SEA LEVEL RISE PRIMER PART II

SEA LEVEL RISE ADAPTATION BEST PRACTICES

CAMPBELL RIVER

RISING SEAS

NOVEMBER 2018

STRUCTURE OF THE SEA LEVEL RISE ENGAGEMENT SUPPORT PROCESS

THE SEA LEVEL RISE ENGAGEMENT SUPPORT PROCESS IS PRESENTED IN FOUR PARTS:

I. **Introduction to Sea Level Rise, Risks and Adaptation Methods** – a summary of why sea level rise adaptation is required, introduction to terms and local risks.

II. **Sea Level Rise Adaptation Best Practices** – a guide to common tools to address sea level rise adaptation in Campbell River, highlighting their strengths and challenges.

III. **Local Adaptation Options and Evaluation Process** – a summary of the evaluation process and proposed options to address sea level rise.

IV. **Sea Level Rise Strategy and Action Plan Recommendations** – Reporting on how sea level rise adaptation may be strategically integrated into ongoing city processes and redevelopment in Campbell River.

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Robert V. Ostler Park, Campbell River. (Credit: Sanctuary Studios)

1.0 BEST MANAGEMENT PRACTICES INTRODUCTION

This document provides an introduction to a range of common best practices to adapt waterfront areas around the world to be more resilient to increasing coastal hazards related to climate change and sea level rise. These are options being considered for Campbell River that will be narrowed with technical analysis results and community input.

THE BEST MANAGEMENT PRACTICES ARE:

- Neighbourhood/Reach Scale
  - Beach Nourishment
  - Living Shorelines
  - Dikes
  - Groynes
  - Offshore Reef / Breakwater
  - Pocket Beach / Headland
  - Rock Armouring
  - Seawalls
  - Temporary Flood Barriers at Driveways
  - Floodbox / Pump Station
- Building/Lot Scale
  - Elevate on Fill
  - Elevate on Piles
  - Wet Floodproofing
  - Protect Building Systems

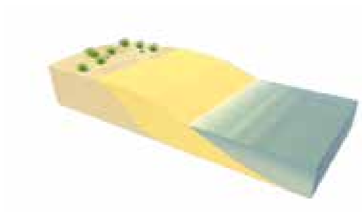
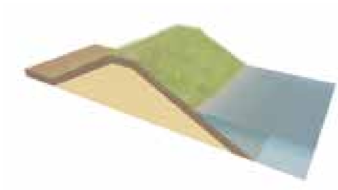
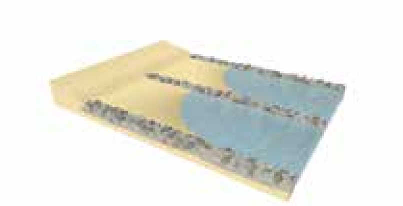
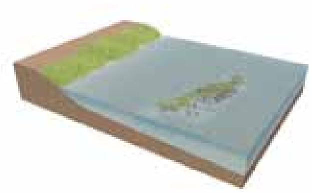
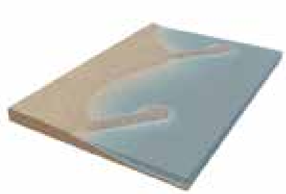
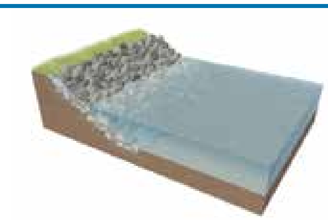
The best management practices are focused upon means of adapting waterfront areas while maintaining as much as possible the existing land usage. Retreat is recognized as a viable means of adaptation, but it results in a major change in land usage. The best management practices in this document are provided within the context of an area for which the community is wishing to evaluate options that allow retention of the existing land usages.

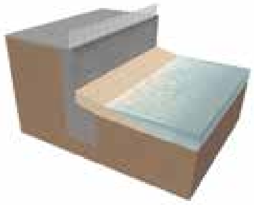
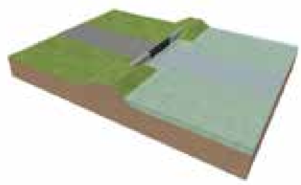
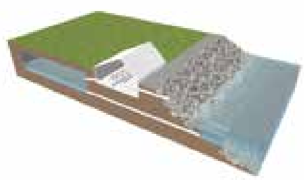
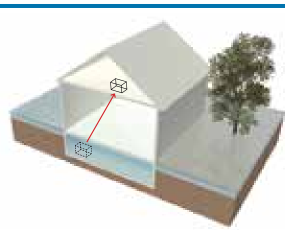
Table II - 1 summarizes the best management practices. The document includes key description of purpose, graphics and diagrams to show scope and application, key design principles, limitations and sizing variables, and maintenance and operations considerations.

Coastal best practices must be designed to meet local geotechnical, seismic, and coastal wave conditions, which vary depending on wind exposure and wave fetch, shoreline morphology and materials, topographic, bathymetric and groundwater conditions. Consultation with technical experts is advised.

All practices that extend onto the foreshore beyond the natural boundary require land tenure from Provincial, Crown, and environmental/riparian approvals from Governments of Canada. Local government regulations including development permits and building permits apply to private lands as well.

Table II - 1: Best Management Practice Summary Table

ADAPTIVE STRATEGY	SCALE	BENEFITS/LIMITS
Beach Nourishment 	Neighbourhood / reach	• Expands the usable beach area, allowing for increased public access and use • Reduces wave runup and wave effect elevations at natural boundary
Living Shorelines 	Neighbourhood / reach	• Provides increased complexity of intertidal habitat and coastal vegetation • May help improve water quality • Provides educational opportunities • Must be sheltered from erosion
Dikes 	Neighbourhood / reach	• Will resist storm waves when surface is properly armoured • Land on top of dikes can be used for paths or roads • May block views of the sea
Groynes 	Neighbourhood / reach	• Can extend lifespan of beach nourishment projects • Wide range of construction methods and materials • Inconvenience to walking along the shore • Can increase beach erosion
Offshore Reefs / Breakwaters 	Neighbourhood / reach	• Can create marine habitat • Provide recreational opportunities • May be augmented as seas rise • Potential visual impact and navigation hazard
Pocket Beach / Headland 	Neighbourhood / reach	• Use a combination of gravel beach nourishment and offshore stone headlands • Provide recreational opportunities • Can be relatively expensive
Rock armouring 	Neighbourhood / reach	• Unlikely to fail catastrophically, and when properly engineered have an indefinite lifespan • Leads to coastal squeeze and intertidal habitat loss • Creates wave splash, but less than seawall

ADAPTIVE STRATEGY	SCALE	BENEFITS/LIMITS
Seawalls 	Neighbourhood / reach	• Smaller footprint compared to other strategies • Can be designed to allow for public use of the waterfront • Not recommended for exposed areas due to high wave runup and overtopping elevations • Leads to habitat loss
Temporary Flood Barriers at Driveways 	Neighbourhood / reach	• Relatively easy to install • Appropriate where grades do not allow raising roadways • Barrier must be placed in advance of storm
Floodbox / Pump Station 	Neighbourhood / reach	• Used to drain large areas that have been inundated by coastal and/or inland floodwaters when storm drains are overwhelmed • Expensive to build and can have high energy consumption
Elevate on Fill 	Building / Lot	• At appropriate elevations, can provide continued protection from flooding due to coastal storms or sea level rise • Neighbouring constraints may limit space for fill slope • May require maintenance to prevent erosion
Elevate on Piles 	Building / Lot	• Provide protection for the broadest range of flooding conditions • May provide for additional parking space under the building. • Emergency access is restricted
Wet Floodproofing 	Building / Lot	• Recognizes some uses like crawl spaces, parking or storage could accept flooding • Does not stop flooding
Protect Building Systems 	Building / Lot	• Relocate critical equipment above flood level • Can often be applied to buildings in place • Can be used in conjunction with other strategies to provide additional protection • Can allow quicker building recovery • Does not stop flooding

City of Campbell River

Beach Nourishment

Beaches and dunes are protective features that reduce the impacts of coastal storms.

