Integrated Climate Change Adaptation to Increase Resilience in Canadian Coastal Communities

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Canada's Coast

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EXECUTIVE SUMMARY

The key findings of the Zuzek Inc. report entitled 'Integrated Climate Change Adaptation to Increase Resilience in Canadian Coastal Communities' was completed for Natural Resources Canada in 2023. The full report, including list of works cited, can be found on the Zuzek Inc. website.

Coastal communities, including those across the north, east, west, and Great Lakes, were recently cited as the second highest area of climate change risks facing Canadians in a 2019 report by the Council of Canadian Academies. In addition, many gaps remain in Canada's preparedness for climate change, as outlined in the recent Canada in a Changing Climate: National Issues report. To address the impacts of climate change, such as sea level rise, extreme storm wind and wave events, shoreline erosion and flooding, habitat and biodiversity loss, melting ice and permafrost, coastal communities across Canada require adaptation actions at a variety of scales.

Integrated adaptation is a holistic, systems-scale approach to solve coastal climate challenges. It requires:

- Co-development of adaptation solutions across a range of scales, jurisdictions, and mandates,
- Collaboration across the diversity of interests, including governments, indigenous communities and organizations, landowners, businesses, and ENGOs, and,
- Consideration of the physical, social, ecological, and economic issues that define the coast in planning and implementation.

Adaptation is the iterative process of adjustment to actual or expected climate and its effects to moderate or avoid harm or exploit opportunities. In coastal communities, the goal is to increase resilience to climate-related threats, including sea level rise risk, flooding, and erosion. **Incremental adaptations**, such as increasing the height of a dike or protecting a road from erosion from sea level rise, are extensions of an existing action to reduce risk, and have been the most common type of climate response across Canada. **Transformational adaptations** change the fundamental attributes of a social-ecological system governance, economic activities, and ecosystem conditions in anticipation of climate change and its impacts (IPCC, 2022: Annex II: Glossary). Integrated adaptation can be incremental or transformational but is defined by a high degree of co-development and collaboration between stakeholders, across jurisdictions and scales, and options consider the full spectrum of physical, social, ecological, and economic aspects of coastal communities.

The research provides a review of opportunities and needs to implement integrated coastal climate change adaptation across four Canadian coasts – Atlantic, Pacific, Arctic and Great Lakes and St. Lawrence River, with knowledge gained from the literature review, expert interviews, and selected case studies.

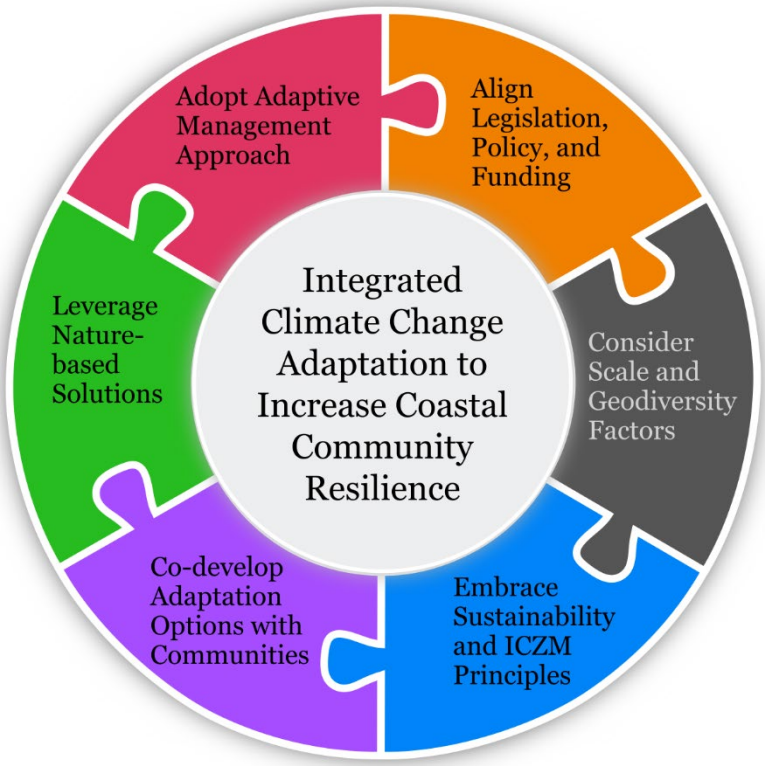
STATE OF PLAY AND KEY FINDINGS

To date, most of the adaptation work in Canada's coastal communities has been incremental - focused on single issues at a local scale, relied on traditional grey engineering solutions, or been focused on capacity building and assessing vulnerability to climate threats, not solving problems and increasing resilience. Integrated and transformative adaptation remains an elusive target, although, as evidenced by the case studies, awareness of these approaches is growing and there

are a few strong examples of their execution to learn from. The literature supports that integrated coastal management is needed, however, several barriers exist to implementation.

Municipal, provincial, territorial, and federal government departments with a mandate for the Canadian coastal zone, have been organized into discrete sectors responsible for human health, land-use planning and development, species management, water quality, wetlands, navigation and harbours, protected areas, and socio-economic factors, for example. No single entity has an overarching responsibility for the coastal zone or climate change adaptation. For decades, this sectoral management approach for the coastal zone has facilitated development on hazardous lands, resulted in extensive shoreline hardening, many species are in decline, wetland habitat continues to disappear, and biodiversity, geodiversity, and overall ecosystem health and resilience are in decline.

The only way to address the complex challenges in coastal regions imposed by a changing climate is to apply integrated approaches. Integrated approaches must address future climate change considerations in all decisions including infrastructure, community planning, long-term economic development, and disaster risk reduction. How to do this remains a challenge, but a number of approaches identified in the literature and summarized in the report present opportunities to address these needs. These approaches are summarized in the adjacent graphic and in the following sections.



Legislation, Policy, and Funding

The first important challenge to achieve more integration is ensuring the necessary legislation and acts exist to drive collaboration. Then it will be necessary to link different policy responses, ranging from spatial and urban planning to disaster risk reduction, from ecosystem conservation and restoration to infrastructure planning and construction, from climate adaptation to agriculture and resource management. Lessons from over 50 years of global experience and learning in Integrated Coastal Zone Management (ICZM) can inform a more integrated approach to climate change adaptation.

Supportive, aligned legislation at the national and provincial levels may be necessary to enable and ensure that climate change adaptation is supported politically, economically, and institutionally. The United States have developed a bill entitled the National Climate Adaptation

and Resilience Strategy Act (US Congress, S.3531) which is currently before Congress and is intended to end the ad hoc nature of climate adaptation planning at the national level and form a consistent basis for the U.S. to build a more resilient country. The bill requires the development not only a national adaptation strategy but also an implementation plan, monitoring, and evaluation mechanisms.

In Canada, the National Adaptation Strategy (NAS), currently under development, seeks to define shared priorities for all orders of government for cohesive adaptation action across the country, and will employ national evaluation and monitoring measures to track progress. Stakeholder and public engagement being undertaken to develop the NAS may provide an opportunity to increase interjurisdictional collaboration and may support greater integration of adaptative measures in Canada. Provincially, Nova Scotia has taken some positive steps, with both an Environmental Goals and Climate Change Reduction Act and a Coastal Protection Act.

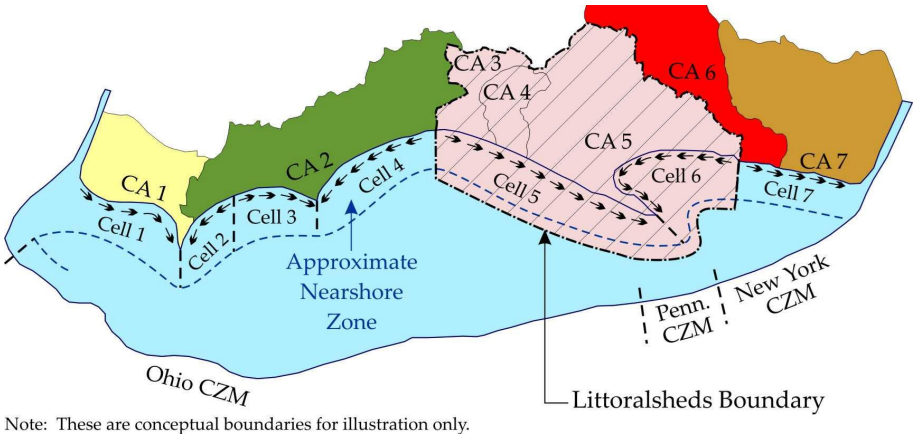
Comprehensive climate change assessments are required that integrate future climate scenarios and socio-economic and land use projections, such as increasing population and urbanization of the coast. Then, early intervention in the planning and policy process is necessary to ensure that adaptation is considered in decisions that have long lifetimes, such as major infrastructure developments or coastal development, to avoid 'lock-in'. It is also important to fast-track early adaptation steps that provide information to improve adaptation decisions in the future (e.g., by enabling research, monitoring, and sharing results).

Dynamic Systems, Geodiversity, and Scale

Climate change is reinforcing the need to reimagine a new relationship with the coastal landscape where a healthy coastal environment protects against the impacts of climate change and where development respects dynamic coastal processes. New research and guidance, such as Making Room for Movement (van Proosdij, 2021) and the International Union for the Conservation of Nature (Crofts et al, 2020) highlights the importance of geodiversity conservation, which includes the variety of rocks, sediments, landforms together with the natural processes that form and alter them in nature.

These emerging concepts recognize the importance of selecting an appropriate scale for integrated adaptation that is consistent with the physical processes that moderate the coast. Traditionally, much of the management in the coastal zone has focused on the land defined by watershed boundaries along the coast. Missing from this approach has been the management of the Canadian coastal zone at the scale of littoral cells, which are compartments that define sediment source areas, transport pathways, and sinks.

To link watershed (land) and coastal management activities in the nearshore (lake), the concept of littoralsheds was developed (Baird, 2013). As seen in the Figure below, a hypothetical littoralshed boundary includes three watersheds (CA3, CA4, CA5) that flow into the nearshore zone of two littoral cells (cells 5 and 6). Linking these watersheds and littoral cells in one management unit recognizes the important scale issues required for integrated climate change adaptation planning and coastal zone management.



Littoral cells, Watersheds, and Hypothetical Littoralshed Management Boundary

Embrace Equity, Sustainability and ICZM Principles

In the broader social policy context, integrated climate change adaptation in Canada should include international commitments and obligations, including the Paris Agreement, the Glasgow Climate Pact, Ocean Decade, and Sustainable Development Goals. When acting to address climate change, they call for the Parties to respect, promote and consider their respective obligations on human rights, the right to health, the rights of Indigenous Peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations, as well as gender equality, empowerment of women and intergenerational equity. Guiding principles of ICZM, including a balanced consideration of physical, social, ecological, and economic factors, must also guide the climate change adaptation design and implementation.

Co-development Solutions with Communities

Meaningful engagement for adaptation planning should involve a broad range of stakeholders, rights-holders and landowners from coastal communities to ensure co-development of integrated adaptation interventions support for implementation. Consideration must also be given to how to implement climate change adaptation on privately owned coastal lands. In Nova Scotia, for example, 87 percent of the province's 13,000 km-long coastline is privately owned.

When striving for more integration at the community scale, adaptation planning efforts need to focus on key climate risks and adaptation issues that capture the interest and values of local residents. Engagement of these groups should be personal and focus on tangible impacts that will directly shape how stakeholders use and experience the coast. This requires an understanding of stakeholders' perceptions and attitudes toward the coast and the impacts of climate change. It is also critical to inform communities of climate hazards and risks, the need for adaptation, and the range of potential responses available.

Embrace Nature-based Solutions and Manage Natural Capital

Nature-based solutions (NbS) have a vital role to play in managing coastal flood and erosion risk in Canada and driving innovative and transformational adaptation. International experience and guidance demonstrate that these measures not only provide protection against coastal flooding and erosion, they also deliver co-benefits, including improved biodiversity, carbon sequestration, enhanced quality of life, and creation of new recreational opportunities.

A review and synthesis of global experiences on ecosystem-based approaches to climate change adaptation (EbA) and to disaster risk reduction (Eco-DRR) found that they enable people to adapt to the impacts of climate change and disasters by sustainably managing, conserving and restoring ecosystems to provide ecosystem goods and services. The literature offers a number of recommendations to scale up the use of NbS in Canada, including developing national standards to support consistent evaluation of the benefits of nature-based solutions when comparing infrastructure options, developing national monitoring standards for coastal protection measures with a focus on NbS, and engaging the private sector to build capacity to finance and deliver NbS. Indigenous Knowledge and the engagement of Indigenous Peoples should be considered centrally in the implementation of NbS at all scales.

A growing number of Canadian local governments are now recognizing that it is as important to understand, measure, manage and account for natural assets as it is for traditional hard/grey infrastructure, by including "natural capital" in their asset management plans. The Municipal Natural Asset Initiative (MNAI) created a simulation model called the Coastal Toolbox (MNAI, 2021) that can help municipalities identify their relevant natural assets, understand their value, and use that information for more integrated municipal planning and management decisions. The Coastal Toolbox is a GIS-based simulation and analytical tool designed to help local governments identify, prioritize, and manage key coastal natural assets as part of their day-to-day asset management practices.

To be successful, a natural asset management strategy should include representation from all levels of government that have jurisdictional overlap with any proposed asset management activities, including development of climate change adaptation strategies. For example, including technical experts on the team such as local planners, geomorphologists, coastal engineers, Indigenous representatives, ecologists, and GIS specialists will help to ensure the right information and coastal system dynamics are being incorporated into the model.

Adaptive Management to Monitoring Adaptations and Progress towards Societal Goals

Adaptation isn't finished following project implementation. We must also plan to continuously monitor and evaluate adaptation actions over time. As conditions change, we can learn from completed adaptation projects and modify future management approaches within an adaptive management framework. Maintaining flexibility and responsiveness to changing conditions will prevent lock-in and path dependence.

PRACTITIONER EXPERIENCES

The findings of this report were also based on interviews with subject matter experts and practitioners, who identified barriers to integrated adaptation and what would be needed to increase uptake of integrated and innovative approaches. The barriers and needs are summarized:

- **Barriers:** Practitioners and experts identified regulatory barriers to innovative solutions, lack of funding mechanisms for transformational regional projects with long time horizons, governance complexity with siloed expertise, mismatch of scale of impact and jurisdictional scope, the complexity of planning and designing projects, and lack of

capacity at local governing levels as barriers to integrative climate adaptation on the coasts.

- **Needs:** Strategic frameworks for coastal planning and management nation wide are needed, along with community collaboration, engagement and mechanisms to work together across jurisdictions. Integrated adaptation also requires more inclusion of Indigenous Knowledge and leadership, capacity building for everyone, public and professional education, access to information, training of experts, and public-private partnerships for creative financing.

In synthesizing the responses from the interviews, a narrative emerged that recommended developing an overarching (national) strategy/approach for coastal management and integrated climate change adaptation in Canada supported with appropriate legislation and policy. All stages of adaptation, from community engagement to implementation, will require funding and resources such as trained staff.

RECOMMENDATIONS FOR FUTURE GOVERNMENT ACTION

Supportive, aligned legislation at the national and provincial levels may be necessary to enable and ensure that climate change adaptation, including integrated approaches, is supported politically, economically, and institutionally. To advance integrated coastal climate change adaptation, the following recommendations are provided for governments:

- **Identify options for government alignment** within existing legislation, acts, agreements, policies, and programs for integrated coastal climate change adaptation. These could range from incremental to transformative changes. Legislation and policies such as recent provincial measures in Nova Scotia and the NAS have started this process across Canada. In the absence of binding legislation, tools such as inter-agency collaboration agreements and working groups provide tools to increase collaboration, share information, and remove siloes.

- **Revise funding formulas** that only support shovel-ready projects to include resources for the necessary community collaboration to co-design, plan, and implement innovative transformative coastal climate change adaptations.

- **Advance the planning and construction of large-scale transformative projects that demonstrate the benefits of integrated coastal climate change adaptation planning** that comes from solution co-development with the community, inclusion of nature-based solutions, and a commitment to long-term monitoring in an adaptive management framework.

- **Support the coordination of regional action** by establishing provincial programs and providing resources to NGOs that coordinate community engagement, planning, and project execution.

- **Support capacity building** to understand the multidisciplinary and complex nature of coastal environments in an adaptation context through skills training, information and

resources such as tools and guidelines for practitioners, and knowledge sharing with future leaders in academic programs across Canada.

SUMMARY OF BEST PRACTICES FOR INTEGRATED ADAPTATION

Based on the literature review findings, interviews, and review of Canadian case studies, six core elements of integrated adaptation have been identified:

- **Align Legislation, Policy, and Funding**: A supportive legislative and policy framework for integrated coastal climate change adaptation is needed with appropriate targeted funding for engagement, planning, and design, not just implementation.

- **Consider Scale and Geodiversity Factors**: Adaptation planning must be completed at appropriate scales to integrate physical processes across the coastal zone, social dimensions across land and water issues, and ecosystem function.

