

# **Adapting to Sea-Level Rise in Vancouver's Employment Lands: Current Best Practices & Approaches in Planning**

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This project was conducted under the mentorship of City staff. The opinions and recommendations in this report, and any errors, are those of the author, and do not necessarily reflect the views of the City of Vancouver or The University of British Columbia.

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# EXECUTIVE SUMMARY

## PROJECT OVERVIEW & BACKGROUND

The City of Vancouver is developing a long-range policy plan to ensure that Vancouver has an appropriate supply of land to support future jobs and the growth of the economy. As part of this review, the City must consider the impacts of sea-level rise on Vancouver's employment lands, many of which are susceptible to flooding from sea level rise. The impacts of sea level rise will especially be felt in Vancouver's industrial areas, 50% of which are located within Vancouver's floodplain. As part of its Employment Lands & Economy Review (ELER), the City of Vancouver has hired a consultant to conduct quantitative forecasting of Vancouver's employment land needs up to 2050. This work also entails considering the impacts of sea level rise on jobs capacity. This Greenest City Scholars project involves a qualitative best practices review to identify policy tools and potential interventions to address sea level rise in employment lands.

The Employment Lands & Economy Review team is working on understanding Vancouver's current supply of job space, issues and opportunities in its economy, and capacity for job growth. Some of the lands in the city designated for "Jobs only" are located in areas under threat by climate change and sea level rise. There is also pressure to consider other uses, such as residential, on "job-only" lands (Hutton 2018). In the absence of adaptation efforts, the impacts of climate change threaten a significant portion of commercial and industrial land. If mitigation measures are not taken, acute events like king tides and storm surges been and long-term rising sea levels will gradually erode away the shoreline in valuable employment areas like the Port of Vancouver, False Creek Flats, South Vancouver Industrial Lands and other foreshore areas along the Fraser River. Sea level rise and associated impacts could produce a number of direct and indirect economic impacts, including the loss of employment land.

The City of Vancouver has been engaged in a number of sea level rise initiatives, including a Coastal Flood Risk Assessment (CFRA), with its third phase completed in 2018 (i.e., delivery of an implementation tool for sea level rise adaptation projects) as well as a development of a Coastal Adaptation Plan (CAP) for the Fraser River Foreshore. Recent developments include a Sea Level Rise Planning Framework (SLRPF), which was part of the Coastal Flood Risk Assessment Phase 3. This framework provides a timeline for planning, funding and implementing shoreline flood protection. In addition, flood proofing requirements such as a higher Flood Construction Level and setbacks from the natural boundary were put in place in 2014 under the Vancouver Building Bylaw, which will be re-iterated in the Zoning and Development Regulations. Employment lands along the City of Vancouver's coastline have incorporated sea level rise into their planning efforts; they include the City of Vancouver's False Creek Flats Plan 2017, the City of Vancouver's Northeast False Creek Plan 2018, and the City of Vancouver's Coastal Adaptation Plan for the Fraser River Foreshore. Other relevant planning initiatives are the recently adopted Marpole Community Plan, which outlines ideas for extension of the Fraser River Trail so the public can experience the Fraser River and benefit from waterfront amenities and greenspace additions. Sea level rise is also a consideration in the Cambie Corridor Plan Phase 3, the East Fraser Lands' (EFL) revised Official Development Plan, the City Wide Plan, and the Jericho Lands policy statement.

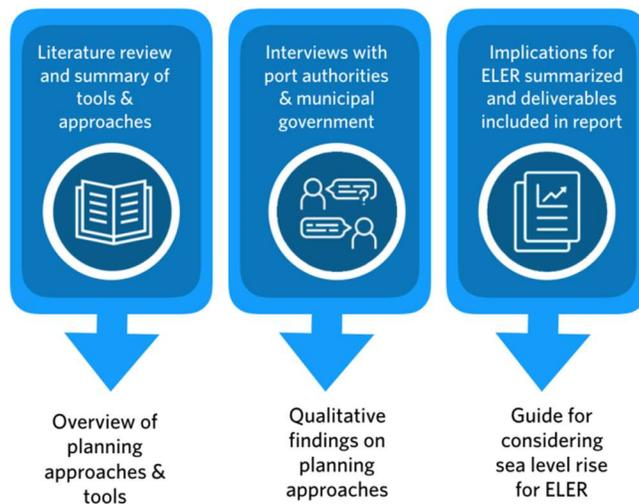
## OBJECTIVES & METHODOLOGY

This project identifies best practices in planning approaches and tools for sea level rise that are being used in Metro Vancouver and elsewhere that could potentially inform the Employment Lands & Economy Review team in their work. The following objectives will help guide the process:

			
<b>Objective 1.</b> Identify current policies, plans, and strategies the City has implemented to address sea level rise.	<b>Objective 2.</b> Identify possible policy tools the City currently has available to address sea level rise in employment areas.	<b>Objective 3.</b> Learn about what other agencies or municipalities are doing to address sea level rise in employment areas.	<b>Objective 4.</b> Highlight implications from the literature review and interviews for the Employment Lands & Economy Review.

Image Sources (left to right: Vancouver.ca Wikipedia, Chemainus Valley Courier, and Vancouver Economic Commission)

The project steps, including the literature review, summary and analysis of tools and approaches, interviews with municipalities and port authorities, and implications summarized are included in the graphic below:



## FINDINGS & ANALYSIS

The literature clearly indicates that municipal inaction to adapt in the face of climate change and sea level rise carries various implications related to land use and Vancouver’s economic wellbeing, including loss of land and assets. Therefore, this project phase involved generating a summary of tools and approaches municipalities can use to address sea level rise. Tools were grouped into six categories: land use/regulatory, engineering, financial, economic resilience planning, multi-stakeholder engagement, and public education/awareness. They were further analyzed for their land use and employment lands implications, how they correspond to common adaptation frameworks and finally, examples of implementation and additional sources.

### Key challenges regarding these tools include:

- difficulty in implementing lands use/regulatory tools for industrial lands that have specific parcel size or access requirements;
- reduction in range of uses that could occur, potential land loss, or changes in land value (either increases or decreases)
- administrative complexity when introducing land use/regulatory tools that involve some form of exchange of land or uses, particularly for heavy industrial uses (e.g., easements, buyouts, transfer of development rights)
- cost associated with larger flood protection projects (which may require cost sharing agreements)

- A bias towards using tools that change the hazard itself [i.e., constructing a dike] rather than altering our relationship with that hazard (i.e., locating a permeable parking lot in an area that is permitted to flood). The former may only be effective in addressing one type of risk in the short-term whereas the latter may result in a more proactive and resilient long-term solution
- A tendency to focus on burden as opposed to a balance of societal benefit and site specific "burden" The burden, e.g. cost, land use change, land value change, is borne by the current land owner.
- some key drivers that would influence implementation are:
  - political feasibility, whereby some tools might have more or fewer positive or negative impacts on individuals, communities, businesses, or politics overall than others
  - equity, which would affect who benefits or who is adversely affected by the tool's use
  - enforceability, which reflects the ability for government to administer the tool and receive compliance

**Key opportunities resulting from strategic use of these tools include:**

- a local and regional economy that is more resilient to the negative impacts of flooding and sea level rise
- Future land owners who benefit from adaptation investment, and, depending on time and place, added value for the land owner who invests earlier in adaptation given that their site will be more resilient to flood hazards
- increased potential for business continuity in response to other shocks and stresses
- prevention of future loss to valuable economic assets and critical infrastructure or harm to public safety
- recreational, social, or environmental co-benefits (e.g., more fish habitat) that could emerge from tools that involve naturalizing the shoreline or increasing green space
- developing strong partnerships with business associations, boards of trade, utilities, infrastructure providers and First Nations that could arise from economic resilience planning and multi-stakeholder engagement approaches
- Possible creation of new economic activities and jobs

**Best Practices from Other Municipalities and Authorities**

This research included a review of how municipalities, port authorities, and other agencies are managing sea level rise risk and planning for it. Information was gathered on coastal hazards present, concerns and challenges, decision-making frameworks used, actions being currently taken to mitigate risk, and potential future actions. Information was gathered from six jurisdictions, including City of Richmond, City of Surrey, Port of Vancouver, Port of Seattle, City of Seattle, and New York City Economic Development Corporation.

A wide variety of coastal hazards, including king tides, storm surge, rapid snowmelt, extreme rainfall, and gradual sea level rise, affected the municipalities and agencies. Some concerns and challenges revolved around the requirement to decontaminate industrial land prior to doing any adaptation work, transportation and lands use conflicts, uncertainty around financing, equity concerns around displacement and distribution of benefits, suitability of solutions to the unique geographic context, and protecting water-dependent uses where retreat isn't possible.

Some plans, strategies, policies that different jurisdictions are using to take action are upgrades on a project-to-project basis that take into account sea level rise, especially for ports, land use tools like development permit areas for hazard lands or new development standards, environmental cleanup projects of industrial lands and water bodies, and innovative engagement strategies and engineering or land use projects. These projects were diverse in nature and promote aspects such as public access, flood protection, economic development, and resilience, and public awareness of the risks and land use impacts of sea level rise.

Future actions for the City of Vancouver could include peer learning around financing, expedited planning processed to accelerate adaptation efforts, applying an equity lens for future projects, and forming additional partnerships with regional bodies, environmental organizations, and Indigenous communities.

## **IMPLEMENTATION CONSIDERATIONS**

Attention should be paid to cost of implementation, public engagement, technical feasibility issues, urban design concerns, and environmental concerns. In addition, a next implementation step would involve consultation with local First Nations, especially regarding archaeological and historic sites, prior to beginning any work on the shoreline. Public engagement as a whole will ensure various criteria are considered in the evaluation and implementation of sea level rise planning measures. As projects will depend on adequate financing to be implemented, the City could consider a variety of funding mechanisms, such as internal or external financing and innovative programs. Examples include grant funding from external agencies or senior levels of government as well as local sources from development, such as community amenity contributions, development cost levies, and local improvement charges.

## **NEXT STEPS**

This project aimed to identify a range of policies and tools that may be used to address sea-level rise in Vancouver's employment areas. The literature review revealed a wide variety of tools that can be categorized into six key themes: regulatory/land use, engineering, financial, economic resilience planning, multi-stakeholder engagement, public education/awareness. Additionally, the review revealed the site-specific and municipal and regional consequences of inaction to sea level rise, including adverse land use and economic impacts. Key challenges and key opportunities were presented.

The key informant interviews revealed concerns and challenges other municipalities, port authorities, and agencies are grappling with around sea level rise planning for industrial and port areas. The project involved some reflection on the limitations and strengths of the different processes and findings that emerged from the literature review, summary of tools, and the interviews.

Recommended next steps encompass the following categories: guiding frameworks and tool selection, funding and regulatory mechanisms, other implementation factors like cost and equity assessment, collaboration, technical analysis, and innovation. They are intended to be open-ended and flexible, depending on the work that is done.

## KEY FINDINGS AND ANALYSIS FROM SUMMARY OF TOOLS & APPROACHES

Table 1 Key Findings from Summary of Tools (condensed)

Category	Tools Discussed	Key challenges	Key opportunities
<b>Land use/ regulatory</b>	Setbacks, conservation easements, right to flood, clustering	<p>Could reduce the range of uses that could occur on land and might reduce or eliminate development opportunities</p> <p>Might be more difficult to implement for industrial lands that require specific parcel sizes or access to the shoreline and are not always compatible with other uses or are legally restricted, preventing relocation; land loss is already a concern for industrial uses</p> <p>Actions falling under “Accommodate” may pose a cost to the asset owner as they may have to manage with occasional flooding</p> <p>Difficulty of intensifying land in industrial areas</p>	<p>If applied strategically, they can generate new economic activities</p> <p>Can prevent future loss to valuable assets</p> <p>Could be combined with engineering approaches to avoid administrative complexity, particularly for industrial uses if relocation is involved</p>
<b>Engineering</b>	dikes, seawalls, object elevation and relocation, building codes or retrofits, Soft shoreline protection measures (e.g., green infrastructure), hard shoreline protection measures (e.g., groins),	<p>Funding mechanisms like cost-sharing may be required</p> <p>Involves changing the hazard as opposed to altering exposure or sensitivity to the hazard, which entails effort and monetary investment protecting assets and safety from coastal hazards</p> <p>Cost of implementation, technical feasibility issues, urban design concerns, and environmental concerns that could impede implementation</p>	<p>Soft shoreline approaches have multiple co-benefits in addition to flood protection</p> <p>Object elevation and building controls would protect job space and infrastructure and sustain business operations</p>
<b>Financial tools</b>	Land or property buyouts, relocation incentives, policies and premiums, transfer of development rights, shifting responsibility to benefactors (insurance)	<p>Loss of developable land may ensue from buyouts</p> <p>Common challenges for implementation: mismatches in supply and demand, ability of or desire from property or business owners to respond to incentives and resulting administrative complexity</p> <p>Disproportionately large impact on small business owners with less financial resources.</p> <p>Many of these financial tools are voluntary and therefore, not enforceable</p>	<p>Can help to protect current or future development allocated for employment purposes</p> <p>May be more politically popular than regulatory approaches</p> <p>Often coupled with land use regulation and engineering options</p>
<b>Economic resilience planning</b>	Economy-wide planning, supply chain planning, cascade analysis	<p>Supply chain planning might be more appropriate in the short-medium term for industrial/port authorities due to challenges of implementing land use regulation and engineering tools</p> <p>Only those that partake in supply chain or other preventative measures may benefit</p> <p>Often not enforceable</p>	<p>Demonstration of climate leadership could attract new businesses and customers</p> <p>In partnership with infrastructure providers, encouragement of system redundancy would minimize risk to infrastructure and industries, leading to less severe disruption and faster recovery</p> <p>Key benefits of these measures is that they are proactive</p>

Category	Tools Discussed	Key challenges	Key opportunities
<b>Public awareness building and Multi-stakeholder engagement</b>	Awareness building with businesses, publicly accessible materials to inform stakeholders about risk and preparedness, multi-stakeholder engagement	<p>May be time consuming</p> <p>Would require consulting and coordinating the interests of stakeholders such as chambers of commerce, business improvement associations, boards of trade, industry associations, insurance groups, property owners' associations, utilities and transportation</p> <p>Relies on businesses/organizations to voluntarily participate.</p>	<p>Could be used to educate stakeholders on vulnerability and risk to coastal flooding and encourage better risk mitigation actions</p> <p>Publicly accessible materials targeted to businesses and infrastructure providers could encourage firm-level response and recovery planning</p> <p>Strong engagement processes could improve effectiveness</p>

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## ACRONYMS

**CAP:** Coastal Adaptation Plan  
**CFAS:** Coastal Flood Adaptation Strategy  
**CFRA:** coastal flood risk assessment  
**CNV:** City of North Vancouver  
**CNY:** City of New York  
**COR:** City of Richmond  
**COV:** City of Vancouver  
**CRD:** Capital Regional District  
**CSE:** City of Seattle  
**CSU:** City of Surrey  
**DCL:** Development Cost Levy  
**DFAA:** Department Financial Assistance Arrangements  
**DMAF:** Disaster Mitigation & Adaptation Fund  
**DNV:** District of North Vancouver  
**DPA:** Development Permit Area  
**DWV:** District of West Vancouver  
**ELER:** Employment Lands & Economy Review  
**FCL:** flood construction level  
**GIS:** Geographic Information Systems  
**I-O:** Input-output  
**LIC:** local improvement charge  
**MST:** Musqueam, Squamish, Tsleil-Waututh  
**PARA:** Protect, Accommodate, Retreat, Avoid  
**PIBC:** Planning Institute of British Columbia  
**POV:** Port of Vancouver  
**PSE:** Port of Seattle  
**OCP:** Official Community Plan  
**RGS:** Regional Growth Strategy  
**ROW:** Right of Way  
**SF:** San Francisco  
**SLR:** sea level rise  
**SLRPF:** sea level rise planning framework  
**SLRPU:** sea level rise planning update  
**SPP:** shoreline protection plan  
**TDR:** transfer of development rights

# PROJECT CONTEXT

## PROJECT OVERVIEW & RELEVANCE TO CITY OF VANCOUVER PRIORITIES

The City of Vancouver is developing a long-range policy plan to ensure that Vancouver has an appropriate supply of land to support future jobs and the growth of the economy. As part of this review, the City must consider the impacts of sea-level rise on Vancouver’s employment lands, many of which are located in floodplains. The impacts of sea-level rise will especially be felt in Vancouver’s industrial areas, 50% of which are located within Vancouver’s floodplain.

As part of its Employment Lands & Economy Review (ELER), the City of Vancouver has hired a consultant to conduct quantitative forecasting of Vancouver’s employment land needs up to 2050. This work also entails considering the impacts of sea level rise on jobs capacity. This Greenest City Scholars project involves a qualitative best practices review to identify policy tools and potential interventions to address sea level rise in employment lands.

Another knowledge gap involves understanding the impacts of sea level rise on economically significant infrastructure (i.e. docks) and industries located within flood plains. Results from this work may inform the land use policy plan currently in development and other work being done by the Employment Lands & Economy Review team who will present to Council in early 2020.

## OVERVIEW OF EMPLOYMENT LANDS AND THEIR SIGNIFICANCE

The Employment Lands & Economy Review team is working on understanding Vancouver’s economy and its capacity for job growth. The external forces being explored include speculation, rising land costs, the changing nature of work, and managing the limited supply of employment lands. 10% of the land is reserved for jobs-only uses and 50% of jobs are located on that 10% of the land. Job-only lands continue to be threatened by forces like climate change and resulting sea level rise. There is also pressure to consider residential and other uses on “job-only” lands (Hutton 2018). In the absence of adaptation efforts, the impacts of climate change threaten Vancouver’s existing commercial and industrial land.

However, job growth is expected to continue into the future. The RGS anticipates the city of Vancouver will add 90,000 jobs by 2041 (from 427,000 total jobs in 2016 (see ELER Roadshow Presentation)). Being the region’s largest job centre, economic activity in Vancouver also represents a base of the regional economy.

Vancouver’s largest share of jobs is found in: 1) professional/commercial services, followed by 2) healthcare, education and government, 3) personal services, hotels, arts and food, and 4) retail (COV ELER Fact Sheet). Growth is occurring in these sectors, but other sectors like manufacturing, wholesale trade, and transportation and warehousing have seen declines from 2006-2016. Increased housing demand and high developer interest is creating pressure to rezone industrial lands to high value residential uses (Hutton 2018). In 2007, the Metro Core Jobs and Economy Land Use Plan (Issues & Directions) addressed future job and economic growth in the city’s core (the “Metro Core”) by ensuring land use regulation does not hinder the city’s economic growth, (McNaney 2007). Similarly, the 2015 Metro Vancouver Industrial Lands Strategy Summary Report brings attention to the importance of protecting industrial land - land that accounted for 23% of jobs in the region in 2011.

Figure 1. Employment Lands & Economy Review Study



Figure 2. Metro Vancouver Industrial Lands Inventory Summary Report 2015





**TABLE 1: ECONOMIC IMPACTS FROM SEA LEVEL RISE**

Economic impact	Examples	Type of impact
Infrastructure damage	Damage to roads, equipment, utilities	Direct, indirect
Building or job site damage	Damage to building exterior or interior Damage to port/industrial facilities	Direct
Accessibility constraints (maritime/port uses, transportation)	Damage to roads, bridges, port terminals, rail infrastructure	Direct, indirect
Disruption to business operations	Could result from direct damage to job site, disruption of critical infrastructure, such as electricity, water, power or temporary loss of workers	Direct, indirect
Loss of inventory	Loss of supplies or equipment needed for business operations from direct damage or inability to transport and receive goods  Could result from disruption of critical infrastructure, such as electricity, water, power, etc.	Direct, indirect
Loss of customer base (long-term)	Inability to access goods/services or firm/business locations due to direct flood impacts, interruption of business operations, loss of inventory, ease of switching to competing businesses, or disruption of transportation infrastructure preventing site access	Indirect
Loss of employee base (long-term)	Inability to access job sites due to direct flood impacts, interruption of business operations, loss inventory, ease of switching to different employer, or disruption of transportation infrastructure preventing access to site	Indirect
Response and repair costs	Costs for response, repair and clean up represent an expenditure to firms and businesses  Time spent in response and repair could be spent on regular business operations	Direct

Source: Chang 2016; Webb; etc.

**TABLE 2: CONSIDERATIONS FOR LAND USE PLANNING  
IN EMPLOYMENT LANDS**

Land Use Planning Considerations	Source
<p><b>Flexibility and Transportation Accessibility</b> Some industries can relocate to a wide range of locations, while other industries must have direct, reliable access to transportation infrastructure</p> <p>Businesses involved in trade, transportation and logistics must have proximity to highways, port terminals, and railyards</p> <p>In cases of industrial and commercial uses, access to major transportation corridors (e.g., road, rail, water) and access or potential access to a sustainable transportation network is important</p>	<p>Metro Vancouver Industrial Lands Inventory Summary Report 2015</p> <p>City of Surrey Employment Lands Strategy [Cushman &amp; Wakefield LePage, Inc. (2008).]</p>
<p><b>Legal/Tenure or Use Limitations</b> Lands owned by the airport authority which are restricted to airport related uses or port lands restricted to port related activities- which affects where industrial land supply occurs</p> <p>The City does not directly own some of the land, which interfere with implementing certain tools</p>	<p>Metro Vancouver Industrial Lands Inventory Summary Report 2015</p>
<p><b>Parcel size requirements</b> For industrial uses, provision for a range of parcel sizes should accommodate various employment activities (2-3 acres minimum) and large parcel sizes (&gt;5 acres)</p> <p>Due to limited land base in the City of Vancouver, it may be difficult relocate uses or eliminate land through setbacks from uses that require large parcel sizes</p> <p>For commercial uses, there needs to be a range of parcel sizes to accommodate various commercial type activities</p>	<p>City of Surrey Employment Lands Strategy [Cushman &amp; Wakefield LePage, Inc. (2008).]</p>
<p><b>Compatibility in uses</b> For industrial uses especially, a locational requirement is proximity to existing or proposed potentially incompatible uses and impacts (e.g., noise, emissions, traffic)</p> <p>Uses should be locally serving and compatible with neighbouring uses</p> <p>There is already a conflict between certain commercial/industrial uses and residential dwellings in the City of Vancouver</p> <p>Compatibility is a consideration when relocating certain industrial uses</p>	<p>City of Surrey Employment Lands Strategy [Cushman &amp; Wakefield LePage, Inc. (2008).]</p> <p>City of Vancouver Employment Lands and Economy Review: What We Heard External Advisory Group Meeting #1 (2019)</p>
<p><b>Environmental Constraints</b> Locational requirements include keeping people and assets safe from environmental hazards present in floodplain areas, liquefaction areas, steep slopes, etc.</p>	<p>City of Surrey Employment Lands Strategy [Cushman &amp; Wakefield LePage, Inc. (2008).]</p>

In the absence of adaptation efforts, the impacts of climate change threaten to take away commercial and industrial land. Acute events like king tides and storm surge and long-term rising sea levels will gradually erode away the shoreline in valuable employment areas.

## Impacts of Sea Level Rise on Vancouver's Employment Lands

**93%**

**of industrial lands are already fully utilized<sup>1</sup>**

**13 km<sup>2</sup>**

**of City lands located in floodplain, with 1 meter of sea level rise, based on major storm scenario<sup>2</sup>**

**4.6 m.**

**Flood construction level required for 1 meter of sea level rise<sup>2</sup>**

Figure 4. Impacts of Sea Level Rise in Employment Lands

Data Sources:

- 1) Metro Vancouver 2015
- 2) Bing Tom Architects as cited by SFU ACT 2011

Image Source: Chemainus Valley Courier

## AT-RISK AREAS

### FLOOD RISK & VULNERABLE AREAS IN VANCOUVER

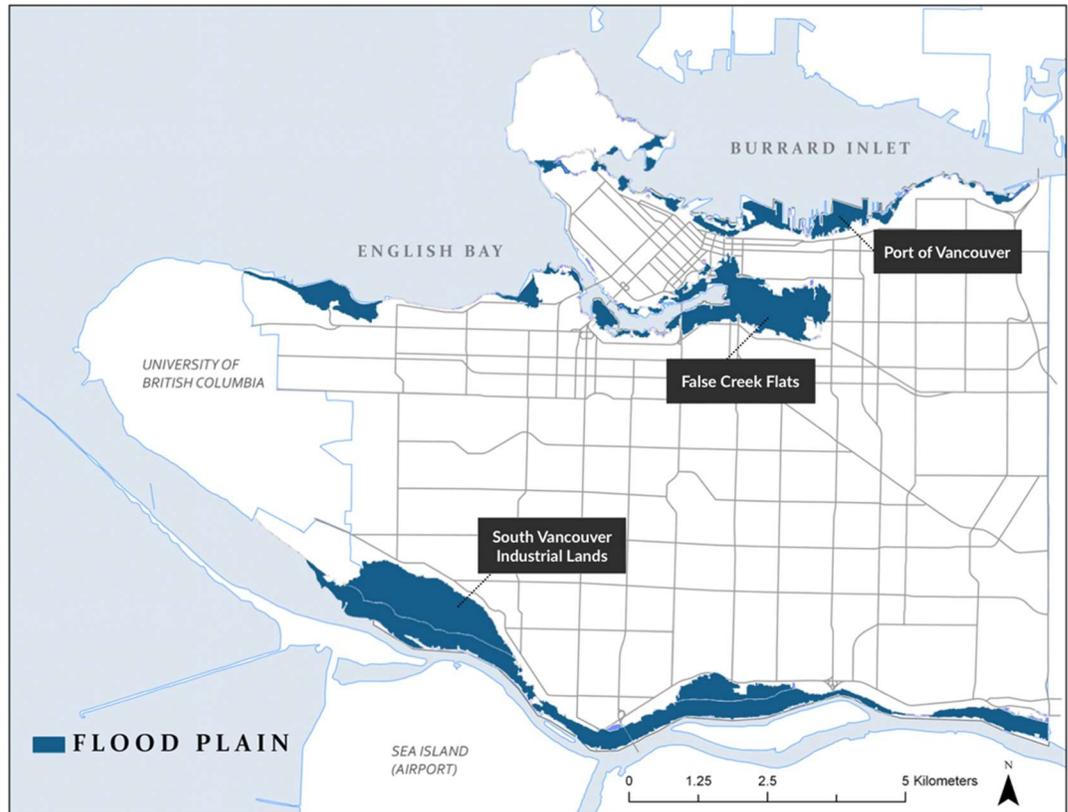


Figure 5 At-risk Areas in Vancouver

Source: City of Vancouver Employment Lands & Economy Review

Many of Vancouver's industrial lands fall within the flood plain, and therefore are susceptible to sea level rise and coastal hazards in the short-term like king tides and storm surges. As seen in the map above, the South Vancouver Industrial Lands, False Creek Flats, and Port of Vancouver are among the most prominent industrial areas that face flooding risk. As will be seen in the next section, adaptation planning is already taking place, for example through the Coastal Adaptation Plan (CAP) for the Fraser River Foreshore, which is especially relevant for the South Vancouver Industrial area.

