City of Pitt Meadows THE Natural PLACE

Staff Report to Council

Engineering

FILE: 11-5225-01/20

REPORT DATE: November 20, 2020 MEETING DATE: December 01, 2020

TO: Mayor and Council

FROM: Andrew Ablenas, Project Manager

SUBJECT: Summary of the Flood Mitigation Plan

CHIEF ADMINISTRATIVE OFFICER REVIEW/APPROVAL:

RECOMMENDATION(S): THAT Council:

A. Receive for information the Staff Report titled "Summary of the Flood Mitigation Plan" as presented at the December 1, 2020 Council Meeting; OR

B. Other.

PURPOSE

This report is intended to provide an overview of the recently completed Pitt Meadow's Flood Mitigation Plan. The Plan builds on the Flood Risk Assessment that was completed in 2018 and provides pro-active recommendations to improve the flood protection infrastructure in the City. A long-term phased approach is suggested to upgrade infrastructure with risk-based prioritization.

☒ Information Report ☐ Decision Report ☐ Direction Report

DISCUSSION

Background:

With 86% of the City's land located in the floodplain, flood protection and drainage is a major focus for the City. The City has completed various dike and drainage improvements over the years, but a detailed plan hadn't been established to help guide future decision making and priorities.

In 2015, the National Disaster Mitigation Program (NDMP) was established to provide funding to help Cities further define the specific flood risks and associated costs to mitigate flood-related events. As part of the NDMP, the City engaged ISL to complete a Flood Risk Assessment in 2018 and a more detailed Flood Mitigation Plan in September 2020.

The 2018 risk assessment outlined vulnerabilities in the City's diking and drainage network and assessed three different scenarios:

- Risk Event 1 – 1 in 500 Year Fraser Freshet
- Risk Event 2 – 1 in 500 Year Fraser Freshet + Climate Change + Sea Level Rise
- Risk Event 3 – Storm Surge

These risk events were mapped and impacts were quantified at a very high-level. The 1-in-500 year freshet (spring rain and snow melt related flooding) would inundate the majority of the City. Flood depths may exceed 4m in certain areas and are shown in Figures 3.1 of Attachment A – Flood Risk Assessment. The majority of Pitt Meadow's urban area is above flood levels; however, all major infrastructure and road networks providing access to and from the City would be submerged. Taking into account expected changes to sea levels and climate, the flood level would rise even higher. In this scenario, up to half of the Pitt Meadows urban area could be under water during the 1-in-500 year freshet as shown in Figure 3.2 of Attachment A. The economic loses of these flooding events are projected to be in the range of $489M – $725M.

The Fraser Basin Council (FBC) has also been modelling potential flooding for several years as part of the Lower Mainland Flood Management Strategy (LMFMS). The LMFMS is aimed at reducing flood risk and improving the flood resilience of communities on a regional scale; however, it does not include recommendations or priorities for specifics Cities.

The Risk Assessment was used as a resource for emergency management and preparedness and provided background information for the detailed Flood Mitigation Plan (FMP). That mitigation plan will be discussed in the remainder of this report.

Flood Mitigation Plan Overview:

As outlined in the 2018 risk assessment recommendations, the City commissioned ISL to prepare a detailed Flood Mitigation Plan (FMP). This Plan assessed the City's dikes and pump stations to identify inadequacies and provide suggestions for flood mitigation through infrastructure upgrades. Several issues were identified with City pump stations; however, most of these are known to the City and recommendations are already being implemented.

The scale of upgrades required for the diking system is much more substantial. Nearly all of the City's dike structures require an increase in height and corresponding widening

(56-99% wider, depending on the location) to ensure long-term protection during flood and seismic events.

Overall performance of the City's dikes during a large seismic event is a significant concern. Roughly half of the areas examined were found to be of high priority for seismic upgrade. Refer to Figure 3.1 and 4.1 in Attachment B for a seismic improvements map and widening cross-section of the dike. With such a large number of projects already ongoing or planned, improvements to the diking system will likely not be the focus until 2024.

The majority of parcels affected by this widening are located in the agricultural reserve and will require some level of land acquisition. In several cases, access to large industrial parcels on land and small structures on water will be an issue. The public will also lose access to portions of the dike walkways and trails for extended periods of time.

Although not stated in the report, the following areas may provide additional challenges for accessibility and land acquisition along Fraser Dyke Road and the Airport. Fraser Dyke Rd acts as the only access point to a few properties and will present issues when the work is completed (detours or others means will be needed) and coordination will be needed with the Airport for expansion of the dike in front of their lands.

Backup Power & Additional Pump Stations:

All existing pump facilities were found to have sufficient capacity and the majority of pumps are in proper working order. Only the pumps at two stations are operating beyond their life expectancy and they are already planned to be replaced (Fenton in 2021, Kennedy in 2022). Additionally, a grant application was submitted earlier in 2020 for the Kennedy pumps. There were pressing risks associated with all pump stations relating to a lack of emergency backup power. Fortunately, backup generators are already planned to be installed in the Fenton, McKechnie, Baynes, and Kennedy pump stations by the end of 2021. The installation of additional backup generators at the Pitt Polder and Alouette facilities is recommended. The City just recently applied for grant funding for this work.

Two locations near the Pitt Meadows Marina have been identified to have additional pump infrastructure to potentially better manage seasonal flooding. A pumping station north of the Alouette River at the existing Charlier floodbox is proposed to service ditches to the north. A second pump station is proposed at the Reichenbach floodbox to service lands to the south. The Reichenbach pump station is currently included in the City's DCC program and budgeted for in 2030, although at a significantly less cost. Further review of both proposed pump stations is recommended prior to coordination of the work. Staff are not currently concerned with the conveyance or capacity of the drainage system in this area and the recommendations are primarily to provide resiliency, so these two new pump stations are not a high priority for the City at this time. Staff will continue to monitor the operation of the drainage network in the area.

Environmental & Archaeological Findings:

As part of the FMP, an environmental assessment was conducted to examine both terrestrial and aquatic habitats to determine which regulations may apply to any proposed system upgrades. In general, habitat was also found to be extensively altered and lacking in both diversity and structure. Two critical habitat polygons have been established in the City; however, ISL identified the probability of any potential Species at Risk inhabiting the area to be either low or unlikely.

Antiquus completed an Archaeological Overview Assessment (AOA) as part of the FMP. The AOA contains sensitive information and cannot be publicly released; however, the review determined that the proposed activities may impact several protected archaeological sites. Archaeological mitigation will likely be necessary in certain areas.

Priorities and Next Steps:

The majority of pump station upgrades are already set to be completed, or under consideration in the business plan. Upon completion of these improvements in the next few years, focus can shift to upgrades/widening of the dike network. Evaluation of risk has been used to prioritize portions requiring upgrade, considering the existing seismic stability of the dike, the probability and consequences of failure and various complexities such as land acquisition. A map of the prioritization is presented in Figure 4.3 of Attachment B.

Complete protection of Pitt Meadows will require coordination with Maple Ridge and the Katzie First Nation for tie-in to dike structures on their respective lands.

COUNCIL STRATEGIC PLAN ALIGNMENT

☒ Principled Governance ☒ Balanced Economic Prosperity ☐ Corporate Excellence
☒ Community Spirit & Wellbeing ☒ Transportation & Infrastructure Initiatives
☐ Not Applicable

FINANCIAL IMPLICATIONS

☐ None ☐ Budget Previously Approved ☒ Referral to Business Planning
☐ Other

The total estimated upgrade costs for the entire dike system (60km) and new pump stations is around $135M, which is a very high level estimate. The highest risk locations due to infrastructure losses are Areas 2 and 3, with respective costs of $15.3M and $38.4M to complete improvements. A much more detailed breakdown of priorities and costs are outlined in Attachment B.

Table 1. Estimated Cost Summary	
Scope	Cost
New Reichenbach & Charlier Pump Stations	$13,808,000
Total Dike Upgrades	$121,273,000
Note that costs for projects currently planned or ongoing not included in the table above.	

As these costs are significantly beyond the capacity of the City, further regional advocacy with Metro Vancouver and the FBC and grant opportunities would be explored. The FMP would assist in supporting any future grant applications.

The first priority for the City would be the stretch of dike that runs along the Fraser River from Fraser Dyke Road/176th St to the City's eastern border and tie-in to a potentially new dike structure on Katzie First Nation's Reserve No.1. This represents roughly 20% of the dike length requiring upgrade in Area 3 (4.5km). Applying this percentage to the remainder, costs for the first priority section of dike would be around $7M, depending on the detailed design.

Current & Planned Projects:

A brief summary of current projects, considerations, and funding sources has been provided below.

Table 2. Grant Summary		
Scope	Grant Value	Status
Fenton, Kennedy, and McKechnie Backup Generators	$678,000	Grant received, work expected to be complete by January 2021.
Fenton Pump Replacements & Baynes Backup Generator	$739,000	Grant received, work expected to be complete by the end of 2021.
Kennedy Pump Replacement	$1,064,000	Grant application submitted, but project also budgeted for in 2022 ($1.5M)
Pitt Polder & Alouette Backup Generators	$750,000	Grant application submitted, but pitt polder generator also budgeted for in 2026 ($280k)
Total	$3,231,000	

Note that if the City is successful in the grants for the Kennedy Pump Replacement and generators at Pitt Polder and Alouette Pump Stations, significant savings will be realized with the deletion of those projects in the City's 10-year business plan.

The City has an annual capital budget of $60,000 for necessary diking repairs and topping. The City also has a dike operating budget of approximately $184,000, which includes annual inspections of the dike, grass cutting and vegetation control (including tree removal), minor repairs, gate maintenance, litter control, signage and other contracted services. These costs are necessary to maintain our current dike infrastructure and ensure any deficiencies are repaired, but they do not support the needs to upgrade our dike infrastructure.

PUBLIC PARTICIPATION

☒ Inform ☐ Consult ☐ Involve ☐ Collaborate ☐ Empower

Katzie First Nation, as a Rights Holder, and stakeholders, including FBC and the City of Maple Ridge, were part of the Flood Management Plan.

Given the property impacts of the recommended dike widening, future consultation will be needed.

KATZIE FIRST NATION CONSIDERATIONS

Referral ☒ Yes ☐ No

The Katzie First Nation were engaged as part of the Flood Mitigation Plan. A meeting was held in March 2020 and the results of the risk mapping, potential dike alignment along River Road and the importance of connectivity were discussed. The draft Flood Mitigation Plan was provided to Katzie First Nation, but feedback has not yet been received. Future collaboration will be essential to ensure adequate protection of both our communities.

SIGN-OFFS

Written by:
Andrew Ablenas,
Project Manager

Reviewed by:
Samantha Maki,
Director of Engineering & Operations

ATTACHMENTS:

A. Pitt Meadows Flood Hazard Risk Assessment (without Appendices)
ISL Engineering and Land Services, April 2018
B. Flood Mitigation Plan – Final Report (without Appendices)
ISL Engineering and Land Services, September 2020

ISL Engineering and Land Services

Inspiring sustainable thinking

City of Pitt Meadows

Report

Pitt Meadows Flood Hazard Risk Assessment

April, 2018

ISL Engineering and Land Services

ISL Engineering and Land Services Ltd. is an award-winning full-service consulting firm dedicated to working with all levels of government and the private sector to deliver planning and design solutions for transportation, water, and land projects.

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FIGURES

1.0 Introduction

This flood hazard risk assessment report was prepared by ISL Engineering and Land Services Ltd. (ISL) for the City of Pitt Meadows (City) as a resource to aid in its emergency management and preparedness. Thurber Engineering Ltd. (Thurber) was a sub-consultant to ISL and provided high-level geotechnical engineering reviews of the City's diking system. This report provides an assessment of the potential for flooding and the potential impacts on the community should flooding occur.

The project was undertaken as part of the National Disaster Mitigation Program (NDMP) under Stream 1 Risk Assessments. Stream 1 allows for a high-level risk assessment and was designed to identify flood hazards and complete risk assessments for chosen risk events. Subsequent NDMP streams will provide the opportunity for more detailed assessments of the selected risk events.

The identification, assessment and ranking of risks and impacts serves to provide a framework for the City in its risk mitigation planning to help determine flood risk mitigation opportunities.

ISL's approach to completing this risk assessment included the below main tasks.

1. Establish a study baseline. This phase of the study was to compile and review existing regional studies, and mapping.
2. Analyze the regional data to determine the design flood and resultant flood levels. Identify hazard scenarios that may contribute to a design flood event.
3. Simulate the effects of the design floods by comparing the modelled design flood mapping on a 3-dimensional (3D) model of Pitt Meadows. This included additional model iterations including each of the various hazard scenarios.
4. Identify the risks based on the consequences of the resultant flood levels from the 3D model by identifying the affected existing developed lands and associated land uses.
5. Assign values to each of the identified consequences and determine the probability of the loss of each occurring.

The risk assessment was based on anticipated inundation depths from hazards defined in previous studies conducted in the region. Comprehensive risk assessments may include analysis of factors not reviewed in this assignment, including: flow velocities, duration of inundation, time of year, sediment loads, and pollution.

1.1 National Disaster Mitigation Program

The NDMP is a federal program developed in 2014 that seeks to build safer and more resilient communities. The objective of the NDMP is to reduce the impacts of natural disasters on Canadians by investing in significant and recurring flood risk mitigation. The four streams of the NDMP are listed below.

- Stream 1 – Risk Assessments
- Stream 2 – Flood Mapping
- Stream 3 – Flood Mitigation Planning
- Stream 4 – Investments in Non-structural and Small Scale Structural Mitigation Projects

Stream 1 allows for an overview of flood hazards in communities and assessments of risk events. Stream 2 allows for more comprehensive risk assessments and flood and hazard maps. Streams 3 and 4 provide funding for the flood mitigation planning and implementation of flood mitigation projects.

ISL prepared this flood hazard risk assessment report in consideration of the below guidelines and resources.

- National Disaster Mitigation Program Risk Assessment Information Template (RAIT), Public Safety Canada
- Risk Assessment Information Template Users' Guide, Emergency Management British Columbia (EMBC) Disaster Mitigation Program
- Professional Practice Guidelines - Legislated Flood Assessments in a Changing Climate in BC, Engineers and Geoscientists of British Columbia (EGBC, formerly the Association of Professional Engineers and Geoscientists of BC)

The NDMP Risk Assessment Information Template is designed to be a tool for improved understanding and prioritizing future resources on a national level. The RAIT is the final deliverable for the Pitt Meadows Flood Hazard Risk Assessment and a condition of NDMP funding. The completed RAIT tables for each risk event can be found in **Appendix A, B, and C**.

1.2 Rationale

Flooding in BC can be attributed to many common factors, including: climatic conditions, geomorphic process (debris flows, debris floods, etc.), structural failures of flood protection, and human activity (urbanization).

The City of Pitt Meadows is susceptible to flooding due to heavy rain, rain-on-snow, spring freshet, and mechanical failure of pump stations. Freshet by definition is a river flood due to heavy rain or snow melt. In the Lower Mainland, freshet is generalized to be spring flooding of rivers caused by annual snow melt. The freshet period in Pitt Meadows typically extends from April to July. Freshet is forecasted using snowpack estimates during winter which improve readiness for downstream municipalities. Other meteorological events such as heavy or intense rain events can be more difficult to predict.

Approximately 95% of the City lies within the Fraser River and Pitt River floodplains. The Alouette River divides the City and confluences with the Pitt River. The City is protected by standard and non-standard (agricultural) diking system of approximately 60 km in length. The municipality is divided into four distinct drainage areas that are defined by dikes and serviced by floodboxes and pump stations. Most of the City's dikes (and drainage pump stations) were built to design criteria established by the Fraser River Flood Control Program (1969) and Agricultural and Rural Development Subsidiary Agreement (ARDSA) and do not meet current provincial design standards.

The Fraser River is the most significant flood hazard in the City as it undergoes annual freshet and has the ability to cause the most damage to the region due to a drainage area of roughly 250,000 sq.km. that extends from the Rocky Mountains to the Lower Mainland of BC. The City of Pitt Meadows' top of dike elevations are at 5.4 m geodetic which approximately corresponds to 8.4 m at the upstream Mission Fraser River hydrometric data gauge. Flood levels of 8.4 m or higher as measured at Mission would cause overtopping of the Pitt Meadows dikes. This threshold was exceeded during the flood of 1984, when the water surface elevation reach an estimated 8.9 m (**Figure 1.1**).

According to the Fraser Basin Flood Management Strategy, a present day Fraser River flood equal to the 1894 flood of record, could result in a total economic loss of $22.9 Billion, displacement of 266,000 people, and an agricultural loss of $67-200M for the Lower Mainland.

EMBC identifies the four components of emergency management as mitigation, preparedness, response and recovery. Preparedness, response, and recovery measures allow for impact management once a disaster occurs. However, mitigation can prevent a disaster from occurring or reduce the potential impacts of a disaster. EMBC qualifies the importance of mitigation as follows: "Investment in disaster mitigation leads to significant relative savings in future response and recovery costs (compared to costs if no mitigation measures were taken)."

