PORT of vancouver | Vancouver Fraser Port Authority

Guidelines

Shoreline protection (Fraser River), inspection, maintenance, design and repair

Version 1

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Canada

Executive Summary

As of 2019 there are approximately 26 sites on the Fraser River between George Massey Tunnel and Port Mann Bridge within the jurisdictional area of the Vancouver Fraser Port Authority (VFPA). Many of these sites are protected by revetments of various designs and age.

It is not uncommon for older portions of the shoreline to be protected with an ad-hoc mixture of construction debris. Inspections of the existing shorelines have found a wide variance in the quality of the shoreline protection, with older portions, in particular, showing evidence of damage or deterioration.

In most cases, VFPA is the direct owner of many of these structures; however, depending upon the terms of the specific lease for individual terminals, the property tenant may be responsible for the maintenance, repair, or decommissioning of the existing shoreline protection.

This document is intended for use by VFPA staff, VFPA tenants, and as a default reference for design professionals providing shoreline related services to VFPA or their tenants for the specific purpose of inspecting, maintaining, and designing repairs or replacement of these VFPA assets.

The document is not intended to supersede or replace the judgement of the Design Engineer or Professionals, or to supersede related standards of practice. The responsibility for shoreline design always remains with the Design Engineer of record for any project.

The document is intended to provide practical guidance and standards of practice for the following routine activities:

a) Inspection of existing shoreline assets.

b) Evaluation and development of maintenance, repair, or replacement activities.

c) Definition of design criteria for repair or replacement projects.

d) General or best practise design guidance.

e) Incorporation of general environmental best practices.

f) Guidance for planning of implementation (construction) activities.

It is generally recognized that as the result of ongoing climate change, both global and local sea levels will rise over time. There is still considerable uncertainty regarding the rate of both global and local sea level in the foreseeable future; however, it is generally acknowledged that the uncertainty is most important over durations of several decades or more. There is significant amount of uncertainties with respect to the impact on the Fraser River due to climate change and sea level rise. The Design Engineer shall make proper judgement on how to apply sea level rise to these shore protection structures.

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DEFINITIONS AND GLOSSARY

Abbreviations, acronym terms, and definitions used in this document are defined below.

Acronym/ Symbol	Term	Definition
AEP	Annual Exceedance Probability	The probability of a specific event occurring (or being exceeded) in any given year.
---	Armour Stone	Individual rock pieces used in **riprap** or rock armour slope protection works.
CD	Chart Datum	Approximately equal to the lowest astronomical tide level. Note that the conversion from Chart Datum to Geodetic Datum continually changes on the Fraser River, depending on location. The Canadian Hydrographic Service (CHS) should be consulted for proper conversion between datums at any particular site.
---	Dike ROW	Dike refers to an embankment, berm, wall, piling, or fill constructed to control flooding of land. Right-of-Way (ROW) is a legally defined strip of land to provide access for maintenance.
D_{n50}	Median Nominal Diameter	The median nominal diameter of rock material. 50% of a sample of material is greater than D_{50} and 50% is smaller. The percentage is generally referring to the mass of material in a sample.
DWL	Design Water Level	The design basis water surface elevation.
---	Encounter Probability	The probability of a specific event with a defined **AEP** occurring (or being exceeded) in a defined number of years.
---	Freeboard	The vertical distance between a **still water level**, usually the **DWL** and the crest of the shoreline protection system.
---	Freeboard Allowance	An allowance usually added to the calculated crest elevation of the shoreline protection system to account for uncertainties in the estimate of **DWL** or **wave effects**.
HHWLT	Higher High Water Large Tide	Average of the annual highest high tides over the 19-year tidal cycle.
LLWLT	Lower Low Water Large Tide	Average of the annual lowest low tides over the 19-year tide cycle.

Acronym/ Symbol	Term	Definition
HWLHD	Higher Water Level High Discharge	HHWLT at Point Atkinson and high discharge in Fraser River.
LWLLD	Lower Low Water Low Discharge	LLWLT at Point Atkinson and low discharge in Fraser River.
---	Overtopping	The passage of water over the top of a coastal structure as a result of wave runup and related surge and local setup. The water may pass as a flow of water or as spray. The characteristics of overtopping are site, structure and wave specific.
---	Riprap	Slope protection system consisting of a wide gradation of rock material placed in bulk. Riprap tends to have smaller voids due to the wide gradation and can result in higher wave runup.
---	Rock Armour	Shoreline protection system consisting of armour stones with a narrower gradation than riprap, individually placed, commonly with two or three layers. Generally placed overtop of under layer materials, which provide both energy dissipation service and filter action for fill or in-situ materials.
SLR	Sea Level Rise	The rise in sea level including: global sea level rise driven by global warming, local effects including tectonic or isostatic (glacial) subsidence or uplift and local oceanographic effects.
---	"Soft" Shoreline Protection	"Soft" shoreline protection systems include, in general terms: beach nourishment, restoration or construction, dune and wetland construction, shore vegetation preservation or restoration and construction of nearshore reefs and berms and similar, generally rocky features as part of the system.
---	Still Water Level	The water level that exists in the absence of waves or wind action.
VFPA	Vancouver Fraser Port Authority	The VFPA is responsible for the stewardship of federal port lands at VFPA of Vancouver.
---	Wave Runup	The vertical height reached by waves on a coastal structure. Measured from the concurrent still water level.

1. INTRODUCTION

1.1 Basis of Document

There are several shoreline assets within the jurisdictional area of the VFPA on the Fraser River. These guidelines were developed based on a review of 35 assets, having a total shoreline length of approximately 9.6 km, and located within 14 general areas as shown in the figures in Appendix A.

Inspections of the Fraser River shorelines have found a wide variance in the quality of the shoreline protection, with older portions, in particular, showing evidence of damage.

In most cases, VFPA is the direct owner of many of these structures; however, depending upon the terms of the specific lease for individual terminals, the property tenant may be responsible for the maintenance, repair, or the decommissioning of the existing shoreline protection. This document is intended to serve as a guideline to inform the inspection, the maintenance, or the design and repair of shorelines in the Fraser River portion of VFPA.

There have been many advances in the understanding of the use of rock for shoreline protection in the marine environment over the past 30 years. There is also an increasing awareness of the interaction between the character of the shoreline and the marine environment. VFPA has a strong preference for shoreline protection systems that reflect good shoreline practice, and which include or consider environmental improvements.

It is also generally recognized that as the result of global climate change, global and local sea levels and related flooding in the Fraser River are going to increase or intensify and the shorelines of VFPA will need to accommodate or adapt to these ongoing processes.

This document is intended for use by VFPA staff, VFPA tenants, and as a default reference for design professionals providing shoreline related services to VFPA or their tenants. This document is not intended to supersede or replace the judgement of the Design Engineer or Professionals, or to supersede related standards of practice. The responsibility for shoreline design always remains with the Design Engineer for any project.

VFPA encourages alternate and innovative or creative design. Where these designs differ from the guideline principles in this document, designers should clearly explain why the alternates are capable of achieving the same ultimate goals of providing functional, robust, and appropriate shoreline protection.

1.2 Purpose and Limitations of Document

Numerous criteria and issues must be considered in the evaluation and design of shoreline protection; however, variations in exposure, local environment, maintenance practices, and upland usage can materially affect individual sites. The anticipated service life of an existing shoreline protection system will also influence the evaluation and design process. This document presents basic principles for the inspection, maintenance, and design and repair of shoreline protection structures. It is intended for use when considering:

a) Repair of locally damaged shorelines.

b) Replacement of existing shoreline structures that have reached their end-of-life or are no longer fit for purpose.

c) Upgrades to shorelines when the adjacent upland area is undergoing change or where new construction is planned.

d) General reinstatement of shorelines to “make good” a shoreline at the end of a lease agreement.

e) New construction of shoreline protection.

This document does not apply to shoreline protection for sites outside of the Fraser River portion of VFPA, for instance, along the Vancouver Harbour or at small creek outlets, where sea state and marine conditions apply. It does not apply to areas of VFPA directly exposed to the environment of the Strait of Georgia.

2. BACKGROUND

2.1 Overview

For the purpose of this document, Fraser River is defined as that part of the Fraser River between George Massey Tunnel and Port Mann Bridge (see Figure 2.1).