## SEA LEVEL RISE PLANNING IN VANCOUVER

Figure 6. Climate Change Adaptation Strategy 2018



Figure 7. Vancouver's Changing Shoreline

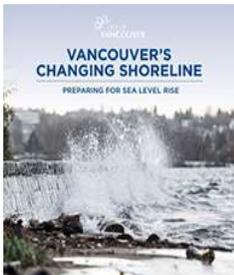
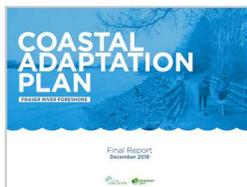


Figure 8. Coastal Adaptation Plan for the Fraser River Foreshore



In response to scientific findings put forth by the province on sea level rise and as part of its Climate Change Adaptation Strategy, the City of Vancouver requested the completion of a Coastal Flood Risk Assessment (CFRA) in 2012 to understand current and future risks (Badelt 2018). Findings revealed that majority of Vancouver's coastline will require flood protection, especially due to the exposure of industrial lands, critical infrastructure, and high value open space. With 1 m of sea level rise, 13 square kilometers of City lands are located in a floodplain based on a major storm scenario (Ebbwater Consulting 2018). CFRA Phase 2 presented a range of adaptation options along a spectrum of possible modes of action and adaptation approaches to enable comparison. A similar framework, known as the Protect, Accommodate, Retreat, and Avoid (PARA), commonly used by communities, professionals, and academic researchers to guide flood management planning and analysis, will be used as a lens in this report and will be described shortly.

The development of a Coastal Adaptation Plan (CAP) for the Fraser River Foreshore, an update to the Building Bylaw in 2014 to reflect new standards and requirements (e.g., higher Flood Construction Level) for development in floodplain areas represent some of the major efforts the city has taken to protect people, assets, and the environment.

As declared in a 2018 Sea Level Rise Planning Update for the city, coastal flood risk information will increasingly inform the design for new coastline projects to ensure their resilience. Examples include the development of "consistent performance standards" for flood protection that provides sufficient flexibility to allow for implementation in diverse but specific locations.

Other additions include a Flood Construction Level (FCL) that was implemented under the Vancouver Building By-law in 2014. The FCL dictates the minimum ground level elevation of habitable structures and a safe setback that keeps people and assets at a safe distance from potential coastal hazards and makes room for flood protection infrastructure (Badelt 2018). The City is currently considering changes to the Zoning and Development By-law that would reiterate the FCL in the Vancouver Building By-law. Lastly, the planning update mentions the creation of a task force, including BC Hydro, Fortis, and TransLink, to conduct a cascade analysis that studies relevant infrastructure interdependencies in the case of infrastructure failure in the city. Funding strategies for long-term implementation of coastal flood protection measures are also mentioned as well as ongoing awareness efforts modeled off of well-known initiatives like Rebuild By Design. (Badelt 2018).

As part of the CFRA Phase 3, the City employed a Sea Level Rise Planning Framework, which will assist the City with effective prioritization and timing for flood management implementation actions. The methodology, based on a 'pathways approach' and used to guide capital planning decisions, is depicted below. Through this framework, the City acknowledges that planning and infrastructure decisions will have to occur incrementally, with changes and priorities being made based on updated scientific information and stakeholder values, as written in its Sea Level Rise Planning Update 2018. Some areas facing frequent nuisance flooding and harboring critical infrastructure or assets to support local economic functioning may require flood protection, relocation, or object raising prior to 2050. However, other areas may not require any intervention until a few decades from now. (Badelt 2018)

Finally, the CFRA Phase 3 provides guidance on how to embed sea level rise considerations into land use and infrastructure plans, particularly through its Sea Level Rise Monitoring Plan. This Sea Level Rise Monitoring Plan recommends that the City follow interpretations of the IPCC's Fifth Assessment Report (AR5) from November 2014 by higher levels of government. AR6 could be released as early as 2020, which will be used to update existing actions. For now, the City is using the scenario based on the IPCC's scientific findings and provincial guidelines, which projects 1 m of sea level rise by 2100. The ELER team should make note of the different scales at which sea level rise projections are being released and updated, including local, regional, and global, which are included in the Sea Level Rise Monitoring Plan.

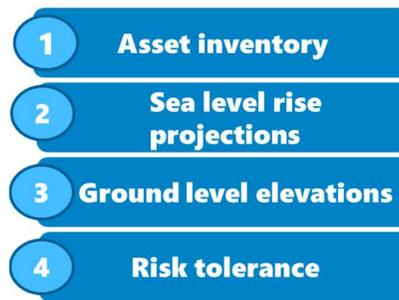


Figure 9. City of Vancouver's Sea Level Rise Adaptation Framework adapted from Badelt 2018

## AREA-SPECIFIC SEA LEVEL RISE PLANNING

Three industrial areas in the city of Vancouver are vulnerable to rising seas and ongoing flood impacts: False Creek Flats, South Vancouver Industrial Areas, the Port of Vancouver and its related industrial areas.

The **False Creek Flats Plan 2017** mentions risk from sea level rise as a key planning consideration and specifically discusses elevation of new development, adaptive building design, and construction methods that are flood resilient as some key interventions that would be line of defenses along the seawall. The predominant approach in Vancouver is to resist flooding and prioritize vulnerable areas. Protection measures for Northeast False Creek include a combination of a sea wall dike and a traditional dike, incorporating 'green shores' approaches. Storm water detention throughout the neighbourhood would also be a complementary approach for mitigation of overland and coastal flooding. Capital funding and Community Amenity Contributions would be used to fund these engineering improvements. (City of Vancouver 2017)

The **Northeast False Creek Plan 2018** mentions sea level rise, resiliency, and sustainability as one of the key considerations for its Phase 3, which emerged from community feedback from the Talk Vancouver Survey. The plan mentions ecological foreshore improvements and the integration of flood resilience principles to ensure the waterfront remains liveable. (City of Vancouver 2018c)

The **Coastal Adaptation Plan for the Fraser River Foreshore** includes three possible approaches for the South Vancouver Industrial lands that would involve resisting, accommodating, or retreating from the flood hazard. Resisting would involve the construction of a shoreline or inland dike, while accommodating would involve retrofitting infrastructure, buildings, and communities for greater resilience and allowing occasional flood events. Retreating in this area would involve moving vulnerable assets as well as people out of the floodplain. (City of Vancouver 2018a). The South Vancouver Industrial area consists of a large mix of industrial, commercial, warehousing, and manufacturing uses and is the site for the South Vancouver Transfer Station, a City works yard, recycling depot, and Vancouver's Transit Centre. As critical infrastructure surrounds the saw mill industrial area in the eastern portion, this area would be a potential site for future clustering of mid-heavy commercial uses and protection through dike infrastructure. (City of Vancouver 2018a)

The **Marpole Community Plan 2014** is another relevant planning initiative recently adopted by Council in 2014. The plan outlines green space additions, including the extension of the Fraser River Trail so the public can experience the Fraser River and a new waterfront park at the southern limit of Cambie Street (Vancouver Public Space Network 2014). Completing a flood management strategy for the Fraser River foreshore, meeting Flood Construction Levels, and introducing flood-resilient design are policies included in the plan to combat sea level rise (City of Vancouver 2014). '

Sea level rise is also a consideration in the Cambie Corridor Plan Phase 3, the East Fraser Lands' (EFL) revised Official Development Plan, the City Wide Plan, and the Jericho Lans policy statement.

## OBJECTIVES

This project helps to identify best practices in planning approaches and tools for sea level rise that are being used in Vancouver and elsewhere could potentially inform the Employment Lands & Economy Review team in their work. The following objectives will help guide the process:



Figure 10. Project Objectives

Image Sources (left to right: Vancouver.ca Wikipedia, Chemainus Valley Courier, and Vancouver Economic Commission)

## METHODOLOGY



### 1. Literature review of best practices to understand and plan for the impacts of sea level rise on employment lands, including industrial and port-related uses

- A review of global municipal and industrial/port precedents and previous work done by the City of Vancouver.
- A summary of key planning approaches/tools to address sea level rise in employment areas divided into major categories
- Description of implications of each sea level rise planning option on the local economy and employment lands
- Coordination with the Sustainability Division at the City of Vancouver, to facilitate knowledge-sharing



### 2. Key informant interviews with 6 government agencies and port authorities to understand their approaches to planning for sea level rise

- A questionnaire asking about impacts of sea level rise on long-range plans, the extent of analysis on the economic impact of sea level rise on employment uses, and preferred approaches to planning for sea level rise impacts on employment lands and associated economic impacts
- Interviewees selected based on recommendations made by staff
- Phone interviews with government agencies in Metro Vancouver and elsewhere in North America to generate a qualitative understanding of approaches and implications to complement the summary of tools and approaches from the literature review



### 3. Compilation of key findings into a report

- Description of implementation considerations for sea level rise planning for the City of Vancouver
- A summary of lessons learned and next steps to help guide the ELER team's future work, particularly on the land use policy plan.



# **Best Practice Approaches in Sea Level Rise Planning: Key Findings & Analysis**

# FINDINGS & DISCUSSION

## FROM LITERATURE REVIEW

### DOING NOTHING (INACTION SCENARIO)

No action is presented as an option in the CFRA Phase 2 (Lyle et al. 2016). However, based on findings from the literature review, taking no action carries various serious implications that would negatively affect land use and economic wellbeing and be costly long-term.

#### **Potential direct and indirect socio-economic consequences sea level rise such as coastal flooding**

A major focus is vulnerability in transportation networks, which can impede economic recovery. The following direct and indirect economic consequences are mentioned: production and sales losses, reduced employee income and tax payments, halting of business operations, temporary or permanent closure, losses to other businesses with linkages, employee or customer access, transportation of goods and supplies, and other costs associated with response, repair, or clean up. (Chang, S.E. 2016. "Socioeconomic Impacts of Infrastructure Disruptions," Oxford Research Encyclopedia, Natural Hazard Science.)

#### **Impacts from sea level rise including loss of job space, disruption of lifeline infrastructure, and challenges for individual businesses to recover post-event**

The importance of looking beyond direct impacts of disasters (e.g., flooding) and loss of job space to give more overall consideration to lifeline infrastructure which would significantly affect business recovery long-term. Various factors influencing firm-level preparedness to direct and indirect impacts are mentioned, including business size, whether the firm uses an ownership or leading model, and the type of business. It is also stated that pre-disaster business climate can help predict how well and business or sector will recover post-event. (Webb, G.R. et al. 2000. "Businesses and Disasters: Empirical Patterns and Unanswered Questions," Natural Hazards Review, Vol.1, No.2, pp.83-90).

#### **Impacts to port-related economic activities due to sea level rise**

Affected commercial activities and industries at ports and waterfronts include shipping, hospitality, restaurants, and commercial fishing as well as any economic activities related to public recreation and natural habitat protection. (Ng, A.K., Chen, S.L., Cahoon, S., Brooks, B. and Yang, Z. (2013). Climate change and the adaptation strategies of ports. Research in Transportation Business & Management, 8, pp.186-194).

#### **Land losses from sea level rise, which could result in shifts in land prices and would have significant economic implications**

There are a large number of studies that assess direct economic impacts of sea level rise but a shortage of studies looking at the effect of land losses from sea level rise on land prices and the overall economy. (Bosello, F., Roson, R. and Tol, R.S., 2007. Economy-wide estimates of the implications of climate change: Sea level rise.)

#### **Impacts on industrial and commercial uses**

Based on modeling of affected land use by percentage for different scenarios of sea level rise, the top land uses affected are industrial, comprehensive development, limited agriculture and commercial. Vulnerability of industrial lands to sea level rise could affect local scale manufacturing, distribution, repair industries, food production, and processing. Long-term planning could stimulate growth in these sectors. (Keenan, E. and Yang, A. (2011). The local Effects of Global Climate Change in the City of Vancouver: A Community Toolkit and Atlas.)

**Monetary impacts found for Vancouver from sea level rise**

Findings from Bing Tom Architects reveal a 12% loss in total land area in the City of Vancouver, with uneven impacts for industrial lands, historic areas and public space such as the open space and transportation routes along the waterfront. With 1 m of sea level rise projected for 2100, the total value of land would translate to \$25 billion in losses. SFU ACT also includes findings from the National Roundtable on the Environment and the Economy (NRTEE), which states that Metro Vancouver could see costs from sea level rise between \$2.1 B and \$7.6 B by 2050. (SFU Adaptation to Climate Change Team (ACT) (2011). Adaptation to Sea level rise in Metro Vancouver: A Review of Literature for Historical Sea Level Flooding and Projected Sea Level Rise in Metro Vancouver.)

**Government inaction towards sea level rise could result in impacts at a variety of geographic scales, from city-wide and regional (macroeconomic) to site-level (microeconomic).**

Some city-wide and regional impacts include a loss of job space, displacement of businesses, and indirect loss in employment. Disruptions in the transportation network supply chain would affect individual businesses, entire industries, and the wider economy. The economic impacts from land loss alone are significant, as shown in SFU ACT’s literature review findings. Site-level impacts might include direct damage or inaccessibility to job sites, firm-level loss of inventory, costs incurred by businesses to recover after flood impacts, and firm-level losses in the employee or customer base. Flooding also brings risk to life safety, equipment, and other assets, as explained in various climate adaptation plans or documents, such as the City of North Vancouver’s 2013 Climate Change Adaptation Plan. Webb et al. 2000 discusses the relationship between pre-event business climate and business continuity after a disaster event. It is found that the performance of a sector in the everyday economy is positively correlated with business continuity post-disaster in that sector. If Webb et al. 2000’s findings are accurate, then additional attention should be paid to sectors in Vancouver that may be struggling (COV ELER Roadshow Presentation) to ensure their smooth recovery after shocks and stresses like acute flooding and sea level rise.

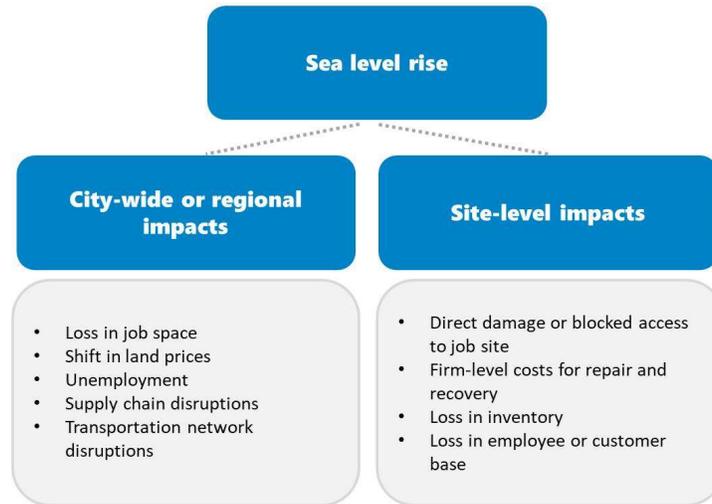


Figure 11. Sea level rise and its site, city-wide and regional impacts

# SUMMARY LIST OF PLANNING TOOLS

## SIX CATEGORIES OF TOOLS AND APPROACHES

The literature review, completed by source (see appendix E), resulted in a summary of planning tools and approaches, which includes a description of tools grouped by five categories, listed in the figure below. Some planning tools and approaches spanned two or more categories.



Figure 12. Categories for Summary of Tools & Approaches

### FRAMEWORKS FOR SEA LEVEL RISE ADAPTATION PLANNING

Tools and approaches were further classified based on where they fall along the PARA framework spectrum. The framework was first used to inform climate change planning in communities facing sea level rise and has been included in both academic and government sources. It is significant as it demonstrates the difference in impacts between “doing nothing” and doing something, whether it is protecting, accommodating, retreating, or avoiding, with specific implications for preserving the city’s jobs base and economic functioning (Doberstein et al., 2018). The CFRA Phase 2 explains how different adaptation actions respond to coastal hazards related to sea level rise and labels this relationship as a mode of action. A similar framework is used by the San Francisco Bay Shoreline Adaptation Atlas, which summarizes numerous approaches for sea level rise planning. **Figure 3 below** shows a similar iteration to this framework, included in the Sea Level Rise Primer: Vancouver’s Changing Shoreline, where *Resist* would be similar to *Protect* and *Avoid*’s depiction is synonymous to *Move*.

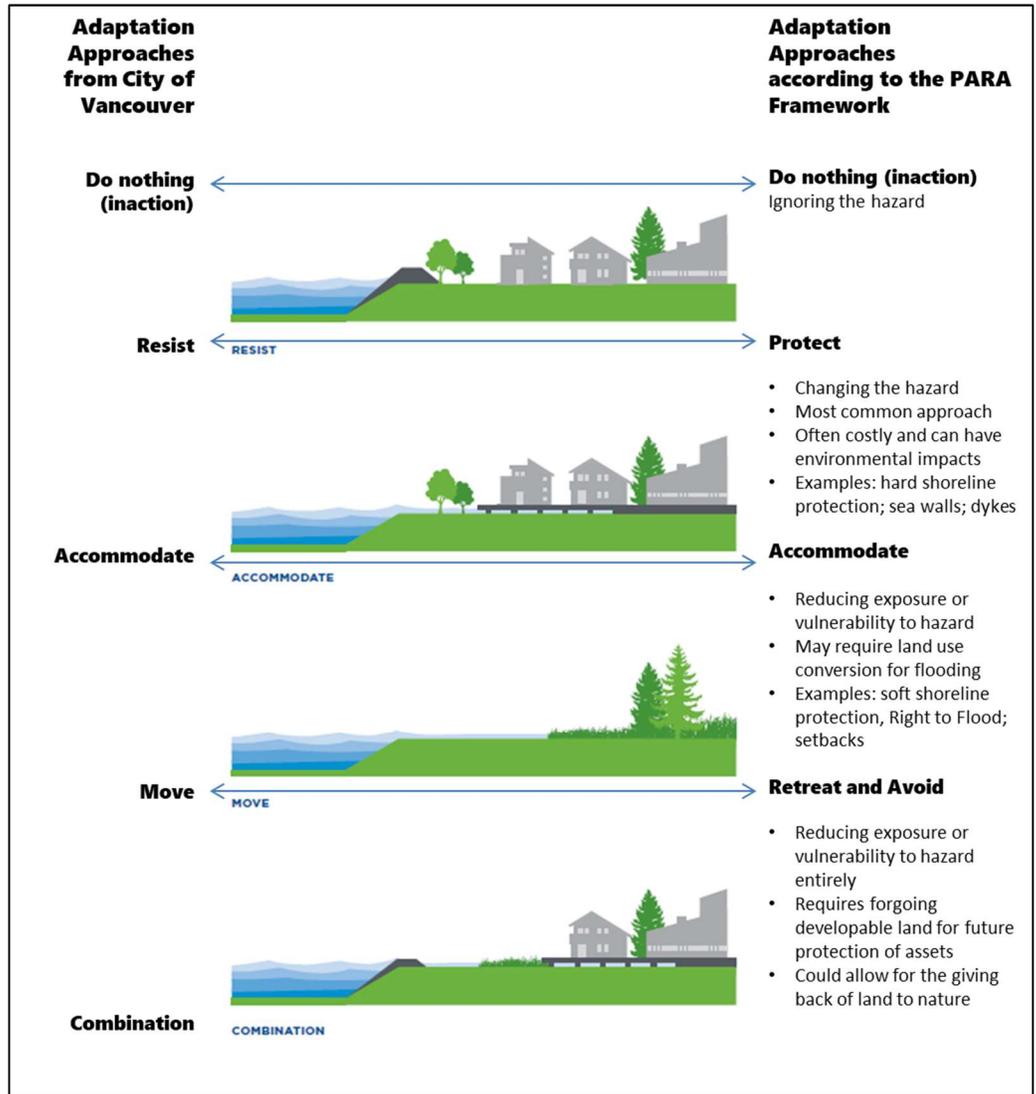


Figure 13. Adaptation Approaches  
Image modified from source: City of Vancouver: Vancouver’s Changing Shoreline 2018

## GLOSSARY FOR SUMMARY LIST OF PLANNING TOOLS

The following is a guide for interpreting the columns of the literature review and summary list of planning tools and approaches:

**Category:** type of planning tool or approach. Categories included Regulatory/Land use, Engineering, Financial tools, Economic resilience planning, Public education and awareness, and Multi-stakeholder engagement

**Sea level rise planning approach:** classifies different possible adaptation actions based on the commonly used PARA framework for sea level rise. These options include Protect, Accommodate, Retreat, and Avoid vs. a Do nothing scenario. Please note that Retreat is sometimes referred to as Move and Accommodate is sometimes referred to as Adapt. Both the CFRA Phase 2 and CAP for the Fraser River Foreshore employ this framework or a version of it.

**Source Type:** explains where the findings came from, such as academic literature review, municipal staff report, formal regulatory document (i.e. municipal policy/plan), consulting report, etc.

**Magnitude of impact on land use:** evaluates impacts on land use based on high impact, moderate impact, and low impact options. High impact might include large direct impacts to land use such as loss of land or protection of critical infrastructure, uses, or industries whereas low impacts might include smaller interventions that would not necessarily involve significant land use loss or change. An example of low impact interventions is cascade analysis, as this is just a modeling exercise and therefore, presents little to no visible land use impacts. Moderate impact interventions would include stormwater code provisions that have a visible impact on the landscape, by introducing permeable materials, infrastructure upgrades, and green areas.

**Degree of reactivity** – proactive vs. reactive was taken from the San Francisco Bay Shoreline Atlas and is another approach to classify tools and approaches in more detail. Proactive might be interpreted as preventative and would encompass most land use tools or economic resilience planning tools, whereas reactive might refer to a tool that preserves Business as Usual by responding to flood events, such as flood protection infrastructure, rather than reducing exposure to the hazard, such as relocation from coastal flood hazards areas

**Land use considerations for Vancouver and ELER:** Implications a particular tool has on the work being carried out for the Employment Lands & Economy Review.

