City of Courtenay

Flood Management Plan Appendix F – Flood Protection Structures Review and Dike Master Plan

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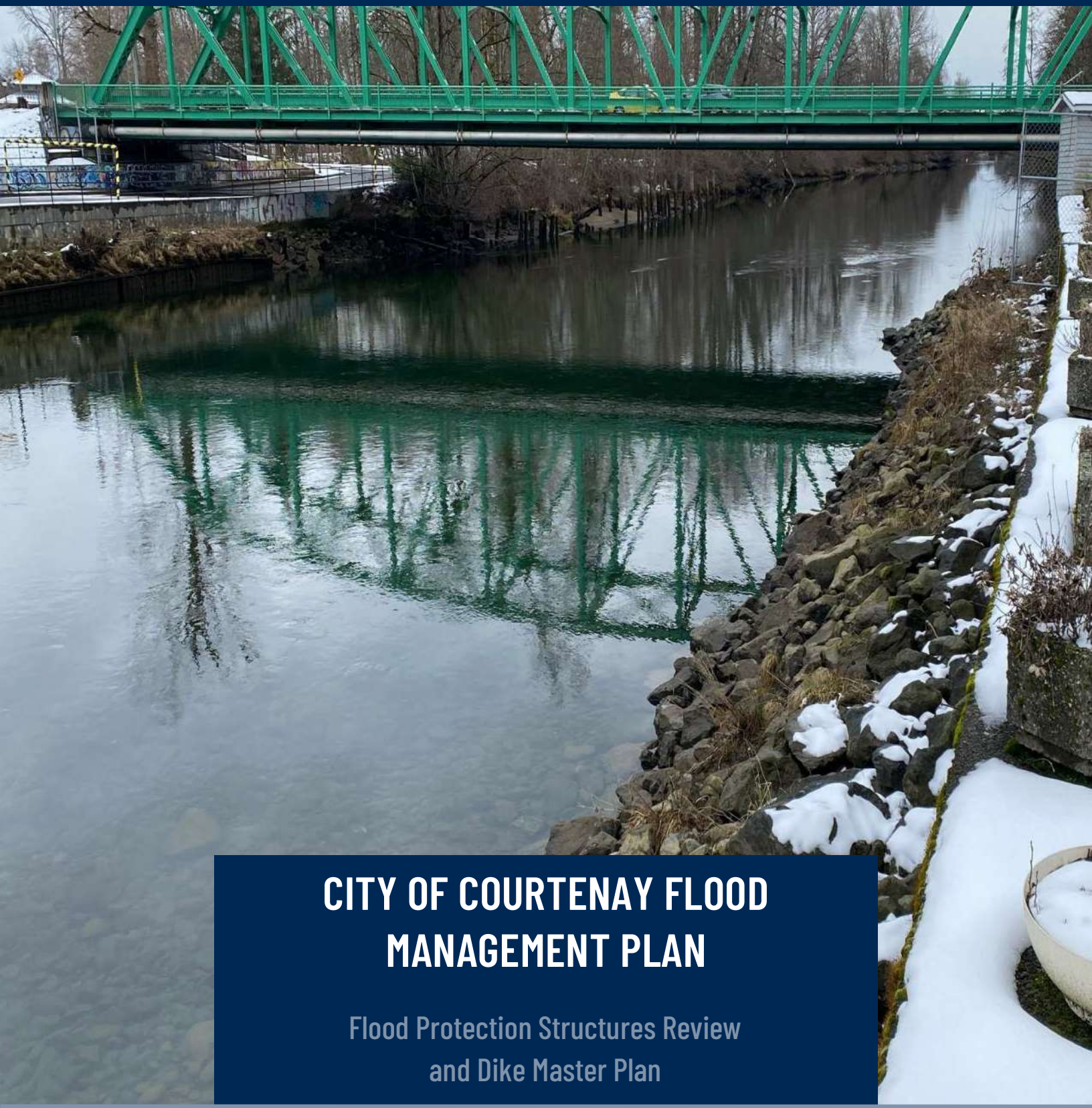

CITY OF COURTENAY FLOOD MANAGEMENT PLAN

Flood Protection Structures Review and Dike Master Plan

Ebbwater Consulting Inc.

06 Sep 2024

WATER STREET ENGINEERING

Document Information

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EGBC permit number 1000830.

Revision History

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A	Draft	10 Nov 2023	Draft for review
B	Draft	29 Nov 2023	Addressed Ebbwater comments
0	Final	06 Sep 2024	Addressed City comments

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

1 INTRODUCTION

1.1 PURPOSE

Water Street Engineering Ltd. (Water Street) was engaged by Ebbwater Consulting Inc. (Ebbwater) to provide engineering support with a Flood Management Plan for the City of Courtenay (the City) to address ongoing flooding concerns in Courtenay, BC. The goals of the Flood Management Plan are to better understand the current and future flood hazards, evaluate existing flood protection infrastructure, and inform preliminary decisions related to actions to mitigate risk and increase resilience.

This report provides an overview of the flood protection structure review carried out by Water Street to support this work. The aims are to review the existing flood protection structures within the City against regulatory standards and against the requirement to offer adequate protection from flood events.

The work undertaken included a detailed review of the following flood protection structures within the City:

- Anderton Avenue Dike
- Lewis Park Dike
- Canterbury Lane Dike
- Condensory Dike

This involved a desktop review of as-built conditions, recent inspection reports, surveyed elevations, and modelled flood profiles. A site visit was carried out to evaluate the current status and condition of each flood protection structure.

This report presents the findings of the flood protection structure review, providing a summary of the condition of each flood protection structure, compliance with current regulations, and ability to provide adequate flood protection. Structural mitigation options recommended through Ebbwater's Flood Management Plan were summarized in a dike master plan (see Section 9) to support future planning and implementation timelines.

1.2 BACKGROUND

Courtenay is located on the east coast of Vancouver Island, within the Comox Valley Regional District (CVRD). It is located at the confluence of the Puntledge River and the Tsolum River, which form the Courtenay River and flows approximately 3 km through Courtenay and into Comox Bay. The Courtenay River covers a watershed area of approximately 870 km^2, including the Puntledge River that drains from its headwaters to the east of Comox Lake and the Tsolum River that drains the north and east-facing slopes of Mount Washington before flowing to the southeast towards Courtenay. Water levels and flow in the Courtenay River are influenced by BC Hydro operations of Comox Lake Dam, located upstream along the Puntledge River, as well as tidal influence from Comox Bay and any storm surge events.

Courtenay has a history of flooding, with major floods recorded along the Courtenay River within the last decade that caused significant damage to community infrastructure and property. For instance, major floods in 2014 and 2016 caused damage including washout of roads and bridges, damage to drinking water wells, erosion along trails and roadways, and localized flooding and damage to private property and buildings.

Flooding in the region can be caused by a range of related factors, including rainfall and snowmelt, extreme high tides and storm surges, and shallow groundwater tables. Climate change is expected to make flooding more severe in the future as rainfall patterns change and sea levels rise. Flood events are typically associated with heavy rainfall events during large storms from the Pacific Ocean. Typically, these large storms lead to low pressure systems and high winds that cause storm surge and wave set-up in Comox Bay that add to flood levels along the Courtenay River (KWL, 2021). These storm events typically occur in the late fall or early winter (November to February).

1.3 FLOOD PROTECTION STRUCTURES

The City has four flood structures that were constructed to protect against flooding. These structures are located along the Courtenay River and Puntledge River and were constructed between the 1960s and the early-2000s. A summary of each flood protection structure is provided below:

The **Anderton Avenue Dike** extends along the west bank of the Courtenay River, extending upstream from the 5th Street Bridge and running directly opposite the Lewis Park Dike. The Anderton Avenue Dike is approximately 300 m long, with 250 m of precast concrete sections and 50 m of steel sheet piling.

The **Lewis Park Dike** follows the south bank and east bank of the Courtenay River as it flows around Lewis Park. It is approximately 450 m long and was constructed from precast concrete sections with riprap placed along the toe of the structure.

The **Canterbury Lane Dike** is a setback concrete floodwall that runs along the south bank of the Puntledge River. It is approximately 260 m long and was constructed as part of the multi-family development adjacent to the river. The embankment in front of the concrete floodwall is armoured with riprap.

The **Condensory Dike** is a compacted earthfill berm located along the south bank of the Puntledge River, upstream and adjacent to the Condensory Bridge. The earthfill berm is approximately 95 m long and includes riprap on its outside bank to provide erosion protection.

The general layout of the study area and location of the flood protection structures is shown in Figure 1-1.

WATER STREET ENGINEERING

EGBC Permit to Practice #1000830

Legend

- Lewis Park Dike
- Condensory Dike
- Canterbury Dike
- Anderton Dike

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PREPARED FOR

CITY OF COURTENAY

Courtenay Flood Management Flood Structures Review

Dike Map

PROJECT NO.	DATE	REVISION
339	06 SEP 2024	0

Figure 1

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2 BACKGROUND

2.1 RECENT WORK

Extensive work has been carried out in recent years to assess and manage flood risk within the City, and to adapt to the increasing potential for flood hazards given the impacts of climate change. The City has taken a proactive approach to addressing flood hazards and improving the management of flood risk within the area. Recent work has included the 2013 Integrated Flood Management Study (McElhanney, 2013), the 2021 Dike Replacement and Flood Management Strategy (Urban Systems, 2021), and the 2022 Courtenay Flood Operations Manual (McElhanney, 2022a). In addition to this, the City has participated as a partner with the CVRD on the 2021 Coastal Flood Mapping Project (KWL, 2021).

The 2021 Coastal Flood Mapping Project created a series of floodplain maps showing various flooding scenarios and parameters to support future flood risk planning and land use planning within the region. The work illustrates Courtenay's risk to flooding during extreme weather events, storm surges, and high tide conditions. The mapping provides data for maximum water levels, maximum water depths, maximum flow velocity, flood hazard rating, sea level rise planning areas, and setbacks. The mapping shows the areas most vulnerable to flooding include Lewis Park and the low-lying area surrounding the confluence of the Tsolum River, Puntledge River, and the Old Tsolum Channel.

The 2021 Dike Replacement and Flood Management Strategy noted that there is no singular solution to flood management as channel widening or partial diking cannot provide protection against a 200-year event, and dike upgrades can protect some properties but at the expense of others.

Work has been carried out since 2016 to review the geotechnical and structural condition of the Anderton Avenue Dike. The City has concerns for the stability of the structure and the safety of adjacent buildings based on evidence of movement of the structures. McElhanney completed a rehabilitation scoping study in December 2021 to assess the general condition of the structure and provide a review of the risks to the City. This study recommended that the City should consider either replacing or extensively rehabilitating the sheet pile wall in the next 2-3 years. Work is ongoing by McElhanney and the City to develop replacement options following this recommendation. The latest version of the Options Analysis report provides three options for replacement or rehabilitation (McElhanney, 2023).

2.2 REGULATORY REQUIREMENTS

The provincial government administers the *Dike Maintenance Act*, while local governments are responsible for the operation and maintenance of flood protection structures as part of this regulation. As defined in the *Dike Maintenance Act*, a dike is a structure or embankment constructed or installed to prevent the flooding of land. Various other guidelines exist that outline design and maintenance requirements.

The *Guidelines for Management of Flood Protection Works in British Columbia* provides a summary of best practice for the management of flood protection works in BC. It defines the standard design flood in BC as the *designated flood* which means 'a flood, which may occur in any given year, of such magnitude as to equal a flood having a 200-year recurrence period interval (Province of British Columbia, 1999).

The *Seismic Design Guidelines for Dikes* (Province of British Columbia, 2014) provide guidelines for consideration of seismic stability for new and major upgrades to certain flood protection structures.

The *Flood Hazard Area Land Use Management Guidelines*, most recently amended in 2018 (Province of British Columbia, 2018), provides guidelines for developing and implementing land-use management plans and development approval decisions for flood hazard areas.

The *Dike Design and Construction Guide - Best Management Practices for British Columbia* provides detailed guidance on the design and construction of dikes to provide protection against flooding, with consideration of potential future changes to flood hazards including sea level rise and changes in precipitation patterns. It provides further definition to the standard design flood for river dikes by stating the standard river dike crest elevation is the higher of the 200-year instantaneous flow plus 0.3 m freeboard, or the 200-year maximum daily flow plus 0.6 m freeboard (Province of British Columbia, 2003).

3 DATA REVIEW

3.1 OVERVIEW

Water Street carried out a review of each flood protection structure based on available information covering the constructed conditions, recent inspection reports, surveyed elevations, and modelled flood profiles. The following sections describe the findings from this review.

3.2 ANDERTON AVENUE DIKE

The Anderton Avenue Dike is a flood protection structure registered as Dike No. 28 with the Province of British Columbia and regulated under the *Dike Maintenance Act*. The diking authority is the City. The Anderton Avenue Dike runs along the west bank of the Courtenay River, extending upstream from the 5th Street Bridge. It is approximately 300 m long, with 250 m of precast concrete sections and 50 m of steel sheet piling with a concrete cap. The precast concrete sections and steel sheet piling were constructed from 1978 to 1980 to replace a log and lagging wooden wall that was built in the 1950s. Remnants of the former log wall remain at the toe of the current structure, which appears to contribute to the anchoring and support of the structure in some places. The crest elevation of the dike is between 4 and 4.5 m geodetic, below the FCL of 6.0 m in this area. A number of geotechnical and structural deficiencies have been noted in assessments since 1998. Following geotechnical and structural inspections in 2016, an emergency repair was required to stabilize the structure. The section of sheet pile wall was temporarily stabilized through the addition of a riprap buttress along the toe of the sheet piles. The design cross section for this repair, showing the current configuration of this section, is shown in Figure 3-1.

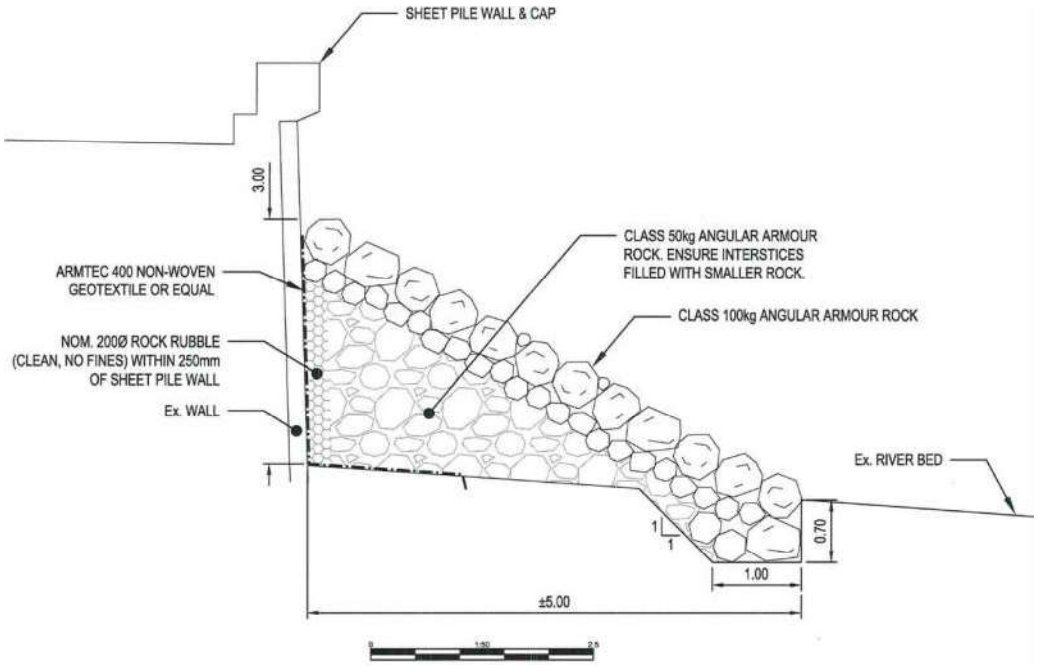


Figure 3-1: Riprap buttress cross section along the Anderton Avenue Dike sheet pile wall section (McElhanney, 2016)

Since completing the repair, monitoring of the sheet pile section of the wall has been conducted quarterly since 2016. The structure has many concerns, including riverbank scour and erosion, the wall gradually moving towards the river, cracks in the concrete cap, and substantial vegetation and root intrusion issues. The structure is reaching the end of its service life and the City is currently working to identify the best path forward to address the risk.

3.3 LEWIS PARK DIKE

The Lewis Park Dike is a flood protection structure registered as Dike No. 29 with the Province of British Columbia and regulated under the *Dike Maintenance Act*. It follows the south bank and east bank of the Courtenay River as it flows around Lewis Park, directly opposite the Anderton Avenue Dike. It provides flood protection to the Lewis Park area, located in the center of Courtenay.

Design or record drawing information for the structure was requested from the City but was not available for review. The Lewis Park Dike is approximately 450 m long and was constructed from precast concrete sections that appear to have replaced a wooden log wall at some point. The crest elevation of the dike is approximately 4.0 m geodetic. River armouring along the toe of the concrete wall includes angular riprap, round rock, and wood material from the original wood wall structure. Over time, vegetation has established along the toe and banks of the dike as well as ongoing deposition of gravels, particularly at the inside of the bend in the Courtenay River.

The City maintains temporary seasonal flood protection through the use of a Tiger Dam (previously an AquaDam) upstream of Lewis Park, typically installed between October and February each year. Maintaining the Tiger Dam is a proactive flood protection measure aimed at providing increased flood protection and reducing resources and staff required for flood response. The Tiger Dam is installed at the north end of Lewis Park, adjacent to the Tsolum River, which is usually the first area to flood during a high flow event (McElhanney, 2022a).

Lewis Park contains 3 culverts that are open to the Courtenay Slough to the south. These were installed to allow flood waters to exit Lewis Park, but they also allow flood waters into Lewis Park via a backwater effect through the Courtenay Slough during times of high water levels.

Recent inspection reports were provided by the City between 2017 and 2022. The main recommendations from these inspection reports include:

- Existing toe protection includes a mix of riprap, wood material, and round rock. The configuration is reported to cause turbulence along the banks increasing scour forces. The existing armouring does not comply with diking standards.
- River bank soils and foundations have several areas where minor erosion and undermining was observed, as well as vegetation growing within soils below concrete precast sections. Vegetation should be removed and erosion repaired with new riprap material where necessary.
- Voids and cracks were observed in the concrete wall, which should be repaired using concrete or grout.

3.4 CONDENSORY DIKE

The Condensory Dike is a flood protection structure registered as Dike No. 363 in the Province's Dike Database. The responsible authority is the City who must ensure compliance with the *Dike Maintenance Act*. The Condensory Dike is located along the south bank of the Puntledge River, upstream and adjacent to the Condensory Bridge.