- **Embrace sustainability, socioeconomic considerations, and Integrated Coastal Zone Management Principles**: Relevant aspects of the UN Sustainable Development Goals, such as health, well-being, and equality should inform the adaptation process. Guiding principles of ICZM, including a balanced consideration of physical, social, ecological, and economic factors, must also guide the adaptation design and implementation.

- **Co-develop Adaptation Options with Communities**: Integrated climate change adaptation requires co-development of options with communities, including landowners, Indigenous communities and stakeholders, and the inclusion of socio-economic considerations. This will increase buy-in for implementation and ensure equity and justice are considered, leading to respect for all stakeholders, particularly those traditionally underrepresented and disadvantaged.

- **Leverage Nature-based Solutions**: Nature-based solutions should be considered to the fullest degree possible for the integrated climate change adaptation solutions developed with communities, including transformational adaptation approaches.

- **Integrate climate change considerations in all decision-making and adopt adaptive management approach:** Apply a climate change lens to all decision making. Adopt an adaptive management program to monitor adaptation actions, learn from completed projects, and modify future management approaches.

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1.0 INTRODUCTION

Coastal communities, including those across the north, east, west, and Great Lakes (see Figure 1.1), were recently cited as the second highest area of climate change risks facing Canadians in a report by the Council of Canadian Academies (CCA, 2019). Action on climate change adaptation is needed to address threats and increase resilience, yet many gaps remain in Canada's preparedness for climate change, as outlined in the recent Canada in a Changing Climate: National Issues Report (Warren and Lulham, 2021). As communities figure out how to adapt and increase resilience, damages due to coastal climate change threats continue. The average insurance payouts related to extreme weather are estimated to have more than quadrupled (to $1.9 billion per year) over the past decade with uninsured losses estimated to be double that amount.

Figure 1.1 Canada's Four Coasts

To address the impacts of climate change, such as sea level rise, extreme storm wind and wave events, shoreline erosion and flooding, habitat and biodiversity loss, melting sea ice and permafrost, coastal communities across Canada require adaptation actions at a variety of scales. To date, most actions have been site-specific and focus on addressing impacts to critical infrastructure (e.g., increasing the height of a seawall to account for rising sea levels). However, given the scale and multitude of climatic and non-climatic risks facing coastal communities, a highly integrated approach to adaptation planning and implementation, wherein collaboration across sectors and actors, including all levels of government, Indigenous Peoples, and other key actors such as universities, the private sector, and NGOs as well as private landowners is essential for achieving regional resiliency goals.

1.1 Climate Change Adaptation

Adaptation, in human systems, is the iterative process of adjustment to actual or expected climate and its effects to moderate or avoid harm or exploit beneficial opportunities. Its overall aim is to maintain and increase the resilience and reduce the vulnerability of ecosystems, infrastructure and people in the face of the adverse effects of climate change (Agard et al., 2014).

Incremental adaptation, which strives to maintain the essence and integrity of a system or process at a given scale (Park et al, 2012), has been the most common type of climate change response across Canada (Hicke et al. 2022). Incremental adaptations to change in climate are understood as extensions of actions and behaviours that already reduce the losses or enhance the benefits of natural variations in extreme weather / climate events.

Increasing the height of a dike or protecting a road from erosion threatened by sea level rise, are examples of incremental adaptation as they are understood to be extensions of actions and behaviours that already reduce the losses or enhance the benefits of natural variations in extreme weather/climate events.

In some cases, incremental adaptation can accrue to result in transformational adaptation (Tàbara et al., 2018; Termeer et al., 2017). When risks are extreme, transformational adaptation is needed to change the fundamental attributes of a social-ecological system, such as the physical characteristics of the coastline, social network and built infrastructure, governance, economic activities, and ecosystem conditions in anticipation of climate change and its impacts (IPCC, 2022: Annex II: Glossary).

Integrated adaptation, as defined for this report, is a holistic systems-scale approach to solve coastal climate change challenges where there is co-development of adaptation solutions across a range of scales, jurisdictions, and mandates as well as collaboration across the diversity of interests -- governments, Indigenous communities and organizations, landowners, businesses, and ENGOs. The adaptations can be incremental or transformational; the defining aspect is the high degree of integration on the solutions planning and implementation that considers the physical, social, ecological, and economic issues that define the coast.

Unfortunately, integrated and transformative adaptation remains an elusive target in Canada. Most of the adaptation work to date has focused on single issues at the local scale (Hicke et al, 2022).

Regardless of the type of adaptation adopted by coastal communities, the ultimate goal is to increase resilience to climate-related threats, including sea level risk, flooding, and erosion. For this paper, resilience is defined as the capacity of physical, social, ecological and economic systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (Agard et al. 2014).

1.2 Report Objectives

This study was commissioned to produce a review of opportunities and needs to implement integrated coastal climate change adaptation across four Canadian coasts – Atlantic, Pacific, Arctic and Great Lakes and St. Lawrence River. Relevant literature was reviewed, experts, primarily, from across Canada were interviewed, and selected case studies that focused on

integration were summarized. The report highlights the necessary components and pathways for integrated coastal climate change adaptation. Gaps in the necessary drivers for integration will be highlighted and recommendations outlined to address these deficiencies. Given the focus on coastal communities and climate change, vulnerability and adaptation requirements for sea level rise, flooding, erosion, and ecosystem degradation were the focus of this review.

2.0 LITERATURE REVIEW AND INTERVIEWS

Section 2.0 summarizes the literature reviewed and interviews conducted with experts and practitioners from across Canada on the topic of integrated coastal climate change adaptation.

2.1 Literature Relevant to Integrated Coastal Adaptation

A keyword search through the scientific peer-reviewed literature, UN- and International NGO-published reports, and national and sub-national climate change adaptation assessments, was conducted to identify the most contemporary research findings, experiences and insights on climate change adaptation. A separate report provides further details on the literature reviewed, including a publication link (if available), overview, findings, and the relevance for integrated climate change adaptation in Canadian coastal communities (Zuzek Inc., 2023b). Key findings from the review are summarized in the following report section.

2.1.1 Key Findings of Literature Review

There is a growing body of literature, experience, and practical guidance available for coastal climate change adaptation in Canada and internationally. Approaches taken to date, and those in planning, offer useful direction for developing integrated approaches to coastal climate change adaptation at a regional and community scale across Canada.

One of the greatest challenges in adapting to climate change is a limited sense of urgency to act, especially at a systems or community scale on some of our most pressing concerns (e.g., coastal management, flood mitigation, wildfire protection, livelihood and economic security). For Canada to develop and successfully implement a comprehensive and highly integrated approach to climate change adaptation for Canada's coasts, it must have in place an equally integrated legal, policy, institutional and management framework that will allow for coordinated and complementary climate change adaptation responses.

Such an integrated framework should recognize the coast as a dynamic and highly integrated physical, social, ecological and economic system. It would be centered on the land-water interface, not divided by it or geopolitical boundaries, and most effectively managed as a boundary spanning initiative including land and water systems. Traditionally, much of the management in the coastal zone has focused on the land within watersheds. Missing from this approach has been the management of the Canadian coastal zone at the scale of littoral cells, which are coastal compartments that define sediment source areas, transport pathways, and sinks.

The need and benefits for integrated land and water management were recognized during the development of Environment and Climate Change Canada's Great Lakes Integrated Nearshore Framework (Baird, 2013). To link watershed (land) and coastal management activities in the nearshore (lake), the concept of littoralsheds was developed. As seen in Figure 2.1, a hypothetical littoralshed boundary includes three watersheds (CA3, CA4, CA5) that flow into the nearshore zone of two littoral cells (cells 5 and 6). Linking these watersheds and littoral cells in one management unit highlights important scale issues required for integrated climate change adaptation planning and/or integrated coastal zone management.

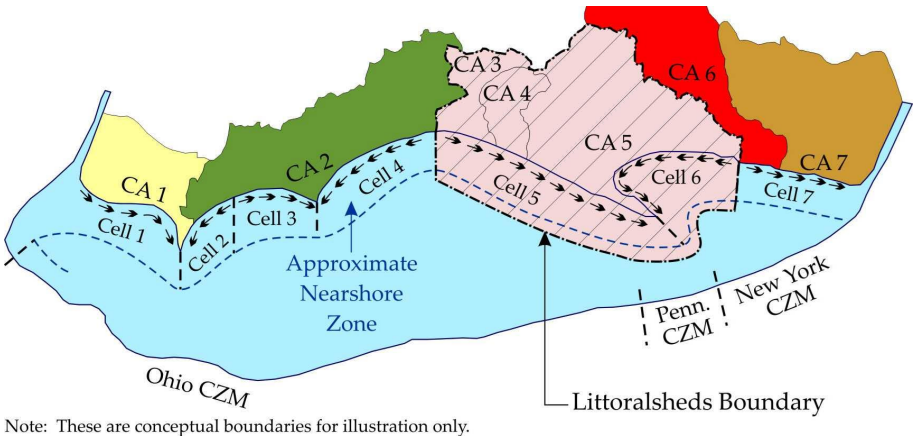

Figure 2.1 Littoral cells, Watersheds, and Hypothetical Littoralshed Management Boundary

Policy, Legislation, and Funding

Governing logic specifies two distinct approaches that governments can take to implement policy: direct provision of services (substantive policy instruments), or indirect efforts to change the beliefs and behavior of actors (procedural policy instruments).

With this in mind, the first important challenge to achieve more integration is ensuring the necessary legislation and acts exist to drive collaboration. Then it will be necessary to link different policy responses, ranging from spatial and urban planning to disaster risk reduction, from ecosystem conservation and restoration to infrastructure planning and construction, from climate adaptation to agriculture and resource management. Lessons from over 50 years of global experience and learning in Integrated Coastal Zone Management (ICZM) can inform a more integrated approach to climate change adaptation.

Supportive, aligned legislation at the national and provincial levels may be necessary to enable and ensure that climate change adaptation is supported politically, economically, and institutionally. The United States has developed a bill entitled the National Climate Adaptation and Resilience Strategy Act (US Congress, S.3531) which is currently before Congress and provides a federal model for Canada to consider. It is intended to end the ad hoc nature of climate adaptation planning at the national level and form a dependable and consistent basis for the U.S. to build a more resilient country. The bill's requirement is to develop not only a national adaptation strategy but also an implementation plan, monitoring, and evaluation mechanisms. Provincially, Nova Scotia has taken some positive steps, with both an Environmental Goals and Climate Change Reduction Act and a Coastal Protection Act.

In Canada, the National Adaptation Strategy (ECCC, 2022), currently under development, seeks to define shared priorities for all orders of government for cohesive adaptation action across the country, and will national evaluation and monitoring measures to track progress. Stakeholder and public engagement being undertaken to develop the National Adaptation Strategy (NAS) may provide an opportunity to increase interjurisdictional collaboration, and may support greater integration of adaptative measures in Canada.

Dynamic Systems, Geodiversity, and Scale

Climate change is driving/reinforcing the need to reimagine a new relationship with the coastal landscape – one where a healthy coastal environment protects against the impacts of climate change and where development respects dynamic coastal processes. These important concepts were recently highlighted in the document Making Room for Movement (van Proosdij, 2021), which recognizes that coastal systems need sufficient space to be dynamic, while protecting infrastructure and people from hazards. Related to these concepts, the International Union for the Conservation of Nature (Crofts et al, 2020) recently published new guidance for the protection of natural areas which highlights the importance of geodiversity conservation, which includes the variety of rocks, sediments, landforms together with the natural processes that form and alter them in nature. Allowing for dynamic shoreline movement is an internationally recognized best management strategy to increase the resilience of coastal systems and enhance their protective function. Further, preserving these natural processes at the appropriate scale, such as littoral cells, is consistent with geoconservation principles (protection of geodiversity). These emerging concepts recognize the importance of selecting an appropriate scale for integrated adaptation studies that is consistent with the physical processes that moderate the coast and ensure natural processes such as erosion and sedimentation are not disrupted and can continue in the future.

Sustainable for the Coast

Our coasts and how we relate to them is also changing, and not just from climate change. An integrated CCA approach will also have to consider how our use and occupation of the coast may change and how that will affect vulnerability, risk, and resilience. What will be the impacts of increasing population and migration to and urbanization of the coast faced with future sea level rise projections and greater water level variability in freshwater lakes? Adaptation policies rarely use future socio-economic and land use projections in their assessments.

Co-develop Solutions with Communities

Meaningful engagement for adaptation planning should involve a broad range of stakeholders, rights-holders and landowners from coastal communities to ensure salience and ownership of integrated adaptation interventions, and therefore more effective implementation and sustainability. Respect for all stakeholders is needed, particularly those traditionally underrepresented and disadvantaged. Identifying how certain stakeholders or groups will be impacted by climate change, and to what extent they can contribute to a collaborative response is a critical undertaking in the climate adaptation process and ensuring equity (and justice).

Consideration must also be given to how to implement climate change adaptation on privately owned coastal lands. In Nova Scotia, for example, 87 percent of the province's 13,000 km-long coastline is privately owned. Therefore, co-developing adaptation options at the community level, involving all stakeholders, will be required and will be critical to successful integrated coastal climate change adaptation planning.

When striving for more integration at the community scale, adaptation planning efforts need to focus on key climate risks and adaptation issues that capture the interest and commitment of local residents. It will need to be personal, in some cases, to engage private landowners. It is also critical to inform communities of climate hazards and risks, the need for adaptation, and the range of potential responses available.

In addition, adaptation planning requires a thorough understanding of people's perceptions and attitudes toward the coast, traditionally and now in light of the coastal impacts of climate change. How do coastal residents, stakeholders and governments 'feel' (and react) in the face of climate change and the need, urgency, and approach to adaptation? Is it considered urgent, are they defiant, indifferent, scared, or feeling a sense of loss? Reason alone does not drive behaviour, as the Southeast Leamington (Zuzek Inc., 2021a) case study presented in Section 3.0 highlights.

Nature-based Solutions

Nature-based solutions (NbS), in particular, have a vital role to play in managing coastal flood and erosion risk in Canada and driving innovative and transformational adaptation. International experience and guidance demonstrate that these measures not only provide protection against coastal flooding and erosion, they also deliver co-benefits, including improved biodiversity, carbon sequestration, enhanced quality of life, and opportunities for recreational activities.

A review and synthesis of global experiences on ecosystem-based approaches to climate change adaptation (EbA) and to disaster risk reduction (Eco-DRR) found that they enable people to adapt to the impacts of climate change and disasters by using opportunities created by sustainably managing, conserving and restoring ecosystems to provide ecosystem goods and services.

Three courses of action were recommended to scale-up the use of nature-based solutions for coastal protection in Canada (Eyquem, 2021):

- Develop national standards to support consistent evaluation of the benefits of nature-based solutions when comparing infrastructure options, including for coastal protection. This should include minimum requirements, region-specific standards, engagement with Indigenous people and recommended methodologies for reflecting the financial value of benefits provided by nature-based solutions.
- Develop national monitoring standards for coastal protection measures, focused on nature-based solutions. This includes consideration of minimum monitoring requirements, as well as how monitoring could be tailored to document performance against project-specific objectives. Funding for long-term monitoring and engagement with Indigenous People could be considered as minimum monitoring requirements to incorporate Indigenous Knowledge.
- Build capacity to finance and deliver nature-based solutions by engaging the private sector. Public-private partnerships can assist in financing, delivering, monitoring, and maintaining nature-based solutions. The insurance industry can also assist in managing construction risks and offering innovative insurance products that provide funds to restore natural features protecting the coastline, should they be damaged during extreme events.

In a similar study focused on increasing coastal resilience in the Great Lakes with nature-based solutions (Zuzek Inc., 2021b), several recommendations were generated to promote adoption, including government collaboration on integrated coastal zone management plans, leverage transformational adaptation to re-align hazardous lands, co-develop NbS with communities, and operationalize NbS in policies and regulations, create pathways with funding, and mandate them for infrastructure projects.

The Value of Nature for Local Governments

A growing number of Canadian local governments are now recognizing that it is as important to understand, measure, manage and account for natural assets as it is for hard/grey ones. Many municipalities are developing an asset management strategy to better manage their infrastructure. A logical extension of the asset management approach is the inclusion of "natural capital". The Municipal Natural Asset Initiative (MNAI) created a simulation model called the Coastal Toolbox (MNAI, 2021) that can help municipalities identify their relevant natural assets, understand the value of those natural assets and use that information for more integrated municipal planning and management decisions. The Coastal Toolbox is a GIS-based simulation and analytical tool designed to help local governments identify, prioritize, and manage key coastal natural assets as part of their day-to-day asset management practices.

To be successful, a natural asset management strategy requires a multidisciplinary, team-based approach, consistent with integrated coastal zone management and adaptation approaches. A coastal natural asset team should include representatives from all levels of government that have jurisdictional overlap with any proposed asset management activities, including development of climate change adaptation strategies. For example, including technical experts on the team such as local planners, coastal engineers, Indigenous representatives, ecologists and GIS specialists will help to ensure the right information and coastal system dynamics are being incorporated into the model and considered when developing climate change adaptation plans.

Introducing a climate change lens to municipal planning may help galvanize the consensus building process by reinforcing the message that "the future will be different than the past" and that intentional, integrated action is necessary to attain goals in light of these changing circumstances.