**Example of implementation:** indicates where and in what form the tool has been executed or at least considered

**Relevant planning approaches or tools used:** any planning approach or tool that was mentioned by the source. This could include tools that are just cited in the source, tools that are recommended, or tools that are being considered or implemented by a community

**Other relevant findings:** any findings generated from the source that might be of interest to the ELER team or be relevant

**TABLE 3. SUMMARY TABLE OF TOOLS & APPROACHES (ABRIDGED VERSION)**

<b>Category</b>	<b>Tools/Approaches</b>	<b>Accountability</b>
<b>Land use/regulatory</b>	Flood mapping	Municipal planning
	Flood hazard area bylaw	Municipal planning
	Development permit areas	Municipal planning
	Setbacks, buffers, and clustering	Municipal Planning
	Consistent design standards	Municipal Planning
	Right to Flood	Municipal Planning
	Rolling/conservation easements – see financial tools	Municipal Planning enabled;
	Covenant on Title	owner-occupied
	Open space provision	Municipal Planning enabled;
		owner occupied
	Relocation of infrastructure or property – see engineering	Municipal planning
	More intensive use of land in other areas	Municipal planning
	Storm water code or integrated storm water management plans	Municipal planning
	Transfer of development rights	Municipal planning
<b>Engineering</b>	Consistent design standards/ building code	Municipal planning
	Relocation of infrastructure or property – see land use/regulatory	Municipal planning
	Protective sea walls/dikes/polders	Municipal planning
	Hard erosion control measures (e.g., riprap, dolos, bulkheads, revetments, breakwater, groins)	Municipal planning
	Soft erosion control measures (green infrastructure)	
	Land reclamation via placement of fill	Municipal planning
	Mandatory building tune-ups	Municipal planning
	Object elevation	Municipal planning
	Flood proofing (dry proofing)	Municipal planning
	Flood proofing (wet proofing)	Municipal planning
	Storm water code or integrated storm water management plan	Owner-occupied
		Owner-occupied
		Municipal planning
<b>Financial Tools</b>	Rolling/conservation easements – see land use/regulatory	Municipal planning/ owner-occupied
	Community amenity contributions	Municipal planning
	Development cost levies	Municipal planning
	Relocation incentives	Municipal planning
	Responsibility shifting to benefactors	Insurance providers
	Policies/ premiums	Insurance providers
	Transfer of development rights	Municipal planning
	Land or property acquisition (buy outs)	Municipal planning
<b>Economic Resilience Planning</b>	Open space provision	Municipal planning
	Cascade analysis and other computer modeling for economic impacts	Municipal planning; utility and infrastructure providers; academic researchers; emergency management
	Computer modeling	
	Critical infrastructure response/recovery	Municipal planning; utility and infrastructure providers; academic researchers; emergency management
	Warning systems/ evacuations	
	Supply chain measures	management
	Economy-wide planning	Municipal planning
See awareness building		

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<b>Multi-stakeholder engagement</b>	Long-term sea level rise engagement with business owners, port authorities, utilities, etc.	Municipal planning
<b>Public education/ awareness</b>	Awareness building programs to educate the public, including businesses, about risks and risk reduction	Municipal planning
	Online materials for businesses on firm-level preparedness	Municipal planning

**TABLE 4. KEY CHALLENGES & OPPORTUNITIES FROM TOOLS & APPROACHES**

Category	Tools Discussed	Key challenges	Key opportunities
<b>Land use/ regulatory</b>	Setbacks, conservation easements, right to flood, clustering	<p>Could reduce the range of uses that could occur on land and might eliminate flexibility in terms of development opportunities, it protects uses from business disruption</p> <p>Might be more difficult to implement for industrial lands that require specific parcel sizes or access to the shoreline and are not always compatible with other uses or are legally restricted, preventing relocation; land loss is already a concern for industrial uses</p> <p>Actions falling under “Accommodate” may pose a cost to the asset owner</p> <p>Difficulty of intensifying land in industrial areas</p>	<p>If applied strategically, they can generate new economic activities and prevent future loss to valuable assets</p> <p>Could be combined with engineering approaches to avoid administrative complexity, particularly for industrial uses</p>
<b>Engineering</b>	Soft shoreline measures, hard shoreline measures, dikes, seawalls, object elevation and relocation, building codes or retrofits	<p>Funding mechanisms like cost-sharing may be required</p> <p>Involves changing the hazard itself as opposed to altering our relationship to the hazard (e.g., exposure or sensitivity)</p> <p>Cost of implementation, technical feasibility issues, urban design concerns, and environmental concerns that could impede implementation</p>	<p>Soft shoreline approaches have multiple co-benefits, such as recreational, ecological and health benefits, in addition to flood protection</p> <p>Elevation of objects, such as buildings and infrastructure, and building controls would protect job space and infrastructure and sustain business operations</p>
<b>Financial tools</b>	Buyouts, relocation incentives, policies and premiums, transfer of development rights, shifting responsibility to benefactors (insurance), development cost/charge, local improvement charge, community amenity contribution	<p>Loss of developable land may ensue from government buyouts</p> <p>Common challenges for implementation: mismatches in supply and demand, ability of or desire from property or business owners to respond to incentives and resulting administrative complexity</p> <p>Equity considerations must be in place to ensure small business owners are also able to relocate if needed</p> <p>Some tools may be more voluntary than others, and therefore, less enforceable</p>	<p>Can help to protect current or future development allocated for employment purposes</p> <p>May be more politically popular than regulatory approaches</p> <p>Often coupled with land use regulation and engineering options</p>
<b>Economic resilience planning</b>	Economy-wide planning, supply chain planning (e.g., export diversion, ship rerouting, checking inventories), cascade analysis	<p>Supply chain planning might be more appropriate in the short-medium term for industrial/port authorities due to challenges of implementing land use regulation and engineering tools</p> <p>Only those that partake in supply chain or other preventative measures may benefit</p> <p>Often not enforceable</p>	<p>Demonstration of climate leadership could attract new businesses and customers</p> <p>In partnership with infrastructure providers, encouragement of system redundancy would minimize risk to infrastructure and industries, leading to less severe disruption and faster recovery</p> <p>Key benefits of these measures are that they are proactive.</p>
<b>Public awareness building and multi-stakeholder engagement</b>	Awareness building with businesses, publicly accessible materials to inform stakeholders about risk and	<p>May be time consuming</p> <p>Would require consulting and coordinating the interests of stakeholders such as chambers of commerce, business improvement associations,</p>	<p>Could be used to educate stakeholders on vulnerability and risk to coastal flooding and encourage better risk mitigation actions</p>

Category	Tools Discussed	Key challenges	Key opportunities
	preparedness, multi-stakeholder engagement	boards of trade, industry associations, insurance groups, property owners' associations, utilities and transportation  Relies on businesses to voluntarily make a change  May be more politically popular	Publicly accessible materials targeted to businesses and infrastructure providers could encourage firm-level response and recovery planning  Strong engagement processes could improve effectiveness

# KEY FINDINGS AND ANALYSIS FROM SUMMARY OF TOOLS & APPROACHES

## Tool definitions

### Development Permit Area

Designated land where guidelines direct development to address special conditions or objectives such as the natural environment, hazardous conditions, commercial revitalization, form and character, energy and water conservation, and GHG emissions reduction (District of West Vancouver Official Community Plan)

### Setback

regulates the minimum distance of a habitable building from coastal hazards (SPUR 2019)

### Conservation/Rolling Easement

Regulation or an interest in land in which a property owner's interest in preventing real estate from eroding or being submerged yields to the public or environmental interest in allowing wetlands, beaches, or access along the shore to migrate inland (Seattle Office of Sustainability and Environment 2017)

### Right to Flood

provision in law that land be allowed to flood during high-water conditions (SPUR 2019)

### Clustering

a zoning strategy whereby buildings are grouped together to preserve larger areas for habitat, green infrastructure, and open space (SPUR 2019)

## 01. REGULATORY/LAND USE TOOLS AND APPROACHES

This category encompasses tools such as flood hazard area bylaws, development permit areas, setbacks, buffers, or clustering strategies, urban design standards, Right to Flood, and conservation or rolling easements. The provincial Ministry of Water, Land, and Air Protection includes flood hazard area bylaws as an approach within the local government's jurisdictional powers to address coastal flooding concerns (Province of BC 2011).

### HIGHLIGHTS

**The implementation of setbacks, conservation easements, or Right to Flood mandates would have various implications of relevance to the employment lands.** Among the benefits for land use tools is the ability to preserve the existing land base for jobs or industrial, port, and/or commercial uses (Metro Vancouver 2014). Land use regulation can also guide the location of future development in a way that protects people and assets and allows for flood protection or storm water infrastructure where needed (Badelt 2018; Lyle et al. 2016). Such land use policies would allocate developable land for the purpose of flood protection infrastructure or flooding. However, this may entail the use of space that would otherwise be dedicated for employment purposes.

**Right to Flood is a legal provision that designates specific land parcels for flooding and its trade-offs should be considered.** While Right to Flood could reduce the range of uses that could occur on land and might eliminate flexibility in terms of development opportunities, it protects uses from business disruption. Knowing that this policy will be imposed in the employment lands ahead of time might encourage building retrofits and flood proofing, object elevation, and response and recovery planning for continued business operations to accommodate flooding. While Right to Flood could reduce the land available for commercial and industrial activities, such policies are more likely to be implemented for lower-quality uses such as parking lots.

**Strategies like clustering are used to intensify development in certain inland areas and keep the majority of development safe from flooding but may be difficult to implement for industrial uses.** A 2015 inventory from the Metro Vancouver Industrial Lands Strategy reveals a net reduction of industrial lands of 350 ha from 2010-2015. It discloses that it is difficult to intensify lands in the short-term as 93% of these lands are already fully utilized. Land use designations, both municipal and regional, can secure industrial lands for long-term protection. However, long-term protection to preserve industrial lands must be considered alongside regulatory tools to protect buildings and facilities within employment lands from coastal flooding. Given the inflexibility of various industrial uses, land use tools may have to be combined with engineering approaches such as flood protection measures and building controls like minimum FCL requirements and flood proofing measures.

**If land use tools are applied strategically, they can help generate new economic activities while preventing future loss to valuable assets.** New economic activities and jobs could result from the conversion of industrial or commercial uses to floodable land such as parks and open space, namely in tourism, recreation, or the environmental/ green jobs sector. Zoning bylaws, setbacks, Development Permit Areas, Right to Flood, and conservation easements could also prevent repeated losses to property and infrastructure from flooding in the long-term. They can partially reduce vulnerability and exposure of employment lands assets to the hazard or eliminate it entirely. If some of these regulatory tools (e.g., rolling easements) are paired with financial incentives, their political popularity would increase. This is an approach currently being considered as part of the City of Seattle's adaptation program (Seattle Office of Sustainability and Environment 2017) as well as select counties in Maryland, USA, which have implemented coastal resilience easements (SPUR 2019).

## KEY LIMITATIONS

- Could contribute to the loss of developable land or potential job space in employment areas
- Land loss is already a concern for industrial lands according to Hutton (2018) and Bing Tom Architects and NRTEE (SFU ACT 2011)
- Intensifying industrial lands is already challenging as most of them are already fully utilized
- Could lead to land value decrease and associated tax base in cases of reduction in land use quality
- Could lead to land value increase in cases of increased pressure on inland or higher elevation areas
- Actions falling under “Accommodate” may pose a cost to the asset owner

### Land Use/ Regulatory Tools Case Study Example: Rolling Easements on the Texas Gulf Coast

Rolling easements can encourage the relocation of buildings and structures further inland. The protected area also follows any changes to the shoreline. The *Open Beaches Act* in Texas prohibits private shoreline protection structures, such as seawalls and buildings, seaward beyond a vegetation line to protect public access. In the case of erosion and sea level rise, which will move beaches further inland, any structures that are on the beach must be removed. Repairs are only permitted under certain cases and if the structure’s base exceeds the high-tide line. The Act was amended in 2013 to allow the easement to move after acute events such as storm surge from hurricanes and gradual events like sea level rise.

Read more:

<https://www.arcgis.com/apps/MapJournal/index.html?appid=1afbf2d80c6c4b1e8084ea37c7a80548>



Image source: Risingsea.net

## Tool Definitions

### Building controls

code provisions to increase flood resistance of new buildings through the use of flood-proofing of exterior and ground floors, elevation of mechanical equipment, ground floor elevation above base flood elevation, or other property-level protections (CFRA Phase 2)

### Co-benefits

added benefits we get when we act to control climate change, above and beyond the direct benefits of a more stable climate (Climate Bonus)

### Hard Shoreline Protection

Method of shoreline protection or erosion control that can include riprap and dolos

### Soft Shoreline Protection

Can include constructed wetland, dune rebuilding, natural erosion control, beach renourishment, barrier island, and involves the placement of natural erosion-control measures which, in the Pacific Northwest, would include wood and grasses. This can reduce wave energy and therefore the impact of coastal flooding (CFRA Phase 2)

### Structural flood protection measures

physical, human-constructed methods of adaptation that lead to coastal hazard and flood management protection; typically using hard materials like concrete, rock and steel as opposed to 'green' or 'soft' biological materials

### Flood Construction Level

establishes the minimum elevation for habitable buildings in relation to anticipated flood levels (Sinclair 2015)

### Stormwater Infrastructure

Building and site design to mitigate the reduced infiltration due to development

### Object Elevation

the elevation of an individual building above the flood level through use of fill, stilts, or other structural means (CFRA Phase 2)

## 02. ENGINEERING TOOLS AND APPROACHES

The second category comprises a range of flood protection measures and building controls, with the majority falling under the "Protect" spectrum of the PARA framework. Flood protection measures include dikes, sea walls, and polders that typically involve changing the hazard. Hard shoreline protection measures, typically made of hard, concrete, or rock structures can be added to the shoreline for erosion control. In contrast, soft shoreline protection measures, which are often referred to as green infrastructure, involve more naturalized means of erosion control and buffering against wave impacts. Other municipalities with Employment Lands Strategies, like Richmond, have publicly acknowledged that some degree of flood protection will be required for the employment lands going forward.

## HIGHLIGHTS

**Soft shoreline protection, an approach that produces various ecological, recreational, and economic co-benefits, involves the placement of boulders, logs, and vegetation along the shoreline to buffer against wave impacts.** More established techniques include dune rebuilding and constructed wetlands, and beach renourishment, which present various ecological and recreational co-benefits (City of Vancouver 2018a; SPUR 2019). Seattle's Green Factor Program is one example of green infrastructure in implementation. Other concepts include New York City's DryLine and WALLED OFF, a design proposal based on a UBC SALA master's thesis to redesign the area around Stanley Park's sea wall to incorporate more natural landscape features. Soft shoreline protection is also being encouraged by municipalities along the North Shore, such as by the District of West Vancouver (2015) through its Shoreline Protection Plan 2012-2015 and associated pilot projects. Lastly, SFU ACT (2015) has presented various economic benefits from green infrastructure investments that could lead to increased land values, improved workplace productivity, improved facilities in the recreation and tourism sectors, and others, which all have wider economic consequences.

**Other engineering approaches are intended to directly protect assets like buildings and infrastructure beyond just the coastline itself, but their costs, land use impacts, and environmental impacts must be evaluated.** Examples include the mandatory enforcement of building tune ups to ensure structures meet the minimum Flood Construction Level, flood proofing of buildings, using dry or wet proofing, which could be required or incentivized, object elevation, particularly for valuable infrastructure, and storm water approaches enforced by code. The City of Seattle has considered building on many of these approaches as part of its Climate Preparedness Strategy. The City of Vancouver also has Floodplain Standards and Requirements that specify Flood Construction Levels, subdivision requirements, and make recommendations for fill, drainage, grades, and erosion protection works (City of Vancouver Planning & Development Services 2014).

**Object elevation and minimum FCL requirements could protect job space and infrastructure, like roads, utilities, equipment, which would help sustain business operations in case of repeat flood events.** These engineering options are all presented under the CFRA Phase 2, some of which are being undertaken by neighbouring municipalities like City of Surrey through its Zoning Bylaw 12000 and considered for the Capital Regional District (Sinclair 2015). Flood proofing could protect buildings, equipment, and work sites necessary for daily business operations and would require minor investment. The Institute for Catastrophic Loss Reduction provides a visual example of property-level flood proofing on their website.

## KEY LIMITATIONS

- Involves changing the hazards itself as opposed to altering our relationship to the hazard (via exposure or sensitivity)
- Could become costly in implementation and would benefit from cost-sharing or other funding mechanisms
- Feasibility issues can ensue from technical and structural constraints (e.g., building tune ups in seismically-active areas)
- May require careful consideration of drainage systems, connectivity, and land use impacts to avoid disruption to neighbouring land uses and infrastructure systems
- Alterations may transform urban design and affect customer or employee access and desirability of retail or commercial districts

### Engineering Tools Case Study Example: New York City's DryLine

A project by the Bjarke Engels Group (Copenhagen/New York) and One Architecture (Amsterdam), the Dryline, also known as BIG U, exemplifies the co-benefits of soft shoreline approaches and open space provision. The ribbon-like DryLine, which took its name from New York's High Line, consists of a 12 km-long barrier to reduce the exposure of a commercial district, Southern Manhattan, to coastal flooding. In cases of high-water, parks, seating, bicycle storage facilities, and skate parks can absorb the impacts, while nearby buildings and key infrastructure are kept safe. Below elevated roadways, embankments provide green space and public pavilions. Shutters close the area to form a flood barrier in the case of acute flood events, like storm surges.

Read more: <https://www.lafargeholcim-foundation.org/projects/the-dryline>



Image source: Lafargeholcim Foundation

## Tool Definitions

### Relocation Incentives

financial tools that help encourage the moving of assets (buildings, businesses, and people) or infrastructure (roads, services) out of flood-prone areas (CFRA Phase 2)

### Development Cost Levies

collected from development help pay for facilities made necessary by growth. Facilities eligible for DCLs include: parks, child care facilities, replacement housing (social/non-profit housing), and engineering infrastructure (City of Vancouver)

### Responsibility Shifting to Benefactors

changes to the Disaster Financial Assistance Arrangement that could better re-align the responsibility and liability (CFRA Phase 2)

### Policies & Premiums

homeowners are provided with incentives (reduced premiums) for buying outside the floodplain or by implementing property-level protections if they live within the floodplain. And when a flood occurs, insurance monies can be used to partly recover losses (CFRA Phase 2)

### Transfer of Development Potential/ Rights

transfer of allowable development potential to an alternate location outside the floodplain (SPUR 2019)

### Land or Property

#### Acquisition (Buy outs)

buy out of property and buildings using public funds to sterilize area, thereby decreasing future assets at risk (CFRA Phase 2)

## 03. FINANCIAL TOOLS

Financial tools are often coupled with land use regulation or engineering approaches and are used to pay for infrastructure projects or land use policies. Examples include relocation incentives, development cost levies, responsibility shifting to benefactors, policies and premiums, transfer of development potential, and acquisition of developed or undeveloped lands through buy outs. Incentives that encourage retrofitting or buy out measures, promoting relocation and infill development elsewhere, can help to protect current or future development allocated for employment purposes.

## HIGHLIGHTS

**Mandatory buyouts, or land acquisition, carry the trade-off that assets may be protected from repeated flood losses, but at the expense of loss of developable land.** Other concerns include loss of land value and impacts to the wider economy. In the case of previously developed land, displacement of existing businesses in the short-term could be problematic. However, in the long-term, retreating would prevent frequent business and industry disruption and lead to long-term cost savings (Badelt 2018; Lyle et al. 2016; SPUR 2019).

**Relocation incentives, an approach presented in the CFRA Phase 2, could be offered to property owners or firms in employment lands to buy outside of the floodplain.** Incentives could be more attractive to businesses than mandatory, unplanned relocation as it would prevent sudden displacement, disruption of operations, and likely loss of customers and employees. According to SPUR 2019, this approach would especially suit uses that do not conform to existing zoning where the likelihood of repetitive loss from flooding is high. Any relocation or retrofitting incentives must carefully consider equity to avoid “checkerboard effect” which could cause urban blight in some areas (SPUR 2019).

**Policies and premiums could provide monetary assistance for loss recovery or incentives for relocation and could be used by businesses to recover losses in inventory, buildings, or equipment and restore business operations.** As such tools are more reactive, businesses may still lose their customer or employee base as they wait for recovery funds in the aftermath of a flood. Another policy option, shifting responsibility to benefactors, would transfer the liability to firms so that they are more likely to move to inland, low-risk areas.

**Some insurance options may inadvertently hurt smaller firms without the resources to relocate or industries like shipping and manufacturing that lack the flexibility to relocate.**

Relocation may be easier for industries that have the flexibility and are not water-dependent; however, retreat measures are often not a feasible option for heavy industrial or port facilities that require direct access to the water for shipping and other maritime/trade activities. Relocation may also be costly and time-consuming, thereby creating barriers for firms of a certain size. Support programs or relocation policies should apply an equity lens.

**Transfer of development potential or rights involves an exchange of allowable development potential to an area outside the floodplain for credit, but may result in administrative complexity, especially if used for industrial lands.** Transfer of development rights has been implemented regionally rather than within one municipality. An increasingly common approach used in the states of Florida, Maryland, and New Jersey, it could be used to support smart growth and infill development (SPUR 2019). The benefits would include future loss to businesses and infrastructure from flooding. A caveat is the issue of supply and demand of land and the dependence on owners’ willingness to buy and sell. For example, safer and higher elevation “receiving” areas might still be in short supply and would only be equipped to serve uses that are easily compatible and do not have large parcel requirements (SPUR 2019). Unfortunately, this would pose a challenge for industrial and port uses or those that require marine access. “Sending” areas could be downzoned or transformed into conservation easements upon sale of development rights (SPUR 2019).

**KEY LIMITATIONS**

- Common challenges are mismatches in supply and demand, the responsiveness of property or business owners to incentives and resulting administrative complexity
- Less enforceable than regulatory and engineering measures as many financial programs are voluntary

**Financial Tools Case Study Example:  
Transfer of Development Rights in Pinelands, New Jersey  
and King County, Washington**

Transfer of Development Rights, or Transfer of Development Potential, involves the transfer of allowable development potential within the floodplain to an area that does not face flood risk. Coupled with smart growth and infill principles, this program would require the designation of sending and receiving areas, whereby property owners in sending areas can sell credits for development and receive a conservation easement in return or waive their right to develop their land further. Downzoning would occur in these areas over time, as additional credits are sold. In receiving areas, property owners would buy credits in order to surpass existing allowable densities. A state agency and third-party organization, the Pinelands Development Credit Bank in Pinelands, New Jersey runs one of the most established TDR programs, which was initiated in 1985. It was initially meant to involve developers in the preservation of environmentally-sensitive lands while promoting economic development through regional growth areas. The program has restricted over 8000 hectares from being developed. Other well-known programs are found in Montgomery County, Maryland and Massachusetts, King County, Washington (Seattle area), and are now being considered in South Florida for sea level rise.

Read more:

<https://www.nj.gov/pinelands/pdcbank/>

<https://www.kingcounty.gov/services/environment/stewardship/sustainable-building/transfer-development-rights/bank.aspx%20>



Image source: NJ.gov

## Tool Definitions

### Supply chain planning

can include ship rerouting, shifting to other ports, export diversion via other transportation modes, conservation, unused capacity, substitution of inputs, recapture post-port opening, production rescheduling )

### Economy-wide planning

could include tools and approaches such as business response and recovery planning, quantifying supply chain impacts from environmental disruptions such as flooding or sea level rise and developing plans to respond accordingly, or developing economy-wide plans related to land use to minimize risk to infrastructure and industries

### Cascade Analysis

used to understand the interrelations between infrastructure failures across a city or region

## 04. ECONOMIC RESILIENCE PLANNING

The fourth category includes tools and approaches such as supply chain planning and economy-wide planning related to land use to minimize risk to infrastructure and industries. Economic resilience could be used to help plan for changes in resource use and availability and economic volatility creates by shocks and stresses. General principles include economic development diversification and cooperation across a regional scale to avoid overreliance on certain sectors or vulnerabilities of supply chains and transportation routes (Chang 2016; City of North Vancouver 2013). Economic resilience planning and branding of a city through its climate leadership can help attract new businesses and customers. Such a stance has been taken by the City of North Vancouver as part of its adaptation initiatives. Likewise, City of Vancouver's CAP for the Fraser River Foreshore reflects a desire to promote job creation through the implementation of climate change mitigation and adaptation actions. Economic resilience planning done by a municipality in partnership with infrastructure providers could be more effective in ensuring prevention, preparedness, and recovery.

## HIGHLIGHTS

**Based on research done by Webb et al (2000), economy wide planning, particularly through firm-level response and recovery planning, protects economic sectors most vulnerable to disruption or loss in a disaster event.** Economy wide planning would also involve looking at both direct and indirect impacts, while giving overall consideration to lifeline infrastructure which could affect business recovery in the long-term (Chang 2016; Webb et al 2000). In addition, Webb et al's (2000) findings on factors that predict business recovery, such as pre-event business climate, business size and type, and ownership or leasing model, could be mentioned in consultations with businesses and industries related to sea level rise impacts on employment lands. Recovery planning for businesses can help to secure political and financial support (e.g., catastrophe bonds), which would support the implementation of various land uses post-event (SPUR 2019). See more examples of awareness building for economic resilience under "Public education/awareness"

**Supply chain planning would be a more suitable approach taken for port and industrial uses, given the challenges of implementing land use regulation and engineering tools for these uses.** Ng et al 2013 present two types of supply chain resilience approaches, particularly for the shipping sector: 1) non-structural approaches, which involve shipping adjustments and modal shifts among others, and 2) technological changes to cargo handling, vessel size, and navigation. High equipment standards, risk management practices, and optimization of procedures could increase resilience. According to Rose & Wei 2013 who studied port shutdowns and their consequences on the economy, approaches to ensure supply chains can withstand impacts might include ship rerouting, shifting to other ports, export diversion to other transportation modes, conservation, input substitution, production rescheduling, and more. Their study found that business related resilience actions such as production recapture and ship rerouting taken up by a port in Texas contributed to a 70% reduction in regional infrastructure disruptions.

**Cascade analysis could also be undertaken to build a better understanding around infrastructure failures and their interrelations across Vancouver and therefore prevent disruption.** As recommended by the SLRPU 2018, performing a cascade analysis locally would require engaging with major infrastructure providers, such as BC Hydro, Fortis BC and TransLink. Computer modeling to understand the direct and indirect impacts of infrastructure disruptions on the economy, especially I-O modeling, is commonly mentioned in the literature on economic resilience planning (Bossello et al 2017; Chang 2016; Rose & Wei 2013). Most importantly, it can prevent losses to other businesses with even indirect linkages to the infrastructure failure. As a proactive approach, cascade analysis may allow for better preparedness and decision-making across a wide variety of scenarios and could also complement other land use planning, engineering, and economic resilience planning initiatives.