The Condensory Dike is a flood protection structure consisting of an earthen berm with a low permeability core. It was constructed in 2005 and provides erosion protection to an undeveloped area of land adjacent to the Puntledge River. It is approximately 95 m long with a 4 m wide crest at a crest elevation of 6.7 m. Riprap placed on its outside banks provides erosion protection but the structure does not provide dependable flood protection as the existing soils surrounding the dike are permeable and floodwater can infiltrate through the structure.

A cross section showing the constructed conditions is included in Figure 3-2 (McElhanney, 2006b).

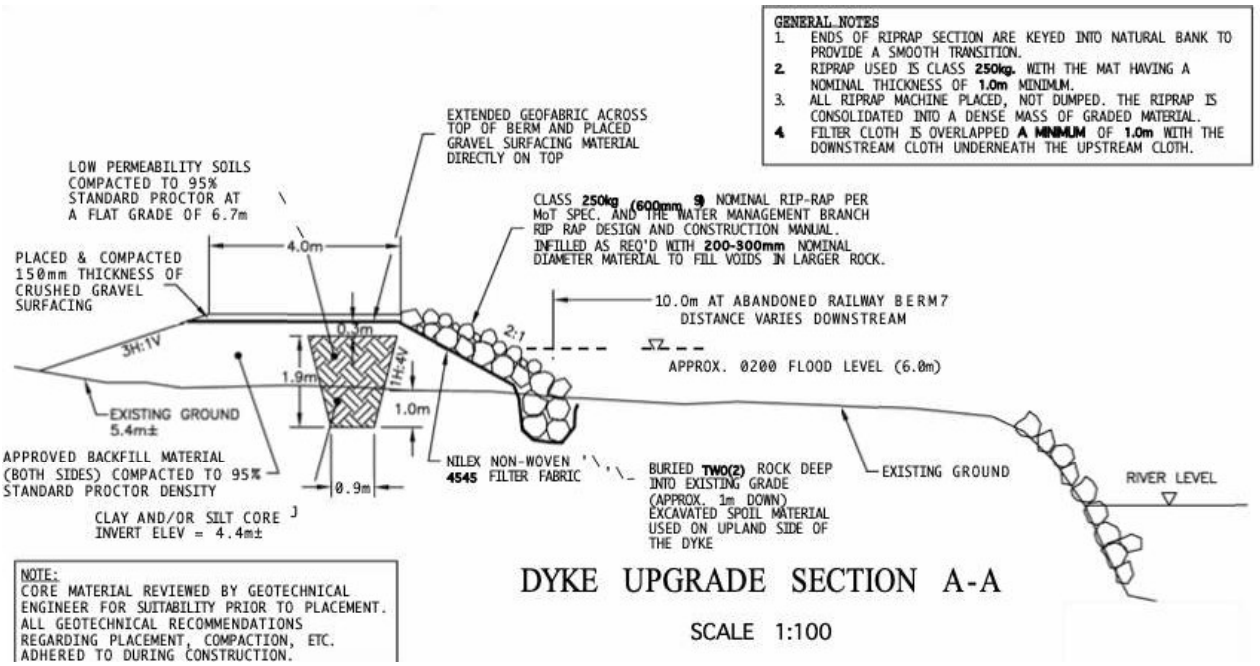


Figure 3-2: As-built cross section of the Condensory Dike (McElhanney, 2006b)

The City provided annual inspection reports between 2017 and 2022, conducted by the City's Public Works Inspector. The inspections found that the dike wall was generally in good condition and recommendations for maintenance were limited to vegetation management.

3.5 CANTERBURY LANE DIKE

The Canterbury Lane Dike is a flood protection structure registered as Dike No. 373 in the Province's Dike Database. The Canterbury Lane Dike is located along the south bank of the Puntledge River, downstream of the Condensory Bridge. The dike is a setback vertical concrete floodwall that was constructed in 1989 as part of the multi-family development adjacent to the river. The embankment in front of the concrete floodwall is armoured with riprap. There is a walking trail through the forested area between the floodwall and the Puntledge River. Residential development is located immediately behind the concrete wall with backyards and gardens on the landside of the wall. The Canterbury Lane Dike is approximately 260 m long and has a typical cross section as shown in Figure 3-3, where C is the height of the concrete retaining wall and D is the height of the wooden fence on top of the concrete wall.

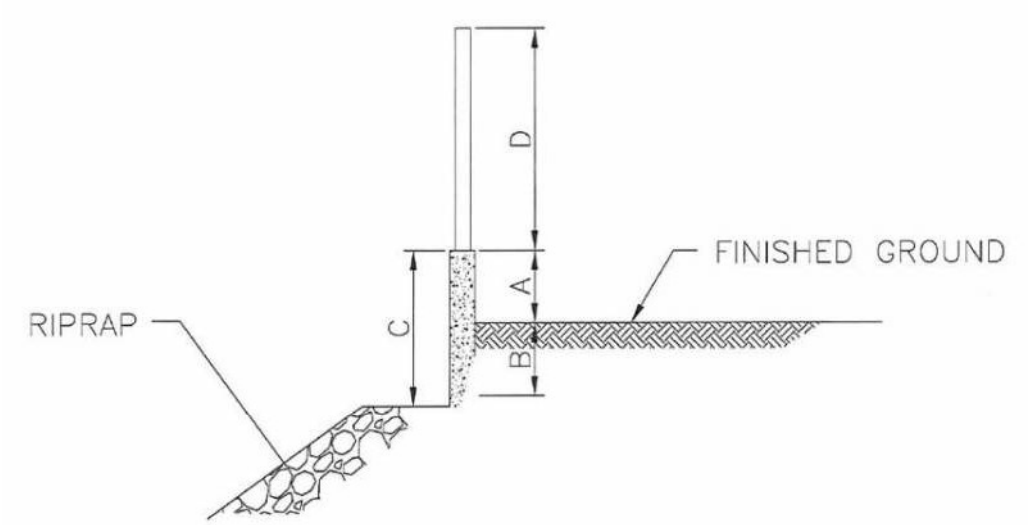


Figure 3-3: Cross section of Canterbury Lane Dike floodwall (McElhanney, 2006a)

The height of the concrete wall above ground, C, varies from 0.5 m to 3.2 m with wooden fencing on top of the concrete wall. The concrete wall has a typical elevation of ~6.0 m geodetic, which is below the FCL of 6.9 m in this area. The finished ground behind the wall (i.e., in the backyards of the residential properties) is higher than the land on the river side of the structure. High-level observations from the field review identified limited deterioration or damage to the dike crest and wall, as well as no major cracking or movement. However, a thorough inspection was not possible because vegetation obscured visibility and no access was available to the backside of the structure (via residents' backyards). The riprap has a typical slope between 2H:1V and 2.3H:1V and was noted to be in a good condition. No signs of riprap movement or slope instability were noted, and the structure appears to be functioning well. Vegetation was encroaching on the riprap which reduced the visibility of the toe.

Ownership of the structure has been disputed as it was built by the residential development to protect patios prior to the *Dike Maintenance Act*. After the *Dike Maintenance Act* became law in 1996, the Province sought to make the City responsible for the structure. Due to the ownership dispute and because the City has no Statutory Right of Way (SRW) in place to access the property, the City has not been maintaining the structure or taking ownership of it. In fall 2023, the Province clarified that their policies do not support designating stratas as diking authorities. The ownership dispute results in significant risk for the property owners and the City.

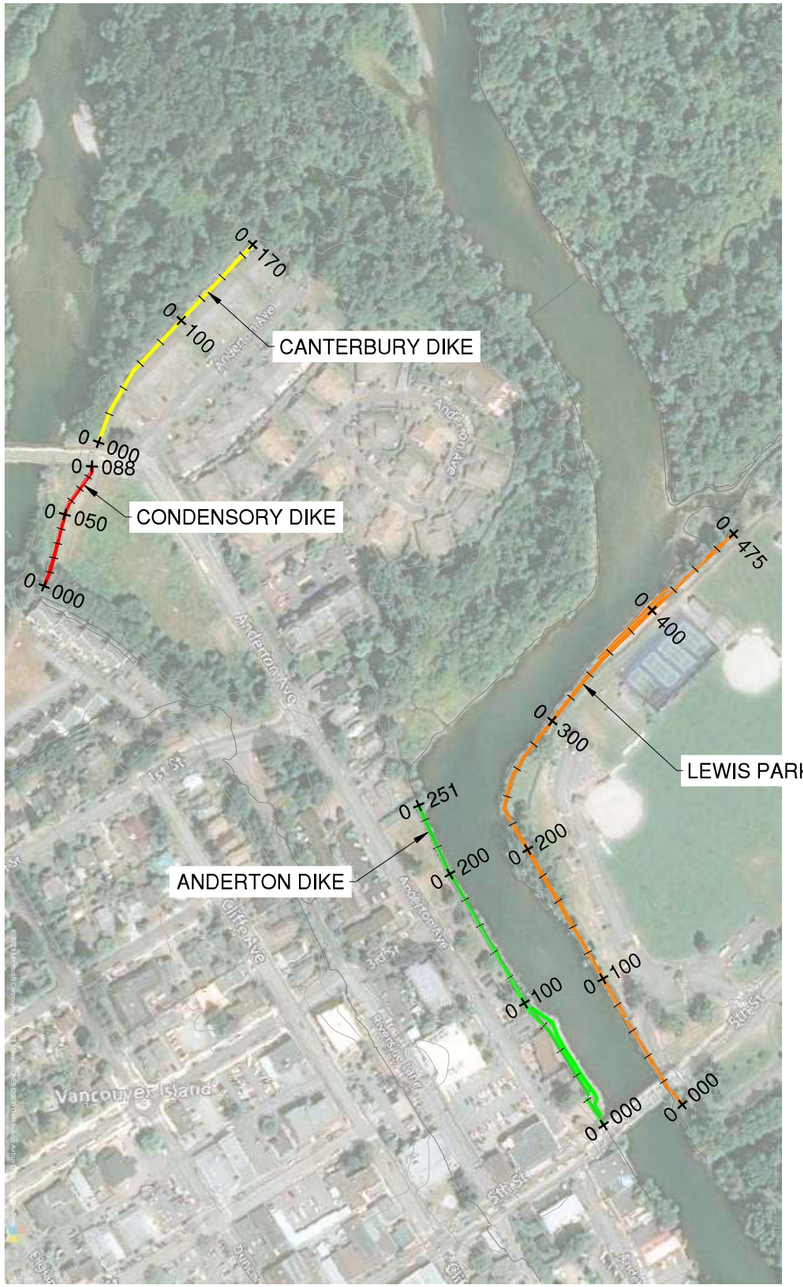
3.6 DIKE CREST SURVEY

Digital survey data containing dike crest elevations for each flood protection structure within the City of Courtenay was provided for review. This data was reviewed against the information provided in other reports, drawings, and inspections.

A summary of the surveyed dike crest elevations is provided in Table 3-1. Plan and profile drawings showing the dike crest elevations for each structure are presented in Figure 3-4.

Table 3-1: Summary of surveyed dike crest elevations

Structure	Crest Elevation (m CGVD2013)
Anderton Avenue Dike	Between 4.0 m and 4.5 m
Lewis Park Dike	Between 3.0 m and 4.0 m
Condensory Dike	Approximately 6.7 m
Canterbury Lane Dike	Approximately 6.0 m



PLAN
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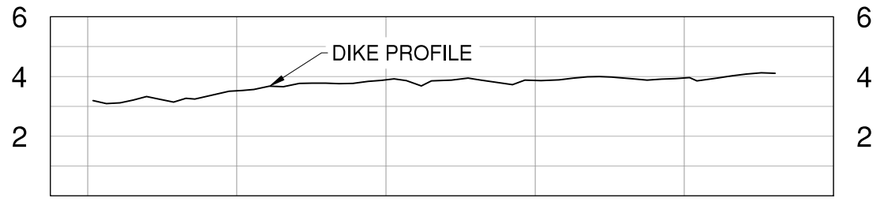
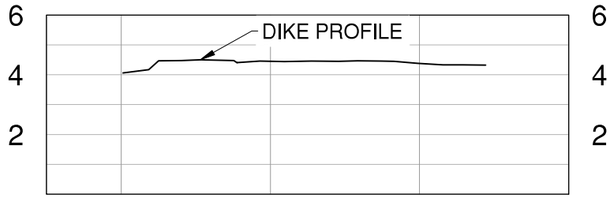
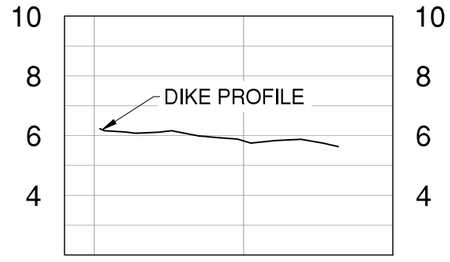


LEWIS PARK DIKE PROFILE
Scale: 1:4000H 1:200V



ANDERTON DIKE PROFILE
Scale: 1:4000H 1:200V

CONDENSORY DIKE PROFILE
Scale: 1:4000H 1:200V



CANTERBURY DIKE PROFILE
Scale: 1:4000H 1:200V

WATER STREET ENGINEERING

DIKE PROFILE INFORMATION SOURCE:

WSP PROVINCIAL DIKE CREST SURVEY, FLOOD PROTECTION WORKS, ACCESSED: 2022-12-14

1:4000
80m 0 80
SCALE

DATE: 06 SEP 2024

CLIENT: CITY OF COURTENAY

COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW

DIKE PROFILES

Figure #3-4

REV 0

3.7 MODELLED FLOOD PROFILES AND EXTENTS

As described in Section 2, the CVRD's Coastal Flood Mapping Project was the first step in a multi-year process to understand and prepare for flood hazards in the region. This work involved detailed analysis and modelling of river and coastal flood hazards to identify areas that might be exposed to flooding during extreme storm conditions (KWL, 2021). This work included analysis of flooding from both coastal and river sources to develop a comprehensive understanding of flood hazards. Flood conditions in rivers and coastal areas are interconnected and were assessed in parallel to understand how water levels in coastal areas might influence river flood dynamics, in accordance with the *Flood Hazard Area Land Use Management Guidelines* (Province of British Columbia, 2018).

The Coastal Flood Mapping Project provided a series of regulatory floodplain maps, showing flood inundation extents for extreme storm events under current conditions and future climate change conditions (KWL, 2021). These floodplain maps are intended to be used for developing floodplain bylaws and informing area plans and official community plans. The floodplain maps show the designated floodplains and flood elevation contours for river flooding, based on a 0.5% Annual Exceedance probability (AEP) event, with 1 m allowance for sea level rise, a 15% allowance for climate change on peak river flows, plus a freeboard allowance of 0.6 m. This scenario is the storm event recommended for communities to consider when designing infrastructure and approving development (Province of British Columbia, 2018).

Modelled river flood elevations were taken from the floodplain maps at the locations of the flood protection structures in the City of Courtenay. These were based on the river chainages used in the hydraulic model, and the River Flood Elevation Contours, defined as lines of equal elevation in the water surface of the river relative to mean sea level (CGVD2013 datum). The data are summarized in Table 3-2 below.

Table 3-2: Summary of modelled river flood elevations (KWL, 2021)

Structure	Location	Modelled Flood Level Including Freeboard (m CGVD2013)
Anderton Avenue Dike	Courtenay River, chainage 0+2250	6.0 m
Lewis Park Dike	Courtenay River, chainage 0+2500	6.0 m
Condensory Dike	Puntledge River, chainage 2+1200	7.2 m
Canterbury Lane Dike	Puntledge River, chainage 2+1000	6.9 m

Modelled flood extents were also reviewed using the floodplain mapping for the area (KWL, 2021). The main observations from this review included the following:

- The majority of Anderton Avenue, including the buildings along the river and on the west side of the street, is within the designated floodplain.
- The entire area of Lewis Park, plus along Old Island Highway to the east, is within the designated floodplain.
- The undeveloped area behind the Condensory Dike is within the designated floodplain.
- The residential properties behind the Canterbury Lane Dike are within the designated floodplain, including the area to the south joining Anderton Avenue.

An excerpt of the designated floodplain extents for the area of interest within the City is provided in Figure 3-5. The pale green areas are the designated floodplain extents.

Figure 3-5: Designated floodplain extents (excerpt from flood mapping by KWL, 2021)

4 FIELD REVIEW

4.1 OVERVIEW

Water Street carried out a field review to assess the condition of the flood protection structures on the afternoon of 27 Feb 2023. The field review was carried out at mid to low tide, with the tide going out during the afternoon to a low tide at 5:45pm. Water Street was accompanied by representatives from the City and Ebbwater for a tour of relevant infrastructure in the morning prior to the field review.

The following sections describe the findings and observations that were made during the field review. Relevant photographs from the field review are included in Attachment 1 and referenced below.

4.2 ANDERTON AVENUE DIKE

The Anderton Avenue Dike consists of a vertical concrete wall that transitions to a vertical sheet pile wall with a concrete cap (Photo 1). Riprap has been placed along the toe of the sheet pile wall and along the first 10 m upstream of the transition to the concrete wall. The riprap along the sheet pile wall was angular rock consistent with a Class 100 kg riprap, with a maximum diameter of approximately 750 mm. The slope of the riprap from the sheet pile wall towards the river was approximately 2H:1V.

Riprap was placed intermittently along the toe of the concrete wall, and remnants of the old log wall were also visible along with broken concrete waste and small diameter rounded rock (Photo 2). These materials do not conform to current standards and offer limited erosion protection to the foundation of the wall. Bank erosion appeared to be occurring upstream of the dike where the river turns approximately 90-degrees east. Existing bank materials did not appear to be sufficient to protect against erosion in this location.

The concrete cap for the sheet pile wall was measured to be 600 mm high and 780 mm wide, and the top of the concrete cap was measured to be 3.1 m above the top of the riprap. Several ground cracks were observed behind the sheet pile wall, in the backyard of the Anderton Arms apartment building (Photo 3). A gap 130 mm wide was observed beneath the concrete cap of the sheet pile wall at this location (Photo 4). This appears to be consistent with other studies that indicated ongoing displacement at the south end of the Anderton Dike due to loss of supporting fill and settlement towards the river.

Significant vegetation issues and root intrusion were observed along the length of the Anderton Dike, within the concrete wall, the sheet pile wall, and in the riprap (Photo 5). Additionally, several stormwater outfall pipes discharge through the dike and discharge above low river levels, therefore contributing to toe erosion.

4.3 LEWIS PARK DIKE

The Lewis Park Dike is a concrete retaining wall (Photo 7) with wood material from a former wall structure acting as armouring along the toe in some locations (Photo 8). Riprap has been placed along the dike at the foundation on the riverside in select locations to protect against erosion (Photos 9 to 11). There are two sets of stairs built into the dike, which are reportedly used for recreational access to the river during the summer months. It is understood that the stairs are not typically used during high flow events. High flow events can occur independent of high precipitation events when BC Hydro releases water from the dam upstream. A river gauge is located upstream of the 5th Street Bridge.

