, but the City shoreline area is sheltered from extreme open ocean waves and tsunamis. Local strong winds can generate moderate local waves and storm surge from within the Strait. Wind waves in the middle of the Strait, at the Halibut Bank buoy, indicate significant wave heights reaching nearly 5 m at the extreme. Astronomical tide ranges are somewhat greater than 5 m, with peak residual storm surges (deep-water plus local) of generally less than 1.5 m, based on the tide gauge at Nanaimo Harbour. Local storm surge will typically be much lower along most of the coastline where steeper sloped bottom contours exist. In areas with extensive shallow mild sloping bottom contours, local storm surge can be somewhat more significant.

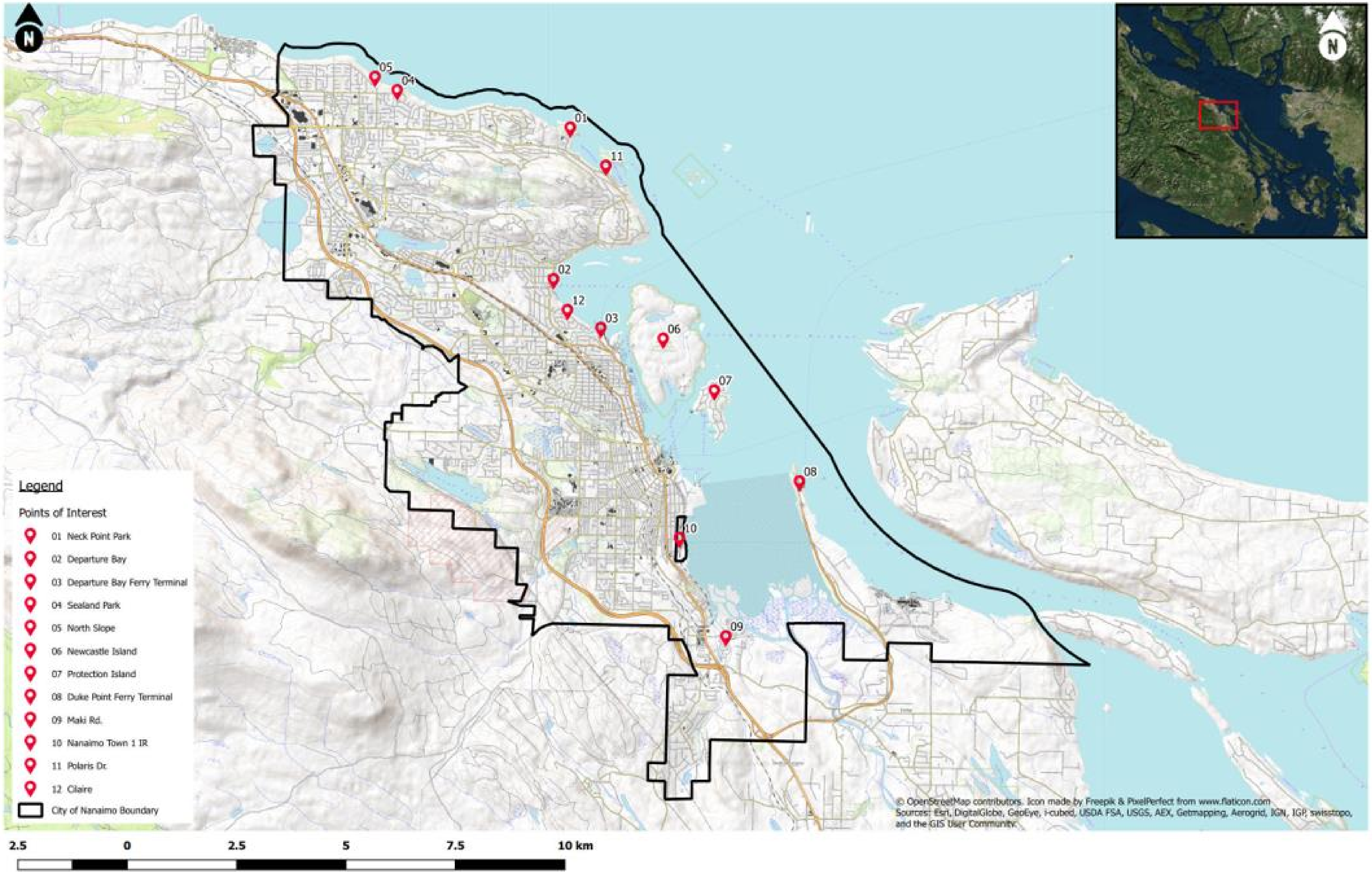


**Figure 1-1**
**Project Overview and Key Location Map**


**Figure 1-2**
**Project Chainage Map**

**Figure 1-3**
**Departure Bay, Looking North**

From discussions with City staff and photographic evidence provided to us at the outset of the project, there are a number of locations directly impacted by coastal processes at present. The Departure Bay area (study chainage 18+000 m) regularly sees elevated tide and wave levels. In particular, Battersea Road (study chainage 18+300 m), adjacent to Cilaire, is subjected to frequent overtopping due to a combination of high tides and wave runup[1]. It is not uncommon for coastal debris to be washed up onshore many metres inland during major storm events. This has also been known to occur on Departure Bay Rd. (study chainage 17+800 m), which can be accompanied by backing up and surcharging of the local storm system that discharges to Departure Bay beach. In terms of relative elevation, proximity and density of development, Departure Bay seems to be the area most vulnerable to sea level rise in the City.

The North Slope area of Nanaimo has seen significant mass-wasting/slope failures in recent history. This area is generally defined as being approximately between Lewis Road (study chainage 0+850 m) and Norasea Road (study chainage 4+000 m). Significant development in the area, and subsequent slope

[1] Discussion with City of Nanaimo Drainage Dept. personnel.

failures have triggered the completion of a number of geotechnical stability assessments. The shoreline is approximately 40-50 m high, with a gradient of 25-30 deg. The stratigraphy of the local area has been well documented by other studies; however, the underlying surficial geology could be classified by the following[2]:

- Marine/glaciomarine sand & gravel.
- Vashon Drift material.
- Quadra Sediments.
- Basal Till.

Weak layers of silt/clay, and relative steepness, give rise to the area's vulnerability to slope failure. Coastal erosion can contribute to this mass-wasting, by attacking and compromising the toes of slopes. However, it is most likely not the sole cause; slope instabilities and shallow failures can occur under wet conditions through the winter months.

[2] Figure 2.1 North Shore Stability Study; Generalized Hydrogeologic Cross Section for Regimes II & III. Golder Associates. April 2000

**Figure 1-4**
**Evidence of slope failure; close to Driftwood Place 2017**[3]

## 1.3 TSUNAMI RISK

### 1.3.1 Summary of Risk

The potential impact of tsunamis reaching the Nanaimo shoreline and influencing the FCL mapping is considered briefly. This assessment is preliminary and should not be construed as replacing the need for an engineering study of tsunami impacts on FCL mapping.

A general assessment of tsunami impacts on the Canadian coastline has been given by Leonard, Rogers and Mazzotti[4]. The following commentary relies on this and simplifies portions of this, but also extends general findings to conditions at the Nanaimo coastline on the basis of judgement. There are three kinds of tsunamis or slide-generated waves that may reach Nanaimo. Each of these, together with an assessment of the magnitude of the resulting wave runup along the Nanaimo shoreline may be summarized as follows:

[3] Storm Group – Erosion and Safety Location Areas. City of Nanaimo. October 19th 2017.

[4] Leonard, L.J., Rogers, G.C., and Mazzotti, S. 2012. A Preliminary Tsunami Hazard Assessment of the Canadian Coastline. Geological Survey of Canada, Open File 7201.

Pacific Ocean Tsunamis: For tsunamis originating from the Pacific Ocean, the most severe possibility is associated with a large (e.g. magnitude 9.0) earthquake along the Cascadia subduction zone (i.e. "the big one"). Computer models show that the resulting tsunami waves will diminish as they move through Juan de Fuca Strait and between the San Juan and Gulf Islands and then northward along the Strait of Georgia. When they reach Nanaimo, the tsunami waves are expected to result in runup of 0.5 – 1.0 m. With respect to the probability of such an event occurring, it is known that the last great earthquake occurred in 1700.

Locally-generated Tsunamis: Locally-generated tsunamis may arise from a local earthquake at shallow crustal depths or from a submarine slide. The most severe possibility is associated with a large submarine slide corresponding to a collapse of the front of the Fraser River delta. However, given the relative location of Nanaimo, there would be a notable reduction of wave energy, and the resulting wave runup along the Nanaimo shoreline is again expected to be 0.5 – 1.0 m. The geological record has revealed no evidence of tsunami deposits along the Fraser River delta, so that the corresponding probability of this large collapse is considered to be very low.

Waves Generated by Landslides and Debris: To be significant, such waves would require a large, sudden slide associated with a steep, unstable coastline very nearby (similar to the coastline along Howe Sound). Consequently, damaging waves due to a landslide or debris avalanche are not expected to occur.

### 1.3.2 Consequence on Flood Construction Levels

As noted above, a tsunami reaching the Nanaimo shoreline has a very low probability of occurrence, and is expected to result in wave runup of 0.5 – 1.0 m. However, the probability of a tsunami arriving simultaneously with HHWL, design storm surge and design storm waves would be even more remote. That is, a tsunami should be considered to be an alternative, not a simultaneous constraint relative to maximum water levels associated with extreme storms. Given that local storm surge and storm waves generally exceed 1 m in contributing to FCLs, it is not expected that tsunamis are a critical constraint with respect to the determination of FCLs. As such, tsunami risk has not been considered any further in this study.

## 1.4 COASTAL FLOODING HISTORY

A desktop investigation of flood history in the local area showed that historic risk to the City from coastal inundation/sea level rise has been minimal. Much of the flood records and news events for the local environs tend to be related to extreme rainfall and subsequent fluvial flooding. Last year's January declaration of emergency in the Regional District of Nanaimo was an example of 'typical' flooding in the area. In this instance, heavy rainfall caused flooding and landslides across parts of Vancouver Island, including Parksville, Whiskey Creek and Lantzville[5]. Low-lying areas in the City along the Chase and Millstone Rivers, as well as Cat Stream, would most likely be affected in similar rainfall events[6].

Despite the lack of newspaper and internet records, as described by anecdotal evidence in Section 1.2, there are low-lying coastal areas of the City frequently impacted by wave overtopping and coastal

[5] https://globalnews.ca/news/3992983/emergency-declared-district-nanaimo-flooding-landslide/

[6] https://nanaimonewsnow.com/article/566407/fast-moving-and-dangerous-rivers-expected-surge-during-incoming-storm

inundation. With the increasing impact of climate change and rising sea levels, it is likely that the coastal flood record will only continue to grow.

## 1.5 BACKGROUND DATA COLLECTION

At the outset of the project, the City provided AE with a number of different information resources in support of our work. These resources included LiDAR (Light Detection and Ranging) information, previous geotechnical studies, tsunami and storm surge mapping, orthoimagery and other pertinent GIS information. Some of the supplied information and their intended uses are discussed in further detail below.

### 1.5.1 LiDAR Information

The LiDAR information was captured in February 2016 by Eagle Mapping Ltd, for the area shown in Figure 1-5. It was supplied to the project team, in DTM format (digital terrain model), with a 0.5 m x 0.5 m cell size. The projection information associated with the LiDAR is shown below:

- Projection: UTM Zone 10N
- Horizontal Datum: NAD83 (CSRS)
- Vertical Datum: CGVD28

At the outset of the project, it was decided that all deliverables be provided in CGVD2013 vertical datum. This is the new reference standard for heights across Canada and replaces the older CGVD28. As per BC government published information[7], a conversion for Central Vancouver Island (+0.15 m) was therefore applied to the LiDAR to meet the new reference standard. The LiDAR has been used to provide elevation data for hydrodynamic modelling, as well as plotting of the completed flood construction levels.

[7] https://www2.gov.bc.ca/gov/content/data/geographic-data-services/georeferencing/vertical-reference-system

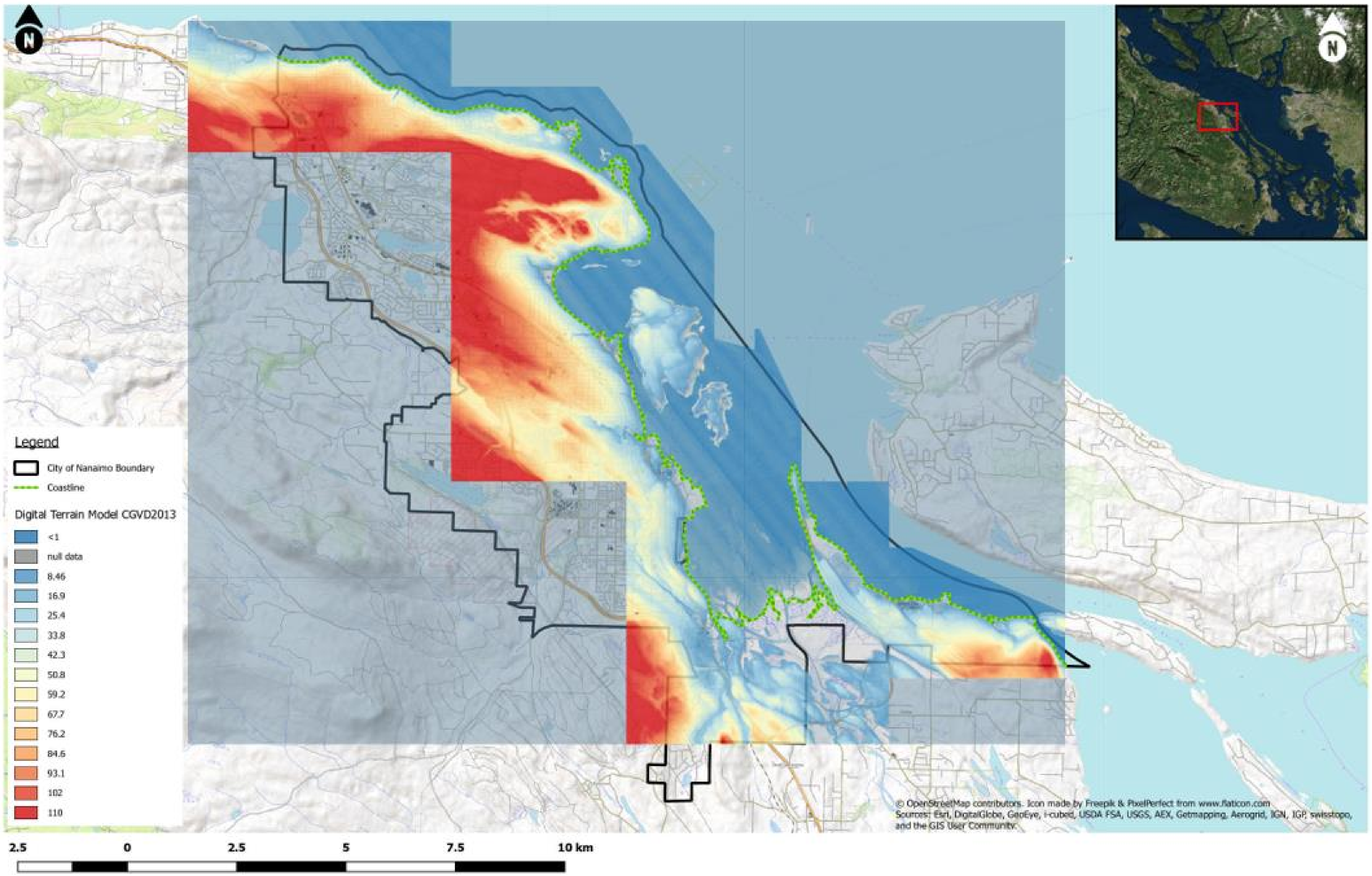


**Figure 1-5**
**LiDAR Coverage Area**

### 1.5.2 Orthorectified Aerial Survey

In the initial information package to AE by the City, hardcopy aerial orthoimages were provided. They were as follows:

- June 30,1972; scale 1:16,000; monochromatic
- April 1999; scale 1:30,000, colour
- June 4, 2003; scale 1:38,000, colour

Upon examination, it was found that these hardcopy datasets, despite being useful as background information, would not be of use for the study's erosion analysis, as detailed in Section 3. This was due to the datasets' relatively large scale and inability to be used in a GIS software package. Therefore, the City subsequently provided the project team with a second aerial imagery pack. This consisted solely of digital, georeferenced files that could be analysed and manipulated in a GIS platform. The datasets in this pack were as below:

- 1996, spatial resolution 25cm (assumed), monochromatic.
- 1999, spatial resolution 50cm (assumed), colour.
- 2002, spatial resolution 50cm (assumed), monochromatic.
- 2003, spatial resolution 10cm (assumed), monochromatic.
- 2006, spatial resolution 10cm (assumed), colour.
- March/April 2009, spatial resolution 10cm, colour.
- July 2012, spatial resolution 10cm, colour.
- July 2014, spatial resolution 30cm, colour.
- March/April 2016, spatial resolution 5cm, colour.

These orthoimages became the backbone by which coastal change was measured as described in Section 3.

### 1.5.3 Previous Geotechnical Studies

In support of our erosion analysis, the City supplied the project team with 3 geotechnical reports related to the critical North Slope area. They were as follows:

- North Shore Stability Study: Review of Geotechnical Information and Recommendations for Further Work. June 1994. HBT Agra Limited.
- North Slope Stability Study: Review of Geotechnical Information and Recommendations. December 1995. Norbert R. Morgenstern, P.Eng.
- North Slope General Slope Stability Study. January 2001. Golder Associates.

Each of the reports add to the understanding of the geotechnical challenges associated with the North Slope. The reports have been useful in this study during the completion of the erosion analysis, as detailed in Section 3. Their findings were used to appropriately classify the North Shore coastline, as well as frame the nature of historic erosion at that location.

# 2 Coastal Processes Analysis

## 2.1 INTRODUCTION

The methodology applied to determine Flood Construction Levels (FCLs) at specific transect locations along the shoreline of Nanaimo is presented in detail in this section of the report.

In brief, the approach consists of utilizing regional parameters provided in the BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) Coastal Floodplain Mapping - Guidelines and Specifications[8] **(Coastal Guidelines 2011)** whenever possible, and to combine these with numerical modelling of local effects (local wind waves, local storm surge, wave setup and wave runup) to determine the FCLs.

It should be mentioned at this juncture that FCLs are not inundation extents. FCLs are the maximum elevation that the sea reaches at the land/beach interface, plus an allowance for freeboard. As will be described in later sub-sections, FCLs are a sum of both the extreme still water level and maximum wave run-up + set-up, with some exceptions. To project these FCLs inward from the coastline is a conservative approach to mapping since adding each flood component together does not take into account the joint probability of the extreme of each component occurring simultaneously.

In reality, in many cases, the wave height would reduce as it propagates inland from the coastline, thus, reducing the actual water level. This could be the case where the still water level plus static wave setup exceeds the shoreline berm crest height and depth limited breaking would limit the wave heights propagating overland, or if the waves break on the shoreline berm, overtop it and pool on the coastline, as well if there is a fetch by which waves could 'regrow'. Thus, the accuracy of mapping could be improved by undertaking further refined, 2D inundation modelling of the floodplain. This will be discussed in further detail in Section 5. With this proviso, for purposes of the present study the estimated FCLs have been converted without modification to inundation contours on the maps. This is an appropriate approach for a high-level, strategic study.

## 2.2 TECHNICAL APPROACH

Coastal Floodplain Mapping - Guidelines and Specifications characterize the Flood Construction Level (FCL) as the sum of the higher high water large tide (HHWLT) elevation, plus relative sea level rise (SLR) tied to a particular time horizon (such as year 2050 or year 2100), plus a SLR adjustment due to uplift or subsidence, plus the estimated storm surge associated with the selected design storm, plus the estimated wave effects (setup and runup) associated with the design storm, and finally an allowance for freeboard.

Stated as an equation:

**FCL = HHWLT + SLR + SLR adjustment + storm surge + wave effects + freeboard** (1)

The estimation of each of these components is now considered in turn.

---

[8] Coastal Floodplain Mapping - Guidelines and Specifications. KWL, for MFLNRO. June 2011

### 2.2.1 Tide Level, Sea Level Rise and Regional Storm Surge

#### 2.2.1.1 HHWLT

HHWLT (Higher High Water Large Tide) is the average of the highest water levels from each year over a 19 year nodal modulation cycle. The elevation of HHWLT at Nanaimo is provided in Volume 5 of the Tide and Current Tables[9]. This indicates that HHWLT relative to MWL (Mean Water Level) datum is 1.9 m.

The Coastal Guidelines 2011 provide recommended values of SLR relative to the year 2000. The year 2000 is the 'benchmark year' in the Coastal Guidelines 2011, from which projections into the future are derived.

For consistency with the study datum of CGVD2013, the HHWLT relative to MWL needs to be adjusted so that it can be inputted into Eq. (1). MWL relative to CGVD2013 in the benchmark year, 2000, has been assessed (taking account of known changes in SLR) as +0.12 m i.e. this is the amount that must be added to the 1.9m from Volume 5 of the Tide and Current Tables.

Therefore, the following value for HHWLT has been adopted in the present study:

**HHWLT** = +2.02m CGVD2013

#### 2.2.1.2 SLR

Sea Level Rise relative to the year 2000 is taken from Fig. 2-2 of the Coastal Guidelines 2011; or, equivalently, a pro-rated value based on the recommended SLR of 1.0 m in 2100 relative to 2000. That is:

| | | |
|---|---|---|
| **SLR** = | +0.18m for year 2018 | (2) |
| | +0.50m for year 2050 | |
| | +1.00m for year 2100 | |

However, the Coastal Guidelines 2011 state: *"These values represent an initial precautionary approach and will require regular updates as new data become available, and sea level rise projections are updated."* Therefore, improvements to these values have been taken into account. Since the Coastal Guidelines were issued in 2011, the actual (measured) SLR value for 2018 is now available[10] and may be used instead for 2018. SLR for the year 2018 is in fact +0.06m rather than +0.18m as proposed in the Guidelines. As this is an actual measured value, we have adjusted the projections for 2050 and 2100 by the same difference in 2018 values (measured vs. projected). That is, rather than rely on the SLR values in equation 2 above, the values of SLR that have been used in this study are:

[9] Canadian Tide and Current Tables, 2018, Volume 5, Juan de Fuca Strait and Strait of Georgia, Canadian Hydrographic Service
[10] see: https://climate.nasa.gov/vital-signs/sea-level/

**Updated SLR** = +0.06m for year 2018
+0.38m for year 2050
+0.88m for year 2100

The above numbers are based on an assumption, using an observation between measured SLR and projected SLR in the original Coastal Guidelines 2011 document. It is noted that the figures for both 2050 and 2100 are estimates only and could be further refined using detailed climate modelling outside the scope of this study.

#### 2.2.1.3 SLR Adjustment

Information on Sea Level Rise adjustment due to land uplift for the East Coast of Vancouver Island and for the year 2100 relative to the year 2000 is available in Table 2-4 of Coastal Guidelines 2011. Since the Guidelines only provide the SLR adjustment for year 2100, a linear interpolation was assumed for the SLR adjustment, with a starting value of zero in year 2010. This leads to:

**SLR adjustment** = -0.02m for year 2018
-0.08m for year 2050
-0.17m for year 2100

(The negative values indicate that the study area is experiencing uplift.)

#### 2.2.1.4 Deep-Water Storm Surge

According to the Coastal Guidelines 2011, storm surge is defined as the sum of deep-water (or regional) surge plus local storm surge. As detailed therein, deep-water storm surge includes contributions from changes in atmospheric pressure but excludes local effects such as shoaling of the deep-water surge in shallow coastal areas and the effect of storm winds blowing over shallow water.

According to Coastal Guidelines 2011, the value of deep-water storm surge associated with the 200-year storm as listed in Table 2.1 of the Guidelines for the Strait of Georgia is based on an analysis of long-term water level records. The Guidelines provide a value of deep-water storm surge = +1.25m for 200-year conditions for the Strait of Georgia. This value is considered suitable for the present analysis and was therefore adopted for the present study.

**Deep-water storm surge** = +1.25m for 200-year conditions

#### 2.2.1.5 Local Storm Surge & Wave Effects

Local storm surge and wave effects (wave set-up and wave-runup) are a focus of this study and have been addressed through numerical hydrodynamic modelling as described in subsequent sections of this report.

#### 2.2.1.6 Still Water Level

An additional definition used in the following discussion is the Still Water Level (SWL). This is the maximum constant water level for a given scenario without accounting for wave effects or freeboard. The SWL includes the summation of HHWLT, SLR, SLR adjustment, and storm surge as described above and in Equation (1).

#### 2.2.1.7 Freeboard

Finally, it is traditional that a nominal value of freeboard is added to the preceding components in order to develop the FCL. Based on the recommendation in the Coastal Guidelines 2011, the freeboard has been assumed as follows:

**Freeboard** = +0.6m

### 2.2.2 Local Storm Surge

Local storm surge is characterized by local winds raising the water surface on shallow nearshore bathymetry and topography and was calculated separately from deep-water storm surge. DHI used the depth-averaged hydrodynamic model MIKE 21 HD FM[11] to compute the local storm surge at the study site.

An Extreme Value Analysis (EVA) of the local winds (recorded at Halibut Bank buoy) was carried out to determine directional wind speeds associated with a return period of 200 years for use as input for the local modelling. The observed Halibut Bank wind was then applied uniformly over the entire model domain and considered as representative of over-water winds.

The design winds were applied as input to the MIKE 21 hydrodynamic model to compute the contribution from local storm surge to the FCL. Details about the EVA of measured winds is presented in Section 2.3 of this report. Section 2.4 describes the numerical modelling of local storm surge using the hydrodynamic model MIKE 21 HD FM.

### 2.2.3 Wave Effects – Wave Setup and Runup

Wind generated waves at the Strait of Georgia contribute to the total FCL and were therefore included in the analyses carried out by DHI.

Swell waves from the open Pacific Ocean are not expected to reach the Nanaimo shoreline and weren't considered for this study. Waves in the Strait of Georgia are generated from local winds blowing over relatively short fetches. DHI applied the 200-year winds from the EVA to a MIKE 21 SW (spectral wave) model[12] to estimate the local wind-wave conditions along the Nanaimo shoreline for different combinations

[11] https://www.mikepoweredbydhi.com/products/mike-21/hydrodynamics
[12] https://www.mikepoweredbydhi.com/products/mike-21/waves/spectral-waves

of water level and wind speed and direction. Section 2.5 of this report describes the numerical modelling of wind waves using the spectral wave model MIKE 21 SW.

The DIM (direct integration method) tool developed for FEMA by Dr. Robert Dean (FEMA, 2005) was applied to calculate wave setup and runup on the natural beaches, using the local wind-wave conditions hindcasted by the MIKE 21 SW model as starting point for the analysis. Details about the calculation of wave effects can be found in Section 2.6 and in Appendices A through C of this report. Finally, Flood Construction Levels are derived in Section 2.7. Figure 2-1 shows an example coastal transect.

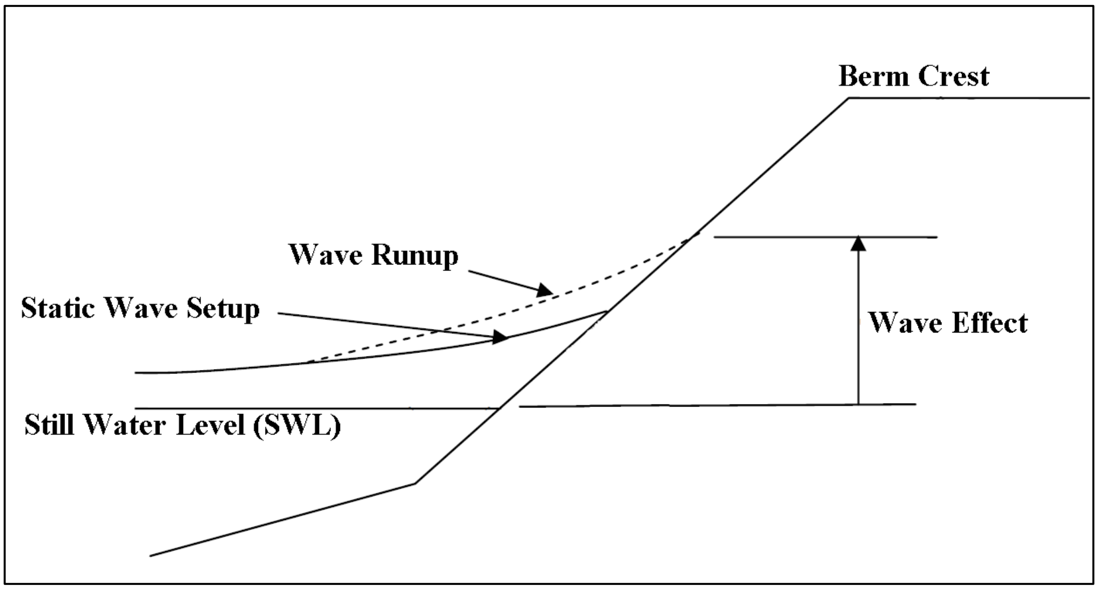


**Figure 2-1**
**Typical Coastal Transect Configuration – with wave effects**

The presence of trees along the shoreline was ignored in the calculation of local storm surge and wave effects. It is assessed that this approach will result in higher (conservative) estimates of local surge elevation and wave setup and runup, since the presence of the trees represents a higher resistance to the overland flow and blocking of the incident waves in real life than in the model setups.

For the purposes of analyses, we have also assumed that the foreshore shape and composition does not change in both the short and long-term. Potential changes to the foreshore shape and/or composition due to erosion/sediment deposition, development or construction of flood defences can affect the calculation of extreme water levels. These activities have not been considered as they are difficult to anticipate and not appropriate for this study's scope.

## 2.3 EXTREME VALUE ANALYSIS (EVA) OF LOCAL WIND DATA

26-years of measured wind data from Environment Canada (EC) station c46146 Halibut Bank, extending to the most recently available wind records, were downloaded. Since the anemometer on the buoy sits 5m above the water surface, the measured wind speeds were corrected to the standard elevation of 10m by use of the 1/7th power law. Corrected wind speeds have been used throughout the rest of this report without explicit reference to this being made.

The location of the Halibut Bank buoy is shown by the red dot in Figure 2-2 below:


**Figure 2-2**
**Position of Environment Canada buoy c46146 Halibut Bank (red dot) in relation to the City of Nanaimo**

Wind data from EC buoy c46146 consist of hourly records over the period March 13, 1992 18:44 – August 22, 2018 22:28 UTC time. The wind record includes data gaps. A wind rose for the entire period of record for station c46146 is shown in Figure 2-3 below:

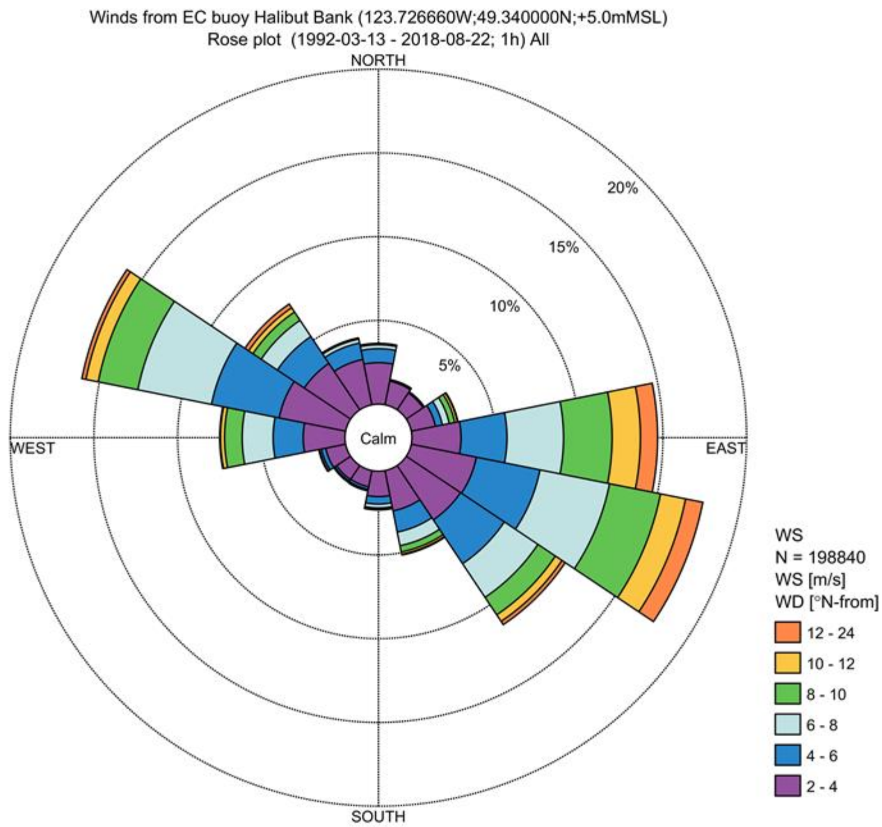


**Figure 2-3**
**Wind rose for winds recorded at EC station c46146 Halibut Bank**

Table 2-1 summarizes the results from the scatter analysis of the hourly wind data from station c46146 for the entire period of the record. Results from the scatter analysis are consistent with the information displayed by the wind rose in Figure 2-3. Strongest and more frequent winds are from the ESE and WNW sectors.

**Table 2-1**
**Scatter Analysis of Wind Records from EC Station c46146 Halibut Bank**

Frequency of Occurrence [%] (1992-03-13 - 2018-08-22; 1h) All

WS [m/s] - WS

| WD [°N-from] - WD | [0-2[ | [2-4[ | [4-6[ | [6-8[ | [8-10[ | [10-12[ | [12-14[ | [14-16[ | [16-18[ | [18-20[ | [20-22[ | [22-24[ | Total | Accum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [326.25-348.75[ | 1.060 | 1.703 | 1.000 | 0.234 | 0.060 | 0.018 | 0.006 | 0.001 | - | - | - | - | 4.082 | 99.997 |
| [303.75-326.25[ | 1.177 | 2.154 | 1.935 | 1.162 | 0.595 | 0.306 | 0.189 | 0.057 | 0.018 | 0.003 | 0.001 | - | 7.597 | 95.916 |
| [281.25-303.75[ | 1.368 | 2.681 | 4.124 | 4.487 | 2.413 | 0.753 | 0.184 | 0.037 | 0.016 | 0.005 | 0.001 | 0.003 | 16.072 | 88.319 |
| [258.75-281.25[ | 1.022 | 1.474 | 1.799 | 1.849 | 1.048 | 0.241 | 0.047 | 0.004 | 0.002 | 0.001 | - | - | 7.488 | 72.247 |
| [236.25-258.75[ | 0.695 | 0.513 | 0.264 | 0.109 | 0.050 | 0.008 | 0.002 | 0.001 | - | - | - | - | 1.640 | 64.759 |
| [213.75-236.25[ | 0.655 | 0.350 | 0.132 | 0.056 | 0.016 | 0.004 | 0.004 | - | - | - | - | - | 1.216 | 63.119 |
| [191.25-213.75[ | 0.611 | 0.374 | 0.159 | 0.071 | 0.022 | 0.004 | 0.002 | - | - | - | - | - | 1.242 | 61.903 |
| [168.75-191.25[ | 0.819 | 0.699 | 0.449 | 0.225 | 0.096 | 0.026 | 0.003 | 0.001 | - | - | - | - | 2.316 | 60.661 |
| [146.25-168.75[ | 0.902 | 1.554 | 1.292 | 0.826 | 0.385 | 0.136 | 0.043 | 0.009 | 0.005 | - | - | - | 5.149 | 58.344 |
| [123.75-146.25[ | 1.207 | 2.690 | 3.151 | 2.415 | 1.255 | 0.472 | 0.162 | 0.058 | 0.012 | 0.002 | - | - | 11.425 | 53.195 |
| [101.25-123.75[ | 1.246 | 2.720 | 3.877 | 4.240 | 3.106 | 1.527 | 0.716 | 0.252 | 0.070 | 0.011 | 0.003 | - | 17.766 | 41.770 |
| [78.75-101.25[ | 1.090 | 1.845 | 2.746 | 3.382 | 2.899 | 1.694 | 0.698 | 0.267 | 0.055 | 0.005 | 0.001 | 0.001 | 14.682 | 24.004 |
| [56.25-78.75[ | 0.787 | 0.680 | 0.424 | 0.420 | 0.334 | 0.156 | 0.036 | 0.007 | 0.001 | - | - | - | 2.846 | 9.323 |
| [33.75-56.25[ | 0.822 | 0.385 | 0.067 | 0.020 | 0.009 | 0.001 | - | - | - | - | - | - | 1.303 | 6.477 |
| [11.25-33.75[ | 0.915 | 0.521 | 0.088 | 0.015 | 0.003 | - | - | - | - | - | - | - | 1.540 | 5.175 |
| [-11.25-11.25[ | 1.120 | 1.357 | 0.835 | 0.231 | 0.065 | 0.020 | 0.004 | 0.001 | - | - | - | - | 3.634 | 3.634 |
| Total | 15.496 | 21.700 | 22.341 | 19.742 | 12.355 | 5.364 | 2.093 | 0.694 | 0.178 | 0.027 | 0.006 | 0.003 | 99.997 | - |
| Accum | 15.496 | 37.196 | 59.537 | 79.278 | 91.633 | 96.998 | 99.091 | 99.784 | 99.962 | 99.989 | 99.994 | 99.997 | - | - |

Wind records from EC station c46146 were subsequently used for the determination of directional wind speeds with associated return periods of 200 years. Wind data from EC station c46146 were sorted by directional sectors and an Extreme Value Analysis (EVA) was carried out on the wind data. Wind directions follow the meteorological convention, i.e. they are 'blowing from'.

The Peak-Over-Threshold method was adopted for the EVA and the threshold wind speed varied by directional sector to extract approximately 1 peak wind speed per year of record for the EVA analysis (~27 peaks in total). The Weibull distribution combined with the Method of Moments was found to consistently provide the best fit to the data sample and was therefore adopted for the calculation of the 200-year wind speeds.

Results from the EVA of wind speeds at Halibut Bank are summarized in Table 2-2 below.

