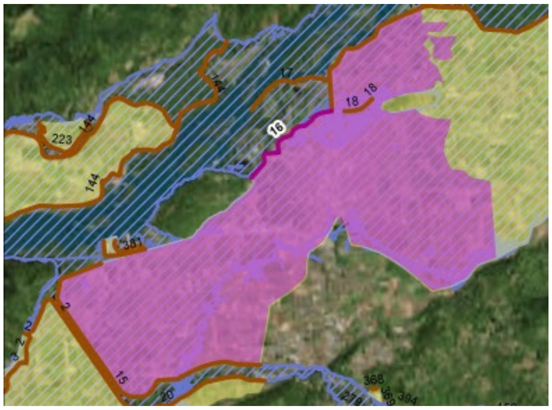
BC DIKE CONSEQUENCE CLASSIFICATION STUDY

FINAL REPORT



Prepared for:

Ministry of Forests, Lands, Natural Resources Operations and Rural Development

31 May 2019

NHC Ref. No. 3003603

northwest hydraulic consultants
water resource specialists

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Prepared for:

Ministry of Forests, Lands, Natural Resource Operations and Rural Development
Victoria, British Columbia

Prepared by:

Northwest Hydraulic Consultants Ltd.
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31 May 2019

NHC Ref No. 3003603

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DISCLAIMER

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- Rudy Sung — Senior Flood Safety Engineer, MFLNRORD

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EXECUTIVE SUMMARY

The BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD) engaged Northwest Hydraulic Consultants Ltd. (NHC) and our subconsultants, Sage on Earth Consulting Ltd. and Thurber Engineering Ltd., to broadly assess the failure consequence and seismic hazard of the Province's dikes. This Dike Consequence Classification Study includes analysis of all regulated dikes in British Columbia (BC) which are owned and maintained by a diking authority.

This project included the following main components:

- Background research to develop a risk assessment approach based on provincial, national and international best practices and ongoing projects;
- Receptor data collection and limitation assessment;
- Flood scenario selection and protected floodplain delineation;
- Development of the consequence classification framework and classification process;
- Exposure (Tier 1) analysis of receptors and application of classification framework for all dikes;
- Illustrative consequence (Tier 2) analysis for three case study dikes;
- Seismic hazard analysis for all high consequence dikes; and
- Development of conclusions based on project process and results and recommendations for future work and improvements.

The classification framework was developed based on available data. Weightings reflect confidence in exposure data, understanding of the potential impacts and the factor's importance for socioeconomic recovery. The classification framework presents one method of consequence classification, however other methods may yield different results. Optimal classification weightings and overall score development should be developed through community consultation. Specifically, consultation with First Nations communities should identify areas of cultural significance protected by dikes and reflect these areas in the overall classification.

The Tier 1 results classify 35 dikes as high consequence, 36 dikes as major consequence, 90 dikes as moderate consequence, 43 dikes as minor consequence, and 8 dikes as insignificant consequence. The 35 dikes classified as high consequence protect 75% of the total area protected by all dikes analyzed, 95% of the total protected population, and 94% of the total protected building value.

Classification was done exclusively based on data analysis rather than observation, but when classified areas were examined, significant patterns were noted. High consequence dikes generally protect medium to large areas of urban land. The majority of the high consequence dikes protect populated areas along the lower Fraser River, but there are several other densely populated areas throughout the rest of the province which were identified as high consequence including Duncan, Golden, Kamloops, Pemberton, Prince George, and Squamish.

The 35 dikes identified as high consequence were assigned seismic hazard ratings. The 25 high consequence dikes located in the Lower Mainland have a seismic hazard rating between moderate and very high. The three high consequence dikes in Duncan have a seismic hazard rating of very high. The two high consequence dikes located in Squamish have a seismic hazard rating of high. The remaining five high consequence dikes (located in Golden (71), Kamloops (90 and 101), and Pemberton (232 and 254)) have a seismic hazard rating of moderate, low or very low.

Of the 212 dikes classified, 56 dikes with a range of consequence classifications have been identified as protecting from a debris, alluvial or ice hazard. These hazards have the potential to cause higher consequences of failure as the hazards can be associated with less warning time, significant debris, and high flow velocities. While the results of the Tier 1 exposure based consequence classification identify dikes which protect from a high hazard, the Tier 1 analysis does not incorporate the higher hazard into the consequence classification.

It is important to note that dikes in small communities can protect most of the development in those towns. These dikes are typically classified as major, moderate, or minor. The impact of the damage caused by a failure of these dikes, while not as large in absolute terms as the damage which would be caused by a failure of a high consequence dike, may have a relatively larger impact to the community.

The dike consequence classification highlights areas where dikes protect significant amounts of exposed assets. Further work remains to be done to refine the area protected by each dike, verify input data through ground-truthing, determine the impact of flooding (i.e. Tier 2 analysis), and engage communities and experts through consultation.

The accuracy of the results allows for comparative analysis (i.e., classifications rather than absolute numbers) such as the assessment presented herein. Upgrading the consequence classification with Tier 2 analysis for all receptors and incorporating the project recommendations would provide a more meaningful understanding of dike failure consequences at individual dikes. To understand the risk of dike failure and inform a risk-based approach to dike management, the probability of dike failure needs to be considered in conjunction with the consequence of failure. While this project provides an understanding of dike failure consequence and recommendations to improve this understanding, it does not provide an assessment of the probability of dike failure.

All results of this report should be considered in the context of the intended project use as a tool for prioritizing future work, policy development, and as a framework for more detailed consequence assessment. The classifications based on Tier 1 analysis should not be used for site specific risk assessments, or any purpose outside the limitations of analysis. This project provides a consistent comparison of consequences from dike failure; significant inputs for further studies; an understanding of data gaps; recommendations for further studies and a tool to develop policy, evaluate investments in risk reduction, and facilitate emergency management planning.

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The BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD) engaged Northwest Hydraulic Consultants Ltd. (NHC) and our subconsultants, Sage on Earth Consulting Ltd. and Thurber Engineering Ltd., to broadly assess the failure consequence and seismic hazard of the Province's dikes. This Dike Consequence Classification Study includes analysis of all regulated[1] dikes in British Columbia (BC) which are owned and maintained by a diking authority.

1.1 Purpose

The primary goal of the Dike Consequence Classification is to classify each dike based on the consequence[2] of failure using a consistent and repeatable methodology. The project assessed the relative consequences of dike failure for the purpose of prioritizing future studies and infrastructure upgrades. It is not a risk assessment, and is not intended to replace detailed risk assessments of individual dikes.

The project incorporated the following steps:

- Extensive background research was completed about best practices internationally and in Canada (see report Section 2).
- Data was collected about receptors[3] potentially impacted in the event of a failure (see report Section 3).
- A flood scenario for analysis was determined, flood data were gathered, and areas protected by each dike were delineated and reviewed (see report Section 4).
- A consequence classification framework was designed for implementation using existing data and available resources (see report Section 5). The framework is designed for two tiers of analysis depending on available data and level of effort.
- Classification procedures were developed to analyze the receptor data for each (see report Section 6.3).
- The receptor data were analyzed to produce classification results at one of the two tiers (see report Section 7).

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[1] Regulated refers to dikes which are listed in the Flood Protection Works Database and identified as regulated under the Dike Management Act (Ministry of Forests, Lands, Natural Resource Operations and Rural Development - Water Management, n.d.).

[2] The impact of a flood on a receptor, i.e., damage to a building (see explanation in section 1.6).

[3] For the purposes of this project, receptors are people, buildings, infrastructure, environment, and cultural assets which may be impacted directly or indirectly by a flood event. A further explanation of terminology relevant to this project is provided in section 1.6.

- The seismic hazard of high consequence dikes was analyzed (see report Section 8).
- Conclusions were drawn from the project process and results (see report Section 9).
- Recommendations were made for each step of the project to outline future work and potential project improvements (see report Section 10).

All results of this report should be considered in the context of the intended project use as a tool for prioritizing future work, policy development, and as a framework for more detailed consequence assessment. This information should not be used for site specific risk assessments, or any purpose outside the limitations of analysis.

1.2 Tiered Analysis

The consequence classification framework can be applied province-wide and used within the limitations of available data. The framework uses two tiers of analysis depending on available data and level of effort.

Tier 1 analysis uses exposed[4] assets located in the protected floodplain as the basis of the consequence assessment. First tier analysis and classification was conducted for all dikes based on provincially uniform data on all receptors. Examples of such receptors include impacted people, buildings, critical infrastructure, agricultural land, cultural areas, and environmentally sensitive areas. This tier of analysis examines asset exposure as a proxy for consequence, as it can be assessed province-wide with available data (specifically flood hazard data).

The Tier 2 analysis incorporates consequence analysis into the framework by calculating the impact of the flood hazard on receptors. This analysis requires more information about the type of flood hazard and more specific receptor characteristics to define their vulnerability. For this project, Tier 2 analysis was demonstrated using two receptors: people and economy. Tier 2 analysis was applied to three dikes, each protecting areas with different land use (urban, rural, institutional, industrial and agricultural). Tier 2 is compatible with the classification framework, however, indicator/modifier classification values were not established as only three dikes were classified.

1.3 Intended Use and Highlighted Scope Limitations

Tier 1 classification results are based on exposure, and were completed based on a desktop study without individualized analyses or field verification. Therefore, the Tier 1 classification results should not be used to understand or assess dike failure consequences outside of the context of the consequence classification framework. The intended purposes of the Tier 1 dike consequence classification results are to:

[4] The location of receptors in flood-prone areas, i.e., a building in a floodplain (see explanation in section 1.6).

- Enable consistent comparison of consequences from the potential failure of each regulated dike in BC.

- Produce classifications which can be used as inputs for further studies, understanding data gaps, policy development, evaluation of investments in risk reduction, and emergency management planning.

- Develop a classification framework which can be used and adapted for future consequence and risk assessment work.

The analysis followed several assumptions including:

- For consistency, dikes were all assumed to provide protection up to a 200-year flood event. In reality, many dikes are sub-standard and would not provide that level of protection. The project did not include consideration of dike condition or design adequacy.
- Analysis was limited to regulated dikes, which are owned and maintained by a diking authority. No orphan dikes were considered.
- All evaluations of exposure and consequence were based on existing conditions of receptors and locations of dikes. No consideration was given to future construction or development plans.
- No floodplain modelling was conducted specifically for project analysis. All floodplain extents were delineated using existing information.
- All flood types were evaluated the same way with no differentiation made between riverine hazards, alluvial fan hazards, debris flow hazards, debris flood hazards, ice hazards, etc.

1.4 BC Flood Risk Management Policy Context

BC is subject to a high level of flood risk of various types including spring freshet floods, fall and winter storm-generated flooding, debris floods and debris flows, winter ice jam floods, coastal flooding, and tsunami hazards. Yet no province-wide assessment of dike consequence (or risk) exists, and no consistent methodology for completing one has been developed. The main gaps in flood risk assessment in BC are:

- There is no consequence or risk assessment covering all areas protected by dikes in BC. As a result, there is no high-level understanding of flood risk or consequence levels across BC. This province-wide overview is needed to support and prioritize investment in more detailed risk assessments, risk reduction efforts, and emergency management policies.

- There is no standard framework or methodology for assessing risk or consequence in BC. A standardized framework is needed to allow comparable and harmonized outputs for understanding risk and supporting decision making.

Historically in BC, a significant amount of Disaster Financial Assistance (DFA) funds have been spent on rebuilding structures following disasters. While post-disaster relief is crucial for recovery and rebuilding, data and research show that pre-disaster risk reduction and preparedness has a high rate of return because it reduces the cost of emergency response and recovery. Assessment and classification of potential flood consequences can be used to engage with stakeholders, evaluate existing emergency management capacities and risk reduction measures, develop risk reduction policies and plans, and prioritize investment in reducing asset vulnerability and improving flood hazard mitigation. The following is a partial list of related national or regional strategies, policies, and public investments that can benefit from the outputs of this project.

- **National Disaster Mitigation Program (NDMP)**: Due to increasing flood risk and costs, in 2014 Public Safety Canada earmarked $200 million over five years, from 2015 to 2020, to establish the National Disaster Mitigation Program (NDMP) as part of the government of Canada's commitment to build safer and more resilient communities (Public Safety Canada, 2018). NDMP's four funding streams are: Risk Assessment, Flood Mapping, Mitigation Planning, and Investment in non-structural and small-scale structural mitigation projects.

- **MFLNRORD 2018/19-2020/21 Service Plan**: MFLNRORD has set up a new goal in its Service Plan (Goal 3), "Resilience to Natural Hazards in a Changing Climate", committing to collaborate with other governments and agencies to build resilience to severe events including flooding (Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2018).

- **BC Flood Response Plan**: EMBC's BC Flood Response Plan requires diking authorities to complete hazard risk assessments, develop appropriate emergency response plans and monitor risks to the community in collaboration with local authorities (Emergency Management British Columbia, 2013).

- **BC Provincial Flood Risk Strategy**: MFLNRORD has identified the development of a provincial Flood Risk Strategy as a major initiative in the Ministry's Strategic Roadmap (2016) to guide the province's approach to flood hazard management. The Flood Risk Strategy includes setting priorities, identifying risks, clarifying roles and responsibilities, building mitigation strategies, and ensuring that resourcing to support flood mitigation is wisely allocated. Phase 1 was conducted in 2018 with the outcomes leading to the launch of Phase 2

- **Review of Landslide Management in British Columbia:** MFLNRORD completed an internal review of current practices associated with the management of landslides in BC in terms of preparedness, mitigation, response, and recovery (MFLNRORD, 2013).

1.5 Overview of Dikes in BC

As defined in the Dike Maintenance Act, "a dike is an embankment, wall, fill, piling, pump, gate, floodbox, pipe, sluice, culvert, canal, ditch, drain, or any other thing that is constructed, assembled, or installed to prevent the flooding of land" (Government of British Columbia, 2018). Diking in BC started as early as 1864 and continues today, governed by the Dike Maintenance Act and other legislation (MOELP, 1999).

The Seismic Design Guidelines for Dikes, 2nd edition, identifies guidelines for consideration of seismic stability and integrity for high consequence dikes (Golder Associates Ltd., 2014). These guidelines are intended to apply to the design and construction of new and major upgrades to high consequence dikes. While the document focuses on explanation of seismic hazard evaluations and design standards, it briefly defines high consequence dikes as:

> "…flood protection dikes where the economic and/or life safety consequences of failure during a major flood are very high. These dikes typically protect urban or urbanizing areas, and failure could result in large economic losses and/or significant loss of life. The majority of the dikes reconstructed under the 1968 to 1994 Fraser River Flood Control Program would be considered High Consequence Dikes." (p. 5)

This project expands upon this definition with a data-based categorization of consequence levels.

1.6 Background on Core Components of Disaster Risk

A flood event may be harmful to people, buildings, infrastructure, agricultural assets, environment, and cultural assets through direct and indirect impacts. These elements are referred to as "receptors" in this project. Flood risk is the "potential loss of life, injury, displacement, psychological impact, destroyed or damaged assets which could occur to a system, society or community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability, and capacity" (United Nations, 2016). Risk can be represented with the following equation, where 'x' represents the interaction between the components and is not a direct mathematical multiplication:

- Risk = Probability of occurrence x Impact

Figure 1-1 shows the components of risk. Terms used in the diagram are defined below with definitions adapted from UN terminology to specifically reflect their application to this project (United Nations, 2016).

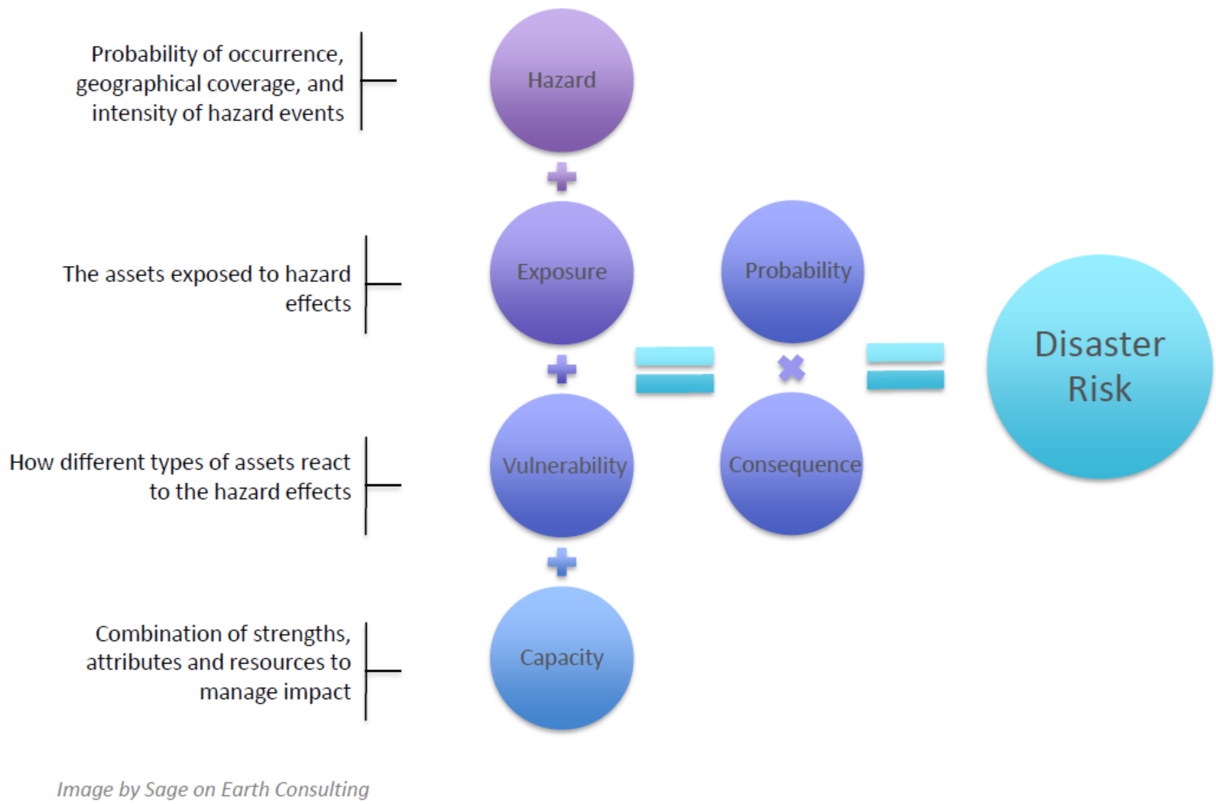


Figure 1-1 Core components of disaster risk

Hazard: The flood hazard is defined by its "probability of occurrence" and "intensity", which manifests as the geographical coverage, water depth, water velocity, debris level, and flood duration. Flood hazard can be characterized through flood types, i.e., riverine, coastal, ice jam floods, or debris flows and debris floods on alluvial fans. In this project, flood hazards were mostly understood in terms of their probability of occurrence, geographical coverage, and flood type. Select areas were analyzed through a more detailed methodology which also incorporated flood depth (see Section 6.3).

Exposure: The location of people, infrastructure, housing, production capacities, and other tangible human assets located in hazard-prone areas (United Nations, 2016). In this project, exposure of receptors is the basis of the classification framework.

Vulnerability: The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of an individual, a community, assets, or systems to the impacts of hazards (United Nations, 2016). Exposed assets have a certain level of vulnerability to flood hazard intensity. When only considering physical vulnerability, it is the degree of damage to an object (e.g., a building) exposed to a given level of hazard intensity (e.g., water depth).

Capacity: The combination of all the strengths, attributes and resources available within an organization, community, or society to manage and reduce disaster risks and strengthen resilience. Capacity may include infrastructure, institutions, human knowledge, and skills, and collective attributes such as social relationships, leadership, and management. Also known as resiliency.

Consequence: The total effect, including negative and positive effects (e.g., economic losses and gains), of a hazardous event or a disaster. The term includes economic, human, and environmental impacts, and may include death, injuries, disease, and other negative effects on human physical, mental, and social well-being. Impact is dependent on the flood hazard type.

2 BACKGROUND RESEARCH

2.1 Risk Assessment Practice and Approaches

The Sendai Framework for Disaster Risk Reduction, which is an international agreement endorsed by 189 countries including Canada in 2015, provides guiding principles for all aspects of disaster risk management, including risk assessments and understanding disaster risk (UNISDR, 2015). The Sendai Framework aims for the substantial reduction of disaster risk and losses in lives, livelihoods, and health, and in the economic, physical, social, cultural, and environmental assets of persons, businesses, communities, and countries. The framework also sets global targets and priorities for action. The Sendai Framework's first priority is Understanding Disaster Risk:

> "Policies and practices for disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment. Such knowledge can be leveraged for the purpose of pre-disaster risk assessment, for prevention and mitigation and for the development and implementation of appropriate preparedness and effective response to disasters." (p. 14)

The development and application of this consequence classification framework is aligned with the Sendai Framework's first priority for action, and contributes to understanding of the exposure and relative flood risk associated with dikes in BC.

The design and implementation of the consequence classification framework is based on research and evaluation of a series of international and Canadian methodologies and risk assessment cases. The following guidelines and literature were reviewed:

- Canada All Hazards Risk Assessment (AHRA) Methodology Guidelines (Public Safety Canada, 2013)
- National Disaster Mitigation Program (NDMP) (Department of Public Safety and Emergency Preparedness, 2017a)
- Risk Assessment Information Template (RAIT) (Department of Public Safety and Emergency Preparedness, 2017b)
- National risk assessment in the Netherlands (The National Network of Safety and Security Analysts, 2016 and Ruud Houdijk 2018, personal communication)[5]

[5] Mr. Ruud Houdijk is a disaster risk management specialist and an independent consultant who has been engaged in various national and regional risk assessments and risk management projects in the Netherlands and across Europe.

- National and regional risk assessment in Germany (Bijan Khazai 2018, personal communication)[6]
- Switzerland national disaster risk assessment methodology (Federal Office for Civil Protection, Switzerland, 2013)
- National Emergency Risk Assessment Guidelines (Australian Institute for Disaster Resilience, 2015)
- Overview of Natural and Man-made Disaster Risks the European Union May Face (Directorate-General for European Civil Protection and Humanitarian Aid Operations (ECHO) (European Commission), 2017)
- Words into Action Guidelines on National Disaster Risk Assessment (UNISDR, 2017)
- National Risk Assessments: A Cross Country Perspective (OECD, 2018)

There are similarities in the approaches and methodologies presented in guidelines or national cases in Canada, Australia, Germany, Netherlands, and Switzerland. In Canada, both the AHRA Guideline and the RAIT have been reviewed. The AHRA is meant for conducting a risk assessment (the potential of impact), while the RAIT, which is a requirement for applying to the NDMP, is based on observed losses from an event that has already occurred. Both documents were developed by Public Safety Canada but there are differences in how the consequence types are categorized. The team also considered the Review of Risk Assessment Methods for Orphan Dikes (Fraser Basin Council, 2018) and discussed methodologies with its authors. Table 2-1 provides a brief comparison of consequence categories used and reviewed for this project.

[6] Dr. Bijan Khazai is a senior research scientist at Karlsruhe University's Center for Disaster Management and Risk Reduction Technology (CEDIM) who has been engaged in national risk assessment projects in Germany.

Table 2-1 Overview of consequence/impact categories used in different countries

<table>
<tr><th>Canada (AHRA Guidelines)</th><th>Canada (RAIT Template)</th><th>Australia</th><th>Netherlands</th><th>Germany</th><th>Switzerland</th></tr>
<tr><td>People</td><td>People and social impact</td><td>People</td><td>Physical safety and health</td><td>Human</td><td>Individuals</td></tr>
<tr><td rowspan="2">Economy</td><td>Local economic impact</td><td rowspan="2">Economic</td><td rowspan="2">Economic safety</td><td rowspan="2">Economy</td><td rowspan="2">Economy</td></tr>
<tr><td>Local infrastructure impact</td></tr>
<tr><td>Environment</td><td>Environmental impact</td><td>Environment</td><td>Ecological safety</td><td>Environment</td><td>Environment</td></tr>
<tr><td>Territorial security</td><td rowspan="3">Public sensitivity impact</td><td></td><td>Territorial security</td><td></td><td rowspan="5">Society</td></tr>
<tr><td>Canada’s reputation and influence</td><td></td><td></td><td rowspan="2">Immaterial[1]</td></tr>
<tr><td>Society and psych-social</td><td>Social setting</td><td>Social and political stability</td></tr>
<tr><td></td><td></td><td>Public administration</td><td></td><td>Public utilities</td></tr>
<tr><td></td><td></td><td></td><td>Safety of cultural heritage</td><td></td></tr>
</table>

[1] In German National Risk Assessment, immaterial refers to the impact on public order and safety, political implications, psych9ological implications, and damage to cultural assets (Federal Office for Civil Protection, 2011).

The methodologies for scoring and weighting various indicators in each case were also evaluated. In the Risks the European Union May Face document, impact/consequence categories and levels are identified for 22 countries (Directorate-General for European Civil Protection and Humanitarian Aid Operations (ECHO) (European Commission), 2017). While these classifications provide reference for this project, they could not be directly applied due to significant differences in geographical density and social risk tolerances between these countries and BC. Based on the criteria of design, the most suitable elements from these guidelines and country cases have been adopted but the design is mostly aligned with the Canada AHRA Guideline and the Risk Assessment Information Template (RAIT). The RAIT provides bin values for level of impact which are based on impact calculations. These values were not used for this project as the Tier 1 assessment is based on exposure rather than impact, and the range of project results do not fit the RAIT ranges.

This project’s consequence classification framework also draws from principles of dam consequence classification. In BC, legislation dictates that a dam’s consequence level be assigned based on the worst ranked consequence category out of loss of life, environment and cultural values, and infrastructure and economics (CDA, 2013) . This was applied to the dike consequence classification system through determining an overall consequence classification using a tipping mechanism in conjunction with a weighted average.

2.2 Ongoing Projects and Developments

Risk and consequence assessment best practice is evolving quickly in BC due to numerous ongoing projects and increased interest in and awareness of a risk-based approach to disaster management. Emergency Management British Columbia (EMBC) has launched an online Hazard, Risk and Vulnerability Analysis Tool Kit designed to assist organizations in prioritizing risks they face based on the frequency and severity of an event (Emergency Management British Columbia, n.d.).

Following completion of the Review of Risk Assessment Methods for Orphan Dikes (Fraser Basin Council, 2018), the orphan dikes project has moved onto a second implementation phase which is ongoing and anticipated for completion in 2020.

The Federal Flood Mapping Guidelines Series is under ongoing development by Public Safety Canada and includes a document titled Canadian Guidelines and Database of Flood Vulnerability Functions. The draft document provides guidelines and reference material which are relevant to this project, especially for Tier 2 analysis (Natural Resources Canada and Public Safety Canada, 2017). References and methodology from this document have been used where possible as it was the most comprehensive, Canadian-specific flood consequence estimation reviewed for this project. In addition to this draft document, Natural Resources Canada (NRCan) is doing extensive, ongoing disaster consequence assessment work and provided some input and data resources for this project (see Section 3.2). A Flood Risk Assessment document is planned as part of the Federal Flood Mapping Guidelines Series, but has not been prepared yet.

Risk assessment methodology also exists for both Alberta and Ontario. Alberta's Provincial Flood Damage Assessment Study is a comprehensive review of available damage assessment methodology, much of which is quoted in the NRCan draft guidelines (Alberta Government, 2015; Natural Resources Canada and Public Safety Canada, 2017). The Ontario Ministry of Natural Resources (OMNR) produced a flood damage estimation guide (Ontario Ministry of Natural Resources, 2007). While this document was reviewed, it was not used as a reference for this project as it is not as comprehensive or geographically comparable as the Alberta flood damage assessment study.

In development of the methodology for this project, other practitioners in flood damage estimation were contacted for input. Dr. David Bristow from the University of Victoria discussed his ongoing critical infrastructure post disaster recovery modelling efforts with the project team (David Bristow, personal communication, May 25th 2018). His work and models were deemed too data-intensive for the broad, comparative purposes of this project, but may be relevant for future detailed assessments. The project team also discussed the National Critical Infrastructure Model (NCIM) with Mr. Paul Chouinard from the Government of Canada's Canadian Safety and Security Program at Defence Research and Development Canada (Paul Chouinard, personal communication, June 1st 2018). The NCIM is meant to analyze functional critical infrastructure (CI) interdependencies and the effects of cascading system failures. It is very data intensive and requires engagement and consultation with CI owners and operators from across BC.

2.3 First Nations' Information Resources

In 2000, the First Nations' Emergency Services Society of British Columbia (FNESS)7 supported the development of flood and erosion damage mitigation plans for four zones in BC: Zone 1 West Coast and Vancouver Island; Zone 2 Lower Fraser Valley; Zone 3 Southern Interior; and Zone 4 Northern Interior (Hay & Company Consultants Inc., 2000; KWL, 2000; NHC, 2000; unknown, 2000) contains a section devoted to each First Nation. For each reserve, the report identifies land use, infrastructure, flood hazards, erosion hazards, other hazards, and potential mitigations. For this study, analysis of cultural impact was based on information about the location of First Nations' reserves and cultural heritage sites as described in Appendix B.

[7] The First Nations' Emergency Services Society of British Columbia (FNESS) is a society with the goal of assisting First Nations in developing and sustaining safer and healthier communities. One of their main focuses is emergency management.

3 DATA COLLECTION AND LIMITATIONS

The consequence classification framework and its development are, in part, driven by data availability and data quality. This section discusses data sources.

3.1 Dike Data

This project assesses failure consequences for all regulated dikes in BC which are owned and maintained by a diking authority. A total of 212 dikes which met these criteria were identified by FLNRORD (Province of British Columbia, 2017). Dike alignments for this project were identified using the Flood Protection Works – Structural Works mapping layer (Ministry of Forests, Lands, Natural Resource Operations and Rural Development - Water Management, n.d.). The assessed dikes are listed in Appendix A with any alternative data sources identified.

Table 3-1 identifies all dikes which had irregular data sources, were removed from analysis, or where unique assumptions were made. A total of 212 dikes were analysed; dikes 12, 17 and 357 were removed from analysis and dike 59 was assessed as part of dike 58. No future diking projects or recent projects which are not yet reflected in the databases were included, and no consideration was given to locations where dikes should exist.

Table 3-1 Comments on irregular dike data sources, removal from analysis, and unique assumptions

Dike Number	Dike Name	Comments
12	Fenwick Street-Boundary Road (Trapp-Byrne Road)	Removed from analysis as this dike consists of three small segments not tied into high ground and therefore the delineation of a protected area was not feasible (Neil Peters, personal communication, Sept. 29th 2018).
17	Island 22 (Wing Dike)	Removed from analysis as this dike does not prevent flooding of the land behind it, rather it reduces design flood levels against other dikes. The delineation of the protected area due to this dike is complex and not possible without further analysis (Neil Peters, personal communication, Sept. 29th 2018).
52	Fairmont Hot Springs Resort	Protected floodplain delineated based on combined protection from the deflection dike, engineered channel, and catchment pond as delineation of protection from the dike alone was not possible. The Fairmont Hot Springs Resort dike is identified in the provincial shapefile as only having 'protection' segments. However, for the purposes of analysis, adequate protection was assumed to exist (RDEK, 2018).
59	North Annex Dike	In the provincial dike shapefile this dike is included as part of dike 58 - Annex Dike, which corresponds to NHC's understanding of dikes in Fernie (Dale Muir, personal communication, Sept. 4th 2018)[8]. To align with this, dike 59 has been considered as part of dike 58.
163	Hill Rd	Dike was included in analysis even though it is currently an orphan dike as work is ongoing to upgrade and transfer ownership of the dike to the Regional District of East Kootenay (Dwain Boyer, personal communication, Sept. 24th 2018).
330	Cold Spring Creek	Protected floodplain delineated based on combined protection from the debris catchment dike, engineered conveyance channels, and additional catchment ponds as delineation of protection from the dike alone was not possible (RDEK, 2018).
357	Elk River South (now called Riverside Bank protection)	Removed from analysis as this dike was identified as substandard bank erosion protection and outside of the 200-year floodplain (Dwain Boyer, personal communication, Sept. 24th 2018). This area did not experience flooding in the 2013 flood of record (approximately 500-year return period), however is within the floodplain based on the 2013 flood of record including freeboard and climate change (NHC, 2017a, 2019).
377	Lakes-Beverly Street Dike	Delineation based on dike alignment data for the Cowichan area (Delcan for Municipality of North Cowichan, 2012).
380	Elbow Creek	Included in analysis based on information available in the operation and maintenance manual and NHC's experience working with this dike (Northwest Hydraulic Consulting Ltd., 2002). (Barry Chillibeck, personal communication, Dec. 3rd 2018)[9].
387	Tsawwassen Sea Dike (Section A)	Delineation based on information provided by FLNRORD on Sept. 10, 2018 (Rudy Sung, personal communication, Sept. 10th 2018).
388	Tsawwassen Sea Dike (Section B)	Delineation based on information provided by FLNRORD on Sept. 10, 2018 (Rudy Sung, personal communication, Sept. 10th 2018).

The mapping layer identifies line feature type as either 'dike' (works that prevent flooding) or 'protection' (works that prevent bank erosion). Segments identified as 'dike' were assumed to be built to an adequate dike design standard whereas segments identified as 'protection' were assumed to be bank armouring or reinforcement of some type. In cases where 'dike' and 'protection' segments are interspersed in the mapping layer, expert review was used to delineate the most likely extent of the dike.

[8] Mr. Dale Muir, P.Eng. is a Principal at NHC who has done several flood studies and dike assessments in the Fernie area.

[9] Barry Chillibeck, P.Eng. is a Principal at NHC who has done flood hazard and dike studies on this dike.

3.2 Tier 1 Receptor Data

In evaluating data sources for use in understanding dike consequences, receptor data consistency, accuracy, and resolution were considered. Data consistency was required to ensure comparable analysis for all dikes and a valid relative ranking of consequence between dikes. All datasets chosen were available for all of BC to ensure no gaps or inconsistent reporting. Data sources were required to be credible and accurate, as scope and timeline to verify data were limited. Only data with reputable sources were used in this project, and it was assumed that data quality assurance and quality control were completed by dataset publishers; no additional QA/QC was undertaken by the project team. High data resolution was required to ensure accurate exposure overlays and accurate estimations for small floodplains.

Numerous data sources were found which met project requirements. Data sources and use limitations are listed below in Table 3-2. Unless otherwise noted, redistribution of source data is not permitted; third-parties interested in use of the source data should contact the providers directly. Appendix B provides a complete list of data used including identification of the receptor it informs, a data description and discussion of limitations. Appendix K lists all datasets used with accompanying data sharing agreements and identifies datasets digitally provided to FLNRORD.

Table 3-2 Tier 1 data sources and use permissions

Data Source	Use Permission
Natural Resources Canada (NRCan)	NRCan provided data for MFLNRORD’s use on this project with expectation that user experience be shared upon the project’s completion.
GeoBC Data Catalogue, Ministry of Forests, Lands, Natural Resource Operations and Rural Development	Data are publicly available through GeoBC’s online data catalogue.
Integrated Cadastral Information Society (ICI Society)	MFLNRORD is a member of the ICI Society. MFLNRORD established a data use agreement to provide dataset access to NHC for use with this project on the condition that data be destroyed on project completion.
Archaeology Branch, Ministry of Forests, Lands, Natural Resource Operations and Rural Development	Historic and archaeological sites located within protected floodplains were identified by the Archaeology Branch of the Ministry of Forests, Lands, Natural Resource Operations and Rural Development and provided for use in this project.

3.3 Tier 2 Receptor Data

Tier 2 assessments used the same data as Tier 1 analysis, with the addition of information about buildings provided by local authorities in each study area.

For Tier 2 assessment of Nicomen Island Dike, Fraser Valley Regional District (A.Swartz, personal communication, Sept. 25th , 2018) provided BC Assessment data (including land and improvement values, actual and manual use codes), parcel boundaries, and Zoning Bylaw 559 data.

For Surrey South Westminster Dike, the City of Surrey (M.Osler, personal communication, Oct. 4th, 2018) provided building footprints and 2017 property assessment data. Zoning data was downloaded from Surrey Open Data.

For Fernie Dike, the City of Fernie (L.Janssen, personal communication, Oct. 9th, 2018) provided building footprints, Zoning Bylaw 1750 data, and 2018 property assessment data.

No information was available about the type of buildings, and for Nicomen Island no building footprint data was available. An explanation of how the data were used is provided in Section 6.3. Information about the flood depth and velocities used for these analyses is provided in Section 4.2.2.

4 FLOOD SCENARIO

A key goal of this project is to assign each dike a specific and consistently developed consequence classification. To develop specific consequence classifications, we needed to determine the receptors exposed to flood damage. Exposure is limited to receptors in the area protected by each dike, referred to here as the 'protected floodplain'. Developing new floodplain mapping was outside the scope of this project, so all protected floodplains were delineated based on existing mapping and available information followed by internal review. Dikes only provide limited protection and most dikes outside the Lower Mainland have not been upgraded to the 1:200 year flood provincial standard.

Protected floodplains were delineated using the assumptions stated in section 1.3 as well as the following floodplain-specific assumptions and simplifications:

- Protected floodplain delineation assumed the absence of a dike rather than a specific failure mode such as overtopping or breach at a prescribed location (i.e., the area that would flood if there was no dike).
- Each dike and its protected floodplain were evaluated separately from other dikes. Any adjacent or nearby dikes were assumed to remain intact during the flood scenario.
- The possible effects of unregulated flood protection works included in MFLNRORD's dike mapping layer (Ministry of Forests, Lands, Natural Resource Operations and Rural Development - Water Management, n.d.) were ignored. These works include various remnant berms, constructed during flood emergencies, and the erosion 'protection' segments referred to in Section 3.1.

4.1 Flood Scenario

4.1.1 Return Period

A 200-year return period flood was chosen as the flood scenario for this project because it has commonly been the standard design flood for dike design (BC Ministry of Water, Land, and Air Protection, 2003). It was also the standard for the former provincial floodplain mapping program, which developed much of the mapping used in this project (MWLAP, 2004).

While different return periods have been used for some floodplain mapping and dike design in the province (e.g., the 1894 flood of record, which has approximately a 500-year return period, is the dike design standard for the Lower Fraser River), a 200-year flood scenario was consistently applied in the Tier 1 analysis for all dikes in this project to provide a common basis for comparing dike consequence province-wide. Flood mapping sources are discussed in section 4.2.1 and include province-wide existing mapping, and an adaptation of existing mapping in the lower mainland.

4.1.2 Flood Type

Dikes in BC are built to protect against a range of flood types including riverine floods, coastal inundation, ice jam floods, and debris flows and debris floods on alluvial fans. Flood types were identified for each dike based on the "Geographic Feature" and "Type of Flooding" information provided in the provincial dike database (Province of British Columbia, 2017) and expert review.

Without site-specific investigation, it can be difficult to accurately classify a flood type. The identification of the hydrogeomorphic process or processes involved in the formation of an alluvial or debris flow fan landform is important because different landslide/flood processes have different associated hazard characteristics (Wilford et al., 2004). For example, debris flows can be very destructive with very high peak discharges 5 to 40 times greater than floods, while debris floods have relative peak discharges of up to twice those of flood discharges (Hungr et al., 2001).

Flood types such as debris flows and debris floods are a higher intensity hazard than riverine and coastal flooding as they are associated with higher velocity flows, less warning time, and higher concentrations of debris. Areas exposed to these higher intensity hazards are flagged as a severe hazard (with a 'red' coloured floodplain on maps or an '*' when results are listed in tables in Section 7.1, Appendix C and Appendix G). The protected floodplain is flagged if a fan, debris, or ice hazard is believed to be present, even though other less severe hazards may also be present and may be predominate. These flood types represent the most severe potential types of flood hazard although and have a higher potential to cause damage and loss of life. The higher severity of these hazards should be considered when interpreting Tier 1 results and included in Tier 2 analyses.

4.1.3 Climate Change

Climate change is expected to have significant and varied impacts including changes in the magnitude and timing of floods and sea level rise (SLR). In BC, climate change is expected to cause, "changes in the amount and intensity of rainfall, changes in snowpack and temperature regime, insect infestations, forest fires and SLR" (EGBC, 2018). The magnitude and direction of most changes to flood flows are uncertain and predictions vary depending on the global climate model selected for analysis. Best practice is to include a combination of simulation outputs. With respect to SLR, the province has recommended a SLR scenario for BC which includes a SLR of 0.5 m by 2050, 1.0 m by 2100, and 2.0 m by 2200 relative to water levels in the year 2000 (BC Ministry of Environment and Climate Change, 2018).

As stated in the APEGBC Guidelines for Flood Mapping in BC (EGBC, 2017):

> "The Pacific Climate Impacts Consortium (PCIC) predicts that by midcentury (2050s), mean annual temperatures will be 1.4°C to 3.7°C higher, on average. Extremely high temperatures will become more frequent. At the same time, in winter, most of BC will likely receive more precipitation (up to 26 percent more in some locations). In summer, northern BC may be up to 15 percent wetter, while southern BC may be up to 20 percent drier. In winter and spring, snowfall may decrease (Zwiers et al. 2011). Other assessments of future climate change and impacts are available through PCIC (Rodenhuis et al. 2009 and PCIC 2016)." (p. 12)

The impact of these temperature and precipitation changes on flooding is complex. There are both direct impacts such as increased rainfall leading to greater streamflow and potentially flooding; and indirect effects such as increased temperatures increasing wildfire occurrence changing landcover, decreasing rainfall infiltration and retention, and increasing flooding (Pike et al., 2010). There are also competing processes and changes at play. For example, in some areas in BC, it is expected that a decreased snowpack will produce lower spring freshets, while increased rainfall, spring temperature patterns, and melt rates will increase spring flooding severity (NHC, 2017b). As changes in these processes vary with time and space, determining the effects of climate change on flooding requires analysis of the direct and indirect effects of expected precipitation and temperature changes unique to individual areas. A simple correction or percentage increase due to climate change cannot be justifiably applied to flood areas to represent the effect of climate change.

For Tier 1 consequence assessments, consideration of climate change was not possible in this project due to requirements for a consistent, defensible approach to protected floodplain determination and new floodplain mapping being out-of-scope. As is discussed in Section 4.2.2, a variety of existing mapping sources were used in Tier 1 including: pre-2004 mapping completed as part of the BC Floodplain Mapping Program; mapping adapted from NHC's Lower Mainland Flood Management Strategy Project 2: Regional Assessment of Flood Vulnerability for the Fraser Basin Council (NHC, 2016); and various other information sources. As much of this mapping does not include consideration of climate change in the flood scenarios, and as there is no defensible correction to account for climate change without doing extensive location-specific analyses, climate change was not accounted for in the Tier 1 consequence assessments.

The Tier 2 consequence assessments model the expected effects of climate change on flood magnitude and depth. The mapping followed modern standards including reporting flood depth and accounting for climate change impacts (i.e., changing flood flows and SLR).

4.1.4 Projection and Datum

For Tier 1 assessments, the NAD 1983 CSRS BC Environment Albers (BC Albers) projection was used to best represent provincial datasets and province-wide shapefiles. The BC Albers projection is the preferred projection for province-wide datasets as it is a single projection that covers the entire province while minimizing distortion across the province. The distortion which occurs using this projection results in smaller errors and inaccuracies than in other steps of the consequence assessment, so does not appreciably affect the accuracy of the Tier 1 consequence assessments.

For Tier 2 assessments, the NAD 1983 Universal Transverse Mercator (UTM) projection was used. This projection, which includes five UTM zones for BC, results in less local distortion than the BC Albers projection. It is suitable for the Tier 2 sites where spatial extents of datasets and floodplains are smaller (each within a single UTM zone) and assessment accuracy is higher.

The CGVD28 vertical datum was used for all elevations in this project. This datum was chosen as it was the original datum for the majority of the data including floodplain maps developed by the former provincial floodplain mapping program and modelled Fraser River water levels. A recent digital elevation model (DEM) of the Lower Fraser River floodplain (Emergency Management BC (EMBC), 2016) was converted from the newer CVGD2013 datum to CGVD28 for use with the Fraser River water levels to determine flood extents.

4.2 Protected Floodplain Development Process

Protected floodplains were delineated for each dike, representing the largest realistic protected area based on mapped floodplains, topography, and local features. The protected floodplain delineation introduced significant uncertainty; results should not be relied upon for any purposes other than the high-level estimation of relative dike failure consequence (Tier 1 assessment). The protected floodplains were delineated and reviewed using the judgement and experience of the project team since new floodplain mapping was outside the scope of the project. The following graphic describes the process, with references to details discussed in the subsequent sections.

Floodplain Data Sources
- Collection of mapping and input data
- See section 4.2.1 and 4.2.2

Protected Floodplain Delineation
- See section 4.2.3

Protected Floodplain Review
- Expert review of division assumptions
- See section 4.2.4

4.2.1 Tier 1 Floodplain Data Sources

Floodplain mapping sources and associated notes are identified in Appendix A.

Existing Floodplain Mapping

Out of the 212 dikes analyzed for this project, 139 are located within floodplains delineated in the 1974 to 2004 BC Floodplain Mapping Program. Sixteen of the project dikes are located within floodplains delineated in recent mapping or hazard zoning completed by local governments. This mapping was identified through searches of local government websites, the BC Floodplain Map Inventory Report (Parsons and BCREA, 2015), and past NHC projects.

Fraser River Floodplain Mapping

Forty-five dikes not covered by existing 200-year floodplain mapping are located in the Fraser Valley. For these 45 dikes, protected floodplains were delineated based on information developed for the “Regional Assessment of Flood Vulnerability” study completed by NHC for the Fraser Basin Council (NHC, 2016). However, the original floodplain areas in this study were determined for a 500-year return period flood. For the current project, the floodplain areas were adjusted to correspond to a 200-year return period flood.

The water level isolines were adapted from those developed for the FBC study (NHC, 2016); 500-year Fraser River water levels were replaced with 200-year levels created by NHC for the FBC study. 200-year water levels were taken from the Final Report on Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios (FLNRO, 2014). For reference, the 200-year discharge of the Fraser River at Hope corresponding with the modelled water levels is 15,200 m^3 (FLNRO, 2014). The water level was then overlain on the 2016 Emergency Management BC Lidar DEM (Emergency Management BC (EMBC), 2016) to determine the flooded area.

For coastal dikes where water levels are controlled by ocean levels rather than river discharge, the difference between the 200-year and 500-year water levels is approximately 10cm (NHC, 2006). As this difference extended over the floodplains is insignificant compared to other sources of error in the mapping, the 500-year water levels were used.

Flood area delineation using this technique is approximate only and results are not suitable for site-specific flood mapping. Flood studies currently under way, such as the development of a two-dimensional (2D) hydraulic model for the Lower Fraser for the Fraser Basin Council, will result in the availability of more accurate 200-year floodplain extents in the near future. The consequence classification could be updated based on this work.

Dikes Without Existing Floodplain Mapping

For approximately 28 dikes, no existing floodplain mapping could be found. See Appendix A for a list of all dikes and floodplain mapping sources. For these dikes, the project team delineated an approximate floodplain using topography, satellite imagery, historical flooding, judgement in channelized areas, and interpretation of alluvial or debris fans. This method relies heavily on the professional judgement of experts and it introduces additional uncertainty into the analysis. Results should not be used for any purpose other than the current project.

4.2.2 Tier 2 Floodplain Data Sources

Three sites were selected for more a detailed assessment including risk modelling and a detailed estimation of dike consequence. These sites are:

- Nicomen Island Dike (#144)
- Surrey South Westminster Dike (#296)
- Fernie Dike (#58)

These areas were chosen to represent diverse conditions in BC including an urban, industrial setting (Surrey South Westminster), a rural/small town setting (Fernie), and an agricultural setting (Nicomen Island). Significant selection criteria for Tier 2 assessment areas include the type and quality of floodplain mapping available. Selected sites would require the following to be available to developed for a detailed, accurate Tier 2 assessment:

- 200-year floodplain mapping;
- Climate change adjustment incorporated into water levels; and
- Flood depth information (required for damage estimation using depth-damage curves).

Nicomen Island Dike (#144)

Nicomen Island Dike encloses all of Nicomen Island. The island is primarily agricultural, including several thousand diary cows, with some residential development on First Nations' reserve land. Access to and from the island is via Highway 7, which is vulnerable to inundation in the event of dike failure.

Flood studies that include this site are currently in progress, but the work is incomplete and could not be used to inform this study[10]. Instead, readily-available data from previous work was used to develop flood mapping required for the Tier 2 analysis.

