Flood Risk Tolerance in British Columbia

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NOVEMBER 2026

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Pacific Institute for Climate Solutions

EXECUTIVE SUMMARY

British Columbia faces increasing climate-related risks. As climate hazards intensify, deciding how much risk society is willing to tolerate is one of the most consequential choices facing policymakers. Risk tolerance thresholds influence infrastructure investment, land use planning, insurance regulation, and disaster response. These decisions shape who is protected, who pays the costs of climate change, and how limited resources are allocated across communities and sectors.

Floods are one of the leading climate risks and are projected to bring rising costs across B.C. without substantial adaptation. Current flood risk governance in the province relies heavily on a standards-based approach, primarily using the one-in-200-year event for design thresholds, floodplain mapping, and policy design. While this approach offers simplicity from a regulatory and planning perspective, it lacks flexibility and fails to capture indirect and long-term impacts, limiting B.C.'s climate adaptation potential. Recent initiatives including the Disaster and Climate Risk and Resilience Assessment (2025) and regulations under the Emergency and Disaster Management Act are expanding risk information, but these do not dictate acceptable risk thresholds. Meanwhile, tolerance choices are made implicitly through disaster assistance eligibility, insurance availability and pricing, and case-by-case professional judgment.

To unpack the nuances and policy implications of risk tolerance decisions, we evaluate current B.C. flood risk standards and governance. Specifically, we compare practices between B.C. and leading nations (Netherlands, New Zealand) to analyze how B.C. can shift towards more resilient, risk-based flood management practices. Unlike standards-based approaches that assume a fixed hazard level (e.g., one-in-200-year flood), risk-based frameworks assess both the likelihood and consequences of events and can reflect a jurisdiction's risk tolerance, enabling more dynamic, place-based, and forward-looking planning. Risk-based approaches are also better suited to account for cascading and compounding climate hazards, equity concerns, and indirect and intangible impacts.

Based on our analysis, five key findings emerged:

- International best practices show the benefits of adaptive, risk-informed planning, cross-jurisdictional coordination, and strong community engagement. Aotearoa (New Zealand) now legislates national risk tolerance for land-use planning through its National Policy Statement for Natural Hazards (2026), while the Netherlands pairs codified risk-to-life standards with a scheduled review cycle.
- Indirect and intangible impacts (e.g., loss of healthcare access, supply chain interruptions) are not well-integrated into flood risk assessments.
- B.C.'s current system is fragmented and lacks clear provincial and professional guidance on risk threshold determination

beyond traditional design standards, even though quantitative risk tolerance criteria already operate within the province for landslides and debris flows. Extending and adapting this existing practice to floods would support a consistent, multi-hazard approach to risk.

- Rural and remote communities face heightened vulnerability to flood hazards due to factors like limited infrastructure, service isolation, and overlapping hazards.
- Experience in both Aotearoa (Matatā) and B.C. (Merritt) shows that where tolerance thresholds are not established in advance, retreat and recovery decisions are improvised in the aftermath of disasters. With limited resilience funding available, explicit criteria would also provide a defensible, transparent basis for deciding what to protect first.

To transition toward a more equitable and climate-resilient flood governance model, B.C. should consider the following strategies:

- **Transition to a variable risk-based framework** that incorporates climate change, loss-of-life metrics, and indirect/intangible impacts, with stricter thresholds for new development and critical assets.
- **Develop a cohesive provincial program** aligned with federal initiatives, including risk threshold determination and transparent prioritization, drawing inspiration from international best practices (e.g., the Dutch Delta Programme).
- **Expand community-engaged planning**, especially with First Nations and rural communities, to co-develop risk thresholds and solutions, identifying the values at stake before thresholds are set and remaining adaptable to each rights and title holder.
- **Pair adaptive pathways and managed retreat strategies** with a clear framework defining the thresholds at which retreat will be considered, who will pay, and how affected communities and First Nations will be supported, so these decisions are made deliberately before disasters rather than improvised after the fact.

FLOOD RISK STANDARDS & GOVERNANCE IN BRITISH COLUMBIA

Flooding is Canada's most costly type of disaster, causing about $2 billion in residential damages each year, and both the frequency and severity of these events are expected to continue to rise with changing climate (Foran et al., 2025). In B.C., river flooding (fluvial), storm water (pluvial), and coastal floods have caused significant impacts to human health, infrastructure, and water quality. The Province is responding with initiatives like the Highway Infrastructure Adaptation Program, the B.C. Flood Strategy, and the B.C. Coastal Marine Strategy (Ministry of Land, Water and Resource Stewardship, 2024). Additionally, Engineers and Geoscientists BC (EGBC) have outlined professional guidelines for flood risk management (EGBC, 2017).

B.C. relies on a standards-based approach to define acceptable flood risk, commonly using a 200-year event (0.5 per cent annual exceedance probability) as the benchmark for floodplain mapping and design of dikes, dams, and other infrastructure. Flood Construction Levels (FCLs) vary depending on the application but do require habitable areas of new structures in floodplains to be built above this 200-year level, plus a freeboard safety margin. This threshold also determines eligibility for federal disaster financial assistance (Public Safety Canada, 2025). Professional guidelines by EGBC suggest a tiered approach, using lower return periods (20 to 200 years) for lower-risk areas and higher periods (500 to 2,500 years) for higher-risk areas (EGBC, 2017), but these are not widely adopted nor provincially mandated (Ebbwater Consulting Inc., 2021). Provincial guidance is implemented by local governments through bylaws and development permits, requiring new construction in risk areas to meet FCLs. Existing developments are usually not required to retrofit (Province of British Columbia, 2018), which can cause challenges for properties built before current standards. For example, a 2019 study in Crescent Beach, B.C., found that new FCLs were reported to intensify water problems for nearby, older homes built before guidelines were in place, highlighting a key limitation of the standards-based approach (Oulahen et al., 2019).

There are several bodies responsible for flood risk planning, risk determination, and implementation and maintenance of infrastructure:

- **The Government of B.C.** sets guidelines, return periods, and oversees dike safety for fluvial floods.
- **The Ministry of Emergency Management and Climate Readiness** (EMCR) coordinates preparedness and disaster assistance with local authorities.
- **Municipalities and regional districts** lead local planning, land use, and flood infrastructure maintenance and are primarily responsible for pluvial, fluvial, and coastal flood risks (Ministry of Environment and Climate Change, 2024).
- **Qualified professionals**, including EGBC, consultants, and contractors, help assess risks and guide resilience planning.