Figure 2.1: Aerial Photograph of the Fraser River
(Ref: Google Earth, 2019)

For shoreline protection features which fall within VFPA's jurisdictional boundary, VFPA desires to see these Guidelines employed for inspection, maintenance, design and repair efforts.

In general, most of the VFPA property shoreline is protected with riprap revetment. In some locations, shorelines are left unprotected for natural habitat purposes. There are numerous instances of shoreline protection which are currently not defined as VFPA assets. These features have usually been installed by others, sometimes to protect land or assets outside VFPA's jurisdictional area, particularly where the boundary closely approximates the existing shoreline.

It will usually be the responsibility of other parties to inspect, maintain, repair, or install new slope protection in these areas. Applications for repairs will be examined on a case-by-case basis during a permit review.

2.2 Shoreline Reference Systems

Not all of the existing defined VFPA shoreline assets have as-built construction or record drawings for the land reclamation and shore protection systems. Where drawings exist, the coordinate systems and reference datum are not always consistent. VFPA is updating their geo-referenced information using a GIS based system for their shoreline assets throughout the Fraser River area. As part of this work, VFPA has designated specific shoreline protection systems or features with unique asset numbers.

VFPA uses a local chainage system for each asset as a means to identify locations and points of interest. The chainage system for a select number of defined shoreline assets in the Fraser River can be provided by VFPA.

Distances are measured along the shoreline using the asset chainage. Offset is measured perpendicular from the chainage baseline. Design and repair documents should use the asset numbers and chainage system.

Horizontal coordinates should be in UTM Zone 10, NAD83. Vertical coordinates may reference either Chart Datum or the Geodetic Datum (see Section 4.3).

The horizontal and vertical datum must be clearly indicated on all documents and drawings.

Designers should consult the latest VFPA Record Drawing Standards, VFPA Linear Referencing Standards, and VFPA Vertical Datum Guidelines for the latest standards. If using Chart Datum, the conversion to Geodetic Datum must be specified.

3. GENERAL INSPECTION AND MAINTENANCE

Nearly all shoreline protection systems require ongoing inspection and maintenance to ensure they continue to provide the service that was intended at the time of design and initial construction. During the service life of any system it is always possible to experience a combination of events that equal or exceed the original design criteria and therefore some damage is likely to be experienced. Older existing systems may reflect an accumulation of damage resulting from occasional exceedance of the original criteria.

In any port, the shoreline protection structures are also going to become exposed to changes in related activities, including the deployment of larger or more powerful vessels or changes in the onshore components of the port activity. These expected changes can result in consequences to the shoreline protection system that also could not be anticipated at the time of design.

The ongoing effects of climate change, including changes in temperature, precipitation, storm characteristics, sea levels, and changes in river flooding will also create situations which may have consequences that also could not be anticipated at the time of design. Periodic inspections and necessary maintenance are the only way to ensure that the service requirements and expectations of the system are sustained over the life of the system.

Maintenance of rock armour shoreline protection systems generally requires either ongoing repairs, to avoid cumulative damage related deterioration, or replacement, depending upon circumstances. Moderate damage may be acceptable in some locations while in other locations, where the slope protection function may be critical, damage should not be left for a less severe but probable event. The assessment of acceptable and allowable damage is often related to upland usage. For instance, a parking area may be able to tolerate a high level of accumulated damage but an occupied building, adjacent to the slope, or to the storage of high value cargo adjacent to the slope, may create a need and a justification for immediate repair or restoration of the area.

It should be noted that most design methods assume a small but allowable amount of damage to a properly designed and built system in the design event. Successive but less severe events can then lead to cumulative damage effects that make subsequent event damage more likely to be more severe.

It is recommended that periodic systematic inspections are undertaken, and that observed damage is put into the context of the rate at which it is occurring and the required life of the shoreline protection system. Any damage that is new, from one inspection to another, is worthy of additional follow-up to determine causes leading to the damage.

3.1 General Inspection Recommendations

Inspections of shoreline assets should be undertaken:

a) At a minimum, every five years.

b) After major flood events, especially flood events that have resulted in flooding of terminal land areas.

c) After flood event resulting in port closure.

d) After reported observed shoreline damages.

3.2 General Repair Recommendations

Several points to consider for emergency repairs:

a) Angular rocks can tolerate relatively steep slopes, and temporary stability at a steepness of 1V:1.3H can be achieved for a short period of time. While not desirable for a long-term repair, steep slopes can be acceptable for an emergency repair to halt erosion or prevent loss of fill material.

b) A filter layer is critical to preventing washout of fines and in-filling of the void spaces in the armour layers. Fines in the armour layer can de-stabilize the surface armour rocks or riprap cover layers. Emergency repairs should include a filter layer if no or only limited rock material remains on the slope of the damaged area.

c) Damage at the top of a slope may be caused by localized surface water drainage issues. If there is evidence of localized drainage concentration at the location of damage, drainage improvements or controls should be considered at the time of the emergency repair to prevent further high velocity run-off over the slope protection.

d) Shoreline protection that abuts vertical and non-porous structures, including bulkhead walls, caissons and sheet-pile walls, should be inspected with specific attention to erosion, or displacement of armour stones at the interface between the vertical or non-porous structure and the shoreline protection system. Attention should be given to undermining or scour at the toe of the shoreline protection. Scour damage should be repaired appropriately.

3.3 Repair Situations

In the event of observed localized damage to shorelines, emergency or temporary repairs are recommended to minimize future damage before any proper repairs are undertaken. The following are common examples of situations where damage or cumulative damage has been observed.

3.3.1 Localized Crest Erosion

Figure 3.1 shows an area with localized damage at the crest of the slope protection. Poor construction may have been a contributing factor as there is no visible filter layer material on the upper slope. Such an area is susceptible to further erosion if exposed to waves or currents at high water conditions, or during intense surface drainage events.

In the event of minor and localized erosion of the crest, emergency placement of rock material as a temporary measure to halt erosion is recommended.

Longer term solutions may include increasing the surface setback of the concrete barrier wall, improvement to surface drainage, and the planting of a riparian strip to help reduce erosion during either high water level and wave events or during heavy rainfall events. Alternatively, the replacement of the upper slope materials to provide protection against wave runup and also provide a free drainage path within the rock matrix may be appropriate.

Figure 3.1: Minor Damage of Upper Crest of a Rock Armour Slope

3.3.2 Mid-Slope Damage

Minor gaps or slumps in the mid-slope sections of a rock system can be repaired by placement of a small amount of armour material and the re-working of the immediate surrounding area using a small excavator with a thumb attachment.

For moderate localized damage to the armour layer, for instance where the interlocking of the armour rocks has been compromised, an excavator with a thumb attachment can also be used to improve contact between individual armour stones to improve their stability, together with addition of a limited amount of extra properly sized material. Individual stones should be reworked to ensure each armour rock on the surface layer has at least three points of contact to adjacent rocks.

3.3.3 Toe Damage

Damage to the shoreline protection system toe can indicate various flaws, including: inadequate rock sizing, poor rock placement, or undermining by scour of the river bed. If damage to the toe is noted, repairs should be conducted as soon as possible, as toe damage can have serious implications to the overall slope stability if up-slope materials rest and rely on a stable toe for support.

The type of repair will depend greatly on the extent and cause of damage. In the case of inadequate rock sizing or improper placement of toe rock, it may be sufficient to repair with large armour stones, which are well-keyed into the surrounding rock. In the case of scour, the repair plan may include backfilling of the scour hole with suitable material to prevent reoccurrence. A self-launching apron on top of the existing toe berm may also be an alternative.

3.4 Geotechnical Stability

The geotechnical and seismic stability of shoreline structures is not covered in the scope of this document; however, over-steep slopes, or heavily loaded crests (including high wheel loads close to the crest, or stacked containers), may require special geotechnical consideration. As such, assets with these features should have a qualified geotechnical engineer assess the static and seismic slope stability.

3.5 Vegetation Control

To facilitate inspections, it is recommended that vegetation at the crest be cut back regularly to ensure that rock armour slopes and the crest details of the rock armour are visible. This is particularly important for creeping vine plants such as invasive blackberry that can cover these structures and prevent thorough inspections.