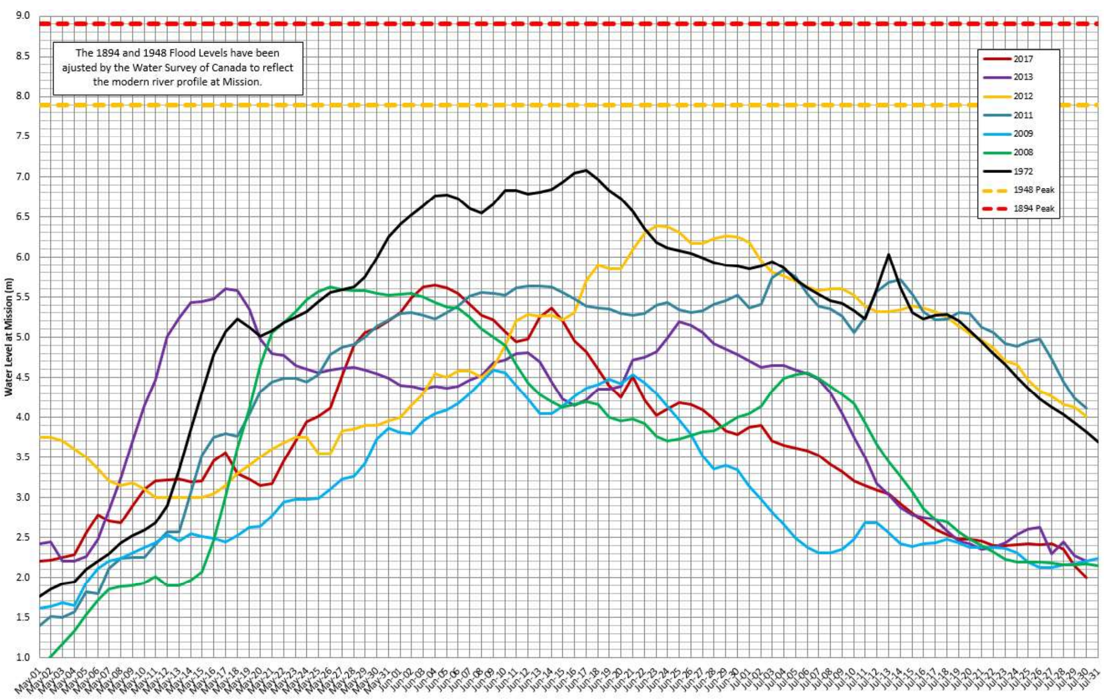


Figure 1.1: Fraser River Water Levels at Mission, BC (Water Survey of Canada)

Within the Professional Practice Guidelines, EGBC indicates that the population of BC is anticipated to grow by one third by 2035. This will have an impact on housing affordability in urban centers, particularly in Greater Vancouver and the Fraser Valley, and will increase development pressure in flood-susceptible areas. This flood hazard risk assessment will help to inform decision-making regarding where future development should be located, and the associated flood hazard related risks for new development areas.

1.3 Project Team

The City of Pitt Meadows Flood Hazard Risk Assessment was led by the project team listed below.

- City of Pitt Meadows Working Group
- ISL Engineering and Land Services Ltd.
- Thurber Engineering Ltd.

The City's Working Group consisted of members from Engineering, Operations, Environmental, Building, and Emergency Coordination divisions and committees. The City provided in-house expertise related to past information and reports, technical information required for the assessments, and coordination of the stakeholders and public meetings.

ISL Engineering led the consultant team and was the primary contact for Pitt Meadows. ISL was consulted on the flood hazards, provided input of flood hazards, compiled risk events, and completed the high level risk assessments.

Thurber Engineering conducted high-level assessment of the City's diking infrastructure. Thurber's report covered general geotechnical considerations for seepage, settlement, and stability (seismic and non-seismic).

Other stakeholders that did not directly contribute to this Stream 1 risk assessment but that may be involved with related future work include:

- Fraser Basin Council;
- Metro Vancouver Utilities Sector;
- Katzie First Nation;
- Maple Ridge Hammond Community;
- BC Ministry of Forests, Lands & Natural Resources Operations;
- BC Ministry of Transportation and Infrastructure;
- Canadian Pacific Railway;
- BC Hydro; and
- Fortis BC.

The structure and composition of the project team and stakeholder group may vary periodically based on the interests of each party during subsequent stages of future work.

Additionally, a public open house was conducted to inform Pitt Meadows residents and businesses to generate public feedback on ideas and important topics related to flooding and flood risks. The objectives of the open house were to gain an understanding of the City's preparedness, and to understand perspectives and priorities for future flood mitigation work.

2.0 Background

2.1 Flood Hazards

Floods hazards in Pitt Meadows vary from high frequency/low consequence (debris blockage of culvert) to low frequency/high consequence (dike breach). Certain hazards may warrant a stand-a-lone risk assessment, such as the diking system and risk of failure due to seismic events. Flood hazards in Pitt Meadows identified for this risk assessment are shown in the **Table 2.1** below.

Table 2.1: Flood Hazards in the Project Area

Flood Hazards in Project Area	Prioritization Rationale
Freshet causing dike overtopping	Freshet occurs annually; since 1894, three significant (causing flooding) Fraser River floods have occurred (1894, 1948, 1972); the City's perimeter (standard) dikes are expected to overtop in a flood similar to the flood of 1894 (considered as 1:500 year).
Dike breach	Dike breaches are difficult to determine the likelihood but the impact can be severe due to the potential to occur without warning.
Storm surge	More common than the above events and less severe, storm surge (or prolonged heavy rainfall during high tides) can overcome the City's drainage infrastructure (pump stations, storm sewers, and ditch network) and cause damage to agricultural land.
Drainage pump station failure/ Power loss	The City's drainage system relies on dikes, flood boxes, and drainage pump stations. The City's 6 drainage pump stations are currently without backup power - in the event of station failure or power loss, the drainage system relies on floodboxes for drainage relief (only operational when the drainage system water levels are higher than the river water levels).
Sea level rise	Sea level is expected to rise by 1m from 2000 to 2100, which will affect the Fraser and Pitt Rivers Dam breach (upstream Alouette River Dam) may come with little warning and in the event of complete failure, signficant flooding in the City.
Upstream dam breach	The Alouette River dam is upstream of Pitt Meadows. BC Hydro has a detailed flood mapping and is responsible to action plan. A complete failure may be unlikely but could be catastrophic to Pitt Meadows and Maple Ridge.
Beaver dams/ Debris build up	Beaver dams are a common issue in the drainage issues but are generally confined and cause local backwater effects and/or flooding.

2.2 Project Area

The project area boundary for the Pitt Meadows Flood Hazard Risk Assessment was focused on the Pitt Meadows Municipal Boundary. However, the flood inundation maps included a portion of Maple Ridge, demarcated as the Model Extent (**Figure 2.1**). The Maple Ridge area was included as it could be affected by flooding caused by a hazard within the City of Pitt Meadows Municipal Boundary and Pitt Meadows is the Diking Authority for this section of Maple Ridge. The study area as it pertains to the flood hazard risk assessment was limited to the City of Pitt Meadows Municipal Boundary.

Pitt Meadows is bound by the Pitt River to the north and west, the Fraser River to the south, the City of Maple Ridge to the east, and the Thompson Mountain Range to the northeast. Two arms of the Alouette River (North Alouette and South Alouette) divide the city, along with a system of sloughs and ditches that convey drainage to the surrounding rivers. The municipality is divided into four drainage areas that are defined by dikes and serviced by floodboxes and pump stations.

2.3 Land Uses and Key Infrastructure

Pitt Meadows is a primarily agricultural and rural residential community with a distinct urban boundary, referred to as the urban area. The urban area includes the Pitt Meadows Airport and the City Center and is bounded by the Lougheed Highway to the north, Maple Ridge to the east and the Fraser River to the south. The west is bound by the Agricultural Land Reserve (ALR) with the exception of a stretch of land that follows the Canadian Pacific Railway (CPR) and Lougheed Highway to the Pitt River.

The population of Pitt Meadows is projected to increase from 15,623 in 2006 to 21,000 by 2028, requiring roughly an additional 2,700 housing units, over the same timeframe. The 2016 Statistics Canada Census lists the City's population as 18,573. The ALR limits the potential for development on agricultural lands and most of this growth must take place on non-ALR zone lands within the urban area. Through land use changes and other strategies outlined in the City's Official Community Plan (OCP), the urban area will develop into a more compact, metropolitan area.

Pitt Meadows and the regional district of Metro Vancouver are growing at a comparable rate. Situated near other rapidly developing communities of Maple Ridge, Coquitlam, Port Coquitlam, Surrey and Langley, Pitt Meadows is involved in ongoing regional transportation improvements. These improvements are designed to connect the entire Metro Vancouver and improve accessibility for the growing population. The City is a connection point that contains the following regional commercial, and transportation and other key infrastructure:

- Pitt River Quarries (PRQ);
- Provincial Infrastructure (Lougheed Highway);
- Regional Infrastructure (Metro Vancouver Water Booster Station and Chlorination Analyzer; Metro Vancouver Sanitary Pump Station);
- Pitt Meadows Regional Airport; and
- Canadian Pacific Rail and Vancouver Intermodal Facility.

Agricultural land use is predominant in Pitt Meadows with approximately 86 percent of total area designated as Agricultural Land Reserve (ALR). Agricultural parcels in the City range from small to large and uses vary from berry farms, horticultural products, crops, grazing and dairy farms. The Agricultural Land Commission must support land use changes of existing ALR land to non-ALR uses.

FIGURE 2.1
PROJECT AREA
FLOOD RISK ASSESSMENT

3.0 Risk Events

Risk events were developed based on the identified hazards listed in **Section 2.0**. Although there are an infinite number of risk events that could be explored, three events were selected, that:

- Met the NDMP criteria;
- Supported the previous regional reports and context;
- Were applicable to the interests of stakeholders; and
- Offered a range in likelihood of occurrence to output structural and non-structural flood mitigation projects with a scale of cost (low to high cost) and timeframe (short to long term).

3.1 Previous Reports

There were previous reports that provided the basis for the development of the risk events and high-level economic loss estimates and flood inundation. The purpose of this flood hazard risk assessment was apply the regional assessments to the City of Pitt Meadows using refined data and information. The primary reports referenced for this risk assessment are below.

- Lower Mainland Flood Management Study, by Kerr Wood Leidal, commissioned by Fraser Basin Council, May 2015
- Lower Mainland Flood Management Strategy Project 2: Regional Assessment of Flood Vulnerability, by Northwest Hydraulic Consultants, commissioned by the Fraser Basin Council, April 2016
- City of Pitt Meadows Drainage and Irrigation Study, by ISL Engineering, commissioned by the City of Pitt Meadows, January, 2018

The Northwest Hydraulic Consultants (NCH) and Kerr Wood Leidal (KWL) commissioned by the Fraser Basin Council provided were the basis for Risk Events 1 and 2.

ISL's drainage and irrigation study, completed in 2018 for the City of Pitt Meadows, provided the basis for Risk Event 3.

3.2 Risk Event 1 – 1 in 500 Year Fraser Freshet

Risk Event 1 was developed by KWL (2015) and modelled by NHC (2016) and was considered to be representative of the 1894 Fraser River flood of record. The flood equates to a peak flow of 17,000 m^3/s at Hope and a 1 in 500 year return period or 0.2% AEP. Current conditions were assumed for land use, population, and sea levels. Refer to the Risk Event 1 inundation map **Figure 3.1.**

3.3 Risk Event 2 – 1 in 500 Year Fraser Freshet + Climate Change + Sea Level Rise

Risk Event 2 was developed by KWL (2015) and modelled by NHC (2016). The flood scenario included the 1 in 500 year Fraser River flood from Risk Event 1 and factored a 17% climate change impact and a sea level rise of 1m (by 2100). Although uncertainty remains in climate change and sea level rise impacts, the event is intended to serve as longer term scenario that is relevant to flood protection infrastructure life spans. Current conditions were assumed for land use, and population. Refer to the Risk Event 2 inundation map **Figure 3.2.**

3.3.1 Risk Event 3 – Storm Surge

Risk Event 3 was designed to approximate the winter storm of January, 2005 in which the City received prolonged rainfall during saturated ground conditions and high river water levels.
The scenario was developed using an existing ISL drainage model for the City and approximated using aerial photographs of the actual 2005 flood. The scenario utilized the Agricultural and Rural Development Subsidiary Agreement (ARDSA) 5 day, 10 year rainfall event which is consistent with regional long duration storms. The event also considered drainage ditches with higher than average water levels, drainage pumps on, but river water levels high so that floodboxes are not operational (freshet and or high tide condition). Current conditions were assumed for land use, population, and sea levels. Refer to the Risk Event 3 inundation map **Figure 3.3.**

3.4 Climate Change

Climate change factors were not incorporated into Risk Events 1 and 3 at the risk assessment stage. Climate change is recommended to be assessed during future work such as the implementation of structural flood mitigation projects. Currently, climate change effects on flooding are difficult to predict. Common approaches in the industry to combat climate change unknowns include designing storm-related infrastructure to events with longer return periods (1 in 200 year) or adding a climate change safety factor (10-20%).

3.5 Existing Flood Hazard Mitigation Measures

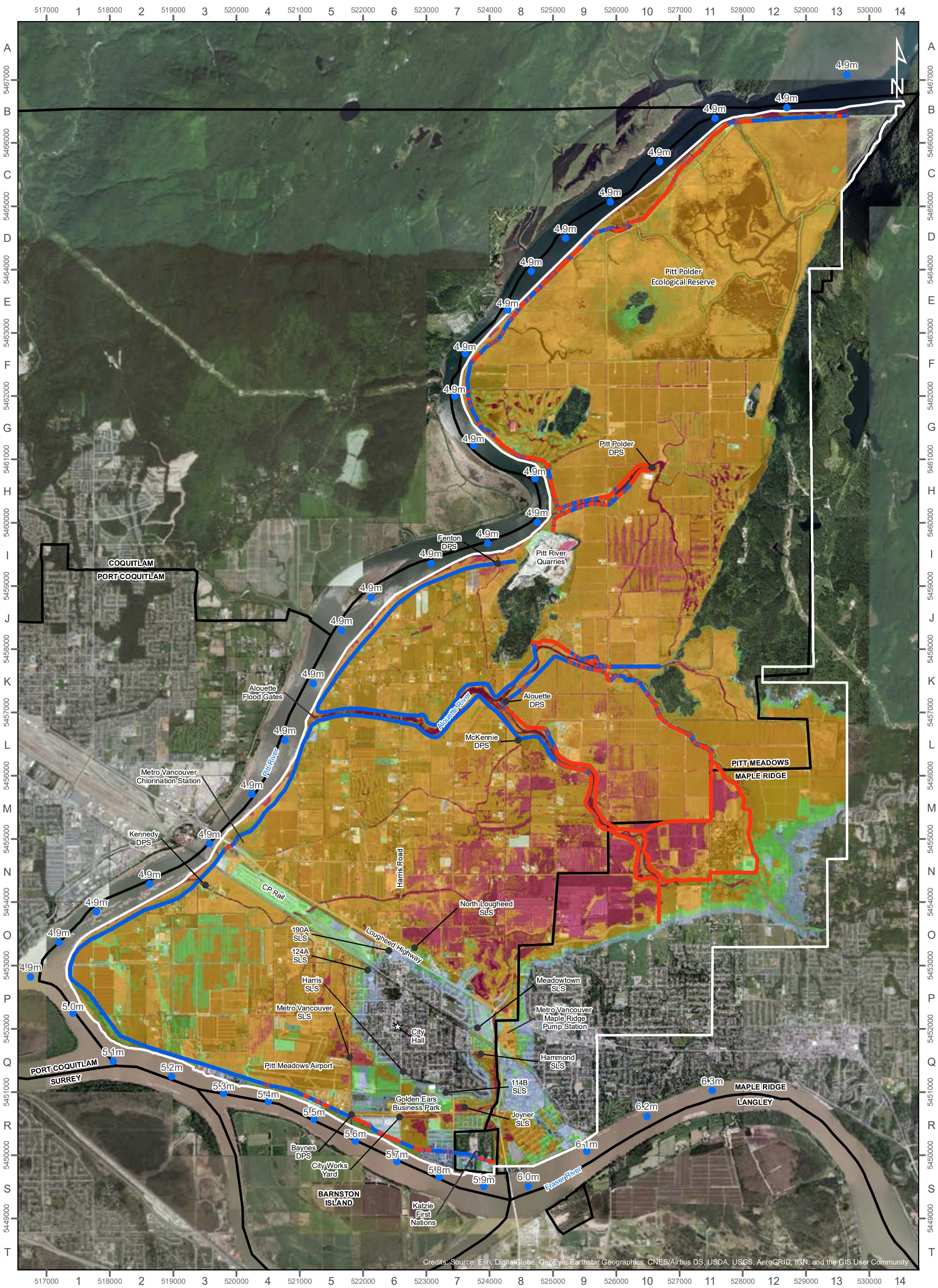
3.5.1 Drainage and Diking Infrastructure

The City's current flood mitigation infrastructure consists of its dikes, ditches, pump stations, and flood boxes. The City is almost entirely protected by perimeter dikes which are critical to protecting the City's low lying areas and key infrastructure from riverine flooding. Pitt Meadows is divided into four main drainage and diking areas:

- Area 1 (Dike Area 1/Alouette Pump Station Catchment), discharges to the Alouette River
- Area 2 (Fenton Drainage Area), discharges to the Alouette and Pitt Rivers
- Area 3 (Kennedy Drainage Area, including McKechnie), discharges to the Alouette, Pitt and Fraser Rivers
- Area 4 (Pitt Polder Catchment Area), discharges to the Pitt River

A fifth catchment area, the Pitt-Addington Catchment Area, is mainly undeveloped.

The majority of the areas are drained through rural (ditch and culvert) systems, with the exception of the urban development Area 3, which is serviced by a combination of ditches, culverts and storm sewers. Because of the low elevation of the catchment areas, at or near sea level, these areas are drained to the Pitt, Alouette and Fraser Rivers by a combination of flood boxes and pump stations (for discharge during higher river water level periods). A list of the pump stations and flood boxes in the study area is provided in **Table 3.1**.