Beyond FCLs and floodplain mapping, the Province lacks sector-specific guidelines on risk-threshold determination, with flood resilience planning often undertaken at municipal or community levels on a case-by-case basis. One such example is the District of North Vancouver's Natural Hazards Risk Tolerance Criteria, a set of risk-to-life requirements for construction development applications (District of Vancouver, n.d.). These requirements were recommended to City Council through consultation with experts in the field as well as public engagement, which were later adopted by the district, but are not provincially mandated (Kovacs, 2018). Although explicit provincial adoption has lagged, choices regarding flood risk tolerance are already made implicitly in the current regulatory landscape. Disaster financial assistance eligibility rules determine how losses are absorbed, insurance availability and pricing set a de facto tolerance for households, and professional practice guidelines leave judgments to case-by-case professional and statutory discretion. Stating these thresholds explicitly would allow for more consistent, equitable, and transparent decisions regarding risk.

This sentiment is reflected in B.C.'s *Flood Strategy to 2035*, published in 2024 and developed with First Nations, local governments, and stakeholders, and calls for updated flood risk assessments, improved coordination between relevant bodies (both across Canadian jurisdictions and internationally), and clearer guidance on acceptable risk levels (Ministry of Land, Water and Resource Stewardship, 2024). These ambitions are aligned with modern best practices, and highlight proactive planning, infrastructure upgrades, and climate adaptation as key components for defining acceptable risk. Priorities outlined include modernizing technical guidelines for flood infrastructure and land use, incorporating climate change and hydrological assessments, improving integrated planning and governance, establishing flood resilience advisory circles for First Nations and Ministries, updating legislation, enhancing forestry practices to reduce risk, as well as promoting equity, ecosystem health, and cumulative effects into decision-making. The plan outlines actions for preparedness, response, and investment, but does not provide detailed targets or renewal specifics (Ministry of Land, Water and Resource Stewardship, 2024), and emphasizes drawing on international best practices in developing B.C.'s flood resilience.

Several damaging events have occurred in recent years, including the October 2024 atmospheric river that caused five deaths in the Lower Mainland, renewed Fraser Valley flooding in December 2025, and spring 2026 flooding on the Central Coast (Waters, 2026). In October 2025, the Province released the Disaster and Climate Risk and Resilience Assessment (DCRRA), covering river and coastal flooding among six hazards and accompanied by a public Hazard Insights Tool (Province of British Columbia, 2025a). In accordance with the Emergency and Disaster Management Act announced in May 2026 (in force January 2027), local authorities must "complete emergency-management plans, business continuity plans and hazard-risk assessments, in consultation and co-operation with Indigenous governing bodies" (Province of British Columbia, 2026b).

Federally, the modernized Disaster Financial Assistance Arrangements (as of April 2025) link recovery cost-sharing to risk, offering a 90 per cent federal share for mitigation protecting high-risk areas versus 50 per cent otherwise (Public Safety Canada, 2025). However, these instruments do not dictate acceptable risk levels. As the number of risk assessments increases under the new regulations, the absence of provincial tolerance criteria will become more consequential. In the following section, modern flood risk practices and their implications are reviewed, and are subsequently discussed in the context of international best-practices.

REVIEW: MODERN FLOOD RISK PRACTICES & IMPLICATIONS

The determination of risk thresholds and design practices, including flood insurance policies, is complex and varies significantly across countries and regions (Ceres et al., 2022; Knittel et al., 2024). A lack of institutional coordination and funding, gaps in policy formation, and community risk perceptions all contribute to poor flood risk management practices globally (Abbas et al., 2016; Bang & Burton, 2021; Fatti & Patel, 2013), enabling disastrous flood events whose impacts may otherwise have been preventable. Determination of acceptable flood risk tolerance (e.g. **standards-based versus risk-based**) in conjunction with assessment of potential impacts (**direct and indirect impacts**) influence the success of flood resilience projects and governance. In addition to the flexibility and efficiency of a risk-based approach, it enables better consideration of climate change and allows for inclusion of indirect and intangible impacts in flood risk assessment. However, implementation is not without challenges as discussed below.

STANDARDS-BASED VERSUS RISK-BASED

Standards-based flood risk approaches consider only the probability of flood events, using established guidelines and regulations to minimize damage by informing the construction of physical flood protection (Krieger, 2013; Vitale, 2023). This often focuses on a single design threshold and tends to be simpler but is less optimized and flexible. Standards-based protection involves building structures above a certain floodplain level, or constructing dams, levees, and dikes to withstand floods of a given magnitude or return period. This method can be applied across large spatial scales using floodplain maps, models, and observational data; however, site-specific nuances are not inherently captured in these assessments, nor are climatic changes. For example, case studies undertaken by the Government of Canada have shown that designing for a 200-year flood is no longer sufficient to protect infrastructure and livelihoods given near-term future climate projections (Natural Resources Canada, 2023). Conversely, in some cases designing to a 200-year flood protection level may not be feasible or necessary. It also promotes a “set and forget” attitude, which is inadequate for today’s rapidly changing climatic conditions and incompatible with adaptive management practices. **A shift away from standards-based flood protection represents a more nuanced approach with various situational levels of protection**.

This enables efficient resource allocation, targeted flood infrastructure investments, and better incorporation of localized climatic and geographic conditions, encouraging adaptive and context-specific flood resilience.

A risk-based approach considers both the probability and consequences of flood events, building adaptive capacity for the changing climate and employing a broad range of solutions beyond physical flood protection (Krieger, 2013; Vitale, 2023). To incorporate the consequences into the framework, risk-based approaches often employ mortality functions, which aim to estimate the number of fatalities associated with a flood event by linking flood characteristics and damage with the number of casualties (Li et al., 2023). Figure 1 illustrates how the existing standards-based flood protection fits within the larger framework of a risk-based approach, highlighting the limitations of relying solely on the former. A "risk to life" or "loss of life" metric is often used to determine acceptable risk levels (APEG, 2018; Kind, 2014). For example, in the Netherlands, the maximum acceptable mortality risk to an individual for a new development is 1:1,000,000 per year, meaning a one in a million chance of death per year per resident. By integrating hydrological models and agent-based models with demographic data and economic factors, loss of life may be estimated in different regions to inform flood resilience practices (Jonkman et al., 2008; Zhang et al., 2022). Frequency vs. number of fatalities curves (FN) use graphical representations of societal or individual risk, showing the frequency (F) of events resulting in a certain number of fatalities (N), helping to quantify the probability of having a certain number of casualties resulting from a flood event (Van der Most et al., 2014). The result is an approach that frames human lives as central to the conversation, while still incorporating economic, environmental, and built environment impacts.