Several areas of localized erosion and undermining were observed along the alignment of the dike. Undermining of the concrete wall behind the remnants of the log wall was also observed, with examples of material lost between the concrete wall and the log wall (Photo 12). Undermining also appeared to be occurring where the river turns east at approximately 1st St and Anderton Avenue (Photo 12). It does not appear that this undermining is currently impacting the dike, however, due to the large amount of vegetation and river gravels deposited in front of the dike wall at this location.

It was noted that vegetation management is a significant issue for the Lewis Park Dike. Vegetation and root intrusions were seen at the dike toe, along the top of the dike, and in between gaps and cracks in the concrete wall (Photo 13). It was also observed that there appeared to be significant gaps at certain points of the concrete wall.

4.4 CONDENSORY DIKE

The Condensory Dike is an earthfill berm with compacted crushed gravel surfacing at the crest and a grass slope on the landside and a riprap slope on the riverside (Photo 14). The structure dimensions appeared to match the record drawings, with the landside slope estimated as 4H:1V, the riverside slope estimated as 3H:1V, and the crest width estimated as 4 m. Riprap material placed on the riverside of the structure appeared to be consistent with the Class 250 kg riprap that was specified, with a maximum diameter of approximately 900 mm (Photo 15).

The toe of the berm is setback approximately 10 m from the edge of the riverbank. The riverbank is protected from erosion with riprap that appears to roughly match the Class 250 kg riprap that was used on the riverside of the Condensory dike (Photo 16). The Condensory Bridge is located just downstream of the dike (Photo 17).

4.5 CANTERBURY LANE DIKE

The Canterbury Lane Dike is a vertical concrete retaining wall with riprap placed along the toe (Photo 18) and wooden fencing on top. The residential development is located immediately behind the concrete wall, with backyards and gardens on the landside of the retaining wall behind the fencing. The riprap at the toe was estimated to have a nominal diameter of approximately 900 mm. There is a walking trail through the forested area between the floodwall and the Puntledge River, with heavy vegetation including brush and blackberries which is consistent with previous inspection reports.

Observations from the field review identified no deterioration or damage to the dike crest and wall. No significant cracking or movement was noticed. Consistent with previous reports and inspections, there were no signs of issues related to seepage, erosion, or deterioration of the structure. However, a thorough inspection was not possible because vegetation obscured visibility and no access was available to the backside of the structure (via residents' backyards). No signs of riprap movement or slope instability were noted and the structure appears to be functioning well. Vegetation was noted to be encroaching on the riprap which reduced visibility of the toe (Photo 19).

5 DISCUSSION

5.1 SUMMARY OF FINDINGS

Based on the review of the flood protection structures, Table 5-1 summarizes the crest elevation and modelled flood level for each structure.

Table 5-1: Summary of crest elevations and modelled river flood elevations (KWL, 2021)

Structure	Crest Elevation (UTM Zone 10N)	Modelled Flood Level (m CGVD2013) (KWL, 2021)
Anderton Avenue Dike	Between 4.0 m and 4.5 m	6.0 m
Lewis Park Dike	Between 3.0 m and 4.0 m	6.0 m
Condensory Dike	Approximately 6.7 m	7.2 m
Canterbury Lane Dike	Approximately 6.0 m	6.9 m

As shown in Table 5-1, none of the flood protection structures have a crest elevation high enough to provide flood protection from the modelled flood elevation during the designated flood event. This is consistent with the modelled floodplain extents (see Figure 3-5) that show the upland areas behind all four flood protection structures to be within the flood extent of the designated flood event.

The likely mechanism of flooding in the City during a high-flow event is outlined within the Coastal Flood Mapping Project (KWL, 2021), and is summarized below:

1. Water levels in Tsolum River side channel overtop Old Island Highway
2. Overland flow through the Courtenay Flats Industrial Park and into Lewis Park
3. Overland flow overtops Highway 19A and enters Courtenay Flats
4. Overland flow ponds in Courtenay Flats while tide is high, then drains out of the Comox Road Floodboxes during low tide periods.

Based on this mechanism of flooding, all areas currently protected by the four flood protection structures within the City would experience flooding during the designated flood event. A summary of the findings for each flood protection structure is provided in the following sections.

5.2 ANDERTON AVENUE DIKE

The Anderton Avenue Dike has well-documented structural and geotechnical problems and recent work has recommended replacing or extensively rehabilitating the sheet pile wall in the next few years. Work is ongoing to develop rehabilitation and replacement options following this recommendation. As the Anderton Avenue Dike is regulated under the *Dike Maintenance Act*, upgrades must be approved by the Dike Inspector in addition to the standard regulatory permits for erosion protection works.

In addition to the structural concerns, the current Anderton Avenue Dike does not provide adequate flood protection for the designated flood event. Flood mapping indicates a large portion of Anderton Avenue and the surrounding area is within the designated floodplain.

5.3 LEWIS PARK DIKE

The Lewis Park Dike is in a reasonable condition but has some observed erosion and vegetation management problems. The Lewis Park Dike does not provide adequate flood protection for the designated flood event as its crest elevation is below the modelled flood level during the designated flood event. Flood mapping indicates the entire area of Lewis Park, plus along Old Island Highway to the east, is within the 200-year modelled floodplain extents.

As the Lewis Park Dike is regulated under the *Dike Maintenance Act*, upgrades must be approved by the Dike Inspector in addition to the standard regulatory permits for erosion protection works.

5.4 CONDENSORY DIKE

The Condensory Dike is a relatively 'new' structure, being constructed in 2006, and is in a good condition with no significant concerns noted during our review. However, it was not constructed to function as a flood protection structure, but to provide erosion protection against high flows in the Puntledge River. Riprap placed on its outside banks provides erosion protection, but the structure does not provide flood protection as the existing soils surrounding the dike are permeable and floodwater can infiltrate through the structure.

For this reason, it does not provide adequate flood protection for the designated flood event. Additionally, its crest elevation is below the modelled flood level during the designated flood event. Flood mapping indicates the area behind the structure is within the 200-year modelled floodplain extents.

The Condensory Dike is not listed as regulated under the *Dike Maintenance Act* in the Province's Dike Database meaning there may be less regulatory requirements for dike upgrades to this structure.

5.5 CANTERBURY LANE DIKE

The Canterbury Lane Dike is in a good condition with no significant concerns noted during our review. It does not appear to have been constructed for flood protection purposes, but to act as a retaining wall for the residential properties to the south.

It does not provide adequate flood protection for the designated flood event as its crest elevation is below the modelled flood level during the designated flood event. Flood mapping indicates the area behind the structure is within the 200-year modelled floodplain extents.

The Canterbury Lane Dike is not listed as regulated under the *Dike Maintenance Act* meaning there may be less regulatory requirements for dike upgrades to this structure.

5.6 SHORT-TERM UPGRADES

Replacement of the Anderton Avenue Dike is already being planned and designed by others. However, currently no upgrades are planned for the other three dikes that the City is responsible for.

To address short-term maintenance issues, the maintenance works outlined in Table 5-2 are recommended.

Table 5-2: Short term upgrades for Lewis Park, Condensory, and Canterbury Lane Dikes

Structure	Short-term Recommendations
Lewis Park Dike	Remove vegetation and add riprap along toe of structure where necessary to protect against erosion until long-term upgrades are completed. Repair cracks and voids in concrete with concrete or grout.
Condensory Dike	Manage vegetation along berm.
Canterbury Lane Dike	Manage vegetation in front of the concrete wall. Obtain SRW to access the structure for inspections and maintenance. Carry out detailed structural assessment to identify any concerns with the structure.

These upgrades would address some minor maintenance concerns but not improve the ability of these structures to provide adequate flood protection during the designated flood event.

6 DESIGN CRITERIA

It is important to define the main design criteria for future upgrades to the City's flood protection structures. These will need to be determined in collaboration with the City and Ebbwater to tie into the overall Flood Management Plan objectives.

Table 6-1 provides a summary of example design criteria that are typically used for developing flood protection structure upgrades.

Table 6-1: Example design criteria for flood protection structure upgrades

Item	Design Criteria
Design flood	Provide flood protection against the designated design flood, based on a 200-year return period event, with 1 m allowance for sea level rise, a 15% allowance for climate change on peak river flows, plus 0.6 m freeboard (Province of British Columbia, 2018).
Dike crest elevation	To meet the modelled water levels under the designated design flood (summarized in Table 3-2 for the flood protection structures within the City).
Geometry and stability requirements	Conform to the following: • Crest width: minimum 4 m wide crest with dike fill core. • Side slopes: minimum 3H:1V land-side slope, 3H:1V river-side slope (or 2H:1V with riprap revetment). • Structure type: dike or natural slope preferred. Use of retaining walls and sheetpiles less preferred. • Stability: meet minimum geotechnical factors of safety.
Land adjacent to dike	Raise land adjacent to dike as much as possible, preferably to meet or exceed the dike crest elevation.
Land ownership	Dike to be located on City-owned land (i.e., not on private property).
Nearby infrastructure	Avoid infrastructure (i.e., stormwater outfalls) within the dike
Seismic performance	Meet seismic performance criteria outlined in the Provincial Seismic Design Guidelines for Dikes (Province of British Columbia, 2014)

7 MITIGATION OPTIONS

7.1 PREVIOUS WORK

Extensive work has been carried out over the last decade to assess the City's flood protection structures and propose upgrades. This work has included the development and analysis of a range of flood protection structure upgrades and flood mitigation strategies.

Discussion on previous options is included for reference only. These options were developed and discussed previously but have not been implemented.

The 2013 Integrated Flood Management Study (McElhanney, 2013) **provided the following options for consideration:**

Option 1: Tsolum River Floodwall

This option proposed the construction of a floodwall along the Old Island Highway abutting the Old Tsolum Channel Bank on the east side of the Courtenay River upstream of the Lewis Park Dike. Based on modelling findings, this option would not meet the 200-year return period criteria but would prevent flooding resulting from smaller and more frequent flood events (e.g., the 2009 and 2010 events). If a floodwall was to be constructed to the 200-year return period standard along the Old Island Highway alignment, it would not prevent flooding of the Ryan Road/Old Island Highway area during extreme events anyway, since backwater from Lewis Park and Courtenay Slough would overtop Old Island Highway near 5th Street and Comox Road. It would have to be considered as part of a broader, more comprehensive flood mitigation strategy, if protection for the 200-year flood is to be achieved.

Option 2: Commercial Area Ring Dike

Concern from the public regarding a full dike down both sides of the Courtenay River and a low requirement for protection on the west side led to the proposed solution of diking around only the Ryan Road commercial area, which includes private and public property and portions of major transportation corridors. This option proposed the development of dike structures along the Old Island Highway north of Ryan Road, building a new dike or raising the existing dike along the Old Tsolum Channel bank (west of Old Island Highway then along the east boundary of Lewis Park), raising Comox Road adjacent to the Courtenay Slough and a section of South Island Highway, and constructing a dike along the south-east boundary of the commercial development area. This option then provides a ring dike to protect the commercial/industrial properties in the Ryan Road/Old Island Highway area. Lewis Park and Centennial Park would be allowed to be flooded and, thus, provide flood relief.

Option 3: Partial Ring Dike with Floodway

This option proposed raising Old Island Highway north of Ryan Road and building a dike along the Old Tsolum Channel bank west of Old Island Highway. The proposed dike ran along the east boundary of Lewis Park and then from the Old Island Highway to the South Island Highway, raising the section of South Island Highway east of the new dike and building a dike to tie into the high ground along the south-east boundary of the commercial/industrial development area. This option also proposed a 30 m wide floodway route through the developed ground between the Old Island Highway and Comox Road intersection to South Island Highway. The floodway would start at the intersection of the Old Island Highway and Comox Road, providing flood relief from Lewis Park into the agricultural area in Courtenay Flats. Drainage structures would be required under the Old Island Highway and Highway 19A to provide flood passage, while maintaining transportation links. This option protects most of the commercial/industrial area near the Ryan Road/Old Island Highway intersection and eliminates the need to raise Comox Road and the southern section of South Island Highway. Properties in the flood risk areas outside of the ring dike adjacent to the Courtenay River banks, not protected by the dikes, would either require to be flood proofed and raised to the FCL or considered under a managed retreat policy. By allowing more water to be conveyed to the agricultural fields during more significant flood events, the upstream peak flood level increases would be reduced.

The 2021 Dike Replacement and Flood Management Strategy (Urban Systems, 2021) **provided the following options for consideration:**

Option 1: Limited Widening of the West Bank of the Courtenay River Between 2nd Street and 10th Street

This option proposed to remove the Anderton Avenue Dike and replace it with a sloped bank. No diking is proposed above the existing grade. To allow for the channel widening proposed in this option, adjacent properties west of the dike (including the sanitary pump station) would be required to be acquired and altered. Widening of the Courtenay River from 2nd Street (Riverside Park) to 8th Street (approximately across from the Courtenay Slough connection point) was modelled. Average channel widening was 15 m with a bank slope of roughly 3H:1V. The river widening would create additional room for floodwaters from river flows, but not protect against coastal flooding or flooding during simultaneous river flooding and high tide conditions.

Option 2: Connection of River Flow Paths through Lewis Park

This option proposed to construct a diversion channel through Lewis Park, forming a controlled flood route connecting the Courtenay River at the north end of Lewis Park with the Courtenay Slough. The proposed channel was modelled as a 15 m wide by 2 m deep channel, which would limit usage of the park. Like Option 1, this option would not protect against coastal flooding or flooding during simultaneous river flooding and high tide conditions.

Option 3: Extreme Channel Widening and Naturalization

This option proposed 60 m of widening of the Courtenay River from Lewis Park to the estuary, removing the existing sheet pile walls and sloping the banks of the rivers. The saw mill has conceived a restoration project of the Fields Sawmill Site, which could be integrated into this option. The extreme river widening proposed in this option would create more room for flood waters from riverine flow but would not protect against coastal flooding or flooding during simultaneous river flooding and high tide conditions.

Option 4: Extreme Diking

This option proposed a containment dike on the east side of the Courtenay River from Lewis Park to the estuary, with tie-in to the high ground to the northeast. The MOTI will not support the highway serving as a dike, so a second parallel dike would need to be created. The dike was modelled to be parallel to the highway and was found to limit flooding adjacent to the dike but cause more flooding upstream.

Option 5: Managed Retreat

This option focuses on re-naturalization of the encroached floodplain. A managed retreat may occur as a response to a flood event, or proactively before a future flood. When conducted opportunistically, managed retreat can be highly cost-effective, with a minimum impact from flooding on people and businesses. A specific example or location for managed retreat was not provided.

The 2023 Anderton Dike Wall Options Analysis (McElhanney, 2023) **provided the following options for the rehabilitation or replacement of the Anderton Avenue Dike:**

Option 1: Structural Repairs to Existing Wall

This option included extensive structural upgrades to the existing Dike Wall elements, including the following:

- Concrete wall cast against the existing sheet pile wall. This will provide additional structural capacity, mitigate ongoing corrosion, and provide a barrier to mitigate soil fines migration. The concrete may be either conventional concrete cast using formwork or shotcrete sprayed against the steel sheets.

- Additional tie-rods or geo-grid may be required to improve seismic performance or allow for future surcharge loading of the wall if the floodwall is extended in the future.

- For the precast concrete wall section, the concrete is understood to be in serviceable condition. There is significant erosion and undermining beneath the concrete wall section. Undermining repairs of the precast concrete wall section would be completed as part of Option 1 with the existing precast concrete wall section remaining in place.

- Excavation of retained fill behind the existing sheet pile and precast concrete wall sections. Recompaction with additional structural fill to repair existing suspected sinkholes.

- The height of the structure will remain the same, and existing buildings (former Cona Hostel and Anderton Arms apartments) will remain in place. Limitations for potential future redevelopment of the building sites would depend on the extent of structural repairs and would typically be defined during detailed design unless there was a specific requirement stated by the City.

Option 2: Waterside Dike

This option included the removal of the existing sheet pile and precast concrete wall sections and the construction of a conventional dike structure built to current diking guidelines and best practices. The option would include the following:

- Flood protection to consider 200-year river elevations.

- Option to tie-in to high ground at 1st Street (Option 2A) or west of Condensory Bridge (Option 2B), providing option for a phased approach.

- Relocation of the existing pump station and hydrometric gauge.

- Demolition of the former Cona Hostel, Anderton Arms and several existing residence building structures.

- Removal and disposal of the existing wall structures including the sheet pile wall and precast concrete sections.

- Salvage of riprap buttress placed in 2016 repairs for reuse in slope armouring.

- Excavation, regrading, and armouring of the foreshore slope.

- Installation of multi-use riverfront pathway on dike crest.

Option 3: Naturalized Foreshore

This option included the removal of the existing sheet pile and precast concrete wall sections and the construction of a naturalized foreshore. The option would include the following:

- Relocation of the existing pump station and hydrometric gauge.

- Demolition of the former Cona Hostel and Anderton Arms building structures.

- Removal and disposal of the existing wall structures.

- Salvage of riprap buttress placed in 2016 repairs for reuse as upper foreshore slope armouring.

- Extensive excavation and regrading of the foreshore slope.

- Vegetative planting and timber log erosion protection. Depending on the extent of scour protection needed, which is to be determined during detailed design, some additional cobble or rock material may be required.
- Armouring of the upper foreshore area to provide slope protection for the Anderton Avenue roadway.
- This option maintains the original ground elevation at the Anderton Ave roadway (no heightening of the foreshore involved).

Based on the options analysis and assessment of feasibility considerations and construction costs, McElhanney recommended the City proceed with Option 3 (McElhanney, 2023).

7.2 OPTIONS DEVELOPMENT

Local areas covering the study area were defined by Ebbwater as part of the Flood Management Plan. Figure 7-1 illustrates the defined local areas.