**Table 2-2**
**EVA Parameters for Directional 200-year Wind Speeds at Nanaimo**

| Sector | Threshold speed (m/s) | Number of peaks | 200-yr wind speed (m/s) | Wind direction (°N) |
|---|---|---|---|---|
| NW | 15.50 | 27 | 23.9 | 315.0 |
| NNW | 10.50 | 28 | 22.6 | 337.5 |
| N | 8.70 | 28 | 18.0 | 0.0 |
| NNE | 7.30 | 30 | 15.5 | 22.5 |

| Sector | Threshold speed (m/s) | Number of peaks | 200-yr wind speed (m/s) | Wind direction (°N) |
|---|---|---|---|---|
| NE | 7.60 | 28 | 15.2 | 45.0 |
| ENE | 11.50 | 29 | 18.2 | 67.5 |
| E | 16.80 | 28 | 29.7 | 90.0 |
| ESE | 17.25 | 29 | 22.7 | 112.5 |
| SE | 16.00 | 27 | 25.1 | 135.0 |
| SSE | 13.00 | 28 | 19.5 | 157.5 |
| S | 10.80 | 29 | 16.0 | 180 |

Based on the results in Table 2-2, it was assessed that winds from nine directional sectors (NW, NNW, N, NNE, NE, ENE, E, ESE and SE) are of relevance for the generation of local storm surge and wind-waves at Nanaimo and were thus adopted for the two-dimensional modelling of local storm surge and wind waves with MIKE 21.

The shoreline of Nanaimo is sheltered from waves propagating from SSE and S by Gabriola, Mudge, De Courcy and other islands south of the city. Furthermore, 200-year winds from these two directions are significantly weaker than e.g. winds from E, ESE or SE. Therefore, winds from directions SSE and S were left out of all subsequent analyses.

## 2.4 LOCAL SURGE MODELLING (MIKE 21 HD FM)

The two-dimensional, depth-integrated hydrodynamic model MIKE 21 HD FM[13] was used to compute local storm surge for the 200-yr wind speeds listed in Table 2-2 for nine wind directions (NW, NNW, N, NNE, NE, ENE, E, SSE and SE).

The bathymetry of the area of interest, which includes the Strait of Georgia, was resolved using an unstructured mesh consisting of triangular elements of different sizes and shapes. Increased resolution (smaller mesh elements) was used to resolve the areas of interest around Nanaimo. Bed elevations were interpolated to the nodes of the triangular mesh elements from LiDAR data provided by the City of Nanaimo (as detailed in Section 1.4.1); this dataset was supplemented as required with data from NOAA's British Columbia 3 arc-second Bathymetric Digital Elevation Model (DEM)[14] and NOAA's Puget Sound 1/3 arc-second NAVD88 Coastal Digital Elevation Model (DEM)[15].

Figure 2-4 shows the overall spatial extent of the MIKE 21 model bathymetry. Due to modelling considerations, the bathymetry does not only cover the Strait of Georgia, but also includes Puget Sound,

[13] https://www.mikepoweredbydhi.com/products/mike-21/hydrodynamics
[14] https://data.noaa.gov/dataset/british-columbia-3-arc-second-bathymetric-digital-elevation-model
[15] https://data.noaa.gov/dataset/puget-sound-1-3-arc-second-navd-88-coastal-digital-elevation-model

the Strait of Juan de Fuca and the islands and channels north of Campbell River. The limits of the present study are bounded on this figure by the red polygon.

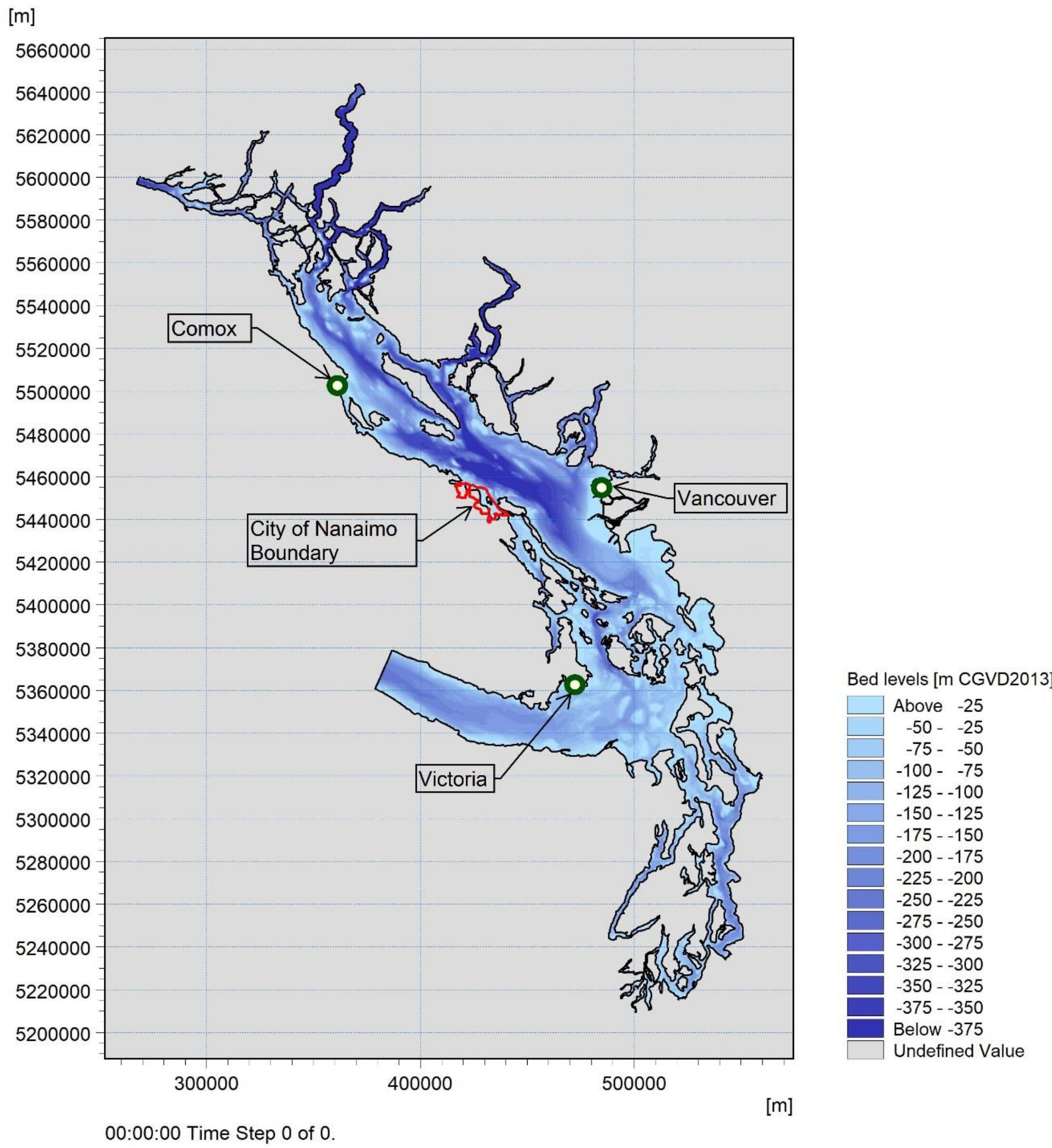


**Figure 2-4**
**Overall extent of the MIKE 21 model bathymetry**

Figure 2-5 shows a detail of the model bathymetry around the project area. Figure 2-6 shows a detail of the unstructured mesh resolution around Nanaimo. The higher resolution within the study area was adopted to better resolve the bathymetry in shallow areas, where local storm surge is expected to be highest.

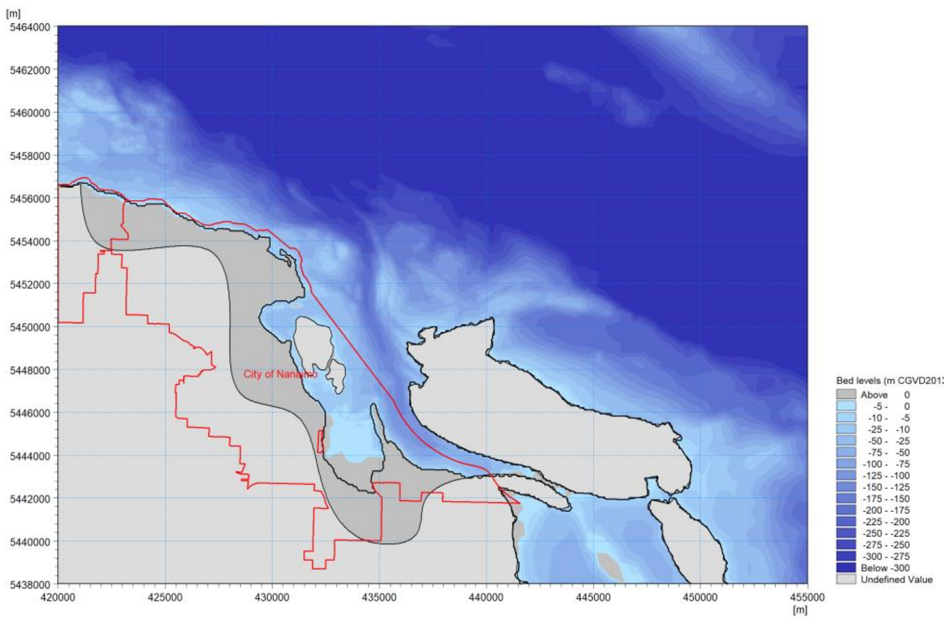


**Figure 2-5**
**Detail of model bathymetry around Nanaimo. The red lines indicate the extent of the study area (City of Nanaimo only)**

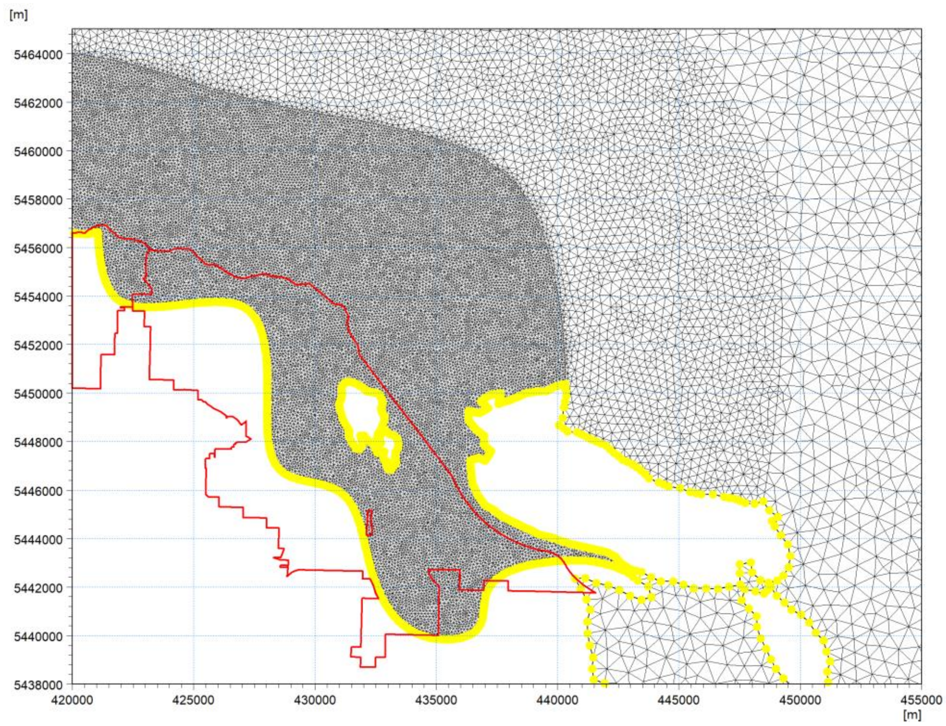


**Figure 2-6**
**Detail of model mesh for the study. The red lines indicate the extent of the study area**

Model simulations were executed for three alternative sea level rise scenarios, with an initial water level, calculated as the addition of HHWLT, SLR, adjustment to SLR, and regional storm surge (see Equation [1] for reference). The resulting initial water levels for the 3 time horizons are as follows:

| | |
|---|---|
| **Initial water level** = | +3.31m for year 2018 |
| | +3.57m for year 2050 |
| | +3.98m for year 2100 |

Three hydrodynamic model simulations, corresponding to the above three water levels for years 2018, 2050 and 2100, were carried out for all 9 wind directions, thus resulting in a total of 27 hydrodynamic model simulations. The hydrodynamic model was forced by the 200-year winds listed in Table 2-2. Other relevant hydrodynamic model parameters have been summarized in Table 2-3 below.

**Table 2-3**
**MIKE 21 HD FM Model Parameters Adopted for the Present Analyses**

| Model Parameter | Value |
|---|---|
| Flood and dry | Default. Drying depth = 0.005 m, flooding depth = 0.05 m, wetting depth = 0.10 m |
| Density | Barotropic (constant) |
| Eddy viscosity | Constant, ε = 10 $m^2/s$ |
| Bed resistance | Constant, Manning number M = 42 $m^{1/3}/s$ |
| Coriolis forcing | Included, varying in domain |
| Wind forcing | Included, constant wind speed and direction (see Table 2-2). Wind friction factor $f_w$ varying with wind speed ($f_w$ = 0.001255 for wind speeds < 7 m/s, $f_w$ = 0.002425 for wind speeds > 25 m/s, linearly varying for wind speeds between 7 and 25 m/s. |
| Boundary conditions | Fraser River boundary condition: constant water level, specified according to SLR horizon (2018, 2050 or 2100). The other boundaries were defined as land (zero velocity). |

Constant wind speed and direction were used to force the hydrodynamic model in each of the 27 runs, which extended in time until a steady-state condition was reached by MIKE 21 HD FM. The local storm surge was subsequently obtained by subtracting the corresponding constant water level from the surface elevation calculated by the hydrodynamic model.

The nine 2D maps of storm surge, corresponding to the nine different wind directions for a given SLR horizon (2018, 2050 or 2100), were interrogated to identify the maximum local surge at any location within the model domain, regardless of wind direction.

Results for maximum local storm surge associated with the three SLR horizons are shown in Figure 2-7 to Figure 2-9 below and were used for the calculation of FCLs. As could be expected, maximum values of local surge occur in relatively shallow areas along the coastline of Nanaimo, for example at Departure Bay.

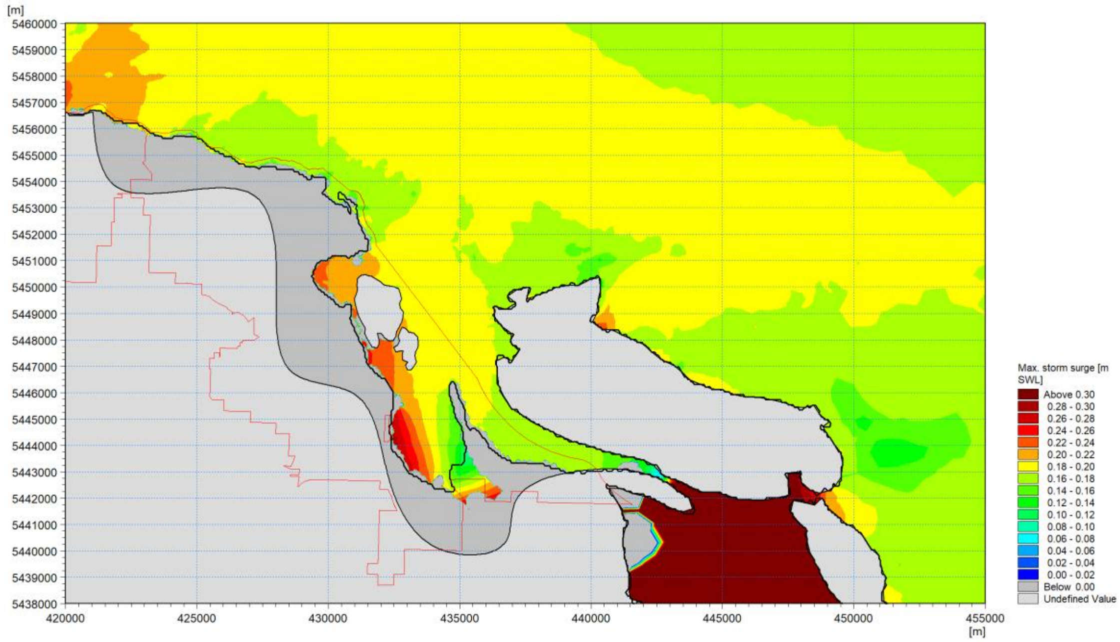


**Figure 2-7**
**Map of maximum local storm surge for Year 2018. Surge levels are relative to constant water level = +3.31 m CGVD2013**

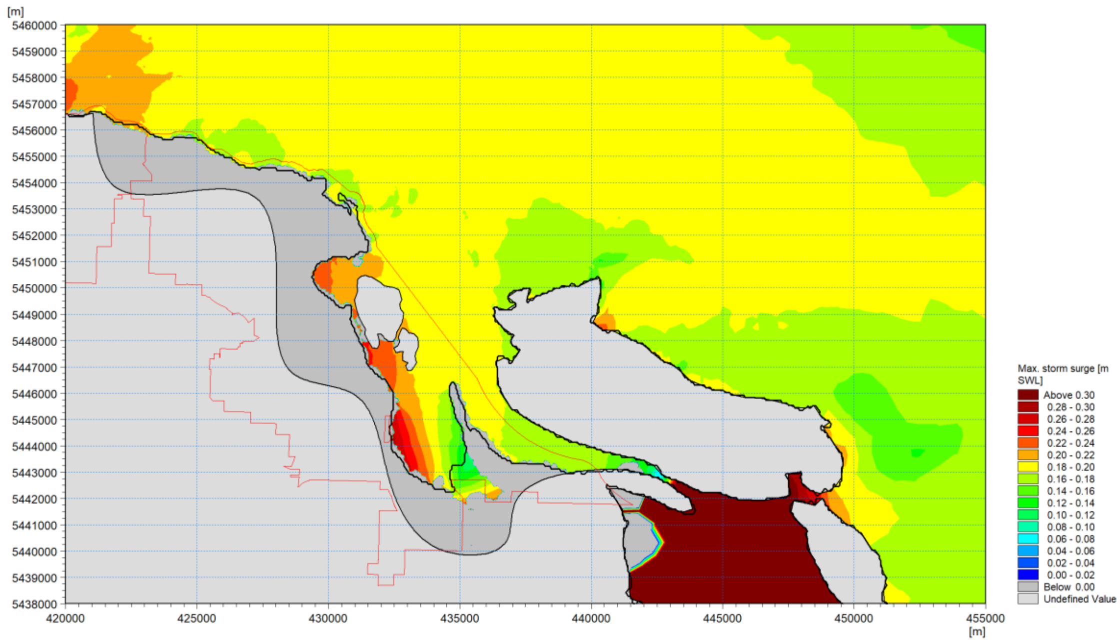


**Figure 2-8**
**Map of maximum local storm surge for Year 2050. Surge levels are relative to constant water level = +3.57 m CGVD2013**

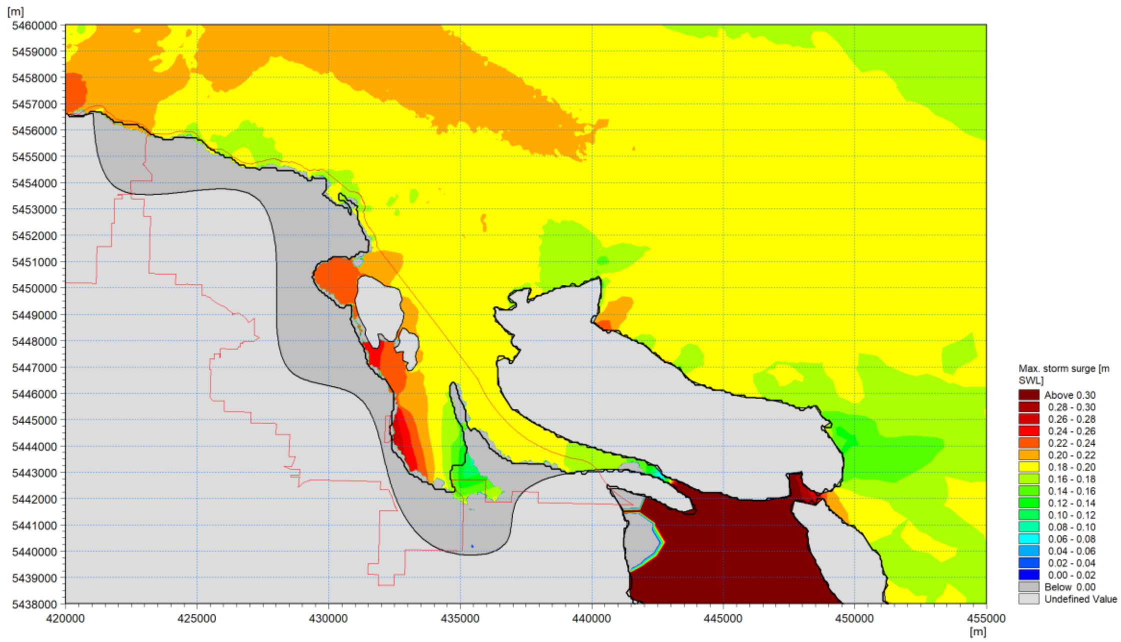


**Figure 2-9**
**Map of maximum local storm surge for Year 2100. Surge levels are relative to constant water level = +3.98 m CGVD2013**

## 2.5 WIND – WAVE MODELLING (MIKE 21 SW)

The spectral wave model MIKE 21 SW[16] was used to hindcast wind-wave conditions along the Nanaimo shoreline.

The same scenarios adopted for the modelling of local storm surge with MIKE 21 HD FM were used for the wave simulations: 200-year wind speeds from nine wind directions (ranging from NW to SE) were applied to the wave mode for three different initial water levels corresponding to SLR scenarios in years 2018, 2050 and 2100, thus yielding a grand total of 27 model simulations.

The same model mesh and bathymetry (shown in Figure 2-4 through Figure 2-6) used for the simulation of local storm surge was used to hindcast local wind-waves along the shoreline of Nanaimo.

Because of the relatively large water depths at the locations where wave parameters are extracted from the MIKE 21 SW model results for the assessment of wave effects, detailed description of depth-limited wave breaking and bottom friction are assumed not to be important. Therefore, wave breaking was included in the model setup with a default constant value of the depth-limited wave breaking parameter $\gamma_2$. Relatively low bottom friction was included in the model, which will result in higher (more conservative) wave heights.

---

[16] https://www.mikepoweredbydhi.com/products/mike-21/waves/spectral-waves

All model boundaries were defined as closed, which is consistent with local wind-wave generation. Relevant model parameters are listed in Table 2-4 below.

**Table 2-4**
**MIKE 21 SW Model Parameters Adopted for the Present Analyses**

| Model Parameter | Value |
|---|---|
| Spectral formulation | Fully spectral |
| Time formulation | Quasi stationary |
| Frequency discretization | Logarithmic, 25 bins, $f_{min}$ = 0.125 Hz, C = 1.0905773 |
| Directional discretization | 360 degrees, 36 bins |
| Water level conditions | Constant; includes HHWLT, SLR, SLR adjustment and deep-water storm surge |
| Wind forcing | Included, constant wind speed and direction (see Table 2-2). Uncoupled formulation, Charnock parameter = 0.02 |
| Wave diffraction | Not included |
| Bottom friction | Constant Nikuradze roughness $k_N$ = 0.004 m |
| Wave breaking | Constant $\gamma_2$ = 0.9 |
| White capping | $C_{dis}$ = 4.5, $\Delta_{dis}$ = 0.5, power of mean angular frequency = -1, power of mean wave number = -1 |
| Boundary conditions | Closed boundaries |

Spectral wave model calibration was not performed. Model parameters were adopted following experience gained from other modelling studies carried out by the project team in similar environments.

Figure 2-10 through Figure 2-12 show examples of MIKE 21 SW model results for winds propagating from NNE, SE and ENE respectively, for a constant water level = +3.31 m CGVD2013, corresponding to SLR in year-2018. As shown in Table 2-2, 200-year winds from SE are significantly stronger than winds from NNE and ENE, which explain the higher waves in Figure 2-12 compared to results in the other two figures. Wave directions are defined as 'propagating from', similarly to wind directions.

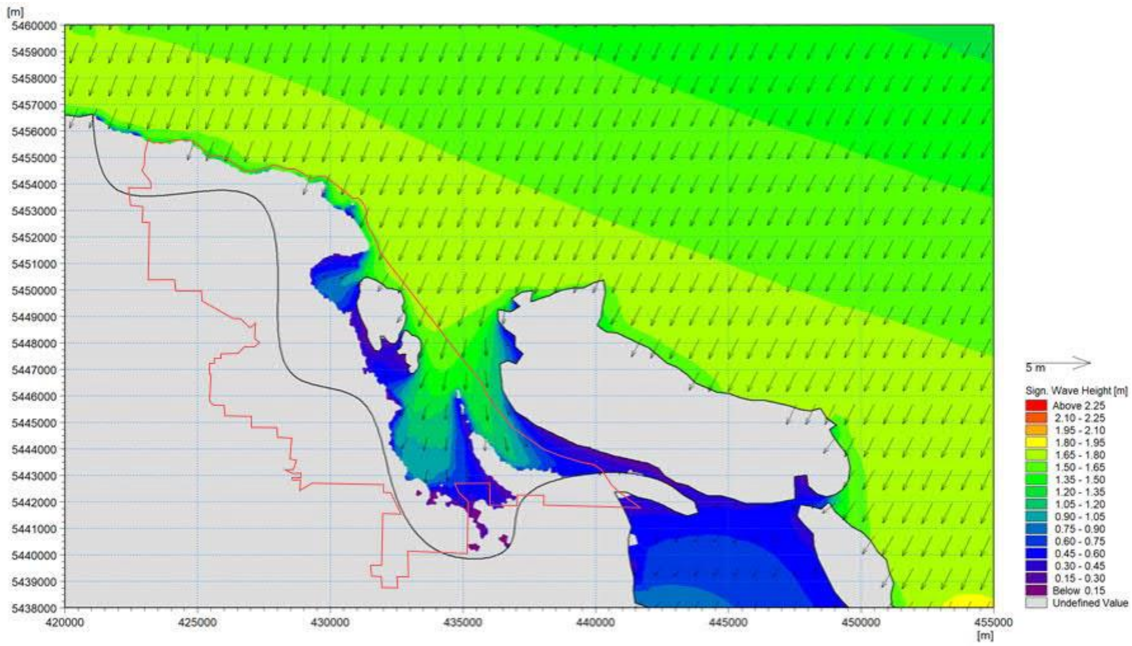


**Figure 2-10**
**Wind-wave field calculated by MIKE 21 SW for 200-year wind from NNE**

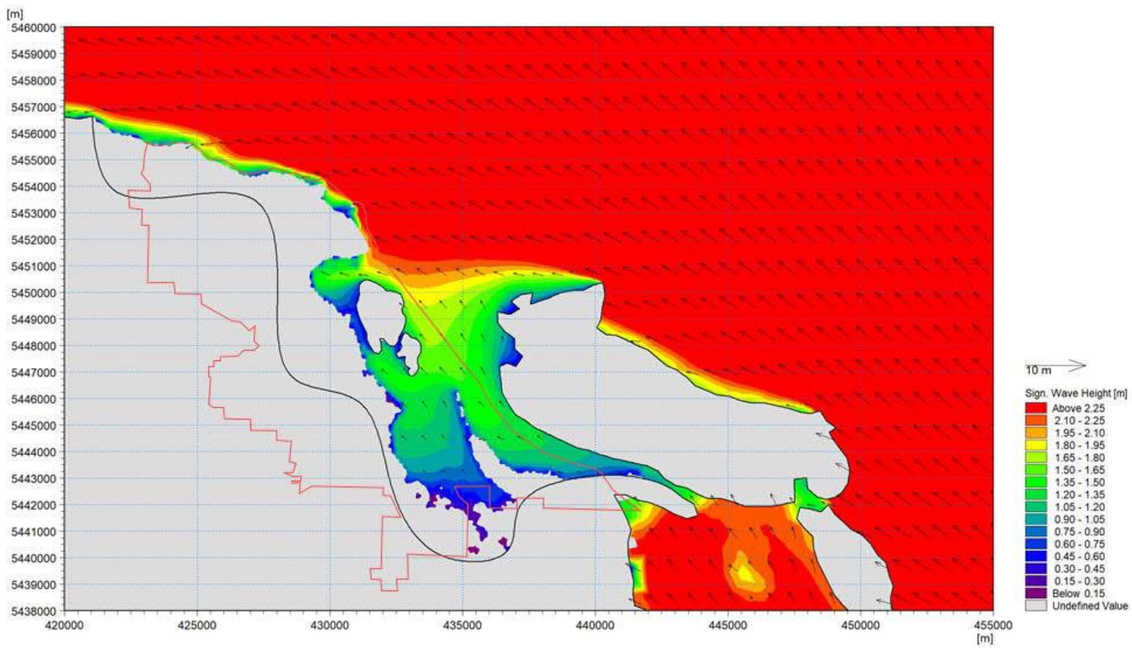


**Figure 2-11**
**Wind-wave field calculated by MIKE 21 SW for 200-year wind from SE**

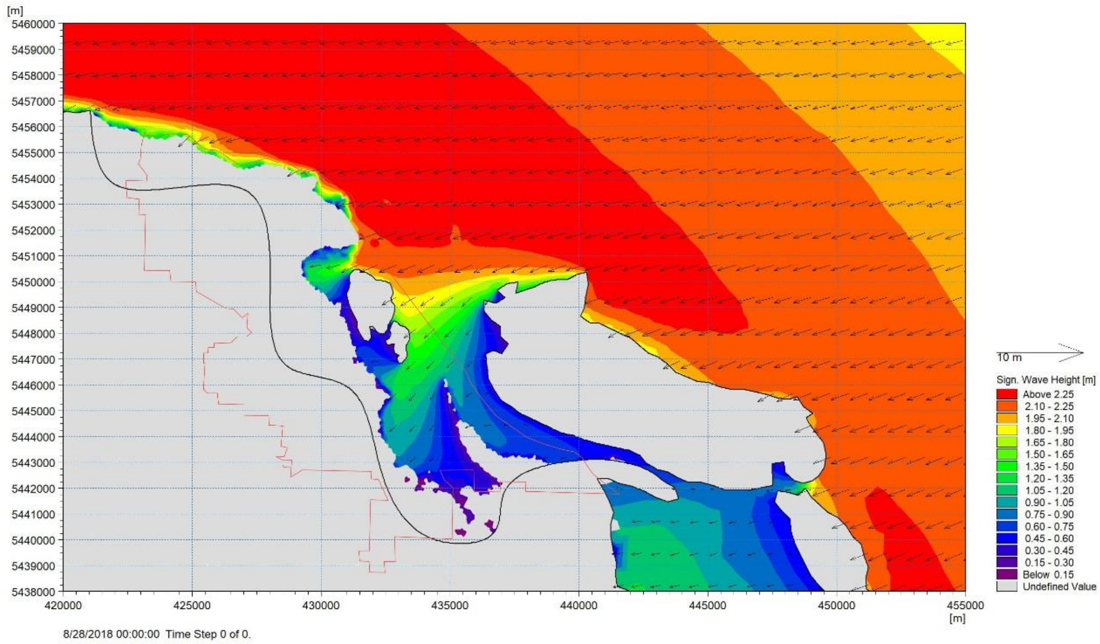


**Figure 2-12**
**Wind-wave field calculated by MIKE 21 SW for 200-year wind from ENE**

## 2.6 CALCULATION OF WAVE EFFECTS – SETUP AND RUNUP

Wave effects (wave setup and runup) were calculated at 41 transects along the coastline of Nanaimo. Location of the coastal transects is shown in Figure 2-13 below. The transects are, with the single exception of Transect 31, aligned perpendicularly to the local depth contours, which explains the change in orientation from transect to transect that can be observed in Figure 2-13.

Wave parameters (significant wave height $H_{m0}$, peak wave period $T_p$ and mean wave direction MWD) were extracted from the MIKE 21 SW model results at the starting point of each transect (transects are as shown in Figure 2-13) for each of the 27 combinations of nine wind directions (NW, NNW, N, NNE, NE, ENE, E, ESE and SE) and three initial water levels (+3.31 m CGVD2013 for year 2018, +3.57 m CGVD2013 for year 2050 and +3.98 m CGVD2013 for year 2100) that were used for the hindcast of local wind-waves.

Likewise, the maximum value of local storm surge calculated by the hydrodynamic model MIKE 21 HD FM along each transect was extracted for each of the three SLR horizons considered, see Figure 2-7 through Figure 2-9 for additional reference.

The extracted wave parameters and water levels were used as input for the calculation of wave setup and runup using the parametric DIM model developed by Dr. Robert Dean for FEMA (2005). As described in FEMA (2005), the static setup component, $\eta$, and root-mean-square of the dynamic setup component, $\eta_{rms}$, can be determined using the DIM equations:

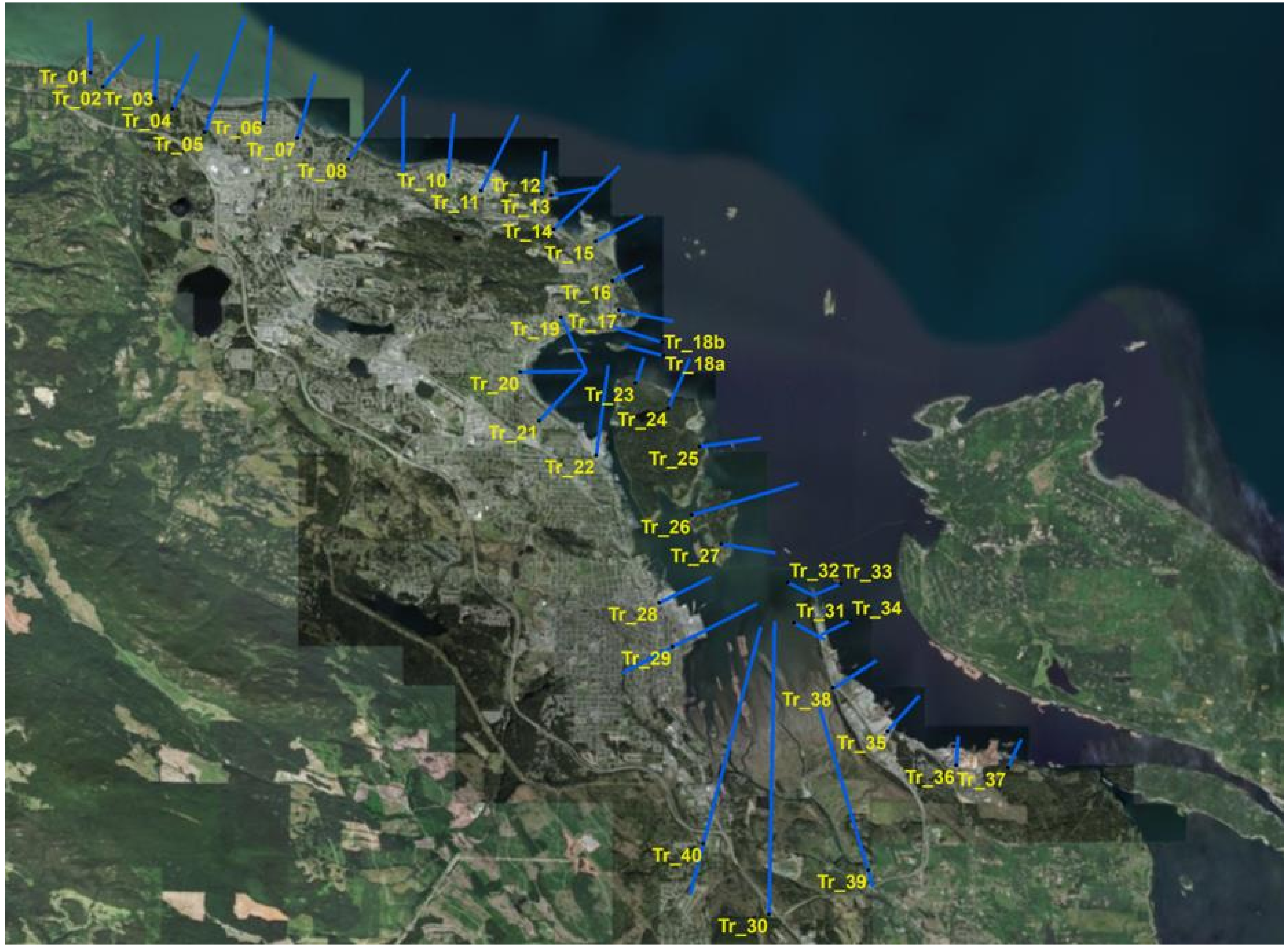


Figure 2-13

**Coastal Transects Used for The Calculation Of Wave Effects**

$$\eta = 4.0F_H F_T F_{Gamma} F_{Slope} \quad (3)$$

and

$$\eta_{rms} = 2.7G_H G_T G_{Gamma} G_{Slope} \quad (4)$$

where the units of $\eta$ and $\eta_{rms}$ are in feet and the factors are for wave height ($F_H$ and $G_H$), wave period ($F_T$ and $G_T$), JONSWAP spectrum narrowness factor ($F_{Gamma}$ and $G_{Gamma}$), and nearshore slope ($F_{Slope}$ and $G_{Slope}$). These factors are defined in Table 2-5 below. Except for the spectral narrowness factors, the F and G factors are the same.

**Table 2-5**
**Summary of Factors to be Applied with DIM (from FEMA, 2005)**

| Variable | Wave Height | Wave Period | Spectral Narrowness | Nearshore Profile Slope |
|---|---|---|---|---|
| $\eta$ | $(H_0/26.2)^{0.8}$ | $(T_p/20)^{0.4}$ | 1.0 | $(m/0.01)^{0.2}$ |
| $\eta_{rms}$ | $(H_0/26.2)^{0.8}$ | $(T_p/20)^{0.4}$ | $(Gamma)^{0.16}$ | $(m/0.01)^{0.2}$ |

According to the description of the DIM method in FEMA (2005), incident wave runup on beaches can be calculated as:

$$\sigma_2 = 0.3\xi_0 H_0 \quad (5)$$

Where $\xi_0$ is Iribarren's number.

The total oscillating wave runup (listed as 'Wave runup' in the tables in Appendices A through C) is then calculated as:

$$\hat{\eta}_T = 2\sqrt{{\eta_{rms}}^2 + {\sigma_2}^2} \quad (6)$$

Input to the DIM model consists of average beach slope m between the breaker line and the upper limit of wave runup, peak wave period $T_p$, spectral peakedness factor *Gamma* and deep-water equivalent wave height $H_0$. $T_p$ was obtained directly from the MIKE 21 SW results, m from the transect geometry and $H_0$ was calculated by de-shoaling to deep water the significant wave height $H_{m0}$ extracted from the MIKE 21 SW results. Finally, a value of Gamma = 3.3 was adopted for the spectral peakedness factor; this value is consistent with a JONSWAP spectrum for a developing wave field.