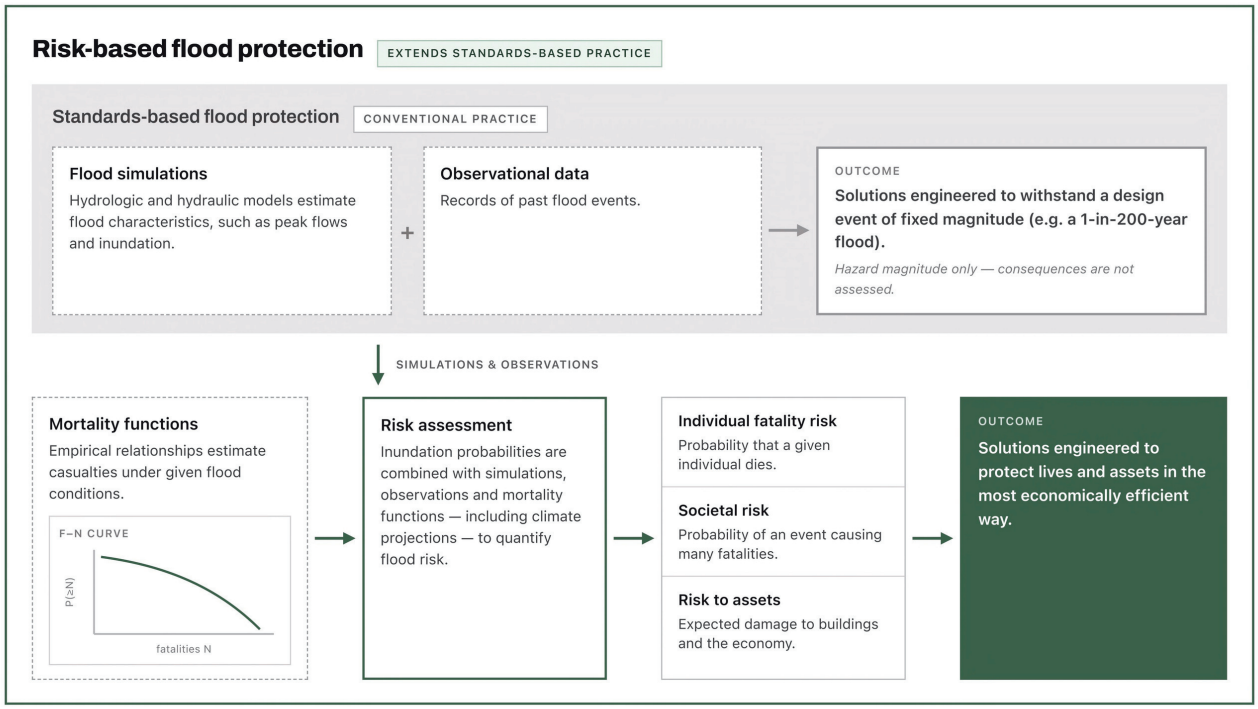

Figure 1. *A graphical representation of risk-based flood protection, demonstrating its scope beyond traditional standards-based methods. B.C.'s current standards-based approach is limited to flood protection engineered to protect against a 200-year flood event. Risk-based approaches often incorporate a risk-to-life metric, and allow for a more flexible, adaptive approach to protecting lives and assets in a more resource-efficient manner.*

TRADE-OFFS AND CHALLENGES TO IMPLEMENTING A RISK-BASED APPROACH

A standards-based approach benefits from lower overall complexity, and tends to be faster and less expensive due to the governance systems in place and the capacity of practitioners (primarily engineers) to conduct flood risk assessment (Ebbwater Consulting Inc., 2021). However, as discussed, it lacks the ability to account for long-term impacts or externalities, including climate change and other consequences on longer temporal scales. Standards-based approaches also poorly capture indirect and intangible impacts, which will be discussed in the following section.

Adoption of a risk-based approach in B.C. is not without challenges. An entrenchment in the standards-based framework hinders the shift towards risk-based thresholds. For example, where significant investment in flood infrastructure exists, the perception is that continued maintenance, investment, and improvement is necessary to justify the infrastructure having been built in the first place (Ebbwater Consulting Inc., 2021; Haer et al., 2020). Breaking away from these pathways may be necessary to adopt a more modern, holistic approach.

B.C. lacks specific risk-based targets to support planning and guidance for implementation at the provincial scale. Although the Government of B.C. has adopted high-level frameworks, such as the Sendai Framework, the translation of principles to tangible targets and practices has been slow (First Nations Leadership Council, 2023). Because these approaches are relatively underdeveloped in Canada, there is a lack of resources, data, methods, and expertise readily available for implementation. In addition, existing policies and regulatory bodies are generally designed with static thresholds which may omit local context (Ebbwater Consulting Inc., 2021). Another challenge is that local governments lack the technical resources and financial resources required to define specific tolerance levels. Introducing a risk-based framework without addressing these challenges could introduce liability concerns for the Government of B.C., which thereby reduces incentive to expand risk assessment (Ebbwater Consulting Inc., 2021).

DIRECT DAMAGE VS. INDIRECT IMPACTS

Direct damage from flooding usually refers to the immediate physical damage to buildings and infrastructure, and is relatively easy to quantify in flood risk assessment (Arrighi et al., 2021; Koks et al., 2015). **Indirect impacts** include cascading effects on the economy, supply chains, transportation, healthcare, and social and cultural impacts, which may persist long after the initial event (Hochrainer-Stigler et al., 2024; Nobile et al., 2023). Indirect impacts make up a significant portion of total damages and losses following major flood events (Arrighi et al., 2021; Koks et al., 2015), and researchers and governments agree that indirect impacts should be considered in the

development of flood risk assessment (Lyle & and Mills, 2016; Natural Resources Canada, 2021; Reiter et al., 2022). Traditional flood risk assessment frameworks often focus on direct impacts, underestimating the full extent of damage (Arrighi et al., 2021; Koks et al., 2015), and a growing body of literature aims to address this as no standard methodology or terminology currently exists (Hochrainer-Stigler et al., 2024; Jafari Shahdani et al., 2023; Nobile et al., 2023). Loss of services from indirect impacts, particularly in the healthcare sector, have been shown to comprise a significant portion of total impacts (indirect + direct impacts) (Arosio et al., 2020), yet few studies examine impacts beyond economic and transportation sectors. Interestingly, one study found that direct damages often exceed indirect damages (by ~50 per cent) for higher probability events, but for lower probability flood events that are larger in magnitude, indirect losses outweigh direct losses (Koks et al., 2015). Most literature on indirect flood impacts focuses on damage to the economy and infrastructure (Carrera et al., 2015; Gil, 2008; Najafi et al., 2021), and those that address indirect impacts do so using macroeconomic indicators, with very few incorporating high-resolution spatial analyses or climate change (Nobile et al., 2023).

