# LOWER MAINLAND FLOOD MANAGEMENT STRATEGY PROJECT 2: REGIONAL ASSESSMENT OF FLOOD VULNERABILITY

## FINAL REPORT

Prepared for:

Fraser Basin Council
Vancouver, BC

25 April 2016

NHC Ref. No. 3000149

nhc
northwest hydraulic consultants
water resource specialists

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Prepared by:

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The following NHC staff participated in the project, under the roles indicated in parenthesis: Monica Mannerström (Project Manager), David McLean (Reviewer), Charlene Menezes (Project Flood Specialist), Sarah North (GIS Specialist) and Vanessa O'Connor (Hydraulic Engineer).

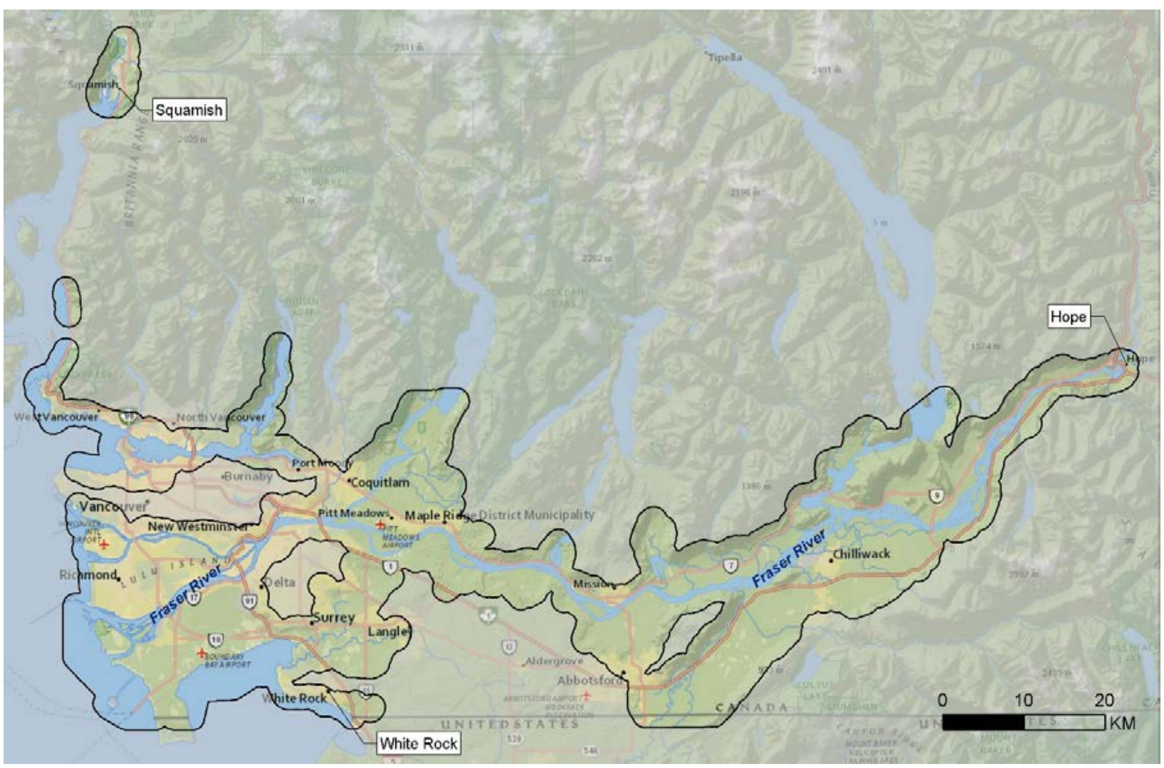
The NHC team included three economists who assisted with specific tasks indicated: David Park (Indirect Economic Losses), Mark Robbins (Agricultural Losses) and Michael Gorecki (Hazus Support). Graham Farstad and Amanda Grochowich of the Arlington Group prepared the inventory of flood vulnerabilities.

# EXECUTIVE SUMMARY

Fraser Basin Council (FBC) announced an initiative to develop a flood management strategy for the Lower Mainland from Hope to Richmond and along the coast from Squamish to White Rock. The total population of the area is in the order of 2.8 million with almost half a million living in potentially flood-prone areas. Following consultations by FBC, a number of organizations expressed their support for a regional collaborative approach to develop a better understanding of flood hazards and the potential losses caused by major flooding. Building on this support by federal, provincial and local governments and other regional entities, FBC initiated a multi-phase initiative to develop a flood management strategy for the Lower Mainland region.

Phase 1, now completed, focussed on three projects:

- Project 1 – Selection of suitable flood scenarios based on previous studies.
- Project 2 – Evaluation of vulnerabilities to coastal and Fraser River flood hazards (this project).
- Project 3 – Assessment of current diking and flood management policy.




**Project Area**

For the purposes of assessing vulnerability in the region, two coastal and two Fraser River flood scenarios were recommended in Project 1. These scenarios are listed in the table below. The coastal flood levels (Scenario A and B) represent a combined winter storm and extreme tide level and apply to the entire coastal area from Squamish to White Rock. Fraser River floods (Scenario C and D) represent freshet flooding involving snowmelt in combination with rain.

**Adopted Flood Scenarios:**

| Scenario | Hazard Type | Time Period | Comment |
|---|---|---|---|
| **A** | Coastal | Present | 1:500 AEP[1] ocean level = 3.4 m GSC[2] |
| **B** | Coastal | Future (2100) | 1:500 AEP ocean level = 4.4 m GSC |
| **C** | Fraser Freshet | Present | Approximate 1:500 AEP Fraser flood (recurrence of 1894 flood of record) |
| **D** | Fraser Freshet | Future (2100) | 1:500 AEP flood + adopted climate change flow increase (17%) and 1 m sea level rise |

The project included the following main components:

- Assessment of coastal and Fraser River flood hazards in the region for the four flood scenarios.
- Assessment of vulnerability of development within the floodplain.
- Estimation of economic losses caused by each flood scenario.
- Summary of limitations of the present project and recommendations for future work.

The vulnerability assessment included: i) residential, commercial and industrial properties; ii) agricultural lands; iii) transportation networks (railways, highways, airports, ports); and iv) other development such as BC Hydro substations; municipal services; emergency response facilities/hospitals and schools.

Total economic losses from a flood are the sum of direct and indirect losses. The direct losses originate from the direct damage to residences, businesses, infrastructure etc. Indirect losses are more difficult to assess and include losses incurred from business shut-downs and rebuilding, disruptions to major transportation arteries and other cascading effects. The following losses were considered:

- Building related losses, both direct and indirect, were estimated using the Canadian version of Hazus (Hazus-MH 2.1) developed by the US Federal Emergency Management Agency

[1] AEP refers to the Annual Exceedance Probability, which is the chance or probability of a natural hazard event (in this case, flooding) occurring annually and is usually expressed as a percentage. A 1 in 500 AEP event has a 0.2% chance of occurring in a given year.

[2] GSC refers to Geodetic Survey Canada datum.

(FEMA) and adapted for Canadian conditions by Natural Resources Canada (NRCan). Building related losses formed the largest portion of the estimated total losses.

- Agricultural losses, other than losses to farmer residences accounted for in Hazus, were estimated based on Land Use Inventory (LUI) information and Stats Canada's 2011 Census of Agriculture data.
- Losses from interruptions to rail traffic were estimated based on freight transshipped through Port Metro Vancouver. Interruptions to highway traffic and to Vancouver International Airport were discussed but not quantified.
- Order of magnitude losses stemming from damage to infrastructure and institutional buildings were included, based on rough assumptions and replacement costs by FEMA.

**Estimated Total Losses in $ Billions:**

| Scenario | Hazus related building losses | Agricultural losses | Transportation losses | Infrastructure/ institutional losses | TOTAL LOSSES $ Billions |
|---|---|---|---|---|---|
| **A** | 14.2 | 0.1 | 3.6 | 1.4 | **19.3** |
| **B** | 19.1 | 0.2 | 3.6 | 1.8 | **24.7** |
| **C** | 9.0 | 1.6 | 7.7 | 4.7 | **23.0** |
| **D** | 18.4 | 1.6 | 7.7 | 5.0 | **32.7** |

Notes:
1. Hazus losses are based on default recovery times ranging from 1 to 33 months.
2. Farmer losses are based on flood inundations exceeding a 2 week critical period.
3. Transportation losses assume 2 week disruptions for coastal floods, 4 weeks for riverine.
4. Order of magnitude infrastructure/institutional losses do not incorporate durations.

The loss estimates illustrate the relative difference between scenarios and show significant increases from previous evaluations. The loss for Scenario C derived in 1994 by Fraser Basin Management Board was $1.8 billion and in 1976 by Fraser River Joint Advisory Board $500 million. The present estimated losses indicate that any of the scenarios would represent the most costly natural disaster in Canadian history, and would severely strain the regional, provincial and national economy. These impacts would be experienced in all communities throughout the region and the costs would be borne by all orders of government, the private sector, families and individual citizens. In addition to the impacts estimated in this project, many other economic, social, and environmental impacts could be experienced, including risk of serious injury, loss of life, and other social hardships.

Limitations associated with the results include: 1) approximate flood extents and depths; 2) incomplete inventory of infrastructure; 3) uncertainties in modelling loss estimates using Hazus; 4) inaccuracies in the agricultural, transportation disruption and infrastructure loss estimates. It is not possible to assign upper/lower bounds to the total loss estimates as some assumptions likely underestimate, while others overestimate the losses. More extreme flooding and flood losses are expected from climate change. The project did not take into account future increases in population density and development, and the total losses for the year 2100 scenarios (B and D) represent lower bound estimates.

The results indicate that the Lower Mainland is presently exposed to a high degree of flood risk and demonstrate that there is an urgent need for improved flood protection and development of a comprehensive flood management strategy. To move forward with Phase 2 and the development of appropriate structural and non-structural flood protection measures, it is imperative that the assessments be refined to clarify appropriate site specific solutions and to ensure that appropriate investments are made and policy changes adopted. A range of future work is recommended.

Significant funds are needed to rehabilitate existing dikes to meet current provincial standards. Upgrades would reduce the likelihood of multiple dike failures during a recurrence of the Fraser River flood of record or a large coastal storm surge. A number of other measures, both structural and non-structural, must also be considered. Most urgently, the provincial government, local governments and First Nations need to prepare for future flood emergencies. This will require updating and refining existing plans or in some cases, developing new detailed emergency preparedness plans. Procedures need to be implemented and practiced. Flood recovery plans, of critical importance during the 2013 Calgary floods, should also be developed.

To develop optimum solutions, the following is recommended:

- Carry out the future work items identified in this report. This work is largely of a technical nature and will allow limited resources to be focussed where most needed to implement flood mitigation measures.
- Extend the vulnerability assessment to include potential for loss of life, social, cultural and environmental losses.
- Develop floodplain mapping for the region, incorporating potential effects of dike breaches and overtopping, climate change and uncertainties in hydrological and hydraulic parameters.
- Refine the loss estimates for individual municipalities and First Nations and prioritize areas where protection is most critical.
- Develop a comprehensive flood management strategy for the Lower Mainland that identifies regional and local priorities as well as recommended management options for the diversity of circumstances that exist throughout the Lower Mainland.

Several Lower Mainland flood studies have been completed in the past. They have typically followed significant flood events such as the Fraser River floods of 1948 and 1972 and the coastal event in 1982. To maximize the value of the present work, it is imperative that recommendations be acted on and measures taken prior to the next large flood. The present results show that, assuming no population increase, flood risks will continue to rise in the future but even under present conditions very high flood losses can be expected.

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# 1 INTRODUCTION

## 1.1 Project Background

Fraser Basin Council (FBC) has announced an initiative to develop a flood management strategy for the Lower Mainland from Hope to Richmond and along the coast from Squamish to White Rock. The region has been exposed to significant flooding in the past, both by the Fraser River freshet and by extreme ocean levels, and is now largely protected by dikes built over a period of several decades to variable standards. Several recent studies commissioned by the BC Ministry of Forests, Lands and Natural Resources (MFLNRO), local municipalities and other groups indicate that the frequency and extent of flooding is likely to increase in the future in response to climate change.

Following consultations by FBC, a number of organizations expressed their support for a regional collaborative approach to develop a better understanding of flood hazards and the potential structural, economic and social losses caused by major flooding. Building on this support by federal, provincial and local governments and other regional entities, FBC initiated a multi-phase initiative to develop a flood management strategy for the Lower Mainland region.

Phase 1 focussed on three projects:

- Project 1 – Selection of suitable flood scenarios based on previous studies (KWL, 2015).
- Project 2 – Evaluation of vulnerabilities (the present project).
- Project 3 – Assessment of current diking and flood management policy. NHC (2015b) completed the diking assessment whereas FBC has conducted the policy review internally.

For the present project (Project 2), FBC retained Northwest Hydraulic Consultants Ltd. (NHC) to carry out a regional assessment of flood vulnerability corresponding to the two coastal and two Fraser River scenarios defined in Project 1. The NHC project team included Arlington Group and three economists: Mr. David Park, Mr. Mark Robbins and Mr. Michael Gorecki.

Commencing in 2016, Phase 2 will develop an appropriate flood management strategy, identifying funding options and outlining implementation actions.

## 1.2 Project Goals and Objectives

To develop a flood management strategy for the Lower Mainland, an important step is to understand the potential magnitude of damages and dollar losses that could be incurred under the specified flood scenarios if no measures were taken to mitigate against flooding. It should be noted that different flood scenarios could occur and actual damages and costs could vary.

The main goal of the project was to develop an understanding of the most significant flood vulnerabilities in the Lower Mainland region and estimate the consequences of the selected flood scenarios, in terms of impacts and costs. Specific objectives outlined by FBC were to:

- Identify vulnerable areas where flood damage will occur under the four selected flood scenarios through the development of a spatial tool for flood vulnerability assessment.
- Determine the vulnerabilities associated with flooding in the Lower Mainland that are of regional, provincial and national interest.
- Estimate the economic losses from flooding on a regional, provincial and national scale.

The project provides an overview level assessment of vulnerabilities and flood consequences. Various limitations and data gaps were identified, and recommendations for future detailed assessments are provided.

There has not been a major flood on the lower Fraser River in the Lower Mainland since the devastating flood of 1948. Although considerable work has been carried out since then to upgrade dikes and improve flood level predictions, there have been relatively few studies to assess vulnerabilities and potential flood damages associated with another major flood event. The effects from climate change (both sea level rise and increases in discharge) are expected to substantially increase flood hazards.

As a result, until this project was undertaken, there has been no quantitative, region-wide basis to assess the potential effects of future flooding in the Lower Mainland. The present overview project represents a first phase in a long-term effort that will be required to fully quantify vulnerabilities and risks in the region. The Lower Mainland encompasses an extremely complex biophysical, social and economic system. Completing a comprehensive, detailed assessment that fully characterizes the complexity and interdependencies will require a sustained effort that is beyond the scope of this preliminary overview. For example, other losses typically considered in flood risk assessments, such as loss of life, environmental losses and cultural/historic losses could not be assessed. Furthermore, increasing flood flows and rising ocean levels will contribute significantly to riverine and coastal erosion. However, damages caused by erosion or loss of land due to coastal squeeze were not considered.

## 1.3 Project Area

The Lower Mainland region for this project (Figure 1) encompasses the communities of Squamish, Lions Bay, West Vancouver, City of North Vancouver, District of North Vancouver, Port Moody, Anmore, Belcarra, Vancouver, Burnaby, New Westminster, Richmond, Delta, Surrey, White Rock, Coquitlam, Port Coquitlam, Pitt Meadows, Maple Ridge, City of Langley, Township of Langley, Mission, Harrison Hot Springs, Kent, Abbotsford, Chilliwack, Hope, and unincorporated areas of the Fraser Valley Regional District downstream of Hope. As of 2015, there are 90 reserves and treaty lands in the project area belonging to nearly 30 First Nations. One-third of the reserves are not subject to inundation; the remaining two-thirds (61 reserves, affecting 26 First Nations) are vulnerable. The total population of the Lower Mainland area is in the order of 2.8 million with about half a million or more living in potentially flood-prone areas.

In addition to coastal and Fraser River flooding, portions of the region are exposed to flooding from several other major rivers such as the Coquihalla, Harrison, Chilliwack, Nooksack, Coquitlam, Serpentine/ Nicomekl and Squamish Rivers. Flooding from these rivers, other streams and local run-off were not considered in this project.

The total Fraser River drainage area is close to 250,000 km$^2$. From Hope, at the upstream end of the Fraser Valley, to Mission some 80 km downstream, the Fraser River has a gravel bed channel. For the lower 85 km from Mission downstream to the ocean outlets, the river gradient reduces and the channel has a sand bed. River characteristics, flood profiles and freshet flooding was described by NHC (2006, 2008a, 2008b, 2008c, 2009, 2014, 2015b).

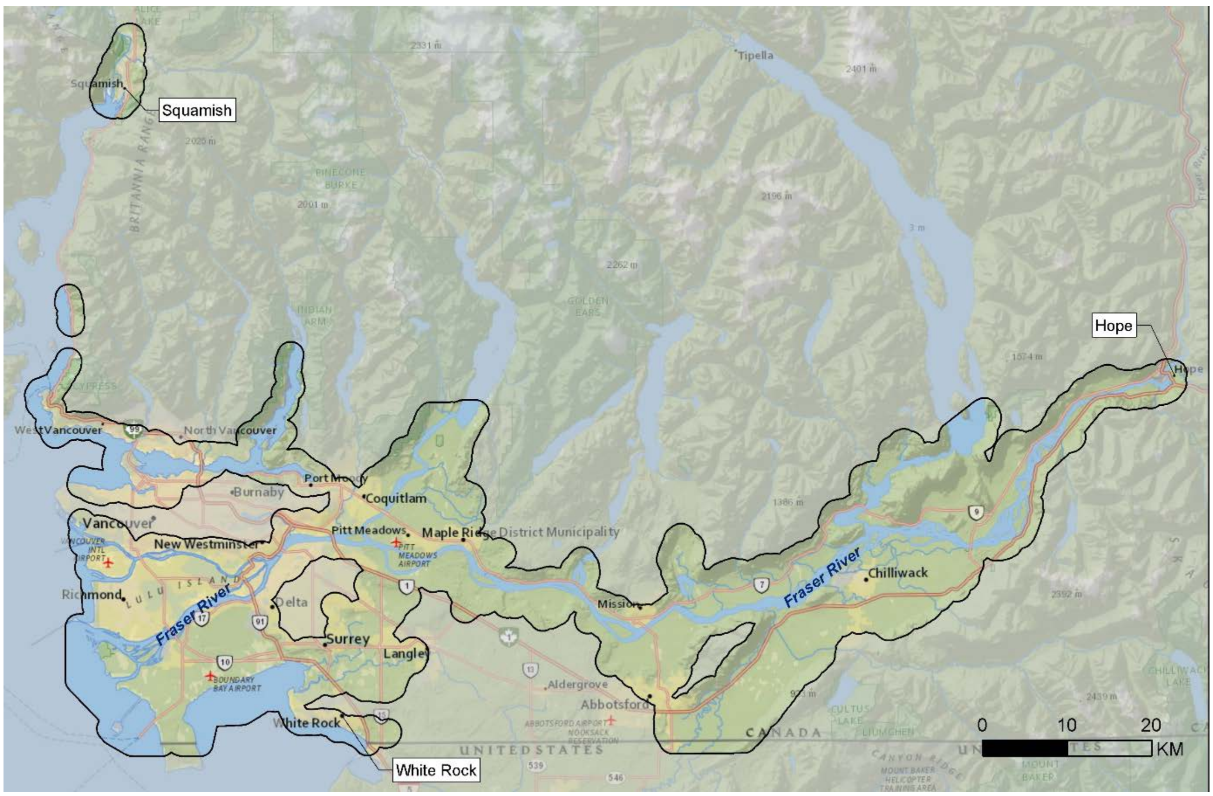


**Figure 1. Project Area**

The area includes a total of 74 dikes, as managed by 35 diking authorities, that extend for over 500 km, comprising about half of the total length of dikes in BC.

Most of the Fraser River dikes were built to design criteria developed in the 1960's and 1970's by the Fraser River Flood Control Program. The Program used a design profile established in 1969 based on extrapolated historic staff gauge readings and high watermarks from 1894 (flood of record) and 1948 (second largest flood on record). Hydraulic modelling by NHC (2006, 2008a) showed that the present design flood levels would be up to 1 m higher in some areas, assuming that flood flows are confined by dikes.

The Fraser River Flood Control Program also developed design criteria for sea dikes in the early 1970's which are now considered inadequate to address projected sea level rise. The Province has recently released sea dike guidelines and is encouraging raising of sea dikes through Dike Maintenance Act applications. At present there are no mandatory standards nor a requirement to raise dikes for sea level rise. Dikes upgraded under the Fraser River Flood Control Program or under more recent funding programs have generally had geotechnical investigations and design. However, many other dikes have had insufficient assessment. As seismic design guidelines have only been in place for a few years, many dikes have not been assessed/designed for seismic stability.

At present, the dikes generally do not meet current provincial standards and none fully meet or exceed the standards. The reasons for this are twofold: 1) recent research and numerical flood modelling have resulted in more accurate but also higher design flood levels; and, 2) structural and geotechnical design criteria have become more stringent over time. Upgrading the dikes to meet the updated standards is costly, particularly where major land acquisitions would be required. There is evidence that the majority of diking systems in the Lower Mainland would not protect against the two coastal and two Fraser River flood scenarios analyzed by this project. This is a key assumption of the project.

More detail on diking is provided in the Project 3 summary report for BC MFLNRO (NHC, 2015b).

# 2 METHODOLOGY, ASSUMPTIONS AND DATA SOURCES

## 2.1 Overview

The project includes the following components:

- Assessment of coastal and Fraser River flood hazards in the region for four flood scenarios (described in Section 3).
- Vulnerability assessment of development within potentially flooded areas (Section 4).
- Estimation of economic losses from damage to residential, commercial and industrial development; agricultural lands; from transportation disruptions; and potential losses from damaged infrastructure (Section 5).
- A summary of the limitations to the present project and an outline of the future work required to provide more detailed information (Section 6).

## 2.2 Coastal and Fraser River Flood Hazards

### 2.2.1 Types of Flood Hazards

Two types of flood hazards were addressed in this project:

- Coastal flooding due to high winter storms combined with high tides.
- Fraser River freshet flooding which typically occurs in May-June during periods of high runoff generated from snowmelt and rainfall in the basin.

Some portions of the project area are subject to both types of hazards (for example Richmond, Delta, Surrey and New Westminster).

### 2.2.2 Flood Scenarios

Project 1 recommended four flood scenarios for this present project (Table 1). The coastal flood levels (Scenario A and B) represent an extreme tide level combined with a winter storm, typically lasting a few days, and applies to the entire coastal area from Squamish to White Rock. The values include an allowance of 0.6 m to account for uncertainties from local conditions such as wave set-up effects, datum adjustments, uplift and subsidence (KWL, 2015). Actual wave heights will vary considerably depending on wind exposure and shoreline geometry. For this project, an estimate of the present day 1:500 Annual Exceedance Probability was used for both scenario A (present) and B (year 2100). The intensity and frequency of storms may increase in the future as a result of a changing climate. However, there is much uncertainty about this aspect of future flood scenarios and assessing this was not within the scope of this project.

**Table 1. Adopted Flood Scenarios**

| Scenario | Hazard Type | Time Period | Comment |
|---|---|---|---|
| **A** | Coastal | Present | 1:500 AEP ocean level = 3.4 m. |
| **B** | Coastal | Future (2100) | 1:500 AEP ocean level = 4.4 m. |
| **C** | Fraser Freshet | Present | Approximate 1:500 AEP Fraser flood (recurrence of 1894 flood of record (peak flow of 17,000 $m^3/s$ at Hope). |
| **D** | Fraser Freshet | Future (2100) | 1:500 AEP flood + adopted climate change flow increase and 1 m sea level rise (peak flow of 19,900 $m^3/s$ at Hope). |

Scenario B represents the adopted coastal flood condition in the year 2100 and incorporates a 1 m sea level rise based on BC MFLNROs adopted guidelines (BC Ministry of Environment, 2011). Predictions of future sea level rise vary widely; recent studies reported values ranging between 0.4 m to 1.2 m by the year 2100 (James, 2015, James et al., 2014, Thomson et al., 2008).

The coastal flood scenarios were applied to all coastal communities, including areas along the Fraser River to the Pitt Meadows/Maple Ridge and Surrey/Langley boundaries. The communities assumed to be affected by the coastal scenarios are: Squamish, Lions Bay, West Vancouver, City of North Vancouver, District of North Vancouver, Port Moody, Anmore, Belcarra, Vancouver, Burnaby, New Westminster, Richmond, Delta, Surrey, Barnston Island, White Rock, Coquitlam, Port Coquitlam, and Pitt Meadows. These communities were identified by mapping land at elevations of 4.4 m GSC or lower based on Canadian Digital Elevation Model medium resolution topographic data.

The Fraser River flood scenario (Scenario C) is equivalent to the 1894 flood of record (peak flow of 17,000 $m^3/s$ at Hope), with a return period of approximately 500 years (0.2% AEP) and current sea levels. Scenario D represents a 500 year Fraser River flood in the year 2100 by applying a 17% increase in the flood discharge (peak flow of 19,900 $m^3/s$ at Hope) and a 1 m sea level rise. Scenario D was based on preliminary studies undertaken by the Pacific Climate Impacts Consortium as reported in Murdock and Spittlehouse (2011) and NHC (2015b). The PCIC study projected that extreme flood flows on the Fraser River are expected to increase due to: i) more rapid snowmelt in the spring; and, ii) occurrence of heavy rainfall overlapping the snowmelt season. The hydrologic projections are approximate only and should be considered plausible representations of the future, given the best current scientific information available.

The two riverine flood scenarios were applied to all Lower Mainland communities along the Fraser River: Vancouver, Burnaby, New Westminster, Richmond, Delta, Surrey, Barnston Island, Coquitlam, Port Coquitlam, Pitt Meadows, Maple Ridge, City of Langley, Township of Langley, Mission, Harrison Hot Springs, Kent, Abbotsford, Chilliwack, Hope, and unincorporated areas of the Fraser Valley Regional District to Hope (including several First Nations' Reserves). Municipalities such as Vancouver, Richmond and Surrey that have both coastal and riverine shorelines, only had flood levels from the Fraser River applied under the riverine scenarios.

The Fraser River flood levels were based on previous one dimensional hydraulic modelling of the Lower Fraser River (NHC 2006 and 2008a and MFLNRO 2014). The levels were computed assuming all flow was confined within the existing dikes (no spills or breaches were represented). Further information on the flood hazard assessment is described in Section 3.

Flood durations vary considerably. For example, the 1894 Fraser flood peak lasted about two weeks whereas the 1948 flood had a peak duration of about four weeks. For the present project, flood levels were based on steady-flow modelling and were projected horizontally across the floodplain, with flood durations having no impact on flood extents or depths.

A flood event typically has three phases: 1) the inundation phase when inhabitants are evacuated and commercial activity in the affected area is at a stand-still; 2) the active recovery phase when floodwaters are drained, salvageable buildings cleaned and transportation routes not requiring repair are re-opened; and, 3) the reconstruction phase when replacement buildings are constructed and permanent dike/infrastructure repairs are undertaken. The assumed durations of each phase affect economic loss estimates as discussed in Section 5.

### 2.2.3 Vulnerability Assessment

Broadly defined, vulnerability means "the potential for loss" (Hebb and Mortsch, 2007) or more specifically as the degree of loss to a given element or component resulting from the occurrence of a natural disaster such as a flood. Vulnerability is a measure of a tendency of a community or system to suffer damage during an extreme event (De Wrachien et al., 2008).

Vulnerability was assessed for residential, commercial, industrial properties and agricultural lands. Vulnerabilities also include critical facilities such as: BC Hydro substations; BC's transmission system; railways; highways; airports; ports; municipal services; emergency response facilities and hospitals; cell towers; as well as public education and communication. To provide a preliminary assessment of these types of vulnerabilities, an inventory of flood prone assets was prepared. Information sources consisted of data compiled by FBC, various municipalities/districts, First Nations/ Aboriginal Affairs and Northern Development Canada, BC Ministry of Transportation and Infrastructure, DataBC and others. Qualitative disruption scenarios were developed to supplement the quantitative assessment of vulnerability.

### 2.2.4 Economic Losses

Economic losses from a flood include direct and indirect losses. The direct losses originate from the direct damage to residences, businesses, infrastructure and agriculture. Indirect losses are considerably more difficult to assess and include costs incurred from business shut-downs and rebuilding, disruptions to major transportation arteries and other cascading effects, such as wage losses.

Following a careful evaluation of the available tools for assessing flood losses, Hazus-MH 2.1 was selected for the flood loss analysis in this project. Hazus is a standardized methodology for estimating potential losses from earthquakes, floods and hurricanes. It uses GIS technology to estimate physical, economic and social impacts of disasters.[3] Hazus was developed by the US Federal Emergency Management Agency (FEMA), is widely used in the US, and is freely distributed. Over the past few years, Natural Resources Canada (NRCan) has worked with FEMA to adapt Hazus for use in Canada.[4] The first non-beta version of the Hazus-MH 2.1 Canadian Flood Module was first made available by NRCan in late summer of 2014, and officially released in November 2015. The software has a number of limitations and the output generally needs to be supplemented with additional assessment. For instance, direct losses from the agricultural sector had to be estimated based on the Provincial Agricultural Land Use Inventory data. However, it was still considered the most viable tool for an overview-level assessment, primarily because its building inventory is tied to census data.

[3] US Federal Emergency Management Agency (FEMA) Hazus, http://www.fema.gov/Hazus

[4] Hazus Canada, http://Hazuscanada.ca/node/134

NHC consulted NRCan regarding apparent Hazus software shortcomings and their assistance with developing workable solutions is acknowledged. Detailed information on the Hazus analysis are presented in Section 5 and in Appendix C.

An important aspect of the flood threat is the potential for disruption of road, rail and air infrastructure. A great majority of the movement of goods and services into and out of the Lower Mainland region relies on rail and road networks, numerous port facilities and airports, as well as the integrity of Fraser River and sea dike systems in the Lower Mainland, which protect this transportation network. Disruption to the flow of goods into and out of Port Metro Vancouver and Greater Vancouver due to either a Fraser River or coastal flood could have serious consequences on the regional, provincial and national economy, with very significant direct and indirect losses. These losses would include losses by the private sector as well as local, provincial and federal governments as a consequence of reductions in industrial and commercial activity coupled with wage and salary losses and consequent declines in taxes and other government revenues.

Whereas the US version of Hazus has an Indirect Economic Loss Module (IELM), a comparable module is presently not available in the Canadian version. However, the Canadian version does estimate some indirect losses associated with building damage.

Within the Hazus software, a range of flood restoration durations are assigned based on building occupancy, flood depth and the building location within the floodplain. Default values range from 1 to 33 months and were not adjusted for the Lower Mainland area.

BC Stats was consulted to estimate flood impacts specific to the BC economy. BC Stats used the British Columbia Input-Output model (BCIOM) to estimate employment impacts and impacts on suppliers based on the Hazus and agricultural loss estimates. The information received from BC Stats is included in Appendix E.

## 2.3 Assumptions

A number of simplifying assumptions were necessary to meet the scope of this preliminary planning level project that limit the quality and accuracy of the quantitative predictions. Some assumptions are likely to overestimate losses, whereas others may underestimate them. Key limitations that should be kept in mind while reviewing the results relate to:

- The accuracy of the flood extents and depths for the four scenarios investigated. Dikes were assumed to be ineffective yet river flood levels correspond to flows being confined between dikes. Floodplains are completely inundated but there is no corresponding attenuation of flood hydrographs. Simplified flood isolines were used to project water levels across the floodplain, potential ponding behind dikes was not considered. Flooding from tributaries was disregarded. The coastal scenarios include a 0.6 m wave allowance which could be exceeded depending on the shore geometry and exposure. All lands behind dikes below the adopted flood level were assumed to be submerged, which may not be the case. Most of these assumptions would likely lead to overestimation of losses.

- The accuracy of the base topography. Additional uncertainty associated with the flood extent and depth mapping arise from the limited accuracy of the base topography used. The mapping should not be used as official floodplain mapping, which would designate floodplains; however the maps are useful for illustrating the approximate extent and depth of flooding as well as the estimated impacts. Flow velocities were disregarded. The mapping may overestimate or underestimate losses.
- The approximate nature of the Hazus loss estimates. A simplified, non-customized modelling approach was adopted. Default US depth-damage curves, restoration durations and building replacement costs were used and the results were multiplied by an approximate factor to account for conditions in BC's Lower Mainland. (The default depth-damage curves are based on historical post-flood surveys and compiled from the following areas in the US: Chicago, Galveston, New Orleans, New York, Philadelphia, and St. Paul.) Based on Lower Mainland building typologies, these default curves likely underestimate losses.
- Potential inaccuracies in the agricultural loss estimates. Agricultural losses were estimated outside of the Hazus model. Agricultural production was grouped into a few different categories to simplify the analysis. It was assumed that most livestock would be moved to higher ground prior to an impending flood. The impact of climate change was likely underestimated because the increased flood depths associated with future flood scenarios were not considered in the agricultural component.
- Flood durations. Flood durations were not specified in Project 1 (KWL 2015). Hazus default restoration times were applied and it is unclear if these values overestimate or underestimate losses for structures in the Lower Mainland. Transportation disruption losses were estimated by multiplying a daily loss value by assumed durations of two weeks for coastal flooding and four weeks for riverine flooding. The time required for major infrastructure reconstruction would be significantly longer but it was assumed that alternate routes would be developed as necessary following the two week/ 4 week disruptions. Agricultural losses were first estimated based on inundation periods of two days and two weeks. The losses were subsequently factored to reflect durations exceeding two weeks, a period critical for most agricultural production.
- Only a subset of key infrastructure and other structures was considered in the vulnerability assessment and it was not possible to accurately estimate the damage to these. (Direct losses related to linear infrastructure are not calculated within the present Canadian version of Hazus, because there are no depth-damage curves for infrastructure such as railways, highways, pipelines, and power lines.) Only rough loss estimates for dikes, bridges, specialized equipment within ports, transformers and other types of infrastructure were included. A much more detailed, localized assessment would be required to assess replacement costs. The loss estimates likely correspond to underestimations.

- The climate change scenarios are approximate projections. Loss of land due to erosion or sea level rise was not considered, nor was the increased frequency of flooding. The projections would result in underestimation.
- For the two future flood scenarios (year 2100), no change in land use, population or development was assumed, likely resulting in significant underestimation.
- Loss of life, environmental, cultural and historic losses were not quantified.
- The Input-Output (I/O) model of the British Columbia economy used by BC Stats to estimate specific impacts to the BC Economy involves linear relationships and gradual changes in economic relationships over time. The modelling was based on the Hazus and agricultural loss estimates. Any inaccuracies in these estimates would result in inaccuracies in the I/O modelling.

## 2.4 Data Sources and Data Gaps

### 2.4.1 Data Summaries

A spatial Geographic Information System (GIS) tool was developed to identify the areas that are vulnerable to flooding under the selected scenarios. To identify these areas and undertake a flood vulnerability assessment, a large amount of background information had to be compiled, such as topographic data for flood-prone areas, asset inventory data and a variety of mapping products. NHC, with FBC's assistance, contacted a number of agencies, including all of the project partner municipalities, to request topographic and asset inventory data. Following the start-up meeting with the project Advisory Committee in December, 2014, initial data requests were sent. Agencies contacted are summarized in Appendix A – Table A1, with data acquired listed in Table A2.

### 2.4.2 Topographic Data

Topographic data was acquired from numerous sources including local, provincial and federal government data sources as well as a Crown Corporation, and several regional entities. Several datasets were processed, thinned, and integrated into a digital elevation model of the surface elevation of the lowlands across the Lower Mainland region. The data sources are summarized in Table C2 (Appendix C).

### 2.4.3 Asset Inventory Data

Asset inventory data acquired for this project includes: road networks and emergency road networks; railway lines, including West Coast Express; Sky Train lines; major bridges; airports; port lands; ferry terminals, Sea Bus and bus terminals; BC Hydro substations and transmission lines; trunk water and sewer infrastructure; fire, ambulance and police stations; emergency operations centres; hospitals; schools and post-secondary institutions; municipal, regional district and Indian Reserve boundaries.

The building stock and demographic (i.e. population) information included within the Hazus analysis (Section 5) is based on aggregated data derived from the Dun and Bradstreet general building inventory and the Stats Canada 2011 Population Census respectively. These national datasets were adapted for use in Hazus by NRCan.

Other data was obtained from individual municipalities or other agencies but not included in the analysis because coverage of the project area was not complete. These data are also listed in Table A2 (Appendix A) and included in the final data deliverables.

### 2.4.4 Data Gaps

Detailed topographic data was obtained for all areas except for parts of Burnaby, New Westminster, Anmore, Belcarra, Mission, Chilliwack and Hope. In some cases, gaps were not considered significant because they were not large, heavily populated areas within the floodplain. FBC, BC Hydro and Port Metro Vancouver (PMV) provided topographic data that filled in some of the gaps. A topographic data gap in New Westminster was filled with data from the Canadian Digital Elevation Model dataset from Geogratis; this dataset has a lower resolution and accuracy than other topographic data used for this project.

The following data sets were not included in the asset inventory because available data did not provide consistent coverage across the project area, or because no data was available: municipal water and sewer infrastructure; firefighting water networks; cell towers; fibre optic networks; oil and gas pipelines and infrastructure; energy facilities; contaminated sites and waste incinerators; municipal works yards; day-care centres and care homes; community centres. There may be a future opportunity to integrate more detailed local building inventories to estimate more accurate impacts from flood scenarios.

### 2.4.5 GIS and Mapping Products

The following GIS and map products were created:

- Digital Elevation Model (DEM) files. These are five-metre or ten-metre resolution DEM raster files created by NHC for the analysis, separated by municipality or other sub-region.
- An ArcGIS file geodatabase containing the asset inventory data described above.
- Documentation of all data sets created (Table A3 in Appendix A).
- Data sharing agreements signed with data providers.

Digital deliverables include all original topographic and asset inventory data received by NHC, including datasets that were not used for the analysis due to incomplete coverage. All GIS data deliverables were provided in ArcGIS 10.2 compatible format with the final project deliverables.

# 3 LOWER MAINLAND FLOOD HAZARDS

## 3.1 Coastal Flooding

### 3.1.1 Historic Coastal Floods

Coastal flood events in the Lower Mainland have typically occurred when storm surge events and king tides coincide. A storm surge is an increase in sea level due to atmospheric pressure and large scale wind stresses, resulting in sea level increases of up to about 1 m in the Strait of Georgia. A king tide is a term commonly used to describe extreme high tide events that happen seasonally, but are typically highest during the winter months.

The most recent coastal flood threats occurred in December of 2012, 2014 and early 2016, when large storm surges nearly coincided with king tide events, resulting in some shoreline flooding. A more notable event was the February 2006 Boundary Bay storm in Delta, which caused extensive flooding in the Beach Grove and Boundary Bay village areas, as well as damage and debris deposition in agricultural areas.

In December 1982, a maximum ocean level of 2.6 m GSC was recorded at the long-term Point Atkinson tidal gauge in West Vancouver. The year 1982 was a strong El Niño year with warmer than usual ocean temperatures, resulting in increased ocean water volumes. The 1982 December king tide coincided with an extreme tidal surge caused by a large low pressure system. The event caused extensive damage to ocean front properties around the Lower Mainland. The 1982 storm created extensive damage to Crescent Beach, King George Highway and the farmlands in Boundary Bay. Millions of dollars were spent on recovery efforts and repairing failed infrastructure and associated flood damages. The storm also resulted in a dike breach at Westham Island in Delta, causing inundation of farmland. However, the dike was repaired prior to the next high tide and no damage was caused to nearby housing.

### 3.1.2 Adopted Coastal Flood Scenarios

Table 1 in Section 2.2.2 summarizes the two coastal flood scenarios that were assessed in this project:

- <u>Scenario A</u> – a 1 in 500 AEP still-water ocean state with a current sea level of 3.40 m GSC.
- <u>Scenario B</u> – a 1 in 500 AEP still-water ocean state with 1 m sea level rise representing year 2100 conditions of 4.40 m GSC.

### 3.1.3 Status of Existing Coastal Flood Dikes

According to Project 3 (NHC, 2015b), the average rating of dikes protecting the Lower Mainland from coastal flooding (primarily in Richmond, Surrey, Delta and Squamish) ranges from 'fair to poor' and from 'poor to unacceptable'. The average rating is based on broad evaluation criteria of the dikes such as: crest elevation relative to design flood level ; geometry; geotechnical stability; erosion protection measures; vegetation/animal control; encroachments; appurtenant structures; and the administrative arrangements established for the structure. It should be noted that in some cases such as dike crest elevation and seismic considerations, dike standards and guidelines have increased in recent years (based on more current hydraulic modeling between 2006 and 2014); however, inadequate funds have been available to upgrade dikes to meet updated standards.

### 3.1.4 Assumed Coastal Flooding Condition

In this project the designated flood level from Scenarios A and B were applied to each area, assuming a horizontal water surface. All land below the designated flood level was assumed inundated. It was also assumed that all dikes in the entire region would be ineffective and that submergence would be near-instantaneous. Significantly more effort would be required to perform area-specific dike breach analyses and detailed risk assessments.

Earth embankments have different possible modes of failure with overtopping, erosion and piping/seepage being the most common. In most coastal locations, it would likely take a number of hours before an entire lowland area became inundated. During a falling tide, flow would move through a breach in the opposite direction, partially draining water from the floodplain. Accurate assessment of the inundation would require detailed 2D modelling and the present overview level work is not intended to evaluate specific breach scenarios.

## 3.2 Fraser River Flooding

### 3.2.1 Historic Fraser River Floods

The Fraser River is the largest river on the west coast of Canada, draining approximately one-quarter of British Columbia. Fraser River flood flows typically occur in May or June and the magnitude of the peak flow is a function of the basin snowpack and the springtime weather: sudden large and sustained temperature increases and significant precipitation can result in high flows. There have been two major floods since European settlement, in 1894 and 1948. NHC (2008b, 2015b) estimated that these floods roughly correspond to return periods of 500 and 200 years respectively. The ten highest observed flows at Hope are:

| Year | Flow at Hope ($m^3/s$) |
|---|---|
| 1894 | 17,000 |
| 1948 | 15,200 |
| 1972 | 13,000 |
| 1950 | 12,600 |
| 2012 | 11,900 |
| 1964 | 11,600 |
| 1955 | 11,500 |
| 1997 | 11,400 |
| 2007 | 11,200 |
| 1999 | 11,100 |

The 1972 flood had a return period of less than 50 years. By careful operation of the Kenney Dam and Bridge Lake reservoirs, the peak flow at Hope was successfully reduced by about 10% and extensive flooding was avoided. Dike seepage problems were reported.

The four highest flood level hydrographs at Mission are plotted in Figure 2 and compared with the moderately high flow year of 2002 (maximum flow of 10,800 $m^3/s$). In 1950, due to large local inflows between Hope and Mission, water levels at Mission were higher than those in 1972, although the 1950 peak flow at Hope was lower. Some flooding took place in 1950; 100-150 homes in un-diked areas were damaged (Septer, 2000).

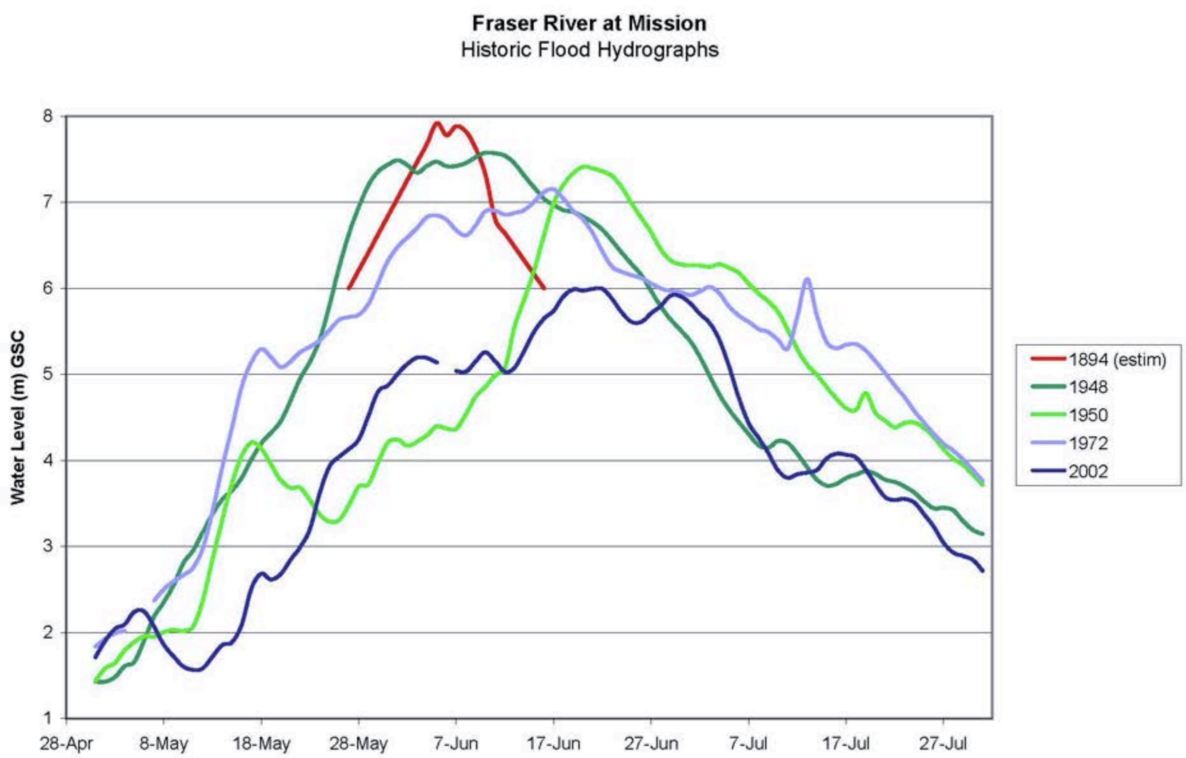


**Figure 2: Fraser River Historic Flood Hydrographs at Mission (NHC 2006)**

### 3.2.2 Adopted Fraser River Flood Scenarios

Table 1 in Section 2.2.2 summarizes the two Fraser River flood scenarios that were assessed in this project:

- Scenario C – The Fraser River design flood (equivalent to the 1894 flood of record, with an approximate return period of 500 years) and current sea levels.
- Scenario D – The 1 in 500 AEP Fraser River flood, incorporating a “moderate” climate change flow increase for year 2100 and a 1 m sea level rise.

### 3.2.3 Status of Existing Flood Protection

Flood protection works along the Fraser River began as early as the 1880's. However, only limited diking was in place by 1894 and the few structures that had been built largely failed. The entire floodplain was inundated, storing significant volumes of water. At Mission, river water level records date back to the 1870's and the 1894 maximum flood level was reported to be 7.92 m GSC. The corresponding 1948 level was 7.61 m GSC. By 1948, a more extensive system of dikes had been built, but a number of structures, such as those in Chilliwack, Kent, Abbotsford, Surrey and at Nicomen and Barnston Islands failed during the 1948 flood event.

Major repairs and upgrades of the diking system occurred throughout the 1950s, 1960s and 1970s under the joint Federal-Provincial Flood Control Program (Fraser River Board, 1963, Sewell, 1965). This program was curtailed in the 1990s. In 2015, NHC conducted a review of the status of Fraser River dikes (NHC, 2015b). Although some Fraser River dikes were rated as 'good to fair', most dikes fell in the 'fair to poor' category with some classified as 'poor to unacceptable'. Consequently, it is likely that a number of dikes would not withstand a flood similar to Scenario C, let alone a future event such as Scenario D.

### 3.2.4 Assumed Flooding Conditions

The existing hydraulic modelling of the Lower Fraser River assumed the flood flows were contained by the existing dikes. This assumption is conservative when applying the computed water levels to assess potential floodplain inundation. During an actual flood that breached the diking system, water would be conveyed and stored on the floodplain, reducing the water levels. This confinement effect from dikes has been observed on many rivers and explains why the observed flood levels in 1894 were often substantially lower than under the current diked conditions.

In most locations, river flood levels were projected perpendicularly across the floodplain, except in areas with available flood mapping, where the mapped isolines were used to guide flood level projections. The presence of diking was ignored and flood levels were directly projected across the dikes to the landside. In most cases, the approach is conservative because in the event of a dike breach, flood levels on the landside would generally be lower than in the river channel. However, in some situations, ponding behind dikes could actually result in higher flood levels.

The assessment disregarded flooding from Fraser River tributaries, other watersheds and local run-off.

## 3.3 Inundation Extents and Flood Depths

Map 1 through Map 15 show sample maps of the flood extent and flood depths generated for the four scenarios throughout the region.

The water level surfaces were developed in GIS for each flood scenario. For the two coastal flood scenarios, a single horizontal water level surface of 3.40 m and 4.40 m GSC was established.

Water levels for the Fraser River flood scenarios were available from BC MFLNRO (2014). The projection of flood isolines did not take into account local differences in terrain and the approach and map products are not intended to replace detailed floodplain mapping. For Chilliwack, Kent and Harrison Hot Springs that have available floodplain maps, more detailed water level isolines were created based on the maps and the BC MFLNRO water level profiles (WMC, 2007a and 2007b). Fraser River flood levels were not available upstream of the Highway 1 bridge at Hope and inundation mapping for District of Hope is incomplete.

Flood level ArcGIS TIN surfaces were created for each flood scenario. By subtracting the digital elevation model (DEM) from the flood level surfaces, flood depths were determined. Similarly, flood extent polygons were derived from the flood depth surfaces. In order to facilitate efficient loss estimate analyses, the project area was grouped into ten Sub-Regions, as described in Table 2 and Figure 3.

**Table 2. Summary of Municipalities in Hazus Sub-Regions**

| Sub-Region | Description |
|---|---|
| 1 | Squamish |
| 2 | North Shore (Lions Bay, West Vancouver, North Vancouver City & District) |
| 3 | Port Moody, Anmore, Belcarra |
| 4 | Vancouver, Burnaby, New Westminster |
| 5 | Richmond, Delta |
| 6 | Surrey, White Rock, Barnston Island |
| 7 | Coquitlam, Port Coquitlam, Pitt Meadows, Maple Ridge |
| 8 | Langley City & Township |
| 9 | Mission, Harrison Hot Springs, Kent, unincorporated areas of FVRD north of the Fraser |
| 10 | Abbotsford, Chilliwack, Hope, unincorporated areas of FVRD south of the Fraser |

Limitations associated with the mapping process and end products are outlined in Appendix C.

Specific GIS and map products created included:

- Flood Extent Maps, including GIS files, for each flood scenario (Maps 1 – 12).
- Flood Depth Maps, including GIS files, for each flood scenario. Map 13 is an example Flood Depth Map.
- Large format Flood Extent Maps of the entire region, including Adobe Illustrator files, for use by FBC in developing communication materials (Maps 14 and 15).
- Flood Extent Google Earth KMZ files (separated by Sub-Region).

Digital (PDF) copies of all flood maps and the flood extent KMZ files were included with the final digital deliverables. Since coastal flood levels were applied as far upstream as Pitt Meadows and Surrey, there is an abrupt end in coastal flood depths and extents at the Pitt Meadows/Maple Ridge and Surrey/Langley boundaries.

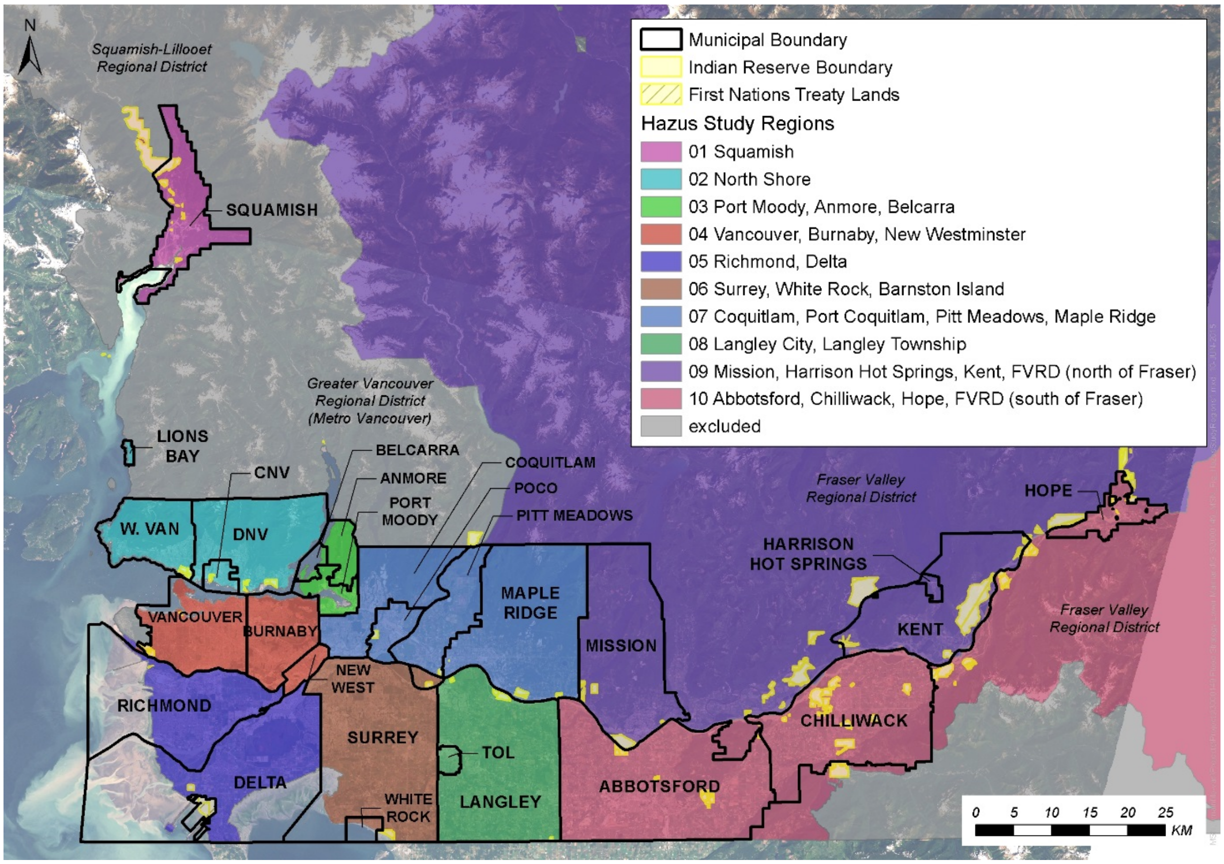


**Figure 3. Map of Sub-Regions for Hazus and Infrastructure Analysis**

# 4 FLOOD VULNERABILITY

## 4.1 Assessment Approach

A number of factors contribute to the overall potential vulnerability of assets in a flood – including water depths (increased depths imply larger renovation/replacement required), velocity (higher speeds, higher damages), wave action (wave energy – waves can be more damaging than still water), and the duration of the flood (including the time-to-peak of a flood). Contamination, sediment and debris can also increase the flood vulnerability, as well the construction type and age of the structures being impacted. Whereas all these factors – in particular, the flood depth – will influence vulnerability, only inundation extents were used in this overview-level assessment to identify the region's flood-vulnerable assets. The limitations and simplifying assumptions associated with the flood extents are summarized in Section 6.

The identification of key vulnerabilities is intended to supplement the broader risk assessment undertaken as described in Section 5. It focussed on First Nations and unique infrastructure elements in the ten sub-regions described in Section 3 and included BC Hydro Infrastructure (e.g. Substations & Transmission Grids), transportation infrastructure (e.g. airports, ports, ferry terminals, railways, highways and rapid transit), emergency services (e.g. police, fire and ambulance first responders and hospitals) as well as other critical assets (e.g. sewage treatment plants, water supplies, schools and universities and key communications such as cell towers).

The framework utilized for the assessment of regional infrastructure vulnerability, included in Appendix B, consists of the following components:

- Brief description of the infrastructure asset.
- General overview of how the infrastructure asset is vulnerable to flooding.
- Identification of the infrastructure vulnerability by sub-region under each of the four scenarios.
- Evaluation of the regional vulnerability of the infrastructure asset.

The following sections summarize key findings of the vulnerability assessment as provided by the Arlington Group.

For reference refer to the Flood Inundation Maps in the map section of the report.

Vulnerable residential, commercial and industrial development is investigated in Section 5.2 and the vulnerability of agricultural lands in Section 5.3.

## 4.2 First Nations

Close to 30 First Nations have reserve or treaty lands within the project area. A large majority have reserve or treaty lands that are vulnerable under one or more scenarios. Six First Nations are affected under Scenarios A and B (Katzie, Musqueam, Kwikwetlem, Semiahmoo, Squamish, Tsawwassen), and twenty-six under both Scenarios C and D (Aitcheliz, Chawathil, Cheam, Katzie, Leq'a:mel, Matsqui, Musqueam, Peters, Kwantlen, Kwaw-kwaw-Apilt, Kwikwetlem, Scowlitz, Seabird Island, Semiahmoo, Shxw'ow'hamel, Skawahlook, Skowkale, Skwah, Skway, Squamish, Squiala, Sts'ailes, Sema:th, Tsawwassen, Yakweakwioose, Yale). The project did not include a detailed assessment of First Nations' vulnerability and individual First Nations were not contacted.

The review of First Nation vulnerability is focused on infrastructure based on previous information (NHC, 2000). Where possible, the information was supplemented with Google Map Streetview data and knowledge of the research team members. Assets include the presence of roads, buildings, built-form community assets and where possible, transmission corridor, and sewer & water servicing information.

Buildings on First Nations lands are included within the Hazus General Building Stock. Social and cultural vulnerability was not included.

As of 2015, there are 90 reserves and treaty lands in the project area. One-third of the reserves and treaty lands are not subject to inundation; the remaining two-thirds (61 reserves and treaty lands, affecting 26 First Nations) are vulnerable. Under Scenario A, 12 First Nations' reserves and treaty lands have some inundation, increasing to 13 under Scenario B. Under Scenario C, 54 First Nations' reserves and treaty lands undergo some inundation, increasing to 56 under Scenario D (Table 3). Four times as many First Nations are impacted in Scenarios C and D compared to Scenarios A and B – largely due to the majority of First Nations' reserves and treaty lands being located along the Fraser River (NHC, 2000). See Appendix B, Annex C for details on the flood vulnerability of First Nations including multiple reserves.

**Table 3. Number of Reserves Predicted to Experience Various Degrees of inundation**

| Scenario | Limited Inundation | Partially Inundated | Substantially Inundated | Completely Inundated | Total with Inundation | No Inundation |
|---|---|---|---|---|---|---|
| A | 5.0 | 5.0 | 0.5 | 1.5 | 12.0 | 8.0 |
| B | 4.0 | 5.5 | 1.5 | 2.0 | 13.0 | 7.0 |
| C | 11.0 | 8.0 | 7.5 | 27.5 | 54.0 | 7.0 |
| D | 9.0 | 9.5 | 8.0 | 29.5 | 56.0 | 5.0 |

## 4.3 Critical Infrastructure

### 4.3.1 Hydro Substations

Substations in nearly all regions are exposed to some flood risk. Substantial flood damage to electrical substations would result in loss of service for an undetermined amount of time, resulting in additional indirect losses that have not been estimated in this project. There are 19 BC Hydro substations subject to inundation in Scenario A, 37 in Scenario B, 23 in Scenario C, and 30 in Scenario D. The main difference between coastal flood Scenario A and Scenario B is 1 m of sea level rise (SLR) which nearly doubles the number of vulnerable substations from 20 to 37. Flood vulnerability from the riverine scenarios also increases between Scenarios C and D but to a lesser extent.

Electrical substations subject to flooding in all four Scenarios are concentrated in one region, Region 5 (Richmond and Delta). Most of the remaining substations subject to inundation are in Region 4 (Vancouver, Burnaby and New Westminster). There is one substation in Squamish that is vulnerable to Scenarios A and B.

### 4.3.2 Transmission Grid

Vulnerability is distributed throughout the project area. Seven regions have three or more major transmission lines that traverse areas subject to inundation. While many transmission towers will be exposed to flooding, the sensitivity (i.e. the degree to which the towers and therefore the transmission lines will be at risk) may be very low. Transmission lines will be elevated well above any floodwaters and exposure of the tower foundations to river erosion poses a much greater risk. However, scouring and undermining of transmission towers could occur if in proximity to the river and/or a dike breach.

## 4.4 Transportation Networks

### 4.4.1 Airports

Several airports in the project region are vulnerable to inundation, with Vancouver International Airport (YVR) potentially vulnerable to inundation under all four Scenarios. Its significance far surpasses the cumulative potential impact to regional airports. It should be noted that the dikes surrounding YVR were not included in the BC MFLNRO dike assessment (Project 3) and that their status is not known in detail by the project team. Similarly, the elevation and vulnerability of electrical controls and other key aspects of YVR airport infrastructure is not known. The Abbotsford Airport is essentially the backup facility in the event that YVR is out of operation. Other airports vulnerable to flooding include Chilliwack, Boundary Bay, Pitt Meadows, and the Delta Heritage and Hope Air Parks.

### 4.4.2 Ports and Ferry Terminals

Port facilities subject to inundation under all scenarios are located in Regions 1 to 7. The flood vulnerability will depend on both exposure and sensitivity to inundation. For example the vulnerability of docks is generally low but the location of electric motors in cranes will greatly affect overall vulnerability. Vulnerability may be greater for intermodal yards, railways, highways and other connecting infrastructure. Ferry terminals subject to inundation consist of both Sea Bus terminals and the Tsawwassen ferry terminal. The Horseshoe Bay terminal may be less vulnerable due to its protected location. In addition, a number of large and smaller marine facilities are susceptible to flooding.

### 4.4.3 Railways

All three Class 1 railways (CN Rail, CP Rail and BNSF) are vulnerable to inundation under all scenarios, including CN Rail in Squamish. The Southern Railway of BC shortline is also vulnerable to flood-related disruption. This could prevent all rail freight from entering or leaving the Lower Mainland. CN Rail has an intermodal yard in Surrey, which is in the Fraser River Floodplain. This area has no dike protection, therefore, there could be potential losses to freight / cargo shipments. CP Rail has intermodal and marshalling yards in Port Coquitlam and Pitt Meadows; both are vulnerable to inundation under three scenarios. The loss or reduction of freight services would also impact supply chains causing a cascading effect. Rail passenger service is also vulnerable under all scenarios, including the West Coast Express within the Lower Mainland and passenger service beyond the region including Via Rail in Canada and Amtrak with service to and from the US.

Major bridges potentially vulnerable to scour damage include the Mission Railway Bridge and CN Rail Bridge at New Westminster. Repair or re-construction of the bridges would be associated with lengthy service disruptions.

### 4.4.4 Critical Regional Routes and Other Arterial Highways

Both Provincial highways north and south of the Fraser River are subject to inundation along several sections. Highway 1 is of particular importance. Multiple sections of Highway 99 are subject to inundation between the Lower Mainland and Squamish and south to the US border as well as highways 10 and 15. Other critical routes subject to inundation within the region include Knight Street, Marine Way, Boundary Road, Highway 91A, Brunette Ave, Stewardson Way/Front Street, King George Boulevard, Highway 7, Highway 7B and the South Fraser Perimeter Road (SFPR). The SFPR is particularly important as a truck route to Port Metro Vancouver container and bulk loading facilities in Roberts Bank. The Paulo Bridge is potentially vulnerable to damage from scour. It should be noted that the definition of "critical routes" in this report does not necessarily match Emergency Management BC's definition.

Numerous municipal arterial roads are also subject to inundation.

### 4.4.5 Rapid Transit

The Expo Line and Millennium Sky Train lines may be subject to inundation in Vancouver. Most of the lines are elevated above grade with the exception of some areas west of the Commercial-Broadway Sky Train station. The elevation of electrical equipment is of critical concern as many power sources and/or electrical equipment are at grade and could be damaged by floodwaters in some areas. The loss of service in any part of a Sky Train line will impact its overall passenger capacity due to switching and other considerations. In addition, the Canada Line is subject to inundation in parts of Richmond where it is at grade.

## 4.5 Municipal Services

All wastewater treatment facilities in Metro Vancouver and the Fraser Valley Regional District are subject to inundation under two or more scenarios. These facilities serve virtually all of Regions 2 to 10 including large areas that are not subject to inundation. Their regional flood vulnerability is considered high as the facilities serve virtually the entire urban population base.

## 4.6 Essential Facilities

### 4.6.1 Emergency Services

Most Emergency Operations Centres (EOCs) are not subject to inundation under any scenario. However, two EOCs are subject to inundation under all scenarios and one of these EOCs has a backup location not subject to inundation under any scenario. Two additional EOCs are subject to inundation under most but not all scenarios.

Police, fire and ambulance emergency services vulnerable to inundation are primarily located in Regions 5 (Richmond and Delta) and Region 10 (Chilliwack and Abbotsford). A very high proportion of emergency services are subject to inundation in these municipalities.

Under Scenario A, 6 police stations, 11 fire halls and 6 ambulance stations are subject to inundation. Under Scenario B, 6 police stations, 12 fire halls and 6 ambulance stations are subject to inundation. Under Scenario C, 6 police stations, 19 fire halls and 6 ambulance stations are subject to inundation. Under Scenario D, 11 police stations, 20 fire halls and 6 ambulance stations are subject to inundation.

### 4.6.2 Health Providers

Hospitals in Regions 5 (Delta and Richmond) are subject to inundation under all scenarios and Region 10 (Chilliwack) under both riverine scenarios. In addition, the Colony Farm Forensic Psychiatric Hospital in Region 7 is subject to inundation under all scenarios. The proposed new location for the St. Paul's Hospital near the Main Street-Science World Sky Train station falls within the floodplain according to the City of Vancouver flood risk assessment (NHC, 2015a).

### 4.6.3 Schools

The number of schools subject to inundation under all scenarios is large. However, they are heavily concentrated in two regions. A majority of schools under all scenarios are located in Region 5 (Richmond and Delta). Most of the remaining schools subject to inundation are located in Region 10 (primarily Chilliwack, but also Abbotsford). Schools in these two regions represent 88% of all schools vulnerable to inundation under both Scenarios C and D.

The number of schools subject to inundation is 80 under coastal flood Scenario A and 95 under Scenario B. Under riverine Scenario C, the number of schools subject to inundation is 116, increasing to 120 under Scenario D. A majority of schools under all Scenarios are public elementary schools.

The number of essential facilities affected are summarized in Table 4.

**Table 4. Number of Affected Essential Facilities**

| Scenario | Fire Stations Damaged | Hospitals Damaged | Ambulance Stations | Police Stations Damaged | Schools Damaged |
|---|---|---|---|---|---|
| A – Coastal | 11 | 3 | 6 | 6 | 80 |
| B – Coastal | 12 | 3 | 6 | 6 | 95 |
| C – Riverine | 19 | 4 | 6 | 6 | 116 |
| D – Riverine | 20 | 4 | 6 | 11 | 120 |

## 4.7 Other Infrastructure

Other infrastructure subject to inundation under one or more scenarios include four municipal halls, seven works yards, three prisons with over 1,000 inmates, and two energy utilities in False Creek and Richmond.

## 4.8 Flood Protection Infrastructure

NHC (2015b) concluded that most dikes in the Lower Mainland do not meet present standards, particularly with respect to freeboard and erosion protection (refer to Section 3.2.3). For the catastrophic flood scenarios considered in this project, it was assumed that dikes would fail. Consequently, dikes and appurtenant structures, such as pump-houses and flood-boxes, have a high vulnerability. Once a dike begins to fail, be it from overtopping, erosion or seepage, it becomes very difficult to prevent a full breach. Typical dike breach widths would be in the order of 200 m, with fill material removed down to natural ground levels. In the event of an overtopping failure, much longer segments of dikes could be affected.

For the two coastal scenarios, 34 dikes were assumed to breach and for the riverine scenarios 36 dikes. The number of pump-houses affected was not assessed.

Similar to post-flood conditions in 1894 and 1948, the population having experienced a flood disaster first hand, there would likely be significant pressure to improve dikes rather than just rebuild, leading to costly land acquisitions.

## 4.9 Qualitative Service Disruption Scenarios

Qualitative Service Disruption scenarios consider impacts well beyond damage or disruption to property, fixed and moveable assets. They have a measureable economic element but they also include non-quantifiable aspects that affect public health and safety, social order, and societal well-being. They include, but are not limited to:

- Environmental contamination
- Environmental risk resulting from extended disruption
- Food storage and contamination
- Transportation
- Public works yards
- Correctional facilities
- Communications
- Social vulnerability

Environmental contamination during a flood event would be significant. Locations where flood damages have an elevated risk of environmental contamination include agricultural land, transportation and industrial sites. A wide range of point sources of contamination include chemicals, fertilizers, petroleum products and raw sewage. There are also hazardous waste storage facilities throughout the region as well as pre-existing contaminated sites. As a result, all flood waters are likely to have some degree of contamination.

Environmental risks include fertilizers and chemicals that may be stored in a safe location but not necessarily in a safe and elevated location above the flood level. Crops intended for human consumption are susceptible to contact with contaminated flood waters as they may contain chemical and biological contaminants. Chemical contamination may include heavy metals, petroleum products, pesticides or other agricultural chemicals whereas biological contamination would include pathogens (e.g. bacteria, parasites, and viruses), and sources of microbial contamination from upstream farms, rural septic systems, and raw manure or feces. As with agricultural uses, water that comes in contact with chemicals and fuels can cause environmental contamination. This includes chemical plants, service stations, contamination of underground storage tanks, leaking fuel from engine motors and gas tanks of flooded automobiles, pest control businesses and dry cleaning businesses.

Groundwater contamination will depend on the nature of the contamination and the purpose for which the groundwater is used.

Residential contamination includes debris that can harbor bacteria and mosquito breeding areas, dry sediment that creates airborne hazards as mold and dust, household chemicals including petroleum, paints, solvents, pesticides, pool supplies and de-icing chemicals. Motor vehicles and motorized equipment contain fuel and chemicals that could contaminate flood waters. Gasoline and diesel fuel as well as coolants are high risk factors for environmental contamination. Sinks, toilets and floor drains in low areas (e.g. basements or garages) may encounter the backflow of sewage. Sewage backflow may enter living areas as well as contaminate flood waters. During a flood, the soil around a septic field will become saturated which prevents the system from functioning correctly. Users will need to minimize water use (including the flushing of toilets) until the soil is less saturated (which may take a few days). Furthermore, post-flood cleaning and recovery will require an alternative method of disposing of flood/cleaning waters due to the septic field soil saturation.

In the event of a major flood, transportation and trade-related impacts will be far reaching as discussed in Section 5. The Lower Mainland may become grid-locked, for people, commercial, and industrial transportation. Supply lines would be disrupted as much of the region's distribution system is based on just-in-time delivery, which is very efficient for most purposes but is not designed for rare events such as flood disasters. The available food supply could be impacted in as little as four days and disruption as a result of flooding could extend over a longer period of time. An interruption in the transportation system, especially the ferry terminals and the Seaspan barge terminals, would have a significant impact on the delivery of goods to Vancouver Island and other coastal communities such as Bowen Island and the Sunshine Coast.

Works yards are typically located on flat land with good access to major roads, often in low-lying areas subject to flooding. Inundated works yards (e.g. Municipalities, School Districts and MoTI) pose challenges during and after a flood. Equipment left on inundated lands will be unavailable, inaccessible or not usable. Repairs may be required and works yards subject to inundation may delay the recovery period if they are not able to function. Inundated works yards pose a risk of contamination due to the storage of various materials (including petroleum, other fuels, coolants, etc.) on site. After a flood, inundated works yards may delay recovery and reconstruction efforts.

Communications facilities are vulnerable to system overload or damage during a flood event. This can affect 911 call centres, cell towers, cables, the internet and telephone land lines. An August 2015 wind storm in southeast BC illustrated the vulnerability of the local communications network. Damaging winds downed trees and power lines, cutting power across the Lower Mainland, Sunshine Coast and parts of Vancouver Island. This represented the single largest outage event in BC Hydro's history and affected 710,000 persons. During the windstorm, 40% of 911 calls failed to connect and callers to the local E-Comm 911 service were met with a busy signal 4 out of 10 times.

Correctional facilities including jails, pre-trial centres, police stations and forensic psychiatric hospitals present a unique type of vulnerability. Maintaining inmate, staff and public safety is paramount in the event of an emergency evacuation of any of these facilities. Pre-emergency evacuation planning is required and expected as part of facility management. Two prisons and a forensic psychiatric hospital are subject to inundation under all flood scenarios. Their total capacity exceeds 1,000 persons.

Cascading effects of a major flood extend well beyond the impairment of a particular infrastructure element and are beyond the scope of this project. Similarly, social vulnerability falls outside the present scope.

# 5 ECONOMIC LOSS ESTIMATES

## 5.1 Overview of Economic Analysis

Section 4 identified a range of assets vulnerable to flooding under Scenarios A to D. In this section, the corresponding economic losses are estimated. The following methods were adopted:

- All building related economic losses (both direct and indirect) were estimated using Hazus.
- Agricultural losses were estimated primarily using Agricultural Land Use Inventory data and Stats Canada's 2011 Census of Agriculture.
- Order of magnitude transportation disruption losses were derived from the annual value of goods shipped through Port Metro Vancouver.
- Infrastructure losses were approximated based on typical valuation costs from FEMA and unit area building costs by Marshall & Swift. Actual damage to infrastructure is difficult to project and estimating associated replacement and repair costs in detail was not feasible.

There are a number of additional losses that could result from a major flood, but due to the limited scope of the present work, are not addressed here.

To estimate impacts specific to the BC economy, BC Stats was consulted to perform Input-Output modelling.

In order to provide some perspective on the projected Lower Mainland losses, the results are compared with past flooding on the Fraser River and recent floods elsewhere: the Southern Alberta floods in 2013 and Hurricane Sandy in 2012.

## 5.2 Hazus Analysis

### 5.2.1 Base Data and Model Input

The default residential inventory in Canadian Hazus 2.1 is derived from 2011 Canadian census data and non-residential data from Dun and Bradstreet (and modified by NRCan). Building replacement costs are based on 2006 RSMeans values for the US, where RSMeans is a widely-used estimation database that helps calculate the costs of construction. Data are aggregated to census dissemination blocks (approximately equivalent to city blocks), and analysis for the Hazus Canadian Flood Module is based largely on this aggregated data. Although there are a number of assumptions and estimations built into this data, it was deemed suitable for a high-level analysis. The 2011 population count and level of development was assumed for both the present and future flood scenarios.

Model input includes flood extent and depth mapping for the areas to be analyzed. Using default or custom-developed depth-damage curves within the Hazus software, area specific losses are estimated.

### 5.2.2 Model Output

The Hazus Flood Model provides results aggregated to the dissemination block level. Hazus results can be viewed spatially as map layers based on dissemination blocks, or in tabular form. Results for this analysis include:

- Damage (in square footage, and by number of buildings) by building type and by occupancy type.
- Building-related economic losses.
- Amount of debris generated.
- Shelter requirements.

The number of damaged essential facilities (fire stations, hospitals, police stations, schools) is also determined. Unlike the other results, this is not based on aggregated data, but is based on site-specific point data.

Building-related economic losses are separated into:

- Building repair and replacement costs (structural and non-structural damage).
- Building contents losses.

- Building inventory losses.
- Relocation expenses.
- Capital related income losses.
- Wage losses.
- Rental income losses.

Losses are predominantly from building repair and replacement costs, and from building content losses. Building contents and inventory values are calculated in relation to building replacement value, depending on building occupancy type (FEMA Flood Module Technical Manual).

The last four categories listed above are time-dependent income losses, and are calculated based on the amount of damage to a building and an estimate of recovery time for the building (FEMA Flood Module Technical Manual). Recovery times incorporate physical restoration, dry-out and clean up, acquisition of permits, contractor availability, and, for some building types, hazardous material clean up.

### 5.2.3 Hazus Limitations

While Hazus is a valuable tool for estimating losses from flooding, highlighting geographic areas of particular concern, and illustrating relative losses between regions, there are many limitations that should be considered when examining the results as listed in Appendix C.

### 5.2.4 Necessary Adjustments

Recognizing that Hazus has significant limitations and likely underestimates losses considerably, adjustment of the Hazus loss outputs were necessary. More detailed analysis to refine Hazus default values was not within the scope of this overview level assessment. Considering that the use of Hazus for flood analysis in Canada is new and somewhat limited, there is no precedent for applying appropriate adjustments in terms of scaling factors. It should be acknowledged that even in the US, where the software was developed, an “out-of-the-box” Hazus assessment using default values is considered approximate only.

A key factor in estimating direct flood losses is the building replacement cost. Canadian Hazus 2.1 inventory data uses 2006 typical building replacement costs from the US, which are unlikely to be representative of 2015 Lower Mainland high building costs. To obtain some confirmation of this, the Hazus replacement costs were compared to construction cost data by Marshall & Swift, and adjusted for the Lower Mainland region (see Appendix C for details). The comparison showed that the Marshall & Swift-adjusted Vancouver 2014 building replacement values are about 1.6 times higher than the Hazus values. Although highly approximate, a scaling factor of 1.6 was adopted for the loss calculations.

To confirm this scaling factor, we reviewed previous work by NHC on a Coastal Flood Risk Assessment for City of Vancouver (2015a). The study used the City’s inventory of individual buildings within the floodplain for a detailed Hazus analysis. This User Defined Facilities (UDF) approach contrasts with the

Lower Mainland Flood Vulnerability Assessment, which uses aggregated inventory data in the form of the Hazus General Building Stock (GBS).

For the comparison, NHC re-ran Hazus for the City of Vancouver using GBS data only. Overall, losses based on UDF were higher, in particular, total building-related economic losses were 2.7 times higher, with structure and content losses both two times higher. Building replacement costs for Vancouver are unlikely representative of the Fraser Valley and the results suggest that adopting a regional scaling factor is unlikely to be an accurate approach. However, in view of the present project limitations, the Hazus results for the Lower Mainland were:

- Increased by 10% to account for an average long-term conversion from US to Canadian currency. (Previous 10 year average.)
- Multiplied by 1.6 to account for general underestimation.

### 5.2.5 Hazus Results

Based on the Hazus analysis, the building related losses for the Lower Mainland are summarized in Table 5. As described above, agricultural building-related losses have been removed, and the resulting values incorporate a currency conversion of 1.1 and a multiplier of 1.6, and have been rounded off.

According to Hazus, Scenario A would inundate 54,700 ha, Scenario B 61,100 ha, Scenario C 99,300 ha and Scenario D 110,300 ha.

**Table 5. Hazus Estimated Building Impacts**

| Scenario | Number of Buildings Damaged | Number of Buildings Destroyed | Total Building-related Losses ($ Billion) | Debris Generated [5] ($10^3$ US tons) | Population Seeking Shelter |
|---|---|---|---|---|---|
| A – Coastal | 7,200 | 1,100 | 14.2 | 656 | 238,000 |
| B – Coastal | 8,200 | 3,700 | 19.1 | 1,650 | 261,000 |
| C – Riverine | 3,600 | 690 | 9.0 | 656 | 266,000 |
| D – Riverine | 9,200 | 1,700 | 18.4 | 1,343 | 311,000 |

[5] It should be noted that although estimates of the volume of debris generated are provided, neither the associated costs, or the capacity of the existing solid waste management system has been considered in this report. The unit for debris is US tons.

The total building related losses estimated by building category is shown in Table 6. The category “Others” refers to religious and non-profit buildings, government general services, emergency response services, colleges, universities and grade schools.

**Table 6. Building Related Losses by Building Category ($ Billion)**

| Scenario | Residential | Commercial | Industrial | Others | Total |
|---|---|---|---|---|---|
| A – Coastal | 5.610 | 6.250 | 1.620 | 0.720 | 14.200 |
| B – Coastal | 7.090 | 8.560 | 2.570 | 0.910 | 19.130 |
| C – Riverine | 2.610 | 3.830 | 1.630 | 0.880 | 8.950 |
| D – Riverine | 6.610 | 7.590 | 2.940 | 1.230 | 18.370 |

The total building related losses can be broken down into the components shown in Table 7. According to the estimates, content losses constitute the largest losses. Relocation, capital related, wages and rental income losses are typically classified as indirect losses. Although the Canadian version of Hazus does not have a presently activated indirect loss module, these specific building related indirect losses are estimated.

**Table 7: Building-Related Economic Losses by Loss Type ($Billion)**

| Scenario | Structure Losses | Content Losses | Inventory Losses | Relocation Losses | Capital Related Losses | Wages Losses | Rental Income Losses |
|---|---|---|---|---|---|---|---|
| A | 6.040 | 7.760 | 0.320 | 0.010 | 0.030 | 0.030 | 0.010 |
| B | 8.240 | 10.350 | 0.450 | 0.010 | 0.030 | 0.040 | 0.010 |
| C | 3.390 | 5.200 | 0.300 | 0.010 | 0.020 | 0.030 | 0.010 |
| D | 7.640 | 10.150 | 0.490 | 0.010 | 0.030 | 0.040 | 0.010 |

Losses for each coastal and riverine flood scenario are presented by sub-region in Figure 4. As expected, losses for the low-lying and densely developed Richmond-Delta sub-region are the highest, with the year 2100 coastal scenario resulting in maximum losses.

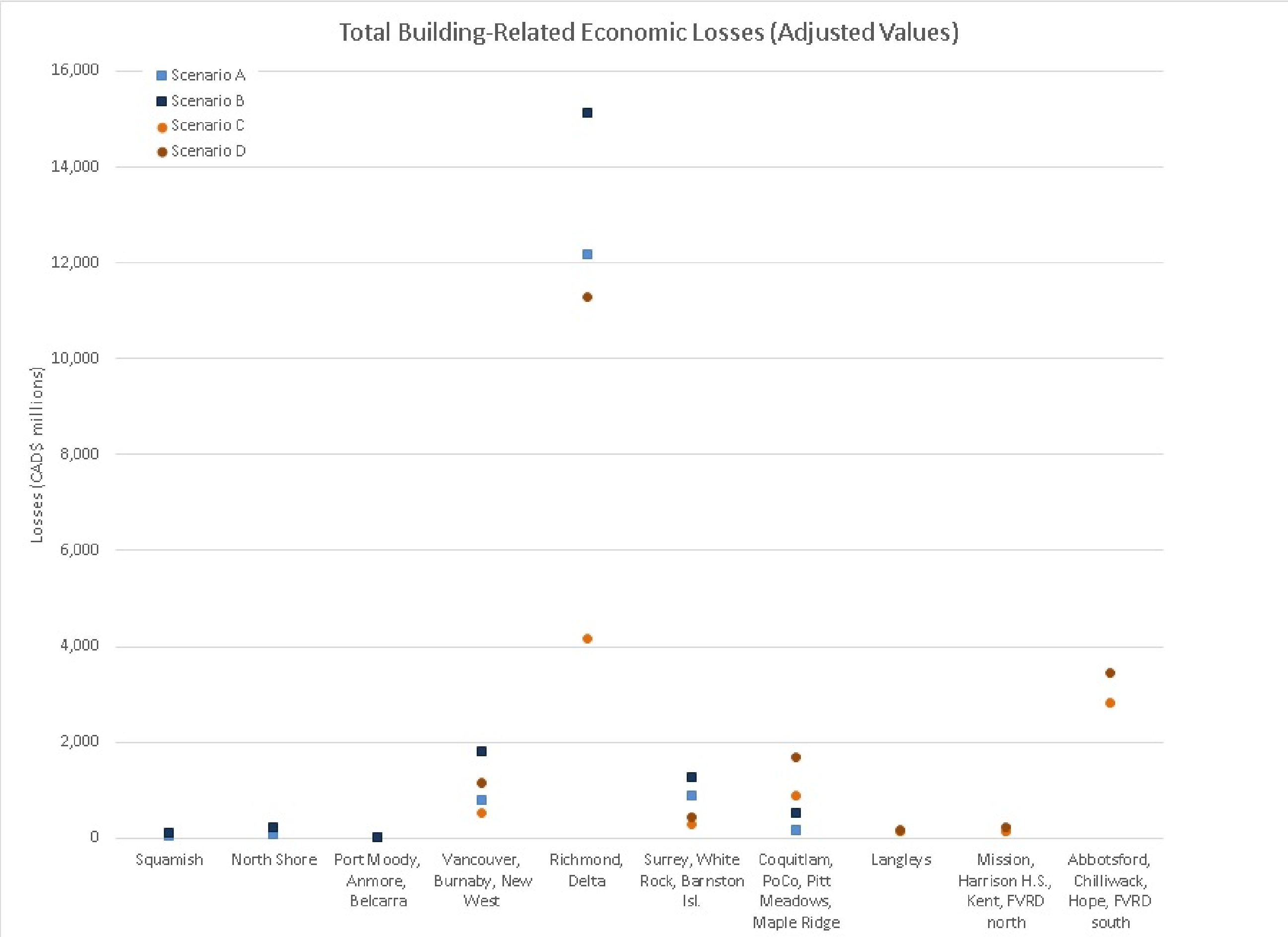


**Figure 4. Hazus Building Related Economic Losses by Sub-Region**

More detailed loss estimates from Hazus, including a breakdown by sub-region, are provided in Appendix C. It should be emphasized that the present overview level assessment is a Lower Mainland regional and sub-regional assessment. Much more detailed work would be required to develop accurate losses at the municipal level.

### 5.2.6 GIS and Mapping Products

The following GIS and map products were developed based on the Hazus output:

- Hazus project (*.HPR) files (compatible with Canadian Hazus 2.1 and ArcGIS 10.0); one file for each Hazus sub-region.
- An Excel spreadsheet summarizing Hazus results, including adjustments applied to loss estimates.

- A series of 24 map figures showing building-related economic losses ($ Millions per square kilometre in each dissemination block) for the four flood scenarios.
- A series of 24 map figures showing damaged buildings (number of buildings per square kilometre in each dissemination block) for the four flood scenarios.
- A series of 24 map figures showing displaced population (number of people in each dissemination block) for the four flood scenarios.

The files are included with the final digital deliverables.