When de-shoaling the waves, a still water level (SWL) defined as:

**SWL = HHWLT + SLR + SLR adjustment + regional storm surge + local storm surge (7)**

was used in all cases.

The approach described above resulted in (at most) nine values of wave setup and runup for each of the 41 transects. Waves associated with wind directions that would propagate away from the coast were discarded form the analysis. The maximum wave effect (setup and runup) calculated at every transect from all applicable wind directions was adopted for the derivation of FCLs for the three SLR scenarios. Additional details about the calculation of wave effects can be found in Appendices A through C for years 2018, 2050 and 2100, respectively.

## 2.7 DERIVATION OF FLOOD CONSTRUCTION LEVEL

In agreement with Equation (1), wave effects together with a nominal freeboard level = 0.6 m must be added to already available components to calculate the FCL and to delineate FCL elevations for the three SLR scenarios considered in the present analyses. This approach was followed for most transects; however, transects 03, 04, 19, 20, 30, 35 and 38 were treated differently.

Transect 19 is sheltered by a low-lying island where waves break for all three scenarios (Year 2018, 2050 and 2100), since the associated SWL does not submerge the highest point of the island. Therefore, wave effects at the mainland shoreline were assumed to be zero.

In transects 03, 04, 20, 30, 35 and 38, waves do not break on the upper backshore, but rather on a relatively low foreshore that is backed by a berm. In this case, wave runup in the classic sense of the term (as shown in Figure 2-1) will not occur; rather, waves will propagate over the berm until they dissipate before reaching the backshore. In these cases, FCL was calculated as either the height of the berm or the foreshore plus the freeboard, or as the sum of SWL plus static wave setup plus freeboard, whichever was highest. For example, for Transect 20, the sum of the height of the berm (+4.81 m CGVD2013) plus freeboard (0.60m) was larger than the addition of static wave setup plus freeboard for all three time horizons, which results in a FCL = +5.41 m CGVD2013 for years 2018, 2050 and 2100.

Results have been summarized in Table 2-6 through Table 2-8 for years 2018, 2050 and 2100, respectively. Note that the values in the 'Wave Effects' column for transects 03, 04, 20, 30, 35 and 38 have been back-calculated from the FCL values determined as discussed in the previous paragraph.

It can be seen from the tables that the wave effect is quite large for some of the coastal transects. This is typically the case for transects backed by a steep bluff or cliff and exposed to large waves, for which the wave runup significantly contributes to the total wave effect. The method by which FCLs have been mapped is discussed in Section 2.8.

**Table 2-6**
**Calculated FCLs for SLR Scenario 2018**

| Transect | Year | HHWLT (m CGVD2013) | Deep Water Surge (m) | Sea Level Rise (m) | Regional adjustment (m) | Local Storm Surge (m) | SWL (m CGVD2013) | Wave Effects (m) | Freeboard (m) | FCL (m CGVD2013) |
|---|---|---|---|---|---|---|---|---|---|---|
| Nanaimo Coastline | | | | | | | | | | |
| 01 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.20 | 3.51 | 1.57 | 0.60 | 5.68 |
| 02 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.21 | 3.52 | 1.52 | 0.60 | 5.65 |
| 03 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.20 | 3.51 | 1.16 | 0.60 | 5.27 |
| 04 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.20 | 3.51 | 1.22 | 0.60 | 5.33 |
| 05 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.19 | 3.50 | 1.04 | 0.60 | 5.14 |
| 06 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.17 | 3.48 | 1.39 | 0.60 | 5.47 |
| 07 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.17 | 3.48 | 1.05 | 0.60 | 5.14 |
| 08 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.17 | 3.48 | 1.28 | 0.60 | 5.37 |
| 09 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.18 | 3.49 | 1.41 | 0.60 | 5.51 |
| 10 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.16 | 3.47 | 1.79 | 0.60 | 5.86 |
| 11 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.18 | 3.49 | 3.67 | 0.60 | 7.77 |
| 12 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.16 | 3.47 | 1.50 | 0.60 | 5.57 |
| 13 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.17 | 3.48 | 2.27 | 0.60 | 6.35 |
| 14 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.18 | 3.49 | 1.96 | 0.60 | 6.05 |
| 15 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.17 | 3.48 | 2.42 | 0.60 | 6.50 |
| 16 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.18 | 3.49 | 2.05 | 0.60 | 6.14 |
| 17 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.19 | 3.50 | 2.62 | 0.60 | 6.73 |
| 18a | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.21 | 3.52 | 1.26 | 0.60 | 5.38 |
| 18b | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.20 | 3.51 | 1.41 | 0.60 | 5.52 |
| 19 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.22 | 3.53 | 0.00 | 0.60 | 4.13 |
| 20 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.23 | 3.54 | 1.27 | 0.60 | 5.41 |
| 21 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.22 | 3.53 | 1.19 | 0.60 | 5.32 |
| 22 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.21 | 3.52 | 2.56 | 0.60 | 6.68 |
| Newcastle Island | | | | | | | | | | |
| 23 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.21 | 3.52 | 1.78 | 0.60 | 5.91 |

| Transect | Year | HHWLT (m CGVD2013) | Deep Water Surge (m) | Sea Level Rise (m) | Regional adjustment (m) | Local Storm Surge (m) | SWL (m CGVD2013) | Wave Effects (m) | Freeboard (m) | FCL (m CGVD2013) |
|---|---|---|---|---|---|---|---|---|---|---|
| 24 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.19 | 3.50 | 1.27 | 0.60 | 5.37 |
| 25 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.20 | 3.51 | 1.51 | 0.60 | 5.62 |
| Protection Island | | | | | | | | | | |
| 26 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.19 | 3.50 | 1.18 | 0.60 | 5.29 |
| 27 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.19 | 3.50 | 1.16 | 0.60 | 5.27 |
| Nanaimo Coastline | | | | | | | | | | |
| 28 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.22 | 3.53 | 0.82 | 0.60 | 4.95 |
| 29 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.20 | 3.51 | 0.55 | 0.60 | 4.66 |
| 30 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.19 | 3.50 | 0.54 | 0.60 | 4.64 |
| 31 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.16 | 3.47 | 1.07 | 0.60 | 5.14 |
| 32 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.18 | 3.49 | 1.20 | 0.60 | 5.30 |
| 33 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.19 | 3.50 | 1.39 | 0.60 | 5.50 |
| 34 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.18 | 3.49 | 1.47 | 0.60 | 5.56 |
| 35 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.18 | 3.49 | 1.11 | 0.60 | 5.20 |
| 36 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.17 | 3.48 | 1.08 | 0.60 | 5.16 |
| 37 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.17 | 3.48 | 0.77 | 0.60 | 4.86 |
| 38 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.18 | 3.49 | 0.64 | 0.60 | 4.73 |
| 39 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.21 | 3.52 | 0.28 | 0.60 | 4.40 |
| 40 | 2018 | 2.02 | 1.25 | 0.06 | -0.02 | 0.26 | 3.57 | 0.51 | 0.60 | 4.68 |

**Table 2-7**
**Calculated FCLs for SLR scenario 2050**

| Transect | Year | HHWLT (m CGVD2013) | Deep Water Surge (m) | Sea Level Rise (m) | Regional adjustment (m) | Local Storm Surge (m) | SWL (m CGVD2013) | Wave Effects (m) | Freeboard (m) | FCL (m CGVD2013) |
|---|---|---|---|---|---|---|---|---|---|---|
| Nanaimo Coastline | | | | | | | | | | |
| 01 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.20 | 3.77 | 1.57 | 0.60 | 5.94 |
| 02 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.21 | 3.78 | 1.52 | 0.60 | 5.90 |
| 03 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.20 | 3.77 | 0.90 | 0.60 | 5.27 |
| 04 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.20 | 3.77 | 1.00 | 0.60 | 5.37 |
| 05 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.19 | 3.76 | 1.06 | 0.60 | 5.42 |
| 06 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.17 | 3.74 | 1.40 | 0.60 | 5.74 |
| 07 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.17 | 3.74 | 1.06 | 0.60 | 5.40 |
| 08 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.17 | 3.74 | 1.29 | 0.60 | 5.63 |
| 09 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.18 | 3.75 | 1.43 | 0.60 | 5.78 |
| 10 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.16 | 3.73 | 1.81 | 0.60 | 6.14 |
| 11 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.18 | 3.75 | 3.74 | 0.60 | 8.09 |
| 12 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.17 | 3.74 | 1.51 | 0.60 | 5.85 |
| 13 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.18 | 3.75 | 2.30 | 0.60 | 6.65 |
| 14 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.19 | 3.76 | 1.97 | 0.60 | 6.33 |
| 15 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.18 | 3.75 | 2.44 | 0.60 | 6.79 |
| 16 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.19 | 3.76 | 2.06 | 0.60 | 6.42 |
| 17 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.19 | 3.76 | 2.63 | 0.60 | 6.99 |
| 18a | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.21 | 3.78 | 1.25 | 0.60 | 5.63 |
| 18b | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.20 | 3.77 | 1.40 | 0.60 | 5.77 |
| 19 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.22 | 3.79 | 0.00 | 0.60 | 4.39 |
| 20 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.23 | 3.80 | 1.01 | 0.60 | 5.41 |
| 21 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.22 | 3.79 | 1.19 | 0.60 | 5.59 |

| Transect | Year | HHWLT (m CGVD2013) | Deep Water Surge (m) | Sea Level Rise (m) | Regional adjustment (m) | Local Storm Surge (m) | SWL (m CGVD2013) | Wave Effects (m) | Freeboard (m) | FCL (m CGVD2013) |
|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.21 | 3.78 | 2.62 | 0.60 | 7.00 |
| Newcastle Island | | | | | | | | | | |
| 23 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.21 | 3.78 | 1.81 | 0.60 | 6.19 |
| 24 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.20 | 3.77 | 1.37 | 0.60 | 5.74 |
| 25 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.20 | 3.77 | 1.51 | 0.60 | 5.88 |
| Protection Island | | | | | | | | | | |
| 26 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.19 | 3.76 | 1.19 | 0.60 | 5.55 |
| 27 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.20 | 3.77 | 1.16 | 0.60 | 5.53 |
| Nanaimo Coastline | | | | | | | | | | |
| 28 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.23 | 3.80 | 0.82 | 0.60 | 5.22 |
| 29 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.24 | 3.81 | 0.54 | 0.60 | 4.95 |
| 30 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.19 | 3.76 | 0.46 | 0.60 | 4.82 |
| 31 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.16 | 3.73 | 1.04 | 0.60 | 5.37 |
| 32 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.18 | 3.75 | 1.21 | 0.60 | 5.56 |
| 33 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.19 | 3.76 | 1.50 | 0.60 | 5.86 |
| 34 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.18 | 3.75 | 1.48 | 0.60 | 5.83 |
| 35 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.18 | 3.75 | 1.08 | 0.60 | 5.43 |
| 36 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.18 | 3.75 | 1.08 | 0.60 | 5.43 |
| 37 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.18 | 3.75 | 0.87 | 0.60 | 5.22 |
| 38 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.18 | 3.75 | 0.38 | 0.60 | 4.73 |
| 39 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.19 | 3.76 | 0.28 | 0.60 | 4.64 |
| 40 | 2050 | 2.02 | 1.25 | 0.38 | -0.08 | 0.26 | 3.83 | 0.51 | 0.60 | 4.94 |

**Table 2-8**
**Calculated FCLs for SLR scenario 2100**

| Transect | Year | HHWLT (m CGVD2013) | Deep Water Surge (m) | Sea Level Rise (m) | Regional adjustment (m) | Local Storm Surge (m) | SWL (m CGVD2013) | Wave Effects (m) | Freeboard (m) | FCL (m CGVD2013) |
|---|---|---|---|---|---|---|---|---|---|---|
| Nanaimo Coastline | | | | | | | | | | |
| 01 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.20 | 4.18 | 1.57 | 0.60 | 6.35 |
| 02 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.22 | 4.20 | 1.51 | 0.60 | 6.31 |
| 03 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.21 | 4.19 | 0.49 | 0.60 | 5.28 |
| 04 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.20 | 4.18 | 0.59 | 0.60 | 5.37 |
| 05 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.20 | 4.18 | 1.10 | 0.60 | 5.88 |
| 06 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.18 | 4.16 | 1.41 | 0.60 | 6.17 |
| 07 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.17 | 4.15 | 1.09 | 0.60 | 5.84 |
| 08 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.18 | 4.16 | 1.29 | 0.60 | 6.05 |
| 09 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.19 | 4.17 | 1.45 | 0.60 | 6.22 |
| 10 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.16 | 4.14 | 1.86 | 0.60 | 6.60 |
| 11 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.19 | 4.17 | 3.83 | 0.60 | 8.60 |
| 12 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.17 | 4.15 | 1.53 | 0.60 | 6.28 |
| 13 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.18 | 4.16 | 2.26 | 0.60 | 7.02 |
| 14 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.19 | 4.17 | 2.00 | 0.60 | 6.77 |
| 15 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.18 | 4.16 | 2.48 | 0.60 | 7.24 |
| 16 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.20 | 4.18 | 2.08 | 0.60 | 6.86 |
| 17 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.20 | 4.18 | 2.63 | 0.60 | 7.41 |
| 18a | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.22 | 4.20 | 1.24 | 0.60 | 6.04 |
| 18b | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.21 | 4.19 | 1.38 | 0.60 | 6.17 |

| Transect | Year | HHWLT (m CGVD2013) | Deep Water Surge (m) | Sea Level Rise (m) | Regional adjustment (m) | Local Storm Surge (m) | SWL (m CGVD2013) | Wave Effects (m) | Freeboard (m) | FCL (m CGVD2013) |
|---|---|---|---|---|---|---|---|---|---|---|
| 19 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.23 | 4.21 | 0.00 | 0.60 | 4.81 |
| 20 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.24 | 4.22 | 0.59 | 0.60 | 5.41 |
| 21 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.23 | 4.21 | 1.20 | 0.60 | 6.01 |
| 22 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.22 | 4.20 | 3.30 | 0.60 | 8.10 |
| Newcastle Island | | | | | | | | | | |
| 23 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.22 | 4.20 | 2.29 | 0.60 | 7.09 |
| 24 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.20 | 4.18 | 1.41 | 0.60 | 6.19 |
| 25 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.21 | 4.19 | 1.53 | 0.60 | 6.32 |
| Protection Island | | | | | | | | | | |
| 26 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.20 | 4.18 | 1.21 | 0.60 | 5.99 |
| 27 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.20 | 4.18 | 1.13 | 0.60 | 5.91 |
| Nanaimo Coastline | | | | | | | | | | |
| 28 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.23 | 4.21 | 0.81 | 0.60 | 5.62 |
| 29 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.24 | 4.22 | 0.55 | 0.60 | 5.37 |
| 30 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.19 | 4.17 | 0.29 | 0.60 | 5.06 |
| 31 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.16 | 4.14 | 1.06 | 0.60 | 5.80 |
| 32 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.19 | 4.17 | 1.23 | 0.60 | 6.00 |
| 33 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.20 | 4.18 | 1.83 | 0.60 | 6.61 |
| 34 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.19 | 4.17 | 1.49 | 0.60 | 6.26 |
| 35 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.19 | 4.17 | 0.66 | 0.60 | 5.43 |
| 36 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.19 | 4.17 | 1.09 | 0.60 | 5.86 |

| Transect | Year | HHWLT (m CGVD2013) | Deep Water Surge (m) | Sea Level Rise (m) | Regional adjustment (m) | Local Storm Surge (m) | SWL (m CGVD2013) | Wave Effects (m) | Freeboard (m) | FCL (m CGVD2013) |
|---|---|---|---|---|---|---|---|---|---|---|
| 37 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.19 | 4.17 | 0.99 | 0.60 | 5.76 |
| 38 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.19 | 4.17 | 0.40 | 0.60 | 5.17 |
| 39 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.16 | 4.14 | 0.30 | 0.60 | 5.04 |
| 40 | 2100 | 2.02 | 1.25 | 0.88 | -0.17 | 0.25 | 4.23 | 0.51 | 0.60 | 5.34 |

## 2.8 FLOOD CONSTRUCTION LEVEL MAPPING PROCEDURE

As is evident from the FCL results presented in Tables 2-6 to 2-8, there is a significant difference between transects across the study area. The SWL is generally consistent, with the majority of difference being accounted for by the wave effects at each transect. This makes the task of plotting the FCL elevation/limit very challenging. To help visualise the change in FCLs between each adjacent transect, the following plots, Figures 2-14 to 2-16, were produced using the results summarised in Tables 2-6 to 2-8. They clearly demonstrate the consistency in SWL, whilst highlighting the differences in wave effects for adjacent transects. In particular, there are large jumps in wave effects, and subsequently in FCL, at transects 11, 22 and 33. These areas have near vertical shoreface slopes, with associated higher values of wave runup than if the coastline were gently sloping.

For the majority of the project coastline, the mapping methodology was as follows:

- FCLs were estimated at each transect, as per Tables 2-6 to 2-8.
- Lines were generated at the midpoints between each transect, as per the pink dashed lines (‘FCL Boundaries’), in the appended FCL mapping.
- Each transect’s FCL was plotted until it hit this ‘boundary line’, where the FCL elevation directly transitioned to the next transect’s corresponding FCL.
- Therefore, this explains the ‘stagger’ in FCL lines for the same time horizon.

However, the project team have made some localised amendments to the above approach using experience and judgment. This was done where estimated FCLs would be considerably localised and not necessarily suitable for locations in the immediate vicinity. An example of this would be transect 22, where we have confined the FCL to the Departure Bay ferry terminal only. The FCL in the Newcastle Island Passage immediately transitions to the FCL applicable for transect 28. As stated, the vertical coastline at transect 22 was not deemed to be representative of that stretch as a whole.

The above procedure is similar to what has been done in previous studies by DHI for FEMA. The locations of the FCL reaches and their boundaries are shown in the appended mapping in Appendices D to F.

As the FCL values on both Newcastle Island and Protection Island do not vary greatly across their respective coastline, we have omitted these areas from Figures 2-14 to 2-16 for ease of display. These figures, therefore, only show the primary Nanaimo coastline.

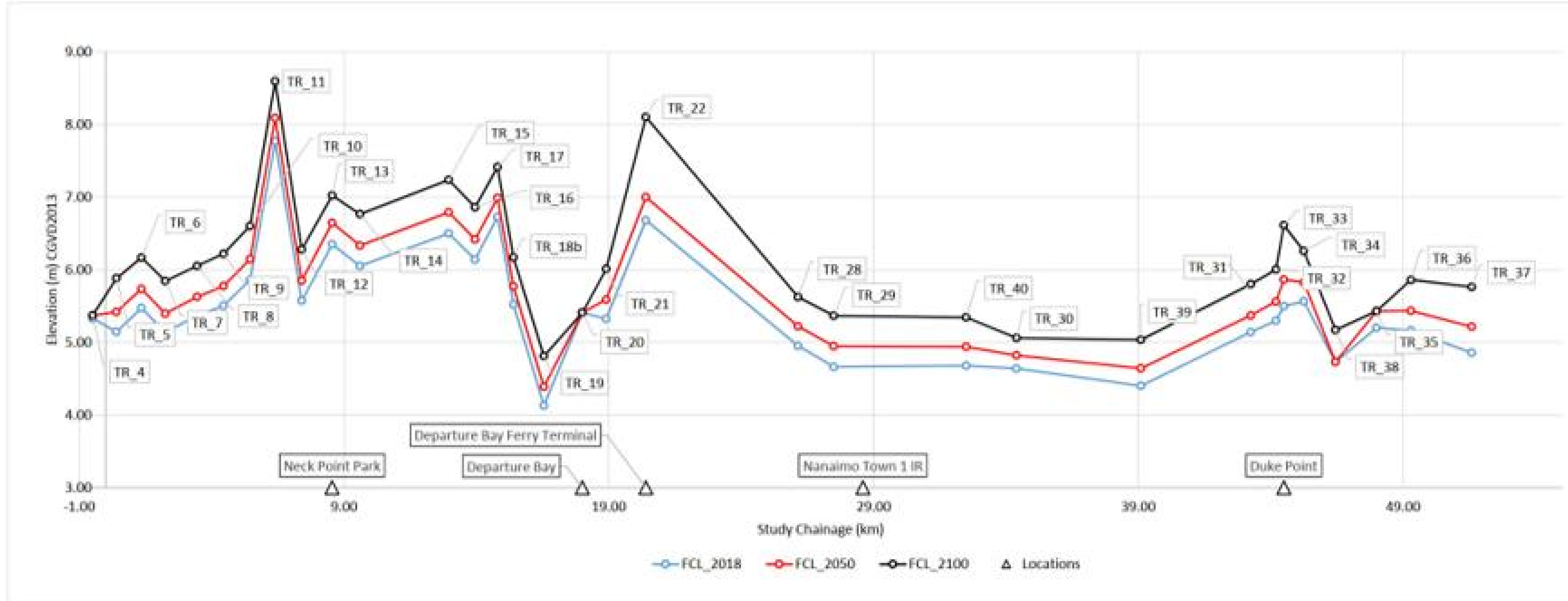


**Figure 2-14**
**Comparative Plot of Flood Construction Levels Along Nanaimo Coastline**

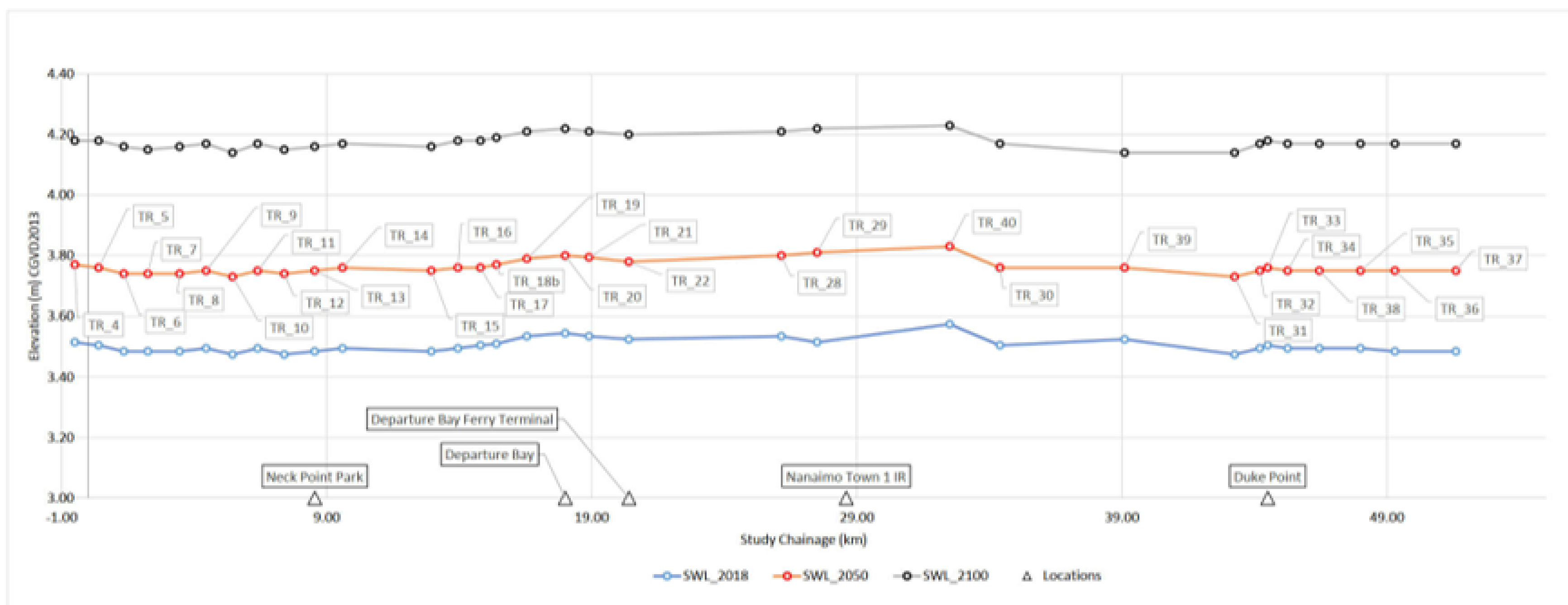


**Figure 2-15**
**Comparative Plot of Still Water Levels Along Nanaimo Coastline**

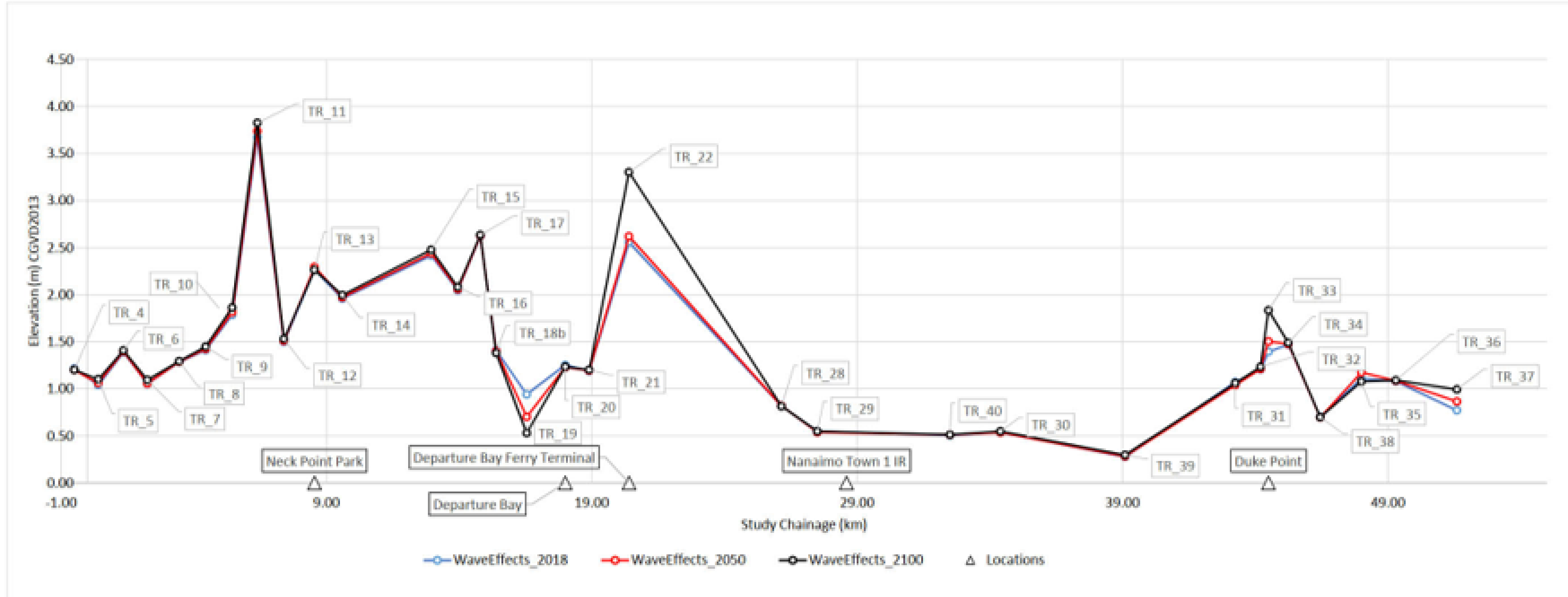


**Figure 2-16**
**Comparative Plot of Wave Effects Along Nanaimo Coastline**

# 3 Erosion Analysis

## 3.1 OVERVIEW

As per Section 1, we have completed a strategic level erosion analysis for this project. The objective of this assessment was to establish a baseline from the existing coastline and subsequently estimate its future likely position in the years 2050 and 2100. This has been undertaken using two complementary methods as follows:

The first was a visual analytical procedure based on a **visual comparison** of the best available, current and historical mapping and aerial orthoimagery. The visual analysis procedure entailed the following steps:

- Data collection & processing
- Coastline classification
- Determination of retreat rate
- Mapping of calculated retreat

However, a key limitation to this method is that it could only be undertaken at a relatively few points along the coastline; the reasons for which are explained in detail in Section 3.2.3.

The second method was based on **numerical model simulations** of bed shear stresses for different flow conditions (tide + wind, tide + waves) using the hydrodynamic model from Section 2. This has led to the identification of hotspots along the coastline where more severe erosion over the long term can be expected.

The two methods and the corresponding results are presented in Sections 3.2 and 3.3. respectively, while Section 3.4 compares the two sets of results and provides the overall findings.

This erosion analysis will provide the City with valuable information for identifying potentially vulnerable areas; facilitating consideration by planners of the hazard and potential risks to proposed development near the coastline.

## 3.2 VISUAL ANALYTICAL PROCEDURE

### 3.2.1 Data Collection & Processing

The first stage of the visual assessment involved collecting the appropriate data necessary for this strategic-level assessment. As previously discussed, the City provided historic, georeferenced, digital orthoimagery (both colour and monochromatic) for a number of years dating back to 1996. In addition to the digital datasets, the project team were also supplied with hardcopy aerial photos, at varying scales, that predated some of the digital files. A digital outline of the City coastline was obtained from iMapBC's[17] Freshwater Atlas open-data and amended locally at points where the line deviated from orthoimagery.

In support of this project, Nanaimo Port Authority was kind enough to offer an opportunity to tour the coastline by boat. A member of AE's project team was able to visually survey the study's coastline and collect invaluable photographic evidence on September 6th 2018. This survey has allowed the project team to more accurately assess the coastline condition and classify reaches as per Section 3.2.2.

### 3.2.2 Coastline Classification

The subsequent stage of the assessment involved classifying the coastline of the study area, as shown in Figure 3-1. This was done to provide an indication of the areas where it was either not possible to quantify the erosion rate or where the erosion rates derived may have been affected by the presence of coastal protection works.

[17] https://maps.gov.bc.ca/ess/hm/imap4m/

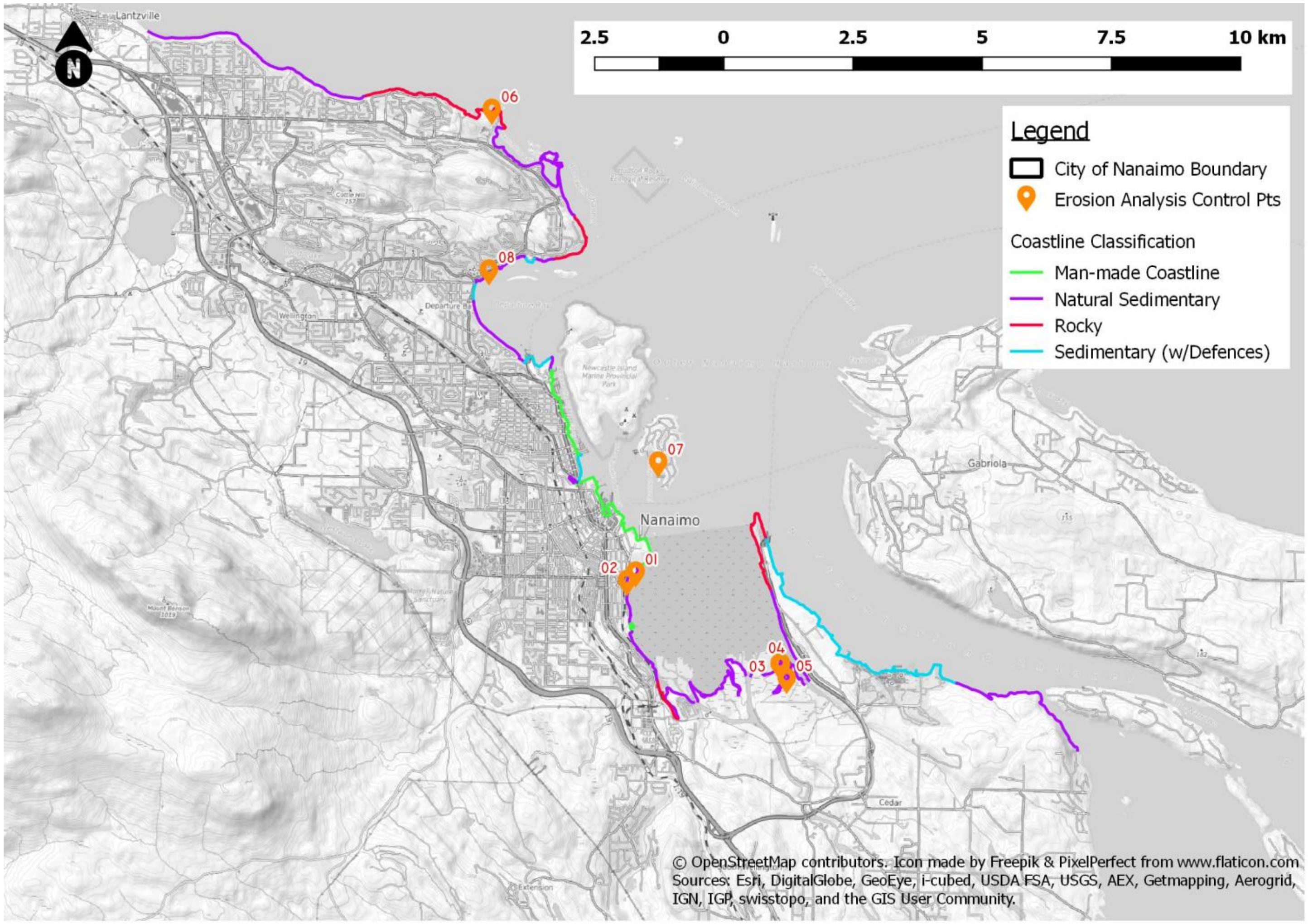


**Figure 3-1**
**Coastline Classification Map**

As per Figure 3-1, the coastline was sub-divided into the following classes:

- Man-made coastline, where the coastline is artificial or has been heavily modified (e.g. man-made structures, harbours, quays, promenades etc.).
- Rocky, where bedrock with little or no overburden forms the coastline.
- Natural Sedimentary, where there is a ‘typical’ beach or ‘soft’ coastline.
- Sedimentary with Defences, where there is a soft coastline but has some defences (e.g. beach with a sea-wall).

This classification was based on a visual review of the aerial imagery and digitized coastline. The review was qualitative in nature and assumptions and simplifications have been made due to the strategic nature of this assessment.

### 3.2.3 Determination of Retreat Rate

After the coastline had been appropriately classified, erosion analysis transects were generated at 500m spacing. The analysis then focused on transects where the historic, visible vegetation line could actually be discerned from the aerial imagery, as shown below in Figure 3-2. For the purposes of our analysis, we selected the 1996 monochromatic imagery dataset as our historical benchmark. Present-day (contemporary) imagery was supplied by both the City’s ortho dataset and ESRI’s World Imagery for 2016[18]. Upon review of the aerial imagery for the entire coastline, it was found that only 8 transects had suitably discernable vegetation lines from historic imagery, and whose locations are shown in Figure 3-1. Only 8 transects were selected for the following reasons:

- In many locations, no discernable coastal retreat could be identified i.e. no coastal erosion over that period. This was particularly obvious in man-made areas and rocky bluff locations.
- Due to the nature of some locations, any potential coastal retreat could not be made out due to the heavily vegetated nature of the coastline. Unfortunately, this was a complicating factor when looking at the North Slope area. The majority of the coastline boundary at this location is obscured by the tree canopy, and as such, casts a shadow or completely hides any potential retreat.
- Finally, the age and resolution of the data made it difficult to pick out retreat, particularly if the retreat was less than a few metres. The spatial resolution of the 1996 dataset seems to be 25cm, which means there is a separate pixel for each 25cm x 25cm area in the captured ortho imagery. However, this means that a 1m retreat in coastline between 1996 and 2016 equates to just 4 single pixels on the orthoimagery. It is extremely difficult, therefore, to pick out such a retreat at an enhanced scale, unless there is a distinct colour change to signify change in material, as shown in Figure 3-2.

At each of the transect locations, digital markers were placed at the visible vegetation line for both the historic and contemporary benchmarks, as shown in Figure 3-2. The distance of retreat was then measured between the two markers and then converted to an annualised erosion rate (m/yr), by dividing by

[18] Esri World Imagery, taken on Thu January 14th 2016. Ground resolution is 0.05 m.

the time elapsed. This annualised erosion rate was then used to 'project' the retreat distances for both the 2050 and 2100 time horizons, as per Table 3-1.


**Figure 3-2**
**Example of Coastal Erosion**

**Table 3-1**
**Results from Visual Inspection of Historic Coastal Retreat**

| Analysis Location | Chainage (m) | Contemporary Benchmark | Historic Benchmark | Retreat Distance (m) | Annualised Erosion Rate (m/yr) | 2050 Retreat Distance (m) | 2100 Retreat Distance (m) |
|---|---|---|---|---|---|---|---|
| 01 | 28+100 | 2016 | 1996 | 9.44 | 0.47 | 16.05 | 39.65 |
| 02 | 28+400 | 2016 | 1996 | 2.90 | 0.15 | 4.93 | 12.18 |
| 03 | 37+750 | 2016 | 1996 | 1.89 | 0.10 | 3.23 | 7.98 |
| 04 | 38+250 | 2016 | 1996 | 0.73 | 0.04 | 1.26 | 3.11 |
| 05 | 39+250 | 2016 | 1996 | 1.04 | 0.05 | 1.77 | 4.37 |
| 06 | 7+950 | 2016 | 1996 | 3.08 | 0.15 | 5.24 | 12.94 |
| 07 | Protection Island | 2016 | 1996 | 1.35 | 0.07 | 2.31 | 5.71 |
| 08 | 17+250 | 2016 | 2003 | 1.02 | 0.08 | 2.65 | 6.55 |
| | | | | Indicative (average) | 0.09 | 3.06 | 7.55 |

Existing literature has estimated that retreat rates for cliffs in the Nanaimo Lowlands can be in excess of 0.3 m per annum[19]. However, this erosion is balanced by local accretion of coastal landforms, thus the coastline has been historically classified as 'stable'. As such, the results shown in Table 3-1 are thought to be reasonable for a coastal environment on the eastern side of Vancouver Island, and are in-keeping with the 'stable' coastline description. As already discussed, it was difficult to include the North Slope area due to the resolution of the photography and the tree canopy obscuring the actual vegetation/beach interface. Therefore, the results have not been skewed by the significant erosion experienced in recent years at that location, which may not have been all potentially, directly attributable to coastal (wave) actions.