The Federation of Canadian Municipalities, Municipalities for Climate Innovation Program, published a guide with straightforward guidance and practical information, particularly for new municipal employees mandated with responsibilities for climate change planning and management. This type of leadership is positive for municipal governments and their future collaboration on climate change adaptation.

The creation and implementation of HalifACT 2050 is guided by a set of common principles of climate change action planning. Those most relevant to coastal climate change adaptation include:

- Leadership: Climate change action planning requires changes to established frameworks and practices, and these in turn are most likely to succeed when they are inspired by an understanding of how they will benefit the community and are encouraged and supported by both the leadership of elected officials and senior managers in the municipality.
- Alignment: Climate change targets and actions are more likely to succeed where they align with community goals, aspirations and policies for public health, fiscal efficiency, self-reliance, economic prosperity, resilience, inclusiveness, full employment and community planning and development.
- Implementation: Climate change literacy for municipal leadership and staff, and community stakeholder relations are mutually empowering.

- Innovation: Action on climate change requires a willingness to learn by doing - take risks, to fail, and to learn.
- Accountability: Transparency is key and includes following an open decision-making process, and setting goals that can be measured, reported, independently verified, and evaluated.

To build coastal resilience to climate stressors, institutions must enable synchronized responses to system vulnerabilities, obtain and apply scientific knowledge in decision-making, and promote the flow of information among the community.

Successful adaptation must therefore be an ongoing, iterative process that addresses immediate threats and prepares for long-term, evolving risks.

HalifACT developed a three-step framework for adaptation planning that can be applied to build resilience in municipalities: (1) develop a knowledge base that presents multiple future outcomes; (2) formulate flexible adaptation policies to respond to climate-induced vulnerability; and (3) create a program for implementation and progress monitoring.

Monitoring Progress Towards Societal Goals

We must also think of integrated climate change adaptation in Canada within the broader/global policy context – meeting international commitments and obligations, including the Paris Agreement, the Glasgow Climate Pact, Ocean Decade, and Sustainable Development Goals. They call for the Parties to, when acting to address climate change, respect, promote and consider their respective obligations on human rights, the right to health, the rights of Indigenous Peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations and the right to development, as well as gender equality, empowerment of women and intergenerational equity.

Governments need to take steps to improve the wider enabling environment for regular climate change risk assessment, notably with measures for:

- strengthening institutional memory and governance;
- sustaining long-term monitoring and reporting systems;
- promoting freedom of access to data and analytical tools;
- growing technical capacities in public and private sectors;
- allocating resources for strategic research programmes and bridging organizations;
- disseminating findings and advice at all levels of governance; and
- piloting different adaptation measures.

2.1.2 Takeaways

Several important takeaways from the literature review are summarized in Table 2.1. We must intervene early to ensure that adaptation and future climate change considerations are considered in decisions that have long lifetimes, such as major infrastructure developments or land-use

planning, to avoid 'lock-in'. It is also important to fast-track early adaptation steps for decisions that have long lead times and to initiate early activities that provide information to improve adaptation decisions in the future (e.g., by enabling research, monitoring and piloting to enhance learning). These three types of intervention are complementary.

Table 2.1 Summary of Literature Findings

Key Aspects of Integrated Coastal Climate Change Adaptation	Relevance
Policy and Legislation	Can enable or hinder integration and action.
Funding	Integrated climate change adaptation for our most pressing challenges requires funding to develop the options, engage, secure permits, etc.
Scale and Geodiversity	Integrated coastal management requires careful consideration of scale of assessment, planning and implementation, and recognition of physical processes at land-water interface (geodiversity).
Sustainability and ICZM	Long-term sustainable solutions should be pursued that recognize the coast is an integrated physical, social, ecological and economic system.
Co-development with Communities	Fundamental to success.
Role of Nature-based Solutions	Leveraging NbS recognizes the role of nature in building resilience.
Value of Nature	If the value of natural systems are recognized, more emphasis will be placed on preserving them with adaptation solutions.
Monitoring Progress towards Societal Goals	When planning climate adaptations and implementing strategies, we must be aware of the larger societal goals established with international commitments, such as the sustainable development goals.

2.2 Perspectives from Practitioners on Coastal Adaptation

Subject matter experts and practitioners were interviewed. The objective was to draw upon their expertise and experiences to understand opportunities and challenges for developing and undertaking integrated coastal climate change adaptation. The insights could be used to inform the development of guidance for implementing integrated coastal adaptation actions.

2.2.1 Process and Methods for the Expert Consultation

The steps in the process for undertaking the expert consultation included:

1. Design, review, and approval of the survey,
2. Initial contact with interview candidates,
3. Interview set-up,
4. Interview execution and transcription,
5. Organization and analysis of interview transcripts, and
6. Summary of findings.

Semi-structured interviews were used rather than an online, close-ended, scaled questionnaire with statistical analysis. Open-ended questions allowed for more extensive, nuanced exploration of topics. Interviewees could reflect upon their experiences and draw upon their expertise as well as current practices to provide insights. Prompts and follow-up questions were used to explore novel or untapped information.

Interviewees were selected for their expertise with integrated coastal management and planning and/or adaptation with respect to climate change in the coastal zone. They had expertise in one of four Canadian coastal regions (Pacific, Arctic, Atlantic, Great Lakes) or general, broad knowledge. One international interviewee was included. Ten interviews were conducted with 12 people over the period February 11 to 14, 2022.

The series of interview questions were organized into a framework of seven themes and intended information outcomes to meet project objectives. The framework allowed for a logical flow of questioning in the interview and reporting out results.

The analysis of the interview outputs consisted of reading through the transcribed information, identifying useful quotes and highlighting important ideas, insights and phrases, and grouping them into themes – a latent content analysis approach. Manifest content analysis - counting the appearance of a word or phrase in the transcript was not used (Cope 2010). The analysis also extracted connections and reoccurring themes and identified unique, innovative ideas as well as lessons learned and needs.

2.2.2 Summary of Findings

Key findings from the interviews are summarized in a series of Tables that draw upon the themes and associated questions organized in the framework for the survey.

2.2.2.1 Q.1: Background - insights on adaptation to increase resilience

Interviewees were asked to draw upon their professional as well as project experiences to share key lessons learned or advice on implementing adaptation measures to increase resilience in

coastal communities. Insights are synthesized into three themes: Lessons, barriers/challenges, and needs in Table 2.2.

Table 2.2 Lessons learned on Implementing Adaptions to Increase Resilience

Q: As a person working in coastal management or hazard reduction, what hazards/risks have you tackled and where?

From that experience, do you have key lessons learned or advice on implementing adaptation to increase resilience in coastal communities to climate change?

"Status quo is what has gotten us into this dilemma…[Need] help with capacity building."

"…Work across these silos, include government agencies…lead[s] into technical side and science and engineering…Transitioning from understanding climate change and vulnerability assessment to action to take. Plenty of information in…assessments into actions to be taken…Neglected part is the social side…20% of the challenges are technical, 80% are the social science challenge."

Lessons:

- Transitions are occurring. Evolving from traditional coastal climate change adaptation through hard infrastructure to mainstreaming nature-based or hybrid solutions.
- Long time horizons. Implementation of legislation, regulations and moratoriums is not nimble, and the impacts and risks continue to evolve and intensify.
- Current funding regime supports implementation of local, shovel-ready infrastructure projects. To collaborate, plan, and co-design innovative, transformative regional projects requires additional financial support with revised requirements and timelines.

Barriers/Challenges:

- Regulatory challenges and barriers to implementing new, alternative solutions. Current regime favours dike and seawall solutions and living dike or breakwater solutions are not in the current repertoire with no streamlined processes for approval.
- Governance complexity with many acts, regulations and jurisdictional responsibilities interacting in the coastal zone with no overarching framework for coordination or mandate for coordinated responses.
- Municipalities are taking a risk with implementing NbS. NbS is innovative and has technical challenges/uncertainties and potentially higher costs. While NbS are place-based solutions, pilot projects serve to support learning by doing and diffusion of ideas on implementation and benefits.
- Mismatch of scale between impacts, system processes and jurisdictional scope (e.g., conservation efforts of land managers are constrained in the coastal zone since sphere of autonomous influence ends at park boundary or land-water-wetland interface)
- Complexity (e.g., issues, stakeholders, interacting impacts, jurisdictions) challenges current management processes but would benefit from an integrated approach.
- Funding cost share requirements can exceed Canadian municipalities' capacity; scope of funding not addressing all needs (e.g., often no funding for planning projects, just shovel ready solutions).

Needs:

- **Strategic framework** for coastal planning and management in Canada; current coastal planning is ad hoc.
- **Scaling up** as the response to changes/impacts/risks requires broader, regional scale assessment and implementation than a local focus.
- **People/community collaboration** to identify issues and solutions with facilitated conversations carefully framed by open-ended questions, recognition of knowledge domains, context, and priorities.
- **Mechanisms to work together** and support integration across sectors, scales, government jurisdictions, professional disciplines.
- **Capacity building** to enhance professional technical knowledge (e.g., innovative coastal solutions), holistic approaches to problems, methods of broad engagement and strategic public and professional education around coastal issues.

- **Operationalized tools** to inform decision-making and access to data.
- **Accelerate development of guidance** or standardized approaches for incorporating NbS into projects, evaluating benefits, and monitoring outcomes (provide evidence-based accounting of benefits).
- **Public-private partnerships**

2.2.2.2 Q.2: Reflections on Framing of the Concepts

Concepts and their definitions were presented in the preamble to the interview; interviewees were asked to reflect and offer interpretations and judgments. Transformative versus incremental adaptation was identified as key to the interview, as it reflects the challenge and where the adaptation process, design and outcome needed to evolve. One interviewee suggested that undertaking shoreline management planning could be transformative adaptation in Canada, since the current process is ad hoc. Additionally, integrated adaptation was characterized as a holistic systems scale approach to solve coastal climate change challenges where government, Indigenous Peoples, landowners, and other stakeholders co-develop solutions. The adaptations can be incremental (maintain existing systems) or transformational (change systems). The essential aspect is a high degree of integration on defining the physical, social, ecological and economic issues and subsequently the planning and implementation of solutions by the participants. It is a means to address the current ad hoc, fragmented, "siloed" context of coastal planning and management in Canada. In public-facing communication, interviewees recommend developing tangible examples to illustrate the unfamiliar concepts such as transformational adaptation, incremental adaptation, integrated adaptation and integrated coastal management. The range of ideas is summarized in Table 2.3.

> "[Process and results of developing Squamish Integrated Flood Hazard Management] Plan was fairly transformative; some things were embedded in community culture like reliance on the dike. Planning to upgrade dike system, transformative change was on the policy side – flood plain regulations. Studies like this are valuable to local governments."

Table 2.3 Exploring key concepts

Q: We defined some concepts at the start of the interview (adaptation, incremental adaptation, transformative adaptation, integrated adaptation, resilience). Can you offer some insights on how and why these ideas might be important as we address climate change impacts on coastal communities?
Resilience • Resilience is a difficult term to define and implement; moreover, it can be co-opted. It can be interpreted as maintaining the status quo -- make our coastlines resilient for what we currently have developed. Resilience can also be thought of as transformative; we can advance/change the system to a different state. **Adaptation** • Adaptation to climate change is a framing challenge for communities and a conundrum for the public sector who often interpret adaptation as a one-time intervention or solution for problems that will evolve over 100 years or more and require a long-term, planned succession of interventions. • A challenge for agencies/governments is how to create the capacity at the local or national level to keep a long-term plan viable. • How we adapt is determined by and a reflection of what we deem important (what we value). • Successfully addressing adaptation will require change in human behaviour and thinking about access to and control over coastlines with the additional challenge of preventing path-dependence. • Adaptation to sea level rise is not only infrastructure or physical solutions, but also can address environmental, social and economic systems. • Adaptation can go hand-in-hand with decolonization based on a tri-part system - Indigenous, federal and provincial law and governance. Indigenous communities can co-lead initiatives to design and plan coastal adaptation. **Adaptation Process** • Action on adaptation is a complex, time-consuming, expensive process ranging from: Establishing need to adapt, developing knowledge and technical expertise, securing leadership and community buy in, developing policy, plans, designs, securing funding, implementing, and monitoring of performance. **Transformative Adaptation** • The need for transformative adaptation is an indication that we are at crucial point where the usual framing is not sufficient and we can no longer use adaptation practices and approaches for a business-as-usual scenario. • Transformative vs Incremental Adaptation. Success has been achieved locally with incremental adaptation (e.g., sea level rise by-laws). This is not addressing the full scope of coastal flooding issues or multi-jurisdictional context but it is easier for people to grasp and benefits are realized in a short period. **Integrated Adaptation** • Thinking about scope and scale of coastal issues, requires looking at the challenges and solutions in an integrated way. However, generally we address issues in a non-integrated fashion (e.g., manage fish, mange coastline, manage wetlands). The concept is to think of issues, jurisdictions and solutions as layers or integrated components that inform adaptation.

2.2.2.3 Q.3: Current Context Examples

For this question, interviewees were asked to provide some illustrations of current successes and benefits related to integrated adaptation, creating resilience, and transformation. There were many examples of current progress; highlights are provided in Table 2.4. Additionally, some case studies reported in Section 3 (e.g., Squamish and Chignecto) were selected based on these responses.

Table 2.4 Highlights of benefits and successes

Q: Do you have examples for your region or Canada or internationally that illustrate:

- Benefits of integrated coastal adaptation;
- Building resilience in coastal communities;
- Transformational change through adaptation to reduce risk and generate co-benefits;
- Your adaptation project successes?

"…we have a vulnerable road that [has] had lots of different departments working their problems differently…Integrated transformative change, [was] getting everyone in a room and people being able to see themselves in the solution, one solution can hit multiple problems, save time and money and duplication. [We were] looking at same issue and not talking to each other…Found a solution for everyone. Looking at hybrid infrastructure…"

Business case for NbS

- Changes associated with adaptations can be more acceptable to a community if there are co-benefits. Miami, FL developed a seawall plan for a 100-year storm plus sea level rise; 99% of the time, the community will have to live with this wall. The NbS and its environmental and social benefits (recreation and birding), as well as amenities from natural elements incorporated with engineered components, support implementation.

Knowledge systems

- Coastal adaptation in Indigenous communities incorporates indigenous knowledge - or traditional knowledge - or uses new methods to produce knowledge so they can monitor and provide advice on sea ice conditions to safely go on the ice.

Integrated Coastal Adaptation

- Chatham-Kent Shoreline study was an example of an integrated coastal adaptation study. However, many municipalities do not have the expertise or financial resources to undertake this type of comprehensive planning study.

2.2.2.4 Q.4: Current Efforts

Scale and complexity were overarching issues related to coastal planning and management and factored into decision making with respect to who to bring together, how to start, and who can lead an endeavor? Another common thread was the requirement for long-term planning or forward thinking for effective and integrated coastal planning and management. Many interviewees have not undertaken integrated, coastal adaptation. Insights into current progress and lessons learned and challenges are summarized in Table 2.5.

The opportunity: "…implement NbS …The ideas are challenging and difficult. They developed an Innovation Laboratory in coastal NJ. Public, private, NGOs, state and federal are coming together to innovate. Change is a loaded word…Innovation is a positive thing, there is change and risk but you get something better at the end of it."

Canada lacks an overarching strategy to address coastal issues and instead relies on piecemeal, uncoordinated, locally-focused efforts. The shoreline management process in the UK was identified as a process that could be applied in the Canadian context with outcomes that would be beneficial. In the UK program, "…shoreline management plans [lay out the management strategies] and appraisal reports [assess actual projects to achieve strategies]. The plans rely on extensive public consultation, multi-stakeholder participation integrated over several municipalities. They include historical trend analysis, information on how the coast evolved over time, and projecting how it will evolve from a geomorphological perspective in the future."

> **The challenge:** "What we need in Canada is a baseline appreciation or strategic overview: where are the 'hot' spots and where sea level rise is. Need to prioritize, need to be strategic. What is the risk? In the National adaptation strategy, need to prioritize; need to assess risk, map to prioritize areas strategically [for action] rather than [funding]…"

City of Surrey was recognized for undertaking an integrated coastal adaptation approach. It invested in engaging different groups and sectors to educate about challenges and potential impacts of climate change and sea level rise, and implications of "no action". The stepwise process used consensus building, scenarios, development of future adaptation strategies, and trade-off assessment. While there were community champions, the project did not neatly align with political election cycles, which affected implementation.