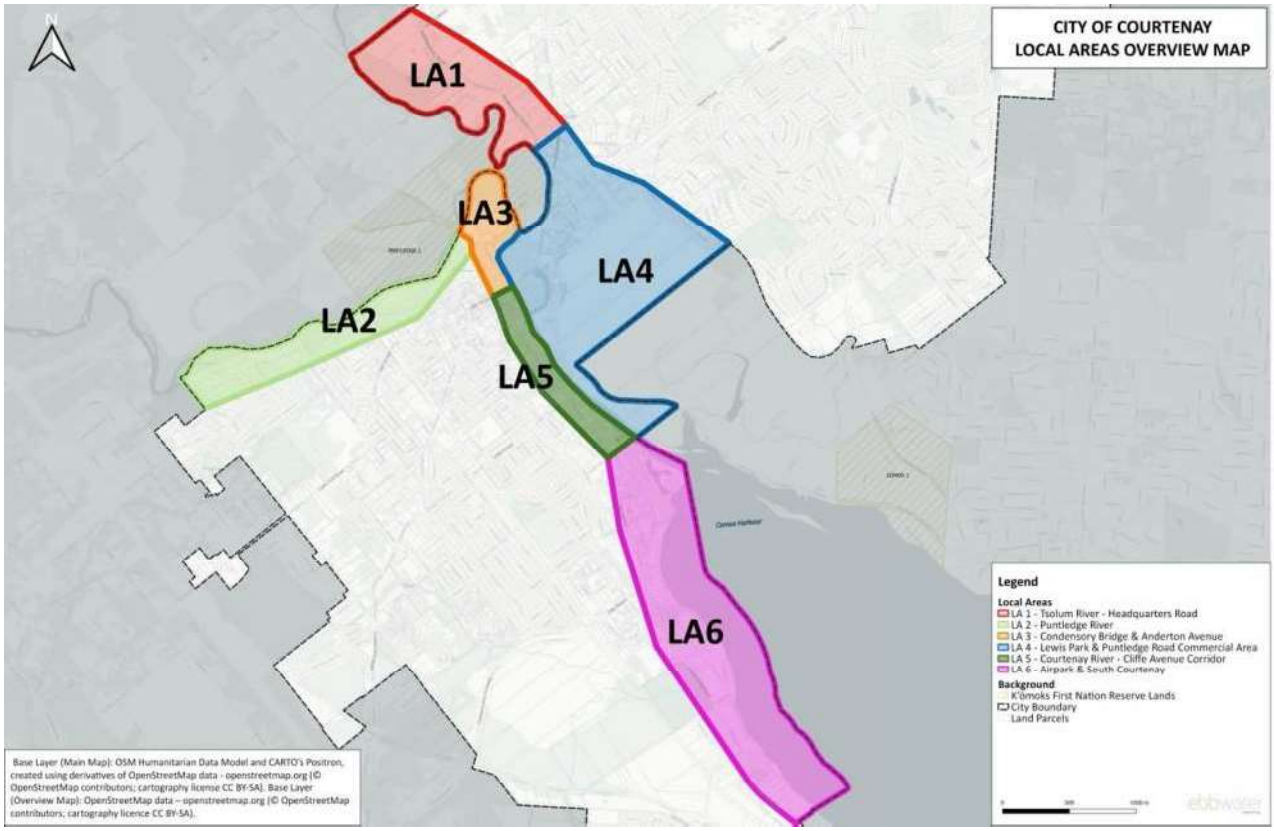


Figure 7-1: Overview of defined local areas

Structural flood protection options were developed for each of the defined local areas in collaboration with Ebbwater. Figures for these options are included in Appendix 2, and descriptions are provided below:

7.2.1 LOCAL AREA 3: CANTERBURY CONDENSORY

Three alternatives were examined for the Canterbury Condensory Area. Each of these alternatives shared a common alignment, which started north of the current Condensory Dike, passing beneath the Condensory Bridge, and subsequently following the path of the existing Canterbury Dike, which is to be replaced. From there, the alignment proceeds south along the Puntledge and Courtenay River before tying in at the Anderton Dike location. Challenges with the tie-in at the Anderton Dike are further discussed in Ebbwater's main report. Three options were considered for the dike structure:

Protect A: Ring Dike Permanent (refer to Figure 1 in Appendix 2): For this option, a berm was considered to include a 4 m wide multi-use pathway at the flood construction level. The ground was sloped at 2.5H:1V to meet with the existing ground. The riverside of the dike would be armoured with riprap to protect against erosion. As shown in Figure 1 of Appendix 2, the dike varied in width from about 20 – 35 m.

Protect B: Concrete Floodwall (refer to Figure 2 in Appendix 2): As shown in Figure 2 of Appendix 2, a concrete floodwall was considered for this option with a crest elevation equal to the FCL. The riverside of the floodwall is proposed to be armoured against erosion by riprap at the toe.

Protect C: Semi-Permanent Floodwall (refer to Figure 3 in Appendix 2): This option is similar to the previous option (Protect B), but instead of constructing permanent structures up to the FCL, a permanent concrete floodwall is constructed only to prevent against minor flooding. Semi-permanent structures (such as the ones described below) are then placed on top of the lower floodwall in cases of extreme flooding.

Possible semi-permanent structures include demountables, self-rising barriers, stop-log barriers, or hydrostatic barriers. Removable stop log-barriers are a semi-permanent system designed to provide similar levels of protection to permanent flood defense infrastructure (Flood Control International, 2023). The stop log barrier consists of a fully removable slot-in structure that can be quickly installed during periods of high flood risk. Stop-log barriers are often paired with existing flood infrastructure to increase the systems' flood tolerance. The design and installation of the barrier can accommodate designs up to 13 ft high, any length, and slopes up to 20 degrees.

Figure 7-2: Stop Log Barrier (Flood Control International, 2023)

Hydrostatic barriers are a passive system that operates from water pressure during a flood event (Flood Proofing, 2023). The presence of water pressure on the system causes the barrier to rise automatically, then after the flood has subsided the barrier lowers without human intervention. The system is ideal in an area prone to flooding with little to no warning due to no manpower or storage being required. Additionally, there is minimal operational cost associated with the design.

Figure 7-3: Hydrostatic Barrier (Flood Proofing, 2023)

7.2.2 LOCAL AREA 4: LEWIS PARK AND PUNTLEDGE ROAD COMMERCIAL AREA

Five options were explored for the Lewis Park and Puntledge Road Commercial Area, which is located near Lewis Park. Option A proposes to remove the existing Lewis Park dike, replacing it with a ring dike along a different alignment. However, Options B1 and B2 propose to raise it to the FCL and Options C1 and C2 propose to repair it, but leave the crest elevation as is. All options include construction of a new dike along Old Island Highway from the end of the existing Lewis Park Dike up to Island Highway N. Options A, C1, and C2 include overflow channels, while B1 and B2 propose to keep all flow in the river up to the FCL.

Protect A: Ring Dike and Overflow Channel (See Figure 4 in Appendix 2): For this option a concrete floodwall was considered along Old Island Highway west of Lewis Park installed up to the FCL and armoured with riprap. A dike with a crest elevation equal to the FCL was considered along Puntledge Road along with the creation of an overflow channel leading to the agricultural lands of the Courtenay flats. The dike would have a 2H:1V riprap slope on the river side and a near-vertical vegetated retaining wall on the non-water side. This option requires regrading of Old Island Highway to tie in to the proposed dike and culverts to convey flow from the overflow channel underneath the Old Island Highway. Concerns with this option are discussed in Ebbwater's main report.

Protect B1: Full Protection Permanent (See Figure 5 in Appendix 2): This option includes raising the existing Lewis Park Dike up to the FCL by using a permanent method such as adding a concrete cap. Riprap would to be added at the toe of the existing dike where necessary to protect against erosion. A new concrete floodwall with a crest elevation equal to the FCL is then added starting at the north end of the existing Lewis Park dike. Unlike Protect A, this option keeps all water flowing in the Courtenay River and does not require an overflow channel.

Protect B2: Full Protection Semi-Permanent (See Figure 6 in Appendix 2): This option has the same alignment and aspects as Protect B1, but instead of raising the existing Lewis Park Dike using a permanent method, the Lewis Park Dike is proposed to be raised using a semi-permanent method such as stop log or hydrostatic barriers (as described above).

Protect C1: Non-Standard Floodwall and Overflow Channel (See Figure 7 in Appendix 2): This option follows the same alignment as Options B1 and B2, but the existing Lewis Park dike is only repaired and the crest elevation is kept the same. A permanent concrete floodwall is then proposed along Old Island Highway up to Island Highway N with a crest elevation equal to the 5% AEP mid-term future water level

(i.e., 1 m sea level rise, 15% increase in flows). Overflows in this option are directed towards the agricultural lands through an overflow channel. Concerns with this option are discussed in Ebbwater's main report.

Protect C2: Non-Standard Floodwall and Overflow Channel (See Figure 8 in Attachment 2): This option is the same as Protect C1, but instead of a permanent floodwall with a crest elevation up to the 5% AEP mid-term future event, a permanent structure was considered to protect against minor flooding and serve as a base for semi-permanent structures (as described above), which can be utilized during storms to protect up to the 5% AEP mid-term future event.

7.2.3 LOCAL AREA 5: COURTENAY RIVER – CLIFFE AVENUE CORRIDOR

As shown in Figure 9 of Appendix 2, this section includes the area along the Courtenay River south of the existing Anderton Dike up to Courtenay Marina Park at 20th Street. For this location, a vertical concrete floodwall was considered up to the FCL. The vertical concrete floodwall includes riprap armouring and crosses underneath the 5th Street and 17th Street Bridges.

7.2.4 LOCAL AREA 6: AIRPARK AND SOUTH COURTENAY

This area is located along Cliffe Avenue north of Park Lane and South of Mansfield Drive. Three options were considered along the same shoreline alignment.

Protect A: Floodwall (See Figure 10 in Attachment 2): For this option a vertical concrete floodwall was proposed with riprap armouring at the toe to protect against erosion.

Protect B: Naturalized Foreshore (See Figure 11 in Attachment 2): For this option a naturalized foreshore (i.e., Green Shores) was proposed. Although naturalized foreshores take up more space than vertical floodwalls or riprap banks, they increase the accessibility of the shoreline, make shorelines more aesthetically pleasing, and benefit the environment (Stewardship Centre for BC, 2023). The intent of this option is to provide erosion protection into the future rather than additional flood protection. As shown in Figure 11, the shoreline is protected from erosion by buried logs, and other features such as groynes could also be considered. This option also includes a 2 m wide pathway along the crest.

Protect C: Riprap (See Figure 12 in Attachment 2): This option includes riprap banks with a 2H:1V side slope which reduces the dike area compared to Protect B; however, the riprap banks are not as environmentally friendly or aesthetically pleasing. This option includes a 4 m wide dike crest, however, because of the 2H:1V riprap bank, it would be difficult to access as a pathway compared to the naturalized foreshore in the foreshore option.

7.3 COST ESTIMATES

Cost estimates were developed for all structural flood protection options (shown in Figures 1 – 12 of Appendix 2). The costs were developed based on conceptual design layouts and are provided only for the purpose of comparing options and should not be used for final budgetary purposes. Annual maintenance costs were also estimated.

Unit rates for the cost estimate were taken from McElhanney's work on the Anderton Dike (McElhanney, 2023), and supplemented with supplier quotes for the stop-log and hydrostatic barriers. Costs provided appear to be current as of 2022, but inflation costs were not accounted for as the implementation timelines for various options are not known. The cost estimate includes a contingency of 50%, which accounts for aspects that were not designed at the time of the estimate or not accounted for. Limitations of this method include the following:

- The contingency only accounts for aspects of the proposed option that have not been designed yet or included in the estimate. It does not account for unforeseen circumstances such as a less competitive bidding market or material delays, shortages, or price increases that can increase the overall project cost.

- The designs used to complete the estimates were developed up to a conceptual stage, and a comprehensive survey has not yet been conducted. It is possible the conceptual designs are not feasible and that the costs for the feasible designs are more expensive.

8 RECOMMENDED OPTIONS

8.1 OVERVIEW

All four existing flood protection structures require upgrades to meet regulatory standards and offer adequate protection from flood events. However, upgrades to individual structures in isolation will have limited impact on the overall level of flood protection provided to the City. There is likely no singular solution to flood protection and options to be considered must be developed as part of an overall flood mitigation strategy. In addition to upgrades to existing flood protection structures, Ebbwater is also assessing new areas for potential protection measures.

Detailed options analysis and evaluation of all mitigation options were completed by Ebbwater. This included meetings and workshops with the City and other stakeholders within the community. Recommended options from this process are outlined below. Note that these recommendations only include the structural ('Protect') recommendations and are supplemented by a wide range of other risk reduction and resilience actions, as discussed in the main report by Ebbwater.

8.2 RECOMMENDED OPTIONS AND ACTIONS

The following options have been recommended for future implementation as part of the overall flood management options assessment carried out by Ebbwater. The recommended options are categorized by Local Area as outlined below.

8.2.1 LOCAL AREA 3 – CONDENSORY AND CANTERBURY

It is recommended to maintain and repair the Condensory and Canterbury structures for erosion protection. However, no structural upgrades are recommended. Instead, non-structural measures such as property-level protection, accommodate, avoid, retreat, and resilience-building are proposed, which is discussed in the main report by Ebbwater.

Maintenance works recommended for the Condensory Dike and Canterbury Lane Dike include vegetation management, which was also recommended during previous dike inspections. The City should clarify Provincial expectations for vegetation management on structures that are only used for erosion protection. Once clear direction has been received, vegetation should be managed in accordance with Provincial guidance. In addition, the dikes should continue to be monitored to ensure that they are not being impacted by issues including erosion and vandalism. Monitoring should include inspecting riprap to ensure that slopes are consistent with previous years. Vegetation should also continue to be monitored to ensure that tree roots are not impacting the stability of the riprap, walls, or berms. The concrete retaining wall for the Canterbury Lane dike should also continue to be monitored for cracking, spalling, chipping, and other damage.

Ownership of the Canterbury Lane Dike has been disputed as it was built by the residential development to protect patios prior to the *Dike Maintenance Act*. After the *Dike Maintenance Act* became law, the Province sought to make the City responsible for the structure. The disputed ownership means that the structure has not been inspected or maintained in accordance with the *Dike Maintenance Act*. This represents a substantial risk to both the strata and to the City. It is recommended that the City work with the Province and the strata to resolve the ownership dispute. Once this is settled, a detailed inspection of the structure should be completed, maintenance should be completed, and any required repairs should be made.

8.2.2 LOCAL AREA 3 – ANDERTON DIKE

Similar to other structures, vegetation management is recommended, along with continued annual inspection and maintenance until further recommendations are implemented. Replacing the existing dike with a naturalized foreshore option was recommended for this structure (McElhanney, 2023). This option reduces overall flood risk through a managed retreat strategy, and involves decommissioning of the existing regulated dike and construction of a naturalized foreshore. This recommendation does not include raising the road to the FCL meaning that buildings on the landside of Anderton Avenue would still be at risk of occasional flooding (e.g. shallow water during more extreme floods in the region). To date, flooding impacts to buildings on Anderton Avenue have not been reported. The flood protection conditions for buildings on

the landside of Anderton Avenue would remain unchanged as the current dike is not higher than the land elevation.

McElhanney indicates this work will take approximately 3-5 years to implement, so urgency is required to move the project forward given the suggested timeline for the service life of the existing seawall.

8.2.3 LOCAL AREA 4 - LEWIS PARK AND COMMERCIAL AREA

In the short term, it is recommended to repair and maintain the existing Lewis Park Dike. As discussed in Section 3.3, this includes the following:

- Investigating the current toe protection configuration to identify ways to reduce ongoing scour along the banks.
- Removing vegetation and repairing erosion with riprap where necessary.
- Repair voids and cracks in the concrete wall using concrete or grout.

In support of these short-term recommendations, the City should clarify Provincial expectations for vegetation management on structures that are only used for erosion protection. Once clear direction has been received, vegetation on the Lewis Park Dike should be managed in accordance with Provincial guidance. Annual inspections to monitor for erosion and other issues should also continue. Long-term recommendations for this area are discussed in Ebbwater's report.

8.2.4 LOCAL AREA 5

No structural upgrades are recommended for this area. There are no dikes or structures currently in this area that were investigated as part of this study. Non-structural upgrades have been recommended and are discussed in Ebbwater's report.

8.2.5 LOCAL AREA 6

Over the very long term, the establishment of Green Shores are recommended for this area (Protect B – Figure 11 of Attachment 2). Naturalized foreshores will need to be designed according to local guidelines in BC meeting the following requirements (Stewardship Centre for BC, 2022):

- Seawall or rock revetment on the water side is not to cover more than 30% of the fronting shoreline length.
- The design cannot infringe upon critical habitat on Crown Land.
- The design must allow public access along the foreshore or the beach.

No dikes or other flood control structures were analyzed for this section as part of this report, so no short-term actions are recommended.

8.3 MAINTENANCE RECOMMENDATIONS

As outlined in Section 5.6 of this report, the maintenance works outlined in Table 8-1 are recommended to address short-term maintenance issues while longer-term options are advanced.

Table 8-1: Short term upgrades for Lewis Park, Condensory, and Canterbury Lane Dikes

Structure	Short-term Recommendations
Lewis Park Dike	Remove vegetation and add riprap along toe of structure where necessary to protect against erosion until long-term upgrades are completed. Repair cracks and voids in concrete with concrete or grout.
Condensory Dike	Manage vegetation along berm.

Canterbury Lane Dike	Manage vegetation in front of the concrete wall. Obtain SRW to access the structure for inspections and maintenance. Carry out detailed structural assessment to identify any concerns with the structure.

These upgrades would address some minor maintenance concerns but not improve the ability of these structures to provide adequate flood protection during the designated flood event.

9 DIKE MASTER PLAN

The purpose of the Dike Master Plan is to guide the timing and implementation of dike upgrades required to address deficiencies and improve community flood protection. Work to develop this plan, including the development and review of flood protection options, the development of conceptual designs for dike upgrades, and consultation with key stakeholders is described in this report and in the main Flood Management Plan report by Ebbwater. Table 9-1 and Figure 9-1 provide a summary of the recommended actions developed through this process.

The plan proposes timelines for each recommended action, categorized into immediate (0-1 year), short-term (1-5 years), medium-term (5-10 years), and long-term (10+ years) objectives. Implementation costs were also estimated for each recommended action at a conceptual level and include engineering and construction costs and a contingency of 50%. No other costs were accounted for such as inflation, taxes, administration, or bonding and insurance.

Table 9-1: Dike Master Plan summary

Dike Name	Recommended Action	Recommended Timeline	Estimated Costs (CAD)[1]
Local Area 3 – Condensory	Vegetation management	Immediate	$15,000
	Monitor for erosion and stability	Annual inspections for life of dike	$5,000/year
Local Area 3 – Canterbury	Address ownership issue	Immediate	TBD
	Detailed structural assessment	Short-term	$40,000
	Vegetation management	Short-term	$15,000
	Monitor for erosion and stability	Annual inspections for life of dike	$5,000/year
Local Area 3 - Anderton	Vegetation management	Immediate	$15,000
	Monitor for erosion and stability	Annual inspections for life of dike	$5,000/year
	Anderton Ave – Naturalized Foreshore Remediation (McElhanney, 2023)	Immediate to Short-term	$10,000,000[2]
Local Area 4 – Lewis Park and Commercial Area	Investigate current toe protection to identify ways to reduce turbulence and scour	Short-term	$50,000
	Remove vegetation and repair erosion with riprap where necessary	Short-term	$15,000
	Repair voids and cracks in concrete	Short-term	$100,000
	Monitor for erosion and stability	Annual inspections for life of dike	$5,000/year
	Naturalized Lewis Park Dike	Long-term	$12,000,000
Local Area 5	Non-structural upgrades – Refer to Ebbwater report		
Local Area 6	Implement Green Shores (Option Protect B)	Long-term	$30,000,000

[1] Breakdown of estimated implementation costs are provided in Appendix 3.