ISL Engineering and Land Services

Kilometers
0 0.5 1 2
1:55,000 UTM Zone 10 Northern Hemisphere

Date: 2018-03-13 Document: \\cgyfs\GIS_DATA\Projects\31889_CoPM_NDMP_Stream_1\251_Figures\31889_flood_scenario_one_11x17.mxd

Legend

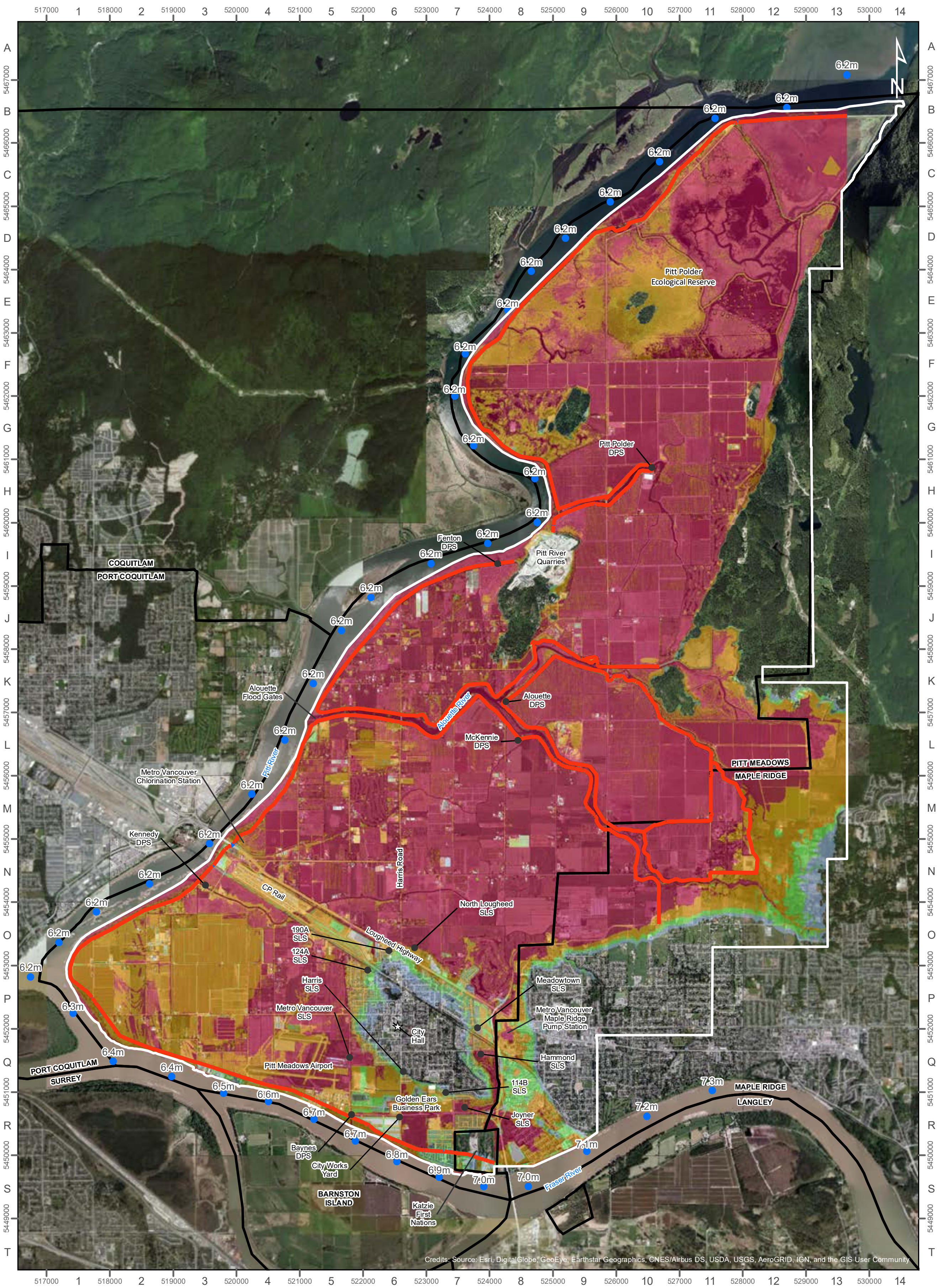
- Water Elevation
- Dike
- Overtopping
- Model Extent
- Municipal Boundary

Flood Depths
1:500 - Year Freshet
- 0 - 1 m
- 1 - 2 m
- 2 - 4 m
- > 4 m

DPS - Drainage Pump Station
SLS - Sanitary Lift Station

City of Pitt Meadows The Natural Place

FIGURE 3.1
1:500 - YEAR FRESHET
FLOOD PLANE
FLOOD RISK ASSESSMENT



ISL Engineering and Land Services

Legend

- Water Elevation
- Dike
- Overtopping
- Model Extent
- Municipal Boundary

Flood Depths

1:500 - Year Freshet + Climate Change + Sea Level Rise

- 0 - 1 m
- 1 - 2 m
- 2 - 4 m
- > 4 m

Kilometers 0 0.5 1 2

1:55,000 UTM Zone 10 Northern Hemisphere

DPS - Drainage Pump Station
SLS - Sanitary Lift Station

City of Pitt Meadows — The Natural Place

FIGURE 3.2
1:500 - YEAR FRESHET + CLIMATE CHANGE + SEA LEVEL RISE
FLOOD PLANE
FLOOD RISK ASSESSMENT

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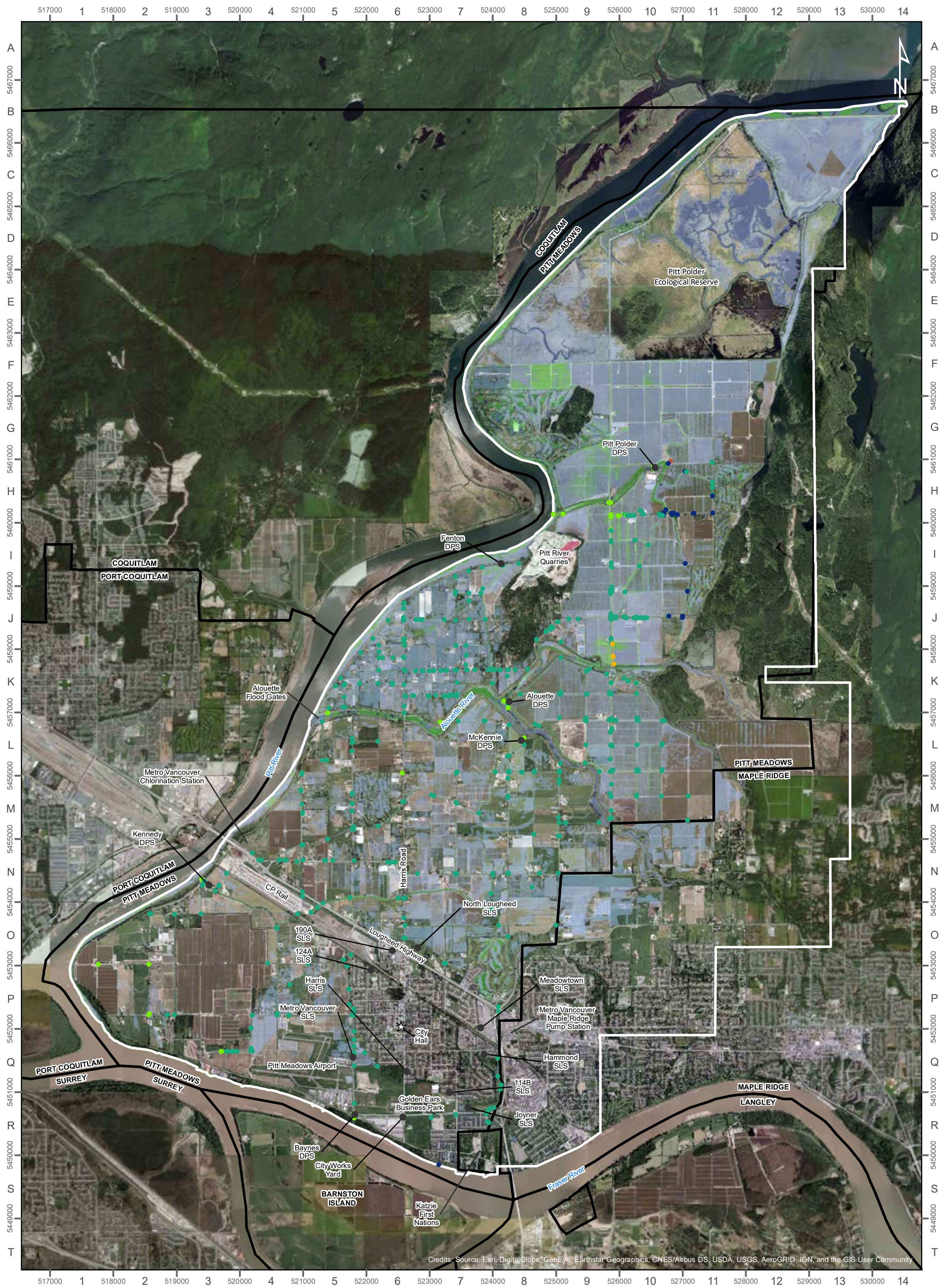

ISL Engineering and Land Services

Legend

Water Elevation
- 0 - 1.0 m
- 1.0 - 2.0 m
- 2.0 - 3.0 m
- 3.0 - 4.0 m
- > 4.0 m

Model Extent

Municipal Boundary

Flood Depths

Storm Surge
- 0 - 1 m
- 1 - 2 m
- 2 - 4 m
- > 4 m

0 0.5 1 2 Kilometers

1:55,000 UTM Zone 10 Northern Hemisphere

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DPS - Drainage Pump Station
SLS - Sanitary Lift Station

City of Pitt Meadows
The Natural Place

FIGURE 3.3
STORM SURGE
FLOOD PLANE
FLOOD RISK ASSESSMENT

Table 3.1: Pump Stations and Flood Boxes in the Study Area

Area	Name	Location	Catchment or Subcatchment	Flood Box	No. of Pumps	Total Rated Pumping Capacity (m^3/s)
1	Alouette Pump Station	14401 Neaves Rd	Alouette	Yes	2	2.5
2	Charlier Floodgate	14495 Charlier Rd	Fenton	Yes	0	N/A
	Fenton Pump Stations	15400 Harris Rd	Fenton	Yes	2	5.46
3	Kennedy Pump Station	17641 Kennedy Rd	Kennedy	Yes	4	7.07
	Cranberry Floodgate	14179 Reichenbach Rd	Cranberry	Yes	0	N/A
	Baynes Pump Station	18800 Airport Way	Ford	Yes	2	3.54
	McKechnie Pump Station	14352 McKechnie Rd	McKechnie	No	3	6.76
4	Sturgeon Slough Floodgate	16391 Rannie Rd	Polder	Yes	0	N/A
	Polder Pump Station	16390 Rannie Rd	Polder	No	2	5.46

The City of Pitt Meadows operates and maintains approximately 60 km of dikes over the four drainage and diking areas which include a portion of the dikes in Maple Ridge. Thurber Engineering Ltd. provided high-level geotechnical engineering considerations regarding the existing diking system. Thurber's report can be found in **Appendix D**.

Table 3.2: Diking Inventory by Area

Dike Name	Length (km)
Area 1	9.9
Area 2	8.7
Area 3	23.4
Area 4	17.7

Dikes were generalized into standard or non-standard categories, referencing the Ministry of Forests, Lands, and Natural Resource Operations and Rural Developments (MFLNRORD's) standard earth fill dike. Non-standard dikes generally are considered low-consequence agricultural dikes and usually have steeper side slopes and narrower crests than standard dikes.

Most of the dikes in Areas 2 and 3 were considered to be standard dikes and were rebuilt between 1977 and 1989 and constructed to 1969 design elevations. As of 2006, the Fraser River design criteria are considered too low.

The dikes in Areas 1 and 4 were considered to be primarily non-standard dikes constructed in the late 1940s and early 1950s. Based on the 2006 design criteria, the dikes in these areas are also too low. The dikes provide protection from the North and South Alouette Rivers.

3.5.2 Response Plans

The City follows the Pitt Meadows Operational Flood Response Plan which is followed during periods of high river levels. The provincial River Forecast Centre assesses flood risks in British Columbia including the analyses of snow pack and prediction of flows. The Fraser River gauges at Hope, BC (08MF005) and Mission, BC (08MH024) are the primary locations in which flood forecasting is predicted for the Lower Mainland communities. The Operational Flood Response Plan is based on the existing dike system relative to the stage readings at Mission. Refer to **Figure 3.5** outlining the City's planned response for corresponding stages.

Fraser River Stages & Response		
Stage at Mission	**Response Action**	**Potential Impacts**
1 to 5.99 meters	Periodic patrols to ensure dykes are clear & accessible. Complete urgent mitigative works as required.	Below Bank Full Conditions
6.0 meters	FLOOD WATCH: Regular dyke patrols and gauge level readings. Monitor conditions	The river has risen beyond its natural banks.
6.5 meters	FLOOD ALERT: Daily dyke patrols are commenced, noting all changes and marking seepage points. EOC Activation Level I Evacuation notification possible given conditions.	The river has risen beyond its banks and is on the dyke structure, but has not spilled over.
7.0 meters	Daily inspections. River bank erosion and areas of seepage/boils monitored and repaired as necessary. Evacuation order considered for all low lying areas depending on river forecast.	The level of the river is well up onto the dyke structure. Flooding areas outside of the city's dyking system.
7.57 meters	Possible declaration of local emergency 24 hour dyke patrols commenced. If conditions persist, widespread evacuation considered.	All non-standard dyking systems at risk of failure if water levels persist for several days.
8.06 meters	Larger scale flood fighting is possible on all dykes. Monitor and repair points of seepage. Final evacuation ordered.	High water is within 0.6 meters (2 feet) of crest of dykes.
8.3 meters	Flood fighting ceased emergency responders are pulled from the affected areas.	Water is at the crest of the dyke; overtopping expected. There is a high probability of dyke failures throughout the Fraser Valley.

Figure 3.5: City of Pitt Meadows Flood Response Plan for Fraser River Stages at Mission, BC (Pitt Meadows, 2013)

4.0 Vulnerability

4.1 Approach

Vulnerabilities for each risk event were estimated using flood inundation maps, aerial photographs, and land use and population information from the City's OCP. Vulnerable populations were considered as those within defined categories that experienced inundation.

The flooding extents were approximated by extrapolating the maximum water surface elevations of each risk event and projecting the surface plane horizontally against the City's 2016 Lidar surface (0.5m contours). This approach is considered to be an overview to identify the vulnerable assets – other factors such as flow velocities, duration of inundation, time of year, sediment loads, and pollution were not considered.

Dike overtopping was considered in Risk Events 1 and 2. As the river stage increases, the hazard of dike breach general increases. Dike breach, although a significant hazard, was not considered in this risk assessment. The developed flood maps are intended to give an indication of the flooding extents for each event. For the purpose of this risk assessment, the affected listed in the following sections were shown as inundated to a depth greater than 0.1 m.

High-level vulnerability was assessed for residential, commercial, industrial, institutional, and agricultural land use. Critical infrastructure was also included, such as dikes, municipal infrastructure (utilities, roads, bridges), and regional infrastructure (water, sewer, highways, rail, airports). Police, fire, and ambulance emergency services were not found to be vulnerable to inundation under the risk events.

4.2 Residential, Commercial, Industrial and Institutional

The urban area in Pitt Meadows is higher in elevation that most of the surrounding flood plain. Risk Event 3 had little effect on the residential, commercial, industrial and institutional land uses compared to Risk Events 1 and 2, summarized in **Table 4.2**. The number of people affected were estimated based on 2.6 people per housing unit. The commercial areas affected included both the Meadowtown and Meadow Vale Shopping Centres. The City's public schools would not be directly affected under Risk Events 1 and 3. However, under Risk Event 2, the Edith McDermott Elementary school will be inundated. The City's main industrial area along Airport Way will only be affected under Risk Events 1 and 2. Although the Pitt River Quarries appears to be elevated above the inundated depth, it would be isolated without accessibility under Risk Events 1 and 2.

Table 4.2: Residential, Commercial, Industrial and Institutional Vulnerability

Affected	Risk Event 1 – Fraser Freshet	Risk Event 2 – Fraser Freshet (2100)	Risk Event 3 – Storm Surge
Housing Units	5,850	6,250	590
People	15,195	16,250	1,530
Commercial/Industrial (floor area)	11.3 ha	11.3 ha	-
Institutional	-	1 school	-

4.3 Agricultural

The farms in Pitt Meadows are the most vulnerable under all three risk events as shown in **Table 4.3**. Based on the inundation maps, the Risk Events 1 and 2 would cause approximately 5,700 ha of flooding in Pitt Meadows. Although, Risk Event 2 would likely be more damaging due to deeper flooding. Risk Event 3 would also include significant inundation in the low lying areas – although shallow in depth, the inundation may also be damaging to farm land. The vulnerability did not consider types of agriculture (livestock, berries, greenhouses, dairy, etc.).

Table 4.3: Agricultural Vulnerability

Affected	Risk Event 1 – Fraser Freshet	Risk Event 2 – Fraser Freshet (2100)	Risk Event 3 – Storm Surge
ALR Affected (hectares)	5,700 ha	5,700 ha	2,900 ha

4.4 Diking System

ISL reviewed the potential for the diking system to be overtopped under the flood scenarios. Under the Risk Events 1 and 2, wide spread overtopping is projected.

Table 4.5: Diking System Vulnerability

Affected	Risk Event 1 – Fraser Freshet	Risk Event 2 – Fraser Freshet (2100)	Risk Event 3 – Storm Surge
Diking System	9 km	50 km	-

In addition to overtopping, ISL consulted Thurber Engineering Ltd. to provide geotechnical engineering input regarding the existing diking system with respect to seepage, settlement, and stability. Thurber's review was limited to a desktop study of available information. Thurber's review has been summarized in **Table 4.4**.