- Flood water levels were taken from the Fraser River one-dimensional hydraulic model (FLNRO, 2014). Values used were for 1:200 year levels with 1.0 metres of SLR for Year 2100 moderate climate change conditions.
- Water levels were mapped across the floodplain by extending cross sections developed for the original model (NHC, 2006).
- The resulting water surface was combined with the DEM to determine flood depths and extents.
- The 2016 Lidar-based DEM was provided by GeoBC (Emergency Management BC (EMBC), 2016). Originally in the CGVD2013 vertical data, the DEM was converted to CGVD28 to make it compatible with flood water level data.
- Freeboard was not included in any of the Tier 2 flood extent or depth mapping.
- This flood mapping is adequate for Tier 2 analysis for this project, but should not be used for other purposes. Flood area delineation using this technique is approximate only and results are not suitable for site-specific flood mapping.

Surrey South Westminster Dike (#296)

The Surrey South Westminster Dike protects an area that includes both residential and industrial development.

[10] These studies include the ongoing study Hydraulic Modelling and Mapping in BC's Lower Mainland – a Lower Mainland Flood Management Strategy Project for the Fraser Basin Council by NHC and the first draft of the Flood Vulnerability Study – Phase 1 Flood Modelling and Mapping project for the Sts'ailes, Leq'á:mel and Sq'éwlets First Nations by NHC, submitted Oct. 26, 2018 (NHC, 2018).

As with Nicomen Island, there are no current completed flood studies for this site, so flood mapping was developed from previous work. The sources and methodologies are the same as described above for the Nicomen Island Dike.

Fernie Dike (#58)

Flood mapping was completed for the City of Fernie in 2017 (NHC, 2017a), and can be adapted for Tier 2 analysis. Flood extent and depth data were used with permission from the City of Fernie (B.Lennox, personal communication., Sept. 9th, 2018). Fernie Dike (#58), which protects a populated area including residential and commercial buildings, was selected for this analysis. As noted in Section 3.1, North Annex Dike (#59) was combined with Fernie Dike (#58).

- City of Fernie 2017 flood mapping used the design flood rather than the 200-year flood. The design flood is based on the 2013 flood and is approximately equal to a 500-year flood. This was deemed suitable for the Tier 2 analysis.
- Original mapping includes 0.6 metres of freeboard. For the Tier 2 analysis, freeboard was removed by subtracting 0.6 m from the flood depth grid. New flood extents without freeboard were derived from the adjusted flood depths. Due to removal of freeboard, mapping developed for the Tier 2 analysis shows slightly different flood extents than the City's official floodplain mapping.
- Mapping developed for Tier 2 analysis for this project should not be used for other purposes. Refer to the City's official floodplain mapping (NHC, 2017a) instead.

4.2.3 Protected Floodplain Delineation

Process

Protected floodplains were delineated for each dike representing the maximum realistic protected floodplain. The delineations were based on mapped floodplains, topography, and localized features. Topography and localized features were referenced from background topographic and imagery reference:

- Satellite imagery base maps available in ESRI ArcGIS software (ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGrid, IGN and the GIS User Community, n.d.)
- World topographic map base maps available in ESRI ArcGIS software (ESRI, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, ESRI Japan, METI, ESRI China (Hong Kong), swiss topo, MapmyIndia, OpenStreetMap contributors and the GIS User Community, 2018)

Quality Parameter

A quality parameter was assigned to each protected floodplain based on the assumed accuracy of the floodplain mapping and level of confidence in the delineation, as outlined in Table 4-1. For example, protected floodplains delineated from existing floodplain mapping were generally designated as "High" quality. With a few exceptions, protected floodplains delineated without existing mapping were generally designated to be "Low" quality.

Table 4-1 Protected floodplain quality parameter categories and descriptions

Protected Floodplain Quality Parameter	Description
High	▪ High accuracy mapping and high to medium delineation confidence ▪ Medium accuracy mapping and high confidence delineation confidence
Medium	▪ High accuracy mapping and low delineation confidence ▪ Medium accuracy mapping and medium delineation confidence ▪ Low accuracy mapping and high delineation confidence
Low	▪ Medium accuracy mapping and low delineation confidence ▪ Low accuracy or no mapping and medium to low delineation confidence

Documentation

Protected floodplain delineations for each dike were documented with:

- Maps showing dike location, original floodplain mapping used, and delineated protected floodplain; and
- Tables listing waterbody, flood type, original flood mapping source, protected floodplain delineation notes, reviewer comments, delineation confidence, and the quality parameter.

Map and documentation outputs are in Appendix C.

Protected Floodplain Review

As there is significant judgement and uncertainty associated with the delineation of protected floodplains, expert reviewers validated the protected floodplain for each dike. Reviewers included Mr. Neil Peters (P.Eng) and Mr. Dwain Boyer (P.Eng). Both are senior water resource engineers who were employed by the Province of BC in the Dike and Flood Safety Programs for many years (as well as Dam

Safety for Mr. Boyer). Through this work they became familiar with the majority of the dikes and floodplains included in this project.

Reviewers examined the draft protected floodplain maps and, in some cases, adjusted the boundaries based on flood mapping experience and local knowledge of past flooding. Reviewers also provided input into the quality parameter for each dike. Reviewer comments are documented for each dike and protected floodplain in Appendix C.

5 CONSEQUENCE CLASSIFICATION FRAMEWORK STRUCTURE

This section of the report describes the consequence classification framework and its development. It provides an overview of the framework (Section 5.1), discusses the criteria used in framework design (Section 5.2), outlines the framework structure (Section 5.3), and describes determination of classification bounds (Section 5.4).

5.1 Overview of the Consequence Assessment Framework

The primary goal of the consequence assessment framework is to assess dike failure consequences with an adaptable, repeatable, and defensible method which can be implemented immediately using available information. This framework meets this goal through a two-tiered analysis approach.

In Tier 1 analysis, all dikes are assessed and classified using an exposure-based analysis. As discussed in Section 1.2, exposure-based analysis identifies what can be impacted during a flood event, but does not incorporate vulnerability or capacity to determine what the magnitude of the impact will be. In this framework, Tier 1 exposure assessment serves as a proxy for consequence estimation. It can be applied to all dikes with the hazard and receptor data currently available province-wide. Socio-economic Vulnerability Index (SVI) was also included in the Tier 1 exposure analysis in the People consequence category[11]. This introduces the vulnerability and capacity elements of a Tier 2 consequence analysis to enhance representation of the population in the Tier 1 analysis.

Tier 2 analysis includes vulnerability and capacity assessments where possible to provide a more in-depth consequence assessment. In this project, Tier 2 analysis is applied to three dikes which have adequate hazard and receptor data available to showcase impact analysis methods. The results of case-study Tier 2 analyses are included in the report to provide better understanding of flood consequence on receptors in the People and Economy consequence categories. Tier 2 analysis is discussed in detail in Section 6.3. The core components of risk are shown in Figure 5-1.

The classification framework as described below is designed to classify the results of a Tier 1 analysis. Tier 2 analysis can be used to supplement understanding of the Tier 1 classification for a particular dike. Tier 2 analysis as outlined below is designed to be compatible with the Tier 1 classification framework by providing more detailed information about the consequences of a flood event. Namely, it identifies the consequences of a flood event on the assets identified as exposed through the Tier 1 analysis.

The classification framework is described as it was implemented in the Tier 1, exposure-based classification for this project. The Tier 2 analysis results fall into categories which are compatible with this framework. The Tier 2 classification framework is not fully developed as expert consultation is

[11] See Box 1 for explanation of SVI.

required to develop the framework weightings and, as only three case study Tier 2 analyses were done, no statistical distribution could be used to develop classification bounds as described in Section 5.4.

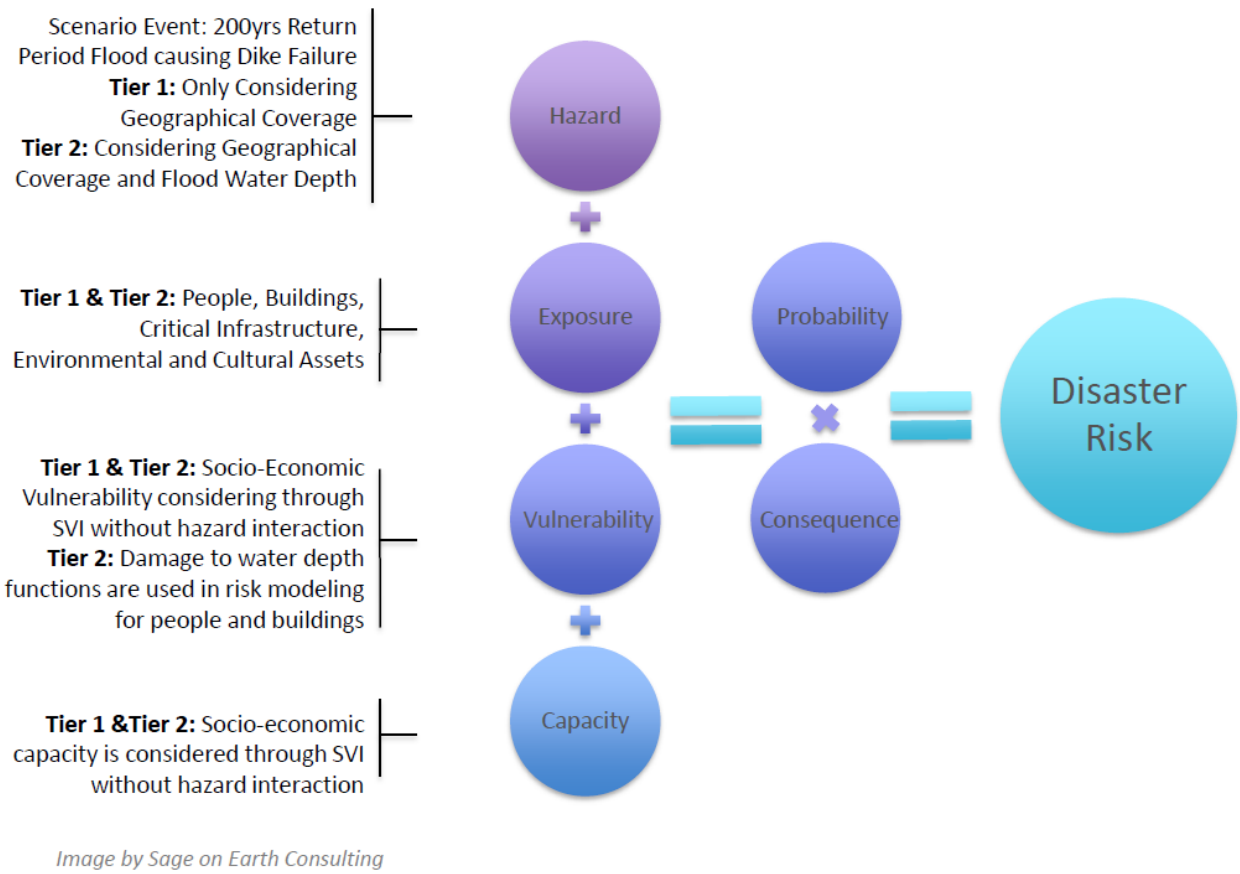


Figure 5-1 Overview of disaster risk components in the consequence classification framework with both Tier 1 (exposure analysis) and Tier 2 (impact analysis)[12]

For each dike, the outputs of the analysis with the consequence classification framework are:

- Indicator value ranges for each receptor (input data), e.g., length of road, value of buildings;
- A classification for each of the consequence categories described below in Section 5.3; and
- An overall weighted classification.

[12] See Box 1 for an explanation of Socio-Economic Vulnerability (SVI).

5.2 Design Criteria

The following criteria were considered in the framework design:

- **Comparability:** The framework should provide a consistent and comparable analysis for all regulated dikes in BC.

- **Robustness:** A dynamic system is required that can be used over the long term as input data availability and quality improves and estimation methodologies are refined.

- **Flexibility:** The framework must be useable with varying estimation methodologies as data and financial/technical resources allow (e.g., geospatial analysis, qualitative expert judgment using historical information, semi-quantitative or probabilistic risk modelling).

- **BC Context:** The framework design, including terminology and analysis methodology, should be aligned with existing approaches, policies and guidelines in BC and in Canada.

5.3 Framework Structure

The main components of the classification framework in hierarchical order from specific datasets to highest level of aggregation are as follows:

- **Receptor**: The specific asset exposed to flooding. For example, roads and bridges are considered as two different receptors under the subordinate factor, “transportation infrastructure”.

- **Indicator**: How the impact on each receptor is measured. For example, kilometres of road exposed is the indicator of impact to the receptor, “roads”.

- **Subordinate Factor**: The sub-categories under each of the main consequence categories. For example, water and sanitation infrastructure and transportation infrastructure are two different subordinate factors under the Economy – Critical Infrastructure consequence category.

- **Consequence Category**: Aggregated groups of receptors. The consequence categories selected for the dike consequence framework are:

  A. **People**
  B. **Economy – Buildings**
  C. **Economy – Critical Infrastructure and Agriculture**
  D. **Environment**
  E. **Cultural Heritage**

  Definitions of each category are presented in Section 6.

Overall Consequence: The aggregation of scores from all consequence categories.

Figure 5-2 provides an overview of the classification framework components.

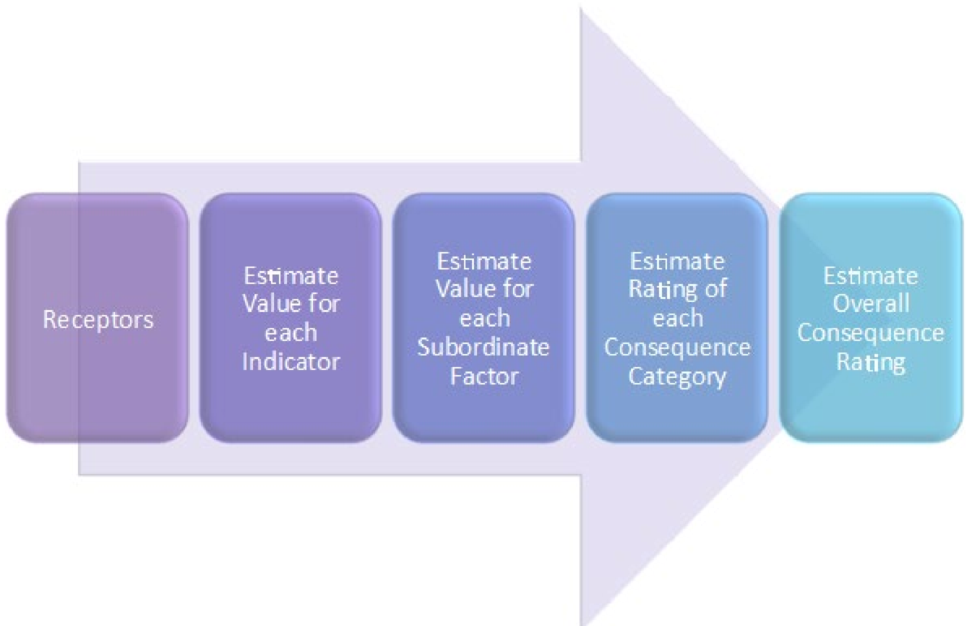


Figure 5-2 Overview of main elements and the analysis process of consequence frameworks

5.4 Determination of Classification Bounds

Raw receptor values are scored and classified by classification bounds. Best practices for determining classification class bounds are to consider the meaning of various levels of impact with expert consultation. As expert consultations were not included in this project, an alternative strategy was employed.

International examples of consequence classification bounds were reviewed (Directorate-General for European Civil Protection and Humanitarian Aid Operations (ECHO) (European Commission), 2017), but could not be applied to this project due to differences in geographical density and social risk tolerances between these countries and BC. Also, these class bounds are based on the impact of flooding (equivalent to a Tier 2 level analysis in this project). Determining the impact of flooding rather than just the exposure of assets to flooding requires both flood extent and flood depth information; the latter is not readily available across BC. While exposure acts as a proxy for consequence and allows for relative comparison, understanding the non-relative consequence of flooding based on exposure is difficult.

5.4.1 Classification Bound Development Process

Table 5-1 identifies the five classifications and associated scores and labels used as the basis for classification.

Table 5-1 Category scores and labels

Category Labels	Classification	Score
Insignificant	1	>0 to <1
Minor	2	≥1 to <2
Moderate	3	≥2 to <3
Major	4	≥3 to <4
High	5	≥4

The framework was developed based on five classifications and associated category labels. The scoring mechanism described below yields numbers (scores) which fit within the five classifications outlined in Table 5-1. The scores range from 0 – 5, with zero representing no assets exposed. For example, a scored value of 4.8 is classified with the classification '5' or 'high', while a scored value of 1.4 is classified with the classification '2' or 'minor'. Careful distinction between raw data, scored values, and classified numbers should be made. Raw data is processed to yield scores (e.g., a population of 3165 is processed to a score of 3.5). The scored value range associated with each classified number is used consistently throughout the project and shown in Table 1 (e.g., the classified value of 4 is associated with scores greater than or equal to 3 and less than to 4). Scored values are used in calculations. Classified numbers are integers associated with a range of scored values, and therefore, a range of raw data values.

The following describes the process used to score the data, i.e. determine scores for indicators. Scores for most indicators were determined based on available data and logarithmic classification. Logarithmic classification or some combination of logarithmic and linear classifications are used internationally to classify impacts. Logarithmic classification emphasizes changes which are small compared to the overall value. For example, logarithmic classification is used to emphasize that the relative difference between impacting one and five people is more significant than the relative difference between impacting 101 and 105 people. After the logarithmic classification, statistical processes are used to distribute the data between 0 – 5. This distribution spreads the data for easier interpretation and matches the 5 classification labels used in this project (see Table 5-1). The processes to determine classification bounds are represented by equations as follows:

- Logarithm of the data is taken using the following equation:

$$Logged\ value = \ log_{10}(raw\ data)$$

- The logged value is normalized using mean normalization according to the following equation:

$$Normalized\ value = {}^{(logged\ value - mean)}\Big/_{(max\ \text{-}\ min)}$$

- The value is then shifted by subtracting the minimum normalized value according to the following equation:

$$Shifted\ value = (normalized\ value) - (minimum\ normalized\ value)$$

- The shifted value is then spread between 0 – 5 according to the following equation;

$$Spread\ value = (shifted\ value) * 5$$

To determine the classification bounds after the binning process (e.g., what *'raw data'* value is represented by a classification of 1), the steps outlined above were reversed and classification values (1,2,3, and 4) were inputted as *'spread values.'*

5.4.2 Classification Bound Process Exceptions for Tier 1

The normalizing procedure described above was not applied to modifiers and binary indicators. Modifiers are factors which are added to indicator scores and therefore have a smaller range than indicators and do not fit the classification system outlined in Section 5.4.1. Binary indicators (i.e., a receptor is either present or absent and no data range is present) also do not fit the binning method outlined above. Binning procedures for modifiers and binary indicators are outlined below:

- Modifier M.A.1.1[13] – Socio-economic Vulnerability Index (SVI) (see Box 1 for explanation). As this dataset was already processed by NRCan using a similar method, no statistical functions were applied to the dataset. As the SVI ranged between 0.00 and 0.43, the entire dataset was multiplied by two to increase the values of the data, thereby increasing its modifying effect.
- Modifier M.B.1.1 – total number of community facilities (i.e., hospitals, education facilities, civic facilities, first responders). As this dataset is based on an integer count with a small distribution, and as only two classes were needed for the modifier, binning was done logarithmically with the following bins: 0<>10; >=10.
- Modifier M.C.2.2 – water crossings (i.e., length in metres of bridges and culverts greater than three metres in diameter). As this dataset is a modifier, it was binned logarithmically with the following bins: <100; 100>= and <1000; >=1000.
- Indicator N.C.2.3 – ports and airports. As this dataset is based on an integer count with a small distribution, it is treated as a binary indicator with the following bins: 0; or >0.

[13] Each receptor, indicator, modifier, subordinate factor, and consequence category has a reference number. See Appendix D for details.

5.4.3 Alternative Methods Attempted

The method outlined above was determined based on best practices and evaluating the results of several other potential methods. The following list qualitatively describes other methods attempted and their results.

- Linear binning – defined linear bins based on an arbitrary interval to fit the data range (e.g., 1-5, 5-10, 10-15). This method was not consistent between receptor datasets and emphasized small changes in large and small numbers equally.
- Logarithmic binning – defined logarithmic bins with logarithmic base 10 (e.g., 1-10, 10-100). As five bins were required, this required that the raw data have a range of at least five orders of magnitude. As many receptor datasets did not have this large a range, this method was not applied.
- 'Half-logarithmic' binning – defined logarithmic bins with logarithmic base 10, and then divided them in half (e.g., 1-5, 5-10, 10-50, 50-100).This only required that the raw data have a range of three orders of magnitude, however, dividing the logarithmic bins in half is not an established, meaningful statistical method, so this method was not applied.
- Logarithmic binning with bases 5 and 10 – defined logarithmic bins with base 10 when the range was at least five orders of magnitude, and logarithmic bins with log base 5 when the range was smaller. While this fit the data, this did not offer suitable comparisons between the data classified with the two different bases, and was not used.
- Logarithmic binning with base 5 – defined logarithmic bins with base 5 (e.g., 5, 25, 125). Some datasets with a large range were not well classified with this system as it only classified a portion of their range. Also, using a logarithmic base other than 10 means that there is a difference in binning depending on units used. For example, a length measurement binned in metres might fall within the bin bounds 625, 3125, 15625, while the same measurement binned in kilometres fall within use the bin bounds 0.2, 1, 5, resulting in different classification results.
- Linear and logarithmic binning – a combination of linear and logarithmic binning applied developed based on qualitative examination of the data distribution. This method was not consistent or justifiable, and was not used.
- Statistically based on a min/max normalization – The same method as is described in Section 5.4 was employed using a min/max normalization instead of mean normalization. Min/max normalization spreads the data evenly between the minimum and the maximum data values. Min/max normalization emphasizes outliers and does not preserve the raw data distribution as effectively as mean normalization.

6 ANALYSIS METHODOLOGY

The consequence classification framework brings together the different indicators and modifiers into subordinate factors, combines subordinate factors into consequence categories, then incorporates the consequence categories into an overall classification. As discussed in Section 1.2, the Tier 1 analysis determines a consequence rating based on exposed receptors following methodology outlined in Section 6.1. The Tier 2 analysis methodology is discussed in Section 6.3. The consequence classification framework is designed to provide consequence ratings based on the level of social, built environment, environmental, and cultural assets located in the protected floodplain of each dike. The steps to apply the framework are as follows:

- Collect receptor data (see Section 3).
- Determine protected floodplains for each dike (see Section 4.2).
- For Tier 1 analysis, identify receptors in each protected floodplain (see Section 6.1).
- Apply the consequence classification framework to the raw data for each dike (see Section 6.1). Aggregate raw data into subordinate factors, consequence categories, and finally an overall score based on a weighted aggregation and applicable tipping.
- For Tier 2 analysis, determine the impact of the flood event on receptors in each protected floodplain (see Section 6.3).

6.1 Tier 1 Analysis Procedure

Determining the receptors exposed in each protected floodplain is a spatial data analysis exercise. Two main analysis tools were selected for this analysis.

- Esri ArcGIS software was used to identify receptors located within protected floodplains. Most input data were available in formats compatible with ArcGIS. Common GIS processes were coded for automation of dataset processing.
- The programming language R was used to collect the outputs from GIS and organize data for framework development and application. R has strong statistical capabilities

Specific receptor analysis was completed as follows: point features were counted; linear features were measured; and the area of polygon features was measured. When polygon features were only partially inside a protected floodplain, a weighted average was completed based on the portion of the polygon within the protected floodplain (i.e., if 20% of a populated area polygon was within the protected floodplain, 20% of the population of the populated area polygon is assigned to the protected floodplain). The framework was then applied to the raw data to determine classification scores. This data processing was done using Microsoft Excel due to client familiarity and general ease of use.

6.2 Classification Framework Implementation with Tier 1 Analysis

This section describes the composition of each consequence category, including weighting of components, weighting of the consequence categories in the overall score, and "tipping" whereby a consequence category with a high score can override the overall consequence rating. Appendix D provides the details of the consequence classification framework including receptors, indicators, subordinate factors, classification bins, and aggregation equations. Appendix E provides a visual flowchart of the consequence classification.

A. People Consequence Category

The people consequence category was determined based on the number of people living in a protected floodplain and their social vulnerability. The number of people was scored between 0-5 (see classification process in Section 5.4) and the Socio-economic Vulnerability Index (SVI) was adjusted to range between 0 – 0.87 (see Section 5.4). These scores were added together with no weighting to yield the people consequence category as shown in Appendix D and Appendix E.

While the population was restricted by the dataset to the polygons representing settled areas, there is still some spatial aggregation of data and potential associated inaccuracies where areas are represented as more or less densely populated. Specific examples of dikes where the data does not accurately represent the populations in their protected floodplains include: dike63 Mountain View Mobile Home Park Sparwood; and dike 306 Cox Creek.

Study of post-disaster recovery processes across the world has shown that people and groups are impacted differentially by damaging events, mitigate against loss in different ways, and react and recover after a disaster in different manners and time spans (Burton et. al, 2014). For example, elderly people may have declined physical ability such as poor health, mobility, sight, and hearing. Lack of adequate services such as support for moving around or access to information can adversely effect their evacuation and emergency management capacities. Populations with lower income levels have lower coping capacity due to lack of social protection mechanisms, livelihood opportunities, contingency financial resources, or insurance.

To consider this in the consequence classification framework, the SVI developed by NRCan is used to adjust the score. The SVI is the basis for the people receptor modifier and the source of additional population information presented in the output for each dike. Box 1 provides an overview of NRCan's scope and approach used in developing the SVI. When using the SVI for this project, only the social system, economic system, and community health components are incorporated, each with an equal weighting. The built environment is not included as it is specific to earthquake hazard.

Overall consequence classification is sensitive to the magnitude of the SVI. If the value of the SVI changes, this has an effect on the overall classification. The value of the SVI has been chosen for this project based on the project team's best judgement, but as described in Sections 6.5 and 10.4 and in Appendix J, expert consultation should be used to refine this value.

Box 1 About Socio-economic Vulnerability Index (SVI)

The SVI model reflects underlying socio-economic drivers of vulnerability for seven distinct community archetypes:

1) Urban Metropolitan Centre
2) Urban Agglomeration Area (Pop>10,000) with administrative subdivisions
3) Urban Agglomeration Area (Pop>10,000) with no administrative subdivisions
4) Exurban Regional District with strong metropolitan influence
5) Exurban Regional District with moderate metropolitan influence
6) Rural District with weak metropolitan influence
7) Rural District with no metropolitan influence

Separate SVI models were developed for each of these seven community archetypes. Each regional SVI model is defined in terms of four major system components:

A. Social System (20 variables: age, family characteristics, language, education, etc.)
B. Economic System (8 variables: household income, individual income, employment status, etc.)
C. Community Health (13 variables: illness, access to health care, quality of life, etc.)
D. Built Environment (4 variables: seismic safety level, proximity to essential facilities)

A principal component analysis (PCA) was run on each of the four model components for all seven community typologies to determine weightings that were then integrated into a multi-level hierarchical model.

2011 Census data has been used in the version of SVI analysis applied to the dike project. NRCan is in the process of updating SVI based on 2016 Census data (pers comm, M. Journay, Oct. 11, 2018).

B. Economy – Buildings Consequence Category

The Economy – Buildings consequence category was determined based on the value of buildings (in $CAD) exposed (scored between 0-5) and the number of administrative facilities, e.g., hospitals, education facilities, community facilities, and first responders facilities (scored between 0-2) (see Section 5.4 for details) . These scores were added together with no weightings to yield the score for Economy – Buildings consequence category as shown in Appendix D and Appendix E. In locations where recent developments have occurred in protected floodplains or buildings are not accurately represented by settled areas data, building values may be underestimated. For example, dike 338 Etna Creek.

Administrative facilities play a crucial role during emergency response and recovery time. During disasters they can be used as shelters, evacuation centres, emergency coordination centres, and supply distribution hubs. During disaster recovery, they can serve as hubs for coordinating community recovery. They are an important indicator for resiliency of a community. To consider this fact in the consequence classification framework, a modifier is used to adjust the base score of the Buildings receptor based on the total number of administrative facilities (see Appendix D).

C. Economy – Critical Infrastructure and Agriculture Consequence Category

The Economy – Critical Infrastructure and Agriculture category was determined based on the amount of exposed utility infrastructure, transportation infrastructure, and area of agricultural land. Individual utilities infrastructure components were scored from 0-5, and combined into a utility subordinate factor based on the maximum score. Individual transportation infrastructure components including roads, water crossings, ports, and airports were scored from 0-5 and combined into a transportation infrastructure subordinate factor using a combination of weighting and tipping as shown in Appendix D and Appendix E. Agricultural land was scored from 0-5. These factors were weighted and added together to get the Economy – Critical Infrastructure and Agriculture score as shown in Appendix D and Appendix E. Due to the significance of utility and transportation infrastructure and the large scale implications of damage to these assets, these subordinate factors were given a weight of 0.4. The agricultural subordinate factor was given a weight of 0.2. These subordinate factors were weighted and added together to determine the Economy – Critical Infrastructure and Agriculture score as shown in Appendix D and Appendix E.

D. Environment Consequence Category

The environment category was determined based on the combined area of parks, environmentally sensitive areas, and critical habitat. The combined area was scored from 0-5 and no weightings were applied as there was only one contributing subordinate factor.

In the overall classification equation, the Environment Consequence Category (D) had a weighting of 0.1.

E. Cultural Heritage Consequence Category

The cultural heritage category was determined based on the First Nations reserve area (scored 0-5) and the number of cultural and historic sites (scored 0-5). These were combined with an equal weight of 0.5 each to determine the cultural heritage consequence category as shown in Appendix D and Appendix E .

<u>Overall Score</u>

The overall dike consequence score is calculated by combining consequence category scores using a weighted aggregation, and by tipping based on high scores of consequence category A or B. The weighting for each consequence category is based on the confidence in the exposure data, the understanding of potential impacts and the importance for socio-economic recovery as shown in Table 6-1. In addition to a weighted equation, tipping is used to emphasize the consequence categories with the highest confidence, impact understanding and importance for socio-economic recovery. If either of the two categories (A – People and B – Economy – Buildings) have a classification of 5, the overall score is classified as a 5. This ensures that a high classification in either of these two categories is reflected in the overall score and not minimized by weighting if the other categories have low scores.

In the overall classification equation, the People Consequence Category (A) has a weighting of 0.4 and tips the overall score to a 5 if it has a classification of 5 (a calculated score of greater than or equal to 4). In the overall classification equation, the Economy – Buildings consequence category (B) had a weighting of 0.2 and tips the overall score to a 5 if it has a classification of 5 (a calculated score of greater than or equal to 4). In the overall classification equation, the Economy – Critical Infrastructure and Agriculture consequence category (C) had a weighting of 0.2. In the overall classification equation, the Cultural Heritage Consequence Category (E) had a weighting of 0.1The weighted aggregation follows the formula: Overall Score= 0.4A + 0.2B + 0.2C +0.1D +0.1E.

If Consequence Category A People or B Economy – Buildings has a score ≥4 (i.e., a classification of 5), the overall classification is tipped to 5

Note that the severity of the hazard event was not accounted for in Tier 1 analysis. Tier 1 analysis is exclusively exposure based, however the severity of the hazard could have a significant effect on the consequence.

Table 6-1 Variables used to assign aggregation weightings to each consequence category

Consequence Category	Types of Potential Impacts	Confidence in Exposure Data	Understanding of the Potential Impacts	Importance for Socio-economic Recovery	Weighting for Overall Score	Tipping for Overall Score
People	Loss of life, injury, displacement, anxiety due to disruption to daily life, loss of income	High	High	High	0.4	=5
Economy – Buildings	Building collapse, damage, debris, disruption to administrative services (health, education, police, emergency management)	High	High	High	0.2	=5
Economy – Critical Infrastructure and Agriculture	Disruption to water and electricity, disruption to transportation, crop loss, long term damage to agricultural land, variety of indirect long term impacts such as loss of commercial activities, tourism, health, etc.	Medium	Medium	High	0.2	None
Environment	Short to mid-term damage to national, local, and regional parks and conservation areas and loss of endangered species. May have long term impacts on health, socio-economic well-being.	Low[14]	Low	Medium	0.1	None
Cultural Heritage	Short to mid-term damage to FN reserves area, damage to cultural heritage sites. May have some long term impacts on tourism and social well-being	Low[15]	Low	Low	0.1	None

[14] While some environmental and cultural values are captured through the data used in this project, more robust datasets and community conversations are needed to refine this category.

[15] While some environmental and cultural values are captured through the data used in this project, more robust datasets and community conversations are needed to refine this category.

With access to a group of sectoral experts and representatives from relevant provincial entities, a consensus-based method could be used for defining the aggregation weightings of subordinate factors and consequence categories. Appendix J provides further discussion of the consultation process.

6.3 Tier 2 Analysis Procedure

While Tier 1 results are useful for comparison and an understanding of the relative potential severity of an event, Tier 2 analysis enables an understanding of the consequences of a flood event through estimating the impact of flooding on the receptors. Three case-study sites were chosen for Tier 2 analysis to showcase different receptor profiles:

- Surrey South Westminster dike (dike #296) – urban and industrial site;
- Fernie dike (#58) – small town/rural site; and
- Nicomen Island dike (dike #144) – agricultural site.

Consequences can be understood as direct or indirect[16]. In this assessment, direct consequences are assessed and indirect consequences are estimated where data are available and well-known consequence relationships exist.

Direct consequences include physical impacts such as injury, damage to property, damage to home contents, and loss of crops. For Tier 2 assessments in this study, direct consequences are estimated for the impact to people and economy (consequence categories A, B, and C). Methods and data required to assess direct consequences for environmental and cultural consequence categories (Consequence categories D and E) are not readily available in Canada, so assessments of these factors requires extensive expert consultation, which was not completed for this project.

Indirect consequences include associated impacts such as loss of productivity, business disruption, and traffic impacts. There is a large range indirect consequences from a major flooding event and numerous qualitative and quantitative methods of estimation for each category of social, micro and macro economic, and environment. For Tier 2 assessments in this study, indirect consequences are estimated based on general relationships to direct consequences. All Tier 2 impacts are considered individually, with no consideration of interdependencies through connecting or cascading impacts (e.g., business disruption estimations are based on established general relationships rather than considering the impacts to roads which serve a particular building).

[16] Indirect consequences or impacts include microeconomic impacts (e.g., revenue declines owing to business interruption), mesoeconomic impacts (e.g., revenue declines owing to impacts on natural assets, interruptions to supply chains or temporary unemployment) and macroeconomic impacts (e.g., price increases, increases in government debt, negative impact on stock market prices and decline in GDP). Indirect losses can occur inside or outside of the hazard area and often have a time lag. As a result they may be intangible or difficult to measure (UN, 2016).

All hazard information was based on a flood event rather than a dike failure scenario (i.e., was based on a 200-year flood) and assumes no dikes present. Consideration of dike failure through a dike breach or overtopping would result in a different hazard profile likely including shorter warning times, depths decreasing with distance from the dike, and higher velocities than associated with a riverine flood scenario.

Flood consequences were estimated with available data and based on available consequence estimation methodologies. Literature-based methodologies were applied to estimate the consequences of the flood event. The primary resource used for this estimation was NRCan's Canadian Guidelines and Database of Flood Vulnerability Functions (Natural Resources Canada and Public Safety Canada, 2017), associated material in the Government of Alberta's Provincial Flood Damage Assessment Study (PFDAS) (Alberta Government, 2015), Hazus methodology (FEMA, n.d.), and UK flood risks to people methodology (HR Wallingford et al., 2006).

For this study, the project team aimed to use a software tool to calculate damages. There are significant ongoing developments in availability and capabilities of flood damage modelling tools. Various available software was evaluated through use and information provided in the following reports: Safaie, 2017; Phillips, 2016; Daniell, 2014; Lyle and Hund, 2017; McGrath, 2017; and Natural Resources Canada and Public Safety Canada, 2017. The software FloodModeller Pro was selected for use in this project, however, due to software limitations, geospatial and tabular analysis were used in conjunction with the FloodModeller Pro software.

Floodmodeller Pro is a proprietary software which simulates water flow in riverine environments through 1D and 2D modelling. It has a variety of modules including a flood damage module which calculates direct property damages based on flood depth, property location, property type, and depth-damage curves based on methods in the UK Multi-coloured Manual (Penning-Rowsell et al, 2005). The software is user friendly, includes robust user-help functionality, has been used extensively on previous projects, includes user editable depth-damage functions, and has straightforward data input. The software is proprietary and available based on a user-fee. It is primarily used in the UK, however it has been used on projects around the world.
Where structure costs are estimated in analysis, they are based on replacement costs rather than depreciated values. This is consistent with the methodologies and value sources used for this assessment (HAZUS, NRCan's Flood vulnerability functions, and PFDAS). Replacement values best represent potential insurance pay-outs and expected monetary flows, however, depreciated costs better express real economic loss (B. Jongman et al., 2012).

Adjustments were made in dollar values to reflect 2018 Canadian dollars as closely as possible based on procedures outlined in the Canadian Guidelines and Database of Flood Vulnerability Functions (Natural Resources Canada and Public Safety Canada, 2017). Analysis methods and calculations used are detailed in Appendix H.

6.4 Classification Framework Implementation with Tier 2 Analysis

Tier 1 and 2 analysis are based on the same classification framework as described in Section 5. In Tier 2 analysis, the two economy consequence classifications have been combined, there are a few different and additional subordinate factors, and the indicators and modifiers are direct and indirect impacts. The flowchart framework has been adjusted to show this variation, as described below and illustrated in the Appendix E flowchart. In addition to impacts included in this study, the cost of emergency management and temporary shelter could also be calculated and considered as an impact to the economy.

A. People Consequence Category

For this study, the impact to people is calculated based on the direct impacts: number of fatalities, number of injuries and number of people displaced. Analysis was restricted to these impacts due to limitations of established methodologies and the absence of consultation. Future analysis could include consideration of: indirect impacts to mental health such as post-traumatic stress disorder (PTSD); indirect impacts such as impact to household financial situation or loss of rental income due to displacement; impact to the economy such as the impact of temporary or permanent job loss to the population; changes in community spirit and public perception of the area.

Table 6-2 Component Impacts of People Consequence Category

Subordinate Factor	Indicators	
	Direct Impacts	Indirect Impacts
A.1 People	- Number of fatalities - Number of physical injuries - Number of people displaced	- Impacts to psychosocial health*

* Not calculated for this project

B. Economy – Buildings Consequence Category

For this study, the impact to the economy – buildings consequence category is calculated based on a selected direct and indirect impacts. Analysis was restricted to these impacts due to limitations of established methodologies, absence of consultation, and limited accessible economic data. Analysis included an estimation of direct impacts to residential, commercial, industrial, institutional, and agricultural buildings. Indirect impacts including the loss of function for residential, commercial and industrial buildings were calculated. Other indirect impacts were not calculated for this assessment but could include contamination of floodwaters, loss of institutional services, and overall impact of damages and loss of function on the economy. Table 6-3 shows the direct and indirect impacts calculated for the Economy – Buildings consequence category.

Table 6-3 Component Impacts of Economy – Buildings Consequence Category

Subordinate Factor	Indicators	
	Direct Impacts	Indirect Impacts
B.1 Economy - building	- Damage to residential building structures - Damage to residential building contents - Damage to commercial building structures - Damage to commercial building contents - Damage to industrial building structures - Damage to industrial building contents - Damage to institutional building structures - Damage to institutional building contents - Damage to agricultural building structures - Damage to agricultural building contents	- Loss of residential building function - Loss of commercial building function - Loss of industrial building function

Note: All impacts in table were calculated for this project.

C. Economy – Critical Infrastructure and Agriculture Consequence Category

For this study, the impact to the Economy – Critical Infrastructure and Agriculture consequence category is calculated based on select direct impacts. Analysis was restricted due to limitations of established methodologies (e.g., functions to characterize flood damage to infrastructure), absence of consultation, and limited accessible economic data.

Direct impact to one component of the transportation infrastructure, roads, was estimated. The direct impacts to utility infrastructure and other components of transportation infrastructure were not calculated. The direct impact to agricultural land in terms of damage to crops and livestock, and land clean-up and replanting costs were calculated. Table 6-4 shows the calculated and not-calculated direct and indirect impacts for the Economy – Critical Infrastructure and Agriculture consequence category.

Table 6-4 Component Impacts of Economy – Critical Infrastructure and Agriculture Consequence Category

Subordinate Factor	Indicators	
	Direct Impacts	Indirect Impacts
C.1 Utility Infrastructure*	- Damage to water and sanitation infrastructure* - Damage to telecommunications infrastructure* - Damage to electrical infrastructure*	- Disruption in service delivery*
C.2 Transportation Infrastructure	- Damage to roads - Damage to water crossings* - Damage to ports and airports* - Damage to vehicles*	- Traffic disruption* - Disruption to economy*
C.3 Agricultural Land	- Damage to crops and livestock - Land clean-up and replanting costs	- Overall impact on economy* - Contamination of floodwaters*

* Not calculated for this project

6.5 Use and Limitations

The dike consequence classification is based on extensive data related to various types of assets. It is a comprehensive baseline assessment providing a consistent evaluation of exposed assets behind all regulated dikes in BC. It allows ranking, comparison, and identification of high consequence dikes. In addition to ranking, the information provided on receptors under each consequence category provides valuable insights to emergency managers and resilience planners working at provincial and local levels.

In the practice of disaster risk assessment for use in risk management, it is sensible to start with a cost-effective baseline assessment before investing heavily in fully probabilistic, quantitative risk assessments. Baseline study allows identification of “hot spot” areas with potentially high consequence levels. Once the objectives of the high-cost risk assessment are defined, the “hot spot” areas would be prioritized for more in-depth risk assessment.

The main limitation of the Tier 1 classification is that it does not incorporate vulnerability or capacity of the assets. It does not directly provide information on impact (consequence), instead, it provides information on exposed assets as a proxy for potential consequence. There are inherent uncertainties in any disaster consequence estimation. Uncertainties are normally grouped in two categories: epistemic and aleatory.

Epistemic uncertainties are the uncertainties due to incomplete scientific understanding of the disaster process. Epistemic uncertainties can be reduced with improved data and methodologies. For the Tier 1 assessment, the main source of epistemic uncertainty is in the simple and cost-effective approach used for defining the protected floodplain for each dike. Another source of epistemic uncertainty in Tier 1 analysis is in the flood hazard mapping based on existing flood hazard models, asset data, and the change in assets due to population and economic growth since the original data were collected (i.e., the population and building data are from the 2011 census data and changes have occurred since then).

Aleatory uncertainty is the inherent randomness associated with natural hazard events, such as earthquakes, hurricanes, and floods and the vulnerability of the exposed assets (how they react to the force of the hazard). Aleatory uncertainty cannot be reduced by the collection of additional data. In Tier 1 results, the main source of aleatory uncertainty is in the flood hazard.

The main limitation of the Tier 2 analysis is that many of the relationships, assumptions, and formulas used to calculate damages were developed outside of BC. While the analysis methodology is robust and efforts were made to use the most applicable methodologies, some results may be inaccurate due to regional differences. To improve estimations, information based on post-flood assessments completed locally is required. Also, Tier 2 analysis is limited by the accuracy of input data, including value estimations. Tier 2 assessments, while they were done with an extensive desktop examination of the protected floodplain, do not include a field assessment or incorporation of local knowledge. Without field assessments and local knowledge, community assets and potential impacts may not be reflected in the results.

Direct impacts to CI infrastructure are difficult to calculate with existing information and available consequence estimation methodologies. Information required includes: more detail about localized flood characteristics for infrastructure such as culverts and bridges; and more information about asset elevation and characteristics for infrastructure such as telecommunications and electrical infrastructure. More published flood consequence relationships and generalized research results are needed to develop usable relationships to estimate damage to CI infrastructure with limited information.

7 CONSEQUENCE CLASSIFICATION RESULTS

7.1 Tier 1 Results

The classification results are provided in several forms both in this report section and in the appendices. Table 7-1 identifies the number of dikes at each consequence level for each consequence category and for overall consequence. This information is shown in Figure 7-1 as a percentage of dikes at each consequence level.

Table 7-1 Number of dikes at each consequence level for each consequence category and overall

Consequence Level	Score	People – A	Economy – Buildings – B	Economy – Critical Infrastructure and Agriculture – C	Environment – D	Culture– E	Overall (Total)	Overall (*)
Insignificant	1	5	6	4	20	5	**8**	**4***
Minor	2	21	34	32	41	21	**43**	**17***
Moderate	3	70	88	73	63	70	**90**	**24***
Major	4	80	47	46	26	80	**36**	**9***
High	5	32	32	57	11	32	**35**	**2***

* Indicates that this dike protects from a severe hazard including an alluvial fan, debris, or ice hazard. Due to the hazard characteristics, the consequence of dike failure may be more severe due to: little to no warning time; high velocity water; and high debris concentrations. Consequences may include high loss of life and significant damage to assets.

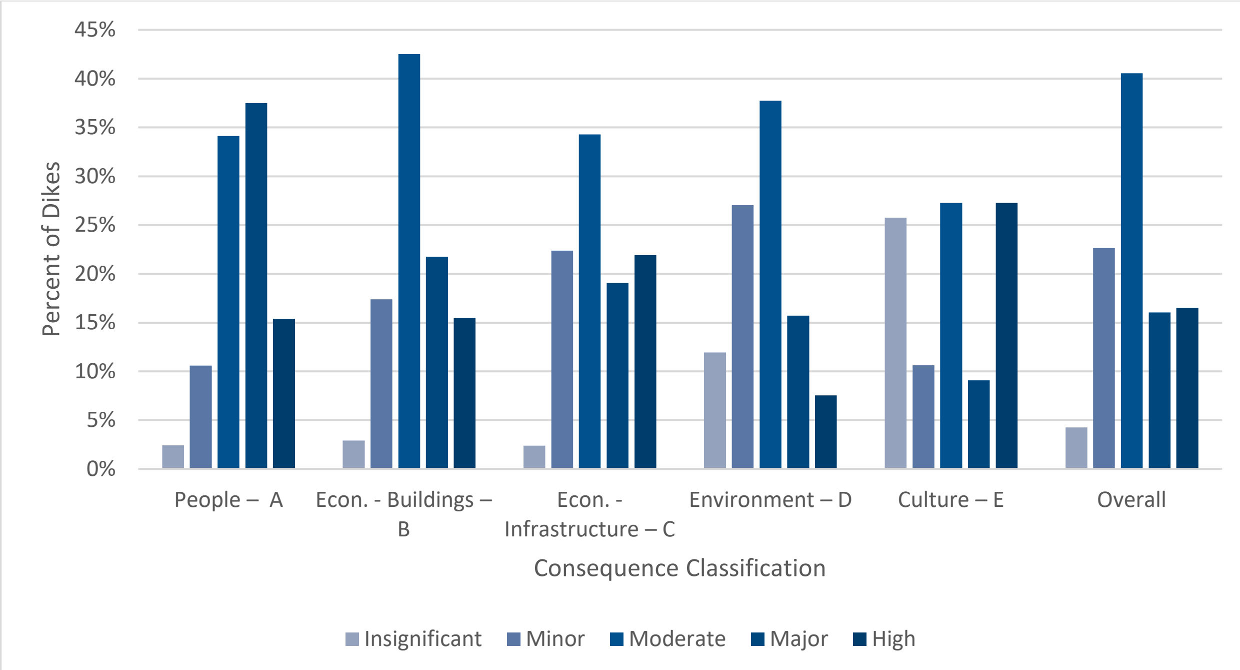


Figure 7-1 Percent of dikes at each consequence level for each consequence category and overall

Appendix C includes a map of each dike, the associated protected floodplain, and the corresponding consequence classification results. The protected floodplains are approximate, and should not be used for any purpose other than the consequence assessments in this study.

Appendix F provides a table with an overview of the consequence classification results. For each receptor score, modifier score, subordinate factor score, and consequence category score (i.e., score from 1-5), the bins which define the score are listed and the number of dikes which fit into each category are listed. With this table, the reader can look at a score for any receptor and determine the range (e.g., maximum and minimum number of kilometres of road) which defines the category and the number of dikes which fit into this category.

Appendix G lists all dikes with their overall score as well as their score for each receptor, modifier, subordinate factor, and consequence category.