Thailand's 2011 flood event

One international example that highlights the significance of indirect losses is Thailand's 2011 flood event, which had economic impacts on a global scale. When above average summer monsoon rainfall coincided with heavy tropical storms, dams across the country were overwhelmed, leading to over 800 deaths (Gale & Saunders, 2013) and causing significant damage to agriculture, industry, local and national economies, and society, with effects propagating to other sectors (Hydro Informatics Institute, n.d.). In addition to the direct and immediate damage from the event, indirect consequences were significant. Higher water levels persisted for several months after the initial event, leading to an increase in water-borne diseases including flu, skin diseases, dengue fever (Govt. Thailand, 2011; Thongtaeparak et al., 2016; World Bank, 2012). Beyond loss of life, 660,000 jobs were affected, with low and middle-income workers in agriculture and manufacturing experiencing job loss, wage reduction, and lasting economic hardship (Poaponsakorn & Meethom, 2013; Weissglass, 2013). Cascading impacts were evident in key industrial sectors critical to global supply chains, including major companies like Toyota, Honda, and Sony. Toyota and Honda took 42 and 174 days, respectively, to resume partial operations (Forslid & Sanctuary, 2023), severely impacting output and revenues (Mehlhorn, 2021). The electronics manufacturing industry was hit especially hard. At the time, Thailand produced about a quarter of the world's hard disk drives, and prices on the global market nearly doubled globally as a result of the flooding. Direct economic losses, which account for temporary changes in economic flow from the time of the flood until full recovery, were estimated at US$14.7 billion. By comparison, indirect economic losses modelled for 2011 to 2030 are estimated at US$55.3 billion in total GDP losses.

The 2021 atmospheric river in B.C.

The 2021 flooding highlights the importance of considering indirect impacts in British Columbia. When a series of atmospheric rivers produced a two-day precipitation event leading to floods and landslides, rippling effects were felt province wide and affected national and international supply chains (Figure 2). Though few formal studies have uncovered the full extent of the indirect impacts of this event, anecdotal evidence suggests that effects beyond the initial infrastructure damage and loss of life were felt far and wide. Weaving direct and indirect impacts into a risk-based framework may aid the Province in prioritizing resource and spending allocation for flood resilience projects by targeting high risk, high consequence zones.

Incorporating localized climatic and geographical conditions will be a key component of estimating the extent and severity of these impacts, as flood impacts will vary with climatic and anthropogenic factors. Addressing these gaps in risk assessment will help address indirect impacts affecting not only capital assets but human lives, well-being, and livelihoods. Incorporating indirect impacts into risk tolerance decisions means accounting for a broader spectrum of risks and consequences, including economic, social, and psychological factors, as well as cascading and compounding effects. It also necessitates expanding risk assessment tools and frameworks for risk threshold determination. All of these factors are complemented by adaptive, risk-based practices, and hindered by the outdated standards-based approach.

