Photo: Tim Shields

1.6 COASTAL FLOODS

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RESILIENCE PATHWAYS

CO-CREATING NEW KNOWLEDGE FOR UNDERSTANDING RISK AND RESILIENCE IN BC

This article is part of the Resilience Pathways Report. The report has the following objectives: a) to share knowledge about existing practices and recent advances in understanding and managing disaster and climate risk in BC, including some information on relevant federal programs, and b) to provide insights on gaps and recommendations that will help build pathways to resilience in BC.

This article belongs to *Chapter 1 Understanding and Managing Climate and Disaster Risk: Hazard Threat*. To read all articles in the report, see DRRPathways.ca.

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1.6 COASTAL FLOODS

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ABOUT COASTAL FLOODS

DESCRIPTION

British Columbia is a coastal province, with the majority of people and infrastructure situated in coastal regions. The ways of life of coastal Indigenous Peoples have been intertwined with the sea in this region for millennia. For instance, salmon has deep cultural significance to Coast Salish peoples, beyond its practical significance as a food source. Today, people in BC remain dependent on proximity to the coast for economic and sociocultural reasons, including needs and desires related to shipping and transportation, tourism, recreation, and connectivity with nature. BC coasts are also home to some of the most unique and sensitive ecosystems in the world, and the coast is arguably the most biologically diverse region of the province.

Coastal flood hazards in BC originate from a variety of sources and combinations of sources, including tides, storm surges, waves, regional fluctuations in sea levels (e.g., due to El Niño–Southern Oscillation), seiches (sloshing of water in bays and inlets), rainfall, river flows and tsunamis. However, in this article, we limit our definition of coastal flooding to inundation of coastal lands driven primarily by elevated sea levels and/or waves; precipitation-driven flooding (such as the floods associated with the damaging November 2021 atmospheric river events) can impact areas much further inland.

Coastal flooding is a natural process contributing to ecosystem function; for example, the disturbances resulting from storms are integral in creating "patchiness" (e.g., in shoreline morphology, sediments, and habitat type) in coastal zones, which supports biodiversity. Risk only arises when there is an intersection of vulnerable people, infrastructure, and other valued assets with coastal flood hazards (Figure 1).

The most damaging coastal flooding events in BC's recent history have tended to occur in fall or winter when spring tides coincide with storm surges and/or high waves, sometimes superimposed on sea levels that are already regionally elevated by El Niño events. The extra-tropical storms that are the predominant drivers of storm surges and high waves also commonly bring intense and prolonged rainfall to BC coastal regions upon landfall, which can lead to jointly occurring fluvial (riverine) and pluvial (rainfall-driven) flood hazards. Storm surges in BC are primarily the result of the inverse barometer effect, which is the rise in water level accompanying a fall in sea-level pressure, such as occurs during the passage of storms. Storm-driven winds, currents, and their interactions with shorelines

Figure 1: Rescue at the White Rock Pier, December 20, 2018 (Photo: Tim Shields).

and bathymetry contribute to locally elevated surges. Progressive or storm-driven erosion can create new pathways for flood hazards to reach people, infrastructure and valued assets. The presence of debris (e.g., logs and trees) in BC coastal waters can exacerbate flood hazards. Over time, coastal flooding is expected to become more frequent and severe in many parts of BC due to relative sea-level rise, which is the combined result of rising global sea levels and vertical land motion (subsidence or uplift).

COASTAL FLOODING THREAT AND PAST EVENTS

Coastal floods resulting from elevated sea levels and/or wave effects have tended to be relatively localized events in BC (compared, for example, to the widespread, predominantly rainfall-driven flooding in mainland BC in November 2021). However, there have been damaging events in recent history. In 1982 (a strong El Niño year), storm surges caused significant flooding damage in parts of the Fraser River delta.[1] A report prepared for the Adaptation to Climate Change Team at Simon Fraser University documented coastal flooding events and near misses in Metro Vancouver from the late 1800s through 2011.[2] Damaging coastal flood events have not been limited to the Lower Mainland; for example, a storm surge event on the coast of Haida Gwaii in 2003 resulted in erosion of a highway and extensive coastal flooding, which damaged buildings and transported driftwood onto roads and properties.[3] However, the major threats from coastal flood hazards in BC lie in the coming decades, with the looming threat of sea-level rise.

DRIVERS OF RISK

Coastal development, population growth, and historical failures in coastal zone management practices are contributing to increased exposure and risk. For example, many parts of the densely populated Lower Mainland coastal region are located at or below mean sea level, protected by sea dikes. These dikes are generally vulnerable to seismic hazards (ground shaking and liquefaction) and, in the event of a damaging earthquake, there may not be sufficient time to repair the entire network of flood protection infrastructure before a coastal storm impacts the region. Without intervention, large swaths of urban and high-value agricultural land in this region (located in Vancouver, Surrey, Richmond, and Delta) are projected to be at high risk of coastal flooding even for non-storm scenarios by the end of the century. Many First Nations communities at risk of coastal flooding are not protected by sea dikes and will be disproportionality impacted by sea-level rise. Extensive historical development in areas of moderate to high hazard limits or restricts the range of adaptation options that are feasible or palatable. Low awareness of risk among the general public has also led to increased vulnerability and perpetuation of planning and development practices and policies that contribute to increased flood risk over time.

Nationally, critical infrastructure that forms part of the Asia-Pacific Gateway and Corridor passes through the coastal floodplain in BC. Though predominantly driven by intense precipitation (as opposed to elevated water levels and/or wave effects), the flooding events in BC's Interior in November 2021 highlighted infrastructure and supply chain vulnerabilities and economic ripple effects that could materialize in the

event of widespread coastal flooding.