Table 2.5 Views on integrated coastal adaptation in the current context

Q: In your professional experience, have you undertaken integrated coastal adaptation as we have defined it or regional- or community-scale coastal adaptation that leads to resilience or transformation? If yes, why, how, outcomes, lessons learned, gaps, additional support that might be needed? If no, why not, what are some constraints, what is missing, and what is needed to support efforts?
Lessons learned: • **Shared resources management** - needs an integrated approach (e.g., coast, river or water body, infrastructure). • **Leadership** – need champions with vision of an integrated approach to coastal management. • **Relationships** – a time-consuming but necessary investment in nurturing relationships is crucial to achieving integrated approaches. • **Community engagement** – better success if issues and needs identified with community. • **Social/Community context** – recognizing and accommodating community needs and capacity (financial, personnel) and not a one-size-fits-all approach. **Challenges:** • **Scale and complexity –** barrier to planning and action. • **Silos** – institutional, governance, jurisdictional, knowledge, professional. • **Funding mechanisms** – mechanisms can bring people together; often opportunistic (who has capacity to develop applications); requirement for matching funding limits municipalities' access (not able to put in the allotted share). • **Integrate coastal management with socio-economic vulnerability reduction** - communities in the North deal with poverty, housing insecurity, food insecurity; can address separately or integrate into coastal adaptation. • **Extensive stakeholder engagement** – ensuring broad engagement and bringing necessary participants to the table; capacity; time commitment. • **Collaborative process** - facilitation of stakeholder participation for scoping and making decisions. • **Transparency and communication** -needed**.** • **Legacies and inertia** - established procedures, policies, regulations, tools (e.g., Benefit-Cost analysis) may represent obstacles for addressing new problems and implementing innovative solutions.

- **Political cycle** – Loss of momentum if lose political champion due to election.
- **Reactive vs Proactive** - tendency to wait until there is a disaster for initiative(s) to be catalyzed; how do we catalyze before disaster?
- **Challenge initiating and supporting change and innovation** – people resist change.

2.2.2.5 Q.5: Stocktaking and Innovative Approaches

The purpose of this question was for practitioners and experts to identify existing and new approaches that could enable implementation of transformative adaptation solutions. Three themes emerged – financing, new ideas/approaches, and engagement processes.

Table 2.6 Approaches supporting transformative adaptation

Q: Can you identify some innovative approaches that would support implementing transformative adaptation solutions in coastal communities? [Prompt: some new ideas/approaches, regional integration efforts, new stakeholders, engagement processes, financing, other?]	"Visions before equations" "Funding is needed for planning, design, and building projects, not just building."

New ideas/approaches:

- Recognizing Indigenous Knowledge (IK) and long-term, local community cultural knowledge in coastal communities.
- Landscape Architecture offers relevant perspective (scale of analysis) and positive processes of engagement to create vision(s) for the future and communicate with communities (amenities and benefits, change).
- Climate liability identified (liability around climate inaction, providing permits in hazardous places, not sharing hazard maps, hazard maps affecting property values).
- Integrated approach would help public-private partnerships (e.g., sediment banks or trading sediment/clean fill for NbS from construction and port dredging).
- Review policy for alignment and flexibility to support innovation (e.g., The BC Dike Maintenance Act has no adequate provisions for NbS; makes flood management through NbS very challenging).
- Review regulatory framework; innovation requires dealing with multiple levels of government; regulation hurdles are hard to overcome, time-consuming, restrictive, and expensive.

Engagement processes:

- Engaging local people in conservation and coastal research, environmental monitoring (e.g., Indigenous Guardians Program) which creates capacity and new perspectives.
- PARA discussions also incorporate 'managed retreat' and address as sustainability and place-based social issues.
- Innovative, transformative adaptations require highly skilled people to problem solve and design; how to facilitate community access to this expertise to assess needs and achieve goals.

Financing

- De-risking and financing NbS projects by using insurance to restore/enhance community-protective natural coastal features (e.g., dunes or beaches) if damaged by storms.
- Natural asset valuation or incorporation into financial statements.
- Innovative financing such as Green funding (green bonds, carbon offsets, climate finance, sustainable financing); payment for ecosystem services (e.g., ALUS in Ontario); Resiliency financing options creating an Adaptation investment fund modelled on GHG mitigation investment fund (endowment from federal government)
- Less funding available for NbS than grey infrastructure projects.
- Public-private financing partnerships.
- Research on building business case on return on investment for adaptation.

2.2.2.6 Q.6: Implementation

In this question, the interviewees were asked to take a long-term, large-scale perspective and judge what factors would contribute to implementation of integrated and/or transformative adaptation in coastal communities (see Table 2.7).

Table 2.7 Factors supporting implementation of integrated and transformative adaptation

Q: Looking to the future and thinking about implementation, what do you think are some essential components for integrated, regional- or community-scale adaptation for transformation and resilience building in coastal communities?

[Prompt: best practices, innovative pathways, leadership structures, engagement models, planning processes, governance approaches, financing]

Regulatory Clarity -- Having more of an integrated approach between regulators. [Currently] It's all standalone within each agency. Integration of that would be helpful.

…we need innovation in policy and law but this is more difficult than physics and engineering.

I don't think we are going to be transformative without being connected across the scale of the issue and doing some work at the larger scale…

Information, access to experts, guidance, incentives

- Creation of "coastal resilience hubs" or "an Innovation Laboratory" within a region(s) where the private sector, academia, NGOs, First Nations and government agencies could collaborate on a network of projects would advance implementation. By supporting innovation through these projects, framed as "innovation spotlights" or "implementation case studies", there would be innovative research, leadership, financing, and coordination. Practitioners and communities would learn by doing, and share knowledge and practical applications.
- Information and guidance would be helpful for communities preparing plans (e.g., flood management, coastal management plans, adaptation plans, etc.) particularly small communities with limited capacity. In an integrated approach, there would be knowledge sharing and capacity building across a broader region (risk-sharing for innovation).
- Relatable, accessible resources not highly technical information, helps people understand coastal processes, climate and sea level rise projections, and hazards and risks. This information provides communities with a baseline understanding to undertake coastal adaptation.

Engagement

- Resources (and research) to help governments effectively communicate hazard mapping (e.g., flooding) to the community and lessen the shock of learning about their risk exposure and assist in "getting to" adaptation.
- Community engagement on a larger, regional scale not just local is required, but need innovation on how to structure process.

Problem framing

- Integrate climate change adaptation into all types of decision making (infrastructure, environmental assessment, resource development).
- Map out coastal littoral cells, identify urgent, priority areas (based on high risk, hot spots) and discuss strategic options including managed retreat, NbS, hybrid responses.
- Opportunity to accelerate shoreline management adaptation in Canada by using best practices that have been successful elsewhere (e.g., UK, Australia, Netherlands).

Incentives for action

- Many cities and organizations want to undertake adaptation, but need connectivity, information, education, and funding to address the challenges. Boundary organizations can support implementation through transfer of knowledge and collaborations.
- Communities want to adapt, however, some existing legislation does not enable/support innovative actions (e.g., BC Dike maintenance Act does not include environmental considerations; ecologically beneficial long-term adaptation cannot be included).

Financing

- Financing is an important issue if want to undertake innovative, regional-scale planning that is integrated beyond local government and communities.

Planning

- "Managed retreat" or "managed realignment", "managed relocation" implementation is a complex, expensive challenge that benefits from an integrated approach and scale. It cannot be addressed solely within a community but requires leadership and support from other levels of government.
- If proposing "managed retreat" or "managed realignment", need to explore options with the community and landowners including where would there be appropriate land for relocation and where could the community expand (e.g., Tuktoyaktuk).

2.2.3 Synthesis of cross-cutting ideas from interviews

In synthesizing the responses from the interviews, a narrative emerged that recommended developing an overarching (national) strategy/approach for coastal management and integrated climate change adaptation in Canada supported with appropriate legislation and policy. Innovation on "what to do" requires careful consideration of scale, and recognition that land and water zone need to be linking in regional study areas focused on littoral cell boundaries in the nearshore with appropriate connections to the upland in order to move beyond local or lot-by-lot assessments to a regional coastal zone perspective. Working at these larger scales is appropriate for consideration of physical processes, coastal and terrestrial ecosystems, societal values and assets, and economic factors.

Integrated coastal zone management principles offer a framework to consider a balanced approach that works for all aspects of our physical, social, ecological and economic systems along the coast. Solutions should be co-developed by government, Indigenous Peoples, practitioners, and communities. Preserving natural coastal systems with high resilience should be prioritized and embracing nature-based solutions that create co-benefits should be given the highest priority. When pursuing transformative adaptation, communities will need technical and scientific support, regulatory and policy clarity that facilitates innovation rather than impedes it, and creative financing mechanisms that support planning and design of innovative solutions.

Implementation will require funding, creative financial options, private-public partnerships, and insurance of NbS to de-risk projects. Finally, climate change adaptation and coastal management is never finished, rather, it is an iterative process involving planning, design of solutions, implementation, monitoring, evaluation and learning, and adjusted management approaches (Kovács et al, 2014). Therefore, in some instances, adopting an adaptive management approach following the initial climate change adaptation will be necessary and beneficial.

Table 2.8 Synthesis of Ideas Across Interview Responses

Social science is equally important as traditional technical studies from the fields of biology, geomorphology, science, and engineering for integrated coastal climate change adaptation.
Require funding for community engagement component (required since high demand for staff resources on other priorities).
Funding for planning and design of integrated coastal climate change adaptation plans is needed, especially for complex transformative adaptation; currently, funding is focused on construction-ready projects and not more innovation or complex transformational adaptations.
Some agencies are not experienced in community collaboration and engagement.
An integrated adaptation approach can overcome "silos" in professions, agencies, communities, physical environment, view of issues, and design of solutions.
Indigenous Knowledge and participation in climate change adaptation is necessary.
Documenting and communicating co-benefits will contribute to developing a business case for innovative, transformative solutions that can be expensive and/or high risk.
Collaboration on integrated adaptation can spread knowledge throughout agencies and communities, and build capacity for future projects.
Policy alignment and regulatory clarity are important to advance integrated adaptation.
Need to transition to pro-active responses to coastal hazards and move away from reactive management (most action typically occurs in response to extreme events or disasters).
Geo-political boundaries often do not align with the scale of the coastal issues and large-scale transformative adaptations. Further, integrated adaptation will require government agencies with different mandates to collaborate on solution development.

3.0 CASE STUDIES

A series of adaptation case studies from across Canada and the United States of America were developed to highlight projects and communities in various stages of integrated adaptation planning and implementation.

3.1 Overview and Lessons Learned

Full case study reviews are provided in Appendix A and key findings are summarized below.

3.1.1 HalifACT Municipal Mitigation and Adaptation Plan, Nova Scotia

In 2020, the Regional Municipality of Halifax adopted a comprehensive climate mitigation and adaptation plan for the 400 km of coastline managed by the Municipality. HalifACT (Acting on Climate Together) was developed with extensive community engagement on coastal climate risks such as sea level rise, flooding, erosion, and saltwater intrusion in freshwater aquifers. The plan was informed by local risk and vulnerability assessments across the large and diverse municipality. The next adaptation step is acting on the recommendations to increase resilience to climate change. The keys to the success of the study to date include the leadership of elected officials and senior managers, alignment of climate actions with community goals, focus on climate literacy, transparent decision making, and a focus on innovation to increase resilience to coastal hazards.

> **Lessons Learned**: Successful plan development was attributed to political leadership, dedicated municipal staff, and alignment of climate adaptations with community goals.

3.1.2 Squamish Integrated Flood Hazard Management Plan, BC

The District of Squamish in southern British Columbia is located on a gently sloping mountain valley that is vulnerable to riverine and coastal flooding. Through extensive collaboration with the community and Squamish First Nation, a new Integrated Flood Hazard Management Plan (IFHMP) was prepared in 2017 to update the original plan prepared in 1994. The plan was developed by a multi-disciplinary team, considers sea levels 1 m higher than present and a 10% increase in peak river flow. The integration focused on assessing flood and flood-related hazards from all possible sources - the ocean, rivers, creeks, lakes, urban storm water, groundwater, and related hazards including erosion, landslides and ground instability. Similarly, a wide range of possible adaptation strategies were considered, with the equitable distribution of risk. The adaptation approaches followed the four PARA approaches: protect, avoid, retreat, and accommodate. Community engagement and collaboration was a critical component of the study to build buy-in and support for the plan. The plan is currently in the implementation stage, where cost-effective measures to reduce risk are being pursued, development is proceeding on the least hazardous lands, and partnerships with senior governments are being explored to execute capital projects.

> **Lessons Learned**: Community engagement was critical to share knowledge of the existing flood risks and develop equitable climate change adaptations.

3.1.3 Chignecto Isthmus Climate Change Adaptation Comprehensive Engineering and Feasibility Study, Nova Scotia - New Brunswick

The Chignecto Isthmus climate change adaptation comprehensive engineering and feasibility study was completed to evaluate adaptation options for the low-lying lands that separate the provinces of New Brunswick and Nova Scotia. Initially constructed in the 1600s, a series of dikes and aboiteaux are now threatened by rising sea levels and coastal storms. The dikes protect an important trade and transportation corridor that moves approximately $35 billion per year in goods and services. The integration component of this study was focused on the Project Steering Committee with representatives from multiple government organizations. The three recommended adaptation options all include traditional grey infrastructure upgrades or new structures, such as higher dikes. Nature-based solutions, such as re-aligning the dikes further inland and restoring salt marshes that could dissipate storm impacts and sequester carbon, were not considered.

Lessons Learned: Challenges remain with promoting NbS over traditional grey infrastructure.

3.1.4 Rondeau Barrier Beach and Navigation Channel Restoration, Lake Erie

Following the completion of a detailed shoreline vulnerability study for the Municipality of Chatham-Kent in 2020 (Zuzek, 2020), an Advisory Committee was assembled with representation from government and the local community to advance the planning, engagement, and design of the conceptual nature-based adaptation solution to restore the Rondeau barrier beach and protect the navigation channel. The existing configuration of the navigation channel is starving the barrier beach of sediment and it has migrated 600 m inland in the last 150 years. More than 500 hectares of coastal wetlands have been permanently lost. This case study is in the early planning and design phases for the adaptation restoration. Strong community engagement has galvanized local interest in the project, but a lack of funding dedicated to 'planning' a nature-based climate change adaptation has made progress limited. To date, existing funding programs for disaster-risk reduction, NbS, and climate change adaptation only provide financial resources for shovel-ready construction projects, not the necessary planning, design, and permitting for a complex transformational solution.

Lessons Learned: Without dedicated funding for planning, engagement, design, and permitting, communities will not be able to advance complex transformative adaptation projects. Multiple landowners (government and private) within the footprint of the NbS, also adds another layer of complexity for planning and implementing the adaptation.

3.1.5 Southeast Leamington Floodplain Re-alignment, Lake Erie

Southeast Leamington features 4,400 hectares of diked agricultural land with field elevations below lake level. In a recent Hazard Identification and Risk Assessment (HIRA) following Public Safety Canada's guidelines, the total risk score for Southeast Leamington considering frequency, consequence, and changing risk was eight times higher than the threshold for an area to have extreme risk (Zuzek Inc., 2021b). Two comprehensive technical studies (Baird, 2007; and Zuzek Inc., 2021) have quantified the flood risk and developed comprehensive adaptation concepts to reduce coastal hazards, protect people and property, and restore habitat. The

recommended approach for the agricultural lands in both cases was a large-scale planned retreat and land use re-alignment with a nature-based solution. Despite more than 15 years of technical studies with integrated teams from all levels of government, planning and community engagement, and development of innovative transformative climate change adaptation solutions, there is no consensus on the path forward and the community prefers incremental adaptation solutions such as protect that involve upgrading shore protection and dike schemes.

Lessons Learned: The complexities and challenges with transformative adaptation through a planned retreat are significant, especially when the agricultural community that owns the lands are resistant to change. Without a well-funded buyout program at offering fair market value for the high-risk lands, owners prefer less disruptive incremental adaptions such as protect. Further studies focused solely on landowner engagement are required to advance planning for the recommended transformative adaptation solution in Southeast Leamington.

3.1.6 Tuktoyaktuk Climate Change Coastal Erosion Plan

Situated on the coast of the Beaufort Sea, just east of the Mackenzie River Delta in western Northwest Territories, Tuktoyaktuk is the most northern community on mainland Canada. The Inuvialuit have lived in this area for thousands of years and many still live on the land, hunting caribou and beluga whales. The population is roughly 1,000, with 88% being Inuvialuit.

The long-term relative sea level in the area has been rising at a rate in the range of 1 to 4 mm per year and consequently, much of the coast is being eroded. The typical long-term erosion rates of coastal bluffs are around 1 to 2 metres per year. It may be impossible to ultimately stop any further erosion in Tuktoyaktuk given sea level rise, melting permafrost, reduced sea ice, and increased storm exposure.

A variety of adaptation experiments have been implemented to slow the erosion rate, including replenishing the bank and beach with sand and gravel, stacked gravel bags, and concrete mats. A recent study tested at the National Research Council laboratories tested the feasibility of a rock revetment system. This solution will provide several decades of protection while the community evaluates managed retreat alternatives.

Lessons Learned: Climate change threats are magnified in the north and planning for a managed retreat adaptation is a long-term process. Relocation and managed retreat are particularly complex in the context of Indigenous communities, where knowledge systems and culture are tied to land and specific environments.