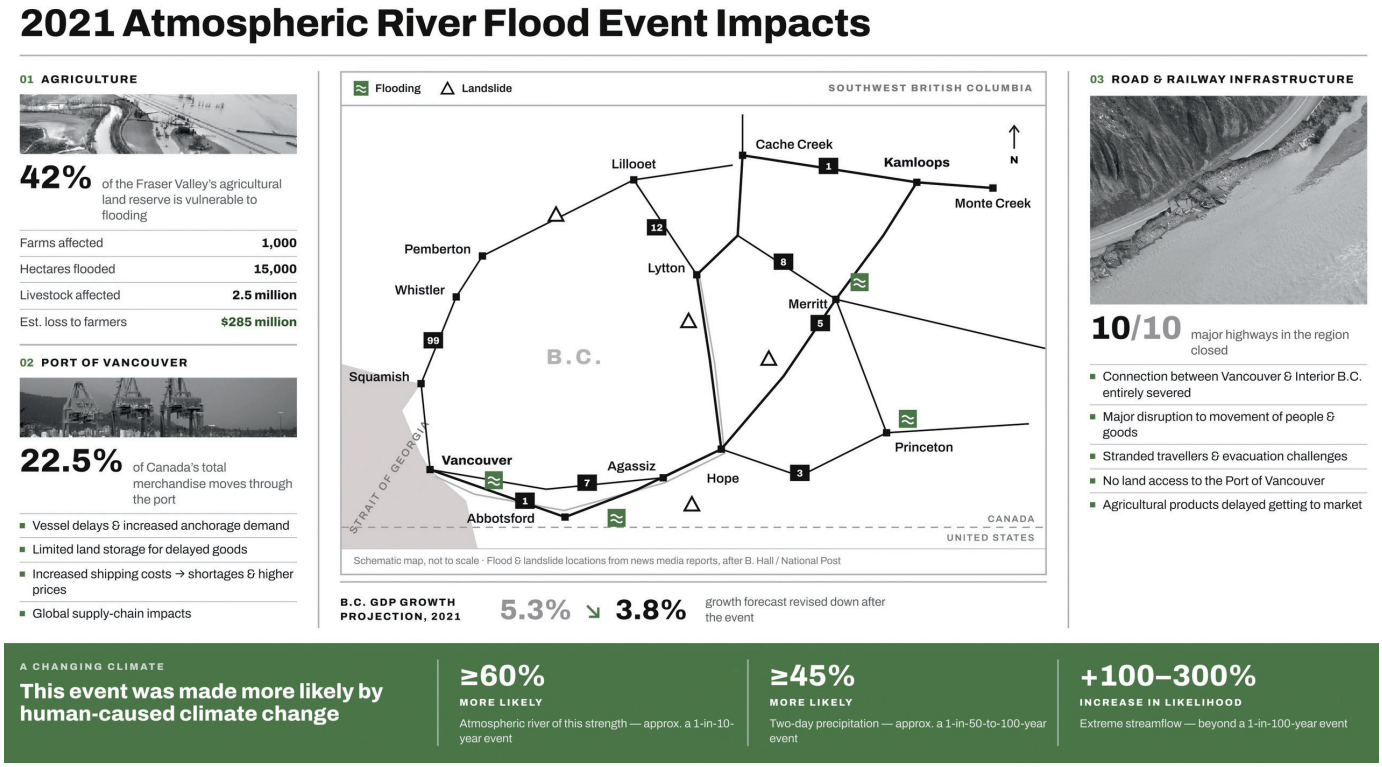

Figure 2. *A summary of the indirect impacts of the 2021 British Columbia flood event. Data and facts from the Standing Senate Committee on Agriculture and Forestry (Standing Senate Committee on Agriculture and Forestry, 2022), central figure from the B.C. Ministry of Transportation and Transit (Ministry of Transportation and Transit, 2021).*

FLOOD RISK PRACTICES OUTSIDE OF CANADA

Frameworks exist to evaluate the robustness and effectiveness of flood risk practices. Sayers et al. (2015) proposed 10 Golden Rules of Strategic Flood Management. Table 1 demonstrates critical areas where B.C. is lacking compared to other jurisdictions, only having fully implemented one of the "golden rules". In contrast, countries like Australia, New Zealand, England, the Netherlands, and Germany fare much better, meeting multiple goals of the framework (Ebbwater Consulting Inc., 2021; Sayers et al., 2015). British Columbia can draw from international practices for their own risk assessment and threshold determination.

B.C.'s evaluation largely reflects its reliance on a fixed one-in-200-year design standard. Planning remains linked to a single design event rather than to exceedance (Rule 1) or a changing future (Rule 4), and residual risk beyond that standard is rarely communicated (Rule 8). Recent provincial and EGBC initiatives incorporating climate projections, tiered design levels, and broader engagement explain the "transitioning" ratings on Rules 4, 5, 8, and 9. By contrast, the Netherlands' codified risk-to-life standards, joint water-authority governance, and Delta Programme coordination satisfy most of the rules, while Aotearoa's national adaptive-planning and community engagement frameworks achieve the strongest overall implementation under this framework. These differences are explored further in the case studies below.

The 10 Golden Rules of Strategic Flood Management

Implementation status by jurisdiction

Yes | Transitioning | No

#	PRINCIPLE	B.C.	N.L.	N.Z.
01	Plan for exceedance, total protection is not feasible	Transitioning	Transitioning	Yes
02	Recognize the value of some flooding	No	Yes	Yes
03	Make decisions despite uncertainty	No	Yes	Yes
04	Plan for a changing future, not the past	Transitioning	Yes	Yes
05	Use a diverse set of tools, not just one	Transitioning	Transitioning	Yes
06	Allocate resources fairly and efficiently	No	No	Yes
07	Clarify roles and share responsibility	Transitioning	Yes	Yes
08	Communicate risk clearly and broadly	Transitioning	Yes	Transitioning
09	Involve stakeholders meaningfully	Transitioning	Transitioning	Transitioning
10	Tailor plans to local context, link to broader efforts	Yes	Yes	Yes

Table 1. *The '10 Golden Rules of Strategic Flood Management', (Sayers et al., 2015). Implementation states are from Ebbwater Consulting Inc., 2021, with the exception of rules # 1 and #7, which have been changed to "Transitioning" to reflect recent progress in B.C.*

THE NETHERLANDS

The Evolution of Dutch Flood Risk Practices

The Netherlands, much of which lies below sea level, excels at cutting-edge flood risk assessment, sustainable operations, and consistent cross-sector coordination. Historically, national flood protection practices were standards-based to protect against 250 to 10,000-year return period events (Jorissen et al., 2016). In 2008, a committee was appointed to provide recommendations for updated flood risk practices considering climate change, and in 2014 a number of decisions were delivered. A multi-layered protection paradigm was adopted, consisting of 1) measures to prevent flooding of dikes, dams, etc. and creating more room for rivers; 2) counteracting consequences of flooding through spatial planning; and 3) counteracting the consequences of flooding through emergency management. During the development of the program, safety standards shifted from standards-based to risk-based, which was codified in 2017 (Jorissen et al., 2016).

An alliance of regional water authorities was formed based on joint responsibility and financing (coast + rivers + lakes) including monitoring, organization, reporting, scientific research, training, standard setting, etc. Prioritization within the Dutch Flood Protection Programme was structured to align the scope of projects with available funding, and proposed reinforcement projects were ranked based on the determined risk, accounting for both the probability of flooding and its consequences. This systematic approach directly informed project prioritization decisions, resulting in a transparent and clearly justified method. The project also highlighted disparities among local authorities in terms of adaptation priority: some faced immediate and substantial threats, while others were more likely to face challenges years into the future. This underscores the necessity of effective resource sharing, resource allocation, and cooperation across orders of government.

The National Delta Programme

The Dutch National Delta Programme encompasses research, measures, and facilities for flood protection (National Delta Programme 2025, 2024). Through a dedicated fund and collaboration of 21 different water authorities, the program aims to have all primary flood defences comply with new standards by 2050. Residents living behind primary flood defences will have minimum base protection of 1:100,000 annually (0.001 per cent chance of annual individual fatality) by 2050 at the latest. This involves upgrading roughly 1,500 km of dikes and more than 400 engineered structures, and also includes projects for knowledge development and innovation. In addition to flood protection engineering such as dike upgrades, the program includes widening of the Rhine and Meuse rivers, whose flows are increasing due to climate change. The program is pioneering with the use of zero-emissions equipment, placing emphasis on circularity, sustainability, nature, and biodiversity conservation.

The Delta Programme's six-yearly review cycle is underway with 2026 decisions expected in 2027, and Dutch researchers have demonstrated methods for risk-aware updating of dike reliability standards under climate change and subsidence (den Heijer et al., 2025; Waterstaat, 2025). The Dutch example also warns that language and priorities can shift without explicit codification. The national principle of "water and soil as guiding" (water en bodem sturend), adopted in 2022, was formally softened in October 2024 to "taking water and soil into account" amid housing development pressure (Ministry of Infrastructure and Water Management (Netherlands), 2024).