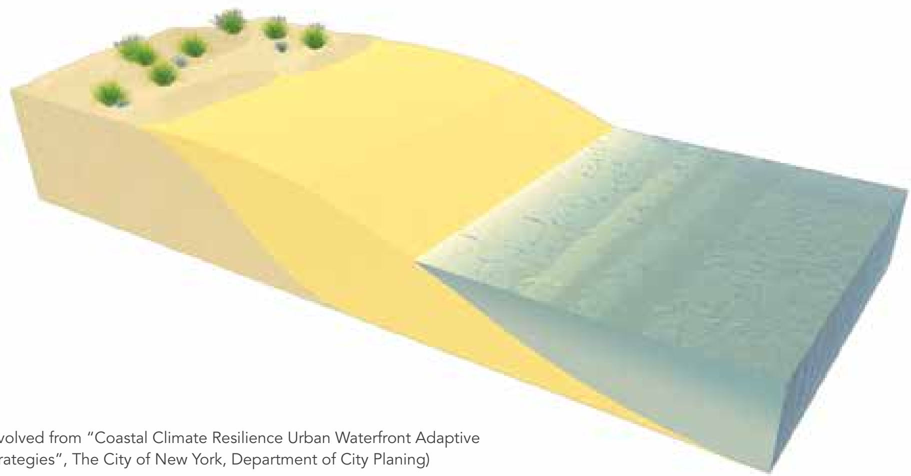
Ability to Address Coastal Hazards

Event Based	Storm Surge (High)	●
	Storm Surge (Low)	●
	Wave Force	●
	Sudden Erosion	◐
Gradual	Flooding Due to Sea Level Rise	●
	Gradual Erosion	◐

Applicability to Landscape Type

Oceanfront Beaches	●
Coastal Marshes	○
Oceanfront Slopes	◐
Sheltered Bay Slopes	○
Hardened Sheltered Bay Slopes	○
Sheltered Bluffs	○
Hardened Sheltered Bluffs	○

● HIGH ◐ MEDIUM ○ LOW



(Evolved from "Coastal Climate Resilience Urban Waterfront Adaptive Strategies", The City of New York, Department of City Planing)

Beach Nourishment Examples

1 Beach nourishment, Campbell River, BC

2 Beach nourishment, Campbell River, BC

3 Beach nourishment, Parksville, BC

4 Log habitat, Campbell River, BC

Design Principles and Limitations

- Placing gravel and sand on beaches increases the elevation and distance between the upland areas and shoreline.
- Beach fill material closely matches the properties of gravel on the natural beach.
- Existing dunes can be reinforced or new ones created to provide additional protection from storm surge.
- The addition of vegetation and/or sand fences increases the longevity of dunes.
- Double dune systems are preferable as they allow the primary dune to break the waves and the secondary dune to reduce surge and replenish the primary dune.
- Best suited for low-lying oceanfront areas with existing sources of sand and gravel.
- Not suitable for shorelines with high erosion or longshore transport rates.

LAND TENURE AND APPROVALS

- Requires foreshore land tenure from Province of BC, environmental approval from Fisheries and Oceans Canada, and permits from local government.

RELATIONSHIP TO ENVIRONMENT

- Beach nourishment is more flexible and typically has a lower environmental impact than coastal armouring structures.
- Environmental impacts during construction and establishment include: disturbance of habitats, increased turbidity, and sedimentation. These impacts can be experienced at both the site of the nourishment as well as the area import material is collected from.
- Beach nourishment projects can alter the flow of sediment along adjacent shorelines.

MAINTENANCE AND MONITORING

- Nourishment projects typically require replenishments between three and ten years depending on wave exposure and must be monitored regularly.

Living Shorelines

Living shorelines use natural materials such as plants, sand, and rocks to protect shorelines from erosion.

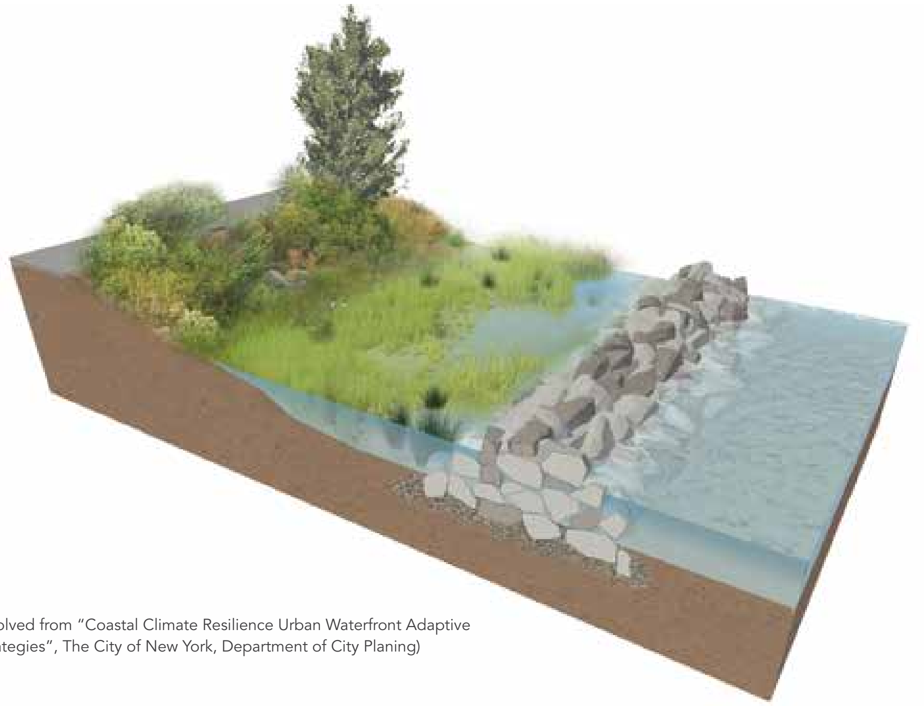
Ability to Address Coastal Hazards

Event Based	Storm Surge (High)	Low
Event Based	Storm Surge (Low)	Medium
Event Based	Wave Force	Medium
Event Based	Sudden Erosion	High
Gradual	Flooding Due to Sea Level Rise	High
Gradual	Gradual Erosion	High

Applicability to Landscape Type

Oceanfront Beaches	Low
Coastal Marshes	High
Oceanfront Slopes	Low
Sheltered Bay Slopes	High
Hardened Sheltered Bay Slopes	High
Sheltered Bluffs	High
Hardened Sheltered Bluffs	High

HIGH MEDIUM LOW



(Evolved from "Coastal Climate Resilience Urban Waterfront Adaptive Strategies", The City of New York, Department of City Planing)

Living Shoreline Examples

1 Image Credit: Sanctuary Studios

Shoreline habitat, Lantzville, BC

2 Image Credit: Sanctuary Studios

Planted wetland, Qualicum Beach, BC

3 Image Credit: Sanctuary Studios

Natural living shore, Lantzville, BC

4 Image Credit: Sanctuary Studios

Constructed side channel, Courtenay, BC

Design Principles and Limitations

- Incorporate ecological function into shoreline stabilization. May feature elements such as wetland vegetation, and oyster or mussel habitat.
- Control erosion and stabilize shorelines.
- Often include some form of breakwater structure to create a calm, vegetated zone.
- Not suitable for high wave energy environments.
- Best suited for areas with flat to moderate slopes.
- May reduce the risk of frequent inundation and periodic low surge flooding.

LAND TENURE AND APPROVALS

- If extending onto public foreshore requires foreshore land tenure from Province of BC, environmental approval from Fisheries and Oceans Canada, and permits from local government.
- All adaptation measures must be contained within property boundaries and avoid encroaching on Crown property on the waterfront, unless senior government permits are gained.

RELATIONSHIP TO ENVIRONMENT

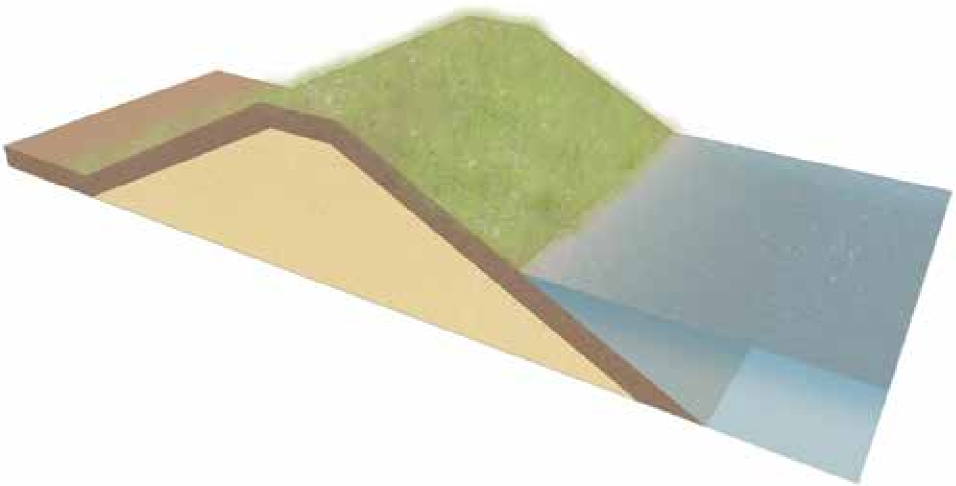
- Provide intertidal habitat and coastal vegetation.
- Can allow for links between aquatic and upland habitats, maintain natural shoreline dynamics, and preserve natural coastal processes that protect and enhance nursery and critical feeding habitats.
- May improve water quality by filtering run-off from upland areas and trapping nutrient rich soils in the shoreline system.
- May disrupt sediment transport and accelerate erosion of adjacent, unreinforced sites on sandy shorelines.