3.1.7 San Francisco Sea Level Rise Resilience Program

The City of San Francisco is planning for and adapting to projected impacts of climate change (sea level rise inundating 6% of the city by end-of-century). A Sea Level Rise Coordinating Committee (twelve City departments with relevant mandates and vulnerable assets) developed the 2016 Sea Level Rise Action Plan -- a key element in San Francisco's comprehensive Sea Level Rise Resiliency Program. This is an active sea level rise planning process (City and County of San Francisco, 2016) and an iterative assessment process with common science, tools, and methods to support collaboration and integration on adaptation (City and County of San Francisco, 2020). The process specifically addresses wastewater, water, transportation, power,

public safety, open space, port, neighbourhoods and changing shoreline issues. The complex and evolving issue of sea level rise requires innovative adaptation solutions created collaboratively with interdisciplinary teams and extensive community engagement. Adaptations are directed at governance-related strategies (e.g., zoning, design standards, maintenance procedures) and innovative coastal designs (e.g., green infrastructure, structure elevations, and flood barriers) and guidance has been developed for incorporating sea level rise into capital projects. Solutions can be implemented at multiple scales and timeframes.

Lessons Learned: Estimating expected losses in public and private property from inaction on sea level rise adaptation informs decisions about balancing costs of post-disaster relief with up-front adaptation costs. Adaptation is recognized as an ongoing process where future actions are part of the cyclical nature of the adaptation process requiring monitoring of sea level rise projections, and best practices for adaptation, and securing funding. Adaptation strategies and actions need to be robust yet flexible, with short- and long-term approaches to resilience.

3.2 Key Findings from Case Studies

Key findings from the case studies reviews are presented in Table 3.1.

Table 3.1 Summary of Case Study Findings

Adaptation Actions	Relevance
Legislation, Acts, Policy	Most senior government departments were established and have a legislative mandate for single components of our integrated coastal systems in Canada. This structure hinders collaboration, especially on complex transformative adaptations to climate change.
Funding	Without dedicated funding for integrated adaptation planning and community engagement, progress will be limited for the most challenging coastal climate change issues.
Planning versus Action	The majority of the integrated adaptation work reviewed for this report was focused on plan development, not action and implementation.
Scale	Transformative adaptations must be planned at an appropriate scale in the coastal zone, which is often larger than traditional site-specific investigations. This makes planning, funding, and implementation more complex than historical infrastructure adaptations, such as raising dike-crest elevations.
Integrated Coastal Zone Management (ICZM)	While the theories and principles behind ICZM align well with integrated and transformational climate change adaptation, planning, funding, and implementing these types of projects has generally not occurred in Canada. As a nation, we are far behind our peers globally.
Community and Stakeholder Engagement	One common theme in all successful projects reviewed was extensive community engagement and co-development of the

	adaptation options, prioritization, and selection of the preferred solution.
Nature-based Solutions	NbS offer tremendous potential for integrated adaptation and in particular transformational adaptation. However, in general, we are stuck in the planning phases of such projects across Canada. Implementation of large-scale integrated adaptation solutions remains an elusive goal in Canada.
Adaptive Management Framing	Coastal management and climate change adaptation will never be finished. It is a continuous process and recognizing the need for monitoring, learning, and adapting the management approach is necessary to build coastal resilience in the long-term.

4.0 CORE ELEMENTS OF INTEGRATED COASTAL ADAPTATION

The information gathered from the literature, interviews, and case studies is synthesized to highlight several key components that would advance integrated coastal climate change adaptation in Canadian communities.

4.1 Government Alignment for Integration

Municipal, provincial, territorial, and federal government departments with a mandate for the Canadian coastal zone have been organized into discrete sectors or components of a complex integrated physical, social, ecological, and economic system; the coastal zone. We have ministries and departments responsible for human health, land-use planning and development, species, water quality, wetlands, navigation and harbours, protected areas, and socio-economic dimensions. This existing approach is depicted graphically in the top half of Figure 4.1. No single entity has an overarching responsibility for the coastal zone or climate change adaptation. Instead, we manage the coastal system by sectors or silos, which creates barriers for integrated adaptation planning, not pathways.

For decades, this sectoral management approach for the coastal zone has facilitated development on hazardous lands, resulted in extensive shoreline hardening, wild species are disappearing, wetland habitat loses continue, biodiversity and geodiversity are threatened, and ecosystem health is in decline. Refer to the chart in the bottom half of Figure 4.1. Collectively, across Canada our siloed management approach to the coast is responsible for the decline of biodiversity, geodiversity, ecological health, and coastal resilience.

If we maintain the status quo management approach, declines in our life sustaining coastal ecosystems and communities will continue, as shown in Figure 4.1 (bottom graph). However, if society and government are willing to embrace integrated coastal climate change adaptation, we can reverse the current system response and start increasing the resilience of coastal communities to climate change with nature-based solutions and ecosystem-based adaptations that also improve biodiversity, will prevent further geodiversity declines, and restore the ecological health of our natural systems.

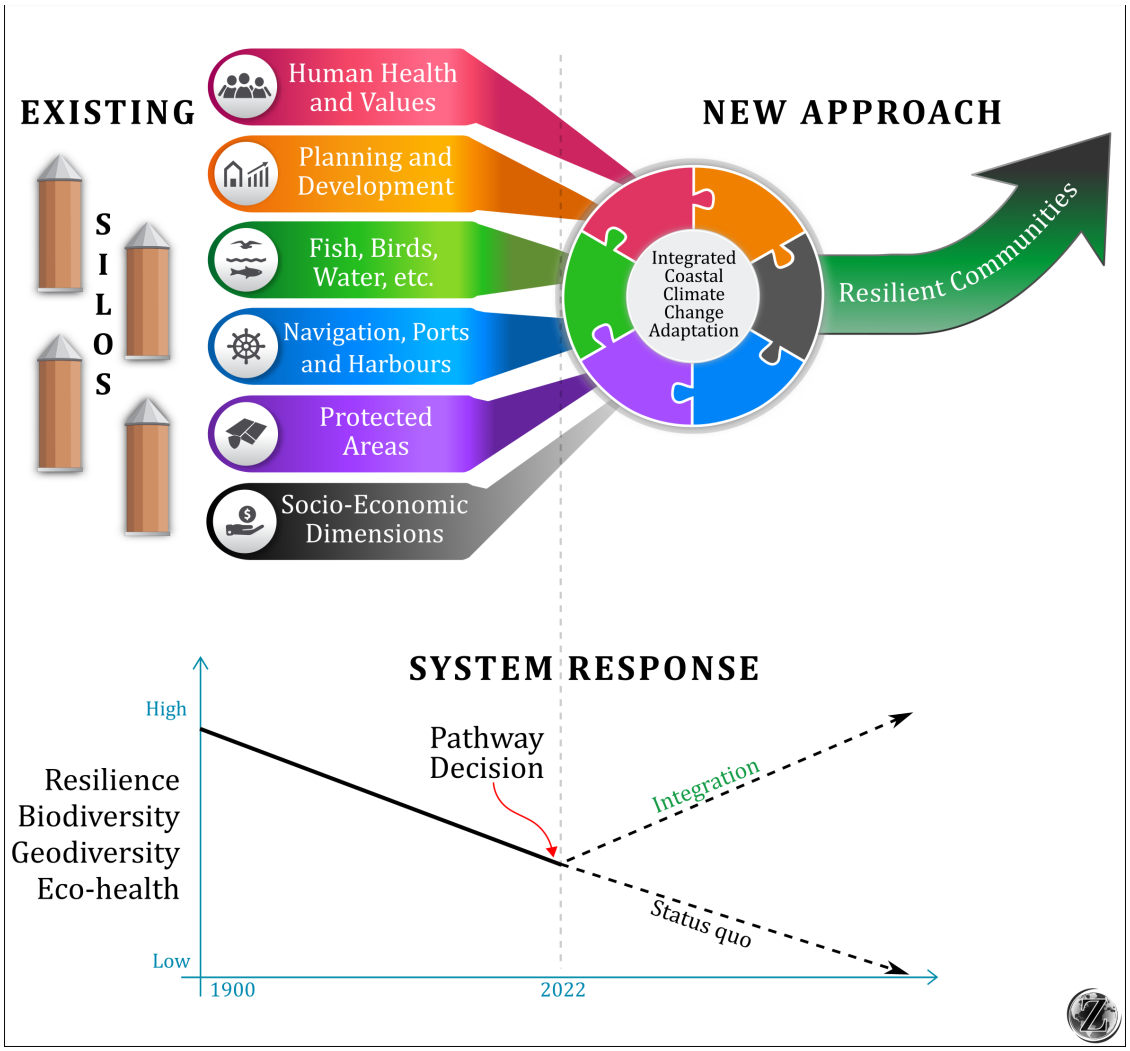

Figure 4.1 Existing Siloed Coastal Management and Recommendation for Integrated Coastal Climate Change Adaptation

4.2 Core Elements of Integrated Coastal Climate Change Adaptation

Based on the literature review findings, interviews, and review of Canadian case studies, six core elements of integrated adaptation have been identified. They are discussed below and presented visually in Figure 4.2, including

- **Align Legislation, Policy, and Funding**: A supportive legislative and policy framework for integrated coastal climate change adaptation is needed with appropriate targeted funding for engagement, planning, design, and implementation.

- **Consider Scale and Geodiversity Factors**: Adaptation planning must be completed at appropriate scales to integrate physical processes across the coastal zone, social dimensions across land and water issues, ecosystem function and potential for restoration, and economic factors.

- **Embrace Sustainability and Integrated Coastal Zone Management Principles**: Relevant aspects of the UN Sustainable Development Goals, such as health, well-being, and equality should also inform the adaptation process. Guiding principles of ICZM, including a balanced consideration of physical, social, ecological, and economic factors, must also guide the climate change adaptation design and implementation.

- **Co-develop Adaptation Options with Communities**: Integrated climate change adaptation requires co-development of options with communities, including landowners, Indigenous communities and stakeholders, and the inclusion of socio-economic considerations. Co-development of solutions will help avoid maladaptation, integrate diverse priorities, and increase buy-in for implementation.

- **Leverage Nature-based Solutions**: Nature-based solutions should be considered to the fullest degree possible for the integrated climate change adaptation solutions developed with communities, including transformational adaptation approaches.

- **Adopt an Adaptive Management Approach:** Integrate climate change considerations in all decision-making and plan to continuously monitor and evaluate adaptation actions over time. As conditions change learn from completed adaptation projects and modify future management approaches within an adaptive management framework. Maintain flexibility and responsiveness to changing conditions to prevent lock-in and path dependence.

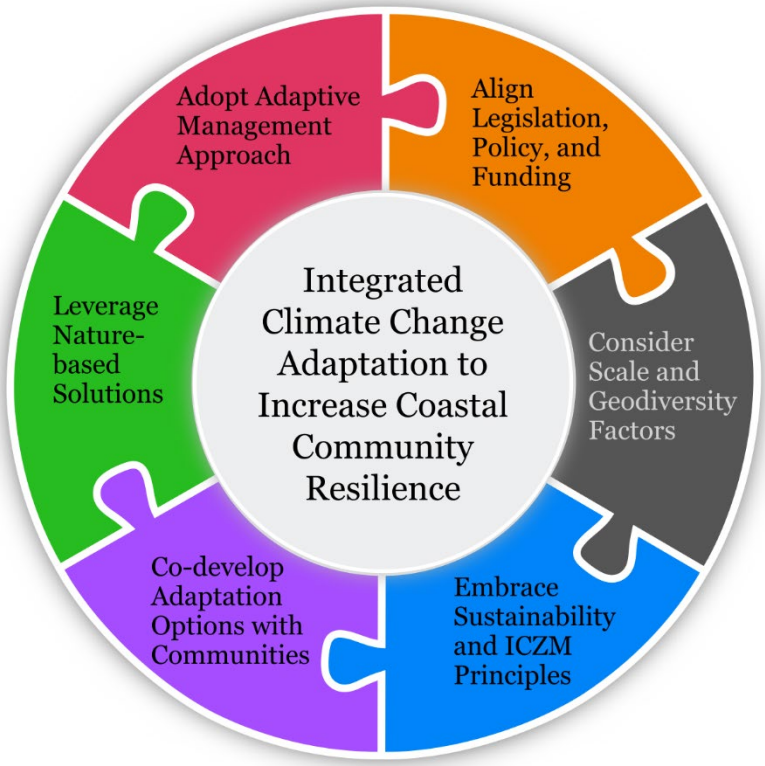

Figure 4.2 Components of Integrated Coastal Climate Change Adaptation

5.0 RECOMMENDATIONS

To date, most of the effort directed at coastal adaptation in Canada and globally has been on plan development and implementation of small-scale, incremental adaptation projects with a focus on traditional grey-infrastructure solutions. Encouragingly though, nature-based solutions are increasingly being explored and hybrid grey-green solutions experimented with. To advance to integrated coastal climate change adaptation, the following recommendations are provided:

- Identify options for government alignment with existing legislation, acts, agreements, policies, and programs for integrated coastal climate change adaptation. These could range from incremental to transformative changes. Recent provincial experience, such as the Nova Scotia Climate Change Plan for Clean Growth, could serve as a blueprint for other provinces. The NAS also presents an opportunity to define a common pathway towards adaptation in the national context, and may offer opportunities for interjurisdictional collaboration, and improved understanding of stakeholder needs to inform integrated approaches to adaptation.

  The benefits of the recently announced National Climate Adaptation and Resilience Strategy Act in the United States of America should be explored in a Canadian context. It intends to support a unified national vision to help vulnerable communities build resilience to climate change. The NAS may provide the context for a similar Act in Canada.

- Revise funding formulas that only support shovel-ready projects to support the full spectrum of adaptation steps including resources for community collaboration to plan and co-design options, secure permits, and implement innovative transformative coastal climate change adaptations.

- Advance the planning and construction of projects that demonstrate the benefits of integrated coastal climate change adaptation planning considering a changing climate, solution co-development with the community, nature-based solutions, and implementation.

- Implement full-scale projects which demonstrate integrated adaptation approaches and disseminate the results from projects that explore the intersection of integrated coastal zone management plans, ecosystem-based adaptation, and nature-based solutions.

- Build capacity and equip current practitioners with the necessary skills, training, information, and resources to apply integrated approaches. Share knowledge with and integrate future leaders from academic programs across Canada into integrated climate change adaptation planning.

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APPENDIX A – Case Studies

EAST COAST:	HalifACT/Acting on Climate Together Halifax Regional Municipality, Nova Scotia

Background: In June 2020, Halifax Regional Council unanimously adopted HalifACT 2050, a community response to the climate crisis and a plan for a healthy and resilient future. Developed through extensive community engagement, the plan emphasizes that climate change is a serious threat to the community and highlights the urgent need for action in response to the existing and predicted future threats of climate change. HalifACT 2050 is the Atlantic region's first comprehensive climate action plan addressing both mitigation and adaptation.

Integration and Adaptation Challenges:

- The Halifax Regional Municipality (HRM), located on the east coast of Nova Scotia, is a geographically large municipality, consisting of ~400 km of coastline and waterfronts and shoreline areas comprised of rural, suburban and urban communities [including Halifax Harbour]. See map below (source: wikimedia.org).

- These coastal communities are at increased risk of climate impacts; specifically, increasing risk of damage to coastal infrastructure, property, and natural areas and assets from inundation, saltwater intrusion, and coastal erosion due to sea level rise, storm surge and extreme events.
- New and revised policies, regulations, standards, codes, and funding mechanisms are needed to reach HRM's targets.
- As vulnerabilities can vary from community to community, adaptation plans need to be developed at a local or neighbourhood scale.
- HRM must now mobilize its resources to support the implementation of the actions in HalifACT 2050, allocating responsibilities across the organization, and in many cases coordinating with partner organizations and other levels of government.

Integrated Adaptation to Increase Resilience:

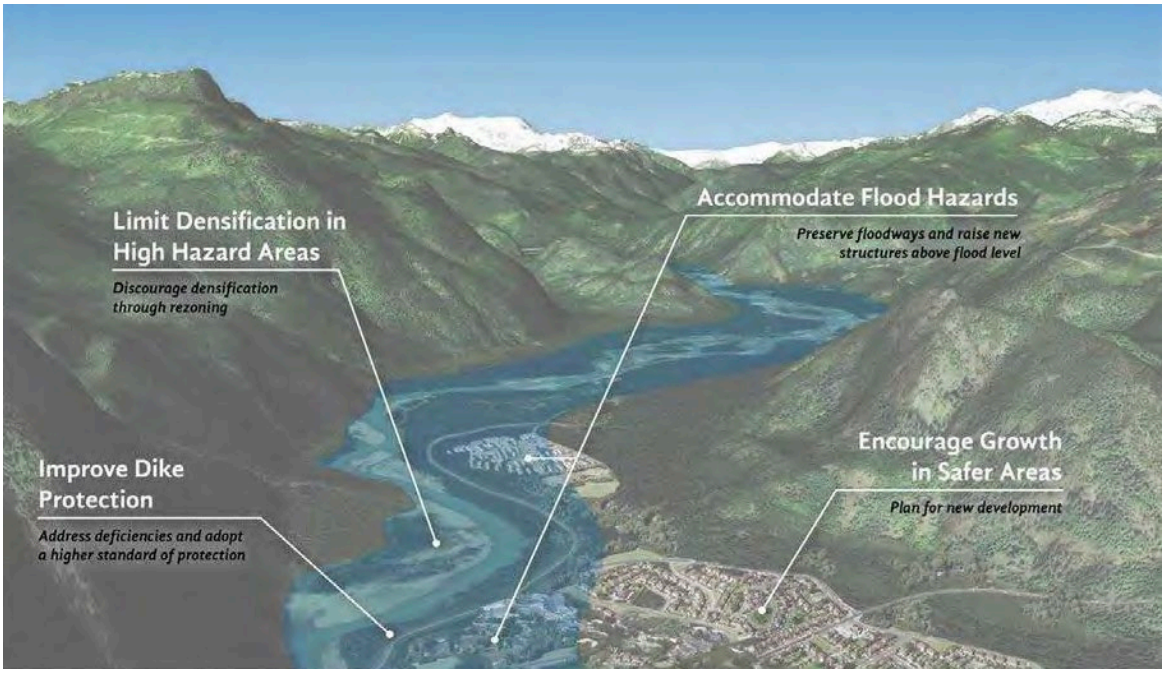
- Coastal preparedness actions include conducting a detailed spatially-based risk and vulnerability analysis of HRM's coastal, waterfront and shoreline area, and developing a coastal-specific adaptation strategy with coastal communities.
- The Municipality has procured a new Digital Elevation Model to allow for detailed flood risk modelling and land-use vulnerability assessments.
- The Municipality will also review and update flood models, land-use by-law regulations and consider the implications of the N.S. Coastal Protection Act – which will further protect coastal properties; regulations for the Act are currently in development.