Climate change effects such as sea-level rise,[4] and, possibly, changes in the frequency and intensity of storms,[5,6] combined with land subsidence in some areas, are contributing to escalating hazards over time. Economic activity, population growth, demand for waterfront property, and failures in urban and land-use planning practices have resulted in significant development in coastal floodplains. Risk management practices to date have not kept pace with the increasing hazards and floodplain development, resulting in increased flood risk. Without intervention or improvement of risk management practices, these risks are projected to continue to increase over time.

UNDERSTANDING RISK

The collective understanding of coastal flood hazard risk in BC is largely based on flood hazard mapping commissioned by local governments, sometimes supported by provincial or federal government funding. Most of this mapping has involved static mapping of water levels and wave runup allowances onto coastal topography to assess the inland extent of exposure for a single, extreme event. Only a few municipalities have been able to muster the resources needed to apply advanced modelling techniques or approaches that consider risk in all its dimensions, including the change in risk over time and the vulnerability of people, communities and ecosystems. Even where sophisticated mapping

NEAR MISS, WHITE ROCK PIER COLLAPSE

Coastal flood hazards can develop with little to no warning, and a hazardous situation during a coastal storm can result in rapidly cascading impacts putting human life at risk. An example of a near miss involving human life safety took place at the White Rock Pier on December 20, 2018. High waves during a large tide and storm surge overtopped the White Rock breakwater, a structure intended to shelter several sail boats moored to the dock at the end of the 470-metre-long pier. During the storm, dock broke free resulting in several boats striking the pier, visible in Figure 2, causing the collapse of one segment and leaving one person stranded. Waves overtopped remaining sections of the pier. A Canadian Forces Cormorant helicopter was dispatched from CFB Comox to assist. Highly trained search and rescue technicians were able to rescue the stranded individual, returning them safely to shore.

Figure 2: White Rock Pier Collapse, December 20, 2018 (Photo: Tim Shields).

Reopening of the pier took place on September 21, 2019, following approximately $16 million in repairs and upgrades, while the moorage facilities have not yet been replaced. Many local businesses were impacted from the reduced tourist and recreational activity during the pier closure. While the pier has not been raised to accommodate sea-level rise, the section that was replaced has been made to be flexible to accommodate raising in the future.

With sea-level rise, life safety, property and infrastructure are expected to be impacted more frequently with greater consequences during storm conditions in the future. There have been at least five other events documented in the Canadian Disaster Database since 1933 for this area.

has been undertaken, communication and dialogue surrounding risk has often been lacking, resulting in a poor collective understanding.

> Economic activity, population growth, demand for waterfront property, and failures in urban and land-use planning practices have resulted in significant development in coastal floodplains. Risk management practices to date have not kept pace . . . resulting in increased flood risk.

The absence of a province-wide hazard or risk mapping program, alongside inconsistent mapping approaches and technical guidance that lags behind international best practices, have contributed to a generally poor understanding of coastal flood hazard risk. Encouragingly, the provincial government has acknowledged the need to prioritize the development of clear, consistent, up-to-date flood maps and has committed to working with other levels of government to achieve this. In March 2022, the federal government committed over $63.8 million to a new national flood hazard identification and mapping program. It remains to be seen how these commitments from multiple levels of government will materialize and be implemented and how they will contribute to an improved understanding of coastal flood risk.

WHAT SOURCES HELP US UNDERSTAND HAZARD AND RISK

The provincial government has published guidelines for the mapping of coastal flood hazards and establishment of setback distances and flood construction levels (Flood Hazard Area Land Use Management or FHALUM guidelines),[7] high-level guidance on sea-level rise adaptation,[8] and prescriptive guidelines for implementing structural flood control structures. The National Research Council published coastal flood risk assessment guidelines for building and infrastructure design applications[9] in 2020, and the federal government is continuing to work on updating and improving federal flood mapping guidelines, with several publications relevant to risk-based analysis for coastal zones expected in 2022. Detailed risk assessments depend on the availability of supporting data (including local datasets) and are often prohibitive due to resource and capacity constraints, or inaccessible to wider audiences due to restrictions arising from confidentiality.

CURRENT PRACTICE IN HAZARD AND RISK ASSESSMENT

Coastal flood hazard assessment practice in BC has mainly followed the provincial FHALUM guidelines.[10] These methods have provided the basis for establishing setback distances and flood construction levels by many local governments. However, the guidelines have not been regularly updated to keep pace with international best practice and emerging climate change projections, nor do they align with risk-based or all-hazards approaches (as per the Sendai Framework for Disaster Risk Reduction) or facilitate options appraisal to guide strategies for flood risk management (e.g., nature-based solutions, managed retreat, property-level resilience measures). The extent to which other guidelines, such as federally developed guidelines or those developed by professional associations (e.g., Engineers and Geoscientists BC), have been used in practice is unclear. Coastal flood risk assessments, in the strict sense (i.e., where consequences and likelihoods of a variety of flood events are assessed), are extremely rare.

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GAPS IN UNDERSTANDING RISK

There are gaps in the data needed to support decision making surrounding coastal flood risk management, particularly in the context of a changing climate. Data collection is often ad hoc, short term, and reliant on the limited fiscal capacity of municipal governments. Lessons learned during post-disaster recovery are often forgotten, not finding their way into planning and preparedness activities.