7.1.1 Results Commentary

The determination of the overall score is based on an aggregated weighting of the five consequence categories, which may be tipped by a high rating in consequence categories People (A) or Economy – Buildings (B) (see Section 6).

Based on this classification system, there are 34 dikes with a 'major' consequence and 35 dikes with a 'high' consequence. The distribution is affected by the tipping of some consequence levels from 'major' to 'high' based on a high consequence score for People (A) or Economy – Buildings (B). With this tipping, some of the dikes which would have a weighted score of ‘major’ are tipped to ‘high’ by their high classification in the People or Economy – Buildings categories. Namely, 13 dikes were tipped from a ‘major’ classification to a ‘high’ classification.

Of the 212 dikes analyzed, 56 of them (26%) have been flagged with a severe hazard flood type including a debris, alluvial, or ice hazard (see definition of ‘flagged’ in Section 4.1.2). These dikes are identified by dike number in Appendices A and C.

The overall score was correlated[17] with a selection of modifiers, indicators, subordinate factors, and consequence categories, chosen to indicate key points in the process. This correlation was done to analyze the connection between the input factors and the overall score and see which factors are most predictive of the overall classification score. The absolute value of the correlation is reported in Table 7-2. The closer the value is to 1, the stronger the correlation. The closer the value is to zero, the weaker the correlation.

Table 7-2 Correlation between factors and overall classification result

Factor	Correlation
Consequence Category A - People	0.92
Indicator N.A.1.1 – Population	0.91
Indicator N.B.1.1 – Buildings	0.89
Consequence Category B – Economy – Building	0.88
Subordinate Factor C.2 Transportation Infrastructure	0.86
Protected Floodplain Area	0.78
Consequence Category C – Economy – Critical Infrastructure and Agriculture	0.78
Subordinate Factor C.1 Utility Infrastructure	0.75
Subordinate Factor C.3 Agricultural Land	0.73
Consequence Category D – Environment	0.66
Consequence Category E – Cultural Heritage	0.46
Modifier M.A.1.1 – SVI	0.06

As can be seen in the correlation values, the most predictive factor for the overall score is the consequence category People (i.e., the number of people in a protected floodplain). Closely following population are buildings and transportation infrastructure. Most areas which have a large population also have significant development. Next most predictive is the protected floodplain area – a larger protected floodplain tends to have a larger consequence of dike failure. After protected floodplain area, the consequence category Economy – Critical Infrastructure and Agriculture followed by its component subordinate factors utility infrastructure and agricultural land are the most correlated. Both the

[17] The Spearman correlation was used to calculate correlation.

environment and cultural heritage consequence categories are somewhat correlated to the final score. The SVI has little correlation with the overall score.

For the dikes with community type(s)[18] reported, an analysis of community type(s) and overall scores was completed. For each overall score, the percent of dikes with each community type was determined and compared to the overall distribution of community types. This analysis shows that the more metropolitan a protected area is, the higher consequence it is likely to be. Conversely, rural areas are likely to be lower consequence. Table 7-3 shows the total percent and the percent of each overall score in each community type.

Table 7-3 The total percent and the percent of each overall score in each community type

Community Type[11]	Percent of each Overall Score in Given Community Type (%)					Total
	1	2	3	4	5	
1 – Urban Metropolitan Centre	25	13	17	26	51	24
2 – Urban Agglomeration Area (Pop>10,000 with administrative subdivisions)	0	16	12	11	29	15
3 - Urban Agglomeration Area (Pop>10,000 with no administrative subdivisions)	0	16	8	9	14	10
4 – Exurban Regional district with strong metropolitan	0	13	6	3	0	5
5 – Exurban Regional district with moderate metropolitan	50	19	18	9	0	14
6 – Rural District with weak metropolitan influence	25	19	38	43	6	30
7 – Rural District with no metropolitan influence	0	3	1	0	0	1
Total percent:	100	100	100	100	100	100

Classification was done exclusively based on data analysis rather than observation, but when classified areas were examined, significant patterns were noted. High consequence dikes generally protect medium to large portions of urban land. The majority of the high consequence dikes protect populated areas along the lower Fraser River, but there are several other densely populated areas throughout the rest of the province which were identified as high consequence. The high consequence dikes are located in the following areas:

- Lower mainland (25 dikes – numbers 1, 2, 3, 15, 16, 18, 19, 20, 42, 45, 46, 108, 140, 244, 252, 253, 271, 293, 296, 365, 382, 383, 386, 387, 388),

[18] Community archetypes are as identified by NRCan's SVI described in Box 1. In the nine cases where more than one community type was protected by the same dike, the most urban designation (i.e., the lowest number) was considered. There were 18 dikes with no community type reported, either because they did protect any population, or SVI and the community archetype were not determined for that area.

- Duncan (3 dikes – numbers 51, 376 and 377)
- Golden (1 dike – number 71)
- Kamloops (2 dikes – number 90 and 101)
- Pemberton (1 dike – number 232)
- Prince George (1 dike – number 254)
- Squamish (2 dikes – numbers 284 and 285)

The major consequence dikes generally protect medium-sized portions of moderate-density urban areas, small portions of high density urban areas, and large rural areas. The moderate consequence dikes generally protect small portions of moderate-density urban areas, medium sized rural areas, agricultural areas or small flood fringe areas along the lower Fraser River, and debris hazard areas. The minor consequence dikes protect similar types of areas as the moderate consequence dikes, with areas generally being smaller and less developed. The insignificant consequence dikes generally provide protection for a very limited area containing some development.

7.2 Tier 2 Results

7.2.1 Impact to A - People

The impact to people was calculated as described in Section 6.3, Section 6.4 and Appendix H. The results are shown in Table 7-4.

Table 7-4 Estimates of Tier 2 Impact to People consequence classification indicators

Subordinate Factor	Indicators	Nicomen Island Dike (#144)	Surrey South Westminster Dike (#296)	Fernie Dike (#58)
Impact to People	Displaced People, #	660	2160	760
	Injured People, #	190 (30%)	350 (16%)	110 (14%)
	Fatalities, #	50 (8%)	50 (2%)	10 (1%)

Note: percentages based on total displaced people.

The injury and fatality rates are significantly higher (almost two times higher) for Nicomen Island than the Surrey South Westminster and Fernie dike failure scenarios. This is due primarily to the significantly higher flood depth and corresponding higher hazard rating leading to a higher expected injury and fatality rate for Nicomen Island. This increased rate and consequence due to flood characteristics is an example of how Tier 2 analysis refines Tier 1 style exposure assessments. When evaluating the impact to people rather than identifying the people exposed to flooding, the Nicomen Island dike and the Surrey South Westminister dike have the same consequence, despite the Surrey South Westminster dike having more than three times the population exposed. Although the Fernie dike has a similar number of people exposed as the Nicomen Island dike, the casualty rates are significantly lower. The number of fatalities is determined using the methodology outlined in Appendix H. Project reviewers believe the actual number of injuries and fatalities may differ significantly from the above estimate. Further exploration of BC-specific input values and assumptions is needed to verify and refine the estimation, as well as a calibration of this model with a local event.

7.2.2 Impact to B - Economy – Buildings

The impact to Economy – Buildings consequence category was calculated as is described in Section 6.3, Section 6.4 and Appendix H. The results are shown in Table 7-5.

Table 7-5 Estimates of residential building impact indicators and contextual calculation information (in italics)

Impact Grouping	*Contextual Information* and Indicators	Nicomen Island Dike (#144)	Surrey South Westminster Dike (#296)	Fernie Dike (#58)
Residential Impact	*Total Buildings Exposed, #*	*133*	*710*	*495*
	Average Value of Building, $	*371,000*[19]	*62,000*	*255,000*
	Total Value of Buildings Exposed, $	*49,344,700*	*44,656,500*	*126,467,900*
	Average Damage to Structures, %	*65*	*57*	*30*
	Average Damage to Contents, %	*59*	*56*	*29*
	Damage to Building Structures, $	31,974,000	25,616,000	38,370,000
	External Damages, $	410,000	1,782,500	1,257,500
	Damage to Building Contents, $	14,554,000	12,422,000	18,356,000
	Loss of Function, $	7,041,000	10,458,000	5,973,000
	Total, $	**53,979,000**	**50,278,500**	**63,956,500**

Total residential impact is highest at the Fernie dike, followed by the Nicomen Island and Surrey South Westminster dikes. While the largest number of residential buildings are exposed by the failure of the Surrey South Westminster Dike, the average value of these buildings is significantly lower than the residential buildings in the other locations. This difference leads to the highest total value of exposed residential buildings in Fernie, and lower values at Nicomen Island and Surrey South Westminster. When the flood depth is taken into account by calculating the damage to the building structures, the higher flood depths at Nicomen Island and Surrey South Westminster are reflected in the proportionally higher

[19] Note, project reviewers believe the actual value per structure is lower than this value. This value is believed to be high because assessed 'improved values' may include property value in addition to structural improvements.

damages at these locations. The damage to the building contents reflects both the total value of contents exposed and comparative damages similar to the average structural damages (highest on Nicomen Island). Overall, the highest total residential damage is found in Fernie, primarily due to the relatively large number of moderately high-value residential buildings.

Table 7-6 Estimates of commercial building impact indicators and contextual calculation information (in italics)

Impact Grouping	*Contextual Information* and Indicators	Nicomen Island Dike (#144)	Surrey South Westminster Dike (#296)	Fernie Dike (#58)
Commercial Impact	*Total Buildings Exposed, #*	*1*	*109*	*44*
	Average Value of Building, $	*186,000*	*884,000*	*202,000*
	Total Value of Buildings Exposed, $	*250,000*	*96,345,000*	*8,868,000*
	Average Damage to Structures, %	*48*	*16*	*13*
	Damage to Building Structures, $	120,000	15,497,000	1,192,000
	Damage to Building Contents, $	228,000	53,783,000	4,089,000
	External Damages, $	440,000	120,000	440,000
	Loss of Function, $	70,100	13,944,000	1,080,200
	Total, $	**858,100**	**83,344,000**	**6,801,200**

Total commercial impact is significantly higher for Surrey South Westminster than for Nicomen Island or Fernie. Even though there is a relatively low average damage to structures at Surrey South Westminster, there is a significantly higher number of buildings exposed and average commercial building value. As described in the methodology details, the loss of function estimate is based a constant proportion of commercial damages, and is not an estimate based on economic or business information specific to these areas. The loss of function value could be significantly higher depending on what is included in a detailed assessment.

Table 7-7 Estimates of industrial building impact indicators and contextual calculation information (in italics)

Impact Grouping	*Contextual Information* and Indicators	Nicomen Island Dike (#144)	Surrey South Westminster Dike (#296)	Fernie Dike (#58)
Industrial Impact	*Total Buildings Exposed, #*	*0*	*575*	*0*
	Average Value of Building, $	*0*	*224,000*	*0*
	Total Value of Buildings Exposed, $	*0*	*128,640,000*	*0*
	Average Damage to Structures, %	*0*	*26*	*0*
	Damage to Building Structures, $	0	33,673,000	0
	Damage to Building Contents, $	0	91,609,000	0
	External Damages, $	0	1,462,500	0
	Loss of Function, $	0	25,348,900	0
	Total, $	**0**	**152,093,400**	**0**

There are no industrial facilities on Nicomen Island or protected by the Fernie dike. The Surrey South Westminster dike protects 575 industrial buildings with an average building value of $224,000. The industrial damage estimate is significant due to the high number of buildings, high building value, and average damage predicted. As described in the methodology details, the loss of function estimate is based a constant proportion of industrial damages, and is not an estimate based on economic or business information specific to these areas. The loss of function value could be significantly higher depending on what is included in a detailed assessment.

Table 7-8 Estimates of institutional building impact indicators and contextual calculation information (in italics)

Impact Grouping	*Contextual Information* and Indicators	Nicomen Island Dike (#144)	Surrey South Westminster Dike (#296)	Fernie Dike (#58)
Institutional Impact	*Total Buildings Exposed, #*	*3*	*3*	*3*
	Average Value of Building, $	*229,000*	*8,987,000*	*301,000*
	Total Value of Buildings Exposed, $	*686,100*	*26,961,000*	*902,300*
	Average Damage to Structures, %	*24*	*15*	*13*
	Damage to Building structures, $	158,200	4,033,000	115,900
	Average Damage to Contents, %	98	90	73
	Damage to Building contents, $	1,014,000	19,599,000	806,000
	External Damages, $	29,000	31,500	60,500
	Total, $	**1,201,200**	**23,663,500**	**982,400**

The Surrey South Westminster Dike protects a high value school and community centre resulting in a high average building value and total value of buildings exposed. While the average damage to structures are relatively low for all three structures, the average damage to building contents is quite high. Institutional depth-damage curves indicate that institutional building contents reach close to 100% damage with much lower flood depths than other curves (around 1.5 m depending on the specific curve). This leads to relatively high damage to building content values, and high overall institutional damage.

Table 7-9 Estimates of agricultural building impact indicators and contextual calculation information (in italics)

Impact Grouping	*Contextual Information* and Indicators	Nicomen Island Dike (#144)	Surrey South Westminster Dike (#296)	Fernie Dike (#58)
Agricultural Impact	*Total Buildings Exposed, #*	*74*	*0*	*0*
	Average Value of Building, $	*325,000*	*0*	*0*
	Total Value of Buildings Exposed, $	*24,025,000*	*0*	*0*
	Average Damage to Structures, %	*7*	*0*	*0*
	Damage to Building Structures, $	1,675,000	0	0
	Total Value of Equipment Exposed, $	*23,687,000*	*0*	*0*
	Average Damage to Equipment, %	*10*	*0*	*0*
	Damage to Equipment, $	2,369,000	0	0
	Total, $	**4,044,000**	**0**	**0**

There is no agricultural activity protected by the Surrey South Westminster dike or the Fernie dike. Significant agriculture is protected by the Nicomen Island dike including approximately 74 structures with an average value of $325,000. The average damage to these structures is relatively low due to the nature of construction of most farm buildings. However, when considering the impact to structures, equipment, crops, livestock, and associated clean-up and replanting costs, the cumulative impact of the flood on agricultural assets is significant.

7.2.3 Impact to C - Economy – Critical Infrastructure and Agriculture

The impact to Economy – Critical Infrastructure and Agriculture consequence category was calculated as is described in Section 6.3, Section 6.4 and Appendix H. The impacts for the subordinate factors C.1 Utility Infrastructure was not calculated. Only one of the indicator impacts for subordinate factor C.2 Transportation Infrastructure was calculated – the indicator for damage to roads. The subordinate factor C.3 Agricultural Land was calculated with the two indicators damage to crops and livestock and land clean-up and replanting costs.

Table 7-10 Estimates of C.2 Transportation Impact subordinate factor indicators and contextual calculation information (in italics)

Subordinate Factor	*Contextual Information* and Indicators	Nicomen Island Dike (#144)	Surrey South Westminster Dike (#296)	Fernie Dike (#58)
C.2 Transportation Infrastructure	*Length of Roads Exposed, km*	*12,300*	*42,700*	*55,200*
	Damage to Roads, $	3,576,400	7,557,800	389,600

The impact to roads is reflective of the length of each type of road (detailed in Appendix H). The Fernie dike, which protects the most road by length, protects only minor roads which are relatively inexpensive to repair. Both the Surrey South Westminster dike and the Nicomen Island dike protect significant lengths of highway which increases the cost of expected damage to roads.

Table 7-11 Estimates of Agricultural Land subordinate factor indicators and contextual calculation information (in italics)

Subordinate Factor	*Contextual Information* and Indicators	Nicomen Island Dike (#144)	Surrey South Westminster Dike (#296)	Fernie Dike (#58)
C.3 Agricultural Land	*Total Farm Receipts, $*	*44,056,990*	*0*	*0*
	Average Loss to Farm Products, %	*35*	*0*	*0*
	Damage to Crops and Livestock, $	8,778,000	0	0
	Clean-up and Replanting Costs, $	2,227,000	0	0
	Total, $	**11,005,000**	**0**	**0**

There is no agricultural activity protected by the Surrey South Westminster dike or the Fernie dike. Significant agriculture is protected by the Nicomen Island. The damage to crops and livestock and cleanup and replanting costs have a significant impact to agricultural assets.

7.2.4 Results Commentary

The total impacts in the economy consequence classification are highest for the Surrey South Westminster dike at approximately $350,000,000, largely due to significant commercial and industrial impacts. The economic impacts due to failure of the Nicomen Island dike are slightly higher than the economic impacts to Fernie dike. The main impact contributors for Nicomen Island include residential impacts, and agricultural impacts, and transportation infrastructure impacts. The main impacts for the Fernie dike include residential impacts, and commercial impacts. The results of the Tier 2 consequence assessment for the people and economy consequence classifications are summarized by the values in Table 7-12.

Table 7-12 Tier 2 impacts to consequence classifications A – People, B – Economy - Building, and C – Economy - Critical Infrastructure and Agriculture

Consequence Classification	Subordinate Factor	Indicator	Nicomen Island Dike (#144)	Surrey South Westminster Dike (#296)	Fernie Dike (#58)
A - People	A.1 People	Displaced People, #	660	2160	760
		Injured People, #	190 (30%)	350 (16%)	110 (14%)
		Fatalities, #	50 (8%)	50 (2%)	10 (1%)
B - Economy - Building	B.1 Economy - Building	Damage to Residential Building Structures, $	32,384,000	27,398,500	39,627,500
		Damage to Residential Building Contents, $	14,554,000	12,422,000	18,356,000
		Loss of Residential Building Function, $	7,041,000	10,458,000	5,973,000
		Damage to Commercial Building Structures, $	560,000	15,617,000	1,632,000
		Damage to Commercial Building Contents, $	228,000	53,783,000	4,089,000
		Loss of Commercial Building Function, $	70,100	13,944,000	1,080,200
		Damage to Industrial Building Structures, $	0	35,135,500	0
		Damage to Industrial Building Contents, $		91,609,000	
		Loss of Industrial Building Function, $		25,348,900	
		Damage to Institutional Building Structures, $	187,200	4,064,500	176,400
		Damage to Institutional Building Contents, $	1,014,000	19,599,000	806,000
		Damage to Agricultural Building Structures, $	1,675,000	0	0
		Damage to Agricultural Building Contents, $	2,369,000	0	0
		Total, $	60,082,300	309,379,400	71,740,100
C – Economy – Critical Infrastructure and Agriculture	C.1 Utility Infrastructure	n/a	n/a	n/a	n/a
	C.2 Transportation Infrastructure	Road Damage, $	3,576,400	7,557,800	389,600
	C.3 Agricultural Land	Damage to Crops and Livestock, $	8,778,000	0	0
		Clean-up and Replanting Costs, $	2,227,000	0	0
		Total, $	14,581,400	7,557,800	389,600

The results of the Tier 1 exposure analysis with the Tier 2 consequence estimation are similar. The Tier 1 classifications are identified for reference in Table 7-13. When based on exposure, the people classification identified the Surrey South Westminster dike as high consequence (5), and the Nicomen Island and the Fernie dikes as major consequence (4). When the flood hazard including depth and velocity is considered during Tier 2 analysis, the estimated consequences predict 50 fatalities for both the Surrey South Westminster dike and the Fernie dike, and 350 and 190 injuries respectively. The Fernie dike is predicted to have 10 fatalities and 110 injuries. While the consequences for the Surrey South Westminster dike are still the highest, the consequences to people from the Nicomen Island dike failure are more similar to the Surrey South Westminster dike than the Fernie dike. As discussed above, the high hazard due to high flood depths at Nicomen Island leads to a higher injury and fatality rate. Depending on risk tolerances, this may be cause to increase the consequence to people rating for the Nicomen Island dike from the Tier 1 classification.

The Tier 1 and 2 economic classifications are not directly comparable at the current level of analysis, as non-transportation infrastructure is not assessed in Tier 2, and emergency management impacts are not estimated for Tier 1. Also, as only three Tier 2 analysis are completed, the range of data required to establish classifications and classification bounds does not exist. However, with this in mind, a comparison between the two tiers can yield insights about the impact of considering the level of flood hazard. Table 7-13 includes values for Tier 2 impacts summed to be comparable with the consequence classification categories as assessed in Tier 1 (see notes below the table).

The Tier 1 Economy – Building classification assigns the Surrey South Wesminster dike as ‘high’ (5), the Nicomen Island dike as ‘major’ (4), and the Fernie dike as ‘moderate’ (3). Based on Tier 2 analysis, the Surrey South Westminster dike remains as the highest consequence. The Fernie dike consequence is higher than the Nicomen Island dike consequence, although their Tier 1 ratings are the opposite. This is likely due to the improved flood mapping used for Tier 2 analysis which significantly increased the area considered in analysis for the Fernie dike.

The Economy – Critical Infrastructure and Agriculture consequence classification for Tier 1 assigns both the Nicomen Island and Surrey South Westminster dikes as ‘high’ (5), and the Fernie dike as ‘moderate’ (3). This aligns with the values estimated in Tier 2 analysis, with Nicomen Island and Surrey South Westminster dikes having a significantly higher estimated damages for these receptors than the Fernie dike. The Tier 2 analysis also allows further differentiation between impacts associated with failure of the Nicomen Island dike and the Surrey South Westminster dike by showing an estimated value for each.

The overall Tier 1 classifications for the three dikes are relatively comparable with the overall Tier 2 results. Depending on the range of consequence values determined through assessments of more locations and risk tolerances, the impact to people due to the Nicomen Island dike failure estimated through Tier 2 analysis could be considered ‘high’. Ranking the impact to people as high for Nicomen Island would trigger the overall classification for the dike to be ‘high’. The Surrey South Westminster dike’s overall classification is ‘high’ in the Tier 1 analysis, which aligns with the impacts to people and economy calculated in Tier 2 analysis. For the Fernie dike, the classification of B – Economy – Building

Classification could potentially increase to 'major' depending on risk tolerances and classification bounds developed for Tier 2.

Table 7-13 Tier 1 classifications for reference

Consequence Category	Nicomen Island Dike (#144)	Surrey South Westminster Dike (#296)	Fernie Dike (#58)
A People Classification (Tier 1)	4	5	4
B Economy – Building Classification (Tier 1)	4	5	3
B Economy – Building Classification Total Values (Tier 2)[1]	$51,883,300	$308,986,400	$68,315,100
C Economy – Critical Infrastructure and Agriculture Classification (Tier 1)	5	5	3
B Economy – Agriculture and Critical Infrastructure Classification Estimate(Tier 2)[2]	$19,735,400	$7,557,800	$389,600
D Environment Classification (Tier 1)	3	2	1
E Cultural Heritage Classification (Tier 1)	4	3	0
Overall Score (Tier 1)	**4**	**5**	**3**

[1] Calculated with residential, commercial, industrial and institutional impacts.

[2] Calculated with agricultural and transportation impacts.

8 SEISMIC HAZARD CLASSFICIATION

8.1 Introduction

Thurber Engineering Ltd. assigned a seismic hazard rating to all high consequence dikes. The rating process is explained in detail in Thurber Engineering Ltd.'s memo in Appendix I. Generally, a seismic hazard rating was developed based on the return period earthquake which could be expected to cause liquefaction and, therefore, large dike deformations. Likelihood of liquefaction was estimated based on the peak ground accelerations in the range of 0.12g to 0.22g. Site investigations of areas and likely peak ground accelerations were desktop-based and primarily used NRCan's online seismic hazard calculator (Natural Resources Canada, 2015).

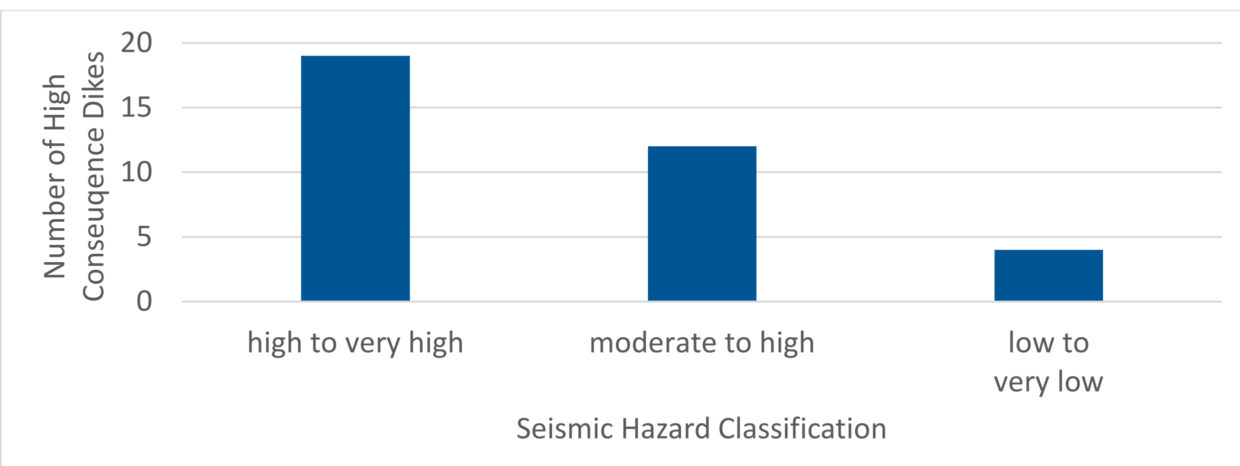
8.1.1 Use and Limitations

While this analysis assigns a hazard classification to each dike, no attempt is made to specify what hazard and associated earthquake return period is an acceptable design standard. These classification results should be interpreted in context of the entire "Dike Consequence Classification Study Geotechnical Input on Seismic Hazard" memo provided in Appendix I and the statement of limitations and conditions included in that document. Under no circumstances should the information herein be used for any purpose outside the statement of limitations and conditions in Appendix I.

8.2 Classification Results

Figure 8-1 shows the number of dikes which fit into each seismic hazard classification category. Specific dike classifications can be found in individual dike results in Appendix C and in the seismic hazard memo in Appendix I.

Figure 8-1 Seismic hazard classification of high consequence dikes



9 CONCLUSIONS

The main objective of this project is to compare and rank all the regulated BC dikes based on the potential consequences from dike failure flooding. The classification framework and Tier 1 analysis meet that objective and provide comprehensive baseline information on exposure to dike failure flooding in BC. There were 35 dikes identified as high consequence, 34 dikes identified as major consequence, 86 dikes identified as moderate consequence, 48 dikes identified as minor consequence, and 9 dikes identified as insignificant consequence.

The 35 dikes identified as high consequence protect 76% of the total area protected by all dikes analyzed, 95% of the total protected population, and 94% of the total protected building value. The 177 dikes classified as major to insignificant protect 24% of the total area protected by all dikes analyzed, 5% of the total protected population, and 6% of the total protected building value.

It is important to note that dikes in small communities can protect most of the development in those towns. These dikes are typically classified as major, moderate, or minor. The impact of the damage caused by a failure of these dikes, while not as large in absolute terms as the damage which would be caused by a failure of a high consequence dike, may have a relatively larger impact to the small community. Larger communities have more resources to recover after a flood as the flood will likely impact a smaller portion of their overall development and economy. While the total damage potentially caused by the failure of major, moderate, and minor dikes is small when compared to the rest of the province, the relative impact to the community should be considered.

The Tier 1 exposure assessment results should be considered in conjunction with the flood type and any severe hazards. Hazards from debris, avulsions, or ice jams may have higher consequences due to low to no warning time, impacts from debris, and high flow velocities. When moving from a Tier 1 exposure assessment to a Tier 2 consequence assessment, a severe flood type may mean a significantly higher consequence, as was illustrated in the calculation of impact to people for the Nicomen Island dike.

The seismic hazard analysis of the high consequence dikes highlights areas where high flood consequence combines with high seismic hazard levels. While levels of seismic hazard were determined, the acceptable seismic risk is a policy decision that remains to be determined by the appropriate levels of government. Out of the 35 high consequence dikes, 25 are located in the lower mainland and all of these have a seismic hazard rating of moderate to high. The three high consequence dikes located in Duncan (numbers 51, 376 and 377) have a seismic hazard rating of very high. The two high consequence dikes located in Squamish (numbers 284 and 285) have a seismic hazard rating of high. The remaining five high consequence dikes (dikes 71, 90, 101, 232 and 254) have a seismic hazard rating of moderate, low, or very low.

The dike consequence classification highlights areas where dikes protect significant amounts of exposed assets. Further work remains to be done to refine the area protected by each dike, verify input data through ground-truthing, determine the impact of flooding (i.e. Tier 2 analysis), and engage communities and experts through consultation. The consequence classification framework uses weightings which reflect the confidence in exposure data, the understanding of the potential impacts and the factors importance for socioeconomic recovery. The weightings may not reflect community values, especially for the cultural consequence category. The cultural heritage consequence category is based on the location of first nation reserve and cultural and historical sites. This data, while accurate and the best available sources, may not reflect the cultural value of an area. Due to this constraint, the cultural heritage consequence category has a relatively low weighting. Areas of importance from a cultural heritage, especially First Nations, perspective may not be well represented through the consequence classification results.

The results of this consequence classification framework provide a preliminary comparative framework to identify the consequence of failure for dikes. The framework's accuracy is limited by the analysis method, data availability, and quality of the data used. Results should only be used for purposes which align with these limitations including: consistent comparison of consequences from dike failure; as inputs for further studies; to understand data gaps; to develop policy; to evaluate investments in risk reduction; and in emergency management planning.

Improvements could be made through:

- Refinement of the protected areas through dike breach modelling and flood mapping that includes flood depths;
- Ground-truthing of input data and improvements in input data quality to confirm that assets are accurately represented by province-wide datasets;
- Improvement of the framework structure through consultation with subject matter experts;
- Refining assessment, from estimating exposed receptors to estimating impacts to receptors (e.g., a Tier 2 assessment, assessment of direct economic loss);
- Including data on additional critical infrastructure assets; and
- Including additional potential impacts in the consequence classification framework such as more indirect losses.

The accuracy of the results is sufficient to allow for comparative analysis (i.e., classifications rather than absolute numbers) such as the assessment presented herein. Upgrading the consequence classification with Tier 2 analysis for all receptors and incorporating the above recommendations would provide a more meaningful understanding of dike failure consequences at individual dikes. Tier 2 assessment would estimate impacts in all categories, would be more comprehensive by adding additional asset types and consequence types, and would have lower uncertainty because of better flood hazard modelling and ground truthing the asset data.

Tier 2 analysis with the improvements outlined above would enable a more accurate, non-relative understanding of the consequences of failure for each dike assessed. For example, dike 368 "Baker Trails" is classified as having a minor consequence. The dike protects from a debris flow hazard and the protected area for the dike includes a mobile home park. The population data used for this dike identifies a population classification of ‘2’ or between 2 and 39 people, likely due to variations in population density across the dissemination block and the potentially transient nature of mobile home parks. A Tier 2 assessment of this area would likely identify a higher consequence due to the severity of the hazard and through use of ground-truthed population data. As to whether or not a Tier 2 assessment is suitable from a cost-benefit perspective, it will vary based on the specific site.

To understand the risk[20] of dike failure, and inform a risk-based approach to dike management, the probability of dike failure needs to be considered in conjunction with the consequence of failure. While this project provides an understanding of dike failure consequence and recommendations to improve this understanding, it does not provide an assessment of the probability of dike failure. Events used to evaluate consequence for this project have an associated probability, however probability of dike failure during the flood event must be considered to assess risk. Section 10 describes specific recommendations for improvement and next steps.

[20] See definition of risk in section 1.6.

10 RECOMMENDATIONS

The findings and outputs of the BC Dike Consequence Assessment provide valuable information on potential dike failure flooding consequences across BC. Based on the assessment, an initial understanding about which dikes protect significant receptors has been developed. This initial understanding should be used to prioritize further investigation, as a methodology model for further study, for information during emergency response situations, and to inform the overall flood protection strategy for BC.

The process of conducting this work has revealed important insights on data gaps and challenges in assessing flood hazard, exposure, and impacts in BC. Specific recommendations for refining future flood consequence and risk assessments are presented below.

To evaluate the value of the recommended improvements, an understanding of how this type of analysis fits into the province's broader floodplain management strategy is needed. The return on investment of implementing the recommendations depends not just on the quality of analysis, but also how the results are used and strategies implemented. Prioritizing the need for improved analysis and developing a standard assessment for return on investment of recommendations should be a part of the development and implementation of a flood strategy. Also, to effectively prioritize asset protection, flood consequences must be considered in their broader context, inclusive of other flood management strategies in addition to dike protection. The cost of implementing the recommendations suggested below is dependent on the scale of implementation, i.e., if they are only implemented for diked areas, selected areas, or for the entire province.

The recommendations below can be implemented individually or as a whole, however improvements to receptor data will have limited impact on the quality of analysis results without implementing improvements to floodplain delineation.

10.1 Improving Delineation of Protected Floodplains

To improve the quality of dike consequence classification results, completion of up-to-date, detailed floodplain mapping is recommended for high-consequence dikes identified through this project.

The delineation and mapping of the area protected by a given dike can be improved through: improved topographic data; ground-truthing of potential conveyance structures (e.g., culverts); ground-truthing the elevation of potential barriers (e.g., major roadways, apparent high-ground); 2D modelling of dike failure and resulting flooding; improved classification of flood hazard type; and local expertise on topography and past flood events.

New floodplain mapping should, where possible, include the following information to ensure detailed risk modelling and consequence estimation can occur:

- Climate change effects – as recommended by EGBC Professional Practice Guidelines (EGBC, 2017);
- Water depth information – required for application of depth-damage curves in Tier 2 analysis;
- Velocity information – can yield insights about risk to individuals and infrastructure;
- Debris estimation – information about debris depth and velocity for debris flow and flood hazards; and
- Duration of flooding – can help determine duration of disruption to housing and economies.

Floodplain mapping is a basic flood management tool that has many applications, including this provincial dike classification project. Through work on this project, a number of floodplain and mapping studies were found that are not documented on the provincial floodplain mapping website nor by the BC Floodplain Map Inventory Report (Parsons and BCREA, 2015). A comprehensive index of floodplain mapping in BC should be maintained to facilitate access to both current and historical mapping.

10.2 Use Impact-based Indicators for all Receptors

For reasons described in Section 1.2, the consequence classification framework developed in this project uses exposure-based indicators for all receptors. Using impact-based indicators for all receptors would require the following:

- Improvements to flood hazard mapping to include water depth (for use in depth-damage curves), water velocity (for hazard to people and building stability analysis), and flood duration (for indirect damage calculations) which reflects flood hazard types;
- Additional data about building attributes including floor elevations, footprint area, type and structural and construction characteristics;
- Use of risk modelling software to conduct quantitative impact assessments as is showcased in Tier 2 analysis of three pilot sites in this project; and

Use of expert consultations to determine impact of flooding on receptors not captured by flood risk modelling software (e.g., critical infrastructure and environmental assets). In consultation, experts provide inputs based on empirical evidence and data, research conducted in their field, and/or knowledge of assets vulnerabilities, maintenance, and performance (see Appendix J).

Upgrading consequence analysis to impact-based classification requires significant investment in data collection, impact modelling, and expertise. Available resources should be directed toward implementing this change at the highest-consequence (ideally, highest risk) dikes. Until such time, the Tier 1 exposure based analysis can be improved with expert consultations.

10.3 Improving Receptor Data

Receptor data can be improved through better quality data and incorporating additional receptor types. Ground-truthing is an effective way to assess and enhance the quality of the available data and to observe and gather data on valuable assets that were not included in the datasets (e.g., visible critical infrastructure, small health clinics in the community, a community garden). Ground-truthing some or all data can identify and correct errors and inaccurate representation of assets in datasets.

Several data gaps were identified through development of the consequence classification framework:

- data which were confirmed to exist but could not be accessed;
- data which could not be found in a digital and spatial form; and
- data which were of insufficiently quality.

The following data were confirmed to exist but could not be accessed:

- Population health data: Information about the physical and mental health of BC residents is collected through the Medical Services Plan (MSP) and stored in a spatial database by the BC Ministry of Health. This information is highly sensitive and specific, and extensive data protocols exist to protect individual privacy and data security. While a process was initiated to establish a data sharing agreement and access this data in an aggregated form, this process was not completed within the project timeline. Population health data based on census information was included in part through the NRCan SVI, but a more detailed understanding of the health vulnerabilities of a population through use of the MSP dataset would improve flood consequence estimations, especially for evaluations of small floodplains.

- BC property assessment data: While assessment data exist for each property in the province, these data are not publicly available. The data can often be accessed through agreements with individual municipalities, though such arrangements were not pursued for Tier 1 analysis due to the potential inconsistency of the data format across municipalities and the limited time and scope of the analysis. Instead, aggregated content and structure values were used from NRCan's building exposure dataset. For the Tier 2 analysis, property assessment data were obtained from individual municipalities.

Information about the following data receptors could not be found in a form which met receptor data requirements:

- Building footprints: There is no source of building footprints which meets the project's requirements for consistency. While some municipalities have building footprint information, and some building footprint information is available through Open Street Maps (OSM), these data are not consistent enough for a province-wide assessment. Building footprints are a key dataset for Tier 2 analysis.

- Building-specific zoning information: While zoning is available at some regional and local government levels, and aggregated in the NRCan Building Exposure dataset, there is no source for zoning information which is building-specific and provincially consistent. Identification of building use or zoning (e.g., commercial, industrial, residential) would improve assessment of the impact associated with a building failure.

- Industrial Facility Location: Industrial facilities have specific consequences associated with flood events such as contamination. A comprehensive dataset of industrial facilities and contamination risk would help evaluate environmental consequences associated with flood events.

- Building construction information: While BC property assessment data provides some information about building types, this information does not have the same categories as depth-damage curves developed in the US or Canada. Having building construction information which aligns with available depth-damage curves would make application of these curves more consistent and accurate. Also, information about ground floor elevation and the presence or absence of a basement is needed to incorporate resiliency measures and depth-damage curves into consequence estimations. Building footprints are a key dataset for Tier 2 analysis.

- Cell network infrastructure: While information about communications infrastructure is available through the ICI Society data, it was limited to cable installations (e.g., Shaw and Telus cables) and does not include locations of cell towers and network facilities. The cell network is important during flood events. Assessing the consequence of a flood event on the communications network would improve the analysis.

- Economic information: Economic information, such as GDP per capita or economic productivity per area or municipality, is not readily available in a spatial format. To evaluate the impact of a flood event in terms of a local or regional economy, spatial information about the economic activity in a region and associated value is required.

- Water treatment and pumping stations: While information about water distribution infrastructure is available through ICI Society data, water treatment and pumping stations are not included in this data, or in any provincial datasets. If these facilities are impacted in a flood event, there could be a significant consequence associated with loss of potable water provision capacity or floodwater contamination.

- Food distribution infrastructure: The effect of a flood event on food distribution infrastructure has significant effects on community resiliency to flood events and ability to rebuild, similar to other infrastructure. There are no spatial datasets available which detail food related infrastructure such as food distribution centres, grocery stores, or wholesalers. While development of a dataset could be done through online mapping resources (e.g., Google maps), dataset development is beyond the scope of this project.

- Emergency Operation Centres (EOCs): Locations of EOCs are not available. Research indicates that there are EOC locations at both a provincial and a local scale, but complete and accurate spatial data is not available or could not be located. These locations are a key part of emergency response, and their exposure to a flood hazard is relevant to overall flood consequence.

- Health Centres: Only the location of hospitals is available, not secondary health centres such as clinics. In urban areas, these centres decrease hospital load, and in rural areas without nearby hospitals, health centres and clinics are the main care facilities for a variety of injury levels. These facilities should be inventoried and added to a consequence assessment when available.

- Local Government Facilities: While location information about community halls and recreation centres is available, there is no aggregated source of information available about the location of government offices such as city halls. This information could be compiled from online mapping resources (e.g., Google maps), but dataset development is beyond the scope of this project.

- Provincial disaster response or evacuation routes: Routes are not available outside of the Lower Mainland. Research indicates that these routes exist across BC, however they are not available in a consolidated spatial form. These routes are a part of emergency response, and their exposure to a flood hazard is relevant to flood consequence.

- Areas of cultural significance: While cultural heritage sites are available, information about locations of cultural significance is not available. To improve the understanding of impact of flood events on culture, more data should be collected about areas of cultural significance. This data is potentially sensitive, so discretion should be used in its publication.

While information about the following receptors was found, higher quality data (in terms of level of detail or spatial specificity) would improve consequence analysis:

- Population data: while population data including number of people and a variety of characteristics about them are available through the Canadian census, all available population data available is aggregated. The spatial units of the aggregated data do not align or necessarily fall within the protected floodplains. Error is introduced when determining the portion of the population from a census area which falls within a protected floodplain, as uniform density must be assumed (spatial aggregation error). The NRCan SVI and building exposure datasets reduce this error by distributing census areas to settled areas, however this redistribution is still an approximation which reduces data quality. Also, as population characteristics used in the SVI are not available at the census Dissemination Block level, the NRCan SVI uses the larger Dissemination Area level of aggregation. Reducing aggregation through refined spatial units based on point or building based population data would improve data analysis quality.

- Infrastructure Data: While infrastructure data was accessed through the ICI Society, this data only includes information about the location of infrastructure, not infrastructure characteristics. To incorporate infrastructure resilience and determine the impact of a flood event to infrastructure, more information about infrastructure characteristics (e.g., material of construction) is required.

- Water Crossings: The water crossings identified only include culverts greater than three metres in diameter. Culverts less than three metres are likely to be impacted in a flood event and present a point of increased vulnerability in roads. Efforts should be made to develop a dataset which includes small water crossings as well as large ones.

10.4 Framework Improvements Through Consultation

Key elements of the consequence classification framework could benefit from expert consultation. Such consultations can incorporate unpublished knowledge and experience in the framework, help customize the framework to the BC context, and engage stakeholders to represent a wide range of perspectives. See Appendix J for all topics to be included in expert consultations for improving the consequence framework with Tier 1 and Tier 2 analysis and guidance to design and manage such consultations.

Expert consultations are also an excellent opportunity to break institutional silos and discuss BC's flood risk, the practice of flood risk assessment, and risk management. Consultations can bring together representatives from many different institutions to discuss the common challenge of flood risk in BC. To facilitate this, expert consultation should be designed as open and dynamic sessions and include participants familiar with the projects, operations, and policy-making processes related to flood risk in their respective institutions.

The consideration of dike failure consequences should be paired with an assessment of the probability of dike of failure to understand risk, rather than just using a consequence based approach. Assessed risk can then be used to inform communities and discuss mitigation prioritization.

10.5 Application and Use of the Framework

The following recommendations should be considered in use and application of the consequence classification framework:

<u>Harmonize methodology and framework:</u> To improve consequence assessment consistency and quality, a standard methodology should be adopted and collectively improved upon by flood consequence estimation practitioners. This should include standard data sources, descriptions of level of analysis (i.e., exposure or consequence), and analysis methodology. Using the same consequence classification framework for both orphaned and regulated dikes is recommended. The project team reviewed the draft framework for orphaned dikes and made an effort to align the framework consequence categories and receptors to the extent possible (Fraser Basin Council, 2018). As that project progresses, we recommend taking advantage of opportunities to align the frameworks and enable comparison.

<u>Apply at local level:</u> The consequence classification results can be examined at a local level to start a conversation about dike failure consequences, assets protected by dikes, and flood mitigation priorities.

At a local level, having expert consultation is very important and useful for improving data, selecting the classification approach, and estimating impact values if Tier 2 analysis is used. The application of the framework at local level and accompanying consultations can become an excellent opportunity to convene stakeholders and experts to talk about flood risk in the area, exchange data, identify challenges, think through flooding scenarios and impacts, and most importantly, build a collaboration and communication mechanism for developing strategy for managing the flood risk.

Develop an interactive database tool that allows analyzing the results: The value of a consequence assessment is not only in the final numbers, but also in the underlying data and insights it can reveal about what is contributing to the high or low consequence levels. In this project, while the final consequence classification score of each dike is useful for ranking the dikes across BC, the real value is in the information that is provided about each of the receptor types protected by dikes across BC. Creating an interactive database tool that would allow the user to create queries to digest and dissect the data by choosing different criteria ideally accompanied by visualization and mapping is highly recommended.

10.6 Other Considerations for Understanding Dike Failure Consequences

The objective of the consequence framework developed in this project is to compare the regulated dikes in BC based on the potential consequence of dikes failure. Depending on the purpose and intended use of future flood risk assessments, the following items should be considered as they can provide important insights. Some of these items are not appropriate for individual dikes consequence classification but are relevant for an in-depth flood risk assessment at regional or sub-regional level:

The severity of impact depending on community type: The consequence classification estimates dike failure flooding consequences in absolute values. The size of a community influences how severely flooding consequences are felt by the residents and businesses. This is especially relevant to consequence category A, B, and C. For example, the severity of 1000 people displaced in a community of 3000 people is much higher than severity of having same number of people displaced in a city of 300,000. For the current analysis, the community archetypes impacted by the dike failure are listed on dike output sheets in Appendix C, however the community archetype does not affect analysis methodology. This could be considered through use of a segmented consequence classification system or additional scaling to account for the magnitude of regional impacts.

- Impact of flood hazard type: The flood hazard type (e.g., riverine, debris flood) has a significant impact on the consequence due to dike failure. A severe flood hazard can have a significantly higher consequence due to lower warning times, higher velocity water, and higher debris quantities. The use and interpretation of the classification should include consideration of the severity of the flood hazard type. Future Tier 2 analysis or refinements of protected floodplains for Tier 1 analysis should include consideration (possibly in the form of a modifier) of the flood hazard type.
- Impact on economy: Flooding can have major impact on the economy of the area and larger region from direct physical loss and damages to assets, loss of jobs, loss of tourism, and impact of CI damage (especially utilities, communication and transportation) to commercial activities and trade.

Evaluation of such direct and indirect impacts on economy are quite complex and very data intensive.

- Critical infrastructure interdependencies and systemic risk: How losses might propagate through the interactions of complex connected systems is a major aspect of how large disaster events impact a region. Methodologies to model CI interdependencies and understand their impact and role in recoverability of a region are advancing and should be used in future flood risk assessments in BC.
- Cascading risk: A major flood can trigger other hazardous events such as release of hazardous material due to damages to containing structures including industrial, agricultural, or urban infrastructure.
- Climate change effects: For understanding the long term flood risk trends in BC, the effects of the climate change should be incorporated as recommended by EGBC Professional Practice Guidelines (EGBC, 2017).

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APPENDIX A: LIST OF DIKES INCLUDED IN ASSESSMENT

This table specifies the dikes used in the project including dike number, name, data source and comments about the dike delineation or data source, protected floodplain determination notes, reviewer comments, delineation confidence, and quality parameter. More information can be found in Sections 3.1 and 4.2 in the main report. This information is also replicated on the map sheet for each dike in Appendix C. People referenced in the table include:

- NP: Mr. Neil Peters, P.Eng. is a Senior Flood Management Engineer at NHC.
- DM: Mr. Dale Muir, P.Eng. is a Principal at NHC who has done several flood studies and dike assessments in the Fernie area.
- DB: Mr. Dwain Boyer, P.Eng. is a Senior Flood Management Engineer at NHC.
- BMC: Mr. Barry Chillibeck, P.Eng. is a Principal at NHC who has done flood hazard and dike studies on this dike.
- RS: Mr. Rudy Sung, P.Eng. is a Senior Flood Safety Engineer at MFLNRORD.