MAINTENANCE AND MONITORING

- Requires annual maintenance, particularly in controlling invasive plants.
- Major repairs and reconstruction may be needed following a major storm or flood event.
- Established living shorelines may be able to self repair over time.

Dikes

Dikes are shoreline embankments that provide protection from flooding.



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Ability to Address Coastal Hazards

Event Based	Storm Surge (High)	●
Event Based	Storm Surge (Low)	●
Event Based	Wave Force	◐
Event Based	Sudden Erosion	◐
Gradual	Flooding Due to Sea Level Rise	●
Gradual	Gradual Erosion	◐

Applicability to Landscape Type

Oceanfront Beaches	○
Coastal Marshes	●
Oceanfront Slopes	○
Sheltered Bay Slopes	◐
Hardened Sheltered Bay Slopes	◐
Sheltered Bluffs	○
Hardened Sheltered Bluffs	○

● HIGH ◐ MEDIUM ○ LOW

Dike Examples

1 Dike with armouring/vegetation, Germany

2 Dike blocking views, Germany

3 Dike with habitat benches, Germany

4 Dike at pump station, Netherlands

Design Principles and Limitations

- Dikes are best suited for low-lying areas that require protection from storm surge and river flooding.
- Typically constructed from soil, sand, or gravel.
- When armoured with rock, dikes can resist heavy storm waves.
- New dike construction is dependent on the suitability of foundation materials, and the availability of both land tenure and materials.
- Stormwater storage and pumping systems are typically required with the installation of new dikes to ensure floodwaters can be properly drained.
- The inland side of dikes must resist erosion due to periodic overtopping. Standard dike side slopes are usually 3:1 on both inside and outside faces.

LAND TENURE AND APPROVALS

- Require an extensive permitting process if extending onto public foreshore.
- All adaptation measures must be contained within property boundaries and avoid encroaching on Crown property on the waterfront, unless senior government permits are gained.
- Requires environmental approval from Fisheries and Oceans Canada, in addition to local government permits.

RELATIONSHIP TO ENVIRONMENT

- Can block views and access to the water.
- Can cause significant ecological disturbance of shoreline and near shore areas.
- Dikes can lead to a false sense of security, inadvertently encouraging development in areas vulnerable to coastal and river flooding. Dikes historically have been subject to occasional breach or failure.
- If it is anticipated that the dike will be raised in the future it is important to prearrange the space through land tenure.

MAINTENANCE AND MONITORING

- Dikes require regular monitoring to ensure they are structurally sound – including against earthquake events.
- All dikes in BC must be constructed under the maintenance jurisdiction of a responsible authority – usually a local government.
- Dikes have a service lane on the surface to allow rapid inspection before and during storm events, and access for heavy equipment if required for repair.

Groynes

Groynes are barriers that extend perpendicularly from the shore to prevent beach erosion, trap sand and gravel, and reduce wave action.

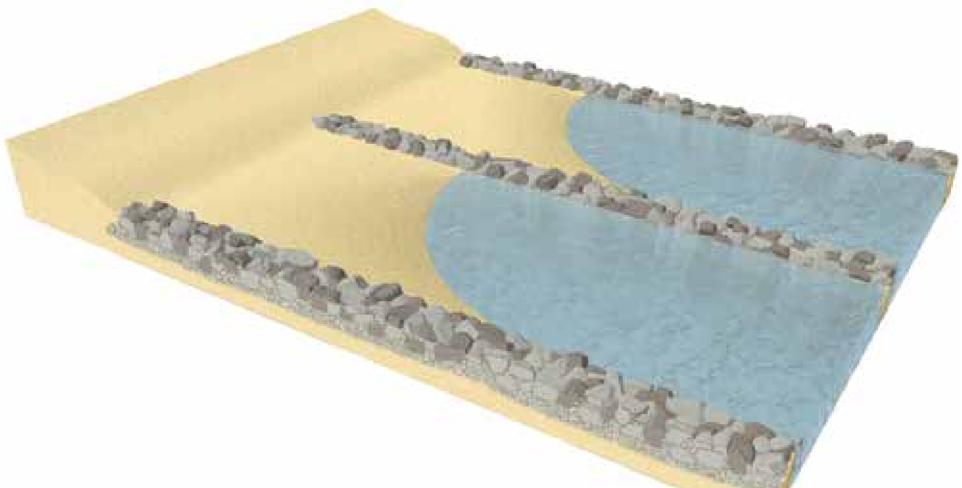
Ability to Address Coastal Hazards

Event Based	Storm Surge (High)	LOW
Event Based	Storm Surge (Low)	LOW
Event Based	Wave Force	MEDIUM
Event Based	Sudden Erosion	MEDIUM
Gradual	Flooding Due to Sea Level Rise	LOW
Gradual	Gradual Erosion	HIGH

Applicability to Landscape Type

Oceanfront Beaches	HIGH
Coastal Marshes	LOW
Oceanfront Slopes	LOW
Sheltered Bay Slopes	LOW
Hardened Sheltered Bay Slopes	LOW
Sheltered Bluffs	MEDIUM
Hardened Sheltered Bluffs	LOW

HIGH MEDIUM LOW



(Evolved from "Coastal Climate Resilience Urban Waterfront Adaptive Strategies", The City of New York, Department of City Planing)

Groyne Examples

1 Image Credit: Sanctuary Studios

Groyne, Germany

2 Image Credit: Sanctuary Studios

Groyne, Germany

3 Image Credit: Sanctuary Studios

Groyne, Germany

4 Image Credit: Sanctuary Studios

Groynes, Surrey, BC

Design Principles and Limitations

- The primary function of a groyne is to prevent the erosion of beaches by trapping sand and gravel moving in longshore currents.
- Groynes are best suited for areas with extensive oceanfront beaches.
- Construction methods can be adapted to a wide range of site conditions.
- Groynes can be notched to help anchor sand and gravel or permeable to allow for sediment transport.
- Construction materials can consist of wood, stone, concrete, steel or sandbags.
- Groynes are most effective when combined with beach nourishment projects and can often extend the lifespan of such projects.
- The length and width of groynes is site specific and should be informed by engineering studies.

LAND TENURE AND APPROVALS

- Requires foreshore land tenure from Province of BC, environmental approval from Fisheries and Oceans Canada, and permits from local government.

RELATIONSHIP TO ENVIRONMENT

- Groynes can increase the rate of adjacent beach erosion by preventing shoreline sediment transport.

MAINTENANCE AND MONITORING

- Groynes require periodic monitoring to ensure they are performing as intended.
- Re-positioning or replacement of the armouring units may be necessary to ensure proper function.
- Sand and gravel bypassing may be required if/when excess sand builds up on the updrift side of the groyne.
- Groynes typically last 50-100 years before requiring reconstruction.

Offshore Reefs / Breakwaters

Offshore reefs, or breakwaters, are fully or partially submerged structures that provide coastal defense and habitat for marine life.

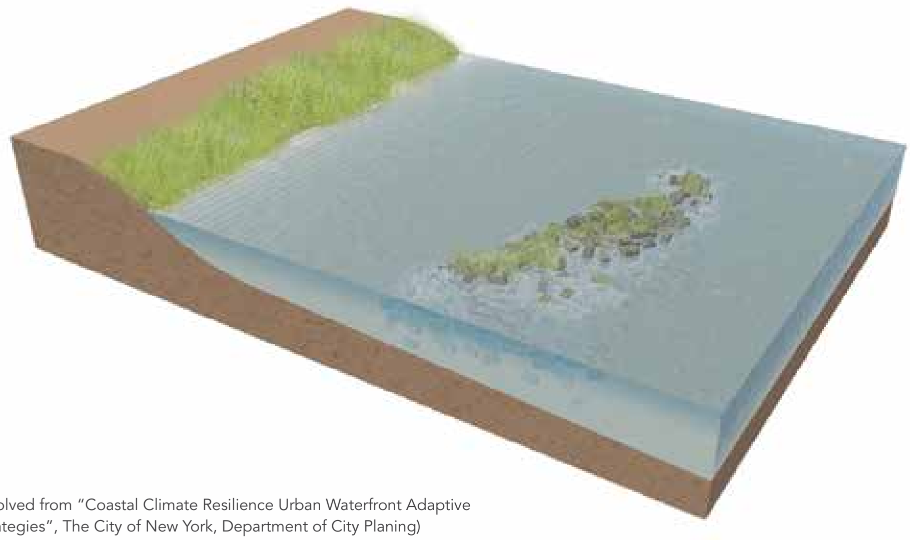
Ability to Address Coastal Hazards

Event Based	Storm Surge (High)	Low
	Storm Surge (Low)	Medium
	Wave Force	High
	Sudden Erosion	High
Gradual	Flooding Due to Sea Level Rise	Low
	Gradual Erosion	High