## KEY LIMITATIONS

- Firm-level response and recovery planning are limited in that only those that partake in it may benefit
- Often not enforceable

### **Economic Resilience Planning Case Study Example: Modeling impacts of supply chain resilience measures at Port Arthur & Beaumont sea ports in Texas**

Economic resilience actions will be most needed for industrial and port lands that are exposed to coastal flooding. The region of Port Arthur/Port Beaumont was heavily impacted by coastal flooding from Hurricane Harvey in 2017. However, a few years earlier, economists used Input-Output (I-O) modeling to assess the impacts of a 90- day port shutdown on the two seaports in this metropolitan region of Texas. The ports complete the first stage of refining raw material imports and then ship processed goods to other locations in the U.S. When the modeling exercise was completed, it led to an analysis of impacts, or losses, in imports and exports across various commodities and disruptions of on-site port operations.

The impacts from various scenarios were calculated based on a variety of “resilience actions”, better known as supply chain measures that could be enacted to better withstand the shutdown. Some of these resilience actions included ship re-routing, SPR, use of inventories, export diversion, conservation, production rescheduling. In addition, a base case (no resilience actions) scenario and “with all resilience adjustments” scenario were calculated. The total impact on regional output was estimated to be \$9.6 billion USD, corresponding to a reduction of 53.9% of all economic activity in Port Arthur MSA. It was found that the port shutdown for both ports led to BI losses of \$13 B USD, equivalent to 72.% of Port Arthur/Port Beaumont MSA total output for the given period. Resilience actions contributed to a reduction in losses by two-thirds and the most effective resilience strategies for the regional scale included production recapture and ship re-routing.

Read more: [Rose & Wei 2013](#)



Image source: [Axios.com](#)

## Tool Definitions

### Awareness Building Programs

programs to educate the public about flood hazard, vulnerability, and risk as well the provision of resources that can aid the public in making good decisions that about flood risk reduction

### Multi-stakeholder Engagement

Includes collaborations with business community, relevant community associations, etc.

## 05 & 06. PUBLIC EDUCATION/AWARENESS & MULTI-STAKEHOLDER ENGAGEMENT

The final category involves long-term, ongoing sea level rise engagement with infrastructure providers such as utilities, port and transportation authorities, and the business community. Public engagement would be accompanied by awareness building around business preparedness, alternate supply chains, local materials, markets, and employment.

### HIGHLIGHTS

**Awareness building programs could be used to educate the public more broadly on vulnerability and risk to flood hazards and encourage stakeholders to make better risk mitigation decisions and allocate resources sensibly.** Awareness building and multi-stakeholder engagement represent some of the most proactive approaches in the summary of tools and approaches provided. City of Surrey, through its CFAS 2016, and the City of Vancouver, through its CAP for the Fraser River Foreshore, have already utilized multi-stakeholder engagement to understand economic development challenges and opportunities around coastal flooding. The City of Surrey supported the formation of a CFAS Advisory Group. In the area of awareness building, the municipality has published educational materials such as a Flood Preparedness Guide for Businesses online. The City of North Vancouver has also taken an interest in awareness building.

**Multi-stakeholder engagement and public awareness could be used to present the various land use regulation, engineering, financial, and economic resilience planning options for public discussion and evaluation.** To plan for sea level rise, the Port San Diego developed partnerships with various local, regional, state, and federal government stakeholders as well as environmental/advocacy, economic/contractual stakeholders. Other relevant stakeholders might include the Chamber of Commerce, Board of Trade, industry associations, insurance groups, property owners' associations, utilities and transportation groups to plan for economic impacts. If well-coordinated, awareness building and multi-stakeholder engagement would ensure prevention of or resistance against flooding events or smooth recovery of businesses and industries on employment lands.

**Municipalities can provide publicly accessible materials to encourage firm-level response and recovery planning to boost economic resilience.** The academic literature reveals that firm-level preparedness actions can better enable businesses to return to normal operational capacity after a disaster event such as a flood. Although municipalities cannot control the actions of businesses, they can facilitate their preparedness through awareness building and provision of online materials. Examples of municipalities or other institutions providing targeted information on flood preparedness to businesses are Surrey's Flood Preparedness Guide for Businesses and the Institute for Catastrophic Loss Reduction's Open for Business Program.

### KEY LIMITATIONS

- No major limitations identified
- However, high coordination, strong engagement processes, and public access to materials and information, and involvement of the right stakeholders would improve effectiveness
- Firm-level response and recovery planning are limited in that only those that partake in it may benefit

## Public Education/Awareness Case Study Example: City of Surrey's Flood Preparedness Guide for Businesses

Businesses that have firm-level evacuation, response, and recovery strategies will be able to return to normal business operations faster, according to research done by Webb et. al 2000. Although municipalities cannot guarantee firm-level preparedness, which would prevent economic disruption from a disaster like flooding, they can provide online materials or businesses that guide the actions to prevent disruption and loss from a flood. An example of this is the City of Surrey, a flood-prone municipality due to its location between the Fraser River and the southern coast of British Columbia. City of Surrey has been proactive in engaging a variety of stakeholders around flood risk and disaster prevention. On its website, it published a Flood Preparedness Guide for Businesses that provides self-help resources on evacuation, doing a pre-flood inventory, and protecting equipment and minimizing property damage through flood proofing measures. The guide is mainly used for businesses in areas susceptible to seasonal flooding from freshet.

Read more: <https://www.surrey.ca/city-services/703.aspx>

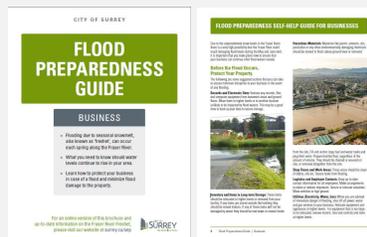


Image source: Surrey.ca

## Multi-stakeholder Engagement Case Study Example: City of Surrey's Coastal Flood Risk Strategy Engagement

In a municipality where the coastal flood plain takes up 20% of the total area, it is no wonder City of Surrey focused much of their coastal flood adaptation efforts on public and stakeholder engagement. City of Surrey held a series of focus groups and workshops and use seven values criteria in their decision making, such as infrastructure, economy, recreation, and more. Stakeholders, including residents, business owners, stakeholders, and partner organizations helped to co-develop these value criteria. Three integrated frameworks, including a Decision Support Framework, Stakeholder Engagement Framework and a Communications and Media Framework were jointly developed.

Read more: [https://www.surrey.ca/files/CFAS\\_Engagement%20Report\\_05092018.pdf](https://www.surrey.ca/files/CFAS_Engagement%20Report_05092018.pdf)



Image source: Surrey.ca

# INTERVIEWS: WHAT OTHER MUNICIPALITIES, PORTS, & AGENCIES ARE DOING

## KEY FINDINGS

Key informant interviews helped to generate information based on how other municipalities, agencies, and port authorities perceive sea level rise and its economic impacts and are taking action, especially with regards to employment areas. Please see Appendix B and see for more details.

## TOOLS DISCUSSED

**Based on findings from key informant interviews, engineering approaches consisting of hard flood protection, object elevation, and infrastructure system upgrades currently dominate.** While many of these flood protection measures may be necessary, particularly for industrial and port uses, structural flood defense has seen a high volume of criticism. Yumagulova & Vertinsky (2019) refer to the dominance of such structural protection tools as “engineering supremacy” (Yumagulova & Vertinsky 2019), due to their hidden costs to society through uneven distributional effects, negative ecological impacts, exacerbation of the flooding problem, and the creation of a false sense of security. Yumagulova & Vertinsky (2019) and their various academic predecessors recommend looking to integrated flood risk management that incorporates other knowledge systems (Yumagulova & Vertinsky 2019).

**Municipalities, ports, and agencies have also exhibited an interest in applying other planning approaches to employment lands, including multi-stakeholder engagement, public awareness, and economy resilience planning.** Some municipalities reported exploring nature-based solutions, such as soil structure innovations that provide multiple co-benefits as well as engaging in cleanup of soil and waterways on or near industrial lands. Multi-stakeholder engagement and public awareness also play a significant role in addressing sea level rise and broader climate change and resiliency concerns in employment areas. A good example of multi-stakeholder analysis can be found under City of Surrey’s [Coastal Flood Adaptation Strategy Project Engagement Summary](#), which involved technical criteria, stakeholder values evaluation, and iterative decision-making processes. In some cases, agencies and port authorities have embarked on economic resiliency initiatives that aim to diversify the local and regional economy or safeguard against infrastructure failure.

## CONCERNS AND CHALLENGES

**Approaches to coastal flooding should be sensitive to the unique geographical context.**

Municipalities, port authorities, and agencies are taking action in various ways, including raising objects, such as port terminals, installing storm water conveyance systems, and performing other structural upgrades, innovating using nature-based solutions, and educating and engaging businesses and infrastructure providers located in flood-prone areas. The unique geography, topography influences the types of coastal hazards present in each location. Therefore, no single approach can be used and approaches should be adapted based on local conditions and differential impacts even within a municipality.

**In the absence of grant funding, the question of “who pays” was a major concern for large projects.**

In many cases, the question around “who pays” has not been answered, but is of interest for municipalities. Some municipalities mentioned that cost-sharing was a point of discussion in stakeholder engagement meetings for flood protection projects. Municipalities often relied on grant funding from internal sources and higher levels of government to implement sea level rise and resiliency initiatives. While some of these funds were allocated toward disaster recovery, others are used to support climate change adaptation.

**Municipalities would like to see more consideration for distributional impacts and trends like green gentrification that may accompany adaptation projects**

Key informants from municipalities and agencies expressed concern about environmental justice and distributional impacts from both inaction and certain adaptation approaches to sea level rise. For example, an adaptation practitioner for City of Seattle articulated the need to protect industrial areas for economic diversification and as a source of middle wage jobs. The topic of green gentrification (see glossary) and displacement pressures from adaptation infrastructure emerged as a concern. Seattle and New York are seeking new opportunities for a thriving, green economy using awareness building around climate change, sea level rise, and resiliency. Through RISE: NYC, economic development planners in New York are targeting workers through artist-in-residence programs and other training opportunities, as well as generating local expertise with alternative, clean energy sources. Buffering against adverse impacts and remaining critical regarding “who benefits” will be the basis of adaptation decisions.

**Transportation and land use conflicts are major challenges when implementing engineering and flood protection measures in industrial and port areas.**

One concern for municipalities and port authorities is around ensuring that certain flood protection measures (e.g., temporary flood control) do not compromise businesses’ requirements for uninterrupted transportation (i.e., vehicle access for trucking and railways). Flood protection measures can also disrupt the urban fabric or render certain locations undesirable due to reduced visual quality. Planning ahead for transportation and land use conflicts is recommended. Although soft shoreline protection measures may produce fewer negative land use impacts than hard shoreline measures, they often require more physical space. Green infrastructure was also perceived by some key informants as being incompatible with certain land uses, especially busy port locations where barges and ships come in.

## FINANCING APPROACHES

**Municipalities and agencies rely on a variety of financing options, including external grants, internal financing, developer-driven finance, and capital budgets.**

The Port of Vancouver has various self-funded projects, especially for upgrades, and has also applied to federal grants from the Transportation Assets Risk Assessment (TARA), which supports climate adaptation work. City of Richmond engages in active budgeting to commit funds to flood protection annually. The municipality has a dedicated utility for drainage and diking upgrades and receives further grant funding from senior government and regulatory bodies tasked with local area or flood protection improvements. Developers also contribute to flood protection works as part of waterfront development. The City of Richmond plans to spend \$50 million in the next 5 years on flood management. Both Surrey and Richmond receive funding from the Disaster Mitigation and Adaptation Fund, a federal grant from Infrastructure Canada. Cost-sharing is used in the Cities of Surrey and Seattle. The City of Seattle is also looking to potential funding contributions through green bonds and involvement from the U.S. Army Corps of Engineers. In New York City, sea level rise planning initiatives can occur through a combination grant funding from the Rebuild By Design competition and federal disaster recovery funds from Hurricane Sandy, capital funding, and Community Block Grants for disaster recovery.

## ADAPTATION ACTIONS AND DECISION-MAKING

**Reliance on a variety of approaches, including development permit areas, innovative public awareness projects, and flood control works that promote public access and pedestrian safety**

The City of Surrey uses Development Permit Areas for Hazard Lands as a land use tool to protect assets from flooding. The City of Seattle is collaborating with a local software company and university system through the Climate Impacts Group to deliver sea level rise visualization and virtual reality opportunities for enhanced risk communication. Seattle will also engage in a berm (see glossary) strategy that ensures flood protection, public access, and industrial and business operations do not conflict. New York City’s Economic Development Corporation has embarked on an innovative resiliency and economic development program known as RISE: NYC, part of which involves ensuring that jobs and operations at a food distribution centre can continue even in the face of climate threats like sea level rise.

**Decision-making frameworks for multi-stakeholder engagement and quantitative analysis**

Various municipalities and agencies spoke about decision making frameworks and tools to implement sea level rise actions. Some examples include stakeholder engagement processes involving internal groups, advisory committees, and specialists to understand economic requirements and risk. The City of Surrey applied a structured decision-making process, a common process in planning and resource management, that involves clarifying the decision making context, developing objectives, creating influence diagrams, identifying alternatives and consequences, evaluating trade-offs, and monitoring and evaluating outcomes. Surrey also used the Triple Bottom Line module from the Planning Institute of British Columbia's Vulnerability Assessment to identify infrastructure owners' drivers in decision-making and outweigh different options. Technical criteria, stakeholder evaluation, and iterative decision-making all underpinned consultations for the Coastal Flood Adaptation Strategy. The New York Economic Development Corporation used a set of guiding principles that was to be agreed upon in different stages of the planning process. Benefit-cost analysis was another approach used in analysis, with co-benefits of adaptation efforts often factored into analysis. Finally, scenario planning using different time horizons and local sea level rise projections was a common approach used to make policy adjustments. The Port of Vancouver also expressed that any future site proposals or developments are considered based on long-term viability and will begin factoring in sea level rise.

**MOVING FORWARD****Enhanced collaboration with additional stakeholders, including other municipalities, regional governance or provincial bodies, and Indigenous groups**

Multiple municipalities and port authorities mentioned the need to collaborate with neighbours affected by flooding or flood protection work. Collaboration with developers of waterfront property was another approach used. In addition, municipalities in the Lower Mainland, like Richmond and Surrey, see benefits in engaging with other municipalities to discuss development and standards of practice. The Port of Vancouver actively participates in the Fraser Basin Council, a key convener and resource for organizations in the Lower Mainland, which contributes numerous studies, meetings, and presentations. The Port also engages in projects with municipalities along Metro Vancouver's North Shore, which did a sea level rise study led by Northwest Hydraulic Consultants. In the Seattle area, collaboration with the county, utility and regional watershed group that consists of both municipalities and Indigenous communities would be another growth opportunity with regards to sea level rise and flood management.

**Other future improvements regarding project implementation, financing, equity, and innovative and alternative flood protection or resilience solutions with multiple benefits.**

As an area for potential improvement, one key informant desired expediting timelines for flood management project implementation. An adaptation practitioner for the City of Seattle took interest in increased peer learning around financing options as well as in partaking in projects that involve green infrastructure and community resilience hubs. Planners and engineers at the Port of Vancouver expressed the desire for more collaboration and added that they would be interested in exploring other solutions, including nature-based, multi-benefit solutions for appropriate areas. These might include Green Shores or green infrastructure solutions. Key informants from City of Seattle and the New York Economic Development Corporation discussed the need to prevent adverse social impacts like displacement pressures and green gentrification, which transcend direct adaptation concerns.

## **STRENGTHS & LIMITATIONS**

While in the literature review stage, regulatory/land use and engineering appeared to be a common approach, engineering and multi-stakeholder engagement dominated as approaches in the key informant interviews. Equity issues were more prominent considerations among the key informant findings, as well as the financing question. A dominant theme was uncertainty around how cities should approach sea level rise planning in employment areas and more important, finance projects. The key informant interviews revealed the importance of a strong, collaborative, and iterative process driven by guiding decision-making frameworks. Decision- support tools were technical and values-based.

The methods of the key informant analysis could be critiqued and improved in future analyses. Among the strengths in the key informant interview process was the ability to hear perspectives across profession. Professionals engaged included planners, project managers, and engineers working for port authorities and municipalities as well as adaptation and economic development practitioners. One area for improvement would involve speaking to representatives across a larger geographic extent. Most respondents contacted were based in the Pacific Northwest region, including both the Lower Mainland of British Columbia and Washington State. This area represents an entirely different risk context from cities on the Eastern Seaboard or Gulf Coast, due to their geography, topography, and levels of urbanization and physical hazards present. In some areas, sea level rise is accelerating at a faster rate or flooding is more severe, and therefore, retreat might be considered as an option instead of protection. Future analysis could involve following up with key informants as projects progress or consulting key informants across a larger geographic extent.

# IMPLEMENTATION CONSIDERATIONS

## COSTS FOR ADAPTATION AND FUNDING AND REGULATORY MECHANISMS

The various tools and approaches will require funding mechanisms to support implementation. Considering cost might involve weighing the trade-offs in investing in policies or infrastructure changes versus inaction. An SFU ACT Report from 2015 considers the following items among others as important when considering decisions around investment: real estate taxes, insurance damages, renewal/upgrade savings, municipal investment, utilities investment, municipal operational costs, utilities operational costs, socio-economic co-benefits from ecologically focused adaptation approaches (e.g., worker productivity, health, safety, new job opportunities)

The City of Vancouver could seek internal financing such as tax increment funding and development cost charges and levies. In Vancouver, common financing mechanisms to implement flood protection include tax-based sources, such as capital funding and local area improvement taxes (i.e., LICs). Regulation-based financing tools include Community Amenity Contributions (CACs), a less defined financing tool that can be used to fund dikes and Development Cost Levies (DCLs), which are more specifically defined than CACs. DCLs could help pay for flood protection structures indirectly by financing transportation projects, for example, a bicycle and pedestrian pathway with a dike on top.

Regulation-based tools can be used to implement flood protection. Under the current subdivision bylaw, rezonings are the most powerful mechanism for implementing flood protection infrastructure. Subdivision requirements that mandate park provision for areas above 20 acres are a potential regulatory mechanism to accommodate flooding. Development Permits and Building Permits can also be issued under the condition that shoreline protection is provided or in exchange for maximizing density. Currently, this is a discretionary procedure, but it is moving toward a more clearly defined one. According to section 565(b) of the Vancouver Charter, development permit conditions can require applicants to provide flood management works to address flooding that results from that proposed development (Danyluk 2018). Minimum Flood Construction Levels are another mechanism; this is currently the approach used for the sea wall at False Creek.

Liaising with senior levels of government may be necessary to secure additional external funding, such as grant funding. Lastly, examining innovation programs such as local incentives and rebates or local improvement charges (LICs) is a third option.

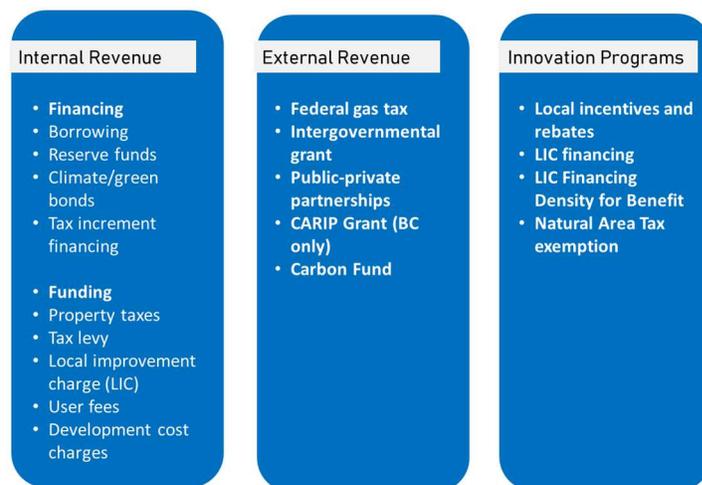


Figure 14. Funding Mechanisms for Flood Adaptation  
Adapted from: SFU ACT 2015

## **JURISDICTIONAL AUTHORITY**

When considering the tools and approaches for sea level rise, local government powers should be revisited. Municipalities have the greatest ability to influence protection of employment lands from sea level rise through regulatory or land use instruments. Most regulatory or land use instruments, like setbacks, land acquisition, and development permit areas, could be implemented at a local level. The Vancouver Charter also gives local government authority over engineering measures like the establishment of and updates to Flood Construction Levels. Financial tools that dictate how insurance programs are structured, such as “shifting to benefactors” would likely transcend the local government level. However, based on the Vancouver Charter, municipalities can take advantage of open-ended, non-prescriptive financial instruments like community amenity contributions to pay for flood management infrastructure, like dikes. Other approaches like rolling easements appear to occur on the jurisdictional level of the state/province.

## **FEASIBILITY BY LOCATION**

Technical and legal feasibility could also interfere with the implementation of the planning tools presented. Technical feasibility must be considered especially for engineering tools. For instance, building tune-ups within flood lands might not be appropriate in seismically active areas, as mentioned by Sinclair (2015). Decisions around flood protection must be carefully considered based on the land and the intention of use. In addition, land use policies for industrial lands may carry additional legal/tenure or use limitations and issues around use compatibility and parcel size.

## **EQUITY**

Distributional impacts on different locations, communities, and businesses warrant attention when evaluating different planning tools and approaches. Key concerns include displacement, for example when determining which areas, businesses, or property owners must retreat, which get to remain in place, and which have access to flood proofing or other flood protection measures. Business size or type may be an influencing factor. Perhaps water-dependent uses and heavy industrial areas will see more flexibility. With infrastructure projects, different areas may benefit from infrastructure, while others feel the negative land use or economic impacts. The question of who will pay for flood protection or what kinds of support mechanisms can be in place to facilitate relocation or recovery should be considered. There is also equity issue of prioritization of industrial uses, as manufacturing and warehousing contribute to important middle income jobs. Another phenomenon that is increasingly seen in cities, especially in the context of resiliency and adaptation planning, is green gentrification and environmental justice. Adaptation and resiliency projects should avoid increasing social conflicts or undo attempts to ‘right historical wrongs’, particularly in areas of historical disinvestment.

## OTHER CRITERIA:

Another important distinguishing factor is whether the approaches are long-term plans or short-term adjustments. Most land use tools might be embedded in a long-range planning, whereas physical adjustments to buildings like flood proofing would be considered a short-term tool. Some planning tools may also require more effort to implement than others. Monitoring and evaluation is recommended for any planning tools that are implemented to ensure their effectiveness over time.

Planning tools can also be chosen based on the adaptation action evaluation criteria provided in the Vancouver Climate Change Adaptation Strategy 2018, displayed below, as well as other considerations like funding, priority, accountability, and effort.

The City of Vancouver can ensure these criteria are considered through effective public engagement.

**Table 5: Other Criteria for Adaptation Project Implementation**

Category	Criteria
<b>Sustainability</b>	Mitigation co-benefits Equity Implementation cost
<b>Effectiveness</b>	Robustness
<b>Risk and uncertainty</b>	Urgency
<b>Opportunity</b>	No-regret Window of opportunity Funding sources
<b>Implementation</b>	Institutional

Adapted from: City of Vancouver 2018

## FIRST NATIONS RELATIONS:

As actions to protect the employment lands from sea level rise take place on the territory of the Musqueam, Tsleil-Waututh and Squamish, there are additional planning considerations regarding First Nations relations. Most interventions on the shoreline should account for historic and archaeological sites. First Nations land use and management practices are reflected in the archaeological record as well as in ethnographic and oral histories. These are all important considerations to planning strategies around land management. Hosting one or more workshops with local First Nations (MST) should inform future planning. Early engagement with the First Nations will also be important to provide a cultural and ecological perspective. Many First Nations have economic development departments and business partnerships that could also be a variable worth considering.

## CONCLUSIONS AND NEXT STEPS

This project aimed to identify a range of policies and tools that may be used to address sea-level rise in Vancouver's employment areas. This involved a literature review and key informant interviews that comprised a larger, qualitative review of best practices in planning for sea level rise that are being used in Metro Vancouver and elsewhere. This work can help inform work being done for the City of Vancouver's Employment Lands & Economy Review.

The literature review revealed a wide variety of tools that can be categorized into six key themes: regulatory/land use, engineering, financial, economic resilience planning, multi-stakeholder engagement, public education/awareness. Additionally, the review revealed the site-specific and municipal and regional consequences of inaction to sea level rise, including adverse land use and economic impacts.

Some key challenges for their implementation of these tools in employment lands relate to administrative complexity in industrial lands, reduction in land use flexibility, land value, or physical loss, cost, equity, and other trade-offs commonly found in adaptation planning. However, key opportunities from the implementation of these tools would arise as well, including increased resilience for businesses and the local economy as whole, stronger partnerships, and the creation of new economic opportunities.

The key informant interviews revealed concerns and challenges other municipalities, port authorities, and agencies are grappling with around sea level rise planning for industrial and port areas. Some concerns related to uncertainty around financing, suitability to the geographical context, and transportation and land use conflicts from flood protection. A variety of tools were used that spanned the six categories from the summary of tools and approaches. In addition, innovative programs were mentioned that could be of interest to the Employment Lands & Economy Review team. Other jurisdictions mentioned interest in enhanced collaboration, learning about financing, and expediting adaptation planning projects in the future. Finally, other implementation considerations were gleaned from the best practice review related to equity, locational feasibility, cost and financing, and First Nations relations.