[2] From (McElhanney, 2023) Option 3. Includes engineering and construction services (20%), escalation (3%/year), and contingency (30%).

LOCAL AREA 1: NON-STRUCTURAL OPTIONS. SEE EBBWATER REPORT

OLD ISLAND HWY

LOCAL AREA 4: EXISTING LEWIS PARK DIKE INVESTIGATE EXISTING TOE PROTECTION, CONTROL VEGETATION AND MONITOR EROSION, REPAIR VOIDS IN CONCRETE, FURTHER INVESTIGATE OPTION PROTECT C1

AGRICULTURAL LANDS OF COURTENAY FLATS

LOCAL AREA 3: EXISTING ANDERTON DIKE UPGRADE DIKE, EXTEND STORM PIPES, CONTROL VEGETATION, MONITOR FOR EROSION

PUNTLEDGE RIVER

LOCAL AREA 3: EXISTING CONDENSORY AND CANTERBURY DIKES: MONITOR FOR EROSION AND CONTROL VEGETATION

COURTENAY RIVER

COMOX RD.

LOCAL AREA 2: NON-STRUCTURAL OPTIONS. SEE EBBWATER REPORT

LOCAL AREA 5: NON-STRUCTURAL OPTIONS. SEE EBBWATER REPORT.

LOCAL AREA 6: GREENSHORES OVER THE LONG-TERM

MARSDEN RD.

COMOX VALLEY PRKWY

DIKE MANAGEMENT PLAN - RECOMMENDED ACTIONS SUMMARY

Scale: 1:15000

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SCALE

DATE: 06 SEP 2024

CLIENT: CITY OF COURTENAY

COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW

DIKE MANAGEMENT PLAN
RECOMMENDED ACTIONS

Figure #9-1

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10 CLOSURE

We trust this document meets your present requirements. Please contact the undersigned with any questions or comments.

WATER STREET ENGINEERING LTD.

David Marshall, PEng
Senior Water Resources Engineer

Allan Bronsro, MSc, PEng
Principal, Senior Civil Engineer

EGBC permit to practice number 1000830.

11 REFERENCES

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APPENDIX 1: FIELD REVIEW PHOTOS

Photo 1: Anderton Dike transitions from concrete wall at northern upstream side (right side of photo) to sheet pile wall with a concrete cap (left side of photo).

Photo 2: Concrete wall portion of Anderton Dike with wood and rock material visible along the toe.

Photo 3: Ground cracking observed behind the Anderton Dike wall in the backyard of the apartment buildings.

Photo 4: Gap underneath the concrete cap of the sheet pile wall of the Anderton Dike on the land side.

Photo 5: Vegetation observed within the Anderton concrete wall and riprap.

Photo 6: Ongoing erosion at the bend upstream of the Anderton Dike at approximately 1st Street and Anderton Avenue.

Photo 7: Lewis Park Dike concrete retaining wall.

Photo 8: Remnants of old log wall in front of concrete structure. Stormwater outfall discharging onto toe.

Photo 9: Large riprap placed around stairs and foundation of the Lewis Park Dike.

Photo 10: Riprap placed around toe of the Lewis Park Dike at the bend in the Courtenay River.

Photo 11: Riprap placed around stairs and foundation of the Lewis Park Dike at the upstream (southern) section.

Photo 12: Localized erosion and undermining of material at the Lewis Park Dike at the river bend at approximately 1st Street and Anderton Avenue.

Photo 13: Vegetation along the toe and face of the Lewis Park Dike.

Photo 14: Condensory Dike crest, with undeveloped land to the left and the Puntledge River to the right.

Photo 15: Riprap on the riverside of the Condensory Dike.

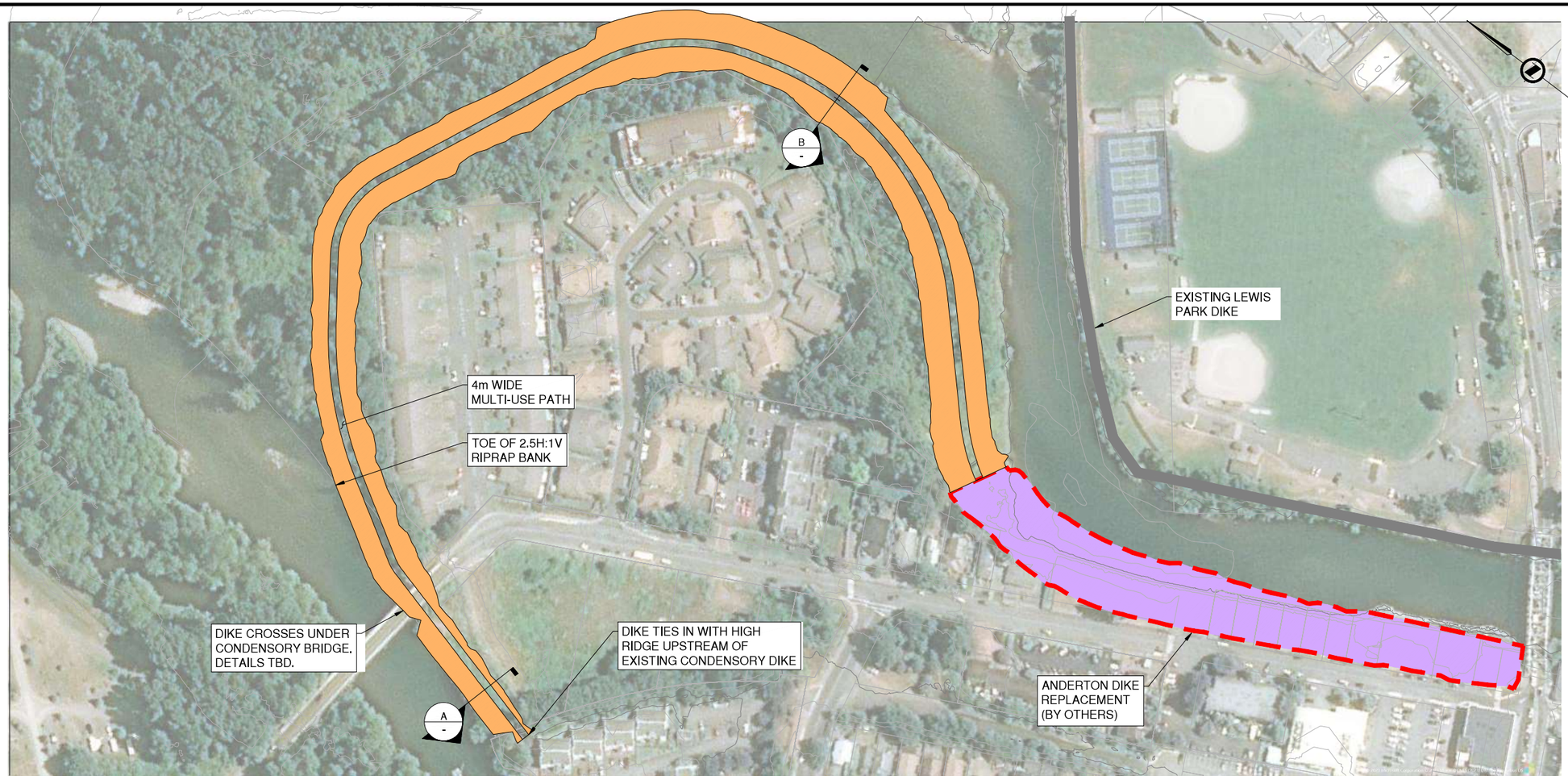
Photo 16: Bank protection adjacent to the Puntledge River.

Photo 17: Condensory Bridge at downstream end of the Condensory Dike.

Photo 18: Canterbury Lane Dike with setback concrete wall, riprap toe protection, and fencing visible.

Photo 19: Canterbury Lane Dike with setback concrete wall and vegetation visible.

APPENDIX 2: CONCEPTUAL OPTION FIGURES



PROTECT A: RING DIKE (PERMANENT)

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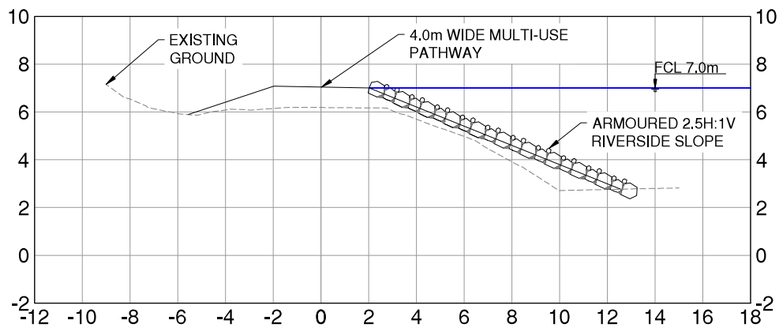

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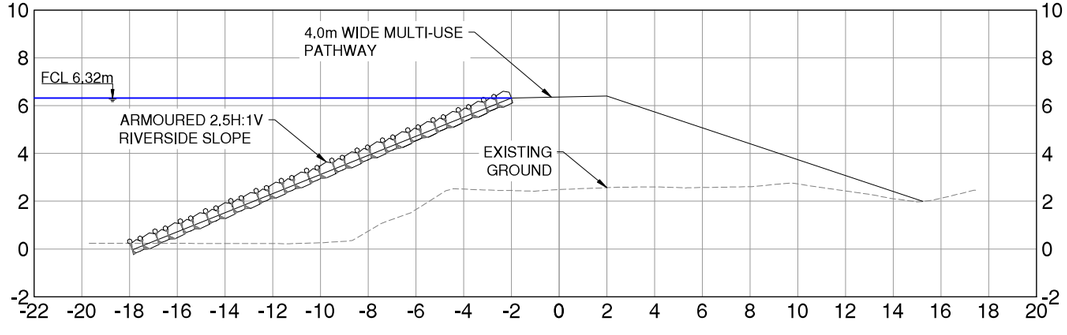

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COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW
DIKE ALIGNMENT OPTIONS

LOCAL AREA 3:
CANTERBURY CONDENSORY

Figure #1

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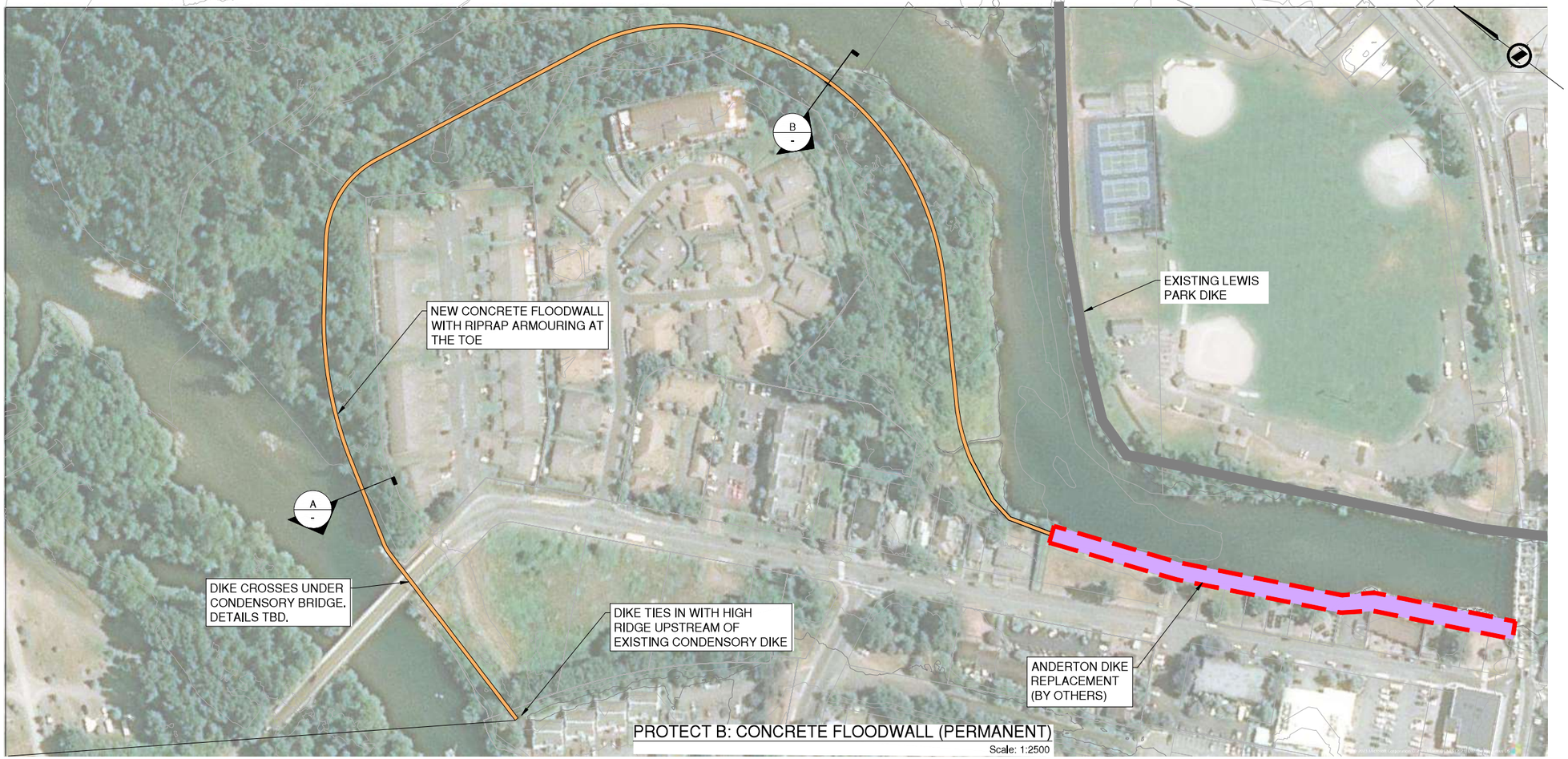

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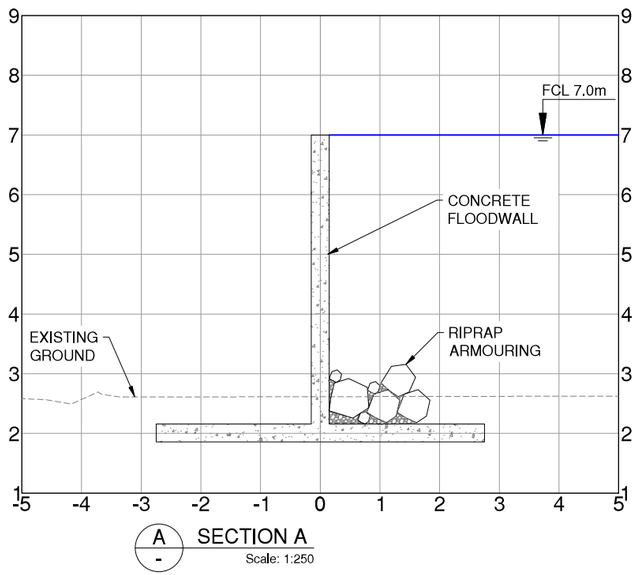

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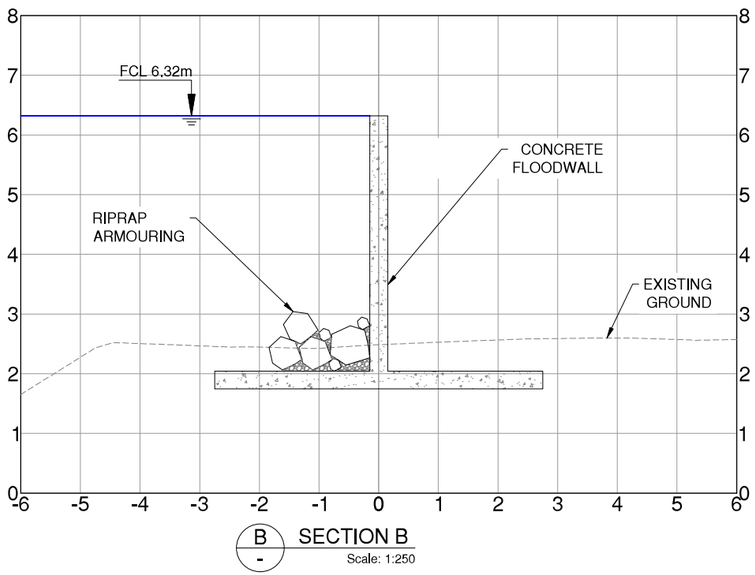

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COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW
DIKE ALIGNMENT OPTIONS

LOCAL AREA 3:
CANTERBURY CONDENSORY

Figure #2

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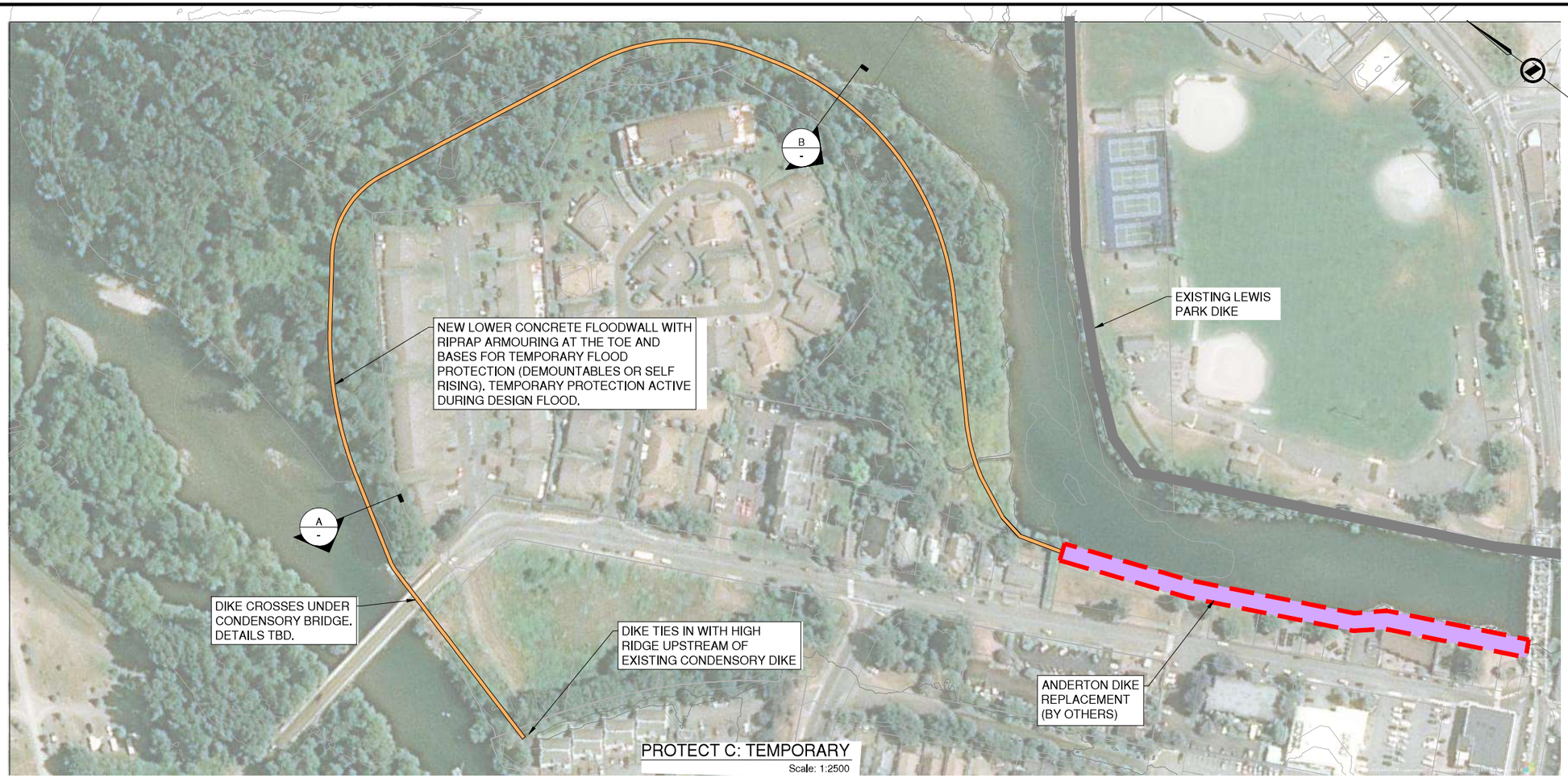