Environmental enhancements that include crest vegetation should be designed and maintained such that the vegetation remains on the top of the crest and does not cover the rock slope. Replacement or new designs should encourage the removal of invasive species, promote the planting of native species of vegetation suitable for marine riparian environments, and preserve established native species as much as possible, as described in Section 6.

In some cases, deliberate planting of vegetation at the top of the slope may also reduce the extent or effects of upland flooding.

4. DEFINITION OF DESIGN CRITERIA

4.1 Design Service Life

The design service or working life of a shoreline asset is generally defined based on the duration for which the shoreline structure has to provide the intended purpose, including expected maintenance. The design service life is often closely related to the business model for the terminal on the landside of the shoreline structure.

The design life for new shoreline construction is generally taken to be 50 years.

The design life for repairs to existing shorelines should be at least 20 years; however, in certain circumstances, the repair design life may be linked to the remaining tenant lease duration.

4.2 Design Event

The concept of a design event or storm that should be considered for design is too simplistic in many situations. The definition of appropriate design criteria, for instance:

a) Design river discharge.

b) Design water levels.

c) Design river current speeds and directions.

d) Design vessel-induced waves.

e) Design vessel-induced current (prop wash).

should be undertaken using a balanced evaluation between the inter-relationship of the various constituents, the risks of the design event occurring, the change in criteria component details that should be expected over the design service life of the shoreline feature, and the functional requirements of the structure. Acceptable encounter probability should be considered when determining the appropriate return period of events.

This design scenario can best be managed at the design stage for repairs or maintenance by adopting a balanced risk design approach. In this approach, the objective is to ensure that the encounter probability[1] of the design basis criteria remains constant over the expected remaining service life of the project.

An example of this balanced risk approach is illustrated for several scenarios in Table 1. The scenarios correspond to the following:

a) The acceptable encounter probability over a finite service life is taken to be 39%, based on the common practice of choosing a 1/100 AEP for a 50-year service life in the Port.

b) The encounter probabilities for the “design event” over the remaining life remains less than 41%. The recommended maximum allowable encounter probabilities are shown in Table 1.

[1] The encounter probability defines the probability of encountering an event with a specific Annual Exceedance Probability (AEP) over a specific lifetime, measured in years.

Table 1: Relationship between Service Life and Allowable Encounter Probability

Description	Design or Remaining Service Life of Project				
	50 Years	25 Years	15 Years	5 Years	2 Years
Acceptable Encounter Probability Over Life of Project	39%	40%	40%	41%	36%
Corresponding Event Return Period	100 Years	50 Years	30 Years	10 Years	5 Years

Specific guidance on design event constituent components is provided below.

4.3 Vertical Datum

The conversion from Chart Datum to Geodetic Datum continually changes on the Fraser River, depending on location. For most purposes, it is easiest to just use Geodetic Datum (North American Vertical Datum 1988, or NAVD88). The conversion to or from Chart Datum on the Fraser River is complex, as the river slowly descends in elevation on its journey to the sea. However, for design purposes, it is important to know the elevations of high and low water, relative to Geodetic Datum for any given site.

The conversions at established tide gauges are provided in Table 2.

Table 2: Conversions between Chart Datum and Geodetic Datum

Location	Chart Datum	Geodetic Datum
New Westminster Tide Gauge (No. 7654)	0.0 m	-1.30 m
Woodward's Landing Tide Gauge (No. 7610)	0.0 m	-1.84 m
Steveston Tide Gauge (No. 7607)	0.0 m	-2.2 m

Until recently, the conversion for other locations was interpolated between the existing tide gauge locations, in steps of 1-kilometre stretches along the main channel, however, Canadian Hydrographic Service (CHS) plans to roll out a new system for continuous conversion based on GPS location.

CHS should be consulted for proper conversion between datums at any particular site.

See also the CHS website for Station Benchmark data for each tide gauge.

http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/twl-mne/benchmarks-reperes/search-recherche-eng.asp?AREA=PAC

4.4 Depths of Water

The general bathymetry of the harbour and the depth of water at a specific terminal site can be obtained from the latest edition of the Canadian Hydrographic Service (CHS) Chart 3490 "Fraser River Sand Heads to Douglas Island". At some sites, the VFPA has more recent, high-resolution multi-beam survey data. The VFPA Engineering Department should be contacted to determine the latest available data for any given site.

4.5 River Discharge

The discharge rate in the Fraser River varies considerably from year to year and from season to season. Snow-melt from headwaters in Rocky Mountains that begins in April and peaks in late May and early June contribute two-thirds of the total runoff. This period is known as freshet. The lowest flows of the year generally occur in the winter.

The 1894 flood had a peak flow of 17,000 m^3/s measured at Hope. The historic 1 in 500-year design flood event has 16,500 m^3/s flow rate.

According to Canadian Tide and Current Tables (2019) published by Fisheries and Oceans Canada, four discharge rates for the Fraser River at Hope as presented in Table 3 shall be considered.

Table 3: Approximate Discharge Rate for the Fraser River at Hope

Discharge Rate	Months of Occurrences
700 m^3/s	January, February, March, and December
2,800 m^3/s	April, August, September, October and November
5,700 m^3/s	May and July
8,500 m^3/s	June

The River Forecast Centre have additional river discharge and water level information as well as forecasts from several numerical models including CLEVER, WARNS, and COFFEE. This additional information can be found from the following website:

> https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/river-forecast-centre/current-streamflow-conditions-and-flood-forecast-modeling

4.6 River Currents

During freshet, currents are predominantly down river. During the low flow season, tides create alternating flood and ebb flows in the Fraser River. The maximum outflow occurs during the freshet may exceed 3 m per second (6 knots) in the lower reaches between New Westminster and Sand Heads. Some shorelines may be particularly exposed to river currents and erosion. The effects of currents should be properly understood and designed for accordingly.

The design river current should be determined based on available current measurement data as well as numerical modelling results (see Section 4.5) by a qualified professional engineer.

4.7 Water Levels

Water levels along the Fraser River are influenced by tidal variations in the Strait of Georgia and river discharge rates. Water levels also rises in the upstream direction. Water levels at Steveston, Deas Island, and New Westminster under varying tide elevations at Point Atkinson and different river discharge rates at Hope are presented in Table 4 (from Canadian Tide and Current Tables, 2019). The water levels are referenced to Chart Datum (CD).

Table 4: Tidal Height at Steveston, Deas Island, and New Westminster

A-Steveston/B-Deas Island/C-New Westminster												
Point Atkinson (m)	Tidal Heights											
	Discharge at Hope											
	700 m^3/s			2,800 m^3/s			5,700 m^3/s			8,500 m^3/s		
	A (m)	B (m)	C (m)	A (m)	B (m)	C (m)	A (m)	B (m)	C (m)	A (m)	B (m)	C (m)
5	4.2	3.8	3.2	4.2	3.9	3.4	4.3	3.9	3.5	4.3	3.9	3.5
4.5	3.7	3.3	2.7	3.8	3.4	3.0	3.8	3.4	3.1	3.8	3.5	3.2
4	3.3	2.9	2.4	3.3	3.0	2.6	3.3	3.0	2.8	3.3	3.1	3.0
3.5	2.8	2.4	1.9	2.8	2.5	2.2	2.9	2.6	2.4	2.9	2.7	2.7
3	2.3	2.0	1.6	2.3	2.1	1.8	2.4	2.2	2.1	2.4	2.3	2.5
2.5	1.8	1.5	1.2	1.8	1.6	1.5	1.9	1.8	1.8	2.0	1.9	2.3
2	1.4	1.1	0.8	1.4	1.2	1.1	1.5	1.4	1.5	1.5	1.5	2.1
1.5	0.9	0.7	0.4	1.0	0.8	0.7	1.0	1.0	1.3	1.1	1.2	1.9
1	0.4	0.2	0.2	0.6	0.4	0.4	0.7	0.6	1.1	0.8	0.8	1.8
0.5	0.1	0.0	0.0	0.2	0.2	0.2	0.4	0.3	1.0	0.5	0.5	1.7
0	-0.2	-0.2	-0.1	0.0	0.0	0.1	0.2	0.2	0.9	0.3	0.3	1.6

In determining the design water levels, high water levels should consider high tide combined with high discharge, and low water level should consider low tide combined with low discharge. The recommended design water levels at Steveston, Deas Island, and New Westminster are presented in Table 5.

