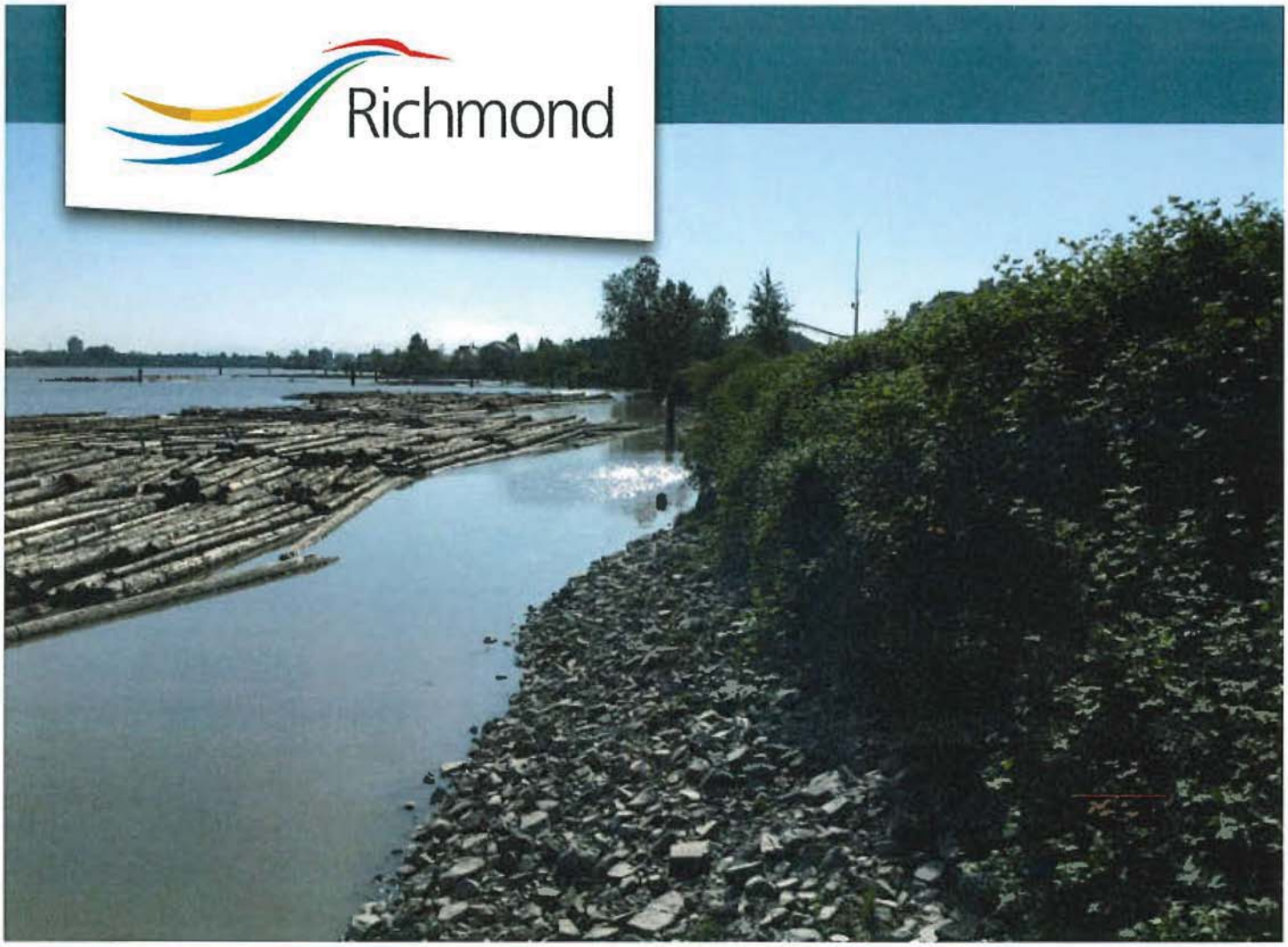
Richmond









Draft Report

Dike Master Plan - Phase 5

November 2018
KWL File No. 0651.129-300

Submitted by:

KERR WOOD LEIDAL
consulting engineers

Contents

Executive Summary i

1. Introduction 1-1
1.1 Background 1-1
1.2 Purpose and Objectives 1-2
1.3 Approach and Methodology 1-2
1.4 Report Format 1-3
1.5 Project Team 1-3

2. Existing Conditions 2-1
2.1 Reaches and Major Features 2-1
2.2 Land Tenure 2-5
2.3 Infrastructure 2-6
2.4 Habitat 2-7

3. Options Assessment 3-1
3.1 Design Considerations 3-1
3.2 Design Criteria 3-7
3.3 Alternative Upgrading Strategies 3-11
3.4 Options and Concepts 3-12
3.5 Stakeholder Engagement 3-23
3.6 Options Evaluation and Selection 3-23
3.7 Cost Opinions 3-29

4. Implementation Strategy 4-1
4.1 General 4-1
4.2 Mitchell Island 4-1
4.3 Sea Island 4-2
4.4 Richmond Island 4-3

5. Reach Summary Sheets 5-1
Mitchell Island 5-2
Sea Island 5-4
Richmond Island 5-6

6. Recommendations 6-1

Report Submission

References

Figures

Figure 1-1: Dike Master Plan Phase Locations 1-5
Figure 1-2: Dike Master Plan Phase 5 Reaches 1-6
Figure 2-1: Existing Land Tenure 2-10
Figure 2-2: Mitchell Island and Richmond Island Existing Ground Elevations 2-11
Figure 2-3: Sea Island Existing Ground Elevations 2-12
Figure 2-4: Existing Fraser River Bathymetry – Mitchell Island 2-13
Figure 2-5: Existing Fraser River Bathymetry – Mitchell Island 2-14
Figure 2-6: Existing Fraser River Bathymetry – Sea Island 2-15
Figure 2-7: Existing Fraser River Bathymetry – Richmond Island 2-16
Figure 3-1: Fraser River Middle Arm Flood Elevations 3-1
Figure 3-2: Option 1A: Build/Raise Standard River Dike and Extend Land-Side 3-2
Figure 3-3: Option 1B: Build/Raise Standard River Dike and Extend River-Side 3-3
Figure 3-4: Option 1C: Build/Raise Dike with Land-Side Retaining Wall 3-4
Figure 3-5: Option 1D: Build/Raise Dike with Sheetpile Wall on River-Side 3-5
Figure 3-6: Option 1E: Build Setback Dike along Cessna Dr. North of BCIT 3-6
Figure 3-7: Option 1E and 1F: Build Setback Dike Along Cessna Dr. 3-7
Figure 3-8: Option 1G: Raise Dike with River-Side Sheetpile Wall and Land-Side Retaining Wall (Interim Option) 3-8
Figure 3-9: Option 2A and 2B: Raise Land 3-9
Figure 3-10: Option 2C: Raise Roadways with Required Land Raising on Private Property (Plan) 3-10
Figure 3-11: Option 2C: Raise Roadways with Required Land Raising on Private Property (Road Typical Section) 3-11
Figure 3-12: Option 2C: Raise Roadways with Required Land Raising on Private Property (Riverbank Section) 3-12
Figure 3-13: Option 3: Install/Maintain Bank Protection Works Only 3-13
Figure 3-14: Phase 5 Dike Master Plan Recommended Upgrade Options 3-14

Tables

Table 2-1: Phase 5 Reaches and Features 2-3
Table 2-2: Existing Flood and/or Erosion Covenants 2-6
Table 2-3: Phase 5 Pump Stations and Locations 2-6
Table 2-4: Environmental Values 2-9
Table 3-1: Ideal Dike Design Principles and Considerations 3-2
Table 3-2: City of Richmond ESA Type Management Objectives 3-6
Table 3-3: Phase 5 Design Criteria Summary 3-8
Table 3-4: Phase 5 Flood Levels and Dike Crest Elevations 3-9
Table 3-5: Proposed Alternative Seismic Performance Criteria 3-10
Table 3-6: High-level Dike Upgrading Strategies 3-11
Table 3-7: Major Dike Alignment and Cross-section Options 3-12
Table 3-8: Significant Space Limitations and Access Issues 3-14
Table 3-9: Recommended Dike Upgrading Options (Phase 5) 3-24
Table 3-10: Summary of Construction Costs ($ in Millions) 3-30

Appendices

Appendix A: Plans and Sections for Richmond Dike Master Plan Phase 5
Appendix B: Geotechnical Engineering Analysis Report (Thurber)

Executive Summary

The City of Richmond uses a Dike Master Planning program to guide future dike upgrading projects, and to ensure that land development adjacent to the dike is compatible with flood protection objectives. The program includes 4 phases for the 49 km of the Lulu Island perimeter dike in Richmond and an additional 5th phase for Sea Island, Mitchell Island, and Richmond Island. The goal is to raise the dikes to 4.7 m CGVD28 to allow for 1 m of sea level rise and 0.2 m of land subsidence, while allowing for further upgrading in the future. The vision is to provide the City with a world-class level of flood protection to keep pace with the rapidly growing population and assets within the dikes.

Phase 5 covers Sea Island, Mitchell Island, and Richmond Island. The Sea Island 15 km perimeter ring dike is shared with Vancouver Airport Authority (YVR), with the City managing a 1.1 km section south of the Moray Channel Bridge plus three road rights-of-way through the YVR sections of the dike. Mitchell Island is not currently protected by a dike, although most of the island is above 2.5 m CGVD28. Richmond Island is a single property that is above the floodplain with flood protection responsibility remaining with the property owner.

This report describes existing conditions, develops an ideal vision for dike upgrading, presents design criteria, identifies options for dike upgrading, and presents recommended dike upgrading options that appropriately address the challenges. This work can be used as a basis for design of dike upgrading projects, recognizing that site-specific refinement of recommended options will be required in some areas. This work can also be used to assist with land use planning activities along the dike corridor. The main features of the recommended options to dike upgrading in Phase 5 are described below.

Mitchell Island

- Raise all land on the island above flood levels including private property and roadways.
- Raise all roadways to dike elevation to provide emergency egress (consider partial raises in low areas).
- During redevelopment, require private properties to be raised to dike elevation and acquire rights-of-way along the river bank. Such rights-of-way will allow for a future dike and/or bank protection works.
- Work with low elevation properties in the short term to mitigate flood and associated contamination risks.

Sea Island

- Widen the dike on the land side rather than into the Fraser River Middle Arm. Retaining walls or extending the dike towards the riparian area may be considered in site-specific constrained areas.
- Coordinate upgrades to the dike with upgrades to Miller Road Pump Station and the Moray Channel Bridge.
- As an interim measure along the Pacific Gateway Hotel, raise the dike to 4.7 m CGVD 28 with a sheetpile wall embedded along the river bank and a land-side retaining wall, until the site redevelops.
- Coordinate dike improvements with YVR and establish agreed upon dike jurisdictions.

Richmond Island

- No changes by the City are proposed as the island is almost entirely above the future dike elevation (5.5 m CGVD28). Flood protection responsibility is recommended to remain with the property owner.

For all phases of the Dike Master Plan, the City should continue to research alternative densification strategies for seismic stability, consider the proposed alternative seismic performance criteria in Section 3.2, and plan to fill land for approximately 200 m inland of the dike to dike elevation. The required fill distance requires additional evaluation and may be addressed in the pending update to the Flood Protection Management Strategy.

1. Introduction

Flood protection in Richmond is guided by the City's 2008-2031 Flood Protection Strategy which includes a comprehensive suite of measures including structural measures (e.g. dikes and pump stations), non-structural measures (e.g. flood construction levels), and flood response and recovery plans.

Dike Master Plans are critical components of the City's 2008-2031 Flood Protection Strategy and are used to guide the implementation of long-term dike upgrades.

The City of Richmond (City) has retained Kerr Wood Leidal (KWL) to prepare the Richmond Dike Master Plan Phase 5.

Phase 5 encompasses the islands on the north side of Lulu Island within the City of Richmond, along the Fraser River North Arm. This includes Richmond Island, Mitchell Island, and Sea Island (primarily under Vancouver Airport Authority (YVR) jurisdiction). These are three distinct islands that require consideration of separate constraints and opportunities, independent of each other, but within the overall context of the Dike Master Plan. Figure 1-1 presents the extent of the City's Dike Master Plan phases and existing ground elevation, based on Emergency Management BC (EMBC) 2016 LiDAR. Figure 1-2 shows the reaches of the Phase 5 Dike Master Plan.

1.1 Background

Richmond has a population of about 220,000 and is situated entirely on islands within the overlapping Fraser River and coastal floodplains (Lulu Island, Sea Island, Mitchell Island, Richmond Island). The City's continued success is due in part to its flat, arable land and its strategic location at the mouth of the Fraser River and on the seashore. The low elevation of the land and its proximity to the water comes with flood risks.

As Richmond is fully situated within the river/coastal floodplain, there is no option to locate development out of the floodplain. The continued success of the City depends on providing a high level of structural and non-structural flood protection measures. Without continued improvements, the flood risk within the City would progressively rise as a result of rising flood levels (due to climate change), subsiding land, and increasing development.

The 2008-2031 Flood Protection Strategy guides the City's flood risk reduction activities across the City's organizational structure and across the spectrum of structural and non-structural flood protection measures. The Flood Protection Strategy is currently in the process of being updated.

While Lulu Island is the most populous and developed Richmond island, Mitchell Island and Sea Island are also very important to the success of Richmond and the region. Mitchell Island and Sea Island are economic and employment hubs with light to medium industrial uses on Mitchell Island and the Vancouver International Airport and associated industries located on Sea Island. There is also a residential community (Burkeville) located on Sea Island. Richmond Island is currently occupied by a single business operating a marina and a pub.

1.2 Purpose and Objectives

The purpose of the Dike Master Plan is to guide the implementation of dike upgrades and provide a starting point for the City to work with proposed developments adjacent to dikes. Unlike the previous Dike Master Plan phases, which focus on the Lulu Island perimeter dike, Phase 5 focuses on areas outside of Lulu Island, including both diked and undiked islands. In diked areas (Sea Island), the Phase 5 Dike Master Plan will focus on upgrading of the City's portion of the existing perimeter dike. In undiked areas (Mitchell Island and Richmond Island), alternative flood protection strategies may be warranted, such as land raising or relying only on non-structural measures (Flood Construction Levels (FCLs), covenants, flood insurance).

The master plan defines the City's preferred and minimum acceptable structural flood protection works upgrading concepts (dikes, land raising, erosion protection). The Dike Master Plan facilitates the City's annual dike upgrading program by providing critical information for the design of dike upgrades, including:

- general design concept;
- alignment;
- typical cross-section (conceptual design);
- footprint and land acquisition and tenure needs;
- design and performance criteria;
- infrastructure changes required for dike upgrading/construction;
- operation and maintenance considerations;
- environmental features and potential impacts;
- social and public amenity considerations;
- guidance for future development adjacent to the dike; and
- guidance on interaction with other structural flood protection measures (e.g. secondary dikes).

The Dike Master Plan is intended to guide dike upgrading over the next 20 to 30 years.

Other flood protection measures, including non-structural measures, are addressed in the City's 2008-2031 Flood Protection Strategy.

1.3 Approach and Methodology

The Dike Master Plan has been developed using a 5-step approach presented and described below.



Define: Confirm Dike Master Plan objectives and design/performance criteria.

Understand: Collect and compile relevant information, including spatial data and background reports from the City and several other parties (Vancouver Airport Authority, provincial regulators, the port, etc.).

Assess: Develop dike upgrading options and identification of constraints and potential impacts. Desktop and field review of options with City staff to identify preferred options.

Consult: Present to and gather feedback from council and stakeholders on preferred options.

Refine: Develop the master plan informed by consultation and review by the City.

The scope for the Dike Master Plan includes the following main tasks:

- goals and objectives development;
- background data collection and review;
- design criteria development and identification of constraints;
- options development and review;
- site visits;
- drainage impacts assessment;
- desktop habitat mapping and impacts review;
- geotechnical assessment;
- public amenity review;
- stakeholder consultation; and
- report preparation.

1.4 Report Format

This report is organized as follows:

- The executive summary provides a high-level overview of the master plan and key features;
- Section 1 introduces the master plan context and process;
- Section 2 documents the existing conditions;
- Section 3 documents the options development and assessment, and presents the recommended options;
- Section 4 provides implementation strategy, including costs, phasing, and coordination;
- Section 5 is a compilation of 2-page summary sheets highlighting existing conditions and key features of the preferred option for each reach; and
- Section 6 provides general and reach specific recommendations for next steps and implementation.

Appendix A provides figures showing conditions along the existing dike alignment, and the preliminary design footprint for a number of upgrading options discussed in Section 3.

1.5 Project Team

The KWL project team includes the following key individuals:

- Colin Kristiansen, P.Eng., MBA – Project Manager;
- Mike Currie, M.Eng., P.Eng., FEC – Senior Engineer and Technical Reviewer;
- Amir Taleghani, M.Eng., P.Eng. – Water Resources Engineer;
- Allison Matfin, EIT – Project Engineer
- Laurel Morgan, M.Sc., P.Eng., P.E. – Drainage Engineer;
- Daniel Brown, B.Sc., B.Tech., BIT – Project Biologist; and
- Jack Lau - GIS/CAD Analyst.

This report was primarily written by Allison Matfin with direction from Amir Taleghani. The report was reviewed by Mike Currie and Colin Kristiansen.

Thurber Engineering Ltd. (Steven Coulter, M.Sc., P.Eng.) provided geotechnical engineering services.

The project was guided on behalf of the City by:

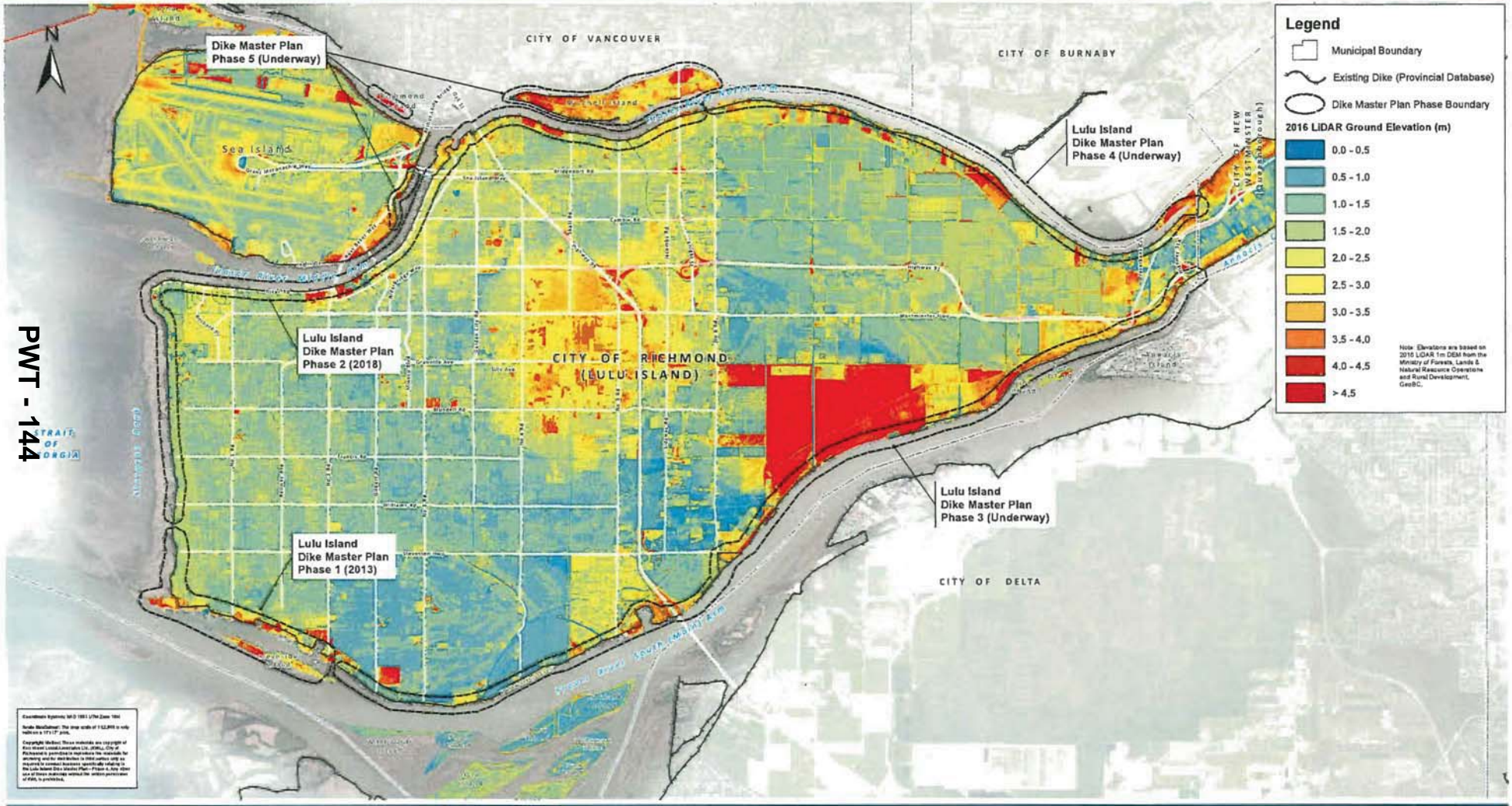
- Lloyd Bie, P.Eng. – Manager, Engineering Planning; and
- Corrine Haer, P.Eng. - Project Engineer, Engineering Planning.

Many additional City staff contributed to the project during workshops, site visits, and in reviewing draft report materials.

Path: O:\0600-0699\651-122\430-GIS\MXD-Rp\Phase5\651122_Phase5_Fig1-1_DikeMasterPlanPhases.mxd Date Saved: 9/26/2018 10:04:53 AM | Author: jbu

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL
consulting engineers



PWT - 144

Project No. 651.129
Date October 2018
Scale 1:62,000
1,000 500 0 1,000 m

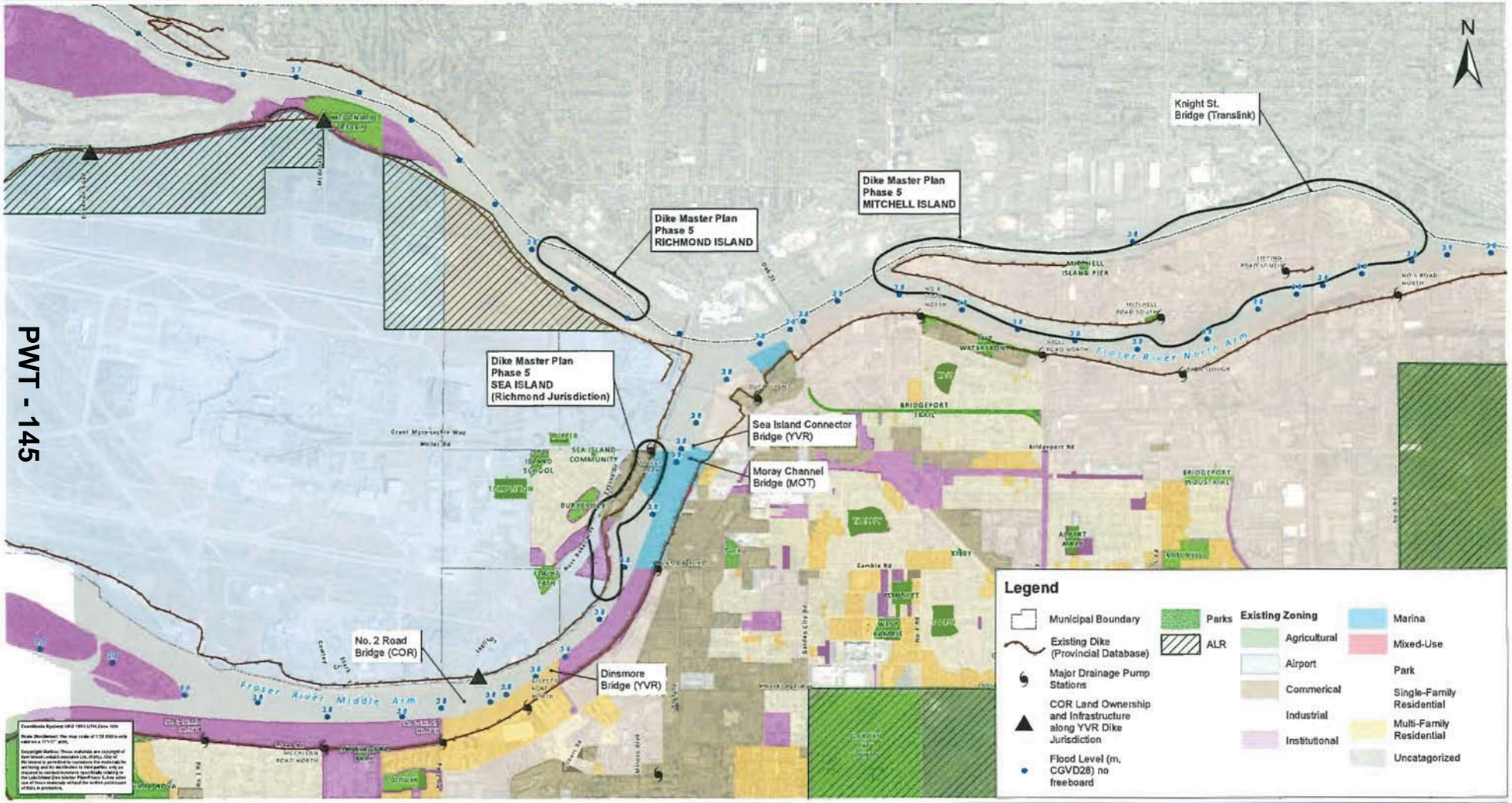
Dike Master Plan Phases

DRAFT
Figure 1-1

Path: O:\0600-0699\651-122\430-GIS\MXD-Rpt\Phase5\651122_Phase5_Fig1-2_DMP_Phase_Reach.mxd Date Saved: 11/20/2018 1:42:54 PM | Author: jlau

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL consulting engineers



Project No. 651-129
Date November 2018
Scale 1:25,000

400 200 0 400 m

Phase 5 Dike Master Plan Study Area

DRAFT
Figure 1-2

2. Existing Conditions

This section summarizes the options development process undertaken, including the following components:

- review of existing conditions;
- design considerations;
- upgrading strategies; and
- preferred options and concepts.

2.1 Reaches and Major Features

Mitchell Island, Sea Island, and Richmond Island are unique areas with varying types and degrees of flood protection. Mitchell Island has an old and unmaintained private dike along the western extent, with areas of private erosion protection and small sections of sheetpile elsewhere on the island. Conversely, Richmond Island has no flood protection works, though private bank protection works is in place. Sea Island is protected by an approximately 15 km long perimeter dike, though diking responsibility largely rests with the Vancouver Airport Authority (YVR) with one eastern reach as the City's responsibility. As a result, these three distinct islands require consideration of separate constraints and opportunities, independent of each other, but within the overall context of the Dike Master Plan.

Phase 5 is divided by Island as each Island has relatively uniform conditions with several locations with unique constraints. Islands/reaches are presented on Figure 1-2.

The sections below and Table 2-1 describe the existing conditions and features of each island. Mitchell Island may need to be further subdivided for future dike upgrading implementation phasing.

Appendix A provides a set of figures showing the existing dike alignment, proposed standard dike raise/construction, adjacent land tenure, municipal infrastructure, and existing habitat.

Reach 1 - Mitchell Island

Mitchell Island was created by filling in the river between three separate islands (Twigg, Eburne, and Mitchell Islands).