Applicability to Landscape Type

Oceanfront Beaches	High
Coastal Marshes	Medium
Oceanfront Slopes	High
Sheltered Bay Slopes	Medium
Hardened Sheltered Bay Slopes	Medium
Sheltered Bluffs	Low
Hardened Sheltered Bluffs	Low

HIGH MEDIUM LOW



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Offshore Reef / Breakwater Examples

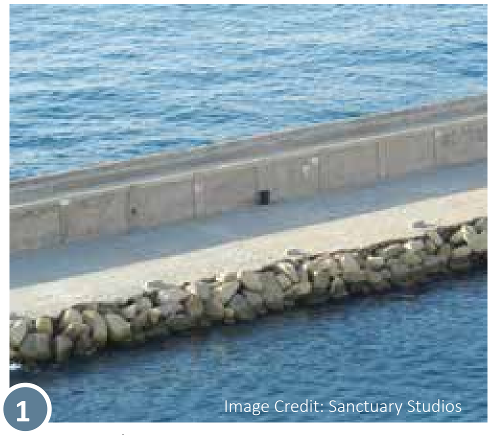


Image Credit: Sanctuary Studios

1 Stone/concrete breakwater, Italy

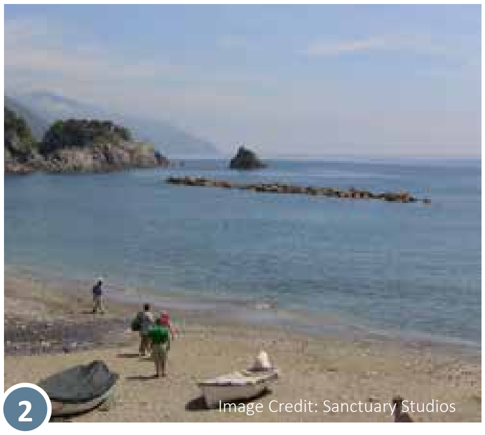


Image Credit: Sanctuary Studios

2 Harbour breakwater, Italy

Image Credit: Sanctuary Studios

3 Submerged breakwater, Italy

Image Credit: Sanctuary Studios

4 Habitat/erosion breakwater, Germany

Design Principles and Limitations

- Offshore reefs diffuse wave energy, stabilize sediments, and reduce marsh retreat.
- Often constructed parallel to the shore.
- Location, foundation conditions, and rock sizing must be engineered with respect for the local environmental, geotechnical and wave exposure conditions.
- Offshore reefs are most effective in shallow water bodies.
- The voids in offshore reefs can be valuable habitat features.

LAND TENURE AND APPROVALS

- Requires foreshore land tenure from Province of BC, environmental approval from Fisheries and Oceans Canada, and permits from local government.

RELATIONSHIP TO ENVIRONMENT

- Preserve coastal habitats.
- May create underwater recreation and ecotourism opportunities.

MAINTENANCE AND MONITORING

- Require ongoing monitoring, especially after large storm events.
- Re-positioning or replacement of the armouring units due to storm surge and wave force may be necessary to ensure proper function.
- May require navigational warning if offshore in navigable waters.

Pocket Beach / Headland

Pocket beaches are small beaches formed between offshore headlands that provide important habitat for a variety of marine plant and animal species

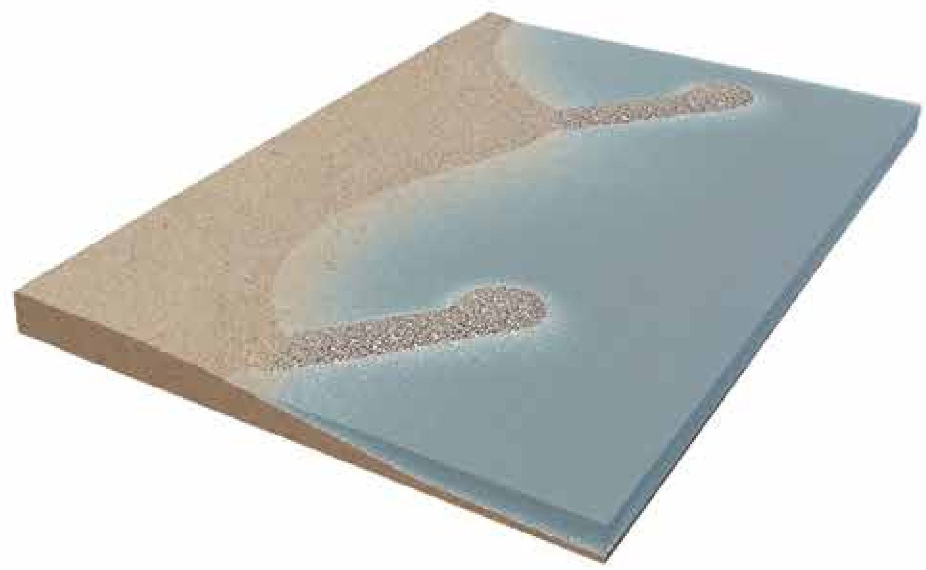
Ability to Address Coastal Hazards

Event Based	Storm Surge (High)	Low
	Storm Surge (Low)	Medium
	Wave Force	High
	Sudden Erosion	High
Gradual	Flooding Due to Sea Level Rise	Low
	Gradual Erosion	High

Applicability to Landscape Type

Oceanfront Beaches	High
Coastal Marshes	Medium
Oceanfront Slopes	High
Sheltered Bay Slopes	Medium
Hardened Sheltered Bay Slopes	Medium
Sheltered Bluffs	Low
Hardened Sheltered Bluffs	Low

HIGH MEDIUM LOW



Pocket Beach / Headland Examples

1 Constructed pocket beach, Bahamas

2 Natural pocket beach, RD of Nanaimo, BC

3 Before: seawall and eroded beach

4 After: constructed pocket beach, Bahamas

Design Principles and Limitations

- Combines the features of offshore breakwaters and beach nourishment. The headlands and beach components must be designed as a coordinated engineered system.
- Length, spacing, material sizing and orientation of headlands must be engineered with respect for the local environmental, geotechnical and wave exposure conditions.
- Pocket beaches between headlands must be engineered with gravel and sand sizing and beach slopes to suit the exposure to waves modified by the headland protection.
- Suitable for shorelines that are gently sloping out into the foreshore.

LAND TENURE AND APPROVALS

- Requires foreshore land tenure from Province of BC, environmental approval from Fisheries and Oceans Canada, and permits from local government.

RELATIONSHIP TO ENVIRONMENT

- May provide restoration of former beaches that have lost finer sand and gravels due to increased water depths and/or shoreline hardening that has stopped upland sources of sediment.
- Improves recreational use of the foreshore and may provide public access along the shoreline.
- Reduces coastal squeeze.
- If properly designed with appropriate materials, the rock headlands may provide intertidal cover and habitat, and sandy/gravelly intertidal shorelines could support forage fish like surf smelt and sand lance.

MAINTENANCE AND MONITORING

- The beach materials may be subject to erosion, needing supplementation from time to time.
- Both headland rocks and beach materials may require supplementary materials to adjust to sea level rise.
- Portions of beach materials extending above the intertidal zone could become vegetated – monitoring and removal of invasive plants will be required.

Rock Armouring

Rock armouring protects banks from erosion caused by wave action.

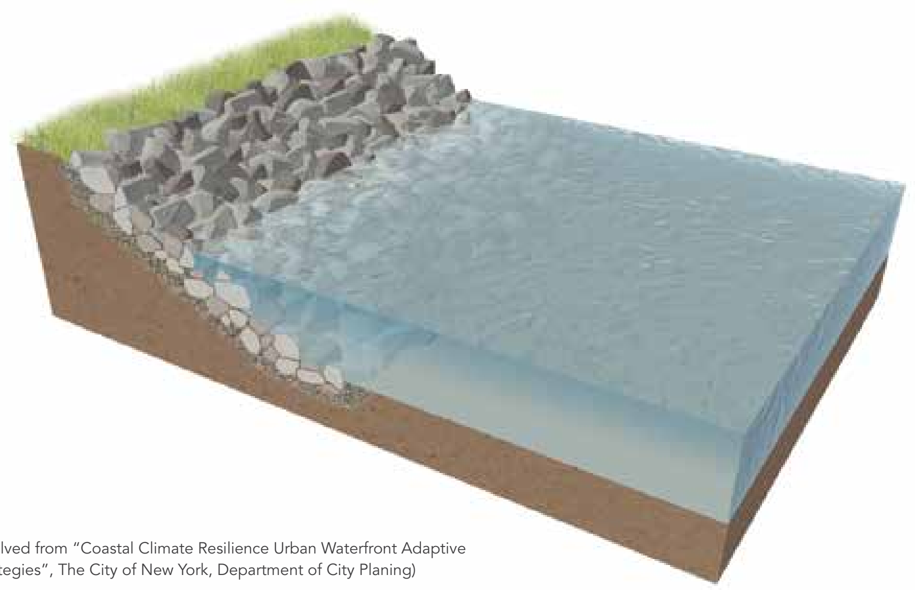
Ability to Address Coastal Hazards

	Hazard	Rating
Event Based	Storm Surge (High)	Low
Event Based	Storm Surge (Low)	Medium
Event Based	Wave Force	High
Event Based	Sudden Erosion	High
Gradual	Flooding Due to Sea Level Rise	High
Gradual	Gradual Erosion	High