AOTEAROA NEW ZEALAND

New Zealand's flood risk practices

Aotearoa New Zealand's flood risk practices incorporate land use planning, structural protection, and emergency response, with an emphasis on public engagement. The central government provides frameworks and funding aid to local governments through a system of integrated national support, and the Civil Defense Emergency Management strategy focuses on reducing risk and improving preparedness. Through an "Avoid, Protect, Accommodate, Retreat" approach, emphasis is placed on the practice of managed retreat, moving homes, businesses, and cultural sites out of harm's way if the first three options fail. This carefully planned process is designed to relocate communities and assets well in advance of increasing flood events linked to climate change. Aotearoa New Zealand practices community-engaged flood resilience planning, and in 2023, the Natural Hazards Commission conducted a literature review to help communities understand their risk tolerance and enable them to make more informed adaptation decisions (EQC, 2023). Risk-to-life metrics such as Annual Individual Fatality Risk (AIFR) have become increasingly prominent in Aotearoa New Zealand following the Canterbury Earthquake Sequence (2010–2011) and have since been integrated into natural hazard risk assessments at various orders of government. Commonly adopted AIFR thresholds range from 1:1,000, representing high or intolerable risk, to 1:100,000 or lower, depending on the sensitivity of the development or hazard type (Christchurch City Council, 2021; Taig, 2022). An AIFR of 1:10,000 is often used as a threshold to determine acceptability, though numeric threshold setting is not nationally dictated as in the Dutch case.

The National Policy Statement for Natural Hazards, in force January 2026, establishes a national likelihood-and-consequence risk matrix for seven hazards (including flooding and coastal inundation), requires that new development in "very high" risk areas be avoided, and mandates consideration of climate change over at least 100 years, effectively legislating national risk tolerance for land-use planning (New Zealand Ministry for the Environment, 2026). A National Adaptation Framework (October 2025) sets out four pillars spanning risk information,

roles and responsibilities, investment in risk reduction, and pre- and post-event cost sharing (*National Policy Statement for Natural Hazards 2025*, 2025). Standards New Zealand is developing national standards for flood modelling and for risk analysis, and a first national flood map is due in 2027 (*New Zealand Flood Map*, 2026). The second national climate change risk assessment estimates roughly 556,000 buildings (NZ$235 billion replacement value) are exposed to inland flooding (New Zealand Climate Change Commission, 2026).

Community engagement case study: The Bay of Plenty

Community engagement is a strong aspect of Aotearoa New Zealand's flood risk platform and has informed risk tolerance and planning in several regions (Kilvington & Saunders, 2015; Otago Regional Council, 2025; Ryan et al., 2022; *Thames Coromandel Shoreline Management*, 2026), with one prominent example being the Bay of Plenty. The Bay of Plenty Regional Council (BOPRC) is the administrative body responsible for overseeing land use and environmental management in the region. In 2013 the BOPRC set out to incorporate community views directly into the determination of acceptable, tolerable, and intolerable risk levels (Kilvington & Saunders, 2015). The engagement prioritized those who would be directly affected and consisted of three key elements: capacity building around risk concepts, clear linkage between risk acceptability and government action, and interdisciplinary collaboration, including Māori liaison and an adaptive process open to reflection and amendment. Initially, officials expressed several concerns: that public involvement might legitimize very high risk levels, increasing community vulnerability and government liability; that communities might not express willingness to engage; and that a lengthy process could expose uncertainties and blur the line between facts and values in risk assessment. Encouragingly, engagement was strong, and the results defined thresholds for risk to life alongside other consequences, including acceptable damage to infrastructure, lifelines, and public well-being. Community judgments on risk tolerance were used to constrain a likelihood-consequence matrix carrying planning force: acceptable risk is permitted, tolerable risk requires consent, and, crucially, intolerable risk must be avoided. A review of the engagement process found it made a strong contribution to policy, produced insights that traditional methods had missed, and eased officials' initial concerns. The framework was also judged transferable to a similar region, though it was acknowledged that places with fewer resources than the Bay of Plenty may find participatory risk-based planning harder (EQC, 2023).

Accepted tolerance categories were given quantitative power at Matatā, a city within the region, where a 2005 debris flow destroyed 27 homes on the Awatarariki alluvial fan (without loss of life). For the next seven years, hazard management focused on engineered the affected properties was completed in 2021 (Hanna et al., 2021; Whakatāne District Council, n.d.). Sixteen years therefore passed between the disaster and the completed

retreat, roughly half of them spent pursuing protection before the risk itself was quantified. Had tolerance thresholds been established in advance, the intolerable classification could have guided decisions from the outset. Commentators highlighted the absence of directive national policy guidance for retreat (Hanna et al., 2020), and the assessments themselves had to borrow tolerability criteria from Australian practice because Aotearoa New Zealand had none (Whakatāne District Council, n.d.).

FLOOD RISK & RESILIENCE IN RURAL AND REMOTE B.C.

While B.C. can learn from the international community, its unique geography and population distribution present distinct challenges. Nearly one fifth of Canadians (and British Columbians) live in areas classified as rural and remote, areas which are being disproportionally affected by climate change. “Almost 20 per cent of [Canada’s] population lives in rural, remote, Indigenous, coastal, or northern communities, and these communities contribute about 30 percent of Canada's economic output. For these communities, diverse geographies and climates present unique challenges, and there is no one-size-fits-all solution” (Government of Canada, 2024). The question then arises: how should B.C. be thinking about flood risk and flood risk tolerance in rural and remote settings in comparison to urban centers? There exists a significant gap in the literature regarding rural and remote flood risk assessment, and B.C. is well poised to be a leader in the space.

Rural Canadian neighbourhoods are among the most susceptible to flooding; for example, close to half of flooded areas were outside of major population centers between 2017 and 2020 (Foran et al., 2025). Furthermore, 22.2 per cent of rural areas were affected by flooding compared to only 4.8 per cent of urban areas, and rural areas were found to be more likely to experience multiple years of successive flooding. Rural areas also experience greater increases in residential instability post-flood. Only a handful of studies have examined the differences in flood risk and resilience between rural and urban settings, but the common wisdom is that rural and remote communities require uniquely tailored solutions, particularly where social vulnerability is a factor (Dhungana & Liu, 2024; Kipp et al., 2021; Komi et al., 2016). Reasons for this include limited access to services, insufficient infrastructure, existing socioeconomic vulnerabilities, the potential for supply chain isolation, and heightened climate risk in some areas (e.g. coastal and northern B.C.). Supply chain disruptions are particularly impactful on rural and remote communities, especially in Canada where routes for essential services like food and medicine may rely on only one or two roads, airstrips, or shipping routes. This service isolation provides further incentive to boost local capacity and reduce reliance on external resources (e.g., using volunteer staff or part-time emergency management officials).