Table App-A-1 Dike information for dike consequence classification

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
1	Matsqui (Abbotsford dike)	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike is tied into high ground at both the upstream and downstream ends.	Reviewed by NP.	High	High
2	Vedder	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	This dike includes the City of Abbotsford's portion of the west Vedder Canal Dike plus a section along the Sumas River.	NP-Fraser River flood levels are higher than flooding from other sources (i.e. Sumas, Nooksack or Vedder Rivers).	High	High
3	Sumas Lake Reclamation	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike connects (along with part of dike 2) the Sumas River Dam at the Barrowtown Pump Station with the railway embankment and high ground at Vedder Mountain.	NP- The protected area consists of the old Sumas Lake bottom area.	High	High
5	Barnston Island	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike forms a complete ring around the protected area.	Reviewed by NP.	High	High

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
7	Big Eddy Dike	Columbia and Illecillewaet River at Revelstoke Floodplain Mapping; map number 5514 sheets 1-4; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Nov 1983.	The dike intersects a floodplain boundary and a railway assumed to be highground.	DB - Q200 estimate unchanged following assessment by KC for BCHydro - MFLNRO Reprt # 1220 ""Revelstoke Dam Downstream Water Levels""; Klohn-Crippen; 1994.	High	High
9	Illecillewaet River BCHPA	Columbia and Illecillewaet River at Revelstoke Floodplain Mapping; map number 5514 sheets 1-4; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Nov 1983.	The dike intersects a floodplain boundary and includes a dike ring.	DB - Flood protection in mapped floodplain area includes periodic dredging of Illecillewaet R channel to reduce the risk of basement (gw) flooding (mainly ice flow generated).	High	High
10	Vicars Road Industrial Site	South Thompson River Kamloops to Chase Mapping; map number 5113 sheets 8-15; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Jun 1976.	The dike is built around infrastructure and ties into high ground at both the upstream and downstream ends.	Reviewed by NP.	High	Medium
12	Fenwick Street-Boundary Road (Trapp-Byrne Road)	Removed from analysis as this dike consists of three small segments not tied into high ground and therefore the delineation of a protected area was not feasible (Neil Peters, personal communication, Sept. 29th 2018).	n/a	n/a	n/a	n/a
13	Bellevue Creek	ESTIMATED: No existing floodplain mapping found.	The area was delineated based on alluvial fan topography. The dike ties into high ground - bank protection is extended along the creek bank.	Reviewed by NP.	Low	Medium
14	Chase Creek	ESTIMATED: No existing floodplain mapping found.	The area was delineated based on alluvial fan topography. The short section of dike appears to tie into the Highway embankment. There is extensive bank protection downstream.	Reviewed by NP.	Low	Low
15	West Dike	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The Vedder setback dike extends upstream to high ground on the Vedder River alluvial fan. It continues downstream along the east side of the Vedder Canal and ties into the Highway 1 embankment.	`NP-the protected area includes part of the Vedder River alluvial fan as well as the Fraser River floodplain. Shallow flooding may extend into the downtown area.	High	Medium
16	Town Dyke (and Wolfe Road pump station)	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The upstream end of the dike connects with relatively high ground at Hope Slough and extends downstream to high ground at Chilliwack Mountain.	NP - Flood levels along Dike 16 depend on Dike 17 (Island 22 Wing Dike). A breach in Dike 16 would be expected to flood most of downtown Chilliwack and all of Greendale. The eastern extent of flooding is difficult to assess without detailed modeling.	Medium	Low

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
18	Hope Slough Wall	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	Hope slough is open to backwater flooding from the Fraser. The Hope Slough Wall forms part of a system including dikes 16, 17 and 19.	NP-The extent of flooding from backwater flooding of Hope Slough is very difficult to determine without detailed modeling and specific assumptions about Dike 17 Island 22 Wing Dike.	Low	Low
17	Island 22 (Wing Dike)	Removed from analysis as this dike does not prevent flooding of the land behind it, rather it reduces design flood levels against other dikes. The delineation of the protected area due to this dike is complex and not possible without further analysis (Neil Peters, personal communication, Sept. 29th 2018).	n/a	n/a	n/a	n/a
19	East Dike Rosedale to Young Rd	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The East Dike extends from high ground near the Agassiz-Rosedale bridge to Hope Slough (Young Road). The protected area includes most of the Fraser River Floodplain areas in Chilliwack.	Reviewed by NP.	Medium	High
20	Vedder River Set Back	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	This dike reduces flooding from both the Vedder River and the Fraser River. The upstream end of the set back dike ties into high ground. The dike extends downstream along the Vedder Canal to the point where it joins Dike 2 which is managed by the City of Abbotsford. With respect to the extent of the protected area to the west, the Fraser River flood levels are higher than Vedder River flood levels.	Reviewed by NP.	High	High
21	Clearwater Flood Protection Works	North Thompson River (Kamloops to Vavenby) Floodplain Mapping; old reference number Project #73-81; map number A5302; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Dec 1982.	The dike ties into high ground at both the upstream and downstream ends.	Reviewed by NP.	High	High
22	Colebrook	Serpentine and Nicomekl Rivers; map number 91-5; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept 1994.	The Colebrook Dike forms part of a sea dike which included dikes 295 and 297. It is located upstream of the sea dam at King George Highway.	NP-The extent of coastal flooding is difficult to assess without detailed modeling. The protected area shown is likely an overestimate for the 1:200 event.	High	Low

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
23	Sims Creek	ESTIMATED: No existing floodplain mapping found.	The dike protects downslope development on the alluvial fan from stream hazards. A few homes along the local access road are likely within the protected area.	Reviewed by NP.	Low	Low
24	Glenmore Road Dike	Oyster River; map number 5532; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; May 1984.	Dike ties into high ground at the upstream end, but not at the downstream end. The dike may provide some protection to a few properties downstream from the end of the dike.	Reviewed by NP.	High	Medium
26	Marathon Industrial Park	ESTIMATED: No existing floodplain mapping found.	The dike intersects with dike 157 and does not appear to be in the Fraser River Floodplain. An approximate protected area was delineated behind the dike between it and the highway, however much of the area has been raised by landfill and the extent of flooding in a 1:200 event is uncertain.	Reviewed by NP.	Low	Low
27	Coquitlam	Coquitlam River, map number 5148;BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct 1976.	The dike ties into higher ground along the left bank of Scott Creek and continues part way along the right bank of the Coquitlam River. It connects to dike 252 which continues up to the Highway 7 bridge.	NP- The protected area shown is likely an overestimate as not all of this area would be flooded from backwater a 1:200 Coquitlam River flood.	High	Low
28	Anderton Ave Retaining Wall (west bank)	Courtenay, Puntledge and Tsolum Rivers; map number 89-13; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1991.	The upstream end of the dike ties into high ground and downstream end ties into the highway bridge.	Reviewed by NP.	High	Medium
29	Lewis Park Dike (east bank)	Courtenay, Puntledge and Tsolum Rivers; map number 89-13; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1991.	The dike is not tied into high ground at the upstream end and only provides limited protection to the park.	Reviewed by NP.	High	Medium
37	Kootenay River (CDD)	Kootenay River; map number A5278; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Aug. 1981.	Dike intersects the floodplain buondary on both sides. Dike number 37 alternates along the river with dike number 120 which is unregulated, protection is assumed to be from both dikes.	DB - Q200 estimate has been updated - Creston Floodplain Management Study; BGC Engineering; approx. 2015.	High	High
38	Duck Lake Unit	Kootenay River; map number A5278; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Aug. 1981.	Dike connects with dike 48, dike 37 and flood protection 120. These works intersect with an unnamed channel to bound the protected floodplain.	DB - Q200 estimate has been updated - Creston Floodplain Management Study; BGC Engineering; approx. 2015.	High	High

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
39	Duck Lake Unit 2	Kootenay River; map number A5278; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Aug. 1981.	Dike connects with 38 to almost form a ring within the larger floodplain. The small gap in the ring is assumed assumed to be high ground, and the ring is delinated as the protected area.	DB - Q200 estimate has been updated - Creston Floodplain Management Study; BGC Engineering; approx. 2015.	High	High
40	Kootenay River (CVWMA)	Kootenay River; map number A5278; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Aug. 1981.	Dike connects to dike 48, 37, 38 and 39. This dike and dikes it is connected to intersect the edge of the floodplain.	DB - Q200 estimate has been updated - Creston Floodplain Management Study; BGC Engineering; approx. 2015.	High	High
42	Boundary Bay	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The eastern end of this coastal sea dike is a continuation of dike 295. The south end does not tie into high ground, but ends in the regional park's natural sand berms with elevations of between 2 and 3 m GSC.	NP-the protected area is difficult to determine without detailed modeling. The area shown assumes the complete absence of the dike and that the 1:200 level extends over much of the coastal floodplain. While this area is a reasonable representation of the benefitting area from the dike, it overestimates the extent of flooding from an actual event.	Medium	Low
43	Westham Island – Sea Reach/Canoe Pass	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike forms a complete ring around the protected area.	Reviewed by NP.	High	High
44	Marina Gardens	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike, along with a section of the Admiral Blvd road embankment and Dike 45, forms a ring around the protected area.	Reviewed by NP.	Medium	Medium
45	River Road DELTA	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The upstream end of the dike ties into high ground near Alex Fraser Bridge and extends downstream to the Ladner area. It is connected to Dike 46 (Delta Sea Dike).	NP-the protected area is difficult to determine without detailed modeling. The area shown assumes the complete absence of the dike and that the 1:200 level extends over the entire coastal floodplain. While this area is a reasonable representation of the benefitting area from the dike, it overestimates the extent of flooding from an actual event.	Medium	Low

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
46	Delta - Sea	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The upstream (north) end of the dike is a continuation of Dike 45. The south end of the dike ties into Highway 17.	NP-the protected area is difficult to determine without detailed modeling. The area shown assumes the complete absence of the dike and that the 1:200 level extends over much of the coastal floodplain. The protected area has been adjusted as it is highly unlikely that 1:200 water levels could inundate the north and east portions of the floodplain. While this area is a reasonable representation of the benefitting area from the dike, it overestimates the extent of flooding from an actual event.	Medium	Low
47	Dewdney	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike ties into high ground at both the upstream and downstream ends.	Reviewed by NP.	High	High
48	Duck Lake Diking District	Kootenay River; map number A5278; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Aug. 1981.	Dike connects to dike 37, 38, 39, 40 and protection 120 to protect an area of the floodplain ringed by dikes and an unnamed channel.	DB - Q200 estimate has been updated - Creston Floodplain Management Study; BGC Engineering; approx. 2015.	High	High
49	Dinsdale Farm Dike	Cowichan, Koksilah Rivers, Quamichan Lake, Somenos Lake and Tributaries at Duncan; map number 91-19; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1997.	Dike connects to dike 88 and intersects with a road assumed to be high ground.	Reviewed by NP.	High	High
51	Cowichan River	Lower Cowichan/Kosilah River Integrated Flood Management Plan Final Report, Prepared by NHC for Cowichan Valley Regional District September 2009.	Dike 51, 376 and 377 form a complete system for protection of the Cowichan/Somenos Ck floodplain in Duncan. It is difficult to assign specific floodplain protected areas for these three dikes as the protected areas largely overlap. For the purposes of this preliminary dike classification, the three dikes are treated as a single system and assigned the same protected area.	Reviewed by NP.	High	Medium

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
52	Fairmont Hot Springs Resort	Fairmont Creek Debris Flow Hazard and Risk Assessment; by Clark Geoscience Ltd. And Golder Associates Ltd.; For Regional District of East Kootenay; Jan 11, 2013. Protected floodplain delineated based on combined protection from the deflection dike, engineered channel and catchment pond as delineation of protection from the dike alone was not possible. The Fairmont Hot Springs Resort dike is identified in the provincial shapefile as only having 'protection' segments. However, for the purposes of analysis, adequate protection was assumed exist.	Protected floodplain delineated based on combined protection from the deflection dike, engineered channel and catchment pond as delineation of protection from the dike alone was not possible.	DB - Changes to protected area made based on area shown in report by Clarke Geotechnical.	Low	Low
53	Boivin Creek	Elk River near Elkford; map number 87-30; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1989.	Dike intersects the edges of the Boivin Creek floodplain map.	DB - Dike and channel rebuilt following 2013 flood.	High	High
54	Elk River	Elk River near Elkford; map number 87-30; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1989.	The dike does not clearly tie into high ground or intersect the floodplain. The protected floodplain was delinated based the highway route and the river flow direction.	DB - New setback dike (built approx 2016) changed the protectd area.	Medium	Low
57	Coal Creek	Regional District of East Kootenay Web Mapping, 2018.	Dike edges intersect the debris hazard area	DB - The protected area east of the railroad should be deleted. My understanding is that the works are erosion protection/berms not dikes. The dike connects to dike 60 and that protected area assumes that water and debris from an avulsion/breach of 57 would be prevented from flowing into the ELk R by dike 60.	Low	Medium
58	Annex Dike	Elk River at Fernie; map number A5196; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; May 1979.	The dike intersects the floodplain boundaries on both sides. Note that the area protected by this dike is also protected by dike 61.	Reviewed by DB.	High	High
59	North Annex Dike	In the provincial dike shapefile this dike is included as part of dike 58 - Annex Dike, which corresponds to NHC's understanding of dikes in Fernie (DM, personal communication, Sept. 4th 2018). To align with this, dike 59 has been considered as part of dike 58.	n/a	n/a	n/a	n/a
60	Mountview Subdivision	Elk River at Fernie; map number A5196; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; May 1979.	The dike intersects the floodplain boundary on one side and the other side is approximated from the location of roads.	Reviewed by DB.	High	High

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61	Great Northern Dike	Elk River at Fernie; map number A5196; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; May 1979.	Dike intersects the highway which is raised and is mapped as a flood barrier on one side and the other side s an estimated extension of the protected area.	Reviewed by DB.	High	High
62	Snootli Creek Hatchery and Atnarko Channel	Bella Coola River; map number 87-56; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept 1989.	Dike intersects with a major road assumed to be high ground on one side, and the extent was deliniated assuming protection of the small parcel of land behind the dike.	Reviewed by NP.	Medium	Low
63	Mountain View Mobile Home Park (Sparwood)	Elk River and Mitchel Creek near Sparwood; map number 91-2; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept 1995.	Dike intersects with the floodplain boundary and highway on one side and a railway assumed to be high ground on the other.	Reviewed by DB.	High	High
65	Fortune Creek Drainage & Diking District	ESTIMATED: No existing floodplain mapping found.	As delineated by 2013 NHC Fortune Creek Dike Assessment report for MFLNROD. See Photo 7.	Reviewed by NP.	Low	Low
66	Cascade Creek	ESTIMATED: No existing floodplain mapping found.	Delineated based on dike alignment and development area. Alluval and debris flow fan areas. Debris flow hazard from Carratt Creek.	Reviewed by NP.	Low	Low
67	Ocean Point Near Newman Creek	ESTIMATED: No existing floodplain mapping found.	Coastal dike and erosion protection.	Reviewed by NP.	Low	Low
68	Glen Valley	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The protected area is bounded by the west dike, the railway embankment (which acts as a dike) and the east dike.	Reviewed by NP.	High	High
69	Old Goat River Channel	Goat River at Creston; map number 84-42; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Dec 1984.	Dike intersects with a major road assumed to be high ground on one side, and the floodplain has indeterminate endings on the other side. There are two main dikes, one with several segments. The segments are assumed to be connected with high ground.	DB - Dike and erosion protection are continuous on right bank upstream of hwy bridge to tie in to valley wall. North side of protected area is the edge of floodplain not a road. Ie the road hugs the base of the steep slope.	Medium	Low
71	Kicking Horse River	Columbia River at Golden; map number A5186; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Feb. 1979.	Dike intersects with major roads and railways on one side, and floodplain boundaries on the other side.	DB - The protected area should be extended to the river.	High	High
72	Grand Forks	Kettle and Granby Rivers Grand Forks Area; map number 90-34; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1992.	Dike intersects with a major road and the edge of a floodplain.	Reviewed by DB. Recent flooding likely to result in major changes and a new design flood.	High	High

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
73	Kettle River	Kettle and Granby Rivers Grand Forks Area; map number 90-34; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1992.	Dike ends do not connect to noticably high ground. The protected area was deliniated assuming roads function as a barrier.	Reviewed by DB. Recent flooding likely to result in major changes and a new design flood.	Medium	Low
74	Colony Farm	Coquitlam River, map number 5148;BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1976 and Lower Mainland Mapping*.	Dike 74 includes dikes on both sides of the Coquitlam River. They provide protection from both Coquitlam River and Fraser River floods.	NP - The Forensic Psychiatric Hospital is protected by a separate private ring dike. For classification purposes, Dike 74 does not provide protection for this facility.	High	Medium
75	Boundary Creek	ESTIMATED: No existing floodplain mapping found.	The protected area was delineated based on topography	DB - The what could loosely be called dikes (more like berms) are on the LB (east side) of the creek provide and limited protection for property on the east side.	Low	Low
76	Harrison Hot Springs	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	Harrison Lake Flood Levels will flood low lying areas behind the dike but will not extend as far as Agassiz. The area shown is a rough approximation of the extent of the protected area, based on 2007 Floodplain Mapping topography.	NP Accurate delineation of the protected floodplain requires careful comparison of ground topography with 1:200 Harrison Lake levels.	Medium	Low
77	Skeena River	Skeena and Bulkley; map number 91-1; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1994.	The north (upstream) end of the dike ties into high ground, and the south (downstream) end is open to backwater flows from the river at very high river levels.	NP-This is a low dike, and while it provides some protection against overland flooding, the primary function of the dike and riprap revetment is to stabilize the outside of the river bank against erosion.	High	Medium
78	River Parade Flood Protection	Coquihalla River at Hope; map number 85-27; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; June 1985.	The upstream end of the dike ties into a high river bank; the downstream end ties into the railway bridge abutment and embankment.	Reviewed by NP.	High	High
79	Glenhalla Subdivision	Coquihalla River at Hope; map number 85-27; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; June 1985.	The dike ties into high ground at the upstream end. The downstream end ties in to the road embankment, which could be overtopped in a large flood.	NP-If the dike is overtopped and breached, the protected area is subject to a river avulsion hazard with high velocity and life threatening flood flows.	High	High
81	Buck Creek Flood Protection	Bulkley River at Houston including Buck Creek; map number 85-14; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Nov. 1985.	The Buck Creek Dikes provide protection for much of the Buck Creek Alluvial Fan. Flooding may also extend to the north of the Yellowhead Highway.	Reviewed by NP.	High	Low

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82	Industrial Area Flood Protection	Bulkley River at Houston including Buck Creek; map number 85-14; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Nov. 1985.	The dike ties into the highway bridge on Buck Creek at the upstream end and into the sewage lagoon embankment at the downstream end.	Reviewed by NP.	High	Medium
83	Town Dike HOU	Bulkley River at Houston including Buck Creek; map number 85-14; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Nov. 1985.	The dike connects to the Yellowhead Highway which is assumed to be high ground on both ends.	NP-The possible extent of flooding south of the Yellowhead Highway would need to be determined by new topographic mapping and hydraulic modeling.	High	Low
84	Vriend Flood Protection	Bulkley River at Houston including Buck Creek; map number 85-14; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Nov. 1985.	The dike connects to high ground at the south end and the railway embankment at the north end.	NP the protected area is difficult to assess without detailed topographic mapping and hydraulic modelling.	High	Low
85	Peachcliff Estates Dike	ESTIMATED: No existing floodplain mapping found.	The dike does not clearly tie into high ground at either end.	NP-detailed topography not available. Extent of protected area is very approximate.	Low	Low
86	Athalmer Flood Protection	Columbia River Windermere Lake to Radium including Toby Creek; map number A5296; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; April 1982.	The dike intersects with a major road on one end and a minor road on the other end which is assumed to be high ground.	Reviewed by DB.	High	Medium
87	Toby Creek Flood Protection	Columbia River Windermere Lake to Radium including Toby Creek; map number A5296; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; April 1982.	The dike intersects the floodplain boundary on both sides.	Reviewed by DB. Note that a sewage treatment plant is located in the protected floodplain, however, due to data limitations, it is not highlighted in the receptors.	High	High
88	Koksilah	Cowichan, Koksilah Rivers, Quamichan Lake, Somenos Lake and Tributaries at Duncan; map number 91-19; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1997.	Dike connects to 49 and intersects with a road assumed to be high ground.	Reviewed by NP.	High	High
90	Schubert Drive (Halston Bridge to Beach Ave)	Thompson River Kamloops Area; map number 5112; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; June 1976.	The upstream end of the dike ties in to a major road bridge. The downstream end appears to terminate at a development site without natural high ground.	Reviewed by NP.	High	Medium
91	Walkem Rd to Halston Bridge	Thompson River Kamloops Area; map number 5112; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; June 1976 and North Thompson River (Kamloops to Vavenby) Floodplain Mapping; old reference number Project #73-81; map number A5302; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Dec 1982.	The dike intersects a major road assumed to be high ground to the south and is continued by dike 90, and approaches the floodplain boundary to the north	Reviewed by NP.	High	Medium
92	Rayleigh (along Huckleberry Place)	North Thompson River (Kamloops to Vavenby) Floodplain Mapping; old reference number Project #73-81; map number A5302; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Dec 1982.	Dike 92 is the upstream section of a diking system that includes regulated dike 93 and unregulated dikes number 185 and 187.	Reviewed by NP.	High	Medium

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
93	Rayleigh - Arab Run to Beachview	North Thompson River (Kamloops to Vavenby) Floodplain Mapping; old reference number Project #73-81; map number A5302; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Dec 1982.	Dike 93 is the middle section of a diking system that includes regulated dike 92 and unregulated dikes number 185 and 187.	Reviewed by NP.	High	Medium
94	Oak Hills	North Thompson River (Kamloops to Vavenby) Floodplain Mapping; old reference number Project #73-81; map number A5302; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Dec 1982.	The dike is tied in to high ground at both the upstream and downstream ends.	Reviewed by NP.	High	High
95	Campbell Creek Industrial Park	South Thompson River Kamloops to Chase Mapping; map number 5113 sheets 8-15; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Jun 1976.	Dike connects with roads roads assumed to be high ground on the east and west ends. The roads tie into the Highway 1 embankment.	Reviewed by NP.	High	High
96	Eighth Ave to Peterson Creek	South Thompson River Kamloops to Chase Mapping; map number 5113 sheets 8-15; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Jun 1976.	The dike connects to roads on either end and these are assumed to be high ground.	Reviewed by NP.	Medium	Low
97	Yacht Club to Tenth Ave	South Thompson River Kamloops to Chase Mapping; map number 5113 sheets 8-15; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Jun 1976.	The dike connects to dike 98. Dike 98 intersects the edge of the floodplain on the west and dike 97 intersects a road assumed to be high ground on the east.	Reviewed by NP.	High	Medium
98	Thirteenth Ave to Yacht Club	South Thompson River Kamloops to Chase Mapping; map number 5113 sheets 8-15; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Jun 1976.	The dike connects to dike 97. Dike 97 intersects the edge of the floodplain on the west and dike 98 intersects a road assumed to be high ground on the east.	Reviewed by NP.	High	Medium
99	Thrupp St to McArthur Park Causeway	Thompson River Kamloops Area; map number 5112; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; June 1976.	The dike connects to roads assumed to be high ground on either end.	Reviewed by NP.	Medium	Low
100	Airport Dike (Aviation Way to Cinnamon Way)	Thompson River Kamloops Area; map number 5112; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; June 1976.	Dike connects to a road assumed to be high ground close to the edge of the floodplain on the west end and a road assumed to be high ground on the east end of the dike.	Reviewed by NP.	High	Medium
101	Kelly Drive to 60 meters East of Singh Street	Thompson River Kamloops Area; map number 5112; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; June 1976.	Dike connects to unregulated dike number 214. Together, these dikes almost intersect the edge of the floodplain on the east and west.	Reviewed by NP.	High	Low
103	Overlander Park	Thompson River Kamloops Area; map number 5112; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; June 1976.	Dike connects to major road assumed to be high ground on the west end, and has an uncertain bound on the east end.	Reviewed by NP.	Medium	Low

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
104	Treated Wastewater Disposal Site (Cinnamon Ridge)	Thompson River Kamloops Area; map number 5112; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; June 1976.	Dike ties into a road and the edge of the floodplain on the north end and dike number 100 on the eastern end.	Reviewed by NP.	High	High
105	Kaslo Flood Protection	Kaslo River at Kaslo ; map number 5521; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Mar. 1984.	Dike ties into the edge of the floodplain on the west end the east end follows the fan boundary.	Reviewed by DB.	High	Medium
106	Adams Road Dike	City of Kelowna Web Mapping, 2018.	The dike ends were extended through the floodplain to major roads assumed to be high ground.	Reviewed by NP. Very approximate - suggest further study required.	Low	Low
108	Kent Dike A	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The upstream end of the dike ties into the railway and Highway 7 embankments. The downstream end ties into high ground.	Reviewed by NP. This dike provides protection for the entire Fraser floodplain within the District of Kent and Village of Harrison Hotsprings.	High	High
109	Keremeos Area	Similkameen River at Keremeos ; map number 91-23; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1995.	Dike 109 is part of a larger diking system consisting of Orphan Dikes 201, 202 and 207. Dike 109 only provides partial protection for the Village of Keremeos.	Reviewed by NP.	High	Low
111	Goose Creek Flood Protection	Kitimat River and Hirsch Creek; map number A5328; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Mar. 1982.	Dike 111 ties into high ground at the upstream end along Goose Creek and extends down to the Kitimat River where is ties into Haisla Blvd road embankment and Dike 112. Dikes 111, 112 and 113 are parts of a single diking system for this area.	Reviewed by NP.	Medium	Low
112	Radley Park Flood Protection	Kitimat River and Hirsch Creek; map number A5328; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Mar. 1982.	Dike 112 ties into Haisla Blvd and extends downstream to Dike 113. Dikes 111, 112 and 113 are parts of a single diking system for this area.	Reviewed by NP.	Medium	Low
113	First St Flood Protection	Kitimat River and Hirsch Creek; map number A5328; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Mar. 1982.	Dike 113 is the most downstream section of the diking system consisting of Dikes 111, 112 and 113.	Reviewed by NP.	Medium	Low
114	Kildala Flood Protection	Kitimat River and Hirsch Creek; map number A5328; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Mar. 1982.	The dike ties into Haisla Blvd on the north and extends about 3 km downstream. It is not known if the dike is tied into high ground at the downstream end.	Reviewed by NP.	High	Medium

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
115	New Remo Flood Protection	Skeena, Zymagotitz and Kitsumkalum Rivers: Lakelse-Terrace-Usk; map number 5375; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1982.	The ends of the dike do not appear to tie into high ground on either end of the structure, so protected area delineation is very approximate.	Reviewed by NP. The protected area shown assumes that the Zymagotitz River flooding would extend across the Skeena River Floodplain to at least Kilby Road.	Medium	Low
117	Fort Langley - Salmon River	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike mitigates fraser flooding of a low lying area that was a former Fraser River Channel. Railway and road embankments are assumed to be the eastern boundary of the protected area.	Reviewed by NP.	Medium	Medium
118	West Langley	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike interesects with the floodplain boundaries on both sides.	Reviewed by NP.	Medium	Medium
119	Greenville Dike	ESTIMATED: No existing floodplain mapping found.	Dike 119 confines Greenville Creek within a narrow channel on an alluvial fan. Extent of flooding was estimated, but would be expected to include most of the fan area, including the areas near the Nass River.	Reviewed by NP.	Low	Low
123	Bessette Creek	Shuswap River, Bessette & Duteau Creeks; map number 96-7; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1998.	The available dike database is out of date - many recent changes have been made to these structures. As shown, the dikes 123 and 124 do not provide significant protection and could not be classified.	Reviewed by NP. Further detailed information required.	High	Low
124	Duteau Creek	Shuswap River, Bessette & Duteau Creeks; map number 96-7; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1998.	The dike database is out of date - many changes have been made to these structures. As shown, the dikes 123 and 124 do not provide significant protection and could not be classified.	Reviewed by NP. Further detailed information required.	High	Low
126	Maple Ridge Road 13	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	Dikes 126 and 128 comprise parts of what is essentially one diking system. Without detailed analysis of flood levels vs road elevations, the protected area is assumed to be the same for both dikes.	Reviewed by NP.	Medium	Low

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
128	Albion	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	Dikes 126 and 128 comprise parts of what is essentially one diking system. Without detailed analysis of flood levels vs road elevations, the protected area is assumed to be the same for both dikes.	Reviewed by NP.	Medium	Low
129	Left Bank (Collettville)	Nicola and Coldwater River: Spences Bridge to Nicola Lake; map number 87-22; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1992.	The dike ties into higher ground at the upstream end but is ""open"" to river flood levels at the downstream end.	Reviewed by NP.	Medium	Low
130	Right Bank Dike (Coldwater River)	Nicola and Coldwater River: Spences Bridge to Nicola Lake; map number 87-22; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1992.	The structure ties into higher ground at the upstream end. The downstream end does not tie into high ground.	Reviewed by NP.	Medium	Low
133	Zymoetz R Flood Protection	Zymoetz (Copper) River Drawing; map number 84-63; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; June 1985.	Dike #133 closes off former channels of the Zymoetz River. It functions primarily as a guide bank to the Highway 16 bridge, but also reduces the potential for flooding of Highway 16.	Reviewed by NP.	Medium	Medium
134	Mission City	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike alignment ties into the railway embankment at the upstream end and to Highway 7 at the downstream end.	Reviewed by NP. The upstream section through the industrial area is significantly below design flood level.	High	High
135	Silverdale	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike ties into the Highway 7 embankment at both ends.	Reviewed by NP.	High	High
136	Mud Bay	Serpentine and Nicomekl Rivers; map number 91-5; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept 1994.	The Mud Bay dikes provide flood protection for the area between the Serpentine and Nicomekl Rivers west of the sea dams (near King George Highway) on both of these streams. The dikes tie into the railway embankment to the west, which forms part of the coastal diking system.	Reviewed by NP. There may be some potential for flooding east of King George Highway depending on highway embankment elevations.	High	Medium
138	Anderson Creek Berm	ESTIMATED: No existing floodplain mapping found.	The protected area was estimated based on the high ground and roads.	DB - revisions to protected area.	Low	Low
139	New Denver - Carpenter Creek	ESTIMATED: No existing floodplain mapping found.	The protected area was based on the dike alignment and high ground.	DB - use hazard zone boundary for delination of protected area.	Low	Medium

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
140	Queensborough	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The Queensborough Dike #140 is the upstream section of the dike ring which protects all of Lulu Island (Queensborough and City of Richmond).	Reviewed by NP.	High	High
141	Closure	Kootenay River; map number A5278; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Aug. 1981.	The protected floodplain is ringed by regulated dikes 141, 142, 143 and unregulated dike number 120.	Reviewed by DB - dikes form a closure	High	High
142	Kootenay River NIDD	Kootenay River; map number A5278; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Aug. 1981.	The protected floodplain is ringed by regulated dikes 141, 142, 143 and unregulated dike number 120.	Reviewed by DB.	High	High
143	Old Channel	Kootenay River; map number A5278; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Aug. 1981.	The protected floodplain is ringed by regulated dikes 141, 142, 143 and unregulated dike number 120.	Reviewed by DB - dikes form a closure. Old channel.	High	High
144	Nicomen Island	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike forms a complete ring around Nicomen Island. The 4.6 km long upstream extension of the dike ties in to the Bell Dam and high ground at Malcolm Road and closes off the upstream channels connecting the Fraser to Nicomen Slough. Although Nicomen Slough is open to the Fraser at the west end of the island, the upstream extension significantly reduces flood levels in Nicomen Slough, allowing reduced dike heights along much of the northern side of the island.	Reviewed by NP. If the upstream extension, including Bell Dam, were to fail during a large flood, flood levels in Nicomen Slough would likely overtop the Nicomen Island Dikes along the slough. Therefore, this extension and the dam are critical components of the Nicomen Island Dike.	High	High
155	Wilson Road Dike	Chilliwack River: Vedder Crossing - Slesse Creek Drawing; map number A5283; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Feb. 1981.	The dike ties into high ground on the east (upstream) end and is open to the river at the downstream end.	Reviewed by NP. This dike protects the residential area from potential channel avulsion and life-threatening high velocity flows.	Medium	Low
163	Hill Rd	Elk River at Fernie; map number A5196; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; May 1979. Dike was included in analysis even though it is currently an orphan dike as work is ongoing to maintain and transfer ownership of the dike to the Regional District of East Kootenay (DB, personal communication, Sept. 24th 2018).	Dike ties into high ground on western end. Protected area is assumed to extend from dike ends to floodplain boundaries.	Reviewed by DB. Suggested revision for protected area	Medium	Low
164	West Fernie Dike	Elk River at Fernie; map number A5196; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; May 1979.	The dike intersects with the floodplain boundary on the north end and follows a road assumed to be high ground on the south end.	Reviewed by DB.	High	Medium

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
168	Lindell Beach (Frosst Creek)	ESTIMATED: No existing floodplain mapping found.	Delineated based on dike alignment as shown in provincial database and alluvial fan boundaries	Reviewed by NP. The provincial database dike alignment does not include recent changes to this dike, including a new dike on the left bank of Frosst Creek, downstream of Columbia Valley Road.	Low	Low
221	Cowichan River South Side Dike	Cowichan, Koksilah Rivers, Quamichan Lake, Somenos Lake and Tributaries at Duncan; map number 91-19; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1997.	The dike ties into the highway bridge on the west end and is open on the east end. The protected area was extended downslope as far as the Koksilah River and other flood channels.	Reviewed by NP.	Medium	Low
222	Deering Island	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike forms a complete ring around the protected area.	Reviewed by NP. The western end of the island is park land.	High	High
223	North Nicomen Dike	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike connects to the railway embankment on the west and the eastern edge is estimated.	Reviewed by NP.	Medium	Medium
224	North Vancouver Outdoor School	Cheakamus River; map number 85-15; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; April 1986.	Dike 224 is the downstream extension of Dike number 281. Both Dikes were assigned the same protected area.	Reviewed by NP.	High	Medium
228	PRRD Rolla Creek	ESTIMATED: No existing floodplain mapping found.	The protected area was delineated based on the dike alignment and imagery.	Reviewed by NP. The protected area likely extends further to the east and reduces flooding over local roads, but the extent cannot be determined.	Low	Low
230	Forestry Road Dike	Lillooet, Green, Ryan and Birkenhead River, Miller and Pemberton Creek; map number 88-44; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1990.	230 Forestry Road Dike is the continuation of 236 Smuks Dike and therefore both dikes have the same protected area. The termination of the protected area at the downstream end of the dike and Forest Service Road seems reasonable for classification purposes.	Reviewed by NP.	Medium	Low

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
231	Ayers Dike	Lillooet, Green, Ryan and Birkenhead River, Miller and Pemberton Creek; map number 88-44; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1990.	Dike 231 Ayers - 1) north boundary, there is some high ground within the old floodplain map boundary (the new housing development is on a knoll). 2) the flooding wouldn't extend up the Birkenhead River alluvial fan - so followed fan boundary. 3) The old "north arm" cuts across Highway 99 and would flood it, so extended flood limit all the way to the banks of the Lillooet River. 4) the eastern boundary is somewhat arbitrary as most of the north arm overland flow would have re-entered the Lillooet, or perhaps Birkenhead River channels.	Reviewed by NP.	Medium	Low
232	Miller - Lillooet Dike	Lillooet, Green, Ryan and Birkenhead River, Miller and Pemberton Creek; map number 88-44; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1990.	232 Miller Lillooet - protected area does not include higher ground on Pemberton Creek Alluvial Fan as per old floodplain map.	Reviewed by NP.	High	High
233	Hungerford	Lillooet, Green, Ryan and Birkenhead River, Miller and Pemberton Creek; map number 88-44; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1990.	This dike does not tie into high ground, therefore the delineation of the protected area is approximate.	Reviewed by NP.	Medium	Low
235	Adventure Ranch Dike	Lillooet, Green, Ryan and Birkenhead River, Miller and Pemberton Creek; map number 88-44; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1990.	Dike 235 forms part of the Miller-Lillooet-Pemberton "dike ring". Given that there are many areas of lower elevation north of Highway 99, backwater flooding from a breach of dike 235 could reach some of the higher density areas in Pemberton - therefore the area was extended north of the Highway.	Reviewed by NP.	Medium	Low
236	Smuks Dike (Salmon Slough)	Lillooet, Green, Ryan and Birkenhead River, Miller and Pemberton Creek; map number 88-44; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1990.	236 Smuk's Dike is the most upstream section of Dike 230 Forestry Road Dike and therefore both dikes have the same protected area. The termination of the protected area at the downstream end of dike 230 and Forest Service Road seems reasonable for classification purposes.	Reviewed by NP.	Medium	Low

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
238	Boneyard Dike	Lillooet, Green, Ryan and Birkenhead River, Miller and Pemberton Creek; map number 88-44; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1990.	Dike 238 protects the left side of the Miller Ck Alluvial fan as well as Lillooet River floodplain areas. A breach of the u/s section of this dike on Miller Creek could potentially flood anywhere in the fan area.	Reviewed by NP.	Medium	Medium
239	Creekside Village Training Berm	Lillooet, Green, Ryan and Birkenhead River, Miller and Pemberton Creek; map number 88-44; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1990.	The dike's northern end ties into the railway embankment and the southern end terminates at the highway. The highway is not expected to act as a flow barrier, so the protected area is extended over the highway.	Reviewed by NP. A breach in these works would likely result in washout, or closure of the Highway and Highway Bridge. This could be significant for classification.	Medium	Medium
240	Pemberton Creek Dike	Lillooet, Green, Ryan and Birkenhead River, Miller and Pemberton Creek; map number 88-44; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1990.	240 Pemberton Creek - includes Pemberton Creek alluvial fan and lower elevation areas below the fan where Pemberton Creek floodwaters could reach. Flood levels from a breach near the Pemberton Creek/Lillooet confluence (during Lillooet River flood) could potentially backwater north of Highway 99.	Reviewed by NP.	Medium	Low
241	Strobl Dike	Lillooet, Green, Ryan and Birkenhead River, Miller and Pemberton Creek; map number 88-44; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1990.	Dike 241 ties into high ground at the upstream end. The protected area extends across Pemberton Meadows Road to the Ryan River and Miller Creek.	Reviewed by NP.	Medium	Medium
242	Ryan Dike	Lillooet, Green, Ryan and Birkenhead River, Miller and Pemberton Creek; map number 88-44; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1990.	At the upstream end of the dike, the protected floodplain is extended perpendicular to the dike to the Lillooet River. On the south end of the dike, the protected floodplain is extended to an old Lillooet River channel.	Reviewed by NP.	Medium	Low
243	Pitt Meadows 1 - Alouette River	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike forms a complete ring around the protected area.	Reviewed by NP.	High	High
244	Pitt Meadows	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike intersects the floodplain boundary on both ends	Reviewed by NP.	High	High

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
245	Pitt Polder - Pitt River (Sturgeon Slough)	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike intersects with the floodplain boundary on the north and high ground to the south. The extent of the protected area is defined by dike 328.	Reviewed by NP.	High	High
246	Pitt Meadows 2 - Pitt River	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike ties into high ground at both the north and south ends.	Reviewed by NP.	High	High
247	Kitsuksis Creek Flood Protection	Somass River at Port Alberni; map number 93-10; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1997.	The dike connects to dike 249 and 248 and together the dikes intersect with floodplain boundaries at all ends assumed to be high ground.	Reviewed by NP.	High	Medium
248	Lugrin Creek Flood Protection	Somass River at Port Alberni; map number 93-10; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1997.	The dikes connect to roads assumed to be high ground. The eastern section ties into dike 247.	Reviewed by NP. Difficult to determine protected area without detailed investigation.	High	Low
249	River Road PALB	Somass River at Port Alberni; map number 93-10; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1997.	The dike ties into high ground on the western (upstream) end and to dike 247 on the downstream end.	Reviewed by NP.	High	High
251	Port Alice Slide Protection	No mapping, but hazard studies were completed prior to construction of the dike in 1976.	Protected floodplain follows estimated debris flow fan boundaries. The most southerly boundary is difficult to determine given unpredictable avulsion paths associated with channel blockages.	Reviewed by NP. NP inspected works in 2011 and is familiar with hazard studies and dike design.	Low	Medium
252	Coquitlam River	Coquitlam River, map number 5148;BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct 1976.	Both left and right bank dikes tie into the Highway 7 Bridge abutments. In the event of channel obstructions at the bridges near Kingsway Ave, flooding could extend further to the east to the Pitt River.	Reviewed by NP.	High	Medium
253	Port Coquitlam (Pitt River)	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike ties into high ground on both ends.	Reviewed by NP.	High	High
254	Queensway Dike at Hudson	Fraser and Nechako Rivers at Prince George; map number 91-3; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1997.	The dike ties into high ground on each end.	Reviewed by NP.	High	High
256	Similkameen-Tulameen	Similkameen River at Princeton; map number 91-22; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1985.	This is a short dike which connects to bank erosion protection downstream.	Reviewed by NP.	High	Low

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
257	Similkameen_02	Similkameen River at Princeton; map number 91-22; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1985.	Very short section of dike. The structure is primarily bank erosion protection.	Reviewed by NP.	High	Low
258	Burton Flats	Similkameen River at Princeton; map number 91-22; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1985.	The dike meets dike 260 at Highway 3 , and the two dikes tie into high ground on both ends.	Reviewed by NP.	High	High
259	Allison Flats	Similkameen River at Princeton; map number 91-22; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1985.	The dike ties into high ground on both ends.	Reviewed by NP.	High	High
260	Tulameen River	Similkameen River at Princeton; map number 91-22; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1985.	The dike meets dike 258 at Highway 3, and the two dikes tie into high ground on both ends.	Reviewed by NP.	High	Medium
264	Fraser River - Rolph Street Dike	Fraser and Quesnel Rivers, Baker Creek at Quesnel; map number 89-43; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1992.	The dike almost ties into the floodplain boundaries at both ends.	Reviewed by NP.	High	Medium
266	Kootenay River Flood Protection	Kootenay River; map number A5278; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Aug. 1981.	Dike connects to dikes 267 and 268. The dikes intersect the edges of the floodplain.	Reviewed by DB.	High	High
267	French Slough Flood Protection	Kootenay River; map number A5278; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Aug. 1981.	Dike connects to dikes 266 and 268. The dikes intersect the edges of the floodplain.	Reviewed by DB.	High	High
268	Boundary Creek Flood Protection	Kootenay River; map number A5278; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Aug. 1981.	Dike connects to dikes 266 and 267. The dikes intersect the edges of the floodplain.	Reviewed by DB.	High	High
269	Illecillewaet River CTYREV	Columbia and Illecillewaet River at Revelstoke Floodplain Mapping; map number 5514 sheets 1-4; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Nov 1983.	Dike intersects floodplain boundaries on both ends.	Reviewed by DB.	High	High
271	Richmond - Sea Dike	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The Richmond ""Sea Dike"" #271 and the Queensborough Dike #140 form a complete ring around Lulu Island. A breach in the upstream (east) sections of Dike 271 could flood parts of Queensborough (eastern end of Lulu Island).	Reviewed by NP. Estimation of potential floodwater depths in the protected area is complex and requires detailed 2D modeling of specific dike breach scenarios.	High	High
276	Sage & Sands Mobile Home Park	Bonaparte River; map number 93-12; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1996.	The Dike ties into floodplain boundaries on both ends.	Reviewed by NP.	High	High
277	Salmo River Dike	Salmo River: including Erie Creek; map number 90-32; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1991.	The protected area has been estimated by extrapolating the protection from the dike ends to the floodplain boundaries based on direction of river flow.	Reviewed by DB. A few adjustments to boundaries made.	Medium	Low

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
278	Silverton Flood Protection	ESTIMATED: No existing floodplain mapping found.	The protected area was deliniated based on extimated fan extent.	Reviewed by DB. A few adjustments to boundaries made. Note that a sewage treatment plant is located in the protected floodplain, however, due to data limitations, it is not highlighted in the receptors.	Low	Medium
281	Cheakamus River Training Berm U/S Outdoor School	Cheakamus River; map number 85-15; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; April 1986.	Dike 224 is the downstream extension of Dike number 281. Both Dikes were assigned the same protected area.	Reviewed by NP.	Medium	Low
282	Cheekye Berm	Cheakamus River; map number 85-15; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; April 1986.	Dike 282 reduces the risk of Cheekye River overflowing the left bank, upstream of the Highway 99 bridge. Without the berm, floodwaters could flow down the east side of the alluvial fan and block, or cut-off Highway 99.	Reviewed by NP.	Medium	Low
283	Town Dike SQAM	Squamish and Mamquam River: Howe Sound - High Falls Creek; map number 5461; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1983.	Dike 283 provides limited protection for downtown Squamish. New sea dike works, as outlined in the Squamish Integrated Flood Management Plan 2017, are required to complete protection for the downtown.	Reviewed by NP.	Medium	Low
284	Mamquam	Squamish and Mamquam River: Howe Sound - High Falls Creek; map number 5461; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1983.	The Left Bank Mamquam River Dike prevents an avulsion (channel shift) of the Mamquam River to the south. The Right Bank Mamquam Dike provides partial flood protection for the Garibaldi Highlands area.	Reviewed by NP. Several dike breach scenarios were modelled in the Squamish IFHMP River Flood Mitigation Options report, Sep 2017. The delineation of the protected area could be refined based on these studies.	Medium	Low
285	Squamish River	Squamish and Mamquam River: Howe Sound - High Falls Creek; map number 5461; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Oct. 1983.	Dike 285 protects two major areas, the upper area north of the Mamquam River, and the lower area south of the Mamquam River. The upper area dike ties into high ground at the toe of the Cheekye Fan and extends downstream to tie into the Mamquam River Dike. The lower area dike ties into the left bank Mamquam dike and extends downstream to the Squamish River training berm.	Reviewed by NP. Several dike breach scenarios were modelled in the Squamish IFHMP River Flood Mitigation Options report, Sep 2017. The delineation of the protected area could be refined based on these studies.	Medium	Low

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
286	Stawamus River	Integrated Flood Hazard Management Plan; by KWL; for Squamish; Oct 2017.	The upstream end of the Stawamus River Dike ties into the Mamquam River Forest Service Road Bridge. The downstream end terminates near Valley Drive.	Reviewed by NP. Various Stawamus flood scenarios were modelled and discussed in the Squamish IFHMP River Flood Mitigation Options report, Sep 2017. The dike consequence classification could be refined based on these studies.	Medium	Low
287	Whitecap Development (Bear Creek)	ESTIMATED: No existing floodplain mapping found.	The dike appears to protect the area from upslope flows and drainage.	Reviewed by NP.	Low	Low
288	Furry Creek Dike	ESTIMATED: No existing floodplain mapping found.	The dike north of Furry Creek extends south along the coast line and ties into the railway embankment at the Furry Creek bridge. The dike south of Furry Creek ties into the left bank of Furry Creek near the rail bridge and extends south along the coastline. In the event of a channel blockage near the rail bridge, flow over the left bank of Furry Creek can enter a relief floodway through the golf course and flow out to Howe Sound through a designated outlet channel.	Reviewed by NP.	Low	High
289	Jason Creek	ESTIMATED: No existing floodplain mapping found.	The dike protects development on the alluvial fan.	Reviewed by NP.	Low	Low
290	Bear River Flood Protection	Bear River at Stewart; map number 5461; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1993.	The dike ties into high ground near Highway 37A and extends downstream to the coastal inlet.	Reviewed by NP.	High	High
291	Trout Creek	ESTIMATED: No existing floodplain mapping found.	The Trout Creek dikes confine Trout Creek to a narrow channel on the fan. The protected area does not include parts of the fan which are geologically inactive.	Reviewed by NP.	Low	Low
292	Hillside Industrial Park	ESTIMATED: No existing floodplain mapping found.	This dike provides flood protection to a small industrial subdivision development site, downslope on the fan of Dakota Creek.	Reviewed by NP.	Low	Low
293	Nicomekl-Serpentine	Serpentine and Nicomekl Rivers; map number 91-5; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept 1994.	This diking system provides protection for almost the entire Serpentine Nicomekl floodplain area.	Reviewed by NP. The extent of possible flooding to the west of King George Blvd is uncertain. Detailed modeling completed for the City of Surrey could help to better define the protected area.	High	Medium

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
294	Crescent Beach Sea Dike	Serpentine and Nicomekl Rivers; map number 91-5; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept 1994.	Dike ties into high ground near railway embankments at both ends.	Reviewed by NP.	High	High
295	West of Colebrooke Sea Dike	Serpentine and Nicomekl Rivers; map number 91-5; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept 1994.	Dike is connected to dike number 22 (Colebrook) on the Surrey side and 42 (Boundary Bay) on the Delta side. Together these dikes form part of a coastal diking system.	NP-The extent of coastal flooding is difficult to assess without detailed modeling. The protected area shown is likely an overestimate for the 1:200 event.	High	Low
296	South Westminster	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	As shown in provincial database mapping, the upstream end of the dike ties into high ground near 115 Ave. and 132 St. However the geometry and alignment of the upstream section of the dike may have changed in recent years due to the construction of the South Fraser Perimeter Road and other construction in this area. The downstream end of the dike ties into higher elevation land that was raised by fill for Port related development. For the purposes of this dike classification project, the provincial database alignment has been used.	Reviewed by NP.	High	Medium
297	East of Colebrook Diking District	Serpentine and Nicomekl Rivers; map number 91-5; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept 1994.	Dike 297 is connected to dike number 22 and forms part of the right bank Serpentine River coastal dike downstream of the sea dam.	NP-The extent of coastal flooding is difficult to assess without detailed modeling. The protected area shown is likely an overestimate for the 1:200 event.	High	Low
298	Tahsis Dike and Floodwall	Tahsis and Leiner Rivers, McKelvie Creek (Village of Tahsis); map number 89-15; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1992.	The dike ties into high ground at the upstream end. The downstream ends at North Maquinna Drive.	Reviewed by NP.	High	Medium
299	Taylor Dike	Similkameen River at Princeton; map number 91-22; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1985.	The dike ties into high ground on the west end. On the east side, the dike intersects a road.	Reviewed by NP.	Medium	Low
300	Riverside Street	Bulkley and Telkwa Rivers: Smithers - Telkwa; map number 84-68; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Dec. 1984.	The dike ties into high ground near the right abutment of the Bulkley River bridge and extends down and parallel with Riverside Street.	Reviewed by NP. The dike provides some protection to areas further downstream - dike extension and upgrading have been considered by the Village.	Medium	Low