There is one outlier, however, at marker 01 (study chainage 28+100 m). This is the example given in Figure 3-2. It is evident that there was significant erosion over the period of 20 years; a rate of erosion that does not seem to be indicative of the study area as a whole, as can be seen from Table 3-1. The marker's location is generally sheltered, relative to the more exposed areas of the study coastline. However, it is feasible that the erosion rate may have been influenced by human activities, as well as maintenance of a local access track. On this basis, we believed it prudent to omit this marker from the final indicative, annualised erosion rate. The **indicative annualised study erosion rate therefore becomes 0.09 m/yr.** This rate is indicative only, as is based on a limited number of points for the reasons already discussed. It is for information purposes and can help inform 'typical' retreat within the City. However, it should not be used for site-specific erosion analysis as the coastline morphology in the City is extremely varied, which would have a significant effect on actual retreat rates at that particular location.

### 3.2.4 Mapping of Calculated Retreat

Upon derivation of an indicative annualised retreat rate for the study area, the final step in the erosion analysis involved the mapping of retreat lines for both the 2050 and 2100 time horizons. The general mapping assumptions were as follows:

- It was assumed that the retreat would be uniform across the full length of the coastline, where 'soft' coastline existed.
- The calculated retreat values were as is estimated in Table 3-1.
- It was assumed that no retreat would occur in coastline areas classified as "Rocky" or "Man-made Coastline". However, there were local exceptions to this assumption where segments of 'softer' coastline existed e.g. Neck Point Park (study chainage 8+000 m). With regard to "Man-made Coastline", the project team have assumed that areas such as the port shoreline and Departure Bay ferry terminal will be continually maintained and appropriately protected.
- It was found when mapping the appropriate retreat rates in GIS software, that it was very difficult to distinguish between retreat lines and coastline when printed on a paper map, at an appropriate scale (1:5,000). Therefore, as the usefulness of paper maps would be very limited in this regard, the retreat lines will be supplied to the City in digital GIS format only.

[19] Geological Survey of Canada Bulletin 505: Sensitivity of the Coasts of Canada to Sea Level Rise. 1998. J. Shaw, R.B. Taylor, D.L. Forbes, M.H. Ruz and S. Solomon.

## 3.3 EROSION MODELLING

As previously mentioned, numerical model simulations of bed shear stresses for different flow conditions (tide + wind, tide + waves) were carried out in support of the visual erosion review. The idea behind the modelling is to identify areas with high shear stress values, and to equate these to coastal erosion hotpots.

The model setups used in the analyses and the results obtained are presented and discussed in the following sections of this report.

### 3.3.1 Technical Approach

Two different simulation periods were adopted for the calculation of bed shear stresses using the hydrodynamic model MIKE 21 HD FM:

- An approximately 6-week long period in June-July 2017 with large tidal amplitudes, especially during spring tide, and,
- A four-day period in early April 2010 in which strong winds and high waves occurred.

The idea behind the selected simulation periods was to identify erosional hotspots under strong tidal flow and wave dominated situations, respectively.

Figure 3-3 shows water levels recorded at Nanaimo during the first simulation period, which extends from June 16 through July 31, 2017. The large tidal amplitude during the spring tide cycles at the beginning and end of the simulation period can be clearly seen from the figure.

Figure 3-4 shows water levels recorded at Campbell River, BC (water level records from Nanaimo do not exist for this period) as well as wind speed and direction and wave height recorded at EC buoy c46146 Halibut Bank.

During the June-July 2017 simulation period, the hydrodynamic model MIKE 21 HD FM was forced by tide; and winds and bed shear stresses were computed for the resulting flow conditions.

Meanwhile, a coupled model consisting of MIKE 21 SW and MIKE 21 HD FM was used to simulate wind-wave generation, tidal flow and to compute the bed shear stresses under combined waves and current, thus accounting for the influence of waves on increasing bed shear stresses compared to the situation without waves. To further highlight this effect, this simulation was repeated without waves.

Model results are presented and discussed in the next section of this report.

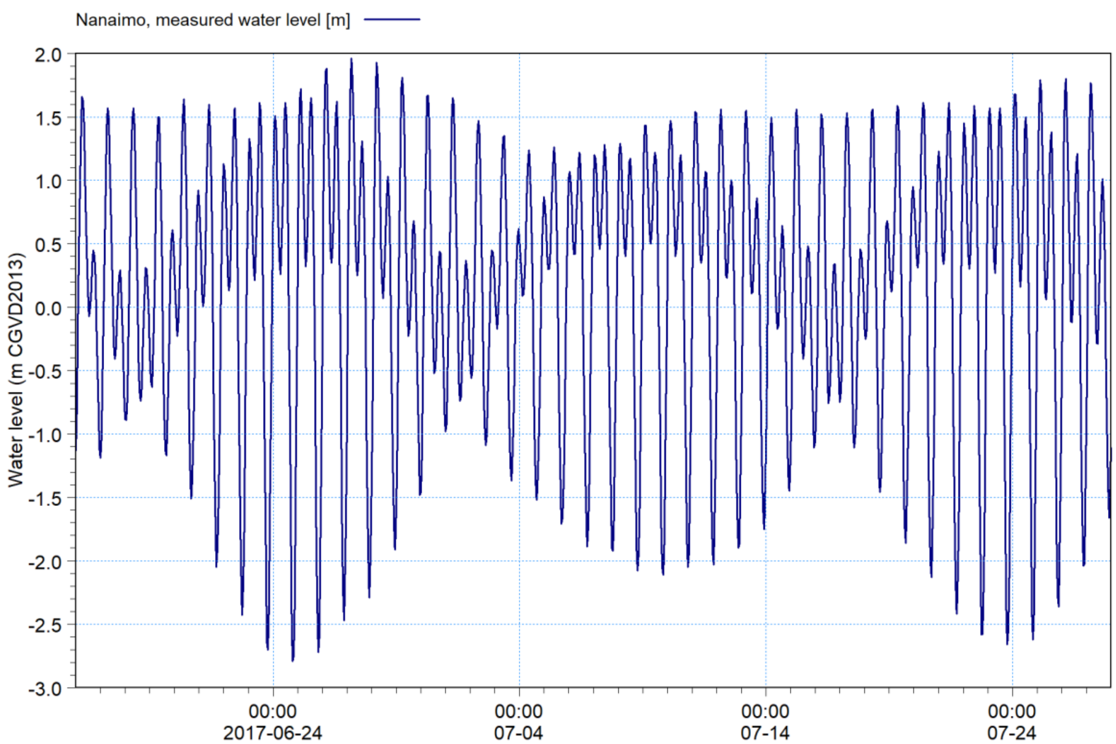


**Figure 3-3**
**Time Series of Water Levels Recorded at Nanaimo in June-July 2017**

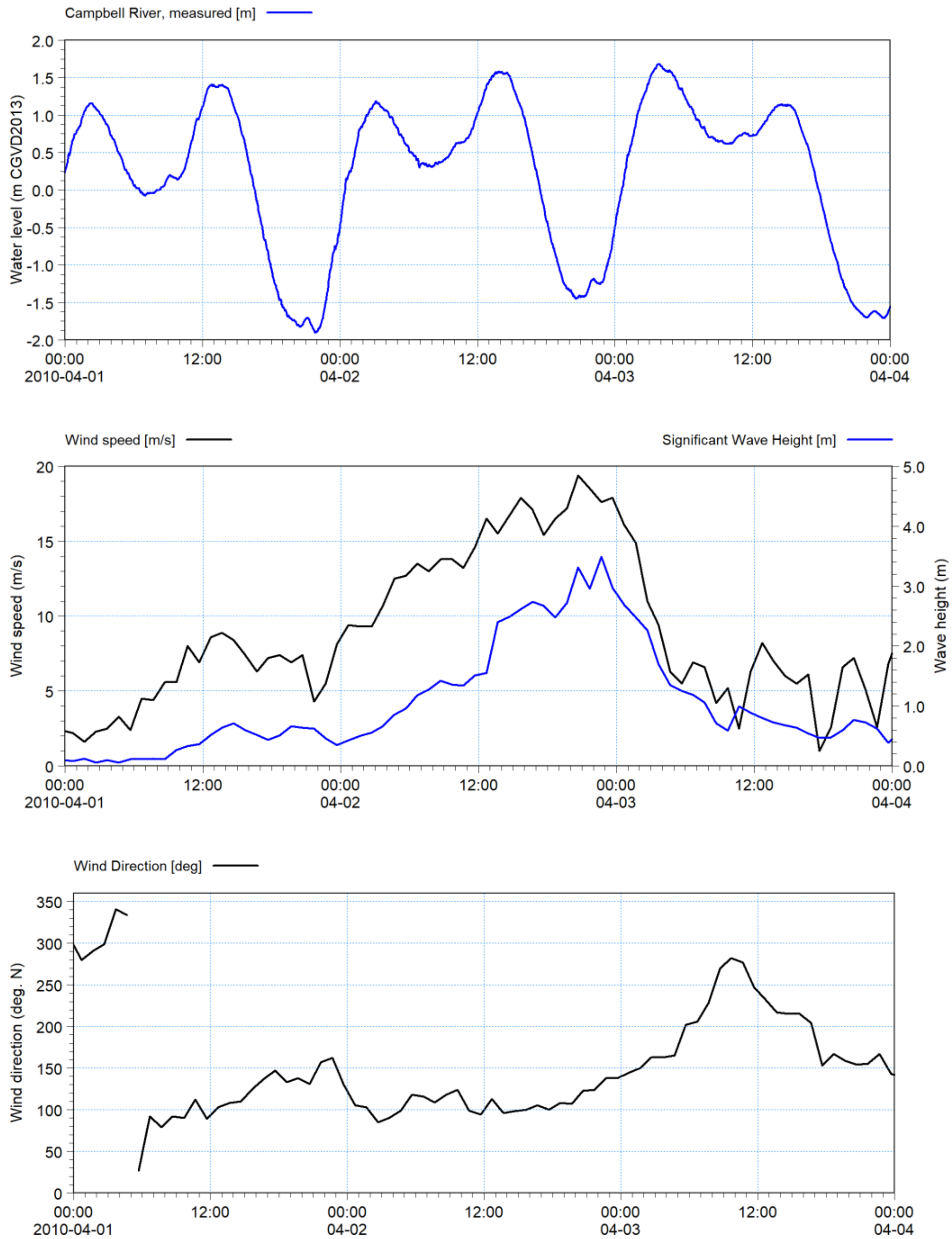


**Figure 3-4**
**Time series of water levels recorded at Campbell River (top), wind speed and wave height from Halibut Bank (centre) and wind direction (bottom) from Halibut Bank in early April 2010**

### 3.3.2 Modelling Results

Figure 3-5 shows the maximum bed shear stresses calculated by the hydrodynamic model under tidal flow and wind forcing conditions during the period June-July 2017.

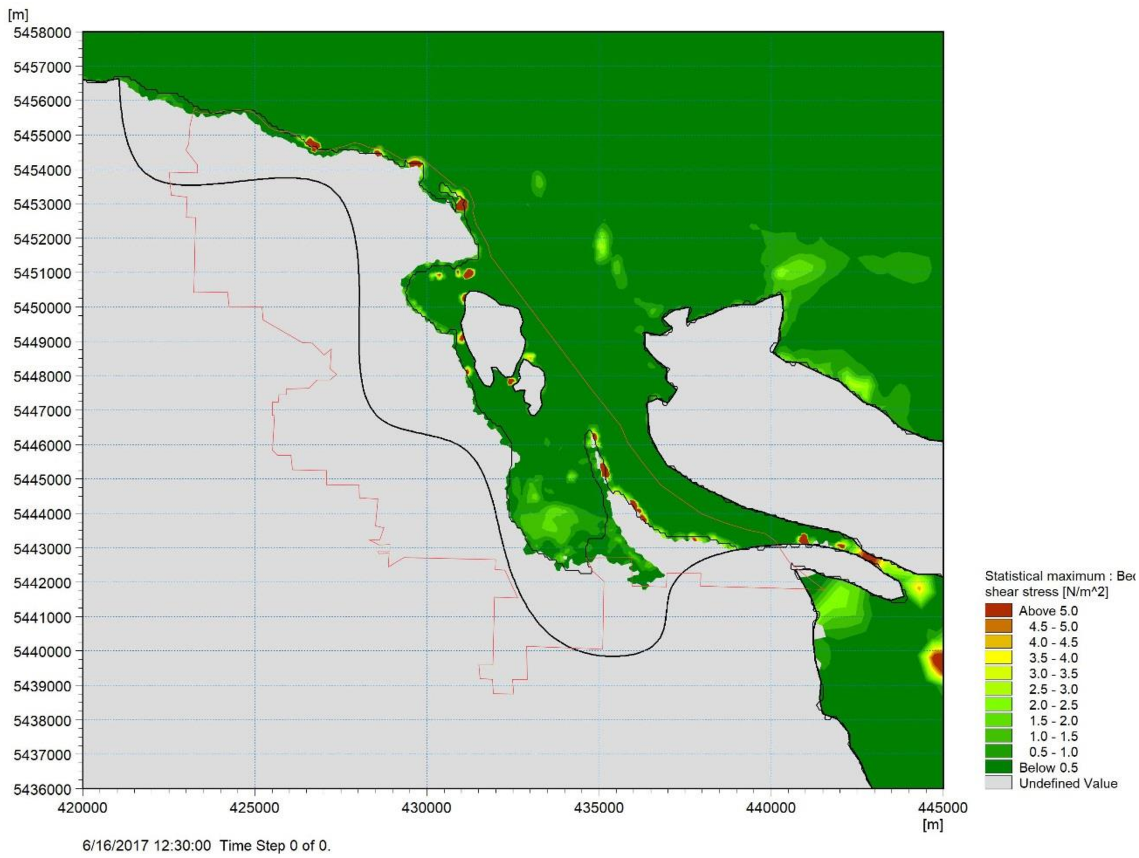


**Figure 3-5**
**Maximum bed shear stresses during simulation period in June-July 2017**

Hotspots for erosion would correspond to areas shown in 'warm' colours, such as yellow, orange and red/brown. Areas of high bed shear stress occur not only in areas of flow constriction, such as narrow channels, but also at several locations along the shoreline of Nanaimo, including Departure Bay.

Figure 3-6 shows similar results for the four-day period in April 2010 for the combined action of waves and tidal flow. Figure 3-7 shows results for the same simulation period but excluding the contribution of the waves to the bed shear stresses. Results in both figures are qualitatively similar. Inclusion of wave effects seems to make the maximum bed shear stresses larger than in the case of tidal flow only, and a few additional erosion hotspots can be seen for the case when waves are included in the analysis.

Results in Figure 3-5 and Figure 3-6 are also similar, qualitatively speaking, which could, to some extent, be expected since both figures show results for hydrodynamic conditions dominated by tidal flow.

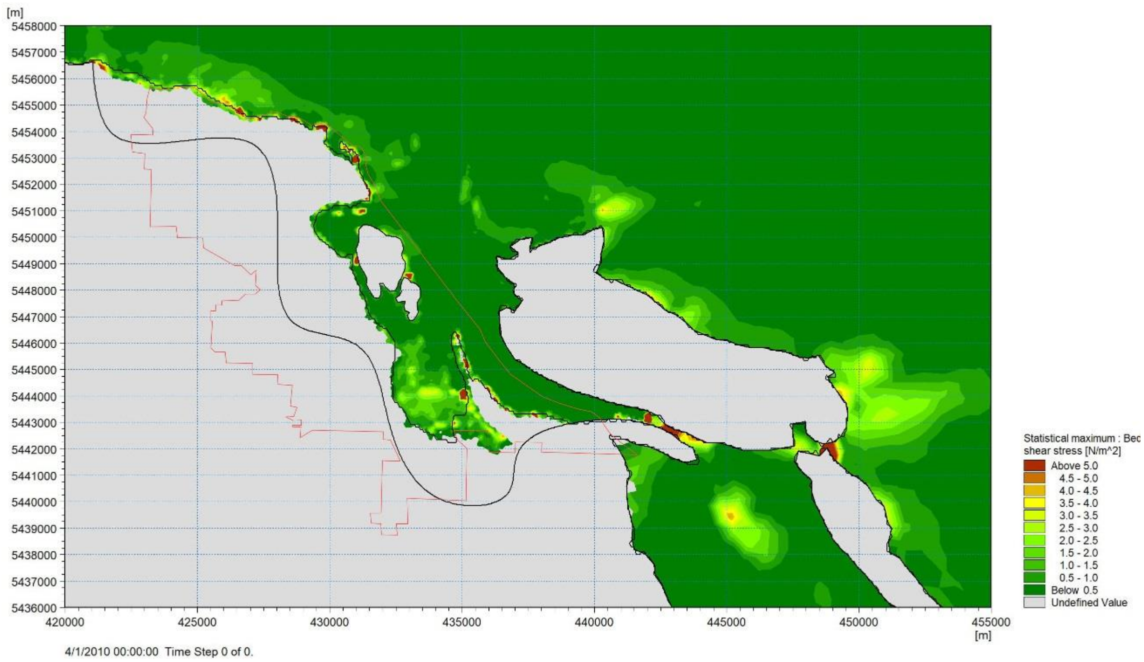


**Figure 3-6**
**Maximum bed shear stresses during four-day simulation period in April 2010. Combined tide and waves**

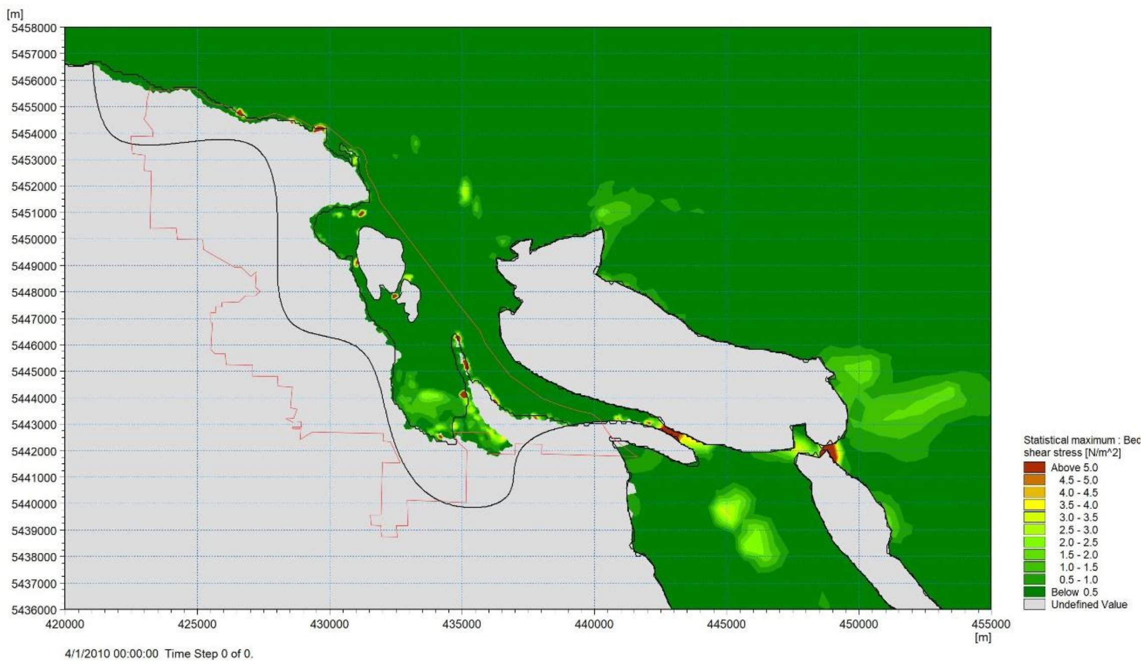


**Figure 3-7**
**Maximum bed shear stresses during four-day simulation period in April 2010. Tide only**

## 3.4 EROSION ANALYSIS FINDINGS

It is clear from both the visual analysis and the hydrodynamic “hotspot” modelling that there are some pockets/areas of the City’s coastline at risk from sustained coastal erosion. It is interesting to note that many of the visual analysis points, as listed in Table 3-1, overlap with ‘warm-colour’ regions flagged in the hydrodynamic model as erosion hotspots. Specifically, Neck Point Park (study chainage 8+000 m), Departure Bay Rd. (study chainage 17+250 m) and the Nanaimo River Estuary (study chainage 37+000 m) are all areas of general correlation between the two approaches.

It is unfortunate that the visual analysis was unable to properly discern the retreat at the North Slope area, as detailed in Section 3.2.3. Of all the coastline areas in the study boundary, it has been the location continuously flagged by City representatives as a concern. The results of the hydrodynamic hotspot modelling reinforce this, as shown in Figure 3-6. It is evident that the combined action of wave and tide has sufficient energy to mobilise bed loads and cause geomorphological change. It must be stressed again however, that coastal action at the North Slope is most likely not the sole cause of failure. But rather, failures can be caused by a combination of factors including slope steepness/instability, excessive rainfall and coastal action. Further work in relation to the North Slope will be discussed in greater detail in Section 5.5.

In summary, the results have shown that the study coastline is relatively quite stable; in agreement with the published literature. Many areas of the coastline experience little or no erosion; with much of the losses being balanced by accretion in other adjacent locations. The areas which would most likely see the most noticeable geomorphological change in the coming years due to rising sea levels would be the North Slope and the Nanaimo River Estuary. Again, this conclusion is reinforced by the results from the hydrodynamic model.

# 4 Sea Level Rise Risk Assessment

As part of this project, a strategic-level assessment of potential impacts of sea level rise in the study area was undertaken. To help with this assessment, the project team downloaded a number of digital GIS datasets from the City's website for specific locations or 'risk receptors' in the study area. 'Risk receptors' are public or private assets that could be negatively impacted by rising sea levels. For the purposes of this assessment, the project team has concentrated on the following 'risk-receptors':

- Local buildings and properties (lots).
- City of Nanaimo drainage infrastructure.
- City of Nanaimo sanitary infrastructure.

It is must be stressed again at this juncture that the flood construction levels generated in this study, and subsequently used for risk assessment, are not inundation extents. They may not give a true reflection of the expected extent or depth of flooding at that particular location for a respective event. However, as this is a strategic-level assessment, the FCLs as estimated have been deemed appropriate for use.

The general approach for this SLR risk assessment was to simply quantify the number of risk receptors located below the plotted water level elevation and examine depths as and when it was necessary. The project team decided to use the more conservative FCL elevation, rather than the Still Water Level as it accounted for freeboard, as well as wave contributions.

## 4.1 ASSESSMENT RESULTS

### 4.1.1 Risk to Buildings & Lots

Risk to buildings and lots was determined by including any areas that were contained below the FCL elevation, as well as those encroached upon i.e. if a lot/building boundary was touched, it was included in this assessment. The results of this GIS exercise are presented in Table 4-1 below.

**Table 4-1**
**Risk to Buildings & Lots**

| Time Horizon | No. of Buildings within FCL limit | | No. of Lots within FCL limit | |
|---|---|---|---|---|
| 2018 (Present Day) | Residential: | 125 | Bare Land Strata | 21 |
| | Industrial: | 57 | Parcel | 673 |
| | Commercial: | 12 | Strata | 41 |
| | Apartment: | 9 | Strata Lot | 9 |
| | General: | 6 | | |
| | Institutional: | 6 | | |
| | Multifamily: | 7 | | |
| | Office: | 7 | | |
| | Gas Station | 2 | | |
| | **Total:** | **231** | | |

| Time Horizon | No. of Buildings within FCL limit | | No. of Lots within FCL limit | |
|---|---|---|---|---|
| 2050 | Residential: | 133 | Bare Land Strata | 23 |
| | Industrial: | 62 | Parcel | 683 |
| | Commercial: | 12 | Strata | 42 |
| | Apartment: | 10 | Strata Lot | 9 |
| | General: | 6 | | |
| | Institutional: | 6 | | |
| | Multifamily: | 7 | | |
| | Office: | 8 | | |
| | Gas Station | 2 | | |
| | **Total:** | **247** | | |
| 2100 | Residential: | 157 | Bare Land Strata | 23 |
| | Industrial: | 67 | Parcel | 721 |
| | Commercial: | 12 | Strata | 42 |
| | Apartment: | 10 | Strata Lot | 9 |
| | General: | 6 | | |
| | Institutional: | 6 | | |
| | Multifamily: | 8 | | |
| | Office: | 8 | | |
| | Gas Station | 2 | | |
| | **Total:** | **277** | | |

As is evident from Table 4-1, there is very little change in no. of lots/buildings affected between each time horizon. This is a function of the relative steepness of the Nanaimo coastline. Despite noticeable gains in flood construction levels at each transect between each time horizon, the majority of the coastline is steep enough so that the only notable differences are evident in low-lying areas such as Departure Bay. However, it is also interesting to note that some of the contributions to the values shown in Table 4.1 come from Protection Island, particularly in the 2100 time-horizon.

In support of this analysis, a heatmap was generated to indicate the concentration of building vulnerability, in the year 2100, in the City of Nanaimo, as per Figure 4-1. Heatmaps are an effective visualisation tool for dense point data, as it allows the reader to easily identify clusters where there is a high concentration of the variable in question (i.e. buildings). The heatmap was generated in GIS software using a statistical process called ‘kernel density estimation’, which converts the point information into a raster dataset.

Figure 4-1 shows a dense cluster of properties affected around Departure Bay, which is to be expected due to its relatively low-lying nature. However, the greatest density of buildings affected tends to be on Protection Island. Much of the properties on the eastern side of the island tend to be relatively low-lying and could show increased vulnerability to rising sea levels in the near future.

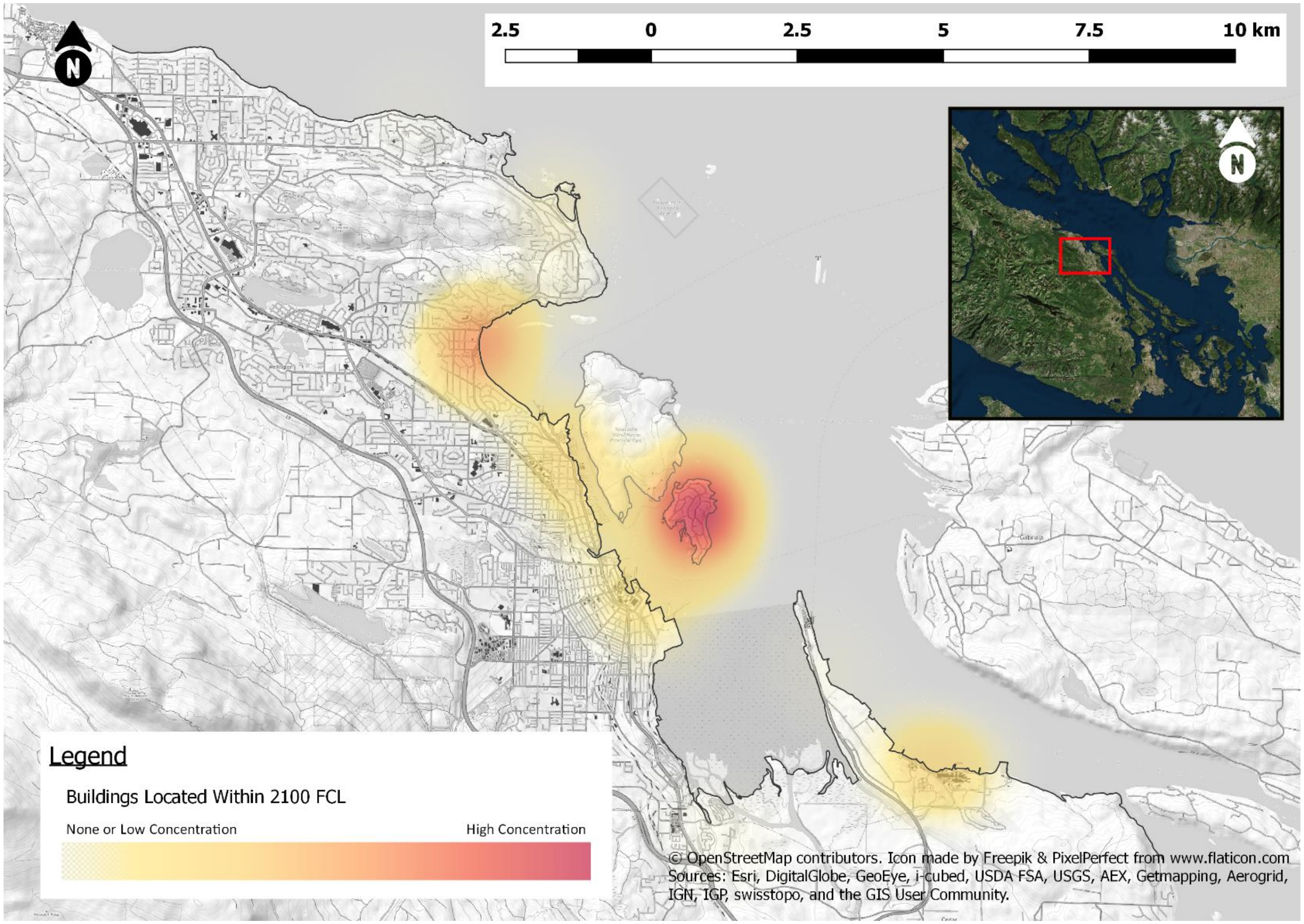


**Figure 4-1**
**Heatmap showing concentration of building vulnerability to 2100 FCL scenario**

### 4.1.2 Risk to Drainage Infrastructure

Risk to drainage infrastructure was determined in a similar fashion to that of buildings/lots; any risk receptors located below the FCL elevation were selected. The results of this GIS operation are shown below, in Table 4-2.

**Table 4-2**
**Risk to Drainage Infrastructure**

| Time Horizon | No. of Storm Assets within FCL Limit | | | |
|---|---|---|---|---|
| | Type | Public | Private | Total |
| 2018 | Manhole | 62 | 52 | 114 |
| | Outlet | 124 | 12 | 136 |
| | Reducer | 2 | 0 | 2 |
| | Pipe (m) | 7145 | 4118 | 11263 |
| 2050 | Manhole | 66 | 55 | 121 |
| | Outlet | 133 | 14 | 147 |
| | Reducer | 2 | 0 | 2 |
| | Pipe (m) | 7703 | 4362 | 12065 |
| 2100 | Manhole | 69 | 58 | 127 |
| | Outlet | 137 | 14 | 151 |
| | Reducer | 2 | 0 | 2 |
| | Pipe (m) | 8045 | 4747 | 12792 |

Like previous results, the bulk of risk to drainage infrastructure is concentrated around Departure Bay and its BC Ferries terminal. It reinforces the anecdotal evidence of flooding discussed in Section 1. A heatmap was also generated for the drainage infrastructure layer, as shown in Figure 4-2. It is interesting to note that drainage infrastructure along the Inner Harbour (study chainage 24+500 m) are also flagged as being potentially vulnerable.

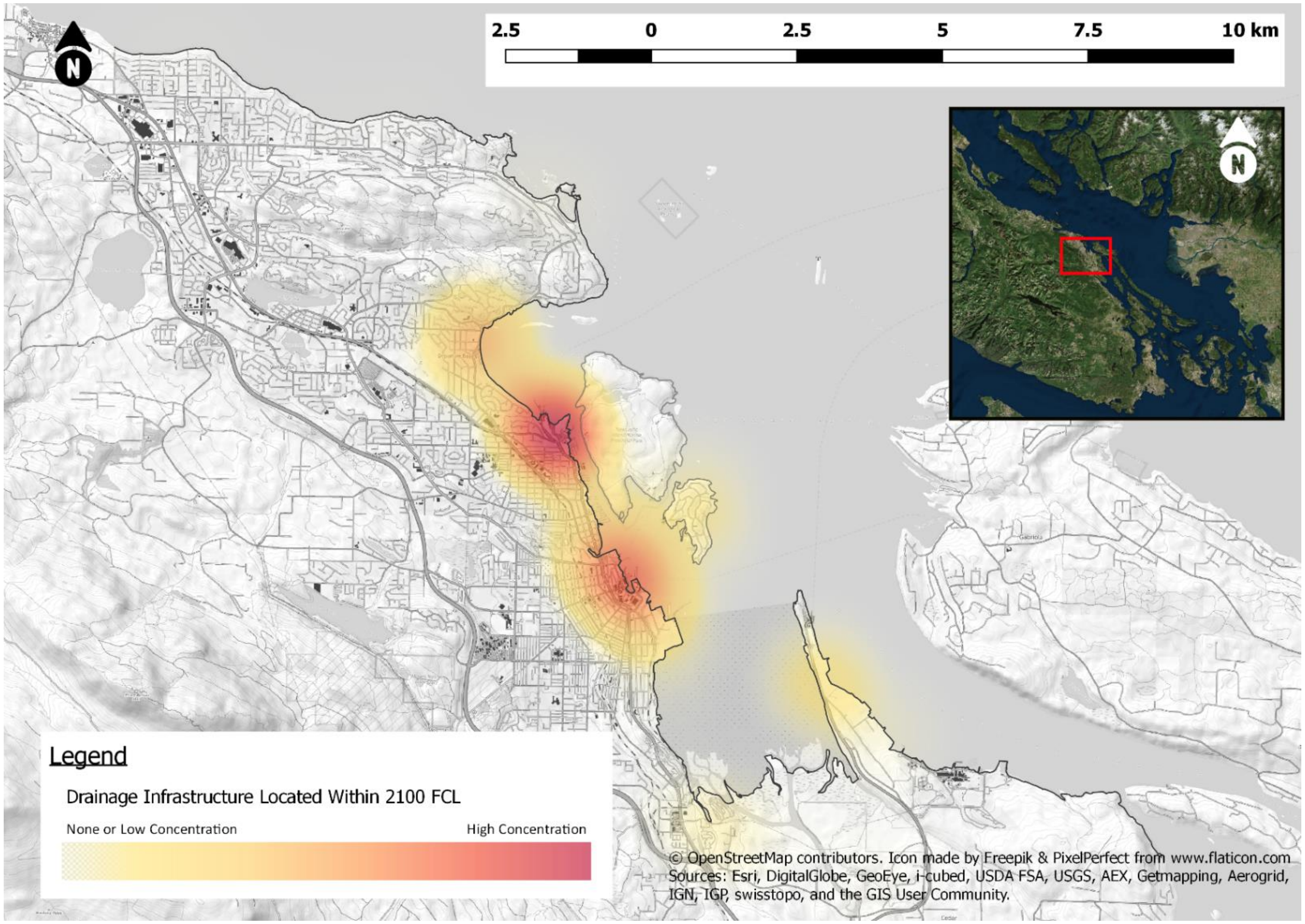


**Figure 4-2**
**Heatmap showing concentration of drainage infrastructure vulnerability to 2100 FCL scenario**

### 4.1.3 Risk to Sanitary Infrastructure

The final set of risk receptors looked at, as part of this assessment, was sanitary infrastructure. As already detailed, we used GIS information downloaded from the City's website, specifically the "Appurtenances" dataset. The results of the analyses are presented in Table 4-3.

**Table 4-3**
**Risk to Sanitary Infrastructure**

| Time Horizon | No. of Sanitary Assets within FCL Limit | | | |
|---|---|---|---|---|
| | Type | Public | Private | Total |
| 2018 | Manhole | 145 | 10 | 155 |
| | Pump Station | 5 | 3 | 8 |
| | Gravity Pipe (m) | 16440 | 851 | 17291 |
| | Pressure Pipe (m) | 1387 | 611 | 1998 |
| 2050 | Manhole | 150 | 10 | 160 |
| | Pump Station | 0 | 8 | 8 |
| | Gravity Pipe (m) | 17305 | 888 | 18193 |
| | Pressure Pipe (m) | 1415 | 649 | 2064 |
| 2100 | Manhole | 166 | 11 | 177 |
| | Pump Station | 0 | 9 | 9 |
| | Gravity Pipe (m) | 18132 | 936 | 19068 |
| | Pressure Pipe (m) | 1951 | 681 | 2632 |

Again, the low-lying Departure Bay area is particularly effected. The accompanying heatmap, shown in Figure 4-3, better conveys the areas of vulnerability. The highest concentration of appurtenances affected tends seems to be in the Inner Harbour once more. Much of the infrastructure here is public manholes, which could experience floodwater ingress or complete removal if not properly sealed and locked. The manholes located within the FCL areas that require sealing would likely operate, on occasion, under a pressurised condition. Standard manholes are not designed for pressurised operation, and as a result, the modification or replacement of the manhole(s) may be required based on further analysis.

Notably, there are also several pump stations, both public and private, located below FCL elevations. These public pump stations are located at the following locations:

- Piper Crescent, City of Nanaimo, approximate project chainage Sta. 9+400.
- Departure Bay Pump Station (2936 Departure Bay Rd.), RDN, approximate project chainage Sta. 17+600.

- Vancouver Island Regional Library (Museum Way), City of Nanaimo, approximate project chainage 25+250.
- Promenade Drive, City of Nanaimo, approximate project chainage Sta. 25+400.