Table 4.4: Existing Diking Considerations

Design Consideration	Existing Diking System Considerations
Seepage	• Area 2 and 3 dikes may have been raised with poorly graded sand. This portion of the fill could be susceptible to piping.
Settlement	• Dikes are likely undergoing long term secondary compression settlement and could be settling in the range of 2mm/year to 5mm/year.
Stability (Seismic and Non-seismic)	• Standard dikes are anticipated to be generally stable in floods. • Non-standard dikes in Areas 1 and 4 have higher risk of not meeting non-seismic targets for stability factor of safety. • Dikes are anticipated to be underlain by sand. Under the 1 in 2,475 year return period earthquake, extensive liquefaction sand is anticipated. • Ground improvements may be required to meet the displacement criteria for the 1 in 475 year return period earthquake and likely required for the 1 in 2,475 year return period earthquake.

4.5 Municipal Infrastructure

Pitt Meadows key infrastructure is exposed under Risk Events 1 and 2. Municipal buildings (City Works Yard), drainage infrastructure, sanitary infrastructure, potable water infrastructure, and municipal transportation were reviewed. Only above ground infrastructure was considered for the vulnerable inventory (pump station, pressure reducing valve (PRV) stations, etc.). However, potable water would likely be compromised in the event of flooding due to loss of sanitation. Collector and arterial roads were reviewed in the vulnerability assessment. Risk Event 3 would likely result in some localized flooding to arterial and collector roads but would not hinder accessibility for extended durations.

Table 4.6: Municipal Infrastructure Vulnerability

Affected	Risk Event 1 – Fraser Freshet	Risk Event 2 – Fraser Freshet (2100)	Risk Event 3 – Storm Surge
Drainage Pump Stations	6 pump stations	6 stations	-
Sanitary Lift Stations	7 lift stations	7 lift stations	-
Potable Water (PRVs)	5 PRVs	5 PRVs	-
Transportation - Roads	27.8 km	36.1 km	-
Transportation - Bridges	5 bridges	5 bridges	-

4.6 Regional Infrastructure

Canadian Pacific (CP) Railway has an intermodal terminal (Vancouver Intermodal Terminal) in Pitt Meadows which is vulnerable under Risk Events 1 and 2. Under Risk Events 1 and 2, most of Highway 7 (Lougheed Highway) will be inundated. Metro Vancouver infrastructure, including the Maple Ridge Booster Station, Chlorination Station and Baynes Road Pump Station will be affected. Hydro substations and telecommunications and gas were not included in the inventory. The Pitt Meadows Airport would be affected by all three risk events.

Table 4.7: Regional Infrastructure Vulnerability

Affected	Risk Event 1 – Fraser Freshet	Risk Event 2 – Fraser Freshet (2100)	Risk Event 3 – Storm Surge
Metro Vancouver Potable Water	2 buildings	2 buildings	-
Metro Vancouver Sanitary Sewer Pump Station	1 building	1 building	-
Lougheed Highway (MOTI)	5.2 km of highway	5.2 km of highway	-
Pitt Meadows Regional Airport	1 airport	1 airport	1 airport
Canadian Pacific Railway	2.7 km	5.7 km	-
Canadian Pacific Vancouver Intermodal Terminal	1 facility	1 facility	-

5.0 Economic Loss Estimates

The economic losses for each risk event were estimated. To align with the regional context, the Fraser Basin Council report by NHC was referenced where possible to obtain loss estimate values.

The NDMP RAIT categories were followed in the estimation of losses. The loss section of the asset inventory included the following for the affected critical assets:

- Key asset-related information;
- Location and size;
- Structure replacement costs;
- Content value;
- Displacement costs;
- Rating rationale;
- Vulnerability rating;
- Average daily cost to operate; and
- Total estimated value of physical assets.

The loss estimates focused primarily on direct losses of structure damage repair and replacement costs of the vulnerable populations and displacement costs for the affected population. Indirect costs that would be experienced, such as: debris cleanup, business shut downs and disruption, contaminated systems, were not accounted for in this risk assessment. However, indirect loss estimates for agricultural damage was included to be to be consistent with the ongoing regional loss estimates prepared by NHC for the Fraser Basin Council.

For the Pitt Meadows Flood Hazard Risk Assessment, economic loss estimates were largely based on the NHC report and Natural Resource Canada (NRCan) published loss estimates, using the approximated inundation depths of vulnerable populations. The NRCan values mostly pertain to direct damage to repair and replace buildings and contents. NRCan has developed depth-damage curves which were referenced for this assessment. Generally, the damage due to flooding will be more extensive as the depth increases. For this high-level loss estimate, the depth at which the damage was maximized was used as the unit cost for each building type.

For infrastructure such as rail, highways, and regional based, ISL used replacement costs from the NHC report for the Fraser Basin Council.

For building types and infrastructure not included in NRCan depth-damage relationships, the structure replacement costs were estimated by the project team experienced in design and construction of similar structures in the City or in nearby municipalities. NRCan also provided the basis for displacement periods.

Consequence ratings were developed using the below rationale.

- **High** - inundation depths > 1.0m; 60-100% of asset class affected; provincial/national impact; may affect accessibility, evacuation required
- **Medium** - indundation depth > 1.0m; 30-60% of asset class affected; regional impact; significant disruption; rehabilitation/replacement required
- **Low** - indundation depth 0.1m < d < 1.0m; 0-30% of asset class affected; local impact; minimal disruption and/or rehabilitation required

The completed RAIT asset inventories can be found for each risk event in the appendices. **Table 5.2** displays the loss estimates for each risk event with specific assumptions to the calculations made.

Table 5.2 Approximate Damage and Loss

Asset Type	Quantity Affected			Displacement Estimate (ppl)			Structure Replacement Cost ($/unit)	Content Value ($/unit)	Average Daily Cost to Operate ($/day)	Corresponding Loss Estimates (Million $)			Assumptions
	Risk Event 1 (Fraser Freshet)	Risk Event 2 (Fraser Freshet + CC + SLR)	Risk Event 3 (Storm Surge)	Risk Event 1 (Fraser Freshet)	Risk Event 2 (Fraser Freshet + CC + SLR)	Risk Event 3 (Storm Surge)				Risk Event 1 (Fraser Freshet)	Risk Event 2 (Fraser Freshet + CC + SLR)	Risk Event 3 (Storm Surge)	
Residential (low, medium and high)	5,850 housing units 15,195 people	6,250 housing units 16,250 people	590 housing units 1,530 people	15,195 / 2 = 7,600	16,250 / 2 = 8,125	80	$300,000[3]	$100,000 [3]	$25[3]	$208.2	$222.5	$2.4	• 2.6 people/housing unit • Long term displacement for inundated residents only. In reality, Risk Event 1 and Risk Event 2 could see the majority of residents evacuate the City for an extended period (> 4 weeks). • 5% of estimated structure and content for inundated housing units • 50% of people find shelter not requiring paid accommodation[1] • Displacement estimated at 240 Days[1] at $50/p/day • Damage curve used at maximum damage 1.0m depth ($2,500/m^2) • For Risk Event 3, 5% of flooding population assumed to require accommodation[3]
Commercial/Industrial/Insitutional	11.3 ha building space	13.7 ha building space	-	-	-	-	$0.01[1]	$0.15[1]	-	$27.1	$32.9	-	• Estimated area from aerial photographs; ground floor only • Damage curve used at maximum damage 2.5m depth ($100/m^2) • Edith Mcdermott Elementary school inundated
Agricultural	5,700 ha ALR	5,700 ha ALR	2,900 ha ALR	-	-	-	$15,200[2]	-	-	$85.1	$85.1	$4.4	• Structure replacement is estimated to cover lost gate sales; damage to equipment; damage to buildings; and replanting loss • Risk Event 3, 10% of estimated damage cost of total amount
Municipal Critical Buildings (City Hall, Works Yard, Police Station, Fire Hall, Hospital)	1 works yard	1 works yard	-	-	-	-	$2,500,000[2]	-	-	$4.0	$4.0	-	Content value is included in the replacement cost. Amount estimated with City staff.
Municipal (Pitt Meadows) Drainage (Pump Stations)	6 pump stations	6 pump stations	-	-	-	-	$5,000,000[3]	$1,000,000[3]	$100[3]	$9.1	$9.1	-	Content value to cover electrical mechanical equipment; no/limited damage to u/g
Municipal (Pitt Meadows) Sanitary Sewer (Lift Stations)	7 pump stations	7 pump stations	-	-	-	-	$600,000[3]	$100,000[3]	$25[3]	$1.3	$1.3	-	Content value to cover electrical mechanical equipment; no/limited damage to u/g
Municipal (Pitt Meadows) Potable Water (PRVs)	5 PRVs	5 PRVs	-	-	-	-	$300,000[3]	$100,000[3]	$25[3]	$0.26	$0.26	-	Content value to cover electrical mechanical equipment; no/limited damage to u/g
Diking System	9 km overtopped dikes	50 km overtopped dikes	-	-	-	-	$5,000[2]	-	-	$45.0	$250.0	-	Total replacement unlikely; overtopped dikes require $5,000/m of repair/ rebuilding
Regional (MV) Potable Water (Chlorination Analyzer, Maple Ridge Pump Station)	2 buildings	2 buildings	-	-	-	-	$6,000,000[3]	$4,000,000[3]	$100 [3]	$10.0	$10.0	-	50% of building costs require upgrades
Regional (MV) Sanitary Sewer (Baynes Road Pump Station)	1 building	1 building	1 building	-	-	-	$6,000,000[3]	$4,000,000[3]	$100 [3]	$5.2	$5.2	$0.5[3]	50% of building requires upgrades
Municipal Transporation (Collector and Arterial Roads, Bridges)	5 bridges; 27.8 km road	5 bridges; 36.1 km road	13.0 km road	-	-	-	$500,000/km $1,000,000 / bridge [3]	-	-	$18.9	$23.1	$1.3	Repairs to bridges required; collector and arterial roads requiring repairs (0-10 years)
Provincial (MOTI) Transportation (Lougheed Highway)	5.2 km of Lougheed Highway	5.2 km of Lougheed Highway	-	-	-	-	$12,500,000[2]	-	-	$65.0	$65.0	-	
Airport (Pitt Meadows Regional Airport)	1 Airport	1 Airport	1 Airport	-	-	-	$3,200,000[2]	-	-	$3.2	$3.2	$0.32	• Content value is included in the replacement cost • 10% used for Risk Event 3
Rail (Canadian Pacific Rail)	2.7 km of CP Rail	5.7 km of CP Rail	-	-	-	-	$1,900,000 (2)	-	-	$5.2	$10.8	-	Total replacement unlikely; spot repairs likely required
Vancouver Intermodal Terminal (Canadian Pacific Rail)	1 Facility	1 Facility	-	-	-	-	$3,300,000 (2)	-	-	$1.7	$3.3	-	• 50% of estimated replacement cost for Risk Event 1 • 100% of estimated replacement cost for Risk Event 2
										$489.3	**$725.8**	**$8.4**	

[1] *Canadian Guidelines and Database of Flood Vulnerability Functions Draft (Natural Resources Canada; Public Safety Canada, March, 2017)*
[2] *Lower Mainland Flood Management Strategy Project 2: Regional Assessment of Flood Vulnerability (April 25, 2016)*
[3] *Estimated by the Project Team*

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6.0 Conclusions and Recommendations

6.1 Conclusions

1. There are a number of flood hazards in Pitt Meadows and the City is vulnerable to flooding based on the three risk events explored. Risk Events 1 and 2 are expected to generate costly floods that would likely affect the region. Risk Event 3 would be costly and disruptive to the City. The flood hazard risk assessments completed to date for Pitt Meadows and the region warrant significant improvements to flood mitigation programs and flood protection systems.
2. The urban area is elevated and would not be significantly inundated under the risk events. However, under Risk Events 1 and 2, the urban area would be landlocked and residents would likely be evacuated for an extended period of time. The displacement due to this isolation was not included in the loss estimates.
3. Future land use was not considered – although the City is largely within the ALR and land use change is regulated, this may become a factor in loss estimates. Particularly for longer term (Risk Event 2) hazards.

Thurber Engineering provided the high-level assessments of the project area diking system, the following conclusions are offered with respect to the dikes.

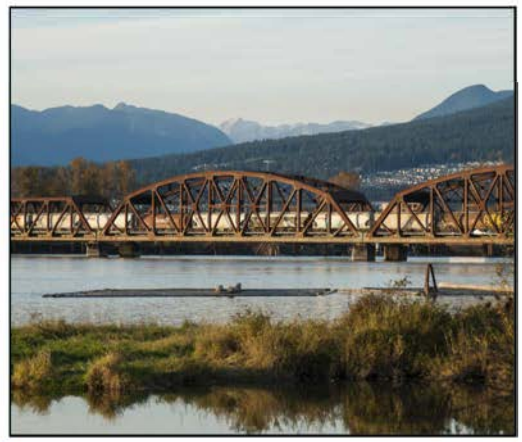
4. The City's dikes are deficient by the current design flood elevations and are likely to have poor seismic performance due to liquefaction and displacement for seismic return periods of 1 in 475 year and 1 in 2,475 year design earthquakes.
5. Dike upgrades to both standard and non-standard may require upgraded seepage control measures under the current design flood or future higher design floods.
6. Overbuilding dikes may be required to compensate for settlement.
7. Stability modifications could be appropriate for dikes where non-seismic stability is a concern. Upgrades could include constructing toe berms on the landside of the dike or installing a seepage cut-off and filter within the dike.
8. Seismic stability due to liquefaction and displacement for return periods of 1 in 475 year and 1 in 2,475 year.
9. The higher dikes (Area 2 and 3) and riverside dikes are anticipated to have poorer seismic performance due to deeper riverbanks and river channels.

Of the other known flood hazards, dike breaching due to flood or earthquake are considered to be high priority for further exploration.

6.2 Recommendations

1. The City should consider applying for NDMP Stream 2 – Flood Mapping program funding. Outcomes from Stream 2 may include the below.
   a) Hazards maps that include velocities, depths and land use.
   b) Detailed economic loss estimates. This may also include a GIS-based modelling, such as the Hazus (or similar) to estimate the economic loss.
   c) Additional stakeholder discussions (where the parties are available) that may add value to any future flood mitigation initiatives.
2. ISL recommends undertaking a more detailed geotechnical assessment of the City's diking system. The City may consider starting with Area 3, as the dikes are of highest consequence and protect the largest population. The assessment should include a structural assessment of the dikes and offer potential upgrade options.
3. Large scale structural projects such as raising the perimeter dikes may not be practical in the short or medium term. The following smaller-scale projects may add value to the City's existing flood hazard mitigation measures.
   a) River stage gauges (upstream) and warning systems. Installation of supervisory control and data acquisition (SCADA) integrated level gauges at key locations along ditches, sloughs, and rivers.
   b) Backup power for the drainage pump stations. The City's drainage pump stations are critical infrastructure and in the event of power outage, the drainage system relies on floodboxes to drain. Backup power would likely consist of diesel generator sets at each pump station.
   c) Localized dike upgrades – likely an output from the detailed geotechnical review and may require property acquisition. Legal survey of the property lines parallel to the diking system may also be an asset for planning and design purposes.
4. The City should develop a Flood Mitigation Strategy – the strategy may follow the priority of dike assessments. Risk mitigation measures outside of structural protections measures exist. Below are common generalized examples of risk mitigation.
   a) Provide protection against flood risks (dikes). This could also include increasing the building elevations using structural fill to an elevation that is considered low risk to flood hazards.
   b) Land use planning. Rezone land use out of higher risk areas – typically the critical infrastructure would be located in low risk areas. This also is considered in planning – new developments and infrastructure consider these areas prior to building.
   c) Education/Tolerable risk. Established through public consultation how much risk can be tolerated by stakeholders.
   d) Emergency planning – improve warning systems and planning. Emergency planning may also include interim structural improvements – such as using inflatable bladder (water) dams to temporarily raise the dike in lower dike areas or high consequence land use areas.

Attachment B



City of Pitt Meadows

Final Report

Flood Mitigation Plan

September 2020

ISL

ISL Engineering and Land Services Ltd. is an award-winning full-service consulting firm dedicated to working with all levels of government and the private sector to deliver planning and design solutions for transportation, water, and land projects.

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FIGURES

1.0 Introduction

The City of Pitt Meadows (City) Flood Mitigation Plan (FMP) was prepared in response to the City's 2018 Flood Hazard Risk Assessment (FHRA). The FHRA identified that the City's existing diking system would be overtopped by the Fraser River design flood which would inundate the majority of the City and cause major social and economic impacts to the municipality, region, and the province. The Fraser River design flood is anticipated to increase in surface profile elevation with the construction of upstream flood protection, and climate change and sea level rise effects, highlighting the need to upgrade the City's diking (and drainage) infrastructure.

The FMP inventories and assesses the critical flood protection infrastructure in the City, identifies potential deficiencies, and offers overview improvement opportunities that would increase the City's resilience to river flooding and the effects of climate change and sea level rise. The document will serve as a planning resource to assist the City in systematically upgrading its drainage and diking infrastructure to meet provincial and federal guidelines and best practices related to river flood mitigation.

1.1 Rationale

Approximately 95% of the City's total area lies within the Fraser River and Pitt River floodplains. The Alouette River divides the City and confluences with the Pitt River. The City is protected by standard and non-standard (agricultural) dikes that are approximately 60 km in length. Most of the City's standard dikes and drainage pump stations were built to design criteria established by the Fraser River Flood Control Program (1969) and Agricultural and Rural Development Subsidiary Agreement (ARDSA) and do not meet current provincial design guidelines.

Floods hazards in Pitt Meadows vary from high frequency/low consequence to low frequency/high consequence. Hazards include: river flood/ freshet, dike breach, storm surge, drainage pump station failure, sea level rise, upstream dam breach, and beaver dams/ debris accumulation. Freshet by definition is a river flood due to heavy rain or snow melt. In Pitt Meadows, freshet generally occurs between April and July and is primarily caused by snow melt. Freshet is forecasted using snowpack estimates during winter which improve readiness for downstream populations. However, other meteorological events such as heavy or intense rain events can be more difficult to predict.