## 5.3 Agricultural Loss Estimates

### 5.3.1 Background Information

The soils in the Fraser Valley are some of the most fertile in Canada and the region has one of the longest frost-free periods in the country, making the area highly favourable for agriculture (Crawford and McNair, 2012). There are many types of agricultural products generated in the Lower Mainland, with dairy and poultry production prominent. More than 25 different types of field vegetables are grown in the region and the majority of BC's berry production occurs in the Lower Mainland (Park, 2014).

In 2010, farms produced $1.9 billion in farm gate receipts on 132,000 ha of farmland. This generated approximately $3.8 billion in economic activity in the Lower Mainland[6]. The region produces a wide variety of products and due to this diversity, estimating flood related agricultural losses is a challenge.

Agricultural losses primarily depend on: 1) the timing of the event during the growing cycle; 2) the salinity of the flood water - whether fresh, saline or brackish; and, 3) the duration of the flood event. The impacts on a particular farm will vary depending on the products grown, the buildings and equipment, the topography of the land, the presence or absence of sub-surface drainage and the specific soil characteristics.

Based on the inundation mapping, approximately 36% of the farmland in the Lower Mainland lies in the Fraser River floodplain and is potentially vulnerable to flooding during extreme freshets resulting in dike breaching. If coastal dikes were to breach, the majority of farmland near the ocean would be vulnerable to flooding during the winter months. The following sub-sections estimate the direct agricultural losses that would incur from the four flood scenarios defined in Section 3. The analysis was completed by Mr. Mark Robbins.

[6] http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/strengthening-farming/800-series/860600-2_economic_impact_of_agric_in_abbotsford.pdf

### 5.3.2 Approach to Estimating Losses

Agricultural flood losses primarily stem from direct crop losses, damage to buildings/equipment and livestock feed crops. To be able to estimate crop losses for different flood scenarios, agriculture production was grouped into the following eight categories that reflect similar production systems and revenue per hectare:

- Livestock (excluding dairy).
- Forage.
- Vines, berries and tree fruits.
- Field vegetables.
- Field nursery, floriculture and trees.
- Poly greenhouses.
- Glass greenhouses.
- Dairy.

BC MFLNRO, with assistance from NHC, provides flood level forecasts during the Fraser River freshet. Similarly, the http://bcstormsurge.ca website provides coastal flood predictions, although specific flood alerts are not issued. For the agricultural loss estimates, it was assumed that most livestock would be moved to higher ground prior to an impending flood and that none of the flood scenarios would impact farm gate revenues for livestock production; except for lactating cows, where disruption in milking and ensuing losses are based on flood duration. For the coastal flood scenarios, sufficient time may not be available for complete evacuations and some losses may result but were not accounted for here. Chickens would unlikely be moved, but the production cycle is relatively short and any losses could likely be made up for within the year.

The flood duration is also a key factor in estimating crop losses, specifically the length of time a field is inundated. Accurately assessing the time required for flood waters to subside is difficult and the duration will vary depending on the characteristics of the flood, the configuration of the dike breach, the topography/drainage of the land, and the capacity of pumps and flood-boxes. For the purposes of this project, minimum durations of a two day coastal flood and two week riverine flood were first evaluated, with longer durations also considered.

A coastal flood would typically occur in December-January while the Fraser River freshet would take place in May-June. For the loss estimates, the timing of the flood was taken into account. For example, perennial crops (vines, berries, trees, field nursery) and forage crops are dormant from mid-November to the end of February. A flood event during this time period will not significantly impact their yield. However, a flood event after February will reduce growth and plant vigor, resulting in yield losses.

Table 8 lists estimated percentage crop losses for the different crop categories depending on the salinity of the flood waters. To estimate coastal flood losses, it was assumed that the flood waters would be brackish. Appendix D provides more detailed data. It is important to note that the crop loss estimates represent averages over a flooded area; specific farms will experience higher or lower levels of crop loss.

**Table 8. Percent Crop Losses in Different Crop Categories from the Two Types of Flood Waters.[7]**

| Flood Type | Water Type | Forage | Annuals | Perennials | Poly Greenhouse | Greenhouses | Dairy |
|---|---|---|---|---|---|---|---|
| Coastal | Brackish Water | 10% | 5% | 10% | 0% | 0% | 2% |
| Riverine | Freshwater | 70% | 50% | 50%-80% | 60% | 70% | 10% |

Buildings and farm equipment would likely be damaged by flood waters. The level of damage to buildings was set at 5% and for equipment at 10% (based on general experience). While most farm buildings are of basic construction, dairy barns have milking and pumping equipment close to the ground that could be extensively damaged. The building damage estimate was increased from 5% to 7% of market value for areas with a lot of dairy farms and berry packaging facilities to account for their more sophisticated building structures. The percentages were not adjusted for future conditions. Farm residences were included in the Hazus flood module and are not double-counted in the agricultural loss estimates.

Farm building footprint comes from the Agricultural Land Use Inventory and the market value of those buildings from the prevailing construction costs.  In relative terms there are not that many large on-farm packaging and processing facilities in the vulnerable area.  There are two in Matsqui Prairie and two in Pitt Meadows.  True non-farm (non-conforming uses as compared to farm uses that have grown beyond permitted size) in the ALR such as repair shops, truck parking and others were not included. Given the relatively small number involved and their small  building size (bigger buildings will generally not be granted permits), their impact would be small.

### 5.3.3 Loss Estimates

Two primary sources of information were used to estimate the crop, building and equipment losses under the four flood scenarios:

- Land Use Inventory (LUI) of farming areas in the Fraser Valley developed by the Ministry of Agriculture for Metro Vancouver (2010) and for the Fraser Valley Regional District (2011-2013). The LUI identifies areas of different land use on every lot in the farming areas and then identifies the specific use through drive-by inventories and aerial photos.

[7] http://www.bcagclimateaction.ca/wp/wp-content/media/Delta-Potential-Impact-Flooding-2014-full.pdf

- Stats Canada's 2011 Census of Agriculture, which provides data on the agricultural industry such as number of farms, farm area, livestock and crop inventories, operating expenses and receipts, farm capital and machinery/equipment information. Data is aggregated over a census area, which often coincides with municipal boundaries.

Estimates of crop revenue per hectare were obtained from Ministry of Agriculture crop budgets, production insurance, grower associations and based on previous experience. Applying average revenues per hectare to the area of crop coverage identified in the LUI provided an estimate of farm gate receipts in the potentially flooded areas. The estimated percent losses were then used to evaluate the loss in farm gate receipts for each crop or livestock group.

The LUI identified the land area occupied by farm buildings and was used to estimate the total capital value of buildings.

Census data provided the value of equipment and machinery in a particular census area. To estimate the amount of equipment and machinery within the flood vulnerable portion of the census area, the value of equipment/machinery in the entire census area was pro-rated based on the proportion of farm gate receipts in the flooded area compared to the entire census area.

Direct agricultural losses under the four flood scenarios were estimated for each municipality as provided in Appendix D. The summary of direct agricultural losses for the entire Lower Mainland region is shown in Table 9.

**Table 9. Direct Agricultural Losses ($ Millions)**

| Scenario | Flood-Vulnerable Area (in Ha) | Lost Farm Gate Sales | Damage to Equipment | Damage to Buildings | Replant Loss | Total Farmer Losses |
|---|---|---|---|---|---|---|
| Scenario A - Coastal | 14,626 | $16.5 | $12.7 | $37.9 | | $67.1 |
| Scenario B - Coastal | 15,214 | $17.4 | $14.6 | $40.9 | | $72.9 |
| Scenario C - Riverine | 43,459 | $410.1 | $50.7 | $223.0 | $9.5 | $693.2 |
| Scenario D - Riverine | 43,813 | $413.0 | $50.7 | $227.3 | $9.5 | $700.6 |

Note: Estimated losses refer to 2-day coastal and 2-week riverine flood durations. For longer duration floods, total losses were subsequently increased by a factor of 2.25 (refer to Section 5.3.5 and Table 13).

### 5.3.4 Discussion of Agricultural Loss Results

General observations from the agricultural loss analysis include:

- The riverine flood scenarios result in ten times higher losses than the coastal flood scenarios. The large difference is attributed to three main factors:
  - The riverine flooding affects three times the area as does coastal flooding.
  - Riverine floods occur during the spring growing season and even short periods can damage crops past the point of economic value. Coastal floods occur during

the winter season when most plant material is dormant and can withstand short periods of flooding without reduced yields in the following growing season. (Livestock losses are not dependent on time of year.)

    - The initially assumed two-week duration of riverine flooding is much longer than the two-day coastal flooding.

- Scenarios B and D, which incorporate climate change effects, suggest minimal future impacts on agricultural flood losses. This follows from the minor increases in inundation areas: 4% for the coastal scenarios and 1% for the riverine scenarios. It is important to note that:
    - Climate change impacts (i.e. year 2100 flood scenarios B and D) will significantly increase the depth of inundation and even if this does not have a major impact on crops, the percentage damage to buildings and machinery will increase.
    - The duration of flooding will increase under the future scenarios but it is unclear by how much, and this was not accounted for.
    - The frequency of extreme floods will increase. Based on PCIC's flow projections, NHC (2014) estimated that a flood of the same magnitude as the 1894-flood, with a present return period of about 500 years, could on average occur every 50 years at the end of the century under a severe climate change scenario. In a study for City of Surrey, NHC (2015c) showed that the return period event coastal dikes will be able to withstand will gradually decrease with time as sea levels rise. In other words, the likelihood of both riverine and coastal dike breaching will increase.
- During a riverine flood, half the agricultural losses in the Lower Mainland are incurred in Abbotsford and Chilliwack. (Note that Barnston Island losses are captured under Electoral Area rather than Surrey.)
- In a riverine flood, lost farm gate sales constitute about 60% of the total losses whereas the value drops to 25% for coastal floods.
- Dairy is the most impacted livestock because of the challenges and loss of production that come from moving lactating dairy cows.

BC produces about 48% of its current food needs. Lower Mainland local supplies are likely to run short in about four days.

### 5.3.5 Long Duration Flooding

The agricultural loss estimates were based on minimum durations, reflecting active inundation periods without accounting for prolonged drainage and recovery. Work undertaken for the Fraser Valley Regional District (FVRD) by Mark Robbins in association with NHC (2016) indicated that two weeks form a critical duration in terms of flood damage to agricultural lands and that durations longer than two weeks have considerably higher associated losses. The FVRD analyses suggested that losses may increase by a factor of about 2.25.

Except for minor localized dike breaches under the coastal scenarios, drainage and recovery times would likely be considerably longer than the initially assumed two days. Similarly, riverine flood inundation could exceed the projected two week period. For these longer durations, the estimated flood losses were multiplied by a factor of 2.25, resulting in the following total agricultural losses used for the total loss estimates:

- Scenario A: $0.1 Billion
- Scenario B: $0.2 Billion
- Scenario C: $1.6 Billion
- Scenario D: $1.6 Billion

## 5.4 Economic Losses caused by Transportation Disruptions

Under all four flood scenarios there is potential for disruption of rail, road, and air infrastructure. The movement of goods and services into and out of the Lower Mainland region relies on rail and road networks, numerous port facilities and airports, as well as the integrity of Fraser River and sea dike systems which protect the transportation network. Disruption to the flow of goods into and out of Port Metro Vancouver and Greater Vancouver due to either a Fraser River or coastal flood could have serious consequences on the regional, provincial and national economy, with significant direct and indirect losses.

Transportation disruptions were investigated by Mr. D. Park as summarized in Appendix E. Due to the limited data available, the evaluation is incomplete and there could be a number of other economic impacts.

The flood depth information indicates that in the event of either coastal or riverine flooding, each of the railway companies transporting freight in the Fraser Valley or coastal areas would experience inundations of their tracks at some locations, with consequent service disruptions. The companies include CP, CN, BNSF, Southern Railway of BC, and the 40 km spur line owned by the provincial government serving the Roberts Bank port. In addition, the highway/roadway leading to Roberts Bank would be subject to inundation. CN has an intermodal yard in Surrey, which is in the Fraser River floodplain. This area has no dike protection, and there would likely be losses to freight / cargo shipments.

The freight carried by the railways is trans-shipped through Port Metro Vancouver. For 2014, the Port estimated that the total value of cargo it handled was $187 billion. If that throughput were averaged over the year, for a two week period the value of throughput delayed or lost would be $7.2 billion. For purposes of a first approximation, Mr. Park proposed that the lost throughput be assumed to be roughly half, or equivalent to cargo with a value of approximately $3.6 billion. (The balance of the throughput lost was presumed to be made up during the remainder of the year.) For durations other than two weeks, loss estimates can be computed assuming a value of $257 million/day. In evaluating total losses, a two week interruption was assumed for Scenarios A and B ($3.6 Billion) and a four week interruption for Scenarios C and D ($7.7 Billion).

Interruptions to highway traffic and Vancouver International Airport are also discussed in Appendix E. However, the estimated losses are significantly smaller than for the rail lines and, considering the limited accuracy, were not included in the total losses.

## 5.5 Infrastructure and Other Vulnerability Losses

For each sub-region, the vulnerability assessment (Section 4) identified flood susceptible infrastructure and institutional buildings such as: substations; airports; marine facilities; rail lines; critical highway routes and arterial roads; rapid transit lines; wastewater treatment plants; police and emergency services; hospitals; municipal halls and work yards; and other structures. Corresponding losses could not readily be estimated in the Canadian version of Hazus and instead a simplified approach was adopted using rough replacement, or valuation, costs developed by FEMA as listed in Table 10, and provided by Mr. M. Gorecki.

**Table 10. FEMA Hazus Valuation Costs (in Canadian Dollars – 1.1 $US Conversion Factor)**

| Category | $C |
|---|---:|
| Highway Major Roads (1km 4 lanes)) | 11,000,000 |
| Highway Urban Roads (1 km 2 lanes) | 5,500,000 |
| Railway Tracks (per km) | 1,650,000 |
| Railway Urban Station | 2,200,000 |
| Railway Fuel Facility | 3,300,000 |
| Railway Dispatch Facility | 3,300,000 |
| Railway Maintenance Facility | 3,080,000 |
| Light Rail Track (per km) | 1,650,000 |
| DC Substation | 2,200,000 |
| Dispatch Facility | 3,300,000 |
| Maintenance Facility | 2,860,000 |
| Bus Urban Station | 1,100,000 |
| Bus Fuel Facility | 165,000 |
| Bus Maintenance Facility | 1,430,000 |
| Waterfront Structures | 1,650,000 |
| Cranes/Cargo Handling Equipment | 2,200,000 |
| Warehouses | 1,320,000 |
| Port Fuel Facility | 2,200,000 |
| Airport Control Towers | 5,500,000 |
| Airport Runway | 30,800,000 |
| Fuel Facilities | 5,500,000 |
| Seaport/Stolport/Gliderport/etc. | 550,000 |
| Heliport Facilities | 2,200,000 |
| Airport Parking Structure | 1,540,000 |
| Airport Maintenance & Hangar Facility | 3,520,000 |
| Airport Terminal Buildings | 8,800,000 |
| Small Water Treatment Plants | 33,000,000 |
| Medium Water Treatment Plants | 110,000,000 |
| Large Water Treatment Plants | 396,000,000 |
| Small Wastewater Treatment Plants | 66,000,000 |
| Medium Wastewater Treatment Plants | 220,000,000 |
| Large Wastewater Treatment Plants | 792,000,000 |
| Lift Station (Small) | 330,000 |
| Lift Station (Med/Large) | 1,155,000 |
| Low Voltage Substation | 11,000,000 |
| Medium Voltage Substation | 22,000,000 |
| High Voltage Substation | 55,000,000 |

The above valuation costs were supplemented with the Marshall & Swift unit area costs for institutional buildings listed in Table 11, also provided by Mr. Gorecki.

**Table 11. Marshall & Swift Unit Area Building Costs (in Canadian Dollars – 1.1 $US Conversion Factor )**

| Category | $C/m$^2$ |
|---|---|
| Police Stations | $2,600 |
| Fire Stations | $2,500 |
| Hospitals | $4,000 |
| | |
| High Schools | $2,300 |
| Middle Schools | $2,200 |
| Elementary | $2,400 |

Flood depths were not incorporated into the assessment of infrastructure and institutional buildings. Depending on the type of construction, the degree of flood-proofing, floor elevations, road crest levels and local flood conditions, the identified vulnerabilities may sustain limited damage, only requiring clean-up to become fully functional, or suffer complete destruction.

The total number of vulnerabilities, the assumed unit repair costs, the approximate losses under each flood scenario and the assumptions made are summarized in Table 12. It should be recognized that the loss estimates, based on valuation costs, are order of magnitude estimates at best. Much more extensive work would be required to refine the results. There may be minor double-counting of select facilities between the "Others" category in the Hazus analysis (Table 6) and the summary of estimated damages for critical infrastructure and essential facilities (Table 12). This would be due to different source data and methodologies and is limited to a few types of facilities such as schools, police stations, and hospitals, representing about 2% of the total damages estimated by Hazus. Local approximate dike and bridge repair costs were also applied.

Total infrastructure and institutional building losses are estimated at:

- Scenario A: $1.4 Billion
- Scenario B: $1.8 Billion
- Scenario C: $4.7 Billion
- Scenario D: $5.0 Billion

**Table 12. Approximate Other Structure and Infrastructure Loss Estimates**

| | Quantity Affected | | | | Valuation Cost | Corresponding Loss Estimate (Million $) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Infrastructure Type | A | B | C | D | ($) | Scenario A | Scenario B | Scenario C | Scenario D | Assumptions |
| Substations | 19 | 37 | 23 | 30 | $ 11,000,000 | $ 209.00 | $ 407.00 | $ 253.00 | $ 330.00 | Assume all substations are of medium size and repair costs amount to 50% of FEMA valuation cost. |
| Airports YVR | 1 | 1 | 1 | 1 | $ 29,260,000 | $ 29.26 | $ 29.26 | $ 29.26 | $ 29.26 | 50% of FEMA valuation cost for key components (1 of each). |
| Airports - local | 4 | 4 | 5 | 5 | $ 2,750,000 | $ 11.00 | $ 11.00 | $ 13.75 | $ 13.75 | Repair and clean-up. |
| Major marine facilities | 10 | 20 | 15 | 15 | $ 3,685,000 | $ 36.85 | $ 73.70 | $ 55.28 | $ 55.28 | 50% of FEMA valuation cost for key components (1 of each). |
| Minor marine facilities | 10 | 20 | 15 | 15 | $ 737,000 | $ 7.37 | $ 14.74 | $ 11.06 | $ 11.06 | 10% of FEMA valuation cost for key components (1 of each). |
| Rail lines | 18 | 18 | 22 | 26 | $ 4,125,000 | $ 74.25 | $ 74.25 | $ 90.75 | $ 107.25 | Assume 5 km must be rebuilt at each inundated section (as tabulated) at 50% of FEMA valuation cost. |
| Critical highway routes | 25 | 27 | 24 | 28 | $ 27,500,000 | $ 687.50 | $ 742.50 | $ 660.00 | $ 770.00 | Assume 5 km must be rebuilt at each inundated section (as tabulated) at 50% of FEMA valuation cost. |
| Rapid transit lines | 5 | 5 | 5 | 5 | $ 4,125,000 | $ 20.63 | $ 20.63 | $ 20.63 | $ 20.63 | Assume 5 km must be rebuilt at each inundated section (as tabulated) at 50% of FEMA valuation cost. |
| Wastewater plants | 3 | 5 | 8 | 9 | $ 22,000,000 | $ 66.00 | $ 110.00 | $ 176.00 | $ 198.00 | Assume all plants are of medium size and repair costs amount to 10% of FEMA valuation cost. |
| Police/emergency services | 23 | 24 | 31 | 37 | $ 2,600,000 | $ 59.80 | $ 62.40 | $ 80.60 | $ 96.20 | Repair and clean-up $2600/m2 * 1000 m2 (ref. Marshall & Swift) |
| Hospitals | 3 | 3 | 4 | 4 | $ 4,000,000 | $ 12.00 | $ 12.00 | $ 16.00 | $ 16.00 | Repair and clean-up $4000/m2 * 1000 m2 (ref. Marshall & Swift) |
| Municipal Halls/work yards etc | 8 | 9 | 7 | 14 | $ 2,500,000 | $ 20.00 | $ 22.50 | $ 17.50 | $ 35.00 | Repair and clean-up $2500/m2 * 1000 m2 (ref. Marshall & Swift) |
| Schools | 80 | 95 | 116 | 120 | $ 2,400,000 | $ 192.00 | $ 228.00 | $ 278.40 | $ 288.00 | Repair and clean-up $2400/m2 * 1000 m2 (ref. Marshall & Swift) |
| **Sub-Total** | | | | | | $ 1,425.66 | $ 1,807.98 | $ 1,702.22 | $1,970.42 | |
| Dikes (pumpstations not incl.) | 34 | 34 | 36 | 36 | $ 1,000,000 | $ 34.00 | $ 34.00 | $ 36.00 | $ 36.00 | Replacemenet/upgrade of 200 m long breached sections, assumed cost of $5,000/m. |
| Bridges | | | 3 | 3 | $ 1,000,000,000 | $ - | $ - | $ 3,000.00 | $3,000.00 | Mission Rail, Patullo, CN Rail |
| Total ($ Million) | | | | | | $ 1,459.66 | $ 1,841.98 | $ 4,738.22 | $5,006.42 | |
| **Rounded Total ($C Billion)** | | | | | | **$ 1.4** | **$ 1.8** | **$ 4.7** | **$ 5.0** | |

Note: 1. The number of units affected are based on vulnerability assessment by Arlington.

## 5.6 Approximate Total Loss Estimates

To develop approximate total loss estimates for each flood scenario, the losses based on Hazus, the agricultural assessment, the rail transport disruption analysis and infrastructure repair costs were summed as shown in Table 13. The present project provides an overview level assessment of losses and illustrates the importance of developing a flood management strategy for the Lower Mainland. Assigning upper/lower bounds to the estimates is not possible, as some assumptions are likely to overestimate losses while others provide underestimates. Limitations of the results are identified in Section 6.

**Table 13. Total Economic Loss Estimates ($ Billion)**

| Scenario | Hazus related building losses | Farmer losses | Transportation losses | Infrastructure/ institutional losses | TOTAL LOSSES ($ Billions) |
|---|---|---|---|---|---|
| **A** | 14.2 | 0.1 | 3.6 | 1.4 | **19.3** |
| **B** | 19.1 | 0.2 | 3.6 | 1.8 | **24.7** |
| **C** | 9.0 | 1.6 | 7.7 | 4.7 | **23.0** |
| **D** | 18.4 | 1.6 | 7.7 | 5.0 | **32.7** |

Notes:
1. Hazus losses are based on default recovery times of 1 to 33 months.
2. Farmer losses are based on flood inundations exceeding a 2 week critical period.
3. Transportation losses assume 2 week disruptions for coastal floods, 4 weeks for riverine.
4. Order of magnitude infrastructure/institutional losses do not incorporate durations.

The loss estimates illustrate the relative difference between scenarios and show significant increases from previous evaluations. The loss for Scenario C derived in 1994 by Fraser Basin Management Board was $1.8 billion and in 1976 by Fraser River Joint Advisory Board $500 million. The present estimated losses indicate that any of the scenarios would represent the most costly natural disaster in Canadian history, and would severely strain the regional, provincial and national economy. These impacts would be experienced in all communities throughout the region and the costs would be borne by all orders of government, the private sector, families and individual citizens. In addition to the impacts estimated in this project, many other economic, social, and environmental impacts could be experienced, including risk of serious injury, loss of life, and other social hardships.

Specific impacts to the BC economy were estimated by BC Stats based on the Hazus and agricultural loss estimates. The BC Input-Output model results and report are included in Appendix E. A discussion of the findings is provided by Mr. Park in the appendix.

## 5.7 Comparison with Past Flooding

Not surprising, the estimated total losses estimated in the previous section are substantially higher than those incurred in 1948 as described below.

In the past 15 years, a number of catastrophic floods have occurred in North America, Europe and Asia. To compare the results of this project with reported damages from recent floods, the Alberta 2013 riverine floods and the Hurricane Sandy 2012 coastal floods were reviewed. Brief summaries of each event are presented here.

### 5.7.1 Fraser River

The 1948 Fraser River flood had an estimated return period of about 200 years. Almost seventy years ago, the population and degree of development within the floodplain was a fraction of today’s and the impacts were significantly less than what would now be expected. At the time, floodwaters severed both transcontinental rail lines; inundated the Trans-Canada Highway; flooded urban and agricultural areas and forced many industries to close.

Approximately 16,000 people were evacuated; 2,300 homes were damaged or destroyed; 1,500 residents were left homeless; 10 people died and the recovery costs were approximately $150 million (in 2010 dollars). The equivalent numbers estimated for present conditions (Scenario C) are 266,000 people evacuated; 4,290 homes damaged or destroyed and total loss of $22.8 billion. (Casualties were not estimated in Hazus.)

### 5.7.2 2013 Southern Alberta Floods

A higher than average snowpack in the eastern Rocky Mountains combined with above average amounts of rainfall across southern Alberta in early June led to major flooding. Numerous flood advisories and warnings were issued for southern Alberta between June 19th and June 29th, 2013[8].

The southern Alberta floods resulted in significant damages:

- Overall cost of $6 Billion (Calgary Herald, September 2013[9]).
- Five people killed (IBI & Golder, 2015).
- 985 kilometres of road affected (Alberta EMA, 2013).
- Over 30 communities declared local states of emergency, First Nations impacted (Alberta EMA, 2013).
- More than 125,000 persons evacuated (Alberta EMA, 2013).
- Over 14,500 homes damaged (Alberta EMA, 2013).
- 80 schools and 10 health facilities were affected (IBI & Golder, 2015).
- 1,100 small businesses impacted, 3000 businesses (Alberta EMA, 2013).
- Almost 2,700 Albertans displaced and requiring accommodations. Approximately 1,400 members from First Nations communities indicated a need for housing assistance (AB Government, 2014).
- Downtown Calgary was shut down for nearly one week due to floodwaters (Business in Focus, 2013).
- Floods disrupted pipelines and rail transport, e.g. Enbridge shut down its Athabasca pipeline (Business in Focus, 2013).

[8] http://albertawater.com/southern-alberta-flood-2013/timeline-of-events

[9] http://www.calgaryherald.com/news/Province+boosts+cost+Alberta+floods+billion/8952392/story.html

- Farmland suffered damage from the floods, but according to the provincial agriculture ministry, damage was not widespread. Initial damage estimates from the Alberta EMA pegged agricultural damages at $50 Million (Alberta EMA, 2013)
- BMO Capital Markets estimated that Canada's GDP would be reduced by $2 Billion in June 2013 as a direct result of the floods (Business in Focus, 2013; Financial Post, June 2013[10]).

  In some cases, the recovery process still continues with costs continuing to incur. A number of businesses closed and will not re-open.

### 5.7.3 Superstorm Sandy

In October 2012, Hurricane Sandy made landfall in the Caribbean and the US. Between the Bahamas and the US, Sandy's wind field had expanded to 1,600 kilometres in diameter. The system came ashore in the US in New Jersey (and New York City) on October 29 with 130 km/hr sustained winds that were also accompanied by record storm tide heights (AON Benfield, 2013). By October 31st, the remnants of Sandy had dissipated over eastern Canada. The following impacts were documented:

- Total economic losses reached $70 Billion USD, according to market estimates (Allianz Global, 2013).
- 650,000 homes were damaged or destroyed and 8.5 million customers lost power (Allianz Global, 2013).
- More than 280 fatalities (Insurance Journal, 2013), which included deaths in the US, as well as in the Caribbean. The storm led to 72 direct deaths in the US (AON Benfield, 2013).
- Storm surge impacts included flooding in New York City's subway tunnels, water overtopping runways at La Guardia and Kennedy airports, and damage to the New Jersey Transit System estimated at approximately $400 Million (NOAA, 2013).
- The New Jersey state government estimated construction costs of $29.5 billion to repair and replace the damage caused by the storm (US Department of Commerce, 2013).
- Insured losses totalled approximately $25.85 Billion. Private insurance companies accounted for approximately three quarters (73%) of this total. Auto, homeowners and business insurance claim payouts totalled $18.75 Billion. The rest was covered by the National Flood Insurance Program ($7.1 Billion) (Allianz Global, 2013).
- In New Jersey and New York, the atmospheric event itself lasted about two days. Wind damage was a factor, with wind damage alone reaching $7 Billion throughout the US (Zhang, 2013).

[10] http://business.financialpost.com/news/economy/alberta-flooding-could-wipe-2-billion-from-canadian-economy-in-june

In the US, private insurance companies and the National Flood Insurance Program insure losses; similar mechanisms for flood coverage has not existed in BC.

# 6 PROJECT LIMITATIONS AND FUTURE WORK

## 6.1 Project Limitations

This preliminary, overview level assessment involved a number simplifying assumptions. In order to ensure correct interpretation of results, limitations have been summarized below. They are classified according to the different components of the project: 1) hydraulics and mapping; 2) vulnerability identification; and 3) loss estimates (Hazus building related losses (direct and indirect), agricultural losses; transportation disruptions; and infrastructure). Other losses typically considered in flood risk assessments, such as loss of life, environmental losses and cultural/historic losses were not within the scope of the present project.

Developing flood management strategies and evaluating different mitigation options will be part of the next phase of the Lower Mainland Flood Management Strategy and are not dealt with in this project.

### 6.1.1 Characterization of Flood Scenarios

All river dikes were assumed to be ineffective but river flood levels were estimated assuming confinement of flow between dikes. Sea dikes were also assumed to be ineffective. Accurate assessment of inundation would require detailed 2D modelling, outside the scope of the present work.

River flood levels were generally projected perpendicularly across the floodplain. The typically observed gradual drop-off in water levels on the landside of breached dikes was disregarded. Flooding caused by Fraser River tributary streams and other adjacent watersheds were not considered. Local drainage problems and severe precipitation events were also disregarded. The effect of ponding behind dikes and obstructions on the floodplain from upstream breaches, which could raise levels on the floodplain above adjacent river levels was not considered.

The quality of the available topographic base mapping was not sufficiently accurate for detailed flood extent and depth mapping. Flood extents and depths are considered approximate and any inaccuracies in the mapping would affect the vulnerability assessment and loss estimates. The flood extent and depth mapping was generated specifically for this overview level assessment. **The maps must not be considered as floodplain mapping for the purposes of official designation of floodplains.** However, they are useful for illustrating the approximate extent and depth of flooding as well as the estimated impacts. More detailed topographic data and hydraulic modelling of specific floodplain areas would be required prior to development of official floodplain maps.

The Hazus analysis was based on embedded default flood recovery durations ranging from 1 to 33 months. Agricultural results assume inundation periods exceeding two weeks. For transportation disruption losses, a four week flood duration was assumed for the riverine scenarios and two weeks for the coastal scenarios. The infrastructure repair/replacement costs did not take into account flood durations. Under all four scenarios, flood interruptions could be considerably longer, resulting in more severe losses. Climate change is likely to prolong inundation periods, particularly for coastal flooding. The potential attenuation of peak flows provided by storage of flood waters on the floodplain was disregarded.

Ocean design levels were projected horizontally across the land, reflecting a worst case scenario. Wave action was represented by a 0.6 m flood wave allowance from Squamish to White Rock. Actual wave heights will vary considerably depending on wind exposure and shoreline geometry. Future increases in storminess due to climate change were not considered.

Increasing flood flows and rising ocean levels will contribute significantly to riverine and coastal erosion. Damages caused by erosion were disregarded, as was the loss of land due to coastal squeeze.

Based on PCIC's flow projections, NHC (2014) estimated that a flood of the same magnitude as the 1894-flood, with a present return period of about 500 years, could on average occur every 50 years at the end of the century under a severe climate change scenario. In a study for City of Surrey, NHC (2015c) showed that the return period coastal event the City's dikes will be able to withstand will gradually decrease with sea level rise. As a result of climate change, both the frequency of extreme floods and the likelihood of both riverine and coastal dikes breaching will increase. Losses were estimated for single flood events rather than for a series of events likely to occur over a certain time span.

Following discussions with the Advisory Committee, the above assumptions were deemed reasonable for a preliminary vulnerability assessment.

### 6.1.2 Vulnerability Identifications

The identification of vulnerable development/infrastructure focussed on key components within the flood extents. Factors such as flood depth and flow velocity, which would influence vulnerability, were not considered and only inundation extents were used. Cascading effects of a major flood would extend well beyond the impairment of particular infrastructure elements but were beyond the scope of this project. The vulnerability of diking was addressed by NHC (2015).

### 6.1.3 Hazus Building Related Loss Estimates

Building related losses (direct and indirect) were estimated using the Canadian Hazus Flood Module. NRCan made a number of assumptions to populate Canadian Hazus with building stock and demographic data using census and Dun and Bradstreet data. Any inaccuracies in the inventory data contribute to inaccuracies in the loss estimations. Specific limitations, as identified in Appendix C, include:

- The Hazus Flood Model assumes a short duration flood (one week or less - FEMA Flood Model User Manual). While this may be appropriate for the coastal flood scenarios, it is less suitable for the riverine scenarios. For the riverine scenarios, actual direct losses may be higher than those estimated by Hazus. (Assumed recovery times range from 1 to 33 months.)
- The default Hazus database was used. With some minor exceptions, the database was not updated with more detailed, accurate or current information. Doing this would require considerably more effort and was outside the scope of this work.
- The population density and level of development in year 2100 (Scenarios B and D) was assumed to be at current levels. Both population, land-use intensity and development are likely to increase significantly.
- For the analysis of aggregated building data, Hazus assumes that the asset inventory is distributed evenly across each dissemination block.
- Canadian Hazus 2.1 uses US building replacement cost data, and as a result, does not account for the high construction costs in most parts of the Lower Mainland. Approximate adjustments were applied.
- The default Hazus depth-damage curves were used and may not accurately represent typical structures in the Lower Mainland. No adjustment was made to Hazus default values for first floor elevations. The default values may be higher than typical in the Lower Mainland, which would result in an underestimation of losses.
- Hazus results were increased by 10% to account for an average long-term conversion from US to Canadian currency and multiplied by 1.6 to account for general underestimation of re-construction costs. (It is acknowledged that the present exchange rate is 27%).
- The Canadian version of the Hazus model does not yet have the capacity to address losses in the agricultural sector, specifically associated with crops and livestock. While direct losses from damage to agricultural buildings can be considered in Hazus, for this project they were dealt with more accurately in a separate analysis using the agricultural land use inventory, as described in Section 5.
- Linear infrastructure is not handled well by the Canadian version of Hazus, and direct losses from damage to utility and transportation lines, such as railways, highways, pipelines, and power lines were not quantified in Hazus because depth-damage curves are unavailable.

### 6.1.4 Limitations of Agricultural Loss Estimates

- To estimate crop losses, agriculture production was grouped into the following categories: livestock (excluding dairy); forage; vines, berries and tree fruits; field vegetables; field nursery, floriculture and trees; poly greenhouses; glass greenhouses; and dairy. Approximate loss percentages were applied to each category.

- It was assumed that most livestock would be moved to higher ground prior to an impending flood and that none of the flood scenarios would impact farm gate revenues for livestock production; except for lactating cows, where disruption in milking and ensuing losses are based on flood duration.
- Total agricultural loss estimates for all scenarios assume inundation periods exceeding two weeks.
- Scenarios B and D, which incorporate climate change effects, suggested minimal future (year 2100) impacts on agricultural flood losses. This followed from the minor increases in inundation areas: 4% for the coastal scenarios and 1% for the riverine scenarios. The results are somewhat misleading since climate change impacts will likely increase the depth of inundation. Even if this does not have a major impact on crops, the percentage damage to buildings and machinery will increase. Also, the duration of flooding will likely increase under the future scenarios but this was not accounted for.

### 6.1.5 Limitations of Transportation Disruption Loss Estimates

The loss estimate related to disruption of rail transport was assumed to equal $257 million/day, or half of the total cargo normally handled by the port in a day.

Insufficient information was available to develop similar estimates for highway and air transport and these losses were not included.

### 6.1.6 Limitations of Other Structures and Infrastructure Loss Estimates

Infrastructure and institutional building losses reflect order of magnitude estimates and were based on assumed extents of damage and highly approximate valuation costs.

## 6.2 Future Work

The Fraser Valley is a hydraulically complex area, where flood levels in one location are not only a function of river flows and ocean conditions but also of dike failures and the degree of inundation in other floodplain areas. The current vulnerability assessment is intended to highlight the need for developing flood management strategies for the Lower Mainland. Considering the simplifying assumptions adopted, actual flood depths may be somewhat less severe but total losses could be higher since not all losses may be accounted for in the present project. To move forward with Phase 2 and the development of appropriate structural and non-structural flood protection measures, it is imperative that the assessments be refined to inform site specific solutions.

It is recommended that more detailed evaluations be carried out to allow available resources to be focussed where most needed. Given the urgency to advance this work, the following specific work items are envisioned to assist with project planning and prioritization:

1. By combining the spatial tool from the present vulnerability assessment and the dike evaluation maps (Project 3), identify problem areas (areas with a high degree of vulnerability protected by poor quality dikes) and highlight potential dike breach locations. Estimate the potential progression of the Fraser River design flood, outlining likely sequencing of dike breaches and resulting inundation scenarios. Identify development in areas that are currently unprotected by dikes.

2. Identify where dike upgrades are most critical in order to minimize economic losses. Review what other flood mitigation measures could be effective in reducing losses.

3. Develop 2D models for key floodplain areas and combine these with the existing 1D model. Run the combined model in unsteady mode for the Fraser River design hydrograph. Introduce the potential breach scenarios from Item 1. Model several breach combinations and identify realistic scenarios for further review. This will allow simulation of more accurate flood levels across the floodplain. Also, the potential reduction in river levels corresponding to water being stored on the floodplain can then be estimated. (From the 1894 high water mark at Mission, the reduction in flood levels due to the entire floodplain being inundated is approximately 1 m at Mission.)

4. Based on the model results, develop hazard mapping showing the depth/velocity relationship across the floodplain. The information would be useful for developing a detailed flood preparedness plan, highlighting high hazard areas and viable access/egress routes during catastrophic flooding and would feed directly into the Phase 2 work. The mapping would be particularly helpful for First Nation lands, traditionally located in low-lying areas.

5. Evaluate ocean flooding more accurately. Consider ocean exposure and beach topography and include modelling of wave heights. Apply a joint probability approach to estimate coastal design levels. Carry out breach modelling taking into account tidal variations. (Unlike the Fraser River modelling that needs to be carried out for the entire project reach, the ocean modelling can optionally be completed separately by individual municipalities.)

6. Based on the refined model results, reassess vulnerabilities. This would improve the accuracy of direct and indirect loss estimates. Include flood depths in the assessment, not just the extents of inundation. Expand the project to include a qualitative assessment of loss of life and environmental, social and cultural losses. Consider modelling projected populations and associated build out of homes, businesses and infrastructure for future conditions.

7. Individual municipalities and First Nations may wish to carry out detailed Hazus assessments, with refined input data and depth-damage curves. Optionally, alternative risk assessment software may be utilized.

8. Refine the loss estimates. On an individual municipality level, refine the flood duration and recovery time estimates. Evaluate the time required to drain flooded lands, repair specific dike breaches and the length of time required before saturated road/railroad embankments can withstand full loading. Include more accurate loss estimates for linear (roads, bridges, culverts) infrastructure and critical infrastructure (police, fire, ambulance stations, emergency centres). Future work should also include a detailed assessment of vulnerable bridge piers and transmission towers that would be at risk due to river erosion for Scenarios C and D.

9. Refine the agricultural loss estimates for Fraser Valley Regional District (current project underway by NHC team) as well as for Metro Vancouver.

10. Based on the more detailed technical results, start developing site specific flood mitigation options. Raising and improving dikes to protect all flood-prone areas is unlikely to be feasible, nor desirable, and instead a variety of solutions will need to be developed, evaluated and implemented.

# 7 CONCLUSIONS AND RECOMMENDATIONS

## 7.1 Conclusions

1. Any one of the four flood scenarios investigated in this project would generate the most costly flood catastrophe in Canadian history. The project results indicate that the Lower Mainland is exposed to a high degree of flood risk and demonstrate that there is an urgent need for improved flood protection and development of a comprehensive flood management strategy.

2. The results from this project provide an updated region-wide assessment of the potential effects from flooding in the Lower Mainland. The project made a number of simplifications in terms of defining the flood hazards and estimating the effects of flooding. Additional work will be required to fully quantify the vulnerabilities and risks in the region. More in-depth analysis to address the simplifying assumptions would likely result in more significant direct and indirect losses as evidenced in similar work undertaken by and for the City of Vancouver.

3. It would be beneficial to identify various levels of vulnerability using a range of flood elevations in the floodplain and coastal areas. For example, which communities / diking systems are vulnerable at what flood elevation. This could be another lens with which to set regional / timeline priorities.

4. More extreme flooding and flood losses are expected from climate change. The project did not take into account future increases in population density or development. Therefore, the total losses for the year 2100 scenarios (B and D) likely represent underestimates.

## 7.2 Recommendations

1. Considering the vulnerability to flooding, the provincial government, local governments and First Nations in the Lower Mainland need to prepare for future flood emergencies. This will require updating and refining existing plans or in some cases, developing new detailed emergency preparedness plans. Procedures need to be implemented and practiced. Flood recovery plans, of critical importance during the 2013 Calgary floods, should also be developed.

2. Carry out the future work items identified in this report (Section 6.2). This work is largely of a technical nature and may considerably reduce the cost of implementing flood mitigation measures.

3. Extend the vulnerability assessment to include potential for loss of life, social, cultural and environmental losses.

4. Develop new floodplain mapping for the region, incorporating potential effects of dike breaches and overtopping, climate change and uncertainties in hydrological and hydraulic parameters.

5. Refine the loss estimates for individual municipalities and First Nations, as well as critical infrastructure, and prioritize areas where protection is most critical.

6. Develop a comprehensive flood management strategy for the Lower Mainland that identifies national, provincial, regional and local priorities as well as recommended management options for the diversity of circumstances that exist throughout the Lower Mainland.

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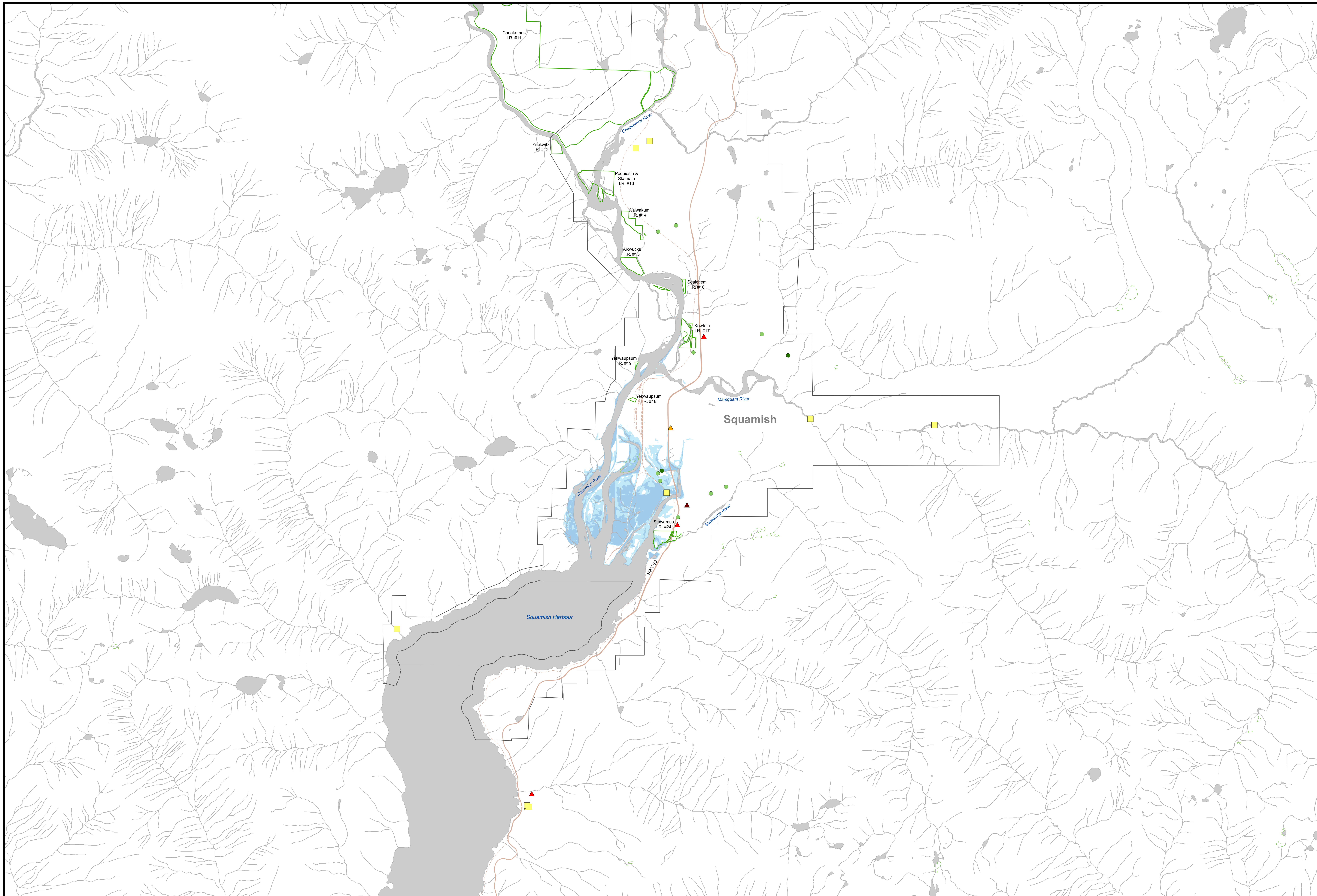
# Maps

(Only Sample Maps Provided. Complete Map Set included in Digital Deliverables)

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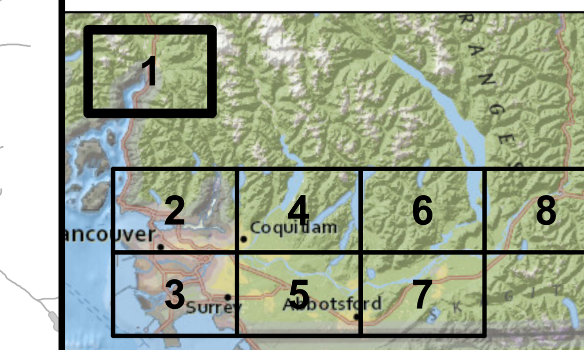


Flood Extent, Scenario A
Flood Extent, Scenario B
Indian Reserves and First Nations Treaty Lands
Fire Hall
Police Station
Emergency Operations Centre
Hospital
Airport
Port Facilities
BC Hydro Substation
School
Post-secondary Institution

**Notes:**

1. Flood extents were developed for two coastal and two riverine flood scenarios. The coastal scenarios, incorporating a 0.6 m wave allowance, are:
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| Job Number | Date |
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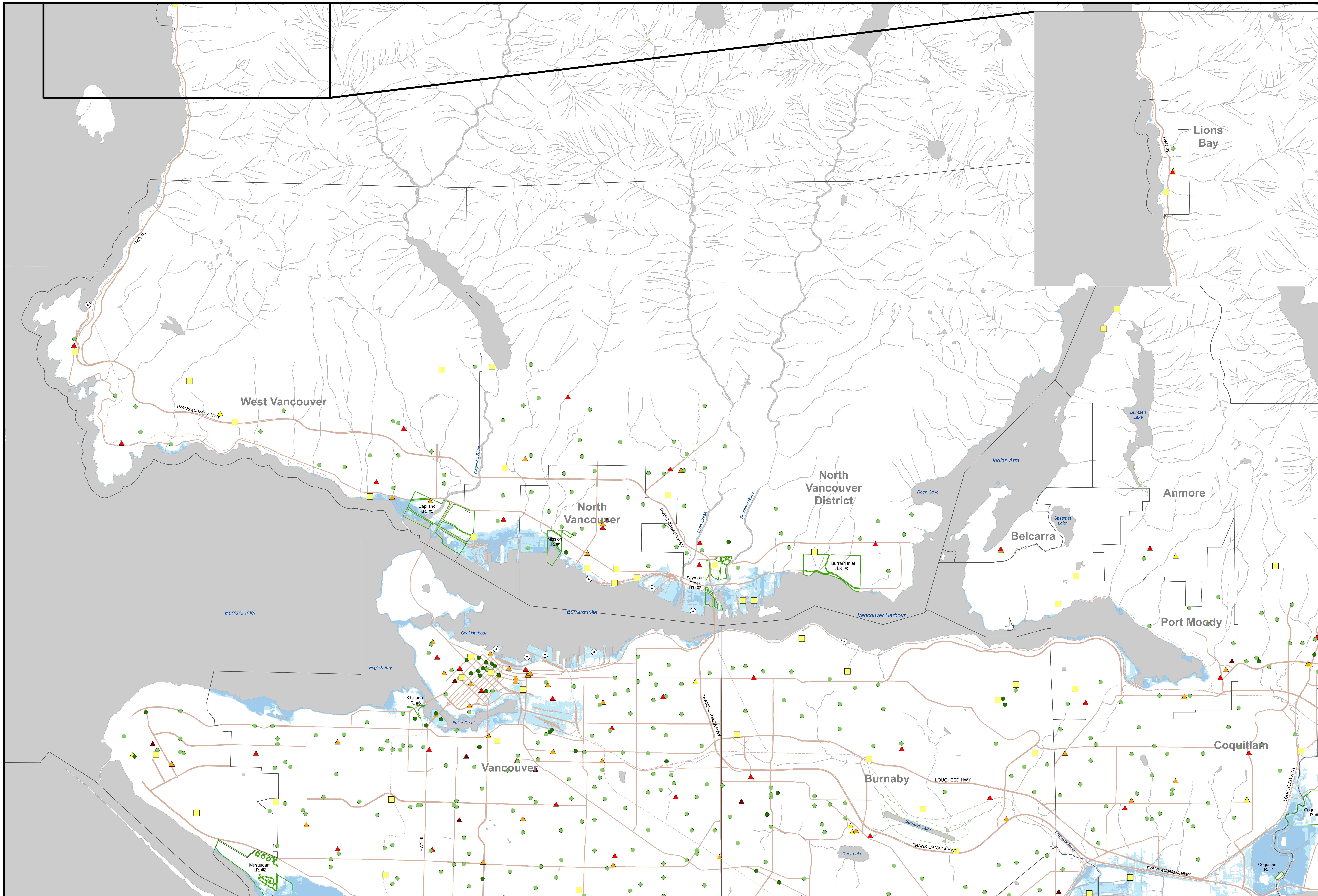
*LOWER MAINLAND REGIONAL FLOOD VULNERABILITY ASSESSMENT*

*FLOOD SCENARIOS A & B ESSENTIAL FACILITIES IN THE STUDY REGION MAPSHEET 1 of 8*

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1 2 3 4 5 6 7 8

Flood Extent, Scenario A
Flood Extent, Scenario B
Indian Reserves and First Nations Treaty Lands
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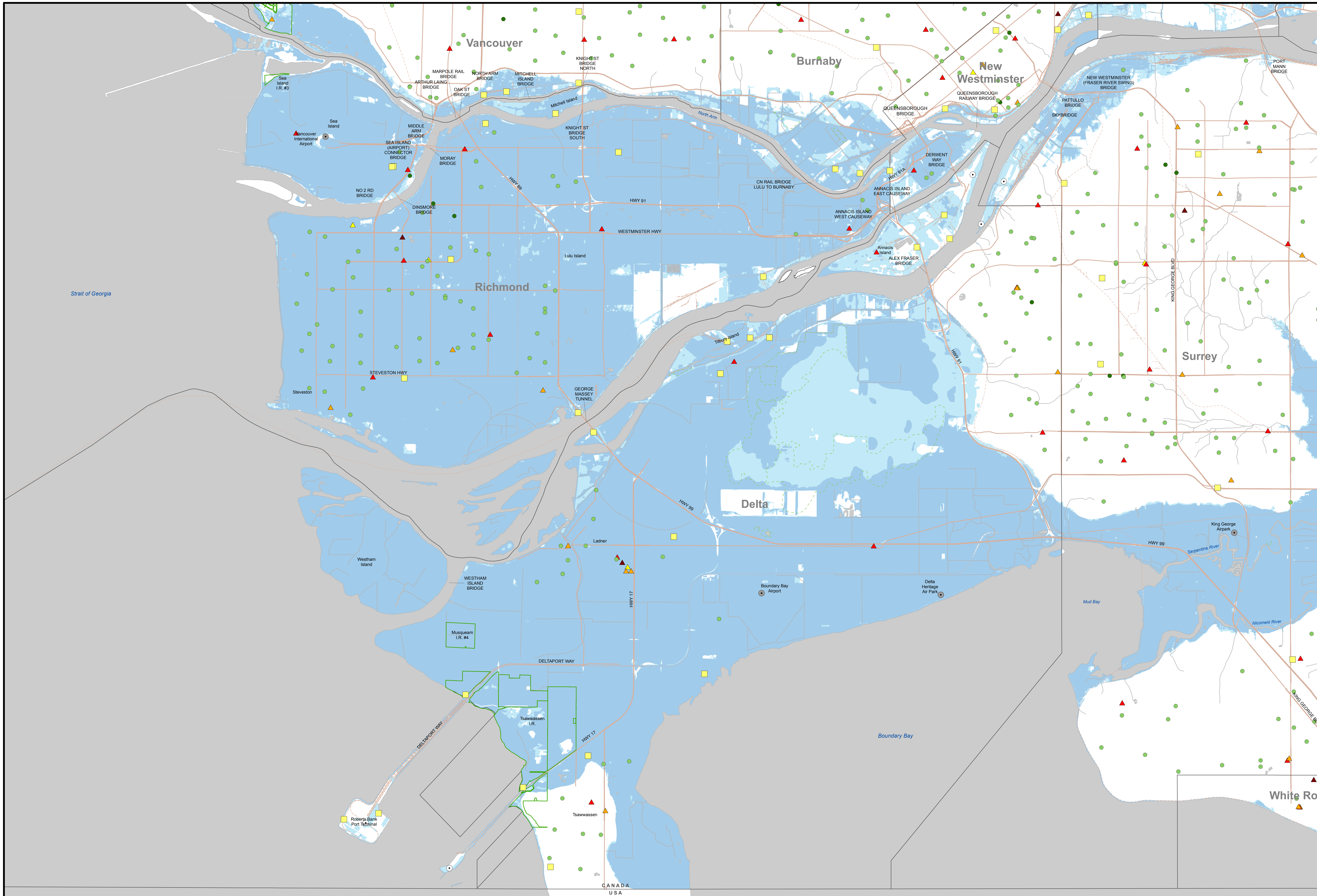
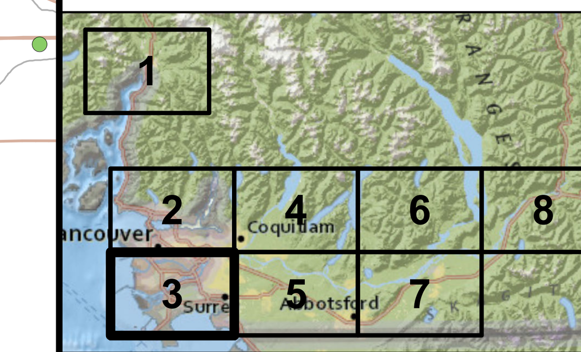
LOWER MAINLAND REGIONAL
FLOOD VULNERABILITY ASSESSMENT

# FLOOD SCENARIOS A & B ESSENTIAL FACILITIES IN THE STUDY REGION MAPSHEET 2 of 8

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- Flood Extent, Scenario A
- Flood Extent, Scenario B
- Indian Reserves and First Nations Treaty Lands
- Fire Hall
- Police Station
- Emergency Operations Centre
- Hospital
- Airport
- Port Facilities
- BC Hydro Substation
- School
- Post-secondary Institution

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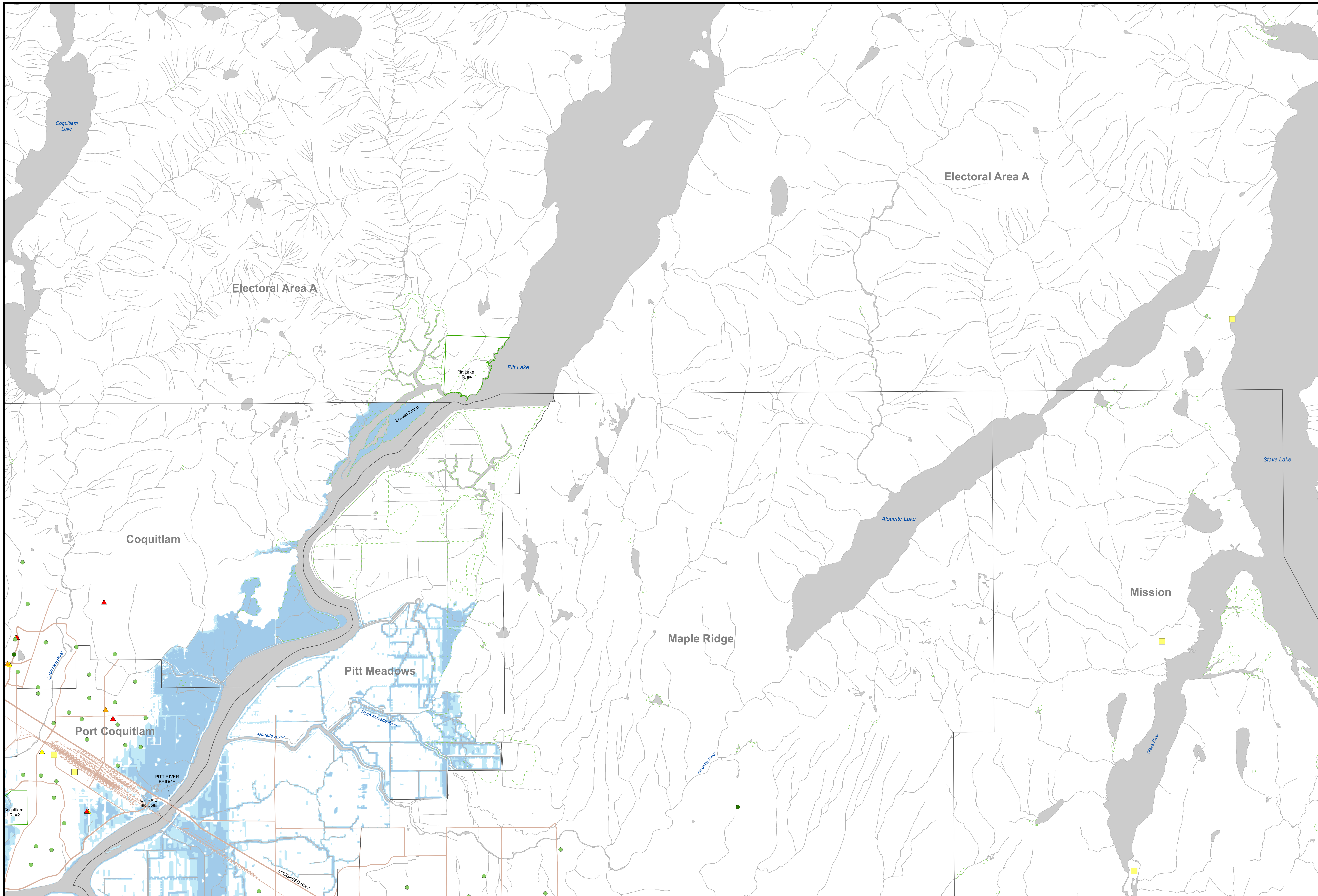
*LOWER MAINLAND REGIONAL FLOOD VULNERABILITY ASSESSMENT*

# *FLOOD SCENARIOS A & B ESSENTIAL FACILITIES IN THE STUDY REGION MAPSHEET 3 of 8*

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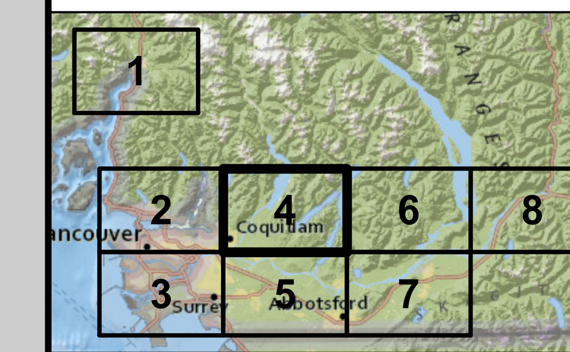


- Flood Extent, Scenario A
- Flood Extent, Scenario B
- Indian Reserves and First Nations Treaty Lands
- Fire Hall
- Police Station
- Emergency Operations Centre
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- Port Facilities
- BC Hydro Substation
- School
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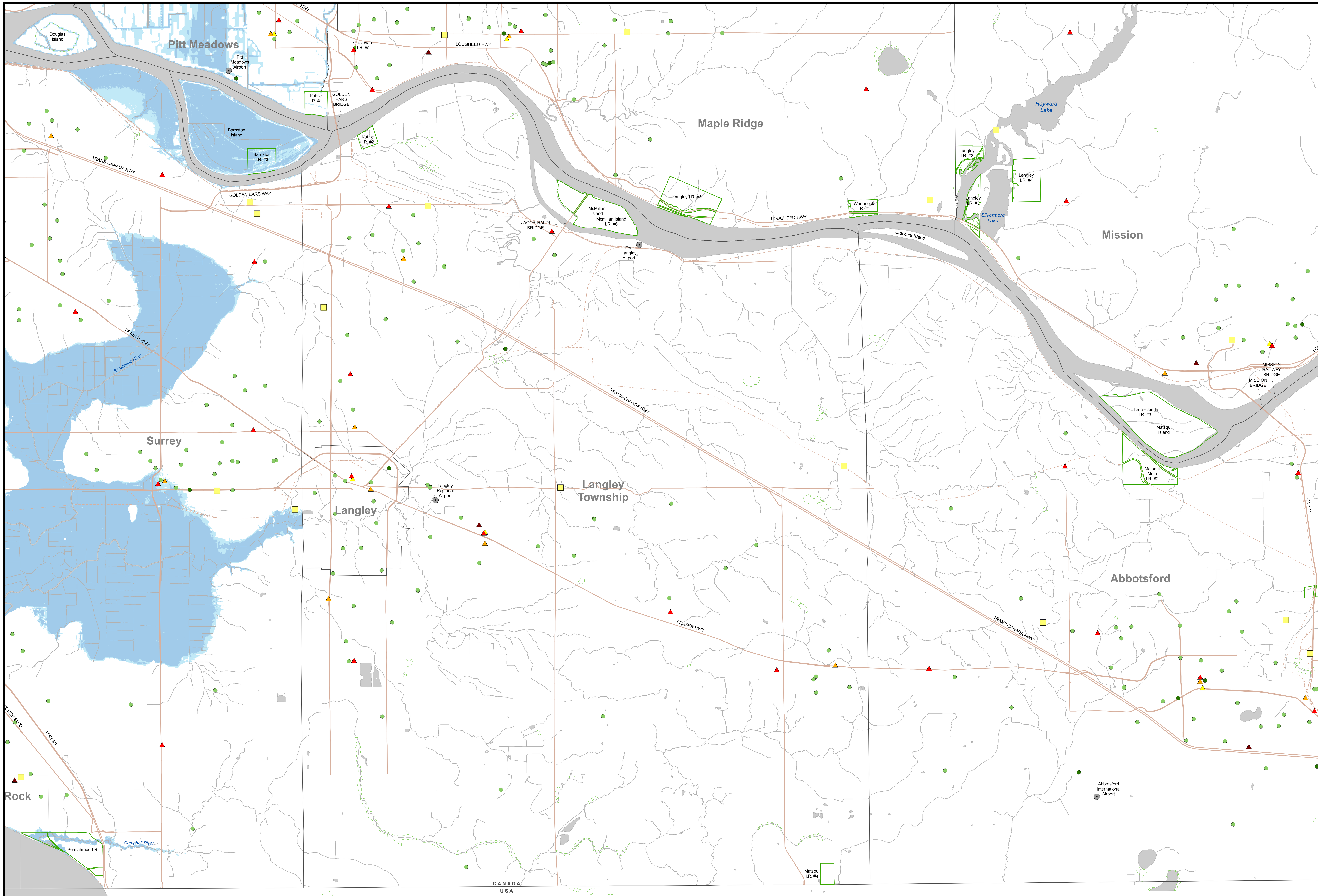
LOWER MAINLAND REGIONAL
FLOOD VULNERABILITY ASSESSMENT

FLOOD SCENARIOS A & B
ESSENTIAL FACILITIES
IN THE STUDY REGION
MAPSHEET 4 of 8





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Flood Extent, Scenario A
Flood Extent, Scenario B
Indian Reserves and First Nations Treaty Lands

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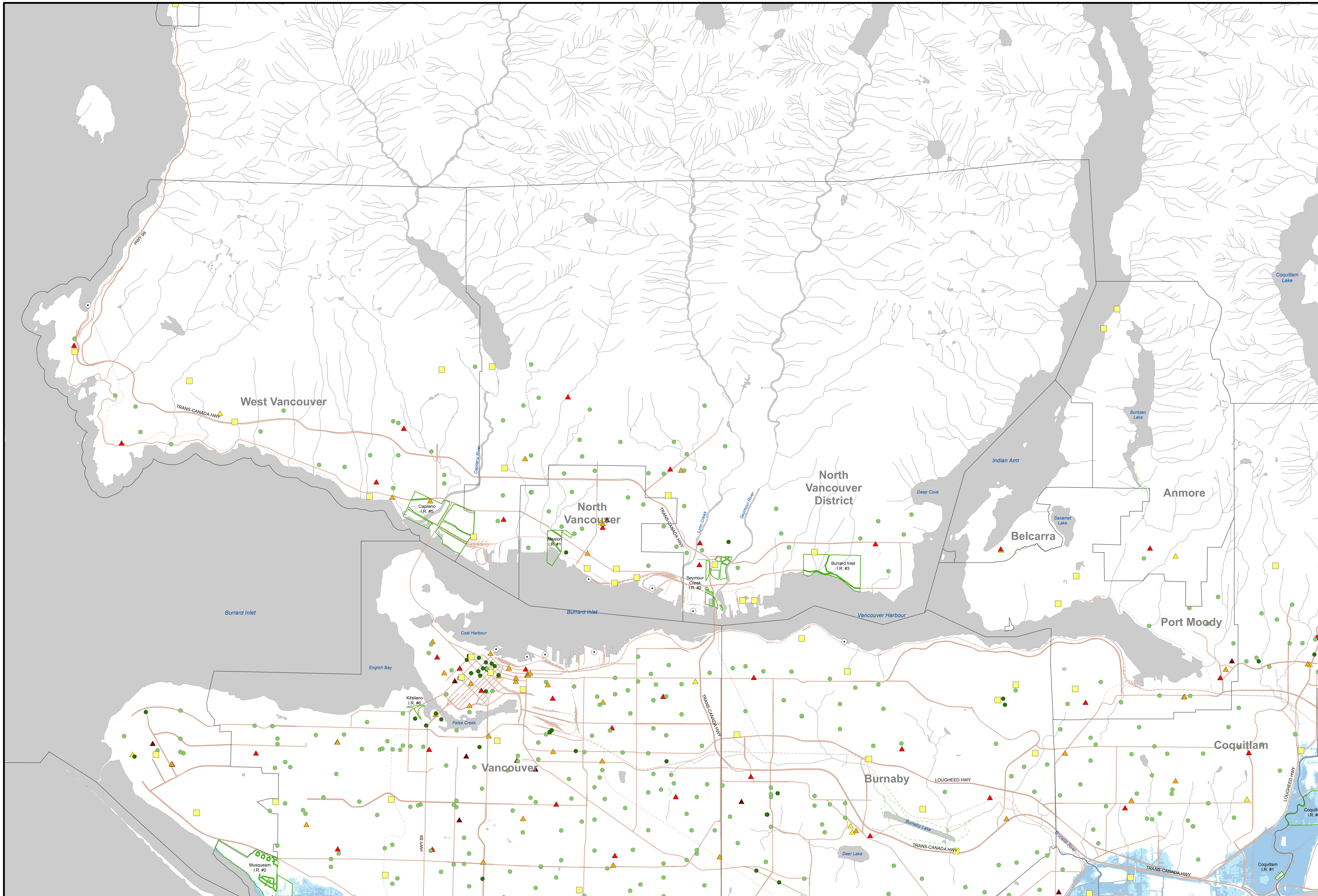
LOWER MAINLAND REGIONAL FLOOD VULNERABILITY ASSESSMENT

FLOOD SCENARIOS A & B
ESSENTIAL FACILITIES
IN THE STUDY REGION
MAPSHEET 5 of 8

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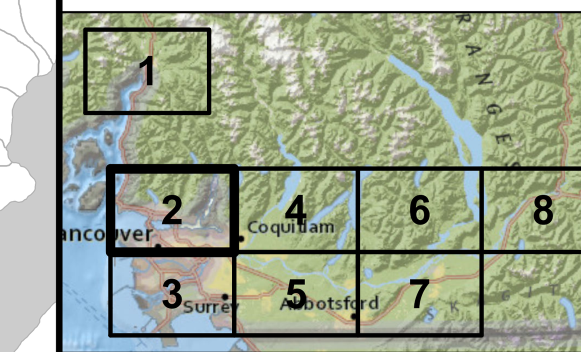


- Flood Extent, Scenario C
- Flood Extent, Scenario D
- Indian Reserves and First Nations Treaty Lands
- Fire Hall
- Police Station
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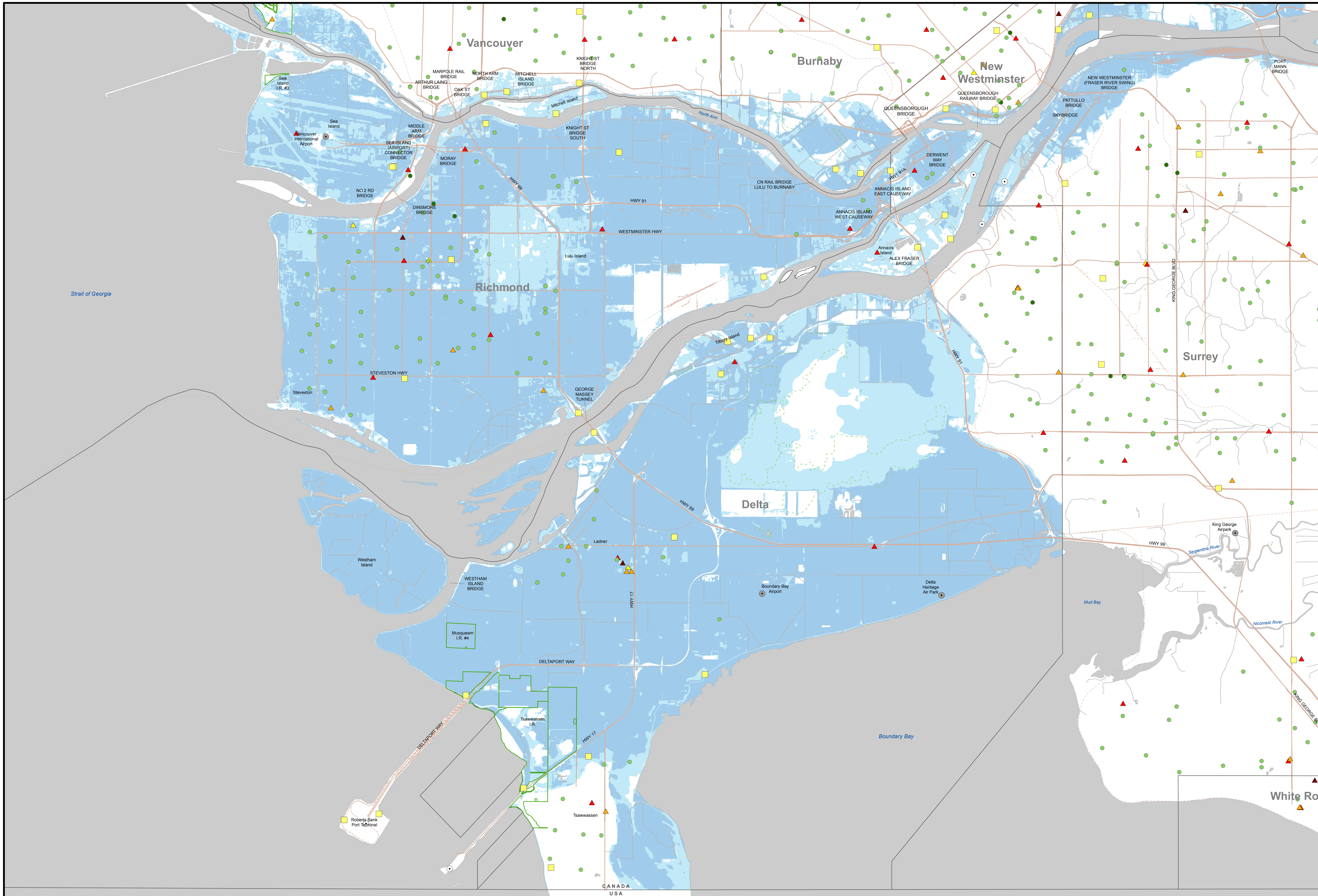
LOWER MAINLAND REGIONAL
FLOOD VULNERABILITY ASSESSMENT

# *FLOOD SCENARIOS C & D ESSENTIAL FACILITIES IN THE STUDY REGION MAPSHEET 2 of 8*

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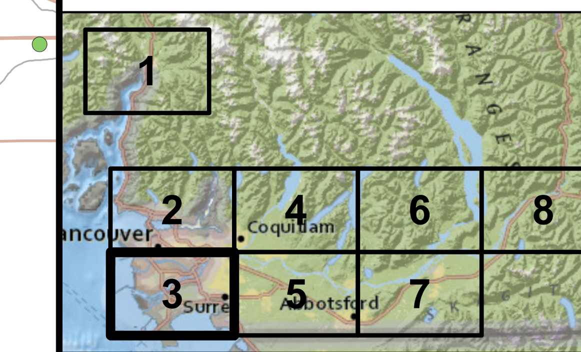


- Flood Extent, Scenario C
- Flood Extent, Scenario D
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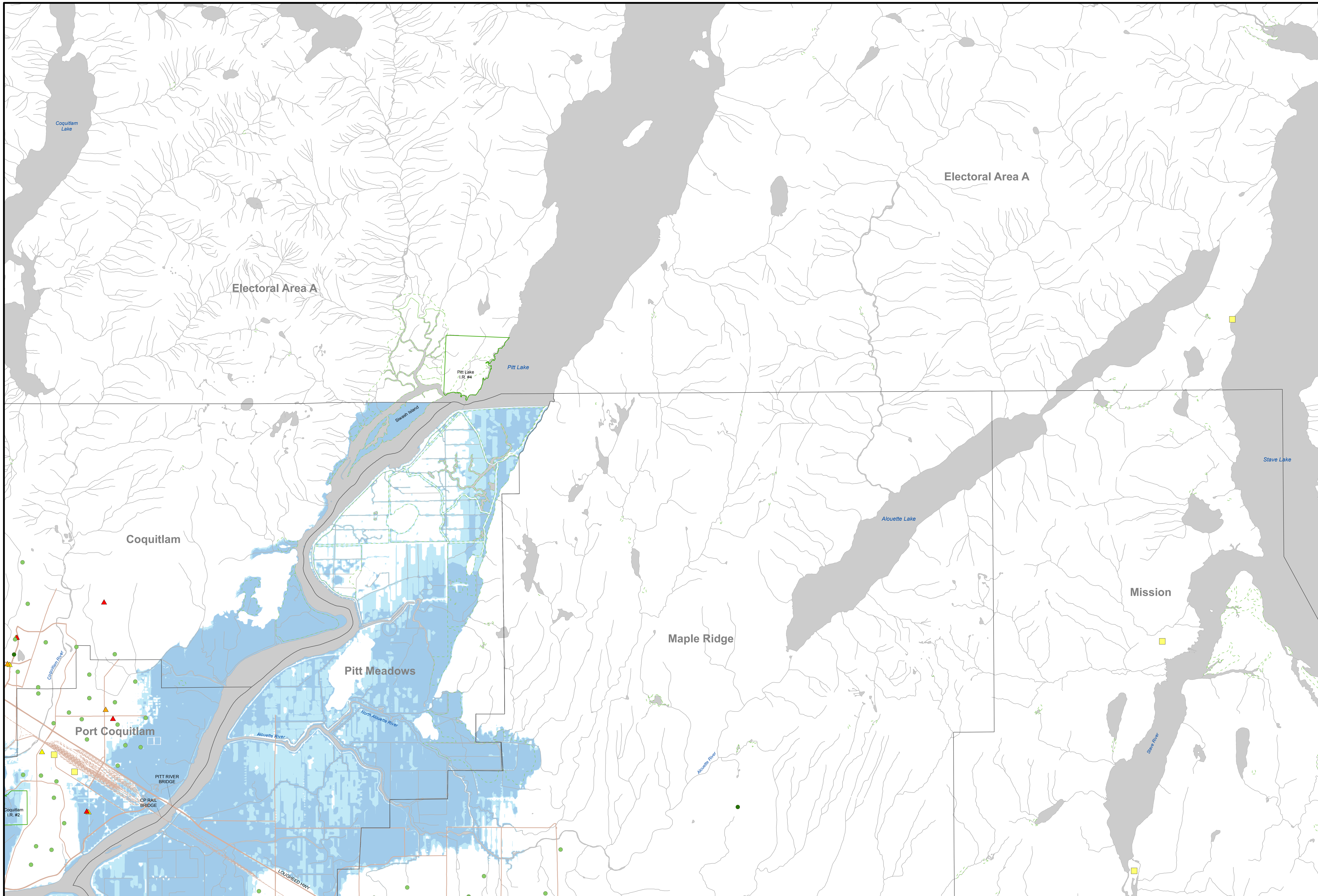
*LOWER MAINLAND REGIONAL FLOOD VULNERABILITY ASSESSMENT*

*FLOOD SCENARIOS C & D ESSENTIAL FACILITIES IN THE STUDY REGION MAPSHEET 3 of 8*





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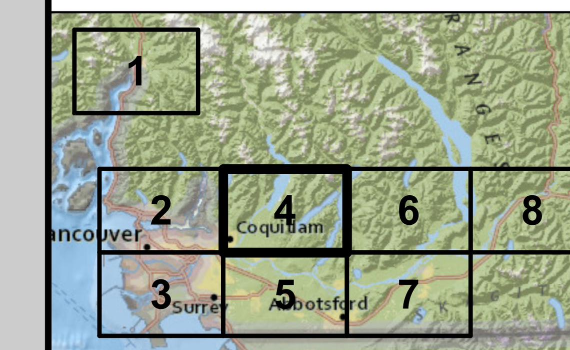

Flood Extent, Scenario C
Flood Extent, Scenario D
Indian Reserves and First Nations Treaty Lands
Fire Hall
Police Station
Emergency Operations Centre
Hospital
Airport
Port Facilities
BC Hydro Substation
School
Post-secondary Institution

**Notes:**

1. Flood extents were developed for two coastal and two riverine flood scenarios. The coastal scenarios, incorporating a 0.6 m wave allowance, are:
   • Scenario A – 1 in 500 AEP still-water ocean state with current sea level (Flood level = 3.40 m GSC).
   • Scenario B – 1 in 500 AEP still-water ocean state with 1 m sea level rise (Flood level = 4.40 m GSC).
   The riverine scenarios, excluding freeboard, are:
   • Scenario C – The Fraser River design flood (equivalent to the 1894 flood of record, with an approximate return period of 500 years) and current sea levels.
   • Scenario D – The 1 in 500 AEP Fraser River flood, incorporating a moderate climate change flow increase for year 2100 and a 1 m sea level rise.
   Note: AEP refers to the Annual Exceedance Probability. A 1 in 500 AEP, or 500-year flood, has a 0.2% chance of occurring in a given year.
2. This map delineates the two riverine flood extents, Scenarios C and D.
3. Topographic data obtained from a variety of sources was used to create a Digital Elevation Model (DEM) for the study area. The DEM horizontal resolution was five metres, except for the upstream portion of the Fraser River (from Mission-Abbotsford to Hope), where the resolution was ten metres. The maps depict flood levels based on ground conditions represented in this DEM.
4. The flood levels are based on a generalized water surface.
5. The accuracy of the floodplain boundary is limited by the resolution of the DEM and the flood level assumptions adopted for this study. The maps are for the overview level assessment of flood vulnerabilities described by NHC et al (2015). They do NOT represent floodplain mapping and should not be used as such.

**Data Sources:**

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2. Rail obtained from Natural Resources Canada. Light rail obtained from Translink.
3. Emergency operations centres obtained from EMBC.
4. Index basemap from National Geographic and Esri.

**References:**


1. NHC (2016). Lower Mainland Flood Management Strategy; Project 2: Regional Assessment of Flood Vulnerability (Final Report). Report prepared for the Fraser Basin Council.