The project involved some reflection on the limitations and strengths of the different processes, the literature review, summary of tools, and the interviews. A strength of the interviews was the ability to hear perspectives from various professionals spanning engineering, planning, and economic development. Different types of tools dominated in each stage of the project. For example, land use/ regulatory and engineering tools seemed to dominate in the literature review, but engineering tools and multi-stakeholder engagement dominated in the interviews. Other common themes around financing and decision-making frameworks were also identified. Future research in this area would include selecting respondents from a larger geographic area, where the rate of sea level rise and types of coastal flooding differ.

Based on the best practice review, next steps have been identified in the following table. These next steps are intended to be open-ended and flexible, depending on the work that is done.

Category	Next Steps
<b>Guiding Frameworks &amp; Tool Selection</b>	<p><b>1.1.</b> Using PARA framework and Vancouver’s Sea Level Rise Planning Framework to facilitate decision-making around which tools to use and which areas to prioritize to make coastal adaptation decisions for employment lands</p> <p><b>1.2.</b> Maintaining a site or use-specific lens when implementing tools, as the land and intention of use will have an impact of the effectiveness and appropriateness of the tool in a given area</p> <p><b>1.3.</b> Look to integrated flood management to manage sea level rise risks while overcoming engineering supremacy</p>
<b>Funding and regulatory mechanisms</b>	<p><b>2.1.</b> Reviewing all available tax-based and regulatory instruments for financing and implementation in the Vancouver Charter and Dike Maintenance Act, including CACs, DCLs, capital funding, LICs, subdivision requirements for park provision, etc.</p> <p><b>2.2.</b> Exploring existing and potential innovation programs for financing flood management infrastructure or facilitating land use change (e.g., transfer of development rights or other incentive programs, tax exemptions, and local improvement charges)</p> <p><b>2.3.</b> Liaising with other levels of government to seek external financing where relevant. Funding can be sought for climate change adaptation, disaster recovery, transportation through public-private partnerships, federal grants from Infrastructure Canada, and other sources.</p>
<b>Other Implementation Factors</b>	<p><b>3.1.</b> Consulting local First Nations and the Heritage Conservation Act registry for archaeological or historic sites prior to beginning any planning work on the shoreline. Liaising with Engineering Archaeologist in Engineering Services at the City of Vancouver for further information.</p> <p><b>3.2.</b> Considering jurisdictional powers, administrative complexity, and locational feasibility when choosing planning tools over others, which may entail evaluating planning tools in collaboration with Engineering Services, the Resilience Office, Law Department, and other departments</p> <p><b>3.3.</b> Maintaining an equity lens in any future work on sea level rise to account for differential impacts, displacement, phenomena like green gentrification, participation of relevant stakeholders, and diverse knowledge systems, and guide prioritization. An equity lens will help buffer against adverse impacts and help planners remain critical around “who benefits”</p> <p><b>3.4.</b> Reducing costs by incorporating sea level rise upgrades into existing project upgrades, but also planning with long-term climate change impacts in mind</p>

**Collaboration**

**4.1.** Forming external partnerships with infrastructure providers, utilities, First Nations, port authority, businesses, regional watershed councils, etc.

**4.2.** Forming internal partnerships with relevant departments, including Sustainability and Engineering Services for issues related to flood management and financing of flood protection works

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**Technical Analysis**

**5.1.** Understanding the different direct and indirect economic impacts, such as effects on property values and assets, and quantifying economic impacts in specific areas and infrastructure facilities

**5.2.** Including both loss data and gains from co-benefits into quantification of risk and risk reduction

**5.3.** Using scenario planning as an approach based on local and provincial sea level rise projections and any relevant scientific upgrades

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**Innovation**

**6.1.** Identifying potential co-benefits for infrastructure and land use projects, including recreational, ecological, public access, and economic opportunities

**6.2.** Integrating sea level rise planning into other innovative programs that promote a green economy and resiliency. A good example is RISE: NYC.

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## GLOSSARY OF TERMS

**Adaptation:** In human systems, adaptation is the process of adjustment to actual or expected climate change and its effects, in order to moderate harm or exploit beneficial opportunities. With respect to sea level rise, adaptation refers to action taken to prepare for its occurrence (CFRA Phase 2 definition)

**Adaptation strategy:** a guiding overall philosophy to developing initial adaptation alternatives; alternatives could, in a first iteration, be designed to protect from, adapt to, or retreat from flood risk. More sophisticated alternatives could later be developed that combine these approaches once learning about their effectiveness has occurred (CFRA Phase 2 definition) ]

**Acquisition of developed land:** buy out of property using public funds to sterilize area, thereby decreasing future assets at risk (CFRA Phase 2)

**Acquisition of undeveloped land:** buy out of property and buildings using public funds to sterilize area, thereby decreasing future assets at risk (CFRA Phase 2)

**Barrier island:** construction of surface “islands” offshore. These are designed to absorb wave energy, therefore reducing the need for erosion protection on the shore. They can also reduce the required height for dikes or sea walls (CFRA Phase 2)

**Beach renourishment:** placement of loose sediment near shore, which is designed to reduce erosion rates (CFRA Phase 2)

**Berm:** a flat strip of land, raised bank, or terrace bordering a river or canal

**Breakwater:** are structures constructed near the coasts as part of coastal management or to protect an anchorage from the effects of both weather and longshore drift. (Wikipedia)

**Building code/ controls:** provisions in code to increase flood resistance of new buildings through the use of flood-proofing of exterior and ground floors, elevation of mechanical equipment, ground floor elevation above base flood elevation, or other property-level protections (CFRA Phase 2; SPUR 2019)

**Cascade analysis:** used to understand the interrelations between infrastructure failures across a city or region; for example, if done locally, stakeholders such as BC Hydro, Fortis, TransLink and the Port could be convened

**Clustering:** a zoning strategy whereby buildings are grouped together to preserve larger areas for habitat, green infrastructure, and open space (SPUR 2019)

**Co-benefits:** added benefits we get when we act to control climate change, above and beyond the direct benefits of a more stable climate; also known as multiple benefits or multi-benefits (the Climate Bonus)

**Complete community:** Neighbourhood with—and in proximity to—a range of different uses and activities, providing convenient opportunities to live, work and play. (District of West Vancouver’s OCP)

**Computer modeling:** may include modeling techniques used in urban and regional economics such as input-output modelling, which consider inter-industry linkages, and computable general equilibrium (CGE) modeling to evaluate impacts from disaster events. These modeling approaches can be used to conduct cascade analysis to understand infrastructure system disruptions and quantify the magnitude of economic impacts (see Chang 2016 for more information)

**Community amenity contribution:** in-kind or cash contributions provided by property developers when City Council grants development rights through rezoning. The demand on City facilities increases with rezonings, because of new residents and employees in the area (City of Vancouver)

**Constructed wetland:** wetlands can be constructed offshore or on the existing shore with the goal of absorbing some of the wave energy during coastal storm events (CFRA Phase 2)

**Covenant on title:** requirement that flood hazard be disclosed on property title (CFRA Phase 2)

**Critical infrastructure:** “systems and assets, whether physical or virtual...so vital that the incapacity or destruction of such systems or assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters” (NIPP p. 29 as cited by Chang 2016 p 2)

**Development Cost Levy (DCL):** collected from development help pay for facilities made necessary by growth. Facilities eligible for DCL funding include: parks, child care facilities, replacement housing (social/non-profit housing), and engineering infrastructure (City of Vancouver)

**Development Permit Area (DPA):** Designated land where guidelines direct development to address special conditions or objectives such as the natural environment, hazardous conditions, commercial revitalization, form and character, energy and water conservation, and GHG emissions reduction. (District of West Vancouver's OCP)

**Dry resistance floodproofing:** products or actions deployed with appropriate warning times, designed to stop water from entering buildings through existing openings through existing openings or by penetrating walls (COV CFRA Phase 2)

**Dune rebuilding:** placement of loose materials offshore to mimic natural dunes that provides a buffer between ocean and shore (COV CFRA Phase 2)

**Economic incentive to relocate:** until there is a flood, individual property owners have no incentive not to live in a floodplain. Economic (not insurance-based) options to incentivise home-buyers to buy outside the floodplain are not commonly used today, but could be implemented in the future. Further, as sea levels rise and the hazard increases, the value of homes in the floodplain may decrease as awareness around the risk and impacts of flooding increase (COV CFRA Phase 2)

**Economic resilience planning:** could include tools and approaches such as business response and recovery planning, quantifying supply chain impacts from environmental disruptions such as flooding or sea level rise and developing plans to respond accordingly, or developing economy-wide plans related to land use to minimize risk to infrastructure and industries

**Environmentally-sensitive area:** Site that has—or with remedial action could reasonably achieve—desirable Environmental attributes worthy of special care to benefit soil, water, vegetation, wildlife or other ecological functions. (District of West Vancouver's Official Community Plan)

**Erosion:** The removal of sediments or materials from a beach by natural forces such as waves and currents (District of West Vancouver SPP)

**Exposure:** refers to the state of elements at risk being exposed to contact with something, such as a coastal flood event (CFRA Phase 2)

**Green infrastructure:** Strategies that provide or support ecosystems, such as green roofs, bioswales, daylighting watercourses, use of permeable surfacing, and natural landscape treatments (District of West Vancouver's Official Community Plan)

**Green Shores:** an approach that provides ecological friendly solutions for shoreline development

**Groins:** A stone breakwater which runs along the beach, perpendicular to the shoreline, to prevent erosion (District of West Vancouver's Shoreline Protection Plan)

**Flood construction level:** establishes the minimum elevation for habitable buildings in relation to anticipated flood levels. In BC, a FCL may be set by a local government as per s.910 of the *Local Government Act*, in accordance with the FHALUMG (Sinclair 2015)

**Foreshore:** The area of shoreline between the high water mark and low water mark. (District of West Vancouver's SPP)

**Hard erosion control:** can include riprap and dolos (COV CFRA Phase 2)

**Green gentrification:** a process whereby providing green amenities or eliminating environmental bads like pollution can increase local property values, attract wealthier residents to a neighbourhood that was previously disenfranchised or polluted, and cause displacement or conflict (adapted from Wikipedia)

**Land reclamation (placement of fill):** the filling in of what is currently ocean to protect inland areas and create new land (CFRA Phase 2)

**Land use regulation:** could include zoning bylaws, development permit areas (DPAs), or other options used to regulate land use within the floodplain with the aim of reducing vulnerability and risk. (COV CFRA Phase 2)

**Local improvement charge:** costs that are shared between property owners and the city when street or neighbourhood improvements are made (City of Vancouver)

**Naturalization:** a process by which the shoreline is made more congruent to shoreline conditions (e.g., via substitution of grey infrastructure with green infrastructure) – District of West Vancouver Shoreline Protection Plan)

**Network redundancy:** a process by which additional instance of network equipment, structures, or corridors are added within network infrastructure to ensure availability of the network in case of failure (Technopedia)

**Non-structural:** non-physical adaptation approaches like financial incentives and disincentives that could help implement structural or policy measures and permits, zoning and general plans that affect land use and risk management in the built environment (SPUR 2019)

**PARA Framework:** based on an abbreviation for Protect, Accommodate, Retreat, Avoid (Sinclair 2015)

- Protect (resist) involves building structures to keep floodwater out and protect areas and community assets (e.g., shoreline and inland dikes, offshore protection measures to reduce wind and wave impacts) (CAP for Fraser River Foreshore)
- Accommodate (adapt) is an alternative to keeping floodwater out and is an attempt to keep community assets dry when flooding occurs or be able to manage temporary flooding (e.g., object raising, design standards for construction, such as wet- or dry- flood proofing) (CAP for Fraser River Foreshore)
- Retreat (move) involves planning for the eventual relocation of people and assets in high exposure, high risk areas (e.g., naturalizing pre-development land, relocation incentives)
- All (combination) involves a combination of protect, accommodate, and retreat options to attain values like habitat conservation, recreation, and livability, and reduce economic losses (CAP for Fraser River Foreshore)

**Policies and premiums (insurance):** homeowners are provided with incentives (reduced premiums) for buying outside the floodplain or by implementing property-level protections if they live within the floodplain. And when a flood occurs, insurance payouts can be used to partially recover losses (COV CFRA Phase 2)

**Public awareness/ education:** programs to educate the public about flood hazard, vulnerability, and risk as well the provision of resources that can aid the public in making good decisions that about flood risk reduction (CFRA Phase 2)

**Object elevation:** the elevation of an individual building above the flood level through use of fill, stilts, or other structural means (CFRA Phase 2)

**Relocation:** moving of assets (buildings, businesses, and people) or infrastructure (roads, services) out of flood-prone areas (CFRA Phase 2)

**Response and Recovery planning:** programs or systems that are in place ahead of a flood event that will ensure a rapid post-event recovery (CFRA Phase 2)

**Resilience:** the capacity to anticipate, prepare for, respond to, and recover from the effects of sea level rise with minimum damage to social wellbeing, the economy, and the environment (CFRA Phase 2)

**Responsibility shifting to sponsors:** At present, in Canada, where overland flood insurance is not widely available, the monetary cost of catastrophic flooding is mostly borne by the Federal Government through the Disaster Financial Assistance Arrangements (DFAA). Local residents are generally provided monetary assistance through this program, and therefore do not have a direct incentive to reduce their individual risk (through moving out of the floodplain, or by implementing property-level protections). Changes to the DFAA could better re-align the responsibility and liability. (CFRA Phase 2)

**Right to Flood:** legal requirement that land be allowed to flood during high-water conditions (CFRA Phase 2)

**Riprap:** Loose broken stone or rock that creates shoreline defences and breakwaters.

**Risk:** vulnerability multiplied by exposure (CFRA Phase 2)

**Rolling easements:** A regulation of or interest in land in which a property owner prevents real estate from eroding or being submerged and submits to the public or environmental interest by allowing wetlands, beaches, or access along the shore to migrate inland (Seattle Office of Sustainability and Environment 2017)

**Setback:** mandates a minimum distance of a habitable building from coastal hazards (Capital Regional District); distance is based on erosion rates and size and life expectancy of the existent structure (SPUR 2019)

**Soft erosion control:** Can include constructed wetland, dune rebuilding, natural erosion control, beach renourishment, barrier island, and involves the placement of natural erosion-control measures such as wood and grasses. This can reduce wave energy and flooding impacts (COV CFRA Phase 2)

**Stormwater management:** Building and site design to mitigate reduction in infiltration from development (District of West Vancouver's Official Community Plan)

**Structural:** physical, man-made adaptation methods that lead to coastal hazard and flood management protection, often using hard materials like concrete, rock and steel as opposed to "soft", biological materials (SPUR 2019)

**Subdivision:** division of land into multiple lots (District of West Vancouver's Official Community Plan)

**Supply chain measures:** can include ship rerouting, shifting to other ports, export diversion via other transportation modes, conservation, unused capacity, substitution of inputs, recapture post-port opening, production rescheduling)

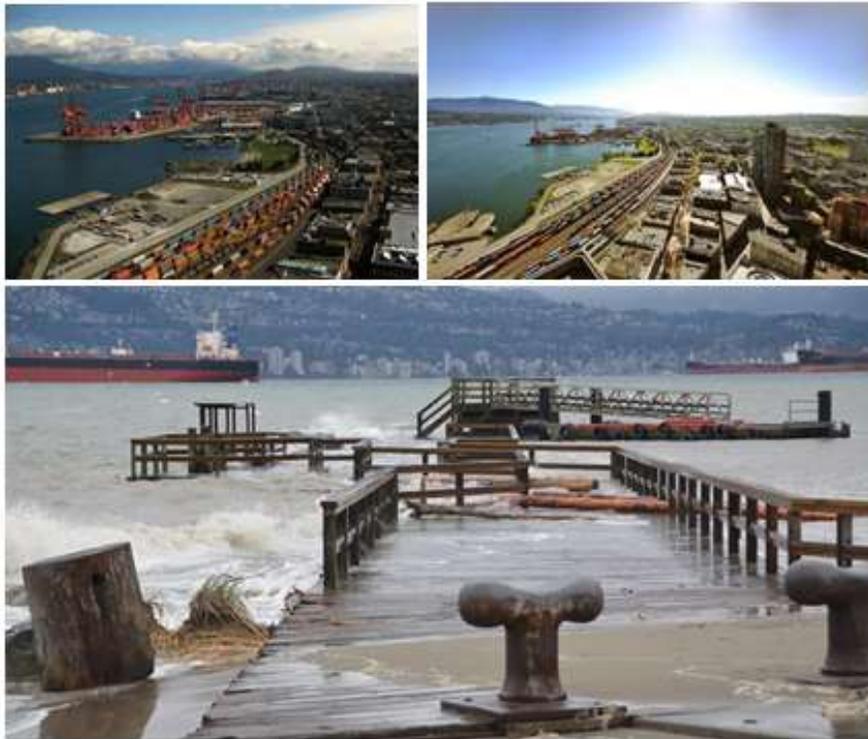
**Transfer of development rights:** transfer of allowable development potential to another location outside the floodplain (CFRA Phase 2); property owners in "sending" areas can sell development credits in exchange for a conservation easement on their property and forgoing additional development (SPUR 2019)

**Vulnerability:** the degree to which a system is susceptible to the adverse climate change effects, including variability and extremes. As seen below, it is a function of exposure, sensitivity and adaptive capacity (Vulnerability = exposure x sensitivity x adaptive capacity)

**Wet resistance flood proofing:** building design and construction aimed at allowing floodwaters, but minimising damage. The use of flood-tolerant building materials (e.g., waterproof replacement for drywall) are an example of this option. (COV CFRA Phase 2)

**Wetland:** Land flooded with water for enough time to promote aquatic processes, demonstrated by poorly drained soils and biological activity adapted to a wet environment, such as a bog, marsh, swamp or riparian area (District of West Vancouver's Official Community Plan)

# APPENDICES



## APPENDIX A. KEY INFORMANTS

Municipality	Abbreviation	Key Informant
City of Vancouver	COV	Sustainability Specialist Planner Engineering Archaeologist Engineer
Port of Vancouver	POV	Asset Management and GIS Integration Specialist
Port of Seattle	PSE	Senior Planner
City of Seattle (Seattle Public Utilities)	CSE	Climate Advisor
City of Richmond	COR	Engineering Project Manager
City of Surrey	CSU	Sustainability Planner
New York City Economic Development Corporation	NYCEDC	Project Manager

## APPENDIX B. QUESTIONNAIRE

Name:

Position:

Agency/Municipality:

Date:

Questions:

- What types of coastal hazards are you currently facing?
- What are your biggest concerns and challenges regarding sea level rise related to the economy/employment lands?
- How do you think sea level rise will impact your long-range plans?
- What is your municipality/agency doing to analyze and mitigate the economic impacts from sea level rise now and in the future?
- What would you like to see done more?
- What decision-making models or frameworks do you use when considering policy options?
- What funding mechanisms are you using?
- What is the time horizon for financing and implementing any sea level rise projects?
- What further collaboration is needed between governments and other partners?
- Could you provide any additional contacts for further reference?

# APPENDIX C. RESULTS FROM QUESTIONNAIRE

## APPENDIX C1: FINDINGS BY TOPIC

**Abbreviations:** POV: Port of Vancouver; PSE: Port of Seattle; CSE: City of Seattle; COR: City of Richmond; CSU: City of Surrey; NYCEDC: New York City Economic Development Corporation

Topic	Finding
Coastal Hazards Faced	<ul style="list-style-type: none"> <li>• Sea level rise</li> <li>• Other hazards exacerbated by climate change: king tides, storm surge, and wave impacts, extreme rainfall, freshet, urban flooding</li> <li>• Other coastal hazards: erosion, damage to the shoreline and impacts on infrastructure</li> <li>• Differential coastal hazards and impacts by location (e.g., COR)</li> </ul>
Concerns and challenges	<ul style="list-style-type: none"> <li>• Topographical and geographical conditions (flat &amp; close to sea level, land subsidence issues, adjacent to rivers or waterbodies) (CSE, CSU, COR)</li> <li>• Exposure of low-lying industrial lands to sea level rise and riverine flooding, which could get inundated on an episodic basis by 2050 and more consistently by 2150 (CSE)</li> <li>• Historical dredging and straightening of waterbodies and industrial lands on areas historically susceptible to flooding (CSE)</li> <li>• Contamination of water and soil in industrial areas which prolongs and increases costs for flood protection and construction work (CSE)</li> <li>• Who Pays question</li> <li>• Flooding impacts on local electricity grid and effect of power outages on the local economy (e.g., food distribution centres that require refrigeration)</li> <li>• Considering non-structural measures (policy, bylaw, strategies, land-use and local area plans that are part of the municipality's flood protection program (COR)</li> <li>• Vulnerability to long duration events (CSU)</li> <li>• Developed areas, areas of special cultural value that require protection</li> <li>• Concerns for agricultural land</li> <li>• Ports are busy sites, so planning for sea level rise is essential</li> <li>• Many independent businesses in port areas that are typically not the owners of the land (POV)</li> <li>• Difficulty of dealing with sites that have been around for a long time that are right on the shoreline (POV)</li> <li>• Undesirability of being behind a dike wall</li> <li>• Transportation disruptions produce the greatest indirect economic impacts (CSU)</li> <li>• Agricultural employment in Lower Mainland (e.g., washing facilities) is especially vulnerable to coastal hazards (CSU)</li> <li>• Businesses outside of active flooding that are less accustomed to flooding</li> <li>• Difficulty for businesses to be prepared for ongoing flood threat, whereas with seasonal risk, it is easier to be prepared</li> <li>• Direct conflicts between flood management infrastructure, especially temporary flood control, and requirement for businesses to have uninterrupted transportation (e.g., vehicle access, railways)</li> <li>• Water-dependent facilities that require access to water, making land use tools like setbacks challenging to implement in these areas</li> <li>• Displacement pressures from drainage projects and desire to mitigate negative social impacts</li> </ul>
Impacts on long-range plans	<ul style="list-style-type: none"> <li>• City of Richmond recently established flood protection measures in 2019, which influence long-range planning</li> </ul>

Topic	Finding
	<ul style="list-style-type: none"> <li>• City of Surrey is working on a sea level adaptation strategy which will be published in 2019</li> <li>• Sea level rise will affect the Official Community Plan, design criteria manuals, tenure management proposals, etc. (CSU)</li> <li>• City of Seattle will embark on an Industrial &amp; Maritime Strategy which incorporates sea level rise and other climate change impacts; the city wants to protect industrial/manufacturing jobs as a contributor to middle wage jobs that help diversify the economy</li> <li>• Freight Master Plan and other modal master plans and capital investments which will consider sea level rise impacts (CSE)</li> </ul>
<b>Actions to analyze economic impacts or mitigate negative economic impacts</b>	<ul style="list-style-type: none"> <li>• Considering economic impacts in planning decisions (CR)</li> <li>• Taking advantage of major renewal projects to do upgrades in the port (POV)</li> <li>• Incorporating sea level rise considerations and risk reduction on a project-by-project basis (POV)</li> <li>• Difficulty collaborating with organizational bodies with different jurisdictional requirements (POV)</li> <li>• Engaging the public in planning for flood protection infrastructure, sea level rise, and climate change (COR, CSU)</li> <li>• Ensuring neighbors are minimally affected in cases of land elevation or other protection measures applied (COR)</li> <li>• Benefit-cost ratio (CSU)</li> <li>• Development Permit Area for Hazard Lands (CSU)</li> <li>• Collaboration with local software company and university system through Climate Impacts Group focused on sea level rise visualization and virtual reality experiences to communicate risks (CSE)</li> <li>• County-wide project that is designing community resilience hubs and green storm water infrastructure to respond to climate threats (CSE)</li> <li>• Considering floodable open space as an option (CSE)</li> <li>• Increasing public access, pedestrian and cyclist safety, and reducing conflicts with local industrial businesses through a walkway as part of the Berm Strategy (CSE)</li> <li>• Quantifying co-benefits in benefit-cost analysis, including health, air quality, local economic development, and resiliency considerations (CSE, NYCEDC)</li> </ul>
<b>Plans, policies, and strategies used (for municipalities)</b>	<ul style="list-style-type: none"> <li>• Short &amp; long-term strategies with long time horizons (~75 years)</li> <li>• Master plans for short-term and long-term development strategies that are geographically based</li> </ul> <p><b>City of Richmond (CR)</b></p> <ul style="list-style-type: none"> <li>• Bylaw 8204 Flood Construction Bylaw</li> <li>• Flood protection measures established in 2019</li> <li>• Flood Protection Management Strategy- moving into details and working with consulting groups to mitigate any conflicts and inconsistencies</li> <li>• Dike Master Plan being actively pursued</li> </ul> <p><b>City of Surrey (CSU)</b></p> <ul style="list-style-type: none"> <li>• Development Permit Area for Hazards Lands</li> <li>• Ongoing Coastal Flood Adaptation Strategy</li> </ul> <p><b>City of Seattle (CSE)</b></p> <ul style="list-style-type: none"> <li>• New comprehensive adaptation plan for 2023 that builds off existing Climate Preparedness Plan</li> <li>• Industrial &amp; Maritime Strategy</li> <li>• Freight Master Plan</li> <li>• Duwamish Valley Program: South Park industrial area exploration</li> <li>• Other modal master plans</li> </ul>