Table 5: Recommended Design Water Levels at Steveston, Deas Island, and New Westminster

Description	Abbreviation	Elevations (m, CD)		
		Steveston	Deas Island	New Westminster
Higher Water Level High Discharge	HWLHD	4.3	3.9	3.5
Low Water Level Low Discharge	LWLLD	-0.2	-0.2	-0.1

Note that the New Westminster tide gauge recorded the historical extreme height of 4.66 m CD on June 10, 1948 (the flood of 1948).

4.8 Global Warming, Climate Change, and Sea Level Rise

It is generally recognized that as the result of ongoing climate change, both global and local sea levels will rise over time. There is still considerable uncertainty regarding the rate of both global and local sea level in the foreseeable future; however, it is generally acknowledged that the uncertainty is most important over durations of several decades or more.

Current BC Provincial Guidelines, Ref. [1], recommends that shoreline planning should consider 1 m of global average SLR by the year 2100 (above year 2000 water levels). Ref. [1] also advises that predictions of future sea level rise should be updated at 10-year intervals or when significant scientific information becomes available.

The climate change impacts on extreme Fraser River flood flows were assessed and the results are published in the final report titled "Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios" by the BC Ministry of Forests, Lands and Natural Resource Operations (May 2014, Ref. [21]). The results show that by the end of the century, a 50-year return period flood event will correspond to an event with present return periods from 200 to 500 years. Sea level rise within the range of scenarios considered (0.5 m to 2 m) can have a significant effect on flood levels and dike design profiles in the lower Fraser River.

It is noted that more recent research and publications show that relative sea level rise, is lower than the global average SLR in BC. According to the following two recent reports:

- NOAA Technical Report NOS CO-OPS 083 (2017) "Global and Regional Sea Level Rise Scenarios for the United States" (Ref. [19]).

- Environment and Climate Change Canada CCCR 2019 Report "Canada's Changing Climate Report" (Ref. [20]).

the relative sea level rise in Pacific Northwest Region is less than the global average SLR partially due to rising round elevations. "Canada's Change Climate Report" shows that in Vancouver, the projected relative sea level change at the end of the century is 0.5 m to 0.75 m (see Figure 4.1).

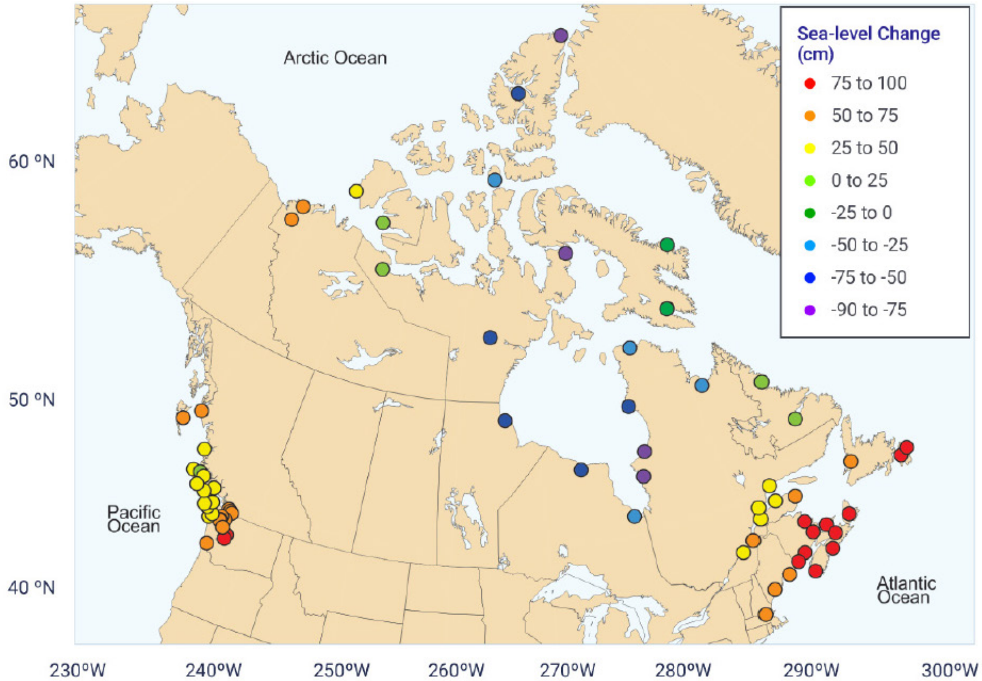

Figure 7.16: Projected relative sea-level change along Canadian coastlines at the end of the century

Figure caption: Projected relative sea-level changes shown at 2100 for the median of a high emission scenario (RCP8.5) at 69 coastal locations in Canada and the northern United States. Values range from a sea-level fall of 84 cm to a sea-level rise of 93 cm and are relative to the average conditions in the 1986–2005 period. For comparison, the projected median global sea-level change at 2100 for the high emission scenario is 74 cm.

Figure 4.1: Projected Relative Sea-Level Change along Canadian Coastlines at the End of the Century (from "Canada's Changing Climate Report" 2019)

Recognizing the complex nature of impact to the Fraser River due to climate change and sea level rise, it is the Design Engineer's responsibility to determine how climate change and sea level rise may impact the shoreline protection projects on the Fraser River.

4.9 Vessel Induced Waves

Fraser River shorelines are exposed to the wake of vessel traffic. Typically, waves generated by speeding small crafts or tugs are much higher than wake waves generated by large tankers or bulk carriers. Boat wake wave heights also decrease away from the vessel hull. The design vessel induced waves should be determined by a qualified professional engineer based on the site locations, vessel type/size/speed, and distance from the vessel to the shoreline.

4.10 Vessel Induced Currents (Prop Wash)

Any shoreline adjacent to vessel operations may experience high current velocities caused by prop wash. High velocity flows from prop wash can damage shoreline protection systems. This is particularly the case where tug boats operate in close proximity or where the system may be exposed to bow thruster or main propulsion wash from larger vessels during berthing or departure manoeuvres.

Design of shoreline protection for prop wash should be undertaken by a qualified professional engineer with coastal engineering experience.

4.11 Wind Generated Waves

Wind generated waves in the Fraser River are limited and typically do not govern in terms of shore protection design.

5. DESIGN

The design of rock armour shoreline protection needs to properly account for site-specific conditions, as discussed in Section 4, and should follow established design principles as described in this section.

All shoreline protection works must be designed by a professional engineer with coastal engineering experience. This document is not intended to replace the judgment of the Design Engineer, and the responsibility for proper shoreline design always remains with the Design Engineer for the project.

5.1 General Design Recommendations

For shoreline protection within the Fraser River for VFPA, the following considerations are recommended:

a) Rock armour should be sized to be statically stable. There should be little to no damage to the armour layer under design conditions.

b) Crest elevations should be set such that no overtopping during operating conditions at the shoreline occurs.

c) Shoreline rock armour slopes should never be steeper than 1V:1.5H. Generally, slopes with a 1V:2H slope or greater are preferred for increased long-term stability and reduced wave runup.

d) A suitable layer of filter rock should always be used with both riprap and rock armour protection to prevent loss of fines from the slope material under combined wave and current loads.

e) Due to the nature of some of the fill materials historically used in the Fraser River, a geotextile is recommended below the filter layer to protect against loss of fines. If placement below water is necessary, the Design Engineer could consider adding a second, smaller grain-sized filter layer instead of a geotextile.

f) When the toe of the slope terminates in material that is susceptible to scour or erosion, the design should include a surplus of material at the toe to accommodate any scour holes that may develop and to maintain the integrity of the slope protection.

g) A freeboard allowance should be included in situations where the upland use of the site has high value. Alternatively, an actively managed setback policy could be considered.

5.2 Rock Sizing

Detailed guidance on the design of rock shoreline protection systems is provided in the following references, standards, or guideline documents: Ref. [7], [8], [9], [16], [17], and [18].

Rock sizing against river current, boat wake waves, and prop wash shall be calculated according to the following methods:

- River Current: Pilarczyk method (1995), Maynord method (1992), or Escarameia and May method (1993) (The Rock Manual, Ref. [9]).

- Boat Wake Waves: Hudson formula (Shore Protection Manual, Ref. [17]) or Van der Meer formula (Coastal Engineering Manual, Ref. [16]).