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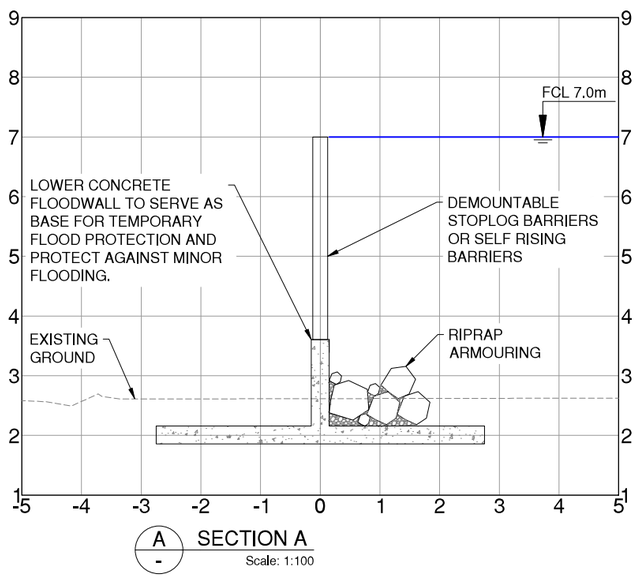

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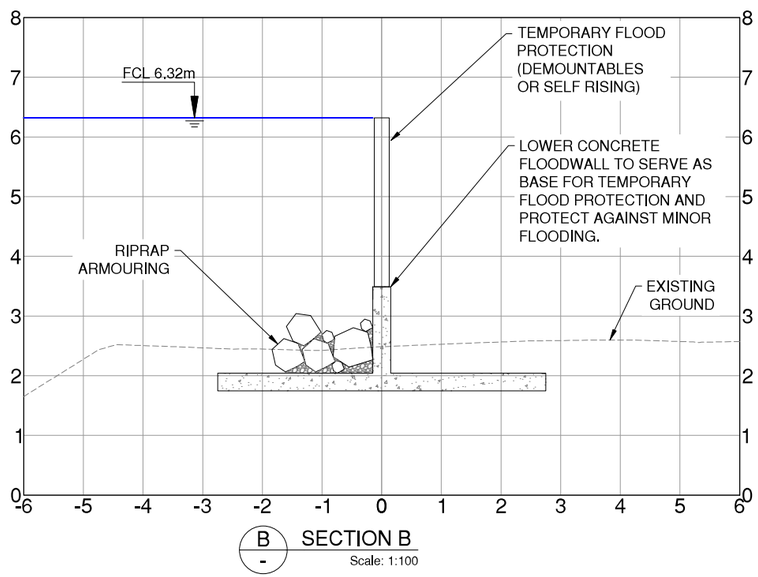

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COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW
DIKE ALIGNMENT OPTIONS

LOCAL AREA 3:
CANTERBURY CONDENSORY

Figure #3

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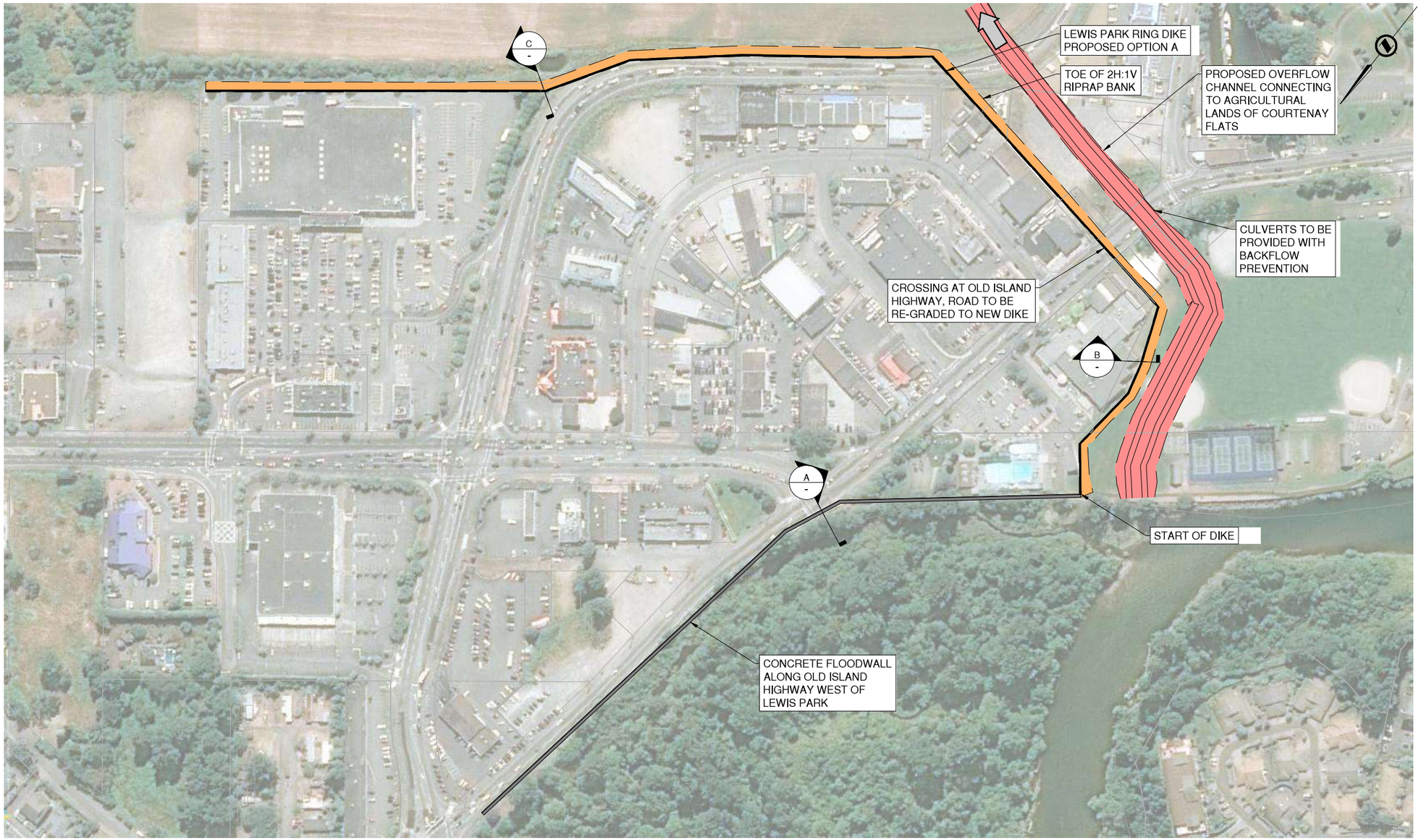

PROTECT A: RING DIKE AND OVERFLOW CHANNEL

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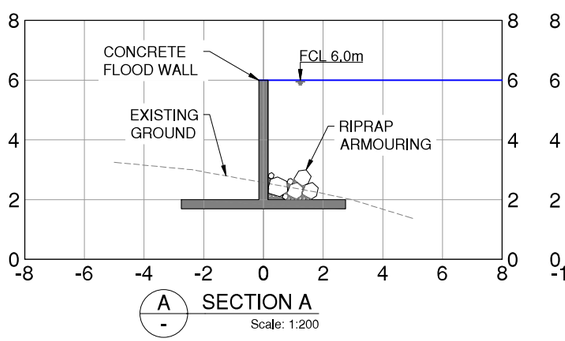

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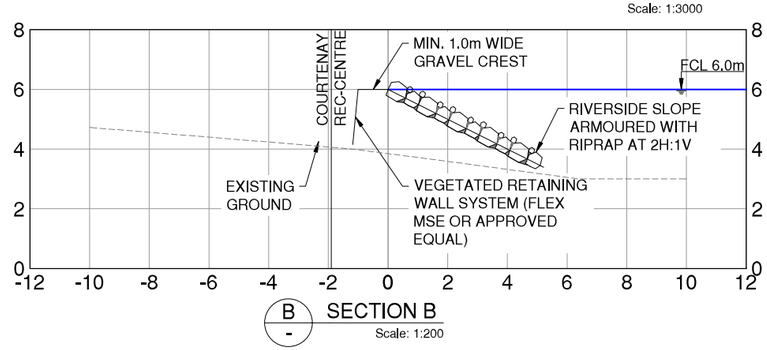

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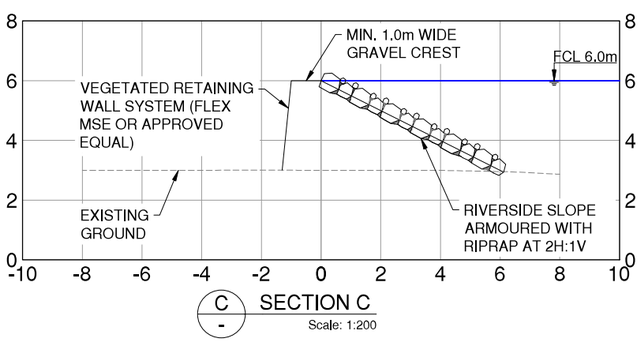

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COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW
LOCAL AREA 4: LEWIS PARK &
PUNTLEDGE ROAD

COMMERCIAL AREA

Figure #4

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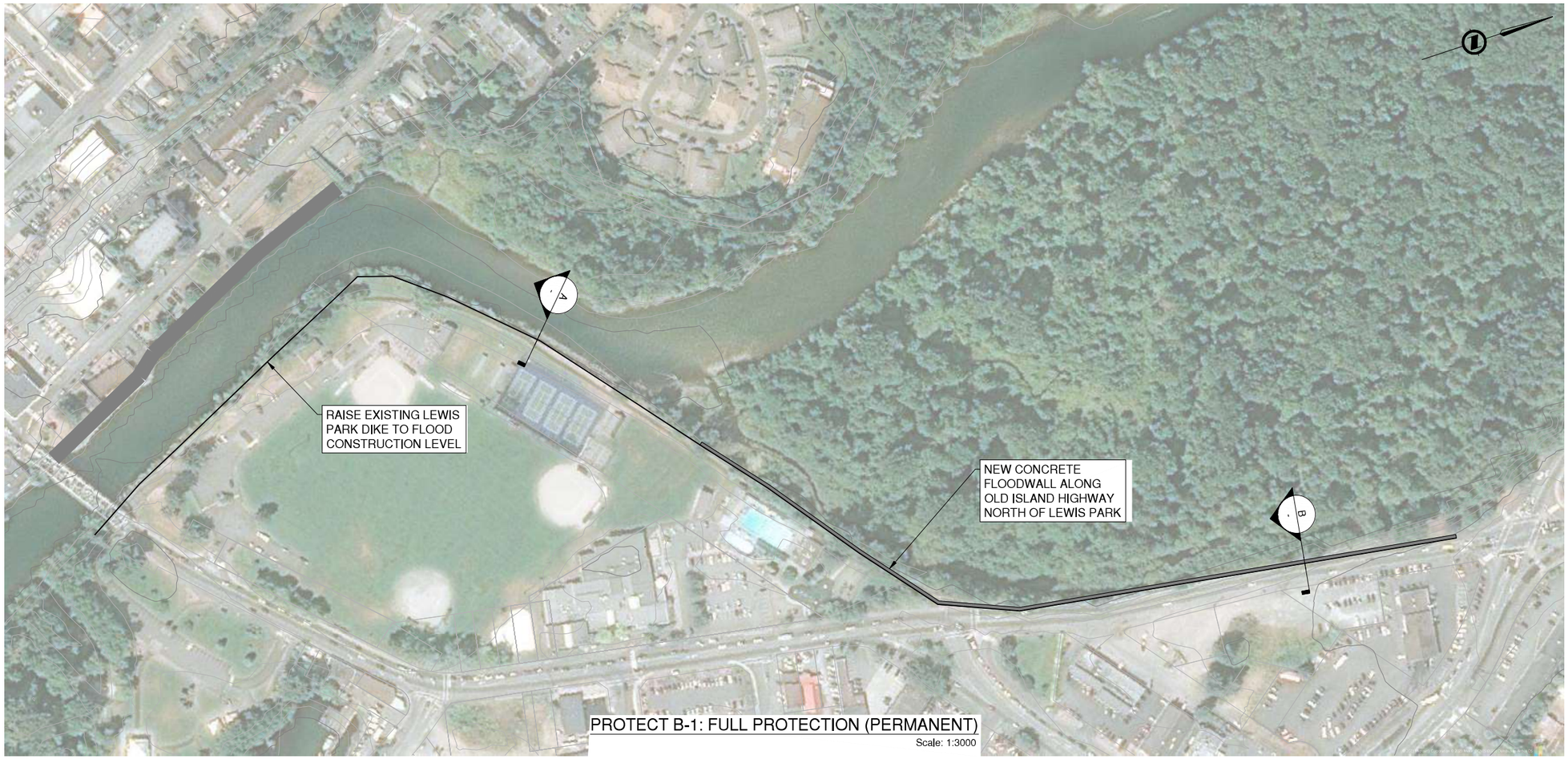

PROTECT B-1: FULL PROTECTION (PERMANENT)

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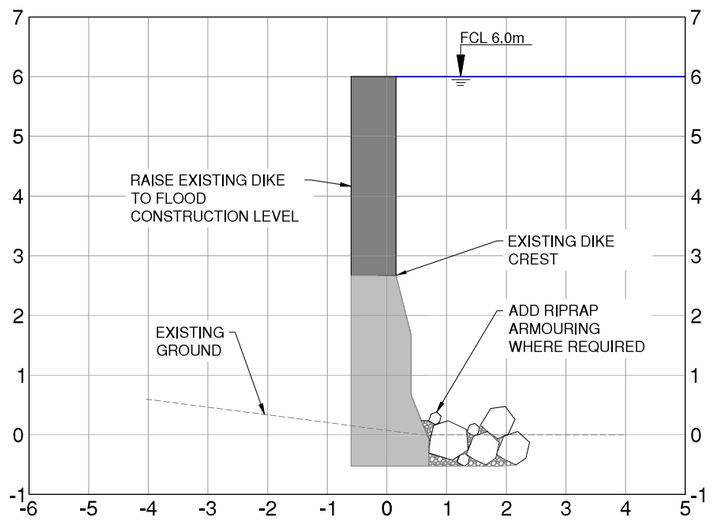

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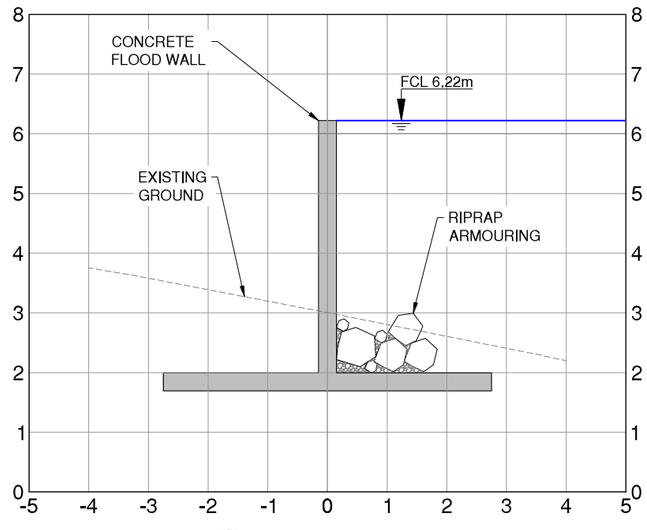

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WATER STREET ENGINEERING

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COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW