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Units: METRES

| Geomorphologist | GIS | Reviewer |
|---|---|---|
| CXM | MSN | MCM |

| Job Number | Date |
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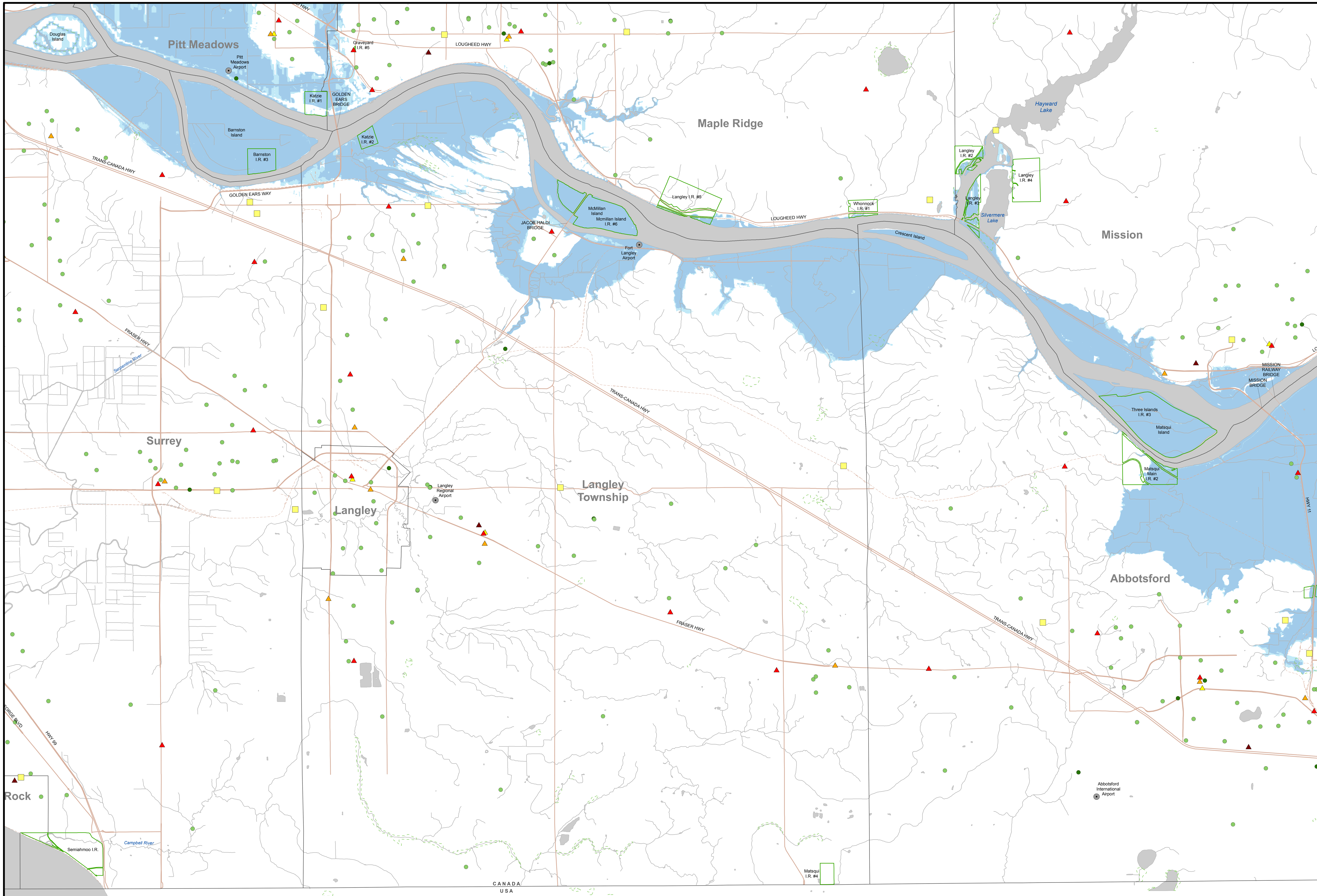
LOWER MAINLAND REGIONAL
FLOOD VULNERABILITY ASSESSMENT

FLOOD SCENARIOS C & D
ESSENTIAL FACILITIES
IN THE STUDY REGION
MAPSHEET 4 of 8

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1 2 3 4 5 6 7 8

- Flood Extent, Scenario C
- Flood Extent, Scenario D
- Indian Reserves and First Nations Treaty Lands
- Fire Hall
- Police Station
- Emergency Operations Centre
- Hospital
- Airport
- Port Facilities
- BC Hydro Substation
- School
- Post-secondary Institution

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| *Geomorphologist* | *GIS* | *Reviewer* |
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| *CXM* | *MSN* | *MCM* |

| *Job Number* | *Date* |
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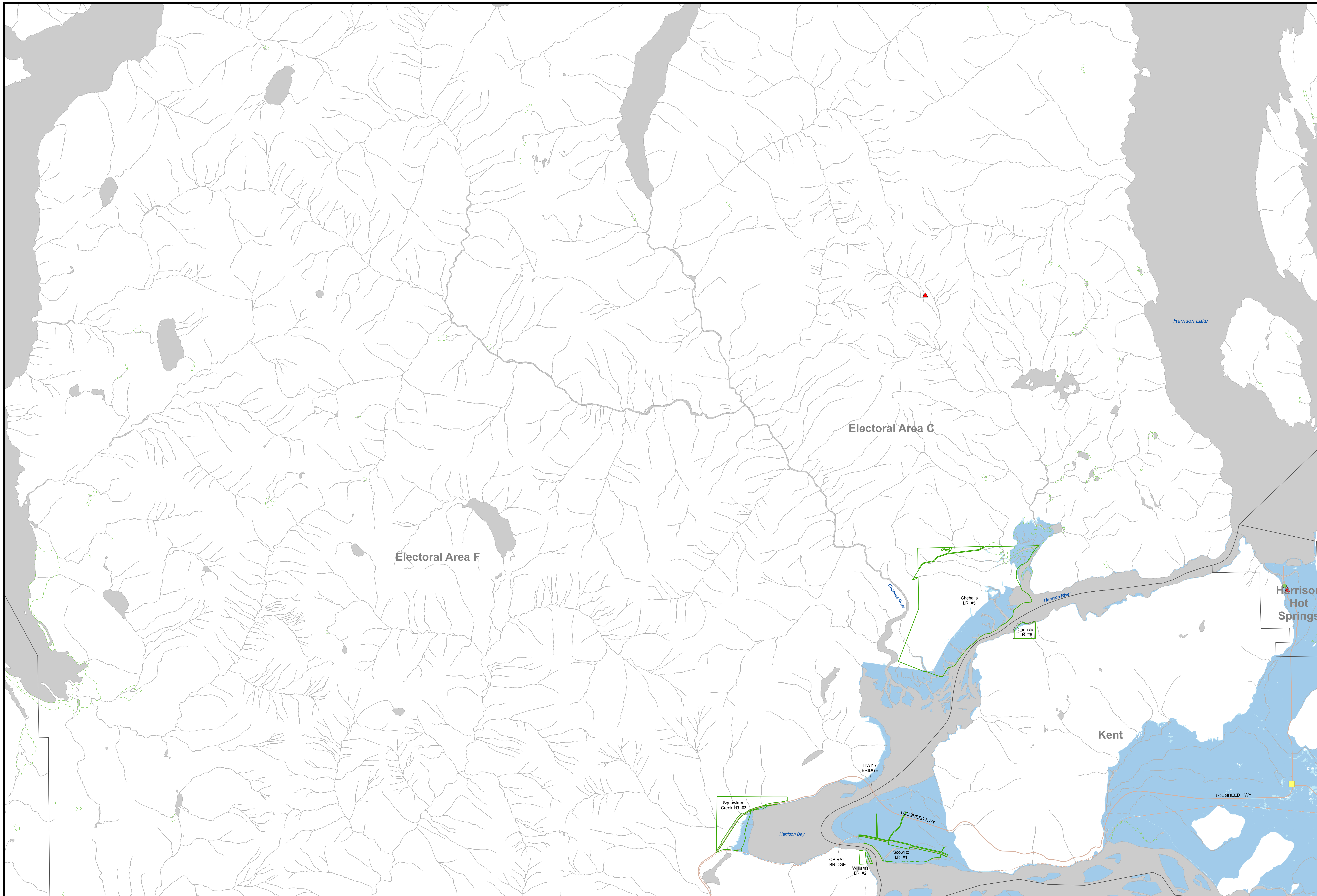
*LOWER MAINLAND REGIONAL FLOOD VULNERABILITY ASSESSMENT*

*FLOOD SCENARIOS C & D ESSENTIAL FACILITIES IN THE STUDY REGION MAPSHEET 5 of 8*





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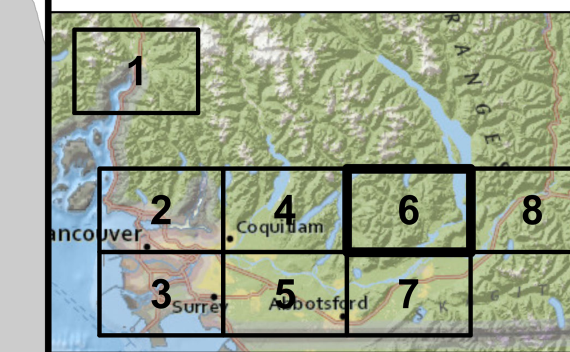


Flood Extent, Scenario C
Flood Extent, Scenario D
Indian Reserves and First Nations Treaty Lands

Fire Hall
Police Station
Emergency Operations Centre
Hospital
Airport
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BC Hydro Substation
School
Post-secondary Institution

**Notes:**

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**References:**


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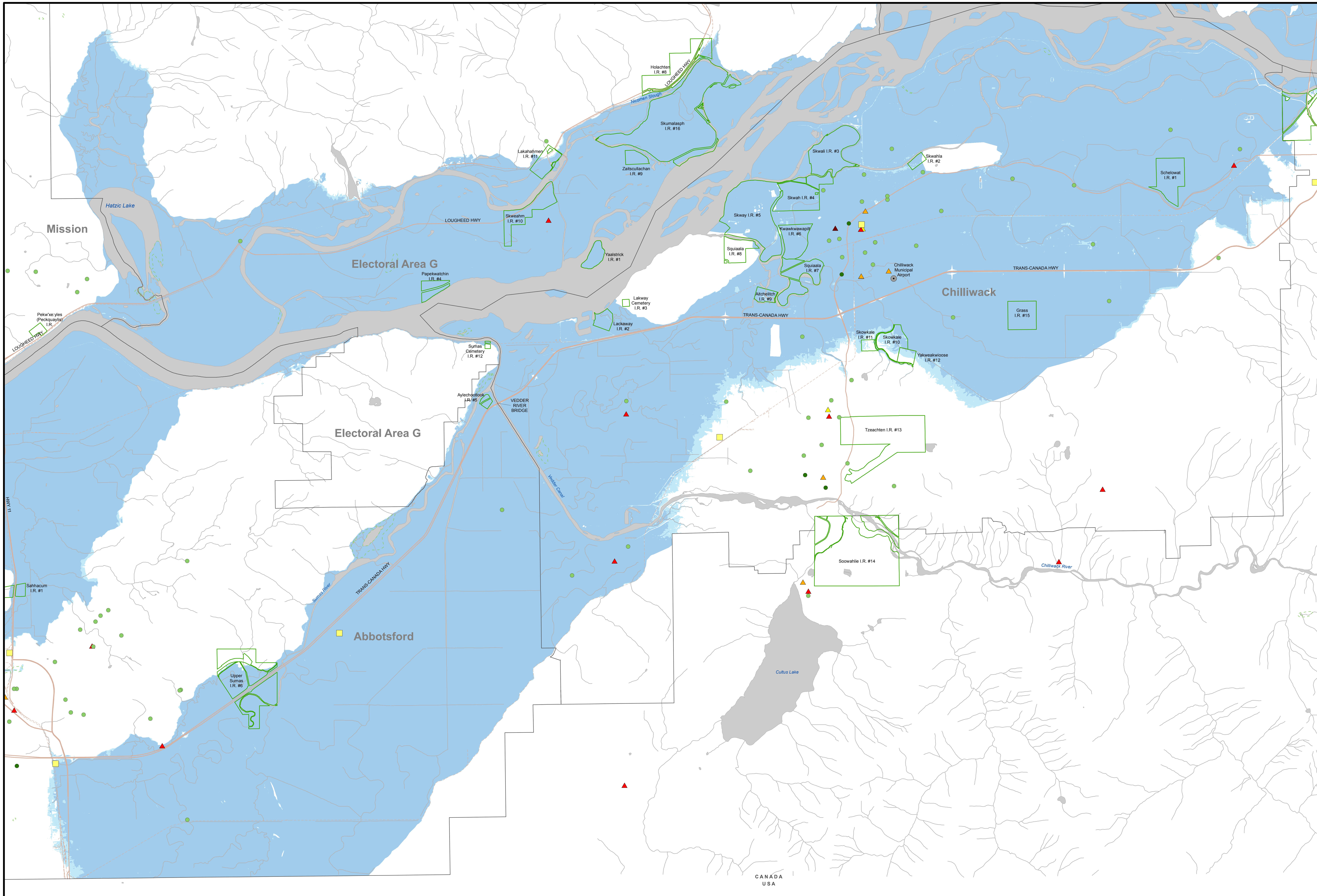
LOWER MAINLAND REGIONAL
FLOOD VULNERABILITY ASSESSMENT

# FLOOD SCENARIOS C & D ESSENTIAL FACILITIES IN THE STUDY REGION MAPSHEET 6 of 8

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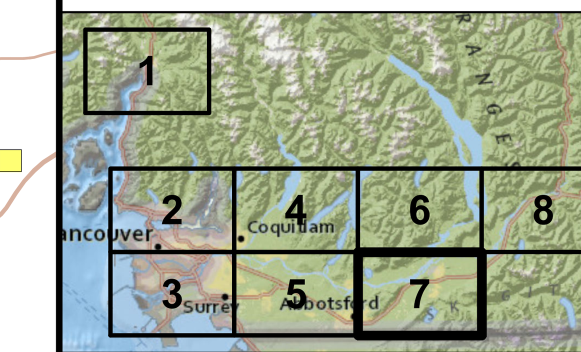


Flood Extent, Scenario C
Flood Extent, Scenario D
Indian Reserves and First Nations Treaty Lands

Fire Hall
Police Station
Emergency Operations Centre
Hospital
Airport
Port Facilities
BC Hydro Substation
School
Post-secondary Institution

**Notes:**

1. Flood extents were developed for two coastal and two riverine flood scenarios. The coastal scenarios, incorporating a 0.6 m wave allowance, are:
   • Scenario A – 1 in 500 AEP still-water ocean state with current sea level (Flood level = 3.40 m GSC).
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   The riverine scenarios, excluding freeboard, are:
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   Note: AEP refers to the Annual Exceedance Probability. A 1 in 500 AEP, or 500-year flood, has a 0.2% chance of occurring in a given year.
2. This map delineates the two riverine flood extents, Scenarios C and D.
3. Topographic data obtained from a variety of sources was used to create a Digital Elevation Model (DEM) for the study area. The DEM horizontal resolution was five metres, except for the upstream portion of the Fraser River (from Mission-Abbotsford to Hope), where the resolution was ten metres. The maps depict flood levels based on ground conditions represented in this DEM.
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**Data Sources:**

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**References:**

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Units: METRES

| Geomorphologist | GIS | Reviewer |
|---|---|---|
| CXM | MSN | MCM |

| Job Number | Date |
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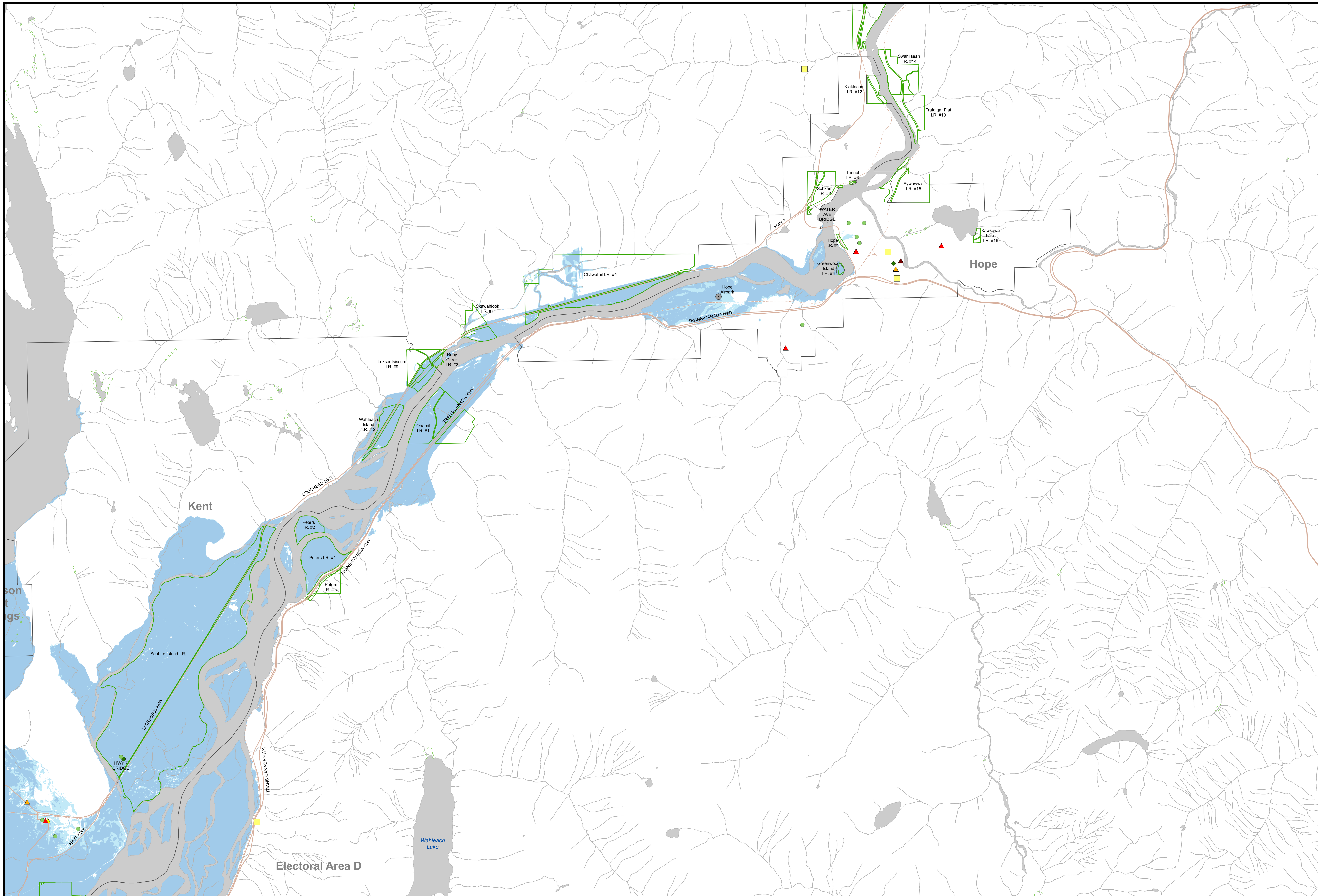
LOWER MAINLAND REGIONAL FLOOD VULNERABILITY ASSESSMENT

# FLOOD SCENARIOS C & D ESSENTIAL FACILITIES IN THE STUDY REGION MAPSHEET 7 of 8

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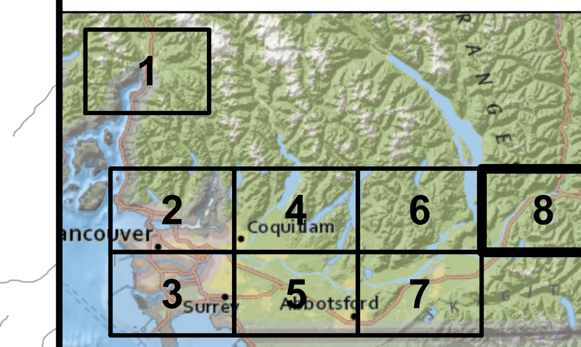


| | |
|---|---|
| Flood Extent, Scenario C | Indian Reserves and First Nations Treaty Lands |
| Flood Extent, Scenario D | |
| Fire Hall | Airport |
| Police Station | Port Facilities |
| Emergency Operations Centre | BC Hydro Substation |
| Hospital | School |
| | Post-secondary Institution |

**Notes:**

1. Flood extents were developed for two coastal and two riverine flood scenarios. The coastal scenarios, incorporating a 0.6 m wave allowance, are:
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   The riverine scenarios, excluding freeboard, are:
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   Note: AEP refers to the Annual Exceedance Probability. A 1 in 500 AEP, or 500-year flood, has a 0.2% chance of occurring in a given year.
2. This map delineates the two riverine flood extents, Scenarios C and D.
3. Topographic data obtained from a variety of sources was used to create a Digital Elevation Model (DEM) for the study area. The DEM horizontal resolution was five metres, except for the upstream portion of the Fraser River (from Mission-Abbotsford to Hope), where the resolution was ten metres. The maps depict flood levels based on ground conditions represented in this DEM.
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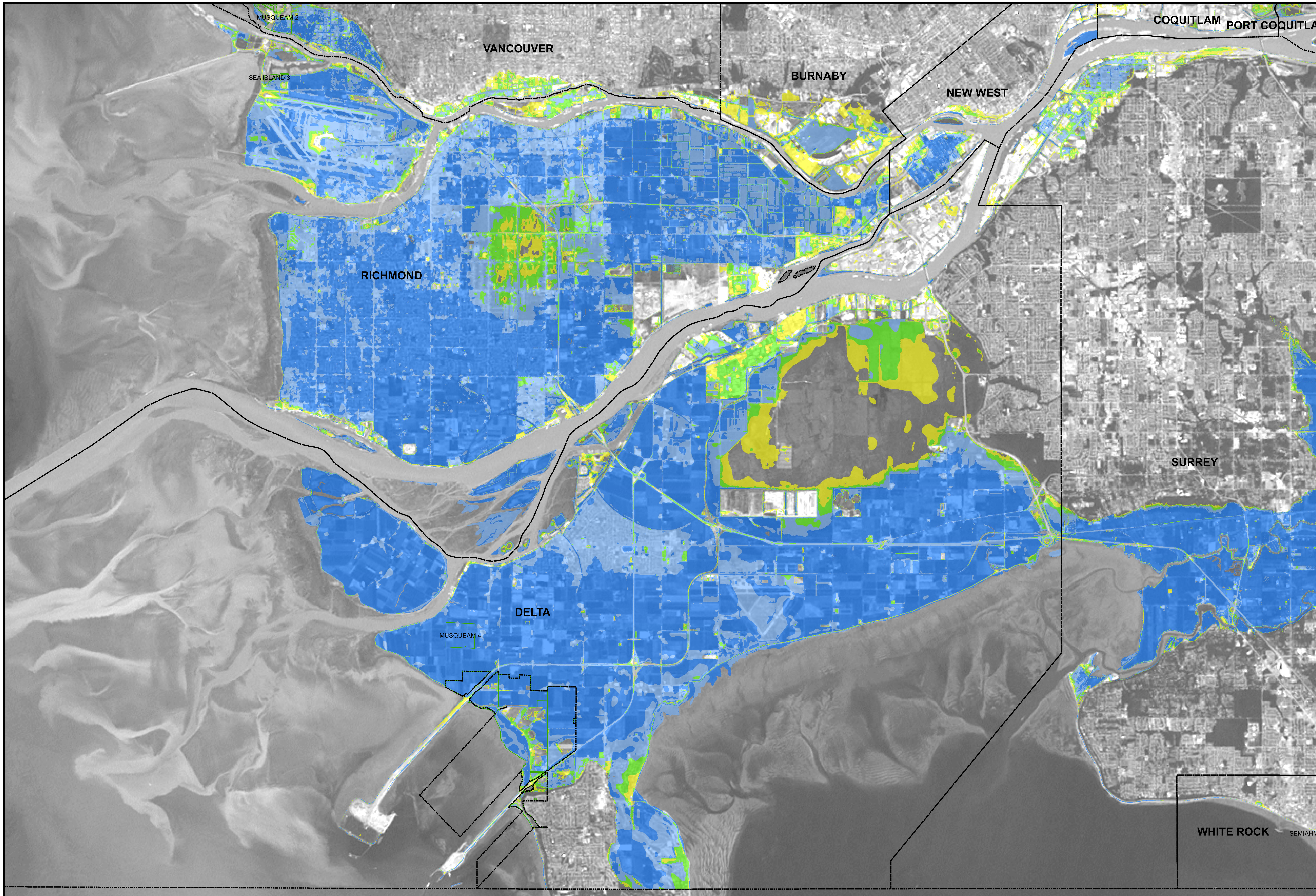
*Units: METRES*

| Geomorphologist | GIS | Reviewer |
|---|---|---|
| CXM | MSN | MCM |

| Job Number | Date |
|---|---|
| 3000149 | 15-APR-2016 |

*LOWER MAINLAND REGIONAL FLOOD VULNERABILITY ASSESSMENT*

*FLOOD SCENARIOS C & D ESSENTIAL FACILITIES IN THE STUDY REGION MAPSHEET 8 of 8*





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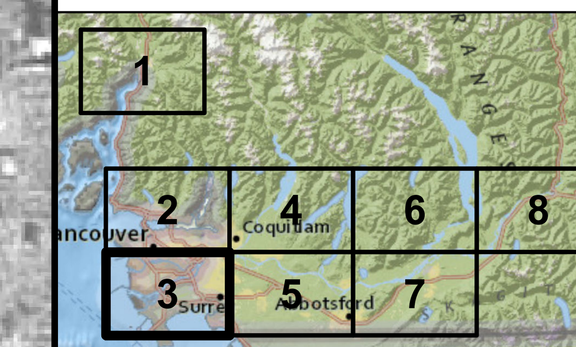


Municipal Boundary

Indian Reserves and First Nations Treaty Lands

Depth (m)

| | |
|---|---|
| 0 to 0.5 | Most houses are dry; walking in moving water or driving is potentially dangerous; basements and underground parking may be flooded, potentially causing evacuation. |
| 0.5 to 1.0 | Water on ground floor; basements and underground parking flooded, potentially causing evacuation; electricity failed; vehicles are commonly carried off roadways. |
| 1.0 to 2.0 | Ground floor flooded; residents evacuate. |
| 2.0 to 5.0 | First floor and often roof covered by water; residents evacuate. |
| > 5.0; River | First floor and often roof covered by water; residents evacuate. |

**Notes:**

1. Flood depths were developed for two coastal and two riverine flood scenarios. The coastal scenarios, incorporating a 0.6 m wave allowance, are:
   • Scenario A – 1 in 500 AEP still-water ocean state with current sea level (Flood level = 3.40 m GSC).
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2. This map delineates flood depths for Scenario A.
3. Topographic data obtained from a variety of sources was used to create a Digital Elevation Model (DEM) for the study area. The DEM horizontal resolution was five metres, except for the upstream portion of the Fraser River (from Mission-Abbotsford to Hope), where the resolution was ten metres. The maps depict flood levels based on ground conditions represented in this DEM.
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**Data Sources:**

1. Municipal boundaries and First Nations boundaries obtained from Data BC.
2. Background Landsat images obtained from Geomatics Canada, Centre for Topographic Information. Imagery collected 30-Jul-2000 and 05-Oct-2001.
3. Index basemap from National Geographic and Esri.

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*LOWER MAINLAND REGIONAL FLOOD VULNERABILITY ASSESSMENT*

*FLOOD DEPTHS SCENARIO A MAPSHEET 3 of 8*


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Flood Extent, Scenario A (2015)
Flood Extent, Scenario B (2100)
Indian Reserves and First Nations Treaty Lands
Fire Hall
Police Station
Emergency Operations Centre
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BC Hydro Substation
School
Post-secondary Institution

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   Note: AEP refers to the Annual Exceedance Probability. A 1 in 500 AEP, or 500-year flood, has a 0.2% chance of occurring in a given year.
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LOWER MAINLAND REGIONAL FLOOD VULNERABILITY ASSESSMENT

FLOOD EXTENTS SCENARIOS A & B

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Flood Extent, Scenario C (2015)
Flood Extent, Scenario D (2100)
Indian Reserves and First Nations Treaty Lands
Fire Hall
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Emergency Operations Centre
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BC Hydro Substation
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Units: METRES
Geomorphologist CXM
GIS MSN
Reviewer MCM
Job Number 3000149
Date 14-APR-2016
LOWER MAINLAND REGIONAL FLOOD VULNERABILITY ASSESSMENT
FLOOD EXTENTS SCENARIOS C & D
Squamish
West Vancouver
North Vancouver
Vancouver
Burnaby
Port Moody
Coquitlam
Port Coquitlam
Maple Ridge
Mission
Surrey
Langley
Abbotsford
Delta
White Rock
Kent
Hope
Electoral Area A
Electoral Area C
Electoral Area D
Electoral Area E
Electoral Area F
Electoral Area G

# Appendix A: Data Summary

### Table A1. Organizations Contacted for Spatial Data

| CONTACT INFO | | | GENERAL INFO | | TOPOGRAPHIC | | ASSET INVENTORY | | OTHER | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Organization** | **Contact Name** | **Phone or Email** | **Status** | **Notes** | **Available** | **Obtained** | **Available** | **Obtained** | **Available** | **Obtained** |
| **PROVINCIAL/NATIONAL** | | | | | | | | | | |
| BC Ministry of Transportation and Infrastructure | Patricia Wong | patricia.wong@gov.bc.ca | PDF file received | | None available | | Disaster response routes (PDF only) | YES | Erosion protection of MoTI bridges;<br>Culverts and catch basins at MoTI roads;<br>Hydrographic surveys and scour evaluations for some bridges; mostly not relevant to study | NO |
| DataBC | Online download | http://www.data.gov.bc.ca/;<br>https://apps.gov.bc.ca/pub/dwds/home.so | Data acquired from website | | | | | | | |
| BC Agriculture Council | | | FBC to follow up | | | | | | | |
| BC Hydro | Faizal Yusuf | faizal.yusuf@bchydro.com | Data received | | 2008 DEM, thinned, Hope to Mission | YES | Substations;<br>Transmission lines | YES | | |
| BC Oil and Gas Commission (OGC) | Online download via DataBC | https://apps.gov.bc.ca/pub/dwds/home.so | Data acquired from website | Could not locate any pipeline data | | | Oil and gas facility locations | YES | | |
| Natural Resources Canada | Murray Journeay (Research Scientist) | Murray.Journeay@Canada.ca, 604-666-1130 | Data received | | Squamish DEM | YES | Translink data | YES | | |
| **REGIONAL** | | | | | | | | | | |
| Fraser Valley Regional District | Shannon Sigurdson (GIS Technician) | ssigurds@fvrd.bc.ca | Data received | Some data is for FVRD (affected Electoral Areas Only), District of Hope and Village of Harrison Hot Springs - contacted other municipalities separately | None supplied | NO | Regionwide: Railways;<br>Firehalls (different from BC data); Airports;<br>Local: Watermains;<br>Hydrants; Works yards;<br>EOCs; Local parks | YES | | |
| Metro Vancouver | Brent Burton (Water Services Dept.; on JPC);<br>Ed von Euw (on JPC);<br>Dan Tancon (GIS);<br>Michael Coombes (GIS Programmer/Analyst) | Brent.Burton@metrovancouver.org, 604-451-6572;<br>Ed.vonEuw@metrovancouver.org;<br>Dan.Tancon@metrovancouver.org, 604-436-6854;<br>Michael.Coombes@metrovancouver.org, 604-451-6620 | Data received | | Have some for lower Seymour and lower Capilano; other data is not theirs to distribute | NO | Storm sewer;<br>Water distribution | YES | | |
| Port Metro Vancouver | Sean Smith (Asset Management GIS) | Sean.Smith@portmetrovancouver.com, 604-665-9251 | Data received | | 2012 McElhanney Lidar LAS or Grid files, various locations (acquired for part of New Westminster) | YES | Port road centrelines;<br>Railroad centrelines;<br>Port bridges;<br>Dock structures;<br>Shoreline rip-rap;<br>Water and sewer infrastructure;<br>Building footprints;<br>Building general use info;<br>Possibly contaminated sites | YES | | |
| TransLink (via NRCan) | Carol Wagner (GIS Specialist, GSC, NRCan) | Carol.Wagner@Canada.ca, 604-666-1315 | Data received | Translink gave permission (via J.Shoubridge, FBC) for NRCan to share Translink data used for Hazus EQ modelling | n.a. | n.a. | Light rail lines & stations;<br>West Coast Express line & stations; bus routes, depots & exchanges; Seabus route & stations; Tranlink bridges | YES | | |

| CONTACT INFO | | | GENERAL INFO | | TOPOGRAPHIC | | ASSET INVENTORY | | OTHER | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Organization** | **Contact Name** | **Phone or Email** | **Status** | **Notes** | **Available** | **Obtained** | **Available** | **Obtained** | **Available** | **Obtained** |
| Vancouver International Airport (YVR) | James Blake (Manager, Engineering Services) | james_blake@yvr.ca, 604-303-4416 | Had initial response from agency, but no data received | Some data in DGN not GIS | 2014 Lidar | NO | Drainage infrastructure;<br>Transportation (roads, bike lanes, etc);<br>Airport specific (runways, taxiways, buildings, etc);<br>Water, Sewer, Telecom, Fuel lines, Gas, Hydro (limited data in GIS, mostly in DGN) | NO | 2012 ortho (2014 ortho pending);<br>2013 flood mapping | NO |
| **LOCAL** | | | | | | | | | | |
| City of Abbotsford | Stella Chiu (Senior Drainage & Wastewater Engineer) | schiu@abbotsford.ca, 604-864-5515 | Data received | | 1m & 2m contours; LAS files (60 GB) (obtained contours; did not obtain LAS files due to file size) | YES | Roads;<br>Railways and hubs;<br>Bridges;<br>Airports;<br>Trunk water and sewer;<br>Municipal water and sewer;<br>Contaiminated sites;<br>Fire and police stations;<br>Hospitals;<br>Municipal works yards;<br>Schools;<br>Cemeteries and crematoriums;<br>Municipal parks; received some of this data | YES | | |
| Village of Anmore | | | No response; see Port Moody | Probably no significant flooding - omit | | | | | | |
| Village of Belcarra | | | No response; see Port Moody | Probably no significant flooding, can omit | | | | | | |
| City of Burnaby | Ed Clark | | Sent contour data for Big Bend area only 21-May-2015, via FBC | | Lidar-based contours (only supplied for Big Bend area) | YES | | | | |
| City of Chilliwack | Frank Van Nynatten (Assistant Manager of Environmental Services);<br>Tara Friesen;<br>Allan Gilbert (GIS Supervisor) | vanny@chilliwack.com, 604-793-2720;<br>tfriesen@chilliwack.com;<br>gilbert@chilliwack.com, 604-793-2985 | Limited data received | Covered by BC Hydro DEM | 2m contour; 2014 DEM; 2013 Lidar | NO | Drainage infrastructure;<br>Roads; Bridges; Waterworks;<br>Stormwater; Wastewater | NO | 2012 Orthophoto;<br>Flood protection infrastructure;<br>Floodplain maps;<br>Flood hazard maps;<br>Flood modelling; Recd some floodplain mapping | YES |
| City of Coquitlam | Melony Burton (Engineering Project Coordinator);<br>Mike Esovoloff | mburton@coquitlam.ca;<br>mesovoloff@coquitlam.ca | Data received | | 2012 & 2014 Lidar LAS | YES | Road centrelines;<br>Community Centres;<br>Municipal parkland and natural areas;<br>Citywide OCP Land Use;<br>Evergreen line & stations;<br>Drainage network;<br>Sanitary network;<br>Water network | YES | | |
| Corporation of Delta | Hugh Fraser;<br>Steve Ellis | HFraser@delta.ca;<br>sellis@delta.ca, 604-946-3292 | Data received | SE indicated that is too much effort to export all data from their Oracle/CAD system, asked for highest priorities.<br>Full Lidar data offered, but beyond scope of project for NHC to acquire and process this. | Spring 2014 Lidar;<br>2014 0.5m contours in NAD83 (supplied contours only) | YES | Sewer, water, parks, facilities, railways | YES | Dike breach/flood risk and consequence report | YES |

| CONTACT INFO | | | GENERAL INFO | | TOPOGRAPHIC | | ASSET INVENTORY | | OTHER | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Organization** | **Contact Name** | **Phone or Email** | **Status** | **Notes** | **Available** | **Obtained** | **Available** | **Obtained** | **Available** | **Obtained** |
| District of Kent | Matthew Connolly (Environmental and Engineering Services Coordinator)<br>Heidi Lam (Archiving/Data/GIS Technician) | Mconnolly@district.kent.bc.ca, 604-796-2235<br>hlam@district.kent.bc.ca, 604-796-2235 | Data received | | Parially Covered by BC Hydro DEM;<br>mix of 5m, 10m (both from older Lidar) and 20m contour data; supplied contours but some data not useable as does not have elevation values | YES | Water, sewer, storm networks (no attributes);<br>Police, ambulance, etc XY locations (only supplied water, sewer and storm data) | YES | | |
| City of Langley | Andrew Brown (Mapping Technician) | abrown@langleycity.ca, 604-514-2821 | Data received | Only requested DEM data | Have Lidar, but not allowed to use on this project;<br>instead provided 2007 1m contours and spot heights | YES | | | | |
| Township of Langley | Julie Gee | jgee@tol.ca<br>https://data.tol.ca (Open Data) | Data received and downloaded | | Contours, year unknown (on Open Data);<br>DEM points (irregular spacing, not grid, spacing varies from detailed to 10m, 25m, etc) | YES | Bridges; Schools; Cemeteries; Various municipal facilities; Water, sewer, drainage networks; Rail; Roads | YES | Watershed boundaries;<br>Areas unprotected by dikes | YES |
| Village of Lions Bay | Nikii Hoglund | nhoglund@lionsbay.ca | Data received | Data rec'd via J.Shoubridge (FBC) | Lidar DEM; 1m contours | YES | | | | |
| District of Maple Ridge | | | No response from agency | Topographic data included with Pitt Meadows data | TRIM II data (1m contours, poor accuracy, 1997);<br>5m DEM, TIN based on TRIM II data; acquired from Pitt Meadows | YES | | | | |
| District of Mission | | | No response from agency (FBC followed up) | | | | | | | |
| City of New Westminster | | | No response from agency (FBC followed up) | | Partial 2012 DEM from PMV | YES | | | | |
| City of North Vancouver | David Matsubara (on JPC) | dmatsubara@cnv.org | Data received | | 2013 BE Lidar | YES | Buildings; Bridges; Parks & cemetery; Water mains; Hydrants; Sanitary mains; Sanitary pump stations; Day care centres | YES | 2013 orthophoto;<br>Flood protection infrastructure;<br>Floodplain maps;<br>Flood hazard maps;<br>Floodplain modelling; not relevant to current study | NO |
| District of North Vancouver | Julie Pavey;<br>Andrew Durnin (GIS);<br>Fiona Dercole (Public Safety) | PaveyJ@dnv.org;<br>DurninA@dnv.org, 604-990-2458;<br>DercoleF@dnv.org, 604-990-3819 | Data received and downloaded | C.Wagner (NRCan) sent list of data from Hazus EQ model, but most that we can use is available from GeoWeb | Contours available on GEOWeb;<br>Lidar available on request | YES | Bridges; Wharfs; Buildings (including fire, school, etc.); Parks; Bus routes & stops; Street centrelines; Sea Bus route; Rail lines; Disaster response routes; Dangerous goods routes; Electrical transmission lines & towers; Fibre optic lines; Sanitary sewer system; Storm system; Water system; Hydrography; Gas mains & valves; Telus cell sites; Care facilities; Day cares; NSEMO (EOC) | YES | | |

| CONTACT INFO | | | GENERAL INFO | | TOPOGRAPHIC | | ASSET INVENTORY | | OTHER | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Organization** | **Contact Name** | **Phone or Email** | **Status** | **Notes** | **Available** | **Obtained** | **Available** | **Obtained** | **Available** | **Obtained** |
| City of Pitt Meadows | Randy Evans (Operations Superintendent);<br>Gord Gillespie (GIS) | revans@pittmeadows.ca, 604-465-2435;<br>ggillespie@pittmeadows.bc.ca, 604-465-2443 | Data received | | TRIM II data (1m contours, poor accuracy, 1997);<br>5m DEM, TIN based on TRIM II data | YES | Railway centrelines; Airports; Municipal water; Sanitary sewer; Storm sewer; Agriculture; Emergency operations; Municipal works yard; Day care centres; Care homes; Community centres; Municipal parks; Drainage infrastructure | YES | 2014 orthophoto;<br>Dike network;<br>Flood hazard maps; not relevant to current study | NO |
| City of Port Coquitlam | Lionel Wang | lw@portcoquitlam.ca | Had initial response from agency, but no data received | Topographic data included with Pitt Meadows data | 2014 5cm contours; 2014 10cm DEM; 2012 Lidar | YES | Drainage infrastructure; Water; Roads; Bridges; Wastewater | NO | 2014 orthophoto;<br>Flood protection infrastructure;<br>Floodplain maps; not relevant to current study | NO |
| City of Port Moody | Neal Carley (General Manager Engineering & Parks);<br>Kristi Smith | ncarley@portmoody.ca, 604-469-4727;<br>ksmith@portmoody.ca | Data received | | 2012 1m contours & 1.37m resn DEM collected by McEllhanney, covers parts of Belcarra & Anmore as well | YES | | | | |
| City of Richmond | Suman (Project Engineer);<br>Teresa Schlossarek (GIS);<br>Serene Pang (Mapping Technician II) | 604-204-8516;<br>TSchlossarek@richmond.ca;<br>spang@richmond.ca, 604-276-4394 | Data received | | 2011 DEM points (30-50m spacing) and breaklines from IMT | YES | community sites; energy utility; drainage network; parks; sanitary sewer network; street lighting; roads and rail; water network; child care facilities | YES | | |
| District of Squamish | David Roulston;<br>Dan Griffin (GIS/Mapping Supervisor) | Droulston@squamish.ca;<br>dgriffin@squamish.ca | Had initial response from agency, but no data received | Mar 2015: data received from NRCan | DEM supplied by NRCan | YES | | | | |
| City of Surrey | Carrie Baron;<br>Matt Osler;<br>Bill McKay (GIS) | CABaron@surrey.ca;<br>MFOsler@surrey.ca | Data received and downloaded from Open Data | | 2013 Lidar DEM (supplied as 2m, 5m & 10m grids) | YES | Roads, including emergency routes;<br>BC Hydro substations and transmission lines (possibly);<br>Oil and gas pipelines (possibly);<br>Energy facilities;<br>Railways;<br>Potable water valves;<br>Sanitary and drainage pump stations | YES | 2014 orthophoto;<br>Flood extent mapping;<br>Flood modelling for coastal areas and Serpentine-Nicomekl Rivers; Agriculture proffit-loss info (older reports) | YES |
| City of Vancouver | Brad Badelt (Senior Sustainability Specialist) | Brad.Badelt@vancouver.ca | Data received or downloaded | | Feb 2013 1m DEM, Lidar, contours | YES | pump stations; streets network; bridges; water network; sewer network; community centres; homeless shelters; schools; parks; skytrain; railway | YES | 2013 ortho;<br>retaining walls;<br>coastal flood maps & flood depth grids; NHC has from previous study (except retaining walls); mostly not relevant to current study | NO |
| District of West Vancouver | Sandra Bicego;<br>Phil Bates (Manager, Engineering Services);<br>Scott Jenvey | sbicego@westvancouver.ca;<br>pbates@westvancouver.ca, 604-925-7039;<br>sjenvey@westvancouver.ca, 604-925-7163 | Data received | | 2011 1m contours, DEM pts & breaklines | YES | parks; water & sewer; roads; municipal facilities | YES | | |
| City of White Rock | Hiep Lo (Engineering Technologist);<br>Boris Zanic (GIS Specialist) | HLo@whiterockcity.ca;<br>bzanic@whiterockcity.ca | Data received | | 1997 10cm contours (supplied as 1m contours); no DEM or Lidar | YES | drainage infrastructure;<br>sanitary system;<br>roads;<br>EPCOR water | YES | 1997 10cm ortho;<br>2005 floodplain & flood hazard maps | YES |

## Table A2. Spatial Data Collected

| DATA TYPE | LOCATION | SOURCE | DESCRIPTION |
|---|---|---|---|
| | | | |
| **TOPOGRAPHY** | | | **STATUS: MOSTLY COMPLETE** |
| | Squamish | NRCan | approx 2.5m resn DEM developed by NRCan for Squamish flood study (sources: District of Squamish, valley bottom BE Lidar, BC Hydro bathymetric data); data in GCS, vertical units feet |
| | Lions Bay | Lions Bay | 2012 Lidar BE LAS files; 1m contours |
| | West Vancouver | District of West Vancouver | 2011 1m Contours, DEM points & breaklines |
| | North Van City | City of North Vancouver | 2013 BE Lidar |
| | North Van District | District of North Vancouver | 2014 FF Lidar |
| | Belcarra | | partially covered by Port Moody; barely in floodplain, so not high priorty to include |
| | Anmore | | partially covered by Port Moody; barely in floodplain, so not high priorty to include |
| | Port Moody | City of Port Moody | 2012 DEM, includes coverage of main parts of Belcarra & Anmore |
| | UBC | | no data - barely in floodplain, can omit |
| | Vancouver | City of Vancouver | 2013 BE Lidar, with edits made for CoV Climate Change flood study |
| | Burnaby (Big Bend) | City of Burnaby via FBC | 1m contours (possibly based on 2014 Lidar) for Big Bend only |
| | New Westminster | PMV/FBC/CDEM | 2012 Lidar DEM from PMV, delivered as 5m grid + FBC 2004 1m Lidar; incomplete coverage, so added CDEM (resampled to 5m resn) for remaining area |
| | Coquitlam | City of Coquitlam | 2012 Lidar LAS files (full coverage); 2014 Lidar point files (partial coverage) |
| | Port Coquitlam | Pitt Meadows | Pitt Meadows data covers most of Port Coquitlam (Coquitlam covers most of remaining gap) |
| | Pitt Meadows | Pitt Meadows | 5m DEM and a TIN based on TRIM II data; small gaps in data; areas outside muni bnds are suspect |
| | Maple Ridge | Pitt Meadows | Pitt Meadows data covers Maple Ridge |
| | Mission | FBC/BCH | FBC 2004 1m Lidar for d/s + FBC 2004 10m Lidar + BCH 2008 10m Lidar |
| | Harrison Hot Springs | FBC | mostly covered by FBC 2004 10m Lidar (also covered by District of Kent contours) |
| | Kent | District of Kent/FBC/BCH | Kent contours (mixed resolution and sources) + FBC 2004 10m Lidar + BCH 2008 10m Lidar |
| | Chilliwack | BC Hydro | BCH 2008 thinned data, converted to 10m grid; not complete coverage of floodplain or Vedder |
| | Hope | BC Hydro/CDEM | partial coverage from BCH, no data for rest of Hope -- data are not very complete, note as data gap if coverage is incomplete, doubt there is more data available as we haven't got it for Hope 300176 study either |
| | Richmond | IMT | 2011 DEM points (30 - 50 m spacing) and breaklines (CGVD28 Ht2) |
| | Delta | Corporation of Delta | Contours (2014; 0.5m) |
| | Surrey | City of Surrey | April 2013 Lidar-based DEM at 2m, 5m and 10m grid resn |
| | White Rock | White Rock | 1m contours |
| | Barnston Island | FBC | FBC 2004 1m Lidar -- combine with Surrey for analysis |
| | Langley City | City of Langley | 2007 1m contours and spot heights |
| | Langley Township | Townshop of Langley | 2012 1m contours; 2010 irregular points |
| | Abbotsford | City of Abbotsford | 1m Contours |
| | | | |
| | Various Locations | PMV | available on request, depending on coverage from municipalities (e.g., provided partial coverage for New West) |
| | Lower Fraser River (Mission to mouth; and Pitt River) | FBC | 2004 Lidar, only nearshore, 1m points |
| | Matsqui/Mission | FBC | 2004 10m resolution DEM from Lidar |
| | Kent-Agassiz, Harrison Hot Springs | FBC | 2004 10m resolution DEM from Lidar |
| | Hope to Mission | BC Hydro | 2008, thinned |
| | | | |
| **ROADS** | | | **STATUS: ROAD CENTRELINES COMPLETE** |
| | Entire study area | DataBC | Digital Road Atlas centrelines, includes road type, name |
| | Note: Also received road data from some individual municipalities | | |
| | | | |
| **EMERGENCY ROAD NETWORKS** | | | **STATUS: DISASTER RESPONSE ROUTES REC'D FROM MOTI (PDF NOT GIS)** |
| | North Van District | District of North Vancouver | Disaster response routes |
| | Surrey | City of Surrey | Disaster response routes |
| | Lower Mainland | MoTI | Critical regional routes for earthquake scenario; PDF only |
| | | | |
| **RAILWAYS, INCLUDING HUBS** | | | **STATUS: COMPLETE (NRWN + TRANSLINK/NRCan FOR WEST COAST EXPRESS)** |
| | FVRD | FVRD | Railway centrelines, operator name |
| | Langley Township | Township of Langley | Railway lines, crossings |
| | North Van District | District of North Vancouver | Railway lines |
| | Pitt Meadows | Pitt Meadows | Railway lines |
| | White Rock | White Rock | Railway lines |
| | Lower Mainland, not Squamish | PMV | Railway lines with operator name |
| | Vancouver | City of Vancouver | Railway lines with operator name |
| | Surrey | City of Surrey | Railway lines with operator name |
| | Abbotsford | City of Abbotsford | Railway lines with operator name |
| | Delta | Corporation of Delta | Railway lines with operator name; had to shift data to correct geographic locn |
| | Richmond | City of Richmond | Railway lines |
| | Lower Mainland | Translink via NRCan | West Coast Express route, stations |
| | Lower Mainland | National Railway Network via GeoGratis | Railway lines with operator names, stations, structures (crossings, junctions, markerposts also available) |
| | | | |
| **SKYTRAIN, INCLUDING INFRASTRUCTURE** | | | **STATUS: INCOMPLETE; USE TRANSLINK/NRCan + CITY OF COQUITLAM** |
| | Study area | City of Coquitlam | Evergreen line route, indicates elevated/ground/tunnel sections |
| | Study area | City of Coquitlam | Evergreen line stations (construction in progress) |
| | Study area | PMV | Existing Skytrain lines |
| | Vancouver | City of Vancouver | Existing Skytrain lines & stations |

| DATA TYPE | LOCATION | SOURCE | DESCRIPTION |
|---|---|---|---|
| | | | |
| | Surrey | City of Surrey | Existing Skytrain guideways |
| | Richmond | City of Richmond | Canada Line station polygons |
| | Lower Mainland | Translink via NRCan | Light rail (Expo, Millenium & Canada lines) lines & stations; not all classified as elevated/tunnel/at grade; no elevation data for elevated; no controls info |
| | | | |
| **BRIDGES** | | | **STATUS: COMPLETE FOR MAJOR BRIDGES ONLY; POINT LOCATIONS DIGITIZED BY NHC** |
| | Township of Langley | ToL | Bridge points, descriptions |
| | North Van District | District of North Vancouver | Road bridges polygons, names |
| | PMV lands | PMV | Overpasses polygons |
| | Surrey | City of Surrey | Road bridge points, names |
| | Abbotsford | City of Abbotsford | Bridge points, names |
| | North Van City | City of North Vancouver | Bridge points, names |
| | Vancouver | City of Vancouver | Bridge and overpass polygons |
| | Lower Mainland | Translink via NRCan | lines for Golden Ears Way, Knight St, Pattullo & Westham Island bridges; no elevation data |
| | Lower Mainland | NHC, etc. | Bridge points (road, rail, light rail) developed by NHC, initially on Fraser, expanded for this project - only includes bridges over major waterbodies (e.g,. Burrard Inlet, False Creek, Fraser River, Pitt River, Serpentine River, Nicomekl River, a few others). Mostly only highways, not other roads (except on Fraser and False Creek). |
| | | | |
| **AIRPORTS** | | | **STATUS: COMPLETE; POINT LOCATIONS DIGITIZED BY NHC** |
| | FVRD | FVRD | Footprint polygons, name |
| | Township of Langley | ToL | Airport point locations |
| | Pitt Meadows | Pitt Meadows | Airport tarmac polygon and buildings polygons |
| | Abbotsford | City of Abbotsford | Airport tarmac polylines |
| | Delta | Corporation of Delta | Airport and Air Park point locations |
| | Lower Mainland | PMV (S.Smith) | Airport locations |
| | Lower Mainland | NHC, etc. | Point locations digitized by NHC, information from various sources |
| | | | |
| **PORTS** | | | **STATUS: HAVE PMV LAND BOUNDARIES, BUT NO INDICATION OF SPECIFIC INDUSTRIES, BUILDING USES** |
| | North Van District | District of North Vancouver | See DNV Buildings layer, which includes names, types for some port buildings |
| | PMV lands | PMV | Building footprints |
| | PMV lands | PMV | Dock structures |
| | Delta | Corporation of Delta | Point locations of Deltaport and Ferry Terminal |
| | | | |
| **OTHER TRANSPORTATION HUBS** | | | **STATUS: COMPLETE** |
| | North Van District | District of North Vancouver | SeaBus route |
| | North Van District | District of North Vancouver | Bus terminus/depot point locations |
| | Metro Vancouver | City of Surrey | Transit routes and stops (but no indication of terminus/depot) |
| | Vancouver | City of Vancouver | Point locations of transportation hubs |
| | Delta | Corporation of Delta | Translink bus exchange point locations |
| | Lower Mainland | Translink via NRCan | SeaBus route & terminals |
| | Lower Mainland | Translink via NRCan | Bus routes, depots & exchanges |
| | | | |
| **BC HYDRO SUBSTATIONS AND TRANSMISSION LINES** | | | **STATUS: COMPLETE** |
| | North Van District | District of North Vancouver | electrical transmission lines |
| | North Van District | District of North Vancouver | electrical transmission towers points |
| | BC | BC Hydro | BC Hydro substation point locations (no elevation, etc. attribute data) |
| | Fraser & Thompson River Floodplains | BC Hydro | extract from BCH report on substations; contains relevant elevation, etc. attribute data |
| | BC | BC Hydro | BC Hydro circuits (i.e., transmission lines) |
| | BC | BC Hydro | BC Hydro structure (i.e., transmission towers) |
| | Delta | Corporation of Delta | BC Hydro substation point locations (no elevation, etc. attribute data) |
| | BC | BC Hydro | BC Hydro ducts and manholes (i.e., underground lines) |
| | | | |
| **TRUNK WATER AND SEWER INFRASTRUCTURE** | | | **STATUS: MOSTLY COMPLETE** |
| | Vancouver | City of Vancouver | GVRD trunk sewer mains (combined, sanitary, storm) |
| | Metro Vancouver | Metro Vancouver | Storm sewer network and features |
| | Metro Vancouver | Metro Vancouver | Water distribution network and features |
| | Study Area | NHC | Point locations of waste water treatment facilities in study area, based on MV and FVRD web sites |
| | | | |
| **WATER AND SEWER INFRASTRUCTURE** | | | **STATUS: INCOMPLETE; USED METRO VAN TRUNK WATER AND SEWER** |
| | FVRD (affected Electoral Areas Only), District of Hope and Village of Harrison Hot Springs | FVRD | Hydrant points |
| | FVRD (affected Electoral Areas Only), District of Hope and Village of Harrison Hot Springs | FVRD | Community watermains lines |
| | Coquitlam | City of Coquitlam | Streams |
| | Coquitlam | City of Coquitlam | Storm drainage network and features (floodboxes, channels, etc.) |
| | Coquitlam | City of Coquitlam | Sanitary network and features |
| | Coquitlam | City of Coquitlam | Water network and features |
| | Township of Langley | ToL | Water network and features; more data available online |
| | Township of Langley | ToL | Sanitary network and features; more data available online |
| | Township of Langley | ToL | Drainage network and features; more data available online |
| | North Van District | District of North Vancouver | Water network and features; more data available online |
| | North Van District | District of North Vancouver | Sanitary network and features; more data available online |

| DATA TYPE | LOCATION | SOURCE | DESCRIPTION |
|---|---|---|---|
| | | | |
| | North Van District | District of North Vancouver | Storm drainage network and features; more data available online |
| | Pitt Meadows | Pitt Meadows | Water network and features |
| | Pitt Meadows | Pitt Meadows | Sanitary network and features |
| | Pitt Meadows | Pitt Meadows | Storm drainage network and features |
| | White Rock | White Rock | Sanitary network |
| | White Rock | White Rock | Storm network |
| | White Rock | White Rock | Streams |
| | PMV lands | PMV | Sanitary, Process & Combined sewer network lines and points |
| | PMV lands | PMV | Storm sewer network lines and points |
| | PMV lands | PMV | Water network lines and points |
| | Vancouver | City of Vancouver | Sewer network lines and points |
| | Surrey | City of Surrey | Sanitary sewer network lines and points |
| | Surrey | City of Surrey | Storm drainage network lines and points |
| | Surrey | City of Surrey | Water network lines and points |
| | Surrey | City of Surrey | Water utility facility point locations |
| | Abbotsford | City of Abbotsford | Water network lines and points |
| | Abbotsford | City of Abbotsford | Sewer network lines and points |
| | North Van City | City of North Vancouver | Water network lines and hydrant points |
| | North Van City | City of North Vancouver | Sanitary sewer network lines and pump & manhole points |
| | Kent | District of Kent | Sanitary sewer network lines and points |
| | Kent | District of Kent | Storm sewer network lines and points |
| | Kent | District of Kent | Water network lines and points |
| | West Vancouver | District of West Vancouver | Sanitary sewer network lines and points |
| | West Vancouver | District of West Vancouver | Water network lines and points |
| | Delta | Corporation of Delta | Trunk watermain network and pumpstations |
| | Delta | Corporation of Delta | Forcemain & gravit sewer networks and pumpstations |
| | Richmond | City of Richmond | Sewer network lines and points |
| | Richmond | City of Richmond | Drainage network lines, ditch lines and points |
| | Richmond | City of Richmond | Water network lines and points |
| | | | |
| **FIREFIGHTING WATER NETWORKS** | | | **STATUS: NO DATA** |
| | | | |
| **CELL TOWERS** | | | **STATUS: INCOMPLETE** |
| | North Van District | District of North Vancouver | Cell tower point locations |
| | | | |
| **FIBRE OPTICS** | | | **STATUS: INCOMPLETE (NOT INCLUDED IN DATA REQUEST)** |
| | North Van District | District of North Vancouver | Fibre optic lines |
| | | | |
| **OIL AND GAS PIPELINES** | | | **STATUS: INCOMPLETE** |
| | North Van District | District of North Vancouver | Gas mains and valves |
| | | | |
| **OIL REFINERIES AND OIL STORAGE TANKS** | | | **STATUS: INCOMPLETE** |
| | Entire study area | DataBC/OGC (Oil and Gas Commission) | Oil and gas facility locations (points); all are FortisBC sites; does not look like this includes all facilities in study area; locations don't match features on ground, appear to be generalized locations, so not useful |
| | Entire study area | DataBC/OGC (Oil and Gas Commission) | Oil and gas facility sites (polygons); all are FortisBC sites; does not look like this includes all facilities in study area; most locations don't match features visible on orthoimagery, so not useful |
| | | | |
| **UTILITIES - OTHER DATA** | | | **STATUS: INCOMPLETE - ONLY FROM BARNSTON ISLAND DOWNSTREAM** |
| | Lower Fraser (d/s Barnston Isl) | Port? | Fraser River Port Authority Transportation & Utility Crossings - PDF map, 2008 |
| | | | |
| **ENERGY FACILITIES** | | | **STATUS: INCOMPLETE** |
| | Vancouver | City of Vancouver | Point location of False Creek NEU |
| | Richmond | City of Richmond | District Energy Utility |
| | | | |
| **CONTAMINATED SITES AND WASTE INCINERATORS** | | | **STATUS: NO DATA** |
| | | | |
| **AGRICULTURE - CROPS, GREENHOUSES, LIVESTOCK, ETC.** | | | **STATUS: INCOMPLETE** |
| | Pitt Meadows | Pitt Meadows | Agricultural land use polygons, detailed (buildings, farming types, facilities) |
| | Pitt Meadows | Pitt Meadows | Agricultural land use generalized by parcel polygons |
| | Pitt Meadows | Pitt Meadows | ALR polygons |
| | | | |
| **FIRE AND POLICE STATIONS** | | | **STATUS: COMPLETE** |
| | Entire study area | DataBC | Point locations, includes name, address |
| | Note: Also received data from some individual municipalities | | |
| | | | |
| **EMERGENCY OPERATIONS CENTRES** | | | **STATUS: COMPLETE** |
| | FVRD (affected Electoral Areas Only), District of Hope and Village of Harrison Hot Springs | FVRD | Building footprint polygons, name of juridiction |
| | Pitt Meadows | Pitt Meadows | Point location of EOC (City Hall) |
| | North Van District | District of North Vancouver | Building footprint polygon, NSEMO |
| | Vancouver | City of Vancouver | Point location of EOC |
| | Delta | Corporation of Delta | Point location of EOCs |
| | Entire study area | NRCan/FLNRO | Point location of EOCs; appears to be out of date and inconsistent with other data sources |
| | Entire study area | EMBC | NHC mapped point locations from addresses supplied by Emergency Management BC |
| | | | |
| **AMBULANCE STATIONS** | | | **STATUS: INCOMPLETE** |

| DATA TYPE | LOCATION | SOURCE | DESCRIPTION |
|---|---|---|---|
| | | | |
| | Township of Langley | ToL | Point locations |
| | Delta | Corporation of Delta | Point locations |
| | Richmond | City of Richmond | Point locations |
| | | | |
| **HOSPITALS** | | | **STATUS: COMPLETE** |
| | Entire study area | DataBC | Point locations of BC Health Authority hospitals, includes name, address |
| | Vancouver | City of Vancouver | Point locations of hospitals |
| | Delta | Corporation of Delta | Point location of hospital |
| | | | |
| **MUNICIPAL WORKS YARDS** | | | **STATUS: INCOMPLETE** |
| | FVRD (affected Electoral Areas Only), District of Hope and Village of Harrison Hot Springs | FVRD | Polygon footprint, address, jurisdiction |
| | North Van District | District of North Vancouver | See DNV Buildings layer - operation centres, etc? |
| | Pitt Meadows | Pitt Meadows | Point location of municipal facility |
| | Surrey | City of Surrey | Municipal works yards buildings point locations |
| | Vancouver | City of Vancouver | Point locations of municipal works yards |
| | Delta | Corporation of Delta | Point location of municipal works yard |
| | Richmond | City of Richmond | Point locations of city hall and municipal works yard |
| | | | |
| **SCHOOLS** | | | **STATUS: COMPLETE** |
| | Entire study area | DataBC | Point locations of public and independent schools |
| | Note: Also received data from some individual municipalities | | |
| | | | |
| **DAY-CARE CENTRES** | | | **STATUS: INCOMPLETE** |
| | Pitt Meadows | Pitt Meadows | Point locations of day care centres |
| | North Van District | District of North Vancouver | Building footprint polygons of day care centres |
| | Surrey | City of Surrey | Day care centres point locations |
| | North Van City | City of North Vancouver | Point locations of childcare centres |
| | Vancouver | City of Vancouver | Point locations of childcare centres |
| | Richmond | City of Richmond | Point locations of childcare centres |
| | | | |
| **POST-SECONDARY INSTITUTIONS** | | | **STATUS: COMPLETE** |
| | Entire study area | DataBC | Point locations of post-secondary institutions |
| | Note: Also received data from some individual municipalities | | |
| | | | |
| **CARE HOMES** | | | **STATUS: INCOMPLETE** |
| | Township of Langley | ToL | Point locations |
| | Pitt Meadows | Pitt Meadows | Point locations of care homes |
| | North Van District | District of North Vancouver | Building footprint polygons of care homes |
| | Surrey | City of Surrey | Point locations of care homes, addition treatment residential facilities, family co-op housing, homeless shelters, etc. |
| | Vancouver | City of Vancouver | Point locations of licensed registered care facilities |
| | West Vancouver | District of West Vancouver | Building footprint polygons of care homes (and other features) |
| | | | |
| **COMMUNITY CENTRES** | | | **STATUS: INCOMPLETE** |
| | Coquitlam | City of Coquitlam | Community centres point locations, with name, type |
| | Township of Langley | ToL | Point locations |
| | North Van District | District of North Vancouver | Building footprints |
| | Pitt Meadows | Pitt Meadows | Point locations of community centres |
| | Vancouver | City of Vancouver | Point locations of community centres |
| | Surrey | City of Surrey | Community, recreation and senior centres |
| | Delta | Corporation of Delta | Community, recreation and senior centres |
| | Richmond | City of Richmond | Community centres point locations |
| | | | |
| **CEMETERIES AND CREMATORIUMS** | | | **STATUS: INCOMPLETE** |
| | Coquitlam | City of Coquitlam | Cemetery polygon, with name |
| | Township of Langley | ToL | Point and polygon locations |
| | Surrey | City of Surrey | Cemetery polygons, with name |
| | Vancouver | City of Vancouver | Point location |
| | Delta | Corporation of Delta | Cemetery polygons (included with Parks data) |
| | | | |
| **GENERAL BUILDING STOCK** | | | **STATUS: COMPLETE (FROM HAZUS, DERIVED FROM 2011 CENSUS AND DUN & BRADSTREET)** |
| | | | |
| **DEMOGRAPHIC INFORMATION** | | | **STATUS: COMPLETE (FROM HAZUS, DERIVED FROM 2011 CENSUS)** |
| | | | |
| **INDIAN RESERVE BOUNDARIES** | | | **STATUS: COMPLETE** |
| | Entire study area | DataBC | Indian Reserve boundaries |
| | | | |
| **MUNICIPAL BOUNDARIES** | | | **STATUS: COMPLETE** |
| | Entire study area | DataBC | Municipal boundaries |
| | Note: Also received data from some individual municipalities | | |
| | | | |
| **REGIONAL DISTRICT BOUNDARIES** | | | **STATUS: COMPLETE** |
| | Entire study area | DataBC | Regional district boundaries |
| | | | |
| **ECOLOGICAL RESERVES, PARKS, PROTECTED AREAS** | | | **STATUS: INCOMPLETE** |
| | Entire study area | DataBC | BC Parks, Ecological Reserves and Protected Areas |
| | Entire study area | DataBC | Wildlife Management Areas |

| DATA TYPE | LOCATION | SOURCE | DESCRIPTION |
|---|---|---|---|
| | | | |
| | FVRD (affected Electoral Areas Only), District of Hope and Village of Harrison Hot Springs | FVRD | Municipal park polygons, names |
| | | | |
| **MUNICIPAL PARKS AND ESAs** | | | **STATUS: INCOMPLETE** |
| | Coquitlam | City of Coquitlam | Municipal parks and natural areas |
| | Coquitlam | City of Coquitlam | OCP and land use, showing ESAs, natural areas |
| | Township of Langley | ToL | Parks and conservation areas |
| | North Van District | District of North Vancouver | Parks |
| | Pitt Meadows | Pitt Meadows | Parks as polygons via cadastral lots |
| | Vancouver | City of Vancouver | Park polygons and point locations |
| | Surrey | City of Surrey | Park polygons |
| | Surrey | City of Surrey | Environmentally Sensitive Area polygons |
| | Abbotsford | City of Abbotsford | Park polygons |
| | North Van City | City of North Vancouver | Park polygons |
| | West Vancouver | District of West Vancouver | Park polygons |
| | Delta | Corporation of Delta | Park polygons (includes cemeteries) |
| | Richmond | City of Richmond | Park polygons |
| | | | |
| **ARCHAEOLOGICAL SITES, DESIGNATED HISTORIC PLACES** | | | **STATUS: INCOMPLETE** |
| | Vancouver | City of Vancouver | Heritage properties points |
| | | | |
| **PREVIOUS FLOOD MAPPING** | | | **STATUS: INCOMPLETE** |
| | Study Area | FLNRO | 200 year floodplain mapping |
| | Selected Floodplains (no | GeoBC | Provincially mapped floodplains within the study area |
| | Chilliwack | City of Chilliwack | FCLs and floodplain extents |
| | Kent and Harrison Hot Springs | FBC | FCLs and floodplain extents (2007 mapping by WMC) |

**Table A3. Spatial Data Created**

| CATEGORY | TITLE | DESCRIPTION | KEY ATTRIBUTE DESCRIPTION | FOLDER | FILE |
|---|---|---|---|---|---|
| | | | | | |
| **TOPOGRAPHY** | | | | | |
| | DEM, Study Region 1 | Five-metre resolution DEM for Study Region 1 (Squamish) based on data from Natural Resource Canada, District of Squamish and BC Hydro. Esri grid format. | Elevation in metres. | GIS\Topography\ | dem01_squam |
| | DEM, Study Region 2 | Five-metre resolution DEM for Study Region 2 (North Shore) based on data from Lions Bay, District of West Vancouver, City of North Vancouver and District of North Vancouver. Esri grid format. | Elevation in metres. | GIS\Topography\ | dem02_nshore |
| | DEM, Study Region 3 | Five-metre resolution DEM for Study Region 3 (Port Moody, Anmore, Belcarra) based on data from City of Port Moody. Esri grid format. | Elevation in metres. | GIS\Topography\ | dem03_pmba |
| | DEM, Study Region 4 | Five-metre resolution DEM for Study Region 4 (Vancouver, Burnaby, New Westminster) based on data from City of Vancouver, City of Burnaby, Port Metro Vancouver and Canadian Digital Elevation Model. Esri grid format. | Elevation in metres. | GIS\Topography\ | dem04_vbnw |
| | DEM, Study Region 5 | Five-metre resolution DEM for Study Region 5 (Richmond, Delta) based on data from Integrated Mapping Technologies and Corporation of Delta. Esri grid format. | Elevation in metres. | GIS\Topography\ | dem05_rmdel |
| | DEM, Study Region 6 | Five-metre resolution DEM for Study Region 6 (Surrey, White Rock) based on data from City of Surrey, City of White Rock and FBC. Esri grid format. | Elevation in metres. | GIS\Topography\ | dem06_swrbi |
| | DEM, Study Region 7 | Five-metre resolution DEM for Study Region 7 (Coquitlam, Port Coquitlam, Pitt Meadows, Maple Ridge) based on data from City of Coquitlam and City of Pitt Meadows. Esri grid format. | Elevation in metres. | GIS\Topography\ | dem07_coqpmmr |
| | DEM, Study Region 8 | Five-metre resolution DEM for Study Region 8 (Langley) based on data from City of Langley and Township of Langley. Esri grid format. | Elevation in metres. | GIS\Topography\ | dem08_langley |
| | DEM, Study Region 9 | Ten-metre resolution DEM for Study Region 9 (Mission, Harrison Hot Springs, Kent, FVRD unincorporated areas north of the Fraser) based on data from FBC, BC Hydro and District of Kent. Esri grid format. | Elevation in metres. | GIS\Topography\ | dem09_fvrdmhk |
| | DEM, Study Region 10 | Ten-metre resolution DEM for Study Region 10 (Abbotsford, Chilliwack, Hope, FVRD unincorporated areas south of the Fraser) based on data from City of Abbotsford, FBC, BC Hydro and Canadian Digital Elevation Model). Esri grid format. | Elevation in metres. | GIS\Topography\ | dem10_fvrdach |
| | | | | | |
| **FLOOD HAZARD MAPPING** | | | | | |
| | Flood depth grids | 28 flood depth grids, one per flood scenario for each Study Region. Esri grid format. | Flood depth in metres. | GIS\FloodDepths\ | gDep?_XX (where ? = Scenario and XX = Study Region) |
| | Flood extents | Flood extent polygons. One file per flood scenario for each Study Region, plus one merged layer for each flood scenario. Esri ArcGIS 10.2.2 file geodatabase feature layer. | None. | GIS\LM_FloodMapping.gdb\FloodExtents\ | floodPoly?_XX and floodPoly?_merged (where XX = Study Region and ? = Scenario) |
| | Flood extents (KMZ) | Flood extents. One file per flood scenario for each Study Region. Google Earth KMZ format. | None. | GIS\FloodExtents_KMZ\ | RegionX_Scenario? |
| | Flood extent comparison | Comparison of current flood extent mapping to previous mapping by BC MFLNRO. For flood extent from current project, used Scenario A and Scenario C extents, combined. Esri ArcGIS 10.2.2 file geodatabase feature layer. | FP_Diff = "Historic FP" if only historic FLNRO mapping showed flooding, "New FP" if only current project showed flooding; "FP" if both sources showed flooding | GIS\LM_FloodMapping.gdb\Comparison\ | Floodplain_HistoricDiff1 |
| | | | | | |
| **ASSET INVENTORY - ADMINISTRATIVE BOUNDARIES** | | | | | |
| | Indian Reserve boundaries | Indian Reserve boundaries obtained from DataBC. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\AdminBoundaries\ | CLAB_INRES_sel1 |

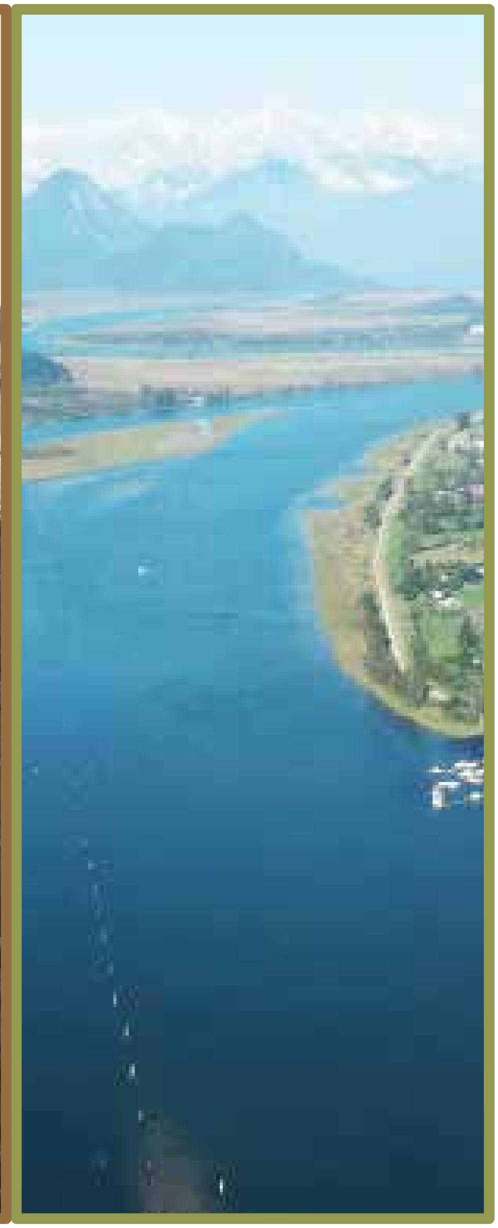
| CATEGORY | TITLE | DESCRIPTION | KEY ATTRIBUTE DESCRIPTION | FOLDER | FILE |
|---|---|---|---|---|---|
| | First Nations Treaty Lands boundaries | First Nations Treaty Lands boundaries obtained from DataBC. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\AdminBoundaries\ | FNT_TRT_sel1 |
| | Municipal boundaries | Municipal boundaries obtained from DataBC. Esri ArcGIS 10.2.2 file geodatabase feature layer. (Note that municipal boundary data was also provided by some individual municipalities and may differ from the DataBC data. The DataBC version was used for this project.) | Refer to dataset. | GIS\LM_AssetInventory\AdminBoundaries\ | TA_MUNICIP_sel1 |
| | Regional district boundaries | Regional District boundaries obtained from DataBC. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\AdminBoundaries\ | REG_DSTRCT_sel1 |
| | | | | | |
| **ASSET INVENTORY - ESSENTIAL FACILITIES** | | | | | |
| | Emergency operations centres | NHC mapped point locations from addresses supplied by Emergency Management BC. Esri ArcGIS 10.2.2 file geodatabase feature layer.<br>NOTE: Possible error in EOC data identified after project completion. Provincial/federal EOCs are separate from local EOCs, but this version of EOCs may exclude some or have them incorrectly combined. This should be addressed for future work. | Refer to dataset. | GIS\LM_AssetInventory\EssentialFacilities\ | EOC_EMBC |
| | Fire and police stations | Fire and police station point locations, acquired from DataBC. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\EssentialFacilities\ | Fire_and_police_sel1 |
| | Health care facilities | BC Health Authority hospital point locations obtained from DataBC. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\EssentialFacilities\ | BCHHLTHCRF_sel1 |
| | Primary and secondary schools | Public and independent schools point locations obtained from DataBC. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\EssentialFacilities\ | bc_schools_sel1c |
| | Post-secondary institutions | Post-secondary institutions point locations obtained from DataBC. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\EssentialFacilities\ | postsec_sel1b |
| | | | | | |
| **ASSET INVENTORY - TRANSPORTATION** | | | | | |
| | Airports | Point locations digitized by NHC, information from various sources. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Name = airport name;<br>Code = airport code | GIS\LM_AssetInventory\Transportation_Air\ | Airports_NHC |
| | Major bridges | Bridge points (road, rail, light rail) developed by NHC, initially on Fraser, expanded for this project - only includes bridges over major waterbodies (e.g,. Burrard Inlet, False Creek, Fraser River, Pitt River, Serpentine River, Nicomekl River, a few others). Mostly only highways, not other roads (except on Fraser and False Creek). Esri ArcGIS 10.2.2 file geodatabase feature layer. | Name = bridge name;<br>Type = Road, Rail or Light Rail;<br>Carries = name of route carried;<br>Waterbody = waterbody crossed | GIS\LM_AssetInventory\Transportation_Bridges\ | Bridges_NHC |
| | Bus routes, depots and exchanges | Metro Vancouver bus routes, depots and exchanges. Supplied by NRCan. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\Transportation_Bus\ | * |
| | Ports | Point locations of main port terminals and docks. Digitized by NHC based on data from Port Metro Vancouver. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Name = port/terminal/dock name | GIS\LM_AssetInventory\Transportation_Ports\ | Ports_NHC |
| | Port structures | Port building structures and dock structures. Supplied by PMV. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\Transportation_Ports\ | PMV_Dock_Structures, STRUCTURES_POLY_PMV |
| | Railway infrastructure | National Railway Network rail lines, stations, bridges and culverts. Obtained from GeoGratis. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\Transportation_Rail\ | Railway_NRWN_BC_* |
| | West Coast Express infrastructure | West Coast Express rail lines and stations. Supplied by NRCan with permission from Translink. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\Transportation_Rail\ | WCXLine_GG_NRC, WCXStations_GG_NRC |
| | Road network | Road centreline. Obtained from DataBC Digital Road Atlas data. Esri ArcGIS 10.2.2 file geodatabase feature layer. | RDNMFLL = road name;<br>ROAD_CLASS = road category | GIS\LM_AssetInventory\Transportation_Road\ | DRA_092G, DRA_092H |
| | SeaBus infrastructure | SeaBus route and terminals. Supplied by NRCan. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\Transportation_SeaBus\ | Seabus_Route_NRC, Seabus_Terminal_NRC |
| | Skytrain routes | Skytrain routes. Supplied by NRCan with permission from Translink. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\Transportation_Skytrain\ | LightRailAll_GG_NRC |

| CATEGORY | TITLE | DESCRIPTION | KEY ATTRIBUTE DESCRIPTION | FOLDER | FILE |
|---|---|---|---|---|---|
| | Skytrain Evergreen Line route | Evergreen Skytrain route. Supplied by City of Coquitlam. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\Transportation_Skytrain\ | Evergreen_Line |
| | | | | | |
| **ASSET INVENTORY - UTILITIES** | | | | | |
| | BC Hydro circuits, ducts, manholes, structures and substations | Point and line locations of BC Hydro facilities, supplied by BC Hydro. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Refer to dataset. | GIS\LM_AssetInventory\Utilities_Electrical\ | * |
| | | | | | |
| **ASSET INVENTORY - SEWER, STORM WATER, WATER DISTRIBUTION** | | | | | |
| | Waste water treatment facilities | Point locations of waste water treatment facilities in study area, based on MV and FVRD web sites. Esri ArcGIS 10.2.2 file geodatabase feature layer. | Name = facility name;<br>Address = facility address;<br>Municip = municipality location;<br>Jurisdictn = owner jurisdiction;<br>URL = source of information | GIS\LM_AssetInventory\WaterSewer\ | WWTP_LowerMainland_NHC |
| | Metro Vancouver sewer and storm water system | Collection of data layers depicting MV sewer and storm water systems, from MV. Esri ArcGIS 10.2.2 file geodatabase feature dataset. | Refer to dataset. | GIS\LM_AssetInventory\WaterSewer_MetroVan_SewerStormWater\ | * |
| | Metro Vancouver water distribution system | Collection of data layers depicting MV water distribution system, from MV. Esri ArcGIS 10.2.2 file geodatabase feature dataset. | Refer to dataset. | GIS\LM_AssetInventory\WaterSewer_MetroVan_WaterDistribution\ | * |
| | | | | | |
| **BASE MAPPING** | | | | | |
| | Municipal boundary lines | Municipal boundary lines for cartographic purposes only. Based on DataBC TANTALIS municipal boundaries. Esri ArcGIS 10.2.2 file geodatabase feature layer. | None. | GIS\LM_BaseMapping.gdb\AdminBoundaries\ | TA_MUNICIP_ln1 |
| | Stream centrelines | Stream centrelines for cartographic purposes only. Based on DataBC Freshwater Atlas data. Esri ArcGIS 10.2.2 file geodatabase feature layer. | GNIS_NAME = stream names, where available | GIS\LM_BaseMapping.gdb\Hydrography\ | CWB_STRM_N_line_sel2 |
| | Water bodies | Water body polygons for cartographic purposes only. Based on DataBC Freshwater Atlas data. Esri ArcGIS 10.2.2 file geodatabase feature layer. | GNSNM1 = water body name, where available | GIS\LM_BaseMapping.gdb\Hydrography\ | FWA_waterarea03 |
| | Wetlands | Wetland polygons for cartographic purposes only. Based on DataBC Freshwater Atlas data. Esri ArcGIS 10.2.2 file geodatabase feature layer. | GNSNM1 = wetland name, where available | GIS\LM_BaseMapping.gdb\Hydrography\ | FWWTLNDSPL1 |
| | Roads | Road centrelines for cartographic purposes only. Based on DataBC Digital Road Atlas data. Esri ArcGIS 10.2.2 file geodatabase feature layer. | RDNMFLL = road name;<br>ROAD_CLASS = road category | GIS\LM_BaseMapping.gdb\Road\ | DRA_mrg02 |
| | Mapsheets for 1:50,000 scale map series | Mapsheet extent polygons for 22" x 34" 1:50,000 scale map series. Esri ArcGIS 10.2.2 file geodatabase feature layer. | ID = map sheet number | GIS\LM_BaseMapping.gdb\ | MapSheets_22x34at40K_4 |
| | Labels | Map annotation for 1:50,000 maps, for cartographic purposes only. Esri ArcGIS 10.2.2 file geodatabase annotation layer. | None. | GIS\LM_BaseMapping.gdb\Labels50K\ | * |
| | Landsat Imagery | Landsat orthoimagery used for base mapping. 30 metre horizontal resolution. Images from 30-Jul-2000 and 05-Oct-2001. GeoTIFF format. | None. | GIS\Imagery\Landsat\ | * |
| | Empty line layer | Empty line layer, for cartographic purposes only. Esri ArcGIS 10.2.2 file geodatabase feature layer. | None. | GIS\LM_BaseMapping.gdb\ | DummyLine |
| | Empty polygon layer | Empty polygon layer, for cartographic purposes only. Esri ArcGIS 10.2.2 file geodatabase feature layer. | None. | GIS\LM_BaseMapping.gdb\ | DummyPoly |
| | Empty raster layer | Empty raster layer, for cartographic purposes only. Esri ArcGIS 10.2.2 file geodatabase raster layer. | None. | GIS\LM_BaseMapping.gdb\ | DummyRaster |
| | | | | | |
| **HAZUS** | | | | | |

| CATEGORY | TITLE | DESCRIPTION | KEY ATTRIBUTE DESCRIPTION | FOLDER | FILE |
|---|---|---|---|---|---|
| | Hazus project files | Ten Hazus project files, one for each Study Region. Each file contains the Hazus asset inventory, flood hazard mapping for two or four scenarios, and analysis results. Canadian Hazus 2.1 HPR format. | n.a. | Hazus\ | Region*.hpr |
| | Provincewide dataset updates | Essential facilities and wastewater treatment plants were updated in the Hazus provincewide dataset for this project. Individual Study Regions were then built from that updated dataset. The updated data layers have been exported using Hazus CDMS software. Esri ArcGIS 10.0 SP2 personal geodatabase file (format required for compatibility with Hazus). | Attributes specified in Hazus manuals and software. | Hazus\ | CDMS_GeoDBExport_11262015101255.mdb |
| | Selected Hazus results - GIS layers and summary tables | Selected results from the Hazus analysis were exported to GIS geodatabase format, merged (e.g., data from all Study Regions for one Scenario) and summarized. Exported data categories include: total number of buildings damaged in each census dissemination block; total building-related economic losses (unadjusted values) in each census dissemination block; and population seeking shelter for each census dissemination block. Esri ArcGIS 10.0 SP2 personal geodatabase file (format required for compatibility with Hazus). | See Hazus software for explanation of attributes. | GIS\LM_HazusResults.gdb\ | * |
| | | | | | |
| **OTHER DIGITAL FILES** | | | | | |
| | Data sharing agreements | Data sharing agreements signed by FBC, or NHC on FBC's behalf, regarding use of specific datasets. | n.a. | DataSharingAgreements\ | various files |
| | Flood depth map PDFs | Flood depth maps. One set per scenario. PDF format. | n.a. | Maps\FloodDepths\ | FloodDepths_Scenario?.pdf |
| | Flood extent map PDFs | Flood extent maps. One set for Scenarios A and B, one set for Scenarios C and D. PDF format. | n.a. | Maps\FloodExtents\ | FloodExtents_Scenario??.pdf |
| | Flood extent wall maps | Large format flood extent wall maps. One for Scenarios A and B, one for Scenarios C and D. PDF and Adobe Illustrator format. | n.a. | Maps\FloodExtents\ | FloodExtentsLargeMaps_??noHillshade_300dpi.pdf and .ai |
| | Hazus results maps | Maps illustrating selected Hazus results, as described in the report. JPEG format. | n.a. | Maps\HazusResults\ | *.jpg |
| | Hazus results spreadsheet | Spreadsheet summarizing Hazus results, including adjustments applied to loss estimates. Excel format. | n.a. | Hazus\ | Hazus_AllResults.xlsx |
| | Original topographic data | Original topographic data received or downloaded from various organizations. This data was used to derive the 5m and 10m resolution DEM grids (listed above) that were used for flood mapping. | n.a. | GIS\All_Data\Topography\ | * |
| | Original asset inventory and other data | Original spatial data sets received or downloaded from various organizations. Where coverage was complete or almost complete for the study area, the data has been included in the geodatabase for the project (GIS\LM_AssetInventory.gdb; described above) . | n.a. | GIS\All_Data\ | * |
| | Flood depth maps - ArcGIS Map Document | ArcGIS 10.2.2 map document used to generate flood depth maps for the project. This MXD references the datasets listed above. ArcGIS 10.2.2 MXD format. | n.a. | GIS\ | Map_FloodDepths.mxd |
| | Flood extent maps - ArcGIS Map Document | ArcGIS 10.2.2 map document used to generate flood extent maps for the project. This MXD references the datasets listed above. ArcGIS 10.2.2 MXD format. | n.a. | GIS\ | Map_FloodExtents.mxd |
| | Flood extent wall maps - ArcGIS Map Document | ArcGIS 10.2.2 map document used to generate large format flood extent wall maps. This MXD references the datasets listed above. ArcGIS 10.2.2 MXD format. | n.a. | GIS\ | Map_FloodExtentsLargeMap.mxd |
| | Hazus results maps - Number of buildings damaged - ArcGIS Map Document | ArcGIS 10.2.2 map document used to generate Hazus results - buildings damaged maps for the project. This MXD references the datasets listed above. ArcGIS 10.2.2 MXD format. | n.a. | GIS\ | Fig_HazusResultsBldgsDamaged.mxd |

| CATEGORY | TITLE | DESCRIPTION | KEY ATTRIBUTE DESCRIPTION | FOLDER | FILE |
| --- | --- | --- | --- | --- | --- |
| | Hazus results maps - Building-related economic losses - ArcGIS Map Document | ArcGIS 10.2.2 map document used to generate Hazus results - building-related economic losses maps for the project. This MXD references the datasets listed above. ArcGIS 10.2.2 MXD format. | n.a. | GIS\ | Fig_HazusResultsBldgsEcLosses.mxd |
| | Hazus results maps - Displaced population - ArcGIS Map Document | ArcGIS 10.2.2 map document used to generate Hazus results - displaced population maps for the project. This MXD references the datasets listed above. ArcGIS 10.2.2 MXD format. | n.a. | GIS\ | Fig_HazusResultsPopulation.mxd |

# Appendix B: Vulnerability Assessment Information



# APPENDIX B
# IDENTIFICATION OF INFRASTRUCTURE & ASSET VULNERABILITY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**Lower Mainland Flood Management Strategy**
Project 2 – Regional Assessment of Flood Vulnerabilities, Consequences and Costs

Prepared for: Fraser Basin Council

## Contents

# Introduction

## Overview

Four flood scenarios were used for the identification of vulnerabilities. The first two (A and B) are coastal flooding scenarios and the second two (C and D) are riverine flooding scenarios:

- Scenario A – 1 in 500 Annual Exceedance Probability (AEP) flood with current sea level (3.4 m GSC)
- Scenario B – 1 in 500 AEP flood with 1 m sea level rise (SLR) to 4.4 m GSC
- Scenario C – 1894 design flood conditions with current sea level
- Scenario D – 1 in 500 AEP freshet flow with moderate climate change and 1 m SLR

The study area has been broken down into ten Study Regions as follows:

1. District of Squamish
2. North Shore (Village of Lions Bay, District of West Vancouver, North Vancouver City and North Vancouver District)
3. City of Port Moody, Villages of Anmore and Belcarra
4. Cities of Vancouver, Burnaby and New Westminster
5. City of Richmond, Corporation of Delta and Tsawwassen First Nation Treaty Lands
6. Cities of Surrey and White Rock and unincorporated Barnston Island in Electoral Area A
7. Cities of Coquitlam, Port Coquitlam, Pitt Meadows and Maple Ridge
8. City of Langley and Township of Langley
9. City of Mission, Resort Municipality of Harrison Hot Springs, District of Kent and unincorporated areas of the Fraser Valley Regional District (FVRD) north of the Fraser River
10. Cities of Abbotsford, Chilliwack, District of Hope and unincorporated areas of the FVRD south of the Fraser River

Study Region 1 is in the Squamish-Lillooet Regional District, Study Regions 2 to 8 are in Metro Vancouver and Study Regions 9 and 10 are in the Fraser Valley Regional District.