Providing local resources in the form of training, funding, technical support, and access to climate data are all tools to help communities develop their flood planning initiatives. This is in line with Canada's plan to modernize flood management practices by focusing on proactive risk reduction rather than reactive responses to large events. Many Indigenous and remote communities have extensive knowledge of local waterways and flood patterns, as well as cultural and recreational values tied to the land. Provincial staff in B.C. have co-developed flood response plans with Indigenous groups by combining Indigenous Knowledges with scientific flood modelling (First Nations Leadership Council, 2023). In addition to respecting local values and assets (e.g., land stewardship, fisheries), this approach builds trust and capacity for long-term resilience in any vulnerable community.

Rural and remote communities may face unique challenges in determining their risk tolerance and thresholds; for example, a smaller tax base might limit their ability to perform comprehensive flood risk assessment, as well as to invest in infrastructure that meets higher flood protection standards. They may also face multiple overlapping hazards like landslides or wildfires, which further complicates overall risk assessment and resource allocation. Additionally, there might not always be clear guidance on how to balance these different risks, which demands that these communities must be even more innovative and community-focused in their approach.

RESILIENCE PATHWAYS: MODERN FLOOD PRACTICES FOR B.C.

The Government of B.C. has mobilized to modernize its flood risk practices, aiming to better address climate change, social inequities, and inclusion of Indigenous voices. Based on initiatives from two leading nations in flood resilience, New Zealand and the Netherlands, and relevant scientific flood risk literature, the following directions are recommended for further exploration.

A RISK-BASED APPROACH

Adopting a risk-based approach

Global leaders on flood resilience are moving from standards-based design (e.g. "one-in-200-year flood" designs) towards risk-based frameworks, which consider both the probability and consequence of flood events and incorporate "loss of life" metrics. A prime example is the Netherlands, who have a stated Annual Individual Fatality Risk of less than one in 1,000,000, and utilize a multi-layered strategy to achieve this. This type of risk-based approach offers a more nuanced and adaptive solution that prioritizes investments that reduce risk the most. B.C.'s *Flood Strategy to 2035* highlights a "risk-informed" approach wherein flood resilience decisions, investments and flood infrastructure design practices are justified through provincial and

community-level assessments, with consideration to climate change, equity, resilience, and cumulative effects.

Risk-based approaches can be tailored to account for changing hazards both spatially and temporally and can be tailored to reflect the values of B.C., including reducing loss-of-life and supply chain interruptions (Ebbwater Consulting Inc., 2021). Standards-based engineering design thresholds are linked to a single design flood, whereas a risk-based approach can consider a range of flood scenarios and their distinct impacts.

Indirect and intangible impacts extend spatially and temporally beyond the initial flood event. Standards-based practices and design thresholds do not explicitly capture indirect and intangible impacts. Risk-based approaches can incorporate these considerations with appropriate methods and data.

Extending existing practices

A transition to explicit risk tolerance criteria would extend practices already operating within B.C. for other hazards. The District of North Vancouver has applied quantitative life-safety criteria since 2009, an annual probability of death of 1:10,000 for existing development and 1:100,000 for new development, coupled with the "as low as reasonably practicable" (ALARP) principle (Tappenden, 2014). The Cowichan Valley Regional District has adopted comparable individual and group (F-N) criteria (Cowichan Valley Regional District, 2019). These criteria have guided real decisions,including the risk-informed design of debris-flow mitigation at Cheekeye Fan (LeSueur et al., 2024), and recent B.C.-based research derives loss-of-life thresholds from historical fatality data (Strouth et al., 2024). Notably, quantitative risk tolerance is operational in B.C. for landslides and debris flows, while flood practice remains anchored to a fixed design standard. Extending and standardizing the Province's own geohazard practice to floods would also serve the Province's interest in a consistent, multi-hazard approach to risk (Ward, 2026).

Risk thresholds and tolerance criteria

Local and international precedent supports stricter thresholds for new development than for existing development (District of North Vancouver; Cowichan Valley Regional District), higher protection where consequences are greater (the Netherlands), and tying tolerance to asset importance (District of Ucluelet, 2022). Decisions regarding new developments are particularly consequential. Recent national analysis estimates that more than 540,000 of the homes that Canada aims to build by 2030 could sit in flood hazard areas, adding up to $2 billion per year in flood damages, and that redirecting roughly three per cent of all planned new homes on the highest-hazard land would avoid almost 80 per cent of new-development flood losses (Canadian Climate Institute, 2025). B.C. is the epicentre of this

risk, and recent research strengthens the case for moving beyond single design events. Probabilistic multi-scenario assessment in the Salish Sea region shows that single-return-period mapping can materially understate hazard (Nederhoff et al., 2026), and a three-decade review of Canadian design-flood practice finds it internally inconsistent, with no established guidance for incorporating climate change (Vidrio-Sahagún et al., 2025).

The province should transition from standards-based to risk-based flood management, adopting variable risk tolerance criteria that are stricter for new development and critical assets. These criteria should incorporate loss-of-life metrics and indirect and intangible impacts, and be grounded in probabilistic, climate-updated assessment rather than a single design event.

UPDATED PROFESSIONAL STANDARDS AND PROVINCIAL GUIDELINES

In transitioning to a risk-based approach, professional guidelines will need to evolve to more clearly define acceptable risk levels, implement impacts like frequency-fatality curves, integrate climate change projections, and standardize risk assessments. Both the Government of B.C. and EGBC already support many of these initiatives and encourage expanding beyond traditional standards (APEG, 2018; EGBC, 2017; Ministry of Land, Water and Resource Stewardship, 2024). 2018 guidelines from EGBC outline both risk-based and standards-based approaches, as well as improved considerations for climate, land use, and risk analysis (APEG, 2018). However, EGBC has yet to formalize or mandate explicit risk tolerance criteria (e.g., acceptable risk to life or economic losses), nor does it fall within their authority to do so. Establishment of clear thresholds will help the province, qualified professionals, and practitioners work together to consistently evaluate and manage risk. For example, the Netherlands designates different dike designs based on the risk-to-life metric.