- Prop Wash: method described in "Guidelines for Design of Armoured Slopes Under Open Piled Quay Walls" (Ref. [18]) or "The Rock Manual" (Ref. [9]).

When riprap is considered for use, riprap that meets the BC Ministry of Transportation and Infrastructure Guidelines classes, as summarized in Table 6, is recommended. Local quarries are typically readily able to provide material conforming to this specification.

Table 6: BC MOTI Highway Guidelines Riprap Classes
Source: Ref. [6]

Class of Riprap (kg)	***Nominal Thickness of Riprap (mm)**	**Rock Gradation Percentage Smaller Than Given Rock Mass (kg)**		
		15%	**50%**	**85%**
10	350	1	10	30
25	450	2.5	25	75
50	550	5	50	150
100	700	10	100	300
250	1,000	25	250	705
500	1,200	50	500	1,500
1,000	1,500	100	1,000	3,000
2,000	2,000	200	2,000	6,000
4,000	2,500	400	4,000	12,000

5.3 Toe Protection

It is a recommended design practice that a shoreline protection system should include specific toe protection at the toe of the slope. Some examples of toe protection systems are provided in Figure 5.1. A typical standard toe is three to five stones wide with a thickness of two or three stones. If the seabed material is erodible, an underlying scour protection mat should also be included in the toe detail unless the toe of the protection system is buried.

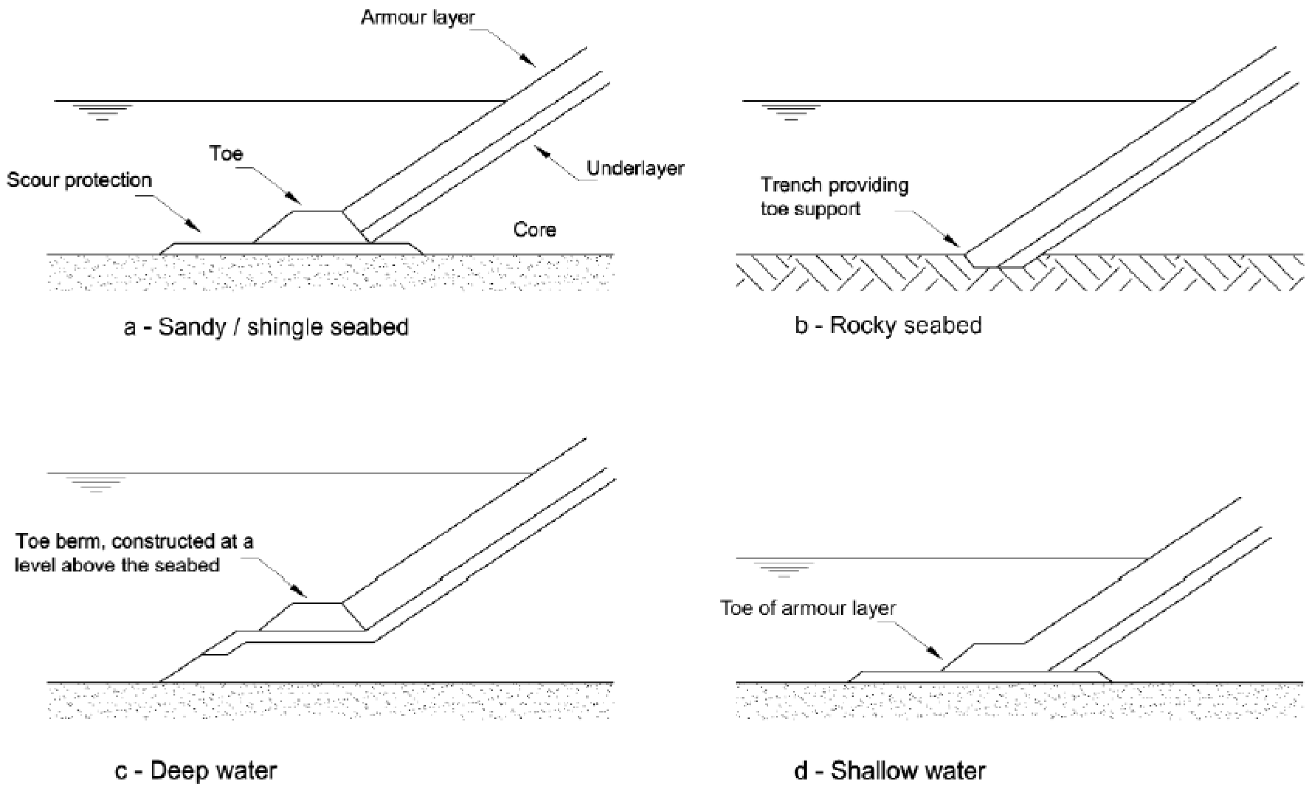

Figure 5.1: Toe Protection Examples
Source: Ref. [9]

5.4 Unusual Shorelines

Shorelines that have unusual geometries, or interfaces with other structures, may require special attention during design. Examples are:

a) Shorelines with sharp or tight radius curves. Where the rock armour must turn an abrupt corner in a convex fashion and is exposed to wave action, larger rock armour stones will be required to achieve stability.

b) Shoreline protection that abut vertical and non-porous structures. The additional wave reflection from these types of structures will require larger rock armour material adjacent to the structure to achieve stability.

c) Shorelines that provide valuable riparian or marine habitat may beneficially incorporate some elements of habitat compensation. These shorelines will require special consideration by a Design Engineer.

5.5 Dike Right-of-Ways

Much of the Fraser River has flood protection works along its banks (generally, dikes, flood boxes, pump stations, etc.) which exist in special Right-of-Ways (ROWs). These flood protection works are generally maintained by the local municipality. In some cases, ROWs may also exist for future dike installation or upgrading. Users should be aware if there are any Dike ROWs and existing, or planned, flood protection works in the vicinity of any shoreline protection. A series of maps, guidelines for design and operation, and other information, is maintained by the Province, as part of the Dike Maintenance Act, on this website:

> https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/integrated-flood-hazard-management/dike-management

Municipalities, and in some cases other operators or agencies, are responsible for the provision and maintenance of flood protection works under the Provincial Dike Maintenance Act. It is the desire of the Port that where any Shoreline Protection works which are near, or may affect, other flood protection works in Dike ROWs, that these Shoreline Protection works enhance, and not hinder or compromise other flood protection works, either existing or proposed.

6. ENVIRONMENTAL CONSIDERATIONS

Social, environmental, and financial sustainability are core values of the VFPA. The VFPA prefers shoreline protection systems that include or consider environmental improvements to the foreshore and the operational requirements for slope repair or improved slope stability.

Ideally, shoreline protection projects should contribute towards the environmental and financial sustainability of the VFPA shoreline assets. This section summarizes some aspects of environmental considerations that pertain to the typical shoreline protection systems found around the perimeter of the Fraser River portion of VFPA.

6.1 Envision™

VFPA is interested in integrating the Envision™ Green Infrastructure rating system into its projects. Envision™ is a framework tool that allows users to rate a project's overall sustainability, in order to assess areas for improvement. The tool also provides guidance on sustainable best practices. More information can be found here: http://sustainableinfrastructure.org/envision/.

While the framework tool and rating system is not necessarily applicable to most stand-alone shoreline protection projects, many of the Envision™ criteria and overarching principles are applicable and should be considered. It is recommended that a living document is developed for each shoreline protection project, which outlines each of the 60 Envision™ credits and possible methods for implementation on the project. For ease of implementation, these may be organized relative to the various implementation phases, including site selection, design, tender, and construction.

Envision™ Credit RA 1.5: Divert Waste from Landfills:

During the design phase, the shoreline protection could be designed to reuse existing rock materials and soil where possible. Designers could also consider replanting vegetation where possible, and how any additional excavated material might be used for other VFPA or local projects.

6.2 Habitat Improvements

There are numerous different types of habitat improvements that can be considered in the development of preliminary designs or design options for shoreline protection. The specific goal or objective for habitat improvements should be stated for each design option. The options should be accompanied with descriptions of feasibility and cost for VFPA's consideration as possible ways to work towards their "Sustainable Port" goals.

6.2.1 Shoreline Slope Habitat Improvements

Although the addition of habitat benches on the slope of a revetment have demonstrated an increase in habitat diversity (Ref. [14]), there are many options to improve the marine habitat or ecological functions that, depending on the circumstances, can also be considered. In many situations the addition of habitat improvements often results in improvements for the slope protection functions of the overall system.