Maps showing the flood extents and flood depths for each Scenario and Region were prepared by NHC. Data sets of critical infrastructure[1] were obtained by NHC from regional districts, local governments, Crown Corporations, senior government ministries and other agencies. This included comprehensive data sets for police stations, fire halls, hospitals, schools, post-

[1] What is considered critical infrastructure varies by project purpose and jurisdiction. However the range is relatively narrow. For example, NOAA defines a critical facility as a structure that, if flooded, would present an immediate threat to life, public health, and safety. HAZUS breaks critical facilities into two groups: essential facilities and high potential loss facilities. Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites. HAZUS also includes critical transportation and utility systems. This results in a total of 18 critical facilities as follows: airports, bus terminals, communications centres, medical centres, dams, electrical power, emergency operations centres, fire stations, hazardous material sites, highway bridges, oil systems, police stations, ports, potable water, railways, railway bridges, schools and wastewater facilities. (Spatial Trends in Coastal Socioeconomics, FEMA HAZUS Critical Facilities, December 2013.)

secondary institutions, roads including critical regional transportation routes, railways, port facilities, SkyTrain lines, Port Metro Vancouver facilities, Seabus and BC Ferry terminals, and truck water and sewer infrastructure. This information was provided on KMZ Google Earth files, which enabled the determination of infrastructure vulnerable to inundation under the four Scenarios to be documented. Partial information on other critical infrastructure was supplemented by additional research in order to fill identified gaps. This information consisted of ambulance stations, municipal halls and airports. This is documented in Annex A.

Other infrastructure was added to Annex A. This included facilities with unique vulnerabilities such as prisons and forensic psychiatric hospitals, waste to heat incinerators and energy utilities. Also included were facilities essential to post flood recovery such as municipal and MoTI contractors' works yards.

Emergency Operations Centres (EOCs) were documented separately. This was done to avoid a perception of duplication as nearly all EOCs are located in police stations, firehalls or municipal halls. EOCs are documented in Annex B.

Extensive but dated information on First Nations Reserves and Treaty Lands is detailed in Annex C. The information was updated where feasible.

This documentation is intended to highlight the vulnerability of key infrastructure to flooding under the four Scenarios. This infrastructure inventory covers a broad range of critical elements whose flood vulnerability varies depending on the nature of the facility in question.

## Vulnerability of Key Infrastructure

Vulnerability refers to the degree to which a system is susceptible or unable to cope with the adverse effects of flooding, including variability and extremes. It is a function of exposure, sensitivity and adaptive change. Exposure refers to the state of the elements at risk to come in contact with a coastal flood event or riverine flood. Sensitivity refers to the degree to which the elements at risk are affected.

Many factors contribute to the overall damaging effects of a flood – including water depths (increased depths imply larger renovation/replacement required), velocity (higher speeds, higher damages), wave action (wave energy – waves can be more damaging than still water), and the duration of the flood (including the time-to-peak of a flood). Effects of contamination, sediment and debris will impact flood damages, as well the construction type and age of the structures being impacted by flood waters.

Vulnerability descriptions, as it relates to water depths, have been adapted by NHC for the local context. For contextual purposes, an approximate breakdown of what the varying levels of water would mean for residents are as follows:

- 0 to 0.5 m – Most of the houses would be dry; attempting to walk or drive through moving water is potentially dangerous; basements and underground parking may be flooded.
- 0.5 to 1.0 m – Water will be on the ground floor; basements and underground parking are definitely flooded (potentially causing the need to evacuate); electricity will fail,

providing the mechanics are placed on the ground  floor or basement; vehicles would be carried off roadways.
- 1.0 m to 2.0 m – The ground floor will be now be flooded; residents will need to evacuate.
- 2.0 to 5.0 m – First floor up to the roof could be covered by water; residents will need to evacuate.
- >5.0 m (and any riverine flooding) – First floor up to the roof could be covered by water; residents would need to evacuate.

The identification of key infrastructure vulnerabilities within the study area has been designed to supplement the broader HAZUS analysis. It required a targeted focus on the unique infrastructure elements found throughout the ten study regions including BC Hydro Infrastructure (e.g. substations & transmission grids), transportation infrastructure (e.g. airports, ports, railways, highways and rapid transit), emergency services (e.g. police, fire and ambulance first responders & hospitals) as well as other critical assets (e.g. sewage treatment plants, water supplies, schools and universities and key communications such as cell towers).

### Framework

The framework utilized for the regional flood vulnerability overview consists of five components:

- Brief description of the infrastructure asset
- General overview of how the infrastructure asset is vulnerable to flooding
- Identification of the infrastructure vulnerability by study region and each of the four scenarios. Detailed information for each study region by scenario is provided in Annex A.
- Evaluation of the overall regional infrastructure vulnerability, by scenario

## Vulnerability of First Nations

A number of First Nations communities are located along Burrard Inlet, Howe Sound and the Fraser River. Many of the First Nation reserves and Treaty Lands[2] are subject to flooding under all four flood scenarios. The locations of these communities have been reviewed, with particular focus given to vulnerable infrastructure, housing, other structures and agriculture.

Detailed information for First Nations land for each study region by Scenario is provided in Annex C.

[2] First Nation reserves refer to reserves established under the *Indian Ac,* 1876 as amended. The only signed Treaty in the study area is in Region 5 with the Tsawwassen First Nation (implemented in 2009).

## General Assumptions

Two general assumptions:

1. If an asset is inundated, regardless of depth, it will not be available for use. Damages may not necessarily occur but the asset will be taken out of service as a precautionary measure[3].
2. Flood-specific time disruptions are assumed to last:
   - two days for coastal flooding (Scenarios A and B),
   - two weeks for Fraser River freshet flooding (Scenarios C and D).

## General Limitations

General limitations found with the identification of regional vulnerabilities include:

- Data applicability – not all data is current and some may no longer applicable. Every attempt has been made to provide the most up to date information available.
- Comparability of data – sources, whether local government, regional district, or government agency may not be operating under the same definition for similar terms (for example, the Cities of Chilliwack and Abbotsford classify 'arterial' roads differently).

3 This is a conservative standard but appropriate for a high level overview. For reference, a 2009 BGC Engineering study for the City of Chilliwack adapted the following depth thresholds developed by FEMA to identify critical facilities that may close during a particular flood scenario: hospitals – 0 m, community services and schools 0.15 m, police stations 0.30 m and fire halls 0.60 m.

# Vulnerability of Key Infrastructure

## Electrical Substations

### Description
In most of BC including the study area, the electrical system is under the purview of BC Hydro. All substations in the study area are operated by BC Hydro. The one exception is the City of New Westminster, which purchases electricity from BC Hydro but operates its own substations and local distribution lines. Most electricity generation occurs in the northern and southern interior of BC while most of the consumption of electricity occurs in the Lower Mainland and Vancouver Island. Ninety five percent of BC Hydro's power generation is hydroelectric.

Hydro Substations are part of the electrical generation, transmission and distribution system. They transform high voltage electricity from main lines into low voltage electricity for residential and commercial consumption. Each substation serves residents within its regional grid. Exposure to flooding under different Scenarios can be documented with a high degree of precision as the water levels surrounding each substation are known Sensitivity, however, is highly variable. The elevation of electrical equipment above ground level and the degree of redundancy built into the transmission and distribution system are two critical elements of sensitivity.

Annex A provides a list of all substations subject to inundation under each Scenario for each of the 10 Regions. The results are summarized in the following regional vulnerability summary table.

### Vulnerability
The vulnerability of substations is related to both their flood exposure and sensitivity. All substations in floodplains are vulnerable. However, risk factors vary greatly. Electrical service can typically be restored quickly (within days), but access to substations, and safe working conditions for service crews are required. Flood damaged equipment must dry or be replaced. In either case, this will require waiting for floodwaters to recede.

Vulnerability to substation outages is affected by the area served by each vulnerable substation. A substation may serve areas that are subject to inundation as well as other areas that are not. If the substation is not available for service, it will affect areas that are inundated as well as those that are not affected by floodwaters. In some instances, most associated with high loads, substation redundancy has been built into the electrical grid. A substation could be taken off-line without a loss of service to customers if another substation is available to serve the affected area. On the other hand, a substation may be taken off-line, even if the result is a complete loss of service, as a precautionary measure. The consequence of an intentional substation shutdown will be much less as a precautionary measure than if the substation is damaged and transformers and other electrical equipment need to be replaced.

Transformer cabinets in substations are typically built 1.5 m above grade so if the depth of flooding is shallow and of a coastal origin, a loss of power may not occur. Where flooding occurs, transformer cabinets are more susceptible to the corrosive damage of saltwater than freshwater.

Socio-economic vulnerability to substation interruptions includes a loss of substation functionality (power outages) and potentially dangerous or deadly hazards near damaged or flooded transmission equipment. Residential customers, in particular the elderly and other sensitive populations, may be the most strongly affected by power outages due to a lack of mobility or sensitive to extreme temperatures (hot or cold). Businesses may not be able to operate during an outage. For many small businesses, this could mean a direct loss of revenue during an outage. However, for large commercial operations, such as financial institutions, power outages may cause further reaching economic impacts. The impacts of a loss of power to hospitals can be severe. As a result, these essential facilities are equipped with secondary electrical generation equipment and are able to withstand most outages for a limited period of time. In the case of a long-term outage combined with restricted transportation access, generators may not be able to be refueled.

Vulnerability can be reduced by flood proofing measures such as above ground infrastructure to elevate transformer cabinets and isolate them through the use of retaining walls. For example, the Cambie substation in Region 5 (Richmond) has an inflatable dike that can be activated in an emergency. In the most critical areas with high loads, redundancy has been built into the grid. BC Hydro has independent communications to critical control centres. Dedicated fibre optic cables are provided. As a result, BC Hydro does not rely on Telus or other cell tower providers for internal emergency communications.

### Regional Vulnerability

Regional vulnerability of electrical substations for the 10 study regions varies as follows:

| Study Region | Vulnerability Overview |
|---|---|
| #1 | *Under Scenarios A and B*<br>Squamish substation is subject to inundation. |
| #2 | *Under Scenario A*<br>No BC Hydro substations within the Study Region are subject to inundation.<br>*Under Scenario B*<br>Four BC Hydro substations (John Lawson, Norgate, Nexen Chemicals and Erco Worldwide) are subject to inundation. |
| #3 | *Under Scenarios A and B*<br>No BC Hydro substations within the Study Region are subject to inundation. |
| #4 | *Under Scenario A*<br>Four BC Hydro substations (Kidd #1, Westcoast Cellufibre, Seegen and Norampac) are subject to inundation.<br>*Under Scenario B*<br>Ten BC Hydro substations (Murrin #1, Kidd #1, Westcoast Cellufibre, Knight Street Terminal, Seegen, Normpac, GVRD Sapperton Pumps, Canfor, Scott Paper and Tree Island Industries) are subject to inundation.<br>*Under Scenario C*<br>Two BC Hydro substations (Seegen and Scott Paper) are subject to inundation. |

| | |
|---|---|
| | *Under Scenario D*<br>Six BC Hydro substations (Kidd #1, Westcoast Cellufibre, Seegen, Norampac, Scott Paper and Tree Island Industries) are subject to inundation. |
| #5 | *Under Scenario A*<br>Seven BC Hydro substations in Richmond (Kidd #2, Steveston, YVR, Sea Island, Massey Tunnel Terminals, Cambie, and Richmond) plus seven in Delta (Tsawwassen Beach Terminal, Tsawwassen, Boundary Bay, Arnott, Massey Tunnels, Canadian Toyota and Buckeye) are subject to inundation.<br>*Under Scenario B*<br>Eight BC Hydro substations in Richmond (Kidd #2, Steveston, YVR, Sea Island, Massey Tunnel Terminals, Cambie, Richmond, Lafarge #1) plus 12 in Delta (Deltaport, Tsawwassen Beach Terminal, Tsawwassen, Boundary Bay Electrode, Arnott, Massey Tunnels, Canadian Toyota, Lehigh Heidelberg, Buckeye, Lantic Real Prop, Annacis Island, Annacis Island Sewage) in Delta are subject to inundation.<br>*Under Scenario C*<br>Seven BC Hydro substations in Richmond (Kidd #2, Steveston, YVR, Sea Island, Massey Tunnel Terminals, Cambie and Richmond) plus nine in Delta (Tsawwassen Beach Terminal, Tsawwassen, Boundary Bay, Arnott, Massey Tunnel, Canadian Toyota, Lehigh Heidelberg, Buckeye, and Lantic) are subject to inundation.<br>*Under Scenario D*<br>Eight BC Hydro substations in Richmond (Kidd #2, Steveston, YVR, Sea Island, Massey Tunnel Terminals, Cambie, Richmond, Lafarge #1) plus 11 in Delta (Tsawwassen Beach Terminal, Tsawwassen, Boundary Bay electrode, Arnott, Massey Tunnels, Canadian Toyota, Lehigh Heidelberg, Buckeye, Lantic Real Prop, Annacis Island, Annacis Island Sewage) are subject to inundation. |
| #6 | *Under Scenario B*<br>One BC Hydro substation (McLellan) is subject to inundation.<br>*Under Scenarios A, C and D*<br>No BC Hydro substations within the Study Region are subject to inundation. |
| #7 | *Under Scenario A*<br>No BC Hydro substations within the Study Region are subject to inundation.<br>*Under Scenarios B, C and D*<br>One BC Hydro substation (Newstech) is subject to inundation. |
| #8 | *Under Scenarios C and D*<br>No BC Hydro substations within the Study Region are subject to inundation. |
| #9 | *Under Scenarios C and D*<br>One BC Hydro substation (Kent) is subject to inundation. |
| #10 | *Under Scenario C and D*<br>Two BC Hydro substations in Abbotsford (Sumas Way and Abbotsford) plus one in Chilliwack (Atchelitz) are subject to inundation. |

Substations in nearly all Regions in the study area exposed to some flood risk. There are 19 BC Hydro substations subject to inundation in Scenario A, 37 in Scenario B, 23 in Scenario C, and 30 in Scenario D. The difference between coastal flood Scenario A and Scenario B is one metre of SLR. This depth may appear modest but the difference nearly doubles the number of vulnerable substations from 20 to 37, an increase of 17. Flood vulnerability from riverine scenarios also increases between Scenarios C and D. However, the increase of 7 substations from 23 to 30 is lower.

A majority of vulnerable substations in all Scenarios are in one region. This is Region 5 (Richmond and Delta). Regions 4 (Richmond and Delta) and 5 (Vancouver, Burnaby & New Westminster) together comprise only two of 10 Regions. However in each Scenario, they represent between two-thirds and five-sixths of all vulnerable substations (67% to 83%).

Many of the vulnerable substations serve specific or a group of industrial customers. Nearly all of these substations are located in Richmond, Delta, Burnaby, New Westminster and North Vancouver District.

The sensitivity of each substation is relative to its ability to withstand a flood event (keep water out, or hold infrastructure above flood levels). A detailed assessment of the socio-economic vulnerability to substation power outage is beyond the scope of this study. However, a basic picture of this can be obtained by identifying the geographic range of each vulnerable substation and determining the population at risk and its characteristics (e.g. age, household structure), the number of affected businesses and their services, and major commercial centers that may have broad economic consequences (e.g. financial service centres).

## Electrical Generation and Transmission Grid

### Description

The generation of electricity in BC is overwhelmingly hydroelectric based. In 2014, 95 per cent of the province's electricity is produced by hydroelectric generating stations, which consist mostly of large hydroelectric dams on the Columbia and Peace Rivers. A large majority of this electricity is produced by BC Hydro, which operates 31 hydroelectric facilities including several in the Lower Mainland. Locally generated hydroelectricity in the lower Fraser River system represents less than 10% of BC Hydro's system capacity.

BC Hydro also purchases electricity under contract from 101 projects defined as independent power producers (IPP), which, in its latest fiscal year, accounted for 24 per cent of the Crown Corporation's supply. Most IPPs operate small hydro run of river projects. Contributions from these sources have increased substantially in the past decade. Non-hydro sources of electricity include several natural gas-fueled thermal power plants[4], biomass and wind generation projects, mainly by IPPs.

BC Hydro provides the electrical transmission system for most of British Columbia including all of the study area[5]. Four corridors are used to transmit electricity from the interior to the Lower Mainland (Fraser Canyon, Harrison Lake/Lillooet Lake and River, Indian River and Arm, and Howe Sound). This consists of a series of 500 kV, 360 kV, 230 kV, 138 kV and 69 kV transmission lines.

BC's electrical grid is linked to Alberta and Washington State. Two 138 kV lines and one 500 kV line connect to Alberta. In addition, there are two 500 kV lines and two 230 kV lines to the United States. Both 500 kV transmission lines to the United States are located in Region 6 in the Lower Mainland (from Ingledow substation in Surrey to Blaine in Washington State). This connects to the Bonneville Power Administration (BPA).

Since 2009, BC Hydro has had North American Electric Reliability Corporation Mandatory Reliability Standards and Western Electricity Coordinating Council standards as mandatory in BC. These reliability standards speak to contingency, contingency reserve and operating reserve requirements.

Annex A provides a list of all transmission lines (69 kV and higher) subject to inundation under each Scenario for each of the 10 Regions. The results are summarized in the following regional vulnerability summary table.

### Vulnerability

Flood vulnerability does not apply to electrical generation facilities as none are located in areas subject to coastal or riverine floods in the four Scenarios. Vulnerability to the transmission grid includes the loss of transmission towers due to undermining of foundations in areas subject to inundation, inundation of substations, overloading of circuits and inability to undertake repairs

[4] The Burrard Thermal facility in the City of Port Moody is no longer used for electrical generation purposes by BC Hydro.
[5] Local electrical distribution in the City of New Westminster is provided by the City's electrical utility.

until flood waters recede. Transmission lines are typically concentrated in a small number of corridors in order to minimize distances between substations.

The socioeconomic vulnerability to interruptions to the transmission grid is similar to those described in the previous section for substations. However, unlike substations, impacts can vary widely. For example, low-voltage power lines may be damaged in a neighbourhood causing a loss of power to a relatively small number of customers and potentially presenting an acute risk of electrocution if cables are downed in residential areas. This effect might be particularly severe if cables are submerged in water. Wide-ranging impacts may be felt if high voltage supply lines are downed. This could disrupt power to multiple substations and have a wide ranging impact. For example, as indicated by the windstorm in August 2015[6], inundation could result in the widespread loss of power.

The vulnerability of particular transmission infrastructure depends on a range of factors. For circuits and transmission lines, vulnerability is related to their exposure to flood hazards and their ability to cope with flood hazards. This is a result of the elevation (height from the floor or ground) of sensitive electrical equipment, the stability of grid infrastructure (e.g. susceptibility of foundations to erosion and possible downing), and debris impact and other potential environmental hazards (e.g. soil erosion causing felled trees that may damage infrastructure such as power lines).

Local electrical distribution lines (up to 35 kV) consist of a mixture of above ground wood or metal poles and underground cables in neighbourhoods with connections to individual loads (e.g. houses, businesses). Vulnerability of this infrastructure will be closely linked to areas subject to inundation. Major transmission lines, in contrast, may serve customers well beyond areas subject to inundation. This is an area where vulnerability may occur but assessment of this is beyond the scope of this report.

### Regional Vulnerability

Regional vulnerability of electrical generating facilities and transmission lines for the 10 study regions varies as follows:

| Study Region | Vulnerability Overview |
|---|---|
| #1 | *Under Scenario A and B*<br>One major transmission line is subject to inundation. |
| #2 | *Under Scenario A*<br>Three major transmission lines are subject to inundation<br>*Under Scenario B*<br>Five major transmission lines are subject to inundation. |
| #3 | *Under Scenarios A and B*<br>Transmission lines within the Study Region are not subject to inundation. |
| #4 | *Under Scenarios A, B and D*<br>13 Transmission lines (six to Vancouver, two through Burnaby and five to New |

[6] This windstorm caused a loss of power to over 500,000 BC Hydro customers for up to 2½ days due to the widespread downing of local transmission circuits.

| | |
|---|---|
| | West) are subject to inundation.<br>*Under Scenario C*<br>Seven transmission lines (two through Burnaby, five through New West) are subject to inundation. |
| #5 | *Under Scenarios A, B, C and D*<br>Seven transmission lines through Richmond and eight transmission lines through Delta are subject to inundation. |
| #6 | *Under Scenarios A and B*<br>Eleven major transmission lines in Surrey are subject to inundation.<br>*Under Scenarios C and D*<br>The major transmission lines in the Study Region are not subject to inundation |
| #7 | *Under Scenarios A, B, C and D*<br>Three transmission lines in Coquitlam, four in PoCo, two in Pitt Meadows/Maple Ridge are subject to inundation. |
| #8 | *Under Scenarios C and D*<br>Two transmission lines are subject to inundation. |
| #9 | *Under Scenarios C and D*<br>Five transmission lines are subject to inundation. |
| #10 | *Under Scenario C and D*<br>Two transmission lines in Hope, five in Chilliwack and three in Abbotsford are subject to inundation. |

The number of transmission lines subject to inundation cannot be aggregated together to provide a total for the 10 Regions. Transmission lines connect substations. The same transmission line may be listed on two Regions, which would result in double counting. Only Region 3 has no major transmission lines that traverse areas subject to inundation. Seven Regions have three or more major transmission lines that traverse areas subject to inundation.

While many transmission lines and towers will be exposed to flooding under each Scenario, the sensitivity (i.e. the degree to which the towers and therefore the transmission lines will be at risk) may be very low as transmission lines will be elevated well above any floodwaters. Vulnerability occurs if any element of the electrical transmission system is unable to function. For example, a transmission system would be vulnerable if floodwaters undermined the structural integrity of a tower, downing transmission lines.

## Airports

### Description

The Lower Mainland and Squamish areas are host to a range of aviation and heliport services. Aviation infrastructure varies from a large international terminal to small regional airports. The seaplane and helicopter airline industries have grown in recent years and there are now many water aerodromes and heliports throughout the area, often being used as a commuter service. Several hospitals and Fire & Rescue services rely on a fleet of helicopters to provide emergency services and are equipped with heliports. Major facilities are profiled below.

**Vancouver International Airport (YVR)**

YVR is the second busiest airport in Canada. YVR is managed by the Vancouver Airport Authority, a not for profit corporation with a Board of Directors appointed by eight different governments and professional associations. In 2014, YVR reported 19.36 million passengers, 256,934 tons of cargo, and over 273,000 aircraft movements (take-offs and landings)[7]. Over 50 airlines provide service to YVR, which connects to 110 non-stop destinations. Airport operations support roughly 24,000 jobs and generate over $5 billion in gross domestic output and $12 billion in total economic output.

Elevations of parts of the Airport are near current sea level (2015). As a result the airport is exposed to hazards associated with sea level rise, storm surge, and heavy precipitation events. Most of the built environment, such as taxiways, runways, roads and buildings, are located above current design flood levels but much of the undeveloped land, such as the grass infields between taxiways and runways, is low lying and subject to flooding during major rainstorm events.

Major retrofits will be required to comply with future flood levels.[8] The airport authority is undertaking a retrofitting initiative to raise the original dikes to a crest elevation of 4 metres with recognition that further retrofits will be needed.

<u>Vancouver Fuel Operations</u>

According to the Vancouver Airport Fuel Facilities Corporation, aviation fuel and other petroleum products are currently received at the Westridge Marine Terminal in Burrard Inlet and a Marine Terminal and Pipeline is proposed to replace the existing system for fuel transport to YVR.

The new Marine Terminal will be located on the north shore of the South Arm of the Fraser River. Based on YVR fuel demands, a barge could be expected to deliver fuel once every two weeks and larger vessels, once every month. In addition, a fuel receiving facility is proposed to be constructed on land adjacent to the new Marine Terminal.

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7 2014 Annual Report, Vancouver Airport Authority

8 Vadeboncoeur, N., Alidina, H., A., Arroz, Carlson, D., Cheung, W., Harley, C., Ianson, D., James, T., Okey, T., Neale, T., Nelitz, M., Pauly, D., Schnorbus, M., Shrestha, R., Sumaila, R., Werner, P. (2016) Perspectives on Canada's West Coast Region; in Canada's Coasts in a Changing Climate: Understanding Impacts and Adaptation, (ed.) D.S. Lemmen, C.M. Clarke and F. Warren; Government of Canada, Ottawa. (2016 publication pending)

The proposed pipeline will run from the new Marine Terminal to an Airport Fuel Storage spot at YVR. It's proposed to be 13 km long and buried for its entire length.

**Abbotsford International Airport (YXX)**
YXX is the second busiest airport by passenger movement in the Lower Mainland, working to provide air transportation services for the Fraser Valley and some long-distance destinations. In 2014, the airport handled over 477,000 passengers and 121,000 aircraft movements.

Complementary initiatives include developing aerospace and other aviation-related industries and corresponding commercial ventures. The airport is owned and operated by the City of Abbotsford.

**Boundary Bay Airport (YDT)**
Boundary Bay Airport is Canada's second busiest flight training centre, the eighth busiest airport in Canada by aircraft movements (approximately 150,000 per year) and the second busiest for general aviation traffic. It hosts a helicopter rebuilding centre, fuel services, airport and flight training staff. In all, it hosts jobs for approximately 900 people and contributes $90 million to local GDP. YDT is located near sea level within a floodplain and is protected by dikes maintained by the Corporation of Delta.

**Regional Airports**
In addition to YVR, YXX, and YDT, the region is serviced by several regional airports[9] and helipads[10]. The fifteen smaller regional airports do not have sufficient runway length and other essential requirements for larger planes to land. The majority of the twelve helipads are connected with a hospital or health care centre (private helipads have not been included). Coastal flooding may also present a risk to aerodromes by exposing docking facilities and supportive coastal infrastructure to potential inundation and/or damage from wave impacts.

## Vulnerability

Airports are vulnerable to a loss of airport functionality, service and access in the event of inundation. Inundation of airport land including runways and taxiways followed by the terminal structure itself may make airports temporarily inoperable. Provision of fuel may also be challenging or disrupted if the airport is inundated. Passenger terminals may be located at a higher elevation than airport runways. However, if an airport's runways are under water, the

[9] Regional Airports, Aerodromes and Seaplane Bases: Squamish Airport, Vancouver Harbour Water Aerodrome/Vancouver Coal Harbour Seaplane Base, Vancouver International Water Aerodrome, Heritage Air Park, Surrey/King George Airpark, Pitt Meadows Airport and Water Aerodrome, Langley Regional Airport, Fort Langley Airport and Water Aerodrome, Harrison Hot Spring Water Aerodrome, Tipella Airport, Chilliwack Airport, Hope Aerodrome (or Hope Regional Airpark).

[10] Helipads: Vancouver Harbour Public Heliport, Vancouver Children's & Women's Health Centre Heliport, Vancouver Film Studios Heliport, New West Royal Columbia Hospital Heliport, Vancouver/Delta North Heliport, Vancouver/Delta Heliport, Aldergrove Hicks Heliport, Langley Russell Farm Heliport, Mission Memorial Hospital Heliport, Abbotsford Regional Hospital & Cancer Centre Heliport, Abbotsford Sumas Mountain Heliport, Hope Fraser Canyon Hospital Heliport.

airport will be unable to function. The elevated location of airport control towers should result in low vulnerability provided communications are not disrupted.

The immediate direct consequence of inundation will result in flight cancellations. Floods are reasonably predictable, at least to the extent that few, if any, flights will need to be diverted while en route.

Indirect aspects of vulnerability include inundation of access routes. Flights will not operate if passengers are unable to reach an airport due to inundated roads, bridge accesses and public transit routes. Similarly, a non-functioning Canada Line and road closures would prevent staff and crews from reaching the airport, further impeding functionality. Cascading effects into the cargo industry (including services provided by Canada Post and private shippers) may be felt as well as those in aviation-related and dependent industries.

The impacts of a loss of airport functionality would be related to the types of services provided by affected facilities. For example, disruption to regional commercial flights could be partially accommodated by road transportation or by ferry if terminal facilities and access roads are operational. Seaplane bases at YVR and Vancouver Harbour may be functional though road access may not.

### Regional Vulnerability

Regional vulnerability of airports for the 10 study regions varies as follows:

| Study Region | Vulnerability Overview |
|---|---|
| #1 | *Under Scenarios A and B*<br>Airports within Study Region not subject to inundation. |
| #2 | *Under Scenarios A and B*<br>Not Applicable (as there are no airports in this Study Region) |
| #3 | *Under Scenarios A and B*<br>Not Applicable (as there are no airports in this Study Region) |
| #4 | *Under Scenarios A, B, C and D*<br>Not Applicable (as there are no airports in this Study Region) |
| #5 | *Under Scenarios A, B, C and D*<br>Vancouver International, Boundary Bay and Delta Heritage Air Park are subject to inundation as are all access roads. |
| #6 | *Under Scenarios A and B*<br>Not applicable<br>*Under Scenarios C and D*<br>Not applicable |
| #7 | *Under Scenarios A, B, C and D*<br>Pitt Meadows Airport is subject to inundation. |
| #8 | *Under Scenarios C and D*<br>Not Applicable |
| #9 | *Under Scenarios C and D*<br>Not Applicable |
| #10 | *Under Scenarios C and D* |

| | |
|---|---|
| | Chilliwack Airport subject to inundation. Hope Airpark is subject to partial inundation in Scenario C and inundation of all buildings in Scenario D. Abbotsford (YXX) is not subject to inundation but most major road accesses to the east and north are subject to inundation. |

Most airports are in the study region are vulnerable to inundation in two or more Scenarios. YVR is vulnerable to inundation in all Scenarios. This includes all runways, taxiways to terminals, the grounds of the main terminal and the south terminal, all access roads to the terminals and the Canada Line. In Scenario C, the connectivity between facilities will be lost although some facilities will remain above the level of inundation. YVR's significance far surpasses the cumulative total of all other airports in the Region.

If YVR is not able to function due to inundation, alternate facilities cannot accommodate this demand except to a limited degree. The best possibility is YXX, which is not vulnerable to inundation and is within a one-hour drive of YVR. YXX has sufficient runway length and is the second busiest airport by passenger movements and cargo volume in the Lower Mainland. YXX will be five kilometres from any area subject to inundation, indicating that some air traffic could be diverted from YVR to YXX in the event of inundation. This would allow some level of operable air traffic service for the study region to be maintained and would reduce overall regional vulnerability. However, Highways 1 and 11 are subject to inundation restricting vehicular access to YXX from the east, north and south. It is also important to note that YVR has 40 times the annual passenger volume as YXX, and its facilities are correspondingly smaller.

Other airports in the study region are subject to inundation and have limited runway length and landing weight capacity.

Some accommodation could be possible by increasing capacity in other regional facilities such as Victoria and Kelowna. However, none of these facilities have the capacity to take up more than a small fraction of demand at YVR. Washington State airports such as Bellingham and SeaTac in Seattle may also be able to accommodate some short-term demand if they remain operational.

## Ports and Ferries

### Description

The Vancouver Fraser Port Authority, operating as Port Metro Vancouver (PMV), is responsible for the federal port lands within the Lower Mainland. It is Canada's busiest port and the third largest port in terms of total tonnage in North America. The Port's facilities and services to the shipping community consist of 28 major marine cargo terminals and two cruise (passenger) terminals. The Port is served by three Class 1 railroads (CN Rail, CP Rail and BNSF), a regional short line railroad and a network of Provincial highways and other arterial routes.

Port Metro Vancouver facilitates trade with more than 160 trading economies annually – valued at $187 billion in goods (2014 cargo volumes). The Port is a major consolidation centre on Canada's west coast for breakbulk and bulk cargo. It is one of the top three west coast ports for vehicular transshipment. Port Metro Vancouver is also the home port for the Vancouver-Alaska cruise industry.

**Ferry Terminals**

Ferry terminals play an important service connecting people and services between the Lower Mainland, Vancouver Island, the Gulf Islands and the Sunshine Coast.

<u>Tsawwassen Ferry Terminal</u>

This serves as the primary connection between the Lower Mainland and Vancouver Island. Operated by BC Ferries, the Tsawwassen Ferry Terminal is a significant transportation asset. It is the terminus of the highest volume ferry route in the Province and also provides service to Duke Point well as the southern Gulf Islands.

<u>Horseshoe Bay Ferry Terminal</u>

This serves as a major connection between the Lower Mainland and mid-Vancouver Island. Operated by BC Ferries, the Tsawwassen Ferry Terminal also provides service to Bowen Island and Langdale on the Sunshine Coast.

<u>Barnston Island Ferry</u>

Operated by Western Pacific Marine, this free-of-charge ferry operates between Parsons Channel on the south side of the Fraser River between Barnston Island (north bank of channel) and Port Kells (south bank of channel). Port Kells is in the northeast corner of Surrey at the bottom of 104th avenue.

Capacity includes 5 vehicles and 52 passengers. The ferry operates 7 days a week, between 6:15am and 11:55pm/12:55am depending on the day of the week.

<u>SeaBus</u>

The SeaBus is a passenger only ferry crossing Burrard Inlet between the Cities of Vancouver and North Vancouver. It is owned by TransLink and operated by the Coast Mountain Bus Company. It serves as a commuter route for many residents and businesses.

There are four vessels, each with a capacity of 385 people. The SeaBus operates 7 days a week, between 6am and 1am, Monday to Saturday, and 6am and 11:30pm on Sunday.

### Vulnerability

Socioeconomic vulnerability to port damage is largely related to business and trade disruption, which could have considerable economic consequences for business that rely on imports and/or exports. The 2014 trucker strike that capped the flow of goods from the Port was estimated to cost $126 million per day. Its relevance for potential flood vulnerability depends largely on the length of disruption and the number of terminals disrupted. Shipments could be diverted within the Lower Mainland from damaged to functional ports, or to Prince Rupert. In such a scenario, the cost of goods could increase due to increased shipping costs, and delays would be expected in deliveries. If cruise ship terminals are damaged, the local service economy would be affected.

The Port infrastructure itself is vulnerable to damage by flood flows and flood-induced restrictions to accessibility. First, Port infrastructure could be damaged by floodwaters and debris leading to inoperability. However exposure of wharves and other Port infrastructure to floodwaters will not necessarily result in damages if the sensitivity is low. Most bulk products shipped from Port Metro Vancouver have low sensitivity to flood waters. Vulnerability of container traffic will be limited and depend on the cargo and its elevation above wharves, etc. Experience from Hurricane Sandy indicated that equipment used by port operators such as electrical motors for cranes had high sensitivity, and therefore vulnerability, to flood inundation.

Second, access is dependent on effective road and railway networks. Port functionality is dependent on the transfer of goods. If access to the Port is impeded by flooded rail and/or road connections, this will be a major hurdle for Port functionality. Given the length of rail and road networks sensitive to disruption, this is an important consideration. During Hurricane Sandy, foreign oil tankers were halted by water debris, pipelines and storage depots were idled by power cuts and tanker trucks were commandeered by emergency agencies. Two problems emerged with the fuel supply: flooding, which shut down two refineries and numerous terminals; and power outages, which disabled gas stations and the area's biggest pipeline. The problem was not so much a lack of gasoline as an inability to transport it where it was needed.[11] Port infrastructure could also contribute to environmental contamination through spills of stored hazardous materials. During Hurricane Sandy, water overflowed into partially filled tanks or lifted them off their foundations, leading to fuel spills.

### Regional Vulnerability

Regional vulnerability of ports for the 10 study regions varies as follows:

| Study Region | Vulnerability Overview |
|---|---|
| #1 | *Under Scenarios A and B*<br>Squamish Terminals are subject to inundation. |
| #2 | *Under Scenarios A and B*<br>Extensive Port Metro Vancouver lands are subject to inundation.<br>North Vancouver Seabus Terminal is subject to inundation.<br>Horseshoe Bay Ferry Terminal may be subject to inundation. |

11 Analysis: Six months after Sandy, New York fuel supply chain still vulnerable Reuters http://www.reuters.com/article/2013/04/30/us-usa-sandy-fuel-idUSBRE93T0DG20130430#7Iwilo5AKMKhRhsw.99

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| | Private marinas will likely be more vulnerable as their dock facilities are generally at a lower elevation. |
| #3 | *Under Scenario A*<br>One major off-dock facility is subject to inundation.<br>*Under Scenario B*<br>Two major marine terminals (including Pacific Coast Terminals) and one major off-dock facility are subject to inundation. |
| #4 | *Under Scenario A*<br>Vancouver Seabus Terminal is subject to inundation.<br>Some PMV (Vancouver) facilities, PMV off-dock facilities along Burrard Inlet and most marine facilities along the Fraser River (North & Middle Arms) are subject to inundation.<br>*Under Scenario B*<br>Vancouver Seabus Terminal is subject to inundation.<br>Major PMV marine terminals and off-dock facilities (including Ballantyne Pier, Lantic, Vanterm, Alliance Grain and Lafarge North America) as well as PMV off-dock facilities along Burrard Inlet and most marine facilities along the Fraser River (North & Middle Arms) are subject to inundation.<br>*Under Scenario C*<br>Most marine facilities along the Fraser River (North & Middle Arms) are subject to inundation.<br>*Under Scenario D*<br>Most marine facilities along the Fraser River (North & Middle Arms) are subject to inundation. |
| #5 | *Under Scenario A*<br>Tsawwassen Ferry terminal is subject to inundation.<br>Roberts Bank terminal and part of causeway may be subject to inundation.<br>*Under Scenarios A and C*<br>11 Port Metro Vancouver Fraser River facilities in Richmond and 4 major off-dock facilities in Delta are subject to inundation.<br>*Under Scenario B*<br>Tsawwassen Ferry terminal and causeway are subject to inundation.<br>Roberts Bank terminal and causeway are subject to inundation.<br>*Under Scenarios B and D*<br>11 Port Metro Vancouver Fraser River facilities in Richmond and 10 facilities in Delta are subject to inundation. |
| #6 | *Under Scenarios A and B*<br>Fraser Surrey Docks & Intermodal Yard is subject to inundation.<br>Barnston Island Ferry Crossing is subject to inundation.<br>*Under Scenarios C and D*<br>Barnston Island Ferry Crossing is subject to inundation.<br>Port lands are not subject to inundation. |
| #7 | *Under Scenario A*<br>Major off-dock facility in Pitt Meadows will be subject to inundation.<br>*Under Scenarios B, C and D*<br>Five major off-dock facilities in PoCo and the off-dock facility in Pitt Meadows are subject to inundation. |

| | |
|---|---|
| #8 | *Under Scenarios C and D*<br>Not Applicable |
| #9 | *Under Scenarios C and D*<br>Not Applicable |
| #10 | *Under Scenarios C and D*<br>Not Applicable |

Port facilities subject to inundation in all Scenarios are located in Regions 1 to 7. The Seabus Terminals in North Vancouver and Vancouver are subject to inundation in both Scenarios. The Horseshoe Bay Ferry Terminal may be subject to inundation in both Scenarios. The Tsawwassen Ferry terminal is subject to inundation. Vulnerability will depend on both exposure and sensitivity to inundation. Wharves may be exposed to floodwaters but will have low sensitivity to inundation. Vulnerability will be higher for equipment damageable by floodwaters, such as electrical equipment, fuel storage facilities, services and goods. Vulnerability may be greater for intermodal yards, railways and other connecting infrastructure.

## Railways

### Description

Railway infrastructure is critical to effectively moving goods and people throughout the region. British Columbia is the only west coast gateway served by three Class 1[12] railways. Rail tracks in the Lower Mainland are owned and operated by three principal railway companies[13] and are primarily used to move freight with passenger rail companies having trackage rights over the routes.

Routes through the Lower Mainland connect to intermodal/transportation hubs with Port Metro Vancouver, throughout BC, across Canada and into the United States. It takes approximately four days for freight to move between Vancouver and Toronto/Chicago.

**Freight Rail**

Canadian National Railway (CN Rail) is the largest rail network in Canada, with rail connections to three coasts. CN Rail operates two rail lines out of Metro Vancouver. One is located along the south side of the Fraser River east to Hope and the other connects North Vancouver north to Pemberton and Prince George with running rights from North Vancouver to Vancouver.

Canadian Pacific Railway (CP Rail) operates one rail line out of Vancouver, a connection from Mission to Huntingdon/Sumas and has trackage and haulage rights along CN Rail lines. CN Rail and CP Rail each provide on-dock rail facilities for Port Metro Vancouver's container and bulk cargo terminals.

Burlington Northern Santa Fe (BNSF) Railway operates only a short section of railway from Vancouver to the Washington State Border along coastal sections of White Rock, Surrey, Delta, and New Westminster.

These three Class 1 railways provide service to Westshore Terminals and Deltaport container facilities at Roberts Bank.

The Southern Railway of British Columbia (SRY) is a short line that provides a link between Vancouver and Chilliwack.

**Passenger Rail**

The West Coast Express (WCE) connects Mission to Vancouver and is owned and operated by TransLink. The WCE has one commuter route with trackage rights over the CP Rail line[14] – five routes run westward in the morning and eastward in the afternoon/evening.

VIA Rail (VIA) is federally owned and operates nine routes across Canada, mainly along CP Rail and CN Rail tracks and from Vancouver through Kamloops to Calgary, Edmonton and to eastern Canada.

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[12] Class 1 Rail carrier is a company that has earned gross revenues exceeding $250 million for each of the previous two years. http://laws-lois.justice.gc.ca/eng/regulations/sor-96-334/page-4.html#docCont

[13] Canadian National, Canadian Pacific and Burlington Northern Santa Fe (Berkshire Hathaway)

[14] https://en.wikipedia.org/wiki/List_of_Canadian_railways

Amtrak connects Vancouver with Seattle on BNSF trackage and to other rail destinations south to Portland and east of the Rocky Mountains.

The Rocky Mountaineer is a passenger rail route running from Vancouver or Calgary to Banff, Jasper and Whistler. It is privately owned by the Armstrong Group and operates various tour routes on CN Rail and CP Rail lines.

### Vulnerability

Vulnerability is due to the inability of all or part of the rail corridor to carry freight or passengers. The length of time lost to service will depend on the degree and extent of damage to rail lines. Socioeconomic vulnerability to rail network disruption will be similar to that described in the previous section (ports), but could be more severe. This is because rail network disruption has the potential to affect access to goods shipped by both land and sea. Not only could import/export industries be affected, but also intra-national trade. As with ports, alternate shipping options are available (such as road), but this would increase the cost of goods via higher shipping charges.

Primary railway vulnerability is due to inundation of railway tracks. Exposure to inundation may cause no damage but would still result in the suspension of train service as a precautionary measure until floodwaters have receded and the tracks inspected for damages. Damage to railway tracks due to inundation could result in water flows affecting alignment, undermining of the rail bed, obstruction of track due to sediment/debris, and impacts to signaling and other equipment. Physical repairs and upgrades may be required post-flood event. This could delay the usability of the rail network infrastructure after flood waters have receded.

CN Rail and CP Rail mitigate vulnerability by providing access to the other railway's facilities in the event of a disruption.

### Regional Vulnerability

Regional vulnerability of railways for the 10 study regions varies as follows:

| Study Region | Vulnerability Overview |
|---|---|
| #1 | *Under Scenarios A and B*<br>Two sections of railway in Squamish (CN main & CN spur to Squamish Terminals) are subject to inundation. |
| #2 | *Under Scenarios A and B*<br>Sections of CN Rail and the railyard north of Vancouver Wharves are subject to inundation. |
| #3 | *Under Scenario A*<br>No railways are subject to inundation.<br>*Under Scenario B*<br>One section of CP Rail (adjacent to Barnet Hwy) is subject to inundation. |
| #4 | *Under Scenario A*<br>Sections of CP Rail (Marine Drive Industrial Area, crossing from Van to Richmond, the Big Bend, and the stretch along Hwy 1 in New West) and CN Rail (Big Bend |

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|---|---|
| | into Richmond, the stretch along Hwy 1 in New West and Queensborough) are subject to inundation.<br>*Under Scenario B*<br>Large sections of track in Vancouver (including WCE, Via Rail lines, CP and CN Railways) and sections of CN and CP lines in Burnaby and New West are subject to inundation.<br>*Under Scenario C*<br>Sections of CN and CP lines in Burnaby and New West will be subject to inundation.<br>*Under Scenario D*<br>Sections of CP Rail (The crossing from Van to Richmond, the Big Bend, and the stretch along Hwy 1 in New West) and CN Rail (Big Bend into Richmond, the stretch along Hwy 1 in New West and Queensborough) are subject to inundation. |
| #5 | *Under Scenarios A, B, C and D*<br>Two sections of CN Rail (Big Bend to Shell Road and Fraser Lands) and one section of CP Rail (North Arm to Gilbert Rd) in Richmond with sections (CN Rail, BCR to Roberts Bank, BNSF and Amtrak) in Delta are subject to inundation.<br>*Under Scenarios B and D*<br>An additional section of railway in Delta will be subject to inundation. |
| #6 | *Under Scenarios A and B*<br>Eight sections (BNSF, CN, BCR and Southern Railway of BC tracks) of railway are subject to inundation.<br>*Under Scenarios C and D*<br>Four sections of railway (CN and Southern Railway of BC) are subject to inundation. |
| #7 | *Under Scenario A*<br>Sections of CP (Brunette to Pitt River, and CP Rail Mainline) and the West Coast Express are subject to inundation.<br>*Under Scenarios B and C*<br>CP Railyard in PoCo and the CP Rail Mainline/West Coast Express are subject to inundation.<br>*Under Scenario D*<br>CP Railyard in PoCo and the CP Rail Mainline/West Coast Express (in PoCo, Pitt Meadows and Maple Ridge) are subject to inundation. |
| #8 | *Under Scenario C*<br>The CN line from Fort Langley to Abbotsford is subject to inundation.<br>*Under Scenario D*<br>The CN line from Surrey to Abbotsford is subject to inundation. |
| #9 | *Under Scenarios C and D*<br>Multiple sections of CP Rail in Mission, Kent and unincorporated areas of the Fraser Valley Regional District are subject to inundation. |
| #10 | *Under Scenarios C and D*<br>CN Rail in multiple locations in Abbotsford, Chilliwack, Hope and unincorporated areas is subject to inundation.<br>Southern Railway of BC throughout Chilliwack and Abbotsford is subject to inundation. |

All three Class 1 railways are vulnerable to inundation under all Scenarios. This could prevent any rail freight from entering or leaving the Lower Mainland. The loss or reduction of freight services would also impacted supply chains causing a cascading effect. Rail passenger service is also vulnerable to inundation in all Scenarios including the West Coast Express within the Lower Mainland and passenger service beyond the Region.

As an example, in Region 9, the CP Rail mainline is subject to inundation for 12.56 km in the District of Mission under Scenario C and 12.96 km under Scenario D. In addition, Highway 7 (Lougheed Highway) is subject to inundation for 5.3 km under Scenario C and 5.7 km under Scenario D. This would affect all rail and road transportation on the north side of the Fraser River.

The economic disruption due to flooding of rail lines merits further analysis. The type, volume, and destination of cargo on a daily basis would enable the economic disruption from flooding to be detailed and better understood. This could be linked to the vulnerability of supply lines to/from Port Metro Vancouver.

## Critical Regional Routes and Other Arterial Highways

### Description

Critical regional routes consist of Provincial highways other critical regional highways as determined by the Ministry of Transportation and Infrastructure. Other arterial highways are as designated on municipal Official Community Plans.

### Vulnerability

Socioeconomic vulnerability to critical regional routes and arterial highways is an important consideration for the region given the high volume of commuter traffic. Disruption to road networks could isolate a portion of the workforce and disrupt intra-regional trade in goods. However, total loss of access to large segments of the population is unlikely given the high number of road access points. It is more likely that travel times would be greatly increased, slowing the movement of people and goods. This would affect economic productivity and create logistical stress.

Vulnerability of major highways is due to inundation of any section of a corridor. Connectivity is lost if access to any section is not available. This can be mitigated if alternative routes are available.

In addition to issues of connectivity, physical repairs and upgrades will be required post-flood event. This could severely delay the usability of the road network infrastructure even if flood waters have receded.

### Regional Vulnerability

Regional vulnerability of critical routes and other arterial highways for the 10 study regions varies as follows:

| Study Region | Vulnerability Overview |
|---|---|
| #1 | *Under Scenarios A and B*<br>Sections of critical routes (Hwy 99) and arterial roads are subject to inundation. |
| #2 | *Under Scenario A*<br>No critical routes but sections of two arterial roads (West 1st and Welch St) are subject to inundation.<br>*Under Scenario B*<br>Sections of critical routes (Hwy 1) and several arterial roads are subject to inundation. |
| #3 | *Under Scenarios A and B*<br>No critical routes and arterial roads within the Study Region are subject to inundation. |
| #4 | *Under Scenario A*<br>Sections of critical routes (Hwy 99, Knight Street, Marine Way, Boundary Road, Hwy 91A, Brunette Ave and Stewardson Way) and arterial roads (North Fraser Way, Byrne Road, Boyd Street/Derwent Way) are subject to inundation.<br>*Under Scenario B* |

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|---|---|
| | Sections of critical routes (Hwy 99 (including Lost Lagoon), SW Marine Drive, Knight Street, Marine Way, Boundary Road, Hwy 91A, Brunette Ave and Stewardson Way) and arterial roads (North Fraser Way, Byrne Road, Boyd Street/Derwent Way, and Columbia Street) are subject to inundation.<br>*Under Scenario C*<br>Sections of critical routes (Marine Way, Boundary Road, Hwy 91A, Brunette Avenue and Stewardson Way/Front Street) and arterial roads (North Fraser Way, Byrne Road, Boyd Street/Derwent Way, and Columbia Street) are subject to inundation.<br>*Under Scenario D*<br>Sections of critical routes (Hwy 99, Knight Street, Marine Way, Boundary Road, Hwy 99, Hwy 91A, Brunette Ave, Stewardson Way/Front Street) and arterial roads (North Fraser Way, Byrne Road, Boyd Street/Derwent Way, and Columbia Street) are subject to inundation. |
| #5 | *Under Scenarios A, B, C and D*<br>Significant sections of critical routes and arterial roads of Richmond and Delta are subject to inundation. (See Annex A for detailed list) |
| #6 | *Under Scenarios A and B*<br>Sections of critical routes (Hwy 99, 17, 10 & King George) and arterial roads (see Annex A for detailed list) are subject to inundation.<br>*Under Scenarios C and D*<br>Sections of two critical routes (SFPR & King George to South Westminster) and four arterial roads (Scott Road, Tannery Road, 108 Ave, Bridgeview Drive) are subject to inundation. |
| #7 | *Under Scenario A*<br>Sections of critical routes (Hwy 7B – Mary Hill and Hwy 7 – Lougheed) and arterial roads (United Boulevard, Old Dewdney Trunk Road, 132$^{nd}$ Ave.) are subject to inundation.<br>*Under Scenarios B, C and D*<br>Sections of critical routes (Hwy 1, 7 (Lougheed), 7B (Mary Hill)) and arterial roads (United Boulevard, King Edward St, Schoolhouse St, Pitt River Road, Kingsway, Fremont/Burns Road, Dominion Ave, Broadway, Old Dewdney Trunk Roads, 132$^{nd}$ Ave.), 132 Avenue west of 224 Street, Kanaka Way, 105 Avenue, and Tamarack Lane (Scenario D) are subject to inundation. |
| #8 | *Under Scenario C*<br>Critical route (Golden Ears Bridge & Way) and select arterial roads (primarily through Fort Langley) are subject to inundation.<br>*Under Scenario D*<br>Select arterial roads (primarily through Fort Langley) are subject to inundation. |
| #9 | *Under Scenarios C and D*<br>Critical Routes (large sections of Hwys 7 & 9) and the arterial Haig Road are subject to inundation. |
| #10 | *Under Scenarios C and D*<br>Sections of critical routes (Hwy 1) and arterial roads (largely in Chilliwack) are subject to inundation. |

Both Provincial highways north and south of the Fraser River (Highways 11 and 7) are subject to inundation in multiple sections. Highway 99 is also subject to inundation in multiple sections between the Lower Mainland and Squamish and south to the US Border. Other critical routes subject to inundation in the Region include Knight Street, Marine Way, Boundary Road, Highway 91A, Brunette Ave, Stewardson Way/Front Street, SFPR & King George Boulevard, Highway 7, Highway 7B and the South Fraser Perimeter Road. Numerous municipal arterial roads are also subject to inundation.

There are only two east-west corridors (Highways 1 and 7) within the study area and one corridor to the north (Highway 99). Alternate accesses do not exist along Highway 99 and most of Highway 7 on the north side of the Fraser River. Alternate accesses are available along Highway 1 but all alternatives in Chilliwack and Abbotsford are also subject to flood inundation.

There are four highway corridors south of B.C. into Washington State. Of these corridors, two are subject to inundation; the Highway 11 connection on Sumas Way and Highway 99.

Vulnerability can be mitigated if alternate routes are available, but this potential is limited in the mountainous terrain along the Sea to Sky corridor and much of the lower Fraser Valley.

## Rapid Transit

### Description

Transit services in the study area are primarily operated by TransLink and BC Transit.

**TransLink (South Coast British Columbia Transportation Authority)**
TransLink is Metro Vancouver's regional transportation authority. Select operating companies deliver TransLink services. British Columbia Rapid Transit Company Ltd (BCRTC) maintains and operates two of the three SkyTrain Lines (Expo and Millennium Lines) and the West Coast Express. InTransit BC operates and maintains the third line (Canada Line). A fourth SkyTrain line (Evergreen Line) to the City of Coquitlam is currently under construction with completion scheduled for 2017.

SkyTrains operate on dedicated tracks separated from all vehicular or pedestrian crossings. The Expo and Millennium Lines operate primarily on elevated guideways. The Canada Line operates primarily in a tunnel through Vancouver and on elevated guideways in Richmond.

Coast Mountain Bus Company Ltd. (CMBC) operates Metro Vancouver's bus service and SeaBus passenger ferries between North Vancouver and downtown Vancouver across the Burrard Inlet. Within the Bus Division, CMBC also administers HandyDART services, West Vancouver's Blue Bus and community shuttle operations in Langley, New Westminster, Tsawwassen First Nation, Lions Bay and Bowen Island.

**BC Transit**
BC Transit operates transit services outside of the Metro Vancouver area, including Squamish, Chilliwack, Central Fraser Valley, and Agassiz-Harrison. No rapid transit infrastructure currently exists in these areas. Transit services are primarily provided by bus.

### Vulnerability

Vulnerability is due to the number of people that would not be able to travel to work, school, healthcare, recreation and other purposes due to inundation of SkyTrain and road transit routes. The extensive rapid transit network (by length) in Metro Vancouver and its high usage rates indicates that inundation would cause major disruption for commuters and would also likely create logistical problems for many patients who rely on transit for medical appointments.

Rapid Transit vulnerability is due to the inundation of tracks and essential electrical equipment. Keeping critical transit infrastructure, including switches and electrical panels, above anticipated flood levels would reduce exposure. Tracks at grade or underground are anticipated to experience inundation and become inoperable. Debris, such as fallen trees, may also impact operability. In addition, service will be impacted if passengers are unable to safely access (or leave) the stations. Transit buses are less vulnerable than SkyTrains as some bus routes may be altered to travel through locations not subject to inundation.

## Regional Vulnerability

Regional vulnerability of rapid transit services for the 10 study regions varies as follows:

| Study Region | Vulnerability Overview |
|---|---|
| #1 | *Under Scenarios A and B*<br>Not Applicable |
| #2 | *Under Scenarios A and B*<br>Not Applicable |
| #3 | *Under Scenarios A and B*<br>Evergreen Line not subject to inundation |
| #4 | *Under Scenarios A, C and D*<br>Access to the Expo and Millennial SkyTrain lines will be impacted.<br>Canada Line will not be impacted.<br>*Under Scenario B*<br>Vancouver Transit Centre and access to the Expo and Millennial SkyTrain lines will be impacted. |
| #5 | *Under Scenarios A, B, C and D*<br>Canada Line and access to the Canada Line on Sea Island will be impacted. |
| #6 | *Under Scenarios A, B, C and D*<br>Expo Line and access to the Expo Line may be impacted |
| #7 | *Under Scenarios A, B, C and D*<br>Evergreen Line not subject to inundation |
| #8 | *Under Scenarios C and D*<br>Not Applicable |
| #9 | *Under Scenarios C and D*<br>Not Applicable |
| #10 | *Under Scenarios C and D*<br>Not Applicable |

The Expo Line and Millennial Line may be subject to inundation in parts of Vancouver. Most of the lines are elevated above grade with the exception of some areas west of the Commercial Broadway SkyTrain station. The elevation of electrical equipment is of critical concern. In addition, the loss of service in any part of a SkyTrain line will impact its overall passenger capacity due to switching and other considerations. The Canada Line is subject to inundation in parts of Richmond where it is at grade.

More detailed analysis of passenger loads by route would provide a better picture of the impact of inundation under different Scenarios by Region. Some SkyTrain Lines would not be affected while others may be partially affected or shut down. Passenger volumes could be used to document the cascading effects of job interruption in other industries/areas.

## Municipal Services

### Description

**Major Water Facilities**

Metro Vancouver manages protected watersheds and storage reservoirs and owns and operates major treatment facilities (including infrastructure required to move water between municipalities). Metro Vancouver owns and operates two drinking water treatment facilities:

- Seymour-Capilano Filtration Plant (SCFP)
- Coquitlam Water Treatment Plant (CWTP)

Municipality owned and operated infrastructure distributes water to individual homes and businesses. A municipality may also operate urban reservoirs, underground pipes, etc. including:

- Pumping stations (more than 15 in the region)
- Rechlorination stations (8)
- In-system reservoirs (22)

<u>Mission and Abbotsford</u>

The Water and Sewer Commission – a joint operation by the District of Mission and the City of Abbotsford – operates the regional water system, servicing approximately 135,000 people. The two municipalities operate their distribution systems independently. The water supply for the system is largely from Cannell Lake (10%) and Norrish Creek north of Mission (85%), with supplementary sourcing from some groundwater wells in south Abbotsford (5%). Dickson Lake (upstream of Norrish Creek) can be used as a storage reservoir to supplement the flow to Norrish Creek.

The District of Mission operates two water systems consisting of the District of Mission Water System and Ruskin Townsite Water System. Approximately 30,000 residents are served with water from the Mission Water System, sourced from the Water and Sewer Commission system while the water supply for the Ruskin Townsite Water System is from Hayward Lake and services about 150 people.

The City of Abbotsford services approximately 100,000 residents from the Water and Sewer Commission system. There are currently 19 groundwater wells in the south region of Abbotsford that supplement the system. They are only operated during peak consumption periods or when the Norrish Creek supply is off-line.

The regional system has two storage reservoirs – Maclure Reservoir in Abbotsford and Mary Ann Reservoir in Mission. The purpose of the reservoirs is for flow balancing and emergency storage.

<u>Chilliwack</u>

In the City of Chilliwack, water is obtained from the Sardis-Vedder Aquifer, a natural underground water reservoir. The Sardis-Vedder Aquifer lies immediately north of the Vedder River in Sardis and extends north to the No. 1 Highway. It is bounded on the west by the City's border with Abbotsford and on the east by Prest Road. The City's wells pump water from a depth of 30-40 m. However, the aquifer is vulnerable to contamination, as the upper layer of groundwater is shallow, at 5-10 m below the ground's surface.

The Fraser Valley Regional District operates or oversees several water systems including:

- Area D Integrated Water Systems
- Bell Acres
- Boston Bar Integrated Water System (outside of study area)
- Deroche (1 groundwater well near Deroche Creek serving 42 customers)
- Dewdney Water System (2 customers on River Road with water supplied from Abbotsford/Mission water supply)
- Dogwood Valley
- East Cultus Parkview Water System
- Hatzic Prairie Water System (2 groundwater wells serving 130 customers)
- Hope Airpark Water System (1 groundwater well in floodplain serving the airpark clubhouse, shop, hangers and one residential building)
- Lake Errock Water System
- Morris Valley
- North Bend (outside of study area)
- Yale (outside of study area)

**Major Wastewater (Sanitary Sewerage) Treatment Facilities**
Metro Vancouver operates five wastewater treatment plants, and maintains a region-wide network of sewers and pumping stations in order to collect and treat the Metro Vancouver region's wastewater. The Lions Gate Wastewater Treatment Plant in West Vancouver also serves North Vancouver City and District. The Iona Wastewater Treatment Plant services much of Vancouver and Sea Island in Richmond. The Lulu Island Wastewater Treatment Plant serves West Richmond. The Annacis Island Wastewater Treatment Plant serves 14 municipalities including the Cities of Burnaby, New Westminster, Surrey, White Rock, Port Coquitlam, Coquitlam, Pitt Meadows and Port Moody. The Northwest Langley Wastewater Treatment Plant services the Township of Langley.

There are five wastewater treatment plants that serve municipalities in the two study area Regions within the Fraser Valley Regional District. The James treatment plant serves most of Abbotsford and Mission and parts of the Township of Langley. The Chilliwack treatment plant serves most of the City of Chilliwack. Treatment plants in the District of Hope, Village of Harrison Hot Springs and District of Kent serve their respective municipalities.

**Solid Waste**
Regional districts are responsible for solid waste management. Metro Vancouver has four goals:

1. minimize waste generation;
2. maximize reuse, recycling and material recovery;
3. recover energy from the waste stream after material recycling; and
4. dispose of all remaining waste in landfill, after material recycling and energy recovery.

The target for the first goal is to reduce the quantity of waste generated per capita to 90% or less of 2010 volumes by 2020. The aspirational target of the second goal is increase the regional diversion rate to 70% by 2015 and 80% by 2020.[15]. Recycled waste is separated by source. The remaining solid waste is collected at transfer stations and transferred to the Vancouver landfill site in Delta or incinerated to create steam energy. The FVRD's target is to divert 80% of the solid waste by 2019 and 90% of the solid waste by 2025.[16] Unlike Metro Vancouver, the FVRD does not support incineration.

### Vulnerability

This assessment does not indicate that drinking water facilities will be impacted by flood hazards. Metro Vancouver's water supply comes from mountain reservoirs. Potable treatment and water storage facilities are located outside or above areas subject to inundation. Pumping stations have also been identified as safe from flood hazards. Water distribution will occur in areas subject to inundation but this infrastructure will be at pressure and is therefore a low vulnerability concern.

Sewage treatment plants are usually located near water in low-lying areas to enable as much of the sewage to be piped to the plant by gravity and then discharged to nearby receiving waters. The study Regions are no exception. All five wastewater treatment plants in Metro Vancouver are subject to inundation. The Lions Gate Wastewater Treatment Plant that serves the north shore is subject to inundation in Scenario B. The Iona Wastewater Treatment Plant serving much of Vancouver and Sea Island is subject to inundation under all four Scenarios. The Lulu Island Wastewater Treatment Plant serving West Richmond is subject to inundation under all four Scenarios. The Annacis Island Wastewater Treatment Plant serves part of all of eight municipalities is subject to inundation under Scenarios B and D. The Northwest Langley Wastewater Treatment Plant is subject to inundation under Scenarios C and D.

In the Fraser Valley Regional District, five major wastewater treatment plants are subject to inundation. The James Treatment Plant, serving most of Abbotsford and Mission and parts of the Township of Langley, is subject to inundation under both Scenarios C and D. The Chilliwack Treatment Plant is subject to inundation under both Scenarios C and D. The District of Hope, Harrison Hot Springs and Kent treatment plants are all subject to inundation under both Scenarios C and D.

In the Squamish–Lillooet Regional District, the Squamish Wastewater Treatment Plant is not subject to inundation from coastal flooding (although it is subject to flooding from the Squamish and Mamquam Rivers). The Britannia Beach Wastewater Treatment Plan is likely subject to inundation from coastal flooding.

Given that 10 wastewater treatment plants are subject to inundation in one or more scenarios, numerous indirect impacts are possible. Inundation may prevent wastewater treatment plants from operating resulting in raw sewage flowing into the Fraser River or directly the Strait of Georgia. Vulnerability may include structural damage from flood waters and debris. Many treatment plants have expansive underground pipe systems holding tanks and pumps that can remain waterlogged and incapacitated long after floodwaters have receded. Treated wastewater is also typically discharged through large underwater pipes, which can cause

15 Integrated Solid Waste and Resource Management, Metro Vancouver (July 2010) Note: Provincial approval July 2011.

16 Solid Waste Management Plan Update 2015-2025, Fraser Valley Regional District (August 2014)

facilities to flood from the inside as water rises, long before surface waters overrun the outside of the structures.[17] An additional vulnerability is loss of power. Wastewater treatment plants cannot operate without a source of power. The Annacis Island Treatment Plant is the largest in the region, providing secondary treatment to over one million residents in 14 municipalities. Electrical power comes from the Annacis Island substation, which is subject to inundation in Scenarios B and D. Sewer back-up could occur regardless of whether or not a wastewater treatment plant is operating. Local environmental contamination would result from any of these events.

The Covanta Waste to Energy facility in south Burnaby is subject to inundation in Scenarios B and D. This incinerator in the Fraser River floodplain at Big Bend processes approximately 25 percent of Metro Vancouver's post-recycled waste (285,000 tonnes), mainly from the North Shore, Burnaby and New Westminster.

Stormwater poses an additional source of vulnerability due to inundation. Flooding of land prevents storm drainage infrastructure from functioning and causes stormwater to back-up. This is a risk for which insurance is available whereas insurance for overland flows is not available for residential development (except strata corporations).

### Regional Vulnerability

Regional vulnerability of municipal services for the 10 study regions varies as follows:

| Study Region | Vulnerability Overview |
|---|---|
| #1 | *Under Scenarios A and B*<br>Wastewater Treatment infrastructure is not subject to inundation. |
| #2 | *Under Scenario A*<br>Wastewater Treatment infrastructure is not subject to inundation.<br>Under Scenario B<br>Lions Gate Wastewater Treatment Centre is subject to inundation. |
| #3 | *Under Scenario A*<br>Wastewater Treatment infrastructure is not subject to inundation.<br>Under Scenario B<br>Annacis Island (in Delta) Wastewater Treatment Centre is subject to inundation. |
| #4 | *Under Scenarios A and C*<br>Iona Island Wastewater Treatment Centre (Richmond) is subject to inundation.<br>*Under Scenarios B and D*<br>Iona (Richmond) and Annacis Island Wastewater Treatment Centres (Delta) are subject to inundation.<br>Covanta Waste to Energy incinerator in south Burnaby is subject to inundation. |
| #5 | *Under Scenarios A and C*<br>Both wastewater treatment centres (Iona and Lulu Island) in Richmond are subject to inundation.<br>*Under Scenarios B and D*<br>All three wastewater treatment centres (Iona and Lulu Island in Richmond and |

[17] Kenward, Aylson et al. Sewage Overflows from Hurricane Sandy. Climate Central (April 2013)

| | |
|---|---|
| | Annacis Island in Delta) in the region are subject to inundation. |
| #6 | *Under Scenario A*<br>One facility (Cloverdale Sanitary Sewer Overflow Storage) is subject to inundation.<br>*Under Scenario B*<br>Two facilities (Annacis Island and Cloverdale) are subject to inundation.<br>*Under Scenario C*<br>Wastewater Treatment infrastructure is not subject to inundation.<br>*Under Scenario D*<br>Annacis Island Wastewater Treatment Centre is subject to inundation. |
| #7 | *Under Scenarios B and D*<br>Annacis Island Wastewater Treatment Centre is subject to inundation.<br>*Under Scenarios A and C*<br>Wastewater Treatment infrastructure is not subject to inundation. |
| #8 | *Under Scenarios C and D*<br>The Northwest Langley Wastewater Treatment Plant is subject to inundation. |
| #9 | *Under Scenarios C and D*<br>Three wastewater treatment plants (Harrison, James & Kent) are subject to inundation. |
| #10 | *Under Scenarios C and D*<br>Three Wastewater treatment plants (Hope, Chilliwack and James) are subject to inundation. |

Regional vulnerability is considered very low for drinking water supply and distribution.

Regional vulnerability is considered high for wastewater treatment facilities as 10 are subject to inundation under two or more Scenarios. This vulnerability affects all major facilities in nine of the 10 Regions including virtually the entire urban population base.

Regional vulnerability for stormwater management is anticipated to be high but will require further analysis.

## Emergency Services

### Description

Emergency and rescue services are organizations that ensure public safety and health. Many of these organizations participate in community awareness and prevention programs to help the public handle emergencies effectively in addition to their first responder/emergency response services.

**Fire, Search and Rescue**

Fire and Search and Rescue (SAR) services are first responders in the event of an emergency, such as fire and rescue operations. They may also deal with secondary emergency service duties.

**Emergency Medical Services**

Emergency Medical Services (EMS) typically provide out-of-hospital acute medical care and medical transport for patients with illnesses and injuries who are unable to transport themselves.

In BC, BC Emergency Health Services (BCEHS) provides pre-hospital emergency services and inter-facility patient transfers. BCEHS oversees the BC Ambulance Service (BCAS) and the BC Patient Transfer Network (BCPTN). Other services include dispatch operations, the critical care transfer (CCT) program and infant transport team (based at BC Children's Hospital in Vancouver). BCAS is only one of two ambulance services in Canada utilizing critical care paramedics.

BCAS maintains both ground and air services, including three airplanes and two helicopters based in Vancouver[18], as well as 40 pre-qualified charter carriers and air ambulance pilot contracts. All requests for critical care transport services (including neonatal, maternal and pediatric) are processed through the Patient Transfer Coordination Centre in Vancouver.

The critical care program is the second-busiest in North America. In 2013-2014, the CCT Program transported 8,600 patients: 4,700 by air ambulance airplane, 1,900 by air ambulance helicopter, and 2,000 by ground ambulance[19]. For the same year, the BCAS spent $57.8 million for the aircraft, ambulances, personnel, training and fuel to support the CCT Program. As of 2014, there are 77 critical care and infant transport paramedics in BC.

<u>Combined Events Radio Project, Richmond BC</u>

The BCAS implemented a live interoperable radio system in conjunction with the RCMP and local fire detachment allowing emergency personnel to be in constant contact prior to their arrival at incidents requiring the response of various emergency services. This initiative is the first in Canada.

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[18] Six airplanes province wide – two in Kelowna, and one in Prince George – and four helicopters – one in Prince Rupert and one in Kamloops – in addition to the Vancouver stock.

[19] Information provided by the *Critical Care Transport Program Factsheet*

**Police Services**
Police services, provided either through a municipal police force or the RCMP, enforce federal, provincial and municipal laws, protect property and limit civil disorder.

**Emergency Operations Centres**
Nearly all Emergency Operations Centres (EOCs) for local governments are located in municipals halls, police stations or fire halls. A list of all EOCs in the study area including addresses and associated emergency facilities is detailed in Annex B. Due to this association with other emergency facilities, EOCs have not been listed separately in Annex A as this would be counting the same facility twice. However, the following table identifies EOCs that are subject to inundation under the four different Scenarios.

**Other Emergency Services**
Other emergency services can include (but are not limited to):

- Coastal protection via the Canadian Coast Guard (& Auxiliary)
- Wildland fire suppression through the BC Wildfire Service
- Emergency Management planning through Emergency Management BC
- St. John Ambulance volunteer services
- Amateur radio emergency communications

## Vulnerability
The socioeconomic potential effects of a reduction in emergency services are serious. However, given that emergency responders are mobile and that they could conceivably share or improvise emergency response centres, the principal vulnerability is likely to be a lack of access. This will be relative to the capacity of emergency responders to access affected citizens via road or boat. A secondary vulnerability is that designated or improvised shelter facilities could be impacted by floods or suffer restricted access.

Vulnerability of emergency services themselves is due to the impairment or inability of police, fire and ambulance stations to function, the inability of emergency vehicles (police, fire and ambulance) to communicate with dispatch offices, and the inability of emergency vehicles to access persons and buildings in need. Again, these vulnerabilities are a product of the transportation options available to responders.

## Regional Vulnerability
Regional vulnerability of emergency operations centres for the 10 study regions varies as follows:

| Study Region | Vulnerability Overview |
|---|---|
| #1 | *Under Scenarios A and B*<br>Squamish EOC is not subject to inundation under either Scenario. |
| #2 | *Under Scenarios A and B*<br>No EOC in the four municipalities is subject to inundation under either Scenario. |
| #3 | *Under Scenarios A and B*<br>No EOC in the three municipalities is subject to inundation in either Scenario. |
| #4 | *Under Scenarios A, B, C and D* |

| | |
|---|---|
| | No EOC in the three municipalities is subject to inundation in any Scenario. |
| #5 | *Under Scenarios A, B, C and D*<br>Main and Backup EOC for Richmond and main EOC in Delta are subject to inundation in all four Scenarios. Backup ECO for Delta is not subject to inundation in any Scenario. |
| #6 | *Under Scenarios A, B, C and D*<br>No EOC in the two municipalities is subject to inundation in any Scenario. |
| #7 | *Under Scenarios A, B, C and D*<br>Port Coquitlam EMO is subject to inundation under 3 Scenarios and is vulnerable under Scenario A.<br>The EOCs in the other 3 municipalities are not subject to inundation in any Scenario. |
| #8 | *Under Scenario C and D*<br>No EOC is subject to inundation under either Scenario. |
| #9 | *Under Scenario D*<br>The combined EOC for the District of Kent and Village of Harrison Hot Springs is subject to inundation under Scenario D. |
| #10 | *Under Scenarios C and D*<br>No EOC in the two municipalities is subject to inundation in either Scenario. |

Most EOCs are not subject to inundation under any Scenarios. Two EOCs are subject to inundation under all Scenarios and one of these EOCs has a backup location not subject to inundation under any Scenarios. Two additional EOCs are subject to inundation under most but not all Scenarios.

Regional vulnerability of emergency services (fire, police and ambulance) for the 10 study regions varies as follows:

| Study Region | Vulnerability Overview |
|---|---|
| #1 | *Under Scenarios A and B*<br>Emergency Service infrastructure is not inundated. |
| #2 | *Under Scenarios A and B*<br>Emergency Service infrastructure is not inundated. |
| #3 | *Under Scenarios A and B*<br>Emergency Service infrastructure is not inundated. |
| #4 | *Under Scenarios A, B and C*<br>Emergency Service infrastructure is not inundated.<br>*Under Scenario D*<br>Ambulance Station 247 – Sapperton is subject to inundation. |
| #5 | *Under Scenarios A, B, and D*<br>Four Ambulance Stations, all seven fire halls and three police and community policing stations in Richmond are subject to inundation. Two ambulance stations, three fire halls and three police, community policing and highway patrol stations in Delta are subject to inundation.<br>*Under Scenario C* |

| | |
|---|---|
| | Four Ambulance Stations, all seven fire halls and three police and community policing stations in Richmond are subject to inundation. Two ambulance stations, two fire halls and three police, community policing and highway patrol stations in Delta are subject to inundation. |
| #6 | *Under Scenario B*<br>Fire Hall 8 in Cloverdale is subject to inundation.<br>*Under Scenarios A, C and D*<br>Emergency Service infrastructure is not subject to inundation. |
| #7 | *Under Scenarios A, B, C and D*<br>One Firehall (Broadway St.) in Port Coquitlam is subject to inundation. |
| #8 | *Under Scenario C and D*<br>Emergency Service infrastructure is not inundated. |
| #9 | *Under Scenario C*<br>Harrison Hot Springs Fire Dept., Agassiz Fire Dept., and North Fraser Fire Dept. (Deroche) are subject to inundation. Mission Fire Hall is not subject to inundation.<br>Other Emergency Service infrastructure is not subject to inundation.<br>*Under Scenario D*<br>Harrison Hot Springs Fire Dept., Agassiz Fire Dept., and North Fraser Fire Dept. (Deroche) are subject to inundation. Mission Fire Hall is not subject to inundation.<br>RCMP and Ambulance Station #215 (Pioneer Ave) in Agassiz is subject to inundation. |
| #10 | *Under Scenarios C and D*<br>4 of 6 fire halls in Chilliwack including the main hall are subject to inundation.<br>2 fire halls in Abbotsford are subject to inundation.<br>4 policing facilities (police station, highway patrol, operational & communications centre, and community policing station) in Chilliwack are subject to inundation.<br>The Young Road Ambulance Station is subject to inundation. |

Emergency services vulnerable to inundation are primarily located in Regions 5 (Richmond and Delta) and Region 10 (Chilliwack and Abbotsford). A very high proportion of emergency services are subject to inundation in these municipalities.

Under Scenario A, six police stations, 11 fire halls and 6 ambulance stations are subject to inundation. Under Scenario B, six police stations, 12 fire halls and 6 ambulance stations are subject to inundation. Under Scenario C, six police stations, 19 fire halls and 6 ambulance stations are subject to inundation. Under Scenario D, 11 police stations, 20 fire halls and 6 ambulance stations are subject to inundation.

## Health Providers

### Description

**Vancouver Coastal & Fraser Health**

Vancouver Coastal and Fraser Health serve a diverse multicultural population, in multiple service areas including mental health care, public health, home and community care in addition to outpatient care and surgery centres.

Vancouver Coastal Health (VCH) provides healthcare services in Vancouver, Richmond, North and West Vancouver, along the Sea-to-Sky Highway, Sunshine Coast and BC's Central Coast – reaching approximately 25% of BC's population. Operations include 14,300 full time/part time staff including 4,400 nurses, 2,100 physicians and 3,000 volunteers[20].

Fraser Health provides healthcare services from Burnaby to White Rock to Hope, serving an estimated 1.6 million people including approximately 38,100 First Nations people associated with 32 bands. Operations involve 12 hospitals[21] and 7,760 residential care beds requiring 22,000 staff, 2,500 physicians and 6,500 volunteers.

| Daily Statistics | VCH | FH | Totals |
|---|---|---|---|
| **Emergency Visits** | 914 | 1,208 | 2,122 |
| **Home Care Visits** | 891 | 630 | 1,521 |
| **Residential care clients** | 6,240 | 7,760 | 14,000 |

In addition to the above healthcare providers, Providence Health Care provides services via Hospitals and Residences in six areas for British Columbians in collaboration with Vancouver Coastal and Fraser Health[22]. Areas of emphasis are heart & lung, Kidney/Renal, HIV/AIDS, Urban Health, Mental Health and Senior Services.

**Other Health Care Facilities**

In addition to hospitals and emergency care services, Lower Mainland residents are served by a network of long-term care facilities where patients have variable levels of independence, walk-in care clinics, crisis hotlines, mental health resources and pharmacy services.

[20] Numbers for nurses excludes casuals and Providence Health Care, and numbers for physicians excludes locums.
Vancouver Coastal Health Quick Facts http://www.vch.ca/about-us/quick-facts/

[21] Hospitals include: Burnaby Hospital, Delta Hospital, Royal Columbian, Surrey Memorial Hospital, Peace Arch Hospital, Eagle Ridge Hospital, Ridge Meadows Hospital, Langley Memorial Hospital, Mission Memorial Hospital, Abbotsford Regional Hospital, Chilliwack General Hospital, and the Fraser Canyon Hospital. There is also the Jim Pattison Outpatient Care & Surgery Centre.
Fraser Health Quick Facts http://www.fraserhealth.ca/about-us/quick-facts/

[22] Hospitals + Residences include: St. Paul's Hospital, Mount Saint Joseph Hospital, Holy Family Hospital, Youville Residence, St. Vincent's: Langara, St. Vincent's: Honoria Conway-Heather (St. Paul's), St Vincent's: Brock Fahrni, St. John Hospice, Providence Crosstown Clinic, Community Dialysis Units.

## Vulnerability

Social vulnerability to negative impacts of health care services is potentially high, and dependent on the type of service that is impacted. These are discussed below. The vulnerability of health care facilities is subject to a wide range of factors. They include inundation of structures, physical damage to structures, loss of power for a period beyond the capability of auxiliary supplies, loss of road access to facilities, loss of essential personnel to staff facilities, loss of supplies, including food and medicine, and contamination of facilities from floodwaters.

Hospitals require multiple access/egress routes to be resilient to flood impacts. This is because even if the hospital itself does not flood, obstructed transportation routes may impact staff and patient access to the hospital. This can create strain to provide services, a problem that could be compounded if a flood event increases the overall demand for services. Emergency and health service providers need to be prepared to deal with increased service demands and limited access to medical facilities. This includes taking measures to deal with emergencies in the field and to temporarily accommodate patients from other hospitals and care facilities that may need to evacuate. Similarly, emergency service providers will need to be prepared for supply chain and medical courier disruptions.

The vulnerability of hospitals and care facilities varies depending on the location of critical infrastructure and of potentially affected persons. For example, on-site vulnerability will be reduced if generators, electrical panels and HVAC equipment are above the flood construction level, and vulnerability to increased strain due to an influx of flood-related injuries and patients can be reduced if few people live in floodplain, and those that do live in buildings with adequate construction and flood-construction levels of living spaces. This latter point is particularly important given the number of home care patients who may be forced to leave their homes due to flood damage or being cut off from access to regular in-home medical services.

## Regional Vulnerability

Regional vulnerability for hospitals varies for the 10 study regions varies as follows:

| Study Region | Vulnerability Overview |
|---|---|
| #1 | *Under Scenarios A and B*<br>The hospital within the Study Region is not subject to inundation. |
| #2 | *Under Scenarios A and B*<br>The hospitals within the Study Region are not subject to inundation. |
| #3 | The hospital within the Study Region is not subject to inundation. |
| #4 | *Under Scenarios A, B, C and D*<br>The hospitals within the Study Region are not subject to inundation.<br>However, under Scenario B, access to the proposed relocation site for St. Paul's Hospital will be subject to inundation. |
| #5 | *Under Scenarios A, B, C and D*<br>Richmond and Delta Hospitals are subject to inundation. |
| #6 | *Under Scenarios A, B, C and D*<br>The hospitals within the Study Region are not subject to inundation. |
| #7 | *Under Scenarios A, B, C and D*<br>Colony Farm Forensic Psychiatric Hospital is subject to inundation. |

| | |
|---|---|
| #8 | *Under Scenarios C and D*<br>The hospital within the Study Region is not subject to inundation. |
| #9 | *Under Scenarios C and D*<br>The hospitals within the Study Region are not subject to inundation. |
| #10 | *Under Scenarios C and D*<br>Chilliwack General Hospital is subject to inundation. |

Hospitals in Regions 5 (Delta and Richmond) and 10 (Chilliwack) are subject to inundation in all Scenarios. In addition, the Colony Farm Forensic Psychiatric Hospital in Region 7 is subject to inundation in all Scenarios. No other hospitals are subject to inundation under any Scenarios.

The Squamish and North Shore regions have low vulnerability in all flood Scenarios as the health infrastructure is not subject to inundation. These facilities would be able to serve the surrounding municipalities' population that are able to access their services. The location of the Squamish Hospital on Hospital Hill places it well above any potential flooding. On the other hand, Highway 99 is a critical regional access route vulnerable to inundation in several locations under both Scenarios A and B. The hospital will not be vulnerable to inundation from flooding but vehicular access to the hospital may be limited or not be available. This would also restrict access by ambulance.

Both hospitals in Richmond and Delta are subject to inundation under all four Scenarios. All existing patients/services would need to be transferred to alternative hospitals that are operational. This poses significant logistical challenges as well as high societal impacts.

Chilliwack General Hospital is subject to inundation under Scenarios C and D. The hospital would need to transfer its existing operations and patients to another facility and would be unable to accommodate flood-impacted patients. The nearest large hospital in Abbotsford is well above any potential floodwaters but key access roads such as Highway 1 in both Abbotsford & Chilliwack and 16 arterial roads in Chilliwack are subject to inundation under both Scenarios C and D.

Coquitlam, Port Coquitlam, Anmore & Belcarra do not have a hospital within their boundaries. Hospitals in adjacent regions as well as most major access roads are not subject to inundation. However, hospitals that are not directly impacted will be required to take patients from hospitals that are not able to function. The number of local residents requiring assistance could increase, impacting already overloaded facilities.

Operating hospitals will be hard-pressed to continue to serve their existing patient base, as well as accommodate patient transfer and increased inflow. Operating hospitals will be tasked with a surplus of patients and care requirements for quite some time, as any hospitals subject to inundation would need to have the flood waters recede prior to re-opening. Damages and the timing of repairs would depend on the location of critical facilities.

In addition to the general health infrastructure, the Colony Farm Forensic Psychiatric Hospital at the confluence of the Coquitlam River with the Fraser River is subject to inundation under all flood Scenarios. These patients, with very specific high need levels, will need to be relocated.

In terms of future planning, access to the proposed relocation for St. Paul's Hospital will be subject to inundation under Scenario B. The building site can be floodproofed to elevate all facilities above potential floodwaters but the hospital would be surrounded by water, with all access roads inundated.

## Other Infrastructure Services

### Description

The previous seven sections cover a broad range of important infrastructure assets throughout the 10 Regions. The following section includes important infrastructure assets with unique features or which are important for post-flood recovery. Most of this infrastructure is not consistently found within all 10 Regions. This inventory should not be considered comprehensive.

**Municipal Halls**

As the seat of local government, Municipal Halls contain important vital records and often serve as emergency operation centres.

**Work Yards**

Where they can be identified, Work Yards subject to inundation have been listed. Included are municipal and Ministry of Transportation and Infrastructure (MoTI) Works Yards subject to inundation. Works Yards do not have large fixed infrastructure assets but typically have a significant inventory of equipment necessary for flood recovery. They often have large site areas important for staging of recovery efforts. The vulnerabilities pertaining to work yards have been addressed in the Qualitative Disruption Scenarios, as it was considered a more effective means of conveying the relevant issues.

**Correctional Facilities**

Correctional facilities subject to inundation are listed in the following table. The vulnerabilities pertaining to correctional facilities have been addressed in the Qualitative Disruption Scenarios, as it was a more effective means of conveying the relevant issues. For more information, see the section on Service Disruptions.