Applicability to Landscape Type

Landscape Type	Rating
Oceanfront Beaches	Low
Coastal Marshes	Low
Oceanfront Slopes	High
Sheltered Bay Slopes	High
Hardened Sheltered Bay Slopes	High
Sheltered Bluffs	Medium
Hardened Sheltered Bluffs	High

HIGH MEDIUM LOW



(Evolved from "Coastal Climate Resilience Urban Waterfront Adaptive Strategies", The City of New York, Department of City Planing)

Rock Armouring Examples

1 Armouring with habitat bench, Germany

2 Rock armouring replacing seawalls, BC

3 Rock armouring and trail, Germany

4 Armouring on Georgia Strait, Parksville, BC

Design Principles and Limitations

- Typically constructed from massive stone, concrete slabs, sand or concrete-filled bags, rock-filled gabion baskets, and concrete blocks. A heavy stone or concrete foundation at the bottom of the armouring prevents the loose material from sliding.
- Work well on sites with preexisting hardened shoreline structures and/or stable foundation soil.
- Last choice option for confined areas where there is not sufficient space for a more ecologically sensitive shoreline treatment.
- Effectively absorb wave energy and stabilize shorelines if properly designed and constructed. However, often fails if slopes are oversteepened, components are undersized for the local wave environment, or filter layer is not installed to prevent erosion of the backing sediment slopes.
- All armoured shorelines are subject to rare overtopping and create wave splash. A route must be designed to return wave splash back down through the armouring.

LAND TENURE AND APPROVALS

- All adaptation measures must be contained within property boundaries and avoid encroaching on Crown property on the waterfront, unless senior government permits are gained.
- Requires environmental approval from Fisheries and Oceans Canada, in addition to local government permits.

RELATIONSHIP TO ENVIRONMENT

- Require more land area compared to other shoreline structures such as seawalls.
- Can lead to loss of intertidal habitat.
- Disrupts sediment transport and accelerates erosion of shoreline in front of armouring and to adjacent unreinforced sites.

MAINTENANCE AND MONITORING

- Typically require limited routine maintenance.
- When sea levels rise, rock armouring will have to be built up to higher crest elevations.

Seawalls

Seawalls are large near vertical structures designed to resist the forces of storm waves and prevent erosion and flooding of upland areas.

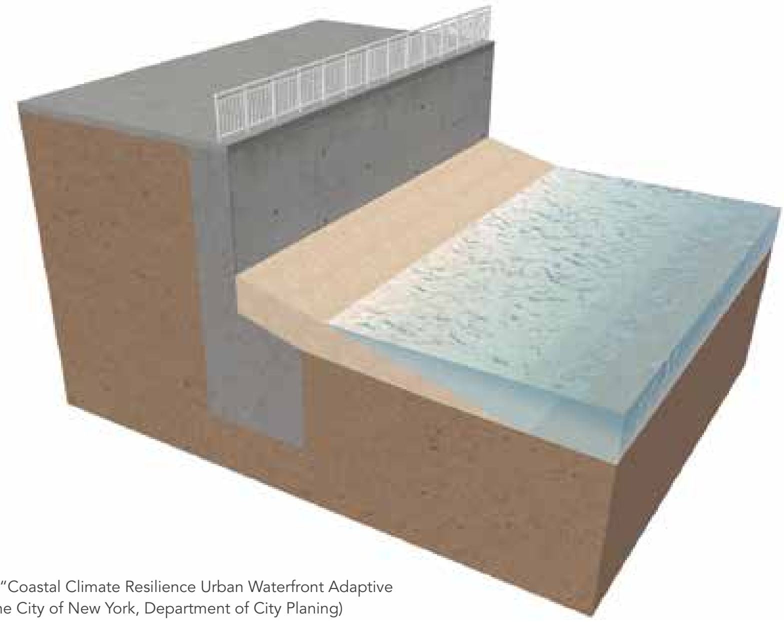
Ability to Address Coastal Hazards

Event Based	Storm Surge (High)	●
	Storm Surge (Low)	●
	Wave Force	●
	Sudden Erosion	●
Gradual	Flooding Due to Sea Level Rise	●
	Gradual Erosion	●

Applicability to Landscape Type

Oceanfront Beaches	◐
Coastal Marshes	◐
Oceanfront Slopes	●
Sheltered Bay Slopes	◐
Hardened Sheltered Bay Slopes	◐
Sheltered Bluffs	○
Hardened Sheltered Bluffs	○

● HIGH ◐ MEDIUM ○ LOW



(Evolved from "Coastal Climate Resilience Urban Waterfront Adaptive Strategies", The City of New York, Department of City Planing)

Seawall Examples

1 Concrete seawall, Austria

2 Sheet pile wall, Netherlands

3 Concrete block wall, Qualicum Beach, BC

4 Stone wall, Germany

Design Principles and Limitations

- The most common types of seawalls include: curved, vertical, and gravity walls.
  - **Curved** seawalls are typically constructed from concrete and dissipate the impact of a wave by deflecting it upwards.
  - **Vertical** seawalls are used in areas that experience less intense wave action and are constructed from concrete or interlocking steel sheets that are driven into the ground.
  - **Gravity** seawalls rely on heavy materials to give them stability and are built in areas with strong, stable soils.
- Local wave energy and soil type determine appropriate materials and type of seawall to be constructed.
- Most applicable in sheltered areas that are protected from wave action.
- Less suitable for oceanfront beaches as they disrupt sediment transport and create high wave splash.
- Overtopping of seawalls can be a public safety hazard. It can also result in seawall failure if drainage mechanisms are not in place to allow water to return to the sea.
- Seawalls can increase wave reflection and turbulence.
- Seawalls often cause loss of sand and lower grade levels in foreshores fronting them and adjacent sites. Seawall foundation undercutting results in wall failure.

LAND TENURE AND APPROVALS

- Habitat loss and beach erosion caused by impacts of seawalls often make approvals difficult.
- Requires environmental approval from Fisheries and Oceans Canada, in addition to local government permits.

RELATIONSHIP TO ENVIRONMENT

- Accelerate erosion in front of, and adjacent to, unreinforced sites on shorelines.
- Can lead to the loss of the intertidal zone.

MAINTENANCE AND MONITORING

- Incorrectly designed seawalls can accelerate foreshore erosion. Careful consideration of how a seawall may affect foreshore and adjacent shorelines is required before installation. Have a professional engineer determine location, foundation, and structural design after review of environmental, technological, and wave exposure conditions
- Many agencies are working to remove existing seawalls where they are too exposed and damaging adjacent environments.
- When located in appropriate sheltered environments like marinas or harbours, seawalls can provide for boat passage or reduce the required length of ramps to floats.
- Monitoring must include review of erosion at the toe of the seawall, and maintenance measures to protect the toe with low impact on adjacent habitat.
- Seawalls may be subject to corrosion, undercutting and impact damage. Many seawalls have a relatively short service period.

Temporary Flood Barriers at Driveways

Temporary flood barriers are removable physical structures installed at driveways/road crossings to prevent water inundation during flooding events.