Topic	Finding
	<ul style="list-style-type: none"> <li>• Berm strategy (pedestrian walkway)</li> </ul> <p><b>New York City Economic Development Corporation (NYCEDC)</b></p> <ul style="list-style-type: none"> <li>• RISE : NYC Program (<a href="https://www.nycedc.com/program/rise-nyc">https://www.nycedc.com/program/rise-nyc</a>), a program that uses emerging technologies and disaster recovery funds to improve the resiliency of small businesses in New York, align with long-term city-wide resiliency efforts, and strengthen the City's small businesses and tech entrepreneurship sector</li> </ul> <p><b>Port of Vancouver (POV)</b></p> <ul style="list-style-type: none"> <li>• Land Use Plan</li> <li>• Upgrades on a project-by-project basis</li> </ul> <p><b>Port of Seattle (PSE)</b></p> <ul style="list-style-type: none"> <li>• Long-term Strategic Plan</li> </ul>
<b>Decision-making models or frameworks used (for agencies)</b>	<ul style="list-style-type: none"> <li>• Thorough internal stakeholder engagement processes, involving internal groups (e.g., Building Licensing/Approvals, Development, Flood Safety), advisory committees, specialists to understand economic requirements and risk (COR, CSU)</li> <li>• Benefit-cost ratio constitutes analysis, often with quantification of co-benefits (COR, CSU, CSE, NYCEDC)</li> <li>• Internal decision analysis framework, consisting of own proprietary process for weighing risk factors (CSE)</li> <li>• Stakeholder meetings to understand economic requirements &amp; risk (COR, CSU)</li> <li>• Adjusting policy based on climate change scientific updates (CF)</li> <li>• Structured decision-making (CSU)</li> <li>• PIBC Vulnerability Assessment: Triple Bottom Line Module to identify drivers in decision-making from infrastructure owners and consider different options (CSU)</li> <li>• Scenario planning based on different timelines and state/provincial sea level rise projections (CSU, PSE, NYCEDC)</li> <li>• Technical criteria, stakeholder values evaluation, and iterative decision-making processes in stakeholder consultations (see <a href="#">Coastal Flood Adaptation Strategy Project Engagement Summary</a> (CSU, NYCEDC))</li> <li>• Guiding principles for project implementation (NYCEDC)</li> </ul>
<b>Dominant Categories Used</b>	<ul style="list-style-type: none"> <li>• Engineering, Land use/regulatory, multi-stakeholder engagement (COR)</li> <li>• Engineering, Land use/ regulatory, public education/awareness, multi-stakeholder engagement (CSU)</li> <li>• Engineering, multi-stakeholder engagement, public engagement/ awareness (CSE)</li> </ul>
<b>Specific Tools Used</b>	<p><b>Engineering</b></p> <ul style="list-style-type: none"> <li>• Object or area elevation</li> <li>• Diking upgrades</li> <li>• Considering sea level rise alongside facility design alongside regular upgrades</li> <li>• Super dikes</li> <li>• Storm water system improvements (e.g., storm water conveyance installations,</li> <li>• Major terminal upgrades for ports</li> <li>• Flood construction levels for buildings</li> <li>• Flood proofing structures</li> <li>• Nature-based solutions</li> <li>• Soil structure innovation (via microbial treatment) for structural strengthening, flood protection, and foreshore stability (CR)</li> <li>• Decontamination of soil and water</li> </ul> <p><b>Land use/Regulatory</b></p>

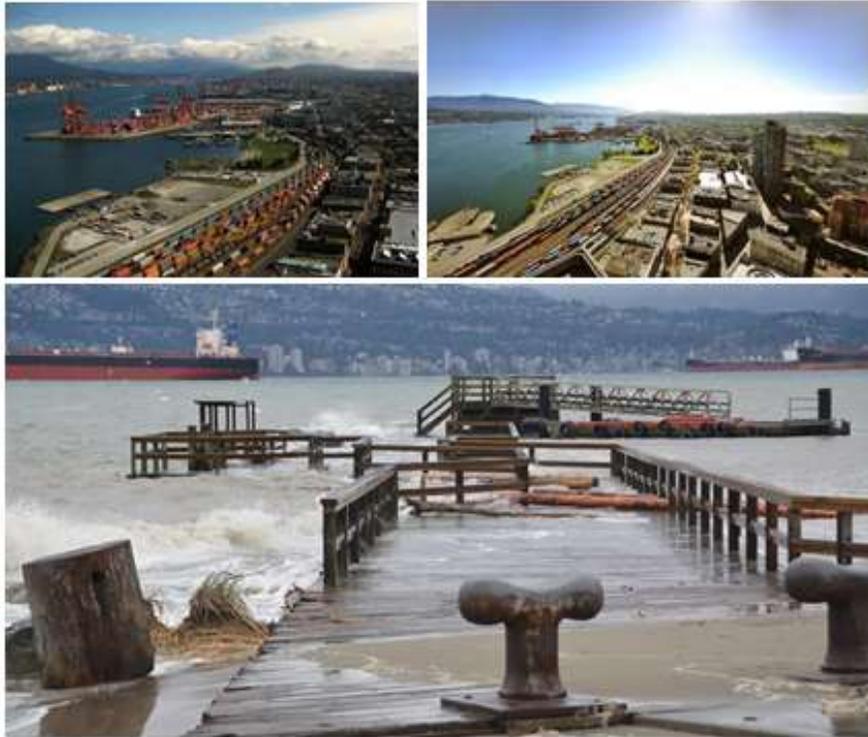
Topic	Finding
	<ul style="list-style-type: none"> <li>• Floodable open space (considered by CSE)</li> </ul> <p><b>Multi-stakeholder engagement</b></p> <ul style="list-style-type: none"> <li>• Collaboration with other agencies, locally and regionally (CSE, COR, CSU, POV)</li> <li>• Consultations with relevant stakeholders</li> <li>• Participation in cross-governmental councils</li> </ul> <p><b>Financing</b></p> <ul style="list-style-type: none"> <li>• External financing via federal and disaster recovery grant funds</li> <li>• Internal financing via capital funding and community block grant disaster recovery funding</li> <li>• Innovation programs (e.g., community block grants)</li> </ul> <p><b>Public education/ awareness</b></p> <ul style="list-style-type: none"> <li>• Training programs and artist-in-residence program (part of RISE : NYC) and awareness building about green economy, climate change, and resiliency</li> <li>• Public workshops</li> </ul> <p><b>Economic resilience planning</b></p> <ul style="list-style-type: none"> <li>• Economic diversification (clean energy and technology jobs)</li> <li>• Alternative energy sources to buffer against energy grid disruptions</li> <li>• Computer modeling for ports</li> </ul>
<b>Funding mechanisms used</b>	<ul style="list-style-type: none"> <li>• Active budgeting to commit set amount of funding per year to flood protection planning (COR)</li> <li>• Dedicated utility for drainage and diking that funds upgrades (COR)</li> <li>• Grant funding from senior government and regulatory bodies tasked with local area or flood protection improvements (COR)</li> <li>• Funding from Disaster Mitigation &amp; Adaptation Fund (COR, CSU)</li> <li>• Spending \$50 M in next 5 years (COR)</li> <li>• Funding from Transportation Assets Risk Assessment (POV)</li> <li>• Grant funding from Rebuild By Design competition and Hurricane Sandy disaster recovery funds (NYCEDC)</li> <li>• City capital funding and Community Block Grant Disaster Recovery Funds (NYCEDC)</li> <li>• Developers contribute to flood protection efforts in exchange for developing waterfront properties (COR)</li> <li>• Cost-sharing used (CSU) or considered (CSE)</li> <li>• Potential funding contributions through green bonds and U.S. Army Corps of Engineers involvement (CSE)</li> </ul>
<b>Current or future collaboration opportunities</b>	<ul style="list-style-type: none"> <li>• Collaborating with a development along diking perimeter &amp; corridor, whereby developer will fund cost of waterfront property and are obligated to build to FCL and pay for costs incurred through development (COR)</li> <li>• Engagement with other municipalities to discuss development, standards of practices, etc. (COR)</li> <li>• Direct communication with neighbours affected by flood protection works (COR)</li> <li>• Collaboration with neighbours affected by flooding in partnership with the municipality (PSE)</li> <li>• Collaboration with local university system and software company on sea level rise visualization initiative (CSE)</li> <li>• Collaboration with county, utility, and regional watershed groups that consist of municipalities and Indigenous communities (CSE)</li> </ul>
<b>Improvement Potentials</b>	<ul style="list-style-type: none"> <li>• Expediting timelines for implementation of flood protection and prevention projects (COR)</li> </ul>

Topic	Finding
	<ul style="list-style-type: none"> <li>• Increased peer learning around financing options (CSE)</li> <li>• Using nature-based or semi-natural engineering solutions (CSE, POV)</li> <li>• Desire to prevent adverse social impacts (e.g., displacement, green gentrification)</li> </ul>

## APPENDIX C2: FINDINGS BY MUNICIPALITY OR AGENCY

Municipality/ Agency	Actions being taken
<b>Port of Vancouver</b>	<ul style="list-style-type: none"> <li>• Considering sea level rise on a project by project basis (e.g., Terminal 1 upgrades)</li> <li>• Engages in projects with North Shore municipalities and Fraser Basin Council</li> <li>• Applied to federal grants through Transportation Assets Risk Assessment</li> </ul>
<b>City of Richmond</b>	<ul style="list-style-type: none"> <li>• Plans to spend \$50 million in the next 5 years on flood management</li> <li>• Engages in annual active budgeting and sets fund aside for flood protection</li> <li>• Received federal grant funding via Disaster Mitigation &amp; Adaptation Fund</li> <li>• Flood Protection Measures established in 2019 and Flood Projection Management Strategy</li> <li>• Dike Master Plan being pursued</li> </ul>
<b>City of Surrey</b>	<ul style="list-style-type: none"> <li>• Embarking on a berm strategy that encourages public access in addition to flood control</li> <li>• Engaged in a multi-stakeholder engagement for Coastal Flood Adaptation Strategy</li> <li>• Has a Development Permit Area for Hazard Lands</li> </ul>
<b>Port of Seattle</b>	<ul style="list-style-type: none"> <li>• Installing storm water conveyance systems, raising objects (e.g., terminals),</li> <li>• Uses scenario planning based on local sea level rise projections &amp; different time horizons</li> </ul>
<b>City of Seattle (Seattle Public Utilities)</b>	<ul style="list-style-type: none"> <li>• Embarking on a berm strategy that encourages public access in addition to flood control</li> <li>• Plans to engage in major clean up project for Duwamus River and surrounding industrial lands</li> <li>• Involved in a sea level rise visualization &amp; VR project partnership with UW &amp; Tableau through Climate Solutions Group</li> <li>• Looking to potential funding contributions through green bonds and involvement from the USACE</li> <li>• Considering sea level rise in upcoming Industrial &amp; Maritimes Strategy &amp; Freight Master Plan</li> <li>• New comprehensive adaptation plan for 2023 that builds off existing Climate Preparedness Plan</li> </ul>
<b>New York Economic Development Corporation</b>	<ul style="list-style-type: none"> <li>• uses emerging technologies and disaster recovery funds to improve the resiliency of small businesses in New York, align with long-term city-wide resiliency efforts, and strengthen the City's small businesses and tech entrepreneurship sector via RISE : NYC</li> <li>• Use post- Sandy recovery funds, capital funding, and Community Block Grants for financing</li> </ul>

# ADDITIONAL APPENDICES



**APPENDIX D****TABLE 1. SUMMARY OF PLANNING TOOLS AND APPROACHES**

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
<b>No action</b>		Status Quo (N/A)	Do nothing	High impact	Reactive	N/A	<ul style="list-style-type: none"> <li>Loss of job space</li> <li>Displacement of businesses</li> <li>Direct loss in employment</li> <li>Access issues for maritime and trade-related uses</li> <li>Costly to respond and recover after flood impacts (microeconomic impacts)</li> <li>Disruptions to wider economy (macroeconomic impacts)</li> <li>Risk to life safety, equipment, and other assets, employment opportunities</li> <li>Loss of customer base for businesses</li> </ul>		Chang 2016  Option presented under CAP for Fraser River Foreshore
<b>Flood mapping</b>	Using GIS or other mapping technologies to assess exposure and vulnerability of assets on employment lands	Land Use/Regulatory	Combination	N/A	Proactive	S-T	<ul style="list-style-type: none"> <li>Would provide a visual representation of assets that must be protected</li> <li>Can be updated regularly to monitor any opportunities, constraints, or risks for land use, particularly around land parcels affected, land use types, lifeline infrastructure, etc.</li> </ul>	Done more broadly by City of Vancouver, City of Seattle	National Institute for Standards and Technology. (2016a.)  City of North Vancouver Climate Change Adaptation Plan 2013
<b>Flood hazard area bylaw</b>	Regulates land use within floodplain to decrease risk and vulnerability	Land Use/Regulatory	Protect Accommodate Retreat	High impact	Proactive	L-R	<ul style="list-style-type: none"> <li>Could ensure safe floodplain development by establishing minimum height requirements or permitted uses in a zone or creating other zones within a space that are vertically above or below</li> <li>Could protect people and assets from various types of flooding by regulating how land, buildings, and other structures ought to be used to support community goals around sustainability and resilience</li> </ul>	Minimum floor elevation for flood risk through City of Surrey Zoning Bylaw-12000 and Surrey Building Bylaw 9011  Policy for building in flood-prone and environmentally sensitive areas in Surrey Building Bylaw 9011  City of Richmond Floodplain Management Policy	Option from COV CFRA Phase 2 (Lyle et al. 2016).  Province of BC website: Zoning Bylaw  Province of BC, Flood Hazard Land Use Management Guidelines  City of Vancouver SLR Planning Update (proposed)*

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
									Vancouver's Zoning and Development Bylaw (SLR Planning Update 2018)
<b>Development Permit areas **</b>	Identifies locations that need special treatment for certain purposes including the protection of development from hazards such as flooding	Land Use/Regulatory	Protect Accommodate Retreat	High impact	Proactive	L-R	<ul style="list-style-type: none"> <li>• Could ensure safe floodplain development</li> <li>• Can supplement a subdivision or zoning bylaw</li> <li>• Must not vary use or density that is permitted in bylaw with exceptions for health, safety, and property damage protection</li> <li>• Can include guidelines for setbacks and minimum building heights based on FCL for lots and permanent structures (see hazardous conditions DPAs from other municipalities)</li> </ul>	<p>City of Richmond Floodplain Management Policy</p> <p>District of North Vancouver Creekside DPA</p>	<p>Option from COV CFRA Phase 2 (Lyle et al. 2016).</p> <p>Province of BC website: Development Permit Areas</p> <p>Ebbwater Consulting 2018</p>
<b>Setbacks (30 m), buffers and clustering</b>	Requires that development be located at a reasonable distance from the shoreline or high-tide mark and that natural features such as shoreline vegetation be maintained; clustering employs a zoning strategy to group together buildings and preserve open space or natural areas	Land Use/Regulatory	Protect Accommodate Retreat	High impact	Proactive	L-R	<ul style="list-style-type: none"> <li>• Would ensure safe floodplain development to reduce future vulnerability and risk</li> <li>• Could lead to land loss and displacement of current businesses and industries</li> <li>• Could be difficult to implement in highly parcelized areas</li> <li>• Could create constraints for maritime/trade related industries that require direct access to the water</li> <li>• Would provide space for green infrastructure or open space which could provide alternative jobs in parks/recreation or tourism</li> </ul>	<p>15 m. coastal setback and 7.5 m dyke ROW setback undertaken through City of Surrey Zoning Bylaw- 12000</p> <p>30 m. setback in Kauai, Hawaii</p> <p>50-year coastal setback in Maui County, Hawaii</p> <p>30.5 m setback in Chesapeake Bay Area, Maryland</p> <p>Administrative Code for Ocean Hazard Areas in North Carolina</p>	<p>Option from SF Bay Shoreline Adaptation Atlas 2019</p> <p>City of Vancouver SLR Planning Update 2018 (proposed setback and bylaw updates)</p> <p>Vancouver's Zoning and Development Bylaw (SLR Planning Update)</p> <p>Wetlands Watch (for implementation examples)</p>
<b>Consistent design standards or building codes</b>	Building code provisions designed to	Land Use/Regulatory	Protect Accommodate	High impact	Proactive	L-R	<ul style="list-style-type: none"> <li>• Would allow adaptable but consistent shoreline flood protection design</li> </ul>	Minimum floor elevation for flood risk through City of	Option from COV CFRA Phase 2(Lyle et al. 2016).

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
<b>for construction in high hazard zones</b>	increase flood resistance of buildings via flood proofing measures or other property level restrictions	Engineering					<ul style="list-style-type: none"> <li>• Would protect people and assets and allow for flood protection infrastructure</li> <li>• May create constraints for businesses choosing to relocate to these areas due to a more complex process for development and occupancy approval</li> </ul>	<p>Surrey Zoning Bylaw-12000 and Surrey Building Bylaw 9011</p> <p>Policy for building in flood-prone and environmentally sensitive areas in Surrey Building Bylaw 9011</p> <p>City of Richmond Floodplain Management Policy</p> <p>City of Vancouver Floodplain Standards and Requirements 2014</p> <p>NYC Climate Resiliency Design Guidelines 2019</p>	<p>City of Vancouver SLR Planning Update 2018 (proposed setback and bylaw updates)</p> <p>City of Vancouver Flood Hazard Design Guidelines</p> <p>Province of BC, Flood Hazard Land Use Management Guidelines</p> <p>National Institute for Standards and Technology. (2016a.) 2014</p> <p>City of Seattle Climate Preparedness Strategy 2017</p> <p>City of North Vancouver- Climate Change Adaptation Plan 2013</p>
<b>Right to Flood</b>	A legal provision that states that land should be allowed to flood in flood event like riverine floods or king tides	Land use/Regulatory	Accommodate/Avoid	Moderate-high impact	Proactive	L-R	<ul style="list-style-type: none"> <li>• Could reduce land available for commercial and industrial activities</li> <li>• Might encourage retrofits, flood proofing, changes in design standards, and object elevation of facilities and buildings within employment lands as well as development of contingency plans for continued business operations to accommodate periodic flooding</li> </ul>		Option from COV CFRA Phase 2 (Lyle et al. 2016).

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
<b>Rolling Easements/ Conservation Easements</b>	A voluntary agreement made to avoid property development for preservation of habitat, open space, or recreation, in exchange for monetary compensation or tax benefits  *rolling easements refer to the prevention of activities on the shoreline	Land use/Regulatory  Financial tools	Accommodate/Avoid	High impact		L-R	<ul style="list-style-type: none"> <li>• Could prevent development of real estate in areas at risk of erosion or inundation</li> <li>• Would incentivize conversion of land to wetlands, beaches, or shoreline open space, which could produce new types of jobs in the recreation, tourism, or environmental sector</li> <li>• Could be more politically popular to prevent development on high-risk land than regulation</li> <li>• Implementation could be encouraged if states/provinces codify local governments' authority to use rolling easements</li> </ul>	Coastal Resilience easements in Maryland  Sand Dune Rules in Maine  Open Beaches Act in Texas	City of Seattle Climate Preparedness Strategy 2017  Option from SF Bay Shoreline Adaptation Atlas 2019  Wetlands Watch (for implementation examples )
<b>Development Cost Levy **</b>	Charged on new development to help pay for public amenities and infrastructure such as parks and engineering infrastructure (e.g., indirectly for flood protection)	Financial tools	Protect Accommodate	High impact	Proactive	S-T	<ul style="list-style-type: none"> <li>• Can be used specifically to fund transportation services but indirectly dykes and sea walls</li> <li>• Can be used to “help transition water, sewer, and drainage infrastructure from development/ rezoning conditions”</li> </ul>	Used in Vancouver to fund infrastructure projects or parks	COV: Vancouver city-wide Development Cost Levy update 2017
<b>Community Amenity Contribution</b>	In-kind or cash contributions provided by property developers when City Council grants development rights through rezoning.	Financial tools	Protect Accommodate	High impact	Proactive	S-T	<ul style="list-style-type: none"> <li>• Can be used to fund dykes</li> </ul>	Used in Vancouver to fund amenities	
<b>Covenant on Title</b>	A requirement to disclose any	Land use/Regulatory	Accommodate	Low-moderate	Proactive	S-T	<ul style="list-style-type: none"> <li>• Would affect incoming businesses in employment lands which could</li> </ul>	District of West Vancouver OCP	Option from COV CFRA Phase 2 (Lyle et

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
	flood hazards on the title of the property			impact			decide, at their own risk, where to locate business operations, infrastructure, and employment space <ul style="list-style-type: none"> <li>• Could disincentivize industries and firms from locating into flood-prone areas</li> <li>• May increase transparency for industries and firms with uses that could not accommodate flooding risk</li> <li>• Can be registered by individuals and non-governmental organizations on private land and limits what landowner can do with the property</li> <li>• May control development and encourage uniformity and thereby enhance property values</li> </ul>	(relevant to development on hazard lands)  District of North Vancouver OCP (relevant to land conservation tools and development on hazard lands)	al. 2016).  BC Land Title & Survey: Authority to Hold Covenants
<b>Open space provision on employment or industrial lands (via Right of Way)</b>	Naturalizing the shoreline or allocating land to open space that can be flooded to allow for accessibility, recreational, interpretative opportunities and other co-benefits (nature)	Land use/Regulatory  Economic resilience planning	Accommodate/Retreat	Moderate-high impact	Proactive	L-R	<ul style="list-style-type: none"> <li>• Would provide interim space in case of economic disruption for recovery phases</li> <li>• Could act as flood area to protect other infrastructure/employment sites from flooding</li> <li>• Lost development potential and could have impact on land prices</li> <li>• Could help produce other types of jobs in parks/recreation or tourism sectors</li> </ul>		Option presented under CAP for Fraser River Foreshore  National Institute for Standards and Technology. (2016a.)
<b>Relocation of infrastructure or property</b>	Moving property, including businesses and assets, or infrastructure, including roads and services out of floodplain  Can be done through buyouts,	Land use/Regulatory  Financial tools  Economic resilience planning	Retreat	High Impact	Proactive	L-R	<ul style="list-style-type: none"> <li>• May promote public safety and can help prevent repeat losses</li> <li>• May not always be feasible, especially for industrial uses that have specific parcel size requirements, access requirements, or potential incompatibility with neighbouring uses</li> <li>• Would lead to lost development potential in employment lands</li> <li>• Could decrease property values and tax base as a result</li> </ul>	New Jersey	Option from COV CFRA Phase 2 (Lyle et al. 2016).  Webb et al 2000  Rose & Wei 2013  Option from SF Bay Shoreline Adaptation Atlas 2019 - implemented in New Jersey

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
	transfer of development rights, land expropriation etc.								
<b>More intensive use of land in other areas (e.g., vacated school sites), especially for displaced businesses</b>	See Glossary definition for clustering	Land use/regulatory	Accommodate/Avoid	Moderate-high impact	Proactive	L-R	<ul style="list-style-type: none"> <li>• Would help preserve number of jobs and continued economic activity</li> </ul>		City of Richmond Employment Lands Strategy 2011
<b>Protective sea walls, dykes, and polders</b>	Large stone, rock, or concrete structures designed to protect upland areas from coastal flooding and wave impacts	Engineering	Protect	Moderate-high impact	Reactive	L-R	<ul style="list-style-type: none"> <li>• Would lead to land loss in employment lands if a setback is required</li> <li>• Would protect valuable assets (e.g., buildings) and infrastructure and preserve business operations</li> <li>• Requires major investment which deflates the economy but can lead to cost-savings over time</li> <li>• May require the demolition of pre-existing structures, which could lead to displacement or disruption in previously developed areas</li> <li>• In the case of certain dikes, does not require large elevation but may require a large footprints, which affects land acquisition costs, whereas this is the opposite for sea walls</li> </ul>	City of Surrey – protection system of dykes  City of Richmond - mandatory flood protection for employment lands and system of dykes  South San Francisco Bay Shoreline Project  NYC Dryline	Option from COV CFRA Phase 2 (Lyle et al. 2016).  City of Surrey CFAS 2016  City of Richmond Employment Lands Strategy 2011
<b>“Hard” erosion protection (e.g., riprap, dolos, bulkheads,</b>	Engineering structures or forms of coastal armoring often	Engineering	Protect	Low impact	Reactive	S-T	<ul style="list-style-type: none"> <li>• Could exacerbate erosion long-term and lead to unexpected or undesired land loss</li> <li>• Could worsen wave impacts from</li> </ul>		Option from COV CFRA Phase 2 (Lyle et al. 2016).