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Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
302	Bartlett Flood Protection	Bulkley and Telkwa Rivers: Smithers - Telkwa; map number 84-68; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Dec. 1984.	The dike connects to dike 303, which ties into high ground at the upstream end. The downstream end of dike 302 is not tied into high ground.	Reviewed by NP.	Medium	Low
303	Cottonwood Flood Protection	Bulkley and Telkwa Rivers: Smithers - Telkwa; map number 84-68; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Dec. 1984.	Dike 303 (referred to as a training berm on the old floodplain map) ties into high ground at the upstream end and extends north to connect with Dike 302. The downstream end of the dike 302 is not tied into high ground.	Reviewed by NP.	Medium	Low
304	Canal Flats	Kootenay River: Columbia Lake at Canal Flats; map number 89-41; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1991.	The dike connects to a floodplain boundary on the northeast and to a highway which intersects the floodplain boundary on the southwest.	Reviewed by DB.	High	Medium
306	Cox Creek	Regional District of East Kootenay Web Mapping, 2018.	THe protected area was deliniated based on dike alignment and flood torrent hazard areas on online mapping.	Reviewed by DB.	Low	Medium
307	Trethewey-Edge	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike connects to dike 243 to form a ring around the protected area.	Reviewed by NP.	High	High
309	Wells (Lowhee Creek Dike)	ESTIMATED: No existing floodplain mapping found.	The protected area delineated includes most of the alluvial fan.	Reviewed by NP.	Low	Low
311	19 Mile - High School	ESTIMATED: No existing floodplain mapping found.	The dikes channelize the Creek down to the Highway 99 bridge.	Reviewed by NP.	Low	Low
312	Greenside Village - White Gold	Whistler Area, Millar Creek, Green River, Nita and Alpha Lake; map number 89-16; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1993.	Both the upstream and downstream ends of the dike tie in to Fitzsimmons Ck bridge abutments.	Reviewed by NP.	High	Medium
313	Mons-Green Lake Dike	Whistler Area, Millar Creek, Green River, Nita and Alpha Lake; map number 89-16; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1993.	The dike ties into Highway 99 on the south end. The extent of the protected area then follows the Fitzsimmons Creek alluvial fan hazard area to dike 315 and the shore of the lake.	Reviewed by NP.	Medium	Low
314	Fitzsimmons Creek Training Berm	Whistler Area, Millar Creek, Green River, Nita and Alpha Lake; map number 89-16; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1993.	Dike 314 protects all of Whistler Village and Whistler Village North. It confines Fitzsimmons Creek to a floodway on the right side of the alluvial fan. The parking lot area is in the floodway.	Reviewed by NP.	High	Medium

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
315	Alta Creek Berm	Whistler Area, Millar Creek, Green River, Nita and Alpha Lake; map number 89-16; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1993.	Dike 315 provides limited protection from overflows from Alta Creek.	Reviewed by NP.	Medium	Low
316	Horstman Creek Berm	ESTIMATED: No existing floodplain mapping found.	Dike 316 protects the development directly behind the berm.	Reviewed by NP.	Low	Low
317	Zeballos River Training Berm	Zeballos River; map number 89-45; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1992.	Dike 191 is the downstream extension of erosion protection works along the left bank of the Zeballos River. The downstream boundary of the protected area is uncertain.	Reviewed by NP.	Medium	Low
318	Privateer Estates Dike	Zeballos River; map number 89-45; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1992.	The upstream end of the dike is part of a training berm for Keno Creek. The extent of the protected area is uncertain.	Reviewed by NP.	Medium	Low
321	Illecillewaet River South	Columbia and Illecillewaet River at Revelstoke Floodplain Mapping; map number 5514 sheets 1-4; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Nov 1983.	Dike intersects floodplain boundaries on both ends.	DB - Illecillewaet River protected area is shown nicely on floodplain map.	High	High
324	Whistler Creek	Whistler Area, Millar Creek, Green River, Nita and Alpha Lake; map number 89-16; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1993.	The protected floodplain includes most of the alluvial fan as outlined roughly on the provincial floodplain map.	Reviewed by NP.	Low	Low
328	North Alouette Right Bank	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike ties into high ground on both ends. The actual extent of possible flooding to the north into Pitt Polder is uncertain.	Reviewed by NP.	High	Low
330	Cold Spring Creek	Cold Spring Creek Debris Flow Hazard and Risk Assessment; By Clark Geoscience Ltd., and Tetra Tech EBA; for Regional District of East Kootenay; Mar 1, 2015. Protected floodplain delineated based on combined protection from the debris catchment dike, engineered conveyance channels and additional catchment ponds as delineation of protection from the dike alone was not possible.	Protected floodplain delineated based on combined protection from the debris catchment dike, engineered conveyance channels and additional catchment ponds as delineation of protection from the dike alone was not possible.	Reviewed by DB.	Low	Low
338	Etna Creek - Sites 1, 2	ESTIMATED: No existing floodplain mapping found.	Dike is a debris deflection berm which protects the entire downstream area.	Reviewed by DB.	Low	Low
340	Lawley Creek	ESTIMATED: No existing floodplain mapping found.	Assumption made based on expert knowledge that the dike protects the subdivision.	Reviewed by DB.	Low	Low

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
352	Axe Creek Dike	ESTIMATED: No existing floodplain mapping found.	Dike 352 confines Axe Creek to the left side of its alluvial fan. The protected area is bounded by the Greenville Creek Dike.	Reviewed by NP.	Low	Low
356	Coal Creek - Joinson Bridge	Regional District of East Kootenay Web Mapping, 2018.	Dike edges intersect the debris hazard area	DB - Outlined a new protected area but not very confident in delineation.	Low	Medium
357	Elk River South	Removed from analysis as this dike was identified as substandard bank erosion protection and outside of the 200-year floodplain (Dwain Boyer, personal communication, Sept. 24th 2018). This area did not experience flooding in the 2013 flood of record (approximately 500-year return period), however is within the floodplain based on the 2013 flood of record including freeboard and climate change (NHC, 2017a, 2019).	n/a	n/a	n/a	n/a
360	Tembec Industries Ltd. & Elk River Developments Berm	Elk River at Fernie; map number A5196; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; May 1979.	The dike almost intersects the floodplain boundary on the eastern edge and connects perpendicularly to dike 61 on the southwest side.	DB - Dike provides a line of defence but is not depended on to protect Fernie proper. When the dike system was designed there was no intension to protect the undeveloped lands north of 61. ie 61 was designed assuming the river would breach 360 and flow through the golf course and into Maiden Lake and then back into the channel u/s of the bridge.	High	Medium
364	Barriere - Community	North Thompson River (Kamloops to Vavenby) Floodplain Mapping; old reference number Project #73-81; map number A5302; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Dec 1982.	Dike 364 is a short section of Dike that connects to erosion protection extending downstream to Highway 5 bridge over the Barriere River.	Reviewed by NP.	Low	Low
365	Byrne Creek	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The actual current protected area of this dike is difficult to assess as much of the Fraser Floodplain has been raised with landfill and the dike system has not been completed. Outer limits of protected area could extend as far as area shown.	Reviewed by NP.	Low	Low
366	Nico-Wynd	Serpentine and Nicomekl Rivers; map number 91-5; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept 1994.	Dike is assumed to be connected to high ground at both ends.	Reviewed by NP.	High	Medium

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
368	Baker Trails (Guy Creek and Tank Creek)	ESTIMATED: No existing floodplain mapping found.	Protected area includes entire mobile home park. An additional sediment basin structure (on Guy Creek) is not shown on the provincial database layer. The highest hazard areas are located near the toe of the hill slope and creek gullies. Homes at some distance from the slope may only experience nuisance flooding.	Reviewed by NP.	Low	Low
376	JUB Lagoons Dike	Cowichan, Koksilah Rivers, Quamichan Lake, Somenos Lake and Tributaries at Duncan; map number 91-19; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1997.	Dike 51, 376 and 377 form a complete system for protection of the Cowichan/Somenos Ck floodplain in Duncan. It is difficult to assign specific floodplain protected areas for these three dikes as the protected areas largely overlap. For the purposes of this preliminary dike classification, the three dikes are treated as a single system and assigned the same protected area.	Reviewed by NP.	High	Medium
377	Lakes-Beverly Street Dike	Cowichan, Koksilah Rivers, Quamichan Lake, Somenos Lake and Tributaries at Duncan; map number 91-19; BC Water Surveys Unit and Canada-BC Floodplain Mapping Program; Sept. 1997. Dike delineation based on dike alignment data for the Cowichan area. (Delcan for Municipality of North Cowichan (2012). *Plan and Profiles, Tier 2 North Flood Upgrades-Cowichan-Somenos North*.)	Dike 51, 376 and 377 form a complete system for protection of the Cowichan/Somenos Ck floodplain in Duncan. It is difficult to assign specific floodplain protected areas for these three dikes as the protected areas largely overlap. For the purposes of this preliminary dike classification, the three dikes are treated as a single system and assigned the same protected area.	Reviewed by NP.	High	Medium
379	Chehalis Dike	ESTIMATED: No existing floodplain mapping found.	The protected area includes a significant area of the larger fan. The boundary of the possible extent of Chehalis River flooding is uncertain	Reviewed by NP.	Low	Low
380	Elbow Creek	ESTIMATED. Included in analysis based on information available in the operation and maintenance manual and NHC's experience working with this dike (Northwest Hydraulic Consulting Ltd., 2002). (BMC, personal communication, Dec. 3rd 2018).	The area protected by the dike is based on the Elbow Creek flood protection location map provided in the operation and maintenance manual.	Reviewed by BC.	High	Medium

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
381	Cattermole	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike, plus a landfilled area, forms a ring around the protected area.	Reviewed by NP.	High	High
382	Kent Dike B	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	Dike 382 ties into high ground at both ends. It is part of the Kent diking system along with Dikes 108 and 383. Because of the east to west slope of the floodplain, the protected area from this dike does not include all of the Agassiz Townsite.	Reviewed by NP. The protected area boundary in the vicinity of the Agassi Townsite was based on the area shown flooded by Dike Breach Simulation â€œB2bâ€� from â€œFloodplain Mapping for the District of Kent and Village of Harrison Hotspringsâ€� prepared by Water Management Consultants Ltd. for Fraser Basin Council, March 2007	High	Medium
383	Kent Dike C	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	Dike 383 ties into high ground at both ends. It is part of the Kent diking system along with Dikes 108 and 382. Because of the east to west slope of the floodplain, the protected area from this dike does not include the Agassiz Townsite.	Reviewed by NP. The protected area boundary in the vicinity of the Agassi Townsite was based on the area shown flooded by Dike Breach Simulation â€œB3â€� from â€œFloodplain Mapping for the District of Kent and Village of Harrison Hotspringsâ€� prepared by Water Management Consultants Ltd. for Fraser Basin Council, March 2007	High	Medium
384	Kent Dike D	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike ties into high ground on both ends.	Reviewed by NP.	High	High
386	Tsawwassen Dike (breakwater dike)	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014.	The dike connects to dikes 44, 45, 46, 387 and 388. Together they intersect the floodplain boundaries or major roads assumed to be high ground.	Reviewed by NP. Dikes 386, 387 and 388 form part of the same diking system as Dike 46 (Delta Sea Dike) and the same protected area as delineated for Dike 46 should be used for classification purposes. Please also see the reviewer comments for Dike 46.	Medium	Low

Dike #	Dike Name	Data Source and/or Comment	Protected Floodplain Determination Notes	Reviewer Comments	Delineation Confidence	Quality Parameter
387	Tsawwassen Sea Dike (Section A)	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014. Dike delineation based on information provided by MFLNRORD on Sept. 10, 2018 (RS, personal communication, Sept. 10th 2018).	The dike connects to dikes 44, 45, 46, 386 and 388. Together they intersect the floodplain boundaries or major roads assumed to be high ground.	Reviewed by NP. Dikes 386, 387 and 388 form part of the same diking system as Dike 46 (Delta Sea Dike) and the same protected area as delineated for Dike 46 should be used for classification purposes. Please also see the reviewer comments for Dike 46.	Medium	Low
388	Tsawwassen Sea Dike (Section B)	Adapted Lower Mainland maps from Regional Assessment of Flood Vulnerability by NHC for Fraser Basin Council, 2016 and Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios by MFLNRORD, 2014. Dike delineation based on information provided by MFLNRORD on Sept. 10, 2018 (RS, personal communication, Sept. 10th 2018).	The dike connects to dikes 44, 45, 46, 386 and 387. Together they intersect the floodplain boundaries or major roads assumed to be high ground.	Reviewed by NP. Dikes 386, 387 and 388 form part of the same diking system as Dike 46 (Delta Sea Dike) and the same protected area as delineated for Dike 46 should be used for classification purposes. Please also see the reviewer comments for Dike 46.	Medium	Low

APPENDIX B: RECEPTOR DATA DESCRIPTIONS

This table details dataset names, sources and receptors they were used for. The Dataset is described, and limitations of the dataset identified. Appendix K provides details about the data source, data sharing agreements and digitally provided data.

Table App-B-1 Dataset Names, Sources, Receptors, Descriptions and Limitations

Dataset Name	Data Source	Receptor(s)	Dataset Description	Dataset Limitations
Social Vulnerability Index (SVI)	NRCan	A.1.1 Population Exposed, A.1.1.a Social Economic Index, A.1.1.b, Social Population Index, and A.1.1.c Social Health Index	Population information is based on the 2011 Canadian census. The census data was adapted and analyzed by Natural Resources Canada (NRCan). NRCan's analysis has not yet been published, but was described to NHC by M. Journeay (pers com, Oct. 11, 2018) and is detailed below. The population data is based on data published at the census dissemination area (DAUID) level and has been refined to cover settled areas (SAUID). This refinement used Statistics Canada land cover information collected through the Landsat remote sensing program. This analysis was adapted to restrict DAUID polygons to settled areas through removing forests, wilderness areas, parks, agricultural land, etc.. This output was refined in rural and remote areas by using NRCan Canvec data. The statistics for a given DAUID were then distributed over the settled areas using a weighted average (rather than an assumption of uniform density) based on the Night Light Development Index (NLDI). The NLDI identifies the concentration of lights seen at night and was developed by the National Oceanic and Atmospheric Administration (NOAA)'s National Centres for Environmental Information. Areas with greater concentrations of light at night were assigned a higher portion of the population. The vulnerability of the population was understood through a social vulnerability index (SVI) developed by NRCan with SAUID spatial units. The SVI developed by NRCan is a combination of an economic index, a population index, a health index and a built environment index. As the built environment index is specific to an earthquake hazard, it was removed from the analysis for this project; the revised SVI is only based on the economic, population and health indices. To capture the differences in the effects of community type on social vulnerability, population characteristics were used to determine seven different community archetypes as follows: Urban Metropolitan Centre; Urban Agglomeration Area (Pop>10,000) with administrative subdivisions; Urban Agglomeration Area (Pop>10,000) with no administrative subdivisions; Exurban Regional District with strong metropolitan influence; Exurban Regional District with moderate metropolitan influence; Rural District with weak metropolitan influence; and Rural District with no metropolitan influence. Each SVI input factor is normalized with a min-max approach between 0-1, with 1 being the highest vulnerability. To develop the economic, social and community health indexes which form the overall SVI, each component index is developed through combining factors using weights specific to each community archetype and developed based on a principal component analysis (PCA). The social index is derived from 20	SVI methodology is under development, and more representative approaches are being considered. While the methodology used by NRCan follows accepted best-practice, inaccurate representations are possible and local nuances are difficult to capture. While data aggregation is reduced from the census dissemination areas, it is still aggregated and there are spatial aggregation errors associated with equal data distribution across SAUIDs.

Dataset Name	Data Source	Receptor(s)	Dataset Description	Dataset Limitations
			variables related to age, family characteristics, language, education, etc.. The economic index is derived from 8 variables related to household income, individual income, employment status, etc.. The community health index is derived from 13 variables related to illness, access to health care, quality of life, etc.. The three component indexes are then combined, with each index being weighted at one third of the total. NRCan anticipates publishing detailed methodology on this dataset within 2018. If available, reference to this material will be included in the final project report. NRCan is also in the process of analyzing 2016 census data to update the SVI. The next update (anticipated Dec. 2018) will include updated methodology and improved spatial de-aggregation techniques.	
Building Exposure Database	NRCan	B.1.1 Buildings Exposed	The building exposure dataset is based on building inventory information at the census dissemination area level. Data includes land use type, population, building total, building construction type, proportion of buildings built to various dated building codes, zoning type, occupancy information by time of day, structural cost, non-structural cost and contents cost. The structural cost and contents cost were used in this project. These values were derived from generic lookup tables based on building characteristics. The spatial unit for this dataset is SAUIDs as described above for the SVI.	Building values are based on reference values associated with the building stock inventoried for a census dissemination area. Building structure and contents values are not specific to assessed values in the area, they are based on a reference table. This does not represent differences in building values across the province. While data aggregation is reduced from the census dissemination areas, it is still aggregated and there are spatial aggregation errors associated with equal data distribution across SAUIDs.
Hospitals	GeoBC	B.1.1.a Hospitals	Point file showing location of hospitals.	Dataset may be incomplete or have inaccuracies.
Childcare Providers, K-12 Schools and Post-secondary Education	GeoBC	B.1.1.b Education Facilities	Child care services including daycares, kindergarten to grade 12 schools, and post secondary education facilities are identified in a point file.	Dataset may be incomplete or have inaccuracies.
Civic Facilities	GeoBC	B.1.1.c Community Facilities	Point file showing location of local arts, culture and recreational facilities.	Dataset may be incomplete or have inaccuracies.
First Responders	GeoBC	B.1.1.d First Responder Facilities	Point file showing location of ambulance, fire, police and coast guard facilities.	Dataset may be incomplete or have inaccuracies.

Dataset Name	Data Source	Receptor(s)	Dataset Description	Dataset Limitations
Digital Road Atlas	GeoBC	B.3.1 Roads	Polyline dataset of roads in BC not including resource roads. While this dataset is not complete, it is the highest quality inventory available.	Roads inventory is not complete, and alignment may be off in some cases.
Ministry of Transportation (MOT) Road Structures	GeoBC	B.3.2 Water Crossing	Polyline dataset including bridges, culverts (greater than or equal to 3 m diameter), retaining walls (perpendicular height greater than or equal to 2m), signs, bridges, and tunnels/snowsheds maintained by MOTI. Only bridges and culverts are used in project analysis to identify water crossing locations.	Dataset may be incomplete or have inaccuracies. Culverts smaller than 3 metres are not included. All bridges are included although some may not be water crossings.
Ports	GeoBC	B.3.3 Ports	Point dataset including all marine ports, terminals, shipyards, and harbours.	Dataset is quite accurate and detailed; however errors in the dataset may exist. Ports are provided as point features, while they occupy large areas. Where portions of a port are flooded, but flooding does not occur at the location of the point, the port's exposure would not be registered in the analysis.
Airports	GeoBC	B.3.4 Airports	Point dataset including all locations where an aircraft may take-off and land are identified including airports, aerodromes, water aerodromes, heliports and airstrips.	Dataset is quite accurate and detailed; however errors in the dataset may exist. Airports are provided as point features, while they occupy large areas. Where portions of an airport are flooded, but flooding does not occur at the location of the point, the airport's exposure would not be registered.
Annual Crop Inventory	GeoBC	B.3.5 Agricultural Land	A 30 metre resolution raster inventory of crops in 2017 is available. It was developed by the Earth Observation Team of the Science and Technology Branch (STB) at Agriculture and Agri-Food Canada (AAFC) using satellite imagery to for all of Canada. Both optical and radar images were combined, and ground truth information was used to verify the inventory. For this project, all agricultural land was analyzed, and the following inventory classes are removed: cloud, water, exposed land and barren; urban and developed; shrubland; wetland; grassland; fallow; forest; coniferous broadleaf; and mixed leaf.	The data has a 30 metre resolution which causes some spatial aggregation. The data was collected Canada-wide, and has some coverage gaps in BC which include 16 protected floodplain areas. There is some error associated with the imagery (i.e. clouds) and with categorization techniques, however the analysis follows best practice and has been verified by some ground truthing.
National Parks, Local and Regional Greenspaces, Parks and Protected Areas, NGO Conservation Areas, Critical Habitat for at Risk Species, Conservation Lands - Ecological	GeoBC	C.1.1 Parks and Environmentally Sensitive Areas	Polygons showing extent of layers identified. National Parks, Local and Regional Greenspaces, Parks and Protected Areas, and NGO Conservation Area files are based on land ownership. Conservation Lands – Ecological includes Wildlife Management Areas (WMA) designated by Order in Council. Critical Habitat for at Risk Species identifies both final and proposed critical habitat for species at risk listed on Schedule 1 of the federal Species at Risk Act (SARA). These layers were merged (overlap and duplication were removed) to provide a receptor file to represent parks and environmentally sensitive areas.	The layers showing parks, greenspaces, etc. are quite accurate and detailed. The Critical Habitat areas are delineated based on habitat potential, not proof of species residence. While they provide an indication of habitat value, there are also many other valuable habitat areas where non-at-risk species live which have high ecological value. A thorough assessment of environmentally sensitive areas would require a biologist's assessment on a site-by-site basis.

Dataset Name	Data Source	Receptor(s)	Dataset Description	Dataset Limitations
First Nations Reserve Areas	GeoBC	D.1.1 First Nations Reserve Areas	Polygons showing the extent of all First Nations reserves.	Dataset is assumed to be complete and accurate. Data does not include any First Nations claim areas or show territorial or valued lands which are not on-reserve.
Water and Sanitation Infrastructure	ICI Society	B.2.1 Water and Sanitation Infrastructure	Polyline showing infrastructure mains as identified by municipalities	Only infrastructure managed by cities or regional governments is included, not private infrastructure. 50 service providers provided records for this database and coverage is fairly complete for BC, however verifications of all areas was not done. City or regional inventories of their infrastructure may be incomplete causing dataset errors.
Telus Cable Wires, Shaw Telecom Lines	ICI Society	B.2.2 Telecom Lines	Polyline of Telus and Shaw telecom lines.	Data is of very high accuracy and resolution. Potential limitations include not capturing lines associated with other, minor telecom providers and any database errors.
Telus Telecom Facilities, Shaw Telecom Facilities	ICI Society	B.2.3 Telecom Facilities	Point file of Telus and Shaw telecom facilities.	Data is of very high accuracy and resolution. Potential limitations include not capturing facilities associated with other, minor telecom providers and any database errors.
Fortis BC Electric and BC Hydro Above and Below Ground primary and Secondary Distribution Electrical Lines	ICI Society	B.2.4 Electrical Distribution Lines	Polyline of electrical distribution lines as part of the Fortis BC and BC Hydro above and below ground primary and secondary distribution grids.	Data is of very high accuracy and resolution. Potential limitations include not capturing lines associated with other, minor power operations and any database errors.
Fortis BC Electric Transmission Lines and BC Hydro Transmission Circuits	ICI Society	B.2.5 Electrical Transmission Lines	Polyline of transmission lines as part of the Fortis BC and BC Hydro electrical grids.	Data is of very high accuracy and resolution. Potential limitations include not capturing lines associated with other, minor power operations and any database errors.
Fortis BC Electrical Transmission Structures, Fortis BC Electrical Underground Transformers, BC Hydro Transmission Structures, and BC Hydro Transmission Substations	ICI Society	B.2.5 Electrical Transmission Facilities	Points showing transmission facilities as part of the Fortis BC and BC Hydro electrical grids.	Data is of very high accuracy and resolution. Potential limitations include not capturing facilities associated with other, minor power operations and any database errors.
Historic and Archaeological Sites	Archaeology Branch (MFLNRORD)	B.2.1 Cultural Heritage Sites	Polygons were provided identifying the location of known historic and archaeological sites within each protected floodplain. Both recognized historic sites protected under a federal, provincial or local act are identified as well as non-protected heritage sites.	While all historic and archaeological sites in the provincial database were searched, many historic and archaeological sites, especially those associated with First Nations culture, are not documented through this dataset and therefore did not appear in the analysis.

Dataset Name	Data Source	Receptor(s)	Dataset Description	Dataset Limitations
BC Assessment Data for Fernie – building footprints, zoning data and 2018 property assessment data	City of Fernie	Tier 2 building analysis	Assessed values and related building and property information in Tier 2 area of interest including building footprints, zoning data (bylaw 1750) and property assessment data.	Data includes zones for each property, assessed values for each building. Limitations include no information about building type or construction.
BC Assessment Data for Surrey – building footprints and 2018 property assessment data	City of Surrey	Tier 2 building analysis	Assessed values and related building and property information in Tier 2 area of interest including building footprints and property assessment data.	Data includes building footprints and assessed values for each property. Limitations include no information about building type or construction.
Zoning Data for Surrey	City of Surrey Open Data	Tier 2 building analysis	Spatial zoning information based on zoning bylaw 12000.	Data is limited by class descriptions in zoning bylaw.
BC Assessment Data for Nicomen Island – building footprints, zoning data 2018 property assessment data	Fraser Valley Regional District	Tier 2 building analysis	Assessed values and related building and property information in Tier 2 area of interest. Zoning information based on zoning bylaw 559.	Data includes assessed values for each property. Limitations include no information about building type or construction, and no building footprints.

APPENDIX C: TIER 1 DIKE CONSEQUENCE RESULTS

Appendix C provided in separate file.

A two-page layout is provided for each dike. The first page provides: a map of the dike, protected floodplain and surrounding area; information about the protected floodplain including original mapping source, protected floodplain determination comments, and protected floodplain review comments; a delineation confidence ranking; and a protected floodplain quality parameter. More information about the mapping can be found in report Section 4. Note that for the maps which do not display a 200-year floodplain (symbolized by a blue hatched polygon), there was no existing 200-year floodplain used for delineation and protected floodplain was estimated (denoted in the table below the map with an original mapping source as 'ESTIMATED').

The second page provides detailed scoring results for each dike. This page includes all receptors, modifiers, subordinate factors and consequence categories used to develop the overall score for the dike. It lists the classification number for each factor and the corresponding raw data range. More information about this consequence classification system and its application is in report Sections 5 through 8.

APPENDIX D: TIER 1 CONSEQUENCE CLASSIFICATION DETAILS

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LIST OF TABLES

INTRODUCTION

This appendix describes the categories, subordinate factors, indicators, receptors and modifiers that comprise the consequence classification framework and are discussed in sections 5-7. For each classification in the framework, the following are identified: the classified number; the associated range of scored values; and the associated raw data range. All framework components are referred to by both names and category numbers for clarity. The flow chart in Appendix E outlines all components.

Careful distinction between raw data, scored values and classified numbers should be made. Raw data is processed to yield scores (i.e., a population of 3165 is processed to a score of 3.5). Classified numbers are whole numbers associated with a range of scored values (i.e., the classified value of 4 is associated with scores greater than or equal to 3 and less than to 4). Scored values are used in calculations. Classified numbers are used to identify the range of raw data associated with a scored value.

A: PEOPLE CONSEQUENCE CATEGORY

The A: People consequence category is based on the total number of people living in the protected floodplain.

Table App-D- 1 Components of consequence category A: People Consequence Category

Consequence Category	Subordinate Factor	Indicator/Modifier	Receptor	Notes
A: People	A.1 People	N.A.1.1 Number of people living in the protected floodplain	A.1.1 People living in the protected floodplain	The output information for each dike includes a profile of the population based on the community archetype(s) as developed for the SVI.
		M.A.1.1 Average social vulnerability index of the people living in the protected floodplain	A.1.1.a Average social economic index of the people living in the protected floodplain	
			A.1.1.b Average social population index of the people living in the protected floodplain	
			A.1.1.c Average social health index of the people living in the protected floodplain	

$$Score\ for\ A: People = A.1$$

The classification labels and values, and corresponding range of scores for the A: People consequence category are shown in Table App-D- 2.

Table App-D- 2 Classification values and corresponding score bounds for A: People Consequence Category

Classification	Score Bounds A
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4

A.1: People Subordinate Factor

$$Score\ for\ A.1 = N.A.1.1 + M.A.1.1$$

The classification labels and values, and corresponding range of scores for the A.1 People subordinate factor are shown in Table App-D- 1.

Table App-D- 3 Classification values and corresponding score bounds for A.1 People subordinate factor

Classification	Score Bounds A.1
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4

The classification values, and corresponding score and raw data ranges for the indicators and modifiers which are a part of A.1 People subordinate factor are shown in Table App-D- 4 and Table App-D- 5.

N.A.1.1 People Indicator

Table App-D- 4 Classification values, corresponding score and raw data ranges for the N.A.1.1 People Indicator

Classification N.A.1.1	Score Bounds N.A.1.1	Number of People Exposed A.1.1
Insignificant – 1	>0 to <1	>0 to <2
Minor – 2	>=1 to <2	≥2 to <39
Moderate – 3	>=2 to <3	≥39 to <680
Major – 4	>=3 to <4	≥680 to <12000
High – 5	>=4	≥12000

M.A.1.1 SVI Modifier

The SVI used in this project, includes the social economic, social population and social health indices, each with an equal weighting (the built environment index is not included as it is specific to earthquake hazard). As the SVI is already a manipulated dataset, further binning of the value was not completed. The original SVI index is developed based on a range of 0.0 to 1.0, however, the range of values for protected floodplains was between 0.033 and 0.434. The value for a protected floodplain was multiplied by two to scale the SVI to have the desired level of impact (i.e., between 0.066 and 0.87). The range of original, un-multiplied SVIs and SVI values multiplied by two are shown in Table App-D- 5.

Table App-D- 5 Raw and multiplied SVI ranges (not including zeros)

Modifier M.A.1.1	Original Value	Multiplied Value
Min	0.033	0.066
Max	0.434	0.87

B: ECONOMY – BUILDINGS CONSEQUENCE CATEGORY

The B: Economy – Buildings consequence category is based on the total number of buildings located in the protected floodplain.

Table App-D- 6 Components of consequence category B: Economy – Buildings Consequence Category

Consequence Category	Subordinate Factor	Indicator/Modifier	Receptor	Notes
B: Economy-Buildings	B.1 Buildings exposed in the protected floodplain	N.B.1.1 Total value (CAD) of buildings located in the protected floodplain	B.1.1.a Total value of building structure exposed	The buildings include residential, commercial, industrial and public buildings.
			B.1.1.b Total value of building contents exposed	
		M.B.1.1 Total number of facilities located in the protected floodplain	B.1.1.c Total number of hospitals (note medical clinics not included)	
			B.1.1.d Total number of education facilities (post-secondary, K-12 and childcare facilities)	
			B.1.1.e Community facilities	
			B.1.1.f First responder facilities (ambulance, coastguard, fire, police)	

$$Score\ for\ B{:}\ Economy - Buildings = B.1$$

The classification labels and values, and corresponding range of scores for the B: Economy – Buildings category are shown in Table App-D- 8.

Table App-D- 7 Classification values and corresponding score bounds for B: Economy – Buildings Consequence Category

Classification	Score Bounds B
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4

B.1: Buildings Exposed Subordinate Factor

$$Score\ for\ B.1.1 = N.B.1.1 + M.B.1.1$$

The classification labels and values, and corresponding range of scores for the B.1 Buildings Exposed subordinate factor are shown in in Table App-D- 8.

Table App-D- 8 Classification values and corresponding score bounds for B.1 Buildings exposed subordinate factor

Label	Score Bounds B.1
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4

N.B.1.1: Buildings Exposed Indicator

Table App-D- 9 Classification values, corresponding score and raw data ranges for the N.B.1.1 Buildings Exposed Indicator

Classification N.B.1.1	Score Bounds N.B.1.1	Economic Value of Buildings Exposed ($M CAD) B.1.1
Insignificant – 1	>0 to <1	>0 to <0.57
Minor – 2	≥1 to <2	≥0.57 to <9.6
Moderate – 3	≥2 to <3	≥9.6 to <160
Major – 4	≥3 to <4	≥160 to <2800
Insignificant – 1	>0 to <1	≥ 2800

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M.B.1.1: Administrative Facilities Modifier

Table App-D- 10 Modifier scores and corresponding raw data ranges for the M.B.1.1 Administrative Facilities Modifier

Modifier M.B.1.1	Number of Admin Facilities B.1.1 c-f
+0.5	< 10
+1.0	≥ 10

C: ECONOMY – CRITICAL INFRASTRUCTURE AND AGRICULTURE CONSEQUENCE CATEGORY

The C: Economy – Critical Infrastructure and Agriculture consequence category is based on the critical infrastructure and agricultural land located in the protected floodplain.

Table App-D- 11 Components of Consequence Category C: Economy – CI and Agriculture Consequence Category

Consequence Category	Subordinate Factor	Indicator / Modifier	Receptor	Notes
C. Economy – Critical Infrastructure and Agriculture	C.1 Utility Infrastructure	N.C.1.1 Kilometres of water and sanitation pipelines that are in the protected floodplain	C.1.1Water and sanitation pipelines	
		N.C.1.2 Kilometres of telecommunication lines in the protected floodplain	C.1.2 Telcom lines (Telus cables, Shaw lines)	
		N.C.1.3 Number of telecom facilities in the protected floodplain	C.1.3 Telecom Facilities (Telus Facilities, Shaw Facilities)	
		N.C.1.4 Kilometres of electrical distribution lines in the protected floodplain	C.1.4 Electrical Distribution Lines	
		N.C.1.5 Kilometres of electrical transmission lines in the protected floodplain	C.1.5 Electrical Transmission Lines	
		N.C.1.6 Number of electrical transmission facilities in the protected floodplain	C.1.6 Electrical Transmission Facilities	
	C.2 Transportation Infrastructure	N.C.2.1 Kilometres of roads in the protected floodplain	C.2.1 Roads	
		M.C.2.2 Kilometres of water crossings in the protected floodplain	C.2.2 Water crossings	
		N.C.2.3 Number of ports and airports in the protected floodplain	C.2.3 Ports and Airports	
	C.3 Agricultural Lands	N.C.3.1 Square kilometres of agricultural lands in the protected floodplain	C.3.1 Agricultural lands	

$$Score\ for\ C{:}\ Economy - Critical\ Inrfrastructure\ and\ Agriculture$$
$$= max(N.C.1.1\ +\ N.C.1.2\ +\ N.C.1.3. + N.C.1.4\ +\ N.C.1.5\ +\ N.C.1.6)$$

The classification labels and values, and corresponding range of scores for C: Economy – Critical Infrastructure and Agriculture category are shown in Table App-D- 12.

Table App-D- 12 Classification values and corresponding score bounds for C: Economy – Critical Infrastructure and Agriculture Consequence Category

Classification	Score Bounds C
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4

C.1 Utility Infrastructure Subordinate Factor

$$Score\ for\ C.1 = \max(\ N.C.1.1,\ N.C.1.2,\ N.C.1.3,\ N.C.1.4,\ N.C.1.5,\ N.C.1.6)$$

Table App-D- 13 Classification values and corresponding score bounds for C.1 Utility Infrastructure subordinate factor

Classification	Score Bounds C.1
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4

The classification values, and corresponding score and raw data ranges for the indicators and modifiers which are a part of C.1 Utility Infrastructure subordinate factor are shown in Table App-D- 14, Table App-D- 15, Table App-D- 16, Table App-D- 17, Table App-D- 18, and Table App-D- 19.

N.C.1.1: Water and Sanitation Infrastructure indicator

Table App-D- 14 Classification values, corresponding score and raw data ranges for the N.C.1.1: Water and Sanitation Infrastructure indicator

Classification N.C.1.1	Score N.C.1.1	Total Length of Water and Sanitation Infrastructure Exposed (in km) C.1.1
Insignificant – 1	>0 to <1	>0 to <0.08
Minor – 2	≥1 to <2	≥0.08 to <0.78
Moderate – 3	≥2 to <3	≥0.78 to <7.6
Major – 4	≥3 to <4	≥7.6 to <74
High – 5	≥4	≥ 74

N.C.1.2: Telcom Lines Indicator

Table App-D- 15 Classification values, corresponding score and raw data ranges for the N.C.1.2: Telcom Lines indicator

Classification N.C.1.2	Score N.C.1.2	Total Length of Telcom Lines (in km) C.1.2
Insignificant – 1	>0 to <1	>0 to <0.19
Minor – 2	≥1 to <2	≥0.19 to <1.5
Moderate – 3	≥2 to <3	≥1.5 to <11
Major – 4	≥3 to <4	≥11 to <86
High – 5	≥4	≥ 86

N.C.1.2: Telcom Facilities Indicator

Table App-D- 16 Classification values, corresponding score and raw data ranges for the N.C.1.3: Telecom Facilities indicator

Classification N.C.1.3	Score N.C.1.3	Total Number of Telcom Facilities C.1.3
Insignificant – 1	>0 to <1	< 10
Minor – 2	≥1 to <2	≥10 to <54
Moderate – 3	≥2 to <3	≥54 to <280
Major – 4	≥3 to <4	≥280 to <1400
High – 5	≥4	≥ 1400

N.C.1.4: Electrical Distribution Lines Indicator

Table App-D- 17 Classification values, corresponding score and raw data ranges for the N.C.1.4: Electrical Distribution Lines indicator

Classification N.C.1.4	Score N.C.1.4	Total Length of Electrical Distribution Lines (in km) C.1.4
Insignificant – 1	>0 to <1	< 0.4
Minor – 2	≥1 to <2	≥ 0.4 to <3.3
Moderate – 3	≥2 to <3	≥ 3.3 to <28
Major – 4	≥3 to <4	≥ 28 to <240
High – 5	≥4	≥ 240

N.C.1.5: Electrical Transmission Lines Indicator

Table App-D- 18 Classification values, corresponding score and raw data ranges for the N.C.1.5: Electrical Transmission Lines indicator

Classification N.C.1.5	Score N.C.1.5	Total Length of Electrical Transmission Lines (in km) C.1.5
Insignificant – 1	>0 to <1	< 0.11
Minor – 2	≥1 to <2	≥ 0.11 to <0.67
Moderate – 3	≥2 to <3	≥ 0.67 to <4
Major – 4	≥3 to <4	≥ 4 to <24
High – 5	≥4	≥ 24

N.C.1.6: Electrical Transmission Facilities Indicator

Table App-D- 19 Classification values, corresponding score and raw data ranges for the N.C.1.6: Electrical Transmission Facilities indicator

Classification N.C.1.6	Score N.C.1.6	Total Number of Electrical Transmission Facilities C.1.6
Insignificant – 1	>0 to <1	< 10
Minor – 2	≥1 to <2	≥ 10 to <20
Moderate – 3	≥2 to <3	≥ 20 to <100
Major – 4	≥3 to <4	≥ 100 to <300
High – 5	≥4	≥ 300

C.2 Transportation Infrastructure Subordinate Factor

$$Score\ for\ C.2 = N.C.2.1 + M.C.2.2\ or\ C.2 = 5\ if\ N.C.2.3 \geq 4$$

Table App-D- 20 Classification values and corresponding score bounds for C.2 Transportation Infrastructure subordinate factor

Classification	Score Bounds C.2
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4

The classification values, and corresponding score and raw data ranges for the indicators and modifiers which are a part of C.2 Transportation Infrastructure subordinate factor are shown in Table App-D- 21, Table App-D- 22, and Table App-D- 23.

N.C.2.1: Roads Indicator

Table App-D- 21 Classification values, corresponding score and raw data ranges for the N.C.2.1: Roads indicator

Classification N.C.2.1	Score N.C.2.1	Total Length of Roads Exposed (in km) C.2.1
Insignificant – 1	>0 to <1	< 0.53
Minor – 2	≥1 to <2	≥ 0.53 to <3.3
Moderate – 3	≥2 to <3	≥ 3.3 to <20
Major – 4	≥3 to <4	≥ 20 to <120
High – 5	≥4	≥ 120

M.C.2.2: Water Crossings Modifier

Table App-D- 22 Scores and raw data ranges for the C.2.2: Water Crossings modifier

Score M.C.2.2	Total Length of Water Crossings Exposed (in m) C.2.2
+0.5	< 100
+1.0	≥ 100 to <1,000
+1.5	≥ 1,000

N.C.2.3: Ports and Airports Indicator

Table App-D- 23 Classification value, corresponding score and raw data range for the C.2.3: Ports and Airports indicator

Classification N.C.2.3	Score N.C.2.3	Total # of Ports and Airports C.2.3
High - 5	5	≥ 1

C.3 Agricultural Land Subordinate Factor

$$Score\ for\ C.3 = N.C.3.1$$

Table App-D- 24 Classification values and corresponding score bounds for C.3 Agricultural Land subordinate factor

Classification	Score Bounds C.3
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4

The classification values, and corresponding score and raw data ranges for the indicators and modifiers which are a part of C.3 Agricultural Land Infrastructure subordinate factor are shown in Table App-D- 25.

N.C.3.1: Agricultural Land Indicator

Table App-D- 25 Classification values, corresponding score and raw data ranges for the N.C.3.1: Agricultural Land indicator

Classification N.C.3.1	Score N.C.3.1	Total km^2 of Agricultural Lands (in km^2) C.3.1
Insignificant – 1	>0 to <1	>0 to <0.02
Minor – 2	≥1 to <2	≥0.02 to <0.14
Moderate – 3	≥2 to <3	≥0.14 to <1.1
Major – 4	≥3 to <4	≥1.1 to <9.3
High – 5	≥4	≥ 9.3

D: ENVIRONMENT CONSEQUENCE CATEGORY

The D: Environment consequence category is based on the total area of parks and environmentally sensitive areas (National Parks, Local and Regional Greenspaces, Parks and Protected Areas, NGO Conservation Areas, Critical Habitat for At Risk Species, Conservation Lands - Ecological) in the protected floodplain.

Table App-D- 26 Components of Consequence Category D: Environment Consequence Category

Consequence Category	Subordinate Factor	Indicator/Modifier	Receptor	Notes
D: Environment	D.1 Parks and environmentally sensitive areas	Square Kilometres of parks and environmentally sensitive areas	D.1.1 National Parks, Local and Regional Greenspaces, Parks and Protected Areas, NGO Conservation Areas, Critical Habitat for At Risk Species, Conservation Lands - Ecological	

$$Score\ for\ D: Environment = D.1$$

The classification labels and values, and corresponding range of scores for the D: Environment consequence category are shown in Table App-D- 27.

Table App-D- 27 Classification values and corresponding score bounds for D: Environment Consequence Category

Classification	Score D
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4

D.1 Parks and Environmentally Sensitive Areas Subordinate Factor

$$Score\ for\ D.1 = N.D.1.1$$

Table App-D- 28 Classification values and corresponding score bounds for D.1 Environment subordinate factor

Classification	Score Bounds D.1
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4

The classification values, and corresponding score and raw data ranges for the indicators and modifiers which are a part of D.1 Environment subordinate factor are shown in Table App-D- 29.

N.D.1.1: Parks and Environmentally Sensitive Areas Indicator

Table App-D- 29 Classification values, corresponding score and raw data ranges for the N.D.1.1: Parks and Environmentally Sensitive Areas indicator

Classification N.D.1.1	Score N.D.1.1	Total Area of Parks and Environmentally Sensitive Areas (in km^2) D.1.1
Insignificant – 1	>0 to <1	>0 to <0.01
Minor – 2	≥1 to <2	≥0.01 to <0.21
Moderate – 3	≥2 to <3	≥0.21 to <3
Major – 4	≥3 to <4	≥3 to <44
High – 5	≥4	≥ 44

E: CULTURAL HERITAGE CONSEQUENCE CATEGORY

The E: Cultural Heritage consequence category is based on the total area of First Nation reserves and the number of cultural heritage sites located in the protected floodplain.

Table App-D- 30 Components of Consequence Category E: Cultural Heritage Consequence Category

Consequence Category	Subordinate Factor	Indicator/Modifier	Receptor	Notes
E. Cultural Heritage	E.1 First Nations reserve area	N.E.1.1 Area of First Nations reserves in the protected floodplain	E.1.1 First Nations reserve area	
	E.2 Cultural heritage sites	N.E.2.1 Total number of cultural heritage sites in the protected floodplain	E.2.1 Number of cultural heritage sites	

$$Score\ for\ E{:}\ Cultural\ Heritage = \max(E.1, E.2)$$

The classification labels and values, and corresponding range of scores for the E: Cultural Heritage consequence category are shown in Table App-D- 31.

Table App-D- 31 Classification values and corresponding score bounds for E: Cultural Heritage Consequence Category

Classification	Score E
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4

E.1. First Nations Reserve Area Subordinate Factor

$$Score\ for\ E.1 = N.E.1.1$$

Table App-D- 32 Classification values and corresponding score bounds for E.1 First Nations Reserve Area subordinate factor

Classification	Score Bounds E.1
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4

The classification values, and corresponding score and raw data ranges for the indicators and modifiers which are a part of E.1 First Nations Reserve Area subordinate factor are shown in Table App-D- 32.

N.E.3.1: Agricultural Land Indicator

Table App-D- 33 Classification values, corresponding score and raw data ranges for the N.E.1.1: First Nations Reserve Area indicator

Classification N.D.1.1	Score N.D.1.1	Total Area of First Nations Reserves (ha) D.1.1
Insignificant – 1	>0 to <1	>0 to <0.04
Minor – 2	≥1 to <2	≥0.04 to <0.13
Moderate – 3	≥2 to <3	≥0.13 to <0.46
Major – 4	≥3 to <4	≥0.46 to <1.7
High – 5	≥4	≥ 1.7

E.2 Cultural Heritage Sites Subordinate Factor

$$Score\ for\ E.2 = N.E.2.1$$

Table App-D- 34 Classification values and corresponding score bounds for E.2 Cultural Heritage Sites subordinate factor

Classification	Score Bounds E.2
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4

The classification values, and corresponding score and raw data ranges for the indicators and modifiers which are a part of E.2 Cultural Heritage Sites subordinate factor are shown in Table App-D- 34.

N.E.3.1: Agricultural Land Indicator

Table App-D- 35 Classification values, corresponding score and raw data ranges for the N.E.2.1: Cultural Heritage Sites indicator

Classification N.D.2.1	Score N.D.2.1	Total Number of Cultural Heritage Sites D.2.1
Insignificant – 1	>0 to <1	>0 to <5.2
Minor – 2	≥1 to <2	≥5.2 to <14
Moderate – 3	≥2 to <3	≥14 to <36
Major – 4	≥3 to <4	≥36 to <93
High – 5	≥4	≥ 93

OVERALL SCORE

The overall dike consequence score is calculated by combining consequence category scores using a weighted aggregation and trigger for categories A and B.

$$
\begin{aligned}
Overall\ Score = {} & (0.4 * A + 0.2 * B + 0.2 * C + 0.1 * D + 0.1 * E), \\
& or\ (if\ the\ score\ of\ A\ \geq 4\ (i.e., a\ classification\ of\ 5), Overall\ Score = 5), \\
& or\ (if\ the\ score\ of\ B\ \geq 5\ (i.e., a\ classification\ of\ 5), Overall\ Score = 5)
\end{aligned}
$$

APPENDIX E: CONSEQUENCE CLASSIFICATION FLOWCHART

Tier 1 Consequence Classification Framework

Legend and Explanatory Notes

Careful distinction between raw data, scored values and classified numbers should be made. Raw data is processed to yield scores (i.e., a population of 3165 is processed to a score of 3.5). Classified numbers are integers associated with a range of scored values. The scored value range associated with each classified number is used consistently throughout the project and shown in Table 1 (i.e., the classified value of 4 is associated with scores greater than or equal to 3 and less than to 4). Scored values are used in calculations. Classified numbers are used to identify the range of raw data associated with a scored value.