While existing flood guidelines from EGBC do not directly address other natural hazards, they do complement their guidelines on landslide assessment, with which some overlap exists (e.g., landslides may drive channel changes or cause damming leading to floods) (APEG, 2018). The landslide assessment practice guidelines detail a risk-based approach and may inform flood risk guidelines in B.C. as they mature (EGBC, 2023).

Risk-based assessment is inherently more technical and data-heavy than a standards-based approach. As such, professional guidelines should embrace modern analytical tools and methods, integrating climate change projections into hydrological models and risk assessment at every step, and embedding risk assessment in land-use planning. This will require that governmental and professional standard bodies foster a culture of holistic risk-based thinking.

The province should look to countries like the Netherlands in determining specific risk-based metrics, with consideration to B.C.'s unique geography and population density. Clear risk tolerance thresholds and criteria should be developed.

INTEGRATED PROVINCIAL AND NATIONAL PROGRAMS

Cohesive national flood programs are useful for aligning local efforts with national goals under a unified strategy. The Netherlands' Delta Programme and New Zealand's National Resilience Plan illustrate this approach well, providing funding, policy guidance, and coordination across orders of government. The Government of Canada is working towards a nationally coordinated flood risk management strategy. Emerging programs, such as a national flood insurance and relocation program and modernized Disaster and Financial Assistance Arrangements, are reflective of a growing commitment to modernizing flood risk practices. B.C.'s *Flood Strategy to 2035* emphasizes improving coordination across jurisdictions, regulators, and different orders of government (both within B.C. and federally).

Recent shortfalls in implementation reinforce the case for explicit prioritization criteria. The proposed national flood insurance program, committed in Budget 2024 and promised for April 2026 during the 2025 federal election, had not launched as of mid-2026, leaving roughly 1.5 million high-risk households effectively uninsurable in the interim (IBC, n.d.; Morin et al., 2025). Provincial implementation of the Flood Strategy has also been uneven. A Flood Resilience Plan has yet to be published, Budgets 2025 and 2026 contained no dedicated implementation funding, and disaster mitigation funding applications from Abbotsford, Merritt, and Princeton were declined in 2024, even as Phase 1 of federal-provincial floodplain mapping delivered updated maps for 58 communities in June 2026 (Ministry of Water Land and Resource Stewardship, 2026; Olsen, 2025; Waters, 2026). A province that cannot fund all needed risk reduction requires a defensible, transparent basis for deciding what to protect first, which is precisely what risk tolerance criteria provide.

In line with Government of Canada initiatives, the Government of B.C. should implement a cohesive provincial program, including risk threshold determination and prioritization, improving coordination between different orders of government, Indigenous groups, and communities.

COMMUNITY-ENGAGED RISK ASSESSMENT

International strategies emphasize the need for community involvement in understanding and managing flood risk, and some modern practices have invested in risk communication and public engagement to co-develop solutions. Aotearoa's community engagement strategies have yielded robust results for flood resilience planning, including determination of risk thresholds. B.C.'s *Flood Strategy to 2035*, created in collaboration with First Nations, regulators, and community members, emphasizes the importance of continued engagement.

Consistent with the Declaration on the Rights of Indigenous Peoples Act, provincial criteria should function as a general architecture adaptable to each First Nations group rather than a single number applied uniformly. The EDMA regulations' consultation-and-cooperation requirements provide a legal foothold for this approach (Province of British Columbia, 2026b). Engagement should identify the values at stake (life safety, but also cultural, ecological, and service-continuity values) before thresholds are set. Recent literature cautions that consultation alone is insufficient, that procedurally just flood governance requires inclusion in decision-making (Watkins & Collins, 2025), and risk communication by itself rarely shifts behaviour or tolerance (Sett et al., 2026).

The province should continue to expand community-engaged flood resilience planning and should consider incorporating engagement more directly into risk threshold determination. First Nations and vulnerable groups, in particular, should be partners in the process.

RISK TOLERANCE, ADAPTIVE PLANNING, & MANAGED RETREAT

As climate change intensifies flood hazards, there will be areas where the risk becomes intolerable for new or existing development, or where the cost of reducing risk further is disproportionate to the benefits gained, a concept captured by the "as low as reasonably practicable" (ALARP) principle. In these cases, communities may need to explore other options, such as managed retreat. Jurisdictions like the Netherlands and New Zealand use adaptive pathways (scenario-based plans) to periodically reassess risks and update plans accordingly. Community-led managed retreat is gaining traction in B.C. as a viable option for areas where staying is deemed to be unfeasible (often restoring those lands to natural buffers). By planning ahead for sea-level rise and more extreme flood events, adaptive management and retreat policies can reduce long-term damages and avoid costly reactive responses.

B.C.'s recent experience illustrates both the promise of and the barriers to this approach. In Merritt, municipal decision-makers seriously considered buyouts after 2021, but

were constrained by policy and funding gaps (Cottar & Wandel, 2024). Buyouts are a strategy by which governments may purchase affected land from homeowners, enabling relocation to a lower-risk area. The Province subsequently invested $60 million to relocate and rebuild Coldwater River dikes to higher standards (Province of British Columbia, 2025b). On Sumas Prairie, a planning initiative between the Province, Semá:th, Máthxwi, and Leq'á:mel First Nations, Abbotsford, and Chilliwack is assessing watershed-scale options (Province of British Columbia, 2026a). Analysis conducted with Semá:th First Nation estimates that returning Sumas Lake would cost roughly $1 billion, less than half the estimated $2.4 billion dike-rebuild alternative (Finn et al., 2024). New Zealand's trajectory is instructive in a cautionary sense: its Independent Reference Group proposed retiring expectations of government buyouts within roughly 20 years, raising unresolved equity questions, including for Māori communities (Independent Reference Group on Climate Adaptation, 2025; Parsons & Jayawardena, 2026). Who pays for retreat, and what happens to those who cannot, is as much a risk tolerance question as any design standard.

The province should pair adaptive planning with a clear managed retreat framework that defines the risk tolerance thresholds at which retreat will be considered, who will pay, and how affected communities and First Nations will be supported, so that these decisions are made deliberately before disasters rather than improvised after them.

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