The Fraser River is the most significant flood hazard in the City as the river undergoes annual freshet and has a drainage area of roughly 250,000 sq.km. that extends from the Rocky Mountains to the Lower Mainland of BC. According to the Fraser Basin Flood Management Strategy, a present day Fraser River flood equal to the 1894 flood of record, could result in a total economic loss of $22.9 Billion, displacement of 266,000 people, and an agricultural loss of $67-200M for the Lower Mainland. Based on the Pitt Meadows FHRA, the same flood could cause an economic loss of $489 Million and displace 15,000 people from the City of Pitt Meadows alone.

1.2 Structure of the Flood Mitigation Plan

The purpose of the Flood Mitigation Plan is to assess the City's critical flood mitigation infrastructure – its drainage pump stations and diking system - to identify inadequacies against established design guidelines and potential mitigation opportunities through infrastructure upgrades. The report compiles geotechnical, archaeological, and environmental assessments as well as legal survey that will assist the City in its plan to systematically upgrade flood protection infrastructure.

The FMP focused on flood protection infrastructure upgrades, however, there are many approaches to effective flood mitigation, some of which are listed below.

- Land use planning. Rezone land use out of higher risk areas – typically the critical infrastructure would be located in low risk areas.
- Education/ Tolerable risk. Establish stakeholder risk tolerance for known flood hazards in the City through public consultation.
- Emergency planning and warning systems. Emergency planning may include interim structural improvements – such as using inflatable bladder (water) dams to temporarily raise the dike in lower dike areas or high consequence land use areas.

The FMP includes conceptual dike raising design drawings based on a typical dike section that would meet current dike crest elevations guidelines and improve seismic resilience. Upgrading the dikes will be a significant undertaking that will be completed in stages and over many years. The FMP builds upon previous reports and can be used to make informed decisions to plan and prioritize infrastructure upgrades.

1.3 Project Team

The FMP was led by the City of Pitt Meadows and ISL Engineering Ltd. The complete project team comprised of the following:

- City of Pitt Meadows: project management and third party consultation;
- ISL Engineering and Land Services Ltd.: consultant management, civil engineering and environmental assessment;
- Golder Associates Ltd.: geotechnical engineering;
- Antiquus Archaeological Consultants Ltd.: archaeological assessment; and
- Bennett Land Surveying Ltd.: legal surveying.

Other stakeholders that had involvement with the FMP included:

- Fraser Basin Council;
- Katzie First Nation; and
- City of Maple Ridge.

In addition to the above stakeholders, the FMP considers the following parties to be stakeholders during future flood mitigation planning and implementation of flood mitigation projects in the City.

- Inspector of Dikes
- Agricultural Land Commission;
- Ministry of Forests, Lands, Natural Resources Operations and Rural Developments;
- Ministry of Transportation and Infrastructure;
- Metro Vancouver Regional District;
- Canadian Pacific Rail;
- Pitt Meadows Airport;
- BC Hydro; and
- Fortis BC.

The structure and composition of the project team and stakeholder group may vary periodically based on the interests of each party and the type of work.

2.0 Background

2.1 Project Area

The Pitt Meadows municipal boundary formed the FMP project area (**Figure 2.1**). Pitt Meadows is bound by the Pitt River to the north and west, the Fraser River to the south, the City of Maple Ridge to the east, and the Thompson Mountain Range to the northeast. Two arms of the Alouette River (North Alouette and South Alouette) divide the city, along with a system of sloughs and ditches that convey drainage to pump stations and flood boxes.

The City's current flood mitigation infrastructure consists of dikes, ditches, pump stations, and flood boxes. The City is almost entirely protected by perimeter dikes which are critical to mitigate river flooding in the City's low lying areas. Pitt Meadows is divided into four main drainage and diking areas (Areas) listed below.

- Area 1, discharges to the Alouette River
- Area 2, discharges to the Alouette and Pitt Rivers
- Area 3, discharges to the Alouette, Pitt and Fraser Rivers
- Area 4, discharges to the Pitt River

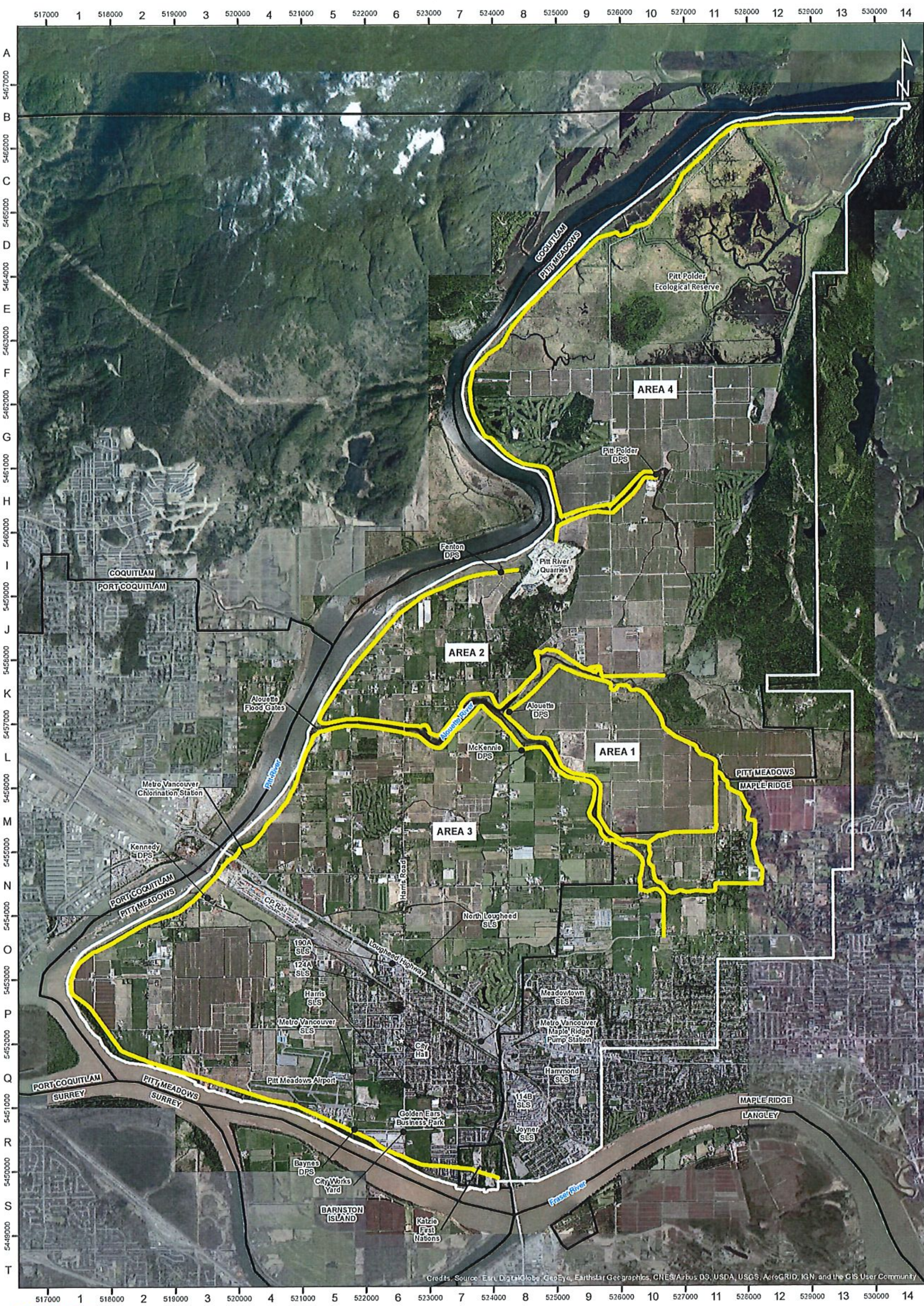
Included in Area 4 is the Pitt-Addington Marsh, an undeveloped and largely natural ecological reserve. The marsh is north of Koerner Road and 100 ha in area. The area is on the Pitt River floodplain and is bordered by the Pitt Polder Dike.

2.2 Land Uses and Key Infrastructure

Pitt Meadows is primarily an agricultural and rural residential community with a distinct urban boundary, referred to as the urban area. The urban area includes the Pitt Meadows Airport and the City Center and is bound by the Lougheed Highway to the north, Maple Ridge to the east and the Fraser River to the south. The west is bound by the Agricultural Land Reserve (ALR) with the exception of a stretch of land that follows the Canadian Pacific Railway (CPR) and Lougheed Highway to the Pitt River.

The population of Pitt Meadows is projected to increase from 15,623 in 2006 to 21,000 by 2028, requiring roughly an additional 2,700 housing units, over the same timeframe. The 2016 Statistics Canada Census lists the City's population as 18,573. The ALR limits the potential for development on agricultural lands and most of this growth must take place on non-ALR zone lands within the urban area. Through land use changes and other strategies outlined in the City's Official Community Plan (OCP), the urban area will develop into a denser populated area.

Pitt Meadows and the regional district of Metro Vancouver are growing at a comparable rate. Situated near other rapidly developing communities of Maple Ridge, Coquitlam, Port Coquitlam, Surrey and Langley, Pitt Meadows is involved in ongoing regional transportation improvements. These improvements are designed to connect the entire Metro Vancouver and improve accessibility for the growing population. The City is a connection point that contains the following regional commercial, and transportation and other key infrastructure:



ISL Engineering and Land Services

0 0.5 1 2 Kilometers

1:55,000 UTM Zone 10 Northern Hemisphere

Legend

Dike System

Municipal Boundary

DPS - Drainage Pump Station
SLS - Sanitary Lift Station

City of Pitt Meadows
The Natural Place

FIGURE 2.1
PROJECT AREA

- Pitt River Quarries (PRQ);
- Provincial Infrastructure (Lougheed Highway);
- Regional Infrastructure (Metro Vancouver Water Booster Station and Chlorination Analyzer; Metro Vancouver Sanitary Pump Station);
- Pitt Meadows Regional Airport; and
- Canadian Pacific Rail and Vancouver Intermodal Facility.

Agricultural land use is predominant in Pitt Meadows with approximately 86 percent of total area designated as Agricultural Land Reserve (ALR). Agricultural parcels in the City range from small to large and include berry farms, horticultural products, crops, grazing, and dairy farms.

2.3 Flood Hazard Risk Assessment

The FHRA applied regional flood hazard assessments and, using data and information specific to the City of Pitt Meadows, developed high-level economic loss estimates for several flood hazards. The FHRA focused on three flood hazards, described as Risk Events.

2.3.1 Flood Risk Events

The primary reports referenced to establish the Risk Events during the preparation of the FHRA were:

- Lower Mainland Flood Management Study, by Kerr Wood Leidal (KWL), commissioned by Fraser Basin Council, May 2015
- Lower Mainland Flood Management Strategy Project 2: Regional Assessment of Flood Vulnerability, by Northwest Hydraulic Consultants (NHC), commissioned by the Fraser Basin Council, April 2016
- City of Pitt Meadows Drainage and Irrigation Study, by ISL Engineering, commissioned by the City of Pitt Meadows, January, 2018

Risk Event 1 was modelled by NHC (2016) and was considered to be representative of the 1894 Fraser River flood of record. The flood equates to a peak flow of 17,000 m^3/s at Hope and a 1 in 500 year return period (or 0.2% Annual Exceedance Probability). The risk event is the current Fraser River design flood for diking upgrades in the Lower Mainland.

Risk Event 2 was developed by KWL (2015) and modelled by NHC (2016). The flood scenario included the 1 in 500 year Fraser River flood from Risk Event 1 and factored a 17% climate change impact and a sea level rise of 1 m (by 2100).

Risk Event 3 was designed to approximate the winter storm of January, 2005 in which the City received prolonged rainfall during saturated ground conditions and high river water levels.
The scenario was developed using an existing ISL drainage model for the City and approximated using aerial photographs of the actual 2005 flood. The event also considered drainage ditches with higher than average water levels, drainage pumps on, but river water levels high so that floodboxes are not operational (freshet and/ or high tide condition).

The Fraser River design flood (Risk Event 1) was the focus of this FMP as the event is the current standard for dike protection in the Lower Mainland. A future Fraser River flood (Risk Event 2) is discussed throughout this document to serve for long term planning (year 2100). The storm surge

(Risk Event 3) is not discussed in this FMP, however, pump station upgrades presented as flood mitigation upgrade opportunities would assist in mitigating the impacts from this hazard.

2.3.2 Vulnerability

Vulnerabilities for Risk Events 1 and 2 were estimated in the FHRA using flood inundation maps, aerial photographs, and land use and population information from the City's OCP.

The flooding extents were approximated by extrapolating the risk event flood profiles and projecting the water surface plane horizontally against the City's topographical Light Detection and Ranging (LiDAR) surface. This overview approach was used to identify the vulnerable assets – other factors such as flow velocities, duration of inundation, time of year, sediment loads, and pollution were not considered in the FHRA.

The developed flood maps are intended to give an indication of the flooding extents for each event. For the purpose of the FHRA, the affected assets in the following sections were shown as inundated to a depth greater than 0.1 m. Refer to **Figure 2.2** and **Figure 2.3** for Risk Events 1 and 2 flood inundation maps.

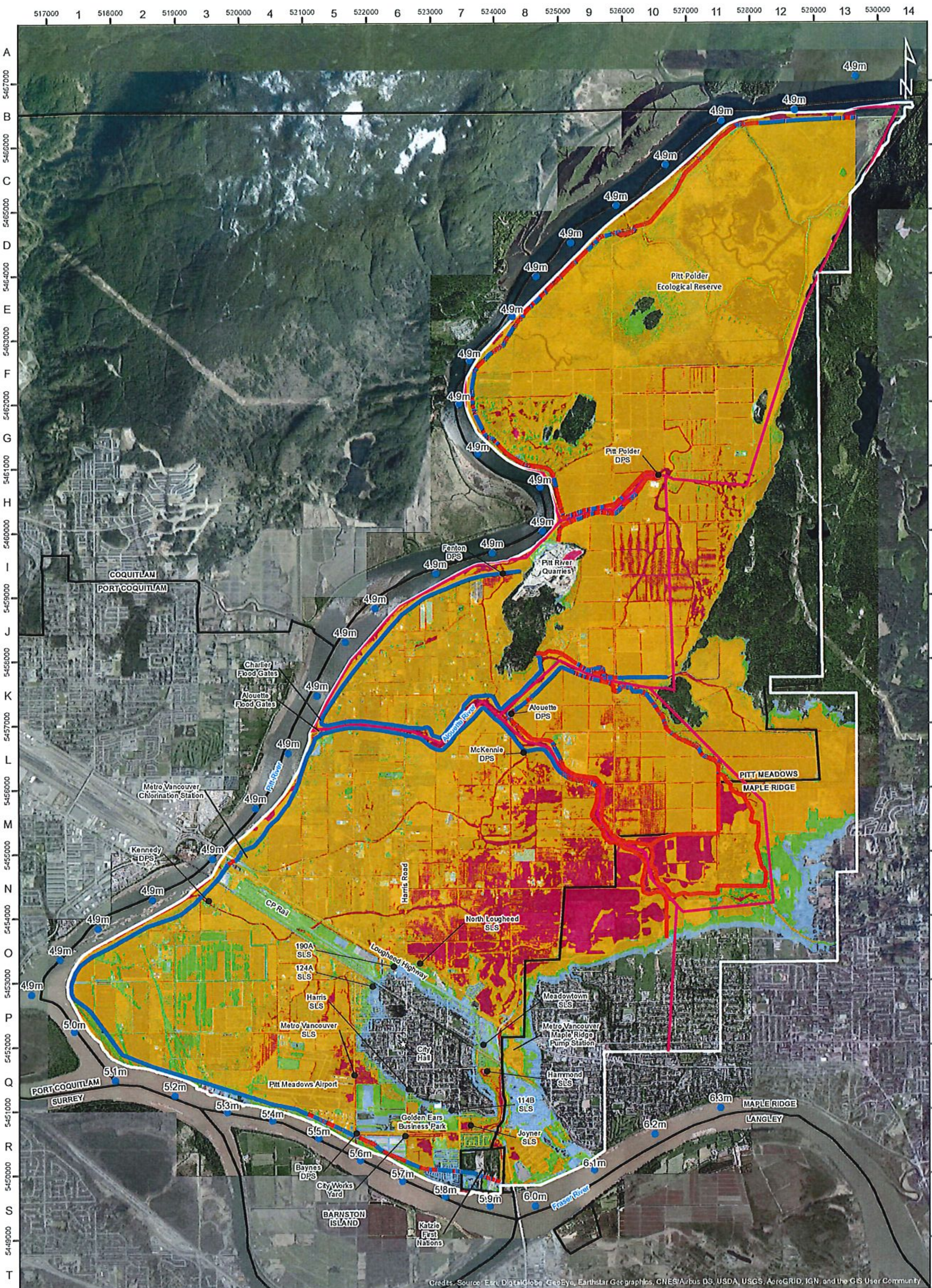
High-level vulnerability was assessed for residential, commercial, industrial, institutional, and agricultural land use. Critical infrastructure was also included, such as dikes, municipal infrastructure (utilities, roads, bridges), and regional infrastructure (water, sewer, highways, rail, airports). Police, fire, and ambulance emergency services were not found to be vulnerable to inundation under the risk events.

2.3.3 Damage and Loss Estimate

The economic losses for each risk event were estimated. To align with the regional context, the Fraser Basin Council's Lower Mainland Flood Management Strategy Project 2: Regional Assessment of Flood Vulnerability (NHC, 2016) was referenced where possible to obtain loss estimate values.