Receptor

Each receptor is identified by name and code.

Indicator

Each indicator is identified by name and code. Classified values are identified on the left, and the associated raw data value ranges are identified to the right of the colon. See Table 1 for the relationship between classified numbers and scored values.

Modifier

The equation or classification for each modifier score is given. Classified and calculated modifier values do not have a range i.e., classification numbers and scored valesare the same.

Subordinate Factor

Subordinate factors are identified by name and code. Equations for subordinate factors are given. See Table 1 for the relationship between classified numbers and scored values.

Consequence Category

Consequence Categories are identified by name and code. Equations for consequence categories are given. See Table 1 for the relationship between classified numbers and scored values.

Overal Score Weighting

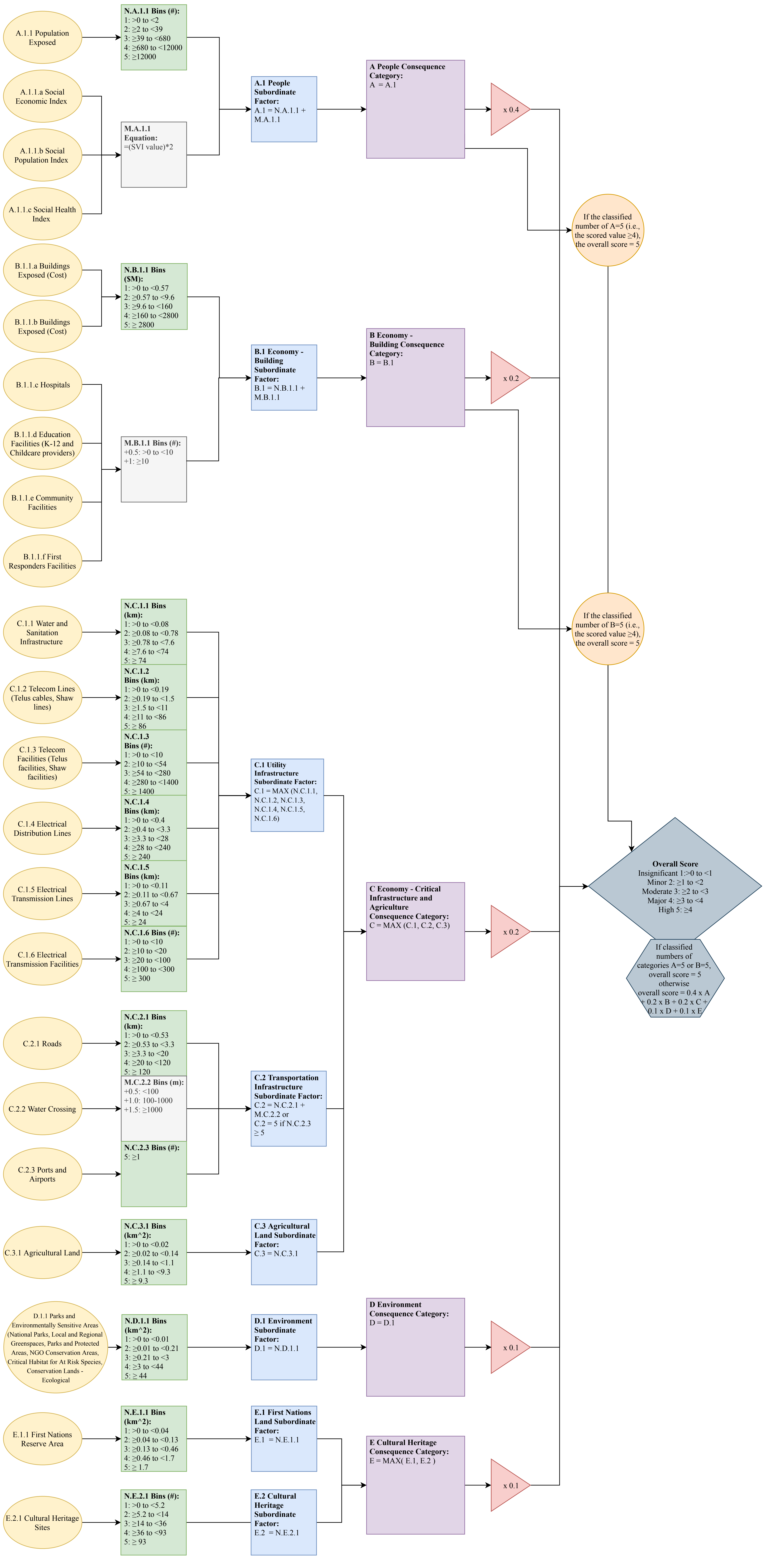
The weightings applied to the consequence categories to determine the overall score are identified.

Overall Score Trigger

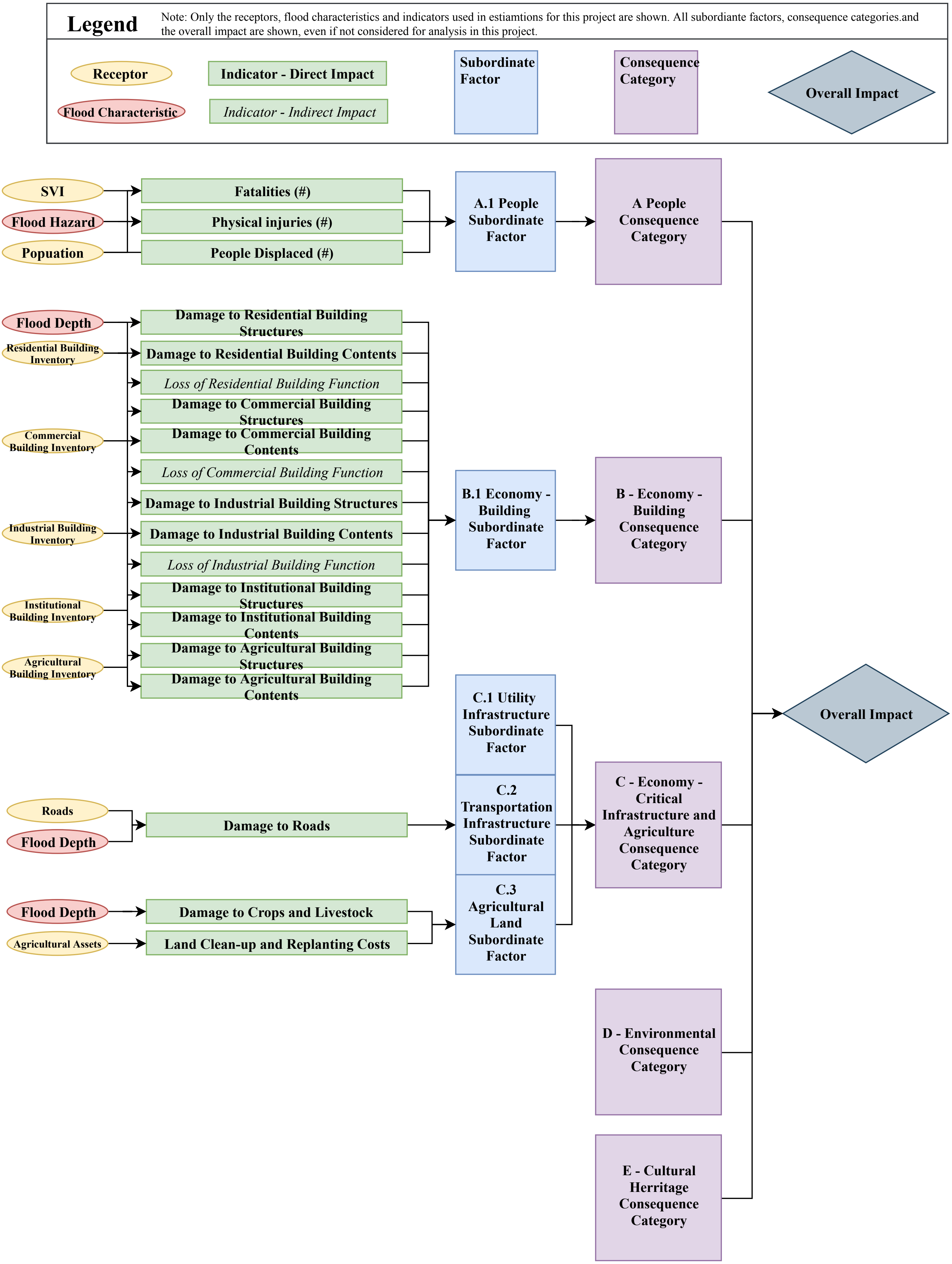
The triggers applied to the overall score are identified.

Table 1: Relationship between classified numbers and scored values

Classified Numbers	Scored Value Range
Insignificant – 1	>0 to <1
Minor – 2	≥1 to <2
Moderate – 3	≥2 to <3
Major – 4	≥3 to <4
High – 5	≥4



Tier 2 Consequence Classification Framework



APPENDIX F: TIER 1 CATEGORY RANGES AND DISTRIBUTION RESULTS

The Category Ranges and Distribution Results table identifies information related to the binning of each receptor, subordinate factor, and consequence category. For each classification (identified in the table heading), the raw data range is identified (in light blue cells) and the number of dikes which fall into this range is identified (grey cells). The classification values correspond with a range of scores as identified in Table 5-1 in the main report.

Tabple App-F-1 Category Ranges and Distribution Results Table

Consequnce Category	Indicator / Modifier	Classification 1	2	3	4	5
A: People	N.A.1.1 Population Total (#):	>0 to <2	≥2 to <39	≥39 to <680	≥680 to <12000	≥12000
		8	47	100	41	11
	M.A.1.1 SVI:	>0 to <0.5	≥0.5 to <1.0			
		33	179			
B: Economy - Building	N.B.1.1 Buildings Exposed ($M):	>0 to <0.57	≥0.57 to <9.6	≥9.6 to <160	≥160 to <2800	≥ 2800
		6	41	98	48	14
	M.B.1.1 Facilities Total (#):	Score 0.5: >0 to <10		Score 1: ≥10		
		63		21		
C: Economy - Critical Infrastructure and Agriculture	N.C.1.1 Water and Sanitation Infrastructure (km):	>0 to <0.08	≥0.08 to <0.78	≥0.78 to <7.6	≥7.6 to <74	≥ 74
		2	6	21	32	19
	N.C.1.2 Telecom Lines (km):	>0 to <0.19	≥0.19 to <1.5	≥1.5 to <11	≥11 to <86	≥ 86
		11	34	26	18	2
	N.C.1.3 Telecom Facilities (#):	>0 to <10	≥10 to <54	≥54 to <280	≥280 to <1400	≥ 1400
		28	24	20	4	2
	N.C.1.4 Electrical Distribution Lines (km):	>0 to <0.4	≥0.4 to <3.3	≥3.3 to <28	≥28 to <240	≥ 240
		11	53	97	30	13
	N.C.1.5 Electrical Transmission Lines (km):	>0 to <0.11	≥0.11 to <0.67	≥0.67 to <4	≥4 to <24	≥ 24
		6	19	25	21	16
	N.C.1.6 Electrical Transmission Facilities (#):	>0 to <10	≥10 to <20	≥20 to <100	≥100 to <300	≥ 300
		8	24	11	14	15
	N.C.2.1 Roads (km):	>0 to <0.53	≥0.53 to <3.3	≥3.3 to <20	≥20 to <120	≥ 120
		29	61	72	27	15
	M.C.2.2 Water Crossings (m):	Score 0.5: <100		Score 1.0 : ≥100 to <1000		Score 1.5 : ≥1000
		25		22		13
	N.C.2.3 Ports and Airports (#):		Score 5: ≥1			
			22			
	N.C.3.1 Agricultural Land (km^2):	>0 to <0.02	≥0.02 to <0.14	≥0.14 to <1.1	≥1.1 to <9.3	≥ 9.3
		3	10	19	26	29
D: Environment	N.D.1.1 Parks and Environmentally Sensitive Areas (km^2):	>0 to <0.01	≥0.01 to <0.21	≥0.21 to <3	≥3 to <44	≥ 44
		20	41	63	26	11
E: Culture	N.E.1.1 First Nations Reserve Area (ha):	>0 to <0.04	≥0.04 to <0.13	≥0.13 to <0.46	≥0.46 to <1.7	≥ 1.7
		2	3	14	10	11
	N.E.2.1 Cultural Heritage Sites (#):	>0 to <5.2	≥5.2 to <14	≥14 to <36	≥36 to <93	≥ 93
		18	4	8	3	7

Subordinate Factor	Classification	1	2	3	4	5
A.1 People	A.1 = N.A.1.1 + M.A.1.1	5	21	70	80	32
B.1 Economy - Buildings	B.1 = N.B.1.1 + M.B.1.1	6	34	88	47	32
C.1 Utility Infrastructure	C.1= MAX (N.C.1.1, N.C.1.2, N.C.1.3, N.C.1.4, N.C.1.5, N.C.1.6)	7	35	86	47	36
C.2 Transportation Infrastructure	C.2 = 5 IF N.C.2.3 >=5 ELSE C.2 = N.C.2.1 + N.C.2.2	28	59	61	19	37
C.3 Agricultural Land	C.3 = N.C.3.1	3	10	19	26	29
D.1 Environment	D.1 = N.D.1.1	20	41	63	26	11
E.1 First Nations Reserve Area	E.1 = N.E.1.1	2	3	14	10	11
E.2 Cultural Heritage Sites	E.2 = N.E.2.1	18	4	8	3	7

Consequence Category	Classification	1	2	3	4	5
A: People	A = A.1	5	21	70	80	32
B: Economy - Building	B = B.1	6	34	88	47	32
C: Economy - Critical Infrastructure and Agriculture	C = MAX (C.1, C.2, C.3)	4	32	73	46	57
D: Environment	D = D.1	20	41	63	26	11
E: Culture	E = MAX (E.1, E.2)	17	7	18	6	18

APPENDIX G: TIER 1 DIKE SCORING TABLE

The Dikes Scoring table identifies the following for each dike: the classification for each receptor, modifier, subordinate factor, and consequence category; the overall score; the area of the protected floodplain; and the community archetype. Results identified for all indicators and subordinate factors include the classified value followed by the score in brackets following the classification scheme identified in Table 5-1 in the main report. The scores are colour-coded with: High scores in red; Major scores in orange; Moderate scores in yellow; Minor scores in light green-blue; and Insignificant scores in darker green. An '*' proceeding an overall score indicates this dike protects from a debris flow or debris flood on an alluvial fan, or an ice jam hazard. Due to the hazard characteristics, the consequence of dike failure may be more severe due to: little to no warning time; higher loss of life; and more significant damage to assets.

Table App-G-1 Dikes Scoring Table

Dike	Classification of Indicators and Modifiers																	Subordinate Factor Classification								Consequence Category					Overall		Area	Community
#	N.A.1.1	M.A.1.1	N.B.1.1	M.B.1.1	N.C.1.1	N.C.1.2	N.C.1.3	N.C.1.4	N.C.1.5	N.C.1.6	N.C.2.1	M.C.2.2	M.C.2.3	N.C.3.1	N.D.1.1	N.E.1.1	N.E.2.1	A.1	B.1	C.1	C.2	C.3	D.1	E.1	E.2	A	B	C	D	E	Classification		(km^2)	Archetype
1	4	0.65	4	0.5	5	3	2	4	4	0	4	1.5	5	5	4	3	3	5	5	5	5	5	4	3	3	5	5	5	4	3	5	High	44.30	1
2	4	0.51	4	1.0	5	3	1	5	5	3	5	1.0	0	5	4	5	0	5	5	5	5	5	4	5	0	5	5	5	4	5	5	High	100.17	1;2
3	4	0.57	4	0.5	5	0	0	4	5	2	5	1.0	0	5	4	2	0	5	5	5	5	5	4	2	0	5	5	5	4	2	5	High	62.06	2;1
5	3	0.59	3	0.0	0	0	0	3	0	2	2	0	0	4	0	4	1	4	3	3	2	4	0	4	1	4	3	4	0	4	3	Moderate	5.71	1
7	3	0.63	3	0.5	0	0	0	3	0	0	3	0	0	0	2	0	0	4	4	3	3	0	2	0	0	4	4	3	2	0	3	Moderate	0.63	6
9	3	0.63	3	0.0	0	0	0	3	1	0	2	0	0	0	2	0	0	4	3	3	2	0	2	0	0	4	3	3	2	0	3	Moderate	0.31	6
10	2	0.64	2	0.0	1	0	0	1	2	0	0	0	0	0	0	0	0	3	2	2	0	0	0	0	0	3	2	2	0	0	2	Minor	0.02	2
13	2	0.59	2	0.0	0	0	0	1	1	0	0	0	0	0	0	0	0	3	2	1	0	0	0	0	0	3	2	1	0	0	*2	Minor	0.04	1
14	2	0.74	2	0.0	0	0	0	2	0	0	1	0	0	0	0	0	0	3	2	2	1	0	0	0	0	3	2	2	0	0	*2	Minor	0.03	2
15	5	0.63	5	1.0	5	0	0	5	5	0	5	1.0	0	5	3	5	3	5	5	5	5	5	3	5	3	5	5	5	3	5	5	High	49.04	2
16	5	0.49	5	1.0	5	0	0	5	5	0	5	1.0	5	5	3	5	3	5	5	5	5	5	3	5	3	5	5	5	3	5	5	High	88.59	2
18	4	0.07	4	0.5	4	0	0	4	0	0	4	0.0	0	4	2	0	0	4	5	4	4	4	2	0	0	4	5	4	2	0	5	High	7.34	2
19	5	0.51	5	1.0	5	0	0	5	5	4	5	1.5	5	5	3	5	4	5	5	5	5	5	3	5	4	5	5	5	3	5	5	High	127.83	2;5
20	4	0.50	4	1.0	5	3	1	5	5	4	5	1.0	0	5	4	5	0	5	5	5	5	5	4	5	0	5	5	5	4	5	5	High	102.62	1;2
21	3	0.66	3	0.0	0	0	0	3	0	0	3	0.0	0	0	3	0	0	3	3	3	3	0	3	0	0	3	3	3	3	0	3	Moderate	0.94	6
22	4	0.59	4	0.0	4	3	0	3	4	1	4	1.0	5	4	3	0	1	4	4	4	5	4	3	0	1	4	4	5	3	1	4	Major	10.84	1
23	1	0.74	2	0.0	0	0	0	2	0	0	1	0.0	0	0	0	0	0	2	2	2	1	0	0	0	0	2	2	2	0	0	*2	Minor	0.04	5
24	2	0.69	3	0.0	0	1	0	2	0	2	1	0.0	0	0	0	0	0	3	3	2	1	0	0	0	0	3	3	2	0	0	2	Minor	0.10	3
26	2	0.58	3	0.0	3	2	0	3	0	0	2	1.0	0	0	1	0	0	2	3	3	3	0	1	0	0	2	3	3	1	0	2	Minor	0.22	1
27	4	0.55	4	0.5	4	3	3	4	3	2	3	0.0	0	0	1	0	0	4	4	4	3	0	1	0	0	4	4	4	1	0	4	Major	0.55	1
28	2	0.68	2	0.5	3	0	1	2	0	0	1	0.0	0	0	1	0	0	3	3	3	1	0	1	0	0	3	3	3	1	0	2	Minor	0.02	3
29	2	0.68	3	0.0	2	0	0	1	0	2	1	0.0	0	0	2	0	1	3	3	2	1	0	2	0	1	3	3	2	2	1	3	Moderate	0.05	3
37	3	0.77	3	0.0	0	0	0	4	4	2	4	0.5	0	5	5	5	0	4	3	4	4	5	5	5	0	4	3	5	5	5	4	Major	30.08	6
38	2	0.77	2	0.0	0	0	0	3	0	3	3	0.0	0	5	5	5	0	3	2	3	3	5	5	5	0	3	2	5	5	5	4	Major	11.55	6
39	0	0.00	0	0.0	0	0	0	0	0	0	2	0.0	0	3	5	0	0	0	0	0	2	3	5	0	0	0	0	3	5	0	1	Insignificant	4.60	NA
40	3	0.77	3	0.0	0	0	0	3	3	2	3	0.0	0	5	5	5	1	3	3	3	3	5	5	5	1	3	3	5	5	5	4	Major	27.36	6;5
42	5	0.55	5	1.0	5	4	3	5	5	0	5	1.5	5	5	4	4	5	5	5	5	5	5	4	4	5	5	5	5	4	5	5	High	84.90	1
43	3	0.55	3	0.0	4	0	0	3	0	0	3	1.0	0	4	3	0	0	4	3	4	4	4	3	0	0	4	3	4	3	0	3	Moderate	7.94	1
44	4	0.52	4	0.5	4	0	0	3	0	2	3	0.0	0	0	2	0	0	4	4	4	3	0	2	0	0	4	4	4	2	0	3	Moderate	0.85	1
45	5	0.55	5	1.0	5	4	3	5	5	2	5	1.5	5	5	5	4	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	High	131.87	1
46	5	0.55	5	1.0	5	4	3	5	5	2	5	1.5	5	5	4	4	5	5	5	5	5	5	4	4	5	5	5	5	4	5	5	High	70.76	1
47	4	0.68	4	0.5	4	1	1	4	0	2	4	1.0	0	5	2	0	0	4	4	4	5	5	2	0	0	4	4	5	2	0	4	Major	26.92	4;1
48	2	0.77	2	0.0	0	0	0	3	0	0	3	0.0	0	5	5	5	0	3	2	3	3	5	5	5	0	3	2	5	5	5	4	Major	16.16	6
49	2	0.69	3	0.0	0	1	1	1	0	0	1	0.0	0	3	4	0	0	3	3	1	1	3	4	0	0	3	3	3	4	0	3	Moderate	0.58	3
51	4	0.78	4	1.0	4	3	3	4	0	0	4	0.0	0	2	3	3	0	5	5	4	4	2	3	3	0	5	5	4	3	3	5	High	2.35	3
52	2	0.58	3	0.5	0	3	2	3	3	0	3	0.0	0	0	3	0	0	3	3	3	3	0	3	0	0	3	3	3	3	0	*3	Moderate	0.04	5
53	3	0.55	3	0.0	3	2	1	2	0	0	2	0.5	0	0	2	0	0	3	3	3	2	0	2	0	0	3	3	3	2	0	*3	Moderate	0.11	6

Dike	Classification of Indicators and Modifiers																	Subordinate Factor Classification								Consequence Category					Overall		Area	Community
#	N.A.1.1	M.A.1.1	N.B.1.1	M.B.1.1	N.C.1.1	N.C.1.2	N.C.1.3	N.C.1.4	N.C.1.5	N.C.1.6	N.C.2.1	M.C.2.2	M.C.2.3	N.C.3.1	N.D.1.1	N.E.1.1	N.E.2.1	A.1	B.1	C.1	C.2	C.3	D.1	E.1	E.2	A	B	C	D	E	Classification		(km^2)	Archetype
54	3	0.55	3	0.0	3	0	0	2	2	0	2	0.0	0	0	2	0	0	3	3	3	2	0	2	0	0	3	3	3	2	0	3	Moderate	0.42	6
57	3	0.18	4	0.5	0	0	0	3	0	0	3	0.0	0	0	2	0	0	4	4	3	3	0	2	0	0	4	4	3	2	0	*3	Moderate	0.50	6
58	3	0.63	3	0.0	0	0	0	3	0	0	3	0.0	0	0	1	0	0	4	3	3	3	0	1	0	0	4	3	3	1	0	3	Moderate	0.34	6
60	3	0.21	3	0.5	0	0	0	3	0	0	2	0.0	0	0	2	0	0	4	4	3	2	0	2	0	0	4	4	3	2	0	3	Moderate	0.34	6
61	3	0.63	3	0.5	0	2	1	3	0	0	3	0.0	0	0	1	0	0	4	4	3	3	0	1	0	0	4	4	3	1	0	3	Moderate	0.14	6
62	1	0.66	1	0.0	0	0	0	0	1	0	0	0.0	0	0	0	0	0	2	1	1	0	0	0	0	0	2	1	1	0	0	*1	Insignificant	0.03	6
63	2	0.61	2	0.0	0	2	2	2	0	3	2	0.0	0	0	0	0	0	2	2	3	2	0	0	0	0	2	2	3	0	0	*2	Minor	0.13	6
65	3	0.60	3	0.0	0	0	0	3	2	0	3	0.5	0	4	0	0	0	3	3	3	3	4	0	0	0	3	3	4	0	0	3	Moderate	2.78	5
66	3	0.61	3	0.0	0	0	0	3	3	1	3	0.5	0	3	3	0	0	3	3	3	3	3	3	0	0	3	3	3	3	0	*3	Moderate	2.61	4
67	1	0.44	1	0.0	0	2	1	2	0	0	1	0.0	0	0	0	0	0	1	1	2	1	0	0	0	0	1	1	2	0	0	1	Insignificant	0.02	1
68	3	0.60	3	0.0	0	0	0	3	4	0	3	0.0	0	4	0	0	0	4	3	4	3	4	0	0	0	4	3	4	0	0	3	Moderate	9.36	1
69	3	0.77	2	0.0	0	0	0	3	1	2	2	0.0	0	0	3	0	0	3	2	3	2	0	3	0	0	3	2	3	3	0	*3	Moderate	1.27	6
71	4	0.62	4	1.0	0	0	0	4	3	0	4	1.0	5	0	3	0	0	5	5	4	5	0	3	0	0	5	5	5	3	0	*5	High	4.31	6
72	3	0.75	3	0.5	0	2	1	0	0	0	3	0.0	0	0	3	0	0	4	4	2	3	0	3	0	0	4	4	3	3	0	3	Moderate	0.11	6
73	3	0.75	3	0.0	0	0	0	2	2	0	3	0.0	0	0	3	0	0	4	3	2	3	0	3	0	0	4	3	3	3	0	3	Moderate	0.53	6
74	3	0.14	3	0.0	3	2	0	2	3	0	2	0.0	0	0	4	0	1	4	3	3	2	0	4	0	1	4	3	3	4	1	3	Moderate	2.41	1
75	2	0.76	2	0.0	0	2	0	1	0	0	1	0.0	0	0	2	0	0	3	2	2	1	0	2	0	0	3	2	2	2	0	2	Minor	0.06	7
76	4	0.67	4	0.5	0	0	0	4	4	0	4	0.5	0	4	4	0	0	4	4	4	4	4	4	0	0	4	4	4	4	0	4	Major	7.16	2
77	2	0.82	2	0.5	0	0	0	2	0	0	2	0.0	0	0	0	0	0	3	3	2	2	0	0	0	0	3	3	2	0	0	2	Minor	0.05	5
78	3	0.85	3	0.0	0	0	0	2	2	0	2	0.0	0	0	0	0	0	4	3	2	2	0	0	0	0	4	3	2	0	0	3	Moderate	0.18	5
79	3	0.84	3	0.0	0	0	0	3	0	0	2	0.0	0	0	1	0	0	4	3	3	2	0	1	0	0	4	3	3	1	0	3	Moderate	0.11	5
81	4	0.68	4	0.5	0	0	0	4	3	0	3	0.0	0	3	2	0	0	4	4	4	3	3	2	0	0	4	4	4	2	0	*4	Major	2.32	6
82	3	0.68	3	0.0	0	0	0	3	3	0	2	0.0	0	0	0	0	0	3	3	3	2	0	0	0	0	3	3	3	0	0	3	Moderate	0.54	6
83	3	0.68	2	0.0	0	0	0	3	0	0	2	0.0	0	0	2	0	0	3	2	3	2	0	2	0	0	3	2	3	2	0	3	Moderate	0.22	6
84	3	0.69	3	0.0	0	0	0	3	0	1	2	0.0	0	0	0	0	0	4	3	3	2	0	0	0	0	4	3	3	0	0	3	Moderate	0.54	6
85	2	0.65	2	0.0	0	2	2	0	0	0	1	0.0	0	0	0	0	0	2	2	2	1	0	0	0	0	2	2	2	0	0	*2	Minor	0.03	3
86	2	0.60	2	0.5	0	1	0	3	0	0	2	0.0	0	0	0	0	0	3	3	3	2	0	0	0	0	3	3	3	0	0	2	Minor	0.11	6
87	3	0.59	3	0.0	0	0	0	3	1	0	3	0.0	0	0	0	0	0	4	3	3	3	0	0	0	0	4	3	3	0	0	*3	Moderate	0.67	6
88	2	0.69	3	0.0	0	1	1	1	0	0	1	0.0	0	3	4	0	0	3	3	1	1	3	4	0	0	3	3	3	4	0	3	Moderate	0.58	3
90	4	0.78	4	0.5	4	2	2	4	0	2	3	0.0	0	0	3	0	0	5	4	4	3	0	3	0	0	5	4	4	3	0	5	High	0.78	2
91	3	0.69	3	0.5	3	1	1	3	0	0	2	0.0	0	0	1	0	0	4	4	3	2	0	1	0	0	4	4	3	1	0	3	Moderate	0.14	2
92	3	0.66	3	0.0	3	0	0	2	0	0	2	0.0	0	0	3	0	0	4	3	3	2	0	3	0	0	4	3	3	3	0	3	Moderate	0.17	2
93	3	0.66	3	0.0	3	0	0	2	0	0	1	0.0	0	0	3	0	0	3	3	3	1	0	3	0	0	3	3	3	3	0	3	Moderate	0.11	2
94	4	0.67	4	0.5	4	3	3	3	0	0	3	0.0	0	0	3	0	0	4	4	4	3	0	3	0	0	4	4	4	3	0	4	Major	0.80	2
95	3	0.64	3	0.0	2	0	0	2	0	0	2	0.0	0	0	0	0	0	3	3	2	2	0	0	0	0	3	3	2	0	0	2	Minor	0.25	2
96	2	0.74	3	0.5	2	0	0	2	0	0	1	0.0	0	0	2	0	0	3	3	2	1	0	2	0	0	3	3	2	2	0	3	Moderate	0.02	2
97	3	0.74	3	0.0	3	2	2	2	0	2	2	0.0	0	0	3	0	0	3	3	3	2	0	3	0	0	3	3	3	3	0	3	Moderate	0.10	2
98	3	0.74	3	0.0	3	2	2	2	0	0	2	0.0	0	0	3	0	0	3	3	3	2	0	3	0	0	3	3	3	3	0	3	Moderate	0.10	2
99	3	0.76	4	0.0	3	2	2	3	0	2	2	0.0	0	0	2	0	0	4	4	3	2	0	2	0	0	4	4	3	2	0	3	Moderate	0.17	2
100	3	0.68	3	0.5	4	0	0	3	0	0	3	0.0	5	0	3	0	1	4	4	4	5	0	3	0	1	4	4	5	3	1	4	Major	4.82	2
101	4	0.73	4	0.5	4	3	2	3	2	0	3	0.0	0	0	3	0	0	5	4	4	3	0	3	0	0	5	4	4	3	0	5	High	0.52	2
103	3	0.80	3	0.0	3	2	2	2	0	2	1	0.0	0	0	2	0	0	4	3	3	1	0	2	0	0	4	3	3	2	0	3	Moderate	0.06	2
104	3	0.68	3	0.0	4	0	0	3	0	1	2	0.0	0	4	3	0	0	3	3	4	2	4	3	0	0	3	3	4	3	0	3	Moderate	2.05	2
105	3	0.79	3	0.5	3	0	0	2	0	2	2	0.5	0	0	1	0	0	4	3	3	3	0	1	0	0	4	3	3	1	0	*3	Moderate	0.25	6

Dike	Classification of Indicators and Modifiers																	Subordinate Factor Classification								Consequence Category					Overall		Area	Community
#	N.A.1.1	M.A.1.1	N.B.1.1	M.B.1.1	N.C.1.1	N.C.1.2	N.C.1.3	N.C.1.4	N.C.1.5	N.C.1.6	N.C.2.1	M.C.2.2	M.C.2.3	N.C.3.1	N.D.1.1	N.E.1.1	N.E.2.1	A.1	B.1	C.1	C.2	C.3	D.1	E.1	E.2	A	B	C	D	E	Classification		(km^2)	Archetype
106	3	0.58	3	0.0	3	2	2	2	2	0	1	0.0	0	0	0	0	0	3	3	3	1	0	0	0	0	3	3	3	0	0	2	Minor	0.13	1
108	4	0.67	4	1.0	4	0	0	4	5	4	4	1.0	0	5	4	0	2	5	5	5	5	5	4	0	2	5	5	5	4	2	5	High	34.73	2
109	4	0.58	4	0.5	0	0	0	3	3	2	3	0.0	0	2	4	0	1	4	4	3	3	2	4	0	1	4	4	3	4	1	4	Major	1.21	5
111	3	0.77	3	0.0	0	0	0	3	2	1	3	0.0	0	0	3	0	0	4	3	3	3	0	3	0	0	4	3	3	3	0	3	Moderate	1.34	6
112	3	0.77	3	0.0	0	0	0	3	2	3	3	0.0	0	0	3	0	0	4	3	3	3	0	3	0	0	4	3	3	3	0	3	Moderate	1.34	6
113	3	0.77	3	0.0	0	0	0	3	2	0	3	0.0	0	0	3	0	0	4	3	3	3	0	3	0	0	4	3	3	3	0	3	Moderate	1.34	6
114	4	0.77	4	0.5	0	0	0	4	0	0	3	0.0	0	0	3	0	0	4	4	4	3	0	3	0	0	4	4	4	3	0	4	Major	1.64	6
115	2	0.83	2	0.0	0	0	0	2	0	0	1	0.0	0	0	0	0	0	3	2	2	1	0	0	0	0	3	2	2	0	0	2	Minor	0.62	4
117	4	0.57	4	0.0	0	1	0	3	4	0	3	0.0	0	4	0	0	2	4	4	4	3	4	0	0	2	4	4	4	0	2	3	Moderate	4.85	1
118	3	0.56	4	0.0	0	3	1	3	0	0	3	0.0	0	3	0	0	0	4	4	3	3	3	0	0	0	4	4	3	0	0	3	Moderate	2.13	1
119	3	0.82	3	0.5	0	0	0	3	3	0	3	0.5	0	0	3	0	0	4	3	3	3	0	3	0	0	4	3	3	3	0	*3	Moderate	0.76	6
123	2	0.65	2	0.0	0	0	0	1	0	0	0	0.0	0	0	0	0	0	3	2	1	0	0	0	0	0	3	2	1	0	0	2	Minor	0.01	4
124	3	0.64	3	0.0	0	1	0	2	0	0	2	0.5	0	2	0	0	0	4	3	2	2	2	0	0	0	4	3	2	0	0	3	Moderate	0.41	5
126	3	0.52	4	0.5	0	2	1	3	0	0	3	0.0	0	3	3	0	0	4	4	3	3	3	3	0	0	4	4	3	3	0	3	Moderate	1.65	1
128	3	0.52	4	0.5	0	2	1	3	0	0	3	0.0	0	3	3	0	0	4	4	3	3	3	3	0	0	4	4	3	3	0	3	Moderate	1.65	1
129	3	0.80	3	0.0	0	0	0	3	2	0	2	0.0	0	2	3	0	0	4	3	3	2	2	3	0	0	4	3	3	3	0	3	Moderate	0.35	6
130	3	0.80	3	0.0	0	0	1	3	0	0	2	0.0	0	1	3	0	0	4	3	3	2	1	3	0	0	4	3	3	3	0	3	Moderate	0.25	6
133	0	0.00	0	0.0	0	0	0	2	0	0	1	0.5	0	0	0	2	0	0	0	2	2	0	0	2	0	0	0	2	0	2	1	Insignificant	0.25	NA
134	3	0.79	4	0.5	4	2	0	3	3	4	3	1.5	0	3	0	0	0	4	4	4	5	3	0	0	0	4	4	5	0	0	4	Major	1.36	1
135	3	0.72	3	0.0	2	2	0	3	3	0	3	0.5	0	4	0	0	0	3	3	3	3	4	0	0	0	3	3	4	0	0	3	Moderate	2.19	1
136	3	0.59	3	0.0	4	0	0	3	3	0	3	1.0	0	4	3	0	1	4	3	4	4	4	3	0	1	4	3	4	3	1	3	Moderate	5.10	1
138	3	0.69	3	0.5	0	2	1	0	0	0	3	0.0	0	0	3	0	0	4	4	2	3	0	3	0	0	4	4	3	3	0	*3	Moderate	0.23	6
139	3	0.63	3	0.5	3	0	0	3	0	0	3	0.5	5	0	2	0	1	4	4	3	5	0	2	0	1	4	4	5	2	1	*4	Major	0.43	6
140	5	0.53	5	1.0	4	5	5	5	5	0	5	1.5	0	5	4	0	4	5	5	5	5	5	4	0	4	5	5	5	4	4	5	High	108.41	1
141	3	0.77	3	0.0	0	0	0	3	3	0	3	1.0	0	4	4	3	0	3	3	3	4	4	4	3	0	3	3	4	4	3	3	Moderate	8.62	6
142	3	0.77	3	0.0	0	0	0	3	3	3	3	1.0	0	4	4	3	0	3	3	3	4	4	4	3	0	3	3	4	4	3	3	Moderate	8.62	6
143	3	0.77	3	0.0	0	0	0	3	3	0	3	1.0	0	4	4	3	0	3	3	3	4	4	4	3	0	3	3	4	4	3	3	Moderate	8.62	6
144	3	0.70	4	0.5	0	0	0	4	0	0	4	0.0	0	5	3	4	0	4	4	4	4	5	3	4	0	4	4	5	3	4	4	Major	22.79	4
155	2	0.10	2	0.0	0	0	0	2	0	0	2	0.0	0	1	2	0	0	2	2	2	2	1	2	0	0	2	2	2	2	0	2	Minor	0.18	2
163	2	0.00	3	0.0	0	0	0	2	2	5	2	0.0	0	0	0	0	0	2	3	5	2	0	0	0	0	2	3	5	0	0	2	Minor	0.96	NA
164	3	0.62	3	0.0	0	0	0	3	0	0	2	0.0	0	0	2	0	0	3	3	3	2	0	2	0	0	3	3	3	2	0	3	Moderate	0.20	6
168	3	0.67	3	0.0	0	0	0	3	0	1	3	0.0	0	0	3	0	0	3	3	3	3	0	3	0	0	3	3	3	3	0	*3	Moderate	0.68	2
221	4	0.77	4	0.0	4	3	3	3	0	0	3	0.5	0	4	0	5	0	4	4	4	4	4	0	5	0	4	4	4	0	5	4	Major	3.73	3
222	2	0.46	2	0.0	3	2	2	2	0	0	1	0.0	0	0	1	0	0	3	2	3	1	0	1	0	0	3	2	3	1	0	2	Minor	0.05	1
223	3	0.70	3	0.0	0	0	0	2	0	0	2	0.0	0	0	0	2	0	3	3	2	2	0	0	2	0	3	3	2	0	2	3	Moderate	1.37	4
224	3	0.55	3	0.0	0	0	0	3	3	0	2	0.0	0	0	0	3	0	3	3	3	2	0	0	3	0	3	3	3	0	3	3	Moderate	1.08	7
228	1	0.68	2	0.0	0	0	0	1	0	0	0	0.0	0	3	0	0	0	2	2	1	0	3	0	0	0	2	2	3	0	0	2	Minor	0.58	4
230	2	0.00	2	0.0	0	0	0	3	0	0	3	0.5	0	4	3	0	0	2	2	3	3	4	3	0	0	2	2	4	3	0	2	Minor	3.26	NA
231	3	0.21	4	0.5	0	3	2	3	2	0	3	0.0	0	3	3	3	0	4	4	3	3	3	3	3	0	4	4	3	3	3	4	Major	3.81	6
232	4	0.08	4	0.5	4	4	3	4	4	0	4	0.5	5	4	3	0	0	4	5	4	5	4	3	0	0	4	5	5	3	0	*5	High	10.07	6
233	2	0.00	1	0.0	0	0	0	3	0	0	1	0.0	0	4	2	0	0	2	1	3	1	4	2	0	0	2	1	4	2	0	2	Minor	2.10	NA
235	4	0.15	4	0.5	1	4	3	3	4	2	3	0.5	0	3	3	0	0	4	4	4	4	3	3	0	0	4	4	4	3	0	4	Major	3.70	6
236	2	0.00	2	0.0	0	0	0	3	0	0	3	0.5	0	4	3	0	0	2	2	3	3	4	3	0	0	2	2	4	3	0	2	Minor	3.26	NA
238	3	0.00	2	0.0	0	3	2	3	0	0	2	0.0	0	3	0	0	0	3	2	3	2	3	0	0	0	3	2	3	0	0	*2	Minor	1.65	NA

Dike	Classification of Indicators and Modifiers																	Subordinate Factor Classification								Consequence Category					Overall		Area	Community
#	N.A.1.1	M.A.1.1	N.B.1.1	M.B.1.1	N.C.1.1	N.C.1.2	N.C.1.3	N.C.1.4	N.C.1.5	N.C.1.6	N.C.2.1	M.C.2.2	M.C.2.3	N.C.3.1	N.D.1.1	N.E.1.1	N.E.2.1	A.1	B.1	C.1	C.2	C.3	D.1	E.1	E.2	A	B	C	D	E	Classification		(km^2)	Archetype
239	2	0.00	3	0.0	0	2	1	2	2	0	2	0.0	0	0	2	0	0	2	3	2	2	0	2	0	0	2	3	2	2	0	*2	Minor	0.05	NA
240	4	0.15	4	0.5	0	4	3	4	4	0	3	0.5	0	3	3	0	0	4	4	4	4	3	3	0	0	4	4	4	3	0	*4	Major	3.65	6
241	2	0.00	2	0.0	0	2	0	3	0	0	2	0.0	0	3	0	0	0	2	2	3	2	3	0	0	0	2	2	3	0	0	2	Minor	1.29	NA
242	3	0.00	3	0.0	0	0	0	3	0	0	3	0.0	0	4	3	0	0	3	3	3	3	4	3	0	0	3	3	4	3	0	3	Moderate	8.51	NA
243	3	0.57	3	0.0	3	0	0	3	0	2	2	0.0	0	4	0	0	2	3	3	3	2	4	0	0	2	3	3	4	0	2	3	Moderate	4.96	1
244	4	0.58	5	0.5	5	4	4	4	4	0	5	0.5	5	5	3	3	3	5	5	5	5	5	3	3	3	5	5	5	3	3	5	High	36.39	1
245	3	0.56	3	0.0	4	2	1	3	4	2	4	0.0	0	4	5	0	3	3	3	4	4	4	5	0	3	3	3	4	5	3	4	Major	29.22	1
246	3	0.57	3	0.0	4	2	1	3	0	0	3	0.0	0	3	2	0	1	4	3	4	3	3	2	0	1	4	3	4	2	1	3	Moderate	4.73	1
247	3	0.87	3	0.0	0	1	1	3	0	0	2	0.0	0	2	2	3	0	4	3	3	2	2	2	3	0	4	3	3	2	3	*3	Moderate	0.54	3
248	2	0.87	3	0.0	0	0	0	2	0	1	1	0.0	0	0	0	0	0	3	3	2	1	0	0	0	0	3	3	2	0	0	*2	Minor	0.08	3
249	3	0.87	4	0.0	0	1	1	3	0	0	3	0.0	0	2	2	3	0	4	4	3	3	2	2	3	0	4	4	3	2	3	3	Moderate	0.98	3
251	3	0.77	3	0.5	0	0	0	3	0	1	3	0.0	5	0	2	0	0	4	4	3	5	0	2	0	0	4	4	5	2	0	*4	Major	0.60	6
252	4	0.56	4	0.5	5	4	3	4	4	0	4	0.0	0	0	3	4	0	5	5	5	4	0	3	4	0	5	5	5	3	4	5	High	2.62	1
253	4	0.54	5	1.0	5	4	4	4	4	0	4	1.0	0	2	3	0	1	5	5	5	5	2	3	0	1	5	5	5	3	1	5	High	10.30	1
254	4	0.79	4	0.5	0	3	2	3	3	3	3	0.0	0	0	3	0	0	5	4	3	3	0	3	0	0	5	4	3	3	0	5	High	0.85	2
256	1	0.71	1	0.0	0	0	0	0	0	4	0	0.0	0	0	1	0	0	1	1	4	0	0	1	0	0	1	1	4	1	0	2	Minor	0.00	5
257	0	0.71	1	0.0	0	0	0	0	0	3	0	0.0	0	0	1	0	0	1	1	3	0	0	1	0	0	1	1	3	1	0	1	Insignificant	0.00	5
258	3	0.71	3	0.0	0	0	0	3	0	4	3	0.0	0	0	3	0	0	4	3	4	3	0	3	0	0	4	3	4	3	0	3	Moderate	0.54	5
259	2	0.70	2	0.0	0	0	0	2	0	3	2	0.0	0	0	2	0	0	3	2	3	2	0	2	0	0	3	2	3	2	0	3	Moderate	0.05	5
260	2	0.71	2	0.0	0	0	0	2	0	0	2	0.0	0	0	3	0	0	3	2	2	2	0	3	0	0	3	2	2	3	0	2	Minor	0.09	5
264	3	0.79	3	0.5	3	2	1	3	0	0	2	0.0	0	0	2	0	2	4	4	3	2	0	2	0	2	4	4	3	2	2	3	Moderate	0.27	3
266	3	0.76	3	0.0	0	0	0	3	3	0	3	0.0	0	5	5	0	0	4	3	3	3	5	5	0	0	4	3	5	5	0	4	Major	28.73	6
267	3	0.76	3	0.0	0	0	0	3	3	0	3	0.0	0	5	5	0	0	4	3	3	3	5	5	0	0	4	3	5	5	0	4	Major	28.73	6
268	3	0.76	3	0.0	0	0	0	3	3	0	3	0.0	0	5	5	0	0	4	3	3	3	5	5	0	0	4	3	5	5	0	4	Major	28.73	6
269	3	0.63	3	0.0	0	0	0	1	0	0	1	0.0	0	0	2	0	0	3	3	1	1	0	2	0	0	3	3	1	2	0	*2	Minor	0.19	6
271	5	0.53	5	1.0	4	5	5	5	5	0	5	1.5	0	5	4	0	4	5	5	5	5	5	4	0	4	5	5	5	4	4	5	High	108.41	1
276	2	0.76	2	0.0	0	0	0	2	2	5	2	0.0	0	0	1	0	0	3	2	5	2	0	1	0	0	3	2	5	1	0	3	Moderate	0.05	6
277	3	0.63	3	0.5	3	0	0	3	3	5	3	0.5	0	0	3	0	0	4	4	5	4	0	3	0	0	4	4	5	3	0	*4	Major	0.80	6
278	3	0.63	3	0.5	0	0	0	3	0	5	2	0.5	0	0	2	0	0	3	4	5	3	0	2	0	0	3	4	5	2	0	*3	Moderate	0.17	6;7
281	3	0.55	3	0.0	0	0	0	3	3	5	2	0.0	0	0	0	3	0	3	3	5	2	0	0	3	0	3	3	5	0	3	*3	Moderate	1.08	7;3
282	0	0.00	0	0.0	0	0	0	2	2	0	2	0.0	0	0	2	0	0	0	0	2	2	0	2	0	0	0	0	2	2	0	*1	Insignificant	0.23	NA
283	4	0.56	4	0.5	4	3	2	3	0	0	3	0.0	0	0	2	0	0	4	4	4	3	0	2	0	0	4	4	4	2	0	4	Major	0.51	3
284	4	0.56	4	1.0	4	4	4	4	4	5	4	1.0	0	0	3	1	0	5	5	5	5	0	3	1	0	5	5	5	3	1	5	High	6.24	3
285	4	0.56	4	1.0	5	4	4	4	4	5	4	1.0	0	0	4	3	0	5	5	5	5	0	4	3	0	5	5	5	4	3	5	High	8.74	3
286	4	0.55	4	0.5	4	3	1	3	2	5	3	0.0	0	0	2	0	0	4	4	5	3	0	2	0	0	4	4	5	2	0	*4	Major	0.85	3
287	1	0.85	1	0.0	0	0	0	2	0	4	1	0.0	0	0	1	0	0	2	1	4	1	0	1	0	0	2	1	4	1	0	*2	Minor	0.15	6
288	2	0.61	2	0.0	3	0	0	2	0	4	2	0.0	0	0	0	0	0	2	2	4	2	0	0	0	0	2	2	4	0	0	*2	Minor	0.11	4
289	2	0.00	2	0.0	0	0	0	2	0	4	1	0.0	0	0	0	0	0	2	2	4	1	0	0	0	0	2	2	4	0	0	*2	Minor	0.09	NA
290	3	0.68	3	0.5	0	0	0	4	3	5	4	0.5	5	0	3	0	0	4	4	5	5	0	3	0	0	4	4	5	3	0	*4	Major	2.72	7
291	3	0.55	3	0.5	0	3	3	2	0	0	3	0.0	0	3	4	0	1	4	4	3	3	3	4	0	1	4	4	3	4	1	*3	Moderate	1.54	4
292	2	0.55	2	0.0	0	0	0	2	0	4	2	0.0	0	0	1	0	0	2	2	4	2	0	1	0	0	2	2	4	1	0	*2	Minor	0.11	5
293	4	0.60	5	0.0	5	4	3	4	5	0	4	1.5	5	5	4	0	3	5	5	5	5	5	4	0	3	5	5	5	4	3	5	High	58.48	1
294	3	0.48	3	0.5	4	2	1	3	0	0	3	0.0	0	1	2	0	5	4	4	4	3	1	2	0	5	4	4	4	2	5	4	Major	0.48	1
295	4	0.59	4	0.0	4	3	0	3	4	0	4	1.0	5	4	3	0	1	4	4	4	5	4	3	0	1	4	4	5	3	1	4	Major	10.84	1