Lessons Learned:

- The creation and implementation of HalifACT 2050 is guided by a set of common principles of climate action planning. Those most relevant to coastal climate change adaptation in HRM and in other Canadian coastal communities include:
    - Leadership: Climate action planning requires changes to established frameworks and practices, and these in turn are most likely to succeed when they are inspired by an understanding of how they will benefit the community and are encouraged and supported by both the leadership of elected officials and senior managers in the municipality. Government leadership will include convening partners, developing policies, leveraging government assets, and supporting research.
    - Alignment: Climate change targets and actions are more likely to succeed where they align with community goals, aspirations and policies for public health, fiscal efficiency, self-reliance, economic prosperity, resilience, inclusiveness, full employment and community planning and development.
    - Implementation: Climate literacy for municipal leadership and staff, and community stakeholder relations are mutually empowering.
    - Accountability: Transparency is key and includes following an open decision-making process, and setting goals that can be measured, reported, independently verified, and evaluated. Thereby, investment in monitoring, data collection, research and evaluation will support an understanding of the current situation, risks, hazards, and opportunities.
    - Innovation: requires a willingness to take risks, to fail, and to learn. HalifACT 2050 is intended to be a living document that will continue to be updated and supported with supplementary costing and technical plans during implementation out to 2050.

WEST COAST:	Integrated Flood Hazard Management Plan District of Squamish, British Columbia

Background: The District of Squamish in southern British Columbia produced an updated Integrated Flood Hazard Management Plan (IFHMP) in 2017. The IFHMP focuses on the coastal margin and river floodplains of four mountain rivers within Squamish. The IFHMP represents an important step forward for the District's flood risk management program. The term "integrated" reflects the District's desire for an inclusive, systems-based approach. It incorporates the latest guidance on climate change issues as well as guidelines, tools and best practices to support the District's liveability and sustainability objectives. The IFHMP is highlighted by recommendations for structural flood protection (i.e., dike) improvements and adoption of a comprehensive flood management policy framework. The Squamish IFHMP has four primary objectives: Reduce flood risks and share them fairly between everyone who uses the floodplain; identify opportunities for continued economic, environmental and social development; make decisions with a long-term focus and that promote social and environmental sustainability; and work with the community to achieve and implement realistic solutions. Refer to the map below. Policy updates include recommendations for a new Official Community Hazard Plan, a Development Permit Area, and a new Floodplain Bylaw to ensure that new development is planned and constructed to ensure Squamish's resiliency to flooding.



Integration and Adaptation Challenges:

- The District of Squamish is set in a beautiful but hazardous location at the head of Howe Sound where five fast-flowing mountain rivers move through gently sloping valley bottomlands toward the sea.
- Much of the community is located within flood hazard areas, including historic Downtown Squamish. Many people outside of the community depend on regional transportation links that cross through the floodplain.

- Flooding is a well-documented risk in the Squamish area. There are written accounts of numerous local floods since the late nineteenth century as well as the oral history of the Skwxwú7mesh Úxwumixw (Squamish Nation).
- The District lies within traditional territory claimed by the Skwxwú7mesh Úxwumixw (Squamish Nation). Ten reserves located in the floodplain create a shared interest in flood protection. The District also lies within traditional territory claimed by the Tsleil-Waututh Nation.
- The District of Squamish is responsible for managing development in flood hazard areas, as well as providing the community with appropriate flood protection. The Squamish Nation has similar responsibilities for reserve lands within the shared floodplain.
- Coastal floods in the District are created by extreme combinations of tide, storm surge, local wind and wave setup, and wave runup on the shoreline. Coastal flood hazards can vary based on a given location's exposure to wind and waves.
- Coastal flood protection is currently provided by low, non-standard works (dikes) around the downtown. The District lacks a comprehensive system of dedicated coastal flood defences. The risk from coastal floods is expected to increase significantly over time due to sea level rise.
- The District relies on a combination of policy measures and structural flood protection works to manage flood risk. To date, policy measures have focussed on the Zoning Bylaw and provisions in the Official Community Plan.
- A generation after it was prepared, the 1994 (non-integrated) Flood Hazard Management Plan no longer meets the community's flood protection needs. Key parts of the 1994 FHMP reflect engineering and policy standards of the time and are now outdated due to community growth, changing priorities, new information about flood hazards, and new tools for managing flood risk.
- The update process to produce the IFHMP was developed with input from the Squamish Nation, community stakeholders, and other flood risk management partners.

Integrated Adaptation to Increase Resilience:

- The goal of the IFHMP was to produce a new suite of tools to manage and mitigate flood risk. The review policy-based flood hazard mitigation tools identified a need to better plan for climate change, particularly sea level rise, as well as the need for a Floodplain Bylaw and flood hazard Development Permit Areas.
- The IFHMP addresses several types of flood-related hazards for Squamish, including coastal floods (and sea level rise due to climate change), river floods, dike breaches, and erosion hazards. Related hazards not addressed in the IFHMP include urban storm water flooding and groundwater.
- The District retained a multi-disciplinary team of specialists to assist in the preparation of the IFHMP. The Technical Working Group (TWG) consisted of representatives from all orders of government as well as non-government stakeholders who have an interest in flood risk management for the Squamish community.
- The guiding principles reflect general integrated flood management concepts like equity and sustainability, community objectives, and specific District priorities for this project. Key principles guiding the development of the IFHMP include:

- Build a safe, sustainable, resilient community.
- Accept that there will always be residual risk.
- Adopt a "multi-generational" long-term view.
- Engage the public but respect project limitations.
- Protect existing development.
- Allow for community growth.
- Equitably share risks, costs, and benefits.
- Work within natural constraints.

- The IFHMP assumes that climate change will raise sea levels 1 metre higher than they are today and increase peak flows during river floods by 10%. It also assumes that development will gradually fill to the maximum density currently allowed, that buildings will be raised or "floodproofed", and that open spaces called "floodways" will help convey flow through the community. These assumptions will help the IFHMP keep new buildings "safe" as the community continues to grow.
- Throughout the project there were extensive community engagement opportunities. However, the engagement process was challenging because many people who held lands had development objectives. There was a lot of contention with the regulations and land use [and development] policies.
- Options for mitigating flood risk are based on balancing four key strategies: Protecting the community to keep floods away from developed areas; Accommodating hazards by adapting land use and development to reduce flood damages; Avoiding new development and densification in high-risk areas; and Retreating vulnerable development from areas where current risks are not acceptable.
- The IFHMP recommends over 100 specific tools for mitigating flood risk. Recommendations address land use, new buildings, dikes, river management, emergency response, public education, and flood insurance.
- The District has adopted a target of updating the IFHMP every 10 years. These updates will be comprehensive, and will incorporate new data, new approaches, and new development.

Lessons Learned:

- The 1994 FHMP required significant updating – like any good plan - in order to stay relevant.
- The IFHMP represents an important step forward for the District's flood risk management program. The process has confirmed that there are no easy or inexpensive ways to reduce and manage flood risk in a growing community where so many hazards overlap.
- An integrated approach means: assessing flood and flood-related hazards from all possible sources - the ocean, rivers, creeks, lakes, urban storm water, groundwater, and related hazards like erosion, landslides or ground instability; identifying opportunities to manage risk based on a wide range of possible actions; and making decisions that consider the different ways each decision might affect people, the community, and the environment.

- Some IFHMP recommendations should be implemented immediately. Others will take decades to plan and build. Some of the most important measures will require long-term financial commitments.
- Collaboration was very important in building the IFHMP and will be even more important for its successful implementation. It will demand significant and ongoing financial, policy and administrative commitment from District Council, staff, and partners.
- Larger communities often study potential consequences for each type of hazard at different probabilities. Even with a limited scope, the Squamish IFHMP is a very large project for a small community to undertake. The IFHMP had to focus on the hazards and probabilities that were most important for the community.
- Partnerships can help the District through cost-sharing, regulation, data collection, monitoring, and ongoing stakeholder engagement.
- The dikes protect both District and Nation lands. As a result, the District and Nation share a common interest in flood protection and will need to continue to work together to implement the IFHMP in a way that minimizes negative impacts on reserve lands while making Squamish a safer community for everyone.
- The community-supported solutions of the IFHMP can help the District achieve its goal of remaining a liveable, sustainable community. In achieving these goals, the District will demonstrate how proactive communities can adapt and respond to the challenges of natural hazards and climate change.
- Developing an IFHMP involves challenging trade-offs and difficult decisions. Stakeholders often have different values, and everyone may not be able to agree on the best solutions. Nonetheless, the engagement process is very important. Engagement is what gives the community a sense of ownership in the IFHMP. Ownership leads to more support from the community as the IFHMP is implemented.
- Community engagement should be a major component of any IFHMP. District leaders must: listen to the public's concerns, priorities and values; consider the public's input when developing and choosing alternatives; and provide feedback on how public input influenced the decision process.
- Many people favour a Protect strategy because it supports a "business as usual" approach for the community, or because costs are typically borne by government. A "protect" strategy may be cost-effective at first but can become very expensive if hazards increase and floodplain development continues.
- A variety of tools and techniques helped to inform the community about flood risk, and helped the District learn about the community's goals and priorities. The community's response was clear: The District should use all practical approaches and tools to mitigate flood risk. This feedback helped to shape the IFHMP's overall strategy for flood risk management.
- The IFHMP also defined guiding principles for funding the recommended capital investments:
    - Be Opportunistic. Look for cost-effective opportunities to combine upgrades with needed repairs, maintenance, and even emergency response initiatives during a flood event. Costs and cost-effectiveness should be evaluated on a long-term basis.

- Build for today, plan for tomorrow. Take steps now to ensure that the community is protected from today's hazards, but make sure that the works will be easy to upgrade in the future. Make sure that land, legal access, community support and political will are available when the works are needed.
- Build partnerships. Seek stable and secure long-term funding commitments from senior governments. Require lot-by-lot implementation of IFHMP capital projects as part of community renewal and growth.
- Share costs equitably within the community. Extend the principles of equitable impact and benefit to funding capital upgrades for the dike system. Funds may be raised through general revenues, gas tax revenues, or levies applied to special service areas. Care should be taken to prevent developers from committing future owners to disproportionate and unfair funding arrangements.

- Having improved information and guidance from provincial and other agencies would be helpful for communities preparing flood management plans. Resources and staff to support small communities would be beneficial.

EAST COAST:	Chignecto Isthmus Climate Change Adaptation Comprehensive Engineering and Feasibility Study, Nova Scotia / New Brunswick

Background:

The Chignecto Isthmus, or land bridge, is 21 km wide and located along the border between New Brunswick and Nova Scotia, separating the waters of the Bay of Fundy from those of the Northumberland Strait in the Gulf of St. Lawrence. See map below. It is a major conduit and trade corridor and the only road and rail connection between the two provinces and, for Nova Scotia, the rest of Canada. The Trans-Canada Highway and CN Rail line carry approximately $35 billion per year in goods and services through the Isthmus. In addition, the trade corridor is home to electricity transmission lines, fibre optical cables, a wind farm, agricultural cropland activities and various utilities. The Isthmus is situated only slightly above sea level and is threatened by rising sea levels, land subsidence and more frequent severe weather events. A 35 km network of earthen dikes and aboiteaux, originally installed in the late 1600s to create farmland, and with their rehabilitation conducted in the 1950s, currently protects communities, infrastructure, private lands and natural resources. Without the current protection provided by the existing earthen dykes, much of the Isthmus would be inundated by today's sea levels resulting in significant negative socio-economic impacts locally, regionally, and even nationally.

Nova Scotia and New Brunswick announced in March, 2022, the results of the $700,000 Chignecto Isthmus Climate Change Adaptation Comprehensive Engineering and Feasibility Study, which identified three options to address rising sea levels and their impact on the dikes. Recommended options include raising the existing dikes, building new dikes, or raising the existing dikes and installing steel sheet pile walls at select locations. The two provinces will decide on a course of action after discussing these options with the federal government. All proposed options are based on engineering solutions wherein the dike and aboiteaux concept, in part or in whole, will form part of one, or all solutions.

Integration and Adaptation Challenges:

- The Chignecto Isthmus Climate Change Adaptation Comprehensive Engineering and Feasibility Study identified three viable and potential solutions for the protection of the trade corridor located within the Isthmus.
- Option A calls for raising the existing dikes as required, by 2 metres, to 10.6 m to protect the Trade Corridor (highways, railway, bridges, etc.). Option B calls for a new dike system to be constructed to 10.6 m on the inland (TCH) side of existing alignment. Option C calls for raising the existing dikes along current alignment + steel sheet pile.
- There would also be a major "water structure" across the tidal Tantramar River – essentially a barrier with huge sluice gates to control the incoming tidal waters. The new dikes, aboiteaux and water control structures can be constructed in isolation and independent from the Trade Corridor operations.
- While there have been several studies on the impacts of climate change and rising sea levels in the area, up until this Study, there had not been an engineering analysis assessing the feasibility of potential options to provide protection to the existing transportation network and infrastructure.
- The estimated timeline for implementation of each option would be 5 to 10 years to allow for all necessary environmental assessments, permitting, geotechnical and engineering design work, archaeological work, and construction.
- At a minimum, next steps include: early engagement with Rights Holders / Stakeholder / Regulatory Engagement; completing a site-specific and detailed hydrotechnical analysis; and detailed geotechnical analysis including a site-specific seismic hazard assessment.
- The two provincial governments will now sit down with the federal government to try to secure funding to complete the work that could cost as much as $300 million and be completed during the next decade. At the time this report was published, the federal Infrastructure Minister and MP for Beausejour, Dominic LeBlanc, told the premiers of NS and NB that the federal government would consider paying half the cost of the project if they picked up 25 percent each.
- Opinions do, however, vary on the Chignecto Isthmus Plan, with some experts and stakeholders calling the proposed engineering approach a '20th century solution for a 21st century problem' and a missed opportunity to incorporate nature-based solutions.
- One option, considered, but deemed insufficient by the engineering consultants to provide adequate protection, would be to move the dikes further inland and redevelop salt marsh in front of them to provide natural protection, store carbon and avoid the expensive annual maintenance costs, even if it meant paying farmers to give up agricultural land.
- The federal infrastructure minister also commented that this was a missed opportunity and that there is a federal fund dedicated to the use of natural methods and that he "would find it personally exciting if a component of this project fit into the $200 million Natural Infrastructure Fund of his department." https://www.canada.ca/en/office-infrastructure/news/2021/06/government-of-canada-announces-new-natural-infrastructure-fund.html
- "If you just build brand new dikes, right on the edge of the bay, where they're already having difficulty keeping them from eroding away, that's going to go on indefinitely."

Integrated Adaptation to Increase Resilience

- Members of multiple government agencies, representing the Provinces, formed a Project Steering Committee (PSC) to oversee the study and provide guidance, as necessary.
- A vulnerability assessment of the existing accessible infrastructure was completed through a combination of field observations and reviews of existing data provided by the Provinces of New Brunswick and Nova Scotia, CN Rail and other Stakeholders.
- A comparative Climate Change Resilience Assessment Risk Review (CCRA) was completed based on a streamlined application of the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol, which is an Infrastructure Canada approved methodology to conduct this type of CCRA. This assessment does not consider the existing infrastructure in the corridor as there is no change proposed to the linear alignment or physical characteristics to these assets (i.e., TransCanada Highway, CN Rail).
- The CCRA concluded that the proposed infrastructure components in the three Options represent an overall "medium" risk from the potential impacts of projected climate change hazards. The medium risk reflects a "grey area", where it is uncertain whether the severity or duration of the impact could trigger the need for further action. The current effort is primarily a screening effort to inform selection of a preferred Option.