BC is in need of an integrated, long-term, open access coastal monitoring system that would provide baseline information needed to support a range of coastal flood risk management activities. At present, data coverage (such as water level and wave records) is scarce and managed by various government departments and academic or non-profit institutions. Sustained, long-term federal and/or provincial investment in a monitoring program is needed to support effective coastal flood risk assessment.

Flood hazard maps are not available for many coastal communities, and for communities where maps exist, many are out of date. Information on vulnerability to, or consequences of, different types of flood events is rarely communicated, which is a major barrier to understanding risk. Mapping methodologies and approaches have been inconsistent, owing to highly variable capacity, expertise, and supporting datasets. These studies vary in quality and emphasis depending on the strengths of the organization undertaking the work. More recently, collaborative efforts at the regional and sub-regional levels have been undertaken.

SEMIAHMOO NATION'S FLOOD STORY

An emerging practice in coastal flood risk management in BC is to include Indigenous oral history along with published data sources early in the process of planning for and understanding risk. Flood events documented following European settlement of the Salish Sea represent a comparatively shorter history than that of First Nations' oral history; such oral history can provide greater context to complement modern data sources.

Figure 3: Chief Chappell speaking on May 4, 2018, at a Classrooms to Community event (Photo: City of Surrey).

In 2016, City of Surrey convened various possible partners in risk reduction to a tour of the coastal floodplain. Each jurisdiction was invited to speak to the group and Semiahmoo First Nation provided its perspective, including an oral history of past floods. Later in the process, Chief Chappell of Semiahmoo First Nation agreed to share his Nation's Flood Story as part of a Classrooms to Community event for local schoolteachers, as shown in Figure 3. It has been made available on the City of Surrey's YouTube account.

Inclusive planning with Indigenous Peoples, such as in the case of Surrey, has helped to build trust and cooperation that is ultimately improving coastal risk reduction. Implementation of specific projects requires additional knowledge exchange that continues to build on the initial planning work.

Workshop-based approaches such as PIEVC, Circle Tool, and BARC Program have been employed but in inconsistent ways. These workshop-based assessments typically help to build a framework to prioritize more technical, focused works. However, resources and organizational mandates to comprehensively maintain and publish the results have not emerged.

REDUCING RISK

WHAT SOURCES HELP US REDUCE RISK

Flood damage in Canada has become the costliest insured loss.[11] While avoidance is generally the preferred risk reduction strategy for coastal flooding, and is the strategy supported by FHALUM guidance, buildings and infrastructure can be designed or retrofitted for enhanced flood resistance[i] or resilience to further reduce residual risk. Unfortunately, the National Building Code of Canada (the model code on which the BC Building Code is substantially based) is largely silent on flood resistance and resilience measures. In 2021, the National Research Council published two reports providing guidance and best practices for increasing the flood resistance of buildings in Canada.[12,13] However, it is not clear if or when such measures might be incorporated in model National Building Codes or mandated by provincial jurisdictions like BC. Applied research and guidance is needed on how to design and retrofit other types of infrastructure to enhance flood resistance and resilience.

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RISK REDUCTION PRACTICE, POLICY, AND CAPABILITIES

Coastal flood risk management practice and policy in BC is affected by a complex history and governance context. Pre-contact, many Indigenous coastal communities relied on oral histories, Traditional Knowledge and seasonal migrations to coexist with flooding. Post-contact, decisions by federal, provincial and municipal governments related to flood management and land use have disadvantaged many First Nations communities or ignored or minimized the role and perspectives of First Nations in managing flood risk. Today in BC, as is the case across Canada, responsibilities for flood risk management are distributed across multiple levels of government.

The fragmented governance context has in some cases locked in decisions of regret (e.g., the need to continue raising dike levels). Recently, there have been some moves towards collaborative, "whole of society" approaches to coastal flood risk management with efforts by municipalities (e.g., City of Surrey[14]) and non-profit groups (e.g., Fraser Basin Council, Living Dike Roundtable), as well as the provincial government's recognition of the need for a province-wide flood strategy, but more is needed to ensure flood risk is managed in a more sustainable way going forward.

While recent flood management decisions have had limited First Nations involvement or engagement, there are signs this is beginning to change. Several examples signaling this shift include establishment of an Emergency Planning Secretariat, First Nations representation on the Leadership Committee of the Fraser Basin Council, inclusion of First Nations in local planning, and commitments from the provincial government to bring all provincial laws into harmony with the *UN Declaration on the Rights of Indigenous Peoples Act*. Through the Federal Disaster Mitigation and Adaptation Fund (DMAF), several projects with First Nations and local government partnerships have been established, and several First Nations are partners in coastal flood risk assessment and management-focused research projects funded by the Canadian Safety and Security Program.

[i] *In this context, "resistance" is taken to mean the ability to prevent flood water ingress and flood damage, whereas "resilience" refers to measures that ensure faster and more economical recovery following a flood event.*

Despite (and hindering) efforts to work towards collaborative whole-of-society approaches, fragmented jurisdiction results in uncertainty and difficulty implementing projects. Conflicting regulations, and regulations that do not keep pace with emerging science (e.g., failing to contemplate the effects of climate change, or to recognize trade-offs between short-term impacts and long-term benefits of nature-based solutions), make it difficult for proponents to proactively adapt. In other cases, the proponent is caught between conflicting legislation such as surface water rights and fisheries protection, resulting in sub-optimal solutions. The complexity of regulatory processes and the funding landscape also hinders timely design and implementation of coastal flood risk management strategies, particularly for smaller communities or those that lack the resources to navigate them.