Dike #	Classification of Indicators and Modifiers																	Subordinate Factor Classification								Consequence Category					Overall Classification		Area (km^2)	Community Archetype
	N.A.1.1	M.A.1.1	N.B.1.1	M.B.1.1	N.C.1.1	N.C.1.2	N.C.1.3	N.C.1.4	N.C.1.5	N.C.1.6	N.C.2.1	M.C.2.2	M.C.2.3	N.C.3.1	N.D.1.1	N.E.1.1	N.E.2.1	A.1	B.1	C.1	C.2	C.3	D.1	E.1	E.2	A	B	C	D	E				
296	4	0.72	4	0.5	5	4	2	4	0	0	4	1.5	0	0	2	0	3	5	5	5	5	0	2	0	3	5	5	5	2	3	5	High	4.95	1
297	4	0.59	4	0.0	4	3	0	3	4	2	4	1.0	5	4	3	0	1	4	4	4	5	4	3	0	1	4	4	5	3	1	4	Major	10.84	1
298	2	0.67	2	0.0	0	0	0	3	0	2	2	0.0	0	0	0	0	0	3	2	3	2	0	0	0	0	3	2	3	0	0	2	Minor	0.16	5
299	1	0.00	2	0.0	0	0	0	2	0	4	1	0.0	0	0	2	0	0	1	2	4	1	0	2	0	0	1	2	4	2	0	2	Minor	0.06	NA
300	2	0.69	2	0.0	0	0	0	2	0	0	2	0.5	0	0	0	0	0	3	2	2	2	0	0	0	0	3	2	2	0	0	2	Minor	0.05	6
302	3	0.69	3	0.5	0	0	0	2	0	4	2	0.0	0	0	3	0	0	3	3	4	2	0	3	0	0	3	3	4	3	0	3	Moderate	0.15	6
303	3	0.69	3	0.0	0	0	0	3	0	0	2	0.0	0	0	3	0	0	4	3	3	2	0	3	0	0	4	3	3	3	0	3	Moderate	0.40	6
304	3	0.59	3	0.5	0	3	2	4	0	5	3	0.0	0	0	4	0	0	4	4	5	3	0	4	0	0	4	4	5	4	0	*4	Major	3.32	6
306	2	0.58	2	0.0	0	0	0	3	0	5	2	0.0	0	0	0	0	0	3	2	5	2	0	0	0	0	3	2	5	0	0	*3	Moderate	0.28	5
307	3	0.51	3	0.0	0	1	0	3	0	5	3	0.0	0	3	0	0	0	3	3	5	3	3	0	0	0	3	3	5	0	0	3	Moderate	1.81	1
309	2	0.82	2	0.5	0	0	0	3	0	4	3	0.0	0	0	3	0	0	3	3	4	3	0	3	0	0	3	3	4	3	0	*3	Moderate	0.28	5
311	3	0.58	3	0.5	0	2	1	2	0	0	2	0.0	0	0	1	0	0	3	3	2	2	0	1	0	0	3	3	2	1	0	*3	Moderate	0.12	5
312	3	0.58	3	0.5	0	3	2	3	0	5	2	0.0	0	0	3	0	0	3	3	5	2	0	3	0	0	3	3	5	3	0	*3	Moderate	0.22	5
313	3	0.57	3	0.0	0	3	3	3	3	0	3	0.5	0	0	1	0	0	4	3	3	3	0	1	0	0	4	3	3	1	0	*3	Moderate	0.54	5
314	3	0.57	4	0.5	0	4	3	3	0	5	3	0.5	5	0	1	0	0	4	4	5	5	0	1	0	0	4	4	5	1	0	*4	Major	0.62	5
315	2	0.57	2	0.0	0	2	2	2	0	5	1	0.0	0	0	0	0	0	3	2	5	1	0	0	0	0	3	2	5	0	0	3	Moderate	0.03	5
316	1	0.58	0	0.0	0	2	0	1	0	3	0	0.0	0	0	0	0	0	1	0	3	0	0	0	0	0	1	0	3	0	0	*1	Insignificant	0.01	5
317	2	0.00	2	0.5	0	0	0	2	0	0	1	0.0	0	0	1	0	0	2	3	2	1	0	1	0	0	2	3	2	1	0	2	Minor	0.03	NA
318	2	0.00	2	0.5	0	0	0	2	0	3	2	0.0	0	0	0	0	0	2	3	3	2	0	0	0	0	2	3	3	0	0	2	Minor	0.15	NA
321	2	0.63	2	0.0	0	0	0	1	0	2	1	0.0	0	0	0	0	0	2	2	2	1	0	0	0	0	2	2	2	0	0	*2	Minor	0.02	6
324	3	0.59	3	0.0	0	3	2	3	0	0	3	0.5	0	0	1	0	0	4	3	3	3	0	1	0	0	4	3	3	1	0	*3	Moderate	0.29	5
328	3	0.56	3	0.0	4	2	1	3	4	0	4	0.0	0	4	5	0	3	3	3	4	4	4	5	0	3	3	3	4	5	3	4	Major	29.22	1
330	3	0.58	3	0.0	0	2	2	3	2	0	3	0.0	0	0	3	0	0	3	3	3	3	0	3	0	0	3	3	3	3	0	*3	Moderate	0.10	5
338	2	0.67	2	0.0	0	0	0	2	0	0	2	0.0	0	0	0	0	0	2	2	2	2	0	0	0	0	2	2	2	0	0	*2	Minor	0.13	3
340	3	0.71	3	0.0	0	3	2	3	0	0	2	0.0	0	0	3	0	0	3	3	3	2	0	3	0	0	3	3	3	3	0	*3	Moderate	0.15	6
352	0	0.00	0	0.0	0	0	0	2	1	0	2	0.0	0	0	2	0	0	0	0	2	2	0	2	0	0	0	0	2	2	0	*1	Insignificant	0.15	NA
356	3	0.00	3	0.0	0	0	0	0	2	0	1	0.0	0	0	0	0	0	3	3	2	1	0	0	0	0	3	3	2	0	0	*2	Minor	0.18	NA
360	3	0.42	3	0.0	0	2	1	2	0	0	2	0.0	0	0	3	0	0	3	3	2	2	0	3	0	0	3	3	2	3	0	3	Moderate	0.88	6
364	3	0.67	2	0.5	0	0	0	2	0	0	1	0.0	0	0	2	0	0	3	3	2	1	0	2	0	0	3	3	2	2	0	3	Moderate	0.12	5
365	4	0.58	4	0.5	4	4	2	4	4	4	4	0.0	5	3	3	0	0	4	5	4	5	3	3	0	0	4	5	5	3	0	5	High	6.62	1
366	3	0.48	3	0.0	2	2	1	2	0	0	1	0.0	0	0	1	0	0	4	3	2	1	0	1	0	0	4	3	2	1	0	3	Moderate	0.21	1
368	2	0.66	2	0.0	0	0	0	2	0	0	2	0.0	0	0	2	1	0	3	2	2	2	0	2	1	0	3	2	2	2	1	*2	Minor	0.11	2
376	4	0.78	4	1.0	4	3	3	4	0	0	4	0.0	0	2	3	3	0	5	5	4	4	2	3	3	0	5	5	4	3	3	5	High	2.35	3
377	4	0.78	4	1.0	4	3	3	4	0	0	4	0.0	0	2	3	3	0	5	5	4	4	2	3	3	0	5	5	4	3	3	5	High	2.35	3
379	3	0.71	3	0.0	0	0	0	3	0	0	2	0.0	0	0	2	5	1	4	3	3	2	0	2	5	1	4	3	3	2	5	*3	Moderate	2.47	5;4
380	2	0.67	3	0.0	0	0	0	3	0	0	3	0.0	0	0	2	0	1	3	3	3	3	0	2	0	1	3	3	3	2	1	*3	Moderate	0.46	4
381	2	0.63	3	0.0	3	0	0	2	0	0	3	0.0	0	2	0	0	0	3	3	3	3	2	0	0	0	3	3	3	0	0	3	Moderate	0.42	2
382	4	0.67	4	0.5	4	0	0	4	4	0	4	1.0	0	5	4	0	1	5	5	4	5	5	4	0	1	5	5	5	4	1	5	High	30.82	2
383	4	0.67	4	0.5	2	0	0	4	4	0	4	1.0	0	5	4	0	1	5	5	4	5	5	4	0	1	5	5	5	4	1	5	High	25.12	2
384	3	0.67	3	0.5	0	0	0	3	0	3	3	0.0	0	4	2	4	0	4	4	3	3	4	2	4	0	4	4	4	2	4	4	Major	4.73	2
386	5	0.55	5	1.0	5	4	3	5	5	0	5	1.5	5	5	4	4	5	5	5	5	5	5	4	4	5	5	5	5	4	5	5	High	70.76	1
387	5	0.55	5	1.0	5	4	3	5	5	0	5	1.5	5	5	4	4	5	5	5	5	5	5	4	4	5	5	5	5	4	5	5	High	70.76	1
388	5	0.55	5	1.0	5	4	3	5	5	0	5	1.5	5	5	4	4	5	5	5	5	5	5	4	4	5	5	5	5	4	5	5	High	70.76	1

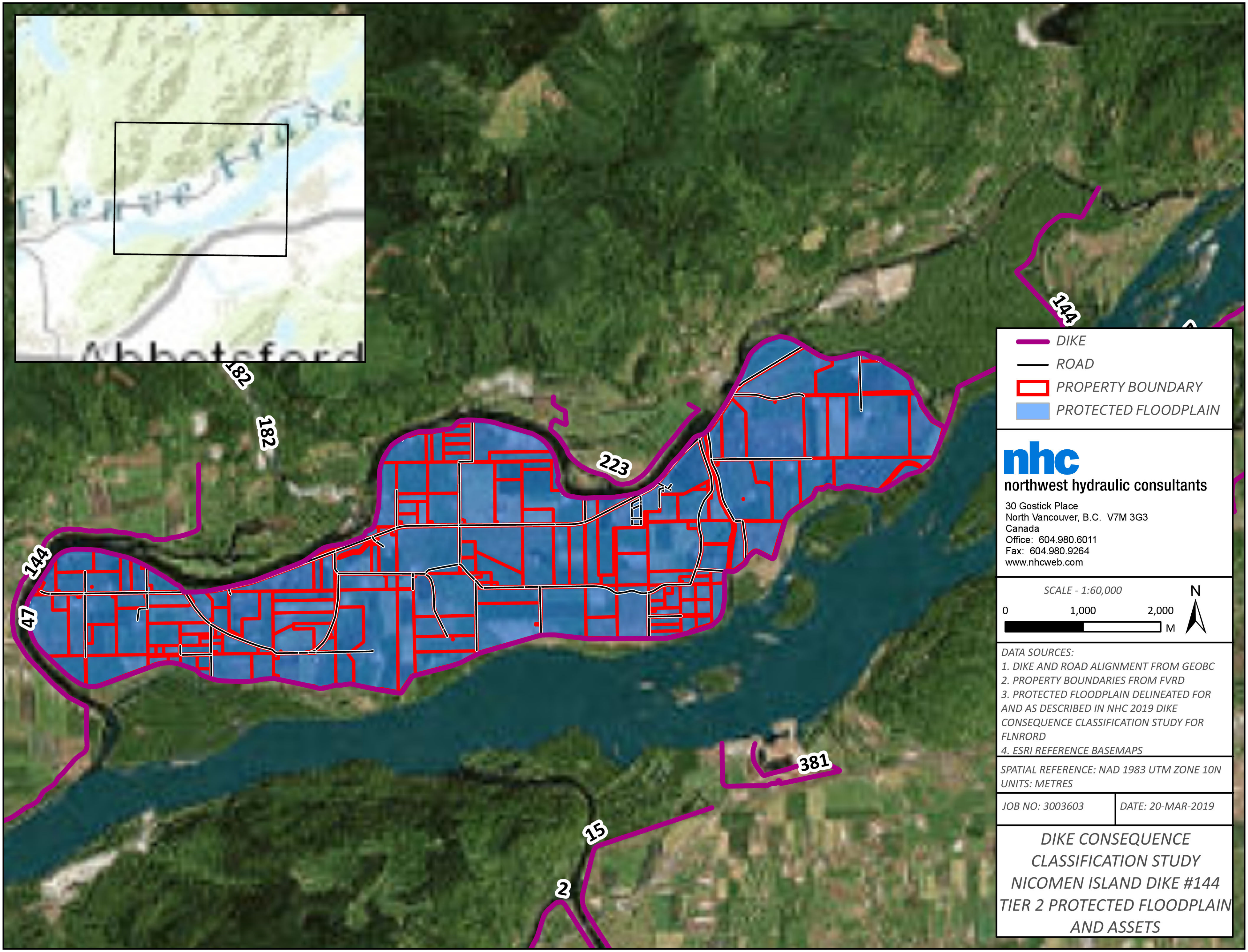
APPENDIX H: TIER 2 DETAILED METHODS AND RESULTS

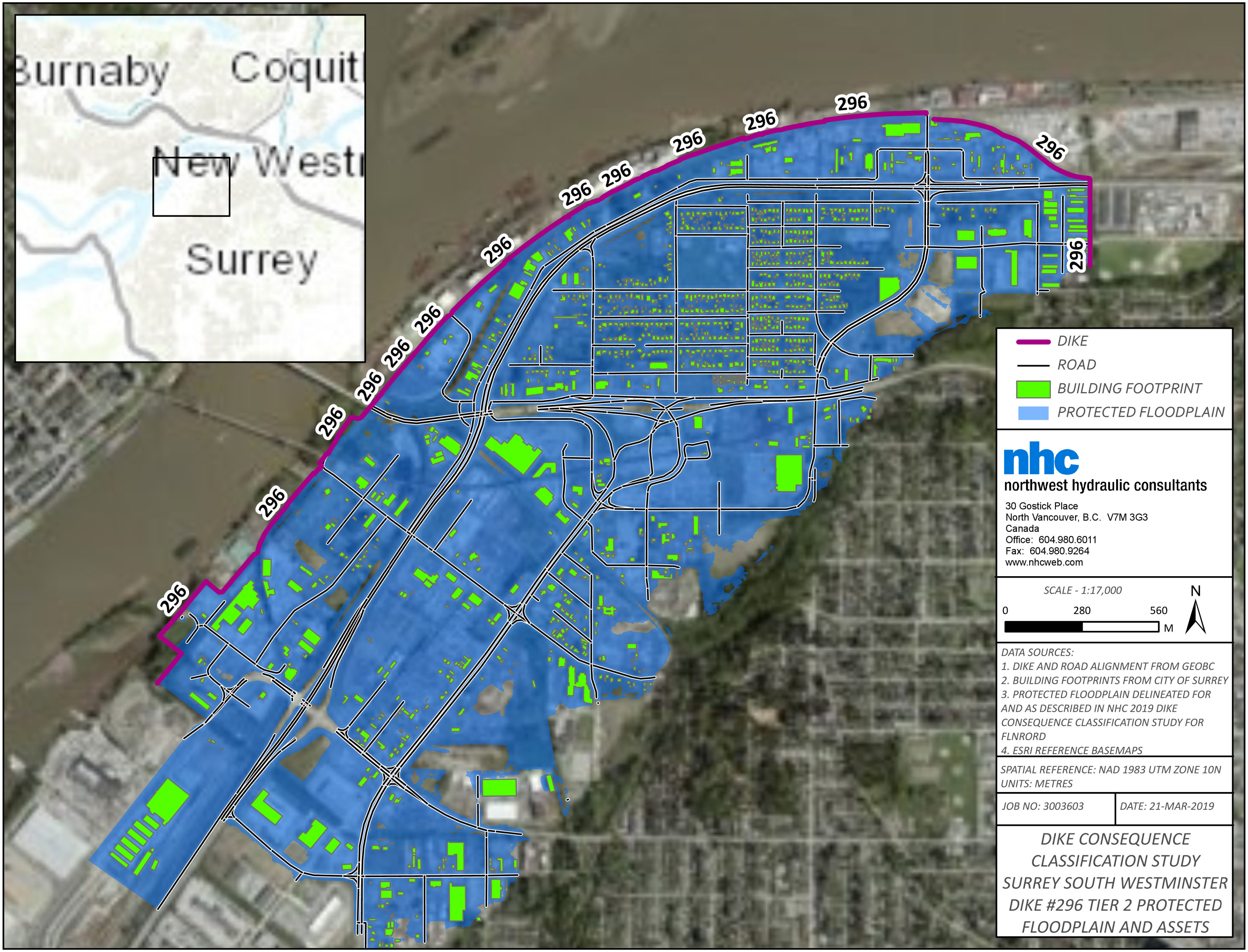
TABLE OF CONTENTS

LIST OF TABLES

1 MAPS OF TIER 2 AREAS

Maps showing the Tier 2 protected areas are provided on the following pages. These maps show the dike, protected floodplain, and roads and building footprints or property boundaries within the protected floodplain.


144
182
182
223
144
47
381
15
2
DIKE
ROAD
PROPERTY BOUNDARY
PROTECTED FLOODPLAIN
nhc
northwest hydraulic consultants
30 Gostick Place
North Vancouver, B.C. V7M 3G3
Canada
Office: 604.980.6011
Fax: 604.980.9264
www.nhcweb.com
SCALE - 1:60,000
0
1,000
2,000
M
N
DATA SOURCES:
1. DIKE AND ROAD ALIGNMENT FROM GEOBC
2. PROPERTY BOUNDARIES FROM FVRD
3. PROTECTED FLOODPLAIN DELINEATED FOR AND AS DESCRIBED IN NHC 2019 DIKE CONSEQUENCE CLASSIFICATION STUDY FOR FLNRORD
4. ESRI REFERENCE BASEMAPS
SPATIAL REFERENCE: NAD 1983 UTM ZONE 10N
UNITS: METRES
JOB NO: 3003603
DATE: 20-MAR-2019
DIKE CONSEQUENCE CLASSIFICATION STUDY
NICOMEN ISLAND DIKE #144
TIER 2 PROTECTED FLOODPLAIN AND ASSETS



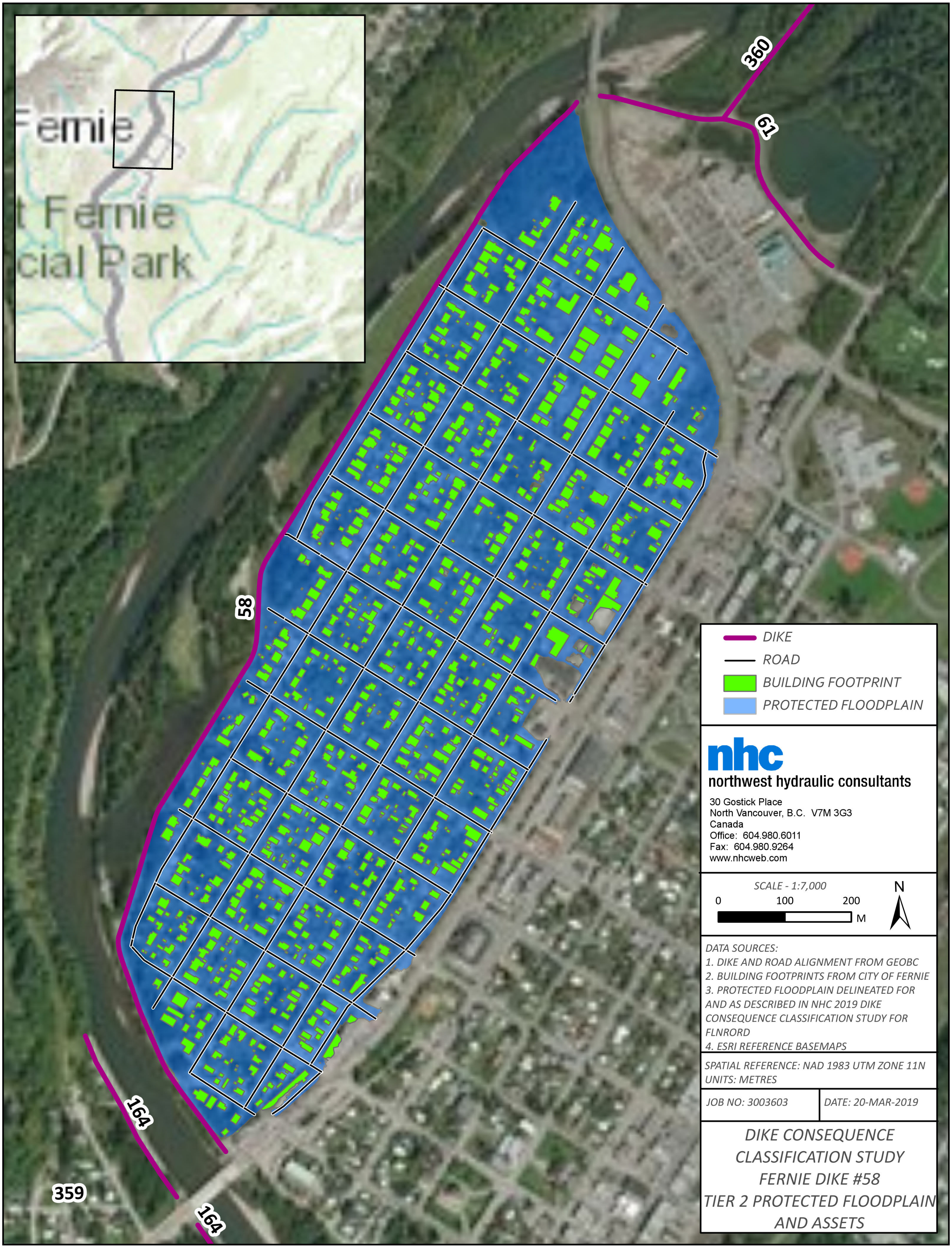
nhc
northwest hydraulic consultants
30 Gostick Place
North Vancouver, B.C. V7M 3G3
Canada
Office: 604.980.6011
Fax: 604.980.9264
www.nhcweb.com

DATA SOURCES:
1. DIKE AND ROAD ALIGNMENT FROM GEOBC
2. BUILDING FOOTPRINTS FROM CITY OF SURREY
3. PROTECTED FLOODPLAIN DELINEATED FOR AND AS DESCRIBED IN NHC 2019 DIKE CONSEQUENCE CLASSIFICATION STUDY FOR FLNRORD
4. ESRI REFERENCE BASEMAPS

SPATIAL REFERENCE: NAD 1983 UTM ZONE 10N
UNITS: METRES

JOB NO: 3003603 | DATE: 21-MAR-2019

DIKE CONSEQUENCE CLASSIFICATION STUDY
SURREY SOUTH WESTMINSTER
DIKE #296 TIER 2 PROTECTED FLOODPLAIN AND ASSETS



Fernie
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360
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58
164
359
164
DIKE
ROAD
BUILDING FOOTPRINT
PROTECTED FLOODPLAIN
nhc
northwest hydraulic consultants
30 Gostick Place
North Vancouver, B.C. V7M 3G3
Canada
Office: 604.980.6011
Fax: 604.980.9264
www.nhcweb.com
SCALE - 1:7,000
0 100 200
M
N
DATA SOURCES:
1. DIKE AND ROAD ALIGNMENT FROM GEOBC
2. BUILDING FOOTPRINTS FROM CITY OF FERNIE
3. PROTECTED FLOODPLAIN DELINEATED FOR AND AS DESCRIBED IN NHC 2019 DIKE CONSEQUENCE CLASSIFICATION STUDY FOR FLNRORD
4. ESRI REFERENCE BASEMAPS
SPATIAL REFERENCE: NAD 1983 UTM ZONE 11N
UNITS: METRES
JOB NO: 3003603
DATE: 20-MAR-2019
DIKE CONSEQUENCE CLASSIFICATION STUDY
FERNIE DIKE #58
TIER 2 PROTECTED FLOODPLAIN AND ASSETS

2 ESTIMATING IMPACT TO A - PEOPLE

For this study, the impact to people is calculated based on the direct impacts; i.e., number of fatalities and injuries. Analysis was restricted to these impacts due to limitations of established methodologies and absence of consultation. Future analysis could include consideration of: direct impacts to mental health; indirect impacts such as impact to household financial situation or loss of rental income due to displacement; and interdependencies with the local economy such as the impact to the population of temporary or permanent lob loss.

Table App-H- 2-1 Subordinate factors and indicators for consequence category A - People

Subordinate Factor	Indicators	
	Direct Impacts	Indirect Impacts
A.1 People	- Number of fatalities - Number of physical injuries - Number of people displaced	

2.1 A.1 People Subordinate Factor

Table App-H- 2-2 Indicators for A.1 People subordinate factor

Indicators	
Direct Impacts	Indirect Impacts
- Number of fatalities - Number of physical injuries - Number of people displaced	

The direct impacts are estimated based on the Flood Risks to People methodology developed by the United Kingdom's Department for Environment, Food and Rural Affairs (HR Wallingford et al., 2006). This method bases the flood risk to people on a combination of hazard, area vulnerability and people vulnerability. For this assessment, the flood hazard (depth and velocity values) is based on the flood model results, not a dike breach analysis. A dike breach would have similar characteristics to a severe hazard event including lower warning times and higher velocities. For future study, a dike breach model could be used to refine the consequence assessment or the flood hazard can be estimated as a function of distance behind a dike through a function based on distance from the dike and the head[1] level at the

[1] Head level refers to the water level above the crest of the dike or the water level above the floodplain.

defence (HR Wallingford et al., 2006). A dike breach approach was not used for this project as no applicable models were available.

Fatalities were calculated based for the protected floodplains analyzed based on settled areas as defined by NRCan's SVI polygons (See Box 1 in the report body). Fatalities (N_f) are calculated as a portion of people injured (N_{inj}) based on the flood hazard rating (HR) using the following equation:

$$N_f = 2 * N_{inj} * HR/100$$

The number of people injured is calculated based on: the number of people exposed (N_z); the flood hazard rating (HR); the area vulnerability (AV); and the people vulnerability (Y) using the following equation:

$$N_{inj} = 2 * N_z * HR * AV/100 * Y$$

By substituting the equation for the number of people injured into the above equation for the number of fatalities, the following equation for the number of fatalities can be derived:

$$N_f = 2 * (2 * N_z * HR * AV/100 * Y) * HR/100$$

Flood hazard rating (HR) was determined based on: the average depth (d) in each settled area polygon; an assumed velocity (v) for each flood; and a debris factor (DF) based on land use, flood depth and flood velocity. The equation for flood hazard is:

$$HR = d * (v + 0.5) + DF$$

Area vulnerability was assessed through the following factors, all scored out of three: speed of onset; the nature of the area; and the flood warning. The speed of onset is assumed based on flood characteristics. The nature of the area is estimated based on the land use. The flood warning is calculated by combining three factors: the percentage of warning coverage target met (P1), the percentage of warning time target met (P2), the percentage of effective action target met (P3). The equation for flood warning is: flood warning = 3 – (P1 x (P2 + P3)). The equation for area vulnerability is as follows:

$$AV = speed\ of\ onset + nature\ of\ area + flood\ warning$$

The people vulnerability (Y) is based on the portion of the population above 75 (Factor 1) and the portion of the population with a limiting long-term illness and/or disability (Factor 2). The people vulnerability is calculated with the following equation:

$$Y = Factor\ 1 + Factor\ 2$$

The results and assumed values are presented in Table App-H- 2-3. An average depth for each SAUID[2] was determined. Velocities were based on average velocities in the protected floodplains gathered from

[2] Settled Area as determined by NRCAN's social vulnerability index model (see Box 1 in the main report).

models NHC has run in each location (NHC, 2019a, 2019b). The debris factor was based on the range of depths and estimated velocities for the protected floodplains based on the Table 3.1 in the methodology document (HR Wallingford et al., 2006). The hazard rating was then calculated for each SAUID.

Values used to calculate area vulnerability were based on the descriptions provided in Table 4.4 in the methodology (HR Wallingford et al., 2006). For all protected floodplains, the speed of onset was designated a '1 - low risk area' as the 'onset of flooding is very gradual (many hours).' For the Surrey South Westminster Dike and the Fernie Dike, the nature of area was designated as a '2 – medium risk area' as it is a 'typical residential area (2-storey homes); commercial and industrial properties.' The nature of area for the Nicomen Island Dike was designated as a '3 – high risk area' as it better fit the profile of having 'bungalows, mobile homes, busy roads, parks, single storey schools, campsites, etc..' The flood warning was calculated based on a warning coverage target met (P1) of 100%, a warning time target met (P2) of 100%, and an effective action target met (P3) of 48%. The warning percentages are based on the significant warning time expected and the anticipated level of emergency response. The percentage that the effective action target is met, or the portion of the evacuation goal which evacuates was chosen to be the same as the UK values (which are consistent across all regions) (Table 4.3 in HR Wallingford et al., 2006). The UK has a goal of 75% evacuation, and has data which shows that 36% of the population takes effective action (0.36 * 0.75 = 0.48). As no comparative Canadian or BC stat is known, 48% was used to represent the rate at which the effective action target would be met. These values were used to calculate a flood warning and area vulnerability score for each protected floodplain.

The portion of the population above the age of 75 was determined with census profiles of the aggregate dissemination area that the study area was located within (Statistics Canada, 2016a, 2016b, 2016c). The 'Not Healthy' factor from the NRCan SVI was used for each SAUID as a proxy for the percentage of people with a limiting illness in the absence of available health data (see report body Section 3.2). While the 'Not Healthy' factor is not a direct percentage of the population with a limiting illness, the 'Not Healthy' values for the case studies ranged from 0.05 to 0.25, which align with percentages of the population with a limiting illness shown in the case studies in the Flood Risks to People methodology.

Project reviewers believe the actual number of injuries and fatalities may differ significantly from the above estimate. Further exploration of BC-specific input values and assumptions is needed, as well as a calibration of this model with a local event.

Table App-H- 2-3 Values used to calculate injuries and fatalities to people

Factor	Nicomen Island Dike (#144)	Surrey South Westminster Dike (#296)	Fernie Dike (#58)
Depth, average m(d)	Varies by SAUID		
Velocity, m/s (v)	2.5	2.3	3.0
Debris factor (DF)	0.5	1.0	1.0
Hazard rating (HR)	Varies by SAUID		
Speed of onset	1	1	1
Nature of the area	3	2	2
Warning coverage target met, %(P1)	100	100	100
Warning time target met, % (P2)	100	100	100
Effective action target met, % (P3)	48	48	48
Flood warning	1.52	1.52	1.52
Area vulnerability (AV)	5.52	4.52	4.52
Total population exposed, # (N_z)	660	2160	760
Population above 75, % (Factor 1)	0.12	0.05	0.06
Population with a limiting long-term illness (and/or disability), % (Factor 2)	Varies by SAUID		
People vulnerability (Y)	Varies by SAUID		
Total injuries, # (N_{inj})	190 (30%)	350 (16%)	110 (14%)
Total fatalities, # (N_f)	50 (8%)	50 (2%)	10 (1%)

3 ESTIMATING IMPACT TO B - ECONOMY - BUILDING

For this study, the impact to the economy is calculated based on a series of direct and indirect impacts as outlined in Table App-H- 3-2. Analysis was restricted to these impacts due to limitations of data, established methodologies and absence of consultation. Thorough economic analysis was not completed for this project due to a lack of regional economic information. Loss of function was estimated using rough relationships between costs of damage and loss of function.

Table App-H- 3-1 Subordinate factors and indicators for consequence category B Economy - Building

Indicator	
Direct Impacts	**Indirect Impacts**
- Damage to residential building structures - Damage to residential building contents - Damage to commercial building structures - Damage to commercial building contents - Damage to industrial building structures - Damage to industrial building contents - Damage to institutional building structures - Damage to institutional building contents - Damage to agricultural building structures - Damage to agricultural building contents	- Loss of residential building function - Loss of commercial building function - Loss of industrial building function

3.1 B.1 Economy - Building Subordinate Factor

Impacts which comprise the B.1 Economy - Building subordinate factor are outlined in Table App-H- 3-2.

Table App-H- 3-2 Indicators of B.1 Economy - Building impact subordinate factor

Subordinate Factor	Indicator	
	Direct Impacts	**Indirect Impacts**
B.1 Economy - building	- Damage to residential building structures - Damage to residential building contents - Damage to commercial building structures - Damage to commercial building contents - Damage to industrial building structures - Damage to industrial building contents - Damage to institutional building structures - Damage to institutional building contents - Damage to agricultural building structures - Damage to agricultural building contents	- Loss of residential building function - Loss of commercial building function - Loss of industrial building function

3.1.1 Residential Building Impacts

Residential indicators which are included in the B.1 Economy – Building subordinate factor are outlined in Table App-H- 3-3.

Table App-H- 3-3 Residential building indicators

Direct Impacts	Indirect Impacts
- Damage to residential building structures - Damage to residential building contents	- Loss of residential building function

Damage to Building Structure and Contents

Damage to building structures are calculated using depth damage curves. Hazus depth-damage curves which indicate damage based on a percentage of assessed value were used as there are no consistent footprint areas available (required for PFDAS curves as developed for the PFDAT and included in NRCan's reference materials). Property values were based on assessment data, and contents values were estimated as a percentage of the structure value based on a relationship identified in Hazus (FEMA, n.d.). As all assessed values are in 2018 dollars, no inflation adjustments were required.

Area-wide damage assessments such as those performed here are not typically based on a building-by-building assessment but on generalized building stock data due to lack of available information. Accordingly, this assessment was based on property assessment and zoning data. The residential buildings protected by each dike were determined by overlaying building footprints, zoning information and property assessment information. Where no building footprints were available, the assessed lot boundaries were used. Through this overlay, residential properties were identified and verified by a desktop study. A building structure value was assigned to each residential building or property identified, with value being divided equally when multiple buildings were located in an assessment area. Finally, the central point for each building footprint or property assessment area was identified. The contents value was estimated to be equal to 50% of the building value based on a reference guide for contents of commercial structures provided in Table 14.6 in the Hazus-MH Technical Manual (FEMA, n.d.). As no building-specific structure data was available, assumptions were made about standard residence characteristics to select residential damage curves for structure and contents. Houses were assumed to be two floors and include a basement. The Hazus curves from the US Federal Insurance and Mitigation Administration (FIA or FIMA) modified to include a basement and account for riverine (A-Zone) as opposed to coastal flooding were used for all residential structures. These curves described as 'two floors, w/basement, structure A-Zone – number 25' and 'two floors, w/basement, structure A-Zone – number 108' were used for all residential structures.

The dataset, flood depth information and curves were imported into and processed with Flood Modeller Pro to determine the flood depth at each central point, and to calculate damage to structure and contents. Aggregated results are shown in Table App-H- 3-6.

A cost was added to each structural damage estimation to represent building external damage. The external damage value added was dependent on the value of the building based on guidelines developed for the PFDAS and presented in NRCan's Draft Flood Vulnerability Guidelines (Natural Resources Canada and Public Safety Canada, 2017). The values used for this project in all external damage assessments are presented in Table App-H- 3-4. Table App-H- 3-5 shows the calculation for external damages for residential structures.

Table App-H- 3-4 External damage costs for each building type

Residential Class	Average Property Value, $	Property Value Range, $	External Damage Cost per building, $/building
AA, Ma and Mw	3,400,000	≥2,400,000	15,000
A	1,400,000	≥1,040,000 to <2,400,000	7,500
B	680,000	≥565,000 to <1,040,000	5,000
C	450,000	<565,000	2,500

Table App-H- 3-5 Calculation of external damages to residential structures

Area	External Damage Values, $	External Damage Structure Count, #	External Damage per Range, $	Total External Damages per Study Area, $
Nicomen Island Dike (#144)	15,000	1	15,000	**410,000**
	7,500	8	60,000	
	5,000	10	50,000	
	2,500	114	285,000	
Surrey South Westminster Dike (#296)	15,000	0	0	**1,782,500**
	7,500	0	0	
	5,000	3	15,000	
	2,500	707	1,767,500	
Fernie Dike (#58)	15,000	0	0	**1,257,500**
	7,500	0	0	
	5,000	8	40,000	
	2,500	487	1,217,500	

Table App-H- 3-6 Calculation of impact to residential structures and contents

Area	Structures, #	Asset Class	Total Value, $	Average Damage, %	Damage, $	External Damages	Total Damage, $
Nicomen Island Dike (#144)	133	Structure	49,345,000	65	31,974,000	410,000	46,938,000
		Contents	24,672,000	59	14,554,000	n/a	
Surrey South Westminster Dike (#296)	724	Structure	44,657,000	57	25,616,000	3,685,000	39,820,500
		Contents	22,328,000	56	12,422,000	n/a	
Fernie Dike (#58)	495	Structure	126,468,000	30	38,370,000	1,782,500	57,983,500
		Contents	63,234,000	29	18,356,000	n/a	

Loss of Residential Building Function

Loss of function was estimated as a percentage of direct damages based on relationships identified in NRCan's draft flood vulnerability guidelines (Natural Resources Canada and Public Safety Canada, 2017). These guidelines indicate that residential loss of function is generally between 10% to 15% of direct damages. Direct damages are calculated as a total of structural, contents and external damages. Due to the likely underestimation of direct damages, 15% was chosen. Values used in the calculation are shown in Table App-H- 3-7.

Table App-H- 3-7 Residential loss of function calculation

Area	Total Direct Damages, $	Loss of Function, $
Nicomen Island Dike (#144)	46,938,000	7,041,000
Surrey South Westminster Dike (#296)	69,720,000	10,458,000
Fernie Dike (#58)	39,820,500	5,973,000

3.1.2 Commercial Building Impact

Commercial indicators which are included in the B.1 Economy – Building subordinate factor are outlined in Table App-H- 3-8.

Table App-H- 3-8 Commercial building indicators

Direct Impacts	Indirect Impacts
- Damage to commercial building structures - Damage to commercial building contents	- Loss of commercial building function

Damage to Building Structure and Contents

Methodology to determine commercial buildings was the same as described above for residential buildings. The contents value was estimated to be equal to 100% of the building value based on a reference guide for contents of commercial structures provided in Table 14.6 in the Hazus-MH Technical Manual (FEMA, n.d.). The USACE – Galveston Hazus curves described as ‘average retail, structure – number 217’ and ‘average retail trade contents (inventory/equipment) – number 90’ were used for all structures. Data processing was completed and external damages were estimated the same way as described for residential buildings and results are shown in Table App-H- 3-10 and Table App-H- 3-9.

Table App-H- 3-9 Calculation of external damages to commercial structures

Area	External Damage Values, $	External Damage Structure Count, #	External Damage per Range, $	Total External Damages per Study Area, $
Nicomen Island Dike (#144)	15,000	0	0	**2,500**
	7,500	0	0	
	5,000	0	0	
	2,500	1	2,500	
Surrey South Westminster Dike (#296)	15,000	8	120,000	**440,000**
	7,500	12	90,000	
	5,000	6	30,000	
	2,500	80	200,000	
Fernie Dike (#58)	15,000	0	0	**120,000**
	7,500	0	0	
	5,000	3	15,000	
	2,500	42	105,000	

Table App-H- 3-10 Calculation of impact to commercial structures and contents

Area	Structures, #	Asset Class	Total Value, $	Average Damage, %	Damage, $	External Damages, $	Total Damage, $
Nicomen Island Dike (#144)	1	Structure	250,000	48	120,000	2,500	350,500
		Contents	250,000	91	228,000	n/a	
Surrey South Westminster Dike (#296)	109	Structure	96,345,000	16	15,497,000	440,000	69,720,000
		Contents	96,345,000	56	53,783,000	n/a	
Fernie Dike (#58)	44	Structure	8,868,000	13	1,192,000	120,000	5,401,000
		Contents	8,868,000	46	4,089,000	n/a	

Loss of Function

Loss of function was estimated as a percentage of direct damages based on relationships identified in NRCan's draft flood vulnerability guidelines (Natural Resources Canada and Public Safety Canada, 2017). These guidelines indicate that commercial loss of function is generally between 15% to 20% of direct damages. Direct damages are calculated as a total of structural, contents and external damages. Due to the likely underestimation of direct damages, 20% was chosen. Values used in the calculation are shown in Table App-H- 3-11.

Table App-H- 3-11 Commercial loss of function calculation

Area	Total Direct Damages, $	Loss of Function, $
Nicomen Island Dike (#144)	350,500	70,100
Surrey South Westminster Dike (#296)	69,720,000	13,944,000
Fernie Dike (#58)	5,401,000	1,080,200

3.1.3 Industrial Building Impact

Industrial indicators which are included in the B.1 Economy – Building subordinate factor are outlined in Table App-H- 3-12.

Table App-H- 3-12 Industrial building indicators

Direct Impacts	Indirect Impacts
- Damage to industrial building structures - Damage to industrial building contents	- Loss of industrial building function

Damage to Building Structure and Contents

Methodology to determine industrial buildings was the same as described above for residential buildings. This assessment showed that the Nicomen Island dike and Fernie dike did not protect any industrial areas. The contents value was estimated to be equal to 150% of the building value based on a reference guide for contents of industrial structures provided in Table 14.6 in the Hazus-MH Technical Manual (FEMA, n.d.). The USACE – Galveston Hazus curves described as 'average heavy industrial, structure – number 545' and 'average heavy industrial contents (equipment/inventory) – number 358' were used for all structures. Data processing was completed and external damages were estimated the same way as described for residential buildings and results are shown in Table App-H- 3-14 and Table App-H- 3-13.

Table App-H- 3-13 Calculation of external damages to industrial structures

Area	External Damage Values, $	External Damage Structure Count, #	External Damage per Range, $	Total External Damages per Study Area, $
Surrey South Westminster Dike (#296)	15,000	8	120,000	**1,462,500**
	7,500	29	217,500	
	5,000	45	225,000	
	2,500	360	900,000	

Table App-H- 3-14 Calculation of impact to industrial structures and contents

Area	Structures, #	Asset Class	Total Value, $	Average Damage, %	Damage, $	External Damages, $	Total Damage, $
Surrey South Westminster Dike (#296)	575	Structure	128,640,000	26	33,673,000	3,685,000	41,723,000
		Contents	192,960,000	47	91,609,000	n/a	

Loss of Function

Loss of function was estimated as a percentage of direct damages based on relationships identified in NRCan's draft flood vulnerability guidelines (Natural Resources Canada and Public Safety Canada, 2017). These guidelines indicate that industrial loss of function is generally between 15% to 20% of direct damages. Direct damages are calculated as a total of on structural, contents and external damages. Due to the likely underestimation of direct damages, 20% was chosen. Values used in the calculation are shown in Table App-H- 3-15.

Table App-H- 3-15 Industrial loss of function calculation

Area	Total Direct Damages, $	Loss of Function, $
Nicomen Island Dike (#144)	0	0
Surrey South Westminster Dike (#296)	126,744,500	25,348,900
Fernie Dike (#58)	0	0

3.1.4 Institutional Building Impact

Institutional indicators which are included in the B.1 Economy – Building subordinate factor are outlined in Table App-H- 3-16.

Table App-H- 3-16 Institutional building indicators

Direct Impacts	Indirect Impacts
- Damage to institutional building structures - Damage to institutional building contents	

Damage to Building Structure and Contents

Institutional impacts are calculated using depth damage curves. Hazus depth-damage curves which indicate damage based on a percentage of assessed value were used as there are not consistent footprint areas available (required for PFDAS curves), and the Hazus curves allowed for more refinement of structure type. Hazus curves used for each property are identified in Table App-H- 3-17, and values corresponding to flood depths determined are identified in Table App-H- 3-18. Property values were based on assessment data, and contents values were estimated as a percentage of the structure value based on established Hazus relationships (FEMA, n.d.). As all assessed values are in 2018 dollars, no inflation adjustments were required. Institutional buildings were located by points based on institutional layers used for Tier 1 assessment, assessed property type and zoning information and with a desktop analysis. Flood depth was determined from the flood depth with a point location for each facility.

Table App-H- 3-17 Description of institutional facilities, designated short names, and corresponding Hazus curves

Description	Short Name	Structure Type (HAZUS curve number for structure, contents)
Nicomen Island Dike (#144)		
Elementary School (Entire)	NicEleSch	Average School (643, 480)
North Fraser Volunteer Fire Department Hall 1	NFFire1	Fire Station (641, 478)
North Fraser Volunteer Fire Department Hall 1	NFFire1	Fire Station (641, 478)
Surrey South Westminster Dike (#296)		
Bridgeview Elementary School	BrEleSch	Average School (643, 480)
Bridgeview Community Centre	BrComCtr	Average Government Services (631, 472)
Khalsa School Old Yale Road Campus	KhSch	Average School (643, 480)
Fernie Dike (#58)		
Kingdom Hall of Jehova's Witnesses	KHallJW	Church (624, 467)
Women's Resource Centre	WResCen	Average Government Services (631, 472)
Mountainside Community Church	MComCh	Church (624, 467)

Table App-H- 3-18 Calculation of institutional facility impact

Descrip-tion	Structure Value, $	Content Value, %	Content Value, $	Flood Depth, m	Structure Damage, %	Structure Damage, $	Content Damage, %	Content Damage, $
Nicomen Island Dike (#144)								
NicEleSch	26,500	100	26,500	3.60	27	7,200	94	25,000
NFFire1	342,000	150	513,000	3.14	18	62,000	100	513,000
NFFire1	317,600	150	476,400	3.93	28	89,000	100	476,000
Total	**686,100**		**1,015,900**			**158,200**		**1,014,000**
Surrey South Westminster Dike (#296)								
BrEleSch	6,961,000	100	6,961,000	2.78	17	1,183,000	79	5,499,000
BrComCtr	10,000,000	100	10,000,000	2.63	21	2,100,000	100	10,000,000
KhSch	10,000,000	100	10,000,000	0.07	7.5	750,000	41	4,100,000
Total	**26,961,000**		**26,961,000**			**4,033,000**		**19,599,000**
Fernie Dike (#58)								
KHallJW	57,300	100	57,300	1.15	12	6,900	92	53,000
WResCen	356,000	100	356,000	1.31	14	50,000	85	303,000
MComCh	489,000	100	489,000	1.64	12	59,000	92	450,000
Total	**902,300**		**902,300**			**115,900**		**806,000**

External damages for institutional structures were calculated the same way as for residential, commercial and industrial structures with damage estimates based on the value of structures as outlined in Table App-H- 3-19.

Table App-H- 3-19 Calculation of external damages to institutional structures

Area	External Damage Values, $	External Damage Structure Count, #	External Damage per Range, $	Total External Damages per Study Area, $
Nicomen Island Dike (#144)	15,000	0	0	**7,500**
	7,500	0	0	
	5,000	0	0	
	2,500	3	7,500	
Surrey South Westminster Dike (#296)	15,000	3	45,000	**45,000**
	7,500	0	0	
	5,000	0	0	
	2,500	0	0	
Fernie Dike (#58)	15,000	0	0	**7,500**
	7,500	0	0	
	5,000	0	0	
	2,500	3	7,500	

Summary of structure, contents and total damages to institutional structures is shown in Table App-H-3-20.

Table App-H- 3-20 Summary of structure, contents and total damages to institutional structures

Area	Structural Damage, $	Content Damage, $	External Damages, $	Total Damages, $
Nicomen Island Dike (#144)	158,200	1,014,000	7,500	1,180,000
Surrey South Westminster Dike (#296)	4,033,000	19,599,000	45,000	23,677,000
Fernie Dike (#58)	115,900	806,000	7,500	929,000

3.1.5 Agricultural Building Impact

Agricultural building indicators which are included in the B.1 Economy – Building subordinate factor are outlined in Table App-H- 3-21. Non-building agricultural impacts are estimated in Section 4.3.