Lessons Learned:

- Sometimes, strictly engineering solutions to climate change vulnerability and risks are the preferred option.
- As the options are further refined, design and construction should proceed in a manner that anticipates, adapts to, and mitigates projected climate change impacts.
- Collaboration between NB, NS and the federal government are key to ensuring this vital economic link between both provinces remains protected.
- Incremental adaptation (maintaining existing systems) is perceived to be more acceptable to the impacted people and communities that are low lying and highly vulnerable.

GREAT LAKES:	Rondeau Barrier Beach and Navigation Channel Restoration Erieau, Lake Erie

Background: Rondeau Bay is located on the north shore of Lake Erie and sheltered from the lake by a barrier beach and provincial park. The bay is home to 8% of the coastal wetlands on the north shore of Lake Erie and provides critical habitat for several endangered species.

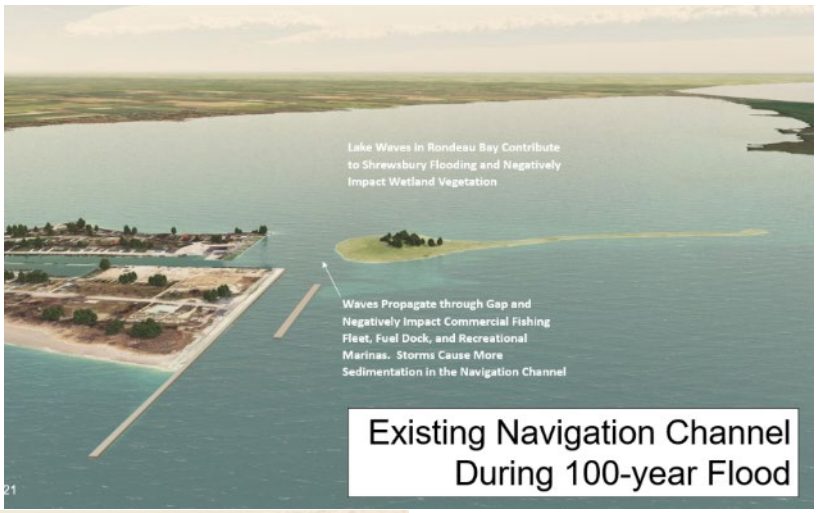
The navigation channel to the bay was stabilized more than 150 years ago with jetties that have starved the barrier beach and southern tip of the provincial park of its natural sediment supply. Consequently, the barrier beach has migrated north more than 600 m and resulted in the loss of more than 500 hectares of coastal wetlands (Zuzek Inc., 2022). The east jetty is no longer connected to the barrier beach and the navigation channel is now a significant sediment sink which threatening safe navigation in the channel and is contributing to further beach erosion.

Following the completion of the Chatham-Kent Lake Erie Shoreline Study in 2020 (Zuzek), which recommended a nature-based solution to restore the barrier beach and the function of the navigation channel, an Advisory Committee was formed to pursue the nature-based adaptation solution for the site. The committee has representation from the federal, provincial, and municipal government, the local conservation authority, First Nations, local businesses, and community members.

Integration and Adaptation Challenges: The east jetty of the Rondeau Navigation Channel has been disconnected from the barrier beach since the 1950s. A long-term permanent solution has been elusive for several reasons:

- Absence of an integrated littoral cell management framework in the Great Lakes to provide a mandate for government to work together.
- No legal or legislative mechanisms to ensure downdrift harbour impacts are mitigated.
- Limited experience with collaboration across governments to plan, fund, and execute transformative adaptation projects.
- Multi-jurisdictional land ownership, as noted in the adjacent image, including the provincial and federal government, municipality and private land owners.
- Existing funding programs are focused on supporting shovel-ready projects and planning for such a large-scale transformative adaptation is not an eligible expenditure.

Integrated Adaptation to Increase Resilience: A conceptual transformational adaptation concept was developed for the Rondeau Bay barrier beach and navigation channel. 3D renderings of the existing site during the 100-year flood and post-project condition during the same flood scenario are provided below. A formal design phase is required to advance and co-develop the solution with the community, complete additional scientific, ecological, and engineering investigations to finalize the NbS, obtain agency approvals, and secure funding to proceed to construction.



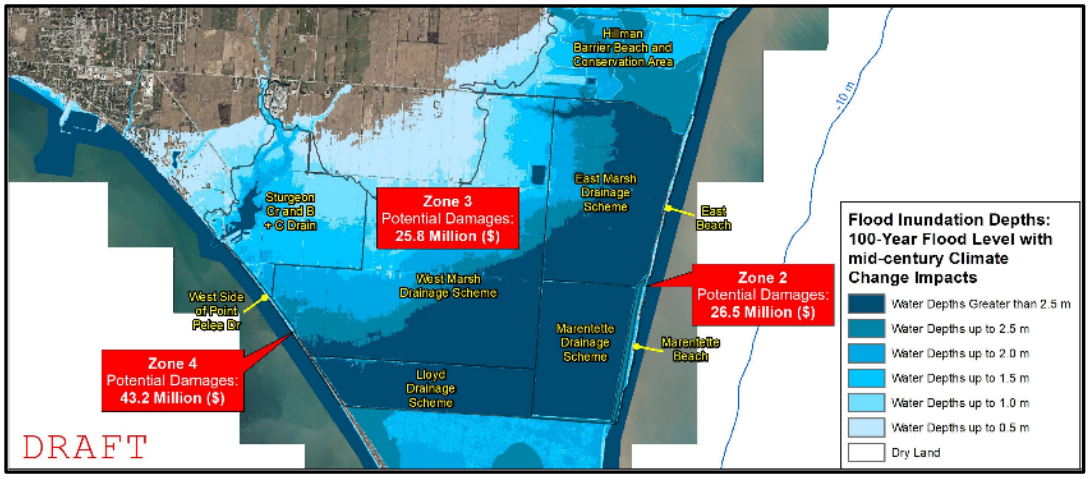
Lessons Learned: The Rondeau case study has identified numerous lessons for communities in the early stages of risk assessments and adaptation planning, including:

- Community support for the NbS was built over multiple interactive community meetings, where options were co-developed and trade-offs were considered (including cost).
- The inclusion of local stakeholders and businesses of the Advisory Committee is building trust in the community.
- After decades of working on single agency mandates (fish, migratory birds, navigation), government is lacking institutional capacity to collaborate on complex transformational adaption solutions in the Great Lakes.
- Due to multiple landowners within the project footprint, no single level of government can implement the NbS adaptation at Rondeau alone. Strong partnerships are building and ultimately an inter-agency collaboration agreement will be needed. Dedicated funding to study and plan the NbS is also needed, along with money for capital costs.

GREAT LAKES:	Retreat and Realignment of the Southeast Leamington Floodplain, Lake Erie

Background: Southeast Leamington is located on the northwest shore of Lake Erie, north of Pelee Island. More than 11,000 acres of wetlands north of Point Pelee National Park (PPNP) were diked and drained for agriculture. Today most of the muck soils have dissappeared and it is not economically viable to repair the dikes to support the agricultural activities on lands located below lake level. The implicatons and risk of a dike breach are severe.

Two vulnerability studies have been completed to document the magnitude of the flood risk (Baird, 2007 and Zuzek Inc, 2020). The extent of the flood inundation if the dike scheme breaches is highlighted below, along with the projected depth of flooding and associated economic damages to buildings and contents (in excess of 100 million) for the 100-year climate change scenario. Other primary and secondary impacts were not quantified.



Both technical studies recommended planned retreat and re-alignment of the diked agricultural land and re-aligning the land use with a coastal wetlal as noted below. This nature-based approach would create new coastal habitat, expand locale recreational opportunities, and buffer the interior lands from coastal hazards with nature. The restoration would also connect the habitat fragments (wetlands) at PPNP with its historical watershed.

Integration and Adaptation Challenges: Despite two thorough technical investigations that highlighted a positive benefit-cost ratio with the planned retreat and NbS, significant challenges remain with advancing the planning for the adaptation solution with the local community, municipal officials, and senior levels of government. They include:

- Even after extensive stakeholder and landowner consultations and visualization of the risk, the majority of the land owners prefer 'protect' alternatives over planned retreat. They also believe and expect the government to fund the protect solutions.
- To date, the Municipal Council has supported the local landowners and have not pursued further collaboration with senior levels of government to advance the planned retreat concept and re-align the land use with a NbS.
- PPNP south of the affected lands does not have any jurisdiction beyond the park boundaries and have not been able to galvanize support for a community scale adaptation solution to increase resilience to coastal hazards and restore the agricultural lands.
- Climate change is reducing the spatial extent of winter ice cover, wave energy exposure is increasing, and future lake levels are projected to be higher than the new record high established in 2019. In short, the risk of a catastrophic dike break is increasing, and the infrastructure is deteriorating.

Integrated Adaptation to Increase Resilience: Both above mentioned technical studies included integrated planning teams with participation from the local government, the conservation authority, Province of Ontario and Federal Departments. Stakeholder engagement was completed, extensive technical studies were done to develop the conceptual nature-based transformative adaptation solution, and the plan was supported by a positive benefit-cost analysis. However, the community and government have not been able to move forward with additional consultation and planning.

Lessons Learned: Technical studies have been ongoing in Southeast Leamington for almost 20 years and no progress on de-risking the community has been made beyond the planning studies and conceptual alternatives. This case study offers the following lessons:

- Planning transformative adaptation projects with multiple landowners and levels of government is very challenging. Multi-generational farming families with strong ties to the land are not interested in planned retreat, regardless of the technical justification.
- The community favours incremental adaptations, such as enhanced shoreline protection over planned retreat and re-alignment. More work on visioning a new future for Southeast Leamington is needed in consultation with the community and landowners.
- Without an existing funded buyout program offering fair market value for the affected lands, most landowners are not interested in planned retreat. Further dedicated consultation with landowners is required.
- It may take a natural disaster to advance a transformative adaptation plan for Southeast Leamington.

ARCTIC COAST:	Hamlet of Tuktoyaktuk: Climate Change and Coastal Erosion Tuktoyaktuk, NWT

Background: The Inuvialuit Hamlet of Tuktoyaktuk (Tuktuyaaqtuuq IPA), NWT, is falling into the Arctic Ocean.

Situated at the northern end of a peninsula extending into Kugmallit Bay on the coast of the Beaufort Sea, just east of the Mackenzie River Delta in western Northwest Territories, it is the most northern community on mainland Canada. Surficial sediments are composed primarily of glaciofluvial sands, typically on the order of 2.0 to 3.0 m thick, and underlain by massive ground ice. Prior to installation of shore protection decades ago, the coast of the peninsula consisted of ice-rich cliffs up to 6 m high, fronted by a narrow gravel beach.

The community has traditionally developed along this 1.2 km-long, north-south-oriented narrow spit of land. The Inuvialuit have lived in this area for thousands of years and many still live on the land, hunting caribou and beluga whales. People in the area hold a deep sense of their culture.

In 1934 the Hudson's Bay Company chose this site as the most suitable harbour in the region for trans-shipping freight brought by barge down the Mackenzie River to deeper-draught coastal vessels for distribution along the Arctic coast. The community has also been the centre for Canadian Beaufort Sea oil exploration for decades. The population of 'Tuk' is less than 1,000, with approximately 88% of the people being Inuvialuit.

Coastal erosion in the Canadian north is not a new phenomenon, but Tuktoyaktuk is the only community in northern Canada where coastal erosion is endemic and having a sustained impact, with significant and sustained loss of developed land and infrastructure, and the associated public health, safety, and financial implications.

The long-term relative sea level in the area has been rising at a rate in the range of 1 to 4 mm per year and consequently, much of the coast is being eroded. The typical long-term erosion rates of coastal bluffs are around 1 to 2 metres per year. Parts of the townsite experienced more than 100 m of erosion between 1935 and 1971. Tuktoyaktuk Island – right off the coast of the community – that shelters both the hamlet and harbour from ocean waves and the harbour itself, has significant cultural and historical importance to the community. The island is eroding by two metres per year, and at this rate, the entire island will be gone by 2050 unless mitigation is put in place. In the Hamlet's short history, erosion has been responsible for the destruction of a curling rink, closure and demolition of an elementary school, relocation of the RCMP detachment building, and the forced relocation of several houses. The community graveyard is now at risk of crumbling into the sea.

The coastal areas of the Beaufort Sea are covered with ice for 8 to 9 months of the year. Storm winds, which occur most often in late August and September, come predominantly out of the west and northwest. The maximum storm surge tide created by wind in the Tuktoyaktuk area is about 2.5 metres above mean water level. Climate change impacts would also affect the extent of sea ice, and the length of the open water season. Along with this may come a change in the frequency and severity of storms, with storm surges and high waves. Subsidence, resulting from thawing of massive ice beneath nearshore sediments, is also suggested as a major

contributory cause of recession. This subsidence may create a sediment demand, supplied by the shore face, that results in ongoing erosion.

Coastline protection to date has stabilized the shoreline position since 1974 but has required considerable maintenance. Previous efforts to reduce the speed of erosion have included installing concrete slabs on the coast, placing geotubes along the coastline and lining it with armour stones, none of which have managed to keep nature at bay. Severe damage by a storm in 1993 demonstrated the tenuous condition of the efforts to date. As a result, the government of the Northwest Territories and the Hamlet have explored a range of alternatives for the future, including possible abandonment.

Tuk Mayor Erwin Elias is quoted as saying "I think inevitably, we are going to be moving, no matter what." … "The idea is to buy us some time so we can plan for the next stage moving forward."

Integration and Adaptation Challenges: It may be impossible to ultimately stop any further erosion in Tuktoyaktuk, even with appropriately engineered and constructed protection measures. The nature of storms impacting Tuktoyaktuk is changing and therefore, a very severe storm surge could in fact overcome any protection mechanism instituted along the Tuktoyaktuk coastline. Even if erosion at the peninsula were stopped completely, it is likely that the peninsula would be breached at its southern end within 50-100 years. Therefore, the most appropriate long-term response is a phased withdrawal (planned retreat). There is still, however, an immediate need to manage the current erosion problem.

Difficulty in limiting erosion is due to the combination of the low coastal elevation, ice content, rising sea level, limited sediment supply and ongoing erosion of neighbouring, unprotected shores. The factors are likely exacerbated by longer open water seasons, accelerated sea-level rise, and more rapid permafrost degradation. Protecting the coast of Tuktoyaktuk from the onslaught of climate change is estimated to cost at least $42 million and is only guaranteed to last until 2052.

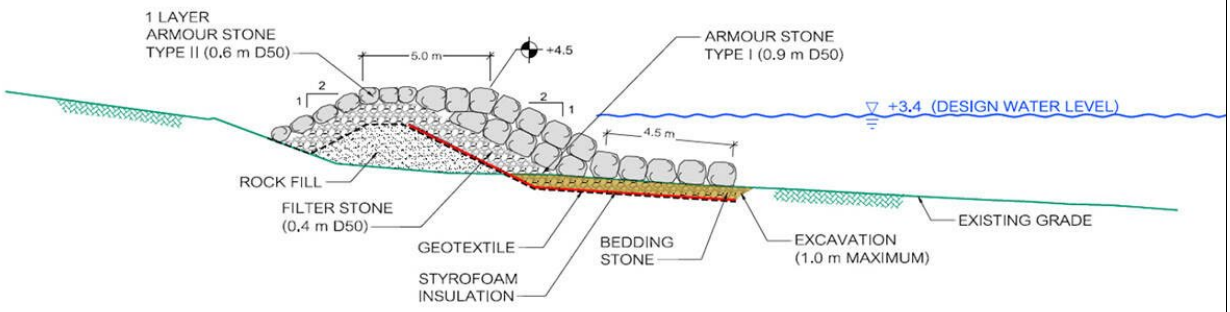
The protection of a particular building that has a higher benefit or value may be the cause of political problems, since benefit or value is somewhat subjective, and differing opinions on this benefit or value may produce strongly divided groups within the community.

Integrated Adaptation to Increase Resilience: Central to the development of any coastal adaptation approaches, are the Inuvialuit community's beliefs and values with respect to conservation and resource management. They recognize that integrated management – where all parts of the environment are interconnected, so they must be managed together - is essential. Conservation, stable economic development and sound resource management can only be achieved if all parties work toward a common goal. The Inuvialuit community of Tuktoyaktuk recognizes the relationship between direct economic security and resource conservation and the importance of maintaining a spirit of cooperation between all people living in the region.

Earlier exploration of the most appropriate options identified for reducing coastal erosion in Tuk Were: (1) annual replenishment of the bank with sand and gravel; (2) stacked overlapping gravel bags; and (3) concrete mats tied together with chains. Each of these options, or a close

variation of them, has been implemented on a trial basis along a portion of the coast, however, none of the trial programs were subject to a comprehensive monitoring program.