Mitchell Island is densely developed with industrial and commercial businesses, and some residences that are not in compliance with current zoning. The City's Official Community Plan (OCP) indicates that Mitchell Island will be maintained as industrial and commercial zoning, to preserve space in the City for these types of economic activities. A private dike was constructed on the western end of Mitchell Island many decades ago and was passed to the City by the Province of British Columbia (the Province); however, the dike has been unmaintained and uninspected and is no longer apparent on the island. The elevation of the island ranges from 2.5 to 4.5 m CGVD28 generally, and private bank protection works and sheetpile walls are in place in many locations.

Implementing structural flood protection works on Mitchell Island would have a significant impact on the existing conditions, as no access or rights-of-way currently exists for the City to complete these works. However, flood protection for Mitchell Island is beneficial as not implementing flood protection would result in economic loss for the region, risk public life at current residences, and could result in contamination from flooding of industrial sites.

Reach 2 - Sea Island

Sea Island has an existing perimeter dike that is largely under the responsibility of YVR. Only one eastern reach is under the City's responsibility, from the Moray Channel Bridge to the southern property boundary of BCIT (approximately 1.1 km). The exact extent boundaries are not clearly defined, and the City and YVR are expected to discuss agreed upon boundaries as part of the consultation for the Phase 5 Dike Master Plan. Dike crest elevation in this reach ranges from 4.7 m to as low as 2.7 m CGVD28 and is set back from the river in a few locations. Little to no bank protection is in place, and ongoing knotweed treatment is resulting in damage to the river bank near the setback dike. The current dike alignment ties into the Moray Channel Bridge, owned by the City of Richmond. Based on 2016 EMBC LiDAR data, the bridge deck on Sea Island is below 4.7 m CGVD28 and would not be sufficient for dike upgrades. The dike borders four large commercial lots with major transportation corridors and the community of Burkeville located behind the commercial areas.

The City also owns the land the dike traverses at McDonald Beach Park road, the No. 2 Road Bridge, and Shannon Road, though YVR is responsible for the dike in these locations. In addition to these noted locations of Richmond ownership with YVR dike responsibility, there may be additional locations where Richmond owns the land the dike crosses (such as Grauer Road or Ferguson Road). This mixed ownership and uncertainty is the result of historic proposed and completed land exchanges with the federal government on Sea Island, as part of the development of the airport. The Phase 5 Dike Master Plan is not expected to resolve long-standing land ownership uncertainties on Sea Island; however, known locations of Richmond ownership will be noted in the final report and consultation may contribute to the process of resolving dike land ownership.

Reach 3 - Richmond Island

No existing dike is in place on Richmond Island. The only flood protection works is riprap bank protection works along the southern bank. The total perimeter of Richmond Island is approximately 1.2 km. The land elevation of Richmond Island ranges from 6.4 m CGVD28 at the north end to 3.4 m CGVD28 at the south end, where the Island is connected to the City of Vancouver. The entire island is one lot leased by Milltown Marina & Boatyard Ltd. which includes a restaurant, marina, and private utilities. Richmond Island is not included in the current OCP.

A covenant[1] was created in November 27, 2012 with North Fraser Terminals Inc., the Milltown Marina & Boatyard Ltd., and the City of Richmond that:

- acknowledges the risk of flooding and erosion on Richmond Island;
- notes that the City has no plans to protect the island from flood and erosion; and
- releases the City from any damage or losses caused by flooding or erosion.

As a result of the terms of this covenant, the City may consider implementing no flood protection measures for Richmond Island.

[1] CA2885848. RCVD: 2012-11-27.

Table 2-1: Phase 5 Reaches and Features

Reach ID and Name	Extent / Length	Existing Dike Alignment	Major Features
1- Mitchell Island	Entire Island (7.8 km perimeter)	None	• Condition and elevation of existing dike and bank protection on western half of Mitchell Island is unknown (no available background information, no inspections or maintenance) • Dense industrial development on the entire island • Mitchell Road South Drainage Pump Station • Tipping Road South Drainage Pump Station • Large number of industries and businesses as stakeholders • Active water lots used by industry • Two City watermains to Mitchell Island from Lulu Island • Metro Vancouver Twigg Island Forcemain underneath existing dike on north side • Land elevation generally between 2.5 m and 4.5 m CGVD28 but as low as 1.5 m CGVD28 • Intermittent bank protection works in some locations • Two City parks along the river bank, no other public access to the river bank • Bathymetry suggests potential scour on the foreshore and scour holes on the north side
2 - Sea Island	South end of BCIT to south side of Airport Connector Bridge (1.1 km)	Walking and cycling trail	• Dike is a pedestrian path • Miller Road Drainage Pump Station • Commercial development directly abuts existing dike in several locations • Marina and restaurant access on the river-side • Tie in and jurisdiction boundaries with YVR adjacent to the Airport Connector Bridge and South of BCIT • Lowest area of dike north of Lysander Lane (<3.5 m CGVD28 elevation) • Low area directly adjacent to Cessna Drive with no established dike right-of-way • One section of dike already upgraded to 4.7 m CGVD28 elevation at 3600 Lysander Lane • Drainage outfall with flap gate at North end of BCIT campus not identified in City drainage utilities

Reach ID and Name	Extent / Length	Existing Dike Alignment	Major Features
			• Sanitary forcemain crossing near BCIT • Little to no bank protection • High value marsh habitat from BCIT to hotel • North of BCIT, there is an old water connection to the foreshore where industrial activity used to take place on the river • The Moray Channel Bridge that the dike currently connects to is below 4.7 m CGVD28 (based on 2016 EMBC LiDAR).
3 - Richmond Island	Entire Island (0.55 km length)	None	• No existing dike • Connected to City of Vancouver via a short causeway, which provides utilities from Vancouver • Majority of the land is higher than the current dike elevation of 4.7 m CGVD28 and future elevation of 5.5 m CGVD28. The only exception is the causeway to Vancouver. • Existing private bank protection works visible on the south side • The north arm of the Fraser River along Richmond Island is a location of channel scour, with elevations as low as -11 m CGVD28. • All of the land on Richmond Island is one lot and is owned by Milltown Marina Moorage Co Ltd. • Restrictive covenant in place as of 2012 (CA2885848): ○ *"the City currently does not have any plans to install a Dike system on or near the Lands or to otherwise protect the lands from flooding and/or erosion."*

2.2 Land Tenure

Land tenure on each island in Phase 5 includes a mixture of rights-of-way, private property, and City-owned land. Flood and erosion covenants have been established in the past for various properties in Phase 5, which are summarized in Table 2-2. Land tenure along the river bank or existing dike is described below for each island and shown on Figure 2-1.

Mitchell Island

Though a private dike was constructed in the past, no land tenure is established on Mitchell Island for a dike. The majority of the river bank is located on either private property or on aquatic Crown land (designated as Fraser River foreshore) where the City has no existing right-of-way. The City owns land along the river bank at two-small parks and at the Knight Street Bridge off-ramps, and there is a short right-of-way immediately west of the Knight Street Bridge on the south side of the island.

Sea Island

Sea Island is protected by an approximately 15 km long perimeter dike, but diking responsibility largely rests with the Vancouver Airport Authority (YVR). Only one eastern reach is under the City's responsibility, from the Moray Channel Bridge to the southern property boundary of BCIT (approximately 1.1 km). The exact extent boundaries are not clearly defined, and the City and YVR are expected to discuss agreed upon boundaries as part of the consultation with YVR for the Phase 5 Dike Master Plan. An active right-of-way is in place from BCIT to Lysander Lane, with one gap north of BCIT, but there is no right-of-way north of Lysander Lane.

The City also owns the land the dike traverses at McDonald Beach Park road, the No. 2 Road Bridge, and Shannon Road, though YVR is responsible for the dike in these areas. In addition to these noted locations of Richmond ownership with YVR dike responsibility, there may be additional locations where Richmond owns the land the dike crosses (such as Grauer Road or Ferguson Road). This mixed ownership and uncertainty is the result of historic proposed and completed land exchanges with the federal government on Sea Island, as part of the development of the airport. The Phase 5 Dike Master Plan is not expected to resolve long-standing land ownership uncertainties on Sea Island, however consultation may contribute to the process of resolving dike land ownership.

Richmond Island

Richmond Island has no existing land tenure in favour of the City (ownership or right-of-way). Richmond Island is one lot owned by North Fraser Terminals Inc., which is leased by Milltown Marina & Boatyard Ltd. The development is connected to the City of Vancouver and its utility network.

A covenant[2] was created in November 27, 2012 with North Fraser Terminals Inc., the Milltown Marina & Boatyard Ltd., and the City of Richmond that:

- acknowledges the risk of flooding and erosion on Richmond Island;
- notes that the City has no plans to protect the island from flood and erosion; and
- releases the City from any damage or losses caused by flooding or erosion.

[2] CA2885848. RCVD: 2012-11-27.

Flood and Erosion Covenants

The City provided a title and covenant information for properties along the Phase 5 dike sections under their authority. This information was provided to the City by Dye and Durham. The following table summarizes the covenants that pertain to flood and erosion protection, for future awareness and consideration while developing flood protection works.

Table 2-2: Existing Flood and/or Erosion Covenants

Covenant ID	Date Established	PIDs	Address
Mitchell Island			
BB2020219	2012/08/22	None	11060 & 11200 Twigg Place
BK187446	1996/06/17	003-684-539 003-684-547 003-684-652 003-684-687	Group 1 New Westminster District Lots: 528, 5587, 1014, 459, 5091, 5782
BP304365	2000/12/19	008-591-857	Group 1 New Westminster District Lots 459, 1014
BX10111	2005/09/06	003-679-837	Group 1 New Westminster District Lot 459
Sea Island			
BB843923	2006/03/25	017-560-616	3800 Cessna Drive
CA3630774	2014/03/13	None	3600 Lysander Lane
CA3630776	2014/03/13	026-601-621	3600 Lysander Lane
Richmond Island			
CA2885848	2012/11/27	025-409-018 003-335-232	Richmond Island and Group 1 New Westminster District Lots 3869 and 3871

2.3 Infrastructure

There is limited municipal infrastructure along the existing dike corridor / island perimeters. This includes pump stations summarized in the table below.

Table 2-3: Phase 5 Pump Stations and Locations

Pump Station	Location
Miller Road	Sea Island - North end of City reach
Tipping Road South	Mitchell Island – South end of Tipping Road
Mitchell Road South	Mitchell Island – South end of Mitchell Road

On Mitchell Island, there may be private infrastructure associated with industrial uses, particularly water-oriented industries, which may conflict with potential diking options. This will be explored through stakeholder consultation.

2.4 Habitat

Desktop Review

A desktop review was conducted the ecological setting along and adjacent to the existing dikes in Phase 5. The study area includes the existing dike alignment and adjacent land or intertidal area. Spatial data were used to identify overlap of known environmental values with the study area.

Spatial data reviewed in the desktop study includes:

- Fraser River Estuary Management Program mapping (FREMP 2012, 2007) mapping used to identify riparian and intertidal habitat types and quality,
- iMapBC web application (iMapBC 2017), and
- City of Richmond aerial photographs and Riparian Area Regulation 5 m and 15 m buffer layers (Richmond Interactive Map 2017).

For the purposes of the desktop review, and to allow for a concise description of the different habitat types in the locations within the Phase 5 study area, seven discrete focal areas were defined. Results of the desktop review are presented below and listed by focal area in Table 2-3.

The location and extent of high-quality Fraser River riparian and intertidal habitat were identified to inform the development of dike upgrade options and their potential impacts. FREMP habitat polygons were assigned the following categories: high quality riparian, high quality intertidal, or other. Deciduous tree woodland polygons were categorized as high-quality riparian habitat because these communities provide cover and nutrients to fish using nearshore habitat. Mud, sand, and marsh polygons were categorized as high-quality intertidal habitat because of the foraging and nesting habitat they provide for bird species and the foraging, egg deposition and rearing habitat they provide for fish species. Aquatic and riparian habitat on the land side of the existing dike was identified and mapped using the Riparian Area Regulation buffer layers and interpretation of recent aerial photography (City of Richmond 2017).

Aquatic and Riparian Habitat

High quality intertidal and riparian habitat is present in all three Phase 5 reaches on the Fraser River side of the dike. This important habitat provides forage and cover habitat as well as a staging area for anadromous salmonids transitioning from saltwater to freshwater. Conversely, armoured sections of shoreline on the Fraser River side of the existing dike are present in Reaches 1 and 3. These sections provide limited habitat value and construction here would have less of a negative impact on fish.

Seven fish habitat compensation projects have been completed between 1988 and 2007 in the Phase 5 study area. These included the creation of intertidal marsh and mudflat habitat and riparian habitat to compensate for damage to habitat elsewhere. More information on these compensation projects is provided in Table 2-4.

Wildlife and Terrestrial Habitat

Terrestrial habitat types in Phase 4 include deciduous tree woodland, tall shrub woodland, low shrub woodland, and vascular plant meadow, as well as uncategorized sections (e.g. paved lots; FREMP 2007). These habitat types have potential to provide nesting habitat to migratory birds in all six reaches of Phase 4. Orthoimagery review identified potential raptor nesting trees in all three reaches of the Phase 5 study area.

Drainage channels that may serve as amphibian breeding habitat were not identified in orthoimagery used for the desktop review. It is possible that amphibian habitat is present in small ponds or ditches along the dike that were not identified in the desktop review.

Species and Ecological Communities at Risk

No known occurrences of terrestrial wildlife species at risk are present in the Phase 5 study area, but several occurrences exist on nearby islands in the Fraser River or on the river banks across from Richmond. It is possible that individuals of these species also occur on the Richmond side of the Fraser River. The Lower Fraser River population of White Sturgeon (*Acipenser transmontanus* pop. 4) is known to occur in the Fraser River next to the dike. Mapped critical habitat for at-risk species is not present within 500 m of the Phase 5 study area.

FREMP mapping (2007) indicates the presence of intertidal marsh communities in Reaches 2 and 3. Many of these communities in British Columbia are considered at-risk (i.e. Blue-Listed; special concern, or Red-Listed; threatened, or endangered). No ecological communities at-risk are shown in either the study area on BC iMap (2017), but it is likely that some are present.

Table 2-4 presents the findings of the desktop review on a reach-by-reach basis and separates Fraser River side results from land-side results.

Table 2-4: Environmental Values

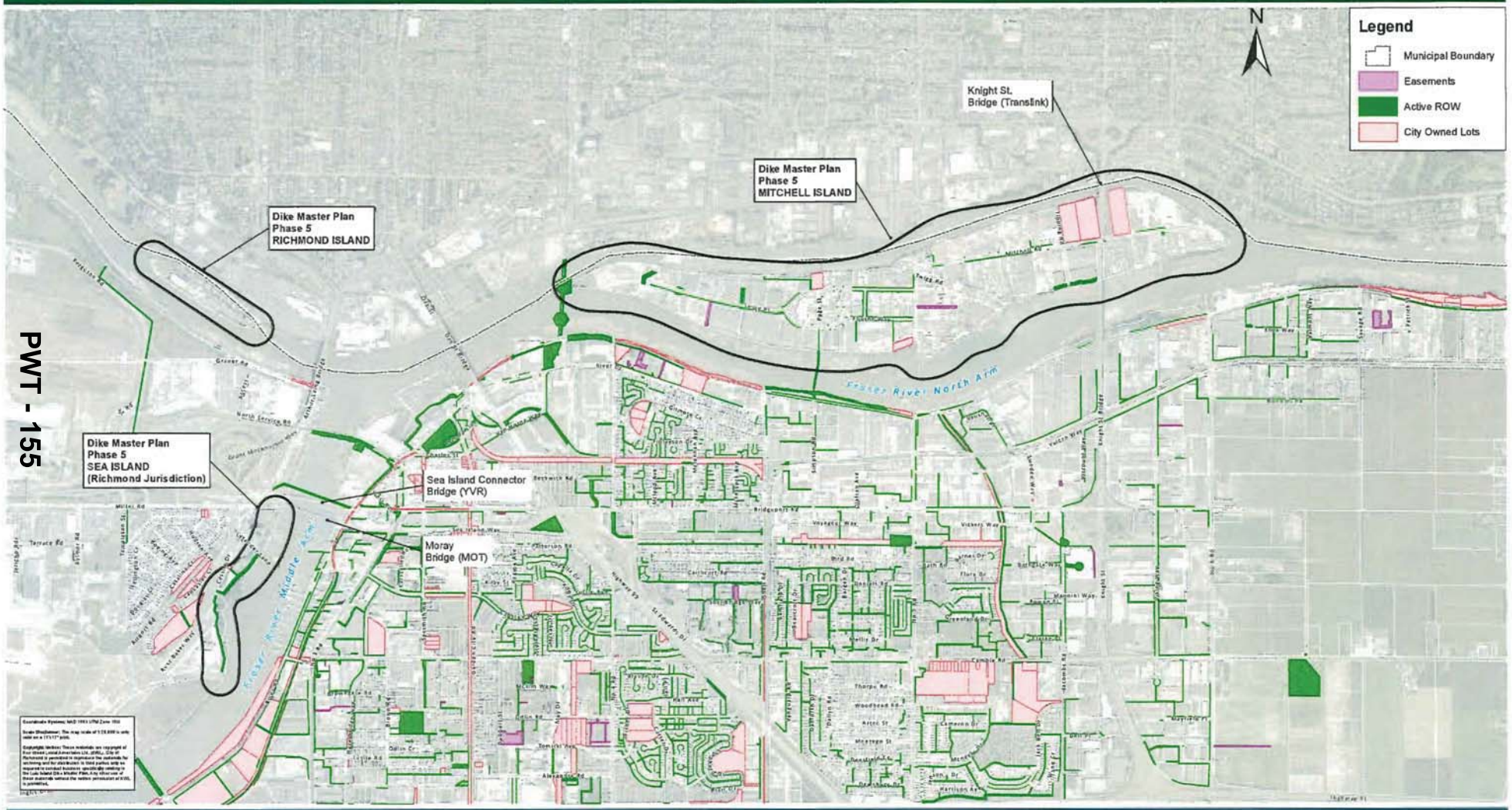
Reach ID and Name	Location	Environmental Setting (organized by inland side and shoreline side of existing dike)	Construction Constraints	Construction Opportunities	FREMP Habitat Types	Known Species at Risk Occurrence Near Dyke Alignment	Potential Raptor Nesting Trees	Potential Migratory Bird Nesting Habitat	Existing Habitat Compensation Sites Present
1 - Mitchell Island	Inland Side	• Low-quality herbaceous habitat at the west end of the island • Small patch of deciduous treed woodland near centre of south side • Sections with no existing dike • Low quality disturbed habitat or paved (no habitat value) along rest of reach	Existing infrastructure Existing habitat compensation site	n/a	Paved Vascular meadow Deciduous tree woodland	White Sturgeon (Lower Fraser River population) (Acipenser transmontanus pop. 4)	Y	Y	Project: Canada Line Year Created: 2005 Industrial development Year Created: 2007 McQueen's Boat Works Year Created: 1989 Project: Miller Road Pump Station Year Created: 1991 Bridgeport Market Year Created: 1988 Project: Arrow Transportation Soil Remediation Year Created: 2007
	Fraser River Side	• High quality deciduous tree riparian habitat in patches along length north side of island • Moderate quality low shrub riparian habitat for most of length north side of island • Sections of moderate quality riparian habitat along south-east side of island (low shrub woodland, deciduous tree woodland) • Sections of high quality mudflat and sandflat intertidal habitat along north and south sides of island • High quality intertidal marsh, on southwest side of island • Low quality armored bank along south west side of island	Moderate-quality riparian along most of length of shoreline on north side of island High-quality intertidal habitat along majority of length of shoreline	n/a	Paved Mud Sand Marsh Gramonoids and forbs Vascula meadow Low shrub woodland Tall shrub woodland Deciduous tree woodland				
2 -Sea Island	Inland Side	• Sections of low quality lawn • Sections of paved parking lots with no habitat value	Existing infrastructure	n/a	Mowed grass Mostly parking lot	White Sturgeon (Lower Fraser River population) (Acipenser transmontanus pop. 4)	Y	Y	
	Fraser River Side	• Sections high quality marsh and mudflat intertidal habitat concentrated around centre of reach • High quality deciduous woodland riparian habitat at south half of reach	High-quality riparian and intertidal habitat in centre of reach Existing habitat compensation site at north end of reach	n/a	Mud Marsh Deciduous tree woodland Shoreline in front of Marina not included in FREMP mapping				
3 - Richmond Island	Inland Side	• No existing dike	No existing dike	n/a	Not included in FREMP mapping	White Sturgeon (Lower Fraser River population) (Acipenser transmontanus pop. 4)	Y	Y	Project: Canfor Year Created: 1988
	Fraser River Side	• High quality mudflat intertidal habitat along full length on north side • Moderate quality low shrub woodland riparian habitat above armoured bank on south side low quality armoured bank along full length of south side	High-quality intertidal habitat along full length north side Moderate-quality riparian habitat along south side Existing habitat compensation site	n/a	Mud Low shrub woodland Sand				

PWT - 154

Path: O:\0600-0699\651-122\430-GIS\MXD-Rp\Phase5\651122_Phase5_Fig2-1_ExistingLandTenure.mxd Date Saved: 10/17/2018 10:11:59 AM | Author: jlau

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL
consulting engineers



PWT - 155

Project No. 651-129
Date October 2018
Scale 1:20,000

500 250 0 500 m

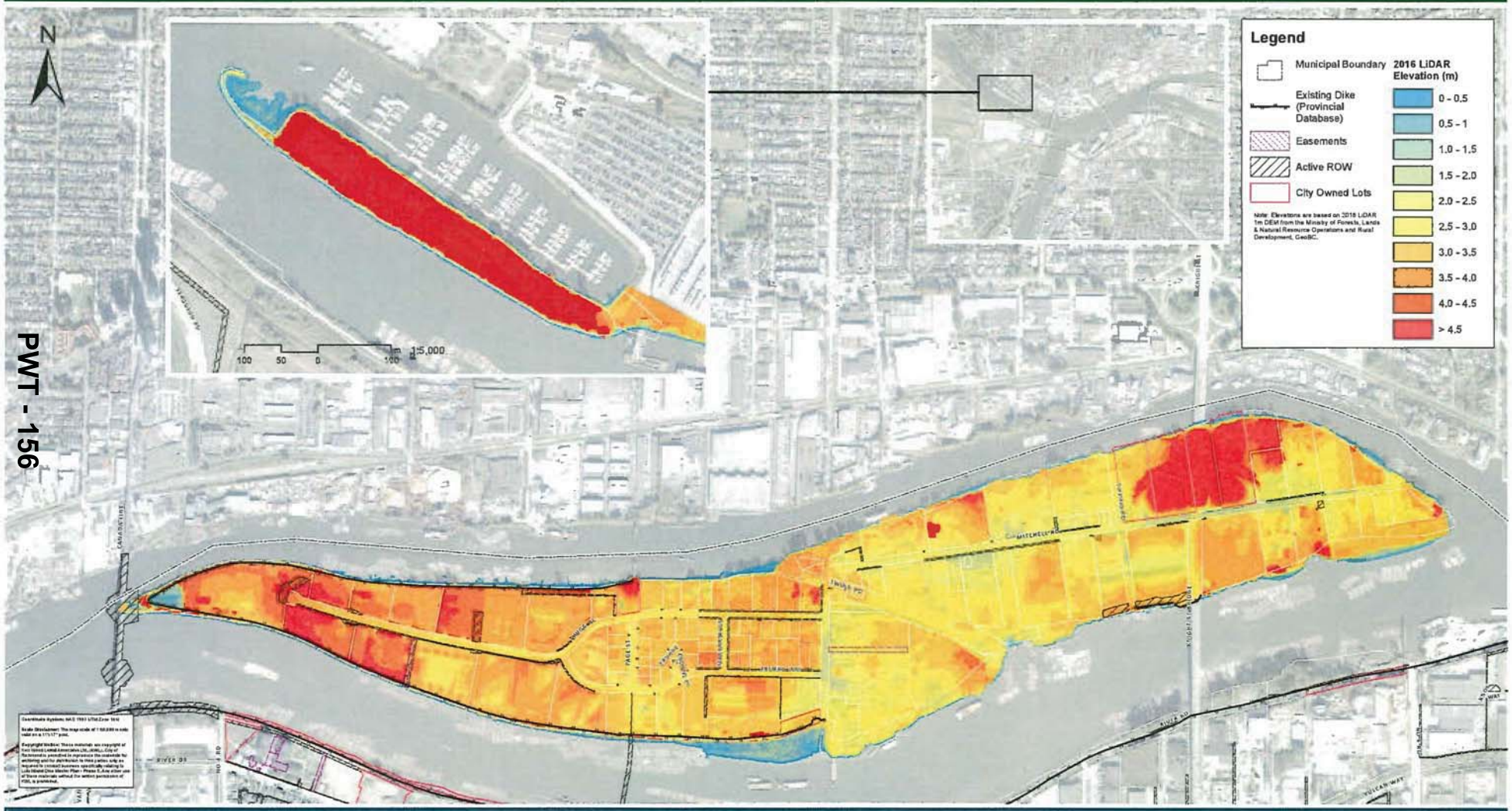
Existing Land Tenure

DRAFT
Figure 2-1

Path: O:\0600-0699\651-122\430-GIS\MXD-Rpt\Phase5\651122_Phase5_Fig2-2_Surface_Mapping_Mitchell_Richmond.mxd Date Saved: 9/26/2018 10:06:02 AM | Author: jlau

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL consulting engineers



PWT - 156

Project No. 651.129
Date October 2018
Scale 1:10,000
200 100 0 200 m

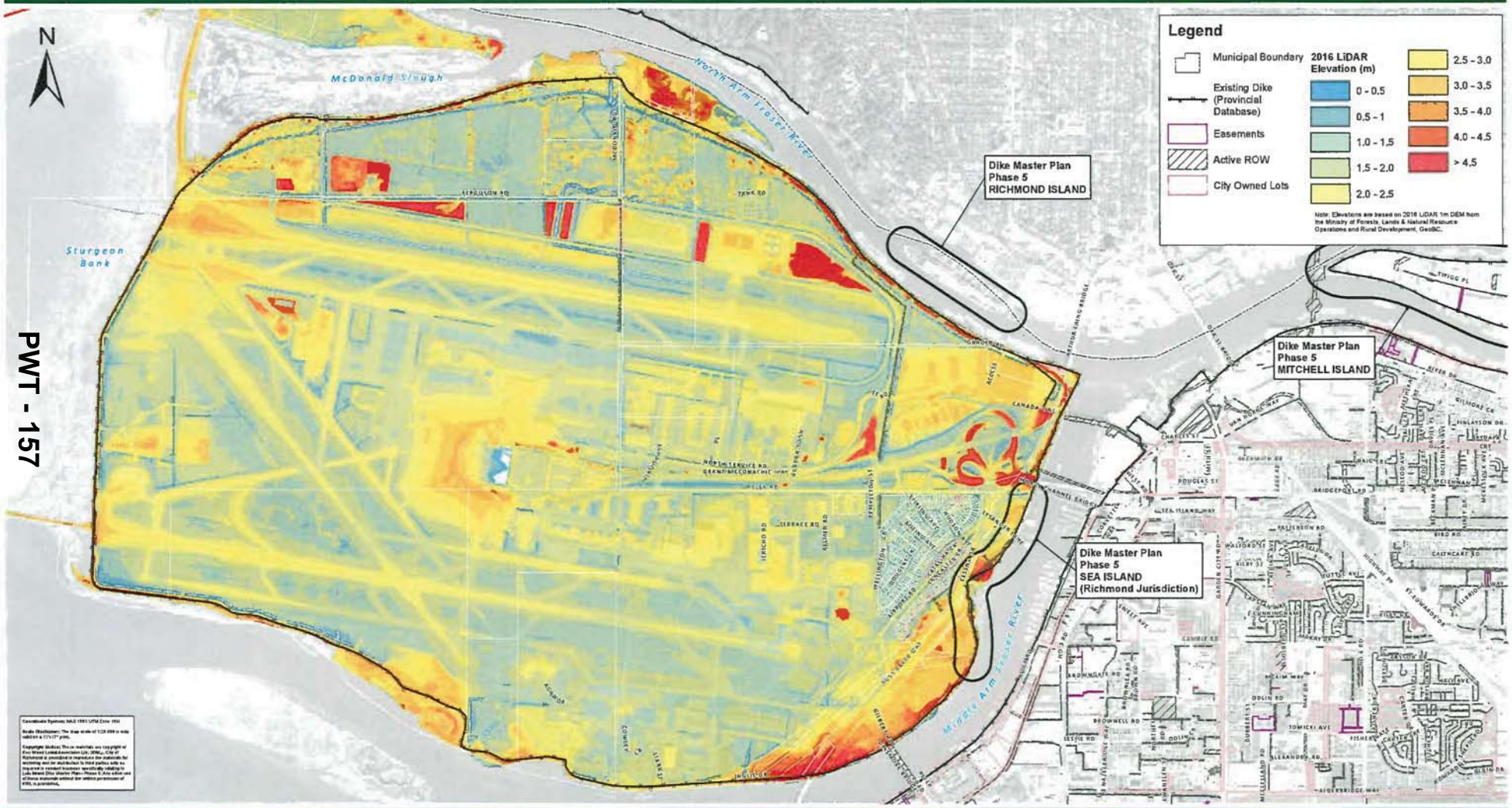
Mitchell Island and Richmond Island Existing Ground Elevations