Land-use planning and regulation of development in areas prone to flooding has primarily remained the responsibility of local governments since the province devolved authority in 2003. However, local governments are required to consider provincial FHALUM guidelines (first published in 2004, with the most recent amendment in effect since 2018) under the *Local Government Act*. Under the *Emergency Program Act*, local authorities are also responsible for developing emergency response plans, with provincial funding assistance.

A significant portion of BC's coastal population and infrastructure is protected from coastal flooding by sea dikes. A range of entities have

PARTNERSHIPS REDUCE COASTAL FLOOD VULNERABILITY

Over a period of four years, the City of Surrey worked to engage various stakeholders to co-develop a Coastal Flood Adaptation Strategy (CFAS) to reduce coastal flood risk and adapt to one metre of global sea-level rise. Figure 4 depicts a portion of the coastal floodplain in Surrey. A four-phase approach to develop CFAS assisted the City of Surrey in strengthening relationships with various stakeholders and all orders of government.

The first intake of the Infrastructure Canada Disaster Mitigation and Adaptation Fund (DAMF) required a minimum project size of $20 million (to access federal funding of 25% to 75%) to increase community resilience to natural hazards and climate change. DAMF provided the opportunity for the City to build upon the relationships developed in CFAS through new partnerships with Semiahmoo First Nation, the Province of British Columbia, and Southern Railway to reduce coastal flood risk by implementing win-win solutions to adapt to sea-level rise.

Figure 4: Coastal Floodplain in Surrey, BC (Photo Credit, City of Surrey).

Within the City of Surrey organization, innovative projects have also been developed because of the DMAF opportunity, including nature-based solutions involving deep collaboration between various departments. Access to federal funding and a shared desire to maximize the evaluation criteria provided the environment to improve the proposal and ultimately to accelerate implementation of complex infrastructure projects to reduce coastal flood risk.

taken responsibility for maintaining the dikes. The province has enacted legislation dating back to 2002 to transfer the responsibilities to maintain and upgrade dikes throughout the region to local governments.[15] The limited fiscal capacity of some local governments to tackle these responsibilities in the face of escalating risks and aging infrastructure is a problem yet to be resolved.

To support local governments engaged in flood management, the provincial and federal governments sporadically provide a portion of capital funding and some technical tools and support. In the event of a damaging flood whereby a state of emergency is established, financial assistance is provided by the federal and provincial governments under a cost-sharing arrangement. A succinct list of federal government departments and their role in flood risk management is provided by Golnaraghi et al.[16]

Federal funding for coastal flood risk management in BC is provided through various programs. For example, funding for large-scale infrastructure projects to help communities better manage the risks of disasters triggered by coastal flooding is available through the DMAF. While large government funding programs have traditionally focused on structural flood mitigation projects implemented by a single organization, DMAF has encouraged a broader range of approaches and explicitly encourages innovation, partnership and nature-based solutions.

Indigenous Services Canada provides funding for flood protection infrastructure, mitigation and preparedness in First Nations communities, and BC-region officials work closely with Indigenous leaders to support emergency response when flooding occurs. The federal government generates and disseminates data often used to support coastal flood hazard or risk assessment and management (e.g., Fisheries and Oceans Canada maintains a network of permanent tide gauges, and the Canadian Hydrographic Service surveys and disseminates bathymetric data). A number of federal government departments and agencies are also engaged in funding or conducting fundamental and applied research on topics related to coastal flood and erosion risk management, including Natural Resources Canada, Fisheries and Oceans Canada, Defense Research and Development Canada, and the National Research Council of Canada.

The BC Storm Surge Forecasting System was developed as a joint program between the BC Ministry of Environment and Fisheries and Oceans Canada. The system provides six-day forecasts of storm surge and total water levels at several coastal sites in southern BC. The system is described as a research tool, and it uses a predictive numerical ocean model and real-time measurements to generate bulletins for Victoria, Vancouver and Campbell River. Long-term financial support to maintain operation and improvement of the system has been lacking, with funding provided by various contributors including Fraser Basin Council, Port of Vancouver, and the municipalities of Vancouver, Richmond, Surrey and Delta. In 2019, the federal government invested $4.9 million over five years for Environment and Climate Change Canada to improve Canada's ability to predict coastal floods and to develop early warning systems; but at the time of writing, there is no federally operated real-time coastal flood forecasting system in use in BC.

GAPS IN REDUCING RISK

GUIDANCE AND GOVERNANCE

While high-level provincial guidance for sea-level rise adaptation planning exists, there is no provincial guidance for implementing nature-based solutions or strategies such as planned or managed retreat (Table 1). The federal government has recently published reports to highlight case studies and the needs and gaps on these topics,[17,18,19] and international guidelines on natural and nature-based features for flood risk management were published in 2021.[20] However, existing guidance lacks the granularity and technical detail needed for local governments to implement these solutions. Government programming, policies and mechanisms to implement planned retreat strategies have yet to be established and are needed for proactive implementation in BC.