### Regional Vulnerability

Regional vulnerability for Other Infrastructure Services for the 10 study regions varies as follows:

| Study Region | Vulnerability Overview |
|---|---|
| #1 | *Under Scenario A*<br>The Municipal Hall is subject to inundation.<br>*Under Scenario B*<br>The Municipal Hall and Squamish Adventure Centre is subject to inundation. |
| #2 | *Under Scenario A and B*<br>The SeaBus Terminal is subject to inundation. |
| #3 | *Under Scenarios A and B*<br>Dock and some commercial facilities at Rocky Point Park are subject to inundation. |
| #4 | *Under Scenarios A and D*<br>A portion of the Manitoba Works Yard is subject to inundation.<br>*Under Scenario B*<br>The Manitoba Works Yard, Kent Works Yard, and Southeast False Creek |

| | |
|---|---|
| | Neighbourhood Energy Utility are subject to inundation.<br>Significant parts of Stanley Park including the seawall and swimming pool are subject to inundation.<br>*Under Scenario C*<br>Not applicable |
| #5 | *Under Scenarios A, B, C and D*<br>Richmond City Hall and the Municipal Works Yard are subject to inundation.<br>Delta Municipal Hall and Delta Works Yard in Ladner are subject to inundation.<br>Alexandra District Energy Utility in the West Cambie neighbourhood of Richmond is subject to inundation.<br>MoTI contractor for the SFPR in Annieville, North Delta is subject to inundation. |
| #6 | *Under Scenarios A, B, C and D*<br>Not applicable |
| #7 | *Under Scenario As and B*<br>Not applicable<br>*Under Scenarios C and D*<br>Pitt Meadows Works Yard is subject to inundation. |
| #8 | *Under Scenarios C and D*<br>Fort Langley National Historic Site is subject to inundation. |
| #9 | *Under Scenarios C and D*<br>The Kent maximum security prison and Mountain medium security prisons in Kent are subject to inundation or completely isolated with no road access.<br>The Kwìkwèxwelhp Healing Village minimum security facility in Harrison Mills is subject to inundation. |
| #10 | *Under Scenarios C and D*<br>City Hall is subject to inundation.<br>MoTI contractor in Rosedale is subject to inundation. |

Other infrastructure subject to inundation under one or more Scenarios include four municipal halls, seven works yards, three prisons with over 1,000 inmates, three ferry terminals, and two energy utilities in False Creek and Richmond. Most parks have not been included as they are not typically considered critical infrastructure. Also, much of their associated 'infrastructure' consists of open areas without buildings. This is not to downgrade the importance of parks – Stanley Park, for example, is considered to be an essential feature of Vancouver. Both the seawall and outdoor swimming pool at Second Beach are subject to inundation.

<u>Other</u>
There are other types of infrastructure that merit inclusion in further research. They include community centres and other public assembly buildings, assisted living facilities, seniors' homes, day care centres, and supermarkets. For the types of assets that haven't been included, their vulnerability is a function of their location (in/out of the immediate floodway), their primary use, how many of that asset type exists within a certain area coupled with how many of them are in the floodway, and their secondary use. This analysis requires a comprehensive picture of critical infrastructure to be able to determine their vulnerability.

## Vulnerability of Schools

### Description

Schools are additional area of vulnerability within the study Regions if any part of the school is subject to inundation. Schools have been identified by five categories consisting of public elementary schools, public secondary schools, private schools (K-12), post-secondary institutions and other schools. The latter group includes alternate education, continued education and school district administration facilities.

Summary tables of impacted schools by Scenario[23]

| | Scenario A | | | | | |
|---|---|---|---|---|---|---|
| | Public Elementary | Public Secondary | Private | Post-Secondary | Other | Total |
| Region 1 | 1 | 0 | 0 | 1 | 0 | 2 |
| Region 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Region 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Region 4 | 1 | 1 | 0 | 0 | 1 | 3 |
| Region 5 | 45 | 11 | 13 | 0 | 5 | 74 |
| Region 6 | 1 | 0 | 0 | 0 | 0 | 1 |
| Region 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| Region 8 | N/A | N/A | N/A | N/A | N/A | 0 |
| Region 9 | N/A | N/A | N/A | N/A | N/A | 0 |
| Region 10 | N/A | N/A | N/A | N/A | N/A | 0 |
| Region Total | | | | | | 80 |

[23] Notes: "Secondary" also includes middle schools; "Other" includes school district administrative centres and district wide programs such as alternative education.

| | Scenario B | | | | | |
|---|---|---|---|---|---|---|
| | Public Elementary | Public Secondary | Private | Post-Secondary | Other | Total |
| Region 1[24] | 1 | 1 | 0 | 1 | 0 | 3 |
| Region 2 | 0 | 0 | 1 | 0 | 0 | 1 |
| Region 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Region 4 | 1 | 1 | 1 | 5 | 2 | 10 |
| Region 5 | 45 | 11 | 13 | 0 | 5 | 74 |
| Region 6 | 2 | 0 | 0 | 0 | 1 | 3 |
| Region 7 | 2 | 0 | 1 | 0 | 1 | 4 |
| Region 8 | N/A | N/A | N/A | N/A | N/A | 0 |
| Region 9 | N/A | N/A | N/A | N/A | N/A | 0 |
| Region 10 | N/A | N/A | N/A | N/A | N/A | 0 |
| Region Total | | | | | | 95 |

| | Scenario C | | | | | |
|---|---|---|---|---|---|---|
| | Public Elementary | Public Secondary | Private | Post-Secondary | Other | Total |
| Region 1 | N/A | N/A | N/A | N/A | N/A | 0 |
| Region 2 | N/A | N/A | N/A | N/A | N/A | 0 |
| Region 3 | N/A | N/A | N/A | N/A | N/A | 0 |
| Region 4 | 1 | 1 | 0 | 0 | 1 | 3 |
| Region 5 | 44 | 10 | 13 | 0 | 5 | 72 |
| Region 6 | 1 | 0 | 0 | 0 | 0 | 1 |
| Region 7 | 3 | 1 | 1 | 0 | 1 | 6 |
| Region 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| Region 9 | 2 | 0 | 0 | 0 | 1 | 3 |
| Region 10 | 14 | 3 | 8 | 2 | 4 | 31 |
| Region Total | | | | | | 116 |

[24] Region 1, Scenario B, Howe Sound Secondary, Reconnect Alternative and Outreach School (SD 48) is counted as one Public Secondary School (not counted double counted within Other)

| | Scenario D | | | | | |
|---|---|---|---|---|---|---|
| | Public Elementary | Public Secondary | Private | Post-Secondary | Other | Total |
| Region 1 | N/A | N/A | N/A | N/A | N/A | 0 |
| Region 2 | N/A | N/A | N/A | N/A | N/A | 0 |
| Region 3 | N/A | N/A | N/A | N/A | N/A | 0 |
| Region 4 | 1 | 1 | 0 | 0 | 1 | 3 |
| Region 5 | 45 | 11 | 13 | 0 | 5 | 74 |
| Region 6 | 1 | 0 | 0 | 0 | 0 | 1 |
| Region 7 | 3 | 1 | 1 | 0 | 1 | 6 |
| Region 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| Region 9[25] | 3 | 0 | 0 | 0 | 2 | 5 |
| Region 10 | 14 | 3 | 8 | 2 | 4 | 31 |
| Region Total | | | | | | 120 |

The number of schools subject to inundation under all Scenarios is very large. However, they are heavily concentrated in two Regions. A majority of schools under all Scenarios are located in Region 5 (Richmond and Delta). Most of the remaining schools subject to inundation are located in Region 10 (primarily Chilliwack, but also Abbotsford). Schools in these two Regions represent 88% of all schools vulnerable to inundation under Scenarios C and D.

A total of 80 schools are subject to inundation under coastal flood Scenario A. With an additional 1 m of SLR, this increases to 95 schools under Scenario B. Under riverine Scenario C, the number of schools subject to inundation is 116. This increases to 120 based on future climate conditions under Scenario D. A majority of schools under all Scenarios are public elementary schools. Most of the remaining schools are public secondary or private schools.

[25] Region 9, Scenario D, the listed Secondary School is K-12. It is not double counted in the Elementary school column.

## Vulnerability of First Nations

Nearly 30 First Nations have reserves and Treaty Lands[26] within the study area. As of 2015, there are 90 reserves[27] and Treaty Lands in the study area. One-third[28] of the reserves are not subject to inundation; the remaining two-thirds (61 reserves, affecting 26 First Nations[29]) are subject to inundation.

In order to identify the vulnerability of First Nation reserves at a high level, an overview of the reserve (focusing on infrastructure (including services, where possible), housing, other structures/development (such as large industrial sites) and agricultural use) and the extent of inundation (broken down by Scenario) have been indicated. The high-level overview was undertaken using data initially collected by NHC and Urban Systems[30], and updated by the consultant team with information from Indigenous Affairs and Northern Development Canada[31] (IANDC), Google Maps and Google Streetview, where possible. The extent of inundation is based on the flood extent maps & KMZ files[32] provided by the consultant team and are approximate evaluations. The extents have been broken down into five categories and are as follows:

- No inundation – no inundation within reserve boundaries

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[26] Refers to the Final Agreement with the Tsawwassen First Nation. This consists of approximately 724 hectares of treaty settlement including 290 hectares of former reserves, 372 hectares of former provincial Crown land and 62 hectares of fee simple lands.

[27] Does not include uninhabited Pitt Lake IR No. 4, which is just outside Region 7. This reserve appears to be subject to some inundation under all Scenarios.

[28] Non-inundated reserves: **Squamish**: Cheakamus IR No. 11, Yookwitz IR No. 12, Poquiosin & Skamain IR No. 13, Waiwakum IR No. 14, Aikwucks IR No. 15, Seaichem IR No. 16, Kowtain IR No. 17, Yekwaupsum IR No. 19, Yekwaupsum IR No. 18; **North Vancouver:** Burrard Inlet IR No. 3 (Tsleil-Waututh IR No. 3); **Vancouver:** Kitsilano IR No. 6; **Langley:** Matsqui IR No. 4; **Pitt Meadows:** Pitt Lake IR No. 4 (outside of study area, not counted in tally); **Maple Ridge**: Graveyard IR No. 5; **Mission**: Pekw'xe:yles (peckquaylis) Indian Reserve, Langley IR No. 2, Langley IR No. 3, Langley IR No. 4; **Kent:** Peters IR No. 1A; **Chilliwack:** Tzeachten 13**,** Soowahlie 14**,** Lakway Cemetery 3; **Hope:** Hope IR No. 1**,** Tunnel 6**,** Schkam 2**,** Kawkaw Lake 16**,** Aywawwis IR No 5**,** Trafalgar Flat IR No. 13**,** Klaklacum IR No. 12**,** Swahliseah IR No. 14**,** Puckatholetchin IR No. 11. Note: non-inundated reserves may be subject to flooding from other riverine sources not within the scope of this Study.

[29] First Nations with reserves affected by inundation: Aitchelitz, Chawathil, Cheam, Katzie, Leq'a:mel, Matsqui, Musqueam, Peters, Kwantlen, Kwaw-kwaw-Apilt, Kwikwetlem, Scowlitz, Seabird Island, Semiahmoo, Shxw'ow'hamel, Skawahlook, Skowkale, Skwah, Shxwhá:y Village, Squamish, Squiala, Sts'ailes, Sema:th, Tsawwassen, Yakweakwioose, and Yale.

[30] *Flood and Erosion Damage Mitigation Plan – Stage 1 – Zone 2 Lower Fraser Valley* by NHC and Urban Systems, 2000. Data from this is source is detailed and thorough, but is over 15 years old. Updated information has been provided, where possible. However the same level of detail as the original report is outside of the scope of this Study. The level of detail between reserves varies.

[31] Formerly Aboriginal Affairs and Northern Development Canada

[32] The focus has been on the extent of flooding. Flood depths have not been taken into consideration.

- Limited inundation – less than a quarter of the reserve is inundated
- Partially inundated – roughly half of the reserve is inundated
- Substantially inundated – roughly three-quarters of the reserve is inundated
- Completely inundated – the entire reserve is inundated (except small pockets).

The high-level overview and evaluation of inundation extents is grouped by First Nation. Details are provided in Annex C. A summary table, indicating the number of First Nation reserves and the extent of inundation by Scenario, is as follows.

**Extent of Inundation of First Nations Reserves and Treaty Lands in Study Area**[33]

| Scenario | Limited Inundation | Partially Inundated | Substantially Inundated | Completely Inundated | Total with Inundation | No Inundation |
|---|---|---|---|---|---|---|
| A | 5.0 | 5.0 | 0.5 | 1.5 | 12.0 | 8.0 |
| B | 4.0 | 5.5 | 1.5 | 2.0 | 13.0 | 7.0 |
| C | 11.0 | 8.0 | 7.5 | 27.5 | 54.0 | 7.0 |
| D | 9.0 | 9.5 | 8.0 | 29.5 | 56.0 | 5.0 |

Of note, Scenarios A & B represent coastal flooding scenarios that do not extend to the three most easterly regions (Regions 8, 9 and 10). Scenarios C & D represent riverine flooding scenarios for the Fraser River, and therefore do not apply to two regions along Burrard Inlet (Regions 2 & 3) as well as Howe Sound (Region 1[34]).

In Scenario A, 12 First Nations reserves and Treaty Lands have some inundation. With 1 m of SLR, this increases to 13 in Scenario B. In Scenario C, 54 First Nations reserves and Treaty Lands have some inundation, which increases to 56 in Scenario D. Four times as many First Nations are impacted in Scenarios C & D compared to Scenarios A & B[35] – largely due to the fact that a large majority of First Nation reserves in the study area are located along the Fraser River as opposed to coastal shoreline areas.

Under Scenarios A & B, 55-65% of the reserves and Treaty Lands are subject to no, or limited, inundation, 25-28% are partially inundated, and 10-15% of the reserves and Treaty Lands are substantially or completely inundated. The majority of the reserves and Treaty Lands that are substantially or completely inundated under Scenarios A & B are largely developed, much of which consists of agricultural uses.

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[33] Those ranked, for example, *Partially-Substantially Inundated*, would receive half a point for "Partially" and half a point for "Substantially".

[34] The District of Squamish is vulnerable to flooding from five rivers, but not the Fraser River, which is a primary focus of this Study. Without this recognition, the vulnerability of Squamish First Nation reserves will be underestimated.

[35] Some reserves have joint-jurisdiction between more than one First Nation. These reserves have only been counted once, in order to not inflate the number. Joint reserves include Grass IR 15 (between the Aitchelitz, Kwaw-kwaw-Apilt, Shxwhá:y Village (Skway Indian Band), Skowkale First Nation, Skwah, Soowahlie, Squiala, Tzeachten, and Yakweakwioose First Nations) and Skumalasph IR No. 16 (between the Aitchelitz, Kwaw-kwaw-Apilt, Shxwhá:y Village (Skway Indian Band), Skwah First Nations and Squiala First Nations) in Chilliwack.

Under Scenarios C & D, 23-31% of the reserves and Treaty Lands are subject to no, or limited, inundation, 13-16% are partially inundated, and 57-60% of the reserves are substantially or completely inundated. Approximately one-third of the reserves and Treaty Lands that are substantially or completely inundated under Scenarios C & D are classified as uninhabited and an additional third are largely used for agricultural purposes.

For some uninhabited First Nation reserves, the consequences of inundation may vary depending on land use and the local First Nation's cultural landscape. Further complications arise as some First Nation reserves include unmarked burial or important archeological/ historical sites.

Within the Study Regions, a number of observations should be made:

- The number of First Nation reserves and Treaty Lands increases by one (12 to 13) from Scenario A to B. The addition of 1 m of SLR has little effect on the flood extent but the additional depth of water will amplify the flood damages.
- Similarly the number of First Nation reserves and Treaty Lands increases by two (54 to 56) from Scenario C to D. The addition of 1 m of SLR has little effect on the flood extent but the additional depth of water will amplify the flood damages.
- Region 1 – only one reserve is located along Howe Sound (Stawamus IR No. 24). Two other freehold sites controlled by the Squamish Nation consist of tidal flats and are subject to flooding under current conditions. Two other reserves along the Squamish River are affected but do not face inundation by tidal action.
- Regions 2 and 4 – much of the residential development on First Nations reserves consists of leasehold tenures held by non-natives – applicable to Burrard Inlet IR No. 3 (Tsleil-Waututh IR No. 3) and Musqueam IR No. 2. Only the latter reserve is impacted in any flood Scenarios.
- Region 5 – the Tsawwassen Treaty Lands substantially expanded the boundaries beyond Tsawwassen IR 0. Tsawwassen Treaty Land boundaries were used for this analysis. Floodproofing will reduce the vulnerability of commercial development currently under construction.
- Region 8 – Seabird Island is home to many community facilities, including an award-winning Health Department and innovative school programs. Community facilities will be subject to extensive inundation.
- Regions 9 and 10 – most First Nations are within the Stó:lō First Nation and Stó:lō Tribal Council, but may vary depending on the circumstances for the particular First Nation.
- Region 10 – the Coqualeetza Cultural Education Centre on Vedder Road is a former residential school that has been transferred from Aboriginal Affairs and Northern Development Canada to the Stó:lō First Nation. It is not subject to inundation under Scenario C or D.

All First Nations land and infrastructure will be subject to the same vulnerabilities as noted elsewhere in the report. For example, CP and CN Rail lines cross many reserves – and in several cases serve as a dike for the community. In addition, community services, such as hydro, sewer, telephone and internet services, as well as road access will be impacted. Given the large number of reserves with agricultural uses, environmental contamination will be a factor, as well as general building damage and loss (for all purposes – agriculture, community development, commercial and residential uses).

Lastly, this indication of vulnerability does not take into consideration the depth of inundation. As a result, this diminishes the differences between Scenarios A & B and between C & D. For any reserve subject to inundation in Scenario A, the depth of inundation increases by 1 m in Scenario B. This will have a significant impact on damages even if the aerial extent of flooding is not substantially different. A similar situation applies to Scenarios C & D. However, there is a significant difference – under Scenario C, most of the First Nation Reserves are substantially or completely inundated, which will be exacerbated by climate change impacts on water level in Scenario D.

## Service Disruptions

There are impacts to services that Hazus does not address that can instead be addressed qualitatively by considering potential impacts beyond damage or disruption to property, fixed and moveable assets. These subjects have a measureable economic impact but they also include non-quantifiable effects to public health and safety, social order, and societal well-being. They include, but are not restricted to, the following:

- Environmental contamination
- Environmental risk resulting from extended disruption
- Food Storage & Contamination
- Transportation
- Work Yards
- Correctional Facilities
- Communications
- Social Vulnerability

**Environmental Contamination**

While challenging to quantify, the overall importance and impact of potential environmental contamination during a flood event is significant. Particular locations where flood damages have an elevated risk of environmental contamination include agricultural land, transportation and industrial sites. A high-level overview of factors during a flood event that may contribute to environmental contamination on a wide range of land uses include:

**Agricultural Land**

- **Fertilizers/Chemical Spillage including Fuels**

  Fertilizers and chemicals may be stored in a safe location but not necessarily in a safe and elevated location above the Flood Construction Level. Unless stored in sealed, waterproof containers, they will mix with and be dispersed by flood waters over an extended area.
- **Human Food Crop Safety**

  Crops intended for human consumption are susceptible to contact with contaminated flood waters as they may contain chemical and biological contaminants. Chemical contamination may include heavy metals, petroleum products, pesticides or other agricultural chemicals whereas biological contamination would include pathogens (e.g. bacteria, parasites, and viruses), and sources of microbial contamination from upstream farms, rural septic systems, and raw manure or feces[36].

  Under the United States Food and Drug Administration (USFDA), if the edible portion of the crop has been exposed to flood waters, it is considered contaminated and should not enter the human food supply. If the edible food portion of the crop has come close to flood waters (but not fully exposed), it needs to be evaluated on a case by case basis. If the edible portion of the crop develops after the flood waters have receded, they are not necessarily considered contaminated and can enter the human food supply. The US

[36] Food Safety for Flood Farms, Produce Safety Alliance, USA

FDA requires a minimum of 60 days between flooding and the planting of the next crop intended for human consumption.

Flood waters may further impact the certification of any organic growers who require land that is free of contamination from pesticides and other unwanted chemicals for several years.

- **Dead livestock**[37]
  The risk to livestock will depend on the depth and velocity of flood waters and the duration of exposure to flood waters. Biosecurity and environmental impacts must be considered when disposing of animal carcasses. Burial of dead livestock undergoes a natural decomposition process and may not pose an environmental risk. Complete decay may take two or more years. Elevated risk may occur where the burial depth is shallow and the water table is high.
- **Groundwater contamination**
  Groundwater contamination will depend on the nature of the contamination and the purpose for which the groundwater is used. In most instances, the contamination is short term in nature.

**Industrial**

- As with agricultural uses, water that comes in contact with chemicals and fuels can cause environmental contamination.
- Chemical Plants (& Spills)
- Petroleum (Refining facilities)

**Commercial**

- **Contaminated Sites**
  - Service Stations (Gasoline and Diesel) – contamination of underground storage tanks, oil slicks near service stations
  - Flooded automobiles – leaking fuel from an engine motor and gas tank
  - Pest Control Businesses – chemical dispersal
  - Dry cleaning fluid – perchloroethylene, the solvent used to clean fabrics, is classified as a Group 2A carcinogen, a probable carcinogen to humans.
- **Dumpsters**
  - Businesses, as well as multi-family residences, utilize dumpsters. Dumpsters can float and overturn easily during a flood. Waste disposal companies may need to have emergency plans in place for predicted floods[38].

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[37] Freeman, Rachel and Fleming, Ron. Water Quality Impacts of Burying Livestock Mortalities. University of Guelph 2003

[38] Reducing Environmental Impacts of Flooding – Local Advice for Businesses and Residents in a Floodplain, Association of New Jersey Environmental Commissions.

**Residential**

- **General Clean-up**
  Unsecured floatable items will need to be secured and cleaned post-flood. Items will need to be collected and sorted between hazardous waste collection, recycling, compost or landfill. Flood waters can generate a significant amount of debris – general floatables (e.g. plastic bags) can be moved quite easily with flood waters. Large debris piles can harbor bacteria and mosquito breeding areas on land, while in water plastics create problems for wildlife[39]. When it comes to post-flood reconstruction, wet and dry sediment – leading to airborne hazards as mold and dust – create hazards and environmental contamination for residents[40].
- **Household Chemicals**
  Flood waters can be contaminated through contact with general household chemicals, including petroleum, paints, solvents, pesticides, pool supplies and de-icing chemicals typically stored in basements, garages and sheds.
- **Vehicles**
  In addition to household chemicals, motor vehicles, motorized equipment and accessories (e.g. cars, trucks, lawn mowers, boat engines) contain fuel and chemicals that could contaminate flood waters. Gasoline and diesel fuel as well as coolants are high risk factors for environmental contamination.
- **Backflow on a Municipal Sewer System[41]**
  Sinks, toilets and floor drains in low areas (e.g. basements or garages) may encounter the backflow of sewage. Sewage backflow may enter living areas as well as contaminate flood waters.
- **Septic Systems**
  During a flood, the soil around a septic field will become saturated which impacts the system from functioning correctly[42]. Users will need to minimize water use (including the flushing of toilets) until the soil is less saturated (which may take a few days). Furthermore, post-flood cleaning and recovery will require an alternative method of disposing of flood/cleaning waters due to the septic field soil saturation.
- **Wells[43]**
  Wells may be contaminated through any crack in the casing or when waters submerge the well head. Post-flood, wells will require testing to determine potable water levels and may require sanitization, depending on the level of flood water contamination.

**Environmental Risk**

Other environmental risks may result from extended disruptions of hazardous cargoes, rail cargoes in unprotected areas, and ships with hazardous cargoes unable to leave PMV.

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[39] Reducing Environmental Impacts of Flooding – Local Advice for Businesses and Residents in a Floodplain, Association of New Jersey Environmental Commissions.
[40] Toxic and Contaminant Concerns Generated by Hurricane Katrina, The Bridge, Spring 2006
[41] Reducing Environmental Impacts of Flooding – Local Advice for Businesses and Residents in a Floodplain, Association of New Jersey Environmental Commissions.
[42] Reducing Environmental Impacts of Flooding – Local Advice for Businesses and Residents in a Floodplain, Association of New Jersey Environmental Commissions.
[43] Reducing Environmental Impacts of Flooding – Local Advice for Businesses and Residents in a Floodplain, Association of New Jersey Environmental Commissions.

**Food Storage and Contamination**
Flood waters can jeopardize the safety of food and may not be safe to consume. It is important to identify and discard potentially unsafe food stores as this will help reduce the risk of food borne illnesses or the consumption of contaminated food[44]. Both unpackaged and packed foods may be contaminated and should be discarded[45]. All food related areas will require cleaning and sanitization after a flood.

Post-flood food waste (including organics) will require safe and effective disposal. The collection and removal of organic and inorganic waste will be dependent on a local government's ability to operate waste removal services post-flood.

In addition to the disposal, cleaning and sanitization requirements, food establishment and food-related businesses will need to contact the local health department and/or public health authorities in order to resume operations. If a large number of these establishments have been affected and all require government attention, there may be further delays in resuming operation (in addition to building reconstruction and supply chain repairs).

The transportation of food relies heavily on 'just in time' delivery of food to retail and wholesale outlets as well as restaurants. This is a very efficient system but is vulnerable to infrastructure and supply disruptions that are rare or unplanned (i.e. disasters).

**Transportation**
In the event of a flood, transportation and trade related impacts will be far reaching – well past the confines of the Lower Mainland Region, into the Western provinces, across Canada, and even internationally. The Lower Mainland may become grid-locked, for people, commercial, and industrial purposes. All western landlocked provinces are heavily reliant on transportation and trade in and out of the Lower Mainland[46].

Transportation and trade related industries include airports, marine ports, intermodal rail yards and border crossings as well as transport service providers, automotive transportation companies, shipping and warehousing services (including consolidators) and wholesale trade.

In a future river flood event (Scenario D), flood waters will sever the Lower Mainland's connectivity into two. The north and south sides of the Fraser River will not be able to connect. The south side will be isolated – caught between flood waters to the east, north and west, and the United States to the south. The north side will be pinched by flood waters and mountains. The communities farthest west may still have access through Hwy 99 up to Squamish through

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[44] Food Safety After a Flood, Public Health Division, Government of Ontario
[45] To highlight the extent of food and food waste that would need to be discarded post-flood, the following are recommended for discard: Food stored in permeable containers; Food wrapped in paper, plastic cloth, fibre or cardboard; Food that has come in direct contact with flood waters; Home-canned food in glass containers that have come into contact with glass containers; Commercially-canned foods that are damaged (e.g. bulging, swelling, leaked, punctured, etc.); Porous items that may come in contact with food/a person's mouth (e.g. baby bottle nipples, wooden bowls, plastic/paper/foam storage containers and utensils).
[46] The Economic Role of the Gateway Transportation System in the Greater Vancouver Region, Economic Development Research Group (September 2008)

Lillooet to Lytton. Both Highway 1 and Highway 7 (Lougheed) will be inundated in several locations. No traffic will be able to move along the only two east-west vehicular routes that connect beyond the Lower Mainland. Limited connections south to the US may be possible. Limited connection may be possible north of the Fraser River along Highway 97 through Squamish and Pemberton to Lytton to connect with the rest of BC.

Vancouver's commuter rail service, the West Coast Express, would be disrupted in all flood Scenarios. With enough warning, the trains can be moved out of the flood hazard areas, thereby preventing damage to them by flood water or debris, as well as from causing damage to their surroundings. However, the CP Rail line would be inundated in one or more locations.

SkyTrain service (including Expo, Millennium and Canada Lines) will be impacted by a coastal flood event (Scenarios A and B). Sections of underground track and service tunnels in the Downtown core, particularly in the vicinity of Waterfront Station, are presumed to flood. Service west of Commercial-Broadway station (on the Expo and Millennium Lines) will be subject to inundation. Service north of Broadway-City Hall station (on the Canada Line) may experience service interruptions. Service connections between the functioning stations (Broadway-City Hall; Commercial-Broadway) and the Downtown core will need to be provided should key electrical and mechanical equipment of the SkyTrain and Canada Line become damaged.[47]

**Works Yards**

Works yards are typically located on flat land with good access to major roads, often in industrial and low-lying areas. Several of these locational criteria are flood risk factors. While the location of all works yards could not be determined, several works yards vulnerable to inundation have been documented under "Other Infrastructure" in Annex A.

Inundated works yards (e.g. Municipalities, School Districts and MoTI) pose a two-fold challenge during a flood. First, equipment left on inundated lands will be unavailable. During inundation, large pieces of equipment will be inaccessible. Post-inundation, any equipment or contents with electrical components below or near the water level are unlikely to function properly. Repairs and component replacements may be required. Works yards subject to inundation may delay the recovery period if they are not able to function. Second, inundated work yards pose a risk of contamination due to the storage of various materials (including petroleum, other fuels, coolants, etc.) on site. After a flood, inundated work yards may significantly delay or impede needed repairs, as fewer resources would be available for reconstruction and rehabilitation purposes.

**Correctional Facilities**

Maintaining inmate, staff and public safety is paramount in the event of an evacuation of any correctional facilities facing an emergency. Pre-emergency evacuation planning is required and expected by facility management. While mutual-aid agreements and notification protocols are likely already established for general facility evacuations, additional, or new, agreements may be required depending on the severity of the flood damage anticipated to occur to the facility. For example, longer-term housing may be required should the facility be out of commission for

[47] Northwest Hydraulic Consultants, City of Vancouver Coastal Flood Risk Assessment. December 2014.

rehabilitation and reconstruction or release agreements prepared for emergency release of low-risk inmates (e.g. those with short sentences or work release inmate programs).[48]

Correctional Service members will need to transport (potentially large numbers of) inmates throughout the region. The inundation of critical routes serves as an additional challenge in safely accomplishing this task. The extent of inundation will dictate if inmates need to be moved out of the region to dry facilities and where that capacity may exist.

As with any building or structure, the placement of electrical equipment is important for the continued operation of correctional facilities. Electrical equipment (operations as well as record keeping equipment) should be located above the flood construction level. Maintaining information technology functioning and record keeping data is significant, as family members and legal council should be informed of any inmate transfers.

Three correctional facilities ranging from minimum to maximum security plus a forensic psychiatric hospital in (Regions 7 and 9) are subject to inundation under all flood Scenarios. Their total capacity exceeds 1,000 persons. Although a prison and hospital have very different functions, a common element is their involuntary detention.

In addition, police stations also include facilities where temporary involuntary detention is involved. All police stations subject to inundations under the different Scenarios are identified in Annex A. Pre-trial centres will also have a holding capacity for persons awaiting trial. Transport of inmates outside the flooded areas will be required for all these facilities subject to inundation.

**Communications**

Specific, detailed communication network data for the Lower Mainland area are currently unavailable for this study. Recent events help to paint a picture of how communication networks could be impacted during a serious flood event (e.g. Superstorm Sandy), while the local wind storm of 2015 gives a preliminary idea about the area's current capacity and resilience.

In 2012, Superstorm Sandy caused significant damages and outages to the New York Metropolitan area, including major impacts to the communication network:

- A quarter of cell towers, across several states, were out of service.[49]
- A quarter of cable TV, broadband Internet, and landline phone services were affected.[50]
- Overall, 10% of the New York area's Internet networks went down.[51]

[48] Two Case Studies on Jail Evacuations During a Natural Disaster: Iowa's 2008 Flooding: Part 1 & Part 2, corrections.com Oct 1st, 2012 http://www.corrections.com/news/article/31330-two-case-studies-on-jail-evacuations-during-a-natural-disaster-iowa-s-2008-flooding-part-2

[49] FCC says Hurricane Sandy knocked out 25 percent of cell towers in its path, Brendan Sasso, The Hill, Oct 31 2012 http://thehill.com/policy/technology/264915-fcc-hurricane-sandy-knocked-out-25-percent-of-cell-towers

[50] Communications Network Outages – Learning from Hurricane Sandy, C Davidson & M Santorelli, ACLP New York Law School, Dec 2012 http://www.nyls.edu/advanced-communications-law-and-policy-institute/wp-content/uploads/sites/169/2013/08/ACLP-Briefing-Network-Outages-December-2012.pdf

- The main undersea cable link connecting North American and Europe (Atlantic Crossing-2) underwent sporadic service challenges. As a result, data was rerouting through redundant lines.[52] There were some reports attributed to cable operators who said they had experienced power issues but back-up generators prevented service disruption. No major service disruption was reported.

Local service providers assessed and repaired damages – steadily increasing service availability in the aftermath of the storm. The areas with widespread damage were affected for the longest periods of time. The damages and service outages highlight how vulnerable many communication networks are to major natural disasters, while recognizing how significant communication networks are to contemporary society.[53]

During Superstorm Sandy, mechanical gear responsible for routing calls placed on landline and cellphone networks was destroyed by flooding.[54] Some 911 call centres went offline as a result of power outages.[55] Cell towers and other essential equipment were demolished or badly damaged.[56] Essentially, communication networks suffered extensive and on occasion irreparable damage, affecting service throughout the region.[57] Scarcity of fuel for generators was a major issue as was the inability to access damaged sites due to downed trees, flooding or other structural concerns (e.g. damaged roofs over important equipment).[58]

Planning in advance of a disaster (e.g. storing needed equipment near at-risk sites) by some local service providers expedited the recovery and repair process as did collaborative and innovative response efforts by local providers:

- Introduced emergency network sharing agreements between two large providers so that impacted customers could use either network.[59]

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[51] Hurricane Sandy Broke Only 10 Percent of New York Area's Internet, Arik Hesseldalh, allthingsd.com Oct 31 2012 http://allthingsd.com/20121031/hurricane-sandy-broke-only-10-percent-of-new-york-areas-internet/

[52] Superstorm Sandy wreaks havoc on internet infrastructure, Barb Darrow, Oct 30th, 2012 https://gigaom.com/2012/10/30/superstorm-sandy-wreaks-havoc-on-internet-infrastructure/

[53] Communications Network Outages – Learning from Hurricane Sandy, C Davidson & M Santorelli, ACLP New York Law School, Dec 2012 http://www.nyls.edu/advanced-communications-law-and-policy-institute/wp-content/uploads/sites/169/2013/08/ACLP-Briefing-Network-Outages-December-2012.pdf

[54] A Look inside Verizon's Flooded Communications Hub, A. Trioanovski, The Wall Street Journal, Nov 1st 2012, http://www.wsj.com/articles/SB10001424052970204707104578091171538491386

[55] F.C.C. Details Storm-Related Cellphone Problems, E Wyatt & B. Chen, The New York Times, Oct 31st 2012, http://www.nytimes.com/2012/11/01/technology/fcc-details-cellphone-problems.html

[56] Hurricane Sandy disrupts Northeast U.S. Telecom networks, S, Carew, Reuters, Oct 30th, 2012, http://www.reuters.com/article/2012/10/30/us-storm-sandy-telecommunications-idUSBRE89T0YU20121030

[57] Communications Network Outages – Learning from Hurricane Sandy, C Davidson & M Santorelli, ACLP New York Law School, Dec 2012 http://www.nyls.edu/advanced-communications-law-and-policy-institute/wp-content/uploads/sites/169/2013/08/ACLP-Briefing-Network-Outages-December-2012.pdf

[58] Communications Network Outages – Learning from Hurricane Sandy, C Davidson & M Santorelli, ACLP New York Law School, Dec 2012 http://www.nyls.edu/advanced-communications-law-and-policy-institute/wp-content/uploads/sites/169/2013/08/ACLP-Briefing-Network-Outages-December-2012.pdf

[59] AT&T and T-Mobile share networks in storm-battered areas, B. Sasso, The Hill, Oct 31st 2012, http://thehill.com/policy/technology/265177-atat-and-t-mobile-share-networks-in-storm-battered-areas

- One internet provider provided its Wi-Fi network for everyone in the area (regardless of who the customer may actually subscribe with).[60]
- Deployed fleets of Wireless Communication Center trucks (equipped with device charging stations, Internet connections and telephones) for everyone (not just customers).[61]
- Several providers extended fee deadlines, waived late-fees, and assured service would continue for those unable to make a payment.[62]
- One major service provider brought in a temporary antenna to support financial transactions and stock exchanges.[63]
- Number of retail outlets (e.g. Starbucks, McDonalds) served as impromptu Wi-Fi hubs and charging stations[64]

More recently, southeast BC experienced the vulnerabilities of the local communications network during a wind storm in August 2015. Damaging winds downed trees and power lines, cutting power across the Lower Mainland, Sunshine Coast and parts of Vancouver Island. This represented the single largest outage event in BC Hydro's history. This outage affected 710,000 persons, nearly 50% of BC Hydro's customers in the Lower Mainland and on Vancouver Island.[65]

During the windstorm, 40% of 911 calls failed to connect.[66] Callers to the local E-Comm 911 service were met with a busy signal 4 out of 10 times. During the peak time, 600 phone calls came in per hour but E-Comm only had 30 staff members operating the phones. Currently, there is no way to 'front-end' triage 911 calls so that the more serious emergency events are handled first.

After the windstorm, stormy weather as well as soggy ground hindered repairs.[67] BC Hydro called in additional crews from around the province to work on restoring power which involved 1,800 individual work orders.[68] All power was restored within 72 hours – the length of time

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[60] Comcast offers free WiFi service in affected storm areas, J. Martinez, The Hill, Oct 31st 2012, http://thehill.com/policy/technology/265207-comcast-offers-free-wifi-service-in-affected-storm-areas

[61] In Sandy's Wake, Verizon stores offer free charging, domestic calls, M. Shaer, The Christian Science Monitor, Nov 1st 2012, http://www.csmonitor.com/Technology/Horizons/2012/1101/In-Sandy-s-wake-Verizon-stores-offer-free-charging-domestic-calls

[62] AT&T, T-Mobile Waive Late Fees, Offer Free Charging After Sandy, S. Mlot, PC Magazine, Nov 1st 2012, http://www.pcmag.com/article2/0,2817,2411655,00.asp

[63] Post-Sandy, Verizon Erects Temporary Antenna in N.J., D. Poeter, PC Magazine, Oct 31st 2012, http://www.pcmag.com/article2/0,2817,2411614,00.asp

[64] Where To Find Internet, Phone Service In New York City After Hurricane Sandy, B. Fitzgerald, The Huffington Post, Nov 1st 2012, http://www.huffingtonpost.com/2012/11/01/internet-service-new-york-hurricane-sandy_n_2057934.html

[65] Windstorm: Cres restore power to more than 705,000 customers, BC Hydro, Sept 2 2015, https://www.bchydro.com/news/conservation/2015/windstorm-outages-updates.html

[66] Windstorm: 40% of 911 calls failed, M. Mui, 24 Hrs, Oct 20th, 2015 http://vancouver.24hrs.ca/2015/10/19/windstorm-40-of-911-calls-failed

[67] B.C. storm: 'Largest outage event' in BC history, CBC News, Sept 1 2015, http://www.cbc.ca/m/touch/canada/british-columbia/story/1.3210919

[68] Windstorm: Cres restore power to more than 705,000 customers, BC Hydro, Sept 2 2015, https://www.bchydro.com/news/conservation/2015/windstorm-outages-updates.html

recommended by PreparedBC for residents to be self-sufficient in the event of a disaster.[69] As with Superstorm Sandy, service availability steadily increased in the aftermath of the storm and the areas with widespread damage were without power for a longer time.

BC Hydro struggled to communicate with customers. Their website was not functioning during the storm, with communication efforts largely pushed through Twitter and other media outlets. TransLink responded well during the windstorm, with effective engagement through their developed social-media networks, back-up generators at several stations, and deployed shuttle buses when SkyTrain services were interrupted due to tree damage.[70]

These large scale power outages highlight the dependency on electricity: food preparation, prescription preservation, overall communication, and general entertainment require electricity or battery power. Batteries do not last indefinitely and much of the electronic equipment in common usage (e.g. cell phones, tablets, and personal computers) would be inoperable within half a day (without a back-up charger such as car-chargers).

For a similar number of people, all impacts experienced during the August 2015 windstorm would be magnified by flood inundation, as well as seasonality (in the case where the flood event occurs in a chillier winter than a relatively mild summer day).

**Social Vulnerability**
Social vulnerability is the product of social inequalities as well as location inequalities, including community characteristics and the built environment. While outside the scope of this study, social vulnerability is recognized as a significant factor in a flood and should be part of a comprehensive flood risk assessment. Pioneering work in this field has been undertaken by Susan Cutter[71]. Strongly correlated variables of social vulnerability include the following[72]:

- Socioeconomic status, race and ethnicity
- Value, quality and density of residential properties
- Presence of renters and transient populations
- Commercial and industrial development
- Occupation, education, family structure and expected population growth
- Medical services and health status,
- Age dependent population (under 16 and frail elderly) and special needs population

Not all variables of social vulnerability identified in American research can be directly transferable to a Canadian context[73]. In addition, some components such as social connectivity

[69] Windstorm: Cres restore power to more than 705,000 customers, BC Hydro, Sept 2 2015, https://www.bchydro.com/news/conservation/2015/windstorm-outages-updates.html
BC Residents need to take windstorm as a wakeup call, authorities say, C. de Silva, CKNW, Aug 31 2015, http://www.cknw.com/2015/08/31/bc-residents-need-to-be-more-prepared-for-an-emergency/
[70] TransLink responded well to Vancouver windstorm, C. Smith, The Georgia Straight, Aug 31st 2015, http://www.straight.com/news/519541/translink-responded-well-vancouver-windstorm
[71] Cutter, S., Boruff, B. and W. Lynn Shirley, Social Vulnerability to Environmental Hazards. Social Science Quarterly, Volume 84, Number 2, June 2003.
[72] In addition to the previous citation, see Abas, Jha et al, Cities and Flooding, A Guide to Urban Flood Risk Management for the 21st Century. International Bank for Reconstruction and Development, 2012.
[73] O'Leary, Jim. Vulnerable Vancouver Finding Residents at Risk in Vancouver, Canada, 2013.

can be of critical significance in a disaster but are challenging to quantify. Despite these qualifications, this is an area of importance which merits further exploration.

## Annex A: Key Infrastructure by Region

# VULNERABILITY STUDY - REGION 1, SCENARIO A

| Region #1, Scenario A | District of Squamish |
| --- | --- |
| **Infrastructure Type** | **Description** |
| Residential Areas | Downtown Squamish |
| Commercial & Industrial Areas | Downtown Squamish |
| Agricultural Areas | N.A. |
| B.C. Hydro Substations | Squamish (Pemberton Avenue) |
| B.C. Transmission Grid - Major Circuits | 69 kV - Cheekye to Squamish |
| Railways | CN main line south of Stawamus River, along Mamquam Blind Channel crossing and along Buckley Ave.<br>CN Spur line south of Pemberton Avenue to Squamish Terminals |
| Critical Regional Routes* | Highway 99 - Mamquam Blind Channel north of Adventure Centre and between Pemberton Avenue and Bernard Street<br>Highway 99 - Britannia Beach floodplain south of Squamish |
| Other Major Routes** | Cleveland Avenue<br>Third Avenue<br>Pemberton Avenue<br>Main Street<br>Loggers Lane |
| Airports | No |
| Ports & Ferry Terminals | Squamish Terminals |
| Police Stations | No |
| Fire Halls | No |
| Ambulance Stations | No |
| Hospitals | No |
| Schools | Squamish Elementary (SD 48)<br>Capilano University |
| Wastewater treatment | No |
| Other infrastructure | Municipal Hall |
| First Nation Reserves | STAWAMUS IR 24 - south of Billy Drive |

* Disaster Evacuation Route

** As designated in Official Community Plan (Arterial Road terminology not used)

# VULNERABILLITY STUDY - REGION 1, SCENARIO B

| Region #1, Scenario B | District of Squamish |
|---|---|
| **Infrastructure Type** | **Description** |
| Residential Areas | Downtown Squamish<br>Dentville |
| Commercial & Industrial Areas | Downtown Squamish<br>Squamish Oceanfront Peninsula |
| Agricultural Areas | N.A. |
| B.C. Hydro Substations | Squamish (Pemberton Avenue) |
| B.C. Transmission Grid - Major Circuits | 69 kV - Cheekye to Squamish |
| Railways | CN main line south of Stawamus River and from Squamish Landing across Mamquam Blind Channel to Squamish Industrial Park<br>CN Spur line south of Squamish Industrial Park to Squamish Terminals |
| Critical Regional Routes* | Highway 99 - Mamquam Blind Channel north of Adventure Centre and between Pemberton Avenue and Bernard Street<br>Highway 99 - Britannia Beach floodplain south of Squamish |
| Other Major Roads** | Cleveland Avenue<br>Third Avenue<br>Pemberton Avenue<br>Main Street<br>Loggers Lane<br>Buckley Avenue |
| Airports | N.A. |
| Ports & Ferry Terminals | Squamish Terminals |
| Police Stations | No |
| Fire Halls | No |
| Ambulance Stations | No |
| Hospitals | No |
| Schools | Squamish Elementary (SD 48)<br>Howe Sound Secondary, Reconnect Alternative and Outreach School (SD 48)<br>Capilano University |
| Wastewater treatment | No |
| Other infrastructure | Municipal Hall<br>Squamish Adventure Centre |
| First Nation Reserves | STAWAMUS IR 24 - south half |

* Disaster Evacuation Route

** As designated in Official Community Plan (Arterial Road terminology not used)

# VULNERABILITY STUDY - REGION 2, SCENARIO A

| Region #2, Scenario A | Village of Lions Bay | District of West Vancouver | District of North Vancouver | City of North Vancouver |
|---|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** | **Description** |
| Residential Areas | No | Sandy Cove waterfront | No | No |
| Commercial & Industrial Areas | Lions Bay Marina | Horseshoe Bay- Sewell's Marina<br>West Vancouver Yacht Club | Port Metro Vancouver facilities:<br>East of Lynn Creek - South of Dollarton Highway (Maplewood) + South of Main Street<br>Industry south of Welsh Street including Vancouver Wharves | Lonsdale Quay<br>Mosquito Creek Marina<br>Industry south of Harbourside Drive |
| Agricultural Areas | N.A. | No | No | No |
| B.C. Hydro Substations | No | No | No | No |
| B.C. Transmission Grid - Major Circuits | No | 69 kV - Norgate to John Lawson | 69 kV - Norgate to John Lawson<br>69 kV - North Vancouver to Norgate<br>69 kV - Walters to Deep Cove | 69 kV - North Vancouver to Norgate |
| Railways | CN Rail - waterfront sections | CN Rail - Ambleside to Capilano River | CN Rail - Capilano IR5 to City of North Vancouver<br>CN Railyard north of Vancouver Wharves<br>Spur lines to most water dependent industry | CN Rail - west of Lonsdale Avenue<br>Spur lines to most water dependent industry |
| Critical Regional Routes* | No | No | No | No |
| Other Arterial Routes** | No | No | West 1st Street<br>Welch Street | West 1st Street |
| Airports | N.A. | N.A. | N.A. | N.A. |
| Ports & Ferry Terminals | No | Horseshoe Bay Ferry Terminal | 2 major Port Metro Vancouver marine terminals (Vancouver Wharves bulk and Lynnterm breakbulk) | Seabus Terminal |
| Police Stations | N.A. | No | No | No |
| Fire Halls | No | No | No | No |
| Ambulance Stations | No | No | No | No |
| Hospitals | N.A. | N.A. | N.A. | No |
| Schools | No | No | No | No |
| Wastewater treatment | | No | No | No |
| Other infrastructure | | | | |
| First Nation Reserves | N.A. | CAPILANO IR5 - South of Park Royal Shopping Centre and CN Rail east of Capilano River | SEYMOUR CREEK IR2 - south of CN Rail | MISSION IR1 - south of CN Rail |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILLITY STUDY - REGION 2, SCENARIO B

| Region #2, Scenario B | Village of Lions Bay | District of West Vancouver | District of North Vancouver | City of North Vancouver |
|---|---|---|---|---|
| Infrastructure Type | Description | Description | Description | Description |
| Residential Areas | No | Sandy Cove waterfront | Southern Norgate neighbourhood | No |
| Commercial & Industrial Areas | Lions Bay Marina | Horseshoe Bay- Sewell's Marina<br>West Vancouver Yacht Club | Port Metro Vancouver facilities:<br>South of Dollarton Highway (Maplewood), Main Street & Low Level Rd.<br>Industry south of Esplanade Avenue and Welsh Street including Vancouver Wharves | Port Metro Vancouver facilities: south of Main Street and Low Level Road including bulk grain and Neptune terminals<br>Lonsdale Quay<br>Industry south of W. 1st Street and Esplanade Ave. east of Bewicke Ave. |
| Agricultural Areas | N.A. | No | No | N.A. |
| B.C. Hydro Substations | No | John Lawson | Norgate<br>Nexen Chemicals<br>Erco Worldwide | No |
| B.C. Transmission Grid - Major Circuits | No | 69 kV - Norgate to John Lawson | 69 kV - Norgate to John Lawson<br>69 kV - North Vancouver to Norgate<br>69 kV - Walters to Deep Cove<br>69 kV - Walters to Nexan<br>69 kV - Walters to North Vancouver | 69 kV - North Vancouver to Norgate<br>69 kV - Walters to North Vancouver |
| Railways | CN Rail - waterfront sections | CN Rail - Ambleside to District of North Vancouver | CN Rail - District of West Vancouver to City of North Vancouver<br>CN Railyard north of Vancouver Wharves<br>Spur lines to all water dependent industry | CN Rail - west of Lonsdale Avenue<br>Spur lines to all water dependent industry |
| Critical Regional Routes* | No | No | Highway 1 - Main Street interchange | No |
| Other Arterial Roads** | No | Marine Drive - Ambleside neighbourhood | West 1st Street<br>Welch Street<br>Main Street<br>Dollarton Highway - Maplewood neighbourhood | West 1st Street<br>Cotton Road |
| Airports | N.A. | N.A. | N.A. | N.A. |
| Ports & Ferry Terminals | No | Horseshoe Bay Ferry Terminal | 8 major Port Metro Vancouver bulk terminals including Fibreco, Cargill, Vancouver Wharves, Neptune, Univar and Canexus<br>Lynnterm breakbulk terminal - Port Metro Vancouver<br>North Vancouver Seabus Terminal | |
| Police Stations | N.A. | West Vancouver (Marine Drive) | No | No |
| Fire Halls | No | No | No | No |

| | | | | |
|---|---|---|---|---|
| Ambulance Stations | No | No | No | No |
| Hospitals | N.A. | N.A. | N.A. | No |
| Schools | No | No | No | Bodwell Academy & High School (private) |
| Wastewater treatment | | Lions Gate | Lions Gate (West Vancouver) | Lions Gate (West Vancouver) |
| Other infrastructure | | | Pacific Environmental Science Centre | |
| First Nation Reserves | N.A. | CAPILANO IR5 - Main Street area west of Park Royal Shopping Centre and south of Welch St. east of Capilano River | SEYMOUR CREEK IR2 - south of Main Street | MISSION IR1 - south and west of 1st Street W. |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 3, SCENARIO A

| Region #3, Scenario A | City of Port Moody | Village of Anmore | Village of Belcarra |
|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** |
| Residential Areas | No | No | No |
| Commercial & Industrial Areas | Waterfront heavy industrial along south shore of Burrard Inlet | No | No |
| Agricultural Areas | N.A. | N.A. | N.A. |
| B.C. Hydro Substations | No | N.A. | N.A. |
| B.C. Transmission Grid - Major Circuits | No | No | No |
| Railways | No | N.A. | N.A. |
| Critical Regional Routes* | N.A. | N.A. | N.A. |
| Other Major Routes** | No | No | No |
| Airports | N.A. | N.A. | N.A. |
| Ports & Ferry Terminals | 1 major off-dock facility | N.A. | N.A. |
| Police Stations | No | N.A. (see Port Moody) | N.A. (see Port Moody) |
| Fire Halls | No | No | No |
| Ambulance Stations | N.A. | N.A. | N.A. |
| Hospitals | No | N.A. | N.A. |
| Schools | No | No | No |
| Wastewater treatment | No | No | No |
| Other infrastructure | Rocky Point Park dock and some commercial infrastructure | No | No |
| First Nation Reserves | N.A. | N.A. | N.A. |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILLITY STUDY - REGION 3, SCENARIO B

| Region #3, Scenario B | City of Port Moody | Village of Anmore | Village of Belcarra |
|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** |
| Residential Areas | Pleasantside waterfront edge | No | No |
| Commercial & Industrial Areas | Waterfront heavy industrial along south shore of Burrard Inlet | No | No |
| Agricultural Areas | N.A. | N.A. | N.A. |
| B.C. Hydro Substations | No | N.A. | N.A. |
| B.C. Transmission Grid - Major Circuits | No | No | No |
| Railways | CP Rail - adjacent to Barnet Highway | N.A. | N.A. |
| Critical Regional Routes* | N.A. | N.A. | N.A. |
| Other Major Roads** | No | No | No |
| Airports | N.A. | N.A. | N.A. |
| Ports & Ferry Terminals | 2 major marine terminals including Pacific Coast Terminals<br>1 major off-dock facility | N.A. | N.A. |
| Police Stations | No | N.A. (see Port Moody) | N.A. (see Port Moody) |
| Fire Halls | No | No | No |
| Ambulance Stations | N.A. | N.A. | N.A. |
| Hospitals | No | N.A. | N.A. |
| Schools | No | No | No |
| Wastewater treatment | Annacis Island (see Delta) | No | No |
| Other infrastructure | Rocky Point Park dock and some commercial infrastructure | No | No |
| First Nation Reserves | N.A. | N.A. | N.A. |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 4, SCENARIO A

| Region #4, Scenario A | City of Vancouver | City of Burnaby | City of New Westminster |
|---|---|---|---|
| Infrastructure Type | Description | Description | Description |
| Residential Areas | Southlands<br>Kits Point - western edge<br>Coal Harbour waterfront<br>Fraser Lands edge<br>East Fraserlands partial inundation | No | Westminster Quay partial inundation<br>Queensborough |
| Commercial & Industrial Areas | Marinas along False Creek, Stanley Park and Coal Harbour<br>Marpole and Marine Drive commercial/industrial | Big Bend - Byrne Road general industrial and business parks south of CP Rail | Queensborough<br>Brunette Creek Industrial - partial inundation<br>Kruger Products (paper mill)<br>Front Street |
| Agricultural Areas | Southlands | Big Bend | N.A. |
| B.C. Hydro Substations | Kidd #1<br>Westcoast Cellufibre | Seegen<br>Norampac | No |
| B.C. Transmission Grid - Major Circuits | 230 kV - Ingledow to Mainwaring<br>69 kV - Kidd #1 to Ingledow<br>69 kV - Kidd #1 to Kidd #2<br>69 kV - Kidd #1 to Sperling<br>69 kV - Kidd #1 to Annacis Island<br>69 kV - Kidd #1 to Richmond Steel | 69 kV - Kidd #1 to Ingledow<br>69 kV -Kidd #1 to Annacis Island | 69 kV - Kidd #1 to Annacis Island<br>69 kV - Newell to Royal 2<br>60 kV - Kidd #1 to Ingledow<br>69 kV - to Tree Island Industries<br>69 kV - to New Westminster |
| Railways | CP Rail - Marine Drive industrial area<br>CP Rail - crossing to Richmond | CN Rail - Big Bend and crossing to Richmond<br>CP Rail - Big Bend | CN Rail - Highway 1 to Front Street to North Arm North<br>CP Rail - Highway 1 to Front Street to North Arm North<br>CN Rail - Queensborough |
| Critical Regional Routes* | Highway 99 - Granville Street & Oak Street Bridges<br>Knight Street - south of SE Marine Drive | Marine Way<br>Boundary Road - south of SE Marine Drive | Highway 91A (Queeensborough)<br>Brunette Avenue<br>Stewardson Way/Front Street |
| Other Arterial Roads** | No | North Fraser Way<br>Byrne Road | Boyd Street/Derwent Way |
| Airports | N.A. | N.A. | N.A. |

| | | | |
|---|---|---|---|
| Ports & Ferry Terminals | Seabus Terminal<br>Some inundation of Port Metro Vancouver facilities | Port Metro off-dock facilities along Burrard Inlet | Inundation of most marine facilities along Fraser River North + Middle Arms |
| Police Stations | No | No | No |
| Fire Halls | No | No | No |
| Ambulance Stations | No | No | No |
| Hospitals | No | No | No |
| Schools | No | No | Queen Elizabeth Elementary (SD 40)<br>Queensborough Middle School (SD 40)<br>Administrative headquarters + specialized programs (SD 40) |
| Wastewater treatment | See Richmond (Iona Island) | No | No |
| Other infrastructure | Manitoba Works Yard<br>Access to Expo and Millineum SkyTrain lines<br>Marinas in Vancouver Harbour | | |
| First Nation Reserves | Musqueam IR2 - south of W. 51 Ave. | N.A. | N.A. |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 4, SCENARIO B

| Region #4, Scenario B | City of Vancouver | City of Burnaby | City of New Westminster |
|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** |
| Residential Areas | Southlands<br>Kits Point - western part<br>Coal Harbour waterfront<br>South False Creek/Olympic Village<br>Fraser Lands<br>East Fraserlands | No | North Arm North/Westminster Quay<br>Queensborough |
| Commercial & Industrial Areas | Granville Island<br>Marinas along False Creek, Stanley Park and Coal Harbour<br>Marpole and Marine Drive commercial/industrial<br>Port Metro Vancouver facilities as noted below | Big Bend - Byrne Road general industrial and business parks south of CP Rail | Queensborough<br>Brunette Creek Industrial<br>Kruger Products (paper mill)<br>Downtown New Westminster - partial<br>Stewardson Way/Lower 12th Street/ Columbia Square |
| Agricultural Areas | Southlands | Big Bend | N.A. |
| B.C. Hydro Substations | Murrin #1<br>Kidd #1<br>Westcoast Cellufibre<br>Knight Street Terminal | Seegen<br>Norampac | GVRD Sapperton Pumps<br>Canfor<br>Scott Paper<br>Tree Island Industries |
| B.C. Transmission Grid - Major Circuits | 230 kV - Ingledow to Mainwaring<br>69 kV - Kidd #1 to Ingledow<br>69 kV - Kidd #1 to Kidd #2<br>69 kV - Kidd #1 to Sperling<br>69 kV - Kidd #1 to Annacis Island<br>69 kV - Kidd #1 to Richmond Steel | 69 kV - Kidd #1 to Ingledow<br>69 kV -Kidd #1 to Annacis Island | 69 kV - Kidd #1 to Annacis Island<br>69 kV - Newell to Royal 2<br>60 kV - Kidd #1 to Ingledow<br>69 kV - to Tree Island Industries<br>69 kV - to New Westminster |

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|---|---|---|---|
| Railways | West Coast Express<br>VIA Rail west of Clark Drive and terminal<br>CN Rail west of Clark Drive<br>BNSF west of Clark Drive and Amtrak terminal<br>TransLink - east of False Creek<br>CP Rail - all connections to Port Metro Vancouver Port facilities along Burrard Inlet<br>CP Rail - Marine Drive industrial area<br>CP Rail - crossing to Richmond | CN Rail - Big Bend and crossing to Richmond<br>CP Rail - Big Bend | CN Rail - Highway 1 to Front Street to North Arm North<br>CP Rail - Highway 1 to Front Street to North Arm North<br>CN Rail - Queensborough |
| Critical Regional Routes* | Highway 99 - Granville Street and Oak Street Bridges and Lost Lagoon<br>SW Marine Drive - at Ontario Street<br>Knight Street - south of SE Marine Drive | Marine Way<br>Boundary Road - south of SE Marine Drive | Highway 91A (Queensborough)<br>Brunette Avenue<br>Stewardson Way/Front Street |
| Other Arterial Roads** | No | North Fraser Way<br>Byrne Road | Boyd Street/Derwent Way<br>Columbia Street - west of Begbie Street |
| Airports | N.A. | N.A. | N.A. |
| Ports & Ferry Terminals | Seabus Terminal<br>Major Port Metro Vancouver marine terminals and off-dock facilities including:<br>Ballantyne Pier<br>Lantic (sugar)<br>Vanterm Terminal<br>Alliance Grain Terminal<br>Lafarge North America | Port Metro off-dock facilities along Burrard Inlet | Inundation of most marine facilities along Fraser River North + Middle Arms |
| Police Stations | No | No | No |
| Fire Halls | No | No | No |
| Ambulance Stations | No | No | No |

| | | | |
|---|---|---|---|
| Hospitals | No existing hospitals<br>Proposed relocation site for St. Paul's Hospital | No | No |
| Schools | UBC - Great Northern Way Campus<br>SFU - Great Northern Way Campus<br>Justice Institute - Vancouver Campus<br>BCIT- Great Northern Way Campus<br>Emily Carr University - Great Northern Way Campus<br>1 private school | No | Queen Elizabeth Elementary (SD 40)<br>Queensborough Middle School (SD 40)<br>Administrative headquarters + specialized programs (SD 40) |
| Wastewater treatment | See Richmond (Iona Island) | See Delta (Annacis Island) | See Delta (Annacis Island) |
| Other infrastructure | Vancouver Transit Centre<br>Manitoba Works Yard<br>Kent Works Yard<br>Southeast False Creek Neighbourhood Energy Utility<br>Access to Expo and Millennium SkyTrain lines<br>Marinas in Vancouver Harbour | Covanta Waste to Energy Incinerator | |
| First Nation Reserves | Musqueam IR2 - east of Crown Street and south of W. 51 Ave. | N.A. | N.A. |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 4, SCENARIO C

| Region #4, Scenario C | City of Vancouver | City of Burnaby | City of New Westminster |
|---|---|---|---|
| Infrastructure Type | Description | Description | Description |
| Residential Areas | Southlands | No | North Arm North/Westminster Quay<br>Queensborough east of Jardine Street |
| Commercial & Industrial Areas | Marpole and Marine Drive commercial/industrial south of Kent Avenue | Big Bend - Byrne Road general industrial and business parks south of CP Rail | Queensborough<br>Brunette Creek Industrial<br>Kruger Products (paper mill)<br>Downtown New Westminster - partial<br>Stewardson Way/Lower 12th Street/ Columbia Square |
| Agricultural Areas | Southlands | Big Bend | N.A. |
| B.C. Hydro Substations | No | Seegen | Scott Paper |
| B.C. Transmission Grid - Major Circuits | No | 69 kV - Kidd #1 to Ingledow<br>69 kV -Kidd #1 to Annacis Island | 69 kV - Kidd #1 to Annacis Island<br>69 kV - Newell to Royal 2<br>60 kV - Kidd #1 to Ingledow<br>69 kV - to Tree Island Industries<br>69 kV - to New Westminster |
| Railways | No | CN Rail - Big Bend and crossing to Richmond<br>CP Rail - Big Bend | CN Rail - Highway 1 to Front Street to North Arm North<br>CP Rail - Highway 1 to Front Street to North Arm North<br>CN Rail - Queensborough |
| Critical Regional Routes* | No | Marine Way - east of Byrne Road<br>Boundary Road - south of SE Marine Drive | Highway 91A (Queensborough)<br>Brunette Avenue<br>Stewardson Way/Front Street |
| Other Arterial Roads** | No | North Fraser Way<br>Byrne Road | Boyd Street/Derwent Way<br>Columbia Street - west of Begbie Street |
| Airports | N.A. | N.A. | N.A. |
| Ports & Ferry Terminals | No | No | Inundation of most marine facilities along Fraser River North + Middle Arms |
| Police Stations | No | No | No |
| Fire Halls | No | No | No |
| Ambulance Stations | No | No | No |
| Hospitals | No | No | No |

| | | | |
|---|---|---|---|
| Schools | No | No | Queen Elizabeth Elementary (SD 40)<br>Queensborough Middle School (SD 40)<br>Administrative headquarters + specialized programs (SD 40) |
| Wastewater treatment | See Richmond (Iona Island) | No | No |
| Other infrastructure | | | |
| First Nation Reserves | Musqueam IR2 - Musqueam Golf Course & Learning Academy | N.A. | N.A. |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 4, SCENARIO D

| Region #4, Scenario D<br>Infrastructure Type | City of Vancouver<br>Description | City of Burnaby<br>Description | City of New Westminster<br>Description |
|---|---|---|---|
| Residential Areas | Southlands<br>Fraser Lands<br>East Fraserlands | No | North Arm North/Westminster Quay<br>Queensborough |
| Commercial & Industrial Areas | Marpole and Marine Drive commercial/industrial | Big Bend - Byrne Road general industrial and business parks south of CP Rail | Queensborough<br>Brunette Creek Industrial<br>Kruger Products (paper mill)<br>Downtown New Westminster - partial<br>Stewardson Way/Lower 12th Street/ Columbia Square |
| Agricultural Areas | Southlands | Big Bend | N.A. |
| B.C. Hydro Substations | Kidd #1<br>Westcoast Cellufibre | Seegen<br>Norampac | Scott Paper<br>Tree Island Industries |
| B.C. Transmission Grid - Major Circuits | 230 kV - Ingledow to Mainwaring<br>69 kV - Kidd #1 to Ingledow<br>69 kV - Kidd #1 to Kidd #2<br>69 kV - Kidd #1 to Sperling<br>69 kV - Kidd #1 to Annacis Island<br>69 kV - Kidd #1 to Richmond Steel | 69 kV - Kidd #1 to Ingledow<br>69 kV -Kidd #1 to Annacis Island | 69 kV - Kidd #1 to Annacis Island<br>69 kV - Newell to Royal 2<br>60 kV - Kidd #1 to Ingledow<br>69 kV - to Tree Island Industries<br>69 kV - to New Westminster |
| Railways | CP Rail - Marine Drive industrial area<br>CP Rail - crossing to Richmond | CN Rail - Big Bend and crossing to Richmond<br>CP Rail - Big Bend | CN Rail - Highway 1 to Front Street to North Arm North<br>CP Rail - Highway 1 to Front Street to North Arm North<br>CN Rail - Queensborough |
| Critical Regional Routes* | Highway 99 - Granville Street and Oak Street Bridges<br>Knight Street - south of SE Marine Drive | Marine Way<br>Boundary Road - south of SE Marine Drive | Highway 99 - Oak Street Bridge<br>Highway 91A (Queensborough)<br>Brunette Avenue<br>Stewardson Way/Front Street |
| Other Arterial Roads** | No | North Fraser Way<br>Byrne Road | Boyd Street/Derwent Way<br>Columbia Street - west of Begbie Street |
| Airports | N.A. | N.A. | N.A. |
| Ports & Ferry Terminals | | No | Inundation of all marine facilities along Fraser River North + Middle Arms |

| | | | |
|---|---|---|---|
| Police Stations | No | No | No |
| Fire Halls | No | No | No |
| Ambulance Stations | No | No | Station 247 - Sapperton |
| Hospitals | No | No | No |
| Schools | No | No | Queen Elizabeth Elementary (SD 40)<br>Queensborough Middle School (SD 40)<br>Administrative headquarters + specialized programs (SD 40) |
| Wastewater treatment | See Richmond (Iona Island) | See Delta (Annacis Island) | See Delta (Annacis Island) |
| Other infrastructure | Manitoba Works Yard | Covanta Waste to Energy Incinerator | |
| First Nation Reserves | Musqueam IR2 - Musqueam Golf Course & Learning Academy | N.A. | N.A. |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 5, SCENARIO A

| Region #5, Scenario A | City of Richmond | Corporation of Delta |
|---|---|---|
| **Infrastructure Type** | **Description** | **Description** |
| Residential Areas | All | Ladner |
| Commercial & Industrial Areas | All except Fraser Lands (Portside Road) | Ladner<br>Tilbury Industrial |
| Agricultural Areas | All | All |
| B.C. Hydro Substations | Kidd #2<br>Steveston<br>YVR<br>Sea Island<br>Massey Tunnel Terminals<br>Cambie<br>Richmond | Tsawwassen Beach Terminal<br>Tsawwassen<br>Boundary Bay Electrode<br>Arnott<br>Massey Tunnel Terminals<br>Canadian Toyota<br>Buckeye |
| B.C. Transmission Grid - Major Circuits | 230 kV - Steveston to Kidd #2<br>230 kV - Arnott to Steveston<br>230 kV - Ingledow to Cambie<br>230 kV - Ingledow to Mainwaring<br>69 kV - Kidd #2 to Richmond<br>69 kV - Kidd #2 to Lafarge #1<br>69 kV - Kidd #1 to Kidd #2 | 230 kV - Arnott to Steveston<br>230 kV - Ingledow to Arnott<br>230 kV - Arnott to Vancouver Island<br>230 kV - Ingledow to Mainwaring<br>69 kV - Deltaport to Canoe Pass<br>69 kV - Kidd #1 to Ingledow<br>69 kV - Arnott to Boundary Bay Electrode<br>69 kV - Arnott to Tsawwassen Beach Terminal |
| Railways | CN Rail - Big Bend crossing to Shell Road to South Arm<br>CN Rail - Big Bend crossing to Fraser Lands<br>CP Rail - North Arm to Gilbert Road | CN Rail to Tilbury Island<br>BCR to Roberts Bank<br>BNSF - south of 64 Avenue<br>Amtrak (on BNSF track) |
| Critical Regional Routes* | Highway 99<br>Highway 91 (Richmond Freeway)<br>Grant McConachie Way<br>George Massey Tunnel | Highway 99<br>Highway 91<br>Highway 17 (South Fraser Perimeter Road)<br>Delta Port Way, Roberts Bank Way |

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|---|---|---|
| Other Arterial Roads** | Bridgeport Road<br>Cambie Road<br>Steveston Highway<br>Westminster Highway<br>Blundell Road<br>No.1, No.2, No.3, No.4, No.5 No. 6 & No. 9 Roads<br>Railway Avenue<br>Gilbert Road<br>Shell Road<br>Knight Street | River Road<br>Arthur Drive<br>56 Street/28 Avenue<br>Highway 10 (Ladner Trunk Road)/48 Avenue |
| Airports | Vancouver International Airport (YVR) | Boundary Bay Airport<br>Delta Heritage Air Park |
| Ports & Ferry Terminals | Port Metro Vancouver facilities:<br>3 major off-dock facilities on the North Arm<br>7 major off-dock facilities on the South Arm<br>1 major marine terminal on the South Arm | Port Metro Vancouver facilities:<br>4 major off-dock facilities - Tilbury Island<br>Annacis Island auto terminal |
| Police Stations | RCMP - No.5 Road<br>Steveston Community Policing<br>South Arm Community Policing | Delta Police<br>Deas Island Highway Patrol<br>Ladner Community Policing |
| Fire Halls | Fire Halls 1 to 7 (all) | Ladner Hall 1<br>Ladner Hall 4 (Highway 99 at #10 Highway)<br>Tilbury Hall 7 |
| Ambulance Stations | 250 Richmond North<br>269 Richmond South<br>270 Richmond (YVR)<br>280 Vancouver (South Terminal) | 251 Delta (Ladner)<br>264 - Nordel Logistics Centre |
| Hospitals | Richmond Hospital | Delta Hospital (Ladner) |
| Schools | 38 Elementary (SD 38)<br>10 Secondary (SD 38)<br>2 Specialized (SD 38) + District Administration<br>1 Elementary + BC Administration (SD 93)<br>9 Private | 6 Elementary (SD 37)<br>1 Secondary (SD 37)<br>1 Specialized (SD 37)<br>4 Private |
| Wastewater treatment | Iona Island - Sea Island including YVR<br>Lulu Island - west Richmond | No |

| | | |
|---|---|---|
| Other infrastructure | City Hall<br>Municipal Works Yard<br>Alexandra District Energy Utility (West Cambie neighbourhood) | Municipal Hall<br>Delta Works Yard<br>Mainroad Fraser Maintenance (SFPR)<br>Road access to Tsawwassen Ferry Terminal |
| First Nation Reserves | Sea Island IR3 | Musqueam IR4<br>Tsawwassen Treaty Lands (183 living on reserve Dec. 2014) |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 5, SCENARIO B

| Region #5, Scenario B | City of Richmond | Corporation of Delta |
|---|---|---|
| **Infrastructure Type** | **Description** | **Description** |
| Residential Areas | All | Ladner<br>Beach Grove<br>Boundary Bay |
| Commercial & Industrial Areas | All except Fraser Lands (Portside Road) | Ladner<br>Tilbury Industrial<br>Annacis Island Industrial |
| Agricultural Areas | All | |
| B.C. Hydro Substations | Kidd #2<br>Steveston<br>YVR<br>Sea Island<br>Massey Tunnel Terminals<br>Cambie<br>Richmond<br>Lafarge #1 | Deltaport<br>Tsawwassen Beach Terminal<br>Tsawwassen<br>Boundary Bay Electrode<br>Arnott<br>Massey Tunnel Terminals<br>Canadian Toyota<br>Lehigh Heidelberg Cement<br>Buckeye<br>Lantic Real Prop<br>Annacis Island Sewage<br>Annacis Island |
| B.C. Transmission Grid - Major Circuits | 230 kV - Steveston to Kidd #2<br>230 kV - Arnott to Steveston<br>230 kV - Ingledow to Cambie<br>230 kV - Ingledow to Mainwaring<br>69 kV - Kidd #2 to Richmond<br>69 kV - Kidd #2 to Lafarge #1<br>69 kV - Kidd #1 to Kidd #2 | 230 kV - Arnott to Steveston<br>230 kV - Ingledow to Arnott<br>230 kV - Arnott to Vancouver Island<br>230 kV - Ingledow to Mainwaring<br>69 kV - Deltaport to Canoe Pass<br>69 kV - Kidd #1 to Ingledow<br>69 kV - Arnott to Boundary Bay Electrode<br>69 kV - Arnott to Tsawwassen Beach Terminal |
| Railways | CN Rail - Big Bend crossing to Shell Road to South Arm<br>CN Rail - Big Bend crossing to Fraser Lands<br>CP Rail - North Arm to Gilbert Road | CN Rail - Annacis Island<br>CN Rail to Tilbury Island<br>BCR to Roberts Bank<br>BNSF<br>Amtrak (on BNSF track) |

| | | |
|---|---|---|
| Critical Regional Routes* | Highway 99<br>Highway 91 (Richmond Freeway)<br>Grant McConachie Way<br>George Massey Tunnel | Highway 99<br>Highway 91<br>Highway 17 (South Fraser Perimeter Road)<br>Delta Port Way, Roberts Bank Way |
| Other Arterial Roads** | Bridgeport Road<br>Cambie Road<br>Steveston Highway<br>Westminster Highway<br>Blundell Road<br>No.1, No.2, No.3, No.4, No.5 No. 6 & No. 9 Roads<br>Railway Avenue<br>Gilbert Road<br>Shell Road<br>Knight Street | River Road<br>Arthur Drive<br>56 Street/28 Avenue<br>Highway 10 (Ladner Trunk Road)/48 Avenue |
| Airports | Vancouver International Airport (YVR) | Boundary Bay Airport<br>Delta Heritage Air Park |
| Ports & Ferry Terminals | Port Metro Vancouver facilities:<br>3 major off-dock facilities on the North Arm<br>7 major off-dock facilities on the South Arm<br>1 major marine terminal on the South Arm | Partial inundation of Tsawwassen Ferry Terminal<br>Port Metro Vancouver facilities:<br>Westshore Terminals - Roberts Bank<br>4 major off-dock facilities - Tilbury Island<br>1 major marine Terminal - Annacis Island<br>5 major off-dock facilities - Annacis Island |
| Police Stations | RCMP - No.5 Road<br>Steveston + South Arm Community Policing | Delta Police<br>Deas Island Highway Patrol<br>Ladner Community Policing |
| Fire Halls | Fire Halls 1 to 7 (all) | Ladner Hall 1<br>Ladner Hall 4 (Highway 99 at #10 Highway)<br>Annacis Hall 6<br>Tilbury Hall 7 |
| Ambulance Stations | 250 Richmond North<br>269 Richmond South<br>270 Richmond (YVR)<br>280 Vancouver (South Terminal) | 251 Delta (Ladner)<br>264 - Nordel Logistics Centre |
| Hospitals | Richmond Hospital | Delta Hospital (Ladner) |

| | | |
|---|---|---|
| Schools | 38 Elementary (SD 38)<br>10 Secondary (SD 38)<br>2 Specialized (SD 38) + District Administration<br>1 Elementary + BC Administration (SD 93)<br>9 Private | 6 Elementary (SD 37)<br>1 Secondary (SD 37)<br>1 Specialized (SD 37)<br>4 Private |
| Wastewater treatment | Iona Island - Sea Island including YVR<br>Lulu Island - west Richmond | Annacis Island |
| Other infrastructure | City Hall<br>Municipal Works Yard<br>Alexandra District Energy Utility (West Cambie neighbourhood) | Municipal Hall<br>Delta Works Yard<br>Mainroad Fraser Maintenance (SFPR) |
| First Nation Reserves | Sea Island IR3 | Musqueam IR2<br>Tsawwassen Treaty Lands (183 living on reserve Dec. 2014) |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 5, SCENARIO C

| Region #5, Scenario C | City of Richmond | Corporation of Delta |
|---|---|---|
| **Infrastructure Type** | **Description** | **Description** |
| Residential Areas | All | Ladner |
| Commercial & Industrial Areas | All except Fraser Lands (Portside Road) | Ladner<br>Tilbury Industrial |
| Agricultural Areas | All | All |
| B.C. Hydro Substations | Kidd #2<br>Steveston<br>YVR<br>Sea Island<br>Massey Tunnel Terminals<br>Cambie<br>Richmond | Tsawwassen Beach Terminal<br>Tsawwassen<br>Boundary Bay Electrode<br>Arnott<br>Massey Tunnel Terminals<br>Canadian Toyota<br>Lehigh Heidelberg Cement<br>Buckeye<br>Lantic Real Prop |
| B.C. Transmission Grid - Major Circuits | 230 kV - Steveston to Kidd #2<br>230 kV - Arnott to Steveston<br>230 kV - Ingledow to Cambie<br>230 kV - Ingledow to Mainwaring<br>69 kV - Kidd #2 to Richmond<br>69 kV - Kidd #2 to Lafarge #1<br>69 kV - Kidd #1 to Kidd #2 | 230 kV - Arnott to Steveston<br>230 kV - Ingledow to Arnott<br>230 kV - Arnott to Vancouver Island<br>230 kV - Ingledow to Mainwaring<br>69 kV - Deltaport to Canoe Pass<br>69 kV - Kidd #1 to Ingledow<br>69 kV - Arnott to Boundary Bay Electrode<br>69 kV - Arnott to Tsawwassen Beach Terminal |
| Railways | CN Rail - Big Bend crossing to Shell Road to South Arm<br>CN Rail - Big Bend crossing to Fraser Lands<br>CP Rail - North Arm to Gilbert Road | CN Rail to Tilbury Island<br>BCR to Roberts Bank<br>BNSF - south of 64 Avenue<br>Amtrak (on BNSF track) |
| Critical Regional Routes* | Highway 99<br>Highway 91 (Richmond Freeway)<br>Grant McConachie Way<br>George Massey Tunnel | Highway 99<br>Highway 91<br>Highway 17 (South Fraser Perimeter Road)<br>Delta Port Way, Roberts Bank Way |

| | | |
|---|---|---|
| Other Arterial Roads** | Bridgeport Road<br>Cambie Road<br>Steveston Highway<br>Westminster Highway<br>Blundell Road<br>No.1, No.2, No.3, No.4, No.5 No. 6 & No. 9 Roads<br>Railway Avenue<br>Gilbert Road<br>Shell Road<br>Knight Street | River Road<br>Arthur Drive<br>56 Street/28 Avenue<br>Highway 10 (Ladner Trunk Road)/48 Avenue |
| Airports | Vancouver International Airport (YVR) | Boundary Bay Airport<br>Delta Heritage Air Park |
| Ports & Ferry Terminals | Port Metro Vancouver facilities:<br>3 major off-dock facilities on the North Arm<br>7 major off-dock facilities on the South Arm<br>1 major marine terminal on the South Arm | Port Metro Vancouver facilities:<br>4 major off-dock facilities - Tilbury Island |
| Police Stations | RCMP - No.5 Road<br>Steveston + South Arm Community Policing Stations | Delta Police<br>Deas Island Highway Patrol<br>Ladner Community Policing |
| Fire Halls | Fire Halls 1 to 7 (all) | Ladner Hall 1<br>Ladner Hall 4 (Highway 99 at #10 Highway)<br>Tilbury Hall 7 |
| Ambulance Stations | 250 Richmond North<br>269 Richmond South<br>270 Richmond (YVR)<br>280 Vancouver (South Terminal) | 251 Delta (Ladner)<br>264 - Nordel Logistics Centre |
| Hospitals | Richmond Hospital | Delta Hospital (Ladner) |
| Schools | 38 Elementary (SD 38)<br>9 Secondary (SD 38) - all except A.R. MacNeill<br>2 Specialized (SD 38) + District Administration<br>1 Elementary + BC Administration (SD 93)<br>9 Private | 5 Elementary (SD 37)<br>1 Secondary (SD 37)<br>1 Specialized (SD 37)<br>4 Private |
| Wastewater treatment | Iona Island - Sea Island including YVR<br>Lulu Island - west Richmond | No |

| | | |
|---|---|---|
| Other infrastructure | City Hall<br>Municipal Works Yard<br>Alexandra District Energy Utility (West Cambie neighbourhood) | Municipal Hall<br>Delta Works Yard<br>Mainroad Fraser Maintenance (SFPR) |
| First Nation Reserves | Sea Island IR3 | Musqueam IR2<br>Tsawwassen Treaty Lands (183 living on reserve Dec. 2014) - part |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 5, SCENARIO D

| Region #5, Scenario D | City of Richmond | Corporation of Delta |
|---|---|---|
| Infrastructure Type | Description | Description |
| Residential Areas | All | Ladner<br>Beach Grove<br>Boundary Bay |
| Commercial & Industrial Areas | All except Fraser Lands (Portside Road) | Ladner<br>Tilbury Industrial<br>Annacis Island Industrial |
| Agricultural Areas | All | All |
| B.C. Hydro Substations | Kidd #2<br>Steveston<br>YVR<br>Sea Island<br>Massey Tunnel Terminals<br>Cambie<br>Richmond<br>Lafarge #1 | Tsawwassen Beach Terminal<br>Tsawwassen<br>Boundary Bay Electrode<br>Arnott<br>Massey Tunnel Terminals<br>Canadian Toyota<br>Lehigh Heidelberg Cement<br>Buckeye<br>Lantic Real Prop<br>Annacis Island Sewage<br>Annacis Island |
| B.C. Transmission Grid - Major Circuits | 230 kV - Steveston to Kidd #2<br>230 kV - Arnott to Steveston<br>230 kV - Ingledow to Cambie<br>230 kV - Ingledow to Mainwaring<br>69 kV - Kidd #2 to Richmond<br>69 kV - Kidd #2 to Lafarge #1<br>69 kV - Kidd #1 to Kidd #2 | 230 kV - Arnott to Steveston<br>230 kV - Ingledow to Arnott<br>230 kV - Arnott to Vancouver Island<br>230 kV - Ingledow to Mainwaring<br>69 kV - Deltaport to Canoe Pass<br>69 kV - Kidd #1 to Ingledow<br>69 kV - Arnott to Boundary Bay Electrode<br>69 kV - Arnott to Tsawwassen Beach Terminal |
| Railways | CN Rail - Big Bend crossing to Shell Road to South Arm<br>CN Rail - Big Bend crossing to Fraser Lands<br>CP Rail - North Arm to Gilbert Road | CN Rail - Annacis Island<br>CN Rail to Tilbury Island<br>BCR to Roberts Bank<br>BNSF<br>Amtrak (on BNSF track) |