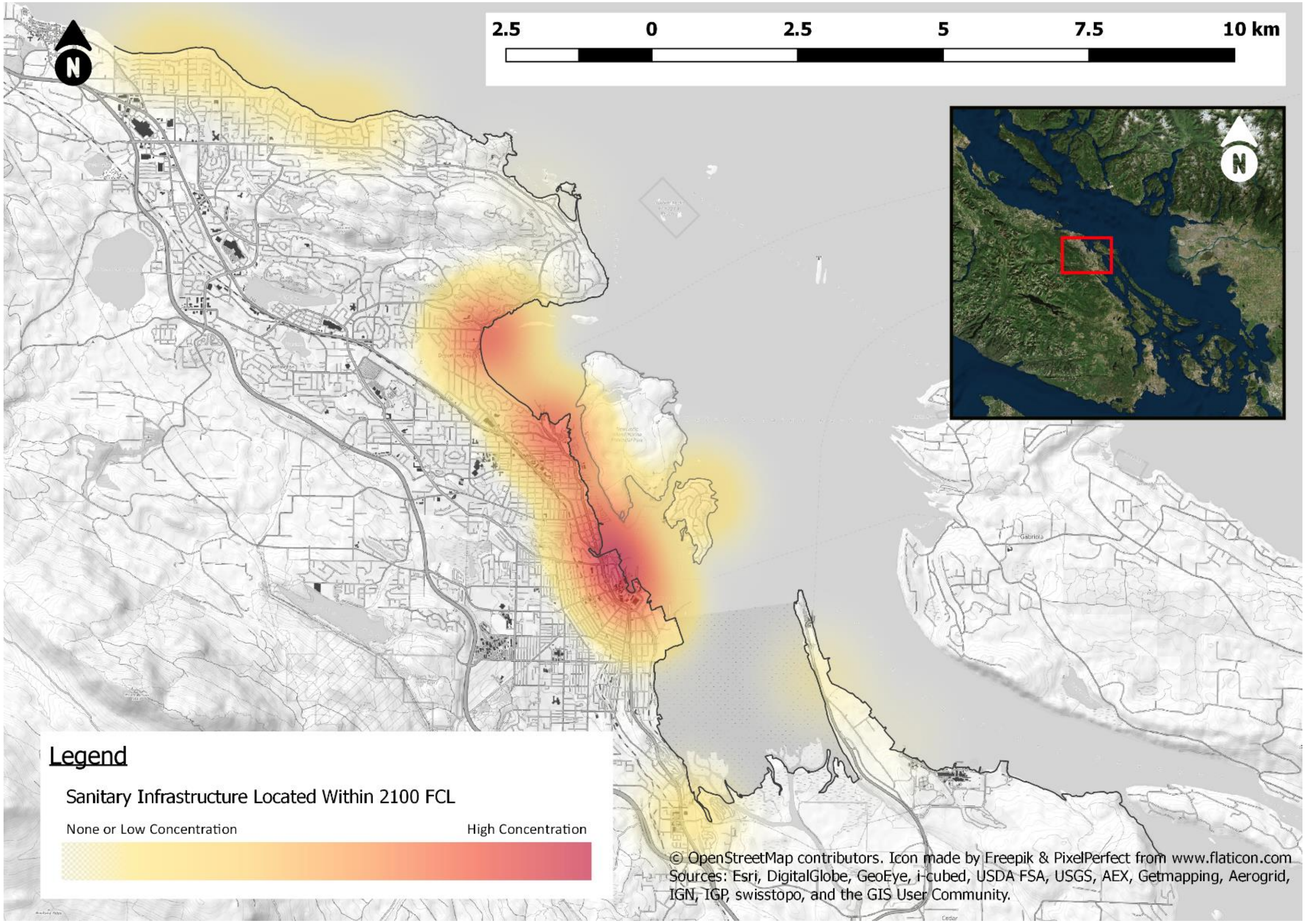


**Figure 4-3**
**Heatmap showing concentration of sanitary infrastructure vulnerability to 2100 FCL scenario**

- Chase River Pumping Station (1174 Island Highway South), RDN, approximate project chainage Sta. 31+200.
- Duke Point Highway, RDN, approximate project chainage Sta. 42+500

Also, worth noting, as can be seen in Figure 4-3, is that there is a reasonable concentration of sanitary infrastructure in easements that will be impacted on the North Slope area. This corresponds to the existing gravity pipeline. Vulnerability to rising sea levels and potential coastal retreat at this location is something that the City should be aware of for future planning.

## 4.2 RISK ASSESSMENT CONCLUSIONS

The risk assessment shows areas of vulnerability that are generally consistent with the locations flagged as having existing flood history and relatively low-lying. However, Protection Island, BC Ferries Departure Bay Terminal and the Nanaimo Inner Harbour are all locations where rising sea levels could have significant impacts on existing buildings, storm and sanitary infrastructure. As already mentioned in this report, further 2D modelling could help refine the FCL estimates at these locations (see Section 5.2), as well as give an enhanced understanding of flood depths and extents.

# 5 Options for Further Analysis

The following sections describe work-items that may offer additional value to the City and interested stakeholders. Some sections detail activities that could be undertaken to further **refine FCL estimates** and/or coastal inundation mapping. Many of the sections describe what the City could do to carry this work through to a **sea level rise/coastal flood risk management plan** and any subsequent protection works. This would be particularly relevant to the lower-lying private residences and businesses located around Departure Bay.

## 5.1 PROBABILISTIC CALCULATION OF SEA LEVEL RISE

The means by which the FCL is calculated using the Coastal Guidelines 2011, using a combined approach as shown in sections 2.1 and 2.2, is a conservative approach as it does not take into account the joint probability of the extreme of each component occurring simultaneously i.e. how likely is that the 0.5% AEP deep water storm surge, the 0.5% AEP wind speed, the HHWLT and the corresponding maximum wave heights all occur at the same time? If one were to undertake a joint probability analysis, it may be found that this ‘combined approach’ yields a much more remote probability than 0.5%.

Further detailed analyses on the joint probability of these components could be undertaken to derive a more refined 0.5% AEP FCL elevation.

## 5.2 REFINED INUNDATION MODELLING

As discussed in Section 2 of this report, the Flood Construction Levels have been projected inward from the coastline, until it hits or ‘cuts’ the same elevation in the study DTM (see Section 1.5.1). For the purposes of this strategic-level study, this is an appropriate approach to mapping. However, flood depths and extents, and consequently FCLs and FCL inundation limits, could be refined using 2D inundation modelling. We have not completed any 2D inundation modelling as part of this project. A 2D inundation model would essentially ‘spill’ tidal volumes and wave overtopping volumes onto the study DTM at the coastline boundary. Floodwater would then inundate the study area, gradually decreasing in momentum, until it reached its maximum extent. There are a number of reasons why 2D inundation modelling would improve upon this project’s approach:

- Coastal flood events can occur over a number of tidal cycles i.e. there may be more than just one peak. The first high-tide may inundate an area, leaving ponded floodwater behind as the tide recedes. The next high-tide may be the actual ‘peak’, exacerbating any flood volumes already in an area as a result of the first high-tide. Such an occurrence can have noticeable impacts on storm drainage infrastructure and building basements for example. A 2D inundation model would account for these volumes and further refine depths and extents.
- The wave heights, as they have been estimated at each transect using detailed MIKE 21 SW modelling have been, for the most part, projected inland. In steep rocky bluff areas, this approach would not need any further refinement. In areas where waves have the opportunity to runup and overtop, 1D calculations could be undertaken to estimate overtopping volumes and use this as

another input into the aforementioned 2D inundation model. However, in areas where waves would have the opportunity to propagate from coastal waters and travel beyond the coastline, a separate 2D computational wave model could be constructed to simulate this wave inundation. An example of this would be at Departure Bay ferry terminal, where SWLs exceed coastline elevations, allowing waves to travel inward.

The project team are more than capable of undertaking the above work to help refine FCLs in targeted areas such as Departure Bay and the Inner Harbour. Much of the groundwork and detailed modelling of inputs has already been completed as part of this project. Therefore, we would be in an advantageous position to provide further detailed outputs in an efficient manner. We would be more than happy to discuss this with the City and interested stakeholders, as and if the need arises.

This additional assessment could also be used to produce detailed Floodplain maps.

## 5.3 ECONOMIC RISK ASSESSMENT

If the City and other stakeholders were interested in estimating the financial implication of rising sea levels to coastal infrastructure and properties, a quantitative economic risk assessment could be undertaken i.e. a “damages assessment”. The damages could be derived from one of two different datasets:

- This study’s FCL mapping, included in Appendices D-F, or,
- The results of the refined inundation modelling, as described in Section 5.2.
  (Both would require an inventory of GIS building attribute and location data.)

Using an input risk receptor such as “Buildings”, “Drainage Infrastructure” etc. and automated GIS routines (e.g. FEMA HAZUS), the depth and extent of coastal inundation can be converted to a net present value (NPV) financial loss. The Annual Average Damage (AAD) for each individual risk receptor could then estimated using the NPV and a range of probabilities. This would be the cost number that the City or other stakeholders could use (via Cost-Benefit Analysis, explained in Section 5.4) to examine if SLR/inundation management measures are worth pursuing.

The calculation of the AAD would require additional coastal inundation analysis covering a range of storm frequencies ranging from the 10-year event to the 1000-year event.

## 5.4 SEA LEVEL RISE MANAGEMENT PLAN

Upon conclusion of the SLR Risk Assessment in Section 4, it was evident that the properties on Protection Island, Battersea Rd., Randle Rd. and parts of Departure Bay Rd. are vulnerable to rising coastal levels. The City may find it necessary to properly plan for and manage potential sea level rise at these locations in the coming years. A means by which this could be done is termed a “Sea Level Rise Management Plan” (SLRMP) or coastal Flood Risk Management Plan. The various input stages of a SLRMP are shown in Figure 5-1. The green boxes denote activities that the project team deem fundamental to the production of an effective management plan. The blue boxes denote activities that, though strongly recommended, could be foregone as part of this work.

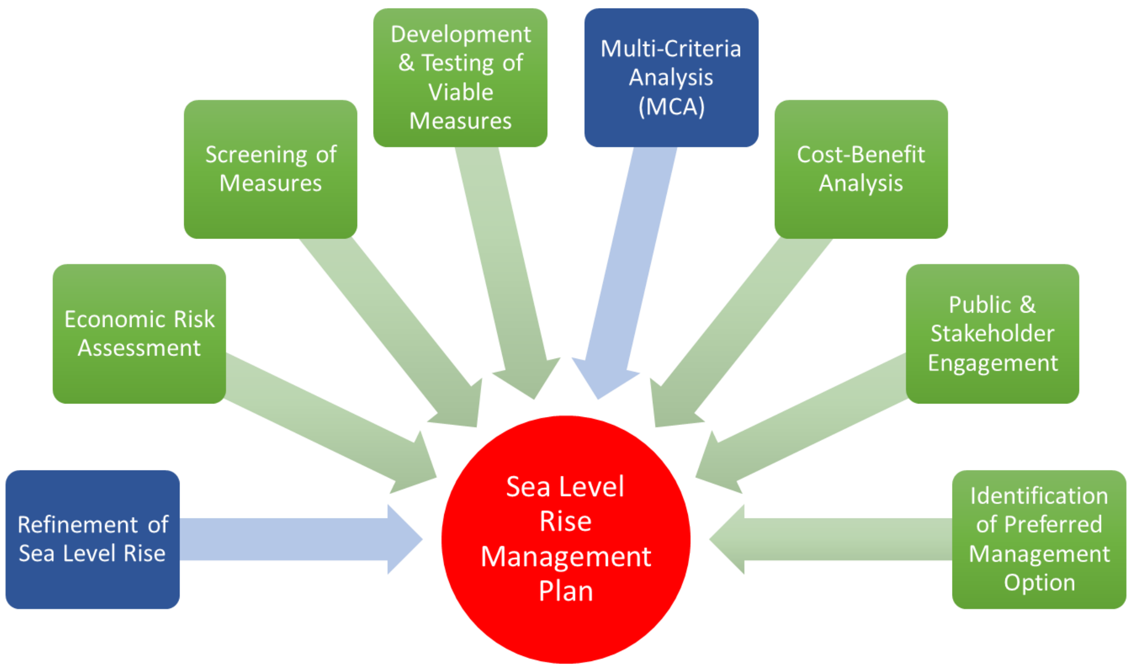


**Figure 5-1**
**Stages of Sea Level Rise Management Plan**

The various input stages of a SLRMP are explained in greater detail below:

Screening of Measures: Screening involves the assessment of possible methods to manage flood risk and identifying those which could be effective and potentially viable. For example, in a coastal environment, a tidal barrage could be screened out immediately if its construction challenges and cost are disproportionate to the area it is protecting. Examples of other measures that could be considered in a coastal environment include sea walls, rubble-mound breakwaters and retreat from affected areas.

Development and Testing of Potentially Viable Measures: This work-item uses the potentially effective measures identified at Screening and refines them for outline design. High-level cost estimates are developed for each potentially viable measure. Any potential measure whose implementation could impact on existing water levels should be tested in a hydraulic model so that a 'post-implementation' benchmark can be established to evaluate its relative performance e.g. an existing drainage outfall emptying to the sea can be a source of flooding during extreme tides. If a non-return valve is installed on the drainage route, is there enough storage in the system upstream for flooding not to occur whilst tide levels are elevated (i.e. tide-locking)?

Multi-Criteria Analysis (MCA): This could also be termed 'Triple-Bottom-Line' Analysis. Potential measures can be assessed and appraised using this analysis to determine their effectiveness in reducing flood risk, as well as their potential benefits, across a range of specific objectives. Criteria under which potential measures could be assessed include environmental performance, technical feasibility, economic impact and social performance.

Cost-Benefit Analysis: This assessment would take the results from the economic risk assessment, as detailed in Section 5.3, and compare them against the high-level cost of any proposed management measure. This would assign a 'cost-benefit ratio' (CBR) or financial score to each measure, allowing the City and other stakeholders to more easily see the most economically advantageous option.

Public & Stakeholder Engagement: During the development of the Sea Level Rise Management Plan, residents, local communities, elected officials and affected stakeholders should be consulted so that everyone's views and opinions can be gathered and taken onboard. This is extremely important in securing 'public buy-in' to a management plan and sometimes offers invaluable insight as to problems experienced on the ground.

Identification of Preferred Sea Level Rise Management Option: This is the selection of the preferred management measure for the local residents, businesses, community and other stakeholders; taking into account the holistic performance of the measures examined. If this measure requires construction of any kind (e.g. flood defence wall), the plan could then be carried through to detailed design and tendering stage.

The above offers an overview of what could be required if the City were to decide that protection of the Departure Bay and/or Protection Island areas, for example, is necessary. It is a roadmap by which a solution could be pursued and would result in the optimum sea level rise management method.

## 5.5 COASTAL EROSION MONITORING

Following on from the results shown in Section 3, it is evident that there are some locations in the study area sensitive to coastal erosion. In open areas such as the Nanaimo River Estuary, retreat can be monitored using aerial orthoimagery, so long as the resolution of the image is sufficient to properly pick out coastline movement. However, in an obscured area such as the North Slope, a different approach would be required.

One option would be to conduct a detailed survey of the area, as has been done previously, perhaps at a couple of key locations e.g. Sealand Park (study chainage 3+000 m). Benchmarks could be established at the slope-toe at a number of known points. This would be a process similar to the physical monitoring of glacial retreat. Through a combination of physical monitoring and subsequent surveying, a pattern of retreat could be established. This would allow the City to prioritise remediation/maintenance efforts, as well as inform local residents.

# 6 Conclusions

## 6.1 IMPLICATIONS OF THE RESULTS

### 6.1.1 Sea Level Rise

The results presented in Sections 2 and 4, as well as Appendices D to F, of this report have shown that, for the most part, the City of Nanaimo is not as vulnerable to rising sea levels as other areas of Vancouver Island and the Lower Mainland. Its location on elevated rocky bluffs affords it a degree of protection from sea level rise and is reinforced by the fact that any historical coastal flooding occurring in the jurisdiction tends to be concentrated in low-lying areas like Departure Bay.

Conversely, Departure Bay and portions of Downtown, Protection Island and Duke Point are seen to be vulnerable to rising sea levels, with swathes of land in these locations being below the corresponding FCL. Without detailed inundation modelling at each of these areas, it is difficult to state with relative certainty the degree to which they are affected. However, the SWL does encroach onto land in these areas for each time horizon, so it is not unreasonable to assume that coastal inundation events may occur more frequently in the foreseeable future.

### 6.1.2 Coastal Erosion

The results shown in Section 3 detail that coastal erosion tends to be an isolated and concentrated problem for the City's coastline. It tends to be focussed on areas with 'softer' coastline and high-energy wave/tidal environments. The North Slope area is a continuous concern for the City, however, the problems encountered here tend to be from a combination of different factors including coastal processes.

With regard to much of the rocky bluff areas of the City coastline, coastal erosion for the time horizons analysed in this report, would be of minor concern. We recommend that the City continues regular monitoring and inspection of the North Slope area, which could potentially incorporate periodic topographic surveying and measurement. It is also imperative to continue to commission aerial photography flights, at detailed resolution (<0.15cm), so that movement of the City's coastline as a whole can be regularly studied.

## 6.2 RECOMMENDATIONS FOR FURTHER WORK/ANALYSIS

As has been heavily repeated throughout this document, the work undertaken is very much a 'strategic-level' assessment of sea level rise implications for the City of Nanaimo. The combined calculation approach, as recommended by the 2011 Coastal Guidelines, is a good starting point for FCL determination and an estimation of flood risk. However, as has been described, these results can be improved upon by development of bespoke 2D inundation models at locations where flood risk needs to be more refined for detailed planning/design purposes.

The project team therefore would recommend that further analysis be carried out in the Departure Bay, Protection Island and downtown areas that will more accurately define inundation limits, as well as potential flood depths. Using a more refined flood depth in these locations, an appropriate FCL can be estimated simply by adding a suitable freeboard (e.g. 600mm) to this number. Much of the preliminary analysis has already been done in this project for such work, with many of our outputs being suitable for inputting into any detailed 2D inundation model. We are available to discuss such an undertaking with the City and interested stakeholders at any time.

As mentioned in Section 4, we would also recommend that the City continue to monitor the effect rising sea levels has on both private and public infrastructure. At a minimum, we would recommend that any storm/sanitary manholes located within the FCL contours, be sealed to prevent ‘popping’ when subjected to significant hydraulic gradients. The manholes located within the FCL areas that require sealing would likely operate, on occasion, under a pressurised condition. Standard manholes are not designed for pressurised operation, and as a result, the modification or replacement of the manhole(s) may be required based on further analysis. The City’s pumping stations may also require review as operating rules may have to change with rising sea levels.

REPORT

# Certification Page

This Sea Level Rise Study report was prepared for the City of Nanaimo to provide input to the City's upcoming Climate Change Resiliency Strategy. We trust the results of this study provide the City with an improved understanding of the potential hazards and increased risk that climate change brings to planning and building towards a resilient City.

The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.

Prepared by:

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA D. FORDE # 2?602
Dec 19 2018

David Forde M.Eng. C.Eng. MIEI, P.Eng.
Water Resources Engineer

Reviewed by:

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA A. J. WIENS # 32790
Dec 15/2018