Table App-H- 3-21 Agricultural building indicators

Direct Impacts	Indirect Impacts
- Damage to agricultural building structures - Damage to agricultural building contents	

Damage to Building Structure and Contents

The farm building values were estimated based on Property Assessment data. The property assessment data was filtered by selecting areas with an actual use code related to farming and an exempt value indicating active farming. The exempt values were summed to estimate the value of farm buildings on the property. Where records and a desktop evaluation showed that a house was also located on the property, $200,000 was subtracted from the exempt values. Farm equipment was estimated to be equal to 100% of the building value based on a reference guide for contents of agricultural structures provided in Table 14.6 in the Hazus-MH Technical Manual (FEMA, n.d.).

Table App-H- 3-22 Estimation of damages to building structures, equipment and related clean-up

Asset Type	Value, $	Flood Loss, %	Flood Loss, $	External Damage, $/building	Total External Damage, $
Glass Greenhouse - Veg.	338,000	5%	17,000	15,000	15,000
Farm Buildings	23,687,000	7%	1,658,000	15,000	1,095,000
Farm Equipment	23,687,000	10%	2,369,000		
Total	**47,712,000**		**4,044,000**		**1,110,000**

Table App-H- 3-23 Summary of structure, contents and total damages to agricultural buildings

Area	Structural Damage, $	Content Damage, $	External Damages, $	Total Damages, $
Nicomen Island Dike (#144)	1,675,000	2,369,000	1,110,000	6,812,000
Surrey South Westminster Dike (#296)	0	0	0	0
Fernie Dike (#58)	0	0	0	0

4 ESTIMATING IMPACT TO C - ECONOMY – CRITICAL INFRASTRUCTURE AND AGRICULTURE

The subordinate factors and indicators for the C – Economy – Critical Infrastructure and Agriculture Consequence Category are listed in Table App-H- 4-1.

Table App-H- 4-1 Subordinate factors and indicators for consequence category C - Economy – Critical Infrastructure and Agriculture consequence category subordinate factors and indicators

Subordinate Factor	Indicator	
	Direct Impacts	Indirect Impacts
C.1 Utility Infrastructure*	- Damage to water and sanitation infrastructure* - Damage to telecommunications infrastructure* - Damage to electrical infrastructure*	- Disruption in service delivery*
C.2 Transportation Infrastructure	- Damage to roads - Damage to water crossings* - Damage to ports and airports* - Damage to vehicles*	- Traffic disruption* - Disruption to economy*
C.3 Agricultural Land	- Damage to crops and livestock - Land clean-up and replanting costs	- Overall impact on economy* - Contamination of floodwaters*

* Not calculated for this project

4.1 C.1 Utility Infrastructure Subordinate Factor

No utility impacts were calculated in this project as standardized relationships between exposure and damage to utilities are not well developed. While such impacts can be calculated on a case-by-case basis, they are not easily comparable between different locations, which would defeat the purpose of the present study.

4.2 C.2 Transportation Infrastructure Subordinate Factor

Impacts which comprise the Transportation Infrastructure Impact subordinate factor are outlined in Table App-H- 4-2.

Table App-H- 4-2 Indicators of C.2 Transportation Infrastructure impact subordinate factor

Direct Impacts	Indirect Impacts
- Damage to roads - Damage to railroads* - Damage to water crossings* - Damage to ports and airports* - Damage to vehicles*	- Traffic disruption* - Disruption to economy*

* Not calculated for this project

To estimate the damage to water crossings, more information about the water crossings and localized flood characteristics is required. An in-progress project by NHC to develop risk ratings for water crossings of Highway 97 between Lemoray, BC and Chetqynd, BC for the Ministry of Transportation could be used as example assessment methodology for impacts due to water crossings.

While there are no ports or airports in the protected floodplains used for Tier 2 analysis in this project, impacts could be estimated based on infrastructure, buildings and operations at the facility.

Calculation of damage to vehicles was not completed for this analysis as it requires more information than was available for this project. Information required includes consideration of evacuation plans, quantity and description of cars, and temporal distribution of cars. Hazus-MH provides a methodology for estimating the damage to vehicles (FEMA, 2018).

Indirect impacts due to traffic disruption of cars, trains, boats or planes and associated economic disruption were not estimated for this project as data collection requires a level of effort that was not practical for project purposes. NRCan's draft flood vulnerability guidelines identify potential methods to estimate the cost of traffic delays (Natural Resources Canada and Public Safety Canada, 2017).

Damage to roads was the only impact to transportation infrastructure estimated for this assessment. The method used to estimate this impact is outlined below.

Damage to Roads

Estimating the damage to roads was done based on values suggested in the Flood Rapid Assessment Model (F-RAM) Development Manual (State of California Department of Water Resources Division of Flood Management, 2008). This manual reviews methods for estimating damage to roads and identifies estimated cost of damage to roads based on the distance of highway inundated for four types of roads. The road type descriptions from the Digital Road Atlas available on GeoBC were reclassified to match the road types costed for F-RAM, and dollar values were converted to 2018 Canadian Dollars as shown in Table App-H- 4-3. Future adjustments were made based on methodology outlined in NRCan's draft flood vulnerability guidelines (Natural Resources Canada and Public Safety Canada, 2017). An increase in costs of 31.07% was applied to adjust 2008 values to 2018 values based on the City of Ottawa infrastructure construction price index published by Statistics, and assuming a consistent change between 2016 and

2017, and 2017 and 2018 (Statistics Canada, 2019a). US dollars were converted to Canadian dollars using the Bank of Canada published average annual exchange rate for 2018 of 1.2957 (Bank of Canada, 2018).

Table App-H- 4-3 Road Classifications and Costs Used to Estimate Damages

F-RAM Road Type	Digital Road Atlas Road Classifications	F-RAM Cost of Damage (in 2008 USD / mile)	Adjusted Cost of Damage (in 2018 CAD / km)
Highway	Highway, collector, ramp	$ 250, 000.00	$ 263,707.14
Major	Arterial	$ 100, 000.00	$ 105,482.86
Minor	Local	$ 30, 000.00	$ 31,644.86
Gravel	Driveway, restricted, strata, recreation	$ 10, 000.00	$ 10,548.29

For each floodplain analyzed in Tier 2, the length of each type of road, total cost per each type of road and total cost of damage to roadways is shown in Table App-H- 4-4.

Table App-H- 4-4 Length of road type, total cost per each road type, and total damage to roadways for each protected floodplain analyzed

Factor		Nicomen Island Dike (#144)	Surrey South Westminster Dike (#296)	Fernie Dike (#58)
Length of Road (m)	Highway	9,700	22,600	0
	Major	100	7,600	0
	Minor	30,000	24,500	12300
	Gravel	2,900	500	0
Cost of Damage ($)	Highway	2,564,600	5,972,900	0
	Major	11,600	799,900	0
	Minor	950,500	776,100	389,600
	Gravel	49,700	8,900	
Total Cost of Damage ($)		**3,576,400**	**7,557,800**	**389,600**

4.3 C.3 Agricultural Land Subordinate Factor

Impacts which comprise the Transportation Impact subordinate factor are outlined in Table App-H- 4-5Table App-H- 4-2 Indicators . Agricultural impacts related to buildings are estimated in Section 3.1.5.

Table App-H- 4-5 Indicators of C.3 Agricultural Land subordinate factor

Subordinate Factor	Direct Impacts
C.3 Agricultural Land	- Damage to crops and livestock - Clean-up and replanting costs

In areas with significant agricultural activity, an assessment of flood consequence which specifically estimates the damage to agricultural impacts is important to capture the value of agricultural resources. Methodology for evaluating agricultural impacts are available from resources including the Hazus -MH technical manual, the draft Canadian Guidelines and Database of Flood Vulnerability Functions, and the Agricultural Flood Damage Analysis User's Manual (FEMA, n.d.; Natural Resources Canada and Public Safety Canada, 2017; US Army Corps of Engineers, 1985). While methods identified in the guidelines vary, they all indicate that the degree of damage to crops is primarily dependent on the time of year and duration of the flooding rather than the depth of flooding.

Due to spatial variation in growing seasons and agricultural costs, area specific information is key to accurately determine agricultural damages. Nicomen Island was the only case study area with agricultural activity, so values specific to the Fraser Valley were used for assessment (Fraser Valley Regional District, 2016). This assessment of the impacts of a freshet flood on agriculture in the Fraser Valley provides specific values for use in estimating flood consequence based on consultation and local growing seasons.

Damage to Crops and Livestock, Clean-up and Replanting Costs

Loss functions, clean-up costs and replanting costs were based on values developed for NHC's evaluation of flooding on agriculture in the Fraser Valley completed in 2016 (Fraser Valley Regional District, 2016).

The reported values reflect a Fraser River freshet occurring on June 1st and both a short (<14 day) and a long (>14 day) duration flood. A short duration (<14 day) flood was assumed for this assessment to align best with a 200 year flood event (BCAF, 2014). The methodology used for this assessment is based on methodology detailed in NHC's evaluation of flooding on agriculture in the Fraser Valley completed in 2016 (Fraser Valley Regional District, 2016). The assessment for this project uses the same unit prices as the 2016 assessment as inflation based on the Canadian Price Index for farm products, crops and livestock have fluctuated almost twice as much as the overall increase (Statistics Canada, 2019b).

The hectares of each crop were determined through the 30 by 30 metre grid of the 2018 annual crop inventory (Agriculture and Agri-food Canada, 2018). The number of dairy and poultry animals were estimated from the detailed maps provided in the 2011 agriculture land use inventory assessment of the Nicomen Island area (Ministry of Agriculture, 2014). The number of dairy and poultry were adjusted from the 2011 values using the average increase in these animals in BC from – 13 and 10 percent respectively (BC Ministry of Agriculture, 2016, 2018).

Table App-H- 4-6 Estimation of flood loss and clean-up and repair costs

Crop/Livestock	Quantity	Value, $/unit	Farm Receipt, $	Flood Loss, %	Estimated Flood Loss, $	Clean -up Cost, $/ha	Re-plant Cost, $/ha	Clean-up & Replant Cost, $
Forage Grass/ Pasture/ Cereal	1310 ha	3,040	3,982,000	25%	996,000	300	300	786,000
Forage Corn	460 ha	3,120	1,435,000	50%	718,000	300	300	276,000
Annuals - Veg/ turf	4.3 ha	7,500	32,000	40%	13,000	300	500	3,400
Blueberries	130 ha	26,260	3,414,000	75%	2,561,000	300	8,500	1,144,000
Field Nursery/ Tree	1.9 ha	30,000	57,000	0%	0	600	7,500	15,400
Glass Greenhouse - Veg.	0.27 ha	600,000	162,000	73%	118,000	600	7,500	2,200
Dairy	# 4390	9,000	34,974,000	13%	4,372,000	n/a	n/a	n/a
Poultry	# 55	18	990	0%	0	n/a	n/a	n/a
Total			**44,056,990**		**8,778,000**			**2,227,000**

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APPENDIX I: GEOTECHNICAL INPUT ON SEISMIC HAZARD

THURBER ENGINEERING LTD.

January 16, 2019 File: 22004

Northwest Hydraulic Consultants
30 Gostick Place
North Vancouver, BC
V7M 3G3

Attention: Matt Gellis, Principal

DIKE CONSEQUENCE CLASSIFICATION STUDY
GEOTECHNICAL INPUT ON SEISMIC HAZARD

Dear Matt:

The Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD) of British Columbia has retained Northwest Hydraulic Consultants (NHC) to carry out the Dike Consequence Classification Study for dikes throughout BC. This letter provides our assessment of the seismic hazard for the 35 high-consequence dikes as classified by NHC.

It is a condition of this letter that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

The relevant geotechnical seismic hazard for dikes is the occurrence of large seismic displacements that could cause damage and reduce the level of flood protection. Large deformations could result in formation of preferential flow paths through the dike that could lead to piping, decreased dike stability (including under flood, rapid drawdown and static conditions) and loss of flood protection due to lowering of the dike crest elevation.

The MFLNRORD's 2014 Seismic Design Guidelines address the required seismic performance of high-consequence dikes by assigning vertical and horizontal deformation limits that must be met, as shown in the table below.

Table 1. 2014 Seismic Design Guidelines Performance Criteria

Seismic hazard return period (years)	Maximum allowable displacement (mm)	
	Horizontal	Vertical
100	<30	<30
475	300	150
2,475	900	500

Thurber has been involved with assessment and design projects for many of the dikes identified as high-consequence dikes. We have observed that the degree of seismic deformations largely depends on whether or not liquefaction of the foundation soils occurs. Typically, if liquefaction is predicted to occur, the above performance criteria will not be met. If liquefaction does not occur, deformations tend to be small (i.e. less than 1 m) and if it does occur, deformations can be much larger (i.e. greater than 1 m). There does not tend to be a gradual increase in displacement with increasing seismic hazard (i.e. stronger earthquakes), but rather a large increase when the earthquake exceeds a threshold intensity that initiates liquefaction. Accordingly, liquefaction is the most significant contributor to the seismic vulnerability for most dikes.

Liquefaction results in the loss of strength and stiffness of granular soil. Seismic deformation of dikes will depend on factors including the earthquake intensity, extent of liquefaction, the dike configuration and the site topography and bathymetry. In general, larger deformations can be expected where:

- dikes are close to a slope (such as a riverbank),
- there are steeper slopes (including the dikes slopes and riverbank slopes),
- dikes are higher,
- more liquefiable soil is present.

Setback dikes, short dikes and dikes on non-liquefiable subgrades (i.e. clay-like soils and sufficiently dense granular soils) can be expected to have smaller seismic deformations under a given seismic hazard.

This seismic assessment was based on data from Natural Resources Canada (NRC). This data was used to estimate the threshold seismic hazard return period at which liquefaction (and consequently larger deformations) is anticipated to initiate.

The NRC's on-line seismic hazard calculator was used to determine the peak ground accelerations (PGAs) for each dike for the 1 in 100, 475 and 2475-year return period seismic hazards. The seismic hazard calculator provides Site Class C PGAs, which are applicable to very dense soil and soft rock. For our assessment we have assumed that the dike foundation soils generally comprise liquefaction susceptible loose to very loose granular soils, which is often typical in floodplains. Accordingly, to reflect the assumed subsurface conditions we adjusted the Site Class C PGAs to Site Class E following the 2018 BC Building Code.

Our estimate of the threshold seismic hazard return period was based on comparison of the NRC data with our project experience on many of the dikes that have been identified as high-consequence under the current study. This project experience includes the following dikes:

- City of Richmond's Lulu Island dikes,
- The City of Burnaby's Big Bend dike (Fraser River),
- City of Surrey's Fraser River dikes,
- The Township of Langley's Fraser River dikes,
- The City of Abbotsford's Matsqui (Fraser River) and Vedder and Sumas River dikes,
- The City of Chilliwack's Vedder River, Town and East dikes.

Based on this comparison, we have identified that larger deformations often initiate when the site-specific (i.e. Site Class E) PGAs are in the range of 0.12g to 0.22g. The return periods according to these PGAs were interpolated from the NRC data.

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We have assigned each of the high-consequence dikes a subjective seismic hazard rating corresponding to a range of earthquake return periods, as shown in Table 2. We note that the assessments of the seismic hazards provided are estimates. The actual seismic hazards would require site-specific investigations and seismic assessments for each dike

Table 2. Seismic Hazard Rating

Seismic hazard (subjective rating)	Earthquake return period resulting in large dike deformations (years)	Probability of exceedance in 50 years (percent)
Very High	<100	>40
High	100-500	10-40
Moderate	500-1000	5-10
Low	1000-2500	2-5
Very low	>2500	<2

The earthquake (i.e. seismic hazard) return period is given as a range of return periods within which liquefaction is anticipated to initiate, potentially resulting in large deformations. For example, a high to very high subjective rating means that we anticipate that liquefaction and associated larger deformations will initiate under earthquakes from less than the 1 in 100 year up to the 1 in 500-year return period seismic hazards. The summary of our assessment of the seismic hazards is provided in Table 3 (attached). Of the 35 dikes in this study, 19 were categorized as having a high to very high seismic hazard, 12 a moderate to high seismic hazard and 4 a low to very low seismic hazard.

We note that our subjective rating is intended to align with the range of return periods included in the MFLNRORD's 2014 Seismic Design Guidelines, and it is not an interpretation of acceptable seismic hazards. Selection of the acceptable level of seismic vulnerability is a policy decision that would likely be the responsibility of the MFLNRORD. For example, The State of California's Urban Levee Design Criteria (May 2012) requires dikes to provide flood protection from a 1 in 200-year return period flood and have acceptable seismic performance under the 1 in 200-year return period seismic hazard. For a frequently loaded dikes, such as sea dikes that often provide flood protection twice a day, this design criteria provides a flood hazard due to overtopping approximately equal to the flood hazard due to dike failure in an earthquake.

It is our opinion that selection of the acceptable seismic hazard for a dike should consider the increase in probability of flooding caused by loss of dike performance in the event of an earthquake. This would have to consider the anticipated seismic deformations of the dike, the return period of flooding anticipated under a seismically damaged dike and timeframe to repair seismic damage.

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We trust that this information is sufficient for your needs. Should you require clarification of any item or additional information, please contact us at your convenience.

Yours truly,
Thurber Engineering Ltd.
Steven Coulter, P.Eng.
Senior Project Engineer

PROFESSIONAL
PROVINCE OF
S. P. N. COULTER
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BRITISH COLUMBIA
ENGINEER

Jan 16/19

David Regehr, P.Eng.
Project Principal

Attachment	Statement of Limitations and Conditions Table 3. Dike Seismic Hazard Assessment

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STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

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All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

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The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

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a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

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c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

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The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

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Table 3. Dike Seismic Hazard Assessment

Dike Number	Site Class E PGA (g)			Earthquake Return Period* (years)	Seismic Hazard (Subjective rating)
	100-year	475-year	2475-year		
1	0.11	0.22	0.29	100-1000	moderate to high
2	0.11	0.22	0.29	100-1000	moderate to high
3	0.11	0.22	0.29	100-1000	moderate to high
15	0.11	0.22	0.29	100-1000	moderate to high
16	0.09	0.19	0.26	100-1000	moderate to high
18	0.09	0.19	0.26	100-1000	moderate to high
19	0.09	0.19	0.26	100-1000	moderate to high
20	0.11	0.22	0.29	100-1000	moderate to high
42	0.17	0.25	0.33	<100-500	high to very high
45	0.16	0.25	0.33	<100-500	high to very high
46	0.17	0.25	0.33	<100-500	high to very high
51	0.20	0.29	0.38	<100	very high
71	0.02	0.07	0.20	100->2500	low to very low
90	0.02	0.05	0.12	>2500	very low
101	0.02	0.05	0.12	>2500	very low
108	0.09	0.19	0.26	100-1000	moderate to high
140	0.16	0.25	0.33	100-500	high
232	0.05	0.13	0.24	500-1000	moderate
244	0.12	0.23	0.30	100-500	high
252	0.12	0.23	0.30	100-500	high
253	0.12	0.23	0.30	100-500	high
254	0.01	0.03	0.09	>2500	very low
271	0.16	0.25	0.33	100-500	high
284	0.09	0.21	0.28	100-500	high
285	0.09	0.21	0.28	100-500	high
293	0.14	0.24	0.31	<100-500	high to very high
296	0.14	0.24	0.31	<100-500	high to very high
365	0.16	0.25	0.33	<100-500	high to very high
376	0.20	0.29	0.38	<100	very high
377	0.20	0.29	0.38	<100	very high
382	0.09	0.19	0.26	100-1000	moderate to high
383	0.09	0.19	0.26	100-1000	moderate to high
386	0.17	0.25	0.33	<100-500	high to very high
387	0.17	0.25	0.33	<100-500	high to very high
388	0.17	0.25	0.33	<100-500	high to very high

*Earthquake return period at which large dike deformations are anticipated to initiate

APPENDIX J: EXPERT CONSULTATION GUIDANCE

TABLE OF CONTENTS

1 BACKGROUND AND OBJECTIVE OF EXPERTS CONSULTATION

Key elements of the consequence classification framework could benefit from expert consultation. Expert consultation can incorporate unpublished knowledge and experience in the framework, help customize the framework to the BC context, and engage stakeholders to represent a wide range of perspectives.

Expert consultations to enhance the consequence framework are an excellent opportunity to break institutional silos and discuss BC's flood risk, the practice of flood risk assessment and risk management. Consultations can bring together representatives from many different institutions to discuss the common challenge of flood risk in BC. To facilitate this, expert consultation should be designed as open and dynamic sessions and include participants familiar with the projects, operations and policy making processes related to flood risk in their respective institutions.

This appendix provides high-level guidance to improve the consequence classification framework with expert consultation. Section 3 highlights design elements in the Tier 1 methodology, which could be improved by expert consultation. Section 4 provides an overview of how to use expert consultation to improve the incorporation of Tier 2 analysis in the consequence classification framework for all receptors. More information about the consequence classification framework elements discussed in this appendix can be found in appendices D and E.

2 CONSULTATION PROCESS RECOMMENDATIONS

Below are a few key recommendations for design and implementation of the consultation sessions:

- Carefully select individuals who take part in the consultation process to ensure relevant but diverse expertise and experiences are included.
- Ensure a balance between experts in subject matter and the policy making processes.
- Encourage attendees to represent their personal expertise rather than positions or policies of the organizations they belong to. As the consultation is meant to develop the framework based on evidence and observations rather than existing policies and politics, its best if the experts have the freedom to share their thoughts and experiences and shape their concluding opinion based on the dialogue at the consultation session.
- Design the process to ensure the consultation session is efficient and effective. Consider creating small groups for focused discussions, which report back to the bigger group with final recommendations.
- Have the consultation session led by a dynamic facilitator and/or experts in structured decision making.
- Start the consultation process with a short session for all participants to introduce the project scope, purpose, methodology, and existing design of the consequence framework and preliminary classification results. This could be efficiently organized as an online webinar
- Provide background materials for review prior to the sessions. Materials shared should include project related documents, recent situational reports from flood events in BC, and literature about consequence classification. Ask participants to share any additional materials they recommend.
- Ask experts to describe the source of their input (i.e., empirical data, model calculations, field observations). Experts often draw from many years of experience and knowledge from various sources when formulating their views.
- At first, the consultation session should include roundtable discussion, suggestion of options, and open voting. If a consensus is not reached, methods can be used to elicit judgments while minimizing psychological biases. These methods include the Delphi Method or a Multi-Criteria Decision Making (MCDM) approach such as Analytical Hierarchy Process (AHP). These methods are briefly introduced below.

<u>Delphi Method:</u> The Delphi Method has been widely used in consultation workshops in the context of disaster risk management. The goal is to reduce biases stemming from background expertise and experiences, narrow the range of responses and establish participant consensus. In this method, participants reply anonymously to questionnaires, then review a statistical representation of the group's responses, and discuss their views and rationale for their responses. The process then repeats itself until a consensus is reached.

Analytical Hierarchy Process (AHP): This method is a structured technique for organizing and analyzing complex decisions based on mathematics and group decision making psychology. Based on inputs from participants, the AHP helps participants find a result that best suits their goals and understanding of the problem. An AHP provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. Free AHP software can be access online.[1]

[1] For example, Business Performance Management Singapore provides a free AHP software and online calculator at https://bpmsg.com/tag/ahp-free-software/

3 CONSULTATIONS WITH TIER 1 ANALYSIS

The following elements from the Tier 1 classification framework could benefit from expert consultation in the context of Tier 1 analysis:

- Consequence Category A. People: Consultation on incorporation of modifier M.A.1.1. Socio-economic Vulnerability.
- Consequence Category B. Economy- Buildings: Consultation on the bins and values for modifier M.B.1.1 Administrative Facilities.
- Consequence Category C. Economy – Critical Infrastructure and Agriculture: Consultation on the overall weighting of subordinate factors included in consequence category C.
- Consequence Category D. Environment: Consultation on additional receptors and receptor aggregation or separation. In the case of separation, consultation on the overall weighting of subordinate factors included in consequence category D.
- Consequence Category E. Cultural Heritage: Consultation on improving incorporation of datasets in this category; adding other cultural heritage assets as receptors; and the overall weighting of subordinate factors included in consequence category E.
- Overall Consequence Classification Score: Consultation on the weighting of each consequence category in the overall score equation.

For each element identified above, the following sections provide: identify the element; briefly describe how it is currently used in the consequence classification framework; list a key consultation question; and identify desirable consultation attendees.

3.1 Consequence Category A- People

Consultation topic: modifier M.A.1.1 Socio-economic Vulnerability

<u>Key Consultation Question:</u> *What is the best way to incorporate the influence of SVI in People Consequence Category?*

The modifier M.A.1.1 is based on the Socio-economic vulnerability index (SVI) developed by NRCan. The value of SVI represents the vulnerability of the exposed community. In the existing consequence framework, if SVI is high, modifier M.A.1.1 increases the consequence category A. People. Consultations with experts could refine the incorporation of SVI on the People consequence category by providing feedback on the appropriate magnitude of the effect of the modifier. A presentation from the developers of the SVI index about their methodology, inputs and outputs should be included in the consultation.[2]

Consultation workshop attendees: Representatives at mid-senior level with management, technical, or operational expertise related to emergency management and/or recovery, risk reduction, resilience development and policies, and climate change adaptation from the following institutions:

- Ministry of Forests, Lands, Natural Resource Operations and Rural Development
- Ministry of Health
- Ministry of Indigenous Relations and Reconciliation
- Ministry of Public Safety and Solicitor General including Emergency BC
- Ministry of Social Development and Poverty Reduction
- Ministry of Municipal Affairs and Housing
- Ministry of Education
- Ministry of Children and Family Development
- Ministry of Jobs, Trade and Technology
- Ministry of Environment and Climate Change Strategy
- Local government representatives[3]
- Fraser Basin Council, Lower Mainland Flood Management Strategy (LMFMS) advisory committee
- Natural Resources Canada - Geological Survey of Canada
- Canadian Red Cross
- University of British Columbia (UBC), School of Community and Regional Planning[4]

3.2 Consequence Category B_ Economy- Buildings

Consultation topic: modifier M.B.1.1 Administrative Facilities

Key Consultation Question: Are the modifier values representative of the change to flood consequences if more administrative facilities are exposed to flooding?

The modifier M.B.1.1 is based on number of administrative facilities located in a dike's protected floodplain. These facilities include hospitals, education facilities, community centres and first responder stations. In the current framework design, the bins and values of the modifier are as shown in Table App-J- 1. The bin values were based on a logarithmic scale, and the modifier values determined through expert judgement.

[2] NRCan Led by Murray Journeay
[3] From municipalities with strong expertise and experience in emergency management, recovery and risk reduction. Municipalities that have recently experience flood consequences are desirable.
[4] The research group focusing on socio-economic vulnerability and resilience under supervision of Dr. Stephanie Chang.

Table App-J- 1 Bins and values for modifier M.B.1.1

M.B.1.1	Number of Admin Facilities B.1.1 a-d
+0.5	<10
+1.0	>=10

Expert consultation could inform the bin values and modifier magnitudes used by leveraging participant's understanding of the impact that damage to these facilities has on the response and recovery process.

Consultation workshop attendees: Representatives at mid-senior level with management, technical, or operational expertise related to emergency management and/or recovery, building damage caused by flooding, flood risk reduction, resilience development and policies, and climate change adaptation from the following institutions:

- Ministry of Public Safety and Solicitor General including Emergency BC
- Ministry of Forests, Lands, Natural Resource Operations and Rural Development
- Ministry of Health
- Ministry of Indigenous Relations and Reconciliation
- Ministry of Municipal Affairs and Housing
- Ministry of Education
- Ministry of Children and Family Development
- Local government representatives
- Fraser Basin Council, LMFMS advisory committee
- Natural Resources Canada - Geological Survey of Canada

3.3 Consequence Category C- Economy – Critical Infrastructure and Agriculture

Consultation topic1: equation for Overall Score for consequence category C. Economy Critical Infrastructure (CI) and Agriculture

Key Consultation Question: Is the equation for consequence category C's overall score representative of how exposure of different CI types and agricultural assets affect flood consequences?

In the current framework design, the equation for overall score of consequence category C is the maximum score of the three sub-ordinate factors for utility infrastructure, transportation infrastructure, and agricultural lands. Damages to CI and agriculture can have significant direct impacts on economic cost and recovery time, and long term indirect impacts to the BC economy. A dialogue among experts from relevant CI institutions and the agricultural sector would help develop the most representative equation for the overall score in this category. Alternative equations for the overall consequence category for the expert committee to consider include:

- The average of the three scores of sub-ordinate factors; and
- A weighted average of the three scores, and appropriate weights.

Consultation topic 2. incorporating additional critical infrastructure and agricultural receptors into consequence category C – Economy Critical Infrastructure (CI) and Agriculture

Key Consultation Question: Are there any additional CI or agricultural assets datasets on which can be used to enhance the consequence framework?

One of the criteria for selection of the receptors in the consequence category C was the availability of BC-wide datasets. The experts attending the consultation session could identify additional CI and agricultural assets datasets for use in the consequence framework. The existing consequence framework design and results could be updated with any additional receptors identified. Consultation could provide advice input on how to update the overall score equation and weightings of sub-ordinate factors if needed.

Consultation workshop attendees: Representatives at mid-senior level with management, technical, or operational expertise in emergency management, CI business continuity planning, disaster recovery, performance of critical infrastructure in flooding, flooding damage to agricultural land and crops, disaster risk reduction and development policies, and climate change adaptation from the following institutions:

- Ministry of Public Safety and Solicitor General including Emergency BC
- Ministry of Forests, Lands, Natural Resource Operations and Rural Development
- Ministry of Agriculture
- Ministry of Indigenous Relations and Reconciliation
- Ministry of Municipal Affairs and Housing
- Ministry of Energy, Mines and Petroleum Resources
- Ministry of Transportation and Infrastructure
- Ministry of Jobs, trade and technology
- Ministry of Environment and Climate Change Strategy
- Local government representatives
- BCHydro
- Fortis BC
- Railway operator representatives
- Telecommunication companies (Telus, Shaw)
- Fraser Basin Council, LMFMS advisory committee

- Natural Resources Canada - Geological Survey of Canada[5]
- University of Victoria (UVIC), Civil Engineering Department [6]

3.4 Consequence Category D- Environment

Consultation topic 1: incorporating additional environmental receptors to improve consequence category D-Environment

<u>Key Consultation Question</u>: Are there additional datasets on environmental assets which can used to enhance the consequence framework design?

One of the criteria in the selection of the receptors in the category D was availability of datasets with BC-wide coverage. Expert consultation could identify unpublished datasets of environmental assets which could be used in the consequence framework design and analysis. the existing consequence framework design and results could be updated with any additional receptors identified and how the corresponding weightings for overall scoring could be adjusted.

Consultation topic 2: grouping environment receptors into subordinate factors in consequence category D – Environment

<u>Key Consultation Question:</u> Is there a better way to put different types of environmental assets into receptor groups? If yes, what would that be and what is the rationale

In the current design of the consequence category D, all receptors (i.e., National Parks, local and regional green spaces, parks and protected areas, NGO conservation areas, critical habitat for at risk species, and conservation lands – ecological) are merged together into one subordinate factor.

The receptors are then assessed with one indicator (area exposed) to determine the score of the subordinate factor D.1. The overall score of the consequence category D is equal to the score of D.1.

To better capture how exposure of different environmental assets could change the flood consequence, experts could advise on separation of the environmental assets into different receptor groups.

Consultation topic 3: equation for the sub-ordinate factors and overall score of consequence category D-Environment

<u>Key Consultation Question</u>: What is the most representative equation for the overall score of consequence category D?

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[5] In collaboration with North Shore Emergency Management (NSEM), NRCan has lead a CI recovery-modeling project with Spatial Vision Group, University of Victoria, and Defence Research Development Canada in the District of North Vancouver. As part of this project a wide range of datasets has been collected and interaction between CIs were studied. The next phase of the project started in January 2019 will expand the geographical coverage to the lower mainland. The project outputs, experiences and insights from this group will be valuable for enhancing the consequence category C of the framework.

[6] Research being conducted on critical infrastructure recovery modeling under supervision of Dr. David Bristow

Once sub-ordinate factors are defined (see consultation topic 2 above), experts could advise on the weightings for receptors within each subordinate factor and the overall scoring equation for the consequence category D – Environment. Options include: using the maximum score among the sub-ordinate factors; using the average sub-ordinate factor score; and using a weighted average.

Consultation workshop attendees: Representatives at mid-senior level with management, technical, or operational expertise related to emergency management and/or recovery, flooding damage to various environmental assets, ecosystem based climate change adaptation and disaster risk reduction, disaster risk reduction and development policies, and climate change adaptation from the following institutions:

- Ministry of Environment and Climate Change Strategy
- Ministry of Indigenous Relations and Reconciliation
- Ministry of Public Safety and Solicitor General including Emergency BC
- Ministry of Forests, Lands, Natural Resource Operations and Rural Development
- Ministry of Tourism, Art and Culture
- Local government representatives
- Fraser Basin Council, LMFMS advisory committee
- NGOs active in environmental assets conservation[7] (i.e. BC Environmental Network (BCEN), Canadian Council on Ecological Areas, Environmental Defense Canada, David Suzuki Foundation, the Land Conservancy of BC, World Wildlife Fund Canada)[8].

3.5 Consequence Category E. Cultural Heritage

Consultation topic 1. incorporating additional cultural heritage assets as receptors

<u>Key Consultation Question:</u> Are there a datasets about cultural heritage assets which can be used to enhance the consequence framework design?

One criteria in selection of the receptors in category E – Cultural Heritage was availability of datasets with BC-wide coverage. Expert consultation could help identify datasets about cultural heritage assets which could be used in the consequence framework. Specifically, any cultural heritage assets which reflect First Nations' value in particular areas would be valuable to identify and include. The consequence framework design and results should be updated any with additional receptors.

Consultation topic 2. improving grouping of receptors in consequence category E – Cultural Heritage

<u>Key Consultation Question</u>: Is there a better way to group different types of cultural heritage assets into receptor groups? If yes, what would that be and what is the rationale

[7] See here for a list of Environmental Groups in Canada: https://www.goodwork.ca/environmental-groups
[8] Advice should be sought from the Ministry of Environment and BCEN on NGO contact.

The current design of the consequence category E-Cultural Heritage includes two types of receptors: First Nations reserve areas and cultural heritage sites. Expert consultation could advise on disaggregation of the two current receptors and any additional receptors.

Consultation topic 3. Equation for the sub-ordinate factors and overall score of consequence category E-Cultural Heritage

Key Consultation Question: *What is the most representative equation for overall score of consequence category E – Cultural Heritage?*

Once the subordinate factors are defined, experts could advise on the weightings for receptor groups within each subordinate factor and the overall scoring equation for consequence category E – Cultural Heritage. Options include: using the maximum score among the subordinate factors; using the average score; using a weighted average score.

Consultation workshop attendees: Representatives at mid-senior level with management, technical, or operational expertise related to emergency management and/or recovery, flooding damage to various cultural heritage assets, impact of climate change and disaster risk on tourism, and disaster risk reduction, climate change adaptation and development policies related to cultural heritage from the following institutions:

- Ministry of Indigenous Relations and Reconciliation
- First Nations representatives[9]
- Ministry of Tourism, Art and Culture
- Ministry of Environment and Climate Change Strategy
- Ministry of Public Safety and Solicitor General including Emergency BC
- Ministry of Forests, Lands, Natural Resource Operations and Rural Development
- Local government representatives
- Fraser Basin Council Expert committee
- NGOs active in cultural heritage conservation (e.g. Heritage BC)

3.6 Consequence Classification Overall Score

Consultation topic: the weightings in the overall score equation

Key Consultation Question: *What is the most representative weighting for each consequence category in the overall consequence classification scoring equation?*

In the current design, the overall dike consequence score is calculated by combining consequence category scores using a weighted aggregation and tipping for categories A and B. This process is represented by the following equation: Overall score= 0.4 A + 0.2 B + 0.2 C +0.1 D +0.1 E, or if A >= 5 or B >=5,overall score = 5.

[9] Advice should be sought from the Ministry of Indigenous Relations and Reconciliation.

As there is no consistent unit of measurement for all consequence categories (i.e., Canadian Dollars)[10], the selection of weightings for overall scoring is subjective. The weightings depend to some extent on the social, economic, environmental, and cultural priorities in development and risk reduction policy in the region. The project team used a set of variables (see Table 5-2 in report body) to determine consequence categories weights . Expert consultation could provide comments on these weightings based on observations and data from emergency response, recovery, and reconstruction after past floods and current policy priorities.

Consultation workshop attendees: Representatives with broader overview and expertise in how flooding events impact different sectors in various communities in BC. Experts at mid-senior level with management, technical, or operational expertise related to emergency management and/or recovery, climate change adaptation, disaster risk reduction and flood risk reduction, and development policies from the following institutions:

- Ministry of Public Safety and Solicitor General including Emergency BC
- Ministry of Forests, Lands, Natural Resource Operations and Rural Development including Utility regulation branch
- Ministry of Agriculture
- Ministry of Indigenous Relations and Reconciliation
- Ministry of Municipal Affairs and Housing
- Ministry of Energy, Mines and Petroleum Resources
- Ministry of Transportation and Infrastructure
- Ministry of Jobs, Trade and Technology
- Ministry of Environment and Climate Change Strategy
- Ministry of Tourism, Art and Culture
- Local government and diking authority representatives
- Fraser Basin Council, LMFMS advisory committee
- Geological Survey of Canada-Natural Resources Canada (NRCan)

[10] In developing the Switzerland National Risk Assessment, dollar value was estimated for every category. While this approach makes the weightings and aggregation process more straight-forward, the assignment of financial values to many of the receptors (i.e., people) and consequence categories is controversial and disputed in Switzerland and internationally.

4 CONSULTATIONS ON CONSEQUENCE CLASSIFICATION FRAMEWORK WITH TIER 2 ANALYSIS

4.1 Background on Pilot Sites and Future Enhancements

The consequence classification framework with Tier 1 analysis has been developed exposure-based indicators for all receptors[11]. To show case use of impact-based indicators in the consequence classification framework, impact analysis (Tier 2 analysis) was conducted to estimate impacts on people (injury) and buildings (physical damage) in three pilot sites. As outlined in the recommendations section of the main report, future enhancement to the consequence classification framework could incorporate impact-based indicators for all receptors.

If adequate hazard, exposure, and vulnerability data are available as inputs, many risk modeling softwares allows fully quantitative assessment of casualty, injury, displacement and physical damage to buildings and contents. Despite advances in risk modeling methodologies in the past three decades, there are still significant challenges in modeling impacts to various critical infrastructure assets, various agricultural lands and crops, environmental assets, and cultural assets. In the absence of fully quantitative assessment tools and research/data on the asset types mentioned above, expert consultation can be used to assign impact values to various receptors in the classification framework. The following sections of the document provide an overview of consultation topics, and key consultation questions for each consequence category. Consultations on method for binning the impact values is relevant to all consequence categories. This topic is covered in section 4.8.

4.2 Consequence Category A- People

Consultation topic1: best method for binning the values in each type of impact (see section 4.8)
Key Consultation Question: Which method for binning impact values can better represent a change in consequence classification from different types of impact on people?

Consultation topic2: the overall score for consequence category A-People
Key Consultation Question: What is the most representative equation for overall score of consequence category A – People?

Once the binning is done, the experts would provide inputs on defining the overall scoring of consequence category A. the options include:

[11] For example: Economic value (CAD) of buildings located in the dike's floodplain area or kilometers of water and sanitation pipelines that are located in the protected floodplain

- Overall score is equal to the highest score among impact types
- Overall score is equal to the average of all scores
- Overall score is equal to the weighted average of all scores, in which case the experts would provide inputs on the weightings

Attendees for the consultation on consequence category A-People would be similar to the list provided in section 3.1. For Tier 2 consultations, it is important to ensure sufficient number of experts with background in numerical risk modeling and social impacts are invited.

4.3 Consequence Category B. Economy- Buildings

Consultation topic: best method for binning the values in each type of impact (see section 4.8)
Key Consultation Question: Which method for binning impact values can better represent a change in consequence classification from different types of impact on buildings?

Attendees for the consultation on category B. would be similar to the list provided in section 3.2. For Tier 2 consultations, it is important to ensure sufficient number of experts with background in numerical risk modeling and physical impacts are invited.

4.4 Consequence Category C- Economy – Critical Infrastructure and Agriculture

Consultation topic 1: The impact estimation for each receptor in consequence category C
Key Consultation Question: For each receptor type, what is the proxy for estimating the impact values based on the exposed assets data?

In absence of fully quantitative methods for modeling damages to CI and agricultural assets, there are two options for upgrading the framework with impact-based indicators:

Option 1. (Applicable to CI and Agricultural Assets): experts define proxies to estimate economic loss values for CI and agricultural assets exposed to the flood event.

Option 2. (Applicable only to CI): The experts, specially representatives of CI entities, provide recovery time[12] for possible interruption to each of the CI systems under the flood scenario (e.g. interruption to transportation system, or telecommunication systems).

Their inputs will be based on their knowledge of empirical damage data, institutional knowledge of the engineering design criteria and maintenance of assets, and studies of the current vulnerabilities.

[12] Time required to recover from the flood event, become operational and provide services

Consultation topic2: best method for binning the values in each type of impact (see section 4.8)
<u>Key Consultation Question:</u> Which method for binning impact values can better represent a change in consequence classification from different types of impact on CI and Agriculture?

Consultation topic3: the overall score for consequence category C-CI and Agriculture
<u>Key Consultation Question:</u> What is the most representative equation for overall score of consequence category C – CI and Agriculture?

Once the binning is done, the experts would provide inputs on defining the overall scoring of consequence category C. The options include:

- Overall score is equal to the highest score among the impact types
- Overall score is equal to the average of all scores
- Overall score is equal to the weighted average of all scores, in which case the experts would provide inputs on the weightings

Attendees for the consultation on category C would be similar to the list provided in section 3.3. For Tier 2 consultations, it is important to ensure sufficient number of experts with background in numerical impact modeling, CI and agricultural flood impacts are invited.

4.5 Consequence Category D-Environment

Consultation topic 1: the impact estimation for each receptor or receptor group in the consequence category D – Environment
<u>Key Consultation Question:</u> What is the proxy for estimating the impact levels based on exposed assets data?

In absence of fully quantitative assessment methods, experts can define proxies to estimate impact levels on environmental assets exposed to the flood event. The experts would define the impact values as the magnitude of efforts and time required for recovery[13]. Their inputs would be based on their knowledge of empirical damage and recovery data and studies of the current vulnerabilities of the environmental assets. Some reflection of the environmental benefits of flooding may also be incorporated into this assessment.

Consultation topic 2: best method for binning the values in each type of impact (see section 4.8)

[13] *All Hazards Risk Assessment Methodology Guidelines* provides some guidance on defining impacts on environmental assets. From Public Safety Canada (2013)

<u>Key Consultation Question:</u> Which method for binning impact values can better represent a change in consequence classification from different types of impact on environment?

Consultation topic 3: the overall score for consequence category D-Environment
<u>Key Consultation Question:</u> What is the most representative equation for overall score of consequence category D- Environment?

Once the binning is done, the experts would provide inputs on defining the overall scoring of consequence category D. The options include:

- Overall score is equal to the highest score among the impact types
- Overall score is equal to the average of all scores
- Overall score is equal to the weighted average of all scores, in which case the experts would provide inputs on the weightings

Attendees for the consultation on category D should be similar to the list provided in section 3.4. For Tier 2 consultations, it is important to invite a sufficient number of experts with background in assessing environmental assets vulnerability to flooding.

4.6 Consequence Category E. Cultural Heritage

Consultation topic 1: The impact estimation for each receptor or receptor group
Key Consultation Question: What is the best approach for estimating the impact levels based on exposed assets data?

In absence of fully quantitative methods, the experts can define proxies to calculate impact levels on cultural heritage assets exposed to the flood. The experts would decide if it is feasible to provide economic values or use the magnitude of efforts and time required for recovery as the indicator of impact[14]. Their inputs would be based on their knowledge of empirical damage and recovery data and studies of the current vulnerabilities of the cultural heritage assets.

Consultation topic 2: best method for binning the values in each type of impact (see section 4.8)
<u>Key Consultation Question:</u> Which method for binning impact values can better represent a change in consequence classification from different types of impact on cultural heritage assets?

[14] *All Hazards Risk Assessment Methodology Guidelines* provides some guidance on defining impacts on environmental assets. From Public Safety Canada (2013)

Consultation topic 3: the overall score for consequence category E-Cultural Heritage
<u>Key Consultation Question:</u> What is the most representative equation for overall score of consequence category E-Cultural Heritage?

Once the binning is done, the experts would provide inputs on defining the overall scoring of consequence category E. The options include:

- Overall score is equal to the highest score among the impact types
- Overall score is equal to the average of all scores
- Overall score is equal to the weighted average of all scores, in which case the experts would provide inputs on the weightings

Attendees for the consultation on consequence category E-Cultural Heritage should be similar to the list provided in section 3.5. For Tier 2 consultations, it is important to invite sufficient number of experts with background in assessing flooding impacts to cultural assets.

4.7 Consequence Classification Overall Score

Consultation topic 1: the weightings in the overall score equation
<u>Key Consultation Question</u>: What is the most representative weighting for each consequence category in the overall consequence classification scoring equation?

The overall dike consequence score is calculated by combining the scores of all consequence categories using a weighted average calculation. The equation used in Tier 1 overall score may be used here, but its best if the experts review the weightings and discuss if it's necessary to change them for the Tier 2 consequence framework.

Attendees for the expert consultation on overall score would be similar to the list provided in Tier 1 on the similar topic.

4.8 Binning Methods

Consultation topic: best method for binning the values in each type of impact
<u>Key Consultation Question:</u> Which method for binning impact values can better represent a change in consequence classification from different types of impact on assets?

Once risk modeling and experts judgment is used to assign impact values to various receptors, expert consultation could provide inputs on how to bin impact values for each type receptor. Options for binning include:

- Linear binning – defined linear bins based on an arbitrary interval to fit the data range (e.g., 1-5, 5-10, 10-15).
- Logarithmic binning – defined logarithmic bins with logarithmic base 10 (e.g., 1-10, 10-100).
- Statistically based on a min/max normalization –using a min/max normalization instead of mean normalization. Min/max normalization spreads the data evenly between the minimum and the maximum data values.
- Statistically based on a mean normalization- this normalization method deemphasizes outliers and better preserves the raw data distribution.

5 FINAL NOTES

This document is meant to provide a high-level overview and guidance on using expert consultation to improve the consequence classification framework with Tier 1 analysis (exposure based) and for future upgrade of the consequence classification with Tier 2 analysis (impact based).

The expert consultation requires substantial resources for planning and effective facilitation as well as the time and commitment from all the participants. In creating the list of participants, its sensible to seek advice or, if possible, use the existing multi-sectoral coordination and consultation mechanisms such as British Columbia Emergency Response Management System (BCERMS), Provincial Regional Emergency Operations Centre (PREOC), and Lower Mainland Flood Management Strategy (LMFMS) advisory committee at Fraser Basin Council. Prioritizing the topics for consultations depending on the objectives and use of the enhanced framework is another way to manage the workload.

The expert consultation process provides an excellent opportunity for discussion and exchange of information among various ministries, technical institutions, Engineers and Geoscientists British Columbia (EGBC) and NGOs on flood hazard, exposure, vulnerability and risk. These consultation groups can become the foundation for creating technical working groups on various aspects of flood risk in BC and serve many future projects and policies.

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APPENDIX K: DIGITALLY PROVIDED DATA

Digital files provided via FTP

Appendix K contains documentation and shareable data in a series of zipped spreadsheets and folders. Appendix K includes the following components:

- “01_AppendixK_ReadMe” identifies the Appendix K components.
- “02_Tier1ClassifyingSpreadsheet” provides the spreadsheet used to classify Tier 1 results from exposure quantities to overall classification.
- “03_DataList” lists all the data used in both Tier 1 and Tier 2. For each dataset, the following information is provided: the dataset name; the dataset download date; the dataset source; the name of the dataset user license agreement; whether the dataset is included with the project outputs in Appendix K section 05; the filename of the dataset if it is included. More information about receptor data characteristics can be found in Appendix B.
- “04_DataSharingAgreements” includes files for all data sharing agreements signed for data used for this project.
- “05_DataFiles” includes all datasets included in project outputs as listed in Appendix K Section 03.