DRAFT
Figure 2-2

Path: O:\0600-0699\651-122\430-GIS\MXD-Rpt\Phase5\651122_Phase5_Fig2-3_Surface_Mapping_Sea_Island.mxd Date Saved: 9/26/2018 10:13:15 AM | Author: jlau

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL consulting engineers



PWT - 157

Project No. 651.129
Date October 2018
Scale 1:20,000
200 100 0 200 m

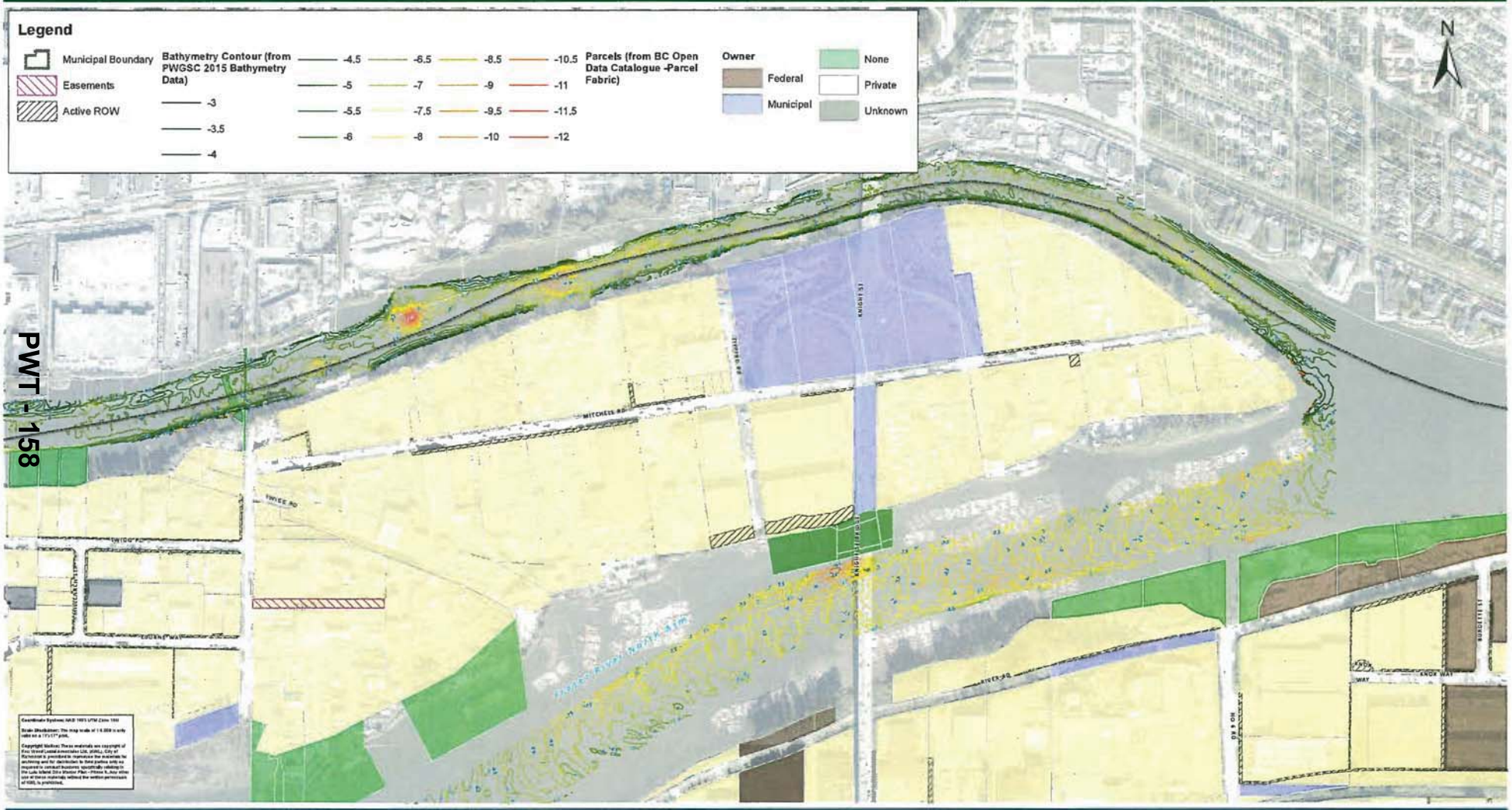
Sea Island Existing Ground Elevations

DRAFT
Figure 2-3

Path: O:\0600-0699\651-122\430-GIS\MXD-Rpt\Phase5\651122_Phase5_Fig2-4_to_2-7_Bathy_Mapping.mxd Date Saved: 8/3/2018 8:55:21 AM | Author: jlau

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL
consulting engineers



PWT - 158

Project No. 651.129
Date October 2018
Scale 1:6,000
50 25 0 50 m

Bathymetry Contours - Mitchell Island

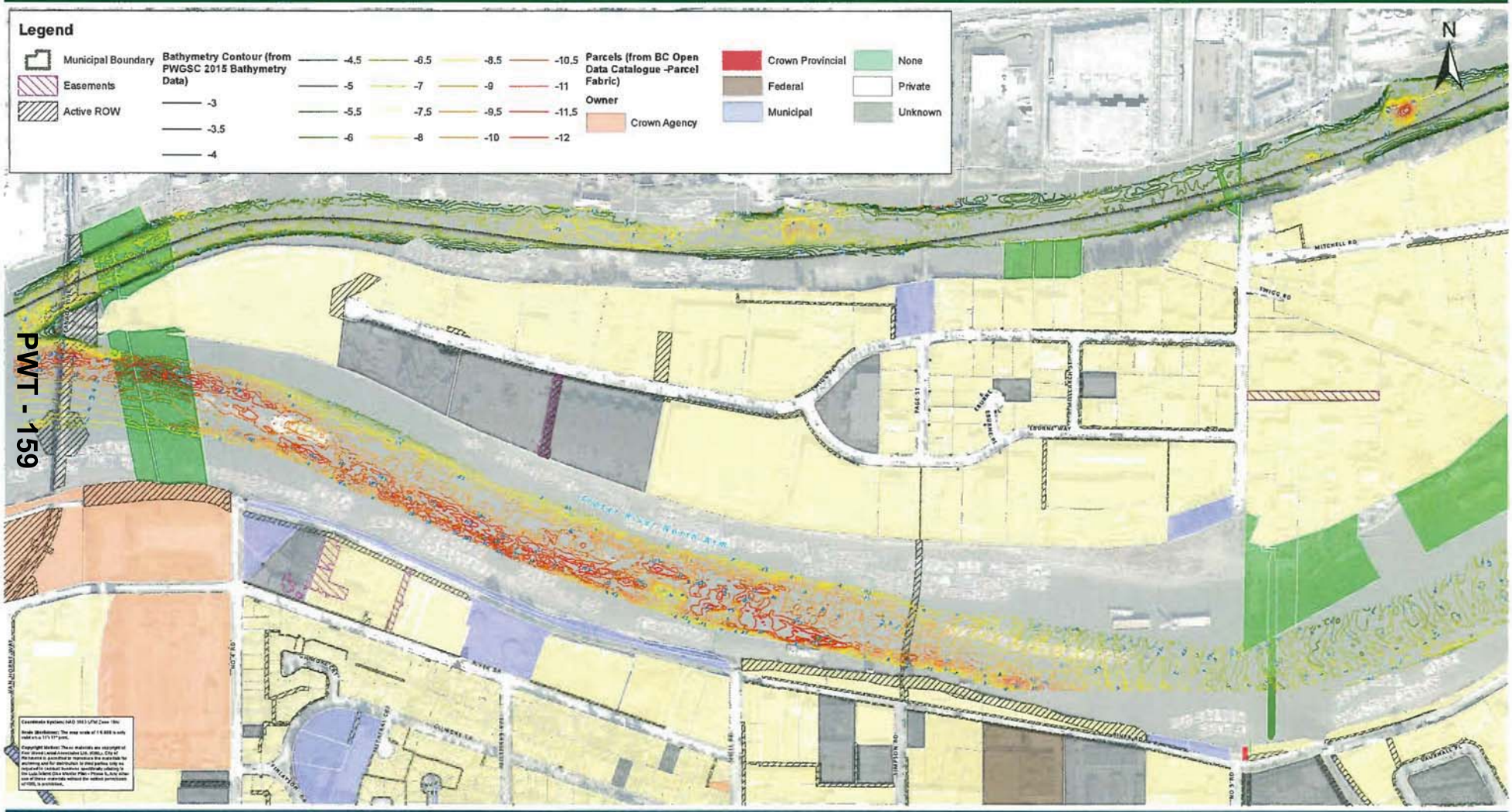
DRAFT
Figure 2-4

Path: O:\0600-0699\651-122\430-GIS\MXD-Rpt\Phase5\651122_Phase5_Fig2-4_to_2-7_Bathy_Mapping.mxd Date Saved: 8/3/2018 8:55:21 AM | Author: jlau

City of Richmond

Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL consulting engineers



PWT - 159

Project No. 651.129

Date October 2018

Scale 1:6,000

50 25 0 50 m

Bathymetry Contours - Mitchell Island

DRAFT

Figure 2-5

Path: C:\0609-0699\651-122\430-GIS\MXD-Rp\Phase5\651122_Phase5_Fig2-4_to_2-7_Bathy_Mapping.mxd Date Saved: 8/3/2018 8:55:21 AM | Author: jlau

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL
consulting engineers



PWT - 160

Project No. 651.129
Date October 2018
Scale 1:4,000
50 25 0 50 m

Bathymetry Contours - Sea Island

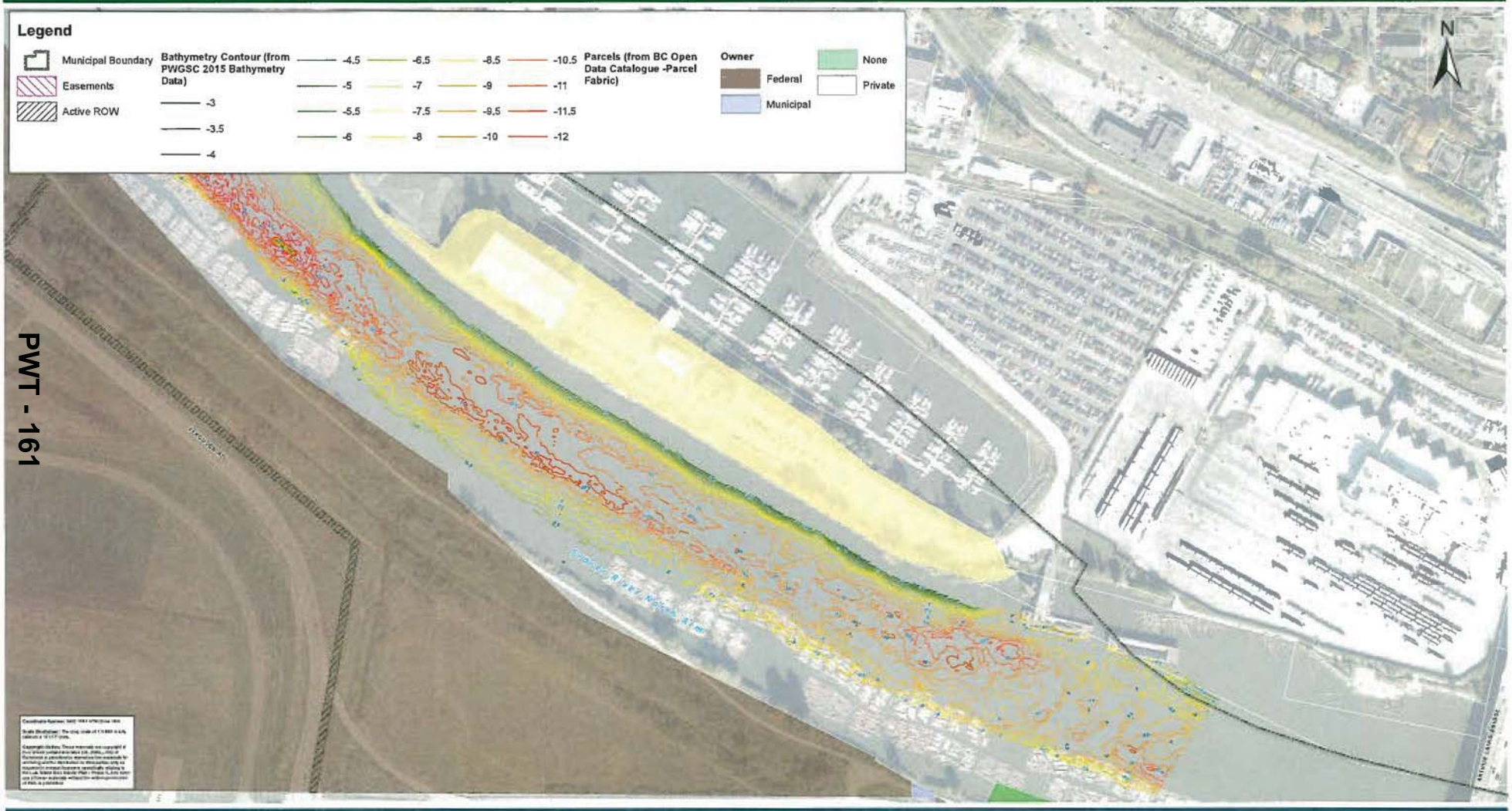
DRAFT
Figure 2-6

Path: O:\0600-0699\651-122\430-GIS\MXD-Rpt\Phase5\651122_Phase5_Fig2-4_to_2-7_Bathy_Mapping.mxd Date Saved: 8/3/2018 8:55:21 AM | Author: jlau

City of Richmond

Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL consulting engineers



PWT - 161

Project No. 651.129

Date October 2018

Scale 1:3,000

50 25 0 50 m

Bathymetry Contours - Richmond Island

DRAFT

Figure 2-7

3. Options Assessment

This section summarizes the options development process, including the following components:

- design considerations and design criteria;
- upgrading strategies;
- upgrading options and concepts;
- options evaluation; and
- recommended options for implementation.

The next version of the draft report will include a summary of external stakeholder engagement results.

3.1 Design Considerations

This section summarizes the main themes and issues that have informed the development of upgrading strategies and options for Phase 5. This includes general design considerations applicable for all three islands, and site-specific considerations for each island as described below.

Dike Performance, Maintenance, and Upgrading

Dike performance, maintenance, and upgrading are the most important design considerations for the Dike Master Plan.

The following themes define an ideal vision for dike upgrading:

1. **Level of Protection:** The City's 2008-2031 Flood Protection Management Strategy sets a target level of protection for structural measures. The City is presently developing an updated flood protection management strategy that will have an even more ambitious flood protection level target. The level of protection translates to a hazard-based design flood scenario to be incorporated into the Dike Master Plan. At this time, the proposed design flood scenario for the City's perimeter dikes is the 500-year return period flood event (0.2 % annual exceedance probability, AEP) with climate change allowances including 1 m of sea level rise. However, the Dike Master Plan should be flexible to accommodate a future change in the design flood scenario in the future.
2. **Form and Performance:** The preferred form of a dike is a continuous, compacted dike fill embankment with standard or better geometry. Walls and other non-standard forms are less reliable and are not preferred. Phase 5 considers alternative structural flood protection options apart from a dike in undiked areas. The level of performance of flood protection works for Sea Island, Richmond Island, and Mitchell Island should be in line with the moderate population (mainly Sea Island) and assets that the dike protects. The dike should meet all relevant design guidelines of the day and in some cases, exceed guidelines to provide a higher level of performance. Dike performance can be expressed in terms of freeboard above the design flood scenario water level and factors of safety against various failure processes, including flood conditions and internal erosion (piping).
3. **Passive Operation:** Minimal human or mechanical intervention or operation should be required to achieve full dike performance. To achieve this, the dike should not have any gaps, gates, or stop log structures.

4. **Enhance Performance** (slow failure)**:** There will always be uncertainties in dike design and performance, and completely preventing any dike failures cannot be guaranteed. However, the likelihood of a catastrophic dike failure causing significant flood damages can be reduced by design features that aim to slow down failure processes, provide redundancy, and provide time to implement emergency repairs. In general, failure can be slowed or controlled with additional setback, crest width, and armouring of the river-side slope, crest, and land-side slope. Such measures can slow the impacts of river erosion, overtopping erosion, and stability failures. Increased monitoring approaches and technology may also be helpful.
5. **Post-earthquake Protection:** The dike should provide adequate protection following a major earthquake until permanent repairs can be implemented. In general, this means avoiding dike conditions where a major earthquake results in a sudden and full failure of the dike cross-section into the river, referred to as a 'flowslide failure'. Other conditions where the dike crest settles, but still provides sufficient freeboard and factors of safety until repairs can be conducted may be acceptable. In general, increased crest width, crest elevation, and setback from the river may be undertaken to help achieve adequate post-earthquake protection. In some cases, improved seismic performance will also require ground improvement and densification works.
6. **Future Upgrading:** Uncertainty in climate change, particularly sea level rise timing, may require the City to further upgrade the dike sooner or higher than anticipated by current guidelines and policies. Sufficient space should be reserved under secured land tenure for future upgrading based on standard geometry. Conceptual design is provided for design flood levels which incorporate 1 m of sea level rise, and proof-of-concept design is provided for design flood levels which incorporate another 1 m water level increase for further climate change impacts (i.e. 2 m of sea level rise).

Some specific design considerations related to the above principles are presented in Table 3-1.

Table 3-1: Ideal Dike Design Principles and Considerations

Design Principle	Ideal Design Principles and Considerations
Level of Protection	• Based on 2008-2031 Flood Protection Management Strategy • Currently proposed: 500-year return period (0.2% AEP) with climate change allowances as per provincial studies
Form and Performance	• Continuous, compacted dike fill with standard or better geometry • Crest elevation and adequate freeboard • Factors of safety against stability • Minimal infrastructure within the dike corridor • Adequate bank protection works or setback
Passive operation	• No gaps, gates, or stop logs • Passive monitoring (e.g. SCADA water levels)
Enhance Performance (slow failure)	• Wide dike crest • Armoured river-bank slope to resist erosion • Paved/armoured crest and/or land-side slope to resist overtopping • Wide setback from the river

Design Principle	Ideal Design Principles and Considerations
Post-earthquake Protection	• No loss of full dike geometry into the river ("flowslide failure") up to a return period to be determined • Adequate post-earthquake freeboard and stability until repairs • Wide dike crest and/or wide setback from the river
Future upgrading	• Space and tenure for upgrading (standard or better geometry) • Avoid need for future infrastructure relocation or land acquisition

Road Safety and Access

The safety of drivers, cyclists, and pedestrians on existing roadways is a consideration in Phase 5, though to a lesser extent than Phases 3 and 4, which are located along River Road or Dyke Road. In Phase 5, some design options consider relocating the dike to an existing roadway (Sea Island) or raising roads to provide emergency egress (Mitchell Island). This includes Cessna Drive, Russ Baker Way, Lysander Lane, and Hudson Avenue on Sea Island, and potentially the entire road network on Mitchell Island.

City transportation engineering staff were consulted during the master plan development to provide input on dike upgrading concepts that will also improve road safety. Current options include providing the same level of service for vehicles, pedestrians, and cyclists as already provided. Travel lane and multi-use path widths are documented in the design criteria in Section3.2.

Vehicle access to properties located along proposed upgrade areas is also an important consideration. Dike raising alignments that raise roadways will impact driveway access for commercial and industrial landowners. Land-use on these properties includes industrial and commercial. As such, a variety of vehicles, including semi-trailer trucks, need safe access from the roadways to these properties. Currently, these properties are generally at grade with and access is provided via asphalt or gravel driveways.

Driveway access was considered in options development by identifying several access upgrading concepts including land filling to raise sites to the dike/road level and raising driveways to tie-in with the upgraded roadways.

Shared Dike Responsibility with YVR on Sea Island

As previously noted, YVR and the City of Richmond share responsibility for the Sea Island perimeter dike. The options development and assessment only include concepts for the reach of the dike the City is responsible for: from the Moray Channel Bridge to the southern property boundary of BCIT (approximately 1.1 km). The boundaries of YVR and Richmond jurisdiction should be further discussed during consultation before finalization of the Dike Master Plan. Shared responsibility requires coordination with YVR at tie-in locations, and to ensure consistent dike upgrade criteria are used for the dike system.

Other reaches of the dike where the City owns land (discussed in Section 2) are understood to be YVR's responsibility, and the City will be consulted as YVR plans upgrades to the dike on City land. YVR has met with the City and noted its plans and progress to upgrade the Sea Island dike to 4.7 m CGVD28. YVR has already upgraded portions of the dike to this elevation along the south airfield and near Grauer Road. YVR plans to complete its own Dike Master Plan in the coming years to guide long-term dike upgrades.

Existing Commercial and Industrial Developments

Sea Island

The dike on the eastern side of Sea Island is closely hemmed in by the river and existing development. Dike improvements will impact waterfront access, the existing developments, and pedestrian access. Major developments along the dike include BCIT, Pacific Autism Family Center, Lysander Holdings Ltd, and the Pacific Gateway Hotel (Van-Ari Holdings Ltd). In addition, the dike closely parallels Cessna Drive in one location with no established dike right-of-way and a low crest elevation. Dike upgrading options consider limiting impacts to these developments while maintaining flood protection.

Mitchell Island

Mitchell Island is tightly constrained by industrial and commercial facilities, including private water-oriented industries and other commercial and industrial sites along the river bank with little setback or access. Dike construction would require significant land acquisition (discussed further below), and consideration of the functionality of industrial sites.

Future dike construction on Mitchell Island may be challenging due to conflicts with site functionality for water-oriented industries as the dike height increases, lack of existing or need for new dike rights-of-way, and limited access to the river bank. The Dike Master Plan considers non-standard dike structures to reduce space required, opportunities to separate the dike alignment from water-oriented industries, and land raising by property owners to allow for continued use of the industrial spaces.

Internal Drainage System

As with any diked area, the drainage for the protected interior area must be integrated with the flood protection measures such that the protected area does not experience flooding due to conflicting functions between the drainage of water from the interior area and prevention of flooding from water exterior to the dike system.

The Phase 5 islands have limited locations where drainage infrastructure is located within likely dike upgrade / construction areas. Drainage infrastructure along the current or potential future dike alignment is limited to pump stations with associated drainage ditches and several drainage pipes that cross the dike with outfalls in the Fraser River. Existing drainage pipes that cross dike upgrades may need to be relocated or upgraded to accommodate the proposed section. As part of upgrades at pump stations, the existing intakes, associated ditch, and outfall may need to be modified or extended, and the pump station piping should be reviewed to consider structural impacts of the preferred dike section. In addition, pump station upgrades in the future should consider higher outfall water levels due to sea level rise and the associated higher required pump capacity.

Land Raising and Acquisition

Land acquisition is an important consideration for the development and evaluation of dike upgrading options. In many areas, the existing dike corridor and river bank (in undiked areas) is confined on both sides by private property with little to no room for expansion of the dike footprint or construction of a new dike. On Mitchell Island in particular, the river bank is very densely developed with no existing dike corridor and minimal land tenure in favour of the City. In options development, the City noted it would prefer securing rights-of-way over acquiring land.

The master plan identifies land acquisition needs for various upgrading options for comparison.

An alternative to land acquisition may be to raise private property lots up to the dike elevation to create a much wider land raising platform (similar to recent developments along the Middle Arm (e.g. Olympic Oval).

River Scour

Dike design along the Fraser River should consider the potential for scour that may undermine the dike. Bathymetry data is collected by the Vancouver Fraser Port Authority ("Port") in the main channel of the river to ensure navigation is unimpeded. Due to the navigational focus of the data collection, near-shore bathymetry along the islands in the Fraser River is not collected. In further stages of design beyond the Dike Master Plan, dike upgrades should consider local scour risks and potential collection of additional near-shore bathymetry data where the Port data indicates scour may be occurring. Due to the large size of the river, constructing bank protection works (riprap or other), below the scour depth is often not practical. Design could consider filling scour holes (see existing scour holes on Figures 2-4 to 2-7), or investigation of site-specific scour protection.

Sea Island Bridges

The Sea Island dike alignment at the north end of the City's reach ties into the Moray Channel Bridge (Ministry of Transportation ownership). The land between the Moray Channel Bridge and the Airport Connector Bridge (YVR ownership) is above the current dike level of 3.5 m CGVD28, based on 2016 EMBC LiDAR data. For future raises, the land between the bridges would need to be raised, but more significantly, the Moray Channel Bridge deck is below 4.7 m CGVD28 and poses a gap in the dike for the future design flood level. In the long term, it would be preferred if the bridge was replaced with a higher deck structure that at least meets the upgrade dike elevation of 4.7 m CGVD28 and exceeds the future dike elevation of 5.5 m CGVD28. In the interim, the City could consider raising the dike and the land between the two bridges until the bridge is replaced.

Mitchell Island Contamination

As a result of the long history of industry and fill from unknown sources, it is expected that a significant portion of Mitchell Island may be contaminated (according to City staff). This has implications for dike design in that material excavated may be contaminated and land acquisition would have greater cost and liability to address potential contamination. In addition, current land use on the island includes industries with oil, fuel, metals, and other potential pollutants, which present an environmental risk if the island were flooded.

Environmental Considerations

City of Richmond Bylaws

The City's Official Community Plan (OCP) bylaw (2011) includes an Ecological Network Management Strategy (ENMS) that identifies ecologically important areas in the City's Ecological Network (EN). These areas include Environmentally Sensitive Areas (ESAs), Riparian Management Areas (RMAs), and EN components (hubs, sites, and corridors, shoreline, city parks).