Andrew Wiens P.Eng.
Senior Water Resources Engineer

Dr. Michael Isaacson, Ph.D., P.Eng.
Senior Reviewer

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

# Appendix A - Details of Calculation of Wave Effects: Year 2018

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| 01 | N | 2.138 | 5.710 | 357.02 | 3.51 | 0.114 | 0.419 | 0.790 | 1.208 |
| | NNE | 1.693 | 4.997 | 21.28 | 3.51 | 0.114 | 0.320 | 0.604 | 0.925 |
| | NE | 1.702 | 5.142 | 54.77 | 3.51 | 0.114 | 0.269 | 0.520 | 0.789 |
| | ENE | 2.322 | 6.157 | 74.85 | 3.51 | 0.114 | 0.266 | 0.536 | 0.801 |
| | E | 4.074 | 6.434 | 84.38 | 3.51 | 0.114 | 0.270 | 0.550 | 0.821 |
| | ESE | 2.718 | 6.289 | 90.88 | 3.51 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.503 | 6.359 | 95.52 | 3.51 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 2.899 | 6.313 | 328.03 | 3.51 | 0.114 | 0.527 | 0.992 | 1.519 |
| | NNW | 2.896 | 6.268 | 340.89 | 3.51 | 0.114 | 0.545 | 1.020 | 1.565 |
| 02 | N | 2.180 | 5.731 | 354.69 | 3.52 | 0.036 | 0.298 | 0.501 | 0.799 |
| | NNE | 1.700 | 4.997 | 20.53 | 3.52 | 0.031 | 0.250 | 0.417 | 0.667 |
| | NE | 1.695 | 5.140 | 54.71 | 3.52 | 0.032 | 0.255 | 0.425 | 0.680 |
| | ENE | 2.295 | 6.150 | 74.21 | 3.52 | 0.040 | 0.344 | 0.581 | 0.925 |
| | E | 4.029 | 6.420 | 84.05 | 3.52 | 0.057 | 0.562 | 0.961 | 1.524 |
| | ESE | 2.654 | 6.277 | 90.58 | 3.52 | 0.041 | 0.354 | 0.598 | 0.951 |
| | SE | 2.449 | 6.347 | 96.03 | 3.52 | 0.037 | 0.310 | 0.523 | 0.833 |
| | NW | 3.079 | 6.313 | 325.87 | 3.52 | 0.034 | 0.283 | 0.477 | 0.760 |
| | NNW | 3.046 | 6.273 | 337.52 | 3.52 | 0.041 | 0.355 | 0.600 | 0.955 |
| 03 | N | 2.190 | 5.737 | 353.98 | 3.51 | 0.064 | 0.379 | 0.659 | 1.039 |
| | NNE | 1.700 | 4.988 | 20.31 | 3.51 | 0.062 | 0.288 | 0.499 | 0.787 |
| | NE | 1.695 | 5.140 | 54.97 | 3.51 | 0.061 | 0.247 | 0.430 | 0.677 |
| | ENE | 2.305 | 6.153 | 74.67 | 3.51 | 0.061 | 0.262 | 0.465 | 0.728 |
| | E | 4.057 | 6.419 | 84.64 | 3.51 | 0.063 | 0.316 | 0.559 | 0.875 |
| | ESE | 2.683 | 6.280 | 91.32 | 3.51 | 0.060 | 0.128 | 0.240 | 0.368 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | SE | 2.488 | 6.353 | 96.91 | 3.51 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.139 | 6.313 | 324.52 | 3.51 | 0.053 | 0.465 | 0.795 | 1.260 |
| | NNW | 3.089 | 6.275 | 336.26 | 3.51 | 0.054 | 0.482 | 0.823 | 1.305 |
| 04 | N | 2.198 | 5.745 | 353.51 | 3.51 | 0.036 | 0.323 | 0.543 | 0.866 |
| | NNE | 1.703 | 4.993 | 20.00 | 3.51 | 0.034 | 0.259 | 0.433 | 0.692 |
| | NE | 1.681 | 5.137 | 54.30 | 3.51 | 0.033 | 0.246 | 0.411 | 0.657 |
| | ENE | 2.238 | 6.137 | 72.66 | 3.51 | 0.036 | 0.304 | 0.512 | 0.817 |
| | E | 3.911 | 6.396 | 82.80 | 3.51 | 0.040 | 0.454 | 0.763 | 1.217 |
| | ESE | 2.516 | 6.261 | 89.31 | 3.51 | 0.035 | 0.281 | 0.473 | 0.754 |
| | SE | 2.310 | 6.321 | 95.14 | 3.51 | 0.033 | 0.235 | 0.396 | 0.631 |
| | NW | 3.185 | 6.311 | 324.46 | 3.51 | 0.038 | 0.373 | 0.628 | 1.001 |
| | NNW | 3.141 | 6.276 | 335.88 | 3.51 | 0.039 | 0.412 | 0.692 | 1.104 |
| 05 | N | 2.201 | 5.736 | 351.85 | 3.50 | 0.024 | 0.302 | 0.500 | 0.802 |
| | NNE | 1.693 | 4.930 | 19.47 | 3.50 | 0.022 | 0.235 | 0.389 | 0.624 |
| | NE | 1.698 | 5.131 | 56.88 | 3.50 | 0.021 | 0.218 | 0.360 | 0.578 |
| | ENE | 2.392 | 6.159 | 78.54 | 3.50 | 0.023 | 0.266 | 0.441 | 0.707 |
| | E | 4.378 | 6.416 | 89.74 | 3.50 | 0.026 | 0.380 | 0.631 | 1.012 |
| | ESE | 3.037 | 6.313 | 97.78 | 3.50 | 0.021 | 0.218 | 0.361 | 0.579 |
| | SE | 2.924 | 6.435 | 103.30 | 3.50 | 0.018 | 0.158 | 0.262 | 0.419 |
| | NW | 3.419 | 6.324 | 319.54 | 3.50 | 0.025 | 0.363 | 0.603 | 0.966 |
| | NNW | 3.270 | 6.291 | 332.21 | 3.50 | 0.025 | 0.391 | 0.648 | 1.040 |
| 06 | N | 2.201 | 5.738 | 351.54 | 3.48 | 0.057 | 0.370 | 0.636 | 1.005 |
| | NNE | 1.692 | 4.923 | 19.41 | 3.48 | 0.052 | 0.276 | 0.471 | 0.747 |
| | NE | 1.696 | 5.131 | 57.06 | 3.48 | 0.049 | 0.234 | 0.400 | 0.634 |
| | ENE | 2.392 | 6.157 | 78.63 | 3.48 | 0.049 | 0.242 | 0.421 | 0.663 |
| | E | 4.395 | 6.415 | 90.03 | 3.48 | 0.050 | 0.247 | 0.430 | 0.676 |
| | ESE | 3.047 | 6.312 | 98.22 | 3.48 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.940 | 6.433 | 103.87 | 3.48 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.442 | 6.323 | 319.22 | 3.48 | 0.061 | 0.496 | 0.855 | 1.351 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NNW | 3.281 | 6.290 | 331.86 | 3.48 | 0.061 | 0.509 | 0.878 | 1.387 |
| 07 | N | 2.198 | 5.752 | 351.92 | 3.48 | 0.020 | 0.292 | 0.482 | 0.775 |
| | NNE | 1.703 | 4.943 | 19.67 | 3.48 | 0.017 | 0.225 | 0.371 | 0.596 |
| | NE | 1.686 | 5.145 | 55.88 | 3.48 | 0.016 | 0.203 | 0.334 | 0.537 |
| | ENE | 2.294 | 6.134 | 74.95 | 3.48 | 0.018 | 0.244 | 0.403 | 0.648 |
| | E | 4.064 | 6.373 | 85.60 | 3.48 | 0.022 | 0.351 | 0.581 | 0.931 |
| | ESE | 2.690 | 6.258 | 93.22 | 3.48 | 0.015 | 0.191 | 0.316 | 0.508 |
| | SE | 2.526 | 6.319 | 99.18 | 3.48 | 0.152 | 0.222 | 0.516 | 0.738 |
| | NW | 3.368 | 6.310 | 321.48 | 3.48 | 0.022 | 0.372 | 0.616 | 0.988 |
| | NNW | 3.236 | 6.280 | 333.39 | 3.48 | 0.023 | 0.396 | 0.655 | 1.051 |
| 08 | N | 2.185 | 5.743 | 350.74 | 3.48 | 0.021 | 0.270 | 0.447 | 0.718 |
| | NNE | 1.690 | 4.894 | 19.74 | 3.48 | 0.019 | 0.224 | 0.370 | 0.594 |
| | NE | 1.691 | 5.135 | 57.63 | 3.48 | 0.019 | 0.224 | 0.370 | 0.594 |
| | ENE | 2.386 | 6.149 | 78.49 | 3.48 | 0.022 | 0.299 | 0.496 | 0.795 |
| | E | 4.458 | 6.408 | 90.77 | 3.48 | 0.029 | 0.483 | 0.801 | 1.284 |
| | ESE | 3.053 | 6.306 | 99.37 | 3.48 | 0.022 | 0.299 | 0.496 | 0.795 |
| | SE | 2.958 | 6.429 | 105.57 | 3.48 | 0.020 | 0.258 | 0.428 | 0.686 |
| | NW | 3.514 | 6.317 | 319.04 | 3.48 | 0.021 | 0.275 | 0.455 | 0.729 |
| | NNW | 3.289 | 6.282 | 331.18 | 3.48 | 0.024 | 0.334 | 0.553 | 0.887 |
| 09 | N | 2.187 | 5.750 | 351.18 | 3.49 | 0.069 | 0.385 | 0.674 | 1.059 |
| | NNE | 1.699 | 4.913 | 19.95 | 3.49 | 0.079 | 0.299 | 0.530 | 0.829 |
| | NE | 1.694 | 5.149 | 57.01 | 3.49 | 0.090 | 0.255 | 0.470 | 0.724 |
| | ENE | 2.352 | 6.143 | 76.74 | 3.49 | 0.091 | 0.255 | 0.486 | 0.740 |
| | E | 4.297 | 6.388 | 88.32 | 3.49 | 0.117 | 0.210 | 0.446 | 0.656 |
| | ESE | 2.885 | 6.277 | 96.14 | 3.49 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.746 | 6.373 | 102.38 | 3.49 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.448 | 6.306 | 320.41 | 3.49 | 0.063 | 0.517 | 0.893 | 1.410 |
| | NNW | 3.255 | 6.275 | 332.20 | 3.49 | 0.063 | 0.518 | 0.893 | 1.411 |
| 10 | N | 2.192 | 5.765 | 350.53 | 3.47 | 0.168 | 0.458 | 0.951 | 1.409 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NNE | 1.700 | 4.907 | 20.03 | 3.47 | 0.208 | 0.365 | 0.810 | 1.176 |
| | NE | 1.696 | 5.152 | 57.41 | 3.47 | 0.257 | 0.326 | 0.829 | 1.155 |
| | ENE | 2.371 | 6.146 | 77.26 | 3.47 | 0.240 | 0.342 | 0.898 | 1.240 |
| | E | 4.388 | 6.399 | 89.44 | 3.47 | 0.227 | 0.354 | 0.912 | 1.266 |
| | ESE | 2.944 | 6.286 | 97.40 | 3.47 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.790 | 6.399 | 102.70 | 3.47 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.526 | 6.312 | 320.24 | 3.47 | 0.142 | 0.603 | 1.178 | 1.781 |
| | NNW | 3.308 | 6.280 | 331.49 | 3.47 | 0.142 | 0.605 | 1.180 | 1.785 |
| 11 | N | 2.203 | 5.781 | 349.14 | 3.49 | 0.637 | 0.560 | 2.334 | 2.893 |
| | NNE | 1.694 | 4.886 | 19.88 | 3.49 | 0.690 | 0.467 | 1.966 | 2.433 |
| | NE | 1.689 | 5.139 | 57.83 | 3.49 | 0.709 | 0.452 | 2.030 | 2.482 |
| | ENE | 2.378 | 6.138 | 78.10 | 3.49 | 0.645 | 0.554 | 2.433 | 2.987 |
| | E | 4.476 | 6.405 | 91.19 | 3.49 | 0.562 | 0.790 | 2.883 | 3.673 |
| | ESE | 3.048 | 6.301 | 100.77 | 3.49 | 0.688 | 0.496 | 2.414 | 2.911 |
| | SE | 2.960 | 6.433 | 107.55 | 3.49 | 0.802 | 0.401 | 2.402 | 2.802 |
| | NW | 3.669 | 6.330 | 319.09 | 3.49 | 0.601 | 0.654 | 2.634 | 3.288 |
| | NNW | 3.414 | 6.295 | 329.63 | 3.49 | 0.584 | 0.703 | 2.701 | 3.404 |
| 12 | N | 2.208 | 5.801 | 349.31 | 3.47 | 0.076 | 0.393 | 0.695 | 1.088 |
| | NNE | 1.704 | 4.903 | 20.20 | 3.47 | 0.076 | 0.299 | 0.527 | 0.826 |
| | NE | 1.697 | 5.155 | 57.63 | 3.47 | 0.076 | 0.255 | 0.457 | 0.712 |
| | ENE | 2.369 | 6.138 | 77.17 | 3.47 | 0.076 | 0.271 | 0.495 | 0.766 |
| | E | 4.413 | 6.397 | 90.20 | 3.47 | 0.076 | 0.263 | 0.486 | 0.750 |
| | ESE | 2.941 | 6.277 | 99.23 | 3.47 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.809 | 6.377 | 106.03 | 3.47 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.639 | 6.324 | 320.30 | 3.47 | 0.075 | 0.544 | 0.955 | 1.499 |
| | NNW | 3.404 | 6.291 | 330.27 | 3.47 | 0.075 | 0.542 | 0.951 | 1.494 |
| 13 | N | 2.210 | 5.820 | 349.32 | 3.48 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 1.711 | 4.911 | 20.48 | 3.48 | 0.201 | 0.287 | 0.654 | 0.940 |
| | NE | 1.699 | 5.166 | 57.35 | 3.48 | 0.174 | 0.354 | 0.749 | 1.102 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | ENE | 2.348 | 6.126 | 76.27 | 3.48 | 0.152 | 0.491 | 0.995 | 1.486 |
| | E | 4.360 | 6.386 | 89.95 | 3.48 | 0.130 | 0.790 | 1.475 | 2.265 |
| | ESE | 2.879 | 6.264 | 100.12 | 3.48 | 0.145 | 0.566 | 1.120 | 1.686 |
| | SE | 2.771 | 6.346 | 108.85 | 3.48 | 0.148 | 0.540 | 1.082 | 1.622 |
| | NW | 3.587 | 6.321 | 321.57 | 3.48 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 3.386 | 6.289 | 330.74 | 3.48 | 0.000 | 0.000 | 0.000 | 0.000 |
| 14 | N | 2.219 | 5.818 | 348.15 | 3.49 | 0.135 | 0.354 | 0.713 | 1.067 |
| | NNE | 1.701 | 4.889 | 20.23 | 3.49 | 0.140 | 0.328 | 0.646 | 0.975 |
| | NE | 1.690 | 5.151 | 57.60 | 3.49 | 0.137 | 0.343 | 0.675 | 1.017 |
| | ENE | 2.361 | 6.125 | 77.07 | 3.49 | 0.122 | 0.447 | 0.862 | 1.309 |
| | E | 4.437 | 6.393 | 90.82 | 3.49 | 0.110 | 0.692 | 1.265 | 1.957 |
| | ESE | 2.998 | 6.285 | 102.23 | 3.49 | 0.120 | 0.464 | 0.894 | 1.358 |
| | SE | 2.953 | 6.409 | 112.31 | 3.49 | 0.126 | 0.410 | 0.815 | 1.225 |
| | NW | 3.729 | 6.334 | 319.24 | 3.49 | 0.191 | 0.238 | 0.609 | 0.847 |
| | NNW | 3.473 | 6.301 | 328.78 | 3.49 | 0.133 | 0.367 | 0.748 | 1.115 |
| 15 | N | 2.213 | 5.836 | 349.04 | 3.48 | 0.317 | 0.331 | 1.005 | 1.337 |
| | NNE | 1.712 | 4.913 | 20.60 | 3.48 | 0.278 | 0.355 | 0.904 | 1.260 |
| | NE | 1.695 | 5.166 | 56.94 | 3.48 | 0.252 | 0.391 | 0.947 | 1.338 |
| | ENE | 2.332 | 6.113 | 75.32 | 3.48 | 0.208 | 0.515 | 1.160 | 1.675 |
| | E | 4.326 | 6.381 | 89.54 | 3.48 | 0.174 | 0.804 | 1.612 | 2.416 |
| | ESE | 2.859 | 6.265 | 100.79 | 3.48 | 0.199 | 0.560 | 1.234 | 1.794 |
| | SE | 2.809 | 6.358 | 112.25 | 3.48 | 0.208 | 0.520 | 1.185 | 1.704 |
| | NW | 3.590 | 6.325 | 322.10 | 3.48 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 3.396 | 6.293 | 330.68 | 3.48 | 0.000 | 0.000 | 0.000 | 0.000 |
| 16 | N | 1.995 | 5.759 | 358.97 | 3.49 | 0.154 | 0.304 | 0.652 | 0.956 |
| | NNE | 1.694 | 4.943 | 23.60 | 3.49 | 0.154 | 0.316 | 0.644 | 0.960 |
| | NE | 1.706 | 5.189 | 56.16 | 3.49 | 0.155 | 0.356 | 0.726 | 1.082 |
| | ENE | 2.312 | 6.114 | 72.27 | 3.49 | 0.158 | 0.487 | 0.999 | 1.486 |
| | E | 4.183 | 6.380 | 84.54 | 3.49 | 0.109 | 0.725 | 1.319 | 2.045 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | ESE | 2.635 | 6.239 | 96.10 | 3.49 | 0.157 | 0.515 | 1.055 | 1.570 |
| | SE | 2.523 | 6.274 | 109.75 | 3.49 | 0.157 | 0.464 | 0.964 | 1.428 |
| | NW | 2.514 | 6.301 | 337.98 | 3.49 | 0.172 | 0.189 | 0.483 | 0.672 |
| | NNW | 2.694 | 6.265 | 344.40 | 3.49 | 0.153 | 0.285 | 0.635 | 0.920 |
| 17 | N | 1.950 | 5.713 | 1.42 | 3.50 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 1.697 | 4.983 | 24.72 | 3.50 | 0.273 | 0.221 | 0.626 | 0.847 |
| | NE | 1.705 | 5.201 | 55.31 | 3.50 | 0.264 | 0.348 | 0.890 | 1.238 |
| | ENE | 2.260 | 6.110 | 69.96 | 3.50 | 0.262 | 0.503 | 1.265 | 1.768 |
| | E | 4.043 | 6.385 | 83.40 | 3.50 | 0.227 | 0.824 | 1.800 | 2.624 |
| | ESE | 2.401 | 6.218 | 95.68 | 3.50 | 0.261 | 0.560 | 1.384 | 1.944 |
| | SE | 2.272 | 4.796 | 113.27 | 3.50 | 0.259 | 0.479 | 1.099 | 1.579 |
| | NW | 2.406 | 6.285 | 338.66 | 3.50 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.561 | 6.251 | 347.08 | 3.50 | 0.000 | 0.000 | 0.000 | 0.000 |
| 18a | N | 1.724 | 5.605 | 11.42 | 3.52 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 1.618 | 4.977 | 30.63 | 3.52 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NE | 1.692 | 5.209 | 55.28 | 3.52 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ENE | 2.221 | 6.100 | 67.76 | 3.52 | 0.000 | 0.000 | 0.000 | 0.000 |
| | E | 3.853 | 6.385 | 79.58 | 3.52 | 0.288 | 0.297 | 0.916 | 1.213 |
| | ESE | 2.203 | 6.194 | 89.74 | 3.52 | 0.293 | 0.310 | 0.941 | 1.251 |
| | SE | 1.974 | 4.715 | 105.97 | 3.52 | 0.307 | 0.344 | 0.912 | 1.257 |
| | NW | 1.897 | 6.321 | 342.44 | 3.52 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.089 | 6.254 | 356.20 | 3.52 | 0.000 | 0.000 | 0.000 | 0.000 |
| 18b | N | 1.736 | 5.616 | 10.82 | 3.53 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 1.622 | 4.962 | 30.12 | 3.51 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NE | 1.693 | 5.207 | 55.55 | 3.51 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ENE | 2.229 | 6.101 | 68.52 | 3.51 | 0.000 | 0.000 | 0.000 | 0.000 |
| | E | 3.861 | 6.372 | 81.19 | 3.51 | 0.308 | 0.345 | 1.064 | 1.409 |
| | ESE | 2.256 | 6.194 | 92.12 | 3.51 | 0.305 | 0.338 | 1.029 | 1.367 |
| | SE | 2.077 | 4.764 | 108.88 | 3.51 | 0.318 | 0.375 | 0.998 | 1.373 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NW | 1.906 | 6.315 | 344.60 | 3.51 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.106 | 6.254 | 356.60 | 3.51 | 0.000 | 0.000 | 0.000 | 0.000 |
| 19 | N | 0.771 | 2.419 | 26.06 | 3.53 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 0.875 | 5.113 | 56.99 | 3.53 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NE | 1.113 | 5.251 | 71.20 | 3.53 | 0.101 | 0.097 | 0.207 | 0.304 |
| | ENE | 1.551 | 6.066 | 73.17 | 3.53 | 0.105 | 0.151 | 0.319 | 0.470 |
| | E | 2.923 | 6.331 | 77.48 | 3.53 | 0.119 | 0.312 | 0.629 | 0.941 |
| | ESE | 1.723 | 6.154 | 86.67 | 3.53 | 0.101 | 0.241 | 0.476 | 0.717 |
| | SE | 1.527 | 3.137 | 108.65 | 3.53 | 0.096 | 0.215 | 0.379 | 0.593 |
| | NW | 0.888 | 2.772 | 308.31 | 3.53 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 0.843 | 2.615 | 340.29 | 3.53 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20 | N | 0.771 | 2.419 | 26.06 | 3.54 | 0.088 | 0.093 | 0.157 | 0.250 |
| | NNE | 0.875 | 5.113 | 56.99 | 3.54 | 0.053 | 0.158 | 0.276 | 0.434 |
| | NE | 1.113 | 5.251 | 71.20 | 3.54 | 0.051 | 0.201 | 0.348 | 0.549 |
| | ENE | 1.551 | 6.066 | 73.17 | 3.54 | 0.047 | 0.274 | 0.471 | 0.745 |
| | E | 2.923 | 6.331 | 77.48 | 3.54 | 0.047 | 0.465 | 0.788 | 1.252 |
| | ESE | 1.723 | 6.154 | 86.67 | 3.54 | 0.047 | 0.304 | 0.521 | 0.824 |
| | SE | 1.527 | 3.137 | 108.65 | 3.54 | 0.048 | 0.208 | 0.348 | 0.556 |
| | NW | 0.888 | 2.772 | 308.31 | 3.54 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 0.843 | 2.615 | 340.29 | 3.54 | 0.000 | 0.000 | 0.000 | 0.000 |
| 21 | N | 0.771 | 2.419 | 26.06 | 3.53 | 0.307 | 0.158 | 0.371 | 0.529 |
| | NNE | 0.875 | 5.113 | 56.99 | 3.53 | 0.203 | 0.217 | 0.534 | 0.751 |
| | NE | 1.113 | 5.251 | 71.20 | 3.53 | 0.118 | 0.231 | 0.460 | 0.691 |
| | ENE | 1.551 | 6.066 | 73.17 | 3.53 | 0.044 | 0.260 | 0.446 | 0.706 |
| | E | 2.923 | 6.331 | 77.48 | 3.53 | 0.048 | 0.440 | 0.748 | 1.189 |
| | ESE | 1.723 | 6.154 | 86.67 | 3.53 | 0.042 | 0.264 | 0.452 | 0.716 |
| | SE | 1.527 | 3.137 | 108.65 | 3.53 | 0.204 | 0.206 | 0.430 | 0.636 |
| | NW | 0.888 | 2.772 | 308.31 | 3.53 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 0.843 | 2.615 | 340.29 | 3.53 | 0.368 | 0.137 | 0.378 | 0.516 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| 22 | N | 0.799 | 4.844 | 27.33 | 3.52 | 1.015 | 0.270 | 1.846 | 2.116 |
| | NNE | 0.930 | 5.087 | 56.35 | 3.52 | 1.002 | 0.271 | 1.895 | 2.165 |
| | NE | 1.214 | 5.262 | 71.99 | 3.52 | 0.747 | 0.271 | 1.530 | 1.801 |
| | ENE | 1.712 | 6.082 | 75.54 | 3.52 | 0.510 | 0.332 | 1.433 | 1.765 |
| | E | 3.154 | 6.346 | 79.47 | 3.52 | 0.526 | 0.518 | 2.038 | 2.556 |
| | ESE | 1.877 | 6.165 | 86.37 | 3.52 | 0.609 | 0.286 | 1.500 | 1.786 |
| | SE | 1.657 | 6.133 | 103.05 | 3.52 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 0.928 | 2.832 | 303.57 | 3.52 | 0.964 | 0.183 | 0.947 | 1.130 |
| | NNW | 0.885 | 2.629 | 337.53 | 3.52 | 1.023 | 0.224 | 1.080 | 1.304 |
| 23 | N | 1.488 | 5.465 | 20.64 | 3.52 | 0.341 | 0.383 | 1.129 | 1.512 |
| | NNE | 1.504 | 4.961 | 37.64 | 3.52 | 0.361 | 0.368 | 1.079 | 1.447 |
| | NE | 1.658 | 5.215 | 56.90 | 3.52 | 0.349 | 0.376 | 1.103 | 1.479 |
| | ENE | 2.191 | 6.093 | 67.32 | 3.52 | 0.278 | 0.447 | 1.191 | 1.638 |
| | E | 3.761 | 6.376 | 77.83 | 3.52 | 0.171 | 0.579 | 1.205 | 1.783 |
| | ESE | 2.120 | 6.185 | 86.16 | 3.52 | 0.374 | 0.371 | 1.253 | 1.625 |
| | SE | 1.829 | 6.184 | 99.27 | 3.52 | 2.866 | 0.344 | 6.227 | 6.571 |
| | NW | 1.545 | 6.377 | 340.43 | 3.52 | 0.346 | 0.387 | 1.248 | 1.635 |
| | NNW | 1.679 | 6.269 | 3.61 | 3.52 | 0.294 | 0.428 | 1.206 | 1.634 |
| 24 | N | 1.968 | 5.733 | 1.95 | 3.50 | 0.095 | 0.369 | 0.678 | 1.046 |
| | NNE | 1.705 | 5.024 | 24.82 | 3.50 | 0.094 | 0.319 | 0.580 | 0.899 |
| | NE | 1.699 | 5.204 | 54.02 | 3.50 | 0.094 | 0.306 | 0.560 | 0.866 |
| | ENE | 2.211 | 6.095 | 67.20 | 3.50 | 0.095 | 0.378 | 0.700 | 1.078 |
| | E | 3.869 | 6.386 | 79.96 | 3.50 | 0.045 | 0.471 | 0.795 | 1.266 |
| | ESE | 2.229 | 6.195 | 93.48 | 3.50 | 0.093 | 0.284 | 0.540 | 0.823 |
| | SE | 2.060 | 4.557 | 114.31 | 3.50 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 2.518 | 6.306 | 338.38 | 3.50 | 0.094 | 0.421 | 0.776 | 1.197 |
| | NNW | 2.669 | 6.264 | 347.59 | 3.50 | 0.066 | 0.431 | 0.753 | 1.185 |
| 25 | N | 2.065 | 5.773 | 358.25 | 3.51 | 0.175 | 0.188 | 0.466 | 0.654 |
| | NNE | 1.706 | 5.064 | 21.42 | 3.51 | 0.048 | 0.214 | 0.367 | 0.582 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NE | 1.556 | 5.138 | 45.22 | 3.51 | 0.051 | 0.245 | 0.420 | 0.665 |
| | ENE | 1.907 | 5.942 | 57.14 | 3.51 | 0.059 | 0.329 | 0.573 | 0.902 |
| | E | 3.150 | 6.318 | 75.12 | 3.51 | 0.076 | 0.546 | 0.959 | 1.505 |
| | ESE | 1.712 | 4.032 | 101.78 | 3.51 | 0.053 | 0.256 | 0.433 | 0.689 |
| | SE | 1.763 | 4.303 | 137.03 | 3.51 | 0.049 | 0.220 | 0.373 | 0.593 |
| | NW | 2.697 | 6.283 | 337.78 | 3.51 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.798 | 6.252 | 344.05 | 3.51 | 0.000 | 0.000 | 0.000 | 0.000 |
| 26 | N | 1.820 | 5.630 | 6.91 | 3.50 | 0.076 | 0.238 | 0.434 | 0.672 |
| | NNE | 1.587 | 5.045 | 21.50 | 3.50 | 0.074 | 0.241 | 0.430 | 0.671 |
| | NE | 1.430 | 5.061 | 38.73 | 3.50 | 0.072 | 0.246 | 0.437 | 0.682 |
| | ENE | 1.674 | 5.679 | 51.24 | 3.50 | 0.058 | 0.292 | 0.508 | 0.800 |
| | E | 2.667 | 6.218 | 76.07 | 3.50 | 0.050 | 0.438 | 0.746 | 1.183 |
| | ESE | 1.511 | 3.928 | 108.82 | 3.50 | 0.076 | 0.234 | 0.409 | 0.644 |
| | SE | 1.656 | 4.187 | 134.56 | 3.50 | 0.090 | 0.219 | 0.396 | 0.615 |
| | NW | 2.049 | 6.280 | 350.30 | 3.50 | 0.114 | 0.183 | 0.391 | 0.574 |
| | NNW | 2.241 | 6.234 | 355.38 | 3.50 | 0.083 | 0.229 | 0.434 | 0.663 |
| 27 | N | 1.910 | 5.719 | 1.16 | 3.50 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 1.524 | 5.072 | 12.79 | 3.50 | 0.500 | 0.136 | 0.689 | 0.825 |
| | NE | 1.232 | 4.812 | 28.91 | 3.50 | 0.137 | 0.171 | 0.364 | 0.535 |
| | ENE | 1.356 | 5.168 | 44.75 | 3.50 | 0.099 | 0.221 | 0.421 | 0.643 |
| | E | 2.209 | 4.352 | 79.62 | 3.50 | 0.151 | 0.399 | 0.764 | 1.164 |
| | ESE | 1.325 | 3.813 | 115.24 | 3.50 | 0.104 | 0.235 | 0.428 | 0.663 |
| | SE | 1.542 | 3.994 | 135.89 | 3.50 | 0.111 | 0.257 | 0.473 | 0.730 |
| | NW | 2.344 | 6.285 | 344.95 | 3.50 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.516 | 6.248 | 351.30 | 3.50 | 0.000 | 0.000 | 0.000 | 0.000 |
| 28 | N | 0.878 | 5.084 | 18.00 | 3.53 | 0.075 | 0.158 | 0.292 | 0.449 |
| | NNE | 0.838 | 4.918 | 38.70 | 3.53 | 0.077 | 0.166 | 0.306 | 0.472 |
| | NE | 0.885 | 4.971 | 49.28 | 3.53 | 0.079 | 0.179 | 0.330 | 0.509 |
| | ENE | 1.111 | 3.816 | 60.37 | 3.53 | 0.081 | 0.197 | 0.349 | 0.546 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | E | 2.032 | 4.372 | 82.96 | 3.53 | 0.052 | 0.303 | 0.513 | 0.816 |
| | ESE | 1.240 | 3.458 | 112.53 | 3.53 | 0.080 | 0.178 | 0.313 | 0.491 |
| | SE | 1.414 | 3.747 | 132.51 | 3.53 | 0.077 | 0.160 | 0.284 | 0.445 |
| | NW | 1.081 | 3.131 | 316.10 | 3.53 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 1.051 | 3.023 | 339.71 | 3.53 | 0.040 | 0.061 | 0.105 | 0.166 |
| 29 | N | 1.616 | 5.581 | 7.85 | 3.51 | 0.012 | 0.172 | 0.283 | 0.455 |
| | NNE | 1.368 | 5.047 | 16.49 | 3.51 | 0.014 | 0.160 | 0.264 | 0.424 |
| | NE | 1.138 | 4.728 | 26.19 | 3.51 | 0.015 | 0.144 | 0.237 | 0.381 |
| | ENE | 1.212 | 3.941 | 37.44 | 3.51 | 0.015 | 0.148 | 0.243 | 0.390 |
| | E | 1.859 | 4.002 | 71.54 | 3.51 | 0.012 | 0.208 | 0.340 | 0.548 |
| | ESE | 1.045 | 3.127 | 120.83 | 3.51 | 0.011 | 0.092 | 0.151 | 0.244 |
| | SE | 1.266 | 3.569 | 145.71 | 3.51 | 0.008 | 0.059 | 0.096 | 0.155 |
| | NW | 1.810 | 6.275 | 342.16 | 3.51 | 0.014 | 0.122 | 0.201 | 0.323 |
| | NNW | 1.951 | 6.210 | 355.93 | 3.51 | 0.012 | 0.181 | 0.298 | 0.478 |
| 30 | N | 1.631 | 5.636 | 3.95 | 3.50 | 0.003 | 0.161 | 0.263 | 0.424 |
| | NNE | 1.308 | 5.033 | 11.45 | 3.50 | 0.003 | 0.127 | 0.207 | 0.334 |
| | NE | 1.035 | 4.640 | 20.68 | 3.50 | 0.005 | 0.114 | 0.187 | 0.301 |
| | ENE | 1.069 | 3.793 | 33.31 | 3.50 | 0.007 | 0.111 | 0.182 | 0.293 |
| | E | 1.581 | 3.379 | 78.02 | 3.50 | 0.007 | 0.088 | 0.144 | 0.232 |
| | ESE | 0.944 | 3.041 | 128.88 | 3.50 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 1.190 | 3.409 | 148.09 | 3.50 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 1.939 | 6.280 | 342.62 | 3.50 | 0.003 | 0.193 | 0.315 | 0.508 |
| | NNW | 2.072 | 6.227 | 354.08 | 3.50 | 0.003 | 0.205 | 0.335 | 0.540 |
| 31 | N | 1.403 | 5.766 | 354.69 | 3.47 | 0.182 | 0.294 | 0.740 | 1.034 |
| | NNE | 0.985 | 5.080 | 358.36 | 3.47 | 0.267 | 0.218 | 0.616 | 0.834 |
| | NE | 0.675 | 4.346 | 8.96 | 3.47 | 0.458 | 0.146 | 0.616 | 0.763 |
| | ENE | 0.679 | 2.185 | 39.08 | 3.47 | 0.000 | 0.000 | 0.000 | 0.000 |
| | E | 1.117 | 2.890 | 100.75 | 3.47 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ESE | 0.804 | 2.813 | 133.28 | 3.47 | 0.000 | 0.000 | 0.000 | 0.000 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | SE | 1.043 | 3.175 | 149.41 | 3.47 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 1.976 | 6.273 | 343.85 | 3.47 | 0.150 | 0.418 | 0.672 | 1.090 |
| | NNW | 2.026 | 6.239 | 351.78 | 3.47 | 0.153 | 0.412 | 0.657 | 1.069 |
| 32 | N | 1.890 | 5.738 | 359.20 | 3.49 | 0.095 | 0.275 | 0.519 | 0.793 |
| | NNE | 1.459 | 5.076 | 8.71 | 3.49 | 2.396 | 0.346 | 4.939 | 5.284 |
| | NE | 1.112 | 4.697 | 23.13 | 3.49 | 3.372 | 0.156 | 3.561 | 3.717 |
| | ENE | 1.160 | 3.703 | 37.61 | 3.49 | 0.000 | 0.000 | 0.000 | 0.000 |
| | E | 1.809 | 4.049 | 71.76 | 3.49 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ESE | 1.055 | 3.186 | 112.60 | 3.49 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 1.263 | 3.479 | 143.07 | 3.49 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 2.413 | 6.288 | 341.87 | 3.49 | 0.105 | 0.417 | 0.787 | 1.204 |
| | NNW | 2.560 | 6.251 | 349.87 | 3.49 | 0.104 | 0.409 | 0.771 | 1.181 |
| 33 | N | 1.940 | 5.901 | 348.97 | 3.50 | 0.425 | 0.270 | 1.067 | 1.337 |
| | NNE | 1.327 | 5.106 | 356.99 | 3.50 | 0.539 | 0.243 | 1.080 | 1.323 |
| | NE | 0.895 | 4.421 | 12.74 | 3.50 | 0.589 | 0.212 | 0.958 | 1.170 |
| | ENE | 0.923 | 3.062 | 44.89 | 3.50 | 0.556 | 0.223 | 0.759 | 0.981 |
| | E | 1.821 | 4.208 | 105.53 | 3.50 | 0.332 | 0.371 | 0.958 | 1.330 |
| | ESE | 1.238 | 3.781 | 127.90 | 3.50 | 0.531 | 0.240 | 0.876 | 1.116 |
| | SE | 1.445 | 3.968 | 136.46 | 3.50 | 0.519 | 0.243 | 0.896 | 1.138 |
| | NW | 2.834 | 6.320 | 337.67 | 3.50 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.900 | 6.274 | 342.89 | 3.50 | 0.412 | 0.281 | 1.113 | 1.393 |
| 34 | N | 1.882 | 5.900 | 348.84 | 3.49 | 0.350 | 0.277 | 0.946 | 1.223 |
| | NNE | 1.285 | 5.111 | 354.57 | 3.49 | 0.373 | 0.222 | 0.778 | 1.000 |
| | NE | 0.864 | 4.336 | 11.30 | 3.49 | 0.381 | 0.190 | 0.642 | 0.832 |
| | ENE | 0.888 | 3.012 | 55.50 | 3.49 | 0.374 | 0.203 | 0.549 | 0.752 |
| | E | 1.871 | 4.392 | 108.44 | 3.49 | 0.349 | 0.377 | 1.015 | 1.392 |
| | ESE | 1.263 | 3.813 | 120.94 | 3.49 | 0.362 | 0.237 | 0.681 | 0.918 |
| | SE | 1.427 | 3.946 | 127.73 | 3.49 | 0.358 | 0.244 | 0.703 | 0.947 |
| | NW | 2.669 | 6.319 | 341.53 | 3.49 | 0.350 | 0.282 | 0.999 | 1.282 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NNW | 2.800 | 6.274 | 344.50 | 3.49 | 0.350 | 0.338 | 1.131 | 1.469 |
| 35 | N | 1.652 | 5.998 | 337.54 | 3.49 | 0.369 | 0.318 | 0.549 | 0.868 |
| | NNE | 1.019 | 5.182 | 346.57 | 3.49 | 0.478 | 0.239 | 0.665 | 0.904 |
| | NE | 0.655 | 2.418 | 28.63 | 3.49 | 0.560 | 0.157 | 0.519 | 0.676 |
| | ENE | 0.755 | 2.978 | 85.77 | 3.49 | 0.547 | 0.171 | 0.611 | 0.782 |
| | E | 1.827 | 4.319 | 99.01 | 3.49 | 0.352 | 0.330 | 0.750 | 1.080 |
| | ESE | 1.178 | 3.634 | 105.82 | 3.49 | 0.498 | 0.213 | 0.754 | 0.967 |
| | SE | 1.257 | 3.645 | 116.02 | 3.49 | 0.529 | 0.188 | 0.722 | 0.910 |
| | NW | 2.728 | 6.338 | 334.58 | 3.49 | 0.288 | 0.444 | 0.729 | 1.173 |
| | NNW | 2.679 | 6.295 | 336.14 | 3.49 | 0.287 | 0.447 | 0.733 | 1.180 |
| 36 | N | 1.450 | 6.003 | 334.73 | 3.48 | 0.049 | 0.252 | 0.435 | 0.687 |
| | NNE | 0.881 | 5.293 | 350.71 | 3.48 | 0.066 | 0.177 | 0.319 | 0.496 |
| | NE | 0.591 | 2.398 | 43.23 | 3.48 | 0.096 | 0.093 | 0.167 | 0.261 |
| | ENE | 0.734 | 2.886 | 76.93 | 3.48 | 0.096 | 0.081 | 0.151 | 0.232 |
| | E | 1.679 | 4.095 | 84.24 | 3.48 | 0.061 | 0.132 | 0.233 | 0.366 |
| | ESE | 1.038 | 3.414 | 91.56 | 3.48 | 0.096 | 0.051 | 0.103 | 0.153 |
| | SE | 1.046 | 3.391 | 103.73 | 3.48 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 2.411 | 6.315 | 329.90 | 3.48 | 0.059 | 0.395 | 0.685 | 1.080 |
| | NNW | 2.305 | 6.281 | 331.79 | 3.48 | 0.058 | 0.382 | 0.662 | 1.044 |
| 37 | N | 0.856 | 3.099 | 328.65 | 3.48 | 0.387 | 0.162 | 0.480 | 0.641 |
| | NNE | 0.544 | 2.185 | 9.52 | 3.48 | 0.611 | 0.132 | 0.458 | 0.590 |
| | NE | 0.471 | 2.249 | 60.58 | 3.48 | 0.644 | 0.113 | 0.434 | 0.547 |
| | ENE | 0.680 | 2.780 | 80.46 | 3.48 | 0.604 | 0.142 | 0.554 | 0.696 |
| | E | 1.608 | 3.949 | 88.78 | 3.48 | 0.210 | 0.239 | 0.531 | 0.771 |
| | ESE | 0.993 | 3.282 | 96.20 | 3.48 | 0.426 | 0.153 | 0.506 | 0.659 |
| | SE | 1.025 | 3.225 | 110.78 | 3.48 | 0.664 | 0.093 | 0.494 | 0.588 |
| | NW | 1.581 | 4.082 | 309.96 | 3.48 | 0.270 | 0.203 | 0.530 | 0.733 |
| | NNW | 1.370 | 3.876 | 315.25 | 3.48 | 0.273 | 0.200 | 0.514 | 0.714 |
| 38 | N | 1.828 | 5.937 | 344.88 | 3.49 | 0.428 | 0.302 | 0.252 | 0.554 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NNE | 1.213 | 5.122 | 351.06 | 3.49 | 0.523 | 0.240 | 0.232 | 0.472 |
| | NE | 0.783 | 3.070 | 13.25 | 3.49 | 0.522 | 0.175 | 0.171 | 0.346 |
| | ENE | 0.812 | 2.964 | 75.16 | 3.49 | 0.528 | 0.198 | 0.179 | 0.378 |
| | E | 1.873 | 4.385 | 105.82 | 3.49 | 0.061 | 0.259 | 0.446 | 0.705 |
| | ESE | 1.242 | 3.720 | 113.49 | 3.49 | 0.507 | 0.250 | 0.239 | 0.489 |
| | SE | 1.364 | 3.827 | 121.10 | 3.49 | 0.508 | 0.249 | 0.239 | 0.488 |
| | NW | 2.722 | 6.319 | 339.82 | 3.49 | 0.361 | 0.358 | 0.320 | 0.679 |
| | NNW | 2.799 | 6.277 | 342.24 | 3.49 | 0.340 | 0.389 | 0.357 | 0.746 |
| 39 | N | 0.856 | 3.141 | 342.40 | 3.52 | 0.002 | 0.069 | 0.113 | 0.183 |
| | NNE | 0.621 | 2.712 | 349.65 | 3.52 | 0.002 | 0.050 | 0.081 | 0.131 |
| | NE | 0.460 | 2.184 | 10.21 | 3.52 | 0.001 | 0.033 | 0.054 | 0.088 |
| | ENE | 0.463 | 1.939 | 58.15 | 3.52 | 0.001 | 0.019 | 0.031 | 0.050 |
| | E | 0.960 | 2.628 | 101.39 | 3.52 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ESE | 0.723 | 2.584 | 131.67 | 3.52 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 0.924 | 2.857 | 145.77 | 3.52 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 1.281 | 3.888 | 328.01 | 3.52 | 0.002 | 0.105 | 0.171 | 0.276 |
| | NNW | 1.205 | 3.699 | 337.36 | 3.52 | 0.002 | 0.098 | 0.160 | 0.258 |
| 40 | N | 1.540 | 5.596 | 5.90 | 3.57 | 0.004 | 0.159 | 0.260 | 0.419 |
| | NNE | 1.267 | 5.029 | 13.65 | 3.57 | 0.003 | 0.129 | 0.211 | 0.340 |
| | NE | 1.036 | 4.659 | 22.36 | 3.57 | 0.005 | 0.114 | 0.186 | 0.300 |
| | ENE | 1.088 | 3.803 | 35.19 | 3.57 | 0.024 | 0.149 | 0.247 | 0.396 |
| | E | 1.634 | 3.444 | 78.93 | 3.57 | 0.023 | 0.151 | 0.249 | 0.399 |
| | ESE | 0.978 | 3.089 | 126.61 | 3.57 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 1.212 | 3.434 | 144.24 | 3.57 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 1.762 | 6.290 | 342.17 | 3.57 | 0.003 | 0.174 | 0.285 | 0.459 |
| | NNW | 1.892 | 6.219 | 355.27 | 3.57 | 0.003 | 0.192 | 0.314 | 0.505 |