An example of a habitat bench is shown in Figure 6.1, which includes a bench that also provides toe protection for a rock armour or riprap revetment. The objective of the habitat component should be stated in advance of design and adequate consideration should be given in the design to ensure that self-launching scour or propeller induced scour does not remove the habitat objectives.

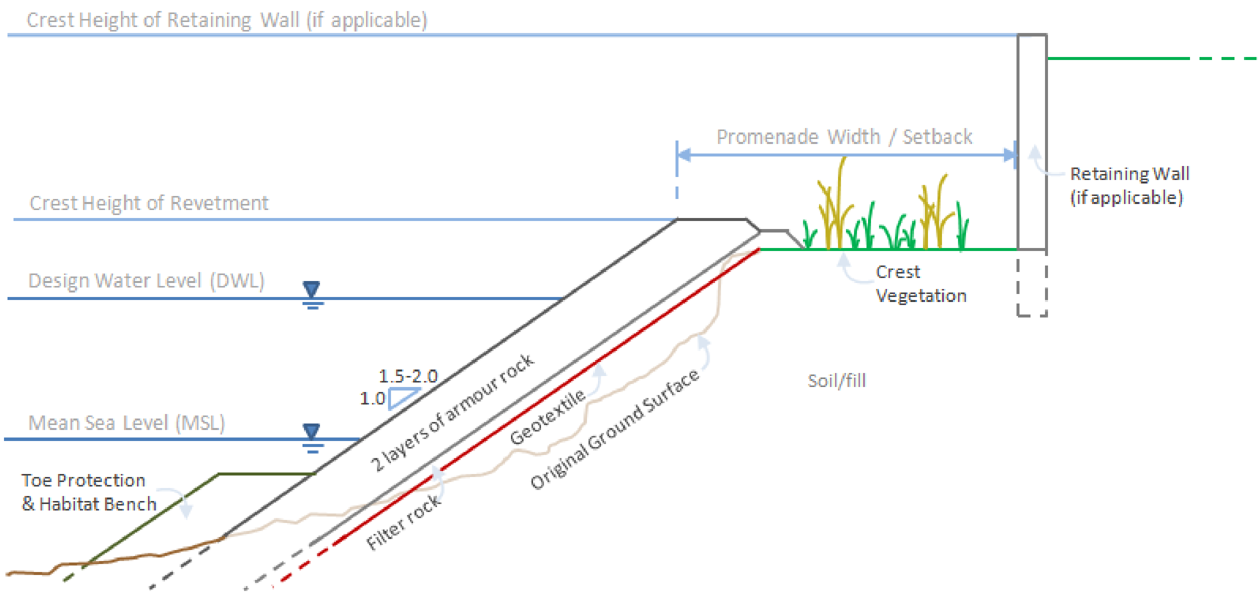

Figure 6.1: Potential Habitat Improvements (Habitat Bench and Crest Vegetation)

Habitat benches can be either continuous along the entire length of shoreline, or can be discontinuous, with variations in width, to create a more natural undulating shoreline. An undulating bench reduces the overall volume of materials and provides a cost benefit.

A roughened revetment slope, which includes distributed, larger than necessary, from purely a stability perspective, armour provides hard points for attachment of marine organisms, provides sheltered void spaces for cover or refuge for marine organism, and can result in reduced wave runup. Reduced wave runup may lead to beneficial contributions to the interaction between waves and the crest elements of a slope protection system, including habitat considerations added at the crest of the shoreline protection system.

Material size, shape, texture, and slopes could be adjusted to increase habitat diversity and promote usage from specific fish species and marine organisms. As an example, the creation of an undulating shoreline, by augmenting existing headland geometry, may allow creation of a small embayment or pocket beach, which can provide both substrate diversity and ecological diversity.

In some cases, existing shoreline protection material can be recycled and re-purposed as the habitat bench.

When space is available, the use of geotextile liners should be discouraged as they may limit the ability of marine organisms to benefit from the substrate and they can result in increased wave runup resulting in unplanned effects at the crest of the shoreline system.

6.2.2 Crest Vegetation

Marine tolerant vegetation at the crest of the structure (as shown in Figure 6.1) can provide several mutually beneficial ecological and engineering considerations, including:

a) Enhances the marine riparian vegetation zone.

b) Limits colonization by invasive species.

c) Improves upland habitat supply and diversity.

d) Provides enhanced resilience of the revetment to future sea level rise.

e) Provides erosion protection against pluvial surface run-off.

f) Results in decreased wave energy erosion at the crest and less erosion potential over the adjacent land area.

g) Can improve safety for upland personnel, equipment, and infrastructure by visibly delineating the shoreline edge.

As an example, a combination of native *Dunegrass*, *Beach Pe*a, and *Goldenrod*, along with *Agrostis* as a cover plant to discourage weed growth, was used in Boundary Bay to achieve these benefits along a shoreline dike and public walkway.

Trees should be preserved during construction in order to help provide a vegetated buffer, manage storm water and surface water functions, provide habitat, and manage heat island effects. However, preservation of trees often requires a larger working area setback to accommodate their growth. The roots of large trees may penetrate filter layers and geotextile liners or filter cloth and may affect the stability of the top of slope by the sheer weight of the tree alone. The presence of large trees or of associated root systems should be specifically assessed.

Maintenance of the crest vegetation, particularly weeding, is required to control growth of invasive species while plants are established. Once established, the plants would likely require less maintenance. Specific design and maintenance guidelines are being developed as part of a separate document.

6.3 Improvements to Shoreline Protection Components

Research, Ref. [15], indicates that improvements can be made to modify shoreline armouring to enhance habitat diversity, including making subtle changes to material shape, size, and texture.

As an example, concrete blocks with a coarse surface were found to be more rapidly colonized by small green algae than those with a smoother surface. Geometric structures within the slabs (e.g. cups and holes) retained water longer during low tide and favoured the initial colonization by larger green algae. Small adaptations of both the texture and structure of materials within the intertidal zone led to better settlement, colonization, and increased diversity of algae and macro benthos.

Ultimately, the creation of macro or micro habitats at a site can act to enhance foreshore habitat diversity and ultimately maintain ecological services.

6.4 Alternate and Developing Methods

The review and design of alternate shoreline protection systems to improve both the engineering performance and the environmental benefits is an ongoing field of research and application. Some of this work is related to aiding and improving environmental performance and some is driven by the need to develop more efficient and resilient systems in response to the challenges being created for ports by expected sea level rise and its implications.

Designers are encouraged to monitor and review the technical literature and emerging product development to identify suitable approaches. Emerging and novel approaches to increase habitat diversity, quality, and abundance in port environments include the following:

a) Shellfish Gardens: Manmade beach flats or terraces near the low water mark to increase habitat for and promote growth of clams or other shellfish.

b) Biogenic Reef Creation: Reefs made of tubes or shells from reef building organisms, to provide hard surfaces for habitation of immobile species, such as barnacles.

c) Seawall Enhancements: hybrid shoreline systems that incorporate seawall portions on the slope can lead to space for habitat benches, flatter slopes allowing different materials, and opportunities to create refugia and habitat enhancement features. Recent examples are summarized here:

   - https://waterfrontseattle.org/seawall
   - https://sites.google.com/a/uw.edu/seattle-seawall-project/home
   - http://www.environment.nsw.gov.au/publications/coasts/090328-env-friendly-seawalls-guide.htm
   - https://www.fishhabitatnetwork.com.au/projects/environmentally-friendly-erosion-protection-rock-revetment-alternatives-fish-friendly-marine-infrastructure

7. IMPLEMENTATION OF REPAIRS

The success of an implementation of a repair or replacement solution is often defined at the implementation (construction) stage of a project. While there are many factors that contribute to the success of a project at the construction stage, this section of this document summarizes some key considerations related to the construction stage that should be considered.