LOCAL AREA 4: LEWIS PARK & PUNTLEDGE ROAD
COMMERCIAL AREA

Figure #5

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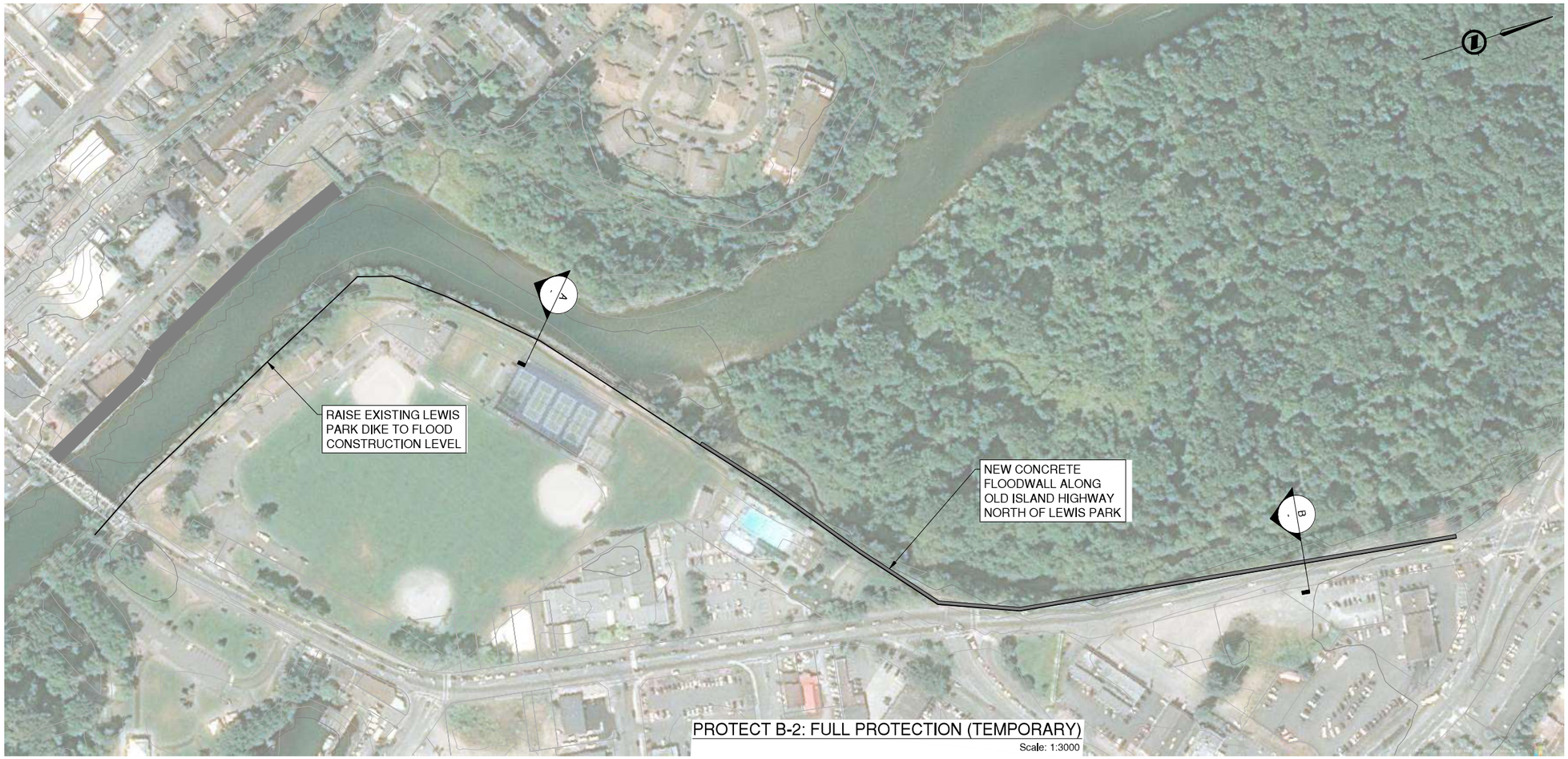

PROTECT B-2: FULL PROTECTION (TEMPORARY)

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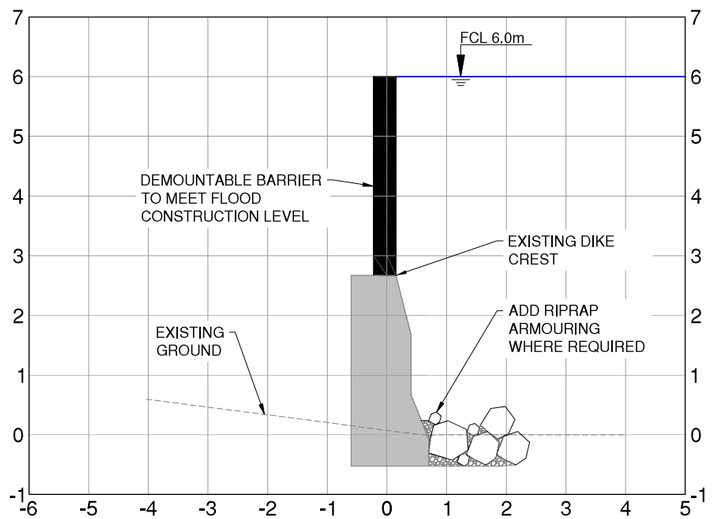

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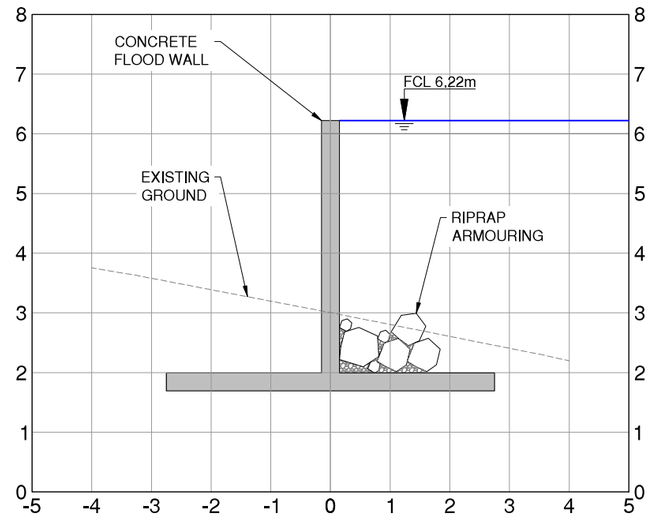

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SCALE

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COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW

LOCAL AREA 4: LEWIS PARK & PUNTLEDGE ROAD
COMMERCIAL AREA

Figure #6

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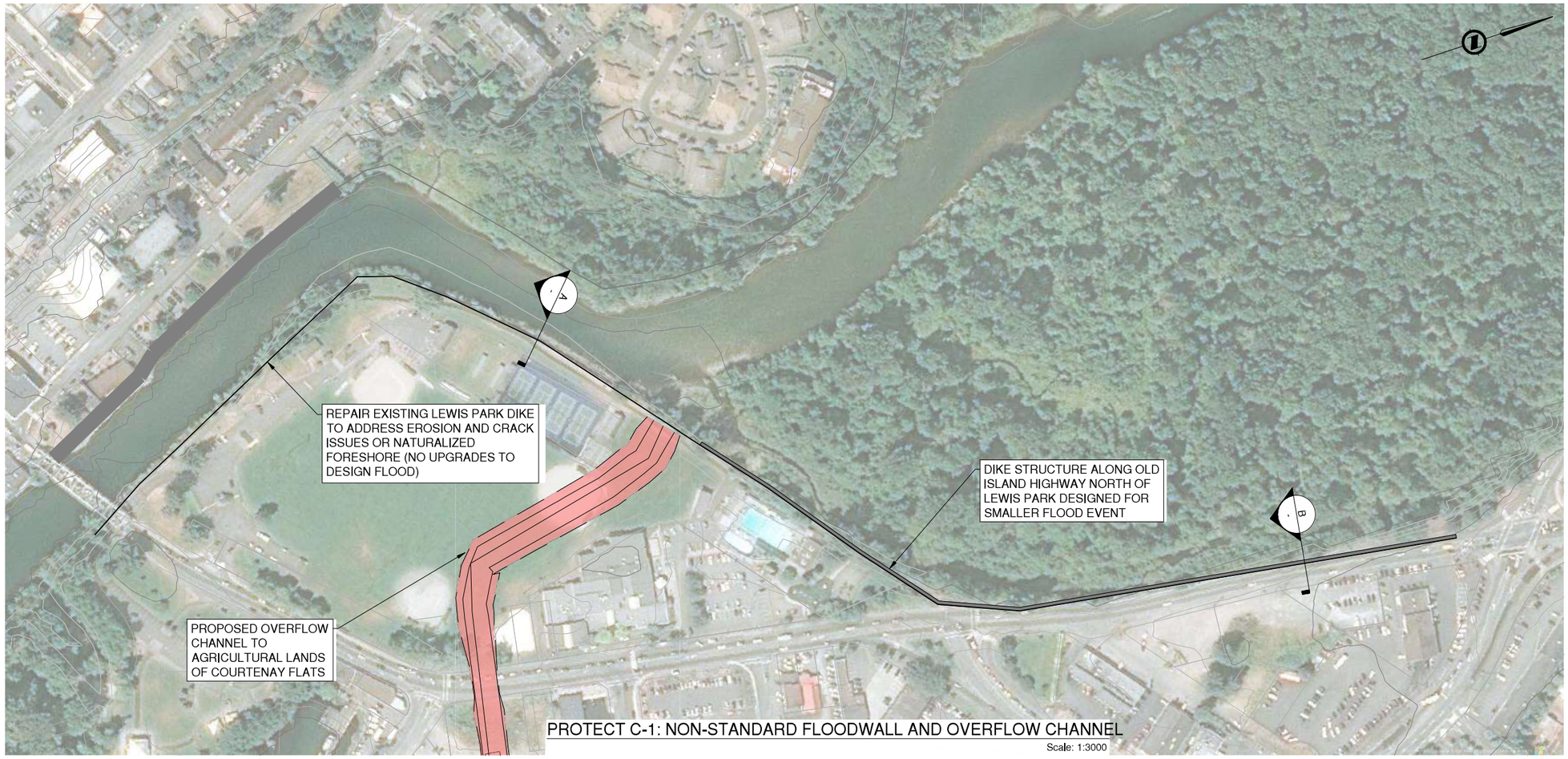

PROTECT C-1: NON-STANDARD FLOODWALL AND OVERFLOW CHANNEL

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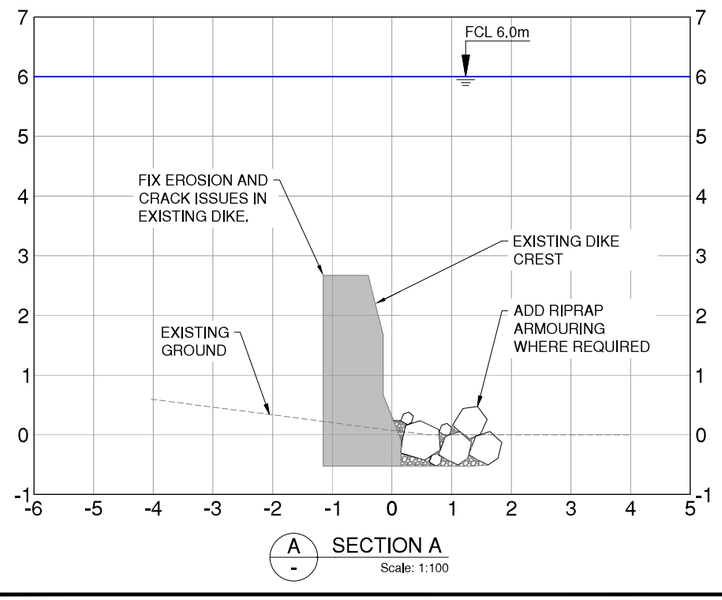

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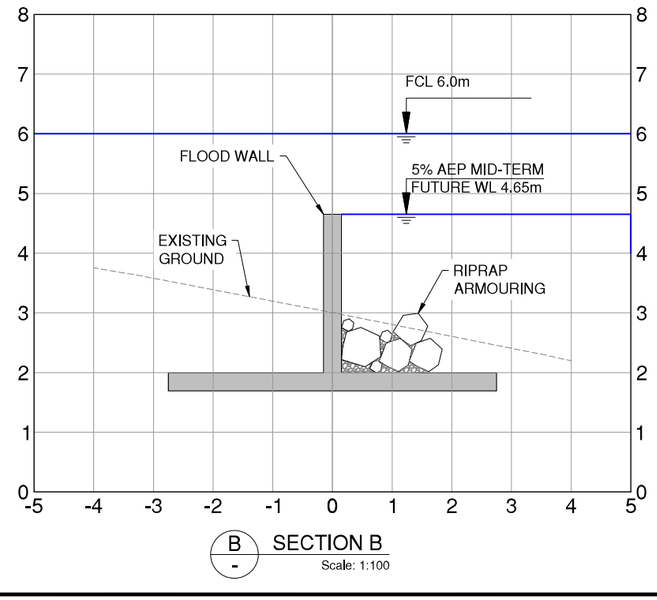

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WATER STREET ENGINEERING

SCALE

DATE: 06 SEP 2024

CLIENT: CITY OF COURTENAY

COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW

LOCAL AREA 4: LEWIS PARK & PUNTLEDGE ROAD
COMMERCIAL AREA

Figure #7

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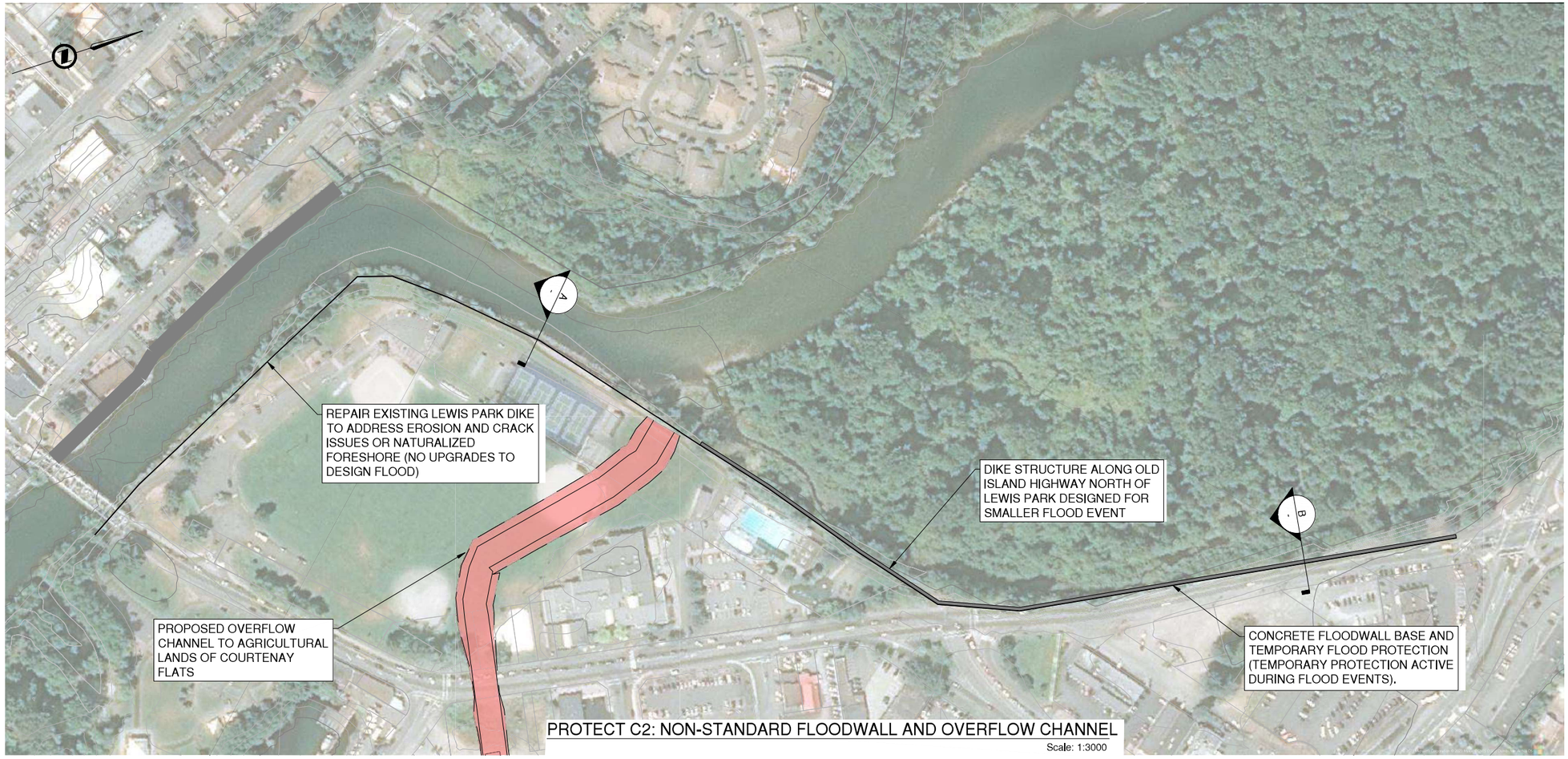

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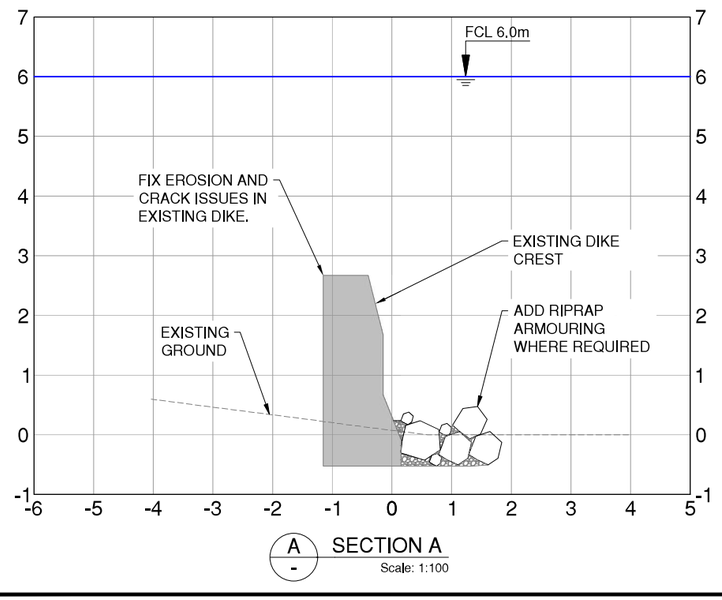

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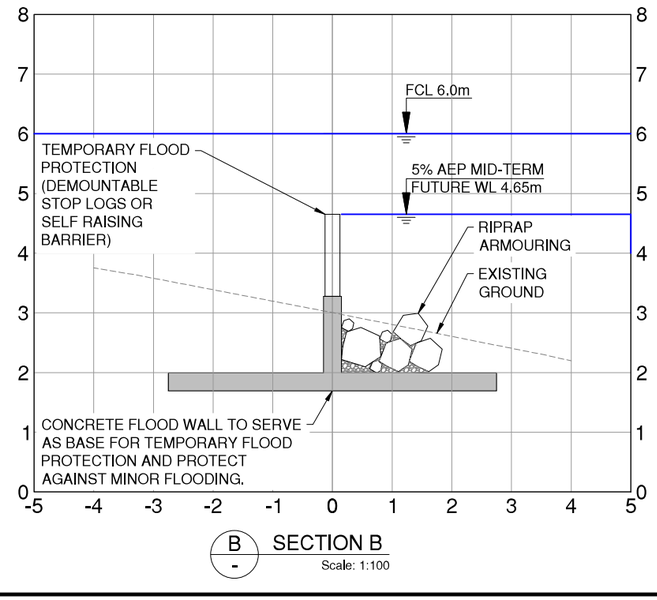