# Appendix B - Details of Calculation of Wave Effects: Year 2050

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| 01 | N | 2.141 | 5.713 | 356.99 | 3.77 | 0.114 | 0.419 | 0.791 | 1.210 |
| | NNE | 1.693 | 4.999 | 21.27 | 3.77 | 0.114 | 0.320 | 0.604 | 0.925 |
| | NE | 1.702 | 5.142 | 54.78 | 3.77 | 0.114 | 0.269 | 0.520 | 0.789 |
| | ENE | 2.323 | 6.157 | 74.90 | 3.77 | 0.114 | 0.265 | 0.535 | 0.801 |
| | E | 4.075 | 6.434 | 84.42 | 3.77 | 0.114 | 0.269 | 0.549 | 0.818 |
| | ESE | 2.720 | 6.289 | 90.92 | 3.77 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.507 | 6.360 | 95.57 | 3.77 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 2.906 | 6.315 | 327.87 | 3.77 | 0.114 | 0.528 | 0.993 | 1.521 |
| | NNW | 2.902 | 6.269 | 340.75 | 3.77 | 0.114 | 0.545 | 1.022 | 1.567 |
| 02 | N | 2.182 | 5.734 | 354.67 | 3.78 | 0.036 | 0.298 | 0.501 | 0.799 |
| | NNE | 1.700 | 4.998 | 20.52 | 3.78 | 0.031 | 0.250 | 0.417 | 0.667 |
| | NE | 1.695 | 5.141 | 54.73 | 3.78 | 0.032 | 0.255 | 0.425 | 0.680 |
| | ENE | 2.296 | 6.151 | 74.26 | 3.78 | 0.040 | 0.344 | 0.581 | 0.925 |
| | E | 4.030 | 6.420 | 84.09 | 3.78 | 0.057 | 0.562 | 0.961 | 1.524 |
| | ESE | 2.658 | 6.278 | 90.63 | 3.78 | 0.040 | 0.354 | 0.598 | 0.952 |
| | SE | 2.453 | 6.347 | 96.07 | 3.78 | 0.037 | 0.310 | 0.523 | 0.833 |
| | NW | 3.088 | 6.315 | 325.76 | 3.78 | 0.034 | 0.283 | 0.476 | 0.759 |
| | NNW | 3.053 | 6.274 | 337.43 | 3.78 | 0.041 | 0.355 | 0.600 | 0.955 |
| 03 | N | 2.193 | 5.739 | 353.97 | 3.77 | 0.051 | 0.362 | 0.618 | 0.980 |
| | NNE | 1.700 | 4.989 | 20.31 | 3.77 | 0.064 | 0.290 | 0.504 | 0.794 |
| | NE | 1.695 | 5.140 | 54.99 | 3.77 | 0.063 | 0.249 | 0.436 | 0.684 |
| | ENE | 2.306 | 6.153 | 74.72 | 3.77 | 0.064 | 0.264 | 0.471 | 0.735 |
| | E | 4.058 | 6.419 | 84.67 | 3.77 | 0.065 | 0.317 | 0.563 | 0.880 |
| | ESE | 2.687 | 6.280 | 91.37 | 3.77 | 0.062 | 0.128 | 0.240 | 0.368 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | SE | 2.492 | 6.354 | 96.96 | 3.77 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.147 | 6.315 | 324.42 | 3.77 | 0.054 | 0.468 | 0.800 | 1.268 |
| | NNW | 3.097 | 6.276 | 336.17 | 3.77 | 0.055 | 0.484 | 0.828 | 1.312 |
| 04 | N | 2.200 | 5.747 | 353.50 | 3.77 | 0.037 | 0.325 | 0.546 | 0.872 |
| | NNE | 1.703 | 4.993 | 20.00 | 3.77 | 0.035 | 0.261 | 0.436 | 0.696 |
| | NE | 1.682 | 5.137 | 54.33 | 3.77 | 0.034 | 0.247 | 0.414 | 0.661 |
| | ENE | 2.240 | 6.137 | 72.74 | 3.77 | 0.037 | 0.306 | 0.516 | 0.822 |
| | E | 3.915 | 6.396 | 82.85 | 3.77 | 0.037 | 0.448 | 0.752 | 1.200 |
| | ESE | 2.521 | 6.261 | 89.38 | 3.77 | 0.036 | 0.282 | 0.477 | 0.759 |
| | SE | 2.316 | 6.321 | 95.26 | 3.77 | 0.034 | 0.236 | 0.399 | 0.634 |
| | NW | 3.193 | 6.313 | 324.38 | 3.77 | 0.036 | 0.369 | 0.631 | 1.001 |
| | NNW | 3.148 | 6.277 | 335.80 | 3.77 | 0.037 | 0.408 | 0.684 | 1.092 |
| 05 | N | 2.203 | 5.737 | 351.86 | 3.76 | 0.025 | 0.303 | 0.502 | 0.805 |
| | NNE | 1.693 | 4.931 | 19.46 | 3.76 | 0.022 | 0.236 | 0.390 | 0.626 |
| | NE | 1.698 | 5.131 | 56.88 | 3.76 | 0.021 | 0.219 | 0.362 | 0.581 |
| | ENE | 2.393 | 6.159 | 78.57 | 3.76 | 0.024 | 0.267 | 0.443 | 0.710 |
| | E | 4.379 | 6.417 | 89.76 | 3.76 | 0.026 | 0.381 | 0.632 | 1.013 |
| | ESE | 3.040 | 6.314 | 97.81 | 3.76 | 0.021 | 0.219 | 0.363 | 0.582 |
| | SE | 2.927 | 6.437 | 103.33 | 3.76 | 0.202 | 0.256 | 0.669 | 0.926 |
| | NW | 3.427 | 6.326 | 319.53 | 3.76 | 0.025 | 0.365 | 0.605 | 0.970 |
| | NNW | 3.276 | 6.292 | 332.17 | 3.76 | 0.027 | 0.399 | 0.662 | 1.060 |
| 06 | N | 2.203 | 5.739 | 351.55 | 3.74 | 0.058 | 0.372 | 0.640 | 1.012 |
| | NNE | 1.692 | 4.924 | 19.40 | 3.74 | 0.053 | 0.278 | 0.475 | 0.752 |
| | NE | 1.696 | 5.131 | 57.05 | 3.74 | 0.050 | 0.235 | 0.404 | 0.639 |
| | ENE | 2.392 | 6.157 | 78.66 | 3.74 | 0.051 | 0.244 | 0.424 | 0.668 |
| | E | 4.396 | 6.415 | 90.05 | 3.74 | 0.051 | 0.248 | 0.433 | 0.681 |
| | ESE | 3.049 | 6.313 | 98.24 | 3.74 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.942 | 6.434 | 103.90 | 3.74 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.450 | 6.324 | 319.22 | 3.74 | 0.062 | 0.498 | 0.861 | 1.359 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NNW | 3.288 | 6.291 | 331.83 | 3.74 | 0.063 | 0.512 | 0.884 | 1.395 |
| 07 | N | 2.200 | 5.754 | 351.91 | 3.74 | 0.020 | 0.293 | 0.484 | 0.777 |
| | NNE | 1.703 | 4.944 | 19.67 | 3.74 | 0.017 | 0.226 | 0.372 | 0.597 |
| | NE | 1.687 | 5.145 | 55.90 | 3.74 | 0.016 | 0.203 | 0.335 | 0.538 |
| | ENE | 2.296 | 6.135 | 75.02 | 3.74 | 0.018 | 0.245 | 0.405 | 0.650 |
| | E | 4.070 | 6.374 | 85.67 | 3.74 | 0.022 | 0.352 | 0.582 | 0.934 |
| | ESE | 2.697 | 6.259 | 93.30 | 3.74 | 0.018 | 0.198 | 0.327 | 0.525 |
| | SE | 2.534 | 6.320 | 99.28 | 3.74 | 0.195 | 0.233 | 0.606 | 0.839 |
| | NW | 3.376 | 6.312 | 321.45 | 3.74 | 0.023 | 0.375 | 0.620 | 0.995 |
| | NNW | 3.244 | 6.281 | 333.35 | 3.74 | 0.023 | 0.398 | 0.658 | 1.055 |
| 08 | N | 2.187 | 5.745 | 350.75 | 3.74 | 0.021 | 0.271 | 0.449 | 0.720 |
| | NNE | 1.690 | 4.895 | 19.72 | 3.74 | 0.020 | 0.228 | 0.376 | 0.604 |
| | NE | 1.691 | 5.135 | 57.62 | 3.74 | 0.020 | 0.228 | 0.376 | 0.604 |
| | ENE | 2.386 | 6.149 | 78.52 | 3.74 | 0.022 | 0.300 | 0.497 | 0.798 |
| | E | 4.459 | 6.409 | 90.78 | 3.74 | 0.029 | 0.484 | 0.803 | 1.287 |
| | ESE | 3.053 | 6.307 | 99.37 | 3.74 | 0.022 | 0.300 | 0.498 | 0.798 |
| | SE | 2.959 | 6.430 | 105.56 | 3.74 | 0.020 | 0.259 | 0.429 | 0.688 |
| | NW | 3.520 | 6.318 | 319.04 | 3.74 | 0.021 | 0.276 | 0.457 | 0.733 |
| | NNW | 3.296 | 6.283 | 331.18 | 3.74 | 0.024 | 0.335 | 0.556 | 0.891 |
| 09 | N | 2.189 | 5.753 | 351.19 | 3.75 | 0.073 | 0.389 | 0.685 | 1.073 |
| | NNE | 1.699 | 4.914 | 19.93 | 3.75 | 0.084 | 0.302 | 0.541 | 0.843 |
| | NE | 1.694 | 5.149 | 57.02 | 3.75 | 0.099 | 0.259 | 0.486 | 0.745 |
| | ENE | 2.353 | 6.143 | 76.79 | 3.75 | 0.100 | 0.259 | 0.504 | 0.763 |
| | E | 4.300 | 6.389 | 88.36 | 3.75 | 0.165 | 0.223 | 0.542 | 0.765 |
| | ESE | 2.889 | 6.279 | 96.19 | 3.75 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.750 | 6.375 | 102.40 | 3.75 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.455 | 6.308 | 320.38 | 3.75 | 0.065 | 0.522 | 0.903 | 1.424 |
| | NNW | 3.262 | 6.276 | 332.18 | 3.75 | 0.065 | 0.522 | 0.903 | 1.425 |
| 10 | N | 2.194 | 5.767 | 350.53 | 3.73 | 0.178 | 0.464 | 0.983 | 1.447 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NNE | 1.700 | 4.907 | 20.01 | 3.73 | 0.231 | 0.373 | 0.860 | 1.233 |
| | NE | 1.697 | 5.152 | 57.40 | 3.73 | 0.299 | 0.336 | 0.921 | 1.257 |
| | ENE | 2.371 | 6.146 | 77.30 | 3.73 | 0.274 | 0.351 | 0.987 | 1.338 |
| | E | 4.390 | 6.400 | 89.45 | 3.73 | 0.256 | 0.362 | 0.992 | 1.354 |
| | ESE | 2.947 | 6.287 | 97.42 | 3.73 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.793 | 6.400 | 102.71 | 3.73 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.534 | 6.314 | 320.22 | 3.73 | 0.148 | 0.609 | 1.202 | 1.811 |
| | NNW | 3.315 | 6.281 | 331.47 | 3.73 | 0.148 | 0.611 | 1.203 | 1.814 |
| 11 | N | 2.205 | 5.784 | 349.15 | 3.75 | 0.663 | 0.565 | 2.419 | 2.984 |
| 11 | NNE | 1.694 | 4.886 | 19.87 | 3.75 | 0.727 | 0.472 | 2.059 | 2.531 |
| 11 | NE | 1.689 | 5.139 | 57.83 | 3.75 | 0.750 | 0.457 | 2.133 | 2.591 |
| 11 | ENE | 2.378 | 6.138 | 78.13 | 3.75 | 0.672 | 0.559 | 2.522 | 3.081 |
| 11 | E | 4.476 | 6.406 | 91.18 | 3.75 | 0.576 | 0.794 | 2.944 | 3.738 |
| 11 | ESE | 3.049 | 6.302 | 100.77 | 3.75 | 0.722 | 0.501 | 2.522 | 3.024 |
| 11 | SE | 2.961 | 6.433 | 107.56 | 3.75 | 0.858 | 0.406 | 2.557 | 2.963 |
| 11 | NW | 3.676 | 6.331 | 319.11 | 3.75 | 0.620 | 0.659 | 2.710 | 3.370 |
| 11 | NNW | 3.421 | 6.295 | 329.65 | 3.75 | 0.600 | 0.708 | 2.771 | 3.479 |
| 12 | N | 2.210 | 5.805 | 349.31 | 3.74 | 0.078 | 0.396 | 0.703 | 1.099 |
| 12 | NNE | 1.704 | 4.903 | 20.18 | 3.74 | 0.079 | 0.301 | 0.535 | 0.836 |
| 12 | NE | 1.697 | 5.155 | 57.63 | 3.74 | 0.080 | 0.257 | 0.465 | 0.723 |
| 12 | ENE | 2.369 | 6.138 | 77.20 | 3.74 | 0.080 | 0.273 | 0.504 | 0.777 |
| 12 | E | 4.413 | 6.398 | 90.20 | 3.74 | 0.080 | 0.266 | 0.496 | 0.762 |
| 12 | ESE | 2.944 | 6.278 | 99.25 | 3.74 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12 | SE | 2.812 | 6.378 | 106.08 | 3.74 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12 | NW | 3.647 | 6.326 | 320.30 | 3.74 | 0.076 | 0.547 | 0.962 | 1.510 |
| 12 | NNW | 3.412 | 6.291 | 330.27 | 3.74 | 0.076 | 0.546 | 0.959 | 1.505 |
| 13 | N | 2.212 | 5.825 | 349.32 | 3.75 | 0.000 | 0.000 | 0.000 | 0.000 |
| 13 | NNE | 1.711 | 4.912 | 20.46 | 3.75 | 0.225 | 0.293 | 0.700 | 0.993 |
| 13 | NE | 1.699 | 5.166 | 57.34 | 3.75 | 0.187 | 0.359 | 0.779 | 1.139 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | ENE | 2.348 | 6.126 | 76.29 | 3.75 | 0.159 | 0.495 | 1.017 | 1.513 |
| | E | 4.361 | 6.387 | 89.94 | 3.75 | 0.135 | 0.797 | 1.499 | 2.295 |
| | ESE | 2.882 | 6.265 | 100.13 | 3.75 | 0.150 | 0.570 | 1.138 | 1.708 |
| | SE | 2.775 | 6.347 | 108.89 | 3.75 | 0.153 | 0.544 | 1.102 | 1.646 |
| | NW | 3.595 | 6.322 | 321.56 | 3.75 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 3.395 | 6.290 | 330.74 | 3.75 | 0.000 | 0.000 | 0.000 | 0.000 |
| 14 | N | 2.221 | 5.823 | 348.16 | 3.76 | 0.144 | 0.359 | 0.736 | 1.095 |
| | NNE | 1.701 | 4.890 | 20.22 | 3.76 | 0.150 | 0.333 | 0.668 | 1.001 |
| | NE | 1.690 | 5.151 | 57.59 | 3.76 | 0.146 | 0.347 | 0.696 | 1.043 |
| | ENE | 2.361 | 6.125 | 77.08 | 3.76 | 0.128 | 0.451 | 0.880 | 1.331 |
| | E | 4.436 | 6.394 | 90.80 | 3.76 | 0.113 | 0.695 | 1.277 | 1.972 |
| | ESE | 3.000 | 6.286 | 102.22 | 3.76 | 0.126 | 0.468 | 0.911 | 1.379 |
| | SE | 2.954 | 6.409 | 112.30 | 3.76 | 0.133 | 0.414 | 0.836 | 1.250 |
| | NW | 3.736 | 6.335 | 319.27 | 3.76 | 0.212 | 0.244 | 0.658 | 0.902 |
| | NNW | 3.480 | 6.301 | 328.82 | 3.76 | 0.141 | 0.372 | 0.773 | 1.145 |
| 15 | N | 2.216 | 5.841 | 349.01 | 3.75 | 0.366 | 0.341 | 1.125 | 1.466 |
| | NNE | 1.713 | 4.913 | 20.58 | 3.75 | 0.311 | 0.363 | 0.977 | 1.340 |
| | NE | 1.695 | 5.167 | 56.94 | 3.75 | 0.275 | 0.398 | 1.004 | 1.402 |
| | ENE | 2.332 | 6.114 | 75.33 | 3.75 | 0.220 | 0.520 | 1.197 | 1.718 |
| | E | 4.326 | 6.382 | 89.50 | 3.75 | 0.179 | 0.808 | 1.632 | 2.441 |
| | ESE | 2.861 | 6.265 | 100.78 | 3.75 | 0.209 | 0.566 | 1.267 | 1.833 |
| | SE | 2.810 | 6.358 | 112.27 | 3.75 | 0.219 | 0.525 | 1.223 | 1.748 |
| | NW | 3.598 | 6.326 | 322.09 | 3.75 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 3.405 | 6.293 | 330.68 | 3.75 | 0.000 | 0.000 | 0.000 | 0.000 |
| 16 | N | 1.999 | 5.765 | 358.87 | 3.76 | 0.155 | 0.305 | 0.656 | 0.961 |
| | NNE | 1.695 | 4.944 | 23.53 | 3.76 | 0.155 | 0.316 | 0.647 | 0.964 |
| | NE | 1.706 | 5.190 | 56.16 | 3.76 | 0.157 | 0.357 | 0.730 | 1.087 |
| | ENE | 2.312 | 6.114 | 72.32 | 3.76 | 0.161 | 0.489 | 1.010 | 1.499 |
| | E | 4.185 | 6.381 | 84.61 | 3.76 | 0.111 | 0.729 | 1.330 | 2.058 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | ESE | 2.637 | 6.240 | 96.18 | 3.76 | 0.162 | 0.519 | 1.071 | 1.589 |
| | SE | 2.524 | 6.275 | 109.85 | 3.76 | 0.161 | 0.466 | 0.975 | 1.441 |
| | NW | 2.525 | 6.301 | 337.88 | 3.76 | 0.200 | 0.194 | 0.533 | 0.727 |
| | NNW | 2.705 | 6.265 | 344.32 | 3.76 | 0.155 | 0.286 | 0.639 | 0.925 |
| 17 | N | 1.954 | 5.719 | 1.32 | 3.76 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 1.698 | 4.984 | 24.66 | 3.76 | 0.306 | 0.225 | 0.682 | 0.907 |
| | NE | 1.705 | 5.202 | 55.30 | 3.76 | 0.277 | 0.352 | 0.919 | 1.271 |
| | ENE | 2.260 | 6.110 | 69.98 | 3.76 | 0.271 | 0.506 | 1.293 | 1.799 |
| | E | 4.041 | 6.385 | 83.39 | 3.76 | 0.228 | 0.824 | 1.803 | 2.627 |
| | ESE | 2.402 | 6.218 | 95.72 | 3.76 | 0.269 | 0.563 | 1.412 | 1.975 |
| | SE | 2.272 | 4.796 | 113.36 | 3.76 | 0.268 | 0.483 | 1.121 | 1.604 |
| | NW | 2.416 | 6.286 | 338.57 | 3.76 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.572 | 6.251 | 346.95 | 3.76 | 0.000 | 0.000 | 0.000 | 0.000 |
| 18a | N | 1.729 | 5.610 | 11.25 | 3.78 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 1.619 | 4.978 | 30.54 | 3.78 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NE | 1.692 | 5.209 | 55.28 | 3.78 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ENE | 2.222 | 6.101 | 67.79 | 3.78 | 0.000 | 0.000 | 0.000 | 0.000 |
| | E | 3.855 | 6.385 | 79.61 | 3.78 | 0.285 | 0.297 | 0.910 | 1.207 |
| | ESE | 2.204 | 6.195 | 89.81 | 3.78 | 0.290 | 0.310 | 0.935 | 1.245 |
| | SE | 1.974 | 4.711 | 106.08 | 3.78 | 0.303 | 0.344 | 0.906 | 1.250 |
| | NW | 1.903 | 6.321 | 342.28 | 3.78 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.097 | 6.254 | 355.99 | 3.78 | 0.000 | 0.000 | 0.000 | 0.000 |
| 18b | N | 1.741 | 5.622 | 10.63 | 3.78 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 1.624 | 4.963 | 30.01 | 3.78 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NE | 1.694 | 5.207 | 55.54 | 3.78 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ENE | 2.229 | 6.102 | 68.55 | 3.78 | 0.000 | 0.000 | 0.000 | 0.000 |
| | E | 3.864 | 6.373 | 81.20 | 3.78 | 0.304 | 0.344 | 1.056 | 1.401 |
| | ESE | 2.258 | 6.194 | 92.17 | 3.78 | 0.302 | 0.338 | 1.021 | 1.360 |
| | SE | 2.078 | 4.761 | 108.97 | 3.78 | 0.315 | 0.375 | 0.991 | 1.366 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NW | 1.915 | 6.315 | 344.32 | 3.78 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.115 | 6.254 | 356.35 | 3.78 | 0.000 | 0.000 | 0.000 | 0.000 |
| 19 | N | 0.775 | 2.424 | 26.08 | 3.79 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 0.879 | 5.113 | 56.85 | 3.79 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NE | 1.119 | 5.251 | 71.06 | 3.79 | 0.089 | 0.094 | 0.194 | 0.288 |
| | ENE | 1.558 | 6.067 | 73.12 | 3.79 | 0.101 | 0.150 | 0.314 | 0.464 |
| | E | 2.933 | 6.332 | 77.46 | 3.79 | 0.115 | 0.310 | 0.333 | 0.644 |
| | ESE | 1.728 | 6.154 | 86.70 | 3.79 | 0.098 | 0.240 | 0.469 | 0.709 |
| | SE | 1.530 | 3.139 | 108.72 | 3.79 | 0.092 | 0.213 | 0.375 | 0.588 |
| | NW | 0.890 | 2.776 | 308.35 | 3.79 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 0.846 | 2.619 | 340.30 | 3.79 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20 | N | 0.775 | 2.424 | 26.08 | 3.80 | 0.032 | 0.077 | 0.127 | 0.204 |
| | NNE | 0.879 | 5.113 | 56.85 | 3.80 | 0.044 | 0.152 | 0.262 | 0.415 |
| | NE | 1.119 | 5.251 | 71.06 | 3.80 | 0.050 | 0.201 | 0.348 | 0.549 |
| | ENE | 1.558 | 6.067 | 73.12 | 3.80 | 0.049 | 0.277 | 0.478 | 0.755 |
| | E | 2.933 | 6.332 | 77.46 | 3.80 | 0.042 | 0.457 | 0.770 | 1.228 |
| | ESE | 1.728 | 6.154 | 86.70 | 3.80 | 0.049 | 0.307 | 0.527 | 0.834 |
| | SE | 1.530 | 3.139 | 108.72 | 3.80 | 0.050 | 0.210 | 0.352 | 0.561 |
| | NW | 0.890 | 2.776 | 308.35 | 3.80 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 0.846 | 2.619 | 340.30 | 3.80 | 0.000 | 0.000 | 0.000 | 0.000 |
| 21 | N | 0.775 | 2.424 | 26.08 | 3.79 | 0.321 | 0.160 | 0.384 | 0.544 |
| | NNE | 0.879 | 5.113 | 56.85 | 3.79 | 0.222 | 0.222 | 0.569 | 0.791 |
| | NE | 1.119 | 5.251 | 71.06 | 3.79 | 0.194 | 0.256 | 0.603 | 0.860 |
| | ENE | 1.558 | 6.067 | 73.12 | 3.79 | 0.050 | 0.268 | 0.464 | 0.733 |
| | E | 2.933 | 6.332 | 77.46 | 3.79 | 0.048 | 0.442 | 0.751 | 1.193 |
| | ESE | 1.728 | 6.154 | 86.70 | 3.79 | 0.048 | 0.272 | 0.469 | 0.741 |
| | SE | 1.530 | 3.139 | 108.72 | 3.79 | 0.230 | 0.211 | 0.459 | 0.670 |
| | NW | 0.890 | 2.776 | 308.35 | 3.79 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 0.846 | 2.619 | 340.30 | 3.79 | 0.357 | 0.137 | 0.371 | 0.508 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| 22 | N | 0.805 | 4.844 | 27.39 | 3.78 | 1.173 | 0.279 | 2.129 | 2.409 |
| | NNE | 0.934 | 5.087 | 56.39 | 3.78 | 1.179 | 0.280 | 2.220 | 2.500 |
| | NE | 1.220 | 5.263 | 71.86 | 3.78 | 1.152 | 0.298 | 2.318 | 2.615 |
| | ENE | 1.720 | 6.083 | 75.46 | 3.78 | 0.534 | 0.337 | 1.498 | 1.835 |
| | E | 3.164 | 6.347 | 79.45 | 3.78 | 0.542 | 0.522 | 2.097 | 2.619 |
| | ESE | 1.883 | 6.166 | 86.38 | 3.78 | 0.766 | 0.300 | 1.861 | 2.161 |
| | SE | 1.660 | 6.135 | 103.14 | 3.78 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 0.929 | 2.835 | 303.54 | 3.78 | 1.015 | 0.185 | 0.994 | 1.179 |
| | NNW | 0.889 | 2.632 | 337.69 | 3.78 | 1.070 | 0.227 | 1.129 | 1.356 |
| 23 | N | 1.492 | 5.470 | 20.47 | 3.78 | 0.388 | 0.394 | 1.250 | 1.644 |
| | NNE | 1.506 | 4.961 | 37.53 | 3.78 | 0.417 | 0.379 | 1.209 | 1.588 |
| | NE | 1.660 | 5.215 | 56.87 | 3.78 | 0.401 | 0.387 | 1.228 | 1.615 |
| | ENE | 2.192 | 6.094 | 67.35 | 3.78 | 0.304 | 0.455 | 1.268 | 1.722 |
| | E | 3.765 | 6.377 | 77.88 | 3.78 | 0.174 | 0.581 | 1.216 | 1.798 |
| | ESE | 2.122 | 6.186 | 86.24 | 3.78 | 0.437 | 0.383 | 1.427 | 1.810 |
| | SE | 1.830 | 6.186 | 99.38 | 3.78 | 4.697 | 0.377 | 10.164 | 10.542 |
| | NW | 1.548 | 6.377 | 340.36 | 3.78 | 0.395 | 0.398 | 1.391 | 1.789 |
| | NNW | 1.683 | 6.269 | 3.35 | 3.78 | 0.324 | 0.437 | 1.298 | 1.735 |
| 24 | N | 1.970 | 5.739 | 1.91 | 3.77 | 0.099 | 0.372 | 0.689 | 1.061 |
| | NNE | 1.706 | 5.025 | 24.78 | 3.77 | 0.098 | 0.322 | 0.590 | 0.912 |
| | NE | 1.699 | 5.204 | 54.02 | 3.77 | 0.098 | 0.309 | 0.571 | 0.879 |
| | ENE | 2.211 | 6.095 | 67.23 | 3.77 | 0.099 | 0.381 | 0.711 | 1.092 |
| | E | 3.871 | 6.387 | 79.99 | 3.77 | 0.061 | 0.501 | 0.864 | 1.365 |
| | ESE | 2.230 | 6.196 | 93.56 | 3.77 | 0.099 | 0.286 | 0.551 | 0.837 |
| | SE | 2.061 | 4.556 | 114.45 | 3.77 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 2.524 | 6.305 | 338.27 | 3.77 | 0.099 | 0.426 | 0.793 | 1.219 |
| | NNW | 2.677 | 6.264 | 347.47 | 3.77 | 0.068 | 0.435 | 0.763 | 1.198 |
| 25 | N | 2.068 | 5.782 | 358.18 | 3.77 | 0.338 | 0.213 | 0.759 | 0.973 |
| | NNE | 1.706 | 5.064 | 21.42 | 3.77 | 0.048 | 0.215 | 0.369 | 0.584 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NE | 1.558 | 5.139 | 45.28 | 3.77 | 0.052 | 0.246 | 0.422 | 0.668 |
| | ENE | 1.908 | 5.942 | 57.20 | 3.77 | 0.060 | 0.330 | 0.576 | 0.907 |
| | E | 3.155 | 6.318 | 75.15 | 3.77 | 0.077 | 0.548 | 0.965 | 1.513 |
| | ESE | 1.714 | 4.034 | 101.86 | 3.77 | 0.053 | 0.257 | 0.435 | 0.691 |
| | SE | 1.766 | 4.308 | 137.24 | 3.77 | 0.049 | 0.220 | 0.374 | 0.595 |
| | NW | 2.707 | 6.285 | 337.71 | 3.77 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.809 | 6.253 | 343.95 | 3.77 | 0.000 | 0.000 | 0.000 | 0.000 |
| 26 | N | 1.825 | 5.635 | 6.76 | 3.76 | 0.089 | 0.245 | 0.459 | 0.704 |
| | NNE | 1.589 | 5.046 | 21.47 | 3.76 | 0.085 | 0.248 | 0.452 | 0.699 |
| | NE | 1.432 | 5.062 | 38.77 | 3.76 | 0.082 | 0.252 | 0.456 | 0.709 |
| | ENE | 1.676 | 5.681 | 51.29 | 3.76 | 0.063 | 0.297 | 0.522 | 0.819 |
| | E | 2.674 | 6.219 | 76.06 | 3.76 | 0.051 | 0.441 | 0.751 | 1.192 |
| | ESE | 1.514 | 3.932 | 109.03 | 3.76 | 0.087 | 0.241 | 0.428 | 0.670 |
| | SE | 1.663 | 4.196 | 134.91 | 3.76 | 0.108 | 0.227 | 0.423 | 0.650 |
| | NW | 2.059 | 6.280 | 350.07 | 3.76 | 0.105 | 0.178 | 0.371 | 0.549 |
| | NNW | 2.253 | 6.235 | 355.12 | 3.76 | 0.100 | 0.237 | 0.467 | 0.704 |
| 27 | N | 1.911 | 5.725 | 1.12 | 3.77 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 1.525 | 5.073 | 12.75 | 3.77 | 0.490 | 0.135 | 0.675 | 0.810 |
| | NE | 1.232 | 4.813 | 28.91 | 3.77 | 0.197 | 0.184 | 0.449 | 0.633 |
| | ENE | 1.356 | 5.167 | 44.80 | 3.77 | 0.138 | 0.237 | 0.491 | 0.728 |
| | E | 2.211 | 4.353 | 79.84 | 3.77 | 0.147 | 0.398 | 0.758 | 1.157 |
| | ESE | 1.329 | 3.826 | 115.65 | 3.77 | 0.104 | 0.236 | 0.429 | 0.665 |
| | SE | 1.551 | 4.003 | 136.31 | 3.77 | 0.111 | 0.258 | 0.475 | 0.733 |
| | NW | 2.352 | 6.286 | 344.85 | 3.77 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.525 | 6.250 | 351.16 | 3.77 | 0.000 | 0.000 | 0.000 | 0.000 |
| 28 | N | 0.881 | 5.086 | 17.97 | 3.80 | 0.067 | 0.154 | 0.280 | 0.434 |
| | NNE | 0.840 | 4.922 | 38.65 | 3.80 | 0.069 | 0.163 | 0.295 | 0.458 |
| | NE | 0.889 | 4.976 | 49.15 | 3.80 | 0.073 | 0.177 | 0.321 | 0.499 |
| | ENE | 1.115 | 3.826 | 60.30 | 3.80 | 0.075 | 0.195 | 0.342 | 0.537 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | E | 2.040 | 4.375 | 83.10 | 3.80 | 0.052 | 0.304 | 0.515 | 0.819 |
| | ESE | 1.247 | 3.473 | 113.13 | 3.80 | 0.073 | 0.175 | 0.305 | 0.480 |
| | SE | 1.429 | 3.779 | 132.97 | 3.80 | 0.068 | 0.157 | 0.275 | 0.432 |
| | NW | 1.083 | 3.136 | 316.06 | 3.80 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 1.053 | 3.028 | 339.65 | 3.80 | 0.035 | 0.060 | 0.101 | 0.160 |
| 29 | N | 1.619 | 5.585 | 7.77 | 3.81 | 0.011 | 0.171 | 0.280 | 0.451 |
| | NNE | 1.370 | 5.048 | 16.44 | 3.81 | 0.014 | 0.160 | 0.263 | 0.422 |
| | NE | 1.138 | 4.728 | 26.19 | 3.81 | 0.013 | 0.140 | 0.229 | 0.369 |
| | ENE | 1.212 | 3.936 | 37.50 | 3.81 | 0.013 | 0.143 | 0.235 | 0.378 |
| | E | 1.860 | 4.001 | 71.89 | 3.81 | 0.011 | 0.203 | 0.333 | 0.537 |
| | ESE | 1.052 | 3.151 | 121.54 | 3.81 | 0.009 | 0.088 | 0.145 | 0.233 |
| | SE | 1.282 | 3.608 | 146.12 | 3.81 | 0.006 | 0.056 | 0.091 | 0.146 |
| | NW | 1.814 | 6.276 | 342.06 | 3.81 | 0.011 | 0.116 | 0.192 | 0.308 |
| | NNW | 1.957 | 6.211 | 355.79 | 3.81 | 0.012 | 0.179 | 0.295 | 0.475 |
| 30 | N | 1.637 | 5.640 | 3.84 | 3.76 | 0.003 | 0.164 | 0.268 | 0.432 |
| | NNE | 1.311 | 5.035 | 11.31 | 3.76 | 0.003 | 0.128 | 0.210 | 0.338 |
| | NE | 1.036 | 4.641 | 20.64 | 3.76 | 0.008 | 0.124 | 0.203 | 0.326 |
| | ENE | 1.069 | 3.789 | 33.33 | 3.76 | 0.009 | 0.115 | 0.189 | 0.304 |
| | E | 1.584 | 3.393 | 78.30 | 3.76 | 0.007 | 0.087 | 0.143 | 0.230 |
| | ESE | 0.953 | 3.063 | 129.57 | 3.76 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 1.207 | 3.445 | 148.57 | 3.76 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 1.945 | 6.280 | 342.51 | 3.76 | 0.003 | 0.191 | 0.312 | 0.503 |
| | NNW | 2.080 | 6.228 | 353.92 | 3.76 | 0.003 | 0.204 | 0.333 | 0.536 |
| 31 | N | 1.411 | 5.773 | 354.47 | 3.73 | 0.223 | 0.307 | 0.450 | 0.757 |
| | NNE | 0.978 | 5.080 | 357.56 | 3.73 | 0.256 | 0.217 | 0.289 | 0.506 |
| | NE | 0.677 | 4.342 | 8.87 | 3.73 | 0.549 | 0.152 | 0.165 | 0.316 |
| | ENE | 0.680 | 2.191 | 39.10 | 3.73 | 0.000 | 0.000 | 0.000 | 0.000 |
| | E | 1.123 | 2.907 | 101.08 | 3.73 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ESE | 0.816 | 2.839 | 133.83 | 3.73 | 0.000 | 0.000 | 0.000 | 0.000 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | SE | 1.062 | 3.247 | 149.91 | 3.73 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 1.988 | 6.274 | 343.52 | 3.73 | 0.081 | 0.371 | 0.673 | 1.044 |
| | NNW | 2.040 | 6.240 | 351.47 | 3.73 | 0.081 | 0.363 | 0.658 | 1.021 |
| 32 | N | 1.893 | 5.745 | 359.14 | 3.75 | 0.120 | 0.288 | 0.574 | 0.862 |
| | NNE | 1.460 | 5.078 | 8.67 | 3.75 | 2.724 | 0.355 | 4.240 | 4.595 |
| | NE | 1.112 | 4.697 | 23.14 | 3.75 | 3.297 | 0.155 | 3.478 | 3.632 |
| | ENE | 1.159 | 3.698 | 37.84 | 3.75 | 0.000 | 0.000 | 0.000 | 0.000 |
| | E | 1.812 | 4.050 | 72.29 | 3.75 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ESE | 1.064 | 3.222 | 113.27 | 3.75 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 1.280 | 3.557 | 143.25 | 3.75 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 2.420 | 6.289 | 341.81 | 3.75 | 0.106 | 0.419 | 0.792 | 1.211 |
| | NNW | 2.569 | 6.252 | 349.77 | 3.75 | 0.105 | 0.412 | 0.778 | 1.189 |
| 33 | N | 1.944 | 5.910 | 348.95 | 3.76 | 0.475 | 0.277 | 1.178 | 1.455 |
| | NNE | 1.328 | 5.107 | 356.97 | 3.76 | 0.592 | 0.248 | 1.174 | 1.422 |
| | NE | 0.895 | 4.420 | 12.73 | 3.76 | 0.625 | 0.214 | 1.010 | 1.224 |
| | ENE | 0.921 | 3.061 | 44.97 | 3.76 | 0.599 | 0.225 | 0.805 | 1.031 |
| | E | 1.821 | 4.210 | 105.68 | 3.76 | 0.351 | 0.375 | 0.995 | 1.370 |
| | ESE | 1.239 | 3.785 | 127.93 | 3.76 | 0.584 | 0.244 | 0.951 | 1.195 |
| | SE | 1.445 | 3.969 | 136.47 | 3.76 | 0.581 | 0.248 | 0.987 | 1.235 |
| | NW | 2.843 | 6.321 | 337.64 | 3.76 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.909 | 6.275 | 342.86 | 3.76 | 0.456 | 0.287 | 1.216 | 1.503 |
| 34 | N | 1.887 | 5.910 | 348.77 | 3.75 | 0.354 | 0.277 | 0.955 | 1.233 |
| | NNE | 1.286 | 5.112 | 354.46 | 3.75 | 0.375 | 0.222 | 0.781 | 1.004 |
| | NE | 0.865 | 4.336 | 11.16 | 3.75 | 0.400 | 0.192 | 0.669 | 0.860 |
| | ENE | 0.888 | 3.013 | 55.59 | 3.75 | 0.383 | 0.204 | 0.559 | 0.763 |
| | E | 1.872 | 4.396 | 108.51 | 3.75 | 0.351 | 0.378 | 1.019 | 1.397 |
| | ESE | 1.265 | 3.819 | 120.95 | 3.75 | 0.373 | 0.238 | 0.697 | 0.935 |
| | SE | 1.428 | 3.947 | 127.73 | 3.75 | 0.370 | 0.246 | 0.722 | 0.967 |
| | NW | 2.679 | 6.321 | 341.44 | 3.75 | 0.352 | 0.282 | 1.004 | 1.286 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NNW | 2.811 | 6.275 | 344.43 | 3.75 | 0.352 | 0.338 | 1.137 | 1.475 |
| 35 | N | 1.654 | 6.003 | 337.52 | 3.75 | 0.392 | 0.323 | 0.482 | 0.805 |
| | NNE | 1.020 | 5.183 | 346.53 | 3.75 | 0.499 | 0.241 | 0.352 | 0.593 |
| | NE | 0.656 | 2.420 | 28.58 | 3.75 | 0.557 | 0.157 | 0.518 | 0.675 |
| | ENE | 0.756 | 2.981 | 85.80 | 3.75 | 0.541 | 0.170 | 0.605 | 0.776 |
| | E | 1.830 | 4.323 | 99.04 | 3.75 | 0.372 | 0.334 | 0.506 | 0.840 |
| | ESE | 1.180 | 3.636 | 105.83 | 3.75 | 0.522 | 0.216 | 0.459 | 0.674 |
| | SE | 1.259 | 3.648 | 116.04 | 3.75 | 0.541 | 0.189 | 0.499 | 0.688 |
| | NW | 2.734 | 6.340 | 334.56 | 3.75 | 0.140 | 0.385 | 0.784 | 1.169 |
| | NNW | 2.685 | 6.296 | 336.14 | 3.75 | 0.139 | 0.388 | 0.788 | 1.176 |
| 36 | N | 1.453 | 6.008 | 334.71 | 3.75 | 0.049 | 0.252 | 0.436 | 0.689 |
| | NNE | 0.882 | 5.295 | 350.72 | 3.75 | 0.039 | 0.160 | 0.273 | 0.433 |
| | NE | 0.593 | 2.400 | 43.23 | 3.75 | 0.050 | 0.082 | 0.139 | 0.221 |
| | ENE | 0.735 | 2.891 | 77.05 | 3.75 | 0.048 | 0.071 | 0.121 | 0.191 |
| | E | 1.685 | 4.104 | 84.36 | 3.75 | 0.056 | 0.130 | 0.227 | 0.357 |
| | ESE | 1.042 | 3.420 | 91.68 | 3.75 | 0.036 | 0.041 | 0.070 | 0.111 |
| | SE | 1.051 | 3.396 | 103.87 | 3.75 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 2.417 | 6.318 | 329.89 | 3.75 | 0.059 | 0.396 | 0.688 | 1.084 |
| | NNW | 2.310 | 6.284 | 331.77 | 3.75 | 0.059 | 0.383 | 0.664 | 1.047 |
| 37 | N | 0.857 | 3.100 | 328.62 | 3.75 | 0.529 | 0.172 | 0.616 | 0.788 |
| | NNE | 0.546 | 2.188 | 9.42 | 3.75 | 0.659 | 0.134 | 0.489 | 0.623 |
| | NE | 0.472 | 2.252 | 60.50 | 3.75 | 0.671 | 0.114 | 0.451 | 0.565 |
| | ENE | 0.681 | 2.782 | 80.49 | 3.75 | 0.647 | 0.144 | 0.589 | 0.733 |
| | E | 1.611 | 3.954 | 88.80 | 3.75 | 0.239 | 0.246 | 0.574 | 0.820 |
| | ESE | 0.996 | 3.288 | 96.18 | 3.75 | 0.623 | 0.166 | 0.699 | 0.865 |
| | SE | 1.028 | 3.232 | 110.69 | 3.75 | 0.681 | 0.095 | 0.510 | 0.605 |
| | NW | 1.583 | 4.082 | 309.95 | 3.75 | 0.339 | 0.212 | 0.625 | 0.837 |
| | NNW | 1.372 | 3.876 | 315.23 | 3.75 | 0.344 | 0.209 | 0.608 | 0.817 |
| 38 | N | 1.832 | 5.945 | 344.85 | 3.75 | 0.050 | 0.197 | 0.345 | 0.542 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NNE | 1.214 | 5.123 | 350.97 | 3.75 | 0.493 | 0.237 | 0.183 | 0.420 |
| | NE | 0.783 | 3.074 | 13.18 | 3.75 | 0.478 | 0.172 | 0.154 | 0.327 |
| | ENE | 0.812 | 2.967 | 75.29 | 3.75 | 0.484 | 0.195 | 0.179 | 0.374 |
| | E | 1.875 | 4.389 | 105.86 | 3.75 | 0.040 | 0.239 | 0.401 | 0.639 |
| | ESE | 1.244 | 3.724 | 113.50 | 3.75 | 0.042 | 0.152 | 0.256 | 0.408 |
| | SE | 1.365 | 3.831 | 121.11 | 3.75 | 0.042 | 0.152 | 0.256 | 0.407 |
| | NW | 2.731 | 6.321 | 339.78 | 3.75 | 0.039 | 0.230 | 0.393 | 0.622 |
| | NNW | 2.809 | 6.278 | 342.21 | 3.75 | 0.042 | 0.257 | 0.439 | 0.696 |
| 39 | N | 0.868 | 3.157 | 342.21 | 3.76 | 0.002 | 0.072 | 0.118 | 0.190 |
| | NNE | 0.627 | 2.718 | 349.51 | 3.76 | 0.002 | 0.050 | 0.082 | 0.133 |
| | NE | 0.465 | 2.195 | 9.83 | 3.76 | 0.002 | 0.036 | 0.059 | 0.095 |
| | ENE | 0.466 | 1.947 | 57.91 | 3.76 | 0.001 | 0.019 | 0.032 | 0.051 |
| | E | 0.974 | 2.654 | 102.38 | 3.76 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ESE | 0.741 | 2.633 | 132.74 | 3.76 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 0.953 | 2.949 | 146.71 | 3.76 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 1.303 | 3.895 | 327.37 | 3.76 | 0.002 | 0.107 | 0.175 | 0.282 |
| | NNW | 1.224 | 3.718 | 336.98 | 3.76 | 0.002 | 0.101 | 0.165 | 0.266 |
| 40 | N | 1.544 | 5.599 | 5.84 | 3.83 | 0.004 | 0.161 | 0.264 | 0.425 |
| | NNE | 1.270 | 5.029 | 13.55 | 3.83 | 0.004 | 0.131 | 0.214 | 0.345 |
| | NE | 1.038 | 4.659 | 22.35 | 3.83 | 0.028 | 0.163 | 0.271 | 0.434 |
| | ENE | 1.089 | 3.800 | 35.23 | 3.83 | 0.682 | 0.290 | 1.202 | 1.492 |
| | E | 1.638 | 3.455 | 79.31 | 3.83 | 0.028 | 0.156 | 0.258 | 0.414 |
| | ESE | 0.988 | 3.112 | 127.32 | 3.83 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 1.230 | 3.483 | 144.76 | 3.83 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 1.766 | 6.290 | 342.02 | 3.83 | 0.003 | 0.176 | 0.288 | 0.465 |
| | NNW | 1.898 | 6.220 | 355.12 | 3.83 | 0.004 | 0.194 | 0.317 | 0.510 |