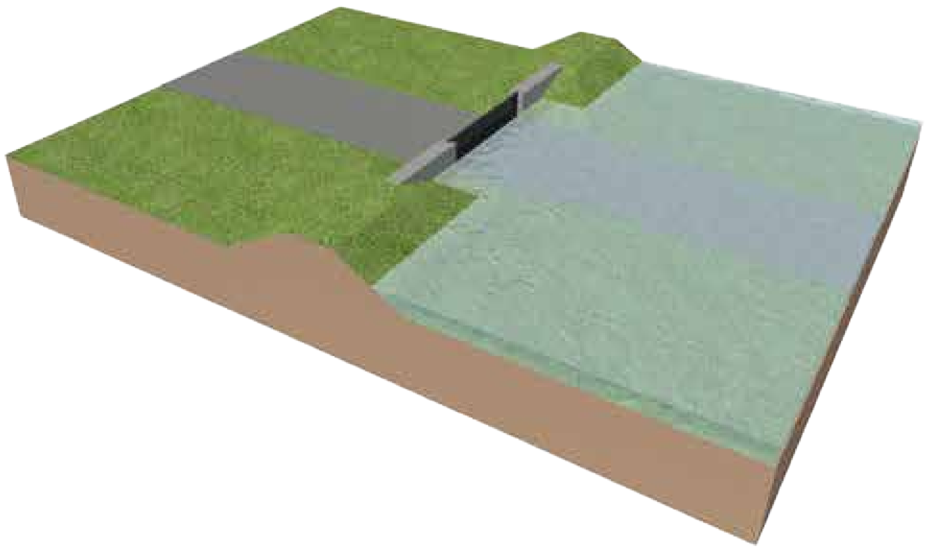
Ability to Address Coastal Hazards

Event Based	Storm Surge (High)	●
Event Based	Storm Surge (Low)	●
Event Based	Wave Force	◐
Event Based	Sudden Erosion	◐
Gradual	Flooding Due to Sea Level Rise	◐
Gradual	Gradual Erosion	◐

Applicability to Landscape Type

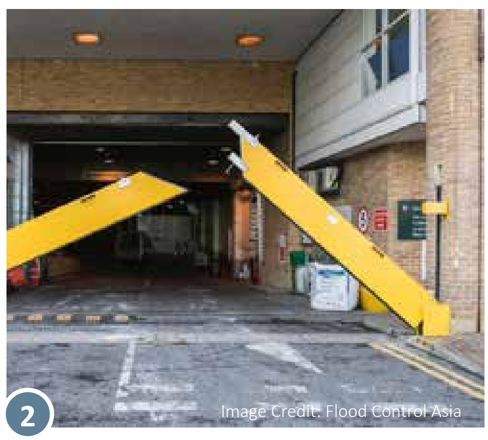
Landscape Type	
Oceanfront Beaches	○
Coastal Marshes	●
Oceanfront Slopes	○
Sheltered Bay Slopes	◐
Hardened Sheltered Bay Slopes	◐
Sheltered Bluffs	○
Hardened Sheltered Bluffs	○

● HIGH ◐ MEDIUM ○ LOW



Temporary Flood Barrier Examples

1 Temp. flood barrier, Europe



2 Automated flood barrier, Europe

3 Temp. flood barrier, North Cowichan, BC

4 Bollards for temp. flood barrier, Germany

Design Principles and Limitations

- Temporary flood barriers typically consist of concrete foundations or posts in which temporary plastic or metal panels are placed during flooding events.
- Often times used in tandem with dikes.
- Location, foundation conditions, and barrier structural design must be engineered with respect for the local environmental, geotechnical and wave exposure conditions.
- Newer, more expensive versions can have mechanical parts that automatically close based on water levels.

LAND TENURE AND APPROVALS

- Require a responsible public agency for maintenance and operations.

RELATIONSHIP TO ENVIRONMENT

- Flood barriers can lead to a false sense of security, inadvertently encouraging development in areas vulnerable to coastal flooding.

MAINTENANCE AND MONITORING

- The concrete foundations of temporary flood barriers should be inspected regularly to ensure they are structurally sound.
- Mechanical systems will require regular inspection and maintenance prior to each flood season.
- If removable elements are used, annual practice is recommended for all operational personnel (prior to each flood season).

Floodbox / Pump Station

Pump stations and floodboxes help protect areas during flooding events by reducing backflow and pumping water over a shoreline dike.

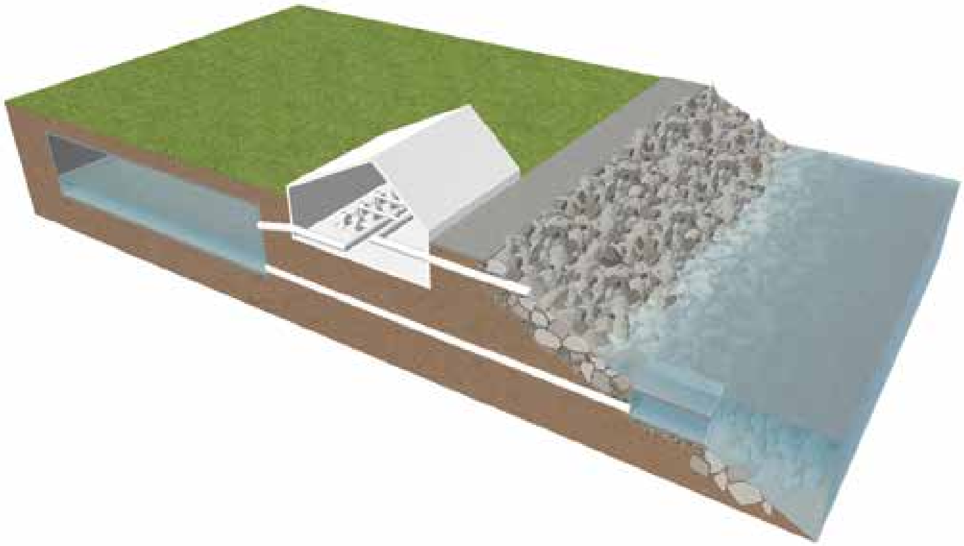
Ability to Address Coastal Hazards

Event Based	Storm Surge (High)	●
	Storm Surge (Low)	●
	Wave Force	○
	Sudden Erosion	○
Gradual	Flooding Due to Sea Level Rise	●
	Gradual Erosion	○

Applicability to Landscape Type

Oceanfront Beaches	◐
Coastal Marshes	◐
Oceanfront Slopes	◐
Sheltered Bay Slopes	●
Hardened Sheltered Bay Slopes	●
Sheltered Bluffs	●
Hardened Sheltered Bluffs	●

● HIGH ◐ MEDIUM ○ LOW



Floodbox / Pump Station Examples

1 Pump station, Netherlands

2 Pump station, Richmond, BC

3 Pump station, Netherlands

4 Floodbox, North Cowichan, BC

Design Principles and Limitations

- Floodboxes are designed to close so that high tides or storm surges do not flow into upland storm drainage systems. When sea levels fall, the floodboxes open, allowing stormwater into the sea via gravity.
- When sea levels rise and drainage is not available, rainfall can exceed the capacity of the storm drainage system, resulting in surface flooding.
- Adding detention storage as ponds or underground tanks can store excess water until sea levels drop and the floodbox can open.
- In some conditions, sufficient stormwater storage cannot be provided, and it is necessary to pump excess stormwater higher – perhaps over a dike – to exit to the sea at a level higher than the tides or storms.
- Pump stations redirect stormwater. They often run intermittently – sometimes only during extreme storm events.
- Because they are essential in a storm emergency, all pump stations require local backup power.

LAND TENURE AND APPROVALS

- Require a responsible public agency for maintenance and operations.
- Requires environmental approval from Fisheries and Oceans Canada and permits from local government.

RELATIONSHIP TO ENVIRONMENT

- The high cost of pump stations often warrants combining small drainage areas to create larger areas for optimal pumping.
- Elevations of pump stations and associated dikes must take into account ongoing sea level rise throughout asset serviceability.
- Local water quality treatment and erosion control are important at the outlet due to concentrated outflows from pumping stations.
- Newer pump stations include interpretation or artistic elements to make them a part of the community recreation experience.
- Energy cost and green house gas emission associated with pumping should factor into design.

MAINTENANCE AND MONITORING

- As mechanical systems, pump stations and their backup energy are high maintenance facilities. A regular and thorough inspection and testing protocol is required.

Elevate on Fill

Building sites are elevated above the flood construction level with additional of fill.

Ability to Address Coastal Hazards

Storm Surge (High)	HIGH
Storm Surge (Low)	HIGH
Wave Force	LOW

Applicability to Building Type

1-2 Family Detached	MEDIUM
1-2 Family Attached	MEDIUM
Low-Mid Rise Residential, Commercial, Mixed	MEDIUM
Industrial	MEDIUM

HIGH MEDIUM LOW

(Evolved from "Coastal Climate Resilience Urban Waterfront Adaptive Strategies", The City of New York, Department of City Planing)

Buildings Elevated on Fill Examples

Image Credit: Sanctuary Studios

1 Raised single family house, RDN, BC

Image Credit: Sanctuary Studios

2 Raised single family house, RDN, BC

Image Credit: Sanctuary Studios

3 Raised public path, Netherlands

Image Credit: Sanctuary Studios

4 Public plaza, Austria

Design Principles and Limitations

- Requires an understanding of local site conditions, soil mechanics, specific characteristics of imported soils, methods used to place and compact the fill, and soil testing procedures.
- Best suited for large lots with low designated flood elevations or sites with existing topography.
- Using structural fill to elevate buildings is not recommended in areas exposed to storm-induced waves higher than 1 metre. Structural fill in these areas will need special protection against erosion and to attenuate wave runup to prevent wave effects from reaching the buildings.
- Elevating sites higher than 1 metre may result in increased flooding of adjacent sites.