ESAs are designated as Development Permit Areas (DPAs) with specific restrictions and guidelines for development controlled through a review and permitting process (HB Lanarc-Golder and Raincoast Applied Ecology 2012). There are five ESA types, based on habitat, each with specific management objectives. These are summarized in Table 3-2 and more detailed guidelines can be found in HB Lanarc-Golder and Raincoast Applied Ecology (2012). According to Richmond's OCP, dike maintenance is exempt from development permits in ESAs. However, the guidelines provide useful direction that can be used to minimize impacts to these areas and provincial and federal legislation (see below) still applies to these areas.

RMAs are setbacks that were implemented in accordance with the provincial *Riparian Areas Protection Act* and act as pre-determined Streamside and Protection Areas (SPEAs) under the Act. They extend 5 m or 15 m back from the top of bank of the City's higher value drainage channels or more natural watercourses and are to remain free from development unless authorized by the City (City of Richmond, 2017). RMAs are not present in Phase 5 reaches.

Hubs, sites, and corridors are components of the City of Richmond's EN, which aren't specifically afforded protection, but often overlap ESAs and RMAs, which are protected. These components are present on Sea Island and Richmond Island.

Dike upgrade options will consider the potential impacts to these areas.

Table 3-2: City of Richmond ESA Type Management Objectives

ESA Type	Reaches Where Present	Management Objectives
Intertidal	All	• Prevent infilling or direct disturbance to vegetation and soil in the intertidal zones • Maintain ecosystem processes such as drainage or sediment that sustain intertidal zones
Shoreline	All	• Preserve existing shoreline vegetation and soils, and increase natural vegetation in developed areas during development or retrofitting
Upland Forest	None	• Maintain stands or patches of healthy upland forests by preventing or limiting tree removal or damage, and maintaining ecological processes that sustain forests over the long-term
Old Fields and Shrublands	None	• Maintain the extent and condition of old fields and shrublands, while recognizing the dynamic nature of these ecosystems • Preservation should recognize the balance between habitat loss and creation with the overall objective of preventing permanent loss of old fields and shrublands
Freshwater Wetland	None	• Maintain the areal extent and condition of freshwater wetland ESAs by preserving vegetation and soils, and maintaining predevelopment hydrology, drainage patterns, and water quality

Source: (HB Lanarc-Golder and Raincoast Applied Ecology 2012)

Fish Habitat and Offsetting

Fish and aquatic habitat is protected by the federal *Fisheries Act*. Under the Act, *serious harm to fish* must be authorized by the Minister of Fisheries and Oceans and impacts that cannot be avoided or mitigated must be balanced through offsetting. Offsetting plans are negotiated on a case-by-case basis and may require consultation with aboriginal groups and the Province. Offsetting measures include habitat restoration or enhancement and habitat creation and must be proportional to the loss caused by the project.

Often, the amount of offsetting habitat created is greater than the area of habitat impacted. The area of offsetting may need to be increased to account for uncertainty of effectiveness and time lag between impacts and offsetting. Selecting offsetting locations and beginning habitat creation works prior to all impacts occurring can help to reduce requirements for additional offsetting area required due to lag time. Creation of a smaller number of larger area habitat restoration, enhancement, or creation sites would allow for a more efficient use of resources and potentially reduce uncertainty.

Wildlife Considerations

Migratory birds, their eggs, and active nests are protected by the *Migratory Birds Convention Act* and appropriate measures must be taken to avoid incidental take. The most effective and efficient of these measures includes scheduling vegetation clearing outside of the migratory bird nesting season. If this is not possible, bird nest surveys can be completed immediately prior to vegetation clearing to identify active nests and delay vegetation clearing until the nest is no longer active.

The nests of Bald Eagles, herons and other raptors (both active and inactive) are protected under the provincial *Wildlife Act*. It is also prohibited under the *Wildlife Act* to disturb or harm birds and their eggs. The detailed design stage for dike upgrading should attempt to avoid the removal of trees where bald eagle nests are located.

Native amphibian species may use the drainage channels on the land side of the dike at certain times of year. These species are protected by the provincial *Wildlife Act* and detailed design should also consider potential impacts to these species

3.2 Design Criteria

This section describes the main design criteria used in the Phase 5 Dike Master Plan. These criteria were developed and reviewed by the City in KWL's memorandum *Richmond Dike Master Plan – Phase 5: Objectives, Key Issues, and Criteria*.

Table 3-3 presents a summary of the criteria and is followed by additional discussion. The criteria are presented in terms of both what is the minimum acceptable level and the preferred level.

Table 3-3: Phase 5 Design Criteria Summary

Item	Value and Description	
	Minimum Acceptable	Preferred
Proposed Dike Crest Elevation	4.7 m CGVD28 downstream of Nelson Road (all of Phase 5)	
Future Dike Crest Elevation (for proof-of-concept design)	5.5 m CGVD28 downstream of Nelson Road (all of Phase 5)	
Geometry and Stability	4 m wide crest with dike fill core 3H:1V land-side slope 3H:1V river-side slope (or 2H:1V with riprap revetment) Retaining walls minimized Sheetpile walls acceptable only with minimum 4 m wide dike fill core behind wall No standalone flood walls Meet minimum geotechnical factors of safety	Meets or exceed provincial dike standard and City dike standard
Land Tenure	Registered standard right-of-way	Dike located on City-owned land
Infrastructure in Dike	Crossings designed with seepage control Locate parallel infrastructure to land-side away from dike core	No infrastructure in dike
Land Adjacent to Dike	Land is raised as much as is practical	Land is raised to meet or exceed dike crest elevation
Seismic Performance	Minimum 3.2 m CGVD28 post-earthquake dike crest elevation and maintain dike core integrity	No damage to dike from earthquakes up to a return period to be determined
River-side Slope and Setback	2H:1V bank slope with riprap revetment designed for freshet flow velocities and vessel-generated waves	>10 m setback between river top of bank and dike river-side slope toe 3H:1V river-side bank slope with acceptable vegetation
Crest Surfacing and Land-side Slope Treatment	Crest surfacing: 150 mm thick road mulch Land-side slope treatment: hydraulically seeded grass	Meet or exceed provincial dike standard and City dike standard Consider paved crest and land-side slope vegetation/armouring to add robustness against overtopping
Road Design Width[a] **To be Confirmed with City Staff**	0.5 m allowance for barrier & 0.6 m min horizontal clearance on road shoulders 3.5 m travel lanes (to existing service level) 3.0 m multi-use path for non-industrial Total width (2-lanes): 9.2 m	0.5 m allowance for barrier & 0.6 m min horizontal clearance on road shoulders 1.5 m min. boulevard along shoulders 1.5 m sidewalks or 3 m two-way path[b] 3.0 m two-way cycling path to replace existing facilities[b] 3.5 m travel lanes (to existing service level)

a. Based on City of Richmond Engineering Design Specifications for Roadworks (2008). https://www.richmond.ca/__shared/assets/Roadworks20127.pdf
b. For industrial areas (Mitchell Island), cycling facilities and two-way paths are not included (maintains current level of service).

Dike Crest Elevation

At this time, the Province has not established a Fraser River flood profile and dike design profile that considers sea level rise and climate change. It is understood that the Fraser Basin Council's Lower Mainland Flood Management Strategy project may produce a recommended future flood profile. The most recent available flood profile information is provided in the Province's 2014 study of climate change and sea level rise effects on the Fraser River flood hazard.

The designated flood profile for developing the master plan is proposed as the maximum of the following flood scenarios:

- 500-year return period coastal water level with 1 m of sea level rise (no wave effects); and
- 500-year return period freshet with moderate climate change impacts and 1 m of sea level rise.

Figure 3-1 shows the estimated flood profile water levels (in CGVD28 vertical datum, excluding freeboard) along the river in the study area. As shown on the figure, the coastal flood scenario governs from the Ocean upstream to approximately Nelson Road.

Dike crest elevations are derived by adding freeboard and an allowance for land subsidence to the flood level. Table 3-4 presents the components that sum to the proposed dike crest elevation for Phase 5, which is entirely located in the area governed by the coastal flood hazard.

Table 3-4: Phase 5 Flood Levels and Dike Crest Elevations

Item	Downstream of Nelson Road
Governing Flood Hazard	Tide + storm surge
Level of Performance	500-year return period (0.2% annual exceedance probability)
Climate Change Allowance	1 m sea level rise
Designated Flood Level (m, CGVD28) [a]	3.8
Wave Effects Allowance (m)	None
Freeboard (m)	0.6
Land Subsidence Allowance (m)	0.2
Minimum Dike Crest Elevation (m, CGVD28) [b]	4.7
Future Dike Crest Elevation (m, CGVD28) [c]	5.5

Notes:

a) From (BC MFLNRO, 2014).

b) The City's adopted downstream design crest elevation (4.7 m) exceeds the minimum required elevation (4.6 m). This is a result of updated coastal water level analysis methods (joint probability analysis) that result in a discrepancy when compared to previous methods (additive method).

c) Expandable for an additional 1 m of sea level rise (no additional freeboard or land subsidence allowance).

The master plan also allows for further upgrading by providing proof of concept for raising to between 5.5 m downstream of Nelson Road (coastal).

Seismic Performance

The current provincial seismic performance criteria for dikes are generally difficult to meet without costly and impractical ground improvement works. Additionally, the guidelines are considered very conservative in some situations because they require performance under extremely rare scenarios. For example, the guidelines require dikes to maintain 0.3 m freeboard in the event of a 10-year return period flood occurring following a 2,475-year return period earthquake which has a probability of 0.004% in a 1-year period. This is significantly rarer than the design event for the dike crest elevation (500-year return period event has a 0.2% annual exceedance probability). It is understood that the Province is conducting a review of the current criteria and associated guidelines.

An alternative seismic performance approach that focuses on failure mechanisms and post-earthquake level of protection is proposed. The alternative criteria are presented below.

Table 3-5: Proposed Alternative Seismic Performance Criteria

Criteria	Description / Value
Failure Mechanisms	Flowslides (resulting in full loss of dike cross-section into the river or ditch) are not acceptable up to a return period to be determined (e.g. 2475-year return period).
Maximum post-earthquake overtopping probability	0.2% Annual exceedance probability. Calculate probability through comparison of various post-earthquake dike crest elevations and future flood levels + 0.3 m freeboard. Assume a minimum 1-year exposure period for dike repairs, or longer if local site conditions warrant. In general, this results in a minimum post-earthquake dike crest elevation of 3.2 m which corresponds to the governing scenario of an average annual maximum coastal water level (1.9 m) with 1 m of sea level rise occurring within 1 year of a 475-year return period earthquake.

This approach would make the service level of the dike in a seismic scenario consistent with the service level for the dike crest elevation which is based on a 500-year return period flood or a 0.2% annual exceedance probability.

For the coastal design dike crest elevation of 4.7 m CGVD28, this approach would allow for up to 1.5 m of vertical settlement, as long as core dike integrity is maintained.

The length of time between earthquake and dike repair will be a critical assumption for analysis to support this approach. The City may wish to specify consistent assumptions through the Dike Master Plan to ensure consistent analyses. For example, reconstruction of a dike that has failed into the river channel following a flowslide failure from an extreme earthquake may take up to 2 years or more, whereas more straightforward compaction and raising of a settled dike could be done in less than a year after an earthquake.

The seismic performance criteria may need to be further reviewed if/when the Province issues updated guidelines for seismic performance of dikes.

3.3 Alternative Upgrading Strategies

Several high-level upgrading strategies, summarized in Table 3-6, were considered to inform the development of specific options for the Dike Master Plan.

Table 3-6: High-level Dike Upgrading Strategies

Strategy	Advantages	Disadvantages
Road Dike *Raise road to dike crest elevation*	• Smaller footprint • Wider crest (more robust) • Smaller impacts to habitat	• Operation and maintenance challenges • Infrastructure within dike • High cost to raise dike in the future
Raise Riverbank Dike *Conventional dike along riverbank extending land-side*	• Minimize footprint	• Limited space • Impacts to river side riparian and intertidal habitat and land side riparian and aquatic habitat • Reduced seismic performance • Erosion hazard
Fill River-Side Dike *Build into river to achieve conventional dike*	• Less impacts to existing development and on-shore infrastructure	• Larger impacts to river side riparian and intertidal habitat • Reduced seismic performance • Erosion hazard
Setback Dike *Realign significantly away from river*	• Increased seismic performance • Reduced erosion hazard • Increased opportunities for riparian and intertidal habitat enhancement	• Increase in unprotected development • High infrastructure impacts • High cost to construct new dike alignment
Land Raising ("superdike") *Raise development and roads adjacent to dike*	• Wider crest (more robust) • Reduced grading issues (after implementation) • Less impacts to raise a dike in the future	• Timing and phasing depends on development • High cost to raise large lots with low-density land use • Grading and access issues for water-oriented developments
Bank Protection Works Only *Protect the river bank from erosion*	• No City responsibility for a dike • Reduced impacts to industrial and commercial activities	• Reliance on private development reliance for land raising • Acceptance by property owners of flood risk • Environmental impact (river works and flooding related contamination)

3.4 Options and Concepts

Through a series of meetings and site visits with City staff, the high-level upgrading strategies have been narrowed down to a set of options and concepts that may be appropriate for each island. The broad overall options developed for Phase 5 are listed below, with specific options by island in the following sections.

- Option 1: Build/raise dike
  - Option 1a: Build/raise standard river dike and extend land-side
  - Option 1b: Build/raise standard river dike and extend river-side
  - Option 1c: Build/raise dike with land-side retaining wall
- Option 2: Raise land
  - Option 2a: Raise land to dike elevation
  - Option 2b: Raise land to acceptable level of flood protection
- Option 3: Maintain/install bank protection works only
- Option 4: No structural improvements

In addition to the above general options, the following options have been developed to address site-specific issues at water-oriented industries and at select other locations.

- Option 1d: Build/raise dike with sheetpile wall on river-side
- Option 1e: Build setback dike along Cessna Drive North of BCIT
- Option 1f: Build setback dike around hotel
- Option 1g: Raise dike with river-side sheetpile wall and land-side retaining wall (interim option)
- Option 2c: Raise roadways with required land raising on private property

Table 3-7 presents a summary of the options as applied to each island based on discussions with City staff and is followed by a discussion of the options.

Table 3-7: Major Dike Alignment and Cross-section Options

Reach ID & Name	Alignment and Cross-section Options
Mitchell Island: General	• Option 1a: Build standard river dike and extend land-side • Option 1b: Build standard river dike and extend river-side • Option 1c: Build dike with land-side retaining wall • Option 2a: Raise land to dike elevation • Option 2b: Raise land to acceptable flooding level • Option 2c: Raise roadways with required land raising on private property • Option 3: Maintain/install bank protection works only • Option 4: No structural improvements
Mitchell Island: Water Oriented Industries	• Option 1d: Build dike with sheetpile wall on river-side
Sea Island: General	• Option 1a: Raise standard river dike and extend land-side • Option 1b: Raise standard river dike and extend river-side • Option 1c: Raise dike with land-side retaining wall (at constrained locations) • Option 2a: Raise land to dike elevation

Reach ID & Name	Alignment and Cross-section Options
Sea Island: Pacific Gateway Hotel and at Cessna Drive north of BCIT	• Option 1e: Build setback dike on Cessna Drive North of BCIT • Option 1f: Build setback dike around hotel • Option 1g: Raise dike with sheetpile wall on river-side and land-side retaining wall (interim option)
Richmond Island: General	• Option 2a: Raise land to dike elevation • Option 2b: Raise land to acceptable flooding level • Option 4: No structural improvements

Option 1A: Build/Raise Standard River Dike and Extend Land-side

The primary option developed for Mitchell Island and Sea Island involves raising or constructing a standard dike and extending the footprint of the fill towards the land-side. Figure 3-2 presents a typical cross-section for this option, and Appendix A contains plan and section views of the footprint of this option for Sea Island.

Figure 3-2 shows a 10 m wide dike crest for a dike elevation of 4.7 m CGVD28. This overwide dike allows for raising to 5.5 m CGVD28 without additional dike footprint needs. Alternatively, the dike could be narrowed to a 4 m crest initially, which would require additional land for future raises. The river bank slope of the dike would include riprap bank protection works. This option is favourable as it would provide a standard dike as per the provincial dike design guidelines without impacting the foreshore beyond the installation of bank protection works. Where bank protection works is not already present, its installation will result in the loss of riparian habitat, which will require offsetting. There is no loss of riparian or aquatic habitat anticipated on the land side of the dike.

On Sea Island, this option is feasible for the majority of the City's dike reach and requires on average an additional 10 to 12 m beyond the current dike toe. However, there are several locations where this dike option could not currently be constructed due to limited space available for the dike (near hotel buildings/infrastructure, the marina, and Cessna Drive immediately north of BCIT). There may also be insufficient space in some additional locations for the future raise to 5.5 m CGVD28 (along BCIT and near Lysander Lane). Rights-of-way or land acquisition is required north of Lysander Lane and for a small section immediately north of the BCIT property. The dike upgrade may require upgrades at the Miller Road Drainage Pump Station, and relocation existing utilities and lighting along the dike path. The existing multi-use path would be maintained at the crest.

On Mitchell Island, there is currently no dike (or the previous dike has not been maintained or inspected). As a result, building a standard dike would require land acquisition or right-of-way for the entire perimeter of the island, with the exception of one small section where a right-of-way already exists. On average, this option would require 7 to 8 m of land from the riverbank landwards. There are several locations on Mitchell Island where construction of a dike would impact permanent or temporary structures, and many more where it would impact industrial operations. For some industrial sites, water access is required, and a standard dike may not be preferable. Any dike upgrade would require upgrades at the Tipping Road South and Mitchell Road South drainage pump stations. For all options, the Twigg Island sanitary forcemain (north side) and a watermain south of Paige Street underly the proposed dike and would need to be considered during detailed design. As Mitchell Island is industrial, a multi-use path would not be included along the dyke crest.

The areas with the most severe space limitations and potential options to address the access issues are presented in Table 3-8.

Table 3-8: Significant Space Limitations and Access Issues

Reach / Location / Description	Photo	Options to Address Footprint and Access
Sea Island Cessna Road north of BCIT property STA 0+430 to 0+460 (refer to Appendix A)		• Retaining wall on landside • Move dike towards River (see Option 1B) • Replace pump station during dike upgrades
Sea Island Pacific Gateway Hotel and Marina STA 0+850 to 1+000 (refer to Appendix A)		• Retaining walls and raised Marina access (see Option 1C) • Relocation of existing utilities and movement of temporary infrastructure
Sea Island Moray Channel Bridge and Airport Connector Bridge STA 1+070 to 1+130 (refer to Appendix A)		• Consider dike elevation in future bridge replacement deck elevation • Raise the land between the two bridges to dike elevation in the interim

Reach / Location / Description	Photo	Options to Address Footprint and Access
Mitchell Island Lafarge 13340-13360 Mitchell Rd STA 0+320 to 0+520 (refer to Appendix A)		• Raise parcel of land at time of redevelopment (see Option 2) • Install sheetpile wall on the riverbank to allow continued river access (see Option 1D)
Mitchell Island Terminal Forest Products Ltd. (south side) 12480-12380 Mitchell Rd STA 1+200 to 1+350 (refer to Appendix A)		• Raise parcel of land at time of redevelopment (see Option 2) • Install sheetpile wall on the riverbank to allow continued river access (see Option 1D)
Mitchell Island Richmond Steel Recycling - Broadway Properties Ltd 11760 Mitchell Road STA 1+400 to 1+450 (refer to Appendix A)		• Raise parcel of land at time of redevelopment (see Option 2) • Install sheetpile wall on the riverbank to allow continued river access (see Option 1D)
Mitchell Island Ontrack Systems Inc. (Container West & Platinum Marine) 11660-11580 Mitchell Rd STA 1+900 to 1+700 (refer to Appendix A)		• Raise parcel of land at time of redevelopment (see Option 2) • Install sheetpile wall on the riverbank to allow continued river access (see Option 1D)

Reach / Location / Description	Photo	Options to Address Footprint and Access
Mitchell Island Tipping Road South Drainage Pump Station STA 2+000 (refer to Appendix A)		• Replace pump station during dike upgrades
Mitchell Island Mitchell Road South Drainage Pump Station STA 2+000 (refer to Appendix A)		• Replace pump station during dike upgrades
Mitchell Island Grand Hale Marine Products Ltd. 11551-11571 Twigg Pl STA 5+150 to 5+400 (refer to Appendix A)		• Raise existing access points and provide dike crest access • Raise parcel of land at time of redevelopment (see Option 2) • Install sheetpile wall on the riverbank to allow continued river access (see Option 1D)
Mitchell Island Terminal Forest Products Ltd. (south side) 12191 Mitchell Rd STA 5+800 to 5+950 (refer to Appendix A)		• Raise parcel of land at time of redevelopment (see Option 2) • Install sheetpile wall on the riverbank to allow continued river access (see Option 1D)

Reach / Location / Description	Photo	Options to Address Footprint and Access
Mitchell Island Lehigh Hanson Materials Ltd. 12571 Mitchell Rd STA 6+150 to 6+350 (refer to Appendix A)		• Raise parcel of land at time of redevelopment (see Option 2) • Install sheetpile wall on the riverbank to allow continued river access (see Option 1D)
Mitchell Island Goldwood Industries Ltd. 12691 Mitchell Rd STA 6+350 to 6+520 (refer to Appendix A)		• Raise parcel of land at time of redevelopment (see Option 2) • Install sheetpile wall on the riverbank to allow continued river access (see Option 1D) *currently operating partially on City of Richmond road dedication
Mitchell Island Savo Lazarian (owner) 13611 Mitchell Rd STA 7+300 to 7+400 (refer to Appendix A)		• Raise existing access points and provide dike crest access • Raise parcel of land at time of redevelopment (see Option 2) • Install sheetpile wall on the riverbank to allow continued river access (see Option 1D)

Option 1B: Build/Raise Standard River Dike and Extend River-Side

A secondary option developed for Mitchell Island and Sea Island involves raising or constructing a dike by extending the footprint of the fill towards to the river-side (onto the Fraser River foreshore in some locations. Figure 3-3 presents a typical cross-section for this option.

Figure 3-3 shows a 10 m wide dike crest, which would be wide enough to accommodate a dike upgrade to 5.5 m CGVD28 without increasing the footprint. This approach would reduce the frequency of impact to the riparian or intertidal habitat by disturbing it more initially to prevent disturbance again when it is upgraded. Alternatively, the dike could be only 4 m wide initially, and require extension for future upgrades. Option 1B would result in the loss of aquatic habitat, which would need to be offset. The river bank slope of the dike would include riprap bank protection works at a minimum, but it could also include a riparian planting bench, saltmarsh, or bioengineering bank protection works to offset riparian habitat impacts. Work in the foreshore would require land acquisition, rights-of-way, or lease from the Province. This option provides a standard dike as per the provincial dike design guidelines and reduces impacts to adjacent properties; however, it would have negative environmental impacts and is not preferred for stability considerations building onto the river foreshore.

On Sea Island, this option could be considered in specific locations that are presently constrained (Cessna Drive north of BCIT), or locations that will be constrained in the future (Lysander Lane and BCIT). This option is generally not preferred for the entire dike reach, due to constraints near the hotel and at the Miller Road pump station, stability building on the foreshore, and habitat impacts. At Cessna Drive north of BCIT, only a small length of the dike runs directly along Cessna Drive and the dike is set back from the river bank. As a result, Option 1B could be selected for a short length in this location with relatively limited environmental impacts and without requiring any construction down the river bank itself. The existing multi-use path would be maintained at the crest.

On Mitchell Island, this option would reduce the need for land acquisition but the need for rights-of-way and access remains the same, given the present lack of access to the riverbank. Option 1B could be considered to reduce impacts to existing operations, though it was not preferred by the City in options development. As Mitchell Island is industrial, a multi-use path would not be included along the dyke crest.

The significant access and space constraints described in Table 3-8 are generally applicable to Option 1B as well.

Option 1C: Build/Raise Dike with Land-Side Retaining Wall

Option 1C involves building a dike with a landside retaining wall. This option was developed for specific locations on Mitchell Island and Sea Island where space is constrained by existing buildings on the land-side. No habitat impacts are anticipated on the land side of the dike in these locations. Riprap installation would, however, impact riparian habitat on the river side. Figure 3-4 presents a typical cross-section for this option.

Figure 3-4 shows a 7 m wide dike crest and retaining wall, which would be wide enough to accommodate a dike upgrade to 5.5 m CGVD28 without increasing the footprint. Alternatively, a narrower (~4.5 m) retaining wall dike could be considered as an interim measure and an alternative option be implemented when a site is redeveloped. Retaining walls should consider the need for handrails for safety, in accordance with applicable regulations.

On Sea Island, this option could be considered in several locations, as described below. The existing multi-use path would be maintained at the crest.

- Along the northern end of the BCIT building where the existing space may not be sufficient for a future raise to 5.5 m CGVD28.
- Immediately north of the BCIT property at Cessna Dr, where the existing space is not sufficient for a dike upgrade without impacting Cessna Dr. or moving the dike towards the river side. A retaining wall would likely not be sufficient to raise to 5.5 m without moving the dike towards the river.

On Mitchell Island, retaining walls are commonly used, and the City has recently approved a development with lock block walls used to reach the required elevation for flood protection. Dikes with retaining walls could be considered as an interim measure until redevelopment, or in locations where water access for industry is not required but the footprint needs to be narrower than a standard dike. As Mitchell Island is industrial, a multi-use path would not be included along the dyke crest.

The significant access and space constraints described in Table 3-8 are generally applicable to Option 1B as well, though it may be able to address some of the concerns on Sea Island.

Option 1D: Build/Raise Dike with Sheetpile Wall on River-Side

Option 1D involves building a dike with a river-side sheetpile wall. This option is only considered for specific locations on Mitchell Island where access is required for water-oriented industries (see Table 3-8), or potentially at pump stations to reduce space requirements. Figure 3-5 presents a typical cross-section for this option.

Figure 3-5 shows a 4 m wide dike crest and sheetpile wall, which would require raising and an increase in footprint for future upgrades. This approach reduces the overall footprint at first. Alternatively, the dike could be widened to a 7 m crest initially, which would allow for future upgrading to 5.5 m CGVD28 without extending the footprint. The sheetpile wall could provide a vertical surface for easier barge access (as it is in several locations currently on Mitchell Island), or it could be setback and the existing river bank slope maintained. A sheetpile wall could also be considered in conjunction with land raising (Option 2). This option would limit impacts to riparian and aquatic habitat. As Mitchell Island is industrial, a multi-use path would not be included along the dyke crest.

Option 1E: Build Setback Dike on Cessna Drive North of BCIT (Sea Island)

This option considers an alternative dike alignment on Sea Island that follows Cessna Drive from the northern end of the BCIT property to Miller road and ties back into the dike at the Miller Road drainage pump station. Figure 3-6 presents a typical cross-section and Figure 3-7 presents a plan conceptual alignment.

Cessna Drive directly parallels Russ Baker Way with only a concrete no-post barrier between, and as a result, creating a setback dike along Cessna Drive would also require raising Russ Baker Way. An alternative to raising Russ Baser Way would be to construct a retaining wall for Cessna Drive, which has not been shown in the attached figures. Figure 3-6 shows Cessna Drive raised with an 11.7 m wide crest, with two driving lanes and a sidewalk on the east side, to match existing amenities. The existing utilities that run along Cessna Drive would need to be relocated. Russ Baker Way would be raised to the 4.7 m CGVD28, with three lanes of traffic on either side of the road and a 1.2 m wide median diving the road. The raised road would tie into the existing high-ground/berm that around the eastern side of Burkeville. To better allow for future raises on Cessna Drive and to improve cycling safety, this option proposes that the north and southbound bike lanes be separated from the roadway and located on the berm above Burkeville. This option would require realignment of the existing drainage ditch and pump station, or relocation closer to Russ Baker Way.