The loss estimates focused primarily on direct losses of structure damage repair and replacement costs of the vulnerable populations and displacement costs for the affected population. Indirect costs that would be experienced, such as: debris cleanup, business shut downs and disruption, contaminated systems, were not accounted for in the FHRA. However, indirect loss estimates for agricultural damage was included to be to be consistent with the regional loss estimates prepared by NHC for the Fraser Basin Council.

The economic loss estimates were largely based on the NHC report and Natural Resource Canada (NRCan) published loss estimates, using the approximated inundation depths of vulnerable populations. The NRCan values mostly pertain to direct damage to repair and replace buildings and contents. NRCan has developed depth-damage curves which were referenced for this assessment. Generally, the damage due to flooding will be more extensive as the depth increases. For the high-level loss estimate, the depth at which the damage was maximized was used as the unit cost for each building type.



ISL Engineering and Land Services

Kilometers
0 0.5 1 2
1:55,000 UTM Zone 10 Northern Hemisphere

Legend

- Water Elevation
- Dike
- Overtopping
- Model Extent
- Municipal Boundary

Flood Depths

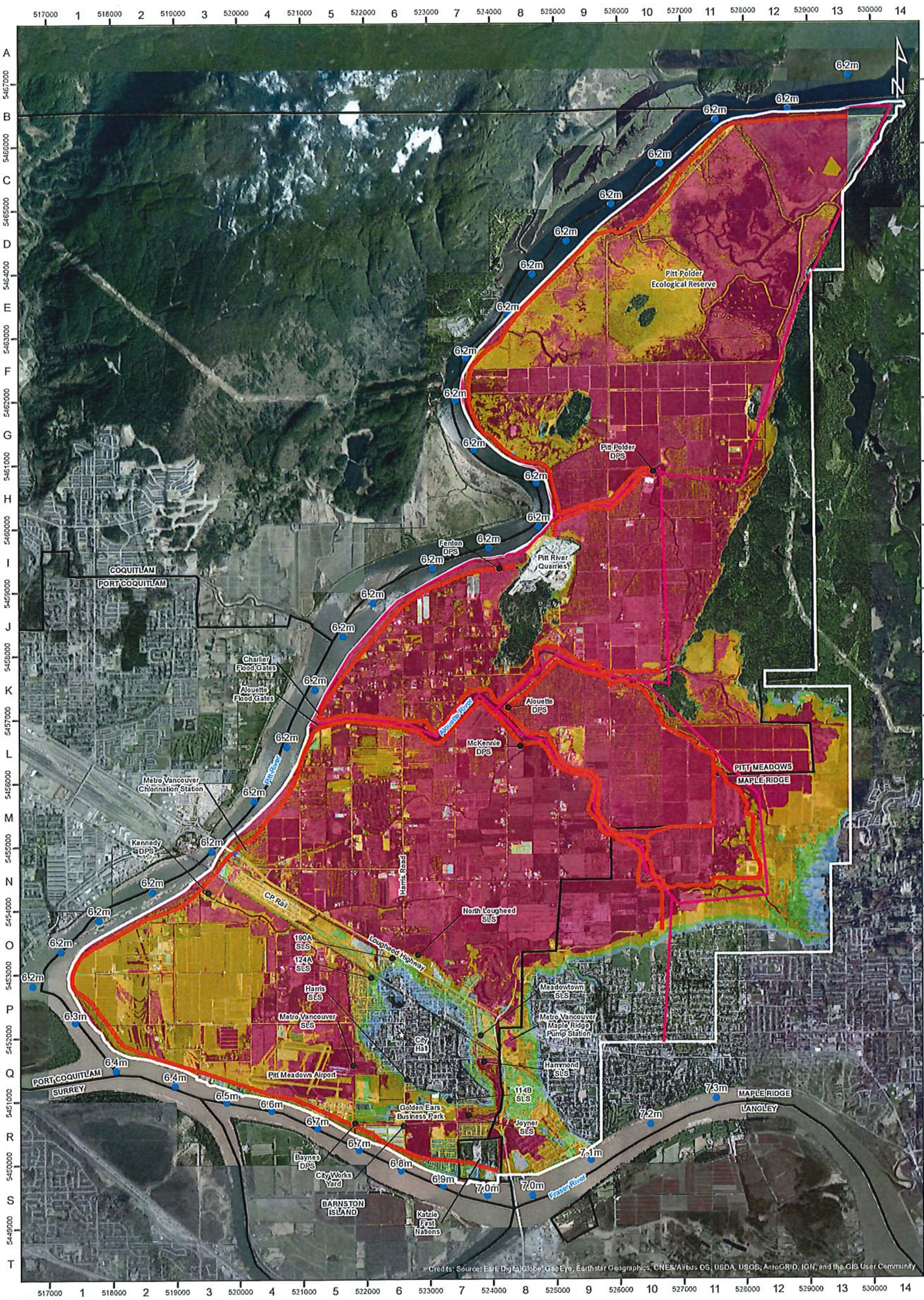
1:500 - Year Freshet

- 0 - 1 m
- 1 - 2 m
- 2 - 4 m
- > 4 m

DPS - Drainage Pump Station
SLS - Sanitary Lift Station

City of Pitt Meadows
The Natural Place

FIGURE 2.2
1:500 - YEAR FRESHET
FLOOD WATER SURFACE
(RISK EVENT 1)



ISL Engineering and Land Services

0 0.5 1 2 Kilometers

1:55,000 UTM Zone 10 Northern Hemisphere

Legend

- Water Elevation
- Dike
- Overtopping
- Model Extent
- Municipal Boundary

Flood Depths

1:500 - Year Freshet + Climate Change + Sea Level Rise

- 0 - 1 m
- 1 - 2 m
- 2 - 4 m
- > 4 m

DPS - Drainage Pump Station
SLS - Sanitary Lift Station

City of Pitt Meadows
The Natural Place

FIGURE 2.3
1:500 - YEAR FRESHET +
CLIMATE CHANGE + SEA LEVEL RISE
FLOOD WATER SURFACE
(RISK EVENT 2)

For infrastructure such as rail, highways, and regional based, ISL used replacement costs from the NHC report for the Fraser Basin Council. For building types and infrastructure not included in NRCan depth-damage relationships, the structure replacement costs were estimated by the FHRA project team experienced in design and construction of similar structures in the City or in other Lower Mainland municipalities. NRCan also provided the basis for displacement periods.

Table 2.1 displays the FHRA loss estimates for the 1 in 500 year Fraser River design flood and the 1 in 500 year Fraser River design flood plus climate change and sea level rise.

Table 2.1: Summary of Loss Estimates from FHRA

Asset Type	Quantity Affected	
	1 in 500 Year (Design Flood)	1 in 500 Year + CC + SLR
Residential (low, medium and high)	15,195 people	16,250 people
Commercial/Industrial/Institutional	11.3 ha building space	13.7 ha building space
Agricultural	5,700 ha	5,700 ha
Municipal Critical Buildings (City Hall, Works Yard, Police Station, Fire Hall, Hospital)	1 City Works Yard	1 City Works Yard
Municipal (Pitt Meadows) Drainage (Pump Stations)	6 pump stations	6 pump stations
Municipal (Pitt Meadows) Sanitary Sewer (Lift Stations)	7 pump stations	7 pump stations
Municipal (Pitt Meadows) Potable Water (PRVs)	5 PRVs	5 PRVs
Diking System	9 km overtopped dikes	50 km overtopped dikes
Regional (MV) Potable Water (Chlorination Analyzer, Maple Ridge Pump Station)	2 buildings	2 buildings
Regional (MV) Sanitary Sewer (Baynes Road Pump Station)	1 building	1 building
Municipal Transportation (Collector and Arterial Roads, Bridges)	5 bridges; 27.8 km road	5 bridges; 36.1 km road
Provincial (MOTI) Transportation (Lougheed Highway)	5.2 km of Lougheed Highway	5.2 km of Lougheed Highway
Airport (Pitt Meadows Regional Airport)	1 Airport	1 Airport
Rail (Canadian Pacific Rail)	2.7 km of CP Rail	5.7 km of CP Rail
Vancouver Intermodal Terminal (Canadian Pacific Rail)	1 Facility	1 Facility

The FHRA estimated that economic losses from the 1 in 500 year Fraser River design flood and the 1 in 500 year Fraser River design flood plus climate change and sea level rise would be $489 Million and $725 Million, respectively, based on the City's existing flood mitigation infrastructure. Refer to **Appendix A** for the loss estimate breakdown and a list of assumptions.

2.4 Katzie First Nation Engagement

The Katzie First Nation (KFN) were identified in the FHRA as being highly effected by the Fraser River design flood. The Katzie Reserve No. 1 (IR1) is in the southeast corner of the City of Pitt Meadows municipal boundary and lies on the north bank of the Fraser River. IR1 is approximately 44 ha and has limited structural flood protection as the existing dike structure is on the land side of the reserve along Wharf Street.

On March 12, 2020, City and ISL staff met with Katzie First Nations representatives. KFN were introduced to the FMP project and work that had been completed to date as part of the Flood Hazard Risk Assessment. The focus of the meeting was to discuss specific concerns related to the existing flood mitigation on IR1 and considerations for future upgrades. It should be noted that there are four other Katzie reserves that are outside of the City Municipal Boundary that were not discussed in detail at this meeting.

The Katzie's primary concern was that the existing diking structure runs along Wharf Street and that the reserve remains unprotected in the event of a Fraser River flood. The representatives at the meeting acknowledged that the Katzie First Nation's main objective for flood mitigation would be to construct a new dike along River Road on the water side of the reserve. The City and Katzie representatives agreed that there were opportunities for future partnering on flood mitigation infrastructure opportunities. Opportunities and impacts of a river side diking structure at IR1 are discussed in Section 4.2.

3.0 Drainage and Diking Inventory and Assessment

The City's drainage pump stations and diking infrastructure were inventoried and assessed to identify upgrade opportunities that would improve flood mitigation. The inventory and assessments were completed by reviewing previous relevant studies and by commissioning several new studies for the FMP, including the geotechnical seismic stability assessment of the dikes.

Environmental and archaeological assessments were completed along the diking system to better understand impacts of dike upgrades and risk factors that may impact future projects. The legal property boundaries along the dike were established to better approximate the extents of property requirements where dike raising is required.

3.1 Drainage Pump Station Inventory

The four Areas in the City of Pitt Meadows all rely on a combination of floodboxes and pump stations to discharge drainage to the surrounding Pitt River, Alouette River, and Fraser River. The floodboxes operate via differential hydrostatic head and require a lower water surface elevation of the receiving watercourse compared to the land side watercourse to function. High tides and high flows in the receiving watercourses generally result in the pump stations being the sole relief to discharge drainage from the City. A list of the pump stations and flood boxes in the study area is provided in **Table 3.1**.

Table 3.1: Drainage Pump Station Inventory

Area	Name	Catchment	Flood Box	No. of Pumps	Backup Power
1	Alouette Pump Station	Alouette	Yes	2	No
2	Charlier Flood Box	Fenton	Yes	0	N/A
	Fenton Pump Station[1]	Fenton	Yes	2	No
3	Kennedy Pump Station[1]	Kennedy	Yes	4	No
	Cranberry Slough Flood Box	Cranberry	Yes	0	N/A
	Baynes Pump Station	Ford	Yes	2	No
	McKechnie Pump Station[1]	McKechnie	No	3	No
4	Sturgeon Slough Flood Box	Polder	Yes	0	N/A
	Pitt Polder Pump Station[2]	Polder	No	2	No

[1]The Fenton, McKechnie, Baynes, and Kennedy Pump Stations will have a backup generator installed by 2021.
[2]The Pitt Polder Pump Station is under construction.

3.2 Diking System Inventory

The City of Pitt Meadows operates and maintains approximately 60 km of dikes over the four Areas. The Ministry of Forests, Lands, and Natural Resource Operations and Rural Developments (FLNRORD) standard dike section comprises of an earth fill dike with nominally 3H:1V landside and waterside slopes and 4.0 m wide crest. Non-standard dikes usually have steeper slopes and a narrower crest than standard dikes. Most of the dikes in Areas 2 and 3 were considered to be standard dikes and were rebuilt between 1977 and 1989 and constructed to 1969 design flood elevations. The dikes in Areas 1 and 4 were considered to be primarily non-standard dikes constructed in the late 1940s and early 1950s. **Table 3.2** displays the approximate diking length by Area.

Table 3.2: Diking Inventory

Area	Length (km)
1	9.9
2	8.7
3	23.4
4[1]	17.7

[1]Approximately 8.4 km of Area 4 dikes are within the Pitt-Addington Marsh ecological reserve.

3.3 Drainage Pump Station Assessment

A review of the City of Pitt Meadows Drainage Pump Station Assessment (ISL, 2012) was completed to identify potential condition and capacity shortfalls related to the City's drainage pump stations.

The existing pump stations were constructed under the Agricultural and Rural Development Subsidiary Agreement and were designed to the Agricultural Drainage Criteria (ARDSA Criteria). The ARDSA Criteria was intended to improve regional drainage for lowland crops to thrive in flood plains by limiting the exposure of crop's roots to excessively saturated soils for long durations, however, it permitted flooding for specified durations during dormant and growing periods. Due to landowner opposition to the temporary flooding, the City commissioned Klohn Crippen in 2006 to develop the Modified ARDSA Criteria which was reported in the Pitt Meadows Drainage and Irrigation Study for the Agricultural Lowlands report. The modified criteria was formulated such that no flooding would occur during the same design events from the original ARDSA Criteria.

The drainage pump stations and flood boxes were assessed to determine pumping upgrades required to meet the Modified ARDSA Criteria. The findings from this hydraulic assessment are displayed in **Table 3.3**.

Table 3.3: Pitt Meadows Pump Station Upgrades Required to meet the Modified ARDSA Criteria

Area	Pump Station Name	Existing Total Rated Pump Station Capacity (m^3/s)	Required Capacity Increase (Modified ARDSA Criteria)
1	Alouette	2.52	None Required
2	Fenton	2.65	None Required
	New Pump Station	N/A	Add 1.77 m^3/s Pump Station at Charlier Floodbox
3	Baynes	3.53	None Required
	Kennedy	7.07	None Required
	McKechnie	5.30	None Required
	New Pump Station	N/A	Add new 3.53 m^3/s Pump Station at Reichenbach Floodbox
4	Pitt Polder[1]	5.46	None Required

[1]Pitt Polder will have a total rated pump station capacity of 7.30m^3/s when completed in 2021.

In general, pumps of similar size and type to those of the City's pumps have a useful life expectancy of 20 to 30 years. Most of the existing pumps were installed in 1984, approximately 36 years ago, under the ARSDA. The existing pumps have been replaced in all pump stations except Fenton (planned for 2021) and Kennedy (planned for 2022). The Pitt Polder Pump Station replacement is under construction and will be completed with new pumps by 2021.

Currently the existing pump stations are not equipped with an emergency power supply (backup generator) in the event of a power failure (Fenton, McKechnie, Baynes, and Kennedy Pump Stations are planned to have backup generators by 2021). In the event of power outage, the drainage system entirely relies on floodboxes to drain.

3.4 Diking System Assessment

3.4.1 Dike Crest Elevation Assessment

The FLRNORD Best Management Practices for British Columbia Dike Design and Construction Guide (Ministry of Water, Land and Air Protection, 2003) provides the design basis for dike upgrades in BC, including establishing the design flood profiles and dike crest elevation requirements.

The current design flood for the Fraser River is a 1 in 500 year flood that represents the 1894 Fraser River flood of record (Risk Event 1 from Section 2.3.1). The Fraser River design flood profile is sloped and varies in elevation. The current Pitt River design flood profile is at a constant of 4.92 m geodetic. Freeboard refers to the difference between the dike crest elevations and water surface profile for the design flood event. The current diking design standard for freeboard for the Fraser and Pitt Rivers is 0.6 m.

Although uncertainty remains in climate change effects and sea level rise impacts, the 1 in 500 year Fraser River design flood plus climate change and sea level rise (Risk Event 2 from Section 2.3.1) is considered to serve as a longer term scenario that is relevant to flood protection infrastructure life spans.

A profile of the City's dike system was created using 2016 LiDAR topography. The LiDAR has an unverified accuracy of less than 0.10 m for vertical points and less than 0.30 m for horizontal points (Root Mean Square Error). By comparing the dike crest profiles to the flood profiles for both the 1 in 500 year Fraser River design flood and the 1 in 500 year Fraser River design flood plus climate change and sea level rise, it was found that dike overtopping occurred under both flood scenarios and in all Areas. The length of the dikes that would require raising to meet the current design flood plus 0.6 m freeboard are shown in **Table 3.4**.

Table 3.4: Estimated Length of Dikes Requiring Raising to Meet Current Design Guidelines

Area	Length of Dike (km)	Length of Dike Requiring Upgrades (km)	% of Dike Area Requiring Upgrades
1	9.9	8.9	90
2	8.7	4.9	56
3	23.4	18.3	78
4	17.7	17.6	99

3.4.2 Geotechnical Overview Assessment of the Diking System

In 2018, Thurber Engineering Ltd. (Thurber) completed an overview geotechnical assessment of the City's existing diking system. The primary objective of Thurber's report was to provide a subjective assessment of the anticipated flood protection performance of the City's dikes. The assessment was based on geotechnical information available in Thurber's files and engineering judgement. No slope stability, seepage or settlement analyses were completed. The report generally characterized the dikes and identify significant geotechnical issues that could affect the viability of the existing or future upgraded dikes to provide an appropriate level of flood protection. Thurber's review offered the below with respect to the City's diking system.

- The City's dikes were deficient by the current design flood elevations and are likely to have poor seismic performance due to liquefaction and displacement for seismic return periods of 1 in 475 year and 1 in 2,475 year design earthquakes.
- Dike upgrades may require upgraded seepage control measures under the current design floods or future design floods.
- Overbuilding dikes may be required to compensate for settlement.
- Stability modifications could be appropriate for dikes where non-seismic stability is a concern. Upgrades could include constructing toe berms on the landside of the dike or installing a seepage cut-off and filter within the dike.