Table 1: Organizations and industries involved in coastal flood risk management

Organization	Type of Organization	Legal Mandate	Role	Key Programs
Public Safety Canada	Federal government	Yes	Emergency preparedness and response; funding for mapping, risk assessment, non-structural or small-scale mitigation	National Disaster Mitigation Program
Indigenous Services Canada	Federal government	Yes	First Nations emergency preparedness and response; funding mitigation; flood insurance	First Nations Adapt
Infrastructure Canada	Federal government	Yes	Infrastructure standards; project funding; research funding	Disaster Mitigation and Adaptation Fund
Natural Resources Canada	Federal government	Yes	Research; research funding; funding for adaptation; data and tools	Federal Floodplain Mapping Guidelines; Sea-Level Rise Projections
Defence Research and Development Canada	Federal government	Yes	Research funding	Canadian Safety and Security Program
National Research Council of Canada	Federal government	Yes	Applied research; data and tools	Ocean, Coastal and River Engineering Research Centre, Ocean Program
Fisheries and Oceans Canada	Federal government	Yes	Research; data provider; regulator	Marine Environmental Data Section, Canadian Hydrographic Service
Environment and Climate Change Canada	Federal government	Yes	Weather forecasts; climate change projections; operational flood forecasting	Environmental data
Emergency Management BC	Provincial government	Yes	Coordination of emergency response, planning, training, testing and exercising	Education; training; response and recovery
Forests, Lands, Natural Resource Operations and Rural Development	Provincial government	Yes	Tools and data; regulating dike safety and upgrades	Coastal floodplain mapping guidelines
Fraser Basin Council	Non-governmental organization*	No	Studies, planning, outreach and education	Facilitator of Regional Flood Management Strategy

Organization	Type of Organization	Legal Mandate	Role	Key Programs
First Nations	Local government	Yes	Infrastructure provider; emergency response; rights holder; advocacy, outreach and education	Land-use regulations; infrastructure maintenance; emergency response; Living Dike Roundtable; community engagement
BC Stewardship Centre	Non-governmental organization*	No	Guidelines, studies, advocacy and outreach	Green Shores for Shoreline Development; Green Shores for Homes; Green Shores for Local Government
Engineers and Geoscientists BC	Professional association / regulatory body	Yes	Protecting the public interest	Professional practice guidelines
Insurance industry	Private sector, for profit	Yes	Risk transfer	Overland coastal flood property insurance
Financing industry	Private sector, for profit	Yes	Providing capital for real estate and resilience investments	Mortgages for real estate; resilience bonds for infrastructure investment
Municipalities	Local government	Yes	Infrastructure provider; emergency response; regulator	Land-use regulations; infrastructure maintenance; emergency response
Post-secondary institutions	Research and education	No	Science, policy and research	Engineering; Coastal Adaptation Lab; community and regional planning

Notes: Non-exhaustive list of non-governmental organizations for illustration. Other organizations are involved in coastal management, advocacy and research, either directly or indirectly contributing to disaster and climate risk reduction.

There is no provincial guidance for implementing nature-based solutions or strategies such as planned or managed retreat. . . . Existing [federal and international] guidance lacks the granularity and technical detail needed for local governments to implement these solutions. Government programming, policies and mechanisms . . . are needed for proactive implementation in BC.

The complex, disjointed governance context has been criticized for contributing to a lack of coordination, imbalances in the distribution of resources for managing flood risk, stilted or absent dialogue, and disincentives for effective risk management. For example, in 2003, the provincial government devolved land-use permitting for flood hazard areas to local governments. However, many local governments lack the fiscal capacity and support needed to assume this burden. Since many municipalities are reliant on taxes from high-value waterfront properties, an obvious conflict arises when it comes to permitting development in coastal areas. Moreover, there is limited incentive or opportunity to proactively consider flood risk management options like planned retreat, particularly when liability for flood damages is shared with provincial and federal governments. Harmonization and coordination of governance, regulations and approaches to flood risk management across all levels of government (including Indigenous government) is needed to remove confusion, blind spots and inconsistencies that currently plague coastal flood risk management practice.

Organizational mandates to reduce risk driven by climate change are missing. Having clear, well-defined organizational mandates will direct staff to be more open about releasing information that will ultimately support better decision making and public support.

INCLUSIVE PLANNING AND RECOVERY

Often, those who bear the costs of flood are not aligned with or involved in risk management decisions. Home financing, for example, is rarely subject to restrictions that depend on coastal flood risk. As well, federal and provincial disaster assistance does not incentivize "building back better," and there is limited guidance or direction to private homeowners on how best to manage their risk or participate in risk reduction on a system-wide basis. A crucial prerequisite for strengthening governance is increased recognition of the role, rights and self-determination of First Nations in accordance with the *UN Declaration on the Rights of Indigenous Peoples* (UNDRIP) and the *Sendai Framework for Disaster Risk Reduction 2015–2030*, and support (and adequate funding) for meaningful involvement of First Nations in decision making surrounding coastal flood risk management. Improving First Nations involvement in flood resilience decision making has been identified as a priority action by the provincial government as it works towards a flood strategy, following the BC *Declaration on the Rights of Indigenous Peoples Act* in 2019 (DRIPA). However, some local governments have called for guidance on how best to work with local First Nations to implement DRIPA and UNDRIP.

SUSTAINABLE FUNDING

Fiscal capacity and resources at the front lines of implementation for coastal flood risk management (i.e., local government level) are rarely commensurate with needs. Funding by federal and provincial governments has been criticized for being reactive (e.g., Disaster Financial Assistance Arrangements (DFAA)) and difficult to access, owing to myriad and complex funding programs. The sustainability of DFAA funding has also been called into question by the escalating number and scale of extreme weather-related disasters across Canada. Funding for proactive disaster risk reduction measures has been less readily available (compared to post-disaster assistance) and previously focused on structural solutions. Following strong and

growing advocacy for nature-based solutions by First Nations, researchers, and (mostly non-profit) groups like Stewardship Centre for British Columbia, Municipal Natural Assets Initiative, Fraser Basin Council, Living Dike Roundtable, and Living with Water initiative, federal government funding agencies are beginning to trial and implement funding programs for green infrastructure.