The benefits of this option are that it creates a wide "superdike" (more stable), reduces the risk of dike erosion by setting it back from the river bank, does not require impacts to aquatic or riparian vegetation, and raises an important transportation corridor that could provide egress in a dike breach scenario. However, this option has significant drawbacks as it would be a significant cost to raise such a major roadway and relocate utilities, disrupt traffic on a busy corridor, and it would leave four properties outside of the dike without City flood protection, one of which recently built a 4.7 m CGVD dike.

Option 1F: Build Setback Dike around Hotel (Sea Island)

Option 1F considers an alternative dike alignment on Sea Island around the Pacific Gateway Hotel, which would place the hotel outside of the dike. The existing dike is closely hemmed in by the hotel and the marina and restaurant on the landside. There is no room for a standard dike raise in this location without relocating buildings and infrastructure or constructing a non-standard dike with a retaining wall or similar. In the long term (to achieve 5.5 m CGVD28), maintaining the current dike alignment would require removal or relocation of some buildings and on-site infrastructure, which could occur when the site is eventually redeveloped. In addition, ongoing work along this section has installed infrastructure in or along the dike without consideration of impacts to the dike. Figure 3-7 presents a plan conceptual alignment for the setback dike.

Figure 3-7 shows the setback dike following Lysander Lane, connecting to Cessna Drive, and tying back into the existing dike alignment at the Miller Road drainage pump station. Land acquisition on the border of the hotel property could be considered to avoid raising Cessna Drive where it is directly adjacent to Russ Baker Way, to avoid also needing to raise Russ Baker Way. Alternatively, Russ Baker Way could also be raised, similar to the description in Option 1E. The existing utilities that run along Cessna Drive, and Lysander Lane would need to be relocated to the water or landside toe. This option would require realignment of the existing drainage ditch and pump station or relocation closer to Russ Baker Way.

This option could provide a wider and more stable dike setback from the river and associated erosion risk and impacts to riparian and aquatic habitat would be limited. However, the dike in its current location is already afforded some protection by the adjacent Marina and setting back the dike leaves the hotel property unprotected from flooding.

Option 1G: Raise Dike with River-Side Sheetpile Wall and Land-Side Retaining Wall (Interim Option on Sea Island by Hotel and Marina)

Option 1G involves an interim non-standard dike raise to 4.7 m CGVD28 with a sheetpile wall on the along the river bank and a landside retaining wall. This option would only be appropriate for the Sea Island dike along the Pacific Gateway Hotel and adjacent marina, where the developments limit raising a standard dike without redevelopment. When the site is developed, a standard dike (Option 1A) could be established. An interim option is considered for this location as it is currently one of the lowest elevation areas on the Sea Island dike, with several locations below the current dike design elevation of 3.5 m CGVD28. Figure 3-8 presents a conceptual cross-section for the interim dike.

Figure 3-8 shows a 4 m wide dike crest with sheetpile wall along the top of the existing river bank and a landside retaining wall. Retaining walls should consider the need for handrails for safety, in accordance with applicable regulations. The existing multi-use path would be maintained at the crest. This option would require raising the access ramps to the marina restaurant. This reduced footprint would result in less loss of riparian and aquatic habitat area.

Option 2: Raise Land to Dike Elevation (2A) or Lower Acceptable Level (2B)

Option 2A and 2B both involve raising the land adjacent to the riverbank, rather than building a dike. For option 2A, land would be raised to the dike elevation or higher, and in Option 2B land would be raised to a lower level that would result in an acceptable level of flood protection, which could be determined by the City during the Dike Master Plan and through stakeholder consultation. It is expected that land raising would either be required by the City when sites redevelop (cost to owners) or that the City would purchase land, raise it, and resell it as improved land. This could be considered on Mitchell Island or Richmond Island. Option 2B would not be considered for Sea Island. Figure 3-9 shows a typical section of land raising.

In both options, bank protection works would be recommended, and it could be installed and maintained by property owners or by the City. The benefit of this option is that it would provide more robust flood protection by raising all of the land on the river bank rather than constructing only a perimeter dike; however, the City would likely need to stipulate acceptable fill and compaction standards to avoid the use of unacceptable or contaminated fill. The downside of this option is that it would likely delay flood protection upgrades until a site develops (in some instances this may not occur for a significant length of time. In such instances, the City may need to consider interim flood protection options or purchasing of the land to expedite upgrades. Riprap bank protection works would result in the loss of riparian habitat which will need to be offset.

On Sea Island, Option 2A could be considered along the entire reach in the long-term, but it might be particularly applicable for the hotel property due to the tight constraints for the existing dike alignment. In this location, the dike could be raised with a retaining wall or similar in the short-term, with a long-term plan to raise the property. On Mitchell Island, raising the land is favourable as the City does not have access or a right-of-way to establish a dike. In addition, land raising by owners would likely have fewer impacts on water-oriented industries than a perimeter dike, which would require appropriate access for the industrial activities. Land raising in these instances could be considered with a sheetpile wall along the waterfront, as exists in several locations already.

Option 2C: Raise Roadways with Required Land Raising on Private Property (Mitchell Island)

Option 2C involves raising the entire road network on Mitchell Island to the dike elevation or lower level and providing access to property owners, with the requirement for private properties to raise their land to dike elevation through redevelopment. This would provide flexibility to properties where land raising is in conflict with industrial activities, but it would maintain an egress route (raised road) for all properties. In addition, this option would include progressive right-of-way acquisition for a future perimeter dike as properties redevelop. Figures 3-10 and 3-11 show a conceptual plan and section of raising the roads on Mitchell Island to 4.1 m CGVD28 (dike elevation less freeboard of 0.6 m); raising roads to the full dike elevation of 4.7 m CGVD28 could be considered in the longer term as sites raise land. Figure 3-12 shows a typical cross-section for right-of-way acquisition along the river.

Figures 3-10 and 3-11 show a 12 m wide roadway with sidewalks and boulevards on both sides, to match existing conditions, which results in an approximately 18 m wide roadway, as per the City of Richmond Engineering Design Specifications for Roadworks. No cycling facilities would be provided given the industrial zoning of Mitchell Island. Driveway accesses would be 13 m wide at a maximum grade of 8%. The current road elevations are 2 to 3 m CGVD28, and as a result raising the roads to the dike elevation would 1 to 2 m of road raising, as shown on Figure 3-10. For road raising with adjacent low properties, the design would need to consider narrowing roadways or constructing retaining walls to avoid impacting private property. Right-of-way acquisition around the riverbank would allow for

maintenance or construction of bank protection works if required and construction of a perimeter dike in the future for dike elevations beyond 4.7 m CGVD28.

The most challenging aspects of this option would be balancing road raising with site access and existing building located along the roadways. As the island is largely industrial, acceptable grades and widths are important for industrial traffic and operations, and there are many locations where current buildings are located directly along the roads with little to no setback. As a result, the implementation would need to consider impacts to adjacent properties, timing of property redevelopment with roadways, and acceptable access. However, this option would provide a raised emergency egress in the event of a flood and allows property owners to raise lands to meet the road over time. Fraser River riparian or aquatic habitat are not anticipated to be impacted by this option, though impacts of private property raising would need to be assessed by land owner.

Option 3: Maintain/Install Bank Protection Works Only (Mitchell Island)

Option 3 considers the alternative where the only flood protection works the City is responsible for is installation and maintenance of bank protection works. This is only considered an option for Mitchell Island, as Sea Island has an existing dike, and Richmond Island is one private lot. On Mitchell Island, all bank protection works are private works and there is no requirement for owners to protect their properties from erosion. However, erosion starting at one unprotected property may place adjacent properties at risk as erosion progresses. City installation and maintenance of bank protection works would provide consistent protection around the island and reduce the risk of erosion and damage to adjacent property as a result of a neighbouring property's negligence. Figure 3-13 shows a section of Option 3.

This option could be considered in conjunction with other flood protection strategies, such as land raising and FCL's or covenants (covered in the 2008-2031 Flood Protection Strategy and not the Dike Master Plan). Bank protection works in areas where not already present would result in impact to riparian habitat and require offsetting.

Option 4: No Structural Improvements

Option 4 is considered to be the status quo for Mitchell Island and Richmond Island, both of which only have private flood protection infrastructure in place. The Province's dike database indicates an unregulated dike on Mitchell Island under Richmond's authority, though no evidence of a dike is apparent on the island.

On Richmond Island, as described previously, a covenant is in place that acknowledges that the City has no plans to protect the Island from flooding and releases the City from any damage or losses caused by flooding or erosion. In addition, the majority of Richmond Island is located above 5.5 m CGVD28, with the exception of the causeway that connects the island to the City of Vancouver. The more significant flooding and erosion concern is expected to be the ongoing scour along the Fraser River North Arm in this location, which the City may wish to notify the owner of, if they are not already aware.

On Mitchell Island, this option would maintain status quo and would not infringe on industrial and commercial operations. In the absence of structural flood mitigation works, consideration could still be given to non-structural measures such as increasing FCL's or covenants that acknowledge that the property is not protected against flooding or erosion. For Mitchell Island, this option is not expected to be preferred as it does not meet the City's general vision of not allowing any part of Richmond to flood. In addition, flooding of the island would have economic and property losses and may cause environmental contamination.

3.5 Stakeholder Engagement

Stakeholder engagement for Phases 3, 4, and 5 of the Dike Master Plan is being completed jointly in two stages. Prior to City Council review, initial stakeholder engagement was completed that included meetings with internal City departments and government agencies. This initial stakeholder engagement allows for input from City groups on options developed, additional background, and future coordination, with the goal of informing the preferred upgrade options. Following Council review, additional stakeholder engagement is planned, which will include meetings with specific stakeholder groups and a public consultation event. The second stage of stakeholder engagement is intended to inform the public on the draft recommended options and seek any feedback the City may wish to consider in finalizing the Dike Master Plan and moving toward implementation.

For Phase 5, the parties consulted to date include the following.

- Vancouver Airport Authority (YVR);
- City of Richmond Transportation;
- City of Richmond Parks, Planning, and Sustainability; and
- Ministry of Forests, Lands, Natural Resource Operations, and Rural Development (MFLNRORD), including Inspector of Dikes, Flood Safety, and Water Authorizations staff.

The Department of Fisheries and Oceans (DFO) declined to meet with the City, stating that input would be provided during later stages in the established review and approvals process. Additional stakeholder consultation following Council review is planned to include the public and specific groups and properties who may be uniquely impacted by dike upgrades.

3.6 Options Evaluation and Selection

The options described in Section 3.4 have been evaluated based on the design considerations and feedback from the stakeholder meetings held to date. Draft recommended options have been identified and are described below. As noted previously, the recommended options are intended to provide a basis for dike upgrades and planning, with the immediate goal is to raise the dikes to allow for 1 m of sea level rise, and to allow for further upgrading in the future. Environmental impacts, drainage impacts, and geotechnical considerations associated with the recommended options are also summarized below.

It is understood that the recommended options will be confirmed through Council, and additional stakeholder consultation.

The recommended options are summarized in Table 3-9 and Figure 3-14, and further described in the following sub-sections.

Table 3-9: Recommended Dike Upgrading Options (Phase 5)

Reach # and Name	Recommended Options
1 – Mitchell Island	• Option 2C: Raise roadways with required land raising on private property
2 – Sea Island	• Option 1A: Raise standard river dike and extend land-side *Site specific options in constrained locations:* • Option 1B: Raise standard river dike and extend river-side • Option 1C: Raise dike with land-side retaining wall *Site specific interim option at hotel and marina:* • Option 1G: Raise dike with river-side sheetpile wall and land-side retaining wall
3 – Richmond Island	• Option 4: No flood protection works

Recommended Option: Reach 1 - Mitchell Island

Mitchell Island has no existing flood protection works other than private bank protection works (riprap and sheetpiles) around most of the island. Due to this, the City is in a position to consider alternatives to diking. There are many locations around the perimeter of the island that are well below the current design dike crest elevation of 3.5 m CGVD28 (in some locations as low as approximately 2.5 m). The island is densely developed with industrial and commercial operations, many of which actively access the Fraser River for their businesses.

As a result, a perimeter dike would be highly disruptive to business and would require significant right-of-way or land acquisition. Alternatively, progressive land raising by redevelopment would provide the benefit of flood protection at a timeline that is not disruptive to business. By raising roadways and providing driveways, the City can provide emergency egress and access for properties as they are gradually raised. This would also reduce cost to the City by requiring developments to cover the cost of raising the majority of the land. The drawback to this approach is that in the short term, low properties below the current dike elevation will continue to be at risk of flooding and related environmental contamination. This may warrant short-term collaboration with owners to reduce these risks. Raising roads in advance of property raising would also require trade-offs between reduced road size and amenities, or infringement onto private properties. To partially address this, road raising could initially be conducted to 4.1 m CGVD28 (dike elevation less freeboard) or a lower elevation selected by the City.

The following option is recommended for Mitchell Island.

- **Raise Roadways with Required Land Raising on Private Property (Option 2C):**
    - Raise all roadways to dike elevation by the City to provide emergency egress (considering partial raises in low areas to reduce impacts to operations).
    - Require owners to raise parcels to dike elevation during redevelopment.
    - Acquire rights-of-way and access during redevelopment along the riverbank for a future dike to 5.5 m CGVD28 and bank protection works.
    - Work with low elevation (below current dike crest elevation of 3.5 m CGVD28) property owners in the short term to mitigate flood and related environmental contamination risks.

The recommended approach, and properties below the current dike elevation of 3.5 m CGVD28, are shown in Figures 3-10, 3-11, and 3-12. Appendix A shows potential right-of-way acquisition around the perimeter of the island.

Recommended Option: Reach 2 - Sea Island

Responsibility for flood protection on Sea Island is shared by YVR and the City. Jurisdictional boundaries and land ownership along the dike are unclear in some locations, including several spots where the City either owns land or has a road dedication along a section of the dike that YVR has assumed responsibility for. The City's portion of the Sea Island dike is generally agreed to be along the eastern portion of the island from BCIT to the Airport Connector Bridge.

The dike within this reach can be upgraded with a standard dike, with the exception of a few locations where space is constrained by existing buildings or roadways. In these locations, moving the dike alignment towards the river, or using retaining walls can be considered. This would limit infrastructure impacts and cost. In particular, the dike between the hotel and marina is below the current dike crest elevation of 3.5 m CGVD28, and there is not enough space to raise any standard form of dike to 4.7 m or 5.5 m CGVD28. As a result, an interim solution would be required for this location until the site redevelops. This could include either a setback dike around the building or a narrower dike with retaining walls.

The following option is recommended for the majority of City's portion of the Sea Island dike.

- **Raise Standard River Dike and Extend Land-Side (Option 1A):**
    - Work with a legal land surveyor and YVR to establish clear jurisdiction boundaries for the dike.
    - Raise the existing dike along the current alignment with a standard dike wide enough to accommodate a raise to 5.5 m CGVD28 (except in the short-term along the hotel and marina). At the northern end of the BCIT building, at Cessna Drive, and at Lysander Lane, this would require either moving the dike towards the river (Option 1B), building retaining walls (Option 1C), and/or raising the road for short sections.
    - When the Miller Road Drainage Pump Station is upgraded (planned for 10 to 15 years in the future), provide structural capacity for loading due to the dike raise and ensure there is sufficient space for the dike raise.
    - Consult with MOT to have the Moray Channel Bridge replaced with a higher structure that is above 5.5 m CGVD28 (when it is at the end of its design life) and raise the land between the two bridges.
    - Acquire and widen existing rights-of-way for City access to the dike.

The following option is recommended as an interim solution at the hotel and marina.

- **Raise Dike with River-Side Sheetpile Wall and Land-Side Retaining Wall (Options 1G):**
    - At the hotel and marina, raise the dike to 4.7 m CGVD 28 with a sheetpile wall embedded along the river-side and a land-side retaining wall.
    - When the hotel area is redeveloped, establish a standard dike in accordance with the remainder of the reach.

The recommended options are shown in Figures 3-2, 3-3, 3-4, and 3-8. Appendix A contains plans and sections of the long-term upgrading recommendation.

A general recommendation for flood protection on Sea Island is to target land raising of the areas behind the dike. For areas where City property is located on the YVR portion of the dike, it is recommended that the City works with YVR to raise the dike at Richmond road crossings.

Recommended Option: Reach 3 - Richmond Island

The majority of Richmond Island is currently above the 5.5 m CGVD28 future dike crest elevation. Richmond Island is a single lot owned by North Fraser Terminals Inc., and leased to Milltown Marina & Boatyard Ltd. The development is connected to the City of Vancouver and its utility network and does not pay the City of Richmond Drainage Utility tax.

A covenant[3] was registered against the land title in November 27, 2012 (between North Fraser Terminals Inc., the Milltown Marina & Boatyard Ltd., and the City of Richmond) that:

- acknowledges the risk of flooding and erosion on Richmond Island;
- notes that the City has no plans to protect the island from flood and erosion; and
- releases the City from any damage or losses caused by flooding or erosion.

The following option is recommended for Richmond Island.

- **No Structural Flood Protection Works (Option 4)**
    - The covenant appropriately addresses the existing situation. In the event of future redevelopment, flood protection on Richmond Island could be reconsidered.

The City may wish to inform/consult with the owners regarding scour in the North Arm.

Drainage Impact Assessment

Mitchell Island

The Mitchell Road South and Tipping Road South Drainage Pump Stations may be impacted by the road upgrades. Considerations for these two pump stations may include structural review and upgrade of the inlet bays and piping, as well as the outfall elevations of the pumps relative to projected sea level rise.

The drainage system within Mitchell Island would also be affected by the proposed road upgrades. The increase in road surface elevations would require adjustments to catch basin inlets and manholes on all roads where the surface would be raised. Some roads currently have drainage in roadside ditches with culverts at driveway crossings. These ditches would likely be required to be either replaced with storm sewer pipes beneath the roadway and additional catch basin inlets to collect runoff or be filled in and moved to be outside the new toe of the raised roadway.

Sea Island

The drainage system on Sea Island is not complete in the City's GIS database and the full range of potential impacts from proposed dike upgrading are not known at this time. The Miller Road Drainage Pump Station will be impacted by dike upgrades, where structural changes may be required to accommodate the increased dike section. In addition, extension of the pump station outlet and review of outfall elevations relative to projected sea level rise should be completed. There may also be impacts to the drainage system where the dike is constrained by Cessna Drive between chainage 0+400 and 0+450, but there is no drainage shown for the road in this location.

Richmond Island

On Richmond Island, no changes are proposed and there is therefore no impact on drainage.

[3] CA2885848. RCVD: 2012-11-27.

Habitat Impact Assessment

Mitchell Island

Based on initial desktop review, road raising on Mitchell Island is not anticipated to result in impacts to riparian or aquatic habitat. Future raising of land parcels by landowners will need to consider environmental impacts including impacts to riparian and aquatic habitat, and the need for offsetting.

Sea Island

The recommended option for Sea Island will result in an estimated impact of 1,100 m^2 of high-quality Fraser River intertidal habitat and 1,900 m^2 of high-quality Fraser River riparian habitat. These areas represent an estimate based on FREMP habitat mapping (2007), and City of Richmond orthoimagery interpretation (2017). Not all Fraser River riparian and intertidal habitat was quantified. The desktop review only quantified high-quality riparian and intertidal habitat types on the Fraser River side of the existing dike. The remaining habitat area, while not calculated, would also be required in calculations for determining offsetting requirements. A more precise calculation of the area of impact would require an aquatic habitat survey, and an aquatic effects assessment.

Richmond Island

As no structural flood protection works are proposed for Richmond Island, no associated impacts to riparian and aquatic habitat will occur.

Geotechnical Considerations for Recommended Options

The proposed dike improvements were assessed with consideration for the BC Seismic Design Guidelines for Dikes.

Thurber Engineering Ltd. (Thurber) assessed 2 sample river dike cross-sections (one for Sea Island and one for Mitchell Island) to estimate the potential deformation resulting from seismic events. The cross-sections were provided by KWL based on a standard river dike cross-section at what was judged to be the most susceptible areas for deformation. Soil conditions were determined by cone penetration tests conducted by Thurber. The analysis included seismic events representing 100, 475 and 2475-year return period events. Seismic performance was assessed using 2 methods: 1-D (i.e. flat ground) liquefaction assessment to estimate reconsolidation settlements, and 2-D numerical deformation assessment to estimate dynamic deformations. The methods are complimentary, and the results are interpreted together.

The preliminary geotechnical report is attached in Appendix B.

The key results of the geotechnical analysis are summarized below.

- Proposed dike cross-sections will not meet the performance requirements of the seismic design guidelines, without ground improvement or alternative approaches, based on the results of both assessment methods.
- The liquefaction hazard is considered insignificant for earthquakes up to the 100-year return period event.
- The liquefaction hazard is considered moderate and high for the 475 and 2475-year return period events respectively. The resulting deformations would be large.

- Liquefaction may result in a flowslide into the river for dike alignments along the river-bank due to lateral spreading, whereas it would result only in vertical deformation for dike alignments significantly set back from the river bank.
- The deformation analysis indicates that dikes may meet the performance requirements of the seismic design guidelines if they are typically set back 50 m to 100 m from the river-bank and have flat slopes or some localized ground improvement.

Options to address seismically induced deformations, and opinions on each, include:

- **Densification** – The typical approach to densification is to install stone columns beneath a dike. To be effective against the liquefaction expected to follow the 2475-year return period event, densification would have to extend the depth of the liquefaction zone, and for a similar width. In a typical scenario, this can be considered as a 30 m (width) by 30 m (depth) densification located at the river-side toe of the dike. Such densification can be very costly (e.g. $9,000 to $18,000 per lineal metre of dike). Alternate experimental techniques are being tested by the City that may offer a more economic solution.
- **Higher Crest** – For the 100-year return period event, additional crest elevation may compensate for deformations caused by settlement. For events that cause liquefaction, added height just results in added deformation, so it is less effective. This is not an effective strategy by itself for return periods above 100-year due to lateral spreading and large vertical deformations.
- **Setback and Slope** – Flatter dike side slopes improve seismic stability. However, to prevent large deformations in the 2475-year return period event, the maximum acceptable slope between the river channel invert and the dike crest would need to be approximately 2%, which would require a significant setback between the dike and river.
- **Wide Crest ("superdikes")** – A very wide dike (e.g. crest width of 100 m to 200 m) could be used to extend the dike beyond the limit of significant lateral spreading due to liquefaction. A portion of the wide crest could be considered sacrificial in the even to major lateral spreading. Raising the land for approximately 200 m inland of the dike is desirable for related flood protection reasons, and may be desired by the City for other reasons such as land use planning. It has already been done as part of multiple family, commercial, and industrial development projects in some waterfront areas. Buildings within such areas must account for liquefaction in foundation design.
- **Dike Relocation** – Place the dike inland of the liquefaction lateral spreading zone (a setback dike approach) or place a secondary dike inland of the liquefaction lateral spreading zone. The wider option above would essentially include a secondary dike. Relocating the dike inland would be a form of retreat and would leave property and buildings exposed outside the dike.

Additionally, the City may wish to use alternative seismic performance criteria, such as the criteria discussed in section 3.2 which aims to develop a consistent level of performance between seismic scenarios and flood level scenarios (i.e. an overall 0.2% annual exceedance probability of failure across all hazards).

Recommendations to manage the seismic risk include:

- Consider the proposed alternative seismic performance criteria provided in Section 3.2. Review the criteria if/when the Province issues updated guidelines for seismic performance of dikes.
- Fill land for approximately 200 m inland of the dike to dike crest elevation. Buildings in this zone should be built above the dike crest elevation and have densified foundations capable of withstanding liquefaction. The required distance requires some additional evaluation and may be addressed in the pending update to the Flood Protection Management Strategy.
- Continue to investigate practical densification options, and consider earthquake induced dike deformations in emergency response and recovery planning.

3.7 Cost Opinions

Cost opinions for the recommended option in each reach are provided to help the City consider the financial implications for planning and comparing options. A breakdown is provided to help understand the proportional cost for items such as separating and raising the road.

Costs are based on unit rate cost estimates and tender results for similar works. The most relevant rates are from the City's Gilbert Road dike project. The City provided a summary of the cost estimate prepared by WSP for this project.

Rates from recent tenders for diking on the Lower Fraser River and other locations within the Lower Mainland were used to check the reasonableness of the rates and estimate other features such as sheet piles or large diameter drain pipes.

The costs were estimated for each island. They were also broken down into the main features that coincide with options that the City may wish to consider further. These features are described below.

- **Dike Raising** – this is the core element required to provide flood protection. It includes a 10 m crest width that can be raised while still achieving a 4 m crest width. This includes site preparation, fill, and erosion protection.
- **Road Structure and Utilities** – this includes stripping, subgrade preparation, pavement structure, drainage and utilities.
- **Road Raising** – this includes the additional fill required to raise the road to the dike crest elevation (4.1 m CGVD28 road raising initially).
- **Other** – features such as landscaping, habitat improvements, multi-use paths, driveway ramps and other amenities typically have a combined impact of less that 10%, so are lumped together for conciseness. This category was used to capture utilities if the option did not include road construction.
- **Contingency** – A 40% contingency is provided because the costs are based on concept plans only.

Table 3-10 presents a summary of all reaches with cost breakdowns for the items described above. Costs for each reach are also provided in the Reach Summary Sheets in Section 5.

Table 3-10: Summary of Construction Costs ($ in Millions)

Item	Mitchell Island[b]	Sea Island[c]	Sea Island Interim Works[d]	Richmond Island 4	Total
Dike Raising	-	$3.6 M	$.8 M	No Flood Protection Works	$4.4 M
Road Structure and Utilities	$15. M	$0.1 M	-		$15.1 M
Road Raising	$36.5 M	$0.2 M	-		$36.7 M
Other[a]	$8.3 M	$0.8 M	$.1 M		$9.1 M
Contingency (40%)	$23.9 M	$1.9 M	$.3 M		$26.1 M
TOTAL	**$83.6 M**	**$6.5 M**	**$1.2 M**		**$91.4 M**

a. Driveway ramps and pathways
b. Includes approximately 5.3 kilometres of road raising, reconstruction, and industrial driveway ramps.
c. Includes approximately 0.9 km of dike raising and road raising at McDonald and Shannon Roads.
d. Interim works refer to 150 m long sheetpile and retaining wall dike along the Pacific Gateway Hotel with access to the marina and hotel land.

Costs that are not included are noted below:

- Land acquisition is not included. Rights-of-way either exist or will be acquired during redevelopment. Similarly, there may be opportunities to have dike improvements tied to adjacent development.
- Densification is not included. The recommendation is to fill 200 m back from the dike face as a preferred strategy to deal with liquefaction. If the road and land behind the dike is not raised, then densification is recommended. Current techniques such as stone columns would cost approximately $9,000 to $18,000 per metre of dike.
- Off-site habitat projects (that may be needed beyond the habitat enhancement provided along the dike corridor) are not included. Such cost could be roughly 5% of the construction cost. It is understood that a separate Dike Master Plan may be prepared to address habitat compensation by identifying and developing medium to large habitat compensation concepts.
- Professional fees (engineering, surveying, environmental, archeological, etc.) are not included. Such costs could be in the range of 10% to 15% of the construction cost.
- Shoreline protection works and land raising on industrials sites on Mitchell Island are not included. Similarly, raising the land behind the dike is not included on Sea Island. These costs are proposed to be a condition of development behind the dike, with the cost and benefit attributed to property owners.
- Contaminated site remediation on Mitchell Island is not included. To ensure land raising keeps pace with increasing flood risk and sea level rise, the City may consider acquiring, raising, and reselling select properties. Based on historical land use on Mitchell Island, land acquisition is expected to involve site investigation for contamination. Contaminated sites investigations include the following, with approximate average cost estimates provided by City staff[4]:
    - Phase 1 Site Investigation (desktop) - $1,500 per property;
    - Phase 2 Site Investigation (sampling) - $25,000 per property; and
    - additional investigation and remediation for a Certificate of Compliance - $250,000 per property.