# VULNERABILITY STUDY - REGION 5, SCENARIO D

| | | |
|---|---|---|
| Critical Regional Routes* | Highway 99<br>Highway 91 (Richmond Freeway)<br>Grant McConachie Way<br>George Massey Tunnel | Highway 99<br>Highway 91<br>Highway 17 (South Fraser Perimeter Road)<br>Delta Port Way, Roberts Bank Way |
| Other Arterial Roads** | Bridgeport Road<br>Cambie Road<br>Steveston Highway<br>Westminster Highway<br>Blundell Road<br>No.1, No.2, No.3, No.4, No.5 No. 6 & No. 9 Roads<br>Railway Avenue<br>Gilbert Road<br>Shell Road<br>Knight Street | River Road<br>Arthur Drive<br>56 Street/28 Avenue<br>Highway 10 (Ladner Trunk Road)/48 Avenue |
| Airports | Vancouver International Airport (YVR) | Boundary Bay Airport<br>Delta Heritage Air Park |
| Ports & Ferry Terminals | Port Metro Vancouver facilities:<br>3 major off-dock facilities on the North Arm<br>7 major off-dock facilities on the South Arm<br>1 major marine terminal on the South Arm | Port Metro Vancouver facilities:<br>Westshore Terminals - Roberts Bank<br>4 major off-dock facilities - Tilbury Island<br>1 major marine Terminal - Annacis Island<br>5 major off-dock facilities - Annacis Island |
| Police Stations | RCMP - No.5 Road<br>Steveston + South Arm Community Policing Stations | Delta Police<br>Deas Island Highway Patrol<br>Ladner Community Policing |
| Fire Halls | Fire Halls 1 to 7 (all) | Ladner Hall 1<br>Ladner Hall 4 (Highway 99 at #10 Highway)<br>Annacis Hall 6<br>Tilbury Hall 7 |
| Ambulance Stations | 250 Richmond North<br>269 Richmond South<br>270 Richmond (YVR)<br>280 Vancouver (South Terminal) | 251 Delta (Ladner)<br>264 - Nordel Logistics Centre |
| Hospitals | Richmond Hospital | Delta Hospital (Ladner) |

| | | |
|---|---|---|
| Schools | 38 Elementary (SD 38)<br>10 Secondary (SD 38)<br>2 Specialized (SD 38) + District Administration<br>1 Elementary + BC Administration (SD 93)<br>9 Private | 6 Elementary (SD 37)<br>1 Secondary (SD 37)<br>1 Specialized (SD 37)<br>4 Private |
| Wastewater treatment | Iona Island - Sea Island including YVR<br>Lulu Island - west Richmond | Annacis Island |
| Other infrastructure | City Hall<br>Municipal Works Yard<br>Alexandra District Energy Utility (West Cambie neighbourhood) | Municipal Hall<br>Delta Works Yard<br>Mainroad Fraser Maintenance (SFPR) |
| First Nation Reserves | Sea Island IR3 | Musqueam IR2<br>Tsawwassen Treaty Lands (183 living on reserve Dec. 2014) |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 6, SCENARIO A

| Region #6, Scenario A | City of Surrey | City of White Rock | Barnston Island |
|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** |
| Residential Areas | Crescent Beach | No | N.A. |
| Commercial & Industrial Areas | South Westminster<br>Bridgeview | No | N.A. |
| Agricultural Areas | Serpentine River Valley<br>Nicomekl River Valley | N.A. | Entire island |
| B.C. Hydro Substations | No | N.A. | N.A. |
| B.C. Transmission Grid - Major Circuits | 500 kV - Nicola to Ingledow<br>500 kV - Clayburn to Ingledow<br>500 kV - Ingledow to USA<br>230 kV - Ingledow to McLellan<br>230 kV - Ingledow to Mount Lehman<br>230 kV - McLellan to Mount Lehman<br>69 kV - Ingledow to Cloverdale<br>69kV - Tap to White Rock<br>69 kV - Ingledow to White Rock<br>60 kV - Ingledow to Cloverdale<br>69 kV - McLellan to Nicomekl | No | No |
| Railways | BNSF - Semiahmoo IR, Mud Bay, South Westminster<br>CN - South Westminster, Bridgeview, Thornton Railyard<br>BCR to Deltaport<br>Southern Railway of BC - South Westminster | No | No |
| Critical Regional Routes* | Highway 99 - Mud Bay area<br>Highway 17 (South Fraser Perimeter Road) - South Westminster, Colebrook to Crescent Roads<br>Highway 10 - 156 Street to 56A Ave. | No | No |

| | | | |
|---|---|---|---|
| Other Arterial Roads** | Scott Road - S. Westminster<br>Tannery Rd/104 Ave.<br>108 Ave. - S. Westminster<br>Bridgeview Drive/110 Ave.<br>Colebrook Rd. east of King George Boulevard<br>40 Avenue<br>32 Avenue - 176 Street<br>152 Street - Nicomekl River to 54 A Ave.<br>168 Street - 32 to 57 Avenues<br>Highway 15 (176 Street) - 32 to 58A Avenues<br>184 Street - Nicomekl River<br>192 Street - Colebrook Road to 52 Ave. | Marine Drive along Campbell River | No |
| Airports | N.A. | N.A. | N.A. |
| Ports | Fraser Surrey Docks/ Intermodal Yard | N.A. | N.A. |
| Police Stations | No | No | No |
| Fire Halls | No | No | No |
| Ambulance Stations | No | No | No |
| Hospitals | No | No | N.A. |
| Schools | Bridgeview Elementary (SD 36) | No | No |
| Wastewater treatment | Cloverdale Sanitary Sewer Overflow Storage Facility (164 St. + Highway 10) | No | N.A. |
| Other infrastructure | No | No | Ferry crossing |
| First Nation Reserves | SEMIAHMOO IR - NW shoreline + along Campbell River | No | BARNSTON ISLAND IR3 |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 6, SCENARIO B

| Region #6, Scenario B | City of Surrey | City of White Rock | Barnston Island |
|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** |
| Residential Areas | Crescent Beach | No | N.A. |
| Commercial & Industrial Areas | South Westminster<br>Bridgeview | No | N.A. |
| Agricultural Areas | Serpentine River Valley<br>Nicomekl River Valley | N.A. | Entire island |
| B.C. Hydro Substations | McLellan | N.A. | No |
| B.C. Transmission Grid - Major Circuits | 500 kV - Nicola to Ingledow<br>500 kV - Clayburn to Ingledow<br>500 kV - Ingledow to USA<br>230 kV - Ingledow to McLellan<br>230 kV - Ingledow to Mount Lehman<br>230 kV - McLellan to Mount Lehman<br>69 kV - Ingledow to Cloverdale<br>69kV - Tap to White Rock<br>69 kV - Ingledow to White Rock<br>60 kV - Ingledow to Cloverdale<br>69 kV - McLellan to Nicomekl | No | No |
| Railways | BNSF - Semiahmoo IR, Mud Bay, South Westminster<br>CN - South Westminster, Bridgeview, Thornton Railyard<br>BCR to Deltaport<br>Southern Railway of BC - South Westminster | No | No |
| Critical Regional Routes* | Highway 99 - Mud Bay area<br>Highway 17 - South Fraser Perimeter Rd.<br>King George Boulevard - South Westminster, Colebrook to Crescent Roads<br>Highway 10 - West Cloverdale | N.A. | No |

| | | | |
|---|---|---|---|
| Other Arterial Roads** | Scott Road - S. Westminster<br>Tannery Rd/104 Ave.<br>108 Ave. - S. Westminster<br>Bridgeview Drive/110 Ave.<br>Colebrook Rd. east of King George Boulevard<br>40 Avenue - King George Blvd. to 184 St.<br>32 Avenue - 164 to 180 Streets<br>152 Street - Nicomekl River to 54 A Ave.<br>168 Street - 32 to 57 Avenues<br>Highway 15 (176 Street) - 32 to 59 Ave.<br>184 Street - north of 32 Avenue toward Colebrook Road<br>192 Street - Colebrook Road to 52 Ave. | Marine Drive along Campbell River | No |
| Airports | N.A. | N.A. | N.A. |
| Ports & Ferry Terminals | Fraser Surrey Docks/ Intermodal Yard | N.A. | Ferry crossing |
| Police Stations | No | No | No |
| Fire Halls | Fire Hall 8 - Cloverdale | No | No |
| Ambulance Stations | No | No | No |
| Hospitals | No | No | N.A. |
| Schools | Bridgeview Elementary (SD 36)<br>Cloverdale Learning Centre (SD 36)<br>Cloverdale Traditional School (SD 36) | No | No |
| Wastewater treatment | Annacis Island (see Delta)<br>Cloverdale Sanitary Sewer Overflow Storage Facility (164 St. + Highway 10) | Annacis Island (see Delta) | N.A. |
| Other infrastructure | No | No | No |
| First Nation Reserves | SEMIAHMOO IR - NW shoreline + along Campbell River | No | BARNSTON ISLAND IR3 |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 6, SCENARIO C

| Region #6, Scenario C | City of Surrey | City of White Rock | Barnston Island |
|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** |
| Residential Areas | No | No | N.A. |
| Commercial & Industrial Areas | South Westminster<br>Bridgeview | No | N.A. |
| Agricultural Areas | No | N.A. | Entire island |
| B.C. Hydro Substations | No | N.A. | N.A. |
| B.C. Transmission Grid - Major Circuits | No | No | No |
| Railways | CN - South Westminster, Bridgeview, Thornton Railyard<br>Southern Railway of BC - South Westminster | No | No |
| Critical Regional Routes* | South Fraser Perimeter Rd.<br>King George Boulevard - South Westminster | N.A. | No |
| Other Arterial Roads** | Scott Road - S. Westminster<br>Tannery Rd/104 Ave.<br>108 Ave. - S. Westminster<br>Bridgeview Drive/110 Ave. | No | No |
| Airports | N.A. | N.A. | N.A. |
| Ports & Ferry Terminals | No | N.A. | Ferry crossing |
| Police Stations | No | No | No |
| Fire Halls | No | No | No |
| Ambulance Stations | No | No | No |
| Hospitals | No | No | N.A. |
| Schools | Bridgeview Elementary (SD 36) | No | No |
| Wastewater treatment | No | No | N.A. |
| Other infrastructure | No | No | No |
| First Nation Reserves | No | No | BARNSTON ISLAND IR3 |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 6, SCENARIO D

| Region #6, Scenario D | City of Surrey | City of White Rock | Barnston Island |
|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** |
| Residential Areas | No | No | No |
| Commercial & Industrial Areas | South Westminster<br>Bridgeview | No | No |
| Agricultural Areas | No | N.A. | Entire island |
| B.C. Hydro Substations | No | N.A. | N.A. |
| B.C. Transmission Grid - Major Circuits | No | No | No |
| Railways | CN - South Westminster, Bridgeview, Thornton Railyard<br>Southern Railway of BC - South Westminster | No | No |
| Critical Regional Routes* | South Fraser Perimeter Rd.<br>King George Boulevard - South Westminster | N.A. | No |
| Other Arterial Roads** | Scott Road - S. Westminster<br>Tannery Rd/104 Ave.<br>108 Ave. - S. Westminster<br>Bridgeview Drive/110 Ave. | No | No |
| Airports | N.A. | N.A. | N.A. |
| Ports & Ferry Terminals | No | N.A. | Ferry crossing |
| Police Stations | No | No | No |
| Fire Halls | No | No | No |
| Ambulance Stations | No | No | No |
| Hospitals | No | No | N.A. |
| Schools | Bridgeview Elementary (SD 36) | No | No |
| Wastewater treatment | Annacis Island (see Delta) | Annacis Island (see Delta) | N.A. |
| Other infrastructure | No | No | No |
| First Nation Reserves | No | No | BARNSTON ISLAND IR3 |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 7, SCENARIO A

| Region #7, Scenario A | City of Coquitlam | City of Port Coquitlam | City of Pitt Meadows | City of Maple Ridge |
|---|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** | **Description** |
| Residential Areas | No | Riverwood | Extensive rural areas | No |
| Commercial & Industrial Areas | Large industrial sites south of United Boulevard | Mary Hill & Coast Meridian<br>Pitt River Bridge<br>Dominion Triangle | Industrial corridor along CP Rail<br>Industry by Airport | No |
| Agricultural Areas | No | Colony Farm<br>North of Dominion Ave. | Extensive areas in ALR | West of Silver Valley |
| B.C. Hydro Substations | No | No | No | No |
| B.C. Transmission Grid - Major Circuits | 500 kV - Meridian to Ingledow<br>230 kV - Meridian to Whalley<br>230 kV - Meridian to Newell | 230 kV - Meridian to Whalley<br>230 kV - Meridian to Newell<br>69 kV - Stave Falls to Como Lake<br>69 kV - Haney to Como Lake | 69 kV - Stave Falls to Como Lake<br>69 kV - Haney to Como Lake | No |
| Railways | CP Rail - Brunette Ave. to Pitt River Road | No | CP Rail Mainline<br>West Coast Express | No |
| Critical Regional Routes* | No | Highway 7B (Mary Hill Bypass) | Highway 7 (Lougheed) | No |
| Other Arterial Roads** | United Boulevard | No | No | No |
| Airports | N.A. | N.A. | Pitt Meadows Airport | N.A. |
| Ports & Ferry Terminals | No | No | Major off-dock facility (Pitt River) | No |
| Police Stations | No | No | No | No |
| Fire Halls | No | Hall 1 (Broadway St.) | No | No |
| Ambulance Stations | No | No | N.A. | No |
| Hospitals | Colony Farm Forensic Psychiatric Hospital | N.A. | N.A. | No |
| Schools | No | No | No | No |
| Wastewater treatment | No | No | No | No |
| Other infrastructure | | | | |
| First Nation Reserves | No | COQUITLAM IR2 - part | No | No |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 7, SCENARIO B

| Region #7, Scenario B | City of Coquitlam | City of Port Coquitlam | City of Pitt Meadows | City of Maple Ridge |
|---|---|---|---|---|
| Infrastructure Type | Description | Description | Description | Description |
| Residential Areas | Fraser Mills<br>Southerly parts of Maillardville | Riverwood | Most rural areas | No |
| Commercial & Industrial Areas | Extensive areas south of Highway 7 | Mary Hill & Coast Meridian<br>Pitt River Bridge<br>Dominion Triangle | Industrial corridor along CP Rail<br>Industry by Airport | No |
| Agricultural Areas | No | Colony Farm<br>North of Dominion Ave. | Most land in ALR | West of Silver Valley |
| B.C. Hydro Substations | Newstech | No | No | No |
| B.C. Transmission Grid - Major Circuits | 500 kV - Meridian to Ingledow<br>230 kV - Meridian to Whalley<br>230 kV - Meridian to Newell | 230 kV - Meridian to Whalley<br>230 kV - Meridian to Newell<br>69 kV - Stave Falls to Como Lake<br>69 kV - Haney to Como Lake | 69 kV - Stave Falls to Como Lake<br>69 kV - Haney to Como Lake | No |
| Railways | No | CP Railyard - part | CP Rail Mainline<br>West Coast Express | No |
| Critical Regional Routes* | Highway 1<br>Highway 7 (Lougheed)<br>Highway 7B (Mary Hill Bypass) | Highway 7 (Lougheed)<br>Highway 7B (Mary Hill Bypass) | Highway 7 (Lougheed) | No |
| Other Arterial Roads** | United Boulevard<br>King Edward Street<br>Schoolhouse Street | Pitt River Road<br>Kingsway<br>Fremont Street/Burns Road<br>Dominion Avenue<br>Broadway | Old Dewdney Trunk Road/132 Avenue | No |
| Airports | N.A. | | Pitt Meadows Airport | N.A. |
| Ports & Ferry Terminals | No | 5 major off-dock facilities | Major off-dock facility (Pitt River) | No |
| Police Stations | No | No | No | No |
| Fire Halls | No | Hall 1 (Broadway St.) | No | No |
| Ambulance Stations | No | No | N.A. | No |
| Hospitals | Colony Farm Forensic Psychiatric Hospital | N.A. | N.A. | No |

| | | | | |
|---|---|---|---|---|
| Schools | No | Blakeburn Elementary (SD 43)<br>Cedar Drive Elementary (SD 43)<br>1 private secondary | Justice Institute- Pitt Meadows Driver Education Centre | No |
| Wastewater treatment | Annacis Island (see Delta) | Annacis Island (see Delta) | Annacis Island (see Delta) | Annacis Island (see Delta) |
| Other infrastructure | | | | |
| First Nation Reserves | No | COQUITLAM IR2 - part | KATZIE IR1 - part | No |

* Disaster Evacuation Route

** As designated in Official Community Plans

| Region #7, Scenario C | City of Coquitlam | City of Port Coquitlam | City of Pitt Meadows | City of Maple Ridge |
|---|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** | **Description** |
| Residential Areas | Fraser Mills<br>Southerly parts of Maillardville | Riverwood | Most of City except urban area near Harris Road | No |
| Commercial & Industrial Areas | Extensive areas south of Highway 7 | Mary Hill & Coast Meridian<br>Pitt River Bridge<br>Dominion Triangle | Industrial corridor along CP Rail<br>Industry by Airport | Industrial land between Highway 7 and Fraser River |
| Agricultural Areas | No | Colony Farm<br>North of Dominion Ave. | Most land in ALR | West of Silver Valley<br>Albion |
| B.C. Hydro Substations | Newstech | No | No | No |
| B.C. Transmission Grid - Major Circuits | 500 kV - Meridian to Ingledow<br>230 kV - Meridian to Whalley<br>230 kV - Meridian to Newell | 230 kV - Meridian to Whalley<br>230 kV - Meridian to Newell<br>69 kV - Stave Falls to Como Lake<br>69 kV - Haney to Como Lake | 69 kV - Stave Falls to Como Lake<br>69 kV - Haney to Como Lake | No |
| Railways | No | CP Railyard - part | CP Rail Mainline<br>West Coast Express | CP Rail Mainline<br>West Coast Express |
| Critical Regional Routes* | Highway 1<br>Highway 7 (Lougheed)<br>Highway 7B (Mary Hill Bypass) | Highway 7 (Lougheed)<br>Highway 7B (Mary Hill Bypass) | Highway 7 (Lougheed) | Highway 7 (Lougheed) |
| Other Arterial Roads** | United Boulevard<br>King Edward Street<br>Schoolhouse Street | Pitt River Road<br>Kingsway<br>Fremont Street/Burns Road<br>Dominion Avenue<br>Broadway | Old Dewdney Trunk Road/<br>132 Avenue | 132 Avenue west of 224 Street<br>Kanaka Way<br>105 Avenue |
| Airports | N.A. | N.A. | Pitt Meadows Airport | N.A. |
| Ports & Ferry Terminals | No | 5 major off-dock facilities | Major off-dock facility (Pitt River) | No |
| Police Stations | No | No | No | No |
| Fire Halls | No | Hall 1 (Broadway St.) | No | No |
| Ambulance Stations | No | No | N.A. | No |
| Hospitals | Colony Farm Forensic Psychiatric Hospital | N.A. | N.A. | No |

| | | | | |
|---|---|---|---|---|
| Schools | No | Terry Fox Secondary (SD 43)<br>Blakeburn Elementary (SD 43)<br>Cedar Drive Elementary (SD 43)<br>1 private secondary | Justice Institute- Pitt Meadows Driver Education Centre | Kanaka Creek Elementary (SD 42) |
| Wastewater treatment | No | No | No | No |
| Other infrastructure | | | Works Yard | |
| First Nation Reserves | No | COQUITLAM IR2 - part | KATZIE IR1 | LANGLEY IR5 - south of Highway 7<br>WHONNOCK IR1 - river edge |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 7, SCENARIO D

| Region #7, Scenario D | City of Coquitlam | City of Port Coquitlam | City of Pitt Meadows | City of Maple Ridge |
|---|---|---|---|---|
| Infrastructure Type | Description | Description | Description | Description |
| Residential Areas | Maillardville<br>Fraser Mills | Riverwood | Most of City except urban area near Harris Road | No |
| Commercial & Industrial Areas | Most land along and south of Highway 7 | Mary Hill & Coast Meridian<br>Pitt River Bridge<br>Dominion Triangle | Industrial corridor along CP Rail<br>Industry by Airport | Industrial land between Highway 7 and Fraser River |
| Agricultural Areas | No | Colony Farm<br>North of Dominion Ave. | All land in ALR | West of Silver Valley<br>Albion |
| B.C. Hydro Substations | Newstech | No | No | No |
| B.C. Transmission Grid - Major Circuits | 500 kV - Meridian to Ingledow<br>230 kV - Meridian to Whalley<br>230 kV - Meridian to Newell | 230 kV - Meridian to Whalley<br>230 kV - Meridian to Newell<br>69 kV - Stave Falls to Como Lake<br>69 kV - Haney to Como Lake | 69 kV - Stave Falls to Como Lake<br>69 kV - Haney to Como Lake | No |
| Railways | No | West Coast Express<br>CP Rail Mainline<br>CP Railyard - part | CP Rail Mainline<br>West Coast Express | CP Rail Mainline<br>West Coast Express |
| Critical Regional Routes* | Highway 1<br>Highway 7 (Lougheed)<br>Highway 7B (Mary Hill Bypass) | Highway 7 (Lougheed)<br>Highway 7B (Mary Hill Bypass) | Highway 7 (Lougheed) | Highway 7 (Lougheed) |
| Other Arterial Roads** | United Boulevard<br>King Edward Street<br>Schoolhouse Street | Pitt River Road<br>Kingsway<br>Fremont Street/Burns Road<br>Dominion Avenue<br>Broadway | Old Dewdney Trunk Road/<br>132 Avenue | 132 Avenue west of 224 Street<br>Kanaka Way<br>105 Avenue<br>Tamarack Lane |
| Airports | N.A. | N.A. | Pitt Meadows Airport | N.A. |
| Ports & Ferry Terminals | No | 5 major off-dock facilities | Major off-dock facility (Pitt River) | No |
| Police Stations | No | No | No | No |
| Fire Halls | No | Hall 1 (Broadway St.) | No | No |
| Ambulance Stations | No | No | N.A. | No |
| Hospitals | Colony Farm Forensic Psychiatric Hospital | N.A. | N.A. | No |

| | | | | |
|---|---|---|---|---|
| Schools | No | Terry Fox Secondary (SD 43)<br>Blakeburn Elementary (SD 43)<br>Cedar Drive Elementary (SD 43)<br>1 private secondary | Justice Institute- Pitt Meadows Driver Education Centre | Kanaka Creek Elementary (SD 42) |
| Wastewater treatment | Annacis Island (see Delta) | Annacis Island (see Delta) | Annacis Island (see Delta) | Annacis Island (see Delta) |
| Other infrastructure | | | Works Yard | |
| First Nation Reserves | No | COQUITLAM IR2 | KATZIE IR1 | LANGLEY IR5 - south of Highway 7<br>WHONNOCK IR1 - river edge |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 8, SCENARIO C

| Region #8, Scenario C | City of Langley | Township of Langley |
|---|---|---|
| **Infrastructure Type** | **Description** | **Description** |
| Residential Areas | No | Fort Langley - edges |
| Commercial & Industrial Areas | No | Port Kells - NW Langley north of Golden Ears Way |
| Agricultural Areas | No | Glen Valley<br>Fort Langley<br>Derby Reach |
| B.C. Hydro Substations | No | No |
| B.C. Transmission Grid - Major Circuits | No | 69 Kv (Ruskin - Ingledow)<br>69 kV (Tap - Balfour) |
| Railways | No | CN Rail - Fort Langley to Abbotsford |
| Critical Regional Routes* | No | Golden Ears Bridge and Way |
| Other Arterial Roads** | No | 88th Avenue - Fort Langley to Abbotsford<br>96th Avenue - Fort Langley<br>Glover Road - Fort Langley<br>96 Avenue - Fort Langley |
| Airports | N.A. | N.A. |
| Ports & Ferry Terminals | N.A. | N.A. |
| Police Stations | No | No |
| Fire Halls | No | No |
| Ambulance Stations | No | No |
| Hospitals | N.A. | No |
| Schools | No | No |
| Wastewater treatment | No | Northwest Langley wastewater treatment plant |
| Other infrastructure | No | |
| First Nation Reserves | N.A. | MACMILLAN ISLAND IR6<br>KATZIE IR2 |

* Disaster Evacuation Route

** As designated in Official Community Plans

# VULNERABILITY STUDY - REGION 8, SCENARIO D

| Region #8, Scenario D | City of Langley | Township of Langley |
|---|---|---|
| **Infrastructure Type** | **Description** | **Description** |
| Residential Areas | No | Fort Langley - part |
| Commercial & Industrial Areas | No | Port Kells - NW Langley north of 98 Ave. |
| Agricultural Areas | No | Glen Valley<br>Fort Langley<br>Derby Reach |
| B.C. Hydro Substations | No | No |
| B.C. Transmission Grid - Major Circuits | No | 69 Kv (Ruskin - Ingledow)<br>69 kV (Tap - Balfour) |
| Railways | No | CN Rail - Surrey to Abbotsford |
| Critical Regional Routes* | No | Golden Ears Bridge and Way |
| Other Arterial Roads** | No | 88th Avenue - Fort Langley to Abbotsford<br>96th Avenue - Fort Langley<br>Glover Road - Fort Langley<br>96 Avenue - Fort Langley |
| Airports | N.A. | N.A. |
| Ports & Ferry Terminals | N.A. | N.A. |
| Police Stations | No | No |
| Fire Halls | No | No |
| Ambulance Stations | No | No |
| Hospitals | N.A. | No |
| Schools | No | No |
| Wastewater treatment | No | Northwest Langley wastewater treatment plant |
| Other infrastructure | No | |
| First Nation Reserves | N.A. | MACMILLAN ISLAND IR6<br>KATZIE IR2 |

* Disaster Evacuation Route

** As designated in Official Community Plans

# Vulnerability Study - Region 9, Scenario C

| Region #9, Scenario C | Harrison Hot Springs | Mission | District of Kent | Unincorporated Areas North of Fraser River |
|---|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** | **Description** |
| Residential Areas | Entire town | SW Silverdale | Agassiz<br>Mount Woodside | |
| Commercial & Industrial Areas | Entire town | South of 1st Ave. + Logan Avenue | Agassiz | |
| Agricultural Areas | N.A. | South of Silverdale Ave.<br>Three Islands<br>Hatzic | Harrison Mills<br>Seabird Island | |
| B.C. Hydro Substations | No | No | Kent | No |
| B.C. Transmission Grid - Major Circuits | No | 69 kV (Ruskin - Clayburn)<br>69 kV (Stave Falls - Clayburn) | 500 kV (Nicola - Ingledow)<br>360 kV (Upper Harrison to Rosedale) | 69 kV (Waleach - Boston Bar)<br>500 kV (Kelly Lake - Clayburn) |
| Railways | N.A. | CP Rail - 12.56 km<br>Mission Railway Bridge (CP Rail) | CP Rail | CP Rail north of Hope Airpark |
| Critical Regional Routes* | Highway 9 (Hot Springs Road) | Lougheed Highway 9 - 5.3 km west of Downtown Mission<br>Most of distance from Highway 7 to Mission Bridge | Highway 7 - Seabird Island, Agassiz, Harrison Mills<br>Highway 9 - Agassiz-Rosedale Bridge to Lougheed Highway, Hot Springs Road | Highway 7 - Hatzic Lake to Deroche, most of Highway 7 east of Ruby Creek |
| Other Arterial Roads** | N.A. | No | Haig Road | No |
| Airports | N.A. | N.A. | N.A. | N.A. |
| Ports & Ferry Terminals | N.A. | N.A. | N.A. | N.A. |
| Police Stations | N.A. | No | Agassiz RCMP | N.A. |
| Fire Halls | Harrison Hot Springs Fire Dept. | No | Agassiz Fire Dept. | North Fraser Fire Dept. (Deroche) |
| Ambulance Stations | No | No | No | No |
| Hospitals | N.A. | No | N.A. | No |
| Schools | Harrison Hot Springs Elementary (SD 78) | No | Seabird College (Seabird Island) | Dewdney Elementary (SD 75) |

# Vulnerability Study - Region 9, Scenario C

| | | | | |
|---|---|---|---|---|
| Wastewater treatment | Harrison Hot Springs treatment plant | James treatment plant (Abbotsford) | Kent treatment plant | No |
| Other major infrastructure | | | Municipal Hall (road access)<br>Kent Institution (maximum security prison for 420 men)<br>Mountain Institution (medium security prison for 440 men) | Kwìkwèxwelhp Healing Village (Harrison Mills minimum security facility for 50 male offenders) |
| First Nation Reserves | N.A. | THREE ISLANDS IR3<br>LANGLEY IR3 - majority | RUBY CREEK IR 2 - south of Highway 7<br>WAHLEACH ISLAND IR2<br>SEABIRD ISLAND IR 12<br>TSEATAH IR 2<br>SCOWLITZ IR 1 | CHAWATHIL IR4 - south of Highway 7<br>SKAWAHLOOK IR1 - south of Highway 7<br>RUBY CREEK IR2 - southeast of Highway 7<br>CHEHALIS IR5 - southeast part<br>SKUMALASPH IR1B<br>ZAITSCULLACHAN IR9<br>PAPEKWATCHIN IR4<br>YAALSTRICK IR1<br>LAKAHAMEN IR11<br>SKWEAHM<br>SKUMALASPH IR16 |

* Disaster Evacuation Route

** As designated in Official Community Plans

# Vulnerability Study - Region 9, Scenario D

| Region #9, Scenario D | Harrison Hot Springs | Mission | District of Kent | Unincorporated Areas North of Fraser River |
|---|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** | **Description** |
| Residential Areas | Entire town | SW Silverdale | Agassiz<br>Mount Woodside | |
| Commercial & Industrial Areas | Entire town | South of 1st Ave. + Fraser Crescent | Agassiz | |
| Agricultural Areas | N.A. | South of Silverdale Ave.<br>Three Islands<br>Hatzic | Harrison Mills<br>Seabird Island | |
| B.C. Hydro Substations | No | No | Kent | No |
| B.C. Transmission Grid - Major Circuits | No | 69 kV (Ruskin - Clayburn)<br>69 kV (Stave Falls - Clayburn) | 500 kV (Nicola - Ingledow)<br>360 kV (Upper Harrison to Rosedale) | 69 kV (Waleach - Boston Bar)<br>500 kV (Kelly Lake - Clayburn) |
| Railways | N.A. | CP Rail - 12.96 km<br>Mission Railway Bridge (CP Rail) | CP Rail | CP Rail |
| Critical Regional Routes* | Highway 9 (Hot Springs Road) | Lougheed Highway 7 - 5.7 km west of downtown Mission<br>Highway 11 -most of distance from Highway 7 to Mission Bridge | Highway 7 - Seabird Island, Agassiz, Harrison Mills<br>Highway 9 - Agassiz-Rosedale Bridge to Lougheed Highway, Hot Springs Road | Highway 7 - Hatzic Lake to Deroche, most of Highway 7 east of Ruby Creek |
| Other Arterial Roads** | N.A. | No | Haig Road | No |
| Airports | N.A. | N.A. | N.A. | N.A. |
| Ports & Ferry Terminals | N.A. | N.A. | N.A. | N.A. |
| Police Stations | N.A. | No | Agassiz RCMP | N.A. |
| Fire Halls | Harrison Hot Springs Fire Dept. | No | Agassiz Fire Dept. | North Fraser Fire Dept. (Deroche) |
| Ambulance Stations | No | No | #215 (Pioneer Ave.) | No |
| Hospitals | N.A. | No | N.A. | No |

| | | | | |
|---|---|---|---|---|
| Schools | Harrison Hot Springs Elementary (SD 78) | No | Seabird College (Seabird Island)<br>1 elementary<br>1 elementary-secondary (Seabird Island) | Dewdney Elementary (SD 75) |
| Wastewater treatment | Harrison Hot Springs treatment plant | James treatment plant (Abbotsford) | Kent treatment plant | No |
| Other major infrastructure | | EOC in Agassiz (combined facility for both local governments) | Municipal Hall<br>Kent Institution (maximum security prison for 420 men)<br>Mountain Institution (medium security prison for 440 men) | Kwìkwèxwelhp Healing Village (Harrison Mills minimum security facility for 50 male offenders) |
| First Nation Reserves | N.A. | THREE ISLANDS 3<br>LANGLEY IR3 | RUBY CREEK IR 2 - south of Highway 7<br>WAHLEACH ISLAND IR2<br>SEABIRD ISLAND IR 12<br>TSEATAH IR 2<br>SCOWLITZ IR 1 | CHAWATHIL IR4 - south of Highway 7<br>SKAWAHLOOK IR1 - south of Highway 7<br>RUBY CREEK IR2 - southeast of Highway 7<br>CHEHALIS IR5 - southeast part<br>SKUMALASPH IR1B<br>ZAITSCULLACHAN IR9<br>PAPEKWATCHIN IR4<br>YAALSTRICK IR1<br>LAKAHAMEN IR11<br>SKWEAHM<br>SKUMALASPH IR16 |

* Disaster Evacuation Route

** As designated in Official Community Plans

# Vulnerability Study - Region 10, Scenario C

| Region #10, Scenario C | Hope | Chilliwack | Abbotsford | Unincorporated Areas South of Fraser River |
|---|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** | **Description** |
| Residential Areas | Flood-Hope | Rosedale<br>Yarrow<br>Greendale<br>Downtown Chilliwack<br>Sardis - north of Wells Rd. | Sumas Prairie (Sumas Road east to Vedder Canal)<br>Matsqui Prairie<br>Clayburn | |
| Commercial & Industrial Areas | Flood-Hope | Downtown Chilliwack<br>West of Evans Road + north of Highway 1<br>Young Rd./Yale Rd. East corridor<br>Yarrow | Sumas Way | |
| Agricultural Areas | Flood-Hope | Yarrow<br>Greendale<br>Rosedale | Sumas Prairie<br>Matsqui Prairie | |
| B.C. Hydro Substations | No | Atchelitz | Sumas Way<br>Abbotsford | No |
| B.C. Transmission Grid - Major Circuits | 69 kV (Waleach -Hope)<br>69 kV (Waleach - Boston Bar) | 500 kV (Nicola - Ingledow)<br>69 kV (Achelitz - Chilliwack)<br>230 kV (Clayburn - Achelitz)<br>69kV (Tap - Waleach)<br>69 kV (Achelitz - Abbotsford) | 500 kV (Nicola - Ingledow)<br>69 kV (Achelitz - Abbotsford)<br>69 kV (Tap - Trans Mountain) | No |
| Railways | CN Rail - Silver Creek | CN Rail<br>Southern Railway of BC | CN Rail<br>Southern Railway of BC | CN Rail |
| Critical Regional Routes* | Highway 1 - west of Silver Creek | Highway 1 | Highway 1<br>Highway 11 (US Border to Mission) | No |

| | | | | |
|---|---|---|---|---|
| Other Arterial Roads** | Flood-Hope Road | Yale Road East & West<br>Chilliwack Central Rd.<br>Industrial Way<br>Keith Wilson Road<br>Lickman Road<br>Evans Road<br>Prairie Central Road<br>Vedder Road<br>Young Road<br>Prest Road<br>South Sumas Road<br>Sumas Prairie Road<br>Adams Road<br>Yarrow Central Road<br>Prest Road<br>Gibson Road | No additional designated arterial roads in Abbotsford OCP | |
| Airports | Hope Regional Airpark - western half | Chilliwack Airport | No | No |
| Ports & Ferry Terminals | N.A. | N.A. | N.A. | N.A. |
| Police Stations | No | Chilliwack RCMP + Operational & Communications Centre (Airport Road)<br>Sumas Highway Patrol (Airport Road)<br>Downtown Community Policing (Yale Road) | No | No |
| Fire Halls | No | Hall #1 Main (Young Rd.)<br>Hall #2 Rosedale<br>Hall #3 Yarrow<br>Hall #6 Greendale | Hall #2 - Sumas Prairie<br>Hall #4 - Matsqui Village | No |
| Ambulance Stations | No | Yes (Young Rd.) | No | |
| Hospitals | No | Chilliwack General Hospital | No | N.A. |

| | | | | |
|---|---|---|---|---|
| Schools | No | 11 elementary (SD 33)<br>2 middle (SD 33)<br>1 secondary (SD33)<br>4 specialized (SD 33)<br>2 post secondary<br>7 private | 3 elementary (SD 34)<br>1 private elementary | No |
| Wastewater treatment | District of Hope sewage treatment plant | Chilliwack treatment plant (Wolfe Road) | James treatment Plant (Gladwin Road) | |
| Other infrastructure | | City Hall<br>Emil Anderson Maintenance Co. - Rosedale (MoTi contractor) | | |
| First Nation Reserves | GREENWOOD ISLAND IR3 | GRASS IR15<br>SCHELOWAT IR1<br>SKOWKALE IR 10 - eastern part<br>SKWAY IR5 & 8<br>SKWAHLA IR2<br>SKWAH IR4<br>SKWALI IR3<br>KWAW-KWAW-A-PLIT IR6<br>AITCHELITZ IR9<br>LACKAWAY IR2A | UPPER SUMAS IR6<br>AYLECHOOTLOOK IR5<br>SAHH-A-CUM IR1<br>MATSQUI MAIN IR2 - east half<br>SUMAS CEMETERY IR12 | Peters 1<br>Peters 2<br>Ohamil 1<br>CHEAM - northwest part |

* MOTI Disaster Evacuation Route

** Local Government Designations on Official Community Plans

# Vulnerability Study - Region 10, Scenario D

| Region #10 - Scenario D | Hope | Chilliwack | Abbotsford | Unincorporated Areas South of Fraser River |
|---|---|---|---|---|
| **Infrastructure Type** | **Description** | **Description** | **Description** | **Description** |
| Residential Areas | Flood-Hope<br>Silver Creek | Rosedale<br>Yarrow<br>Greendale<br>Downtown Chilliwack<br>Sardis - north of Wells Rd. | Sumas Prairie (Sumas Road east to Vedder Canal)<br>Matsqui Prairie<br>Clayburn | |
| Commercial & Industrial Areas | Flood-Hope | Downtown Chilliwack<br>West of Evans Road + north of Highway 1<br>Young Rd./Yale Rd. East corridor<br>Yarrow | Sumas Way | |
| Agricultural Areas | Flood-Hope | Yarrow<br>Greendale<br>Rosedale | Sumas Prairie<br>Matsqui Prairie | |
| B.C. Hydro Substations | No | Atchelitz | Sumas Way<br>Abbotsford | No |
| B.C. Transmission Grid - Major Circuits | 69 kV (Waleach -Hope)<br>69 kV (Waleach - Boston Bar) | 500 kV (Nicola - Ingledow)<br>69 kV (Achelitz - Chilliwack)<br>230 kV (Clayburn - Achelitz)<br>69kV (Tap - Waleach)<br>69 kV (Achelitz - Abbotsford) | 500 kV (Nicola - Ingledow)<br>69 kV (Achelitz - Abbotsford)<br>69 kV (Tap - Trans Mountain) | No |
| Railways | CN Rail - Silver Creek area | CN Rail<br>Southern Railway of BC | CN Rail<br>Southern Railway of BC | CN Rail |
| Critical Regional Routes* | Highway 1 - west of Silver Creek | Highway 1 | Highway 1<br>Highway 11 (US Border to Mission) | No |

| | | | | |
|---|---|---|---|---|
| Other Arterial Roads** | Flood-Hope Road | Yale Road East & West<br>Chilliwack Central Rd.<br>Industrial Way<br>Keith Wilson Road<br>Lickman Road<br>Evans Road<br>Prairie Central Road<br>Vedder Road<br>Young Road<br>Prest Road<br>South Sumas Road<br>Sumas Prairie Road<br>Adams Road<br>Yarrow Central Road<br>Prest Road<br>Gibson Road | No additional designated arterial roads in Abbotsford OCP | No |
| Airports | Hope Regional Airpark | Chilliwack Airport | No | No |
| Ports& Ferry Terminals | N.A. | N.A. | N.A. | N.A. |
| Police Stations | No | Chilliwack RCMP + Operational & Communications Centre (Airport Road)<br>Sumas Highway Patrol (Airport Road)<br>Downtown Community Policing (Yale Road) | No | No |
| Fire Halls | No | Hall #1 Main (Young Rd.)<br>Hall #2 Rosedale<br>Hall #3 Yarrow<br>Hall #6 Greendale | Hall #2 - Sumas Prairie<br>Hall #4 - Matsqui Village | No |
| Ambulance Stations | No | Yes (Young Rd.) | No | |
| Hospitals | No | Chilliwack General Hospital | No | N.A. |

| | | | | |
|---|---|---|---|---|
| Schools | No | 11 elementary (SD 33)<br>2 middle (SD 33)<br>1 secondary (SD33)<br>4 specialized (SD 33)<br>2 post secondary<br>7 private | 3 elementary (SD 34)<br>1 private elementary | No |
| Wastewater treatment | District of Hope sewage treatment plant | Chilliwack treatment plant (Wolfe Road) | James treatment Plant (Gladwin Road) | No |
| Other infrastructure | | City Hall<br>Emil Anderson Maintenance Co. - Rosedale (MoTI contractor) | | |
| First Nation Reserves | GREENWOOD ISLAND IR3 | GRASS IR15<br>SCHELOWAT IR1<br>SKOWKALE IR 10 & 11<br>SKWAY IR5 & 8<br>SKWAHLA IR2<br>SKWAH IR4<br>SKWALI IR3<br>KWAW-KWAW-A-PLIT IR6<br>AITCHELITZ IR9<br>LACKAWAY IR2A<br>YAKWEAKWIOOSE IR12 - northern half | UPPER SUMAS IR6<br>AYLECHOOTLOOK IR5<br>SAHH-A-CUM IR1<br>MATSQUI MAIN IR2 - east half<br>SUMAS CEMETERY IR12 | Peters 1<br>Peters 2<br>Ohamil 1<br>CHEAM - northwest part |

* MOTI Disaster Evacuation Route

** Local Government Designations on Official Community Plans

## Annex B: Emergency Operation Centres

**Abbotsford**
32315 South Fraser Way
Abbotsford, BC, V2T 1W7
(Abbotsford City Hall)

**Anmore**
2690 East Road,
Anmore, BC

**Belcarra**
4084 Bedwell Bay Road,
Belcarra, BC, V3H 4P8
(Volunteer Fire Department)

**Bowen Island**
788 Grafton Road, Bowen Island
(Fire Hall)

**Burnaby**
Burnaby EOC
6263 Deer Lake Avenue
Burnaby, BC, V5G 3Z8
(BC Court Registry)

Burnaby Alternate EOC
4949 Canada Way
Burnaby, BC, V5G 1M2.
(Burnaby City Hall)

**Chilliwack**
Fire Hall #4
45433 - South Sumas Road
Chilliwack. BC, V2R 2N6

**Coquitlam**
3000 Guildford Way,
Coquitlam, BC
(City Hall)

Alternate EOC
500 Mariner Way, Coquitlam
Austin Service Centre or Works Yard West

Tertiary
1300 Pinetree Way, Coquitlam
(Town Centre Fire Hall)

**Delta**
4500 Clarence Taylor Crescent,
Delta, BC
(Delta Municipal Hall)

Alternate
11375-84th Avenue, Delta
(North Delta Public Safety Building)

**Fraser Valley Regional District**
45950 Cheam Avenue
Chilliwack, BC, V2P 1N6
(Main Fire Hall #1)

**Hope**
325 Wallace Street
Hope, BC, V0X 1L0
(Municipal Hall)

**Kent/Harrison**
7170 Cheam Avenue, Box 70
Agassiz, BC, V0M 1A0
(Municipal Hall)

**Langley** (Township & City)
22170 – 50$^{th}$ Avenue, Langley
(Fire Hall #6)

Alternate
5785 – 203$^{rd}$ Street, Langley
(Fire Hall #1)

**Lions Bay**
410 Centre Road,
Lions Bay, BC
(Fire Hall)

**Maple Ridge**
11995 Haney Place,
Maple Ridge, BC
(Maple Ridge Municipal Hall)

**Mission**
33330 - 7th Avenue
Mission, BC, V2V 2E3
(Fire Hall #1)

**New Westminster**
600 Eighth Street,
New Westminster, BC
(Century House)

**North Vancouver** (City & District)
147 East 14th Street,
North Vancouver, BC
(RCMP)

**Pitt Meadows**
12007 Harris Road,
Pitt Meadows, BC
(Pitt Meadows City Hall)

**Port Coquitlam**
Primary EOC:
#1 Fire Hall
1725 Broadway Street
Port Coquitlam, BC

Secondary EOC
City Hall
2580 Shaughnessy Street
Port Coquitlam, BC

**Port Moody**
3051 St. Johns Street,
Port Moody, BC, V3H 2C4
(Police Dept.)

**Port Metro Vancouver**
100 The Pointe, 999 Canada Place
Vancouver, British Columbia
V6C 3T4

**Richmond**
Room M.2.004 at 6911 No. 3 Rd
Richmond, BC
(City Hall).

Back up EOC is at 5599 Lynas Lane
Richmond, BC (City Works Yard)

**Squamish**
1000 Finch Road,
Squamish, BC
(RCMP)

**Surrey**
8767-132 Street,
Surrey, BC
(Fire Hall #1)

**UBC**
2329 West Mall,
Vancouver, BC
(Land and Building Services Building,
Telestudio Dept.)

**Vancouver**
3301 East Pender Street,
Vancouver, BC
(E-Comm Building)

Alternate
312 Main Street,
Vancouver, BC
(Police Station)

**West Vancouver**
3755 Cypress Bowl Road,
West Vancouver, BC
(Municipal Works Yard &Operations Centre)

**White Rock**
15315 Pacific Avenue,
White Rock, BC
(Fire Hall)

## Annex C: First Nation by Scenario

Number of reserves predicted to experience various degrees of inundation for each Fist Nation and for each flood scenario. A detailed breakdown for each affected First Nation reserve and Treaty Lands[74] follows.

| | Extent of Inundation – Scenario A | | | | |
|---|---|---|---|---|---|
| **First Nation** | **Not Inundated** | **Limited Inundation** | **Partially Inundated** | **Substantially Inundated** | **Completely Inundated** |
| Aitcheliz | | | | | |
| Chawathil | | | | | |
| Cheam | | | | | |
| Katzie | 2.0 | | 1.0 | | |
| Leq'a:mel | | | | | |
| Matsqui | 3.0 | | | | |
| Musqueam | | 1.0 | 1.0 | | 1.0 |
| Peters | | | | | |
| Kwantlen | 3.0 | | | | |
| Kwaw-kwaw-Apilt | | | | | |
| Kwikwetlem | | 2.0 | | | |
| Scowlitz | | | | | |
| Seabird Island | | | | | |
| Semiahmoo | | 1.0 | | | |
| Shxw'ow'hamel | | | | | |
| Skawahlook | | | | | |
| Skowkale | | | | | |
| Skwah | | | | | |
| Skway | | | | | |
| Squamish | | 1.0 | 3.0 | | |
| Squiala | | | | | |
| Sts'ailes | | | | | |
| Sema:th | | | | | |
| Tsawwassen | | | | 0.5 | 0.5 |
| Yakweakwioose | | | | | |
| Yale | | | | | |
| **Total** | **8.0** | **5.0** | **5.0** | **0.5** | **1.5** |

[74] Applies to Tsawwassen

Denotes Reserve is not applicable under the Scenario

| | Extent of Inundation – Scenario B | | | | |
|---|---|---|---|---|---|
| **First Nation** | **Not Inundated** | **Limited Inundation** | **Partially Inundated** | **Substantially Inundated** | **Completely Inundated** |
| Aitcheliz | | | | | |
| Chawathil | | | | | |
| Cheam | | | | | |
| Katzie | 1.0 | 1.0 | | 1.0 | |
| Leq'a:mel | | | | | |
| Matsqui | 3.0 | | | | |
| Musqueam | | 1.0 | 0.5 | 0.5 | 1.0 |
| Peters | | | | | |
| Kwantlen | 3.0 | | | | |
| Kwaw-kwaw-Apilt | | | | | |
| Kwikwetlem | | 1.0 | 1.0 | | |
| Scowlitz | | | | | |
| Seabird Island | | | | | |
| Semiahmoo | | 1.0 | | | |
| Shxw'ow'hamel | | | | | |
| Skawahlook | | | | | |
| Skowkale | | | | | |
| Skwah | | | | | |
| Skway | | | | | |
| Squamish | | | 4.0 | | |
| Squiala | | | | | |
| Sts'ailes | | | | | |
| Sema:th | | | | | |
| Tsawwassen | | | | | 1.0 |
| Yakweakwioose | | | | | |
| Yale | | | | | |
| | | | | | |
| **Total** | **7.0** | **4.0** | **5.5** | **1.5** | **2.0** |

Denotes Reserve is not applicable under the Scenario

| | Extent of Inundation – Scenario C | | | | |
|---|---|---|---|---|---|
| **First Nation** | **Not Inundated** | **Limited Inundation** | **Partially Inundated** | **Substantially Inundated** | **Completely Inundated** |
| Aitcheliz | | | | 0.5 | 1.5 |
| Chawathil | | | | | 2.0 |
| Cheam | | | 1.0 | | 1.0 |
| Katzie | | | 1.0 | 1.0 | 1.0 |
| Leq’a:mel | | 1.0 | 1.5 | 0.5 | 6.0 |
| Matsqui | | | 1.0 | 1.0 | 1.0 |
| Musqueam | 1.0 | 1.0 | | | 1.0 |
| Peters | | | | | 2.0 |
| Kwantlen | | 2.0 | | | 1.0 |
| Kwaw-kwaw-Apilt | | | | | 1.0 |
| Kwikwetlem | | 1.0 | 1.0 | | |
| Scowlitz | | 2.0 | | | 1.0 |
| Seabird Island | | | | | 1.0 |
| Semiahmoo | 1.0 | | | | |
| Shxw’ow’hamel | | | | 1.0 | 1.0 |
| Skawahlook | | | | 1.0 | 1.0 |
| Skowkale | 1.0 | | 1.0 | | |
| Skwah | | | | 1.0 | 4.0 |
| Skway | | | | | 1.0 |
| Squamish | 4.0 | | | | |
| Squiala | | 1.0 | | | 1.0 |
| Sts’ailes | | 1.0 | 1.0 | | |
| Sema:th | | | | 1.0 | |
| Tsawwassen | | | 0.5 | 0.5 | |
| Yakweakwioose | | 1.0 | | | |
| Yale | | | | | |
| | | 1.0 | | | |
| **Total** | **7.0** | **11.0** | **8.0** | **7.5** | **27.5** |

| | Extent of Inundation – Scenario D | | | | |
|---|---|---|---|---|---|
| **First Nation** | **Not Inundated** | **Limited Inundation** | **Partially Inundated** | **Substantially Inundated** | **Completely Inundated** |
| Aitcheliz | | | | | 2.0 |
| Chawathil | | | | | 2.0 |
| Cheam | | | 1.0 | | 1.0 |
| Katzie | | | 1.0 | | 2.0 |
| Leq'a:mel | | 1.0 | 1.5 | 0.5 | 6.0 |
| Matsqui | | | 1.0 | 1.0 | 1.0 |
| Musqueam | | 1.0 | 1.0 | | 1.0 |
| Peters | | | | | 2.0 |
| Kwantlen | | 2.0 | | | 1.0 |
| Kwaw-kwaw-Apilt | | | | | 1.0 |
| Kwikwetlem | | | 1.0 | 1.0 | |
| Scowlitz | | 2.0 | | | 1.0 |
| Seabird Island | | | | | 1.0 |
| Semiahmoo | 1.0 | | | | |
| Shxw'ow'hamel | | | | 1.0 | 1.0 |
| Skawahlook | | | | 1.0 | 1.0 |
| Skowkale | | | 1.0 | 1.0 | |
| Skwah | | | | 0.5 | 4.5 |
| Skway | | | | | 1.0 |
| Squamish | 4.0 | | | | |
| Squiala | | 1.0 | | | 1.0 |
| Sts'ailes | | 1.0 | 1.0 | | |
| Sema:th | | | | 1.0 | |
| Tsawwassen | | | | 1.0 | |
| Yakweakwioose | | | 1.0 | | |
| Yale | | 1.0 | | | |
| | | | | | |
| **Total** | **5.0** | **9.0** | **9.5** | **8.0** | **29.5** |

**Breakdown by First Nation:**

**Aitchelitz First Nation**
Information update largely supplied by Google & Streetview where possible.
Aitchelitch IR No. 9

- Has an area of approximately 21.4 ha in the Sardis region of Chilliwack (IANDC).
- Land uses appear to be industrial, some housing and forest/riparian areas.
- Infrastructure services are unconfirmed.
- Access appears to be via public roads, including Evans Road, Atchelitz Road and Aitken Road.

Extent of Inundation:

- Scenario C: Substantially - completely inundated
- Scenario D: Completely inundated

Grass IR No. 15

- Has an area of 64.8 ha and is located in south east Chilliwack (IANDC).
- Land use appears to be entirely agriculture.
- The reserve is bounded by Prairie Central Rd to the north and Banford Road to the west.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

**Chawathil First Nation**
Information largely supplied by NHC & Urban Systems Report and Google maps/Streetview where possible.
Chawathil IR No. 4

- Has an area of 551.5 ha located along the north bank of the Fraser River, north of the District of Hope.
- Community buildings include housing, a band office, fire hall, church, community hall and storage building. There is also a playing field and cemetery. (NHC report)
- Highway #1 and the CP Rail line pass through the reserve. A natural gas pipeline also crosses the reserve.
- The houses have individual septic tanks and fields.
- As of 1999, the water system consisted of a well, a well house, an underground reinforced concrete reservoir and a gravity fed supply network.

Extent of Inundation:

- Scenario C: Completely inundated (Developed areas moderately inundated)
- Scenario D: Completely inundated (Developed areas substantially inundated)

Greenwood Island IR 3 (Xwelqamex)

- Has an area of 4 ha and is located on a mid-channel island in the Fraser River, near Hope.
- The reserve is uninhabited.
- As of 1980, contains a traditional burial ground.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

**Cheam First Nation**
Information largely supplied by NHC & Urban Systems Report and Google maps/Streetview where possible.
<u>Cheam IR No. 1</u>

- Has an area of 344 ha – consisting primarily of rolling hills.
- Highway 9 divides the reserve in a north-south direction. The CN Railway crosses from the southwest to the northeast, following the south bank of the Fraser River along the eastern half of the reserve.
- A BC Hydro Transmission Line crosses the reserve.
- The reserve has hydro, gas and telephone services (formerly serviced as BC Hydro, BC Gas and BC Tel – now BC Hydro, FortisBC and Telus).
- An industrial area is within the floodplain. In 1999, a sand and gravel facility was located south of the CN Rail line, including a large vehicle maintenance area and several fuel stations. North of the CN Rail line, was an asphalt plant. Appears to be still there.
- Main residential development is located west of Highway 9 and is connected to Chilliwack's municipal water supply.
- A small number reside east of Highway 9 and obtained their water from groundwater wells. Current status is unconfirmed.
- Community buildings may consist of an administration office, a storage building, community hall, church and a concession stand, in addition to any other buildings constructed since the 1999 survey.
- As of 2011, no new subdivisions appear to have been constructed, but may be planned.
- Approximate population is 200+.

Extent of Inundation:

- Scenario C: Partially inundated (Developed areas not largely inundated)
- Scenario D: Partially inundated (Developed areas not largely inundated)

<u>Tseatah IR No. 2</u>

- Has an area of 97 ha and is located on the north bank of the Fraser River, just east of the Rosedale-Agassiz Bridge within the District of Kent.
- Land is flat, lying on the Fraser River floodplain, outside of the Kent District dike system.
- The reserve is bounded by agriculture land to the east, north and west.
- A BC Hydro Transmission Line crosses the reserve north to south.
- As of 1999, the reserve had hydro and telephone services (formerly serviced as BC Hydro and BC Tel – now BC Hydro and Telus).
- Reserve access is through Highway 9.
- Very few buildings exist on site (e.g. five or less). Land is largely reserved for agricultural uses.
- As of 1999, existing buildings were serviced via septic tank and adsorption fields with drinking water obtained from groundwater wells. Current status is unconfirmed.
- A campground/recreational site (Cheam Fishing Village) is situated at the south east corner of the reserve (along Apple Road).
- Level of protection provided by existing dikes (upgraded in 1999 on non-engineered designs and elevations) is uncertain.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

**Katzie First Nation**

Information largely supplied by NHC & Urban Systems Report and Google maps/Streetview where possible.

Katzie IR No. 1

- Has an area of 40 ha on the north bank of the Fraser River downstream of Port Hammond.
- Access to the reserve is via public roads.
- Dock facilities for Band fishing boats. Upper west corner contains a storage facility for boats/trucks/recreational vehicles.
- Woodlot and what appears to be a gravel storage site exist mid-reserve.
- A shake mill used to operate on the leased industrial area at the east end of the reserve. Current status unknown. Lot is situated next to a recycling station (City of Maple Ridge).
- Reserve contains Band Administration office, community buildings (some under construction) and housing, outside of dike protected areas.
- As of 1999, all buildings are on the Pitt Meadows municipal sewer and water systems. Reserve has hydro and telephone services.

Extent of Inundation:

- Scenario A: Not inundated
- Scenario B: Limited inundation
- Scenario C: Partially inundated (Developed areas largely spared inundation)
- Scenario D: Partially inundated (Developed areas suffer some inundation)

Katzie IR No. 2

- Has an area of 23 ha, located on the south bank of the Fraser River, east of Golden Ears Bridge.
- As of 1999, there is a registered archaeological site at the mouth of Yorkson Creek.
- The reserve is outside the Langley Dike.
- The reserve is accessed from the east via a public road, Allard Crescent.
- The reserve is solely used for housing and has remained largely forested. All housing is connected to the Township of Langley Municipal Water system. Septic tanks and adsorption fields are used. Reserve has hydro and telephone services.
- As of 1999, local heavy rains and Fraser River freshets could cause backups for the existing housing.

Extent of Inundation:

- Scenario A: Not inundated
- Scenario B: Not inundated
- Scenario C: Completely inundated
- Scenario D: Completely inundated

Barnston Island IR No. 3

- Has an area of 54.6 ha and is located on the south shore of Barnston Island in the Fraser River, opposite the City of Surrey (IANDC).
- The reserve is largely forested.
- Housing has been developed primarily along the Fraser River, off of Dyke Road (also referred to Centre Road).
- Playfield exists, unconfirmed if other community facilities/amenities exist on the reserve.

Extent of Inundation:

- Scenario A: Partially inundated
- Scenario B: Substantially inundated
- Scenario C: Completely inundated
- Scenario D: Completely inundated

**Leq'a:mel First Nation (formerly Lakahahmen First Nation)**
Information largely supplied by NHC & Urban Systems Report and Google maps/Streetview where possible.

<u>Aylechootlook IR No. 5</u>

- Has an area of 8.10 ha and is located at the junction of Sumas River and the Vedder Canal within the City of Chilliwack (IANDC).
- The reserve appears to be uninhabited, with a service road through the middle, and largely forested.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

<u>Holachten IR No. 8</u>

- Has an area of 110.5 ha and is located on the north bank of the Nicomen slough in the Fraser River (IANDC).
- Highway #7 and the CP Rail line cross the reserve.
- The reserve has community and housing developments in the southwest section, north of Highway #7.

Extent of Inundation:

- Scenario C: Very limited inundation (south of Hwy #7)
- Scenario D: Very limited inundation (sough of Hwy #7)

<u>Lackaway IR No. 2</u>

- Has an area of 15.8 ha on the south bank of the Fraser River at the mouth of Wilson Slough (IANDC).
- The reserve appears to be undeveloped and may be uninhabited.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

<u>Lakahahmen IR No. 11</u>

- Has an area of 38.1 ha and is located on the north bank of Nicomen Slough, at the mouth of Deroche Creek (IANDC).
- Two roads pass through the reserve – Taylor Road and North Nicomen Road.
- The reserve is crossed by the CP Rail line.
- Western sections of the reserve appear to be used for agricultural purposes.
- As of 1999, there were three mobile home parks on the reserve, with hydro and telephone services, but no natural gas. Mobile homes had well water and sceptic sewage systems. Current service status is unconfirmed.

Extent of Inundation:
- Scenario C: Partially - Substantially inundated (One mobile home park inundated)
- Scenario D: Partially - Substantially inundated (One mobile home park inundated)

Papekwatchin IR No. 4
- Has an area of 95.1 ha and is located on the south shore of Nicomen Island in the Fraser River (IANDC).
- The southern portion of the reserve, along the river, is forested while the northern half appears to be for agriculture use.
- The reserve may be uninhabited.

Extent of Inundation:
- Scenario C: Completely inundated
- Scenario D: Completely inundated

Skweahm IR No. 10
- Has an area of 69.4 ha and is located on Nicomen Island in the Fraser River (IANDC).
- Highway #7 crosses the reserve in the north section.
- The reserve leases land for hay production, hosts a mobile home park, as well as several homes and community facilities (e.g. Band office).
- Well water and septic sewage systems supply the buildings on the reserve.
- As of 1999, the reserve has hydro and telephone services but no natural gas lines.

Extent of Inundation:
- Scenario C: Completely inundated
- Scenario D: Completely inundated

Sumas Cemetery IR No. 12
- Has an area of 2.5 ha on the south bank of the Fraser River near the mouth of the Sumas River (IANDC).
- The CN Rail line crosses the reserve.
- The reserve appears to be forested and uninhabited.

Extent of Inundation:
- Scenario C: Partially inundated
- Scenario D: Partially inundated

Yaalstrick IR No. 1
- Has an area of 114.9 ha and is an island in the Fraser River, near Deroche (IANDC).
- The reserve appears to be forested and uninhabited.

Extent of Inundation:
- Scenario C: Completely inundated
- Scenario D: Completely inundated

Zaitscullachan IR No. 9
- Has an area of 22.5 ha and is located along the Zaits-Cullachan Slough of the Fraser River (IANDC).
- Athey No. 1 Road crosses the reserve along the eastern boundary.
- The reserve appears to be for agricultural use. Structures seemingly related to agriculture appear to be on the reserve.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

**Matsqui First Nation**
Information largely supplied by NHC & Urban Systems Report and Google maps/Streetview where possible.

<u>Sahh-a-cum IR No. 1</u>

- Has an area of 20.2 ha and is located south of Clayburn (IANDC).
- The reserve is bisected by two rail tracks and the Abbotsford-Mission Highway.
- The western portion of the reserve appears to be forested.
- The western portion of the reserve appears to be for agriculture use.

Extent of Inundation:

- Scenario A: Not inundated
- Scenario B: Not inundated
- Scenario C: Substantially inundated (Developed areas (eastern section) inundated)
- Scenario D: Substantially inundated (Developed areas (eastern section) inundated)

<u>Matsqui Main IR No. 2</u>

- Has an area of 129.7 ha and is located on the south bank of the Fraser River, near Mt. Lehman (IANDC)
- The CN Rail line crosses the reserve along the north boundary. A second rail line winds through the middle of the reserve.
- A pedestrian/equestrian trail (Trans Canada Trail) crosses the reserve.
- The reserve is bounded by Harris Road to the south and Glenmore Road to the east.
- As of 1999, buildings on the reserve are connected to the Matsqui municipal water and sewerage system. The reserve has hydro, gas and telephone services.
- The western part of the reserve is forested.
- The middle section appears to be for agriculture and industrial use.
- The southeast portion contains housing developments and community facilities.
- A new subdivision development appears to be under construction.

Extent of Inundation

- Scenario A: Not inundated
- Scenario B: Not inundated
- Scenario C: Partially inundated (eastern half of reserve – existing developments)
- Scenario D: Partially inundated (eastern half of reserve – existing developments)

<u>Three Islands IR No. 3</u>

- Has an area of 246.3 ha and is an island in the Fraser River, southwest of Mission (IANDC)
- The reserve appears to be uninhabited and forested.
- Access to the island is only by boat.

Extent of Inundation

- Scenario A: Not inundated
- Scenario B: Not inundated
- Scenario C: Completely inundated

- Scenario D: Completely inundated

**Musqueam First Nation**
Information largely supplied by NHC & Urban Systems Report with updating by on-site observations and Google maps/Streetview.

Musqueam IR No. 2

- Has an area of 180 ha and is located along the north shore of the north arm of the Fraser River, adjacent to the City of Vancouver (IADNC).
- The land is largely developed and primarily used for housing. There are golf courses located on the reserve.
- The reserve is connected to the City of Vancouver water and sanitary sewer systems. It has hydro, gas and telephone services.

Extent of Inundation:

- Scenario A: Partially inundated (largely golf course area & some developed areas)
- Scenario B: Partially - Substantially inundated (lower lying developed areas & golf course)
- Scenario C: Limited inundation (golf course area)
- Scenario D: Partially inundated (golf course and creek)

Musqueam IR No. 4

- Has an area of approximately 60 ha and is located behind the Ladner Dike.
- The reserve is cultivated for agriculture. A few buildings exist on the reserve.
- As of 1999, the reserve has hydro, gas and telephone services. Water is supplied through the Ladner water system. Waste disposal status is unconfirmed.

Extent of Inundation:

- Scenario A: Completely inundated
- Scenario B: Completely inundated
- Scenario C: Completely inundated
- Scenario D: Completely inundated

Sea Island IR No. 3

- Has an area of 6.5 ha and is located at the northwest corner of Sea Island at the outlet of the North Arm of the Fraser River (IANDC). The island holds the Vancouver International Airport, a nature conservation area, the neighbourhood of Burkeville, in addition to the lands under administration by Musqueam.
- The reserve appears to be wetlands and uninhabited.

Extent of Inundation

- Scenario A: Limited inundation (southern tip inundated)
- Scenario B: Limited inundation (southern tip inundated)
- Scenario C: Not inundated
- Scenario D: Limited inundation (southern tip inundated)

**Peters Band**

Information largely supplied by NHC & Urban Systems Report and Google maps/Streetview where possible.

Peters IR No. 1

- Has an area of 170 ha[75] and is located on the south bank of the Fraser River, upstream from the Agassiz-Rosedale Bridge, near Hope.
- The reserve contains several community buildings including a hall, an office building, and houses.
- As of 1999, water was supplied from groundwater wells, and each house had an individual septic tank and adsorption field.
- Land is typically used for housing, agriculture with a portion for raising beef cattle.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated
- *Peters IR No.1A is not inundated.*

Peters IR No. 2

- Has an area of approximately 36 ha and is located on the western half of Peters Island, in the Fraser River.
- The reserve is uninhabited. An access road runs on top of the dike along the north side of the Island.
- Land typically used for growing hay and open pasture.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

**Kwantlen First Nation**

Information largely supplied by Google maps/Streetview where possible.

Whonnock IR No. 1

- Has an area of 34.4 ha and is located on the north bank of the Fraser River (IANDC).
- The reserve is largely forested.
- Highway #7 and the CP Rail line cross the reserve.
- A few structures exist on the reserve, including an industrial (wood mill) situated off Hwy #7.

Extent of Inundation:

- Scenario A: Not inundated
- Scenario B: Not inundated
- Scenario C: Limited inundation (section south of Hwy 7)
- Scenario D: Limited inundation (section south of Hwy 7)

Langley IR No. 5

- Has an area of 140.6 ha and is located on the north bank of the Fraser River (City of Maple Ridge) (IANDC).
- Highway #7 and the CP Rail line cross the reserve.

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[75] IANDC lists the reserve with an area of 131 ha. http://pse5-esd5.ainc-inac.gc.ca/fnp/Main/Search/FNReserves.aspx?BAND_NUMBER=586&lang=eng

- The reserve is largely forested.
- A few structures exist on the reserve. Appears to have begun activity on the northern half of the reserve – appears to be for either industrial or subdivision development.

Extent of Inundation:

- Scenario A: Not inundated
- Scenario B: Not inundated
- Scenario C: Limited inundation (southern section along river)
- Scenario D: Limited inundation (southern section along river)

McMillan Island IR No. 6

- Has an area of 191.0 ha and is an Island in the Fraser River, near the Township of Langley/Fort Langley.
- Ferry services (to Maple Ridge) have ceased, however the docks are still there.
- Access is provided by Glover Road bridged over a channel of the Fraser River.
- Northern portion of the reserve is forested. Southern portion is open field, partially used for agriculture and playing fields.
- Community facilities exist on the reserve, including a heritage church and a newly constructed cultural facility.

Extent of Inundation:

- Scenario A: Not inundated
- Scenario B: Not inundated
- Scenario C: Completely inundated
- Scenario D: Completely inundated

**Kwaw-kwaw-Apilt First Nation**

Kwakwawapilt IR No. 6

- Has an area of 62.7 and is located southwest of Chilliwack (IANDC).
- The northern portion of the reserve is forested.
- The southern portion is used for agricultural.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

**Kwikwetlem First Nation**

Information largely supplied by NHC & Urban Systems Report and Google maps/Streetview where possible.

Coquitlam I.R. 1 (slakəya'nc)

- Has an area of 2.6 ha and is located along the west bank of Coquitlam River, just upstream of the confluence with the Fraser River (IANDC).
- Very developed reserve, with many structures including the Band Office and housing.

Extent of Inundation:

- Scenario A: Very Limited inundation (strip along river)
- Scenario B: Limited inundation (strip along river)
- Scenario C: Limited inundation (strip along river)
- Scenario D: Partially inundated (Developed areas impacted)

Coquitlam I.R. 2 (setłama'kmən)

- Has an area of 81.9 ha and is located on the east bank of the Coquitlam River, upstream from slakəya'nc (IANDC).
- Construction appears to be underway in the southeast portion of the reserve. Remainder of the reserve is forested.
- Traboulay PoCo Trail crosses the reserve north-south.

Extent of Inundation:

- Scenario A: Limited inundation
- Scenario B: Partially inundated
- Scenario C: Partially inundated
- Scenario D: Substantially inundated

**Scowlitz First Nation**

Information largely supplied by NHC & Urban Systems Report and Google maps/Streetview where possible.

Scowlitz IR No. 1

- Has an area of 69 ha, and is located on the north shore of the Fraser River, near Harrison Bay (IANDC).
- Dyke Road runs along the southern boundary of the reserve, next to the Fraser River.
- The land is generally flat and forested. As of 1994, a western portion had been leased for farmland (as of 2015 – land still used for agricultural purposes).
- As of 1999, a possible village site with important archeological value was thought to be along the shoreline. Status to be confirmed.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

Williams IR No. 2

- Has an area of 9.7 ha and is located on the western bank of Harrison River, across from Scowlitz IR No. 1 (IANDC).
- Appears to be forested and uninhabited.

Extent of Inundation:

- Scenario C: Limited inundation (mainly 'island' is inundated)
- Scenario D: Limited inundation (mainly 'island' is inundated)

Squawkum Creek IR No. 3

- Has an area of 158.0 ha and is located along the southwest shore of Harrison Bay (IANDC).
- Access to the reserve is off of Highway 7.
- Recent development has occurred – additional subdivisions have been built as well as community buildings (e.g. administration buildings or a cultural centre – to be confirmed), a playground, sports fields, etc.
- As of 1999, the buildings were on water and had individual septic tanks and fields. The reserve was connected to hydro and telephone services.

Extent of Inundation:

- Scenario C: Limited inundation
- Scenario D: Limited inundation (waters abut new development)

**Seabird Island First Nation**
Information supplied by Google maps/Streetview where possible.
Seabird Island
- Has an area of 2,179 ha and is located in the Fraser River, east of Agassiz (IANDC).
- Highway 7 & the CP Rail line cross the reserve.
- The reserve appears to be largely for agriculture use.
- There is a community development on the southwest side of the reserve. Community facilities include Administration offices, community centre, playing fields, hockey box, housing developments and an EcoStation (composting facility)
- Reserve is the site for the Seabird Island Community School as well as Seabird College.
- Seabird Nation provides Wi-Fi to community members.

Extent of Inundation:
- Scenario C: Completely inundated
- Scenario D: Completely inundated

**Semiahmoo First Nation**
Information supplied by Google maps/Streetview where possible.
Semiahmoo IR
- Has an area of 129.1 ha and is located along Semiahmoo Bay, southeast of White Rock (IANDC).
- The reserve is largely forested. Campbell river crosses the northern section of the reserve.
- Beach Road crosses the reserve.
- Housing developments next to the water, along Beach Road.

Extent of Inundation:
- Scenario A: Limited inundation (some development impacted)
- Scenario B: Limited inundation (some development impacted)
- Scenario C: Not inundated
- Scenario D: Not inundated

**Shxw'ow'hamel First Nation**
Information supplied by NHC & Urban Systems Report and Google maps/Streetview where possible.
Ohamil IR No. 1
- Has an area of 163.50 ha on the south bank of the Fraser River, downriver from the District of Hope (IANDC).
- Highway #1 and the CN Rail line cross the reserve.
- Access is via St. Elmo Road from the north.
- Reserve is largely forested. The 200 NHC & Urban Systems Report indicates an apple & hazelnut orchard and a commercial cottonwood plantation. Orchards are still there, commercial status uncertain.
- Community facilities include the Band Administration Office, a church and houses. The houses are serviced by a community well and have individual septic tanks and adsorption fields.
- As of 1999, hydro and telephone services were provided by BC Hydro and BC Tel (now Telus).

- NHC Report indicates a high voltage power line and a pipeline cross the reserve. Unconfirmed via Google Maps for 2015.

Extent of Inundation:

- Scenario C: Substantially inundated
- Scenario D: Substantially inundated

Wahleach Island IR No. 2

- Has an area of approximately 56.50 ha and is located on the north bank of the Fraser River (IANDC). It is now part of a slough.
- It is largely uninhabited. There are a few buildings on the northern part of the reserve – campground was attempted years ago. Status is unknown.
- Highway 7 and the CP Rail mainline cross the reserve.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

**Skawahlook First Nation**

Information largely supplied by Google maps/Streetview where possible.

Skawahlook IR No. 1

- Has an area of 58.3 ha and is located on the north shore of the Fraser River, 1 mile from Ruby Creek (IANDC).
- Highway 7 and the CP Rail line cross the reserve
- The northern portion of the reserve appears to be forested. The southern portion has a few structures and some informal agricultural (e.g. orchard).

Extent of Inundation:

- Scenario C: Partially inundated (southern portion subject to inundation)
- Scenario D: Partially inundated (southern portion subject to inundation)

Ruby Creek IR No. 2

- Has an area of 16.6 ha and is located on the north shore of the Fraser River at the mouth of Ruby Creek (IANDC).
- Highway 7 and CP Rail line cross the reserve.
- Appears to be no development between the CP Rail line and the shore.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

**Skowkale First Nation**

Information supplied by NHC & Urban Systems Report and Google, where possible.

Skowkale IR No. 10

- Has an area of 56.7 ha and is located one mile east of Sardis (IANDC).
- Chilliwack River Road runs through the reserve on the western boundary. Housing developments are off of Chilliwack River Road.
- Northern portion of the reserve has many housing subdivisions.
- Southeastern portion of the reserve appears to be for agricultural uses (adjoins Yakweakwioose IR No. 12)
- There is a cemetery on the reserve.

Extent of Inundation:
- Scenario C: Partially inundated
- Scenario D: Substantially inundated

<u>Skowkale IR No. 11</u>
- Has an area of 12.3 ha and is located opposite Skowkale IR No. 10 (IANDC).
- Reserve is bounded by Knight Street to the north.
- Western portion of the reserve is housing subdivisions.
- Northeast section is for commercial/industrial use.
- Northwest section is agricultural.

Extent of Inundation:
- Scenario C: Not inundated
- Scenario D: Partially inundated

**Skwah Indian Band**
Information supplied by NHC & Urban Systems Report and Google, where possible.
<u>Schelowat IR No. 1</u>
- Has an area of 85.2 ha and is located on the Hope Slough bank, east of Chilliwack (IANDC).
- Reserve is bounded by Chapman Road to the east and Yale Road to the south.
- Reserve has a few structures on the northeast corner.
- Land use appears to be fields with some agricultural in the northwest corner.

Extent of Inundation:
- Scenario C: Completely inundated
- Scenario D: Completely inundated

<u>Skwahla IR No. 2</u>
- Has an area of 11.7 ha and is located on the Hope Slough (IANDC).
- Land appears to be entirely forested and uninhabited.
- As of 1999, the reserve is reported to contain unmarked burial grounds.

Extent of Inundation:
- Scenario C: Substantially - Completely inundated
- Scenario D: Substantially - Completely inundated

<u>Skwali IR No. 3</u>
- Has an area of 188.5 ha and is located northwest of Chilliwack (IANDC).
- Eastern portion of the reserve appears to be for agricultural uses.
- Western portion appears to be forested.
- Few structures on the reserve. Not largely habited.

Extent of Inundation:
- Scenario C: Completely inundated
- Scenario D: Completely inundated

<u>Skwah IR No. 4</u>
- Has an area of 126.3 ha and is located west of Chilliwack (IANDC).
- Lower Landing Road crosses the reserve east-west and Dyke Road crosses meanderingly north-south.

- Reserve is bounded by Ashwell Road to the east.
- Northern portion of the reserve is largely for agricultural uses with some community facilities, including housing developments, and as of 1999, a community hall and school.
- Southern portion appears to be for industrial/commercial uses, including the Greg Moore Raceway.
- As of 1999, the buildings had hydro, gas and telephone service. Additionally, most buildings on the reserve were connected to the Chilliwack water supply and sewer network.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

<u>Skumalasph IR No. 16</u>

- Has an area of 468.4 ha and is located northwest of Chilliwack (IANDC).
- Reserve is bounded by Dyke Road to the east/south. Nicomen Slough to the north.
- Appears to be forested and potentially uninhabited.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

**Shxwhá:y Village (Skway Indian Band)**

Information supplied by NHC & Urban Systems Report and Google maps/Streetview where possible.

<u>Skway IR No. 5 (Shxwa:y Village)</u>

- Has an area of 255 ha, consisting of flat low-lying ground, west of the City of Chilliwack along the Fraser River (IANDC)
- The Chilliwack District Dike crosses the southeast corner of the reserve. The reserve has hydro, gas and telephone services (formerly serviced as BC Hydro, BC Gas and BC Tel – now BC Hydro, FortisBC and Telus). It is connected to the City of Chilliwack water supply.
- Access to the reserve is via Chilliwack Mountain Road and Wolfe Road. Potentially through Lower Landing Road as well.
- A large portion of the land has been cleared and leased for farming.
- Gravel extraction has been carried out in several locations.
- Two man-made lakes have been constructed as part of future development plans for a marina, boutique hotel, fishing services and recreational activities (Shxwhá:y Village).
- A major infrastructure development is underway – White Feather Tissue Plant Inc. (Shxwhá:y Village).
- The developed land has been mostly used for houses – the majority built post-1980.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

**Sk̲wxwú7mesh (Squamish) First Nation**

Information largely supplied by Arlington Group research and Google maps/Streetview where possible.

<u>Stawamus IR No. 24 (St'a7mes)</u>

- Has an area of 22.1 ha and is located at the mouth of the Stawamus River at the head of Howe Sound (IANDC).
- Highway 99 crosses the reserve as does the CN Rail line.
- Western section of the reserve is developed, with community facilities (e.g. education and health services), housing and satellite offices for the Squamish Nation.
- Some industrial use on the southwestern corner of the reserve.
- Eastern section of the reserve is for commercial use.

Extent of Inundation:

- Scenario A: Limited Inundation
- Scenario B: Partially inundated

Capilano IR No. 5 (Xwemelch'stn/Homulchesan)

- Has an area of 155.6 ha and is located on the north shore of Burrard Inlet at First Narrows, at the north end of Lions Gate Bridge (IANDC).
- Rail line crosses the reserve.
- Some forested pockets on the reserve.
- Largely developed, with over 500 houses and community facilities, including administration & community facilities.

Extent of Inundation:

- Scenario A: Partially inundated (developed areas subject to inundation)
- Scenario B: Partially inundated (developed areas subject to inundation)
- Scenario C: Not inundated
- Scenario D: Not inundated

Mission IR No. 1 (Eslha7an)

- Has an area of 59.6 ha and is located on the north shore of Burrard Inlet on Wagg and Mosquito Creeks, bounded on the north and east by the City of North Vancouver (IANDC).
- Rail line crosses the reserve.
- It is a National Historic Site of Canada (very old church).
- Land is very developed, including housing, community facilities (e.g. Training Centre, Employment Centre, Health & Family Centre) and commercial (e.g. Mosquito Creek Marina)

Extent of Inundation:

- Scenario A: Southern sections partially inundated/ Northern sections not inundated
- Scenario B: Southern sections partially inundated/ Northern sections not inundated
- Scenario C: Not inundated
- Scenario D: Not inundated

Seymour Creek IR No. 2

- Has an area of 45.5 ha and is located on the north shore of Burrard Inlet, on the (right) bank of Seymour Creek, near the mouth of Second Narrows (IANDC).
- Reserve is bounded by Seymour Boulevard to the west.
- Land use appears to be largely industrial/commercial.

Extent of Inundation:

- Scenario A: Southern sections partially inundated/ Northern sections not inundated
- Scenario B: Southern sections partially inundated/ Northern sections not inundated

- Scenario C: Not inundated
- Scenario D: Not inundated

**Squiala First Nation**
Information largely supplied by Google maps/Streetview where possible.
<u>Squiaala IR No. 7</u>

- Has an area of 86.6 ha and is located southwest of Chilliwack (IANDC).
- Evans Road crosses the road in a north-south direction.
- The southern portion of the reserve is forested.
- The northern portion of the site is for commercial – including a Walmart Supercentre.

Extent of Inundation:

- Scenario C: Completely inundated
- Scenario D: Completely inundated

<u>Squiaala IR No. 8</u>

- Has an area of 46.5 and is located on the left bank of the mouth of Chilliwack River (IANDC).
- Chilliwack Mountain Road crosses and provides access to the reserve.
- The reserve is largely forested.
- The reserve has a few established homes/structures.

Extent of Inundation:

- Scenario C: Limited inundation
- Scenario D: Limited inundation

**Sts'ailes First Nation (formerly Chehalis Indian Band)**
Information largely supplied by NHC & Urban Systems Report and Google maps/Streetview where possible.
<u>Chehalis IR No. 5</u>

- Has an approximate area of 881 ha along the north bank of the Harrison River, downstream of Harrison Lake (IANDC)
- Access to the reserve is from the Morris Valley Road, via Chehalis Road.
- Forestry and fishery related economic development activities occur on the reserve.
- As of 1999, hydro and telephone services were provided. Private housing was serviced by electricity or propone and had individual septic tanks and fields. Current status is unknown.
- According to the 2015 website, the Reserve has 15 Community Buildings, one community long house, two family owned longhouses, eight social housing units, one Elder Care Facility, one community church, 55 band rental units, 85 individually owned homes, and five trailers.
- Community facilities include 2 soccer fields, 1 hockey box, 1 skate park, and a community hall. There is a Gas Bar & Store and Fire Hall.

Extent of Inundation:

- Scenario C: Partially inundated (inundation largely south of Chehalis Road)
- Scenario D: Partially inundated (inundation largely south of Chehalis Road)

Chehalis IR No. 6

- Has an area of 25.5 ha and is located on the south bank of Harrison River, opposite Chehalis IR No. 5 (IANDC).
- Reserve appears to be forested and uninhabited.

Extent of Inundation:

- Scenario C: Limited inundation
- Scenario D: Limited inundation

**Sema:th (Sumas) First Nation**

Information largely supplied by NHC & Urban Systems Report and Google maps/Streetview where possible.

Upper Sumas IR No. 6

- Has an area of approximately 235 ha and is located near Kilgard (Abbotsford).
- A section of non-reserve land (industrial use) occupies a space surrounded by reserve land.
- Reserve land is leased for farming to the south, with administration buildings and additional housing developments to the north and east.
- As of 1999, water supply came from two wells. The houses are connected to the municipal sewage system. The reserve has hydro and telephone services. Natural Gas services are unconfirmed.
- Highway #1 and a BC Hydro transmission line cross through the middle of the reserve.

Extent of Inundation:

- Scenario C: Substantially inundated
- Scenario D: Substantially inundated

**Tsawwassen First Nation**

Information supplied by NHC & Urban Systems Report, Indigenous and Northern Affairs Canada and Google maps/Streetview where possible.

Tsawwassen Final Agreement consists of 724 ha of Treaty Settlement Land with

- 290 hectares of former reserves
- 372 hectares of former provincial Crown land.
- 62 hectares of fee simple land along Boundary Bay Fraser River near Ladner.
- 495 hectares of former reserve and provincial Crown land will remain excluded from the ALR or not be subject to ALC jurisdiction.
- Tsawwassen First Nation has right of refusal for 80 years (2089) to purchase approximately 278 hectares of lands in Brunswick Point.
- The South Fraser Perimeter Road/Highway #17 crosses the land.
- Tsawwassen Drive provides access to the land, from the SFPR.
- Two large-scale indoor malls with 63,000 m2 of commercial floor space are under construction with completion scheduled for 2016.

Extent of Inundation:

- Scenario A: Substantially – Completely inundated
- Scenario B: Completely inundated
- Scenario C: Partially - Substantially inundated
- Scenario D: Substantially inundated

**Yakweakwioose**

Information supplied by Google maps/streetview where possible.

Yakweakwioose IR No.12

- Has an area of 19.4 ha and is located southwest of Skulkayn IR No. 10 (IANDC).
- Reserve is bounded by Chilliwack River Road along the south.
- Reserve is largely agricultural with related housing/structures established.

Extent of Inundation:

- Scenario C: Limited inundation
- Scenario D: Partially inundated

**Yale First Nation**

Information supplied by Good maps/Streetview where possible.

Lukseetsissum IR No. 9

- Has an area of 53.9 ha and is located on the north bank of the Fraser River at Ruby Creek (IANDC)
- Development, including housing, exists to the northeast of the reserve.
- Ruby Creek IR No. 2 is adjacent to the reserve.

Extent of Inundation:

- Scenario C: Limited inundation
- Scenario D: Limited inundation

# Annex D: List of Acronyms

List of acronyms used in report:

IANDC – Indigenous Affairs and Northern Development Canada (formerly Aboriginal Affairs and Northern Development Canada)
AEP – Annual Exceedance Probability
BCAS – British Columbia Ambulance Services
BCEHS – British Columbia Emergency Health Services
BCPTN – British Columbia Patient Transfer Network
BCOL – BC Rail
BCRTC – British Columbia Rapid Transit Company Ltd.
BNSF – Burlington Northern Santa Fe Railway
BPA – Bonneville Power Administration
CMBC – Coast Mountain Bus Company Ltd.
CN Rail – Canadian National Railway
CP Rail – Canadian Pacific Railway
CCT – Critical Care Transfer (part of BCPTN)
CWTP – Coquitlam Water Treatment Plant
EMS – Emergency Medical Services
FVRD – Fraser Valley Regional District
HVAC – Heating, Ventilation and Air Conditioning
MoTI – Ministry of Transportation and Infrastructure
NOAA National Oceanic and Atmospheric Administration
SAR – Search and Rescue
SCFP – Seymour-Capilano Filtration Plant
SFPR – South Fraser Perimeter Road
SLR – Sea Level Rise
SRY – Southern Railway of British Columbia
VCH – Vancouver Coastal Health
VIA – VIA Rail
YVR – Vancouver International Airport
YXX – Abbotsford International Airport

# Appendix C: Hazus Analysis Information

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# 1 HAZUS ANALYSIS INFORMATION

## 1.1 Introduction to Hazus Modelling

Different software options are available for estimating the direct losses associated with flooding. Following careful evaluation, Hazus-MH 2.1 was selected for the analysis. Hazus is a “standardized methodology that contains models for estimating potential losses from earthquakes, floods and hurricanes. Hazus uses GIS technology to estimate physical, economic and social impacts of disasters”[1]. Hazus was developed by the US Federal Emergency Management Agency (FEMA), is widely used in the US, and is freely distributed. Over the past few years, Natural Resources Canada (NRCan) has worked with FEMA to adapt Hazus for use in Canada[2]. The first non-beta version of the Hazus-MH 2.1 Canadian Flood Module was made available by NRCan in late summer 2014, and officially released in November 2015.

Although Hazus was developed in the US, is relatively new to Canada, and the Canadian version has a number of limitations, it was still considered the most viable tool for an overview-level assessment, primarily because its building inventory is tied to census data. For this study, we used Canadian Hazus MH 2.1. This was run with Esri ArcGIS 10.0 (SP2), including the Spatial Analyst extension.

NHC consulted NRCan regarding apparent Hazus software shortcomings and their assistance with developing workable solutions is acknowledged.

## 1.2 Hazus Analysis: Study Region Setup

### 1.2.1 Study Regions

It was anticipated that running the entire Lower Mainland study area as a single analysis region in Hazus could cause problems in terms of file sizes and processing times. However, running each municipality as a separate analysis region would have been too time consuming. As a compromise, the study area was divided into ten Hazus Study Regions, as described in Table 1 and Figure 1.

Flood hazard mapping for the Lower Mainland was generated based on these Study Regions.