LAND TENURE AND APPROVALS

- Unless off site tenure and approvals are gained, any adaptation measures must be contained within property boundaries and avoid encroaching on Crown property on the waterfront.
- The Natural Boundary is the waterfront property line. It is defined in the Land Title Act, and generally is where the vegetation and the soil itself changes due to the influence of sea water. As sea level rise continues, the natural boundary will move inland. For planning purposes, a future estimated natural boundary based on expected sea level rise at the end of service function of a building may be defined. Provincial guidelines suggest a minimum 15 m setback from natural boundary to buildings, and to the toe of structural fill that supports any buildings. (Flood Hazard Area Land Use Management Guidelines, 2018)
- Lands outside the natural boundary are Crown property unless a foreshore lease and senior government environmental approvals have been arranged.

RELATIONSHIP TO ENVIRONMENT

- Adjacent grades, lot lines, and access implications may restrict the use of this method.
- Importing fill material from other locations can have negative environmental impacts.

MAINTENANCE AND MONITORING

- Requires regular monitoring to ensure structural stability of fill material.

Elevate on Piles

Buildings are elevated on piles so that all living spaces are located above the flood construction level.

Ability to Address Coastal Hazards

Storm Surge (High)	●
Storm Surge (Low)	●
Wave Force	●

Applicability to Building Type

1-2 Family Detached	◐
1-2 Family Attached	◐
Low-Mid Rise Residential, Commercial, Mixed	◐
Industrial	◐

● HIGH ◐ MEDIUM ○ LOW

(Evolved from "Coastal Climate Resilience Urban Waterfront Adaptive Strategies", The City of New York, Department of City Planing)

Buildings Elevated on Piles Examples

1 Image Credit: Sanctuary Studios

Restaurant on piles, Alaska

2 Image Credit: Sanctuary Studios

Cabin in floodplain, Austria

3 Image Credit: Sanctuary Studios

Office on piles, Germany

4 Image Credit: Sanctuary Studios

Office/restaurant, Nanaimo, BC

Design Principles and Limitations

- Pile foundations provide protection for the broadest range of flooding conditions.
- Best suited for areas that experience strong, ocean-generated waves during a storm event.
- Consists of pile supports, horizontal beams, longitudinal support, and foundation bracing.
- Pilings, unlike piers and posts, are not supported by concrete footings or pads and are driven into the ground by means of large construction machinery.
- Piles for residential construction are typically made from wood, but can also be constructed from concrete or steel.
- Existing houses must be temporarily relocated and existing foundations be removed for pile driving.

LAND TENURE AND APPROVALS

- All adaptation measures including piles must be contained within property boundaries and avoid encroaching on Crown property on the waterfront.
- The Natural Boundary is the waterfront property line. It is defined in the Land Title Act, and generally is where the vegetation and the soil itself changes due to the influence of water. As sea level rise continues, the natural boundary will move inland. For planning purposes, a future estimated natural boundary based on expected sea level rise at the end of service function of a building may be defined. Provincial guidelines suggest a minimum 15 m setback from natural boundary to buildings, and to the foundation of piles or other structure that supports any buildings.
- Lands outside the natural boundary are Crown property unless a foreshore lease and senior government environmental approvals have been arranged.

RELATIONSHIP TO ENVIRONMENT

- Reduces street level uses, negatively impacting the pedestrian experience.
- Since piles are the foundation of the building, the longevity of the building is restricted to the life of the piles.
- Building and pile/decks will need to be designed to withstand uplift from waves and wave-driven debris.

MAINTENANCE AND MONITORING

- Piles require a minimum bury to remain effective. Monitoring by qualified professionals of erosion around the piles is warranted.
- Fatigue of piles due to rot of wood or wear of concrete/metal structures will require regular monitoring and may require repair or replacement.

Wet Floodproofing

Buildings are constructed on top of an enclosure designed to be flooded. All living spaces are located above the flood construction level.

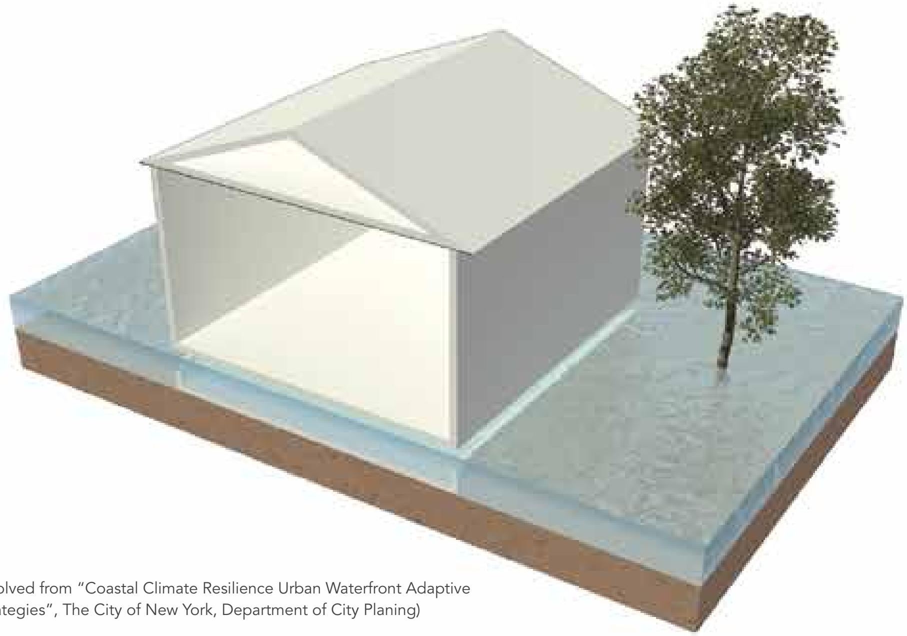
Ability to Address Coastal Hazards

Storm Surge (High)	●
Storm Surge (Low)	●
Wave Force	○

Applicability to Building Type

1-2 Family Detached	●
1-2 Family Attached	●
Low-Mid Rise Residential, Commercial, Mixed	◐
Industrial	◐

● HIGH ◐ MEDIUM ○ LOW



(Evolved from "Coastal Climate Resilience Urban Waterfront Adaptive Strategies", The City of New York, Department of City Planing)

Wet Floodproofing Examples

Image Credit: Sanctuary Studios

1 Floodable restaurant terrace, Austria

Image Credit: Sanctuary Studios

2 Floodable concession, Austria

Image Credit: Sanctuary Studios

3 Flow-through inlet/outlet, Germany

Image Credit: Sanctuary Studios

4 Flow-through parking under office, Germany

Design Principles and Limitations

- Lower level spaces, designed to be inundated during flooding events, are constructed out of flood-damage resistant materials such as pressure-treated wood, concrete, and cement board.
- Walls feature flood vents that allow water to flow freely in and out of the lower level.
- Does not protect the building against wave action or fast-moving waters. Not appropriate for areas that experience storm-induced waves higher than 1 metre.
- Best suited for areas at the outer edge of floodplains that experience infrequent flooding.
- Works well for low-density residential buildings or parking garages.

LAND TENURE AND APPROVALS

- All adaptation measures including wet floodproofing must be contained within property boundaries and avoid encroaching on Crown property on the waterfront.
- Building design which allows flooding of lower floors is likely to require a covenant on land title recognizing that the local government is not liable for damage, if the local government would approve this floodable design at all.

RELATIONSHIP TO ENVIRONMENT

- Wet floodproofing allows water to flow freely in and out of a building. The pathways for water to flow through the building and site must not create flooding on adjacent property.
- If building flooding is to be accommodated, structural design of building walls must withstand flood loads, and building openings need to allow flood water to enter and exit the building without structural damage.

MAINTENANCE AND MONITORING

- Building materials and stored goods / furnishing in the flood area must be designed and installed to withstand flooding and be suitable for rapid cleanup after a flood.

Protect Building Systems

Critical building systems, like utilities, are protected from water infiltration by means of relocation, watertight enclosures, or adaption.