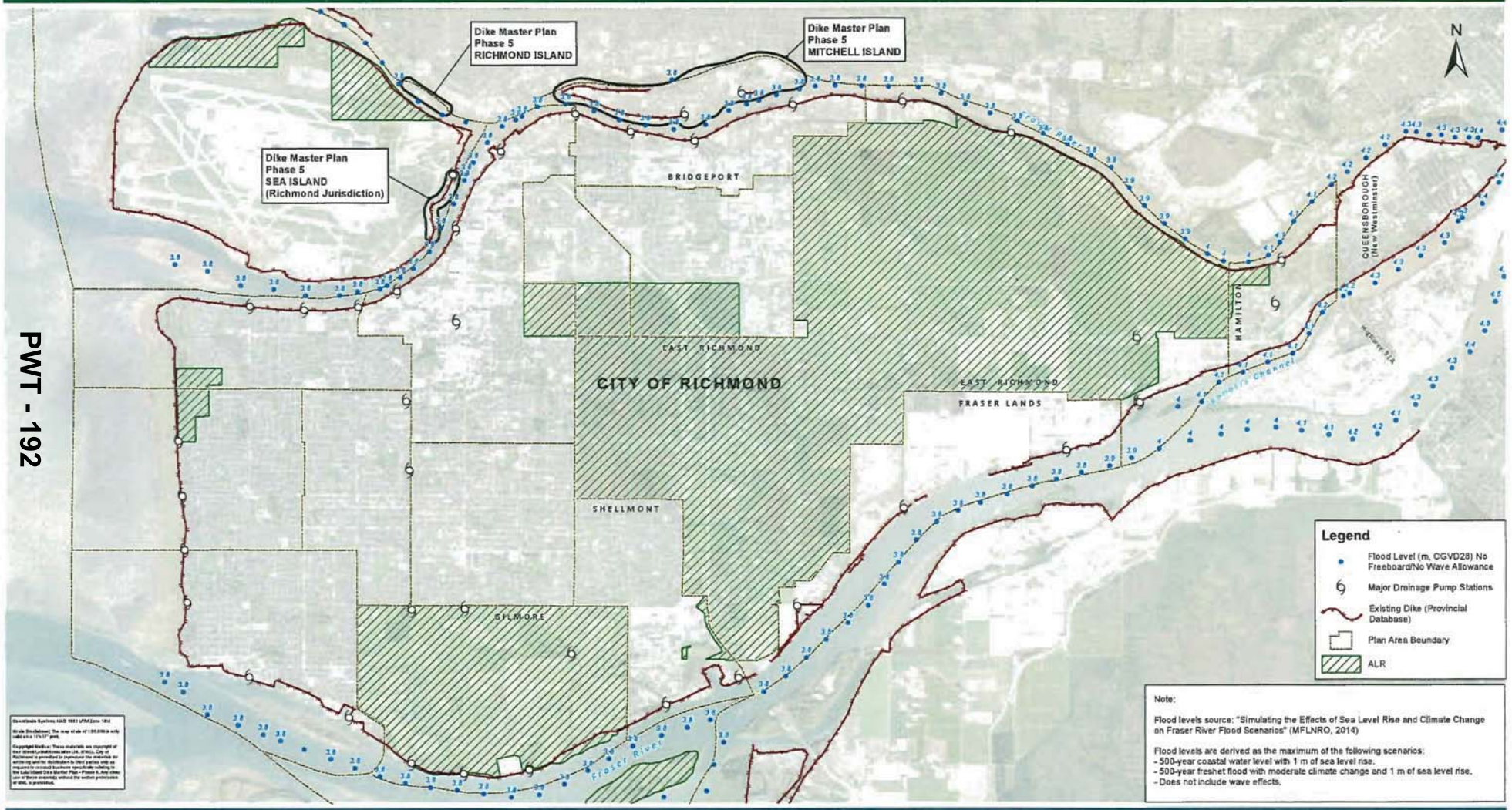
  City staff estimate that all properties on Mitchell Island will require Phase 1 investigations, approximately 75% of properties may require Phase 2 investigations, and approximately 40% of properties may require additional investigation and remediation.

[4] City Hall Transmittal #5905343 Mitchell Island Pollution Prevention and Known Contamination

Path: O:\0600-0699\651-122\430-GIS\MXD-Rpt\Phase5\651122_Phase5_Fig3-1_FraserRiverFloodElevations.mxd Date Saved: 8/7/2018 12:49:06 PM | Author: jbu

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL
consulting engineers



PWT - 192

Project No. 651.129
Date October 2018
Scale 1:55,000

1,000 500 0 1m 1,000

Fraser River Flood Elevations

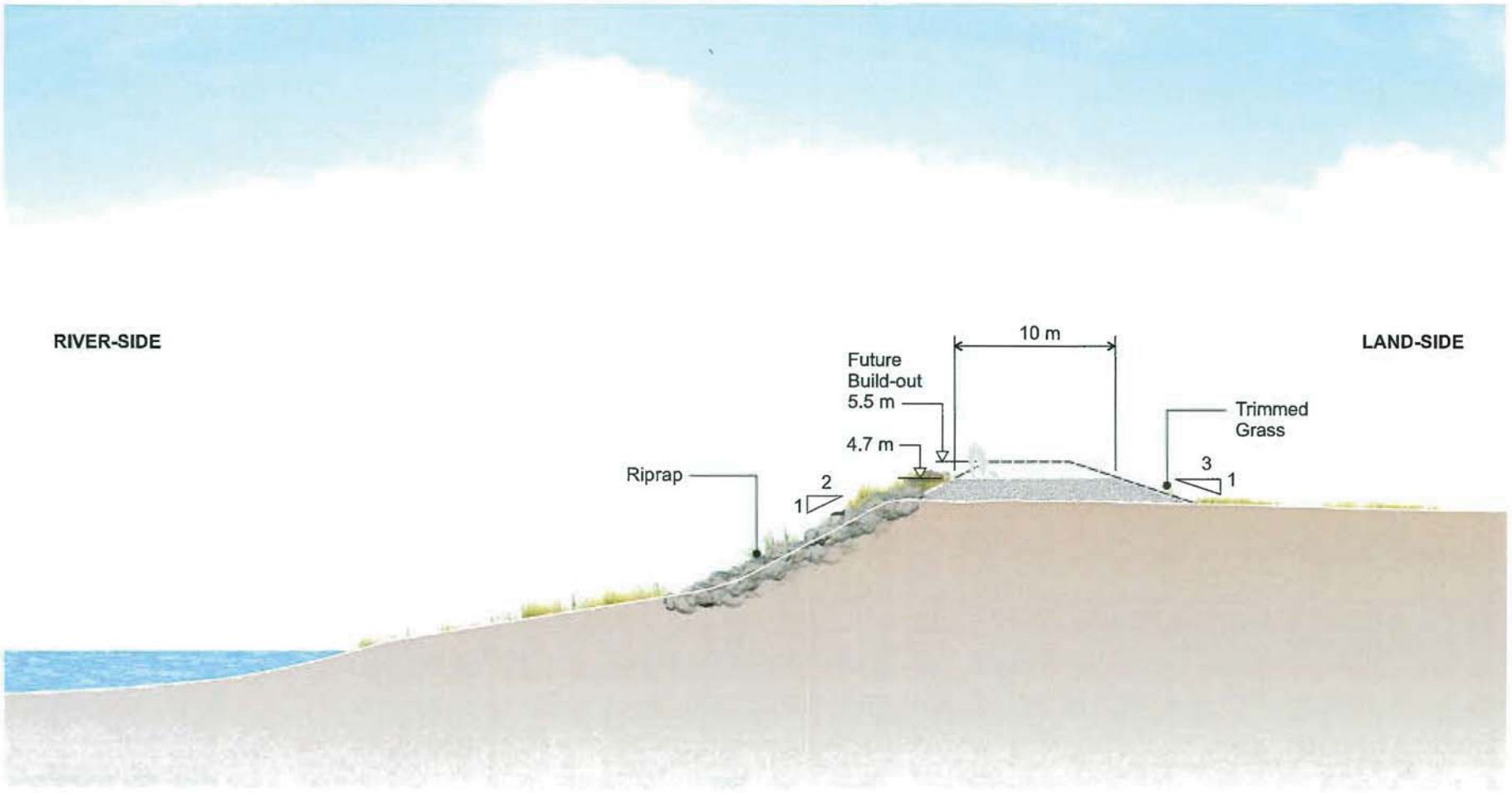
DRAFT

Figure 3-1

O:\0600-0699\651-122\501-Drawings\b_Figures\651122_Phase5_Fig_Dike.cdr

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL
consulting engineers



PWT - 193

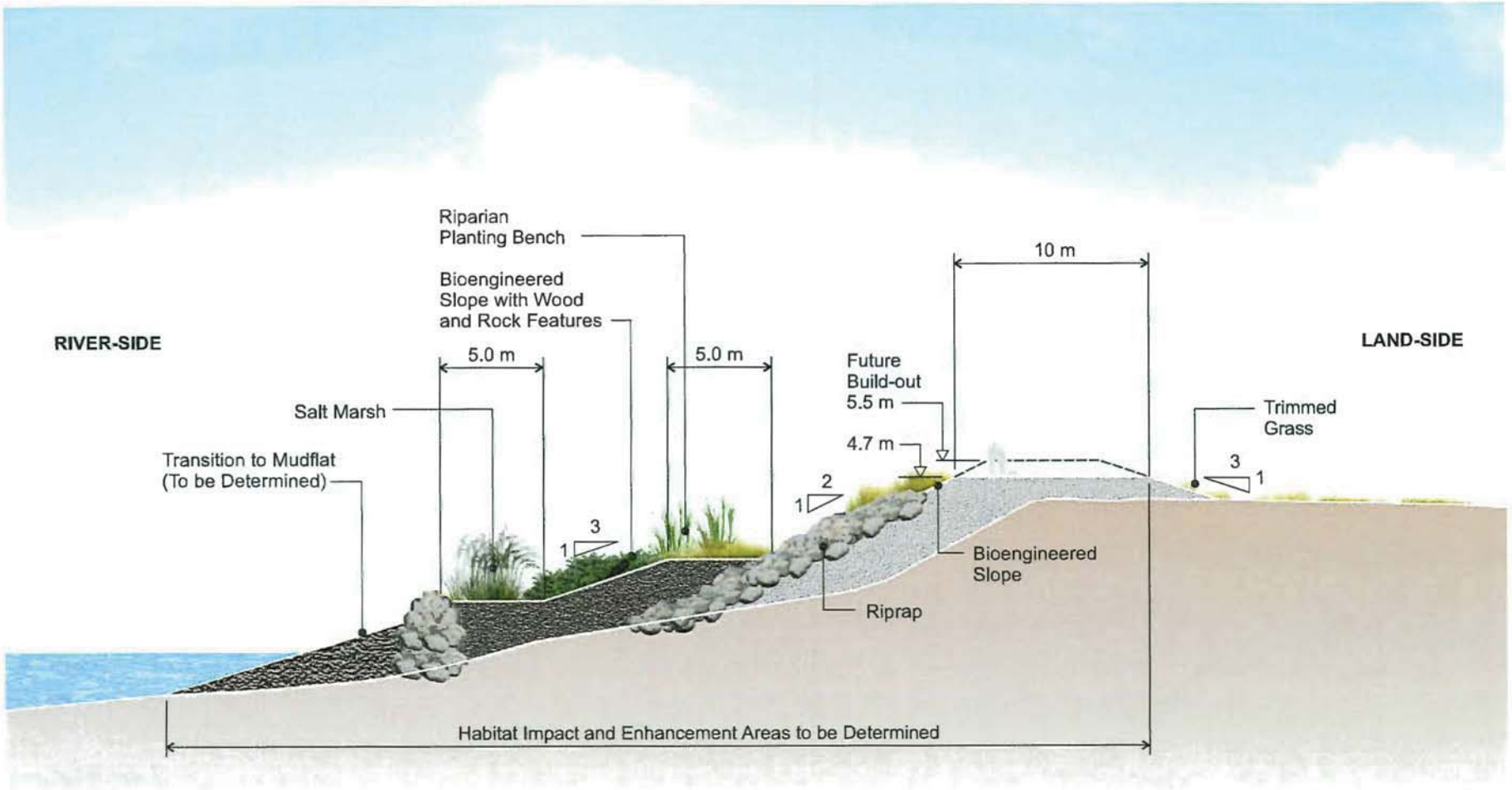
Project No.	651.129
Date	October 2018
Scale	Not to Scale

Option 1A: Build/Raise Standard River Dike and Extend Land-Side

Figure 3-2

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL
consulting engineers



Project No.	651.129
Date	October 2018
Scale	Not to Scale

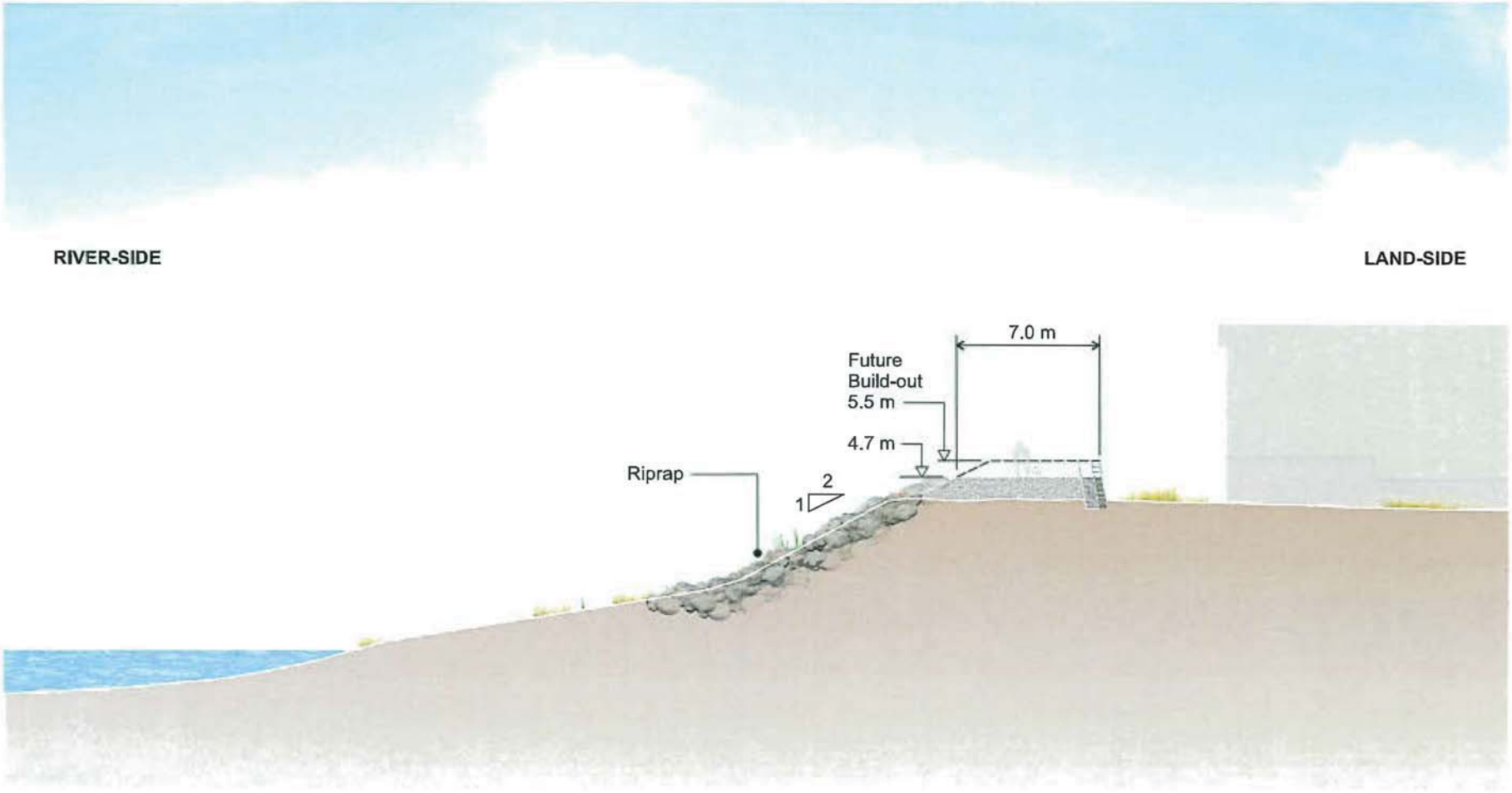
Option 1B: Build/Raise Standard River Dike and Extend River-Side

Figure 3-3

O:\0600-0899\651-122\501-Drawings\b_Figures\651122_Phase5_Fig_Dike.cdr

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL
consulting engineers



PWT - 195

Project No.	651.129
Date	November 2018
Scale	Not to Scale

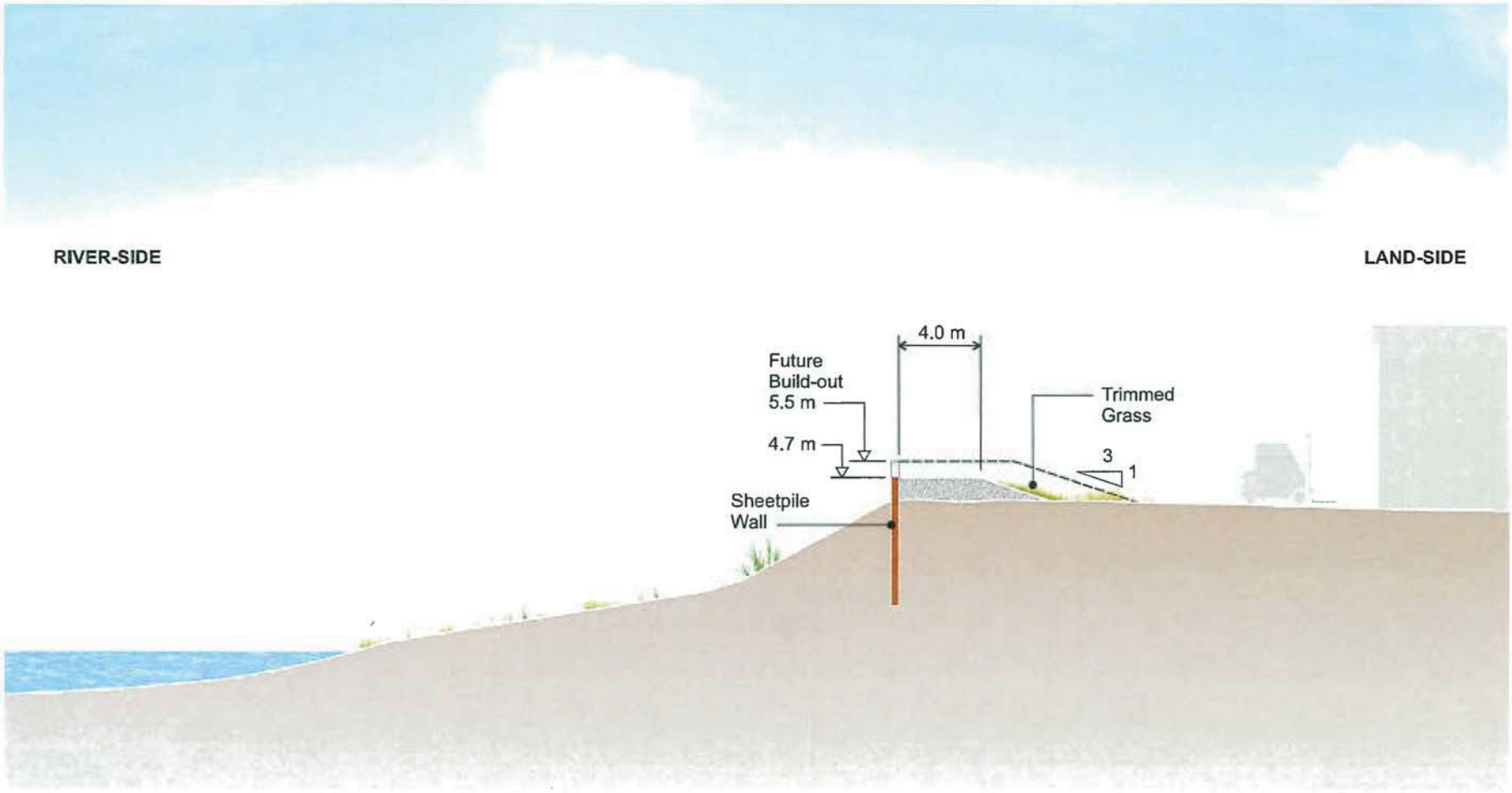
Option 1C: Build/Raise Dike with Land-Side Retaining Wall

Figure 3-4

O:\0600-0699\651-122\501-Drawings\b_Figures\651122_Phase5_Fig_Dike.cdr

City of Richmond
Lulu Island Dike Master Plan - Phase 5

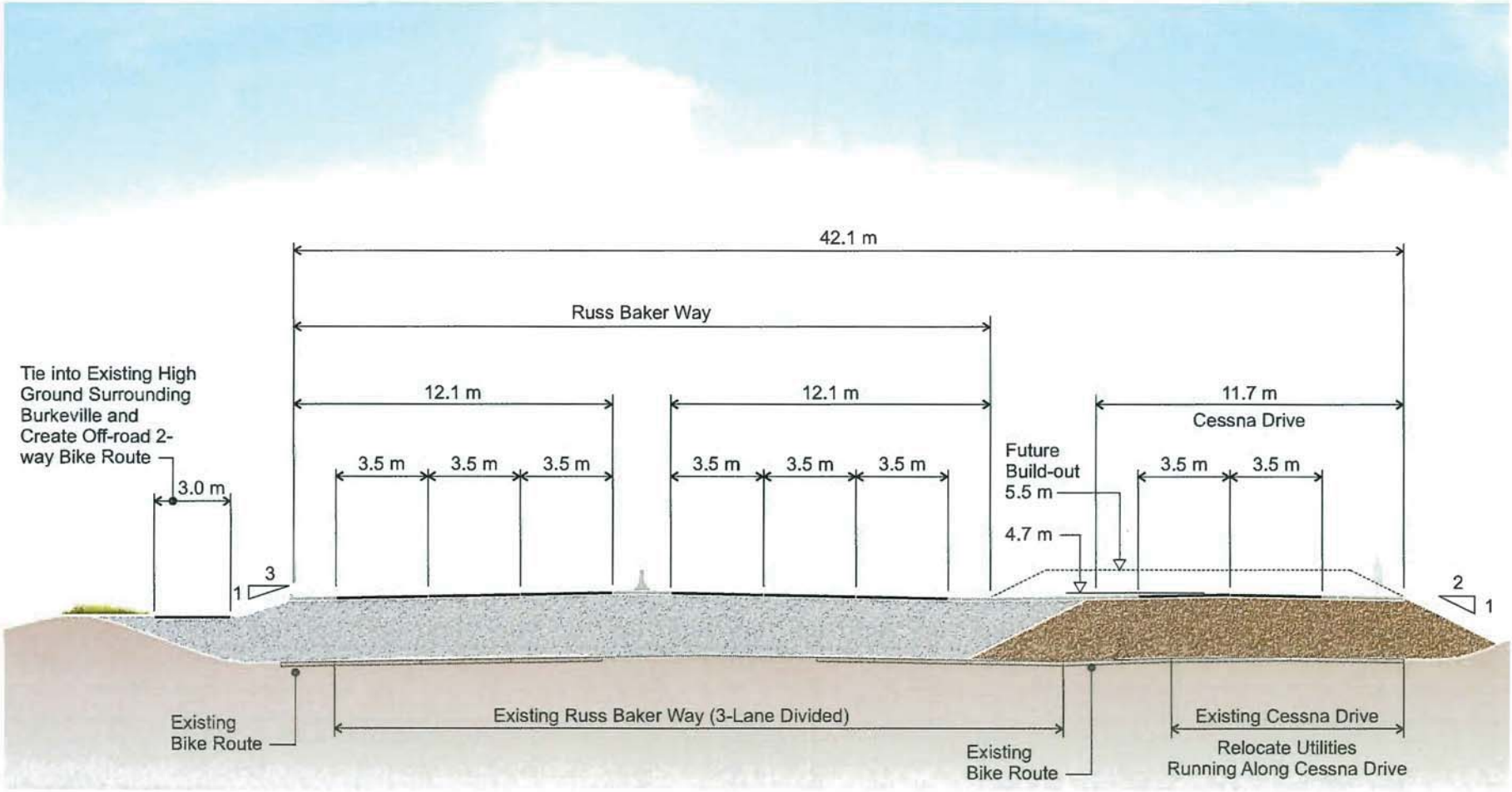
KERR WOOD LEIDAL
consulting engineers



Project No.	651.129
Date	November 2018
Scale	Not to Scale

Option 1D: Build/Raise Dike with Sheetpile Wall on River-Side

Figure 3-5



PWT - 197

Project No.	651.129
Date	November 2018
Scale	Not to Scale

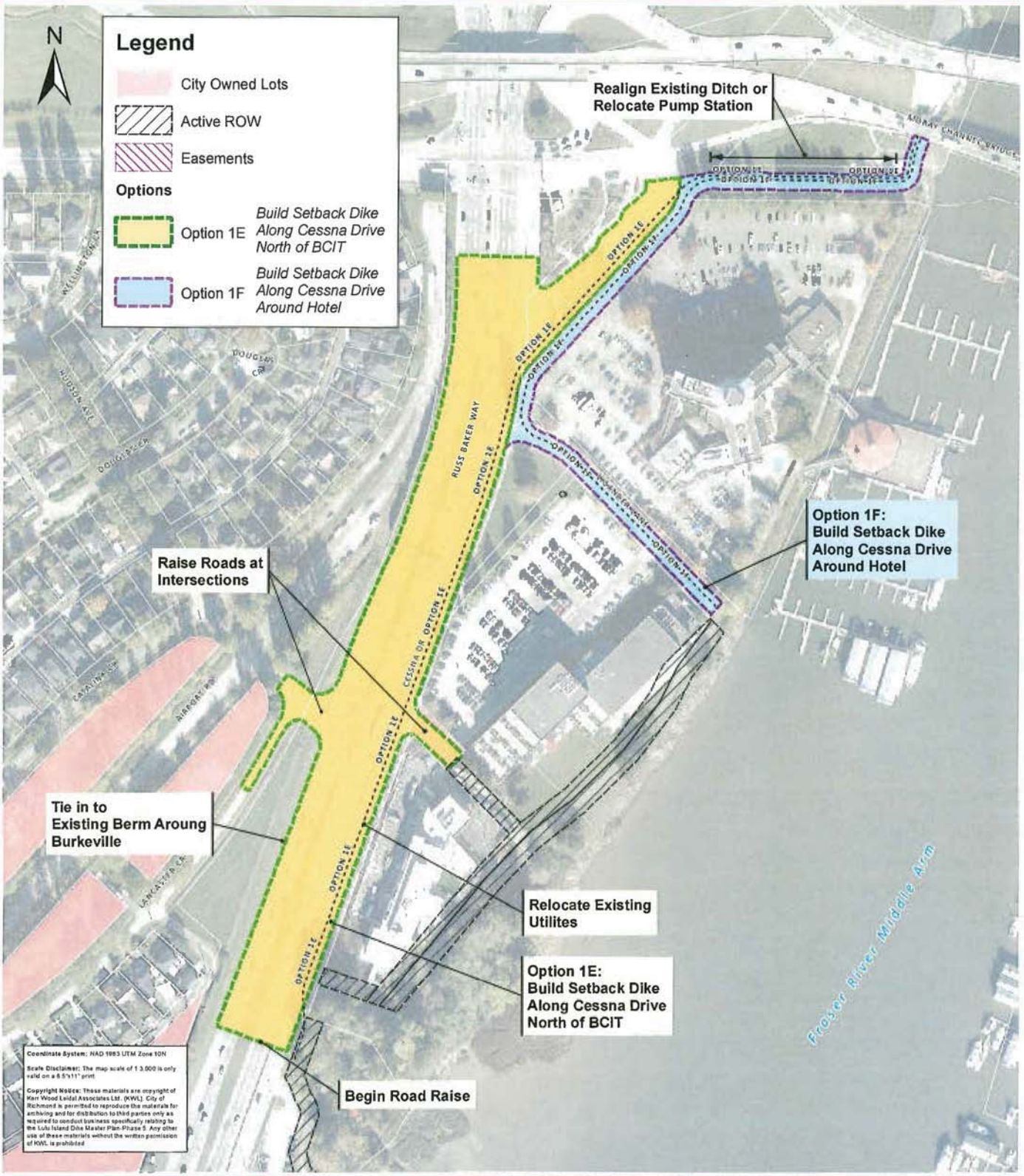
Option 1E: Build Setback Dike along Cessna Dr. North of BCIT