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[1] US Federal Emergency Management Agency (FEMA) Hazus, http://www.fema.gov/Hazus

[2] Hazus Canada, http://Hazuscanada.ca/node/134

**Table 1. Summary of municipalities in Hazus Study Regions**

| Study Region | Description |
|---|---|
| 1 | Squamish |
| 2 | North Shore (Lions Bay, West Vancouver, North Vancouver City & District) |
| 3 | Port Moody, Anmore, Belcarra |
| 4 | Vancouver, Burnaby, New Westminster |
| 5 | Richmond, Delta |
| 6 | Surrey, White Rock, Barnston Island |
| 7 | Coquitlam, Port Coquitlam, Pitt Meadows, Maple Ridge |
| 8 | Langley City & Township |
| 9 | Mission, Harrison Hot Springs, Kent, unincorporated areas of FVRD north of the Fraser |
| 10 | Abbotsford, Chilliwack, Hope, unincorporated areas of FVRD south of the Fraser |

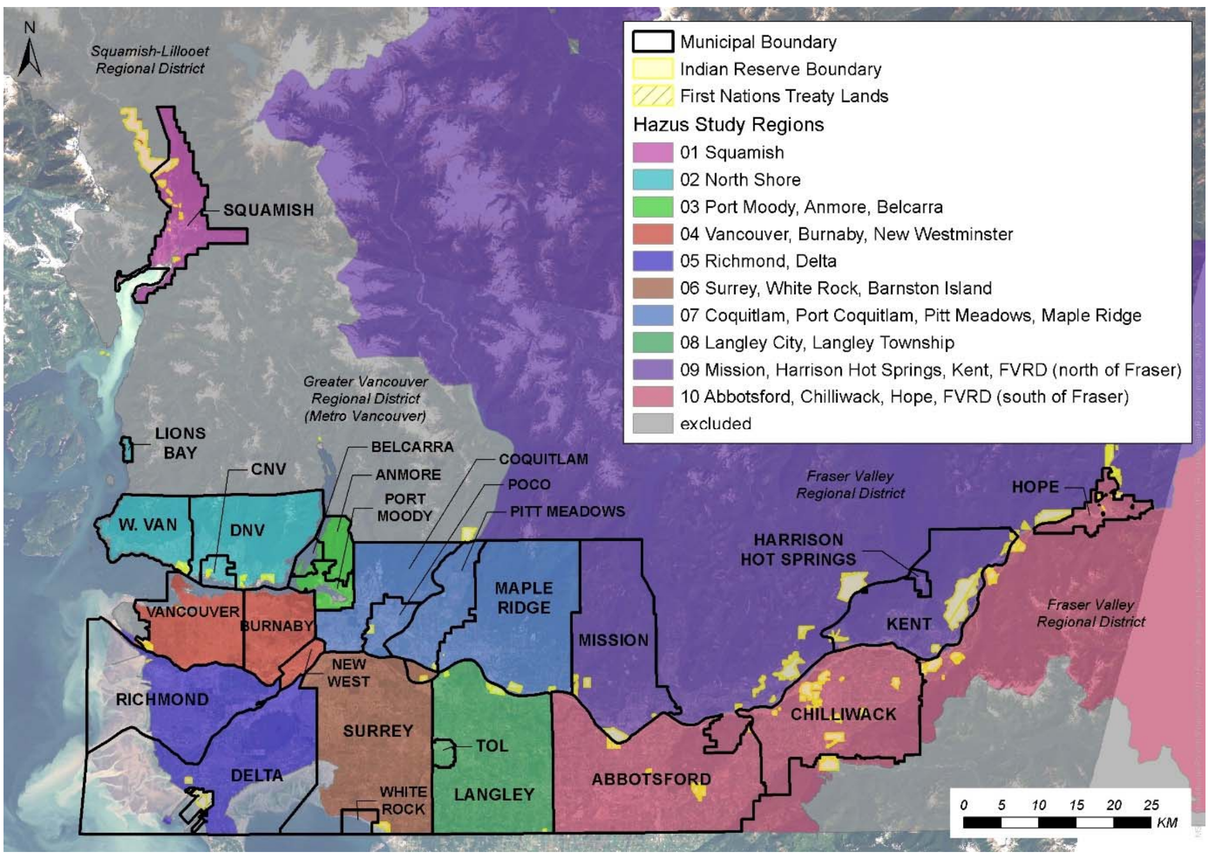


**Figure 1. Map of Hazus Study Regions**

The coastal flood scenarios were modelled for Study Regions 1 to 7; the riverine scenarios were modelled for Study Regions 4 to 10. For the City of White Rock within Study Region 6, only the coastal flood scenarios were modelled, not the riverine scenarios. In addition, within Study Region 7, the City of Maple Ridge was only assessed for riverine flood scenarios, and not coastal scenarios.

### 1.2.2 Software Bugs and Workarounds

Several bugs were identified while using Hazus for this project. NHC documented these bugs, and worked with NRCan to try to resolve them. In all cases, workarounds were found, and there was no significant impact on the analysis results reported for this project.

For details, see the following threads on the Hazus Canada Discussion page (http://Hazuscanada.ca/node/162/content/discussions):

- "Loss calculation errors after updating inventory data" (started 24-Mar-2015)
- "Hospital Damage report will not generate" (started 27-May-2015)
- "Shelter Requirements do not generate" (started 28-May-2015)

## 1.3 Hazus Analysis: Flood Hazard Mapping

Flood depths were determined by subtracting the digital elevation model (DEM) from the flood water level for each scenario. Flood extent polygons were derived from the flood depth surfaces. In order to facilitate efficient analysis in Hazus, flood hazard mapping was grouped into several Study Regions.

Development of flood water level surfaces is described in Section 3 of the main report.

### 1.3.1 DEM Processing

DEM data was obtained from various sources, listed in Table 2 and illustrated in Figure 2. These data were combined to create a single DEM for each of the ten Study Regions.

**Table 2. DEM Data Sources**

| Municipality | Data Source | Description |
|---|---|---|
| Squamish | Natural Resources Canada, District of Squamish, BC Hydro | 2.5 m DEM from Lidar |
| Lions Bay | Lions Bay | 2012 Lidar |
| West Vancouver | District of West Vancouver | 2011 one-metre contours |
| North Vancouver (City) | City of North Vancouver | 2013 Lidar |
| North Vancouver (District) | District of North Vancouver | 2014 Lidar |
| Port Moody, including parts of Belcarra and Anmore | City of Port Moody | 2012 1.37 m DEM |
| Vancouver | City of Vancouver, NHC | 2013 Lidar |
| Burnaby (Big Bend) | City of Burnaby, FBC | 2014? one-metre contours |
| New Westminster | Port Metro Vancouver, FBC, CDEM | 2012 Lidar (PMV), 2004 Lidar (FBC), CDEM |
| Coquitlam | City of Coquitlam | 2012 & 2014 Lidar |
| Port Coquitlam | City Pitt Meadows, City of Coquitlam | 5 m DEM (Pitt Meadows), 2012 & 2014 Lidar (Coquitlam) |
| Pitt Meadows | Pitt Meadows | 5 m DEM |
| Maple Ridge | Pitt Meadows | 5 m DEM |
| Mission | FBC, BC Hydro | 2004 Lidar (FBC), 2008 Lidar (BC Hydro) |
| Harrison Hot Springs | FBC | 2004 Lidar |
| Kent | District of Kent, BC Hydro, FBC | various contours (Kent), 2004 Lidar (FBC), 2008 Lidar (BC Hydro) |
| Chilliwack | BC Hydro | 2008 Lidar |
| Hope | BC Hydro, CDEM | 2008 Lidar, CDEM |
| Richmond | Integrated Mapping Technologies | 2011 DEM |
| Delta | Corporation of Delta | 0.5 m 2014 contours |
| Surrey | City of Surrey | 2013 Lidar |
| White Rock | City of White Rock | one-metre contours |
| Barnston Island | FBC | 2004 Lidar |
| Langley (City) | City of Langley | 2007 one-metre contours |

| | | |
|---|---|---|
| Langley (Township) | Township of Langley | 2012 one-metre contours; 2010 spot elevations |
| Abbotsford | City of Abbotsford | one-metre contours |
| Lower Fraser River (Mission to mouth; and Pitt River) | FBC | 2004 Lidar |
| Matsqui/Mission | FBC | 2004 Lidar |
| Kent-Agassiz, Harrison Hot Springs | FBC | 2004 Lidar |
| Hope to Mission | BC Hydro | 2008 Lidar |

**Notes:**

1. FBC = Fraser Basin Council
2. CDEM = Canadian Digital Elevation Model, available from Geogratis.ca
3. Belcarra and Anmore are missing coverage along Indian Arm. Note that there is not extensive coastal flooding in this area.
4. The University of British Columbia has no coverage. Note that there is not extensive coastal flooding in this area.
5. The City of Burnaby did not provide coverage for the Burrard Inlet shoreline. Note that there is not extensive coastal flooding in this area.

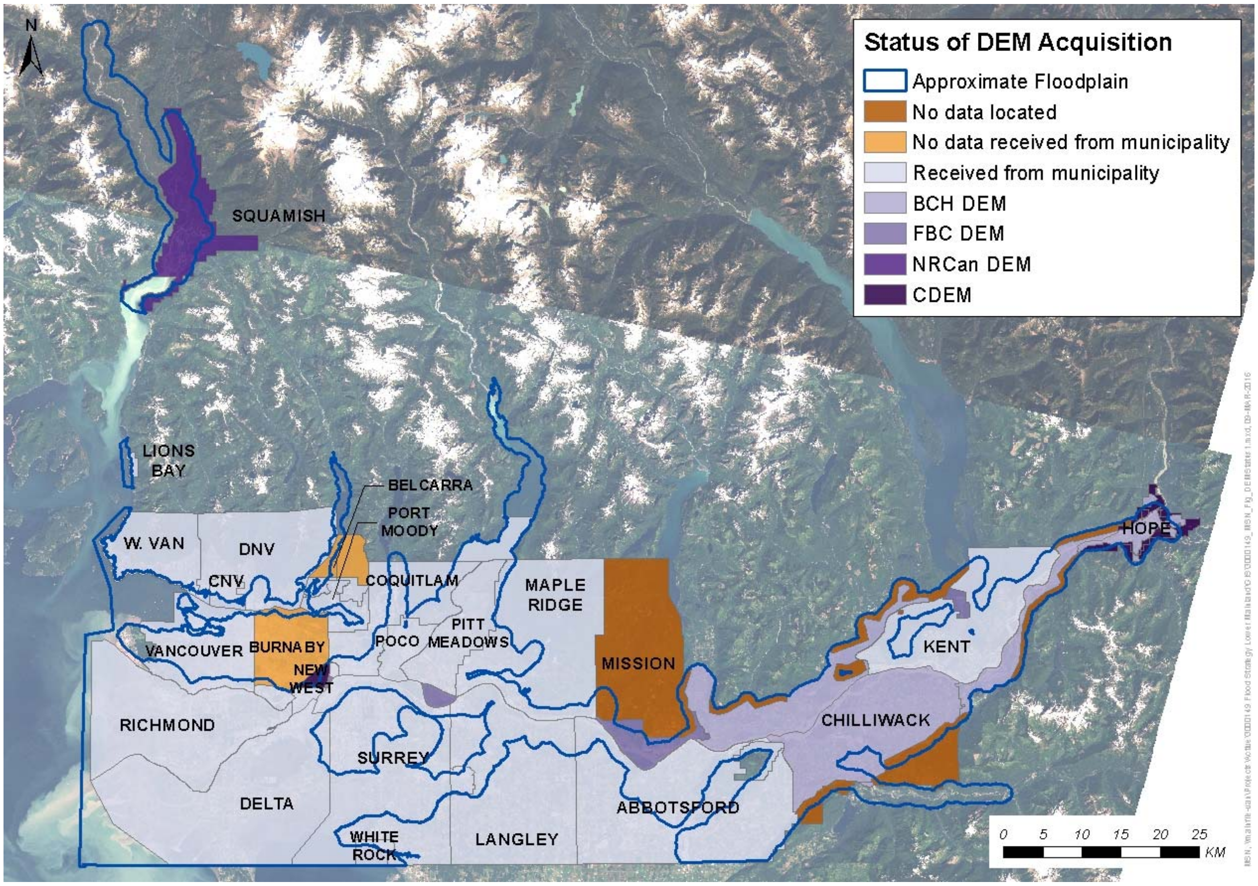


**Figure 2. Topographic Data Sources**

Individual DEM surfaces with a horizontal resolution of five metres were mostly used to create the Study Region DEMs. For Study Regions 9 and 10, where input data was primarily of a lower resolution, a horizontal resolution of ten metres was used for the DEM surfaces.

Due to the varied data sources, some of the input DEM data includes bathymetric elevations for river and ocean areas whereas other input DEMs do not. It was beyond the scope of this project to normalize this data by masking out the bathymetric data from select DEMs. The final DEMs, depth grids and flood extent polygons cover water bodies in some locations, and exclude water bodies in others. This may affect the appearance of the depth and extent mapping, but does not have a significant impact on economic loss calculations, which are derived from land-based assets only.

### 1.3.2 Flood Depths

For the coastal scenarios, flood depth raster surfaces were generated by subtracting the DEM from a constant water level (3.4 m or 4.4 m GSC, respectively). For the riverine scenarios, flood depth raster surfaces were generated by subtracting the DEM from the sloped water level TIN surface. The flood depth grids were used as input to the Hazus model.

Coastal flood levels were applied as far upstream as Pitt Meadows and Surrey. As a result, there is an abrupt end in coastal flood depths and extents at the Pitt Meadows-Maple Ridge and Surrey-Langley boundaries.

### 1.3.3 Flood Extents

Flood extent polygons were generated in ArcMap by converting the flood depth grids to polygons.

### 1.3.4 Flood Hazard Mapping Limitations

Limitations introduced by the flood hazard mapping methodologies include:

- A relatively coarse DEM resolution of five or ten metres was used. This level of generalization is suitable for an overview-level study, but may not be suitable for site-specific mapping of flood depths and extents.
- DEM coverage is incomplete in several areas, including: the Indian Arm shoreline along Anmore and Belcarra; UBC; and the Burrard Inlet shoreline in Burnaby. Flood extents are minimal in these areas, as there is limited areal extent or steep topography. As a result, the lack of flood mapping is not significant in the context of this overview-level study, but could be significant for a more detailed, site-specific study.
- As flood levels were not available for the upstream portion of Hope, flood depth and extent mapping ends just upstream of the Highway 1 bridge at Hope. This will limit the economic loss analysis results.
- Mapped flood extents include some discontiguous polygons, which are typically low-lying areas inland that may not actually flood as they are not directly connected to the water source. No attempt was made to edit the flood extents to remove these discontiguous areas or fill in small holes in the extents, as this was beyond the scope of the project.

## 1.4 Hazus Analysis: Asset Inventory

Hazus uses an asset inventory of building stock, infrastructure, and population exposed to a flood hazard for estimating losses. For this study, the default Hazus inventory was used, and was not updated with additional data, with the exception of some essential facilities (schools, hospitals, police, ambulance, emergency operation centres) and utilities (potable water distribution facilities, waste water treatment plants).

The default residential inventory in Canadian Hazus 2.1 contains building counts derived from 2011 Canadian census data and non-residential data from Dun and Bradstreet information (both of which were modified by NRCan). Building replacement costs are based on 2006 RSMeans values for the US, where RSMeans is a widely-used estimation database that helps calculate the costs of construction. Data are aggregated to census dissemination blocks (approximately equivalent to city blocks), and analysis for the Hazus Canadian Flood Module is based largely on this aggregated data. Although there are a number of assumptions and estimations built into this data, it was deemed suitable for a high-level analysis. Table 3 summarizes some of the key default data in Hazus for the ten Study Regions. These values apply to the entire Study Region before taking into consideration floodplain extents.

**Table 3. Description of Hazus Study Regions**

| Study Region | | Area (sq.km) | Population | Num. Households (thousand) | Num. Buildings | Percent Residential Buildings | Total Building Replacement Value ($ mil) |
|---|---|---|---|---|---|---|---|
| 1 | Squamish | 124 | 17,521 | > 7 | 4,726 | 90.3 | 1,187 |
| 2 | North Shore (Lions Bay, West Van, North Van City & District) | 267 | 181,433 | > 73 | 43,275 | 88.3 | 13,239 |
| 3 | Port Moody, Anmore, Belcarra | 60 | 35,693 | > 14 | 6,743 | 91.2 | 2,018 |
| 4 | Vancouver, Burnaby, New Westminster | 223 | 893,455 | > 383 | 139,330 | 85.3 | 64,563 |
| 5 | Richmond, Delta | 316 | 290,909 | > 103 | 63,906 | 89.8 | 22,417 |
| 6 | Surrey, White Rock, Barnston Island | 332 | 487,687 | > 163 | 98,408 | 91.8 | 28,811 |
| 7 | Coquitlam, Port Coquitlam, Pitt Meadows, Maple Ridge | 510 | 276,799 | > 101 | 64,422 | 92.9 | 17,952 |
| 8 | Langley City & Township | 321 | 129,810 | > 49 | 34,673 | 90.4 | 9,905 |
| 9 | Mission, Harrison Hot Springs, Kent, unincorporated areas of FVRD north of the Fraser | 9,624 | 50,558 | > 18 | 16,108 | 92.5 | 3,475 |
| 10 | Abbotsford, Chilliwack, Hope, unincorporated areas of FVRD south of the Fraser | 3,010 | 225,392 | > 83 | 57,380 | 91.1 | 15,646 |
| 1 - 10 | All Study Regions | 14,786 | 2,589,257 | > 994 | 528,971 | 90.4 | 179,213 |

The 2011 population count and level of development was assumed for both the present and future flood scenarios.

Essential facilities data was updated using:

- Point locations of grade schools, post-secondary schools, police stations, fire stations, and BC Health Authority hospitals obtained from DataBC.

Utility data was updated using:

- Point locations of water distribution facilities supplied by Metro Vancouver (complete data not available for the FVRD).

- Point locations of wastewater treatment facilities mapped by NHC based on publically available information.

The following data layers were included in the spatial database but not used for the Hazus analysis:

- Road centrelines from the DataBC Digital Road Atlas.

- Rail lines from the GeoGratis National Railway Network and from NRCan with permission from Translink.

- Skytrain lines from NRCan with permission from Translink and from City of Coquitlam.

- Point locations of major bridges mapped by NHC from publically available information.

- Point locations of airports mapped by NHC from publically available information.

- Electrical substations and transmission lines from BC Hydro.

- Point locations of emergency operations centres obtained from Emergency Management BC, Fraser Valley Regional District, City of Vancouver, District of North Vancouver, City of Pitt Meadows and Corporation of Delta.

These layers were excluded from Hazus mainly because Hazus does not calculate losses for these types of infrastructure. Emergency operations centres were excluded from Hazus because the data was received after Hazus analysis was completed.

Some agencies provided additional datasets such as: local bridges, municipal water and sewer infrastructure, cell towers, fibre optics, oil and gas pipelines infrastructure, agricultural land use, ambulance stations, municipal works yards, day-care centres, care homes, community centres, and cemeteries and crematoriums. These were generally not included because coverage was inconsistent across the entire study area. It was beyond the scope of this project to conflate multiple datasets with inconsistent coverage, so only datasets with near-complete coverage of the study area were used.

## 1.5 Hazus Analysis: Results

The Hazus Flood Model analyses data aggregated to the dissemination block level. The analysis is done for the General Buildings Stock (GBS), which "includes residential, commercial, industrial, agricultural, religious, government, and educational buildings."

Hazus analysis results can be viewed spatially, as map layers based on dissemination blocks. Results can also be viewed in tabular form. Results for this analysis include:

- damage (in square footage, and by number of buildings) by building type and by occupancy type;

- building-related direct economic losses;

- amount of debris generated; and
- shelter requirements.

Damage to essential facilities (fire stations, hospitals, police stations, schools) is also determined. Unlike the other results, this is not based on aggregated data, but is based on site-specific point data.

Building-related economic losses are separated into:

- building repair and replacement costs (structural and non-structural damage);
- building contents losses;
- building inventory losses;
- relocation expenses;
- capital related income losses;
- wages losses; and
- rental income losses.

Losses are predominantly from building repair and replacement costs, and from building content losses. Building contents and inventory values are calculated in relation to building replacement value, depending on building occupancy type (FEMA Flood Module Technical Manual).

The last four categories listed above are time-dependent income losses, and are calculated based on the amount of damage to a building and an estimate of recovery time for the building (FEMA Flood Module Technical Manual). Recovery times incorporate physical restoration, dry-out and clean up, acquisition of permits, contractor availability, and, for some building types, hazardous material clean up. Default values are provided in Hazus, and are typically 12 to 30 months depending on building occupancy type.

### 1.5.1 Hazus Limitations

While Hazus is a valuable tool for estimating direct losses from flooding, highlighting geographic areas of particular concern, and illustrating relative losses between regions, there are many limitations that should be considered when examining the results. Below is a summary of the limitations grouped by focus area.

General

- This is a regional assessment, based on aggregated data. This data is not suitable for site-specific analysis.

Hazard

- The area of inundation at a given depth for a given dissemination block is used to determine percent damage. "It is assumed that the entire composition of the GBS within a given dissemination block is evenly distributed throughout the block." (Hazus Flood User Manual, p. 3-9).

- The Hazus Flood Model uses flood depth to estimate losses. The velocity of flooding is not considered.

- The Hazus Flood Model assumes a short duration, slow rise flood when analyzing losses (FEMA Flood Model User Manual). While this is appropriate for the coastal flooding scenarios, it is less appropriate for the riverine scenarios with a duration of several weeks. Actual direct losses are likely to be higher than estimated by Hazus for the riverine scenarios. In calculating building-related economic losses (e.g. relocation costs, income losses, wage losses, rental income losses), the Hazus Flood Model assumes certain flood restoration times (typically, 12 - 30 months) depending on building occupancy type.

- The Hazus Flood Model assumes water is clear and free of debris.

<u>Inventory</u>

- The default Hazus database was used for this analysis. With some minor exceptions, the database was not updated with more detailed, accurate or current information for the Study Region, such as individual building details, property values, or business information.

- The Hazus inventory is based on 2011 census data and Dun and Bradstreet commercial business data (and modified by NRCan), and so is not current to 2015.

- Population and level of development has been assumed to be at current levels, even for flood scenarios under future climate conditions (Scenarios B and D).

- For the analysis of aggregated building data, Hazus assumes that the asset inventory is distributed evenly across each dissemination block. For example, if 25% of the block has one metre of water, it is assumed that 25% of the buildings in the block are in one metre of water. This could lead to errors, for instance, if most of the buildings in the block are located further from the river or if the high-value industrial buildings are closer to the river. Note that the problems introduced by this aggregation are likely to be less significant for a larger study area (with more dissemination blocks), such as this one, due to averaging of the error.

- Canadian Hazus 2.1 uses US building replacement cost data, and as a result, doesn't account for the relatively high construction costs in the Lower Mainland. In addition, there is no conversion from US to Canadian dollars applied within the Canadian Hazus model.

- Some assumptions were made by NRCan in order to convert the census data to aggregated data in Hazus. For example, some of the data required by Hazus was not available at the Canadian dissemination block level, and so was approximated from larger dissemination areas, based on area ratios.

- RSMeans data is based on US national average data. This will not take into account regional variations. For example, the industrial sector in BC has a different composition than industry in Quebec and Ontario, and so is not well-represented by the national average. An area with a concentration of high-tech industrial buildings is another example site that may be undervalued using the national average data.

- Inventory losses are unexpectedly low in comparison to structure and content losses. This is most likely due to the use of Hazus default aggregated GBS data, which has not been updated with accurate local information on building structure, content and inventory values.

- Hazus does not assess damage to linear infrastructure, specifically, damage to utility and transportation lines, such as railways, highways, pipelines, and power lines. Whereas Hazus can identify certain (non-linear) utilities and most essential facilities within the flood extents, and in some cases report percent damage to the structure, associated economic losses cannot be estimated by the model.

Depth-damage curves

- The default Hazus depth-damage curves were used for this analysis, which may not accurately represent typical building structures in this region. No adjustment was made to Hazus default values for first floor elevations (i.e., the elevation at which damage starts). The default values may be higher than they should be for the Lower Mainland region, which would result in an underestimation of losses by Hazus.

The Canadian version of the Hazus model does not yet have the capacity to address flood losses to the agricultural sector, specifically associated with crops and livestock. While direct losses from damage to agricultural buildings can be considered in Hazus, they were dealt with more accurately in a separate analysis that uses the local agricultural land use inventory available from the provincial government. Losses from damage to farm residences are captured under the residential building losses estimated by Hazus.

Hazus can be used to estimate flood damage to bridges due to scour. However, suitable flood depth grids for areas around the piers of most of the major bridges in the study area were not available, so bridge losses were not estimated. Hazus does not include an assessment of the flood impacts by inundation of bridge on-ramps or the bridge deck.

### 1.5.2 Necessary Adjustments

Recognizing that there are limitations associated with the Hazus analysis, and that these limitations are expected to greatly underestimate losses, adjustments were made to the Hazus loss outputs. There were two available sources of information that provided an indication of the possible scaling factor to be applied:

1. Building Replacement Costs

Canadian Hazus 2.1 default inventory uses 2006 values for typical building replacement costs from the US, which may not accurately reflect building replacement costs in the Lower Mainland today. These values, obtained from US 2006 RSMeans, were compared to another source of construction costs' data: Marshall & Swift building replacement costs as of October 2014, with values adjusted for the Lower Mainland region. This comparison shows that the Marshall & Swift-adjusted 2014 building replacement values are about 1.6 times higher than the 2006 RSMeans values used in Hazus.

## 2. City of Vancouver Hazus Analysis

NHC completed a Coastal Flood Risk Assessment for the City of Vancouver in 2014, as part of which a detailed Hazus analysis was conducted by the City and Ebbwater Consulting (NHC, 2015). The City created an inventory of individual buildings within the floodplain, including up-to-date information on building type, structure, and replacement cost. This User Defined Facilities (UDF) approach contrasts with the Lower Mainland Flood Vulnerability Assessment, which uses aggregated inventory data in the form of the Hazus General Building Stock (GBS), and does not include any updates of individual residential, commercial or industrial buildings.

For comparison, NHC ran a Hazus analysis for the City of Vancouver only using Hazus GBS data and evaluated the results against the UDF results for the same flood scenario. Overall, losses reported in the City of Vancouver UDF study were higher:

- Number of buildings damaged was more than eight times higher, with number of residential buildings damaged more than 25 times higher. Number of buildings destroyed (more than 50% damaged) was lower – no buildings were destroyed in the City UDF study, whereas seven buildings were destroyed in the GBS analysis. The number of buildings of each type was significantly different in the two studies.

- Debris generated was four times higher.

- Population displaced was two times higher.

- Total building-related economic losses were 2.7 times higher in the City UDF study, with building and content losses both two times higher, while inventory losses were 25 times higher.

The comparison highlights: (1) the high-level nature of the out-of-the-box Hazus GBS data, and (2) the likelihood that the Hazus direct loss estimates obtained for the Lower Mainland study are too low.

In addition, a US to Canadian currency conversion was incorporated. One-year average currency conversion rates over the past ten years range from 1.0 to 1.3. The average of the past ten one-year rates is 1.1.

Accordingly, the following adjustments have been made to the Hazus results for the Lower Mainland:

- Increase by 10% to account for conversion from US to Canadian currency.
- Then multiply by 1.6 to account for underestimation.

The factor of 1.6 was selected based on the comparison of US 2006 RSMeans values to Vancouver 2014 Marshall & Swift values.

Scaling Hazus values in this way is not without precedent. During a March 2015 presentation to the Canadian Hazus Users Group, Edward Fratto, Executive Director of the Northeast Emergency Consortium in New Hampshire, an experienced Hazus user, noted that his approach is to report the total Hazus results from a GBS analysis as a range: (modelled results / 2) to (modelled results * 2) (Fratto and Kates, 2015).

## 1.6 Building Related Loss Estimates

Based on the Hazus analysis, the building related losses for the Lower Mainland are summarized in Table 4 and Table 5**Error! Reference source not found.**. As described above, agricultural building-related losses have been removed, and the resulting values incorporate a currency conversion of 1.1 and a multiplier of 1.6, and have been rounded off.

Losses for each coastal and riverine flood scenario are presented by Study Region in Figure 3.

Figure 4 to Figure 7 show the total number of buildings damaged for each scenario, separated by building occupancy type.

## Table 4. Hazus Direct Losses - Damage and Shelter Requirements

| | | | Damage | | | | | | | | | Shelter Requirements | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study Region | | Scenario | Buildings > 10% Damaged | % Buildings Significantly Damaged | Buildings Destroyed | Fire Stations Damaged | Hospitals Damaged | Police Stations Damaged | EOCs Damaged | Schools Damaged | Debris Generated (tons) | Households Displaced | Population Seeking Shelter | % Population Seeking Shelter |
| 1 | Squamish | A - Coastal | 35 | 0.7% | 4 | 0 | 0 | 0 | 0 | 1 | 2,230 | 482 | 1,314 | 7.5% |
| | | B - Coastal | 80 | 1.7% | 17 | 0 | 0 | 0 | 0 | 3 | 6,553 | 850 | 2,334 | 13.3% |
| 2 | North Shore (Lions Bay, West Van, North Van City & District) | A - Coastal | 32 | 0.1% | 0 | 0 | 0 | 0 | 0 | 0 | 2,896 | 221 | 389 | 0.2% |
| | | B - Coastal | 90 | 0.2% | 2 | 0 | 0 | 0 | 0 | 2 | 10,519 | 573 | 1,345 | 0.7% |
| 3 | Port Moody, Anmore, Belcarra | A - Coastal | 0 | 0.0% | 0 | 0 | 0 | 0 | 0 | 0 | 707 | 52 | 117 | 0.3% |
| | | B - Coastal | 0 | 0.0% | 0 | 0 | 0 | 0 | 0 | 0 | 1,584 | 79 | 203 | 0.6% |
| 4 | Vancouver, Burnaby, New | A - Coastal | 173 | 0.1% | 21 | 1 | 0 | 0 | 0 | 2 | 34,084 | 3,037 | 8,430 | 0.9% |
| | | B - Coastal | 389 | 0.3% | 36 | 1 | 0 | 2 | 0 | 8 | 76,413 | 6,831 | 19,714 | 2.2% |
| | | C - Riverine | 121 | 0.1% | 19 | 1 | 0 | 0 | 0 | 5 | 16,813 | 2,545 | 7,210 | 0.8% |
| | | D - Riverine | 272 | 0.2% | 31 | 1 | 0 | 0 | 0 | 6 | 52,807 | 3,706 | 10,708 | 1.2% |
| 5 | Richmond, Delta | A - Coastal | 6775 | 10.6% | 1014 | 11 | 2 | 6 | 3 | 75 | 549,960 | 72,063 | 215,507 | 74.1% |
| | | B - Coastal | 7250 | 11.3% | 3517 | 12 | 2 | 6 | 3 | 76 | 1,387,194 | 73,539 | 219,959 | 75.6% |
| | | C - Riverine | 1680 | 2.6% | 10 | 10 | 2 | 3 | 2 | 68 | 161,487 | 61,724 | 184,162 | 63.3% |
| | | D - Riverine | 6491 | 10.2% | 328 | 12 | 2 | 6 | 2 | 75 | 519,024 | 71,540 | 213,866 | 73.5% |
| 6 | Surrey, White Rock, Barnston Island | A - Coastal | 191 | 0.2% | 68 | 0 | 0 | 0 | 0 | 1 | 60,840 | 3,282 | 9,091 | 1.9% |
| | | B - Coastal | 306 | 0.3% | 117 | 1 | 0 | 0 | 0 | 3 | 154,129 | 3,853 | 10,660 | 2.2% |
| | | C - Riverine | 82 | 0.1% | 6 | 0 | 0 | 0 | 0 | 1 | 4,755 | 888 | 2,419 | 0.5% |
| | | D - Riverine | 100 | 0.1% | 13 | 0 | 0 | 0 | 0 | 1 | 15,534 | 1,022 | 2,825 | 0.6% |
| 7 | Coquitlam, Port Coquitlam, Pitt Meadows, Maple Ridge | A - Coastal | 41 | 0.1% | 0 | 0 | 0 | 0 | 0 | 0 | 5,125 | 1,187 | 3,212 | 1.2% |
| | | B - Coastal | 121 | 0.2% | 12 | 1 | 0 | 0 | 0 | 1 | 13,886 | 2,736 | 6,637 | 2.4% |
| | | C - Riverine | 183 | 0.3% | 34 | 1 | 0 | 0 | 0 | 3 | 39,687 | 4,492 | 12,684 | 4.6% |
| | | D - Riverine | 417 | 0.6% | 107 | 1 | 0 | 0 | 1 | 6 | 102,637 | 7,061 | 20,308 | 7.3% |
| 8 | Langley City & Township | C - Riverine | 59 | 0.2% | 40 | 0 | 0 | 0 | 0 | 0 | 23,536 | 712 | 1,914 | 1.5% |
| | | D - Riverine | 65 | 0.2% | 55 | 0 | 0 | 0 | 0 | 0 | 41,538 | 963 | 2,659 | 2.0% |
| 9 | Mission, Harrison Hot Springs, Kent, unincorporated areas of FVRD north of the Fraser | C - Riverine | 125 | 0.8% | 53 | 3 | 0 | 1 | 0 | 3 | 37,543 | 2,772 | 7,557 | 14.9% |
| | | D - Riverine | 191 | 1.2% | 81 | 3 | 0 | 1 | 1 | 7 | 53,195 | 3,186 | 8,721 | 17.4% |
| 10 | Abbotsford, Chilliwack, Hope, unincorporated areas of FVRD south of the Fraser | C - Riverine | 1330 | 2.3% | 531 | 6 | 1 | 4 | 1 | 32 | 371,955 | 17,094 | 49,942 | 22.2% |
| | | D - Riverine | 1708 | 3.0% | 1051 | 6 | 1 | 4 | 1 | 33 | 558,287 | 17,847 | 52,109 | 23.1% |
| 1 - 10 | All Study Regions | A - Coastal | 7247 | 1.4% | 1107 | 12 | 2 | 6 | 3 | 79 | 655,842 | 80,324 | 238,060 | 9.2% |
| | | B - Coastal | 8236 | 1.6% | 3701 | 15 | 2 | 8 | 3 | 93 | 1,650,278 | 88,461 | 260,852 | 10.1% |
| | | C - Riverine | 3580 | 0.7% | 693 | 21 | 3 | 8 | 3 | 112 | 655,776 | 90,227 | 265,888 | 10.3% |
| | | D - Riverine | 9244 | 1.7% | 1666 | 23 | 3 | 11 | 5 | 128 | 1,343,022 | 105,325 | 311,196 | 12.0% |

## Table 5. Hazus Direct Losses - Building-Related Economic Losses

| | | | Building-Related Economic Losses by Occupancy Type | | | | Building-Related Economic Losses by Loss Type | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study Region | | Scenario | Residential ($ mil) | Commercial ($ mil) | Industrial ($ mil) | Others ($ mil) | Structure Loss ($ mil) | Contents Loss ($ mil) | Inventory Loss ($ mil) | Relocation Loss ($ mil) | Capital Related Loss ($ mil) | Wages Losses ($ mil) | Rental Income Loss ($ mil) | Total Building-Related Losses ($mil) |
| 1 | Squamish | A - Coastal | 10 | 30 | 10 | 10 | 20 | 40 | 0 | 0 | 0 | 0 | 0 | 60 |
| | | B - Coastal | 30 | 60 | 10 | 30 | 40 | 80 | 0 | 0 | 0 | 0 | 0 | 120 |
| 2 | North Shore (Lions Bay, West Van, North Van City & District) | A - Coastal | 0 | 70 | 10 | 0 | 20 | 50 | 0 | 0 | 0 | 0 | 0 | 80 |
| | | B - Coastal | 10 | 200 | 30 | 10 | 80 | 160 | 10 | 0 | 0 | 0 | 0 | 240 |
| 3 | Port Moody, Anmore, Belcarra | A - Coastal | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 10 |
| | | B - Coastal | 0 | 10 | 0 | 0 | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 20 |
| 4 | Vancouver, Burnaby, New | A - Coastal | 260 | 330 | 180 | 30 | 310 | 460 | 30 | 0 | 0 | 0 | 0 | 800 |
| | | B - Coastal | 480 | 860 | 410 | 60 | 670 | 1,070 | 70 | 0 | 0 | 10 | 0 | 1,810 |
| | | C - Riverine | 220 | 160 | 110 | 20 | 210 | 280 | 20 | 0 | 0 | 0 | 0 | 520 |
| | | D - Riverine | 390 | 410 | 320 | 40 | 440 | 660 | 40 | 0 | 0 | 0 | 0 | 1,160 |
| 5 | Richmond, Delta | A - Coastal | 5,160 | 5,180 | 1,220 | 630 | 5,330 | 6,560 | 250 | 10 | 20 | 20 | 10 | 12,190 |
| | | B - Coastal | 6,290 | 6,460 | 1,630 | 740 | 6,820 | 7,940 | 300 | 10 | 30 | 30 | 10 | 15,130 |
| | | C - Riverine | 1,210 | 1,950 | 660 | 360 | 1,490 | 2,500 | 140 | 10 | 10 | 20 | 0 | 4,170 |
| | | D - Riverine | 4,560 | 4,830 | 1,290 | 600 | 4,800 | 6,170 | 260 | 10 | 20 | 20 | 10 | 11,290 |
| 6 | Surrey, White Rock, Barnston Island | A - Coastal | 150 | 540 | 160 | 40 | 310 | 540 | 40 | 0 | 0 | 0 | 0 | 890 |
| | | B - Coastal | 200 | 750 | 270 | 60 | 460 | 770 | 50 | 0 | 0 | 0 | 0 | 1,280 |
| | | C - Riverine | 30 | 80 | 160 | 10 | 80 | 180 | 20 | 0 | 0 | 0 | 0 | 280 |
| | | D - Riverine | 40 | 140 | 250 | 10 | 130 | 280 | 30 | 0 | 0 | 0 | 0 | 440 |
| 7 | Coquitlam, Port Coquitlam, Pitt Meadows, Maple Ridge | A - Coastal | 30 | 80 | 50 | 0 | 60 | 100 | 10 | 0 | 0 | 0 | 0 | 170 |
| | | B - Coastal | 90 | 220 | 210 | 10 | 180 | 330 | 30 | 0 | 0 | 0 | 0 | 530 |
| | | C - Riverine | 180 | 300 | 390 | 20 | 300 | 540 | 50 | 0 | 0 | 0 | 0 | 890 |
| | | D - Riverine | 350 | 570 | 700 | 50 | 590 | 1,000 | 80 | 0 | 0 | 0 | 0 | 1,680 |
| 8 | Langley City & Township | C - Riverine | 30 | 80 | 20 | 0 | 60 | 80 | 0 | 0 | 0 | 0 | 0 | 140 |
| | | D - Riverine | 40 | 110 | 20 | 0 | 70 | 90 | 10 | 0 | 0 | 0 | 0 | 170 |
| 9 | Mission, Harrison Hot Springs, Kent, unincorporated areas of FVRD north of the Fraser | C - Riverine | 50 | 60 | 20 | 20 | 60 | 90 | 0 | 0 | 0 | 0 | 0 | 150 |
| | | D - Riverine | 70 | 90 | 20 | 30 | 90 | 120 | 0 | 0 | 0 | 0 | 0 | 220 |
| 10 | Abbotsford, Chilliwack, Hope, unincorporated areas of FVRD south of the Fraser | C - Riverine | 890 | 1,180 | 290 | 460 | 1,200 | 1,540 | 70 | 0 | 0 | 10 | 0 | 2,820 |
| | | D - Riverine | 1,150 | 1,440 | 340 | 520 | 1,520 | 1,830 | 80 | 0 | 10 | 10 | 0 | 3,450 |
| 1 - 10 | All Study Regions | A - Coastal | 5,610 | 6,230 | 1,630 | 710 | 6,040 | 7,760 | 320 | 10 | 30 | 30 | 10 | 14,200 |
| | | B - Coastal | 7,100 | 8,560 | 2,560 | 910 | 8,240 | 10,350 | 450 | 10 | 30 | 40 | 10 | 19,130 |
| | | C - Riverine | 2,610 | 3,810 | 1,650 | 890 | 3,390 | 5,200 | 300 | 10 | 20 | 30 | 10 | 8,970 |
| | | D - Riverine | 6,600 | 7,590 | 2,940 | 1,250 | 7,640 | 10,150 | 490 | 10 | 30 | 40 | 10 | 18,410 |

Note 1: Agricultural buildings (except farm residences) are accounted for in a separate analysis. See Appendix D for details on this loss type. Losses from damage to farm residences are captured under “Residential” losses in the above table.

Note 2: Building-related economic losses have been adjusted and rounded.

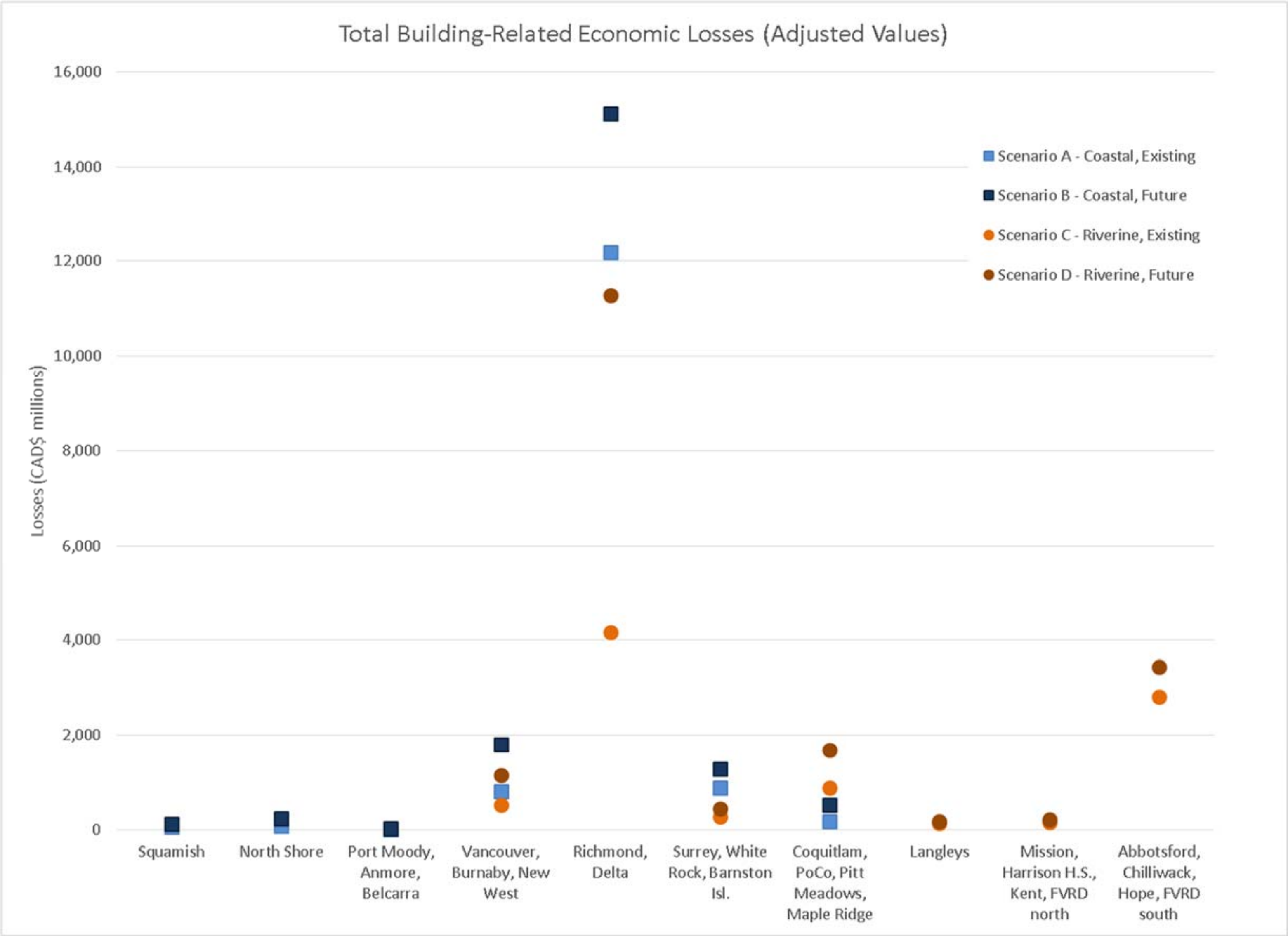


**Figure 3. Hazus Direct Economic Losses by Study Region**

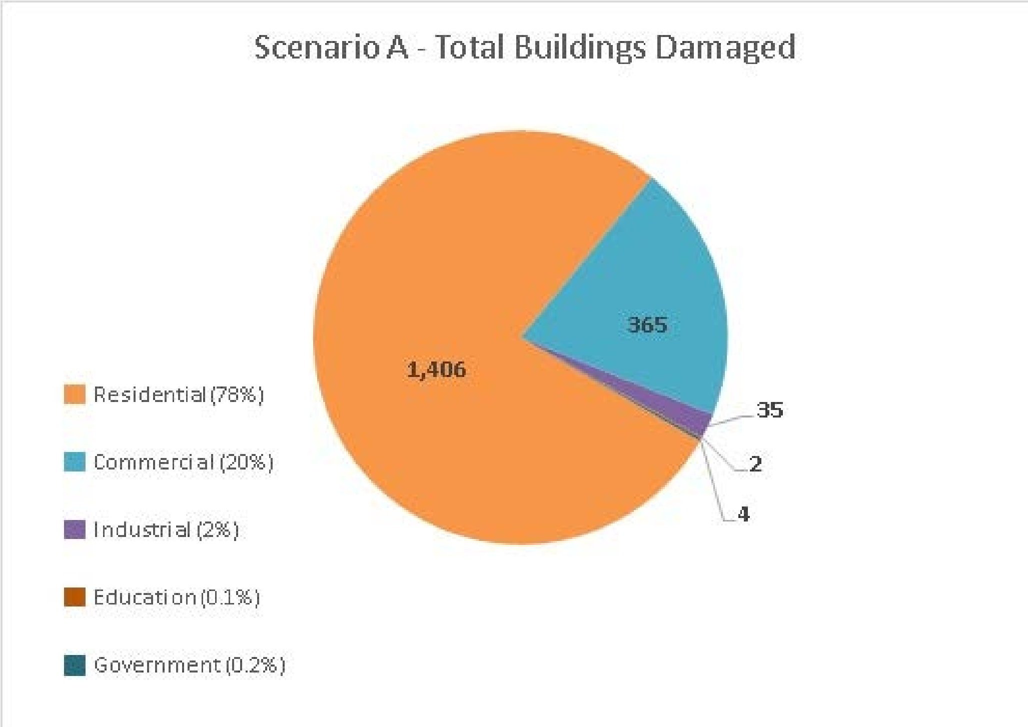


**Figure 4. Total Buildings Damaged, Scenario A**

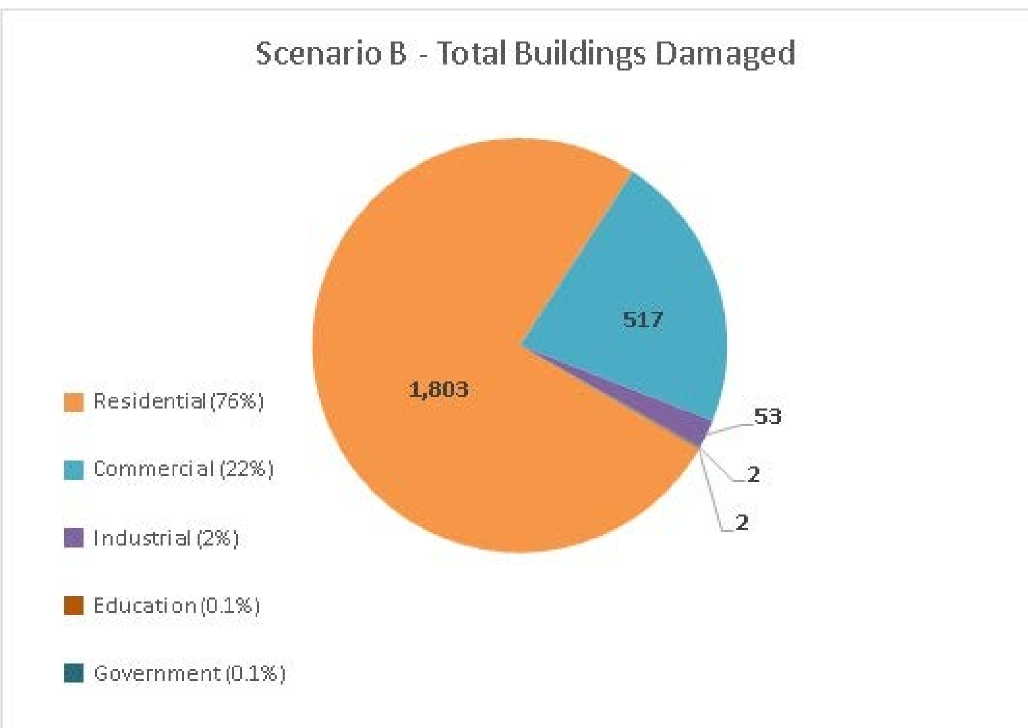


**Figure 5. Total Buildings Damaged, Scenario B**

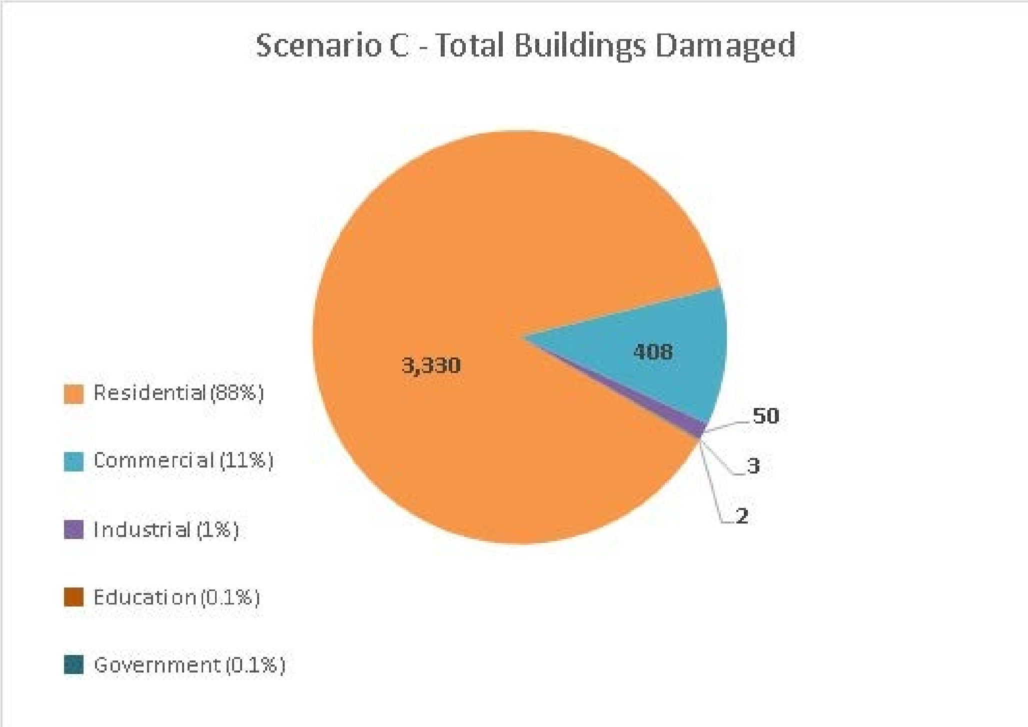


**Figure 6. Total Buildings Damaged, Scenario C**

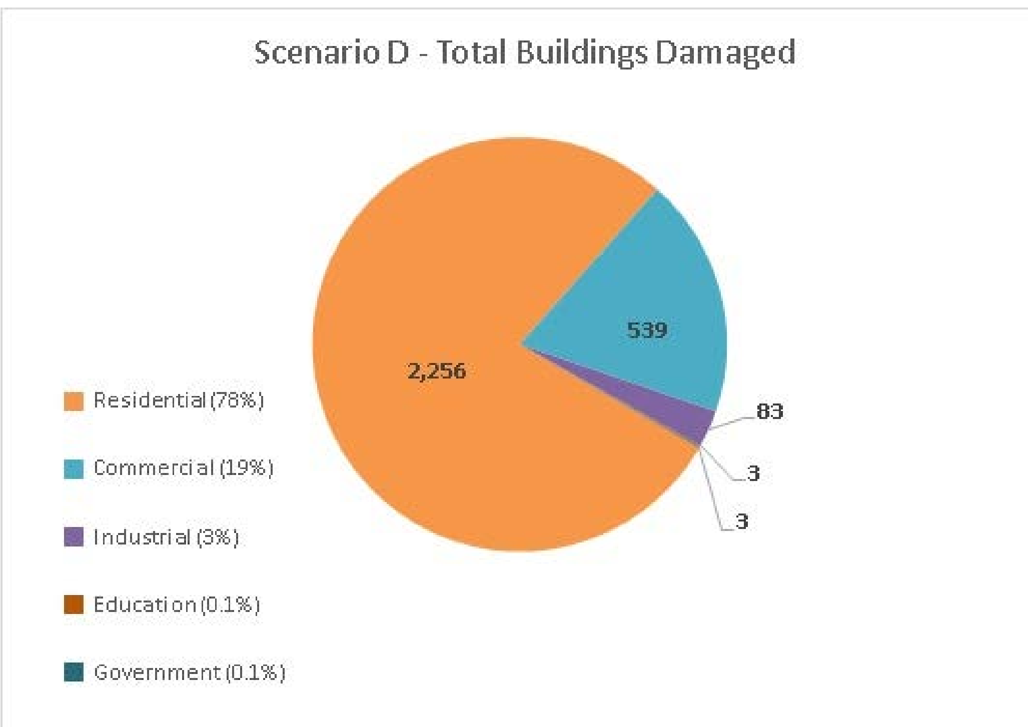


**Figure 7. Total Buildings Damaged, Scenario D**

Hazus results can also be presented spatially. For example, maps have been prepared showing the number of people displaced, the number of damaged buildings, and the building-related economic losses by census dissemination block. Samples of each map are included in Figure 8 to Figure 10, while the full map set is included with the final digital deliverables.

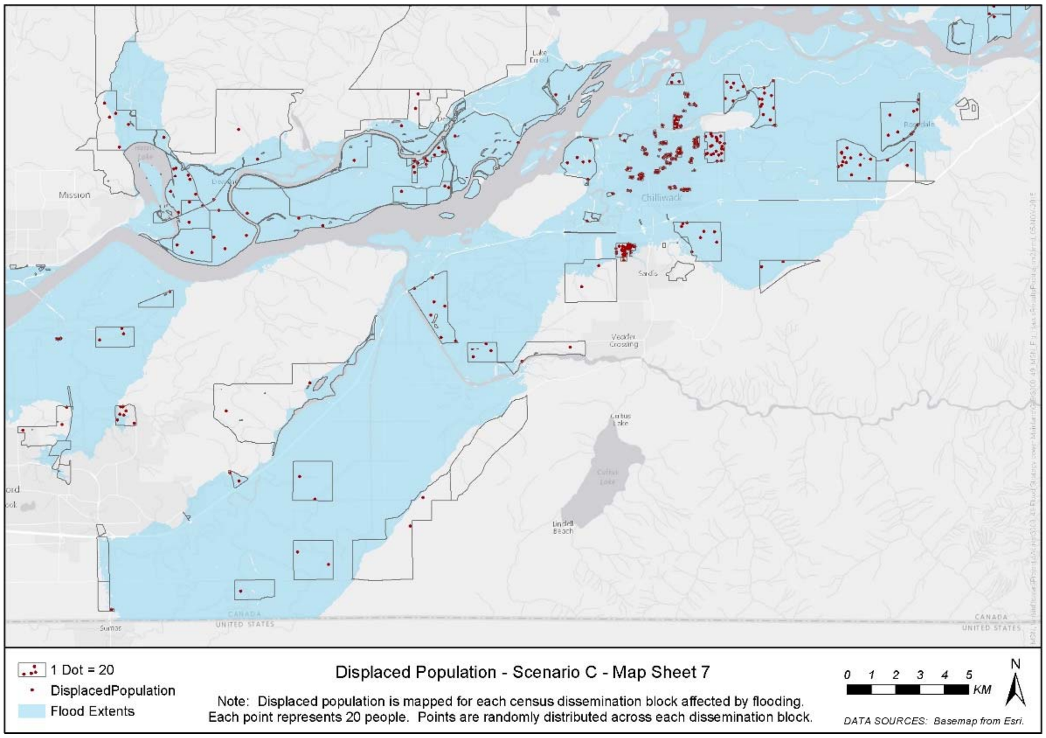


**Figure 8. Example Results - Displaced Population**

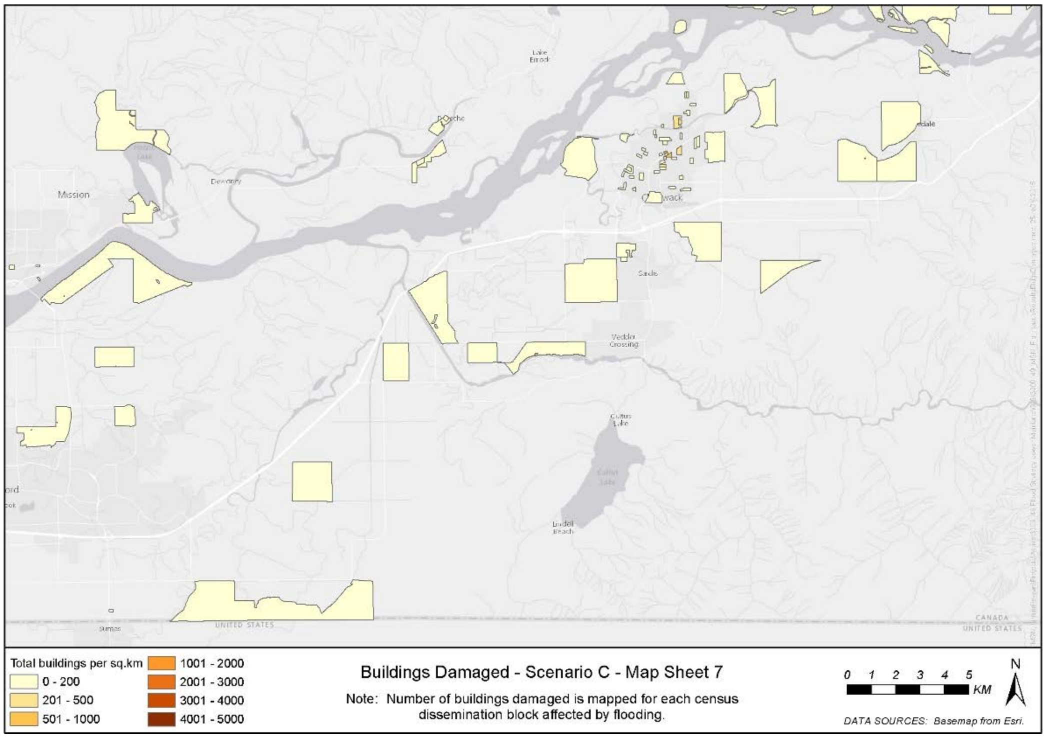


**Figure 9. Example Results - Buildings Damaged**

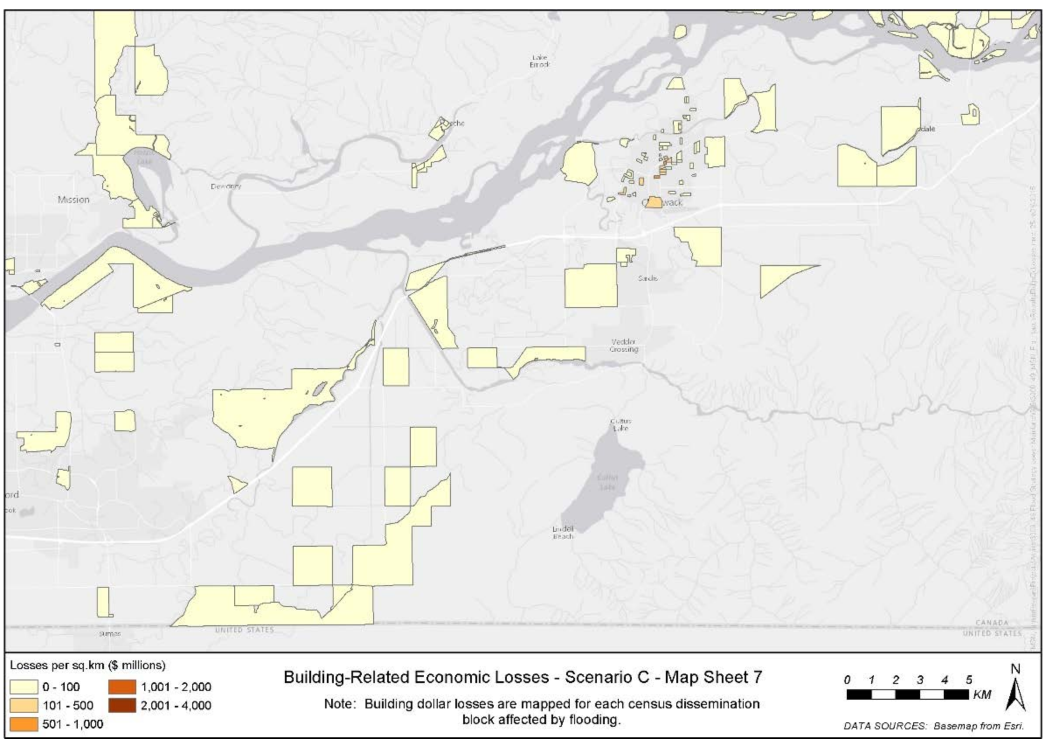


**Figure 10. Example Results - Economic Losses**

### 1.6.1 Recommendations for Future Use of Hazus

- Update the aggregated data with more accurate data – for example, using provincial assessor data and municipal property and business data. This updated data should reflect current building replacement costs for residential, commercial and industrial buildings in the region.

- To account for increases in population and level of development for future flood scenarios, create a modified version of the asset inventory with predicted future building and demographic information.

- Develop depth-damage curves that are appropriate for the Lower Mainland region.

## 1.7 GIS and Mapping Products

The following GIS and map products were created during this portion of the study:

- Table documenting all data sets created.

- Data sharing agreements signed with data providers.

- Digital Elevation Model (DEM) files. These are five-metre or ten-metre resolution DEM raster files created by NHC for the analysis, for each Hazus Study Region.

- An ArcGIS file geodatabase containing the asset inventory data described above.

- Flood Extent Maps: One set for the riverine flood scenarios, and one set for the coastal flood scenarios. Twelve 22 x 34” maps in total, PDF format.

- Flood Depth Maps: One set per flood scenario. Twenty four 22 x 34” maps in total, PDF format.

- Flood Extent Google Earth KMZ files: One set per flood scenario, for each Study Region. Twenty eight files in total.

- Flood Depth Grids: Twenty eight Esri Grid raster files in total, one per flood scenario for each Study Region.

- Flood Extent GIS polygons: Four GIS layers, one per flood scenario.

- Hazus project (HPR) files (compatible with Canadian Hazus 2.1 and ArcGIS 10.0); one file for each Hazus Study Region. All Hazus tabular and spatial results can be derived from these files.

- An Excel spreadsheet summarizing Hazus results, including adjustments applied to loss estimates.

- A series of 24 map figures showing building-related economic losses ($ millions per square kilometre in each dissemination block) for the four flood scenarios.

- A series of 24 map figures showing damaged buildings (number of buildings per square kilometre in each dissemination block) for the four flood scenarios.

- A series of 24 map figures showing displaced population (number of people in each dissemination block) for the four flood scenarios.

These files will be included with the final digital deliverables.

Digital deliverables will also include all original topographic and asset inventory data received by NHC, including datasets that were not used for the analysis due to incomplete coverage.

All GIS data deliverables will be provided in ArcGIS 10.2 compatible format with the final project deliverables.

## 1.8 References


Fratto, E. and J.Kates (2015). All Hazard Analysis of City of Nashua, New Hampshire. Presentation to Canadian Hazus Users Group, 18-Mar-2015.

NHC (2015). City of Vancouver Coastal Flood Risk Assessment – Final Report. Report for City of Vancouver. 483 pp.

FEMA. “Multi-hazard Loss Estimation Methodology – Flood Model – Hazus-MH – User Manual”. 382 pp.

FEMA. “Multi-hazard Loss Estimation Methodology – Flood Model – Hazus-MH – Technical Manual”. 569 pp.

FEMA and Natural Resources Canada (2012). Enhanced L313: Canadian Hazus-MH Basic Course and Introduction to Data Management Tools and Strategies. Course Manual.

# Appendix D: Agricultural Loss Information

| Agricultural Losses Under Different Flood Scenarios | | | | | | |
|---|---|---|---|---|---|---|
| | Hectares Vulnerable | Lost Farm Gate Sales | Damage to Equipment | Damage to Buildings | Replant loss | Total Losses |
| Scenario A - Coastal | 14,626 | $16.5 | $12.7 | $37.9 | | $67.1 |
| Scenario B - Coastal | 15,214 | $17.4 | $14.6 | $40.9 | | $72.9 |
| Scenario C - River | 43,459 | $410.1 | $50.7 | $223.0 | $9.5 | $693.2 |
| Scenario D - River | 43,813 | $413.0 | $50.7 | $227.3 | $9.5 | $700.6 |

| Scenario A - Coastal Flood ($ million) | | | | | | |
|---|---|---|---|---|---|---|
| Local Government Area | Hectares Vulnerable | Lost Farm Gate Sales | Damage to Equipment | Damage to Buildings | Replant Loss | Total Losses |
| Burnaby | 95.14 | $0.18 | $0.00 | $0.09 | | $0.27 |
| Coquitlam | 253.36 | $0.54 | $0.08 | $0.36 | | $0.98 |
| Delta | 6,690.70 | $5.82 | $4.82 | $13.63 | | $24.27 |
| PittMeadows | 451.50 | $1.13 | $0.90 | $1.43 | | $3.46 |
| Port Coquitlam | 118.00 | $0.22 | $0.13 | $0.91 | | $1.26 |
| Richmond | 2,727.70 | $3.50 | $3.09 | $7.44 | | $14.03 |
| Surrey | 3,773.00 | $4.64 | $3.22 | $11.73 | | $19.59 |
| Vancouver | 32.30 | $0.01 | $0.00 | $1.68 | | $1.69 |
| Electoral A | 483.80 | $0.44 | $0.56 | $0.58 | | $1.58 |
| Total | 14,625.50 | $16.5 | $12.8 | $37.9 | | $67.1 |

| Scenario B - Coastal Flood ($ million) | | | | | | |
|---|---|---|---|---|---|---|
| Local Government Area | Hectares Vulnerable | Lost Farm Gate Sales | Damage to Equipment | Damage to Buildings | Replant Loss | Total Losses |
| Burnaby | 101.53 | $0.18 | $0.00 | $0.13 | | $0.31 |
| Coquitlam | 256.78 | $0.54 | $0.08 | $0.38 | | $1.00 |
| Delta | 6694.08 | $5.79 | $6.30 | $13.73 | | $25.82 |
| PittMeadows | 910.35 | $1.98 | $1.24 | $2.97 | | $6.19 |
| Port Coquitlam | 121.8 | $0.22 | $0.13 | $0.97 | | $1.32 |
| Richmond | 2742.7 | $3.52 | $3.10 | $7.52 | | $14.14 |
| Surrey | 3845.31 | $4.67 | $3.24 | $12.57 | | $20.48 |
| Vancouver | 32.78 | $0.01 | $0.00 | $1.69 | | $1.70 |
| Electoral A | 508.51 | $0.45 | $0.50 | $0.94 | | $1.89 |
| Total | 15213.84 | $17.4 | $14.6 | $40.9 | | $72.9 |

| Scenario C - River Flood ($ million) | | | | | | |
|---|---|---|---|---|---|---|
| Local Government Area | Hectares Vulnerable | Lost Farm Gate Sales | Damage to Equipment | Damage to Buildings | Replant Loss | Total Losses |
| Burnaby | 78.02 | $1.00 | $0.00 | $0.01 | $0.00 | $1.01 |
| Coquitlam | 257.34 | $2.77 | $0.08 | $0.38 | $0.00 | $3.23 |
| Delta | 6643.61 | $104.44 | $6.30 | $14.63 | $1.89 | $127.26 |
| Langley | 1302.69 | $9.17 | $5.98 | $6.31 | $0.28 | $21.74 |
| Maple Ridge | 364.56 | $5.54 | $1.16 | $4.21 | $0.08 | $10.99 |
| PittMeadows | 2393.47 | $27.38 | $1.24 | $7.56 | $0.21 | $36.39 |
| Port Coquitlam | 122.26 | $1.48 | $0.13 | $1.38 | $0.03 | $3.02 |
| Richmond | 2742.66 | $26.87 | $3.10 | $10.36 | $0.22 | $40.55 |
| Surrey | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Vancouver | 13.91 | $0.03 | $0.00 | $0.53 | $0.00 | $0.56 |
| Electoral A | 510.1 | $2.84 | $0.50 | $1.46 | $0.09 | $4.89 |
| Abbotsford | 10910.93 | $107.17 | $11.82 | $65.06 | $2.28 | $186.33 |
| Chilliwack | 9718.1 | $70.67 | $16.75 | $76.35 | $2.36 | $166.13 |
| Hope | 91.42 | $0.19 | $0.01 | $0.31 | $0.03 | $0.54 |
| Kent | 3799.91 | $19.41 | $1.48 | $11.52 | $0.97 | $33.38 |
| Mission | 247.53 | $0.70 | $0.01 | $0.77 | $0.07 | $1.55 |
| FVRD Electoral | 4262.64 | $30.43 | $2.10 | $22.11 | $0.97 | $55.61 |
| Total | 43459.15 | $410.1 | $50.7 | $223.0 | $9.5 | $693.2 |

| Scenario D - River Flood ($ million) | | | | | | |
|---|---|---|---|---|---|---|
| Local Government Area | Hectares Vulnerable | Lost Farm Gate Sales | Damage to Equipment | Damage to Buildings | Replant Loss | Total Losses |
| Burnaby | 98.32 | $1.33 | $0.00 | $0.10 | $0.00 | $1.43 |
| Coquitlam | 257.86 | $3.31 | $0.08 | $0.54 | $0.00 | $3.93 |
| Delta | 6691.73 | $102.21 | $6.30 | $15.29 | $1.92 | $125.72 |
| Langley | 1338.06 | $9.27 | $5.98 | $6.68 | $0.29 | $22.22 |
| Maple Ridge | 364.56 | $5.54 | $1.16 | $4.21 | $0.08 | $10.99 |
| PittMeadows | 2393.47 | $31.31 | $1.24 | $7.56 | $0.21 | $40.32 |
| Port Coquitlam | 122.26 | $1.06 | $0.13 | $1.00 | $0.03 | $2.22 |
| Richmond | 2540.34 | $24.47 | $3.10 | $9.43 | $0.22 | $37.22 |
| Surrey | 0 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Vancouver | 13.91 | $0.01 | $0.00 | $0.53 | $0.00 | $0.54 |
| Electoral A | 510.77 | $2.84 | $0.50 | $1.47 | $0.09 | $4.90 |
| Abbotsford | 10929.21 | $107.75 | $11.82 | $65.29 | $2.28 | $187.14 |
| Chilliwack | 10010.37 | $72.01 | $16.76 | $79.29 | $2.36 | $170.42 |
| Hope | 111.87 | $0.23 | $0.01 | $0.52 | $0.03 | $0.79 |
| Kent | 3899.47 | $20.41 | $1.48 | $12.29 | $0.98 | $35.16 |
| Mission | 248.97 | $0.70 | $0.01 | $0.77 | $0.07 | $1.55 |
| FVRD Electoral | 4281.99 | $30.57 | $2.10 | $22.32 | $0.97 | $55.96 |
| Total | 43813.16 | $413.0 | $50.7 | $227.3 | $9.5 | $700.5 |

# Appendix E: Economics Discussion and Input / Output Modelling Results

# 1 DISCUSSION OF ECONOMIC LOSSES

This appendix contains a discussion of economic losses compiled by Mr. D. Park and a summary report prepared by BC Stats on Input/ Output Modelling for the project. The Input/ Output (I/O) modelling was undertaken to investigate the implications of flood losses specific to the BC economy. The I/O report follows the general discussion.

## 1.1 Introduction to Indirect and Induced Losses

Several economic indicators are commonly used to express the magnitude of the importance of an entity in economic terms. These include the value of output, employment, payrolls and contribution to Gross Domestic Product (GDP). GDP (at Factor Cost) comprises wages and salaries, supplementary labour income (cash benefits), net income of unincorporated businesses and corporate profits before taxes.

The importance of an entity to the economy cannot be gauged just by its direct economic impact only. To produce a product or service, an organization purchases goods and services from other organizations. The impact of this is the indirect effect of the entity.

An organization pays its employees to produce products or services. The spending of these wages and salaries generates more economic activity in other organizations, resulting in the induced effect. The combined indirect and induced effects may be lumped together and in combination referred to as indirect effects, although this may lead to confusion.

Complicating the situation is the fact that in repairing/restoring flood damage, a substantial part of the materials, supplies, etc. may be imported from other countries or other provinces. Calculation of the cost of the damages and the restoration impact requires that this be taken into account as shown later in this appendix. The net impact on the BC economy is then apparent, as spelled out in the accompanying BC Stats report.

A key aspect of the flood threat is the potential for disruption of road, rail and air infrastructure. A great majority of the movement of goods and services into and out of the Lower Mainland region relies on rail and road networks, numerous port facilities and airports, as well as the integrity of Fraser River and sea dike systems in the Lower Mainland, which protect this transportation network. Disruption to the flow of goods into and out of Port Metro Vancouver and Greater Vancouver due to either a Fraser River or coastal flood could have serious consequences on the regional, provincial and national economy, with very significant direct and indirect losses. These losses include losses by the private sector as well as local, provincial and the federal government as a consequence of reductions in industrial and commercial activity coupled with wage and salary losses and consequent declines in taxes and other government revenues.

For the purposes of this project, flood damage estimates were made to account for interruption of cargo shipments through Port Metro Vancouver and railways serving the port. Other potential flooding damages include the trans-border traffic of BNSF Railway, the interruption of highway traffic by flooding in the lower Fraser Valley and Fraser River delta area, and Vancouver International Airport service interruption by flooding.

## 1.2 Input / Output Modelling

Whereas the US version of Hazus has an Indirect Economic Loss Module (IELM), a comparable module is presently not available in the Canadian version. However, building related indirect losses were included as discussed in Section 5 of the main report. BC Stats was consulted with respect to net losses to the BC economy and for indirect/induced loss estimation based on input/output modelling. Given available estimates of the building related losses incurred from a flood scenario, corresponding indirect and induced losses were estimated.

Input-output models are based on statistical information on the flow of goods and services among various industries. This information provides a comprehensive and detailed representation of the economy. An input-output model consists of three components:

- An input matrix showing the cost of inputs (goods and services, labour and capital consumed by each industry in a production process).
- An output matrix showing which goods and services are produced by each industry.
- A final demand matrix showing which goods and services are available for consumption by final users. The final demand matrix includes goods and services that are locally produced, as well as those that are imported from other regions.

Typically, input-output models are used to assess the total economic impact associated with a change in industry output or a change in the demand for one or more commodities. These models use known information about inter-industry relationships to trace through all of the changes in the output of supplier industries that are required to support an initial increase or decrease in an industry's output, or an increase in commodity expenditures.

The British Columbia Input-Output model (BCIOM) can be viewed as a snapshot of the BC economy. It is derived from Interprovincial Input-Output tables developed by Statistics Canada and includes details on 727 commodities, 300 industries and 170 "final demand" categories, plus a set of computer algorithms to do the calculations required for the solution of the model.

BC Stats (the statistical agency of the Province of British Columbia) used the BCIOM to estimate indirect and induced impacts, based on the loss estimates developed in Section 5 utilizing the Hazus analysis and agricultural loss estimates. This appendix presents the BCIOM results and provides the estimated indirect impacts of the four flood scenarios. The information received from BC Stats is included at the end of this appendix.

## 1.3 Estimated Economic Impacts to Lower Mainland Developed Areas

The total estimated economic losses for each flood scenario can be divided into several categories of buildings, including residential, commercial, industrial and government/education. These categories are self-explanatory, except for residential. The economic losses from flooding as shown for the commercial or industrial sectors are borne by that sector unless there is a conscious decision from government to offset the loss, or unless insurance is in place for damaged property that covers the particular form of flooding that occurs. In Canada, overland flooding generally is not covered by insurance for the residential sector. The vulnerabilities involved in this situation are increasingly being recognized by the insurance industry and by government. In the case of commercially owned residential buildings, the buildings may be insured.

### 1.3.1 Impacts of Repair and Replacement of Flood Damage

The economic impact of repair and replacement of flood damage would be spread over a number of different sources. The Input-Output Model of the British Columbia Economy has been used to analyze these effects. As shown in Table E.1, using the example of Scenario D, imports from other countries would be a substantial supply source (estimated value $7.1 Billion out of a total of $18.4 Billion). Imports from other provinces would be significant ($1.2 Billion) but not relatively large. Purchases of goods and services (including labour and profits) produced in BC would be the single largest source of resources for repair and replacement of flood damage, with the estimated amount $9.9 Billion. Thus, the positive economic impact of the restoration effort following the flood would be roughly half in BC, with most of the rest of the expenditures on imports from other countries and to a lesser extent imports from other provinces.

As shown in Table E.1, the construction industry, as might be expected, would be by far the largest supplier of resources for repair and replacement. Other substantial suppliers would be manufacturing; wholesale trade; professional, scientific and technical services; finance, insurance, real estate and rental and leasing; retail trade; and transportation and warehousing.

Not surprisingly, by far the largest regional effect in British Columbia would involve suppliers in Metro Vancouver and the Fraser Valley. The direct impact on suppliers in those areas as a consequence of repairs and replacement with respect to Scenario D is estimated to be $6.2 Billion in Gross Domestic Product (GDP). The impact in the rest of BC is projected to be $1.4 Billion.

Employment impact in Metro Vancouver and the Fraser Valley with respect to repair and replacement is anticipated to be 71,000 (person-years, full time equivalents), and in the rest of British Columbia 17,000.

Total tax revenue received by governments in Canada as a result of repair and replacement involved in Scenario D is forecast to be $1.7 Billion, of which the federal government share would be $0.9 Billion, provincial receipts $0.7 Billion, and local taxes $0.1 Billion.

**Table E.1. Economic Impacts Extracted from Output Prepared by BC Stats Based on Hazus Analysis**

| Flood Scenario: | A | B | C | D |
|---|---|---|---|---|
| **Replacement of Losses re Buildings and Contents** ($ Billions) | | | | |
| Total Flood Damages per Hazus Analysis | 14.2 | 19.1 | 9 | 18.4 |
| Minus: Imports from Other Countries | 5.4 | 7.2 | 3.7 | 7.1 |
| Imports from Other Provinces | 0.9 | 1.2 | 0.6 | 1.2 |
| Equals: **Purchases of Goods and Services Produced in BC** | 7.7 | 10.5 | 4.6 | 9.9 |
| | | | | |
| **Impact on Suppliers of Repairs and Replacements - GDP** | | | | |
| In Metro Vancouver and the Fraser Valley ($Billions) | 4.8 | 6.6 | 2.8 | 6.2 |
| In the Rest of British Columbia | 1.1 | 1.5 | 0.7 | 1.4 |
| Total for Province | 5.9 | 8.1 | 3.5 | 7.6 |
| | | | | |
| **Employment Impact - Metro Vancouver and Fraser Valley** | 56,000 | 76,000 | 32,000 | 71,000 |
| (person-years) - Rest of British Columbia | 13,000 | 17,000 | 8,000 | 17,000 |
| - Total Employment Impact in BC | 69,000 | 93,000 | 40,000 | 88,000 |
| | | | | |
| **Employment Impact - In Direct Supplier Industries** | 42,000 | 56,000 | 24,000 | 53,000 |
| (person-years) **-** In Residential Building Construction | 19,000 | 24,000 | 9,000 | 23,000 |
| - In Non-residential Building Construction | 11,000 | 17,000 | 8,000 | 15,000 |
| - In Other Suppliers | 20,000 | 27,000 | 12,000 | 26,000 |
| - Induced | 7,000 | 10,000 | 4,000 | 9,000 |
| | | | | |
| **Tax Revenue** - Federal ($ Millions) | 730 | 990 | 430 | 940 |
| - Provincial (BC) | 520 | 710 | 310 | 670 |
| - Local | 110 | 140 | 60 | 140 |
| - Total | 1,360 | 1,850 | 800 | 1,750 |
| | | | | |

**Notes:**

1. Final dollar losses and employment numbers in this table have been rounded off.
2. Building-related data is based on the Hazus General Building Stock (GBS), based on 2011 Canadian Census and Dun&Bradstreet data.
3. This table excludes agricultural data.
4. Received by governments in Canada/British Columbia as a result of replacement/rebuilding of flood damage.

## 1.4 Additional Impacts of Flood Scenarios

Any one of the totals above would represent the most costly natural disaster in Canadian history, and the largest would be three times or more than the previous highest cost event of this type, the Alberta floods of 2013. In addition, there are other economic impacts of the projected Lower Mainland floods that would increase those totals. These additional impacts include the effects of flooding of agricultural land, the impacts of flooding interruption of cargo shipments through Port Metro Vancouver and railways serving the port, BNSF railroad traffic interruption from flooding, highway traffic interruption that would occur under these scenarios, and Vancouver International Airport service interruption by flooding. The evaluations of these impacts is incomplete, and there could be other economic damage impacts from the flooding.

### 1.4.1 Effects of Flooding of Agricultural Land

The effects of farmer losses under the four flood scenarios laid out as the basis for assessment of potential damages for areas susceptible to flooding in Metropolitan Vancouver, the Fraser Valley, and some smaller areas in the Lower Mainland have been analyzed for the agriculture sector.

The direct losses include lost farm gate sales, damage to equipment, damage to agricultural buildings, and replanting losses. For Scenarios A and B, those losses total around $70 Million for either scenario. For Scenarios C and D, they total $700 Million or slightly less for either case. (Assumed durations of flooding are two days for coastal scenarios and two weeks for riverine scenarios).

Lost farm gate sales are by far the largest component of the farmer losses projected to occur from the riverine flood scenarios, amounting to $410 Million in the case of Scenario C and $413 Million for Scenario D. Damage to buildings is the next most significant loss category for these scenarios, amounting to $223 Million and $227 Million respectively. Damage to equipment is anticipated to be $51 Million for either of these scenarios, and replanting losses close to $10 Million for either.

Agricultural damage is expected to be much less for either of the storm surge coastal floods, Scenarios A and B. Damage to buildings would be $38 to $41 Million, lost farm gate sales close to $17 Million, and damage to equipment $13 to $15 Million. The lower costs are related to less agricultural land being flooded, and the fact that coastal floods occur in the winter when crops are not in the ground.

While these losses are an order of magnitude less than the losses described earlier in the Hazus analysis, they are very significant in general terms and particularly to the agricultural sector. They are compared to other types of flood losses in a tabular comparison later in this appendix.

***Impacts of Restoration and Replacement of Flood Damage to Agriculture***

As noted above, the cost of agricultural losses resulting from flood scenarios analyzed differ from approximately $70 Million for coastal storm surge floods (Scenarios A and B) to about $700 Million for spring freshet river floods (Scenarios C and D). The economic impacts from the expenditures of those amounts were analyzed by BC Stats using the Input-Output model of the BC economy. The resulting impacts are summarized in Table E.2, and are described below using Scenario D as an example. This example follows closely the format used previously to describe the economic impact of the rehabilitation of flooding involved in that scenario.

**Table E.2. Economic Impacts Extracted from Output Prepared by BC Stats Based on Agriculture**

| Flood Scenario: | A | B | C | D |
|---|---|---|---|---|
| | | | | |
| **Replacement of Farmer Losses** ($ Millions) | 67.1 | 72.9 | 693.2 | 700.5 |
| Minus: Imports from Other Countries | 11.5 | 13.1 | 45.7 | 45.7 |
| Imports from Other Provinces | 0.7 | 0.8 | 7.3 | 7.2 |
| Other Leakages | 0.3 | 0.4 | 4.4 | 4.4 |
| **Purchases of Goods and Services Produced in BC** ($ Millions) | 54.5 | 58.5 | 643.1 | 643.1 |
| | | | | |
| **Impact on Suppliers of Repairs and Replacements - GDP** | | | | |
| In Metro Vancouver and the Fraser Valley | 27.6 | 29.6 | 348.0 | 351.8 |
| In the Rest of British Columbia | 13.7 | 14.7 | 118.1 | 119.9 |
| Total for Province ($Millions) | 41.3 | 44.3 | 466.1 | 471.7 |
| | | | | |
| **Employment Impact** - Metro Vancouver and Fraser Valley | 360 | 380 | 5,100 | 5,100 |
| (person-years) - Rest of British Columbia | 140 | 150 | 1,300 | 1,300 |
| - Total Employment Impact in BC | 500 | 530 | 6,400 | 6,400 |
| | | | | |
| **Employment Impact** - In Direct Supplier Industries | 290 | 310 | 4,000 | 4,000 |
| **(person-years)** - In Crop & Animal Production | 130 | 140 | 3,100 | 3,100 |
| - In Construction | 160 | 180 | 1,000 | 1,100 |
| - In Other Suppliers | 160 | 170 | 1,900 | 1,900 |
| - Induced | 50 | 60 | 500 | 500 |
| | | | | |
| **Tax Revenue** - Federal ($ Millions) | 5.2 | 5.5 | 55.7 | 56.3 |
| - Provincial (BC) | 3.5 | 3.7 | 33.4 | 33.9 |
| - Local | 0.7 | 0.7 | 8.0 | 8.1 |
| - Total | 9.3 | 9.9 | 97.1 | 98.3 |
| | | | | |

**Notes:**

1. Final dollar losses and employment numbers in this table have been rounded off.
2. Received by governments in Canada/British Columbia as a result of replacement/rebuilding of flood damage

The economic impact of restoration and replacement of flood damage to agriculture in the Lower Mainland would be spread over a limited number of sources. As shown, using the example of Scenario D, imports from other countries would be modest (estimated value $46 Million out of a total of $700 Million). Imports from other provinces would be less significant ($7 Million).

Purchases of goods and services (including labour and profits) produced in BC would be the single largest source of resources for repair and replacement of flood damage, with the estimated amount $643 Million. Thus, the economic impact of the restoration effort following the Scenario D flood as analyzed for the agriculture sector would be very largely in BC, with relatively little of the expenditure on imports.

As shown in Table E.2, crop and animal production as well as the construction industry would be key suppliers for repair and replacement of agricultural capacity. Not surprisingly, the largest regional effect in British Columbia would involve suppliers in Metro Vancouver and the Fraser Valley. The direct impact on suppliers in those areas as a consequence of repairs and replacement with respect to agricultural losses sustained in Scenario D is estimated to be $352 Million in Gross Domestic Product (GDP). The impact in the rest of BC is projected to be $120 Million.