RECOVERY PLANNING

The lack of clarity on roles and responsibilities at different levels of government is a barrier to enhancing disaster preparedness and recovery. The flooding in BC's Lower Mainland in November 2021 (driven by extreme precipitation) highlighted vulnerabilities and gaps in emergency response coordination and the extent of supply chain disruption that could result from widespread coastal flooding. Many communities reported a lack of early warning, and delays in receiving support and assistance. Early warning is of particular concern for coastal flooding events when without sustained, long-term funding to support development and maintenance of operational flood forecasting systems. Sustained and increased investment is needed to support the modernization of forecasting tools and dissemination techniques (e.g., social media, mapping) so that they can guide preparedness and response. While emergency response planning is conducted by local governments with provincial funding assistance, post-flood recovery planning is virtually non-existent. Building back better requires planning in advance for recovery following a damaging event (during which resources are always stretched) and dedicated, rapidly accessible funding programs for post-flood improvement works (in parallel to DFAA).

EDUCATION

A shortage of highly qualified professionals with coastal flood risk assessment and management expertise has contributed to a lack of consistency and innovative practice in understanding and managing risk. There are few programs or institutions where individuals can receive in-province post-secondary training in coastal flood risk management concepts and practice; such programs would support the development of a homegrown network of expertise and innovation. Governments and private-sector firms are therefore heavily reliant on attracting professionals from elsewhere and often struggle to retain talent, resulting in a transient professional community. This transience limits the extent to which local knowledge, and First Nations' Traditional Knowledge in particular, is applied in coastal flood risk management practice. Professional associations are slow to recognize needs for dedicated, specialist designations to raise technical standards, instead relying on publishing professional practice guidance that is often underfunded or conflicting with other technical guidance. Recently, a number of academic and government research institutions, led by the University of Windsor, have proposed to establish a nation-wide coastal careers training network. If funded, such an initiative has potential to be a game-changer in training and developing the next generation of skilled, multi-disciplinary coastal hazard and risk professionals.

OPPORTUNITY

RECOMMENDATIONS

A range of actions are needed (Table 2) to reduce coastal flood risk that involve the organizations listed in Table 1. The recommendations are grouped to align with the four priorities of the Sendai Framework.

THE CHALLENGE

A key challenge is moving beyond coastal flood risk management strategies that are based solely on protecting the most valuable assets indefinitely. Funding programs and risk assessments in BC have focused on monetary valuation of cost-to-benefit, with limited evaluation of environmental and social impacts or benefits, and have prioritized structural flood protection measures. This has incentivized municipalities and others applying for coastal disaster risk reduction funding to develop proposals that prioritize reducing risks to the most valuable infrastructure and urban land but ignore or de-emphasize the inherent (if perhaps less tangible from a monetary perspective) value of other assets and land uses (e.g., natural assets, farmlands, heritage, cultural

Table 2: Recommendations

Recommendation	Description of Impact	Priority Level	Capabilities Needed
Understanding Disaster Risk			
1. Develop strategic shoreline management plans for all coastal reaches in BC.	Provides a strategic framework for managing risk (to guide more specific, local actions) and defines system boundaries within which whole-of-society needs, risks and opportunities are identified. Raises public awareness of risk. Takes a long-term view.	Necessary	Federal and/or provincial government leadership; multi-disciplinary expertise and whole-of-society participation.
2. Develop a more comprehensive understanding of flood hazard event types and scenarios impacting coastal communities.	Increases awareness and understanding that multiple event types can impact communities. Moves towards an "all hazards" understanding of risk.	Necessary	Federal and/or provincial government leadership; multi-disciplinary expertise and whole-of-society participation.
3. Conduct comprehensive post-event analyses that consider stakeholder and community values.	Establishes a cycle of continuous improvement where learnings from flood events inform planning and preparedness in ways that reflect stakeholder and community values and perspectives.	Necessary	Federal and/or provincial government leadership; multi-disciplinary expertise and whole-of-society participation.
4. Establish an integrated, province-wide coastal monitoring network and program.	Provides the baseline data needed to support flood risk assessment, forecasting and early warning, adaptation planning, and preparedness.	Recommended	Sustainable, long-term funding; federal and provincial government commitment and accountability; partnership with private sector and academic/non-profit technical specialists.
5. Enshrine risk-based approaches and a broader portfolio of adaptation strategies in updated provincial guidance on coastal flooding.	Modernizes provincial coastal flood risk management practice and expands portfolio of risk management strategies.	Recommended	Adequate funding for updates to guidance; peer review of guidance prior to publication.

Recommendation	Description of Impact	Priority Level	Capabilities Needed
Strengthening Disaster Risk Governance			
6. Implement UNDRIP best practice guidelines in flood management and increased First Nations participation in all aspects of risk reduction.	Meaningfully engages First Nations and includes Traditional Knowledge in decision making.	Critical	Competencies needed, technical guidance and training to enable practitioners to implement UNDRIP; financial capacity to First Nations to meaningfully participate.
7. Harmonize and modernize regulations and guidelines.	Reduces conflicting regulations/guidelines that prohibit implementation of risk reduction measures and innovative solutions.	Necessary	Public awareness to build political support.
8. Establish risk reduction mandates.	Enables information sharing to understand risk and increased collaboration to implement risk reduction measures.	Recommended	Public awareness to build political support.
Investing in Disaster Risk Reduction			
9. Set up sustainable funding and planning.	Allow for long-term planning and implementation of solutions outside of the status quo.	Critical	Long-term, sustained cost sharing programs to implement strategic work.
10. Streamline, consolidate and modernize funding programs and application processes.	Enables flood risk managers to quickly and easily access funding streams for a broader range of risk management activities and works (e.g., for green infrastructure). Align DFAA funding with "build back better" principles.	Necessary	Engagement at multiple levels of government; communications expertise; financial resources needed.