# Appendix C - Details of Calculation of Wave Effects: Year 2100

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| 01 | N | 2.144 | 5.716 | 356.91 | 4.18 | 0.114 | 0.420 | 0.792 | 1.212 |
| | NNE | 1.693 | 5.000 | 21.27 | 4.18 | 0.114 | 0.320 | 0.605 | 0.925 |
| | NE | 1.703 | 5.142 | 54.79 | 4.18 | 0.114 | 0.269 | 0.520 | 0.789 |
| | ENE | 2.324 | 6.157 | 74.97 | 4.18 | 0.114 | 0.265 | 0.535 | 0.800 |
| | E | 4.077 | 6.434 | 84.47 | 4.18 | 0.114 | 0.268 | 0.547 | 0.815 |
| | ESE | 2.725 | 6.291 | 91.00 | 4.18 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.512 | 6.360 | 95.66 | 4.18 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 2.917 | 6.317 | 327.62 | 4.18 | 0.114 | 0.529 | 0.995 | 1.524 |
| | NNW | 2.911 | 6.270 | 340.54 | 4.18 | 0.114 | 0.546 | 1.024 | 1.570 |
| 02 | N | 2.185 | 5.738 | 354.61 | 4.20 | 0.036 | 0.299 | 0.501 | 0.800 |
| | NNE | 1.700 | 4.998 | 20.52 | 4.20 | 0.031 | 0.250 | 0.417 | 0.667 |
| | NE | 1.696 | 5.141 | 54.75 | 4.20 | 0.032 | 0.254 | 0.425 | 0.679 |
| | ENE | 2.298 | 6.151 | 74.34 | 4.20 | 0.040 | 0.344 | 0.581 | 0.925 |
| | E | 4.034 | 6.420 | 84.14 | 4.20 | 0.055 | 0.559 | 0.953 | 1.512 |
| | ESE | 2.663 | 6.279 | 90.71 | 4.20 | 0.040 | 0.354 | 0.598 | 0.952 |
| | SE | 2.459 | 6.348 | 96.12 | 4.20 | 0.037 | 0.310 | 0.524 | 0.834 |
| | NW | 3.100 | 6.318 | 325.59 | 4.20 | 0.034 | 0.282 | 0.476 | 0.758 |
| | NNW | 3.064 | 6.276 | 337.28 | 4.20 | 0.041 | 0.355 | 0.601 | 0.956 |
| 03 | N | 2.195 | 5.742 | 353.91 | 4.19 | 0.053 | 0.365 | 0.624 | 0.989 |
| | NNE | 1.700 | 4.990 | 20.31 | 4.19 | 0.048 | 0.274 | 0.466 | 0.740 |
| | NE | 1.696 | 5.140 | 55.01 | 4.19 | 0.046 | 0.233 | 0.398 | 0.631 |
| | ENE | 2.308 | 6.153 | 74.80 | 4.19 | 0.047 | 0.248 | 0.428 | 0.676 |
| | E | 4.061 | 6.419 | 84.73 | 4.19 | 0.050 | 0.300 | 0.519 | 0.820 |
| | ESE | 2.692 | 6.281 | 91.44 | 4.19 | 0.063 | 0.127 | 0.239 | 0.366 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | SE | 2.499 | 6.354 | 97.01 | 4.19 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.160 | 6.318 | 324.28 | 4.19 | 0.055 | 0.471 | 0.807 | 1.278 |
| | NNW | 3.106 | 6.277 | 336.06 | 4.19 | 0.056 | 0.487 | 0.834 | 1.322 |
| 04 | N | 2.202 | 5.750 | 353.45 | 4.18 | 0.034 | 0.320 | 0.537 | 0.857 |
| | NNE | 1.703 | 4.994 | 20.00 | 4.18 | 0.033 | 0.258 | 0.430 | 0.688 |
| | NE | 1.683 | 5.138 | 54.37 | 4.18 | 0.032 | 0.244 | 0.408 | 0.652 |
| | ENE | 2.243 | 6.137 | 72.85 | 4.18 | 0.034 | 0.301 | 0.506 | 0.807 |
| | E | 3.921 | 6.396 | 82.93 | 4.18 | 0.037 | 0.449 | 0.752 | 1.201 |
| | ESE | 2.529 | 6.262 | 89.49 | 4.18 | 0.033 | 0.279 | 0.469 | 0.748 |
| | SE | 2.324 | 6.321 | 95.25 | 4.18 | 0.032 | 0.234 | 0.394 | 0.628 |
| | NW | 3.205 | 6.316 | 324.27 | 4.18 | 0.036 | 0.370 | 0.621 | 0.991 |
| | NNW | 3.159 | 6.279 | 335.68 | 4.18 | 0.037 | 0.408 | 0.685 | 1.093 |
| 05 | N | 2.204 | 5.739 | 351.85 | 4.18 | 0.026 | 0.306 | 0.508 | 0.814 |
| | NNE | 1.692 | 4.931 | 19.46 | 4.18 | 0.023 | 0.238 | 0.393 | 0.631 |
| | NE | 1.698 | 5.131 | 56.88 | 4.18 | 0.022 | 0.221 | 0.366 | 0.587 |
| | ENE | 2.394 | 6.159 | 78.62 | 4.18 | 0.024 | 0.268 | 0.446 | 0.714 |
| | E | 4.381 | 6.419 | 89.79 | 4.18 | 0.026 | 0.382 | 0.634 | 1.016 |
| | ESE | 3.043 | 6.316 | 97.85 | 4.18 | 0.022 | 0.220 | 0.367 | 0.587 |
| | SE | 2.930 | 6.440 | 103.37 | 4.18 | 0.271 | 0.271 | 0.829 | 1.101 |
| | NW | 3.439 | 6.329 | 319.51 | 4.18 | 0.028 | 0.374 | 0.622 | 0.995 |
| | NNW | 3.286 | 6.293 | 332.12 | 4.18 | 0.027 | 0.401 | 0.665 | 1.066 |
| 06 | N | 2.204 | 5.741 | 351.54 | 4.16 | 0.060 | 0.375 | 0.647 | 1.022 |
| | NNE | 1.692 | 4.924 | 19.39 | 4.16 | 0.056 | 0.280 | 0.480 | 0.761 |
| | NE | 1.696 | 5.131 | 57.05 | 4.16 | 0.053 | 0.238 | 0.410 | 0.647 |
| | ENE | 2.393 | 6.157 | 78.71 | 4.16 | 0.053 | 0.246 | 0.430 | 0.676 |
| | E | 4.398 | 6.417 | 90.08 | 4.16 | 0.054 | 0.250 | 0.439 | 0.688 |
| | ESE | 3.052 | 6.315 | 98.28 | 4.16 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.946 | 6.437 | 103.94 | 4.16 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.462 | 6.327 | 319.21 | 4.16 | 0.064 | 0.503 | 0.870 | 1.373 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NNW | 3.299 | 6.292 | 331.79 | 4.16 | 0.064 | 0.516 | 0.892 | 1.408 |
| 07 | N | 2.203 | 5.756 | 351.89 | 4.15 | 0.021 | 0.296 | 0.490 | 0.786 |
| | NNE | 1.703 | 4.944 | 19.66 | 4.15 | 0.018 | 0.226 | 0.373 | 0.599 |
| | NE | 1.687 | 5.145 | 55.93 | 4.15 | 0.019 | 0.211 | 0.349 | 0.561 |
| | ENE | 2.300 | 6.135 | 75.14 | 4.15 | 0.019 | 0.246 | 0.406 | 0.652 |
| | E | 4.080 | 6.375 | 85.77 | 4.15 | 0.022 | 0.353 | 0.584 | 0.937 |
| | ESE | 2.708 | 6.260 | 93.43 | 4.15 | 0.025 | 0.211 | 0.351 | 0.562 |
| | SE | 2.546 | 6.322 | 99.42 | 4.15 | 0.304 | 0.253 | 0.841 | 1.094 |
| | NW | 3.389 | 6.315 | 321.40 | 4.15 | 0.023 | 0.378 | 0.626 | 1.003 |
| | NNW | 3.256 | 6.282 | 333.29 | 4.15 | 0.024 | 0.401 | 0.663 | 1.064 |
| 08 | N | 2.189 | 5.748 | 350.75 | 4.16 | 0.022 | 0.273 | 0.452 | 0.725 |
| | NNE | 1.690 | 4.895 | 19.70 | 4.16 | 0.024 | 0.237 | 0.392 | 0.628 |
| | NE | 1.691 | 5.135 | 57.62 | 4.16 | 0.024 | 0.237 | 0.392 | 0.629 |
| | ENE | 2.386 | 6.149 | 78.56 | 4.16 | 0.023 | 0.301 | 0.500 | 0.801 |
| | E | 4.459 | 6.411 | 90.79 | 4.16 | 0.030 | 0.485 | 0.807 | 1.292 |
| | ESE | 3.055 | 6.308 | 99.38 | 4.16 | 0.023 | 0.302 | 0.500 | 0.802 |
| | SE | 2.960 | 6.432 | 105.56 | 4.16 | 0.021 | 0.260 | 0.432 | 0.692 |
| | NW | 3.530 | 6.320 | 319.03 | 4.16 | 0.022 | 0.278 | 0.460 | 0.738 |
| | NNW | 3.306 | 6.283 | 331.18 | 4.16 | 0.024 | 0.338 | 0.560 | 0.897 |
| 09 | N | 2.192 | 5.755 | 351.17 | 4.17 | 0.079 | 0.396 | 0.704 | 1.100 |
| | NNE | 1.699 | 4.914 | 19.91 | 4.17 | 0.096 | 0.310 | 0.565 | 0.876 |
| | NE | 1.694 | 5.149 | 57.02 | 4.17 | 0.118 | 0.268 | 0.522 | 0.791 |
| | ENE | 2.355 | 6.144 | 76.86 | 4.17 | 0.120 | 0.268 | 0.548 | 0.817 |
| | E | 4.304 | 6.391 | 88.41 | 4.17 | 0.213 | 0.233 | 0.640 | 0.873 |
| | ESE | 2.895 | 6.280 | 96.25 | 4.17 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.756 | 6.378 | 102.43 | 4.17 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.467 | 6.310 | 320.34 | 4.17 | 0.069 | 0.529 | 0.920 | 1.448 |
| | NNW | 3.273 | 6.277 | 332.15 | 4.17 | 0.069 | 0.529 | 0.920 | 1.449 |
| 10 | N | 2.197 | 5.771 | 350.51 | 4.14 | 0.198 | 0.474 | 1.042 | 1.517 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NNE | 1.700 | 4.907 | 19.99 | 4.14 | 0.278 | 0.387 | 0.967 | 1.354 |
| | NE | 1.697 | 5.151 | 57.40 | 4.14 | 0.401 | 0.357 | 1.149 | 1.506 |
| | ENE | 2.372 | 6.146 | 77.34 | 4.14 | 0.353 | 0.369 | 1.197 | 1.566 |
| | E | 4.391 | 6.401 | 89.48 | 4.14 | 0.321 | 0.379 | 1.173 | 1.551 |
| | ESE | 2.951 | 6.288 | 97.46 | 4.14 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.797 | 6.403 | 102.75 | 4.14 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.545 | 6.316 | 320.19 | 4.14 | 0.158 | 0.618 | 1.240 | 1.858 |
| | NNW | 3.326 | 6.282 | 331.44 | 4.14 | 0.157 | 0.620 | 1.242 | 1.862 |
| 11 | N | 2.207 | 5.788 | 349.14 | 4.17 | 0.708 | 0.573 | 2.569 | 3.141 |
| | NNE | 1.694 | 4.886 | 19.85 | 4.17 | 0.794 | 0.480 | 2.228 | 2.708 |
| | NE | 1.689 | 5.139 | 57.83 | 4.17 | 0.823 | 0.466 | 2.321 | 2.786 |
| | ENE | 2.379 | 6.138 | 78.16 | 4.17 | 0.719 | 0.566 | 2.681 | 3.247 |
| | E | 4.475 | 6.407 | 91.16 | 4.17 | 0.594 | 0.799 | 3.025 | 3.825 |
| | ESE | 3.050 | 6.303 | 100.77 | 4.17 | 0.781 | 0.510 | 2.715 | 3.225 |
| | SE | 2.962 | 6.434 | 107.59 | 4.17 | 0.959 | 0.415 | 2.841 | 3.256 |
| | NW | 3.686 | 6.333 | 319.14 | 4.17 | 0.653 | 0.668 | 2.843 | 3.511 |
| | NNW | 3.432 | 6.296 | 329.67 | 4.17 | 0.629 | 0.717 | 2.892 | 3.609 |
| 12 | N | 2.213 | 5.810 | 349.30 | 4.15 | 0.081 | 0.400 | 0.714 | 1.114 |
| | NNE | 1.704 | 4.903 | 20.16 | 4.15 | 0.084 | 0.305 | 0.545 | 0.851 |
| | NE | 1.697 | 5.155 | 57.64 | 4.15 | 0.087 | 0.261 | 0.478 | 0.739 |
| | ENE | 2.370 | 6.138 | 77.24 | 4.15 | 0.086 | 0.277 | 0.517 | 0.794 |
| | E | 4.414 | 6.399 | 90.20 | 4.15 | 0.087 | 0.270 | 0.510 | 0.780 |
| | ESE | 2.948 | 6.279 | 99.30 | 4.15 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 2.819 | 6.381 | 106.21 | 4.15 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 3.659 | 6.327 | 320.30 | 4.15 | 0.079 | 0.553 | 0.976 | 1.529 |
| | NNW | 3.425 | 6.292 | 330.28 | 4.15 | 0.079 | 0.551 | 0.973 | 1.524 |
| 13 | N | 2.216 | 5.831 | 349.30 | 4.16 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 1.711 | 4.912 | 20.44 | 4.16 | 0.272 | 0.304 | 0.793 | 1.097 |
| | NE | 1.699 | 5.166 | 57.33 | 4.16 | 0.211 | 0.368 | 0.834 | 1.202 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | ENE | 2.349 | 6.126 | 76.31 | 4.16 | 0.169 | 0.502 | 1.051 | 1.553 |
| | E | 4.362 | 6.388 | 89.92 | 4.16 | 0.123 | 0.783 | 1.474 | 2.256 |
| | ESE | 2.887 | 6.266 | 100.15 | 4.16 | 0.158 | 0.577 | 1.165 | 1.741 |
| | SE | 2.781 | 6.350 | 108.94 | 4.16 | 0.161 | 0.551 | 1.132 | 1.684 |
| | NW | 3.609 | 6.324 | 321.56 | 4.16 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 3.409 | 6.291 | 330.76 | 4.16 | 0.000 | 0.000 | 0.000 | 0.000 |
| 14 | N | 2.224 | 5.829 | 348.16 | 4.17 | 0.161 | 0.367 | 0.780 | 1.147 |
| | NNE | 1.701 | 4.890 | 20.20 | 4.17 | 0.170 | 0.342 | 0.709 | 1.051 |
| | NE | 1.690 | 5.151 | 57.58 | 4.17 | 0.164 | 0.355 | 0.736 | 1.091 |
| | ENE | 2.361 | 6.124 | 77.11 | 4.17 | 0.138 | 0.458 | 0.910 | 1.368 |
| | E | 4.435 | 6.395 | 90.78 | 4.17 | 0.117 | 0.701 | 1.295 | 1.995 |
| | ESE | 3.001 | 6.287 | 102.20 | 4.17 | 0.135 | 0.475 | 0.941 | 1.416 |
| | SE | 2.956 | 6.410 | 112.30 | 4.17 | 0.145 | 0.422 | 0.872 | 1.294 |
| | NW | 3.745 | 6.337 | 319.32 | 4.17 | 0.249 | 0.254 | 0.744 | 0.998 |
| | NNW | 3.491 | 6.301 | 328.89 | 4.17 | 0.156 | 0.382 | 0.817 | 1.199 |
| 15 | N | 2.219 | 5.849 | 348.97 | 4.16 | 0.473 | 0.359 | 1.396 | 1.755 |
| | NNE | 1.713 | 4.914 | 20.55 | 4.16 | 0.379 | 0.378 | 1.128 | 1.506 |
| | NE | 1.696 | 5.167 | 56.94 | 4.16 | 0.321 | 0.410 | 1.116 | 1.526 |
| | ENE | 2.332 | 6.114 | 75.35 | 4.16 | 0.240 | 0.530 | 1.263 | 1.793 |
| | E | 4.326 | 6.383 | 89.44 | 4.16 | 0.186 | 0.815 | 1.663 | 2.477 |
| | ESE | 2.864 | 6.266 | 100.76 | 4.16 | 0.225 | 0.575 | 1.324 | 1.899 |
| | SE | 2.812 | 6.359 | 112.29 | 4.16 | 0.239 | 0.535 | 1.290 | 1.825 |
| | NW | 3.610 | 6.328 | 322.08 | 4.16 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 3.418 | 6.294 | 330.69 | 4.16 | 0.000 | 0.000 | 0.000 | 0.000 |
| 16 | N | 2.005 | 5.772 | 358.69 | 4.18 | 0.163 | 0.308 | 0.674 | 0.982 |
| | NNE | 1.697 | 4.945 | 23.43 | 4.18 | 0.163 | 0.319 | 0.662 | 0.982 |
| | NE | 1.707 | 5.190 | 56.16 | 4.18 | 0.164 | 0.361 | 0.748 | 1.108 |
| | ENE | 2.313 | 6.115 | 72.39 | 4.18 | 0.168 | 0.493 | 1.031 | 1.524 |
| | E | 4.186 | 6.382 | 84.70 | 4.18 | 0.115 | 0.734 | 1.346 | 2.080 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | ESE | 2.640 | 6.241 | 96.30 | 4.18 | 0.168 | 0.523 | 1.092 | 1.614 |
| | SE | 2.526 | 6.275 | 110.01 | 4.18 | 0.168 | 0.469 | 0.996 | 1.465 |
| | NW | 2.543 | 6.302 | 337.70 | 4.18 | 0.260 | 0.202 | 0.643 | 0.845 |
| | NNW | 2.722 | 6.266 | 344.19 | 4.18 | 0.163 | 0.289 | 0.658 | 0.946 |
| 17 | N | 1.960 | 5.727 | 1.16 | 4.18 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 1.699 | 4.986 | 24.57 | 4.18 | 0.386 | 0.235 | 0.818 | 1.054 |
| | NE | 1.706 | 5.202 | 55.29 | 4.18 | 0.301 | 0.358 | 0.973 | 1.331 |
| | ENE | 2.259 | 6.111 | 70.00 | 4.18 | 0.287 | 0.512 | 1.344 | 1.855 |
| | E | 4.039 | 6.385 | 83.38 | 4.18 | 0.229 | 0.825 | 1.809 | 2.634 |
| | ESE | 2.403 | 6.218 | 95.77 | 4.18 | 0.283 | 0.569 | 1.461 | 2.030 |
| | SE | 2.273 | 4.794 | 113.49 | 4.18 | 0.284 | 0.488 | 1.162 | 1.650 |
| | NW | 2.431 | 6.286 | 338.43 | 4.18 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.589 | 6.252 | 346.76 | 4.18 | 0.000 | 0.000 | 0.000 | 0.000 |
| 18a | N | 1.736 | 5.617 | 10.99 | 4.2 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 1.621 | 4.979 | 30.40 | 4.2 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NE | 1.693 | 5.209 | 55.27 | 4.2 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ENE | 2.222 | 6.102 | 67.83 | 4.2 | 0.000 | 0.000 | 0.000 | 0.000 |
| | E | 3.858 | 6.386 | 79.65 | 4.2 | 0.281 | 0.298 | 0.904 | 1.202 |
| | ESE | 2.205 | 6.196 | 89.92 | 4.2 | 0.283 | 0.310 | 0.921 | 1.230 |
| | SE | 1.975 | 4.704 | 106.26 | 4.2 | 0.297 | 0.343 | 0.892 | 1.236 |
| | NW | 1.912 | 6.319 | 342.05 | 4.2 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.111 | 6.254 | 355.66 | 4.2 | 0.000 | 0.000 | 0.000 | 0.000 |
| 18b | N | 1.748 | 5.628 | 10.35 | 4.19 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 1.626 | 4.965 | 29.85 | 4.19 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NE | 1.695 | 5.207 | 55.53 | 4.19 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ENE | 2.230 | 6.103 | 68.59 | 4.19 | 0.000 | 0.000 | 0.000 | 0.000 |
| | E | 3.868 | 6.374 | 81.21 | 4.19 | 0.296 | 0.343 | 1.036 | 1.379 |
| | ESE | 2.260 | 6.195 | 92.24 | 4.19 | 0.294 | 0.337 | 1.004 | 1.341 |
| | SE | 2.079 | 4.757 | 109.10 | 4.19 | 0.307 | 0.373 | 0.975 | 1.349 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NW | 1.922 | 6.314 | 344.18 | 4.19 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.131 | 6.254 | 355.99 | 4.19 | 0.000 | 0.000 | 0.000 | 0.000 |
| 19 | N | 0.781 | 2.430 | 26.07 | 4.21 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNE | 0.887 | 5.114 | 56.77 | 4.21 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NE | 1.127 | 5.253 | 70.92 | 4.21 | 0.081 | 0.092 | 0.184 | 0.276 |
| | ENE | 1.568 | 6.067 | 73.05 | 4.21 | 0.097 | 0.149 | 0.306 | 0.455 |
| | E | 2.947 | 6.332 | 77.43 | 4.21 | 0.013 | 0.200 | 0.330 | 0.530 |
| | ESE | 1.735 | 6.154 | 86.74 | 4.21 | 0.091 | 0.238 | 0.255 | 0.493 |
| | SE | 1.534 | 3.142 | 108.86 | 4.21 | 0.089 | 0.212 | 0.224 | 0.437 |
| | NW | 0.894 | 2.782 | 308.45 | 4.21 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 0.850 | 2.625 | 340.29 | 4.21 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20 | N | 0.781 | 2.430 | 26.07 | 4.22 | 0.027 | 0.074 | 0.123 | 0.198 |
| | NNE | 0.887 | 5.114 | 56.77 | 4.22 | 0.044 | 0.154 | 0.265 | 0.419 |
| | NE | 1.127 | 5.253 | 70.92 | 4.22 | 0.052 | 0.204 | 0.353 | 0.557 |
| | ENE | 1.568 | 6.067 | 73.05 | 4.22 | 0.046 | 0.275 | 0.472 | 0.747 |
| | E | 2.947 | 6.332 | 77.43 | 4.22 | 0.043 | 0.460 | 0.775 | 1.234 |
| | ESE | 1.735 | 6.154 | 86.74 | 4.22 | 0.043 | 0.300 | 0.510 | 0.810 |
| | SE | 1.534 | 3.142 | 108.86 | 4.22 | 0.054 | 0.213 | 0.359 | 0.573 |
| | NW | 0.894 | 2.782 | 308.45 | 4.22 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 0.850 | 2.625 | 340.29 | 4.22 | 0.000 | 0.000 | 0.000 | 0.000 |
| 21 | N | 0.781 | 2.430 | 26.07 | 4.21 | 0.363 | 0.165 | 0.418 | 0.584 |
| | NNE | 0.887 | 5.114 | 56.77 | 4.21 | 0.287 | 0.236 | 0.687 | 0.923 |
| | NE | 1.127 | 5.253 | 70.92 | 4.21 | 0.225 | 0.266 | 0.666 | 0.932 |
| | ENE | 1.568 | 6.067 | 73.05 | 4.21 | 0.066 | 0.285 | 0.507 | 0.792 |
| | E | 2.947 | 6.332 | 77.43 | 4.21 | 0.048 | 0.444 | 0.755 | 1.200 |
| | ESE | 1.735 | 6.154 | 86.74 | 4.21 | 0.062 | 0.287 | 0.508 | 0.795 |
| | SE | 1.534 | 3.142 | 108.86 | 4.21 | 0.298 | 0.222 | 0.535 | 0.757 |
| | NW | 0.894 | 2.782 | 308.45 | 4.21 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 0.850 | 2.625 | 340.29 | 4.21 | 0.339 | 0.136 | 0.359 | 0.495 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| 22 | N | 0.813 | 4.842 | 27.64 | 4.20 | 1.201 | 0.283 | 2.188 | 2.471 |
| | NNE | 0.941 | 5.085 | 56.64 | 4.20 | 1.206 | 0.283 | 2.274 | 2.557 |
| | NE | 1.229 | 5.263 | 71.68 | 4.20 | 1.218 | 0.303 | 2.459 | 2.763 |
| | ENE | 1.731 | 6.083 | 75.34 | 4.20 | 0.688 | 0.357 | 1.895 | 2.253 |
| | E | 3.179 | 6.348 | 79.40 | 4.20 | 0.570 | 0.530 | 2.199 | 2.729 |
| | ESE | 1.891 | 6.167 | 86.40 | 4.20 | 1.244 | 0.332 | 2.970 | 3.302 |
| | SE | 1.665 | 6.139 | 103.33 | 4.20 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 0.932 | 2.839 | 303.48 | 4.20 | 1.053 | 0.187 | 1.031 | 1.218 |
| | NNW | 0.893 | 2.635 | 337.91 | 4.20 | 1.115 | 0.230 | 1.177 | 1.407 |
| 23 | N | 1.497 | 5.476 | 20.22 | 4.20 | 0.498 | 0.415 | 1.538 | 1.954 |
| | NNE | 1.509 | 4.962 | 37.36 | 4.20 | 0.558 | 0.403 | 1.538 | 1.940 |
| | NE | 1.661 | 5.215 | 56.83 | 4.20 | 0.527 | 0.409 | 1.536 | 1.945 |
| | ENE | 2.194 | 6.095 | 67.39 | 4.20 | 0.356 | 0.470 | 1.429 | 1.899 |
| | E | 3.770 | 6.378 | 77.95 | 4.20 | 0.216 | 0.607 | 1.368 | 1.975 |
| | ESE | 2.125 | 6.186 | 86.38 | 4.20 | 0.601 | 0.408 | 1.884 | 2.292 |
| | SE | 1.833 | 6.188 | 99.57 | 4.20 | 4.733 | 0.375 | 10.194 | 10.569 |
| | NW | 1.552 | 6.377 | 340.12 | 4.20 | 0.514 | 0.419 | 1.740 | 2.159 |
| | NNW | 1.690 | 6.268 | 2.98 | 4.20 | 0.388 | 0.454 | 1.494 | 1.948 |
| 24 | N | 1.975 | 5.746 | 1.78 | 4.18 | 0.105 | 0.378 | 0.708 | 1.086 |
| | NNE | 1.706 | 5.026 | 24.72 | 4.18 | 0.106 | 0.327 | 0.607 | 0.934 |
| | NE | 1.699 | 5.205 | 54.03 | 4.18 | 0.106 | 0.314 | 0.588 | 0.902 |
| | ENE | 2.211 | 6.096 | 67.28 | 4.18 | 0.105 | 0.386 | 0.729 | 1.115 |
| | E | 3.872 | 6.387 | 80.03 | 4.18 | 0.068 | 0.512 | 0.893 | 1.406 |
| | ESE | 2.231 | 6.196 | 93.68 | 4.18 | 0.108 | 0.291 | 0.571 | 0.862 |
| | SE | 2.062 | 4.556 | 114.65 | 4.18 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 2.535 | 6.306 | 338.13 | 4.18 | 0.105 | 0.432 | 0.813 | 1.245 |
| | NNW | 2.690 | 6.264 | 347.29 | 4.18 | 0.102 | 0.473 | 0.877 | 1.350 |
| 25 | N | 2.072 | 5.793 | 358.08 | 4.19 | 0.409 | 0.221 | 0.892 | 1.112 |
| | NNE | 1.707 | 5.065 | 21.41 | 4.19 | 0.051 | 0.217 | 0.374 | 0.591 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NE | 1.560 | 5.140 | 45.38 | 4.19 | 0.054 | 0.248 | 0.428 | 0.676 |
| | ENE | 1.910 | 5.943 | 57.29 | 4.19 | 0.062 | 0.333 | 0.582 | 0.915 |
| | E | 3.162 | 6.317 | 75.18 | 4.19 | 0.079 | 0.552 | 0.973 | 1.525 |
| | ESE | 1.718 | 4.038 | 101.96 | 4.19 | 0.055 | 0.259 | 0.440 | 0.699 |
| | SE | 1.772 | 4.317 | 137.55 | 4.19 | 0.051 | 0.222 | 0.379 | 0.601 |
| | NW | 2.723 | 6.287 | 337.59 | 4.19 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.826 | 6.255 | 343.79 | 4.19 | 0.000 | 0.000 | 0.000 | 0.000 |
| 26 | N | 1.832 | 5.643 | 6.54 | 4.18 | 0.117 | 0.259 | 0.515 | 0.774 |
| 26 | NNE | 1.592 | 5.048 | 21.40 | 4.18 | 0.111 | 0.262 | 0.502 | 0.763 |
| 26 | NE | 1.434 | 5.065 | 38.83 | 4.18 | 0.104 | 0.265 | 0.501 | 0.767 |
| 26 | ENE | 1.679 | 5.684 | 51.37 | 4.18 | 0.073 | 0.306 | 0.546 | 0.853 |
| 26 | E | 2.684 | 6.222 | 76.06 | 4.18 | 0.053 | 0.445 | 0.761 | 1.206 |
| 26 | ESE | 1.519 | 3.937 | 109.32 | 4.18 | 0.116 | 0.256 | 0.473 | 0.729 |
| 26 | SE | 1.671 | 4.209 | 135.42 | 4.18 | 0.117 | 0.231 | 0.437 | 0.667 |
| 26 | NW | 2.074 | 6.281 | 349.72 | 4.18 | 0.114 | 0.178 | 0.382 | 0.561 |
| 26 | NNW | 2.271 | 6.237 | 354.75 | 4.18 | 0.117 | 0.243 | 0.501 | 0.744 |
| 27 | N | 1.916 | 5.733 | 0.99 | 4.18 | 0.000 | 0.000 | 0.000 | 0.000 |
| 27 | NNE | 1.526 | 5.074 | 12.69 | 4.18 | 0.419 | 0.130 | 0.579 | 0.710 |
| 27 | NE | 1.232 | 4.814 | 28.92 | 4.18 | 0.426 | 0.215 | 0.560 | 0.775 |
| 27 | ENE | 1.355 | 5.165 | 44.88 | 4.18 | 0.145 | 0.239 | 0.503 | 0.741 |
| 27 | E | 2.214 | 4.356 | 80.20 | 4.18 | 0.132 | 0.390 | 0.727 | 1.117 |
| 27 | ESE | 1.335 | 3.836 | 116.21 | 4.18 | 0.143 | 0.252 | 0.488 | 0.740 |
| 27 | SE | 1.564 | 4.016 | 136.92 | 4.18 | 0.109 | 0.258 | 0.473 | 0.732 |
| 27 | NW | 2.364 | 6.288 | 344.71 | 4.18 | 0.000 | 0.000 | 0.000 | 0.000 |
| 27 | NNW | 2.540 | 6.252 | 350.93 | 4.18 | 0.000 | 0.000 | 0.000 | 0.000 |
| 28 | N | 0.884 | 5.089 | 17.90 | 4.21 | 0.055 | 0.149 | 0.262 | 0.411 |
| 28 | NNE | 0.845 | 4.929 | 38.59 | 4.21 | 0.054 | 0.156 | 0.274 | 0.429 |
| 28 | NE | 0.894 | 4.984 | 49.04 | 4.21 | 0.057 | 0.170 | 0.298 | 0.468 |
| 28 | ENE | 1.121 | 3.837 | 60.22 | 4.21 | 0.061 | 0.188 | 0.324 | 0.512 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | E | 2.053 | 4.379 | 83.32 | 4.21 | 0.050 | 0.303 | 0.511 | 0.814 |
| | ESE | 1.257 | 3.497 | 113.95 | 4.21 | 0.057 | 0.167 | 0.285 | 0.452 |
| | SE | 1.449 | 3.839 | 133.73 | 4.21 | 0.056 | 0.151 | 0.260 | 0.412 |
| | NW | 1.086 | 3.143 | 315.98 | 4.21 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 1.054 | 3.037 | 339.39 | 4.21 | 0.029 | 0.056 | 0.094 | 0.151 |
| 29 | N | 1.624 | 5.591 | 7.64 | 4.22 | 0.013 | 0.175 | 0.288 | 0.464 |
| | NNE | 1.371 | 5.050 | 16.38 | 4.22 | 0.012 | 0.156 | 0.256 | 0.411 |
| | NE | 1.138 | 4.728 | 26.20 | 4.22 | 0.011 | 0.135 | 0.221 | 0.356 |
| | ENE | 1.211 | 3.929 | 37.61 | 4.22 | 0.011 | 0.138 | 0.227 | 0.366 |
| | E | 1.861 | 4.002 | 72.44 | 4.22 | 0.012 | 0.207 | 0.340 | 0.547 |
| | ESE | 1.062 | 3.193 | 122.50 | 4.22 | 0.007 | 0.085 | 0.140 | 0.225 |
| | SE | 1.303 | 3.647 | 146.79 | 4.22 | 0.005 | 0.052 | 0.085 | 0.137 |
| | NW | 1.820 | 6.278 | 341.91 | 4.22 | 0.009 | 0.112 | 0.184 | 0.296 |
| | NNW | 1.966 | 6.214 | 355.56 | 4.22 | 0.013 | 0.184 | 0.302 | 0.486 |
| 30 | N | 1.645 | 5.644 | 3.68 | 4.17 | 0.003 | 0.163 | 0.266 | 0.429 |
| | NNE | 1.316 | 5.036 | 11.22 | 4.17 | 0.003 | 0.131 | 0.214 | 0.345 |
| | NE | 1.038 | 4.641 | 20.60 | 4.17 | 0.007 | 0.120 | 0.196 | 0.316 |
| | ENE | 1.070 | 3.785 | 33.38 | 4.17 | 0.006 | 0.107 | 0.176 | 0.283 |
| | E | 1.588 | 3.414 | 78.76 | 4.17 | 0.010 | 0.091 | 0.149 | 0.240 |
| | ESE | 0.965 | 3.093 | 130.41 | 4.17 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 1.229 | 3.520 | 149.32 | 4.17 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 1.955 | 6.281 | 342.35 | 4.17 | 0.003 | 0.193 | 0.316 | 0.509 |
| | NNW | 2.094 | 6.230 | 353.66 | 4.17 | 0.003 | 0.208 | 0.340 | 0.547 |
| 31 | N | 1.421 | 5.781 | 354.14 | 4.14 | 0.074 | 0.248 | 0.449 | 0.697 |
| | NNE | 0.982 | 5.079 | 357.28 | 4.14 | 0.059 | 0.162 | 0.288 | 0.450 |
| | NE | 0.680 | 4.337 | 8.82 | 4.14 | 0.456 | 0.146 | 0.162 | 0.309 |
| | ENE | 0.684 | 2.198 | 39.43 | 4.14 | 0.000 | 0.000 | 0.000 | 0.000 |
| | E | 1.131 | 2.936 | 101.60 | 4.14 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ESE | 0.830 | 2.881 | 134.53 | 4.14 | 0.000 | 0.000 | 0.000 | 0.000 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | SE | 1.087 | 3.308 | 150.65 | 4.14 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 2.008 | 6.275 | 343.04 | 4.14 | 0.084 | 0.376 | 0.685 | 1.061 |
| | NNW | 2.062 | 6.241 | 351.00 | 4.14 | 0.084 | 0.368 | 0.671 | 1.039 |
| 32 | N | 1.898 | 5.753 | 359.04 | 4.17 | 0.205 | 0.322 | 0.770 | 1.092 |
| | NNE | 1.461 | 5.079 | 8.62 | 4.17 | 2.977 | 0.362 | 3.390 | 3.752 |
| | NE | 1.112 | 4.697 | 23.17 | 4.17 | 3.177 | 0.153 | 3.344 | 3.498 |
| | ENE | 1.159 | 3.691 | 38.14 | 4.17 | 0.000 | 0.000 | 0.000 | 0.000 |
| | E | 1.816 | 4.051 | 73.14 | 4.17 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ESE | 1.077 | 3.283 | 114.14 | 4.17 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 1.304 | 3.650 | 143.57 | 4.17 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 2.433 | 6.292 | 341.71 | 4.17 | 0.111 | 0.424 | 0.808 | 1.233 |
| | NNW | 2.583 | 6.255 | 349.61 | 4.17 | 0.110 | 0.418 | 0.797 | 1.215 |
| 33 | N | 1.948 | 5.921 | 348.92 | 4.18 | 0.600 | 0.290 | 1.456 | 1.746 |
| | NNE | 1.328 | 5.109 | 356.94 | 4.18 | 0.640 | 0.251 | 1.261 | 1.513 |
| | NE | 0.894 | 4.419 | 12.71 | 4.18 | 0.699 | 0.219 | 1.119 | 1.338 |
| | ENE | 0.918 | 3.059 | 45.09 | 4.18 | 0.663 | 0.230 | 0.875 | 1.105 |
| | E | 1.820 | 4.214 | 105.91 | 4.18 | 0.386 | 0.382 | 1.063 | 1.445 |
| | ESE | 1.240 | 3.789 | 127.96 | 4.18 | 0.639 | 0.249 | 1.029 | 1.278 |
| | SE | 1.447 | 3.970 | 136.49 | 4.18 | 0.635 | 0.253 | 1.066 | 1.319 |
| | NW | 2.856 | 6.324 | 337.58 | 4.18 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NNW | 2.925 | 6.278 | 342.81 | 4.18 | 0.589 | 0.302 | 1.532 | 1.834 |
| 34 | N | 1.894 | 5.920 | 348.66 | 4.17 | 0.374 | 0.281 | 1.003 | 1.284 |
| | NNE | 1.289 | 5.114 | 354.31 | 4.17 | 0.399 | 0.225 | 0.823 | 1.048 |
| | NE | 0.865 | 4.336 | 11.09 | 4.17 | 0.432 | 0.195 | 0.712 | 0.906 |
| | ENE | 0.886 | 3.014 | 55.81 | 4.17 | 0.419 | 0.207 | 0.596 | 0.803 |
| | E | 1.874 | 4.403 | 108.63 | 4.17 | 0.354 | 0.379 | 1.028 | 1.406 |
| | ESE | 1.266 | 3.827 | 120.96 | 4.17 | 0.382 | 0.240 | 0.711 | 0.951 |
| | SE | 1.430 | 3.950 | 127.74 | 4.17 | 0.378 | 0.247 | 0.734 | 0.981 |
| | NW | 2.695 | 6.323 | 341.32 | 4.17 | 0.373 | 0.285 | 1.050 | 1.335 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NNW | 2.829 | 6.278 | 344.33 | 4.17 | 0.356 | 0.340 | 1.149 | 1.488 |
| 35 | N | 1.656 | 6.010 | 337.47 | 4.17 | 0.123 | 0.256 | 0.520 | 0.776 |
| | NNE | 1.022 | 5.184 | 346.47 | 4.17 | 0.483 | 0.240 | 0.297 | 0.537 |
| | NE | 0.657 | 2.421 | 28.54 | 4.17 | 0.587 | 0.159 | 0.193 | 0.352 |
| | ENE | 0.757 | 2.986 | 85.90 | 4.17 | 0.578 | 0.173 | 0.208 | 0.381 |
| | E | 1.834 | 4.328 | 99.08 | 4.17 | 0.124 | 0.269 | 0.511 | 0.780 |
| | ESE | 1.183 | 3.641 | 105.86 | 4.17 | 0.509 | 0.215 | 0.262 | 0.477 |
| | SE | 1.262 | 3.652 | 116.06 | 4.17 | 0.556 | 0.190 | 0.225 | 0.415 |
| | NW | 2.743 | 6.344 | 334.53 | 4.17 | 0.112 | 0.369 | 0.702 | 1.071 |
| | NNW | 2.695 | 6.299 | 336.13 | 4.17 | 0.113 | 0.373 | 0.707 | 1.080 |
| 36 | N | 1.456 | 6.015 | 334.69 | 4.17 | 0.050 | 0.253 | 0.439 | 0.692 |
| | NNE | 0.884 | 5.297 | 350.74 | 4.17 | 0.039 | 0.160 | 0.274 | 0.435 |
| | NE | 0.594 | 2.404 | 43.37 | 4.17 | 0.024 | 0.071 | 0.118 | 0.189 |
| | ENE | 0.738 | 2.901 | 77.29 | 4.17 | 0.021 | 0.060 | 0.099 | 0.159 |
| | E | 1.693 | 4.119 | 84.55 | 4.17 | 0.033 | 0.116 | 0.196 | 0.312 |
| | ESE | 1.048 | 3.431 | 91.84 | 4.17 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 1.057 | 3.404 | 104.03 | 4.17 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 2.425 | 6.322 | 329.87 | 4.17 | 0.060 | 0.398 | 0.692 | 1.090 |
| | NNW | 2.318 | 6.287 | 331.74 | 4.17 | 0.059 | 0.385 | 0.668 | 1.053 |
| 37 | N | 0.859 | 3.101 | 328.57 | 4.17 | 0.658 | 0.180 | 0.743 | 0.924 |
| | NNE | 0.549 | 2.191 | 9.28 | 4.17 | 0.689 | 0.136 | 0.510 | 0.646 |
| | NE | 0.472 | 2.254 | 60.50 | 4.17 | 0.698 | 0.115 | 0.467 | 0.582 |
| | ENE | 0.683 | 2.785 | 80.52 | 4.17 | 0.688 | 0.146 | 0.622 | 0.768 |
| | E | 1.616 | 3.961 | 88.83 | 4.17 | 0.308 | 0.260 | 0.679 | 0.939 |
| | ESE | 0.999 | 3.296 | 96.16 | 4.17 | 0.675 | 0.169 | 0.754 | 0.923 |
| | SE | 1.031 | 3.241 | 110.61 | 4.17 | 0.704 | 0.097 | 0.531 | 0.628 |
| | NW | 1.587 | 4.082 | 309.93 | 4.17 | 0.440 | 0.224 | 0.768 | 0.992 |
| | NNW | 1.375 | 3.875 | 315.21 | 3.49 | 0.000 | 0.000 | 0.000 | 0.000 |
| 38 | N | 1.837 | 5.955 | 344.79 | 4.17 | 0.032 | 0.181 | 0.306 | 0.487 |

| Transect | Wind sector | Hm0 (m) | Tp (s) | MWD (°N) | SWL (m CGVD2013) | Slope (-) | Static setup (m) | Wave Runup (m) | Wave effect (m) |
|---|---|---|---|---|---|---|---|---|---|
| | NNE | 1.215 | 5.125 | 350.89 | 4.17 | 0.025 | 0.131 | 0.219 | 0.349 |
| | NE | 0.784 | 3.077 | 13.12 | 4.17 | 0.019 | 0.090 | 0.148 | 0.238 |
| | ENE | 0.812 | 2.970 | 75.55 | 4.17 | 0.021 | 0.104 | 0.172 | 0.276 |
| | E | 1.879 | 4.394 | 105.91 | 4.17 | 0.040 | 0.239 | 0.401 | 0.640 |
| | ESE | 1.247 | 3.730 | 113.52 | 4.17 | 0.027 | 0.139 | 0.230 | 0.369 |
| | SE | 1.368 | 3.838 | 121.12 | 4.17 | 0.026 | 0.138 | 0.230 | 0.368 |
| | NW | 2.745 | 6.324 | 339.71 | 4.17 | 0.039 | 0.230 | 0.393 | 0.624 |
| | NNW | 2.826 | 6.281 | 342.17 | 4.17 | 0.042 | 0.258 | 0.441 | 0.698 |
| 39 | N | 0.887 | 3.182 | 341.99 | 4.14 | 0.002 | 0.074 | 0.122 | 0.196 |
| | NNE | 0.637 | 2.739 | 349.13 | 4.14 | 0.002 | 0.053 | 0.086 | 0.139 |
| | NE | 0.470 | 2.206 | 9.68 | 4.14 | 0.002 | 0.036 | 0.060 | 0.096 |
| | ENE | 0.471 | 1.957 | 57.45 | 4.14 | 0.004 | 0.026 | 0.042 | 0.068 |
| | E | 0.998 | 2.703 | 103.82 | 4.14 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ESE | 0.761 | 2.725 | 133.85 | 4.14 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 0.987 | 3.040 | 147.81 | 4.14 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 1.334 | 3.907 | 326.58 | 4.14 | 0.002 | 0.112 | 0.184 | 0.296 |
| | NNW | 1.251 | 3.750 | 336.42 | 4.14 | 0.002 | 0.105 | 0.172 | 0.277 |
| 40 | N | 1.551 | 5.602 | 5.74 | 4.23 | 0.004 | 0.163 | 0.266 | 0.429 |
| | NNE | 1.274 | 5.030 | 13.54 | 4.23 | 0.004 | 0.136 | 0.222 | 0.358 |
| | NE | 1.040 | 4.659 | 22.36 | 4.23 | 0.681 | 0.309 | 1.429 | 1.738 |
| | ENE | 1.090 | 3.797 | 35.34 | 4.23 | 0.697 | 0.292 | 1.224 | 1.516 |
| | E | 1.645 | 3.474 | 79.91 | 4.23 | 0.695 | 0.294 | 1.163 | 1.457 |
| | ESE | 1.001 | 3.149 | 128.20 | 4.23 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SE | 1.254 | 3.566 | 145.60 | 4.23 | 0.000 | 0.000 | 0.000 | 0.000 |
| | NW | 1.773 | 6.290 | 341.81 | 4.23 | 0.004 | 0.182 | 0.298 | 0.480 |
| | NNW | 1.908 | 6.221 | 354.87 | 4.23 | 0.004 | 0.195 | 0.318 | 0.513 |

# Appendix D - FCL Mapping: Year 2018

# Appendix E - FCL Mapping: Year 2050

# Appendix F - FCL Mapping: Year 2100