Figure 3-6

Path: O:\0600-0699\651-122\430-GIS\MXD-Rp\Phase5\651122_Phase5_Fig3-7_Option1E_1F.mxd Date Saved: 8/3/2018 8:56:50 AM | Author: jlau

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL
consulting engineers



Project No. 651.129
Date October 2018
Scale 1:3,000

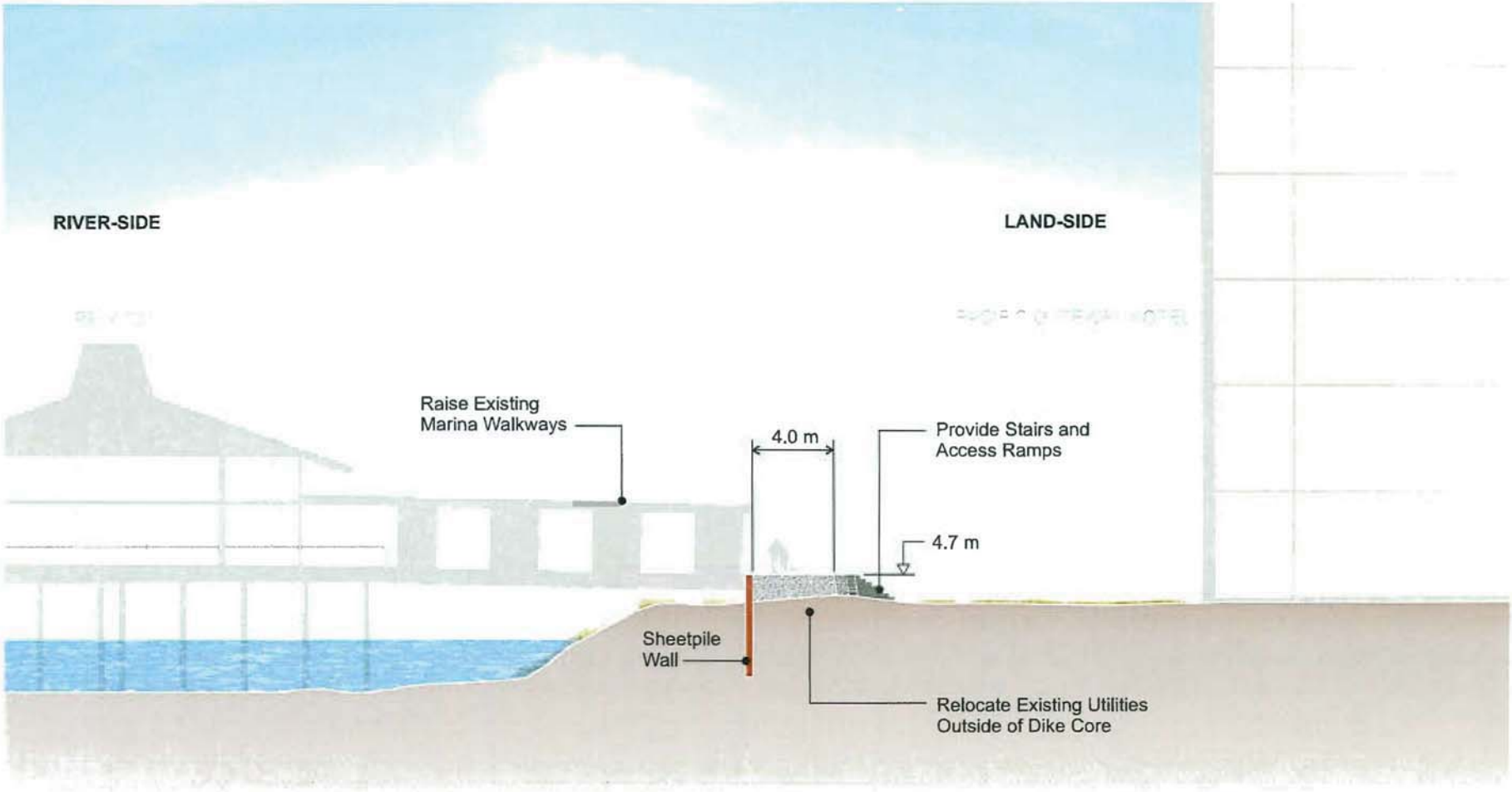
Option 1E and 1F: Build Setback Dike Along Cessna Drive

DRAFT

Figure 3-7

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL
consulting engineers



Project No.	651.129
Date	October 2018
Scale	Not to Scale

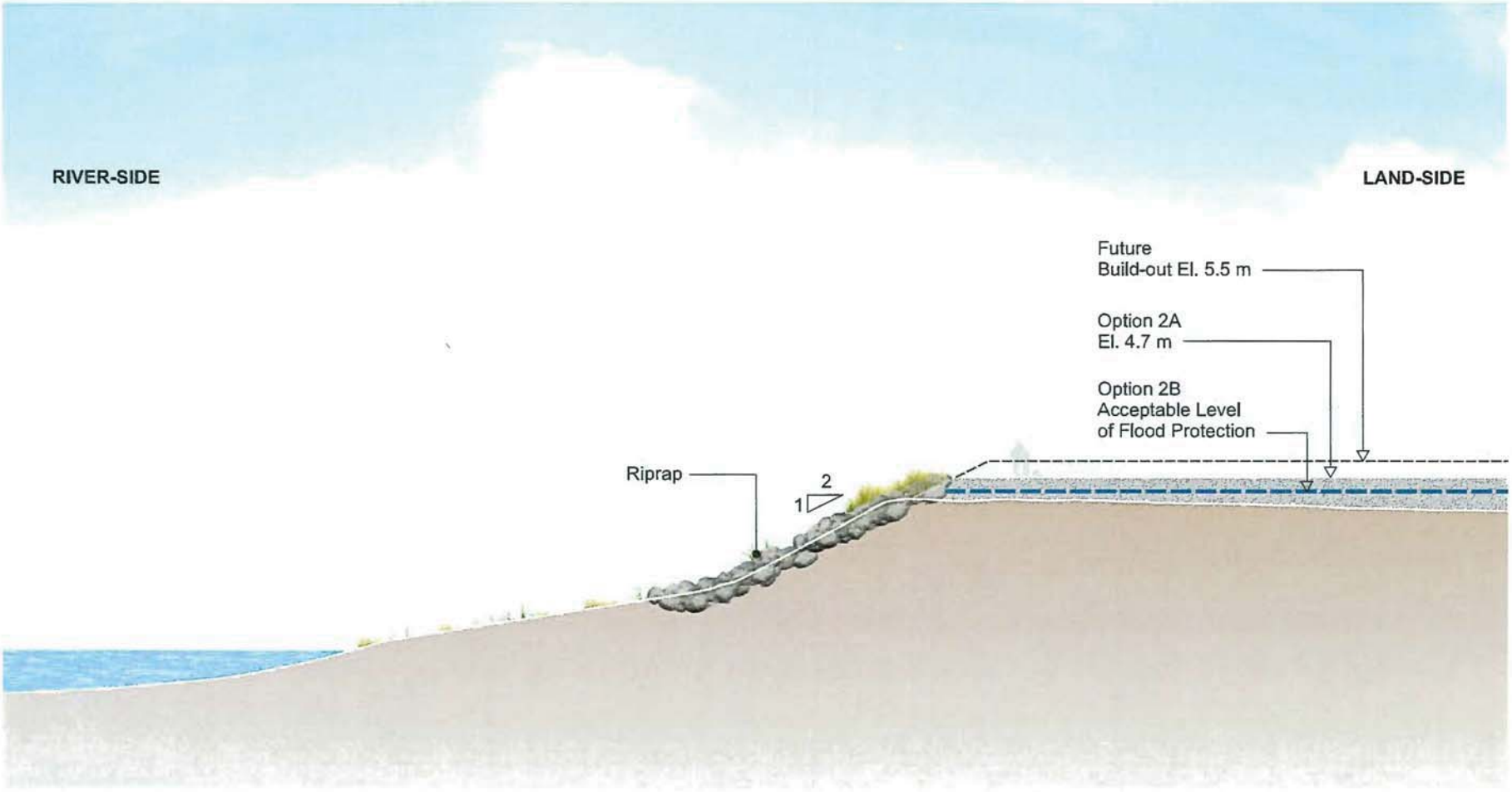
Option 1G: Raise Dike with River-Side Sheetpile Wall and Land-Side Retaining Wall (Interim Option)

Figure 3-8

D:\3800-0899\651-122\501-Drawings\b_Figures\651122_Phase5_Fig_Dike.cdr

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL
consulting engineers



PWT - 200

Project No.	651.129
Date	October 2018
Scale	Not to Scale

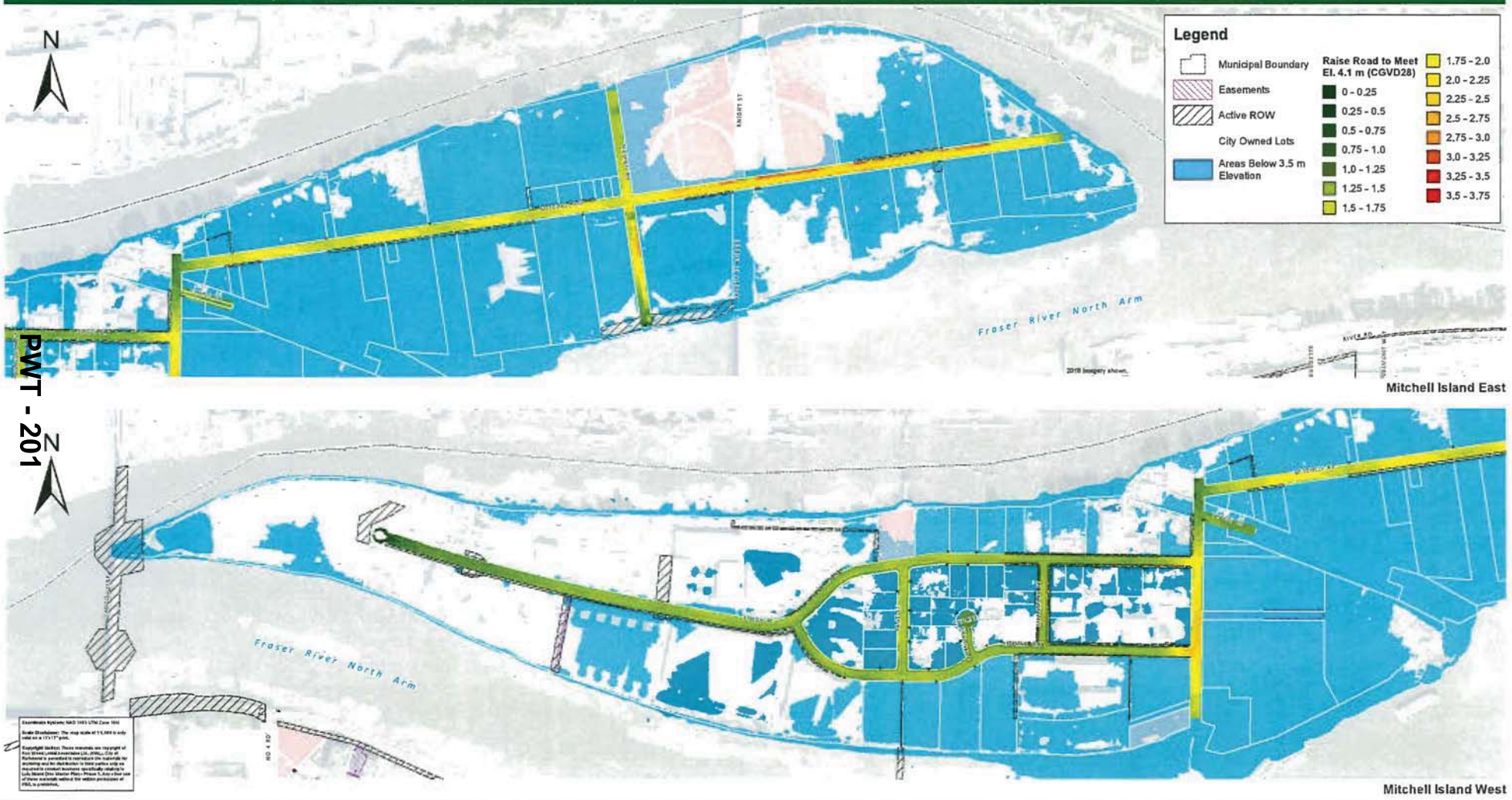
Option 2A and 2B: Raise Land

Figure 3-9

Path: O:\0600-0699\651-122\430-GIS\MXD-Rpt\Phase5\651122_Phase5_Fig3-10_Option2C.mxd Date Saved: 10/23/2018 10:26:21 AM | Author: jtau

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL consulting engineers



PWT - 201

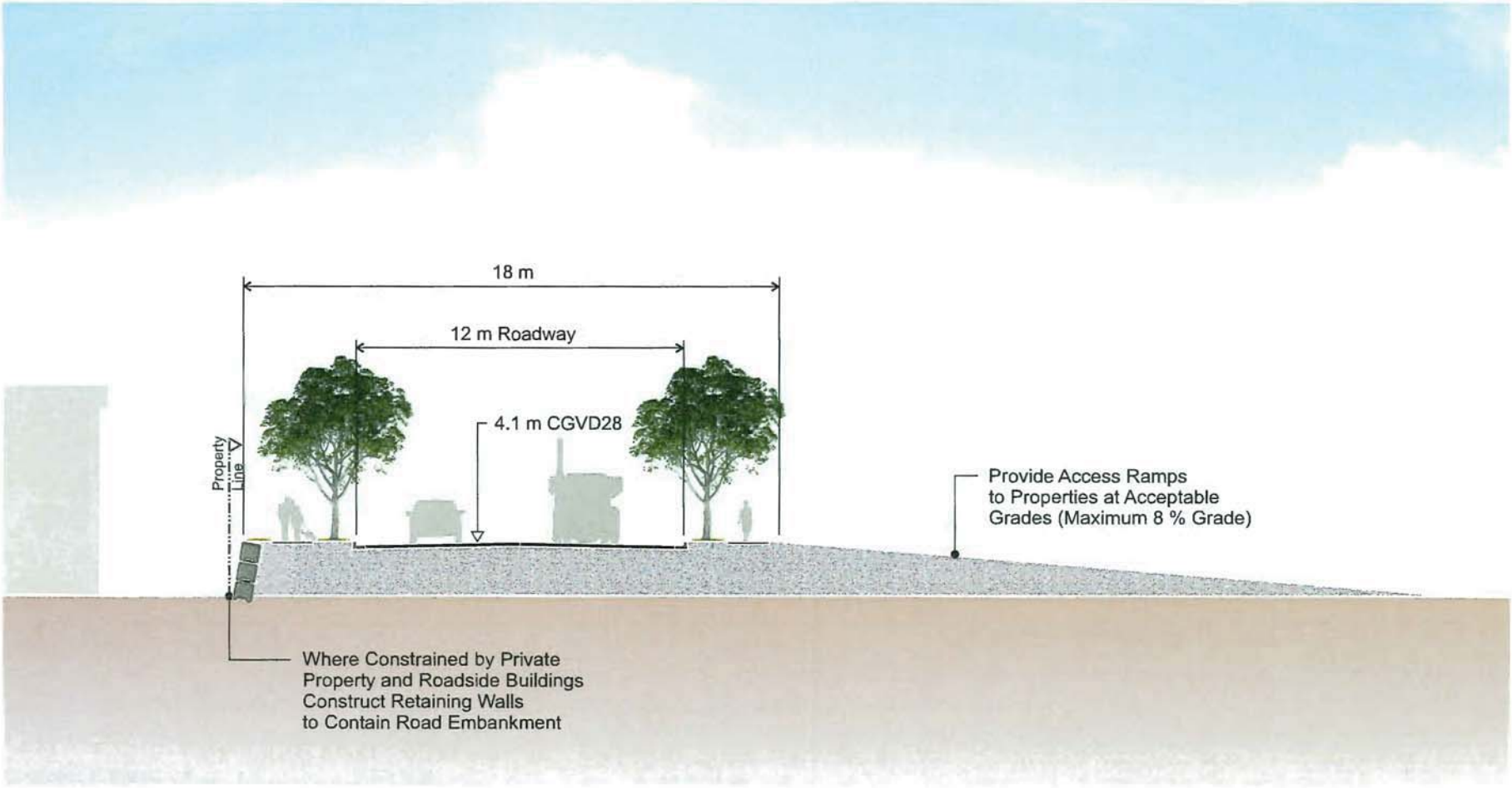
Project No.	651.129
Date	October 2018
Scale	1:6,500

100 50 0 100 m

Option 2C: Raise Roadways with Required Land Raising on Private Property (Plan)

DRAFT

Figure 3-10



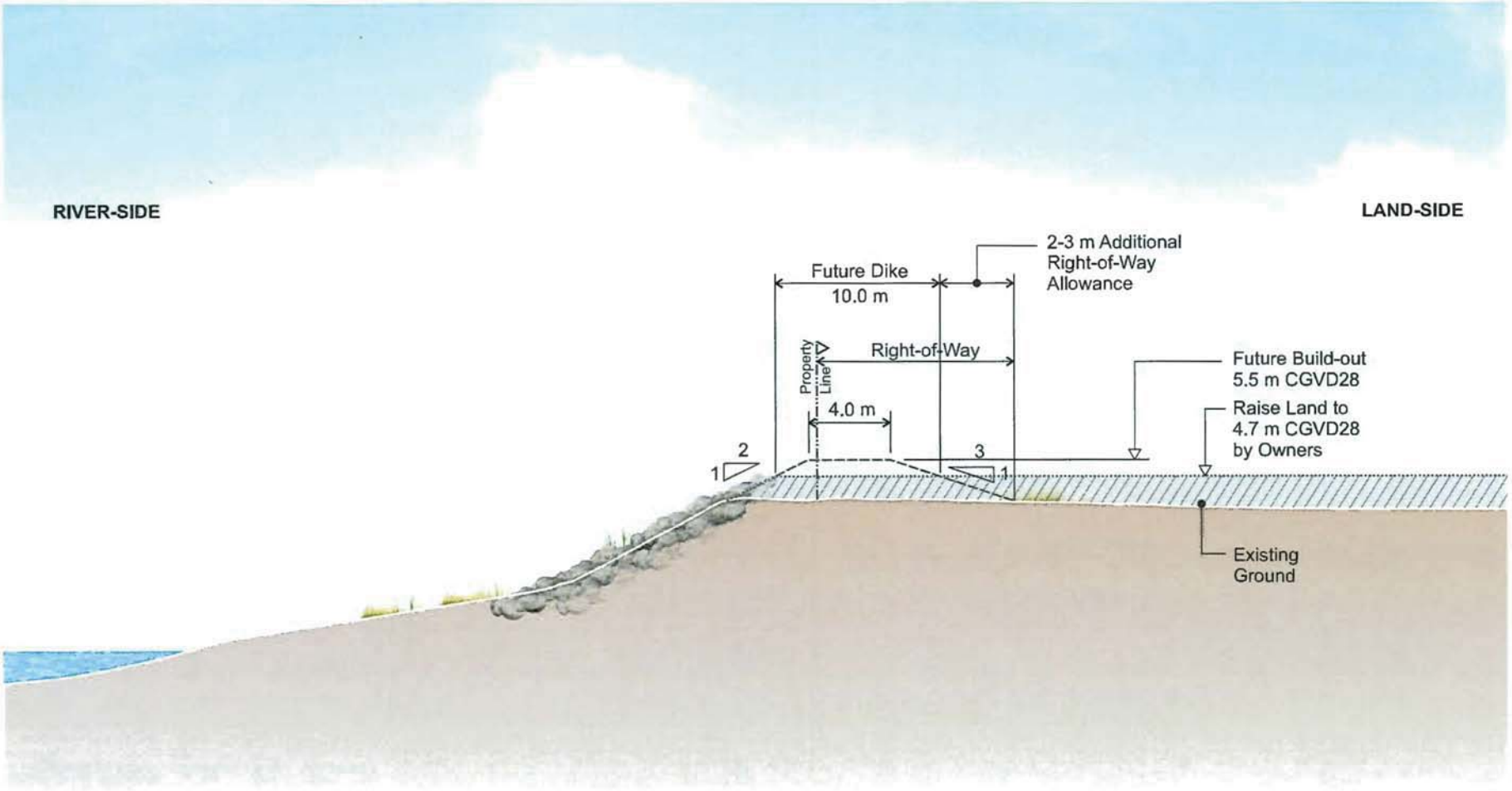
Project No.	651.129
Date	October 2018
Scale	Not to Scale

Option 2C: Raise Roadways with Required Land Raising on Private Property (Road Typical Section)

Figure 3-11

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL
consulting engineers



PWT - 203

Project No.	651.129
Date	October 2018
Scale	Not to Scale

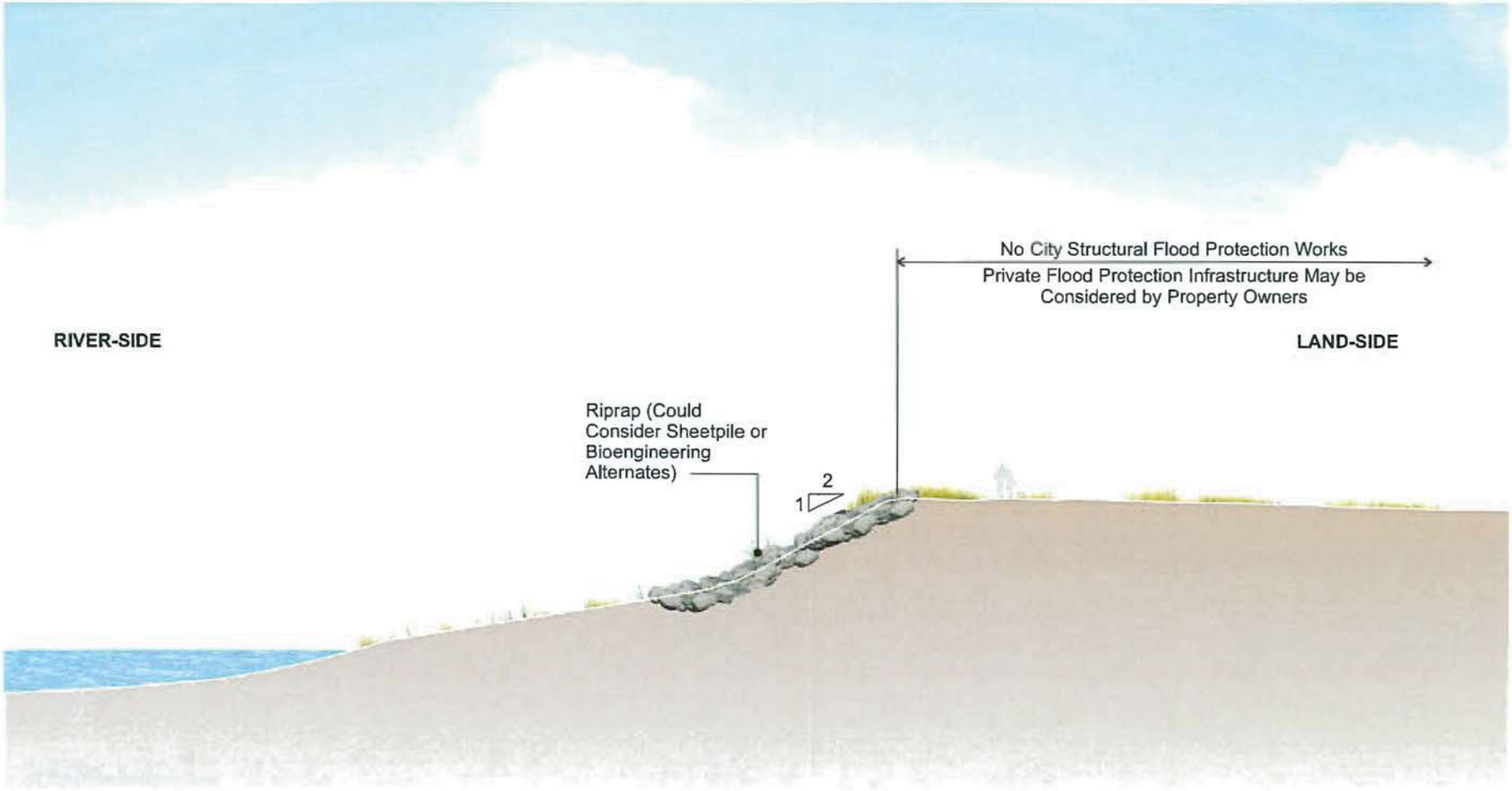
Option 2C: Raise Roadways with Required Land Raising on Private Property (Riverbank Section)

Figure 3-12

O:\0600-0699\651-122\501-Drawings\b_Figures\651122_Phase5_Fig_Dike.cdr

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL
consulting engineers



PWT - 204

Project No.	651.129
Date	October 2018
Scale	Not to Scale

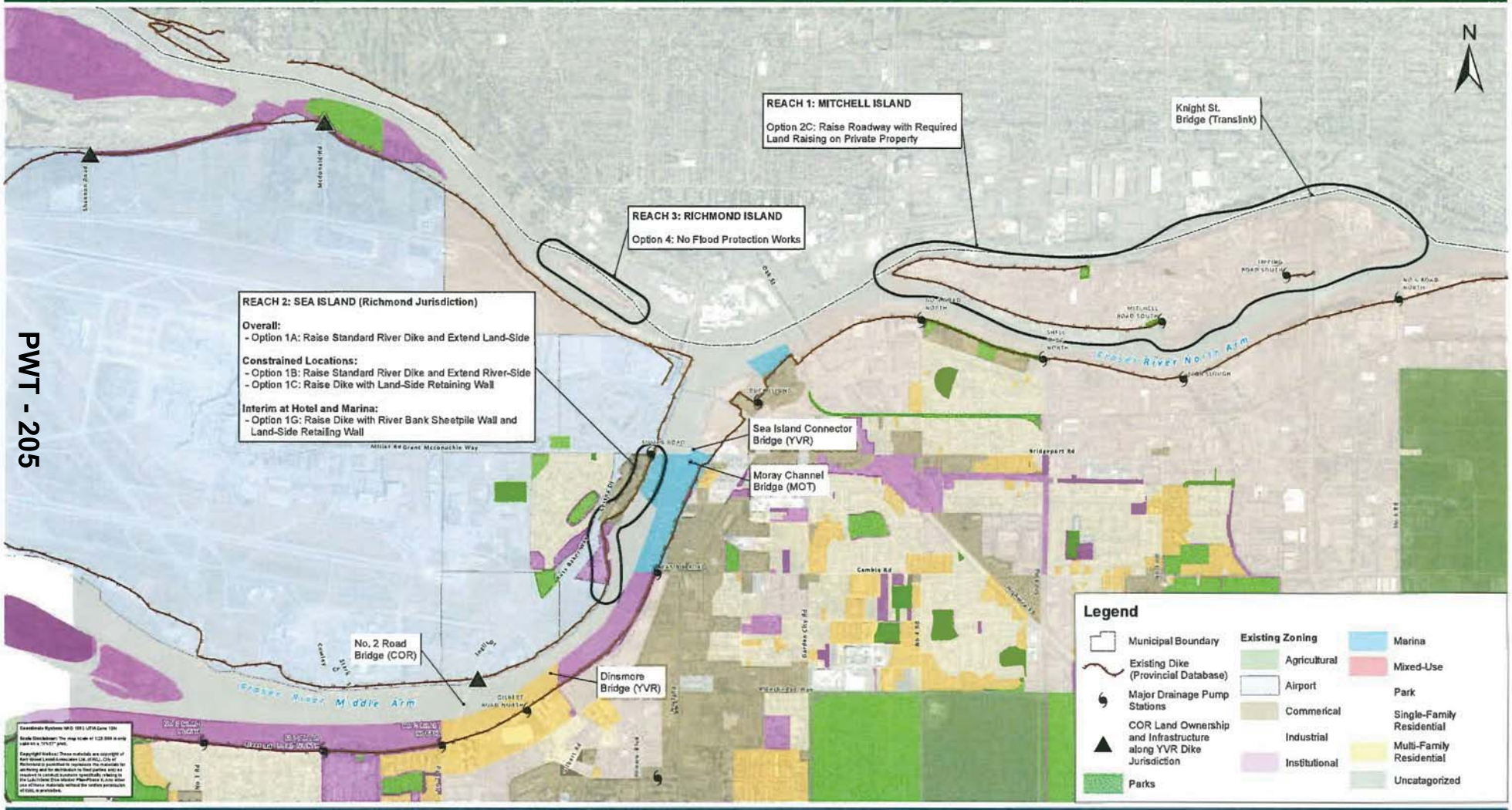
Option 3: Install/Maintain Bank Protection Works Only

Figure 3-13

Path: O:\0600-0699\651-122\430-GIS\MXD-Rpt\Phase5\651122_Phase5_Fig3-14_DMP_RecommendedOptions.mxd Date Saved: 11/20/2018 1:45:49 PM | Author: jlau

City of Richmond
Lulu Island Dike Master Plan - Phase 5

KERR WOOD LEIDAL consulting engineers



PWT - 205

Project No. 651-129
Date November 2018
Scale 1:25,000

400 200 0 400 m

Phase 5 Dike Master Plan Recommended Upgrade Options

DRAFT
Figure 3-14

4. Implementation Strategy

The implementation strategy is intended to guide the City in progressing the Dike Master Plan from an engineering planning document to constructed works. It suggests priority within Phase 5, key considerations moving forwards, coordination with other parties, and it addresses potential challenges. The implementation strategy for Phase 5 is described below by Island, given the unique recommendations for each area.