7.1 Timing of Work

There are a number of constraints on the timing of construction that can influence the cost or feasibility of the repairs. Four specific constraints related to work on the Fraser River are:

a) Fisheries permit regulations restrict the time when work can be undertaken in the intertidal and subtidal areas. For Vancouver (Area 28), the DFO timing window of least risk is from June 16 to February 28 (ref: http://www.dfo-mpo.gc.ca/pnw-ppe/timing-periodes/bc-s-eng.html#area-28). It is possible to get approval for work outside of this timing window; however, extra effort for permitting and often extra costs for construction are usually involved, so, in general, it is best practice that shoreline work is planned to occur within the timing window of least risk.

b) It is sometimes necessary to restrict against any work (excavation, rock placements, etc.) occurring in-water. For winter months when the lowest tides occur during the night, this can result in extra construction effort and cost. Generally, it is best practice to plan construction for when the largest low tides are during the day. Typically, July and August provide the best daytime tides for this work.

c) In addition to unfavourable tides, summer or early fall work is often preferred due to increased storm activity in the winter, which can lead to significant delays, damage the work area, and/or impact site safety.

d) Construction during the fall, winter, and early spring can often be exposed to rainfall or snowfall events that lead to additional costs and delays. Run-off from upland facilities can lead to turbidity in the local area.

7.2 Construction Methodology

Construction methodology should be considered carefully, giving due regard to site access, environmental conditions, and the shoreline protection design. Construction may be largely or entirely completed from water or from land.

Water-based construction will typically include a spud barge with a large derrick crane and a clamshell bucket, or possibly a long-reach excavator to prepare the slopes and place material. A crew boat may also then be needed. Materials may also then need to be transported to site using tug boats and barges (see Section 7.3).

The feasibility of working from the water will be largely based on environmental restrictions, upland access considerations, equipment availability, and cost. However, barges and tugs may not be able to operate at the site without sufficient draft (water depth below the hull), which may constrain the work window to high tides only. The reach of excavators/equipment located on the barge will depend on the tide and shoreline slope, which may only allow for short periods when work at the slope crest can be completed. Operations will also be restricted in areas with strong tidal currents or during periods of large winds/waves. In addition, the site may not have any area to tie-up or access the upland from water, which can cause work flow/access complications.

Water-based construction is also typically more expensive due to a limited number of contractor's who can complete the work in the area and increased equipment costs.

Depending on the shoreline protection design, some work may still be required from land. For example, placing geotextile, placing rock materials at the slope crest, placing topsoil, or planting vegetation may all require personnel and/or equipment on-land.

The feasibility of working from land will be largely based on upland usage and space constraints. For example, in areas where the site is actively being used, other construction works are ongoing, or important infrastructure (i.e. buildings) is located close to the shoreline, it may be necessary to use water-based construction.

If an excavator is used to place riprap, whether from land or water, it will require a bucket with a thumb. If below-water works are planned, excavators will need to be equipped with elevation and location monitoring equipment at the bucket, so that elevations and slopes of place material can be monitored during construction. Underwater placement of material can lead to an increase in placed volumes with implications to cost and to habitat offset requirements.

7.3 Transportation and Traffic

Transportation methods typically include barges (water-based) and trucks (land-based). Selection of transportation methodology should consider a wide variety of factors, including:

a) Total Quantity of Material: Typically, trucks will be more economical for low-quantity projects, such as localized shoreline repairs.

b) Distance from and Locations of Sources: Nearby quarries to the Fraser River are generally located in areas that will require at least a portion of the journey to be completed by truck. Depending on the source location, it may not be practical to use water-based transportation for material.

c) Availability of Transport Methodology: There are a limited number of local contractors with barges available for material transport. Depending on other ongoing projects in the region, certain transportation methods may not be feasible due to a lack of available equipment.

d) Construction Methodology: If water-based construction is chosen, it may improve work flow to have materials available on a barge nearby.

e) Approvals: When material is provided by barge, approval of materials should occur prior to loading of the barge.

f) Environmental Constraints: Barges may not be able to operate without sufficient draft (water depth below the hull), in strong tidal currents, or in large winds/waves.

g) Space Constraints on Land: Some sites may not have sufficient upland space to permit construction on land or stockpiling of material on land. If other work is ongoing upland (construction or active site use), the traffic management on the site may necessitate water-based operations.

In addition to these considerations, materials should be transported such that segregation and breakage is limited. In general, double or repetitive handling of materials can lead to breakage and quality issues.

A Traffic Management Plan should also be developed in collaboration with all stakeholders utilizing the site at the time of construction. This may include the VFPA, upland operators, contractor, and operators of nearby sites. The Traffic Management Plan should consider water-based traffic control measures if water-based construction or transportation is chosen.

7.4 Site Preparation

When preparing the site, care should be taken to ensure that the contractor's Health and Safety Plan and Environmental Management Plans are properly followed at project onset.

A pre-construction survey should be conducted prior to commencement of other work on site; this will inform quality assurance/quality control measures and payment. Take clear photographs of all areas on site prior to work. Particular attention should be paid to areas that will need to be restored to their pre-construction condition.

During site preparation, remove any invasive vegetation and clearly mark-off any native vegetation that is to remain, so that it is not damaged during the construction process. Set aside any reusable materials.

7.5 Placement of Materials

Placement of materials should generally follow the order and best practices outlined below:

a) Placement of Fill (if any):

- Should be placed in lifts, typically less than 0.4 m, and compacted.

b) Placement of Geotextile (if any):

- Geotextile should be placed directly on a 'fill' material to provide a relatively flat and smooth bedding surface. Armour rock should not be placed directly on top of the geotextile.
- When placing geotextile, lay the geotextile on top of the prepared slope, secure at the top, and roll the geotextile down the slope.
- Ideally, geotextile should be placed in the dry. If this is not possible, the geotextile roll will need to be weighed down/ballasted to avoid floatation during placement. For shallow water placement, contractors can place a steel/heavy pole through the centre of the geotextile roll. The geotextile can then be rolled down the slope, while the steel/heavy pole will weigh down the underwater end and prevent floatation. Filter rock can then be placed on the slope to secure/ballast the geotextile and the pole can be retrieved.
- Each strip of geotextile should have at least 0.3 m of overlap with adjacent sections.

c) Placement of Filter Rock:

- Filter rock may be placed in bulk and trimmed.
- Filter rock shall be placed beginning from the toe of the slope, working up the slope. The finished surface shall be densely placed and uniform.

- Prevent segregation of the fine and large portions of the gradation when placing.
- Prevent damage to the geotextile. Avoid scraping movements during placement and avoid dumping rock from high elevations.

d) Placement of Rock Armour or Riprap:

- Rock armour or riprap placement should be planned such that no sections of fill, geotextile, or filter rock are left exposed overnight.
- Care must be taken when placing armour rock to avoid disturbing the filter layer.
    - The toe should be constructed first and to the highest precision – as it is the most important piece.
    - Generally, the largest armour stone should be reserved for the toe of the slope and the crest of the slope.
    - The finest one-third of the armour stone should be evenly distributed throughout the slope. Remove and replace any portion in which material becomes segregated during placement to avoid large areas of undersized armour rock.
    - The finished surface should be densely placed, well-keyed, and uniform. Individual rocks shall have at least three points of contact to adjacent rocks.

7.6 Environmental Management

The following Best Management Practices (BMPs) are applicable when working near the foreshore or riparian areas:

a) Disturbance to intertidal, riparian, or existing adjacent vegetation is to be kept to the absolute minimum required to conduct the works.

b) Ideally, there should be no in-water works during the construction period. This often requires scheduling work to align with low tides. If in-water works cannot be avoided, additional permitting or environmental restrictions may be required. Environmental measures may include placing silt curtains around the work area or monitoring turbidity levels in the water.

c) Vehicles used for hauling material on-site and off-site shall be restricted to predefined roads and turnaround areas, to have the least environmental impact. The work should be planned to minimize the number of vehicles/equipment operating on/near the intertidal zone to reduce impacts on the foreshore.

d) Hauling vehicles and equipment should be cleaned of mud at an off-site location.

e) All equipment and machinery should be in good operating condition and free of leaks or excess oil and grease.

f) All hydraulic machinery should use environmentally sensitive hydraulic fluids which are non-toxic to aquatic life and are readily or inherently biodegradable.

g) Equipment should be fuelled prior to arrival on site and no onsite fuelling should be permitted.

h) The contractor should have an appropriate spill prevention, containment, and clean up contingency plan for hydrocarbon products (e.g. fuel, oil, hydraulic fluid, etc.), and other deleterious substances.

i) All fill or rock materials that will contact the waters of the Fraser River, should be clean material, free of organic materials and substances harmful to fish.

j) All debris and deleterious material generated by the subject works should be collected and disposed of at appropriate upland locations in accordance with all applicable legislation and permits for the works.

k) Works should be halted if it is observed that ongoing work is causing environmental degradation in the immediate vicinity of the works, or if turbidity levels in the local area are observed to be noticeably higher than before the commencement of work.

l) During construction, the contractor should alert the client representative if any reptiles are found during excavation or earthworks, and halt work until authorized to continue.

m) To ensure that the environmental BMPs are followed, it may be necessary to have an environmental representative on-site during construction.