Employment impact in Metro Vancouver and the Fraser Valley is anticipated to be 5,100 (person-years), and in the rest of British Columbia 1,300 for a total of 6,400. Employment in direct supplier industries is projected to be 4,000, including 3,100 in crop and animal production and 1,100 in construction. The employment among “other” suppliers is anticipated to be 1,900.

According to the input-output analysis, total tax revenue resulting from agricultural restoration and replacement following Scenario D is forecast to be $98 Million, of which the federal government share would be $56 Million, provincial receipts $34 Million, and local taxes $8 Million.

### 1.4.2 Flooding Interruptions of Cargo Shipments through Port Metro Vancouver and Railways Serving the Port

The flood depth information indicates that in the event of either coastal storm surge flooding or river freshet flooding, each of the railway companies/organizations transporting freight in the Fraser Valley or Fraser River delta would experience inundations of their tracks at some location or locations, with consequent interruptions to their services. Those companies/organizations include CP, CN, BNSF, Southern Railway of BC, and the 40 km spur line owned by the provincial government and serving the Roberts Bank port. In addition, the highway/roadway leading to Roberts Bank would be subject to inundation. CN has an intermodal yard in Surrey, which is in the Fraser River Floodplain. This area has no dike protection, therefore, there could be potential losses to freight / cargo shipments.

The freight carried by these railways or facilities in the Fraser Valley or Fraser River delta, on the highway leading to Roberts Bank or through the inner harbour (Burrard Inlet) is transshipped through Port Metro Vancouver (PMV). For 2014, the Port has estimated that the total value of cargo it handled was $187 Billion. If that throughput were averaged over the year, for the two week period of a flood corresponding to scenario C or scenario D, in 2014 the value of throughput delayed or lost would have been $7.2 Billion.

The term “lost” here relates to the opportunity cost involved when the operations of the railways and the port are interrupted by flooding. The corresponding reduction in the throughput of these facilities has a cost associated with it. While there could be damage to freight/cargo in transit, the loss here does not include that.

Like some other aspects of this analysis, estimating the magnitude of numerical indicators involved in illustrating the extent of floods and the economic losses they entail requires some approximations. However, the results still provide an appreciation of the magnitude of the economic impact involved.

A key question is the extent to which the supply chain including the port itself, railways, highways and production facilities in conjunction with surge capacity could make up for the impact of a flood. This likely would depend upon the time of year, the commodities being shipped, the labour situation, and other variables. For purposes of a first approximation, it is proposed that the lost throughput in the case of flood scenario C or scenario D be assumed to be roughly half of the average output for a two week period, or equivalent to cargo with a value of approximately $3.6 Billion. The balance of the throughput lost because of the flood (i.e. approximately another $3.6 Billion) is presumed to be made up during the remainder of the year.

The approach used in this analysis with respect to GDP centres on Canadian producers. Given that this report has a special focus on British Columbia and impacts on the provincial economy, it is necessary to address impacts on this province from flood interruptions in rail and port traffic, as distinct from impacts on producers elsewhere in Canada. Nevertheless, the effects on Canadian producers outside of BC also must be estimated to arrive at Canada-wide impacts in addition to those confined to this province.

To the extent that the $187 Billion estimate for Port Metro Vancouver throughput in 2014 includes shipments originating in other countries, that needs to be addressed. For example, imports such as motor vehicles or motor vehicle parts imported from Asia or consumer goods manufactured offshore and imported to Canada need to be considered, and an adjustment made in evaluating losses from flood interruption of cargo flow. This will reduce the estimates of loss to Canadian producers and thus the Canadian economy by taking account of value added (or lost) in Canada rather than levels based on the full value of the cargo.

An economic impact study periodically is prepared with respect to Port Metro Vancouver. That study includes the function of the port itself and the impact of the operation of the railways and other supporting services, including related rail employment elsewhere in British Columbia and elsewhere in Canada. The analysis includes the direct, indirect and induced impacts of the Port, and thus provides a means of calculating the overall economic loss from the projected flood in relation to cargo shipments (InterVISTAS, 2013).

The most recent economic impact analysis of the Port is based on the year 2012 (and some data for 2011), but the key ratios involved are not likely to have changed much between then and 2014. Thus these ratios can be used to help analyze the impacts of the $187 Billion in throughput that the Port achieved in 2014.

The highest value category of cargo handled through Port Metro Vancouver in 2011 was Consumer & Related Goods, with a total estimated value of $100.2 Billion. This accounted for 58 per cent of the estimated value of cargo shipped through the Port in 2011. Commodities totalled 20 per cent; Autos, Machinery and Parts 13 per cent; Forest Products 5 per cent; and other categories 6 per cent (InterVISTAS, 2013).

The commodities and forest products noted above likely originate in Canada. Much of the remainder of the cargo value is associated with imports. As a first approximation, perhaps one-half of the total cargo value could be assigned to shipments from Canada, or $94 Billion of the 2014 total.

With respect to flood Scenarios C and D, losses for a two week period prorated to the annual total for 2014 would amount to approximately $7.2 Billion. Correlating that with the $94 Billion annual total cited immediately above yields approximately $3.6 Billion in output losses for Canadian sources for the two week period of a flood corresponding to Scenario C or D.

The 2012 Economic Impact study for Port Metro Vancouver (InterVISTAS, 2013) shows a direct GDP to economic output ratio of 44 per cent "--- related to on-going operations at Port Metro Vancouver across Canada." Thus the direct GDP loss for Canada corresponding to the $3.6 Billion flood loss indicated above would be $1.6 Billion.

For a future year where the capacity of the port and its utilization would be expanded, the impacts would be greater. However, for purposes of the current analysis the assumed loss in economic output from a two week freshet flood interrupting railway operations and hence PMV would be $3.6 Billion. Based upon the ratio of direct GDP to economic output for Port Metro Vancouver (InterVISTAS, 2013) the corresponding loss of direct GDP for PMV dependent operations across Canada would be $1.6 Billion. For British Columbia alone, the direct GDP impact (loss) would be $1.5 Billion. These figures and those below are shown in Table E.3.

**Table E.3. Economic Impact of Two Week Freshet Flood Interrupting Operations of Railways and Port Metro Vancouver - Loss or Delay in Cargo/Freight Throughput**

| Assumed Loss in Total Economic Output: 3.6 Billion | | |
|---|---|---|
| | GDP Loss ($ Billions) | |
| Type of Impact | All Locations in Canada | BC Impacts Only |
| Direct | 1.6 | 1.5 |
| Indirect | 1.4 | 1.0 |
| Induced | 0.5 | 0.4 |
| Total | 3.5 | 2.9 |

The indirect GDP impact for all locations in Canada from this flood would be $1.4 Billion, and for British Columbia would be $1.0 Billion. The induced GDP loss for PMV ongoing operations across Canada would be $0.5 Billion and for operations in BC would be $0.4 Billion.

Taking account of the direct, indirect and induced GDP impacts corresponding to the $3.6 Billion flood loss indicated above, the total GDP impact for Canada as a whole would be $3.5 Billion and for BC alone would be $2.9 Billion.

This does not take account of any losses due to flood damage to the tracks or road bed of the railways or the highways involved. This presumably would be less than the total losses cited above, but could significantly impact the duration of the interruption due to the need for repairs prior to business continuity.

These estimates are approximations, dependent upon the overall magnitude of the loss in economic output resulting from a two week freshet flood interrupting railway and PMV operations. However, these figures give an appreciation for the potential order of magnitude of these effects. This is an approximation that suggests the seriousness of the potential economic damage of the projected flood scenarios.

In the case of a two day coastal storm surge flood as assumed in Scenarios A and B, the impact on the railways and the port and highways serving the port would appear to parallel the situation as outlined above. Each of the railways or components listed would be affected, although potentially some aspects of the operations of CP, CN and the Southern Railway of BC could be able to continue. However, the impact on road traffic including personnel commuting to and from work and truck traffic servicing rail facilities would have effects even on those operations.

For purposes of this analysis, it is proposed to assume that the two day flood duration of scenarios A or B would translate to a corresponding interruption in the function of Port Metro Vancouver and the railways enabling the operation of the port. This would result in a loss of $0.5 Billion in the value of cargo handled during the course of a year, with 2014 taken as the reference year.

Based upon the ratio of direct GDP to economic output for Port Metro Vancouver (InterVISTAS, 2013) the projected $0.5 Billion loss in the value of cargo handled by the port on an annual basis would result in a loss of $0.2 Billion in direct GDP for Canada as a whole. In terms of rounded numbers, the impact for BC would be the same.

The indirect GDP loss from a two day storm surge flood interrupting the operations of PMV and the railways supporting the port operations is estimated to be $0.2 Billion for all locations in Canada, and $0.1 Billion for BC impacts only. The corresponding induced GDP impact is calculated to be $0.1 Billion for Canada and the same rounded number for British Columbia.

The total estimated direct, indirect and induced GDP loss resulting from a two day storm surge flood interruption of PMV and the supporting railways amounts to $0.5 Billion for the whole of Canada, and $0.4 Billion for BC impacts only. These impacts are included in Table E.4.

**Table E.4. Economic Impact of Two Day Storm Surge Flood Interrupting Operations of Railways and Port Metro Vancouver - Loss or Delay in Cargo/Freight Throughput**

| **Assumed Loss in Economic Output: 0.5 Billion** | | |
|---|---|---|
| | **GDP Loss ($ Billions)** | |
| **Type of Impact** | **All Locations in Canada** | **BC Impacts Only** |
| Direct | 0.2 | 0.2 |
| Indirect | 0.2 | 0.1 |
| Induced | 0.1 | 0.1 |
| Total | 0.5 | 0.4 |

### 1.4.3 Economic Costs and Impacts of Principal Flood Components

In Table E.5, the direct costs for the four flood scenarios are noted together with the total costs from the Hazus analysis, the replacement of farmer losses and the losses from flooding interruptions of cargo shipments. These three categories are the major components of flood loss and their totals represent the salient indicators of both the negative cost of each flood scenario and the positive economic impact that the restoration and replacement of flood damage will create. Damage to infrastructure is not included.

As shown in the table, the results of the Hazus analysis represent the largest part of the total flood cost. The projected flood cost totals for the three principal flood components are as follows: Scenario A: $14.8 Billion; Scenario B: $19.8 Billion; Scenario C: $13.3 Billion; Scenario D: $22.7 Billion. Any of these scenarios would be by far the most costly natural disaster in Canadian history, and would severely strain the national economy.

The cost information for the flood scenarios is subject to some uncertainty, but provides a good indication of the order of magnitude of these threats.

**Table E.5. Economic Impacts ($ Millions) Using BC Input-Output Model**

| **Flood Scenario:** | **A** | **B** | **C** | **D** |
|---|---|---|---|---|
| **Losses from Three Key Causes** ($ Millions) | | | | |
| Replacement of Losses per Hazus | 14,200 | 19,100 | 9,000 | 18,400 |
| Replacement of Farmer Losses | 67 | 73 | 693 | 701 |
| Flooding Loss re Interruptions of Cargo Shipments | 500 | 500 | 3,600 | 3,600 |
| Total | 14,767 | 19,673 | 13,293 | 22,701 |
| **Rounded Total** ($ Millions) | **14,800** | **19,700** | **13,300** | **22,700** |
| | | | | |
| **Purchases of Goods and Services Produced in** BC ($ Millions) | | | | |
| Re: Replacement of Losses per Hazus | 7,700 | 10,500 | 4,600 | 9,900 |
| Re: Replacement of Farmer Losses | 54 | 58 | 643 | 643 |
| Re: Flooding Loss re Interruptions of Cargo Shipments | 900 | 900 | 6,600 | 6,600 |
| Total | 8,655 | 11,459 | 11,843 | 17,143 |
| **Rounded Total** ($ Millions) | **8,700** | **11,500** | **11,800** | **17,100** |
| | | | | |
| **Impact on Suppliers of Repairs and Replacements – GDP** | | | | |
| Re: Replacement of Losses per Hazus | 5,900 | 8,100 | 3,500 | 7,600 |
| Re: Replacement of Farmer Losses | 41 | 44 | 466 | 472 |
| Re: Flooding Loss re Interruptions of Cargo Shipments | 400 | 400 | 2,900 | 2,900 |
| Total (BC) | 6,341 | 8,544 | 6,866 | 10,972 |
| **Rounded Total** ($ Millions) | **6,300** | **8,500** | **6,900** | **11,000** |

### 1.4.4 BNSF Railroad Traffic Interruption Through Flooding

The BNSF rail line linking Metropolitan Vancouver with the United States at the Pacific Highway border crossing is an important route for freight traffic. In 2012 this line carried $2.8 Billion in Western Canadian exports and $1.8 Billion in corresponding imports. Of these, British Columbia exports amounted to $1.5 Billion and British Columbia accounted for all of the imports. This was the route for 54 per cent of all British Columbia rail freight to and from the United States (Economic Development Research Group, Inc., 2014).

Amtrak operates two passenger trains daily in each direction over this track, providing a significant link between Vancouver and points along the coast of Washington state and further south.

This rail line is quite susceptible to flooding through the Nicomekl and Serpentine River lowlands including a lengthy trestle across the mouth of the Serpentine River where it enters Mud Bay. Thus, the coastal surge flooding risk outlined previously applies to this line, with the assumed two day interruption of traffic. The total annual value of Western Canadian export and import freight carried on this BNSF link in 2012 was $4.6 Billion, with the British Columbia share of this amounting to $3.2 Billion. A two day interruption in this flow on average would total $25 Million in total and $18 Million for the British Columbia share.

The proposed shipment of coal from the United States through Fraser Surrey Docks to overseas markets would add several additional daily trains on the BNSF line and thus would increase flood losses from the interruption noted above.

### 1.4.5 Highway Traffic Interruptions by Flooding

The assumptions being used in this analysis are that a coastal storm surge flood would last for two days, including the flooding and the subsequent drainage of flood waters. This would apply to the delta area of the Fraser River as discussed below. The assumption with respect to spring freshet flooding is that such a flood would last for two weeks, including one week of flooding and a week of subsequent drainage of flood waters. While the calculations provided are not precise, they provide an indication of the magnitude of the economic losses involved.

It appears that British Columbia Ministry of Transportation and Infrastructure (MOTI) highways may experience serious disruptions under the coastal flood scenarios, given the apparent extensive submergence of high traffic volume major highways. Highway 99 appears to be particularly vulnerable, at least through the Serpentine and Nicomekl lowlands between the Massey tunnel and the hill leading up to South Surrey/White Rock. Other highways crossing the Serpentine and Nicomekl Rivers also would be inundated under scenarios A or B.

The highway system is vital to the regional economy, including fresh food imports from the US, general imports and exports from/to the United States, tourist traffic and traffic to and from the Tsawwassen ferry terminal and Roberts Bank facility, and general commuter traffic. For the two day duration assumed under scenario A or B, commuter traffic to or from South Surrey/White Rock, Tsawwassen, Ladner and other areas of Delta would be interrupted by inundation of highways.

Operation of the Pacific Highway crossing would be interrupted by the flooding outlined above. In 2012, truck traffic accounted for $4.7 Billion in Western Canadian exports through that crossing and $14.9 Billion in imports. Of those amounts, British Columbia exports represented $4.2 Billion in exports and $12.7 Billion in imports (Economic Development Research Group, Inc., 2014, *Economic Impact of the Greater Vancouver Gateway,* prepared for the Greater Vancouver Gateway Council by Economic Development Research Group Inc., Boston, September 2014.). The following figures are calculated based upon the statistics cited above:

If BC export shipments were halted for two days by flooding, the loss in export shipments is projected to be $23 Million. The corresponding reduction in BC imports would be $70 Million. A substantial proportion of those imports would be food for the population of British Columbia, currently 4.7 Million persons. The system of food importing and distribution would experience shortages within a few days of an interruption of this magnitude.

journey is prevented by flooding in this situation is approximately $250[2]. Thus, the economic loss (whether to a commuter or their employer depending on the basis for remuneration) from a two day flood would be approximately $500, and the total loss for all commuters would approach $10 Million.

The average volume of traffic in each direction passing through the Massey Tunnel on Highway 99 on a typical weekday in winter (based on non-holiday periods in December, 2014) exceeds 40,000 vehicles. Using a conservative number of 35,000 vehicles to allow for non-commuters, the total loss for all commuters on this route if prevented from using the tunnel as a result of a two day flood would be approximately $18 Million.

It should be kept in mind that the financial totals in the two cases cited above are mutually exclusive, since they in part apply to the same commuters. However, the larger figure captures many commuters from Tsawwassen, Ladner and other locales, and the lesser number allows in part for ferry users and others to whom the loss calculation does not apply. While these calculations are not precise, they provide an indication of the magnitude of the economic losses involved.

MOTI highways also appear to be very vulnerable with respect to the freshet flood scenarios. The flood map overlays show quite deep and extensive submergence between Chilliwack and Abbotsford, affecting a substantial distance along the Highway 1. While it is not as clear with respect to the situation affecting most of Highway 7 on the north shore of the Fraser River in the case of a freshet flood, review of the flood depth documentation shows that there would be serious submergence there and on islands in the river such as Seabird Island and NIcomen Island. For both Highway 1 and Highway 7 the presumption of a two week interruption in traffic as a result of flooding applies.

While there is no doubt significant commuter traffic along both Highway 1 and Highway 7 in the Fraser Valley, there is also a great deal of other traffic. Accordingly, no attempt has been made to consider the economic impact of flooding with respect to commuter traffic on these routes.

### 1.4.6 Vancouver International Airport Service Interruption from Flooding

Based upon statistics for 2014, interruption of the services of Vancouver International Airport (YVR) for two days as a result of flooding would result in the cancellation of 1,700 combined takeoffs and landings from the airport's runways over the two day period. This number is based on the average daily number of flights for that year.

The total number of enplaned and deplaned passengers for the airport in 2014 was 19.36 Million. Extrapolating from the number of passengers in 2010 and applying this to the direct wages of employees at the airport with an allowance for inflation results in an estimate of $1.25 Billion for direct wages in 2014. The average direct total wages for a two day period during that year would be $6.8 Million. Either the workers would lose their wages for the two day period or their employer would lose the economic benefit of their employment for two days.

[2] Statistics Canada, CANSIM table 281-0027

In 2010 the ongoing operations of Vancouver International Airport involved 23, 614 direct jobs, which accounted for 21,633 direct person-years of employment. Given the growth of activity at the airport, it is estimated that in 2014 these numbers would have risen to 27,200 direct jobs and 24,900 direct person-years.

According to the *Vancouver International Airport Economic Impact Report* for 2010 (Ference Weiker & Company Consulting Ltd., 2011), the number of indirect and induced jobs stimulated by the Airport was 2.5 times the number of direct jobs, or 23,000 indirect and 15,200 induced jobs. The combined number of direct, indirect and induced jobs in 2014 is estimated to have been 61,800 jobs.

The passengers and cargo delayed by the flooding presumably would either be diverted elsewhere, or would be delayed and flown in and out of YVR later. With respect to diversion, as outlined elsewhere in this report, the two day flood would prevent travel by road or railroad to other airports, with the possible exception of Abbotsford International Airport. The use of that facility would depend upon the passengers and airport/airline and supporting services employees and service suppliers being able to reach that airport. Road access to the Tsawwassen ferry terminal would be interrupted, so that Victoria International Airport would not be a practical alternative.

For the two day period of the flood, the estimated loss of direct Gross Domestic Product (for Canada as a whole) would be $13 Million, the indirect GDP loss would be $14 Million, and the induced GDP loss $9 Million, for a total of $36 Million. These figures are extrapolated from the airport's economic impact report for 2010, are very small compared with most of the other types of flood loss analyzed in this report and are not included in the flood loss tables in this document. It should be noted that there is potential for damage to airport facilities and associated infrastructure. Therefore the duration of service interruption, and the associated direct, indirect, and induced losses could be significantly higher than the estimates provided within this report.

The losses directly associated with YVR would be echoed by other losses as a consequence of the disruption of the overall airline system affected by the interruption of the operation of YVR. There would be a corresponding reduction in activity at the airports with aircraft that were scheduled to depart for YVR, or that would have received aircraft from YVR. The disruption of the airline system would have a ripple effect on many other airports, including from the loss of use of aircraft stranded at YVR. The effect would be similar to the closure of an airport as a consequence of fog, blizzard, or other weather conditions interrupting airport operations for a similar length of time. The Abbotsford airport is deemed as the emergency airport – not to reroute passenger airlines but to bring in supplies for the Lower Mainland during an emergency situation.

## 1.5 Conclusion

The economic losses and estimated impacts to the BC economy are approximate. However, they provide an indication of the severe impacts of large riverine and coastal floods and demonstrate the need for a flood management strategy for the Lower Mainland. The results are also indicative of the relative increase in losses from present to future flood scenarios, providing a better understanding of the increasing risks.

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# BC Input-Output Model Report: Estimated Impact of Flood Damage in the Fraser Basin

## BACKGROUND

This report summarizes the results of an input-output analysis that assesses the economic impact of flood damage in the Fraser Basin, using various flooding scenarios. The report evaluates the economic impact associated with estimated losses in the agriculture sector, as well as losses to existing buildings, contents and inventory under four different flooding scenarios.

The impact analysis is based on loss estimates provided to BC Stats by Northwest Hydraulic Consultants. The impact study focusses primarily on the cost of replacing structures, equipment and contents damaged in a flood.

The British Columbia Input-Output Model (BCIOM) was used to generate the estimates. A description of the BCIOM, and the assumptions underlying input-output analysis, is included in the Appendix.

## ABOUT INPUT-OUTPUT ANALYSES

Input-output analyses highlight the relationships among producers and consumers (businesses as well as individuals) of goods and services. An input-output analysis is based on first identifying a basket of goods and services used by a specific project[1] and then tracing through all of the steps involved in producing those goods and services to identify the total extent to which the British Columbia economy will be affected by project expenditures.

## THREE TYPES OF IMPACTS

Three different types of impacts are reported in a typical input-output analysis:

The **direct impact** measures the impact on BC industries supplying goods and services directly used by the project.

The **indirect impact** measures the impact on BC industries that are further back in the supply chain. The indirect impact is cumulative, and includes transactions going all the way back to the beginning of the supply chain.

[1] Or, in the case of an industry analysis, the total value of production by one or more industries.

The **induced impact** measures the effect that spending by workers (those employed by the project, or by direct and indirect supplier industries) has on the economy.

## HOW ARE ECONOMIC IMPACTS MEASURED?

Output, GDP, employment and tax revenues are the key measures used to assess the economic impacts associated with a project. In order to properly interpret the results of a BCIOM analysis, some background information about what these measures represent and how they are calculated may be helpful. A brief explanation of terms and concepts follows.

**Output** is simply a measure of the total value of production associated with a project. In an ***industry-based*** analysis, output is equal to the value of goods and services produced by the BC industry or industries that are affected by a specific project. In an ***expenditure-based*** analysis, it can be measured as the total dollar amount of all spending on ***goods and services produced in BC***. It should be noted that purchases of goods and services produced outside the province do not directly affect BC businesses, so these expenditures are explicitly excluded from the analysis. This is usually the main reason why the direct impact on BC industries is less than initial project expenditures.

**Gross Domestic Product (GDP)** is a measure of the value added (the unduplicated total value of goods and services) to the BC economy by current productive activities attributable to the project. It includes **household income** (wages, salaries and benefits, as well as income earned by proprietors of unincorporated businesses) from current productive activities as well as profits and other income earned by corporations. Only activities that occur within the province are included in GDP.

**Employment** estimates generated by the model are derived from estimated wage costs using information on average annual wages in each industry in 2013 (the latest year for which this information is available). Two different employment estimates are presented in the report tables: employment and full-time equivalent (FTE) measures.

The employment estimates reflect the wages paid and hours spent on the job by a typical worker in each industry. In an industry where most employees work full time, the numbers will be very similar to FTE counts. However, in an industry where part-time work is more common, the job counts will be quite different from FTEs.

The full-time equivalent estimates are calculated based on the assumption that a full-time employee works 35 hours a week, for 50 weeks of the year. This assumption can be modified when the model is run.

**Government tax revenue** estimates generated by the model include income and commodity taxes. The revenue estimates are calculated based on the current tax structure (i.e., tax rates in effect in 2015).

*Provincial and federal tax revenues* include federal and provincial personal and corporation income taxes. Also included are PST, GST and other *commodity* taxes. These include taxes on products (e.g., gas taxes, environmental taxes, liquor and lottery taxes and profits, air transportation taxes, duties and excise taxes) and taxes on factors of production (e.g., licences, permits, fees and property taxes).

*Municipal tax revenues* include taxes on products (primarily accommodation taxes) and taxes on production (business taxes, developer's fees, licences, permits, fees and property taxes).

A more detailed explanation of input-output modelling in general and the BCIOM in particular is included in the Appendix.

**Output or GDP: which measure should be used to evaluate economic impacts associated with a project?**

Output and GDP are both valid economic measures. However, there are some key differences between them that should be kept in mind when analyzing the results of an input-output analysis.

*Output measures correspond to total spending or production, but may overstate the economic impact of a project because the value of a good or service is counted each time it changes hands.*

If one is only looking at direct effects, output is a meaningful measure since it shows the total dollar value of industry production. However, there is a danger of double-counting when activities in industries further up the supply chain are also included. Output measures may overstate the indirect economic impact associated with a particular project since the activities of every industry that has contributed in some way to the creation of a final product are counted each time a good or service changes hands.

For example, when a construction company builds a house, the selling price of the house includes:

- the cost of the land on which it is built;
- the cost of inputs (lumber, shingles, cement, carpets, paint, hardware, plumbing fixtures, architectural services and so on) purchased and used by the builder; and
- the value of the work done by the construction company.

An **output-based impact measure** would include the entire selling price of the house (including all these imbedded costs) in the direct output of the construction industry. The value of architectural services included in the cost of the house would also be counted as an indirect output impact on the architectural services industry. The value of the lumber used would be counted as an indirect output impact on the wood industry, and going further back in the supply chain, the value of the logs used by the sawmill would be counted in the indirect output impact on the logging industry. In this example, the value of the logs used to produce the building materials is counted at least three times: once in the direct output impact, and twice in the indirect output impacts on the sawmill and logging industries. In other words, the indirect output impact could be quite high simply because goods (or services) used in production have changed hands many times.

*Indirect output impacts provide useful information about the total amount of money that has changed hands as goods and services are transformed into final products. GDP is a better measures of the economic impact since the value of the work done by each industry is attributed only to the producing industry, and is counted only once.*

GDP is calculated by subtracting the cost of purchased goods, services and energy from the total value of an industry's output. As a result, the value of the work done by a producing industry is only counted once. In the construction example, the direct GDP impact would only include the value of the work done by the construction firm. The indirect impact on the sawmill industry would only include the value of the work done to transform the logs into lumber, and the indirect impact on the logging industry would be a measure of the value of the work done by the loggers. There is no double counting in GDP measures.

It should be noted that the relationship between GDP and output is a useful analytical measure since it shows the extent to which industries rely on labour and capital as opposed to material and service inputs in production. The analysis of economic impacts relies on this relationship, since output is more easily and directly measured than GDP. In fact, the starting point for most input-output analyses is a measure of the direct output associated with a project. From this, known relationships between output and other indicators such as GDP and employment can be used to estimate the economic impact associated with a specific project.

## REGIONAL IMPACTS

The BCIOM is a provincial model, based on the structure of the British Columbia economy in 2011. Thus, the impact estimates (output, GDP, employment, household income and tax revenues) calculated by the model are produced at the provincial level.

The regional impact estimates reported in the model outputs are derived by using information about the composition of the province's labour force. This information comes from two sources: the National Household Survey (NHS) and the monthly Labour Force Survey (LFS). The NHS data are available for detailed geographies (development region, regional district, census subdivision, etc.) and industries. They show the composition and industrial structure of the province's work force in 2010.

Information from the LFS is not as detailed (at either the industry or geography level), but is more timely than the NHS information (LFS data are currently available for 2014). When calculating regional impacts, the NHS data for the selected region is extrapolated based on trends in the LFS data for the more aggregated region or industry. The NHS-based estimates are then used to calculate the share of total British Columbia employment, by detailed industry, in the selected region. These shares are then applied to the detailed output data generated by the model to estimate the percentage of total employment in each affected industry that could potentially be allocated to the study region.

Information on the regional labour force and employment is used to determine whether the local area could potentially supply the number of workers needed by each industry affected by the project. For some industries (e.g., resource industries, construction, accommodation and food services), it is assumed that the pool of potentially available workers is not restricted to those who were previously employed in these industries. For other industries, the region's share of total employment is based on the existing pool of workers in the affected industry.

# SUMMARY OF RESULTS, ESTIMATED IMPACT OF FLOOD DAMAGE IN THE FRASER BASIN

## SOURCES OF DATA

The results presented in this report are derived from information provided by Northwest Hydraulic Consultants (NHC). NHC prepared estimates of damage to structures, equipment and contents for four different flooding scenarios: two involving a coastal flood, and two involving a freshet flood.

In total, eight scenarios were run through the model. These include four agriculture scenarios and four scenarios associated with estimated damage to structures, equipment and contents, and business interruption costs. The loss estimates were generated by the HAZUS model.

For the agriculture scenarios, the information provided by NHC included estimated losses for various types of crops, livestock and nursery stock, as well as losses in buildings and equipment. The BCIOM was used to estimate the economic impact associated with rebuilding the structures, purchasing new equipment, and replacing the lost crop, nursery stock, and livestock.

The BCIOM estimates for each of the HAZUS scenarios reflect the economic impact associated with replacing the residential, commercial, industrial, and government and educational buildings, their contents, and inventories. For commercial buildings, the loss estimates also included an allowance for business interruption costs, which include lost income, relocation costs, rental income and wages. These amounts were treated as expenditures and included in the impact calculations.

No information on the specific industries included within these categories, or the specific goods expected to be damaged or destroyed in the flooding was provided. Therefore, model information was used to distribute the expected losses to specific BCIOM categories.

The economic impact for building replacement was calculated using model information for the residential and non-residential building construction industries.

For the contents, model information on typical household purchases of furniture, furnishings and fixtures by households was used to determine the allocation of replacement costs for residential contents lost in flooding. A similar approach was used to estimate the impact associated with replacing contents and inventories in commercial buildings occupied by wholesalers, retailers, and various types of service industries and for industrial, government and educational buildings. The content loss estimates were allocated to BCIOM categories using model information about typical purchases of equipment and fixtures for the relevant industries. Inventory losses were allocated based on the value of production in the affected industries.

Each of the scenarios was run through the BCIOM in order to determine the direct, indirect and induced impacts associated with the estimated losses.

## KEY ASSUMPTIONS

The wage component of the labour cost estimate is assumed to include pre-tax wages, salaries and benefits (e.g., the employer's share of contributions to EI or CPP). The model's estimates of income tax revenues are calculated by estimating income taxes associated with a given wage. For the calculation of induced effects, it is assumed that 80% of workers' earnings will be used to purchase goods and services in the province (it is assumed that the remaining 20% goes to taxes, payroll deductions, and savings).

It is assumed that a social safety net is in place, and that workers hired to work on the project previously had some income from EI or other safety net programs (note: the social safety net assumption only affects the estimate of worker spending, which is the induced effect associated with the project).

All of the tax revenue impacts have been calculated based on the current tax structure, which assumes a PST of 7% is applied to items subject to the tax.

Employment estimates are generated by the model based on the wage bill and average earnings in each affected industry. The model estimates represent average jobs in an industry. In some industries, most workers are employed full time, but in others (e.g., accommodation and food services) the typical work week is usually shorter. The model output also includes FTE estimates, based on the assumption that a full-time employee would work 1,750 hours per year.

## SUMMARY OF RESULTS: AGRICULTURE SCENARIO A

For agriculture, Scenario A assumes total losses of $67.0 million, with most of the loss being damage to buildings ($37.9 million) or equipment ($12.7 million). Losses to crops, livestock and nursery stock are estimated at $16.5 million.

In order to replace the lost buildings, equipment and crops, it is estimated that $12.2 million will be used to purchase goods imported from other provinces or countries, while $0.3 million will be spent on goods withdrawn from inventories held by producers. Total purchases of goods and services produced in British Columbia are estimated at $54.5 million. This is the amount that was used to shock the model.

The economic impact associated with a total expenditure of $54.5 million on goods and services produced in British Columbia includes $28.9 million of goods and services purchased from supplier industries, and another $8.6 million in spending by workers.

The GDP associated with the replacement activities includes $22.6 million generated by direct supplier industries (primarily construction, at $16.5 million and crop and animal production, at $5.7 million). Another $13.3 million of GDP would be produced by industries further back in the supply chain (e.g., professional services such as engineering, manufacturing, and other business services). Spending by workers employed as a result of the replacement activities is expected to contribute another $5.4 million to total GDP.

Total employment associated with the replacement of lost buildings, equipment, crops and livestock is estimated at 293 jobs in direct supplier industries, another 155 jobs in industries further back in the supply chain, and 53 jobs generated as a result of spending by workers.

### Estimated Impact of Flooding on Agriculture (replacement of crops, livestock & equipment) Scenario A (replacement of losses)

| Total impact, including Scenario A, supplier industry & induced effects | Direct | Other suppliers | Total Indirect* | Induced** | Total impact |
|---|---|---|---|---|---|
| Total Scenario A ($M) | **67** | | | | |
| Supplier industry & induced impacts ($M) | *54* | *29* | **83** | 9 | **92** |
| GDP at basic prices ($M) | | | | | **41** |
| Scenario A*** | | | | | |
| Supplier industry & induced impacts | *23* | *13* | **36** | 5 | 41 |
| Employment (#)**** | | | | | **502** |
| Scenario A (Model estimate) | | | | | |
| Supplier industry & induced impacts | *293* | *155* | **449** | 53 | 502 |
| Employment (FTES) | | | | | **522** |
| Scenario A (Model estimate) | | | | | |
| Supplier industry & induced impacts | *315* | *158* | **473** | 48 | 522 |
| Household income ($M) | | | | | **32** |
| Scenario A | | | | | |
| Supplier industry & induced impacts | *19* | *9* | **28** | 4 | 32 |
| Average annual wage ($ per employee) | | | | | |
| Scenario A | | | | | |
| Supplier industry & induced impacts | 63,740 | 60,835 | **62,735** | 73,435 | **63,860** |
| Tax revenue ($M) | | | | | **9** |
| Scenario A | | | | | |
| Supplier industry & induced impacts | *6* | *3* | **8** | 1 | 9 |

* The total indirect impact is the sum of the effect on direct suppliers and other supplier industries

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

*** Project expenditure data provided by clients may not include all components of GDP (e.g., operating surplus)

**** Employment estimates are based on average annual wages in 2013. Includes total employment over the life of the project

| Allocation of Flood Losses<br>Scenario A (replacement of losses) | |
|---|---|
| **Total Scenario A expenditures ($M)** | **67.0** |
| *minus leakages:* | |
| *imports from other countries* | *11.5* |
| *imports from other provinces* | *0.7* |
| *other leakages (e.g. withdrawals from inventory)* | *0.3* |
| *Equals:* | |
| **Purchases of goods & services (including labour and profits) produced in BC ($M)** | **54.5** |
| *Of which:* | |
| *Wages, benefits, mixed income and operating surplus ($M)* | 0.0 |
| *Taxes on products net of subsidies ($M)* | 0.0 |
| *Taxes on factors of production net of subsidies ($M)* | 0.0 |
| ***Direct BC supply ($M)*** | **54.5** |
| *( the change in BC supplier industry output associated with Scenario A)* | |

Indirect & Induced Impacts resulting from project expenditures

**Indirect & Induced Impacts resulting from Scenario A**

| | Direct suppliers | Other suppliers | Total indirect impact (all suppliers) | Induced Impact** | Total indirect & induced impacts |
|---|---|---|---|---|---|
| Output ($M) | 54 | 29 | 83 | 9 | 92 |
| GDP at basic prices* ($M) | 23 | 13 | 36 | 5 | 41 |
| Employment (#)* | 293 | 155 | 449 | 53 | 502 |
| FTEs (#) | 315 | 158 | 473 | 48 | 522 |
| Household income ($M) | 19 | 9 | 28 | 4 | 32 |
| **Total tax revenue ($M)** | **5.6** | **2.8** | **8.4** | **1.0** | **9.3** |
| Federal ($M) | 3.1 | 1.6 | 4.7 | 0.5 | 5.2 |
| *Personal income tax* | *2.9* | *1.3* | *4.2* | *0.4* | *4.6* |
| *Corporation income tax* | *0.3* | *0.2* | *0.5* | *0.1* | *0.6* |
| *Net taxes on products* | *0.0* | *0.0* | *0.0* | *0.0* | *0.0* |
| Provincial ($M) | 2.2 | 1.0 | 3.2 | 0.3 | 3.5 |
| *Personal income tax* | *1.0* | *0.5* | *1.5* | *0.1* | *1.6* |
| *Corporation income tax* | *0.1* | *0.1* | *0.3* | *0.0* | *0.3* |
| *Net taxes on products* | *1.0* | *0.4* | *1.4* | *0.1* | *1.5* |
| Local ($M) | 0.3 | 0.2 | 0.5 | 0.2 | 0.7 |

* Includes wages, benefits, mixed income, operating surplus and net taxes on factors of production

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

## SUMMARY OF RESULTS: AGRICULTURE SCENARIO B

For agriculture, Scenario B assumes total losses of $72.8 million, with most of the loss being damage to buildings ($40.9 million) or equipment ($14.6 million). Losses to crops, livestock and nursery stock are estimated at $17.4 million.

In order to replace the lost buildings, equipment and crops, it is estimated that $13.9 million will be used to purchase goods imported from other provinces or countries, while $0.4 million will be spent on goods withdrawn from inventories held by producers. Total purchases of goods and services produced in British

Columbia are estimated at $58.5 million. This is the amount that was used to shock the model.

The economic impact associated with a total expenditure of $58.5 million on goods and services produced in British Columbia includes $30.9 million of goods and services purchased from supplier industries, and another $9.2 million in spending by workers.

The GDP associated with the replacement activities includes $24.2 million generated by direct supplier industries (primarily construction, at $17.9 million and crop and animal production, at $6.0 million). Another $14.3 million of GDP would be produced by industries further back in the supply chain (e.g., professional services such as engineering, manufacturing, and other business services). Spending by workers employed as a result of the replacement activities is expected to contribute another $5.8 million to total GDP.

Total employment associated with the replacement of lost buildings, equipment, crops and livestock is estimated at 314 jobs in direct supplier industries, another 166 jobs in industries further back in the supply chain, and 57 jobs generated as a result of spending by workers.

**Estimated Impact of Flooding on Agriculture**
**(replacement of crops, livestock & equipment)**
**Scenario B (replacement of losses)**

**Total impact, including Scenario B, supplier industry & induced effects**

| | Direct | Other suppliers | Total Indirect* | Induced** | Total impact |
|---|---|---|---|---|---|
| Total Scenario B ($M) | **73** | | | | |
| Supplier industry & induced impacts ($M) | *58* | *31* | **89** | 9 | **99** |
| GDP at basic prices ($M) | | | | | **44** |
| Scenario B*** | | | | | |
| Supplier industry & induced impacts | *24* | *14* | **39** | 6 | 44 |
| Employment (#)**** | | | | | **538** |
| Scenario B (Model estimate) | | | | | |
| Supplier industry & induced impacts | *314* | *166* | **481** | 57 | 538 |
| Employment (FTES) | | | | | **559** |
| Scenario B (Model estimate) | | | | | |
| Supplier industry & induced impacts | *338* | *169* | **507** | 52 | 559 |
| Household income ($M) | | | | | **34** |
| Scenario B | | | | | |
| Supplier industry & induced impacts | *20* | *10* | **30** | 4 | 34 |
| Average annual wage ($ per employee) | | | | | |
| Scenario B | | | | | |
| Supplier industry & induced impacts | 63,960 | 60,900 | **62,900** | 73,435 | **64,010** |
| Tax revenue ($M) | | | | | **10** |
| Scenario B | | | | | |
| Supplier industry & induced impacts | *6* | *3* | **9** | 1 | 10 |

* The total indirect impact is the sum of the effect on direct suppliers and other supplier industries

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

*** Project expenditure data provided by clients may not include all components of GDP (e.g., operating surplus)

**** Employment estimates are based on average annual wages in 2013. Includes total employment over the life of the project

| Allocation of Flood Losses<br>Scenario B (replacement of losses) | |
|---|---|
| **Total Scenario B expenditures ($M)** | **72.8** |
| *minus leakages:* | |
| *imports from other countries* | *13.1* |
| *imports from other provinces* | *0.8* |
| *other leakages (e.g. withdrawals from inventory)* | *0.4* |
| | |
| *Equals:* | |
| **Purchases of goods & services (including labour and profits) produced in BC ($M)** | **58.5** |
| *Of which:* | |
| *Wages, benefits, mixed income and operating surplus ($M)* | 0.0 |
| *Taxes on products net of subsidies ($M)* | 0.0 |
| *Taxes on factors of production net of subsidies ($M)* | 0.0 |
| ***Direct BC supply ($M)*** | **58.5** |
| *( the change in BC supplier industry output associated with Scenario B)* | |

Indirect & Induced Impacts resulting from project expenditures

**Indirect & Induced Impacts resulting from Scenario B**

| | Direct suppliers | Other suppliers | Total indirect impact (all suppliers) | Induced Impact** | Total indirect & induced impacts |
|---|---|---|---|---|---|
| Output ($M) | 58 | 31 | 89 | 9 | 99 |
| GDP at basic prices* ($M) | 24 | 14 | 39 | 6 | 44 |
| Employment (#)* | 314 | 166 | 481 | 57 | 538 |
| FTEs (#) | 338 | 169 | 507 | 52 | 559 |
| Household income ($M) | 20 | 10 | 30 | 4 | 34 |
| **Total tax revenue ($M)** | **6.0** | **3.0** | **9.0** | **1.0** | **10.0** |
| Federal ($M) | 3.3 | 1.7 | 5.1 | 0.5 | 5.5 |
| *Personal income tax* | *3.1* | *1.4* | *4.5* | *0.4* | *4.9* |
| *Corporation income tax* | *0.3* | *0.3* | *0.5* | *0.1* | *0.6* |
| *Net taxes on products* | *-0.1* | *0.0* | *0.0* | *0.0* | *0.0* |
| Provincial ($M) | 2.3 | 1.1 | 3.4 | 0.3 | 3.7 |
| *Personal income tax* | *1.1* | *0.5* | *1.6* | *0.1* | *1.7* |
| *Corporation income tax* | *0.2* | *0.1* | *0.3* | *0.1* | *0.4* |
| *Net taxes on products* | *1.1* | *0.4* | *1.5* | *0.1* | *1.6* |
| Local ($M) | 0.3 | 0.2 | 0.5 | 0.2 | 0.7 |

* Includes wages, benefits, mixed income, operating surplus and net taxes on factors of production

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

## SUMMARY OF RESULTS: AGRICULTURE SCENARIO C

For agriculture, Scenario C assumes total losses of $683.7 million, with most of the loss being damage to crops, livestock and nursery stock ($410.1 million). Damage to buildings ($223.0 million) and equipment ($50.7 million) is also expected to be significant.

In order to replace the lost buildings, equipment and crops, it is estimated that $53.0 million will be used to purchase goods imported from other provinces or countries, while $4.4 million will be spent on goods withdrawn from inventories held by producers. Total purchases of goods and services produced in British Columbia are estimated at $626.3 million. This is the amount that was used to shock the model.

The economic impact associated with a total expenditure of $626.3 million on goods and services produced in British Columbia includes $359.7 million of goods and services purchased from supplier industries, and another $88.0 million in spending by workers.

The GDP associated with the replacement activities includes $256.1 million generated by direct supplier industries (primarily crop and animal production, at $150.0 million, and construction, at $97.5 million). Another $155.1 million of GDP would be produced by industries further back in the supply chain (e.g., professional services such as engineering, manufacturing, and other business services). Spending by workers employed as a result of the replacement activities is expected to contribute another $54.9 million to total GDP.

Total employment associated with the replacement of lost buildings, equipment, crops and livestock is estimated at 3,950 jobs in direct supplier industries, another 1,875 jobs in industries further back in the supply chain, and 539 jobs generated as a result of spending by workers.

**Estimated Impact of Flooding on Agriculture**
**(replacement of crops, livestock & equipment)**
**Scenario C (replacement of losses)**

| Total impact, including Scenario C, supplier industry & induced effects | Direct | Other suppliers | Total Indirect* | Induced** | Total impact |
|---|---|---|---|---|---|
| Total Scenario C ($M) | **684** | | | | |
| Supplier industry & induced impacts ($M) | *626* | *360* | **986** | 88 | **1,074** |
| GDP at basic prices ($M) | | | | | **466** |
| Scenario C*** | | | | | |
| Supplier industry & induced impacts | *256* | *155* | **411** | 55 | 466 |
| Employment (#)**** | | | | | **6,364** |
| Scenario C (Model estimate) | | | | | |
| Supplier industry & induced impacts | *3,950* | *1,875* | **5,825** | 539 | 6,364 |
| Employment (FTES) | | | | | **6,529** |
| Scenario C (Model estimate) | | | | | |
| Supplier industry & induced impacts | *4,126* | *1,907* | **6,033** | 496 | 6,529 |
| Household income ($M) | | | | | **348** |
| Scenario C | | | | | |
| Supplier industry & induced impacts | *200* | *109* | **309** | 40 | 348 |
| Average annual wage ($ per employee) | | | | | |
| Scenario C | | | | | |
| Supplier industry & induced impacts | 50,625 | 58,035 | **53,010** | 73,435 | **54,740** |
| Tax revenue ($M) | | | | | **97** |
| Scenario C | | | | | |
| Supplier industry & induced impacts | *54* | *33* | **87** | 10 | 97 |

* The total indirect impact is the sum of the effect on direct suppliers and other supplier industries

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

*** Project expenditure data provided by clients may not include all components of GDP (e.g., operating surplus)

**** Employment estimates are based on average annual wages in 2013. Includes total employment over the life of the project

| Allocation of Flood Losses<br>Scenario C (replacement of losses) | |
|---|---|
| **Total Scenario C expenditures ($M)** | **683.7** |
| *minus leakages:* | |
| *imports from other countries* | *45.7* |
| *imports from other provinces* | *7.3* |
| *other leakages (e.g. withdrawals from inventory)* | *4.4* |
| | |
| *Equals:* | |
| **Purchases of goods & services (including labour and profits) produced in BC ($M)** | **626.3** |
| *Of which:* | |
| *Wages, benefits, mixed income and operating surplus ($M)* | 0.0 |
| *Taxes on products net of subsidies ($M)* | 0.0 |
| *Taxes on factors of production net of subsidies ($M)* | 0.0 |
| ***Direct BC supply ($M)*** | **626.3** |
| *( the change in BC supplier industry output associated with Scenario C)* | |

Indirect & Induced Impacts resulting from project expenditures

| Indirect & Induced Impacts resulting from Scenario C | Direct suppliers | Other suppliers | Total indirect impact (all suppliers) | Induced Impact** | Total indirect & induced impacts |
|---|---|---|---|---|---|
| Output ($M) | 626 | 360 | 986 | 88 | 1,074 |
| GDP at basic prices* ($M) | 256 | 155 | 411 | 55 | 466 |
| Employment (#)* | 3,950 | 1,875 | 5,825 | 539 | 6,364 |
| FTEs (#) | 4,126 | 1,907 | 6,033 | 496 | 6,529 |
| Household income ($M) | 200 | 109 | 309 | 40 | 348 |
| **Total tax revenue ($M)** | **54.2** | **33.2** | **87.4** | **9.7** | **97.1** |
| Federal ($M) | 32.3 | 18.7 | 51.0 | 4.7 | 55.7 |
| *Personal income tax* | *29.9* | *15.3* | *45.3* | *3.6* | *48.9* |
| *Corporation income tax* | *3.7* | *3.0* | *6.7* | *0.9* | *7.5* |
| *Net taxes on products* | *-1.4* | *0.4* | *-1.0* | *0.2* | *-0.8* |
| Provincial ($M) | 18.1 | 12.2 | 30.3 | 3.1 | 33.4 |
| *Personal income tax* | *10.4* | *5.4* | *15.7* | *1.3* | *17.1* |
| *Corporation income tax* | *2.1* | *1.7* | *3.8* | *0.5* | *4.3* |
| *Net taxes on products* | *5.6* | *5.2* | *10.8* | *1.3* | *12.1* |
| Local ($M) | 3.8 | 2.3 | 6.1 | 1.9 | 8.0 |

* Includes wages, benefits, mixed income, operating surplus and net taxes on factors of production

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

## SUMMARY OF RESULTS: AGRICULTURE SCENARIO D

For agriculture, Scenario D assumes total losses of $691.0 million, with most of the loss being damage to crops, livestock and nursery stock ($413.0 million). Damage to buildings ($227.3 million) and equipment ($50.7 million) is also expected to be significant.

In order to replace the lost buildings, equipment and crops, it is estimated that $52.9 million will be used to purchase goods imported from other provinces or countries, while $4.4 million will be spent on goods withdrawn from inventories held by producers. Total purchases of goods and services produced in British Columbia are estimated at $633.6 million. This is the amount that was used to shock the model.

The economic impact associated with a total expenditure of $633.6 million on goods and services produced in British Columbia includes $363.6 million of goods and services purchased from supplier industries, and another $89.1 million in spending by workers.

The GDP associated with the replacement activities includes $259.0 million generated by direct supplier industries (primarily crop and animal production, at $151.2 million, and construction, at $99.3 million). Another $156.9 million of GDP would be produced by industries further back in the supply chain (e.g., professional services such as engineering, manufacturing, and other business services). Spending by workers employed as a result of the replacement activities is expected to contribute another $55.5 million to total GDP.

Total employment associated with the replacement of lost buildings, equipment, crops and livestock is estimated at 3,996 jobs in direct supplier industries, another 1,897 jobs in industries further back in the supply chain, and 546 jobs generated as a result of spending by workers.

**Estimated Impact of Flooding on Agriculture**
**(replacement of crops, livestock & equipment)**
**Scenario D (replacement of losses)**

**Total impact, including Scenario D, supplier industry & induced effects**

| | Direct | Other suppliers | Total Indirect* | Induced** | Total impact |
|---|---|---|---|---|---|
| Total Scenario D ($M) | **691** | | | | |
| Supplier industry & induced impacts ($M) | *634* | *364* | **997** | 89 | **1,086** |
| GDP at basic prices ($M) | | | | | **471** |
| Scenario D*** | | | | | |
| Supplier industry & induced impacts | *259* | *157* | **416** | 56 | 471 |
| Employment (#)**** | | | | | **6,438** |
| Scenario D (Model estimate) | | | | | |
| Supplier industry & induced impacts | *3,996* | *1,897* | **5,893** | 546 | 6,438 |
| Employment (FTES) | | | | | **6,605** |
| Scenario D (Model estimate) | | | | | |
| Supplier industry & induced impacts | *4,174* | *1,929* | **6,103** | 502 | 6,605 |
| Household income ($M) | | | | | **353** |
| Scenario D | | | | | |
| Supplier industry & induced impacts | *202* | *110* | **313** | 40 | 353 |
| Average annual wage ($ per employee) | | | | | |
| Scenario D | | | | | |
| Supplier industry & induced impacts | 50,655 | 58,055 | **53,035** | 73,435 | **54,765** |
| Tax revenue ($M) | | | | | **98** |
| Scenario D | | | | | |
| Supplier industry & induced impacts | *55* | *34* | **89** | 10 | 98 |

* The total indirect impact is the sum of the effect on direct suppliers and other supplier industries

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

*** Project expenditure data provided by clients may not include all components of GDP (e.g., operating surplus)

**** Employment estimates are based on average annual wages in 2013. Includes total employment over the life of the project

| Allocation of Flood Losses<br>Scenario D (replacement of losses) | |
|---|---|
| **Total Scenario D expenditures ($M)** | **691.0** |
| *minus leakages:* | |
| *imports from other countries* | *45.7* |
| *imports from other provinces* | *7.2* |
| *other leakages (e.g. withdrawals from inventory)* | *4.4* |
| *Equals:* | |
| **Purchases of goods & services (including labour and profits) produced in BC ($M)** | **633.6** |
| *Of which:* | |
| *Wages, benefits, mixed income and operating surplus ($M)* | 0.0 |
| *Taxes on products net of subsidies ($M)* | 0.0 |
| *Taxes on factors of production net of subsidies ($M)* | 0.0 |
| ***Direct BC supply ($M)*** | **633.6** |
| *( the change in BC supplier industry output associated with Scenario D)* | |

Indirect & Induced Impacts resulting from project expenditures

**Indirect & Induced Impacts resulting from Scenario D**

| | Direct suppliers | Other suppliers | Total indirect impact (all suppliers) | Induced Impact** | Total indirect & induced impacts |
|---|---|---|---|---|---|
| Output ($M) | 634 | 364 | 997 | 89 | 1,086 |
| GDP at basic prices* ($M) | 259 | 157 | 416 | 56 | 471 |
| Employment (#)* | 3,996 | 1,897 | 5,893 | 546 | 6,438 |
| FTEs (#) | 4,174 | 1,929 | 6,103 | 502 | 6,605 |
| Household income ($M) | 202 | 110 | 313 | 40 | 353 |
| **Total tax revenue ($M)** | **54.9** | **33.6** | **88.5** | **9.8** | **98.4** |
| Federal ($M) | 32.7 | 18.9 | 51.6 | 4.7 | 56.3 |
| *Personal income tax* | *30.3* | *15.5* | *45.8* | *3.7* | *49.5* |
| *Corporation income tax* | *3.7* | *3.0* | *6.7* | *0.9* | *7.6* |
| *Net taxes on products* | *-1.4* | *0.4* | *-1.0* | *0.2* | *-0.8* |
| Provincial ($M) | 18.4 | 12.3 | 30.7 | 3.2 | 33.9 |
| *Personal income tax* | *10.5* | *5.4* | *15.9* | *1.3* | *17.3* |
| *Corporation income tax* | *2.1* | *1.7* | *3.8* | *0.5* | *4.3* |
| *Net taxes on products* | *5.8* | *5.2* | *11.0* | *1.3* | *12.3* |
| Local ($M) | 3.9 | 2.3 | 6.2 | 1.9 | 8.1 |

* Includes wages, benefits, mixed income, operating surplus and net taxes on factors of production

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

## SUMMARY OF RESULTS: HAZUS SCENARIO A

For the HAZUS estimates, Scenario A assumes total losses of $14.2 billion.

Losses of residential ($3.5 billion), commercial ($2.0 billion), industrial ($0.4 billion) and government & education ($0.2 billion) buildings are expected to total $6.0 billion.

Losses to contents and inventories are estimated at $2.1 billion for residential buildings. Losses to contents and inventories, including business disruption costs (income, relocation, rental income and wages) are estimated at $4.3 billion for commercial operations, $1.2 billion for industrial operations, and $0.6 billion for government and educational operations. The total value of these losses is estimated at $8.2 billion.

Of the $14.2 billion spent to replace the damaged buildings, contents and inventories, and cover business interruption costs, it is estimated that $6.3 billion will be used to purchase goods imported from other provinces or countries, while $84 million will be spent on goods withdrawn from inventories held by producers. Total purchases of goods and services produced in British Columbia are estimated at $7.7 billion. This amount includes some estimated wages ($60 million) and commodity taxes ($190 million). The direct BC supply—the change in BC supplier industry output associated with Scenario A losses—is estimated at $7.5 billion. This is the amount that was used to shock the model.

The economic impact associated with a total expenditure of $7.5 billion on goods and services produced in British Columbia includes $3.7 billion of goods and services purchased from supplier industries, and another $1.2 billion in spending by workers.

The GDP associated with the replacement activities includes $3.4 billion generated by direct supplier industries (primarily construction ($2.7 billion), manufacturing ($247 million), wholesale ($246 million) and retail ($215 million) trade). Another $1.7 billion of GDP would be produced by industries further back in the supply chain (e.g., professional scientific & technical services, manufacturing, and finance, insurance, real estate and rental and leasing services). Spending by workers employed as a result of the replacement activities is expected to contribute another $0.8 billion to total GDP.

Total employment associated with the replacement activities is estimated at 41,804 jobs in direct supplier industries, another 19,900 jobs in industries further back in the supply chain, and 7,379 jobs generated as a result of spending by workers.

**Estimated Impact of Flooding (Hazus; losses to buildings and contents)**
**Scenario A (replacement of losses)**

| Total impact, including Scenario A, supplier industry & induced effects | Direct | Other suppliers | Total Indirect* | Induced** | Total impact |
|---|---|---|---|---|---|
| Total Scenario A ($M) | **14,200** | | | | |
| Supplier industry & induced impacts ($M) | *7,500* | *3,653* | **11,153** | 1,204 | **12,357** |
| GDP at basic prices ($M) | | | | | **5,971** |
| Scenario A*** | *60* | | | | |
| Supplier industry & induced impacts | *3,430* | *1,730* | **5,161** | 751 | 5,911 |
| Employment (#)**** | | | | | **69,561** |
| Scenario A (Model estimate) | *478* | | | | |
| Supplier industry & induced impacts | *41,804* | *19,900* | **61,704** | 7,379 | 69,083 |
| Employment (FTES) | | | | | **72,068** |
| Scenario A (Model estimate) | *524* | | | | |
| Supplier industry & induced impacts | *44,669* | *20,092* | **64,761** | 6,784 | 71,544 |
| Household income ($M) | | | | | **4,652** |
| Scenario A | *30* | | | | |
| Supplier industry & induced impacts | *2,866* | *1,214* | **4,081** | 542 | 4,622 |
| Average annual wage ($ per employee) | | | | | |
| Scenario A | | | | | |
| Supplier industry & induced impacts | 68,565 | 61,015 | **66,130** | 73,435 | **66,910** |
| Tax revenue ($M) | | | | | **1,555** |
| Scenario A | | | | | |
| Supplier industry & induced impacts | *865* | *363* | **1,228** | 133 | 1,361 |

* The total indirect impact is the sum of the effect on direct suppliers and other supplier industries

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

*** Project expenditure data provided by clients may not include all components of GDP (e.g., operating surplus)

**** Employment estimates are based on average annual wages in 2013. Includes total employment over the life of the project

| Allocation of Flood Losses<br>Scenario A (replacement of losses) | |
|---|---|
| **Total Scenario A expenditures ($M)** | **14,200.0** |
| *minus leakages:* | |
| *imports from other countries* | *5,425.9* |
| *imports from other provinces* | *874.5* |
| *other leakages (e.g. withdrawals from inventory)* | *83.6* |
| | |
| *Equals:* | |
| **Purchases of goods & services (including labour and profits) produced in BC ($M)** | **7,749.9** |
| *Of which:* | |
| *Wages, benefits, mixed income and operating surplus ($M)* | 60.0 |
| *Taxes on products net of subsidies ($M)* | 189.8 |
| *Taxes on factors of production net of subsidies ($M)* | 0.0 |
| ***Direct BC supply ($M)*** | **7,500.1** |
| *( the change in BC supplier industry output associated with Scenario A)* | |

Indirect & Induced Impacts resulting from project expenditures

| Indirect & Induced Impacts resulting from Scenario A | Direct suppliers | Other suppliers | Total indirect impact (all suppliers) | Induced Impact** | Total indirect & induced impacts |
|---|---|---|---|---|---|
| Output ($M) | 7,500 | 3,653 | 11,153 | 1,204 | 12,357 |
| GDP at basic prices* ($M) | 3,430 | 1,730 | 5,161 | 751 | 5,911 |
| Employment (#)* | 41,804 | 19,900 | 61,704 | 7,379 | 69,083 |
| FTEs (#) | 44,669 | 20,092 | 64,761 | 6,784 | 71,544 |
| Household income ($M) | 2,866 | 1,214 | 4,081 | 542 | 4,622 |
| **Total tax revenue ($M)** | **865.4** | **362.8** | **1,228.2** | **133.1** | **1,361.3** |
| Federal ($M) | 457.2 | 207.8 | 665.0 | 64.2 | 729.2 |
| *Personal income tax* | *421.6* | *169.6* | *591.2* | *49.8* | *641.0* |
| *Corporation income tax* | *33.0* | *31.9* | *64.9* | *11.9* | *76.8* |
| *Net taxes on products* | *2.6* | *6.3* | *8.9* | *2.4* | *11.4* |
| Provincial ($M) | 353.4 | 127.9 | 481.4 | 42.9 | 524.2 |
| *Personal income tax* | *150.6* | *60.1* | *210.7* | *18.0* | *228.7* |
| *Corporation income tax* | *18.6* | *18.0* | *36.7* | *6.7* | *43.4* |
| *Net taxes on products* | *184.2* | *49.8* | *234.0* | *18.1* | *252.1* |
| Local ($M) | 54.8 | 27.0 | 81.9 | 26.1 | 107.9 |

* Includes wages, benefits, mixed income, operating surplus and net taxes on factors of production

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

## SUMMARY OF RESULTS: HAZUS SCENARIO B

For the HAZUS estimates, Scenario B assumes total losses of $19.1 billion.

Losses of residential ($4.4 billion), commercial ($3.0 billion), industrial ($0.6 billion) and government & education ($0.2 billion) buildings are expected to total $8.2 billion.

Losses to contents and inventories are estimated at $2.7 billion for residential buildings. Losses to contents and inventories, including business disruption costs (income, relocation, rental income and wages) are estimated at $5.6 billion for commercial operations, $1.9 billion for industrial operations, and $0.7 billion for government and educational operations. The total value of these losses is estimated at $10.9 billion.

Of the $19.1 billion spent to replace the damaged buildings, contents and inventories, and cover business interruption costs, it is estimated that $8.4 billion will be used to purchase goods imported from other provinces or countries, while $110 million will be spent on goods withdrawn from inventories held by producers. Total purchases of goods and services produced in British Columbia are estimated at $10.5 billion. This amount includes some estimated wages ($80 million) and commodity taxes ($258 million). The direct BC supply—the change in BC supplier industry output associated with Scenario B losses—is estimated at $10.2 billion. This is the amount that was used to shock the model.

The economic impact associated with a total expenditure of $10.2 billion on goods and services produced in British Columbia includes $5.0 billion of goods and services purchased from supplier industries, and another $1.6 billion in spending by workers.

The GDP associated with the replacement activities includes $4.7 billion generated by direct supplier industries (primarily construction ($3.7 billion), wholesale ($336 million) trade, manufacturing ($330 million), and retail ($282 million) trade). Another $2.4 billion of GDP would be produced by industries further back in the supply chain (e.g., professional scientific & technical services, manufacturing, and finance, insurance, real estate and rental and leasing services). Spending by workers employed as a result of the replacement activities is expected to contribute another $1.0 billion to total GDP.

Total employment associated with the replacement activities is estimated at 56,185 jobs in direct supplier industries, another 26,966 jobs in industries further back in the supply chain, and 10,086 jobs generated as a result of spending by workers.

**Estimated Impact of Flooding (Hazus; losses to buildings and contents)**
**Scenario B (replacement of losses)**

| Total impact, including Scenario B, supplier industry & induced effects | Direct | Other suppliers | Total Indirect* | Induced** | Total impact |
|---|---|---|---|---|---|
| Total Scenario B ($M) | **19,130** | | | | |
| Supplier industry & induced impacts ($M) | *10,202* | *4,955* | **15,157** | 1,645 | **16,802** |
| GDP at basic prices ($M) | | | | | **8,123** |
| Scenario B*** | *80* | | | | |
| Supplier industry & induced impacts | *4,663* | *2,354* | **7,017** | 1,026 | 8,043 |
| Employment (#)**** | | | | | **93,874** |
| Scenario B (Model estimate) | *637* | | | | |
| Supplier industry & induced impacts | *56,185* | *26,966* | **83,151** | 10,086 | 93,236 |
| Employment (FTES) | | | | | **97,323** |
| Scenario B (Model estimate) | *698* | | | | |
| Supplier industry & induced impacts | *60,111* | *27,242* | **87,353** | 9,272 | 96,625 |
| Household income ($M) | | | | | **6,325** |
| Scenario B | *40* | | | | |
| Supplier industry & induced impacts | *3,893* | *1,651* | **5,544** | 741 | 6,285 |
| Average annual wage ($ per employee) | | | | | |
| Scenario B | | | | | |
| Supplier industry & induced impacts | 69,290 | 61,240 | **66,680** | 73,435 | **67,410** |
| Tax revenue ($M) | | | | | **2,113** |
| Scenario B | | | | | |
| Supplier industry & induced impacts | *1,176* | *493* | **1,669** | 182 | 1,851 |

* The total indirect impact is the sum of the effect on direct suppliers and other supplier industries

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

*** Project expenditure data provided by clients may not include all components of GDP (e.g., operating surplus)

| Allocation of Flood Losses<br>Scenario B (replacement of losses) | |
|---|---|
| **Total Scenario B expenditures ($M)** | **19,130.0** |
| *minus leakages:* | |
| *imports from other countries* | *7,211.4* |
| *imports from other provinces* | *1,183.2* |
| *other leakages (e.g. withdrawals from inventory)* | *109.5* |
| | |
| *Equals:* | |
| **Purchases of goods & services (including labour and profits) produced in BC ($M)** | **10,540.0** |
| *Of which:* | |
| *Wages, benefits, mixed income and operating surplus ($M)* | 80.0 |
| *Taxes on products net of subsidies ($M)* | 257.8 |
| *Taxes on factors of production net of subsidies ($M)* | 0.0 |
| ***Direct BC supply ($M)*** | **10,202.3** |
| *( the change in BC supplier industry output associated with Scenario B)* | |

Indirect & Induced Impacts resulting from project expenditures

**Indirect & Induced Impacts resulting from Scenario B**

| | Direct suppliers | Other suppliers | Total indirect impact (all suppliers) | Induced Impact** | Total indirect & induced impacts |
|---|---|---|---|---|---|
| Output ($M) | 10,202 | 4,955 | 15,157 | 1,645 | 16,802 |
| GDP at basic prices* ($M) | 4,663 | 2,354 | 7,017 | 1,026 | 8,043 |
| Employment (#)* | 56,185 | 26,966 | 83,151 | 10,086 | 93,236 |
| FTEs (#) | 60,111 | 27,242 | 87,353 | 9,272 | 96,625 |
| Household income ($M) | 3,893 | 1,651 | 5,544 | 741 | 6,285 |
| **Total tax revenue ($M)** | **1,176.1** | **493.2** | **1,669.2** | **181.9** | **1,851.1** |
| Federal ($M) | 623.7 | 282.9 | 906.6 | 87.7 | 994.3 |
| *Personal income tax* | *574.7* | *230.9* | *805.6* | *68.1* | *873.7* |
| *Corporation income tax* | *45.4* | *43.5* | *88.9* | *16.3* | *105.1* |
| *Net taxes on products* | *3.6* | *8.5* | *12.1* | *3.3* | *15.5* |
| Provincial ($M) | 480.4 | 173.8 | 654.2 | 58.6 | 712.8 |
| *Personal income tax* | *205.3* | *81.8* | *287.1* | *24.6* | *311.7* |
| *Corporation income tax* | *25.6* | *24.6* | *50.2* | *9.2* | *59.4* |
| *Net taxes on products* | *249.5* | *67.5* | *317.0* | *24.8* | *341.7* |
| Local ($M) | 71.9 | 36.4 | 108.4 | 35.7 | 144.0 |

* Includes wages, benefits, mixed income, operating surplus and net taxes on factors of production

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

## SUMMARY OF RESULTS: HAZUS SCENARIO C

For the HAZUS estimates, Scenario C assumes total losses of $9.0 billion.

Losses of residential ($1.6 billion), commercial ($1.2 billion), industrial ($0.4 billion) and government & education ($0.2 billion) buildings are expected to total $3.4 billion.

Losses to contents and inventories are estimated at $0.9 billion for residential buildings. Losses to contents and inventories, including business disruption costs (income, relocation, rental income and wages) are estimated at $2.7 billion for commercial operations, $1.3 billion for industrial operations, and $0.7 billion for government and educational operations. The total value of these losses is estimated at $5.6 billion.

Of the $9.0 billion spent to replace the damaged buildings, contents and inventories, and cover business interruption costs, it is estimated that $4.3 billion will be used to purchase goods imported from other provinces or countries, while $55 million will be spent on goods withdrawn from inventories held by producers. Total purchases of goods and services produced in British Columbia are estimated at $4.6 billion. This amount includes some estimated wages ($50 million) and commodity taxes ($135 million). The direct BC supply—the change in BC supplier industry output associated with Scenario C losses—is estimated at $4.4 billion. This is the amount that was used to shock the model.

The economic impact associated with a total expenditure of $4.4 billion on goods and services produced in British Columbia includes $2.1 billion of goods and services purchased from supplier industries, and another $0.7 billion in spending by workers.

The GDP associated with the replacement activities includes $2.0 billion generated by direct supplier industries (primarily construction ($1.5 billion), wholesale ($180 million) trade, manufacturing ($166 million), and retail ($126 million) trade). Another $1.0 billion of GDP would be produced by industries further back in the supply chain (e.g., professional scientific & technical services, manufacturing, and finance, insurance, real estate and rental and leasing services). Spending by workers employed as a result of the replacement activities is expected to contribute another $0.4 billion to total GDP.

Total employment associated with the replacement activities is estimated at 24,186 jobs in direct supplier industries, another 11,513 jobs in industries further back in the supply chain, and 4,352 jobs generated as a result of spending by workers.

**Estimated Impact of Flooding (Hazus; losses to buildings and contents)**
**Scenario C (replacement of losses)**

| Total impact, including Scenario C, supplier industry & induced effects | Direct | Other suppliers | Total Indirect* | Induced** | Total impact |
|---|---|---|---|---|---|
| Total Scenario C ($M) | **8,950** | | | | |
| Supplier industry & induced impacts ($M) | *4,404* | *2,121* | **6,525** | 710 | **7,235** |
| GDP at basic prices ($M) | | | | | **3,531** |
| Scenario C*** | *50* | | | | |
| Supplier industry & induced impacts | *2,028* | *1,010* | **3,038** | 443 | 3,481 |
| Employment (#)**** | | | | | **40,529** |
| Scenario C (Model estimate) | *478* | | | | |
| Supplier industry & induced impacts | *24,186* | *11,513* | **35,699** | 4,352 | 40,051 |
| Employment (FTES) | | | | | **41,999** |
| Scenario C (Model estimate) | *524* | | | | |
| Supplier industry & induced impacts | *25,845* | *11,629* | **37,474** | 4,001 | 41,475 |
| Household income ($M) | | | | | **2,731** |
| Scenario C | *30* | | | | |
| Supplier industry & induced impacts | *1,674* | *707* | **2,381** | 320 | 2,701 |
| Average annual wage ($ per employee) | | | | | |
| Scenario C | | | | | |
| Supplier industry & induced impacts | 69,230 | 61,420 | **66,710** | 73,435 | **67,440** |
| Tax revenue ($M) | | | | | **933** |
| Scenario C | | | | | |
| Supplier industry & induced impacts | *506* | *212* | **718** | 79 | 796 |

* The total indirect impact is the sum of the effect on direct suppliers and other supplier industries

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

*** Project expenditure data provided by clients may not include all components of GDP (e.g., operating surplus)

**** Employment estimates are based on average annual wages in 2013. Includes total employment over the life of the project

| Allocation of Flood Losses<br>Scenario C (replacement of losses) | |
|---|---|
| **Total Scenario C expenditures ($M)** | **8,950.0** |
| *minus leakages:* | |
| *imports from other countries* | *3,659.8* |
| *imports from other provinces* | *615.4* |
| *other leakages (e.g. withdrawals from inventory)* | *55.0* |
| *Equals:* | |
| **Purchases of goods & services (including labour and profits) produced in BC ($M)** | **4,588.2** |
| *Of which:* | |
| *Wages, benefits, mixed income and operating surplus ($M)* | 50.0 |
| *Taxes on products net of subsidies ($M)* | 134.5 |
| *Taxes on factors of production net of subsidies ($M)* | 0.0 |
| ***Direct BC supply ($M)*** | **4,403.7** |
| *( the change in BC supplier industry output associated with Scenario C)* | |

Indirect & Induced Impacts resulting from project expenditures

| Indirect & Induced Impacts resulting from Scenario C | Direct suppliers | Other suppliers | Total indirect impact (all suppliers) | Induced Impact** | Total indirect & induced impacts |
|---|---|---|---|---|---|
| Output ($M) | 4,404 | 2,121 | 6,525 | 710 | 7,235 |
| GDP at basic prices* ($M) | 2,028 | 1,010 | 3,038 | 443 | 3,481 |
| Employment (#)* | 24,186 | 11,513 | 35,699 | 4,352 | 40,051 |
| FTEs (#) | 25,845 | 11,629 | 37,474 | 4,001 | 41,475 |
| Household income ($M) | 1,674 | 707 | 2,381 | 320 | 2,701 |
| **Total tax revenue ($M)** | **506.0** | **211.9** | **717.9** | **78.5** | **796.4** |
| Federal ($M) | 270.3 | 121.5 | 391.8 | 37.8 | 429.6 |
| *Personal income tax* | *247.5* | *99.0* | *346.5* | *29.4* | *375.9* |
| *Corporation income tax* | *21.1* | *18.8* | *39.9* | *7.0* | *46.9* |
| *Net taxes on products* | *1.7* | *3.7* | *5.4* | *1.4* | *6.8* |
| Provincial ($M) | 205.1 | 74.8 | 279.9 | 25.3 | 305.2 |
| *Personal income tax* | *88.3* | *35.1* | *123.4* | *10.6* | *134.0* |
| *Corporation income tax* | *11.9* | *10.6* | *22.5* | *4.0* | *26.5* |
| *Net taxes on products* | *104.9* | *29.1* | *134.0* | *10.7* | *144.7* |
| Local ($M) | 30.6 | 15.7 | 46.2 | 15.4 | 61.6 |

* Includes wages, benefits, mixed income, operating surplus and net taxes on factors of production

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

## SUMMARY OF RESULTS: HAZUS SCENARIO D

For the HAZUS estimates, Scenario D assumes total losses of $18.4 billion.

Losses of residential ($4.2 billion), commercial ($2.4 billion), industrial ($0.7 billion) and government & education ($0.3 billion) buildings are expected to total $7.6 billion.

Losses to contents and inventories are estimated at $2.4 billion for residential buildings. Losses to contents and inventories, including business disruption costs (income, relocation, rental income and wages) are estimated at $5.2 billion for commercial operations, $2.2 billion for industrial operations, and $0.9 billion for government and educational operations. The total value of these losses is estimated at $10.7 billion.

Of the $18.4 billion spent to replace the damaged buildings, contents and inventories, and cover business interruption costs, it is estimated that $8.2 billion will be used to purchase goods imported from other provinces or countries, while $107 million will be spent on goods withdrawn from inventories held by producers. Total purchases of goods and services produced in British Columbia are estimated at $9.9 billion. This amount includes some estimated wages ($70 million) and commodity taxes ($260 million). The direct BC supply—the change in BC supplier industry output associated with Scenario D losses—is estimated at $9.6 billion. This is the amount that was used to shock the model.

The economic impact associated with a total expenditure of $9.6 billion on goods and services produced in British Columbia includes $4.7 billion of goods and services purchased from supplier industries, and another $1.5 billion in spending by workers.

The GDP associated with the replacement activities includes $4.4 billion generated by direct supplier industries (primarily construction ($3.4 billion), wholesale ($342 million) trade, manufacturing ($325 million), and retail ($268 million) trade). Another $2.2 billion of GDP would be produced by industries further back in the supply chain (e.g., professional scientific & technical services, manufacturing, and finance, insurance, real estate and rental and leasing services). Spending by workers employed as a result of the replacement activities is expected to contribute another $1.0 billion to total GDP.

Total employment associated with the replacement activities is estimated at 53,077 jobs in direct supplier industries, another 25,354 jobs in industries further back in the supply chain, and 9,474 jobs generated as a result of spending by workers.

**Estimated Impact of Flooding (Hazus; losses to buildings and contents)**
**Scenario D (replacement of losses)**

| Total impact, including Scenario D, supplier industry & induced effects | Direct | Other suppliers | Total Indirect* | Induced** | Total impact |
|---|---|---|---|---|---|
| Total Scenario D ($M) | **18,370** | | | | |
| Supplier industry & induced impacts ($M) | *9,609* | *4,661* | **14,270** | 1,546 | **15,816** |
| GDP at basic prices ($M) | | | | | **7,648** |
| Scenario D*** | *70* | | | | |
| Supplier industry & induced impacts | *4,402* | *2,212* | **6,615** | 964 | 7,578 |
| Employment (#)**** | | | | | **88,383** |
| Scenario D (Model estimate) | *478* | | | | |
| Supplier industry & induced impacts | *53,077* | *25,354* | **78,431** | 9,474 | 87,905 |
| Employment (FTES) | | | | | **91,605** |
| Scenario D (Model estimate) | *524* | | | | |
| Supplier industry & induced impacts | *56,764* | *25,608* | **82,372** | 8,710 | 91,081 |
| Household income ($M) | | | | | **5,940** |
| Scenario D | *30* | | | | |
| Supplier industry & induced impacts | *3,663* | *1,551* | **5,215** | 696 | 5,910 |
| Average annual wage ($ per employee) | | | | | |
| Scenario D | | | | | |
| Supplier industry & induced impacts | 69,020 | 61,185 | **66,485** | 73,435 | **67,235** |
| Tax revenue ($M) | | | | | **2,005** |
| Scenario D | | | | | |
| Supplier industry & induced impacts | *1,107* | *464* | **1,570** | 171 | 1,741 |

* The total indirect impact is the sum of the effect on direct suppliers and other supplier industries

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

*** Project expenditure data provided by clients may not include all components of GDP (e.g., operating surplus)

**** Employment estimates are based on average annual wages in 2013. Includes total employment over the life of the project

| Allocation of Flood Losses<br>Scenario D (replacement of losses) | |
|---|---|
| **Total Scenario D expenditures ($M)** | **18,370.0** |
| *minus leakages:* | |
| *imports from other countries* | *7,060.4* |
| *imports from other provinces* | *1,187.1* |
| *other leakages (e.g. withdrawals from inventory)* | *106.8* |
| *Equals:* | |
| **Purchases of goods & services (including labour and profits) produced in BC ($M)** | **9,938.1** |
| *Of which:* | |
| *Wages, benefits, mixed income and operating surplus ($M)* | 70.0 |
| *Taxes on products net of subsidies ($M)* | 259.5 |
| *Taxes on factors of production net of subsidies ($M)* | 0.0 |
| ***Direct BC supply ($M)*** | **9,608.6** |
| *( the change in BC supplier industry output associated with Scenario D)* | |

Indirect & Induced Impacts resulting from project expenditures

| Indirect & Induced Impacts resulting from Scenario D | Direct suppliers | Other suppliers | Total indirect impact (all suppliers) | Induced Impact** | Total indirect & induced impacts |
|---|---|---|---|---|---|
| Output ($M) | 9,609 | 4,661 | 14,270 | 1,546 | 15,816 |
| GDP at basic prices* ($M) | 4,402 | 2,212 | 6,615 | 964 | 7,578 |
| Employment (#)* | 53,077 | 25,354 | 78,431 | 9,474 | 87,905 |
| FTEs (#) | 56,764 | 25,608 | 82,372 | 8,710 | 91,081 |
| Household income ($M) | 3,663 | 1,551 | 5,215 | 696 | 5,910 |
| **Total tax revenue ($M)** | **1,106.7** | **463.8** | **1,570.5** | **170.9** | **1,741.4** |
| Federal ($M) | 586.9 | 265.8 | 852.7 | 82.4 | 935.1 |
| *Personal income tax* | *539.9* | *216.8* | *756.7* | *64.0* | *820.7* |
| *Corporation income tax* | *43.5* | *41.0* | *84.5* | *15.3* | *99.8* |
| *Net taxes on products* | *3.4* | *8.0* | *11.5* | *3.1* | *14.6* |
| Provincial ($M) | 451.2 | 163.6 | 614.8 | 55.0 | 669.8 |
| *Personal income tax* | *192.8* | *76.8* | *269.6* | *23.1* | *292.7* |
| *Corporation income tax* | *24.6* | *23.1* | *47.7* | *8.6* | *56.3* |
| *Net taxes on products* | *233.8* | *63.6* | *297.5* | *23.3* | *320.7* |
| Local ($M) | 68.6 | 34.4 | 103.0 | 33.5 | 136.5 |

* Includes wages, benefits, mixed income, operating surplus and net taxes on factors of production

** Assumes a social safety net is in place. Includes effects generated by project spending and activities of supplier industries

## INTERPRETING THE BCIOM RESULTS

BCIOM model results are summarized in the tables included in this report. This section defines some of the terms and concepts used in the report tables and explains how they are calculated.

### *Variables that are calculated directly from information supplied by clients*

**Total project expenditure** is usually provided by the client, and includes all direct expenditures associated with the project.

There are no jobs, GDP or output associated with the production of goods and services that are imported into the province. Therefore an estimate of the value of imported goods and services is deducted from project direct spending to determine the value of **project expenditure in BC**.

Estimates of wages, salaries and other components of GDP provided by the client are reported in **project direct GDP at basic prices**.

> ***About Project Direct GDP Estimates***
>
> *It should be noted that project direct GDP figures are derived from information provided by clients. These figures are usually project-specific, but they are not always based on complete information. For example, it is often possible to get good data on wages and salaries associated with a project or activity. Labour costs are the biggest component of GDP, but other variables which ought to be included in the estimate (such as operating surplus) are not always known. When the GDP figures generated by the BCIOM are based on partial information, they may understate the project's direct contribution to GDP.*

**Project direct employment** is derived based on the project's wage bill and estimates of average annual wages in the affected industry.

**Household income** is calculated based on project direct wages, benefits and mixed income.

### *Variables that are estimated using model information*

**Commodity taxes less subsidies** is calculated using information on average sales and other tax rates associated with each good or service purchased by the project.

The **direct BC supply** includes the value of all goods and services produced by BC industries, but excludes direct project spending on wages, salaries, operating surplus and taxes.

An estimate of **corporate and personal income taxes** associated with these project direct expenditures is calculated using information on average tax rates from the model.

### *BCIOM impact estimates*

The model is shocked using the direct BC supply calculated from the information provided by the client. The total economic impact of the project on the BC economy, which is reported in terms of direct, indirect and induced impacts.

The **direct impact** measures the change in economic activity required to satisfy the initial change in demand. The ***direct output impact*** is equal to the direct BC supply–the change in the economic activity of the industries producing the goods and services purchased by the project.

The ***direct GDP impact*** is the GDP generated as a result of the activities of the industries that produce the goods and services directly used by the project.

The ***direct employment impact*** shows total employment in these industries, and the ***direct household income impact*** is a measure of the wages, salaries, benefits and other income earned by these workers.

The ***direct tax revenue impact*** includes personal, corporation, sales and other taxes generated as a result of the activities of the industries that supply the goods and services used by the project.

The allocation of tax revenues to federal, provincial and local governments is based on model information.

### *Induced effects*

The induced effect, which measures the impact associated with expenditures by workers, includes purchases of a variety of goods and services, including housing.

***More detailed information about the impacts is available in the report tables included in this document.***

# APPENDIX

## SOME BACKGROUND ON INPUT-OUTPUT MODELS AND ANALYSIS

Input-output analysis is based on statistical information about the flow of goods and services among various sectors of the economy. This information, presented in the form of tables, provides a comprehensive and detailed representation of the economy for a given year. An input-output model is essentially a database showing the relationship between commodity usage and industry output. It consists of three components:

- a table showing which commodities–both goods and services–are consumed by each industry in the process of production (the input matrix)
- a table showing which commodities are produced by each industry (the output matrix)
- a table showing which commodities are available for consumption by final users (the final demand matrix).

These data are combined into a single model of the economy which can be solved to determine how much additional production is generated by a change in the demand for one or more commodities or by a change in the output of an industry. Changing the usage or production of a commodity or group of commodities is often referred to as shocking the model. The known relationship between goods and services in the economy is used to generate an estimate of the economic impact of such a change.

If a change in demand is met by increasing or decreasing imports from other jurisdictions, there is no net effect on domestic production. All of the benefits or costs associated with employment generation or loss, and other economic effects, will occur outside the region. Therefore, it is important to identify whether or not a change in the demand for a good or service is met inside or outside a region.

## ASSUMPTIONS AND CAVEATS

Commodities made in BC have a much bigger impact than those imported into the province. The analysis presented here is based on using default import ratios for most commodities: i.e., assuming they are purchased locally, but allowing for the fact that they may have been manufactured elsewhere.

All tax data were generated using the model structure, and are based on averages for an industry or commodity. Economic modelling is an imprecise science, and the precision of the figures in the tables should not be taken as an indication of their accuracy.

## THE BRITISH COLUMBIA INPUT-OUTPUT MODEL

The BCIOM can be viewed as a snapshot of the BC economy, based on 2011 data. It is derived from inter-provincial input-output tables developed by Statistics Canada and includes details on 481 commodities, 235 industries, 280 “final demand” categories, and a set of computer algorithms to do the calculations required for the solution of the model. It can be used to predict how an increase or a decrease in demand for the products of one industry will have an impact on other industries and therefore on the entire economy.

## LIMITATIONS AND CAVEATS ASSOCIATED WITH INPUT-OUTPUT ANALYSIS

Input-output analysis is based on various assumptions about the economy and the inter-relationships between industries. These assumptions are listed below:

Input-output models are linear. They assume that a given change in the demand for a commodity or for the outputs of a given industry will translate into a proportional change in production.

Input-output models do not take into account the amount of time required for changes to happen. Economic adjustments resulting from a change in demand are assumed to happen immediately.

It is assumed that there are no capacity constraints and that an increase in the demand for labour will result in an increase in employment (rather than simply re-deploying workers).

It is assumed that consumers spend an average of 80% of their personal income on goods and services. The remaining 20% of personal income is consumed by taxes, or goes into savings.

The BCIOM is based on a “snapshot” of the BC economy in 2011. It is assumed that relationships between industries are relatively stable over time, so that the 2011 structure of the economy continues to be applicable today. However, it should be noted that employment estimates have been adjusted to reflect wage levels for the year of the expenditures in each case.

The BCIOM is based on the structure of the provincial economy, which is used to estimate the supplier industry impacts. The initial supplier industry impacts are calculated based on this structure, and do not differentiate between the economic impact of a plant located in one region of the province and a similar plant elsewhere in BC. It is assumed that both plants will use similar inputs in production.