4.1 General

1. Use the Dike Master Plan as a planning tool with City land use planning to acquire land during redevelopment, and to rezone land with conditions for land raising inland of the dike.
2. Prioritize implementation in areas below the current design dike elevations of 3.5 m CGVD28.
    a. This includes low-lying properties on Mitchell Island, and the dike on Sea Island from Lysander Land northwards.
3. In conjunction with other Dike Master Plan phases, develop habitat compensation opportunities in Richmond. By considering all Dike Master Plan phase impacts together, habitat compensation work could be completed at a larger scale and provide more significant habitat, as opposed to small site-by-site compensation.
    a. Consult and coordinate this work with MFLNRORD to develop compensation opportunities amenable to the Province, to streamline and reduce uncertainty during the approvals process.
4. Develop an overall phasing strategy and timeline for dike upgrades for all of Richmond, considering other phases of the Dike Master Plan.
5. Consider the need for an appropriate building setback from the land-side toe of any future flood protection works in view of the current BC setback guideline of 7.5 m. This should consider the planned dike upgrade to 4.7 m CGVD28, as well as future buildout to 5.5 m CGVD28. This may require consultation with the Inspector of Dikes.

4.2 Mitchell Island

1. Work with low elevation (below current dike crest elevation of 3.5 m CGVD28) property owners in the short term to mitigate flood and related environmental contamination risks. This could include consultation, development of emergency policies, and short-term private flood protection measures. Consultation with low properties may also inform the sequencing of road raising.
2. Establish development policies on Mitchell Island that require the following at redevelopment:
    a. right-of-way acquisition along the riverbank to provide a 12 m wide band of access for the City along the entire perimeter of Mitchell Island, and
    b. land raising to 4.7 m on all properties (including considerations for excavation of contaminated soil and fill quality to reduce environmental contamination).
3. Consult with IOD regarding removal of listed flood protection infrastructure on Mitchell Island from the provincial inventory.

4. Progressively raise all roadways to dike elevation. Newer developments on Mitchell Island are relatively high, given the current Mitchell Island FCL of 4.35 m CGVD28, and as a result, raising the roads in these areas may improve access. Conversely, low lying areas (as low as 2 to 2.5 m CGVD28) would require access ramps to allow for continued operations and retaining walls or narrower roads to avoid impacts to private property. To address access challenges in low areas, the City could consider progressive raising or raising in conjunction with redevelopment. A road elevation of 4.1 m CGVD28 (dike elevation less freeboard) would be appropriate as an initial target, with refinement for specific areas.
5. As rights-of-way are acquired around the perimeter of the island, assess the need for additional bank protection works. Consider whether bank protection works should be the responsibility of the City or private land owners.
6. In the long term, if low-lying sites are not redeveloping or raising land and may be putting other property at risk as sea levels rise, consider purchasing and raising the land to be resold.
7. To achieve the future scenario dike elevation of 5.5 m CGVD28, consider further land raising or establish a perimeter dike.

4.3 Sea Island

1. Work with a legal land surveyor and YVR to resolve long-standing dike jurisdiction and land ownership uncertainties as they relate to the dike on Sea Island.
2. Work with YVR to raise the dike at Richmond road crossings. This includes the jurisdiction boundaries of the City's dike and agreements for locations where City land is located along a portion of the dike that is operated by YVR (such as at McDonald Beach Park).
3. Raise the existing dike along the current alignment, prioritizing dike upgrades from Lysander Lane northwards first, to target low areas below the current dike design elevation of 3.5 m CGVD28.
4. Consult with YVR regarding opportunities to raise the dike at Cessna Drive to 4.7 m CGVD28 in conjunction with planned bike path improvements.
5. Consult with the Pacific Gateway Hotel and marina to develop an interim design to raise the dike to 4.7 m CGVD28 along the current alignment, while allowing for access for each business. When the site eventually redevelops, establish a standard dike in accordance with the remainder of the reach.
6. At Lysander Lane, consider either raising the road or constructing a retaining wall to avoid moving the dike towards the river.
7. When the Miller Road drainage pump station is upgraded (planned for 10 to 15 years in the future), provide structural capacity for loading due to the dike raise and ensure there is sufficient space for the dike raise. To reduce overall construction costs, consider designing and constructing pump station and floodbox upgrades in conjunction with dike raising.
8. When the Moray Channel Bridge is at the end of its design life, replace it with a higher structure that is above 5.5 m CGVD28 and raise the land between the two bridges.
9. The current dike along BCIT limits the recommended dike upgrade option and would require moving the dike towards the river or retaining walls. Consider raising dike with a landside retaining wall, moving towards the river, or raising with a narrower crest initially until the site redevelops in the long term.
10. Consider establishing development policies on Sea Island that require land raising to dike elevation during site redevelopment.

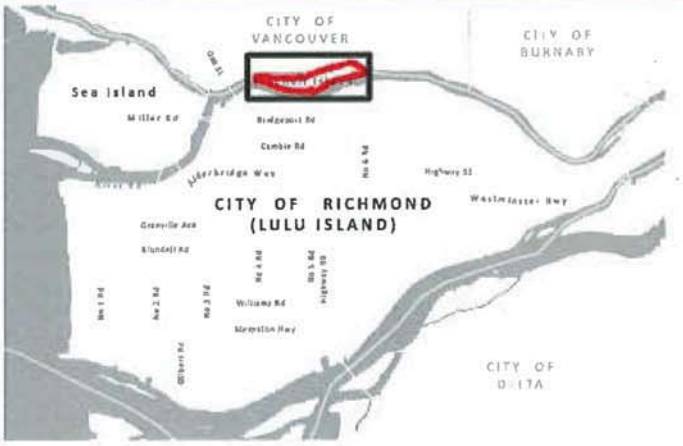
4.4 Richmond Island

1. No flood protection works are recommended as the island is predominantly above 5.5 m CGVD28.
2. Consider informing the owner of Richmond Island of the scour risk that has been identified in the North Arm of the Fraser River adjacent to the Richmond Island.

5. Reach Summary Sheets

The following section contains 2-page, reach-by-reach summary sheets that summarize the existing conditions, design considerations and potential constraints for each reach of Phase 5. The second sheet summarizes the features of the master plan through each reach including typical cross-sections, plan features, costs and priority for upgrade. The second sheet will be completed after stakeholder consultation and option selection.

Mitchell Island





Existing Conditions

The island is heavily developed with industrial and commercial operations, including sawmills, cement manufacturing, recycling, mechanics, warehouses, and more. Water oriented lots often have sheeptile walls along the river bank that allow for easier access and riprap bank protection works along the bank in adjacent areas.

An unmaintained private dike is located on the western perimeter of the island. There is no existing dike on Mitchell Island that meets current standards. Private bank protection works installed on the majority of the river bank, with sheetpile walls in several locations.

Unique Features

- Complex patchwork of properties with full occupancy of the lot right up to the river bank.
- Drainage pump stations at Tipping Road South and Mitchell Road South.
- No access to the riverbank for dikes except at a few isolated locations.
- Industrial operations that use the river to conduct their work, with sheetpile walls and barge facilities.
- Twigg Island sanitary forcemain crosses from Vancouver.
- Watermain below Page Street.
- Limited riparian habitat around the island.
- Two small existing Richmond parks.
- Log boom storage along the river bank.
- Two sawmills located directly on the water.

Considerations

Flood Protection

- Dike alignment
- Dike crest elevation
- Erosion protection
- Seismic performance
- Static stability and seepage
- River toe stability and setbacks
- Boat waves

Industrial

- Water access for industrial sites along the Fraser River
- Land acquisition or rights-of-way required to build and maintain flood protection works
- Road design and driveway grade to accommodate large trucks

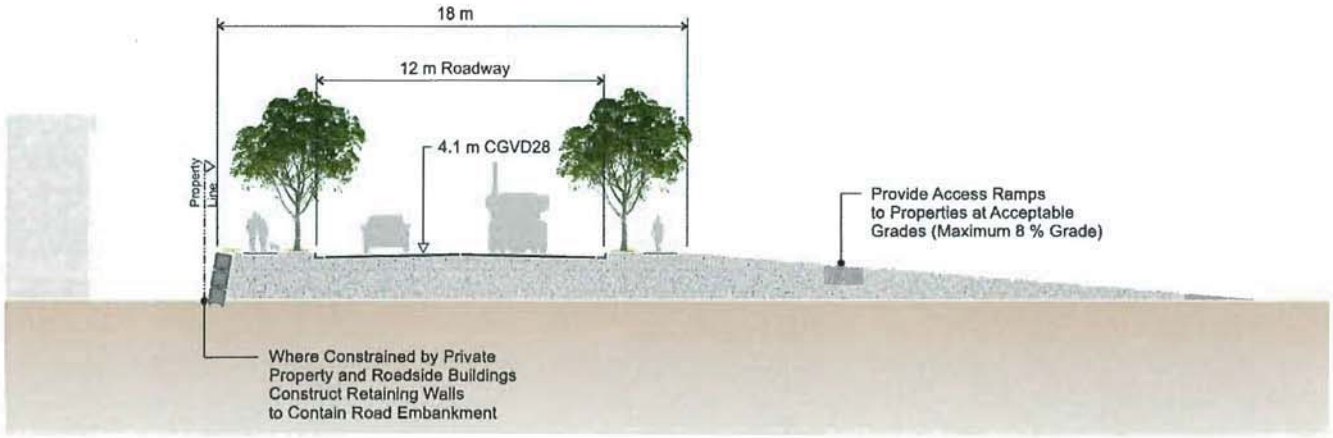
Social

- Mitchell Island Pier
- Park at south end of Mitchell Road
- Align with 2009 Waterfront Strategy
- Connect to existing and planned trails and public amenities
- Wayfinding and public information signs

Environmental

- High quality intertidal habitat in many locations
- Limited riparian habitat
- Log boom storage along the foreshore in many locations
- Several large habitat compensation projects completed around Mitchell Island

Mitchell Island - Recommended Improvements



Master Plan Features

Flood Protection

Raise roads to dike elevation to provide emergency egress

Require landowners to raise land to dike elevation at redevelopment

Acquire rights-of-way around the island perimeter for future bank protection works or perimeter dike

Industrial

Work with low industrial properties to mitigate short term flood and environmental contamination risks

Provide access driveways to properties during road raising

Social

No plans for additional parks or trails around Mitchell Island

Raise land at current parks and trails and reconstruct as needed

Environmental

No anticipated impacts to riparian or aquatic habitat caused by road raising

Landowner management of environmental impacts during raising

Excavation and fill standards to consider historical contamination risks

Priority

Priority is secondary to Sea Island as the majority of Mitchell Island is higher than Sea Island. Implementation priority on Mitchell Island is described below.

1. Work with low properties to mitigate flood and related environmental contamination risks.
2. Establish redevelopment policies on Mitchell Island that require right-of-way acquisition along the riverbank and land raising to 4.7 m on all properties.
3. Progressively raise roads to dike elevation, considering interim raises in low areas to reduce impacts to access and operations.
4. As rights-of-way are acquired around the perimeter of the island, assess the condition and presence of existing bank protection and consider the need for City-owned and maintained bank protection works.
5. In the long term, if low-lying sites are not redeveloping or raising land, consider purchasing and raising the land to be resold.

Construction Cost

Dike works are proposed to be fully funded as part of site raising with redevelopment over long term. 5.3 km of road costs for are expected to be borne by the City that would include driveway access ramps for private properties.

Item	Cost per metre	Cost
Road Structure	$2,900	$15,000,000
Raise Road to Dike Height	$6,900	$36,500,000
Other (Driveways)	$1,600	$8,300,000
Contingency (40%)	$4,500	$23,900,000
Total	**$15,900**	**$83,600,000**

Cost opinions are in 2018 Canadian Dollars.

Sea Island





Existing Conditions

The City of Richmond reach of the Sea Island dike stretches from BCIT north to the YVR Connector Bridge. The remainder of the dike is YVR responsibility.

This reach has a gravel/paved walking path along the crest and is bordered by four large commercial lots including BCIT, the Pacific Autism Family Centre, and the Pacific Gateway Hotel.

The Moray Channel Bridge located at the north end of the reach is lower than the proposed future dike elevation.

The dike is tightly hemmed in by the hotel and adjacent marina with private utilities installed along it. There is little to no bank protection works along the dike.

Unique Features

- Dike tie in at the Moray Channel and YVR Connector Bridges
- Miller Road drainage pump station
- Sanitary forcemain crossing
- Lack of right of way north of BCIT with low spot in the dike near Cessna Drive
- One section of the dike has already been raised to 4.7 m CGVD28 (design elevation)
- Evidence of old timber crib wall

Considerations

Flood Protection

Dike alignment
Dike crest elevation
Erosion protection
Seismic performance
Static stability and seepage
River toe stability and setbacks
Boat waves

Industrial

Commercial and institutional space
Russ Baker Way borders the existing dike
Access and use of the marina

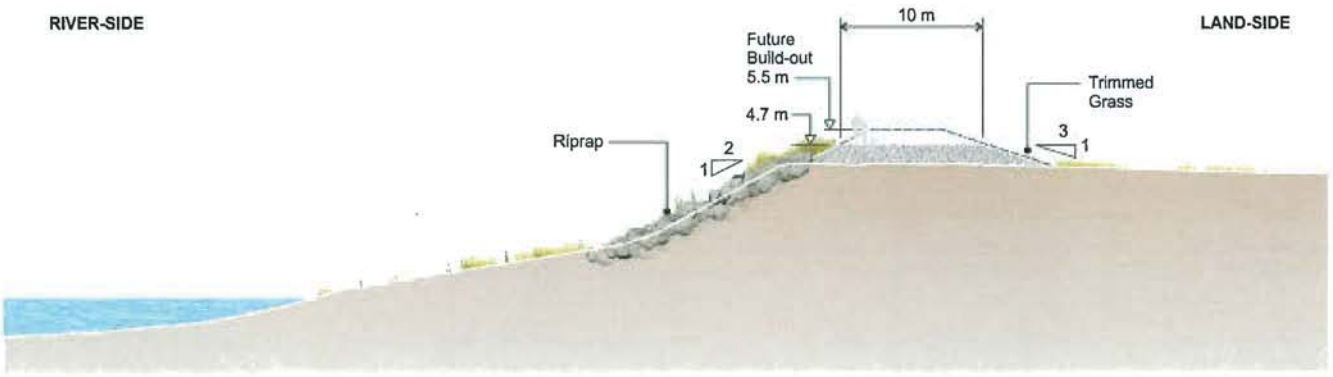
Social

Align with 2009 Waterfront Strategy
Connect to existing and planned trails and public amenities (consideration for YVR trails)
Wayfinding and public information signs

Environmental

High quality intertidal habitat for majority of the reach
High quality riparian habitat for majority of the reach
FREMP habitat mapping did not include the area in front of the hotel and marina. Further investigation would be required to characterize this area.
One existing habitat compensation site near the Miller Road Drainage Pump Station

Sea Island - Recommended Improvements



Master Plan Features

Flood Protection

Raise dike along existing alignment wide enough to accommodate future raise

Consider moving dike towards river-side or building retaining walls in constrained locations

Along the hotel and marina, raise the dike with sheetpile and retaining wall in the interim

At end of life, replace the Moray Channel Bridge with a higher structure

Acquire and widen rights-of-way

Industrial

Raise access ramps at Marina during dike raise

Reduce impacts to infrastructure along hotel with interim non-standard dike raise

Social

Provide landside pedestrian access to the dike along the hotel

Maintain existing multi-use path on the dike crest

Environmental

Dike raise towards the landside where feasible to reduce habitat impacts

The proposed footprint would impact an estimated 1,100 m^2 of high quality Fraser River intertidal habitat and 1,900 m^2 high quality Fraser River riparian habitat

An aquatic habitat survey and aquatic effects assessment would need to be completed to confirm impacts during design

Priority

Sea Island is the first priority reach in Phase 5. Implementation priority on Sea Island is described below.

1. Work with a legal land surveyor and YVR to resolve dike jurisdiction and land ownership uncertainties.
2. Raise the existing dike along the current alignment, prioritizing dike upgrades from Lysander Lane northwards first (below 3.5 m CGVD28).
3. Consult with the Pacific Gateway Hotel and marina to develop an interim design to raise the dike to 4.7 m CGVD28 along the current alignment.
4. At the Miller Road drainage pump station, consider designing and constructing pump station and floodbox upgrades in conjunction with dike raising.
5. Work with MOT to have the Moray Channel Bridge replaced with a higher structure that is above 5.5 m CGVD28 and raise the land between the two bridges.
6. Establish development policies that require land raising to dike elevation for river bank properties.

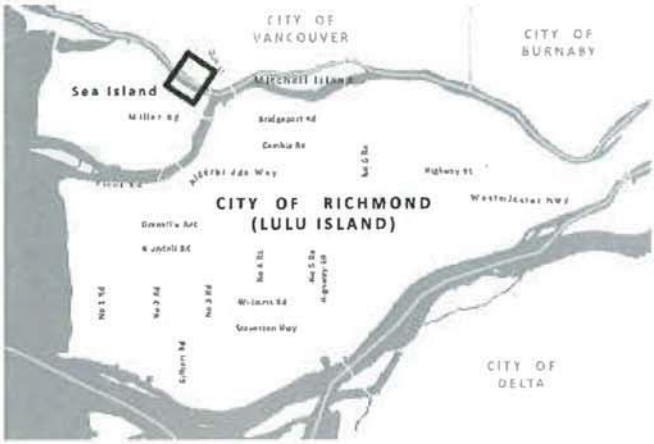
Cost

1.1 km of dike works may be funded as part of site raising with redevelopment or by the City, with 200 m that has already been raised to 4.7 m CGVD28. 40 m of dikes in City road rights-of-way may be covered as part of YVR dike improvements (Shannon and McDonald Roads). 150 m of interim works along the hotel.

Item	Cost per metre	Cost
Interim Dike Raising at Pacific Gateway Hotel	$6,000	$900,000
Dike Raising	$4,500	$3,600,000
Road End Improvements (McDonald Beach, Shannon Road)	$7,200	$300,000
Other (Pathway and access)	$1,000	$800,000
Contingency (40%)	$2,100	$2,200,000
Total	**$7,100**	**$7,800,000**

Cost opinions are in 2018 Canadian Dollars.

Richmond Island





Existing Conditions

Richmond Island is connected to the City of Vancouver via a small causeway. There is no existing dike on Richmond Island. The majority of the island is above both the dike upgrade elevation of 4.7 m CGVD28 and the future allowance to 5.5 m CGVD28, with the exception of the causeway. The entire Island is one private lot.

In 2012, a covenant was established that acknowledges that the City has not plans to protect the island from flooding and releases the City from any damage or losses covered by flooding or erosion.

The Fraser River North Arm is deep, and bathymetry indicates scour along this section. Riprap bank protection is in place around the island.

Utilities are provided by the City of Vancouver.

Unique Features

- Richmond Island is one private lot with a restaurant and marina that is serviced by the City of Vancouver.
- Covenant in place that acknowledges Richmond has no plans to protect the island from flooding or erosion.
- Fraser River north arm along this reach is deep due to scour.
- The majority of the island is above the dike elevation of 4.7 m CGVD28.

Considerations

Flood Protection

- Dike alignment
- Dike crest elevation
- Erosion protection
- Seismic performance
- Static stability and seepage
- River toe stability and setbacks
- Boat waves

Industrial

- Private marina on north side of the island.
- Road design and driveway grade

Social

- Align with 2009 Waterfront Strategy
- Connect to existing and planned trails and public amenities
- Wayfinding and public information signs

Environmental

- High quality intertidal habitat around the island
- FREMP mapping did not include riparian area, though based on orthimagery interpretation, riparian habitat is present
- Large habitat compensation project is located at the western tip of the island

Richmond Island - Recommended Improvements

No Works Proposed

Master Plan Features

Flood Protection

No flood or erosion protection works by the City

Inform property owner of scour risk in the North Arm

Industrial

No impacts to business or industry

Social

No impacts to public infrastructure

Environmental

No impacts to existing habitat

Priority

1. Consider informing the property owner on Richmond Island of the scour risk that has been identified in the North Arm of the Fraser River adjacent to the Richmond Island.

Cost

No works are proposed. Flood protection to remain the responsibility of this single lot.

6. Recommendations

It is recommended that the City adopt the Phase 5 Dike Master Plan as documented in this report, including the main features described below.

Mitchell Island

- During redevelopment, require private properties to be raised to dike elevation and acquire rights-of-way along the river bank. Rights-of-way allow for a future dike and bank protection works.
    - As rights-of-way are acquired around the perimeter of Mitchell island, assess the condition of existing bank protection works and consider whether the works should be the responsibility of the City or private land owners.
- Raise roadways to dike elevation to provide emergency egress (consider partial raises in low areas to reduce impacts to operations).
- Work with low elevation properties to mitigate flood and associated contamination risks.

Sea Island

- Raise the dike crest to 4.7 m CGVD28 to allow for 1 m of sea level rise. Widen the dike on the land side rather than into the Fraser River Middle Arm. Retaining walls or extending the dike towards the riparian area may be considered in site-specific constrained areas. Recent raises have been completed on some sections of the dike, including up to 4.7 m CGVD28 in one location.
- Establish development policies on Sea Island that require land raising to dike elevation during site redevelopment.
- Coordinate dike upgrades with upgrades to the Miller Road Drainage Pump Station and the Moray Channel Bridge.
- As an interim measure along the Pacific Gateway Hotel, raise the dike to 4.7 m CGVD 28 with a sheetpile wall embedded along the river-side and a land-side retaining wall.
- Coordinate dike improvements with YVR and establish agreed upon dike jurisdictions.

Richmond Island

- No changes by the City are proposed as the island is predominantly above 5.5 m CGVD28. Flood protection responsibility is recommended to remain with the property owner.
- Inform the property owner on Richmond Island of the scour risk that has been identified in the North Arm of the Fraser River adjacent to the Richmond Island.

For all phases of the Dike Master Plan, continue to research alternative densification strategies for seismic stability, consider the proposed alternative seismic performance criteria in Section 3.2, and plan to fill land for approximately 200 m inland of the dike to crest elevation. The required fill distance requires additional evaluation and may be addressed in the pending update to the Flood Protection Management Strategy.

It is also recommended that the City prepare a comprehensive implementation plan for dike upgrading that incorporates the elements of Phase 5 and the other Dike Master Plans. To address habitat compensation issues associated with the Dike Master Plans, it is further recommended that the City consider development of a habitat banking program that could provide effective large-scale compensation for the environmental impacts of dike upgrading.

Report Submission

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.

DRAFT

Allison Matfin, EIT
Project Engineer

DRAFT

Amir Taleghani, M.Eng., P.Eng.
Water Resources Engineer

Reviewed by:

DRAFT

Mike V. Currie, M.Eng., P.Eng., FEC
Project Director and Technical Reviewer

DRAFT

Colin Kristiansen, MBA, P.Eng.
Project Manager

Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of CITY OF RICHMOND for the Richmond Dike Master Plan – Phase 5. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents KWL's best professional judgment based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practicing under similar conditions. No warranty, express or implied, is made.

Copyright Notice

These materials (text, tables, figures, and drawings included herein) are copyright of Kerr Wood Leidal Associates Ltd. (KWL). CITY OF RICHMOND is permitted to reproduce the materials for archiving and for distribution to third parties only as required to conduct business specifically relating to Richmond Dike Master Plan – Phase 5. Any other use of these materials without the written permission of KWL is prohibited.

Revision History

Revision #	Date	Status	Revision	Author
C	November 21, 2018	DRAFT	3rd draft to City (revised based on City's comments)	ARM
B	October 25, 2018	DRAFT		ARM

OQM CERTIFIED