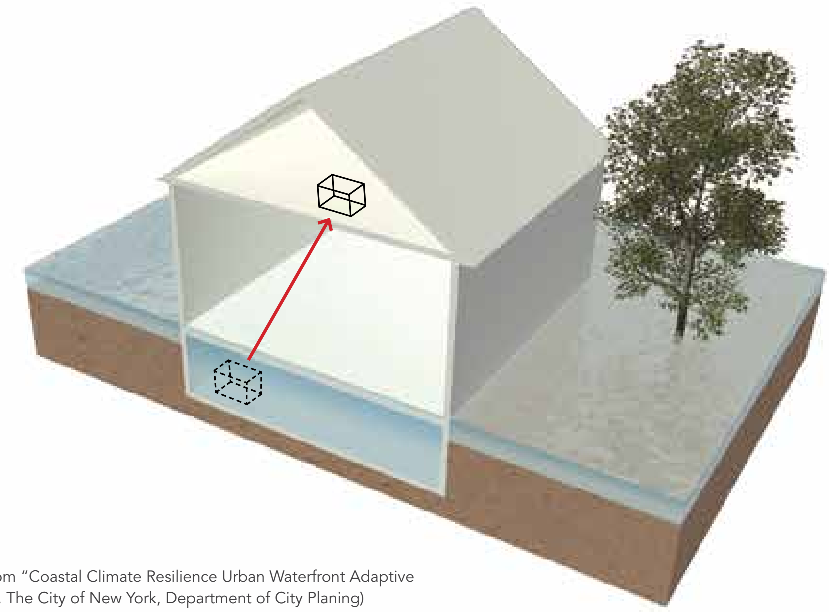
Ability to Address Coastal Hazards

Storm Surge (High)	●
Storm Surge (Low)	●
Wave Force	●

Applicability to Building Type

1-2 Family Detached	●
1-2 Family Attached	●
Low-Mid Rise Residential, Commercial, Mixed	●
Industrial	●

● HIGH ◐ MEDIUM ○ LOW



(Evolved from "Coastal Climate Resilience Urban Waterfront Adaptive Strategies", The City of New York, Department of City Planing)

Building System Protection Examples

1 Image Credit: Sanctuary Studios

Raised utilities, Germany

2 Image Credit: Sanctuary Studios

Raised mechanical systems, Nanaimo, BC

3 Image Credit: Sanctuary Studios

Raised habitable areas, Germany

4 Image Credit: Sanctuary Studios

Floodable lower walls, Alaska

Design Principles and Limitations

- Measures to protect building systems include the following: sealing or relocating external utilities, elevating mechanical equipment and electrical wiring, installing ground fault circuit interrupters, installing a tankless water heater, and installing backflow devices.
- Elevating some building system elements may be in conflict with certain building codes.
- Protecting building systems is often done in conjunction with wet floodproofing.

LAND TENURE AND APPROVALS

- Building design which allows flooding of lower floors is likely to require a covenant on land title recognizing that the local government is not liable for damage, if the local government would approve this floodable design at all.

RELATIONSHIP TO ENVIRONMENT

- If floodable areas of the building are part of the design, it must be noted that protecting building systems does not stop floodwater intrusion inside the building.
- If building flooding (see Wet Floodproofing) is to be accommodated, structural design of building walls must withstand flood loads, and building openings need to allow flood water to enter and exit the building without structural damage.

MAINTENANCE AND MONITORING

- Building materials and stored goods / furnishings in the flood area will also need to be designed and installed to withstand flooding and be suitable for rapid cleanup after a flood.

COMBINING BEST MANAGEMENT PRACTICES

Coastal flood management considers a wide range of objectives, including environmental, recreational, infrastructure, property and risk management. Balancing these objectives across a waterfront neighbourhood often involves combinations of best practices.
A neighbourhood in a waterfront bay or reach might mix approaches – some each of avoid, retreat, accommodate, and protect, as illustrated below.

Neighbourhood Combinations of Best Management Practices

These combinations of approach could be applied to private property at the building/lot scale – but similar mixes of solutions could apply at the neighbourhood scale either in new development or with long-term land acquisition.

Where historic settlements of Europe have adapted to flooding over centuries, it is common to see a corridor of public lands and public uses along the main floodplain area. Between floods, these lands are intensively used.

In order from regularly flooded to rarely flooded elevations, common land uses include:

- foreshore and shoreline habitat and recreation features
- marina or docking facilities
- public walkways and bikeways
- seasonal RV or campground areas
- public gardens or agriculture
- public plazas or monuments
- transportation corridors and parking
- outdoor cafes and temporary market and amenity areas
- and sometimes diking or other flood defense

Vegetated shore, Germany. (Credit: Sanctuary Studios)

Vegetated shore and dike, Germany.

Wet floodproofing and armouring, Germany.

Above these public shorelines, private building uses are restricted to the edge of the floodplain, including:

- new buildings raised by mounding or piles
- heritage buildings with provision on non-residential (commercial) lower floors for wet floodproofing or fast recovery from rare short-term flooding
- residential quarters are kept above the highest flood level

INTEGRATION WITH OTHER RISKS

While focusing on risks related to sea level rise, the best practices described may be designed to provide co-benefits for other risks.

Seismic Risk

BC is in a high-risk zone for earthquakes. The design of dikes and other shoreline defenses must meet seismic standards to prevent risk of an earthquake event that lowers or weakens coastal defenses needed to protect people and property from larger scale flooding.

To manage seismic risk, the stability of underlying soils to provide adequate and stable foundation during earthquake conditions is paramount. Design of slopes, materials and installation techniques of the shoreline are all critical to seismic performance. British Columbia's Ministry of Environment has published guidelines that address design criteria for dikes.

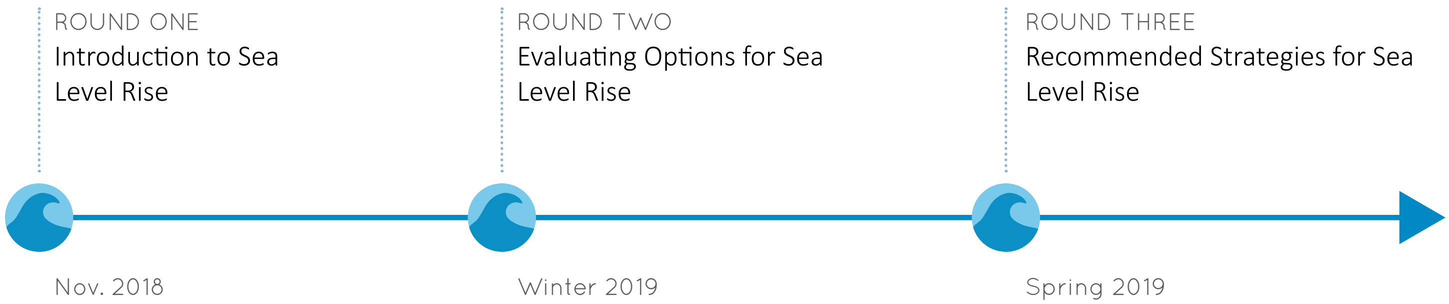
Tsunami Risk

Extraordinary large waves (tsunami) may be caused by earthquakes or landslides. While study of tsunami risk and associated adaptations are beyond this sea level rise primer, the implementation of these best practices combined with well prepared emergency plans are complementary to tsunami preparedness.

Ecosystem Risk

Indicators of large-scale changes to coastal ecosystems along Vancouver Island and the Georgia Strait include declining southern resident orca and salmon populations, and disease in sea stars. These changes may be largely due to the loss of critical shoreline habitat. When shorelines are hardened to protect property, many ecosystem risks can be made worse. There are opportunities to restore or enhance habitat and reduce ecosystem risk through thoughtful design of shoreline coastal flood management.

2.0 WHAT'S NEXT



OPPORTUNITIES FOR INPUT

- November 28, 2018: Introduction to Sea Level Rise (Small-group Public Workshop #A1)
- November 29, 2018: Introduction to Sea Level Rise (Small-group Public Workshop #A2)
- Winter 2019: Understanding Values and Evaluating Options for Sea Level Rise
(Small-group Public Workshop #B)
- Spring 2019: Recommended Sea Level Rise Strategies (Small-group Public Workshop #C)
- Online at www.campbellriver.ca/rising-seas
- By email: policy@campbellriver.ca
- By phone: (250) 286-5727

Painter Barclay shoreline (Credit: Sanctuary Studios)

FOR MORE INFORMATION

CITY OF CAMPBELL RIVER WEBSITE LINKS

www.campbellriver.ca/rising-seas

BACKGROUND INFO FROM OTHER SOURCES

Engineers and Geoscientists BC
Legislated Flood Assessments in a Changing Climate in BC
https://www.egbc.ca/getmedia/f5c2d7e9-26ad-4cb3-b528-940b3aaa9069/Legislated-Flood-Assessments-in-BC.pdf.aspx

Flood Hazard Area Land Use Management Guidelines (2018)
https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/integrated-flood-hazard-mgmt/flood_hazard_area_land_use_guidelines_2017.pdf

Ausenco Sandwell
Climate Change Adaptation for Sea Dikes and Coastal Flood Hazard Land Use
http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/draft_policy_rev.pdf

Ministry of Forests, Lands and Natural Resource Operations
Coastal Floodplain Mapping – Guidelines and Specifications (June, 2011)
http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/coastal_floodplain_mapping-2011.pdf

BC Ministry of Environment and Climate Change
Sea Level Rise Adaptation Primer A Toolkit to Build Adaptive Capacity on Canada's South Coasts (January 2013)
https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/resources/slr-primer.pdf

BC Ministry of Environment and Climate Change
Professional Practices in Assessing Flood Protection Guidelines (June 30, 2014)

BC ADAPTS VIDEO SERIES

Includes a BC Climate Change Backgrounder, plus six video shorts on Coastal Flood Management
www.gov.bc.ca/gov/content/environment/climate-change/adaptation/bc-adapts

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