A more recent engineering assessment, tested at the National Research Council laboratories in Ottawa from Dec. 2020 to March 2021, listed three possible options for a protective layer over the coastline. A rock revetment system, where layers of Styrofoam insulation and geotextile to protect the permafrost from rising temperatures on the surface, is considered to be the less costly, easier to maintain and having less impact on the surrounding ecology. After the insulation is buried, the coastline will be covered in large boulders, which will serve as armour stone. The boulders are considered more flexible than the concrete slabs currently being used to protect the coastline. The rock revetment plan also includes refilling the southern beach along the hamlet with over 33,000 m^3 of sand.



How engineers plan to slow the erosion of the Arctic coastline around Tuktoyaktuk

A research team at the NWT's Aurora Research Institute is developing a plan to manage erosion using native plant species – a nature-based solutions approach. Cultivating local vegetation could be one way to combat permafrost thaw by keeping the ground cold and intact. All such options should be considered.

A concerted scientific effort has been focused on monitoring, and analyzing the shoreline erosion and its potential influencing factors. This information has provided a basis for a 25-year prediction of the shoreline erosion along the peninsula. In order to develop an appropriate adaptation strategy, an evaluation was completed on the erosion risk over this period to quantify both the value, and the cost versus benefit of protecting or relocating particular buildings. The objective is to develop a locally-managed program to monitor climate change impacts in Tuktoyaktuk and in areas used by the Inuvialuit for traditional activities.

The Tuktoyaktuk Community Corporation has developed innovative partnerships with researchers and institutions in the Inuvialuit Settlement Region, to develop climate monitoring capacity and build research skills. Trained monitors track permafrost variables, ice thickness, ice thaw dates, snow depth, and water quality at monitoring locations, informed by Traditional Knowledge.

The Government of Northwest Territories received federal funding of $240,000 through Public Safety Canada's National Disaster Mitigation Program to develop a coastal erosion mitigation plan, including enhancement of public safety and reduction of future erosion damage through the identification of coastal erosion hazards. Various stakeholders were involved, including the territorial government, Indigenous governments, local authorities and the residents themselves, in monitoring the extent of coastal erosion caused by rapidly melting sea ice.

Since 2016-2017, the Climate Change Preparedness in the North Program has contributed $3,655 million to support the implementation of a suite of adaptation measures, including the relocation of residents from the peninsula to a different subdivision located in the community that is at a higher elevation and to plan future steps toward the hamlet's preferred adaptation option to mitigate the severe current and future impacts. More specifically, the funding will assist establishing the final coastal protection design, meet assessment, permitting and tendering requirements, and provide on-site construction services for the community's proposed hybrid option.

In addition to the funding to address the issue around coastal erosion, the Climate Change Preparedness in the North program has also contributed to other climate change adaptation initiatives in partnership with the community of Tuktoyaktuk. The Hamlet received funding to support climate change scientists in engaging with the community to disseminate scientific knowledge on coastal dynamic processes and to structurally assess the morgue to determine whether it can withstand a move to a new location where there is minimal risk of coastal erosion. In addition, the Tuktoyaktuk Community Corporation also received funding to operationalize the SmartICE technology to generate sea-ice information for community safe travel, to respond to the impacts of deteriorating sea ice conditions and to engage the Youth of the community by producing a climate change adaptation documentary. Overall, the combined support of CIRNAC through its different climate change programs represents a contribution of $5.516 million by the Government of Canada in support to Tuktoyaktuk to address the community climate adaptation and mitigation needs.

In parallel to climate change adaptation developments, Tuktoyaktuk developed a community-based Community Conservation Plan. The Inuvialuit of the Beaufort Sea coastal area have relied upon the area's wildlife for many years. This plan was developed to help protect the environment in the Delta / Beaufort Sea coastal area and onshore and offshore areas to ensure cultural survival of the Inuvialuit Community, in accordance with the Western Arctic (Inuvialuit) Claims Settlement Act and the Inuvialuit Renewable Resource Conservation and Management Plan. Considerable effort was made to obtain opinion and advice from Inuvialuit members of the Community as well as government agencies. The plan is intended to express the Inuvialuit community's specific goals and objectives with respect to conservation of lands, waters and living resources in the vicinity of Tuktoyaktuk in the Inuvialuit Settlement Region. Linkages to and integration with the climate change adaptation efforts in the community would bring a more holistic approach to both conservation and climate change adaptation.

Lessons Learned: The Hamlet of Tuktoyaktuk has the administrative means to control land development in the shoreline erosion risk area. These measures should be applied for all future development in the shoreline erosion risk area in order to minimize the risk of loss of life and property, health and safety hazards, disruption of commerce and governmental services, extraordinary public expenditures for erosion protection and relief. These administrative means need to be applied with community consideration and consultation in order for the community to decide the priorities for the limited financial resources available.

The Tuktoyaktuk Community Conservation Plan should be integrated with proposed climate change adaptation efforts. This will require ongoing efforts to educate, train and exchange information among community members, responsible authorities and other stakeholders, to ensure that a comprehensive and integrated community approach is pursued.

General adaptation measures for the high and moderate-high risks that were identified and their impacts on every type of infrastructure as selected for each infrastructure category have been identified:

- Address identified data gaps as new information becomes available;
- Adopt policy requiring design practitioners to investigate pending changes to design standards and codes related to infrastructure design in a changing climate;
- Adopt policy where all infrastructure and retrofit projects have a detailed climate risk assessment completed at the design phase and owner signs off on accepted level of risk;
- Proceed to update climate change risk assessments in five years;
- Prioritize infrastructure sensitive to cascading climate hazards (e.g. wildfire accelerating permafrost degradation);
- Reassessment of permafrost, flood and wildfire hazards in some area would be required as more data is available;
- Implement maintenance programs to improve the life of infrastructure (e.g. snow maintenance program to insulate permafrost around buildings in spring);
- Increase monitoring of permafrost and hydrological conditions near critical infrastructure;
- Seize opportunities regarding climate change impact on infrastructure (e.g. increasing winter temperature will decrease energy expenses due to buildings heating load, extended operations for coastal operations due to extended ice-free season);
- Increase emergency preparedness in high-risk areas;
- Adapt zoning and land-use to limit development in high-risk areas.

WEST COAST:	San Fransisco Sea Level Rise Resiliency Program City and County of San Fransisco, California, USA

Background: The shoreline of the San Francisco Bay comprises approximately one third of the total California coastline.

- San Francisco is planning for and adapting to projected impacts of climate change (sea level rise (SLR) inundating 6% of the city by end-of-century) in an innovative manner that boosts the local economy while reducing greenhouse gas emissions.
- Approximately four square miles of San Francisco are located within the City's Sea Level Rise Vulnerability Zone.
  - Land ownership is public land (local, State, and federal agencies), private residential and commercial properties.
  - SLR vulnerable areas contain approximately 37,200 residents, 17,100 businesses, 167,300 jobs, new development, and infrastructure (roads, water and wastewater pipelines, power infrastructure, emergency services, transit lines, parks and open spaces, the Port of San Francisco).
- March of 2015, the mayor convened an interagency task force of twelve City departments to work together to develop a collaborative Sea Level Rise Action Plan for San Francisco. Charge consisted of 1) identifying what is at risk (public and private assets); 2) reviewing the complex regulatory environment that governs coastal planning and development activities; 3) identifying actions can undertake now and in the near future, in partnership with its neighbours and regional leaders.
- The vision is to make San Francisco a more resilient city in the face of immediate and long-term threats of SLR to the Bayshore and Pacific Coast, by taking measures to protect and enhance public and private assets, natural resources, and the quality of life for all.

Integration and Adaptation Challenges:

- SLR-related impacts are projected to increase in frequency and extent. More areas will be affected by periodic coastal and/or urban flooding. Shorelines built on bay fill and at risk of subsidence may have greater flooding risks. Higher groundwater levels can increase liquefaction during earthquakes.
- Coastal hazards associated with SLR include: temporary coastal flooding from extreme tides damaging infrastructure and sewage systems, and road closures; urban flooding (rainfall runoff) causing service disruptions and sewage discharge into Bay; shoreline erosion impairing roadways and reducing recreation and natural areas; and regular flooding during King Tide (typically 12 inches higher than average daily high tide) and more frequent closures along the Embarcadero tourism area.
- For long-range planning, defined a SLR Vulnerability Zone that represents upper range (unlikely, but possible), end-of-century projections for permanent SLR inundation (up to 66 inches) plus temporary flooding due to a 100-year extreme storm (up to 42 inches) for a total of 108 inches above current MHHW.
  - Projected daily tidal inundation in some areas and permanent inundation of 6% of San Francisco by 2100.

- Projected losses with no adaptation for 66" SLR is $20 Billion Private property and $35 Billion Public property, and with 108" SLR (66" SLR plus 100-year extreme tide) $39 Billion Private property and $37 Billion Public property.

- Risk assessments (quantitative or qualitative) identify potential consequences from asset failures due to SLR.
  - Critical service consequences. Disruptions to power, communications, water and wastewater services, medical facilities, and transportation.
  - Social consequences. Impacts to public health and safety, displacement and homelessness, and loss of services.
  - Economic and financial consequences. Workforce disruptions, loss of real estate, impacts to tourism or other significant industries
- SLR can exacerbate current and former industrial uses of waterfront areas and environmental issues (e.g., soil contamination and hazardous materials).
- Increase resiliency with respect to multiple hazards -- seismic events, natural disasters, and SLR
- Time horizons are mismatched for plans and projects to address SLR where impacts are expected to accelerate and worsen over time.
  - More difficult to secure funds for medium-and long-term projects since most capital funding is available for projects that can start immediately, not at some time farther in the future.
  - Most climate actions do not have a return-on-investment, which attract traditional sources of private capital, putting pressure on scarce existing public funding sources.
- Adaptation strategies and actions need to be robust yet flexible, with short- and long-term approaches to resilience. SLR adaptation responses are being planned along major waterfront development projects, but existing built environment along the Bayshore and Pacific Coast remain vulnerable.
- The complex and evolving nature of climate change-related impacts requires innovative and implementable adaptation solutions created collaboratively with interdisciplinary teams of designers, engineers, economists, scientists, community leaders, government entities, and more.

Integrated Adaptation to Increase Resilience: A strategic focus on the immediate and long-term threats of SLR and associated coastal flooding resulted in the City's 2014 "Guidance for Incorporating Sea Level Rise into Capital Planning in San Francisco" (updated in 2015, 2019, 2020).

- Components of the guidance: 1) SLR Science Review- What does the science tell us today? 2) Vulnerability Assessment: Which assets are vulnerable to SLR? 3) Risk Assessment: What vulnerable assets are at greatest risk to SLR? 4) Adaptation Planning: What can be done to increase resilience of at-risk assets? This Guidance focuses on coastal flooding hazards from SLR but acknowledge some projects may need to incorporate additional climate change impacts.
- The Guidance recommends a common approach across all departments by using the same science, tools (i.e., inundation maps), and methods for seamless collaboration and integration.

In 2015, a Sea Level Rise Coordinating Committee was formed with representatives from twelve City departments (necessary mandates, and assets vulnerable to SLR). Outcome was 2016 Sea Level Rise Action Plan -- a key element in San Francisco's comprehensive SLR Resiliency Program.

- The Action Plan called on City departments to collaborate to understand SLR impacts and develop strategies to protect shoreline, critical public assets and infrastructure, and public and private lands and structures from current and future flooding.
- The process specifically addresses wastewater, water, transportation, power, public safety, open space, port, neighbourhoods and changing shoreline.
- Identified strategic partnerships and collaborations with local and regional stakeholders as essential for successful adaptation planning and implementation.

The goal of SLR Action Plan is:

- A resilient city that is adaptable to the impacts of SLR, and recognizes and protects physical, economic, and social value
- Communities understand and are reassured by a comprehensive response to SLR, and are mobilized and empowered to support efforts over the long term
- Interagency and regional collaboration and partnerships that are coordinated, transparent, and focused on delivering implementable and innovative solutions for a resilient future for San Francisco and the Bay Area region
- Capacity building that enables leadership and staff to implement good solutions

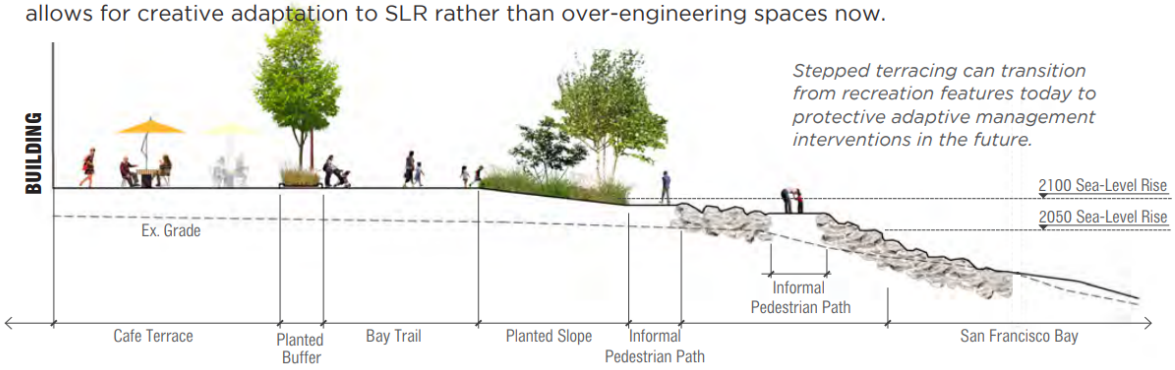
Adaptation efforts will be focused on governance-related strategies (e.g., zoning, design standards, maintenance procedures) and innovative designs (e.g., green infrastructure, structure elevations, and flood barriers). Solutions may be implemented at multiple scales and timeframes and in combination in order to optimize performance and efficiency.

SLR adaptation requires one or a combination of three options: accommodate (raise or waterproof assets in place), protect (create natural or engineered barriers, such as wetlands or levees), or retreat (relocate sensitive assets to low-risk areas and/or transition high-risk areas to lower-risk uses).

Examples of innovative, transformational adaptation plans:

- **Crane Cove Park**: The design accommodates end-of-century SLR by reconstructing major portions of the shoreline for flexible recreation and habitat uses, as well as strategic site grading to allow the Bay to reclaim portions of the site. The sloped historic slipway is inherently adaptive to varying tides and the northern shoreline improvements protect key street infrastructure.
- **Pier 70 Special Use District (SUD):** The SUD's innovative waterfront design accommodates potential future SLR conditions.

Pier 70 Special Use District (SUD). The SUD's innovative waterfront planning provides safe and practicable public enjoyment of the Bayshore while accommodating potential future SLR conditions. The design incorporates a variety of tiered treatments, responding to specific site conditions. Based on the principles of 'living with the Bay' and 'managed retreat' a shoreline zone allows for creative adaptation to SLR rather than over-engineering spaces now.



- **India Basin Waterfront:** The waterfront design incorporates a living shoreline with a 100-year horizon. Natural coastal processes incorporated into shoreline protection -- wave attenuation, habitat creation, and upland habitat migration. Potential bioengineered devices include expanded tidal marshes, dunes, floating islands, terraced wetlands, artificial reefs, and eel grass beds.
- **Treasure Island, Adaptive Management for Sea Level Rise:** Redevelopment of a 450-acre former military base into a model community of sustainable living in low-lying Treasure Island includes initial adaptation strategies and flexible longer-term adaptive management to address SLR. Elevated grades will protect buildings and streets from SLR and development set back from water will allow for future perimeter SLR adaptation projects. Graduated elevations allow for adaptive recreation and habitat areas. Special Taxes collected via new Community Facilities Districts will pay for future SLR adaptation. SLR adaptation beyond 2050 includes SLR monitoring and periodic flood risk assessments and potential response actions include additional perimeter levees or floodwalls, storm water pumps, and natural shoreline areas that limit wave damage and provide public shoreline access.
- **Ocean Beach Master Plan, Shoreline Protection, Pacific Coast**: Shoreline protection options --accommodate, protect, and retreat-- are being incorporated into SLR planning along the Pacific Coast. The Ocean Beach Master Plan, an iterative planning process with robust stakeholder and community engagement, recommends eventual retreat and rerouting along some portions of the Great Highway.

Lessons Learned:

- The SLR Sea Level Rise Action Plan Assessment is based on best current available science and as the climate science evolves, changes in SLR projections may require adjustment to adaptation plans.
- The regulatory framework with complex land ownership and governance of coastal protection underscores the need for collaborative approaches to SLR adaptation planning. SLR Projects need to coordinate with multiple jurisdictional agencies and property owners, and comply with local, State, and Federal regulations. Partnerships with

stakeholders are crucial and engagement helps to develop and implement cost-effective solutions at local and regional scales.

- SLR is a regional issue that requires regional commitment. City of San Francisco will collaborate with its neighbours to develop cooperative SLR adaptations for the Bay Area.
- Assessing the cost of inaction on SLR adaptation by estimating expected losses in public and private property informs decisions about balancing costs of post-disaster relief with up-front adaptation costs.
- The Resilience program recognizes that adaptation is an ongoing process and future steps and actions are part of the cyclical nature of the adaptation process that requires monitoring for updated SLR projections and best practices, and securing funding.
- San Francisco's 2021 Climate Action Plan (CAP) acknowledges a climate resilient city integrates mitigation and adaptation. CAP incorporates equity, a just transition, resilience, innovation, and nature into planning and action.