Recommendation	Description of Impact	Priority Level	Capabilities Needed
Enhancing Disaster Preparedness for Effective Response and to "Build Back Better"			
11. Increase capacity and reduce barriers to implementing natural and nature-based solutions.	Sets out a path forward for solutions outside of the status quo. Avoids decisions of regret. Provides more sustainable options for managing flood risk. Harnesses ecosystem services to deliver multiple co-benefits.	Necessary	Competencies needed, invest in training programs for professionals; financial capacity to support pilot projects; harmonization of regulations; long-term research and monitoring programs centred around pilot projects.
12. Develop and maintain a province-wide coastal flood forecasting system.	Provides early warning to communities and emergency managers to enhance preparedness.	Necessary	Initial investment to bring existing systems up to "state-of-the art" and sustained, ongoing financial investment to maintain and operate.
13. Raise performance standards for buildings and infrastructure to provide enhanced resistance and resilience.	Reduces residual risk, emergency response resource demands, and post-flood recovery times in the event of flood exposure.	Necessary	Investment in rapid advancement of building codes, and/or alternative mechanisms (e.g., standards); training of construction professionals; insurance industry involvement.

sites). More balanced methodologies for options appraisal are needed to ensure risk reduction plans better reflect community values—such as the expectation of food security and recreational opportunities—and are more equitable. Shoreline management plans can provide an effective platform for options appraisal on a whole-of-society basis and facilitate discussion on difficult strategies like planned or managed retreat (in a proactive rather than reactive way); such strategies are increasingly being adopted by communities across Canada.

Moving forward, greater incentives must be offered to avoid decisions of regret. For example, a transportation mandate to construct or widen a highway within a coastal floodplain is not currently subject to any provincial requirements for flood risk assessment or flood risk mitigation measures. By contrast, infrastructure investments funded by the federal government require a climate lens assessment[21] to align investments with acceptable risk.

Perhaps the greatest challenge is to overcome the barriers create by the fragmented governance of coastal flood risk management in BC, which hinders coordination and progress. This will require whole-of-society dialogue and political will to adapt to changing flood hazards.

RESOURCES

BC AND CANADA

1. High-level coastal planning and engagement for the Fraser River Foreshore area that identifies community values:

City of Vancouver. *Vancouver Coastal Adaptation Plan – Fraser River Foreshore*. 2018. https://vancouver.ca/files/cov/coastal-adaptation-plan-final-report.pdf

2. A master plan for a coastal community on Vancouver Island that sets out short-term actions to advance the vision for the waterfront:

Town of Qualicum Beach. *Waterfront Master Plan*. 2020. https://www.qualicumbeach.com/waterfront-master-plan

3. An action plan for a coastal community on Vancouver Island that prioritizes key actions to year 2050:

City of Campbell River Sea Level Rise Action Plan. 2020. https://www.campbellriver.ca/docs/default-source/default-document-library/sealevelriseactionplanfinal---w-copyright-no-watermark.pdf?sfvrsn=4c026b08_0

INTERNATIONAL

1. A state-wide coastal adaptation plan that prioritizes projects, updated on a five-year cycle.

Coastal Protection and Restoration Authority of Louisiana. *Louisiana's Comprehensive Master Plan for a Sustainable Coast.* 2017. http://coastal.la.gov/wp-content/uploads/2017/04/2017-Coastal-Master-Plan_Web-Single-Page_CFinal-with-Effective-Date-06092017.pdf

2. A comprehensive international guide to conceptualizing, planning, designing, engineering, and operating nature-based solutions for flood and erosion risk management in coastal and riverine settings:

Bridges, T. S., J. K. King, J. D. Simm, M. W. Beck, G. Collins, Q. Lodder, and R. K. Mohan, eds. *International Guidelines on Natural and Nature-Based Features for Flood Risk Management* (Vicksburg, MS: U.S. Army Engineer Research and Development Center, 2021). https://ewn.erdc.dren.mil/?page_id=5630 (Overview document: https://ewn.erdc.dren.mil/?page_id=5698)

3. The first of two volumes of technical guidance for developing shoreline management plans in England and Wales:

Department for Environment, Food and Rural Affairs. *Shoreline management plan guidance – Volume 1: Aims and requirements* (London, 2006). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69206/pb11726-smpg-vol1-060308.pdf

4. Part of a series of guidelines on national disaster risk assessment, compiling useful international examples and resources for coastal erosion hazard and risk assessment:

UNISDR. *Words into Action Guidelines: National Disaster Risk Assessment Hazard Specific Risk Assessment, 7. Coastal Erosion Hazard and Risk Assessment*. 2017. https://www.unisdr.org/files/52828_07coastalerosionhazardandriskassess.pdf

5. One of a series of books by international experts on water management, specifically providing guidance on strategic flood risk management techniques that enable longer-term, system-wide approaches.