- Under the 1 in 100 year return period earthquake, liquefaction could be limited. Ground improvements or other seismic mitigation measures may be required to meet the displacement criteria for return periods of 1 in 475 year and 1 in 2,475 year.
- The higher dikes (Area 2 and 3) and riverside dikes are anticipated to have poorer seismic performance due to deeper riverbanks and river channels.

3.4.3 Geotechnical Seismic Stability Assessment of the Diking System

Golder Associates Ltd. (Golder) assessed the seismic stability of selected dike segments within the City and provided geotechnical input to evaluate the seismic vulnerability of the diking system. One of the primary objectives was to inform the City of diking upgrade priorities that considered the probabilities and consequences of dike failures. Golder's Geotechnical Seismic Stability Assessment can be found in **Appendix B**.

Golder completed a geotechnical field exploration program to obtain information on the subsurface conditions at various dike sections of Areas 1 to 4. The exploration included advancing 20 Seismic Cone Penetration Tests (SCPTs) with nine paired Auger Holes (AH) at selected locations. One test hole (AH/SCPT 19-01) was located off of the existing dike and near Koerner Road and was completed for the future development of a flood control system and not considered in Golder's dike assessment.

The seismic performance and post-earthquake structural integrity of each dike segment was evaluated at 19 of the test hole locations for 100-year, 475-year, and 2,475-year return periods by comparing calculated displacements against the criteria referenced from Seismic Design Guidelines for Dikes (SDGD) published in June 2014 by the Flood Safety Section of the MFLNRORD. Golder developed a qualitative probability of failure using the performance criteria and categorized each location into one of six probability of failure categories shown below.

- Low
- Low to Medium
- Medium
- Medium to High
- High
- Very High

Golder referenced the Project Summary – Draft Preliminary Dike Consequence Classification for Seismically Active Areas in British Columbia published by the Flood Safety Section of the FLNRORD in September 2014 to categorize the consequence of failure. Consequence classifications were provided in terms of Low, Moderate and High and considered loss of life and economic and social issues. Area 1 and Area 4 dikes were found to be Low Consequence while Area 2 and Area 3 dikes were considered to be High Consequence.

Applying a subjective risk matrix using the probabilities of failure and consequences from above, Golder produced the prioritization in **Table 3.5** and on **Figure 3.1**.

Table 3.5: Prioritization of Seismic Upgrades Based on Subjective Risk

Area	Location	Subjective Probability of Failure	Consequence Classification of the Dike	Upgrade Prioritization Rating
1	19-12	Low	Low	Low
	19-13	Low to Medium	Low	Low
2	19-14	Low	High	High
	19-15	Medium to High	High	High
	19-16	Medium to High	High	High
	19-17	Medium to High	High	High
	19-18	Medium to High	High	High
3	19-02	Low	High	Low
	19-03	Medium to High	High	High
	19-04	Medium to High	High	High
	19-05	Low	High	Low
	19-06	Low	High	Low
	19-07	Medium to High	High	High
	19-08	Low	High	Low
	19-09	Medium to High	High	High
	19-10	Low	High	Low
	19-11	Low	High	Low
4	19-19	Medium to High	Low	Low
	19-20	Medium	Low	Low

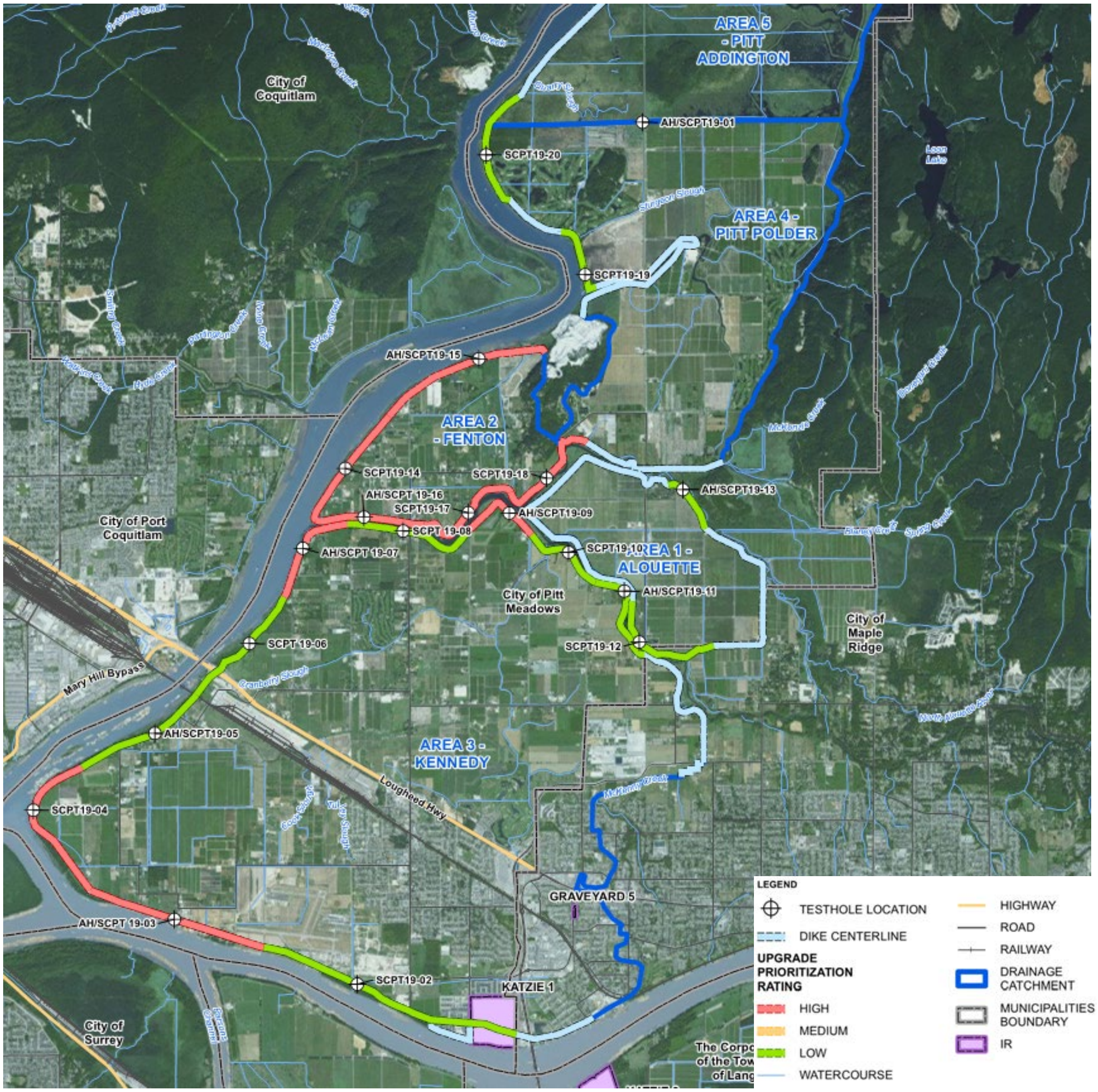


Figure 3.1: Prioritization of Seismic Improvements to the Diking System

3.5 Environmental Assessment along the Diking System

An environmental assessment (EA) was conducted by ISL Engineering and Land Services Ltd. (ISL) to inventory the aquatic and terrestrial habitat features along the dikes. The purpose of the EA was to establish the environmental conditions along the City's diking system and to identify environmental regulations that may apply prior to and during the implementation of flood mitigation upgrades. ISL completed desktop and field investigations to collect the qualitative and quantitative data on which to develop the EA and to determine the implications of the EA findings of which are summarized below. Refer to **Appendix C** for the complete Environmental Assessment Report.

Throughout the sampling locations, the water quality was found to be very low with low dissolved oxygen levels and high water temperatures. Fish diversity was very low with only two native species captured, no salmonids, and predominately Invasive Alien Species (IAS) present. IAS are fish that are introduced into an ecosystem that is beyond their natural range. IAS can often tolerate extremely low oxygen levels, a range of water temperatures and other water quality conditions that BC's native fish cannot. The extreme water quality parameters observed and the coverage of IAS presence throughout the sample sites indicated that the inland areas of City's dikes would not be effective in providing spawning habitat for salmonids.

ISL's review of the terrestrial habitat along the sampled reaches found that the vegetation diversity and structure were lacking. The vegetation covering the dikes were limited to common grasses. With exception to some observations of wildlife trees, the vegetation of the inland areas lacked canopy cover and was dominated by non-native shrubs species. The habitat surrounding the ditches have been extensively altered through dike construction, which has resulted in significant habitat limitations for many species.

The below species at risk were identified within Pitt Meadows and are known to utilize similar ecosystems to what are present within the project boundaries.

- Western Painted Turtle (*Chrysemys picta bellii)*
- Marbled Murrelet (*Brachyramphhus marmoratus)*
- Great Blue Heron (*Ardea Herodias fannini)*
- Green Heron (*Butorides virescens*)
- Johnson's Hairstreak (*Callophrys johnsoni)*
- Two-edged Water-starwort (*Callitriche heterophylla var. heterophylla)*
- Vancouver Island Beggarticks (*Bidens amplissima*)

There are established critical habitat polygons for the Marbled Murrelet and the Western Painted Turtle within the City, however, in both cases ISL considered the likelihood of the species presence in the identified areas to be low. The Marble Murrelet habitat requirements include old-growth trees for nesting which were not found to present. Aquatic habitat within some of the sampled reaches possessed slow moving and often stagnate water with organic and fine substrate, which aligns with the desired attributes for the aquatic habitat of Western Painted Turtle. Based on the low water quality and poor terrestrial habitat the likelihood of Western Painted Turtle utilizing these ditches and inland areas as habitat was considered to be low. Based on the biophysical attributes observed, it is unlikely that the other potential Species at Risk identified during the desktop assessment would occupy the project area.

3.6 Archaeological Overview Assessment along the Diking System

Antiquus Archaeological Consultants Ltd. (Antiquus) completed an Archaeological Overview Assessment (AOA) study along the City's existing diking system. The objectives of the desktop AOA was to indicate areas along the dikes where archaeological potential may exist and to provide recommendations and future management strategies to support any planned diking upgrades.

The City's diking system is located within the traditional territory of Katzie First Nation, Stó:lo Nation, Kwantlen First Nation, Kwikwetlem First Nation, Tsleil-Waututh Nation and Musquem First Nation. Antiquus' desktop study concluded that there were 34 previously recorded archaeological sites directly intersecting with the dike or in close proximity to the dike. Notable sites include, DhRp-9 the 'Cod Island' village site, DhRp-11 the 'Caruthers' village site and DhRp-17 the 'Port Hammond' village site. The 34 archaeological sites range from large village sites with significant deposits of lithic artifacts (diagnostic artifacts) to isolated finds.

In the event of any land-altering activities to the dike that are near the archaeological sites, archaeological surveys, testing, monitoring, and/or archaeological mitigation may be necessary. Antiquus' AOA can be found in **Appendix D**.

3.7 Diking System Legal Boundaries

The legal boundaries for the City's diking system were established by Bennett Land Surveying Ltd. (Bennett). The purpose of this exercise was to establish or confirm land ownership along the existing diking system and to estimate the land requirements associated with upgrading dikes. Bennett's scope of work included:

- Develop cadastral using ParcelMap BC;
- Validate the cadastral against registered plans from the Land Title office; and
- Verify boundaries where discrepancies existing via field survey.

The outcome of Bennett's review and survey was an updated legal boundary for the City's diking system in Areas 1, 2, 3, and 4 to a +/- 10 centimeter accuracy. The updated legal boundaries were included in the conceptual dike upgrade drawings developed in Section 4.2.

4.0 Flood Mitigation Infrastructure Upgrade Opportunities

4.1 Drainage Pump Stations

The City's drainage pump stations are relied upon for relief of drainage for both small and large storm events. In the event of a flood they are critical to discharge drainage from the Areas into the surrounding rivers. The pumps in the Fenton and Kennedy Pump Stations are considered to be past their useful service lives and are recommended for replacement. New drainage pump stations in Area 2 (Charlier Floodbox) and Area 3 (Reichenbach Floodbox) may be required to meet the Modified ARDSA drainage criteria and to assist with flood mitigation. The City noted that the existing drainage pump stations are generally considered to have sufficient capacity and more analysis is recommended prior to design and construction of the new stations.

Currently none of the City's drainage pump stations are equipped with backup power in the event of a power outage. By the end of 2021 the Fenton, Kennedy, Baynes, and McKechnie stations will be upgraded to include backup generators. Installation of backup generators is recommended at the remaining Alouette and Pitt Polder Pump Stations.

The probable costs of replacing drainage pumps, constructing the new pump stations, and providing backup generators are provided in **Table 4.1**. The pump replacements assume that the pumps will be replaced as sized in the 2012 Pitt Meadows Drainage Pump Station Assessment. The generators were estimated based on the Fenton, Kennedy, Baynes, and McKechnie civil and electrical work and equipment that is planned to be completed in 2021.

Table 4.1: Pump Station Upgrades Opinion of Probable Costs

Item No.	Description	Amount ($)
1.0	**Pump Replacements - Fenton Pump Station**	
1.1	Pumps Replacement (2 pumps)	270,000
1.2	Discharge Columns, Accessories and Installation	30,000
1.3	Electrical	195,000
1.4	Contingency and Engineering @ 35%	208,250
	TOTAL – Fenton Pump Station	**803,250**
2.0	**Pump Replacements - Kennedy Pump Station**	
2.1	Pumps Replacement (4 pumps)	615,000
2.2	Discharge Columns, Accessories and Installation	255,000
2.3	Electrical	250,000
2.4	Contingency and Engineering @ 35%	392,000
	TOTAL – Kennedy Pump Station	**1,512,000**

Item No.	Description	Amount ($)
3.0	**New Pump Station – Area 2 (Charlier Floodbox)**	
3.1	Environmental Requirements	400,000
3.2	Structural/ Architectural	1,500,000
3.3	Pumps (1)	150,000
3.4	Discharge Columns, Accessories and Installation	200,000
3.5	Electrical	450,000
3.6	Civil	1,250,000
3.7	Standby Generator and Electrical	150,000
3.8	Contingency and Engineering @ 50%	2,050,000
	TOTAL – New Area 2 Pump Station	**6,150,000**
4.0	**New Pump Station – Area 3 (Reichenbach Floodbox)**	
4.1	Environmental Requirements	450,000
4.2	Structural/ Architectural	1,750,000
4.3	Pumps (2)	300,000
4.4	Discharge Columns, Accessories and Installation	255,000
4.5	Electrical	550,000
4.6	Civil	1,500,000
4.7	Standby Generator and Electrical	300,000
4.8	Contingency and Engineering @ 50%	2,552,500
	TOTAL – New Area 3 Pump Station	**7,657,500**
5.0	**Backup Generator – Pitt Polder Pump Station**	
5.1	Civil Work	10,000
5.2	Standby Generator and Electrical	400,000
5.3	Contingency and Engineering @ 35%	143,500
	TOTAL – Pitt Polder Pump Station	**553,500**
6.0	**Backup Generator – Alouette Pump Station**	
6.1	Civil Work	60,000
6.2	Standby Generator and Electrical	200,000
6.3	Contingency and Engineering @ 35%	91,000
	TOTAL – Alouette Pump Station	**351,000**

4.2 Diking System

The City of Pitt Meadows' existing diking system was found to be largely deficient in both crest height and seismic stability based on the current dike design guidelines. The Fraser River and Pitt River design flood profiles were shown to overtop a significant length of the dikes in all four Areas. Based on the design floods, there is approximately 50 km of dikes that require raising to meet the design flood plus 0.6 m freeboard criteria.

Geotechnical exploration and seismic assessment of the dikes in Areas 1 to 4, found that 12 of the 19 test locations would exceed horizontal and vertical displacement design parameters when evaluated for a 1 in 2,475 year earthquake. When evaluated for a 1 in 475 year earthquake, 10 of 19 test locations exceeded both the horizontal and vertical displacement parameters. A subjective probability of failure found that 9 of 19 test locations had a Medium to High probability of failure, where failure may imply a compromised structural integrity following a seismic event rather than a complete collapse.

Based on the above, overbuilding the dikes to meet the current design flood levels and to improve seismic stability are considered to be critical flood protection upgrades. The typical section for overbuilding the dike as shown in Golder's Geotechnical Seismic Stability Assessment is displayed in **Figure 4.1**.

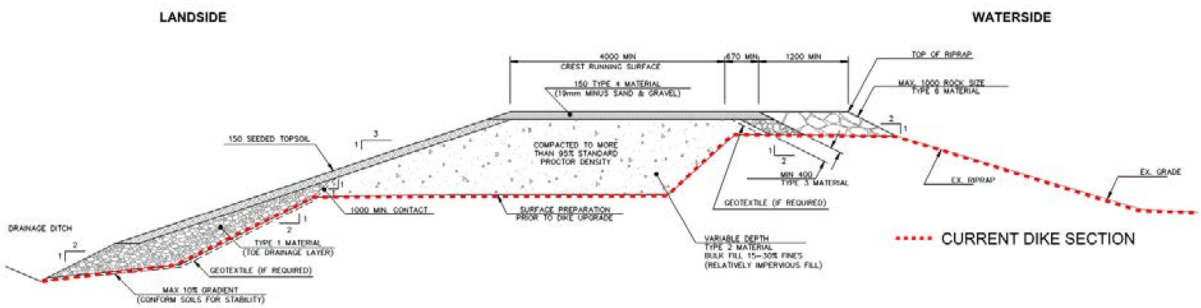


Figure 4.1: Typical Dike Overbuild Section

Utilizing this typical section and a dike crest elevation to meet the design flood plus 0.6 m freeboard, conceptual dike upgrade drawings were created and are provided in **Appendix E**. The drawings were developed using the LiDAR surface. Property and dike right-of-way boundaries were updated using the legal boundaries established for the FMP.