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WATER STREET ENGINEERING

SCALE

DATE: 06 SEP 2024

CLIENT: CITY OF COURTENAY

COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW

LOCAL AREA 4: LEWIS PARK & PUNTLEDGE ROAD
COMMERCIAL AREA

Figure #8

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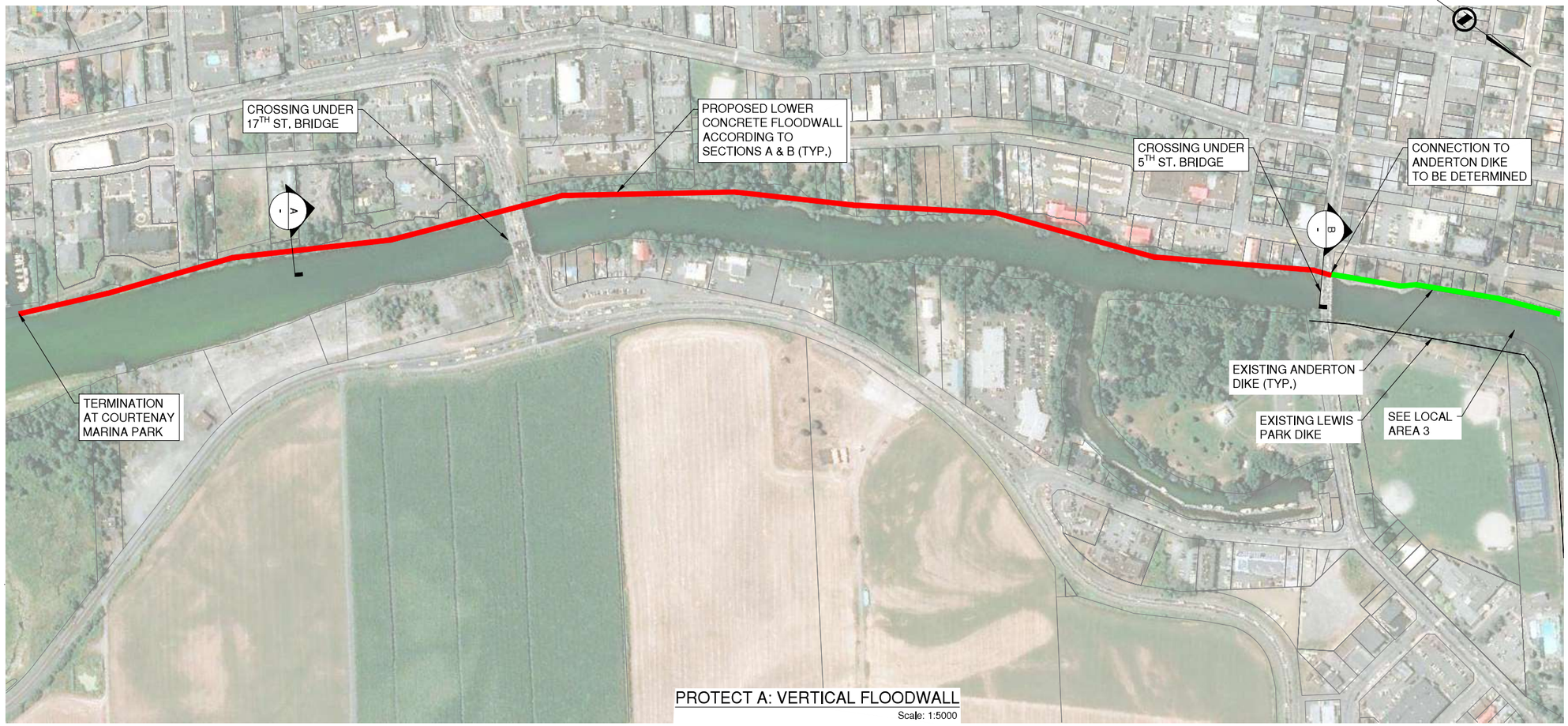

PROTECT A: VERTICAL FLOODWALL

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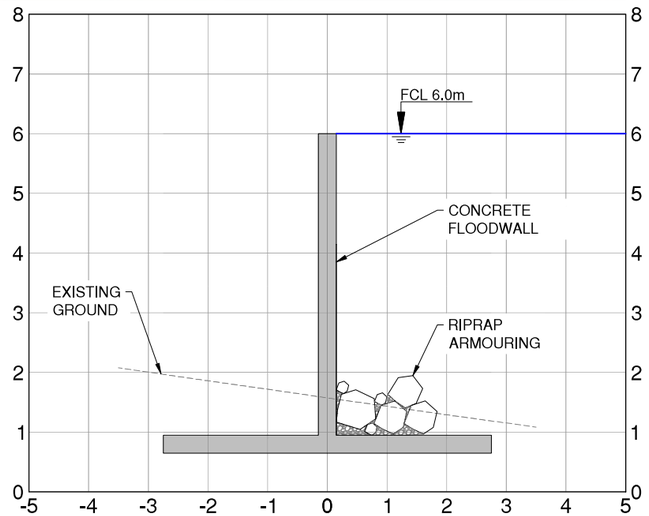

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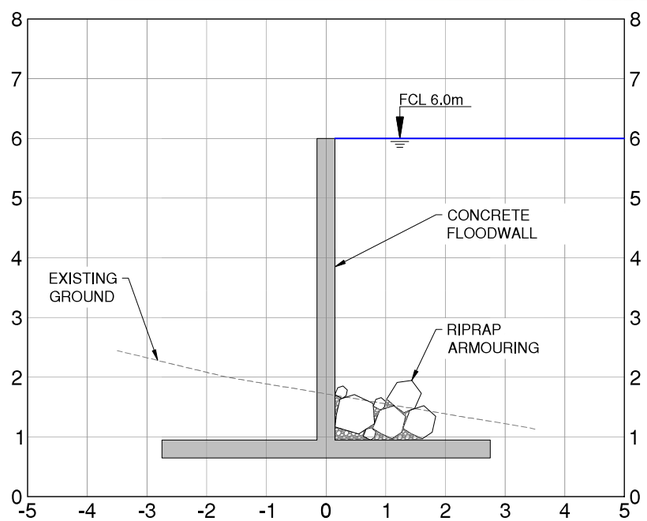

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WATER STREET ENGINEERING

SCALE

DATE: 06 SEP 2024

CLIENT: CITY OF COURTENAY

COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW

LOCAL AREA 5: COURTENAY RIVER - CLIFFE AVENUE CORRIDOR

Figure #9

REV 0

PROTECT A: FLOOD WALL

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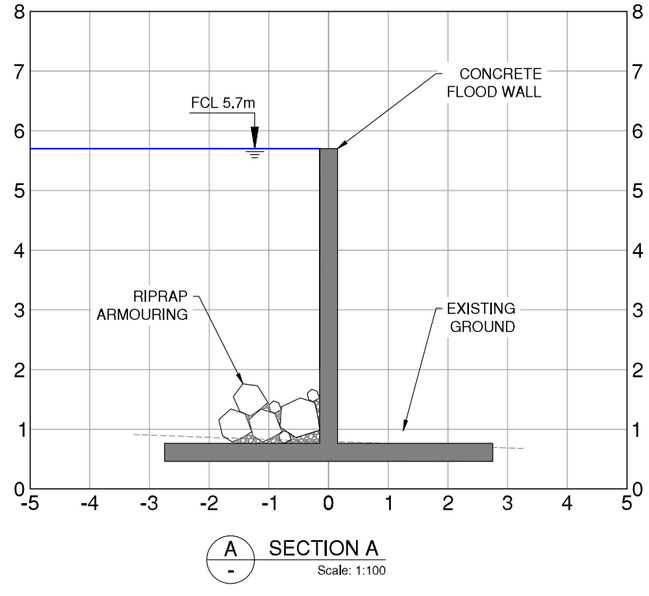

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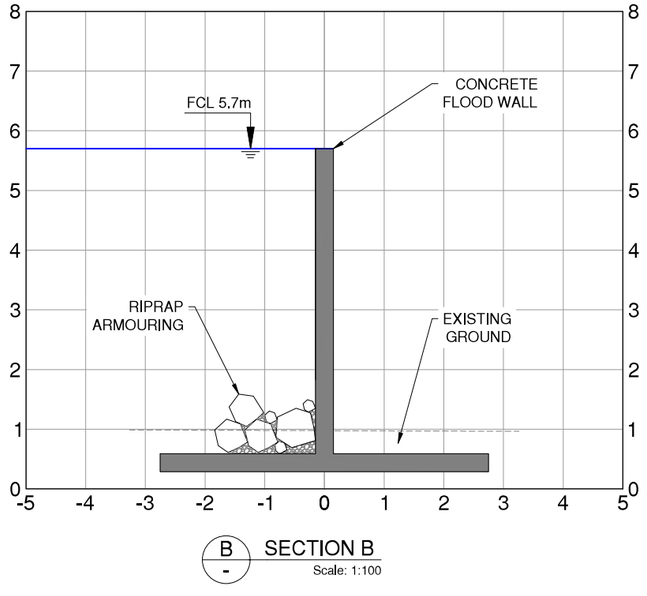

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WATER STREET ENGINEERING

SCALE

DATE: 06 SEP 2024

CLIENT: CITY OF COURTENAY

COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW
DIKE ALIGNMENT OPTIONS

LOCAL AREA 6:
AIRPARK AND SOUTH COURTENAY

Figure #10

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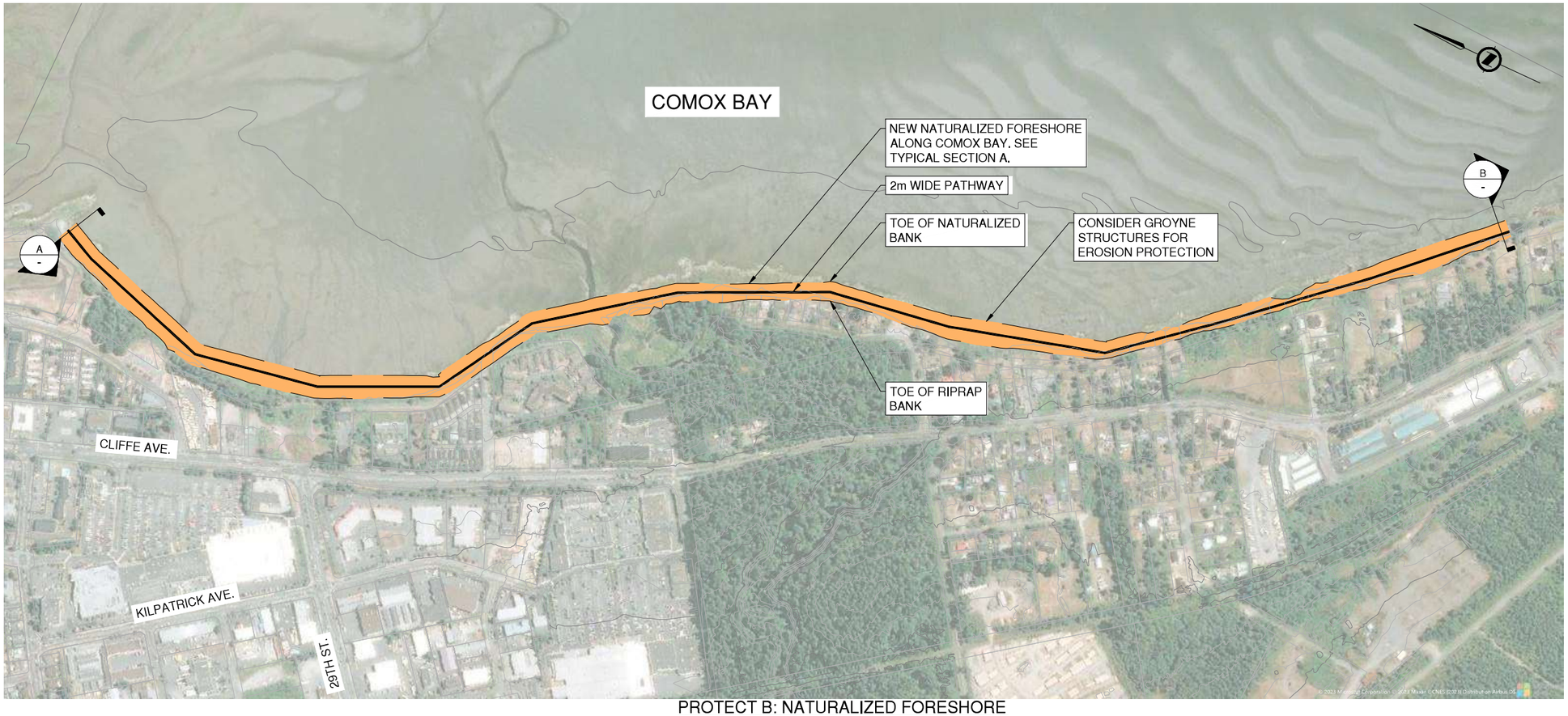

PROTECT B: NATURALIZED FORESHORE

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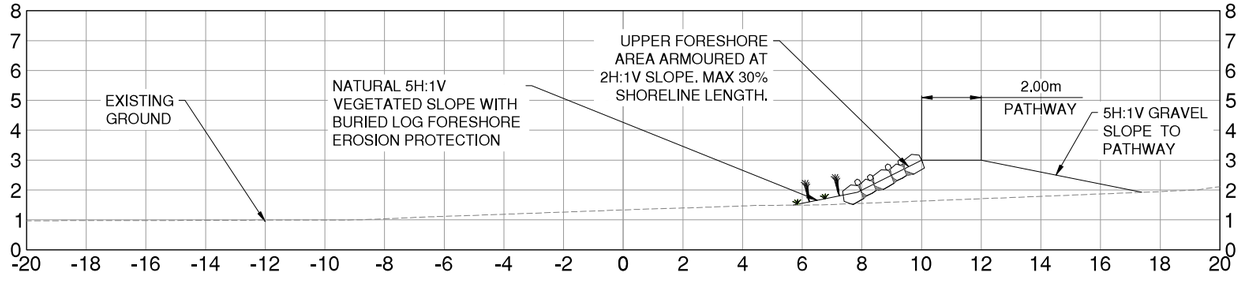


A / - SECTION A

Scale: 1:100

WATER STREET ENGINEERING

SCALE

DATE: 06 SEP 2024

CLIENT: CITY OF COURTENAY

COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW
DIKE ALIGNMENT OPTIONS

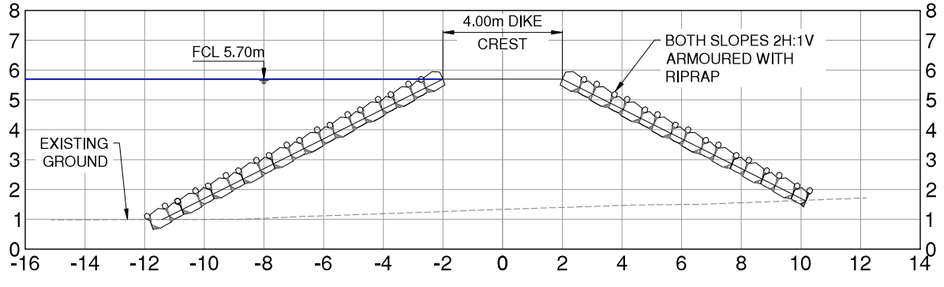
LOCAL AREA 6:
AIRPARK AND SOUTH COURTENAY

Figure #11

REV 0

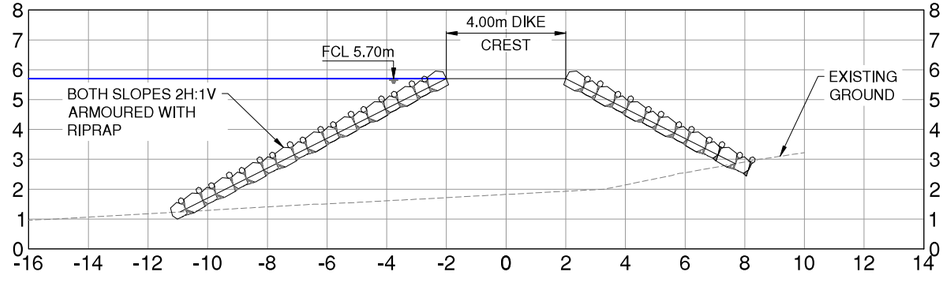
PROTECT C: RIPRAP

Scale: 1:8000



A - SECTION A

Scale: 1:200



B - SECTION B

Scale: 1:200

WATER STREET ENGINEERING

SCALE

DATE: 06 SEP 2024

CLIENT: CITY OF COURTENAY

COURTENAY FLOOD MANAGEMENT
FLOOD STRUCTURES REVIEW
DIKE ALIGNMENT OPTIONS

LOCAL AREA 6:
AIRPARK AND SOUTH COURTENAY

Figure #12

REV 0

APPENDIX 3: FLOOD MITIGATION OPTIONS COST ESTIMATE SUMMARY

Location	Option Description	Estimated Construction Cost	Contingency (50%)	Engineering and Contract Administration (20%)	Estimated Capital Cost	Estimated Maintenance Cost ($/yr)
Local Area 3: Canterbury Condensory	Protect A: Ring Dike	$6.8M	$3.4M	$1.4M	**$12M**	**$5,000 to $15,000**
	Protect B: Vertical Floodwall	$15.6M	$7.8M	$3.1M	**$27M**	**$5,000 to $15,000**
	Protect C: Semi-Permanent - Demountables	$9.7M	$4.9M	$1.9M	**$17M**	**$15,000 to $30,000**
	Protect C: Semi-Permanent - Self Raising Barrier	$23.6M	$11.8M	$4.7M	**$40M**	**$15,000 to $30,000**
Local Area 4: Lewis Park and Puntledge Road Commercial Area	Protect A: Ring Dike & Overflow Channel	$30.9M	$15.5M	$6.2M	**$53M**	**$5,000 to $15,000**
	Protect B-1: Full Protection (Permanent)	$7.6M	$3.8M	$1.5M	**$13M**	**$5,000 to $15,000**
	Protect B-2: Full Protection (Semi-Permanent) - Demountables	$6.4M	$3.2M	$1.3M	**$11M**	**$15,000 to $30,000**
	Protect B-2: Full Protection (Semi-Permanent) - Self Raising	$14.5M	$7.3M	$2.9M	**$25M**	**$15,000 to $30,000**
	Protect C-1 Non-standard Flood Wall (concrete wall) & Overflow Channel	$16.9M	$8.4M	$3.4M	**$29M**	**$15,000 to $30,000**
	Protect C-2: Non-Standard Semi-Permanent - Demountables	$13.8M	$16.9M	$2.8M	**$24M**	**$15,000 to $30,000**
	Protect C-2: Non-Standard Semi-Permanent - Self Raising	$22.4M	$11.2M	$4.5M	**$38M**	**$15,000 to $30,000**
Local Area 5: Courtenay River – Cliffe Ave Corridor	Protect A: Vertical Floodwall	$36.3M	$18.2M	$7.3M	**$62M**	**$5,000 to $15,000**
Local Area 6: Airpark & South Courtenay	Protect A – Flood Wall	$51.5M	$25.8M	$10.3M	**$88M**	**$25,000 to $50,000**
	Protect B – Naturalized Foreshore	$7.5M	$3.7M	$1.5M	**$13M**	**$25,000 to $50,000**
	Protect C – Riprap	$16.7M	$8.3M	$3.3M	**$28M**	**$25,000 to $50,000**