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
<b>revetments, rip rap, breakwater, groins )</b>	placed offshore that help reduce erosion rates and wave impacts						storm surge, which would affect coastal properties and businesses <ul style="list-style-type: none"> <li>• May reduce flood insurance rates in existing developed areas</li> <li>• Requires less investment to maintain than sea walls and more effective for emergency flood events</li> </ul>		Option from San Francisco Bay Shoreline Adaptation Atlas (SPUR 2019)
<b>“Soft” erosion protection /green infrastructure</b>	Can help buffer oceans and shores and absorb wave impacts to reduce erosion rates  Includes constructed wetlands, dune rebuilding, natural erosion control, beach renourishment, barrier island	Engineering	Protect accommodate	Moderate impact	Proactive	Both	<ul style="list-style-type: none"> <li>• Could lead to land loss in employment lands if a setback is required</li> <li>• Could lessen wave impacts from storm surge and thereby protect coastal properties and businesses</li> <li>• Could help produce other types of jobs in parks/recreation or tourism sectors</li> <li>• It is already a requirement that construction sites and industrial facilities use best management practices and monitoring to manage runoff</li> </ul>	City of Seattle does green infrastructure & stormwater management via the Green Factor Program  West Vancouver-Shoreline Protection Plan 2012-2015- see pilot projects  NYC Dryline	Option from COV CFRA Phase 2 (Lyle et al. 2016).  Option from San Francisco Bay Shoreline Adaptation Atlas (SPUR 2019)  National Institute for Standards and Technology. (2016a.)  City of Seattle Climate Preparedness Strategy 2017  West Vancouver-Shoreline Protection Plan 2012-2015  Lees & Associates (n.d.)  LafargeHolcim Foundation (n.d.)
<b>Land reclamation through placement of fill</b>	The placement of fill in areas that are currently ocean to protect inland areas or create new land	Engineering	Protect	Moderate-high impact	Both	S-T	<ul style="list-style-type: none"> <li>• Would protect people and assets and allow for flood protection infrastructure, especially critical infrastructure, valuable equipment, or industries for which relocation or retrofitting is not possible</li> <li>• The creation of new land could add physical space to the employment lands</li> <li>• Requires major investment which deflates the economy but can lead to cost savings over time</li> </ul>		Option from COV CFRA Phase 2 (Lyle et al. 2016).  Province of BC, Flood Hazard Land Use Management Guidelines

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
<b>Mandatory Building Tune ups – building retrofits and controls based on FCL</b>	Regulation of new construction or existing construction (via retrofits) to help development withstand flooding via legislative decree	Engineering  Land use/Regulatory	Protect Accommodate	Moderate impact	Both	Both	<ul style="list-style-type: none"> <li>• Would protect people and assets and allow for flood protection infrastructure, especially critical infrastructure or valuable equipment</li> <li>• Might not be implementable in seismically active areas</li> <li>• building elevation increases and ground floor flood-proofing has urban design implications which could affect customer or employee access and desirability of retail or commercial districts</li> </ul>	New Orleans, New Jersey, Seattle	<p>Option from COV CFRA Phase 2 (Lyle et al. 2016).</p> <p>Option from SF Bay Shoreline Adaptation Atlas (SPUR 2019)</p> <p>City of Seattle Climate Preparedness Strategy 2017</p> <p>Capital Regional District SLR Planning Approaches Project Report 2015</p>
<b>Object elevation</b>	Elevation of an existing building or structure above the flood level using stilts, fill or other structures	Engineering	Protect Accommodate	Moderate-high impact	Reactive	S-T	<ul style="list-style-type: none"> <li>• Would protect people and assets in the short-term by moving them out of the hazard zone</li> <li>• Construction may cause disruption to existing land uses or necessitate their temporary or permanent relocation</li> <li>• Might not be flexible in the long-term</li> <li>• May cause incongruence in land use patterns and transit connectivity</li> </ul>		<p>Option from COV CRA Phase 2 (Lyle et al. 2016).</p> <p>City of Seattle Climate Preparedness Strategy 2017</p> <p>Option from SF Bay Shoreline Adaptation Atlas (SPUR 2019)</p>
<b>Flood proofing: Permanent and temporary resistance (dry flood proofing)</b>	Products or actions designed to stop water from entering buildings through existing openings or by penetrating walls	Engineering	Protect Accommodate	Low impact	Reactive	S-T	<ul style="list-style-type: none"> <li>• Would protect people and assets and allow for flood protection infrastructure, especially critical infrastructure or valuable equipment</li> <li>• Requires minor investment</li> </ul>	Undertaken through City of Surrey Zoning Bylaw- 12000	<p>Option from COV CFRA Phase 2 (Lyle et al. 2016).</p> <p>Option from Institute for Catastrophic Loss Reduction</p>
<b>Flood proofing: Resilience (Wet flood proofing)</b>	Building design and construction that allows floodwaters to enter but minimizes	Engineering	Protect Accommodate	Low impact	Reactive	S-T	<ul style="list-style-type: none"> <li>• Would protect people and assets and allow for flood protection infrastructure, especially critical infrastructure or valuable equipment</li> <li>• Requires minor investment</li> </ul>	Undertaken through City of Surrey Zoning Bylaw- 12000	<p>Option from COV CFRA Phase 2 (Lyle et al. 2016).</p> <p>Option from Institute for Catastrophic Loss</p>

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
	damage using flood-tolerant building materials								Reduction
<b>Stormwater Code or Integrated Stormwater Plan</b>	Could help retain stormwater upland in an urban watershed, and reduce flooding from sea level rise and wave impacts from more frequent and intense storms	Engineering Land Use/ Regulatory	Avoid Accommodate	Moderate impact	Proactive	L-R			Option from SF Bay Shoreline Adaptation Atlas (SPUR 2019)  City of Seattle Climate Preparedness Strategy 2017  City of North Vancouver- Climate Change Adaptation Plan 2013
<b>Cascade analysis and other computer modeling for economic impacts</b>	used to understand the interrelations between infrastructure failures across a city or region; can be completed using computer modeling techniques	Economic resilience planning	Protect Accommodate	Low impact	Proactive	S-T	<ul style="list-style-type: none"> <li>• Would contribute to understanding around the interrelations between infrastructure failures across Vancouver</li> <li>• Would bring together large infrastructure providers to ensure infrastructure safety: BC Hydro, Fortis, Translink, and others</li> </ul>		Bossello et al 2007  Chang, S.E. 2016.  City of Vancouver Sea Level Rise Update (proposed)  Rose & Wei 2013
<b>Computer modeling</b>	Could include I-O or DART model to predict indirect economy-wide impacts from infrastructure failures	Economic resilience planning	Protect Accommodate	Low impact	Proactive	S-T	<ul style="list-style-type: none"> <li>• Would contribute to understanding around the interrelations between infrastructure failures across Vancouver</li> </ul>		Bossello et al 2007  Chang, S.E. 2016.  Rose & Wei 2013
<b>Critical infrastructure response &amp; recovery</b>		Economic resilience planning	Protect Accommodate	Low impact	Both	L-R	<ul style="list-style-type: none"> <li>• Would protect against long-term losses and increase chances of economic recovery</li> </ul>		Chang, S.E. 2016.  National Institute for Standards and Technology. (2016a.)

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
<b>Warning systems, evacuations</b>	A program or automated system that warns of imminent flood events	Economic resilience planning  Other/ additional	Protect Accommodate	Low impact	Both	S-T	<ul style="list-style-type: none"> <li>Would protect assets and people (first aid approach) from direct impacts in the short-term</li> </ul>		Option from COV CFRA Phase 2 (Lyle et al. 2016).
<b>Firm level-Evacuation and response planning protocols</b>	A program or plan that can be implemented by a firm for emergency response in case of sudden flood events  can be introduced by the City through its engagement with the business community	Economic resilience planning	Protect Accommodate	Low impact	Both	S-T	<ul style="list-style-type: none"> <li>Would enable smooth response to direct impacts and public safety of workers</li> <li>May not lead to protection of all infrastructure and assets in employment lands, creating temporary disruption</li> </ul>		<p><b>General</b> Option from COV CFRA Phase (Lyle et al. 2016).</p> <p><b>Firm-level</b> Webb et al 2000  Rose &amp; Wei 2013</p>
<b>Firm level-Recovery planning/ Business continuity programs</b>	A program or plan in place before a flood event to ensure rapid-post event recovery  can be introduced by the City through its engagement with the business community	Economic resilience planning	Protect Accommodate	Low impact	Both	S-T	<ul style="list-style-type: none"> <li>Would enable smooth recovery of businesses, ports and industries to direct and indirect impacts (e.g., wider disruptions to core infrastructure)</li> <li>Can help to secure political and financial support (e.g., catastrophe bonds) to allow for the implementation of different land uses post-event</li> </ul>		<p><b>General</b> Option from COV CFRA Phase (Lyle et al. 2016).</p> <p>Option from SF Bay Shoreline Adaptation Atlas – under Rebuilding and Redevelopment Restrictions (SPUR 2019)</p> <p><b>Firm-level</b> Webb et al 2000  Rose &amp; Wei 2013  Chang, S.E. 2016.</p>

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
									Option from Institute for Catastrophic Loss Reduction
<b>Supply chain measures</b>	Program or plan to manage supply chain disruptions from flood events, such as: ship rerouting, shifting to other ports; export diversion to other transportation modes; and more	Economic resilience planning	Protect Accommodate	Low impact	Proactive	L-R	<ul style="list-style-type: none"> <li>Would enable smooth recovery of businesses, ports and industries to direct and indirect impacts (e.g., wider disruptions to core infrastructure)</li> </ul>	Sea ports at Beaumont and Port Arthur, Texas (see Rose & Wei 2013)	Rose & Wei 2013  Ng et al. 2013. Chapter 2
<b>Economy-wide planning</b>	Involves increasing economic resilience via economic development diversification, and regional cooperation to prevent sector overreliance, supply chain or transport route vulnerabilities	Economic resilience planning	Combination	High impact	Proactive	L-R	<ul style="list-style-type: none"> <li>Advertising City’s climate leadership can help to attract new businesses and customers</li> <li>Would protect economic sectors that might be hurt the most in event of disaster(s); considering pre-event business climate</li> <li>Promoting new economic development and job creation through advertising and implementing climate change mitigation and adaptation actions</li> </ul>		City of North Vancouver- Climate Change Adaptation Plan 2013  City of Vancouver via CAP for Fraser River Foreshore  Chang, S.E. 2016.
<b>Land or property acquisition (Buy outs)</b>	Using public funds to buy out and sterilize an area and reduce future assets at risk	Financial tools	Avoid Retreat	Moderate-high impact	Proactive	L-R	<ul style="list-style-type: none"> <li>May promote public safety and can help prevent repeat losses</li> <li>Would lead to lost development potential in employment lands</li> <li>Could alter property values and tax base as a result</li> <li>Could lead to displacement of existent businesses in the short-term</li> <li>Could prevent future disruption to industries that would otherwise locate to high risk areas to sea level rise and lead to cost-savings by encouraging businesses and</li> </ul>		Option from COV CFRA Phase 2 (Lyle et al. 2016).  Option from SF Bay Shoreline Adaptation Atlas -see Buyouts (SPUR 2019)

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
							industries to locate further inland		
<b>Relocation incentives (i.e., tax incentives, buyouts)</b>	Economic incentives to incentivise property owners or firms to buy outside of a floodplain	Financial tools	Retreat	Moderate-high impact	Proactive	L-R	<ul style="list-style-type: none"> <li>• Would be suitable for uses that do not conform to existing zoning or where repetitive loss is likely</li> <li>• Would encourage protection of development through retrofitting or relocation to low risk, infill-like areas</li> <li>• Should be undertaken through a comprehensive, equitable approach to avoid checkerboard effect</li> </ul>	Blue Acres Program in New Jersey  New York, New Jersey, Florida, New Orleans	Option from COV CFRA Phase 2 (Lyle et al. 2016).  Option from SF Bay Shoreline Adaptation Atlas (SPUR 2019)
<b>Responsibility shifting to benefactors</b>	A measure that would put the liability on individual property owners; would involve a change to the DFAA which currently provides monetary incentive for property owners to stay in the floodplain	Financial tools	Protect Accommodate Retreat	N/A	Proactive	L-R	<ul style="list-style-type: none"> <li>• Would give firms the liability to move out of the floodplain into inland or lower-risk areas</li> <li>• Might not be feasible, especially for smaller firms who do not have financial ability to relocate or large firms (e.g., industrial, port uses) that do not have this flexibility</li> </ul>		Option from COV CFRA Phase 2 (Lyle et al. 2016).
<b>Policies/premiums</b>	Provides property owners with an incentive to relocate out of floodplain or provides monetary assistance for loss recovery	Financial tools	Accommodate Retreat	N/A	Reactive	L-R	<ul style="list-style-type: none"> <li>• Can be used to recover losses and restore business operations in the financial sense and long-term</li> <li>• As a reactive approach, does not prevent disruption in the short-term which could lead to loss of workers</li> </ul>	FloodSmart Canada	Option from COV CFRA Phase 2 (Lyle et al. 2016).
<b>Transfer of development potential</b>	Transfer of allowable development potential to an alternate location out of the floodplain	Land use/regulatory  Financial tools	Retreat	Moderate-high impact	Proactive	L-R	<ul style="list-style-type: none"> <li>• Could support smart growth and infill development outside of high-hazard areas through zoning and development credits</li> <li>• Would prevent future loss to businesses and infrastructure as a result of flooding</li> <li>• There may be a shortage of “receiving” areas that are safer and higher elevation</li> </ul>	Montgomery County, Maryland  Beach Transfer Program in Ocean City, Maryland  New Jersey Pinelands  Miami-Dade County,	Option from COV CFRA Phase 2 (Lyle et al. 2016).  Option from SF Bay Shoreline Adaptation Atlas (SPUR 2019)  Urban Land Institute Resilience Panel

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
							<ul style="list-style-type: none"> <li>“Receiving” areas might be best used for uses that are easily compatible, do not have large parcel size requirements, or necessarily require marine access</li> </ul>	Florida Collier County, Florida	Focus Group, SE Florida/ Caribbean 2017  Wetlands Watch (for implementation examples)
<b>Long-term sea level rise engagement for business owners, port authorities, utilities, etc.</b>	Engagement which could be done in partnership with Board of Trade, industry associations, insurance groups, property owners’ associations, utilities and transportation groups to plan for economic impacts from sea level rise	Multi-stakeholder engagement	Combination	N/A	Proactive	L-R	<ul style="list-style-type: none"> <li>Would enable smooth recovery of businesses, ports and industries to direct and indirect impacts (e.g., wider disruptions to core infrastructure)</li> </ul>	Implemented by Port of San Diego (see Ng et al. 2013. Chapter 2)  City of Surrey via CFAS Advisory Group  City of Vancouver via CAP for Fraser River Foreshore  SF Bay Resilient By Design	Port of San Diego case in Ng et al. 2013. Chapter 2  City of Surrey CFAS 2016  City of Vancouver CAP for Fraser River Foreshore
<b>Awareness building programs</b>	Programs to educate the public, including businesses about vulnerability and risk to flood hazards and guide the provision of resources to assist stakeholders to make better risk reduction decisions	Public education and awareness  Economic resilience planning	Combination	Low impact	Proactive	L-R	<ul style="list-style-type: none"> <li>Awareness building could be done in partnership with Chamber of Commerce and Business Association</li> <li>Could enable smooth recovery in case of supply chain or business disruption</li> <li>Awareness building directed at the firm-level may not lead to protection of all infrastructure and assets in employment lands, creating temporary disruption</li> <li>Firm level recovery programs can help to secure political and financial support (e.g., catastrophe bonds) to allow for the implementation of different land uses post-event</li> </ul>	City of Surrey via Flood Preparedness Guide for Businesses	City of North Vancouver- Climate Change Adaptation Plan 2013  City of Surrey Flood Preparedness webpage  Option from SF Bay Shoreline Adaptation Atlas – under Rebuilding and Redevelopment Restrictions (SPUR 2019)  Option from COV CFRA Phase (general evacuation and response planning) (Lyle et. al 2016)

Planning tool or approach	Description of Tool	Type of planning tool (category)	Sea level rise planning approach	Magnitude of impact on land use	Degree of Reactivity	Type of Policy (L-R plan or S-T adjustment)	Land use implications for Vancouver and ELER	Example of implementation	Source
									<p><b>Firm-level</b></p> <p>Webb et al 2000</p> <p>Rose &amp; Wei 2013</p> <p>Chang, S.E. 2016.</p> <p>Option from Institute for Catastrophic Loss Reduction</p>
<b>Online materials for businesses on firm-level preparedness</b>	Public information provided by a municipality on business risk reduction measures	Public education and awareness  Economic resilience planning		Low impact	Both	S-T		<p>City of Surrey via Flood Preparedness Guide for Businesses</p> <p>Institute for Catastrophic Loss Reduction via Open for Business Program</p>	<p>Option from Institute for Catastrophic Loss Reduction</p> <p>City of Surrey CFAS 2016</p>

**Key for Table**

\*\* can't be implemented in Vancouver due to jurisdictional constraints under Local Government Act

**TABLE 2. LITERATURE REVIEW BY SOURCE**

Source	Source Type	Relevant planning tools and approaches used	Other Relevant Findings
<b>Sea Level Rise Update, Vancouver 2018</b>	Municipal Government: staff report to council	<p><b>LAND USE/REGULATORY</b></p> <ul style="list-style-type: none"> <li>• Vancouver Building Bylaw 2014 update with new FCL</li> <li>• Zoning and Development Bylaw to ensure safe floodplain development (recommended)</li> <li>• Safe setback to protect people and assets and allow for flood protection infrastructure (recommended)</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• Bylaws, zoning regulations, and policies to design shoreline flood protection that is adaptable and based on consistent performance standard</li> <li>• Consistent performance standard for shoreline flood protection (recommended)</li> </ul> <p><b>ECONOMIC RESILIENCE</b></p> <ul style="list-style-type: none"> <li>• Cascade analysis to understand the interrelations between infrastructure failures across Vancouver (recommended/in-progress) <ul style="list-style-type: none"> <li>○ BC Hydro, Fortis, TransLink, Port, etc.</li> </ul> </li> </ul> <p><b>FINANCIAL TOOLS</b></p> <ul style="list-style-type: none"> <li>• Long-term funding strategy for implementation of coastal flood protection (to be developed) <ul style="list-style-type: none"> <li>○ With other senior levels of government</li> </ul> </li> </ul> <p><b>PUBLIC EDUCATION AND AWARENESS</b></p> <ul style="list-style-type: none"> <li>• Building ongoing public awareness <ul style="list-style-type: none"> <li>○ Models such as Rebuild by Design</li> </ul> </li> </ul>	
<b>Coastal Flood Risk Assessment Phase 2 Report for City of Vancouver (Lyle et al. 2016)</b>	Consulting report for municipal government	<p><b>Options proposed below:</b></p> <p><b>STATUS QUO</b></p> <ul style="list-style-type: none"> <li>• No action taken</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• Protective sea walls, dykes</li> <li>• Building retrofits/ controls (based on FCL)</li> <li>• Infrastructure Retrofits (e.g., elevation of critical infrastructure)</li> <li>• Erosion protection (riprap, dolos)</li> <li>• Breakwater, groins, etc.</li> <li>• Constructed wetlands, dune rebuilding, natural erosion control (soft shoreline), beach renourishment, barrier islands</li> <li>• Diversion channels</li> <li>• Land reclamation/ placement of fill</li> </ul>	<ul style="list-style-type: none"> <li>• Different options presented to change the hazard (protect), reduce exposure to the hazard (accommodate, move), or reduce sensitivity or vulnerability (accommodate)</li> <li>• Presents different economic impacts and options to measure them, including: Damage to infrastructure (value weighted km of roads impacted), damage to buildings (\$M), business disruption (# employees working in impacted businesses), loss of inventory (\$M), and emergency response costs (estimated cost in \$M per event)</li> </ul>

Source	Source Type	Relevant planning tools and approaches used	Other Relevant Findings
		<ul style="list-style-type: none"> <li>● Object elevation</li> <li>● Permanent and temporary resistance (dry flood proofing)</li> <li>● Resilience (wet flood proofing)</li> </ul> <p><b>LAND USE/REGULATORY</b></p> <ul style="list-style-type: none"> <li>● Land use regulation (DPA, zoning bylaw)</li> <li>● Right to Flood</li> <li>● Covenant on Title</li> <li>● ~15-30 m setback</li> <li>● Open space provision on industrial lands</li> <li>● Relocation of infrastructure</li> <li>● Relocation of property</li> <li>● Acquisition of undeveloped land</li> <li>● Acquisition of developed land</li> <li>● Transfer of development potential</li> </ul> <p><b>PUBLIC EDUCATION AND AWARENESS</b></p> <ul style="list-style-type: none"> <li>● Warning system, evacuations, etc.</li> <li>● Evacuation and response planning</li> <li>● Public and media education</li> <li>● Recovery planning</li> </ul> <p><b>FINANCIAL TOOLS</b></p> <ul style="list-style-type: none"> <li>● Economic incentives to relocate from floodplain</li> <li>● Responsibility shifting to benefactors</li> <li>● Policies and premiums</li> </ul>	
Source	Source Type	Relevant planning tools and approaches used	Other Relevant Findings
<p><b>City of Vancouver 2018 Coastal Adaptation Plan for the Fraser River Foreshore</b></p>	<p>Municipal Government: community plan</p>	<p><b>LAND USE/ REGULATORY</b></p> <ul style="list-style-type: none"> <li>● Restricting new development (halting permitting) in the floodplain (East Fraser Lands)</li> <li>● Zoning Changes</li> <li>● Integration of flood management strategy with relevant city-wide and neighbourhood plan</li> <li>● Open space provision along Fraser River for accessibility, recreational and interpretive opportunities, and other co-benefits (nature)</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>● Designing safe-to-fail infrastructure systems by reducing risks to lifeline infrastructure and services and adding redundancy to systems</li> </ul> <p><b>PUBLIC EDUCATION</b></p> <ul style="list-style-type: none"> <li>● Awareness building around flood risk, decision-making, and management</li> </ul>	<p><b>Findings related to local and regional economy</b></p> <ul style="list-style-type: none"> <li>● Fraser River Foreshore has 280 industrial, warehouse, and commercial buildings (south of Marine Drive, within floodplain) equivalent to 700 businesses, many of which require access to Fraser River for business operations</li> <li>● Accommodate/adapt options seem to have best economic benefits (see page 58)</li> </ul> <p><b>Relevant Community Engagement Feedback</b></p> <ul style="list-style-type: none"> <li>● Flood management should minimize permanent displacement of businesses or loss of employment lands</li> <li>● Economic concerns that were prioritized included business interruptions and asset damage from flooding (buildings, inventory), regional service, supply chain, and goods movement disruptions, employment land loss, and interruptions to employment and job loss</li> </ul>

Source	Source Type	Relevant planning tools and approaches used	Other Relevant Findings
		<p><b>FINANCIAL TOOLS</b></p> <ul style="list-style-type: none"> <li>• Cost-sharing options for flood control infrastructure building and maintenance</li> </ul> <p><b>MULTI-STAKEHOLDER ENGAGEMENT</b></p> <ul style="list-style-type: none"> <li>• Engagement sessions with asset owners and operators and MST, community workshops with business owners, etc.</li> </ul>	
<p><b>Ebbwater Consulting: City of Vancouver Sea Level Rise Planning Tools Final Report 2018</b></p>	<p>Consulting report</p>	<p><b>LAND USE/ REGULATORY</b></p> <ul style="list-style-type: none"> <li>• City of New York amendment in building code to increase freeboard requirements and increase flood resistance of homes post-Sandy</li> <li>• Green Waterfront Design Charrette between West Coast Environmental Law and SFU: enabling and establishing reciprocal agreements between land owners in coastal areas where upland landowners would get density bonuses and waterfront property owners could ‘pull back’</li> <li>• Development Permit Areas (E.g., DNV’s Creekside DPA)</li> </ul> <p><b>FINANCIAL TOOLS</b></p> <ul style="list-style-type: none"> <li>• Financing and insurance options (e.g., San Francisco Restoration Parcel Tax)</li> <li>• Stormwater Surcharge in Mississauga and Surrey</li> <li>• Cost sharing for WaterFront Toronto</li> <li>• Land acquisition/ Buyout Programs (e.g., State of New Jersey Superstorm Sandy Buyout Program via Disaster Mitigation Adaptation Fund)</li> <li>• Financing and insurance options (e.g., San Francisco Restoration Parcel Tax)</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• Retrofitting Buildings for Flood Risk Design Manual by the City of New York to facilitate building code advancements</li> <li>•</li> </ul>	
<p><b>City of Vancouver: Vancouver City-wide Development Cost Levy Update (2017-2026)</b></p>	<p>Municipal Government: staff report</p>	<p><b>FINANCIAL TOOLS</b></p> <ul style="list-style-type: none"> <li>• Development cost levy for infrastructure and public amenities, including transportation, engineering infrastructure for water, sewer, and drainage, and parks</li> </ul>	<ul style="list-style-type: none"> <li>• The Vancouver Charter (s.523D) authorizes Council to help fund eligible municipal services and infrastructure needed for growth in the City; DCLS can be used for most new development (e.g., development via rezoning)</li> <li>• The Vancouver Charter includes the list of eligible services:</li> <li>• The addition of utilities to the city-wide DCL has been recommended; this would help the City transition eligible water, sewer, and drainage infrastructure from developing/rezoning for enhanced transparency and predictability</li> <li>• Can be used to pay for growth-related Capital infrastructure</li> </ul>
<p><b>City of Vancouver: Floodplain Standards and Requirements 2014</b></p>	<p>Municipal Government: guidelines</p>	<p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• Flood Construction Levels</li> <li>• Subdivision Requirements</li> </ul>	