Sayers, P., Y. Li, G. Galloway, E. Penning-Rowsell, F. Shen, K. Wen, Y. Chen, and T. Le Quesne. *Flood Risk Management: A Strategic Approach* (Paris: UNESCO, 2013). http://www.sayersandpartners.co.uk/uploads/6/2/0/9/6209349/flood-risk-management-web.pdf

ENDNOTES

[1] Richard E. Thomson, Brian D. Bornhold, and Stephane Mazzotti, *An examination of the factors affecting relative and absolute sea level in coastal British Columbia.* (Sidney: Fisheries and Oceans Canada, Institute of Ocean Sciences, 2008). https://publications.gc.ca/collections/collection_2015/mpo-dfo/Fs97-18-260-eng.pdf

[2] Patrick Forseth, *Adaptation to Sea Level Rise in Metro Vancouver: A Review of Literature for Historical Sea Level Flooding and Projected Sea Level Rise in Metro Vancouver.* (Burnaby: Simon Fraser University, 2012).

[3] Dilumie S. Abeysirigunawardena, Dan J. Smith, and Bill Taylor, "Extreme sea surge responses to climate variability in coastal British Columbia, Canada," *Annals of the Association of American Geographers*, 101, 5 (2011): 992-1010.

[4] Thomas James et al., *Relative Sea-Level Projections for Canada Based on the IPCC Fifth Assessment Report and the NAD83v70VG National Crustal Velocity Model*, (Ottawa: Geological Survey of Canada, 2021).

[5] Julien Cousineau, and Enda Murphy, "Numerical Investigation of Climate Change Effects on Storm Surges and Extreme Waves on Canada's Pacific Coast," *Atmosphere,* 13, 2 (2022): 311. https://doi.org/10.3390/atmos13020311

[6] Patrick L. Barnard et al., "Coastal Vulnerability across the Pacific Dominated by El Nino/Southern Oscillation," *Nat. Geosci.*, 8 (2015): 801–807.

[7] BC Ministry of Forests, Lands and Natural Resource Operations and Rural Development, ***Flood Hazard Area Land Use Management Guidelines***, (Vancouver: 2018). https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/integrated-flood-hazard-mgmt/flood_hazard_area_land_use_guidelines_2017.pdf

[8] BC Ministry of Environment, *Sea Level Rise Adaptation Primer: A toolkit to build adaptive capacity on Canada's south coasts*, (Vancouver: 2013). https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/resources/slr-primer.pdf

[9] Enda Murphy et al., *Coastal flood risk assessment guidelines for building and infrastructure design: supporting flood resilience on Canada's coasts*, (Ottawa: National Research Council Canada, 2020). https://nrc-publications.canada.ca/eng/view/ft/?id=b4e8e5cd-ace2-4777-866f-1bb18bff77f0

[10] Ministry of Forests, Lands, Natural Resource Operations and Rural Development, *Flood Hazard Area Land Use Management Guidelines*, (Vancouver: 2018). https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/integrated-flood-hazard-mgmt/flood_hazard_area_land_use_guidelines_2017.pdf

[11] KPMG, *Research Project: Water Damage Risk and Canadian Property Insurance Pricing*, (Ottawa: Canadian Institute of Actuaries, 2014) https://www.cia-ica.ca/docs/default-source/2014/214020e.pdf

[12] William L. Coulbourne et al., *Guide for Design of Flood-Resistant Buildings*, (Ottawa: National Research Council of Canada, 2021). https://nrc-publications.canada.ca/eng/view/ft/?id=96b3275c-b731-4fa6-847e-e2a9a0f080d8

[13] Randall L. Behm et al., *Guidelines for improving flood-resistance for existing buildings*, (Ottawa: National Research Council of Canada, 2021). https://nrc-publications.canada.ca/eng/view/ft/?id=c3b54b84-2a25-4e7e-ba3e-01c80378f086

[14] City of Surrey, *Surrey Coastal Flood Adaptation Strategy*, (Surrey: 2013). https://www.surrey.ca/sites/default/files/media/documents/CFASFinalReportNov2019.pdf

[15] City of Surrey, *Dyking Districts in the City of Surrey – Repeal of the Drainage, Ditch and Dike Act*, (Surrey: 2013). https://www.surrey.ca/sites/default/files/corporate-reports/RPT_2009_R003.pdf

[16] Maryam Golnaraghi et al., *Flood Risk Management in Canada: Building flood resilience in a changing climate*, (Zurich: The Geneva Association—International Association for the Study of Insurance Economics, 2020). https://www.genevaassociation.org/sites/default/files/research-topics-document-type/pdf_public/frm_canada_web.pdf

[17] Ivana Vouk et al., *Nature-Based Solutions for Coastal and Riverine Flood and Erosion Risk Management*, (Toronto: Canadian Standards Association, 2021). https://www.csagroup.org/article/research/nature-based-solutions-for-coastal-and-riverine-flood-and-erosion-risk-management/

[18] Joanna L. Eyquem, *Rising Tides and Shifting Sands: Combining Natural and Grey Infrastructure to Protect Canada's Coastal Communities*, (Waterloo: Intact Centre on Climate Adaptation, University of Waterloo, 2021). https://www.intactcentreclimateadaptation.ca/wp-content/uploads/2021/12/UoW_ICCA_2021_12_Coastal_Protection_Grey_NbS.pdf

[19] Patrick Saunders-Hastings, Michael Bernard, and Brent Doberstein, *Planned Retreat Approaches to Support Resilience to Climate Change in Canada*, (Ottawa: Natural Resources Canada, 2021). https://doi.org/10.4095/328323

[20] Todd S. Bridges et al., eds., *International Guidelines on Natural and Nature-Based Features for Flood Risk Management,* (Vicksburg: U.S. Army Engineer Research and Development Center, 2021). https://ewn.erdc.dren.mil/?page_id=5630

[21] "Climate Lens – General Guidance -Infrastructure Canada," last modified October 31, 2019 https://www.infrastructure.gc.ca/pub/other-autre/cl-occ-eng.html

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