At the Katzie IR1, a new dike on the river side of the reserve has been shown (Appendix E, Sheet 36) that would meet the Fraser River design flood profile for crest height and using the dimensions from **Figure 4.1**. A standard dike on this alignment is shown to have significant impacts to property along River Road and River Road itself would need to be relocated or eliminated. Other opportunities for structural flood mitigation measures may include a dike alignment that is constructed offshore, a steeper sectioned dike, and/ or a flood wall.

Area 4 diking upgrades include 8.4 km of overbuilding along the Pitt-Addington Marsh, north of Koerner Road. The marsh is an ecological reserve, and there may be benefit to installing a new dike on Koerner Road, approximately 5 km in length, as opposed to upgrading the existing dike in the undeveloped marsh. A dike along Koerner Road would require more material than the upgrade along Pitt-Addington Marsh however it would be shorter and more accessible for monitoring and maintenance purposes. A new dike would require coordination with several layers of government, stakeholders, and updates to policy regarding ownership and maintenance of the existing Pitt Polder dike. Costs and other implications for a new dike along Koerner Road were not considered further as part of the FMP.

Probable costs for overbuilding the dike to meet current guidelines and to extend the dike at the Katzie IR1 are provided in **Table 4.2**. It should be noted that remedial measures and raising the dikes are site specific and require geotechnical detailed design. In some cases it is anticipated that the dike section may be increased or reduced from the typical section.

Table 4.2: Dike System Upgrades Opinion of Probable Costs

Item No.	Description	Amount ($)
1.0	**Area 1**	
1.1	Excavation and Dike Fill	7,500,000
1.2	Armouring	1,780,000
1.3	Drainage Improvements	3,560,000
1.4	Property Requirements	25,000
1.5	Engineering and Permitting @ 20%	2,573,000
1.6	Contingency @ 50%	6,432,500
	TOTAL – Area 1	**21,870,500**
2.0	**Area 2**	
2.1	Excavation and Dike Fill	6,000,000
2.2	Armouring	960,000
2.3	Drainage Improvements	1,920,000
2.4	Property Requirements	140,000
2.5	Engineering and Permitting @ 20%	1,804,000
2.6	Contingency @ 50%	4,510,000
	TOTAL – Area 2	**15,334,000**

Item No.	Description	Amount ($)
3.0	**Area 3**	
3.1	Excavation and Dike Fill	6,900,000
3.2	Armouring	3,664,000
3.3	Drainage Improvements	7,328,000
3.4	Property Requirements	1,200,000
3.5	Katzie First Nation Dike Extension	3,500,000
3.6	Engineering and Permitting @ 20%	4,518,400
3.7	Contingency @ 50%	11,296,000
	TOTAL – Area 3	**38,406,400**
4.0	**Area 4**	
4.1	Excavation and Dike Fill	15,000,000
4.2	Armouring	3,520,000
4.3	Drainage Improvements	7,040,000
4.4	Property Requirements	1,300,000
4.5	Engineering and Permitting @ 20%	5,372,000
4.6	Contingency @ 50%	13,430,000
	TOTAL – Area 4	**45,662,000**

Property values for each lot were based on 2019 land assessments and do not include building or improvement assessments.
KFN property values were not available and were excluded from items 3.4 and 3.5.
Unit costs were estimated for excavation and dike fill, armouring, and drainage improvements as $30/m^3$, $200/m, and $400/m respectively for dike upgrades. Costs should be refined during design based on actual design measures proposed, size of project, market conditions, accessibility, and other variables not considered during the FMP.

4.3 Prioritization of Flood Mitigation Upgrade Opportunities

As described in Section 2, without structural flood upgrades, a flood equal to that of the Fraser River design flood would have a widespread community and regional impact. However, the proposed flood mitigation upgrades are significant in cost and will take many years to complete. To assist the City in its planning of flood protection infrastructure upgrades, the following prioritization of upgrades is offered. Priorities are anticipated to change as new data and findings from ongoing studies, condition assessments, maintenance requirements, and emergency works are completed and made available to the City.

The suggested prioritization considers subjective risk, where risk is defined as the probability of failure times the consequence of failure. The probability of dike overtopping was considered to be similar for all Areas. The probability of seismic failure from Section 3 were considered to be higher in higher in Areas 2, 3, and 4 than Area 1. The consequence of failure, based on the FHRA and the Geotechnical Seismic Stability Assessment from Section 3, would be higher in Areas 2 and 3 than in

Areas 1 and 4. Based on this subjective risk assessment, the risk of river flooding due to the inadequacies of the dike structure is higher in Areas 2 and 3 and priority for upgrades should generally focus on these Areas first.

Based on a review of the City's tax-based budget for years 2019 to 2023, the City allocates an average of $2 Million annually for drainage and diking infrastructure projects. The budget includes condition assessments, maintenance, and the design and construction of culvert replacements, and electrical and mechanical upgrades to the drainage pump stations. Based on the estimated construction costs from Section 4, the City may consider prioritizing pump station upgrades when using its annual tax based budget. Dike system upgrades may be most feasible by applying for Provincial and Federal grants that are designed to assist municipalities in upgrading critical flood protection infrastructure. The City is currently following this approach and has several drainage pump station upgrades planned utilizing its capital budget, including: Fenton pump replacements (budgeted for 2021), Kennedy pump replacements (planned for 2022), Fenton, McKechnie, Kennedy, and Baynes backup generators (budgeted for 2021), and the Pitt Polder backup generator (planned for 2026).

The location of the infrastructure upgrade opportunities are shown on **Figure 4.2**.

4.3.1 Drainage Pump Stations

Replacing the pumps and installing backup generators at drainage pump stations are both considered to be high priority for flood protection, provided that the drainage pump stations are the only means to discharge drainage water from the City when the floodboxes are not functioning (high river flows or high tides). Priority was given to drainage pump stations that are the sole pump station for an Area followed by pump stations that had the highest total rated capacity. This approach would result in pump replacements being completed in Fenton followed by Kennedy. The backup generators would be installed at Pitt Polder before Alouette. The new pump station in Area 2 (Charlier Floodbox) would be installed followed by the new pump station in Area 3 (Reichenbach Floodbox).

4.3.2 Diking System

The City's diking structure requires significant upgrades to meet current standards and to lower the risk associated with a Fraser River flood. In general, priority should be given to the higher consequence Areas 2 and 3 and to the dikes that are more than 1 m below the current design flood profile. If property requirements allow, any upgrades should be overbuilt to the current design flood plus the 0.6m freeboard and to improve structural resilience during and following seismic events.

As a significant amount of the dike overbuilding is anticipated to require property acquisition, the City should consider prioritizing the upgrades in areas where property is not required over areas where property is needed. In Areas 2 and 3, the City should begin engaging property owners where the dike upgrades will require additional property. **Figure 4.3** displays the suggested prioritization sections of the dike system based on the above criteria.

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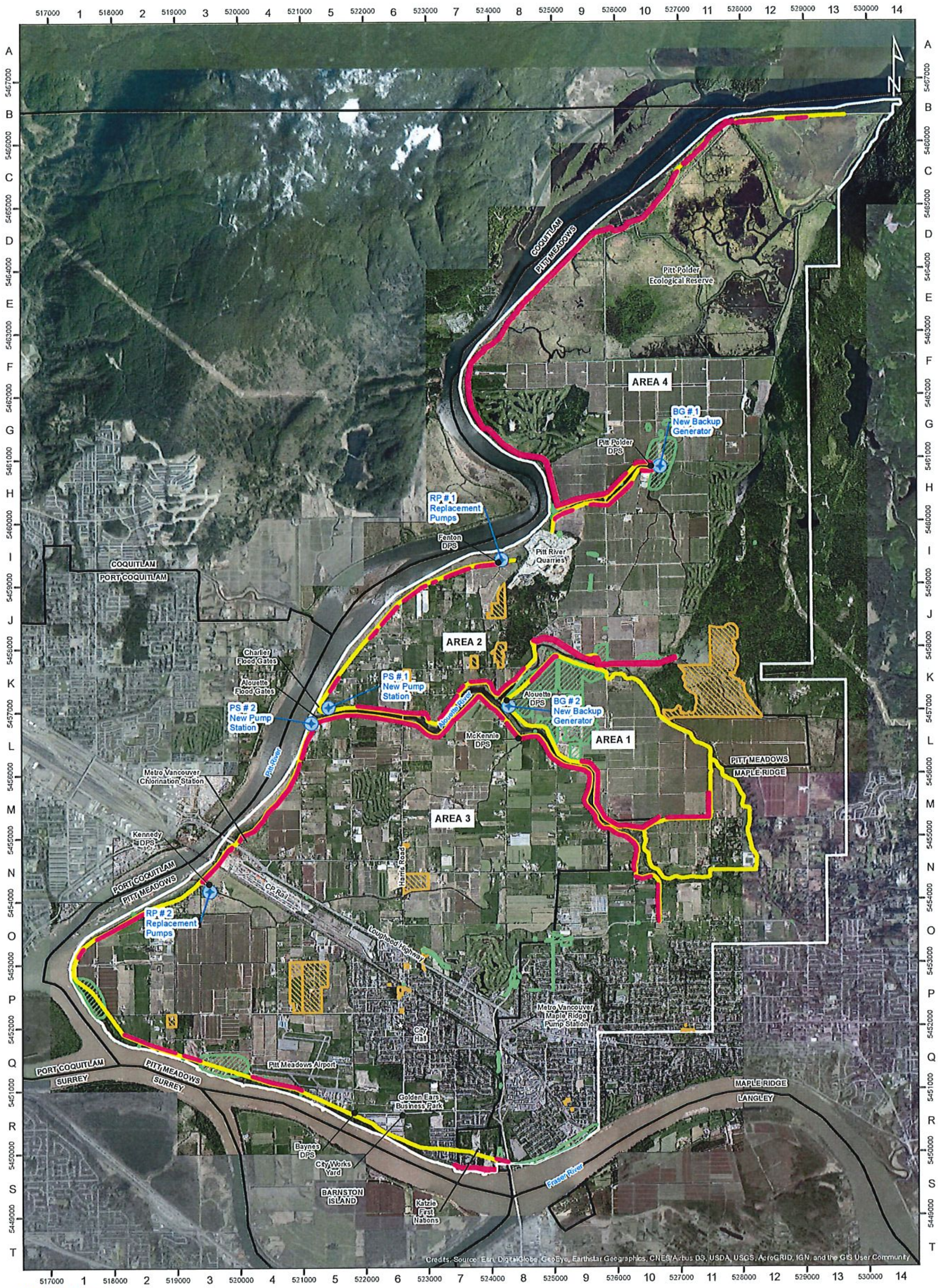


Legend

- Upgrades
- Dike System
- Property Access Required
- Archaeology Site
- Heritage Site
- Municipal Boundary

ISL Engineering and Land Services

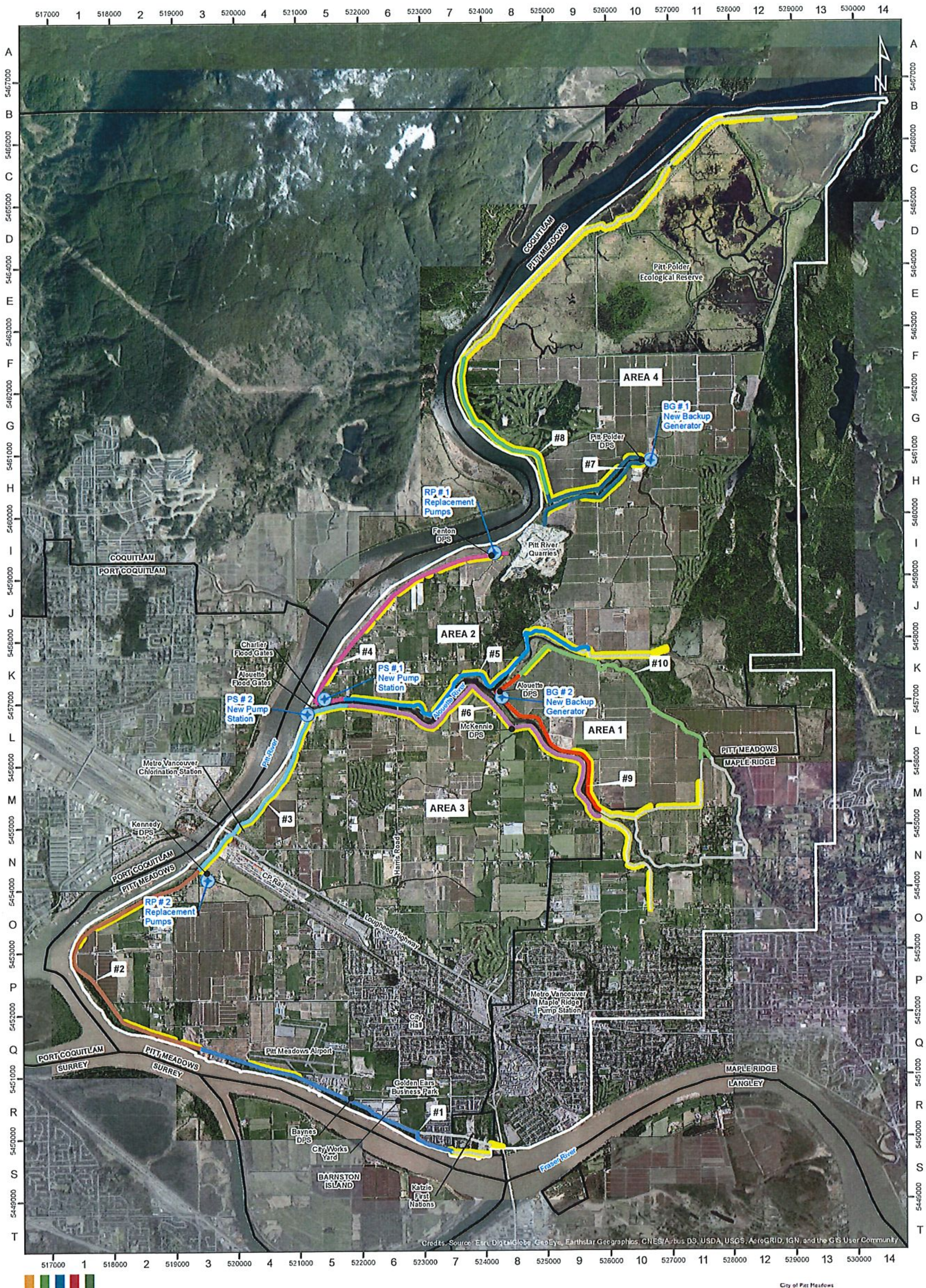
0 0.5 1 2 Kilometers

1:55,000 UTM Zone 10 Northern Hemisphere

DPS - Drainage Pump Station

FIGURE 4.2
INFRASTRUCTURE UPGRADE OPPORTUNITIES AND CONSTRAINTS

City of Pitt Meadows — The Natural Place



ISL Engineering and Land Services

Legend

- Upgrades
- Dike System
  - Unprioritized
- Priority: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
- Property Access Required
- Municipal Boundary

Kilometers
0 0.5 1 2
1:55,000 UTM Zone 10 Northern Hemisphere

RP # - Replacement Pump Prioritization
BG # - Backup Generator Prioritization
PS # - New Pump Station Prioritization
DPS - Drainage Pump Station

City of Pitt Meadows
The Natural Place

FIGURE 4.3
INFRASTRUCTURE UPGRADE SUGGESTED PRIORITIZATION

5.0 Conclusions and Recommendations

The FMP inventoried and assessed the critical flood protection infrastructure in the City. The assessments found that the City's diking system is largely deficient based on current provincial guidelines for dike crest height and for seismic displacements evaluated for the 1 in 475 year and 1 in 2,475 year earthquakes. The FMP identified that two additional drainage pump stations are required and, of the City's six existing drainage pump stations, two require replacement pumps based on pump life expectancy and two require backup generators in case of power failure. The below points are offered for consideration.

- Dike upgrades offered as part of the FMP are conceptual. Any upgrades to the City's dikes will require geotechnical detailed design and will be subject to an approval through the Dike Maintenance Act.
- The Katzie First Nation IR1 is currently not protected by a dike as the existing structure is on the land side of the reserve (to the north). Future dike upgrades near the IR1 boundary should be planned in consultation with the Katzie First Nation.
- A new dike along Koerner Road may be a viable option to explore when considering upgrading Area 4 dikes. The option should be discussed with First Nations, Inspector of Dikes, FLNRORD, management for the Grant Narrows Regional Park, and other stakeholders.
- Where infrastructure (pump stations, bridges, culverts, flood boxes) is planned for replacement along a dike that will require upgrading, the design should allow for the ultimate crest elevation that will meet current guidelines.
- It is understood that there is a current project being undertaken by the Province to survey all dike crests in BC. As ground survey data is made available to the City, it is recommended that the dike crest elevations are updated as the ground survey would be considerably more accurate than the LiDAR.
- Dike upgrades which impact existing watercourses (rivers, sloughs, irrigation channels) will be subject to environmental review and would require additional environmental permitting and applications. Where possible the design of the diking upgrades should avoid critical habitat polygons (species at risk) to reduce environmental regulator triggers and required environmental mitigation measures.
- Where possible avoid upgrades to the dikes that alter the land near the identified archaeological sites. Where work is near archaeological sites, additional archaeological exploration and mitigation may be required.
- The FMP did not explore implications to utilities that exist within dikes. Future upgrades of dikes with existing utilities may require additional municipal design and 3rd party coordination (Metro Vancouver, Telus, FortisBC, and BC Hydro).
- A significant portion of the City of Pitt Meadows lies within the Agricultural Land Reserve (ALR), there may be additional coordination with the Agricultural Land Commission (ALC) that is required.

6.0 References

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