Source	Source Type	Relevant planning tools and approaches used	Other Relevant Findings
		<ul style="list-style-type: none"> <li>• Fill, Drainage and Grades requirements and recommendations</li> <li>• Recommendations for training and erosion protection works</li> </ul>	
<b>Province of BC, Ministry of Water, Land, and Air Protection: Flood Hazard Land Use Management Guidelines (2004) and general website (updated 2019)</b>	Provincial Government: guidelines	<p><b>LAND USE/REGULATORY</b></p> <ul style="list-style-type: none"> <li>• Flood hazard area bylaws (no provincial approval needed, but in alignment with policies &amp; guidelines)</li> <li>• Flood hazard area land development exemptions (must be consistent with province’s guidelines; certified by Qualified Professional like geoscientist or engineer)</li> <li>• <b>Requirements for subdivision in flood prone areas based on engineering reports that assess flood hazards and restrictive covenants</b></li> <li>• Building setbacks</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• Placement of fill and erosion protection works</li> <li>• Protective flood management (dykes, sea walls)</li> <li>• Protective flood management (soft shoreline, green infrastructure)</li> <li>• Building site ground elevations according to FCLs</li> <li>• Building code: Flood proofing policies</li> <li>• Allowing flooding of underground and ground floor areas</li> </ul>	<p>N/A</p> <ul style="list-style-type: none"> <li>• Consider different flood types and common causes of flooding for the BC context</li> </ul>
<b>Province of BC, Land Use Regulation: Development Permit Areas</b>	Provincial Government website	<p><b>LAND USE/ REGULATORY</b></p> <ul style="list-style-type: none"> <li>• designation of hazardous conditions development permit areas</li> </ul>	<ul style="list-style-type: none"> <li>• Local governments can identify locations of special conditions (e.g., hazardous conditions or environmentally-sensitive area) and establish objectives, guidelines, and exemptions for proposed development in these areas</li> <li>• DPA guidelines may be specified through the zoning bylaw</li> </ul>
<b>Province of BC, Land Use Regulation: Zoning Bylaws</b>	Provincial Government website	<p><b>LAND USE/ REGULATORY</b></p> <ul style="list-style-type: none"> <li>• Zoning bylaws</li> </ul>	<ul style="list-style-type: none"> <li>• Zoning bylaws dictate how land, buildings and other structures may be used</li> <li>• They can limit building or structure heights, create new zones that are vertically above or below within a space</li> <li>• Through zoning bylaws, local governments can prohibit any use(s) within a zone</li> <li>• Within a zone, a local government can regulate the use and density of land, buildings, and other structures; siting, size and dimensions of permitted buildings, structures, and uses; the location of uses on land and inside buildings and other structures; and the shape, dimensions and area of land parcels</li> <li>• Zoning bylaws can be amended over time or one can apply for a development variance permit for changing circumstances</li> </ul>
<b>SFU ACT Adapt: Adaptation to Sea level rise in Metro Vancouver: A Review of Literature for Historical Sea level Flooding and Projected Sea Level Rise in Metro</b>	Academic paper		<ul style="list-style-type: none"> <li>• Bing Tom Architects found 12% loss in total land area in COV – disproportionate impacts on industrial lands, historic area and public space (e.g., sea wall, open space by the waterfront) (p 28)</li> <li>• Value of square meters of land in Vancouver – \$25 B estimated loss with 1 m of SLR (by 2100) (p 28)</li> <li>• National Roundtable on the Environment and the Economy (NRTEE)*- Metro Vancouver could see costs between \$2.1 and \$7.6 B</li> </ul>

Source	Source Type	Relevant planning tools and approaches used	Other Relevant Findings
Vancouver			by 2050 due to SLR (p 30)
E. Keenan and A. Yan, "The Local Effects of Global Climate Change in the City of Vancouver: A Community Toolkit and Atlas," 2011.	Consulting Report	<p><b>LAND USE/ REGULATORY</b></p> <ul style="list-style-type: none"> <li>• designation of sea level rise planning areas</li> <li>• siting buildings of longer lifespan or large infrastructure investments (e.g., industrial facilities, major transportation routes) outside of 2100 planning area</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• dikes, sea walls,</li> </ul> <p><b>OTHER/ADDITIONAL</b></p> <ul style="list-style-type: none"> <li>• a region-wide open data catalogue</li> </ul>	<ul style="list-style-type: none"> <li>• Shows different scenarios of sea level rise (king tide, 0 m+ to 6m+) and affected land use by percentage, including industrial, comprehensive development, limited agriculture, commercial, etc.</li> <li>• Graph shows the vulnerability of stock of industrial lands in the context of sea level rise and demonstrates the need for long-term planning and city and regional level</li> <li>• These land use types may become more important due to increasing fuel costs that spur growth at a local scale in manufacturing, distribution, repair industries, food production and processing</li> <li>• Dives into land use implications of certain planning approaches and tools</li> <li>• recommends a metropolitan level planning approach, not city-by-city to avoid piecemeal decision-making</li> </ul>
Rose, A., & Wei, D. (2013)- Estimating the economic consequences of a port shutdown: The special role of resilience	Academic paper	<p><b>ECONOMIC RESILIENCE PLANNING(PORT-SPECIFIC)</b></p> <ul style="list-style-type: none"> <li>• Supply chain measures, including: ship rerouting, shifting to other ports; export diversion to other transportation modes; use of inventories; conservation; unused capacity; recapture after port opening; substitution of inputs; production rescheduling</li> </ul>	<ul style="list-style-type: none"> <li>• Port resilience actions can help in port recovery but they consist mostly of altering supply chains and business operations</li> <li>• Such actions may have to be done in conjunction with flood protection measures</li> <li>• Article provides a methodology for calculating total economic consequences of a seaport disruption, factoring in the major types of resilience</li> <li>• Modeled shutdowns of sea ports and found that business related resilience actions led to a 70% reduction in infrastructure disruptions across the region</li> </ul>
National Institute for Standards and Technology. (2016a.) - Toward a more resilient community: An overview of the Community Resilience Planning Guide for Buildings and Infrastructure	Government: planning guide	<p><b>LAND USE/REGULATORY</b></p> <ul style="list-style-type: none"> <li>• Building codes and inspections pre- and post-event</li> <li>• Design standards for construction in high hazard zones (DPAs/ building bylaws)</li> <li>• Open space provision for interim use</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• Green infrastructure</li> </ul> <p><b>ECONOMIC RESILIENCE PLANNING</b></p> <ul style="list-style-type: none"> <li>• Critical infrastructure response and recovery via improvements in reliability and functions, added redundancy to transport routes</li> <li>• Pre-event land use, repair, and reconstruction for future development</li> <li>• Mapping critical infrastructure</li> <li>• Area revitalization (e.g., providing open space; new types of jobs in recreation or environmental sectors)</li> </ul>	
Chang, S.E. 2016. "Socioeconomic Impacts of Infrastructure Disruptions"	Academic	<p><b>ECONOMIC RESILIENCE PLANNING</b></p> <ul style="list-style-type: none"> <li>• Rapid restoration of services from infrastructure, business response planning and resilience strategies (behaviour and hardware)</li> <li>• Cascade analysis to understand the interrelations between infrastructure failures</li> </ul>	<ul style="list-style-type: none"> <li>• Network redundancy is important especially for transportation systems → rapid economic recovery</li> <li>• Be aware of range of losses to businesses and the economy from inaction, including production and sales losses, reduced employee income and tax payments, halting of business operations, temporary</li> </ul>

Source	Source Type	Relevant planning tools and approaches used	Other Relevant Findings
		<ul style="list-style-type: none"> <li>Computer modeling to assess indirect economic impacts</li> <li>Economy wide planning via infrastructure network redundancy</li> </ul>	<p>or permanent closure, losses to other businesses with linkages, employee or customer access, transportation of goods and supplies, and other costs associated with response, repair, or cleanup</p>
<p><b>Bosello, F., Roson, R. and Tol, R.S., 2007. Economy-wide estimates of the implications of climate change: Sea level rise</b></p>	<p>Academic paper</p>	<p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>Beach renourishment</li> <li>Dike building</li> </ul> <p><b>ECONOMIC RESILIENCE PLANNING</b></p> <ul style="list-style-type: none"> <li>Computer modeling (e.g., DART model) to understand estimated economic implications of sea level rise</li> </ul>	<ul style="list-style-type: none"> <li>Many studies apply the direct cost method to assess economic impacts of sea level rise, but this method leaves out the effect of land losses on land prices, which has significant economic implications</li> </ul>
<p><b>Webb, G.R. et al. 2000.- Businesses and Disasters: Empirical Patterns and Unanswered Questions</b></p>	<p>Academic paper</p>	<p><b>LAND USE/REGULATORY</b></p> <ul style="list-style-type: none"> <li>Programs to arrange for business relocation</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>Building/job site evaluations</li> </ul> <p><b>ECONOMIC RESILIENCE</b></p> <ul style="list-style-type: none"> <li>Firm level: Direct first aid</li> <li>Firm level: Indirect disruption preparedness through business response and recovery planning</li> <li>Economy-wide planning – protect sectors that might be hurt the most due to pre-event business climate</li> </ul>	<ul style="list-style-type: none"> <li>Look not just at direct impacts to employment lands and loss of job space and give overall consideration to lifeline infrastructure impacts which could affect business recovery more long-term</li> <li>Additional attention should be paid to sectors, such as manufacturing that are experiencing decline, to ensure their recovery after shocks and stresses like acute flooding and sea level rise</li> <li>Factors influencing firm-level preparedness to direct and indirect impacts: business size, ownership vs. leasing model, type of business</li> </ul>
<p><b>Ng, A.K., Chen, S.L., Cahoon, S., Brooks, B. and Yang, Z., 2013. Climate change and the adaptation strategies of ports. Research in Transportation Business &amp; Management, 8</b></p>	<p>Academic book</p>	<p><b>LAND USE/ REGULATORY</b></p> <ul style="list-style-type: none"> <li>flood mapping and risk assessment via GIS</li> <li>port relocation (see Chapter 4)</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>raising piers and wharves to accommodate a working range for loading and unloading of cargo, passengers</li> <li><b>structural changes</b> including dredging and other capital projects</li> </ul> <p><b>ECONOMIC RESILIENCE PLANNING</b></p> <ul style="list-style-type: none"> <li><b>Non-structural changes</b> including adjusting seasonal cargo loadings, topping off (a form of shipping adjustment), modal shift</li> <li><b>technological changes</b> to vessel size, cargo handling, navigation, improved environmental impacts via engineering and management</li> <li>reducing vulnerability of port-related value chain elements through enforcing higher standards for equipment, risk management, optimisation of procedures, etc.</li> <li><b>Storm preparation and response plans</b></li> </ul> <p><b>MULTI-STAKEHOLDER ENGAGEMENT</b></p> <ul style="list-style-type: none"> <li>Collaboration for adaptation planning for Port of San Diego, including local public policy stakeholders, regional, state/provincial, and federal public policy stakeholders, environmental/advocacy stakeholders, economic/contractual stakeholders and port authority and port technical advisory team</li> </ul>	<ul style="list-style-type: none"> <li>Port-based economic activities that could be susceptible to sea level rise include commercial activities and industries like shipping, hospitality, restaurants, and commercial fishing as well as any economic activities related to public recreation and natural habitat protection</li> <li>Risk assessment approach for Port of San Diego involved developing a GIS model, estimating likelihood of inundation, estimating consequences, and determining risk for port functions in planning districts (see Chapter 2, p 11 for GIS model inputs)</li> <li>applied Theory of Change (ToC) in adaptation plan development</li> <li>See Chapter 2 case study on a multi-stakeholder engagement for adaptation planning at the Port of San Diego</li> </ul>

Source	Source Type	Relevant planning tools and approaches used	Other Relevant Findings
<p><b>City of Surrey General Website: Coastal Flood and Adaptation Strategy 2016</b></p> <p><b>City of Surrey Zoning Bylaw 12000</b></p> <p><b>City of Surrey Building Bylaw 9011</b></p> <p><b>City of Surrey Flood Preparedness Guide for Businesses</b></p>	<p>Municipal Government: bylaw and community plan</p>	<p><b>LAND USE/REGULATORY</b></p> <ul style="list-style-type: none"> <li>• Building Bylaw 9011- restriction on environmentally sensitive lands, use of QPs for inspection prior to construction/ occupancy</li> <li>• Floodplain mapping</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• System of dykes and sea dams (see CFAS)</li> <li>• Flood proofing standards (see Zoning Bylaw 12000), including fixed equipment policies, minimum setback (30 m), and minimum elevation standards/object elevation</li> </ul> <p><b>ECONOMIC RESILIENCE PLANNING</b></p> <ul style="list-style-type: none"> <li>• business-focused flood preparedness planning</li> </ul>	<ul style="list-style-type: none"> <li>• City of Surrey has an employment lands strategy but only information about environmentally sensitive lands is provided</li> </ul>
<p><b>City of Richmond- General Website Flood Protection Strategy 2008-2031</b></p> <p><b>City of Richmond Employment Lands Strategy Staff Report 2011</b></p>	<p>Municipal Government: community plan</p>	<p><b>LAND USE/REGULATORY</b></p> <ul style="list-style-type: none"> <li>• City of Richmond Floodplain Management Policy – establishes minimum FCL and future flood protection initiatives</li> <li>• Proposed Floodplain Bylaw will include new setback, FCL, and minimum building habitable space requirements where FCL cannot be met, and limited site-specific exemptions aligned with provincial standards</li> <li>• Proposed flood standards (e.g., flood proofing buildings and structures)</li> <li>• Alternate requirements for exemptions to flood standards</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• Drainage system with pump stations, flood boxes, irrigation structures, and storm sewer</li> <li>• System of defense through dykes, dyke survey program, 24/7 river- level monitoring program, dike seismic study, new infrastructure,</li> <li>• Proposed in strategy: raising land levels</li> <li>• Stormwater retention and detention</li> <li>• Dredging</li> </ul> <p><b>FINANCIAL TOOLS</b></p> <ul style="list-style-type: none"> <li>• Cost sharing mechanisms</li> </ul> <p><b>ECONOMIC RESILIENCE PLANNING</b></p> <ul style="list-style-type: none"> <li>• Flood preparedness, recovery, and response plans</li> <li>• More intensive use of land in other areas (e.g., vacated school sites), especially for displaced businesses</li> <li>• Requirement for improved flood protection for employment land development and ensuring water lots/leases are protected</li> </ul>	<ul style="list-style-type: none"> <li>• Employment and economic development specific adaptation actions</li> </ul>
<p><b>Metro Vancouver Industrial Lands Strategy Inventory Summary Report 2014</b></p>	<p>Regional Government: Summary report</p>	<p><b>LAND USE/REGULATORY</b></p> <ul style="list-style-type: none"> <li>• extending lifespan of available vacant lands</li> <li>• securing industrial lands for long-term protection via designations or land use policies</li> </ul>	<ul style="list-style-type: none"> <li>• Pressures of land conversion of industrial to other uses</li> <li>• Limited industrial land base – but it is vital to protect this to support economic growth and preserve employment</li> <li>• From 2015 inventory, trends of net reduction of industrial lands was observed (from 2010 to 2015, net reduction of 350 ha)</li> <li>• Municipal policies and regional land use designations can be used to secure industrial lands for long-term protection</li> </ul>

Source	Source Type	Relevant planning tools and approaches used	Other Relevant Findings
			<ul style="list-style-type: none"> <li>• There are not enough large sites for “trade enabling” logistics uses (e.g., large sites near transportation infrastructure for efficient and regional truck trips</li> <li>• There is the potential for extension of the lifespan of available vacant lands</li> <li>• Difficulty of intensifying lands in the short-term - General Industrial (93% of lands) are fully utilized</li> </ul>
<p><b>City of North Vancouver-Climate Change Adaptation Plan 2013</b></p>	<p>Municipal Government: community plan</p>	<p><b>LAND USE / REGULATORY</b></p> <ul style="list-style-type: none"> <li>• Flood map updates</li> <li>• Development Permit Area guidelines for properties in floodplains (in progress as of 2013) such as a setback, vegetation requirements, and FCL</li> <li>• Provision of parks and greenspace for stormwater management, flood protection of other lands, and rainwater collection (planned)</li> <li>• Land use and development based risk management for key transportation assets (transit hubs, depots, bridges, main thoroughfares) for flooding and storms (ongoing)</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• Retrofitting/replacement and structural protection</li> <li>• Soft erosion and flood control through land use and development regulation and integrated stormwater management plan (<b>ongoing</b>)</li> <li>• Integrated Stormwater Management Plan 2016 accounting for sea level and hydrological change for all existing and new infrastructure, buildings, and developments</li> <li>• Consideration of climate vulnerabilities in asset management and infrastructure planning</li> </ul> <p><b>ECONOMIC RESILIENCE PLANNING</b></p> <ul style="list-style-type: none"> <li>• Risk management for key transportation assets from power outages – backup power supply and ventilation systems for electrical equipment</li> <li>• Transportation Plan renewal and updates in climate change data</li> <li>• Inventory and regular risk assessments of municipal transportation infrastructure</li> <li>• Telecommuting for city staff and other officials in emergencies, emergency recovery, emergency response and recovery planning</li> </ul> <p><b>ECONOMIC RESILIENCE PLANNING</b></p> <ul style="list-style-type: none"> <li>• Using climate change mitigation and adaptation actions to improve local economy via advertising City’s climate leadership to attract new businesses and customers</li> <li>• Increasing economic diversification and number of jobs</li> </ul> <p><b>PUBLIC EDUCATION AND AWARENESS</b></p> <ul style="list-style-type: none"> <li>• Awareness building around vulnerabilities, mitigation and adaptation options around emergency preparedness, alternate supply chains, local materials, markets and employment in partnership with Chamber of Commerce and Business Association</li> </ul>	<p>Various policies presented in Climate Change Adaptation Plan 2013 on flood risk mitigation and mitigating disruption to transportation from climate change caused hazards</p> <p>Strong focus on land use tools</p> <p>Employment and economic development specific adaptation actions (p 20)</p>

Source	Source Type	Relevant planning tools and approaches used	Other Relevant Findings
<p><b>City of Seattle Climate Preparedness Strategy 2017</b></p>	<p>Municipal Government: community plan</p>	<p><b>LAND USE/REGULATORY</b></p> <ul style="list-style-type: none"> <li>• Coastal development standards</li> <li>• Reduce flood hazards through Floodplain Development Ordinance</li> <li>• Flood exposure and vulnerability mapping and regular updates for shoreline and creeks</li> <li>• Regulation for development in flood prone areas</li> <li>• Shoreline Master Plan</li> <li>• Rolling easements, which involves a property owner’s interest in preventing erosion or submerging of real estate and its subsequent conversion to public or environmental assets such as wetlands, beaches, or public access</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• Green stormwater infrastructure and on-site rainwater storage</li> <li>• Stormwater code and drainage improvements for property owners</li> <li>• Mandatory building tune-ups</li> <li>• Reduction in minimum construction FCL</li> </ul> <p><b>FINANCIAL TOOLS</b></p> <ul style="list-style-type: none"> <li>• insurance mechanisms (e.g., reduced rates)</li> <li>• incentives for building upgrades to ensure climate preparedness</li> </ul>	
<p><b>San Francisco Bay Shoreline Adaptation Atlas 2019</b></p>	<p>Consulting Report</p>	<p><b>LAND USE/REGULATORY</b></p> <ul style="list-style-type: none"> <li>• zoning and overlay zones</li> <li>• setbacks, buffers, and clustering</li> <li>• rebuilding and redevelopment restrictions</li> </ul> <p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• Soft erosion control measures (e.g., green stormwater infrastructure)</li> <li>• Hard erosion control measures (e.g., sea walls, dykes, levees)</li> <li>• Land elevation</li> <li>• Building codes and building retrofits</li> </ul> <p><b>FINANCIAL TOOLS</b></p> <ul style="list-style-type: none"> <li>• Conservation easements</li> <li>• Transfer of development rights</li> <li>• Tax incentives</li> <li>• Geologic Hazard Abatement District - independent governmental districts that can assess properties within a defined area and dedicate the revenue to abating or controlling hazards such as landslides, earthquakes, and erosion.</li> <li>• Buyouts</li> </ul> <p><b>ECONOMIC RESILIENCE PLANNING</b></p> <ul style="list-style-type: none"> <li>• Considering protecting or relocating job centres</li> <li>• Considering protecting access to jobs by securing roads, ports, ferry, and rail</li> </ul>	<p>Currently there is a setback for high residential areas but job centres are still at risk</p> <p>Also included a variety of natural or nature-based solutions (e.g., tidal marshes, migration space preparation, etc.)</p>

Source	Source Type	Relevant planning tools and approaches used	Other Relevant Findings
<p><b>Mayor’s Office of Recovery and Resiliency: Climate Resiliency Design Guidelines</b></p>	<p>Municipal government: design guidelines</p>	<p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• Climate resiliency design guidelines that help to inform building code and design standards for NYC capital projects</li> <li>• Design based interventions for managing sea level rise include:                             <ul style="list-style-type: none"> <li>- Relocation</li> <li>- Permanent barriers</li> <li>- Deployable flood barriers</li> <li>- Natural approaches (living shorelines, wetland restoration)</li> <li>- Equipment protection for critical or expensive-to-replace electrical or mechanical objects</li> <li>- Wet proofing</li> <li>- Dry proofing</li> <li>- Redundant communications and backup power for telecommunications equipment</li> <li>- Physical installations for all buildings and infrastructures within floodplain and behind flood barriers (e.g., backflow preventers and valves)</li> <li>- Shoreline improvements to reduce wave heights</li> </ul> </li> </ul> <p><b>OTHER/ADDITIONAL</b></p> <ul style="list-style-type: none"> <li>• exposure screening tool for capital projects for sea level rise on page 32</li> <li>- Current flood risk</li> <li>- Future flood risk</li> <li>- Current tidal inundation</li> <li>- Future tidal inundation</li> </ul>	<p>Distinguishes between soft resiliency (green infrastructure operational measures or investments) and hard resiliency strategies (built or intensive investments)</p> <p>Recommends single interventions or risk reduction measures that can address multiple hazards at once and also attain co-benefits/other goals like climate change mitigation</p> <p>Distinguishes between major and critical facilities. Major projects are capital projects whose total cost for design and construction exceeds \$50 Million</p> <p><b>Relevant to sea level rise:</b> Requires that all major capital projects be evaluated for coastal flood risk even if outside of the boundaries of the 100-year flood zone</p> <p>Guidelines apply to all capital projects except for coastal flood risk protection that must meet different standards and should consider other stressors that coincide with sea level rise such as coastal erosion</p>
<p><b>Institute for Catastrophic Loss Reduction website</b></p>		<p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• property-level protection measures that protect equipment and flood proof buildings</li> </ul> <p><b>ECONOMIC RESILIENCE PLANNING</b></p> <ul style="list-style-type: none"> <li>• Open for Business Program (business preparedness and recovery program)</li> </ul>	
<p><b>Wetlands Watch</b></p>	<p>Non-profit informational website</p>	<p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• setbacks</li> <li>• Conservation/rolling easements</li> <li>• Transfer of development rights</li> </ul>	
<p><b>Sinclair 2015: Capital Regional District SLR Planning Approaches Project Report 2015</b></p>	<p>Municipal government: report</p>	<p><b>PLANNING TOOLS</b></p> <ul style="list-style-type: none"> <li>• climate change action plans</li> <li>• structural and non-structural protection for sites</li> <li>• regulatory tools for private land</li> <li>• policy and procedural tools for public works and projects</li> </ul> <p><b>LAND USE/REGULATORY TOOLS</b></p> <ul style="list-style-type: none"> <li>• Flood Construction Levels and Setbacks</li> <li>• Development Permits</li> <li>• Covenants</li> <li>• Development restrictions</li> <li>• Policies and standards</li> <li>• relocation of assets</li> </ul>	<p>Highlights Adaptation Framework</p> <ul style="list-style-type: none"> <li>- Avoid, Protect, Accommodate, Planned or Managed Retreat</li> </ul> <p>Highlights a 4-step Decision-making process for sea level rise</p> <ul style="list-style-type: none"> <li>- Identify sea level rise scenarios</li> <li>- Select adaptation strategies</li> <li>- Select adaptation measures</li> <li>- Develop implementation tools</li> </ul> <p>See page 11 table: Draft Sea Level Rise Adaptation Framework</p> <p>Provides caveats for each Adaptation Approach from PARA Framework</p> <ul style="list-style-type: none"> <li>• <b>Avoid</b> options risk the loss of development potential and lowered property values and tax base</li> </ul>

Source	Source Type	Relevant planning tools and approaches used	Other Relevant Findings
		<p><b>ENGINEERING</b></p> <ul style="list-style-type: none"> <li>• grey infrastructure</li> <li>• green infrastructure</li> <li>• asset retrofits</li> </ul> <p><b>FINANCIAL TOOLS</b></p> <ul style="list-style-type: none"> <li>• Retrofit incentives</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Protect</b> measures are often expensive as they are large capital investments for the government</li> <li>• <b>Accommodate</b> options often pose costs to the owner of the asset</li> <li>• <b>Retreat</b>, similar to avoid, risks the loss of development potential and lowered property values and tax base</li> </ul>