7.7 Quality Control/Quality Assurance (QA/QC)

QA/QC is essential to ensuring that the shoreline protection design is executed properly. Best practices include the following:

a) Inspect rock materials at the quarry prior to them being brought to site. This is especially important for sites with a small work area where it is not possible to sort material on site.

b) Have personnel experienced in rock placement on site to provide guidance to equipment operators during the initial days of the project. Past experience with rock placement in the foreshore has found that the quality of the work will vary greatly depending upon the skills of the equipment operators, so guidance will often improve the quality of the finished works.

c) Have an engineering representative on site to perform inspections of rock placement. Inspections should ideally occur daily and be well documented in reports and photographs.

d) Surveys should be conducted following excavation, placement of fill, and placement of armour rock or riprap. It is standard practice for the contractor to furnish an independent surveyor to undertake these 'check' surveys. The Engineer of Record or a qualified representative should review the surveys to ensure that material excavation and placement is within tolerances.

e) In-water works will pose particular difficulty for inspections by the engineering representative during construction. To allow for inspection of rock placement quality underwater, the contractor should conduct regular multi-beam bathymetric scans of the placed rock that is of good enough resolution to resolve individual placed rocks and void space.

7.8 Additional Considerations

7.8.1 Noise Mitigation

Generally, the VFPA shorelines are not located in areas with particular noise sensitivity; however, noise restrictions may limit work to weekdays or daytime hours (8:00 a.m. to 5:00 p.m.). Where necessary, measures to reduce noise, which could include erecting noise barriers or using quieter equipment, should be considered and specified in advance if possible.

7.8.2 Excavated Marine Materials

Materials excavated or removed from the marine environment often exceed acceptable limits of sodium for disposal at a landfill. Special disposal may be needed.

As many of the VFPA shorelines are located in highly industrial areas and some of the existing shoreline protection or fill materials are non-standard, it may be necessary to test materials for additional contaminants.

Contaminated material may require special handling and disposal considerations and must be addressed when the contaminants are identified. The presence of contaminants may influence design options and therefore could trigger an iterative design and permitting process.

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CLIENT:	Vancouver Fraser Port Authority (VFPA)
OWNER:	Vancouver Fraser Port Authority (VFPA)
PROJECT:	Shoreline Protection Assessment - Fraser River

PREPARED BY: Gary Yang, PH.D., P.E., P.Eng. *Original sealed*

Senior Coastal Engineer

REVIEWED BY: Anthony Peterson, P. Eng. *Original Signed*

Project Manager

APPROVED BY:

VFPA Project Manager

REVISION INDEX

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1	*G. Yang*	*A. Peterson*	*A. Peterson*	*08-Jan-2019*	*Issued for Re-Use Advisian Document No. 317071-16152-00-MA-REP-0003*

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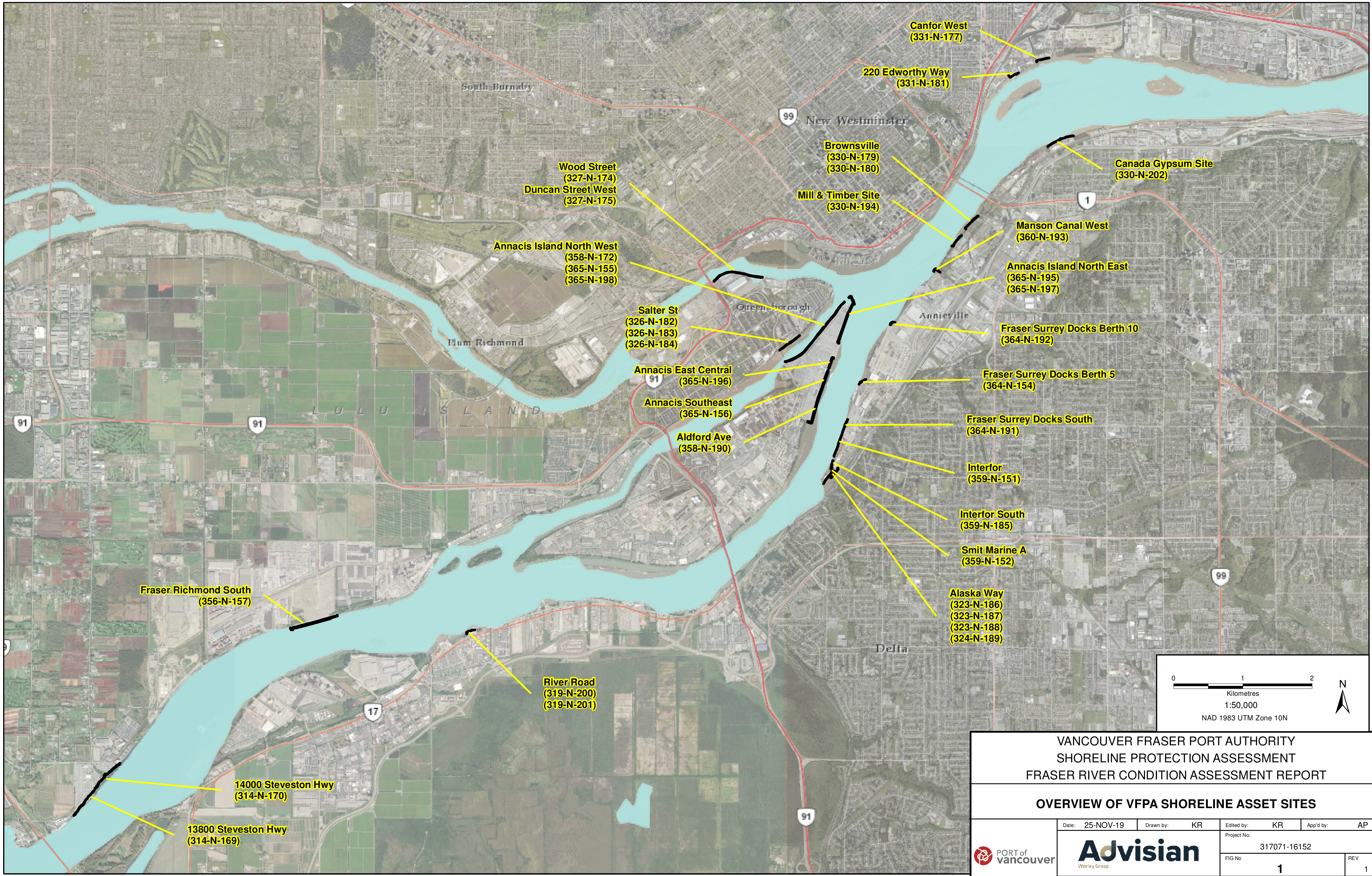
APPENDIX A
VFPA FRASER RIVER ASSETS



VANCOUVER FRASER PORT AUTHORITY
SHORELINE PROTECTION ASSESSMENT
FRASER RIVER CONDITION ASSESSMENT REPORT

OVERVIEW OF VFPA SHORELINE ASSET SITES

Date:	25-NOV-19	Drawn by:	KR	Edited by:	KR	App'd by: AP
PORT of vancouver	Advisian Worley Group			Project No.	317071-16152	
				FIG No	1	REV 1

"This drawing is prepared solely for the use of our customers as specified in the accompanying report. Worley Canada Services Ltd. assumes no liability to any other party for any representations contained in this drawing."

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Sources: Esri, Garmin, USGS, NPS

FILE LOCATION: O:\VFPA_RipRap_Assessment\01_Mxd\Condition_Assessment_Figures\2019-10-16_Fig1_All_Sites_Overview_SiteID_Rev0.mxd

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SAVE DATE & TIME: 25/11/2019 2:30:27 PM