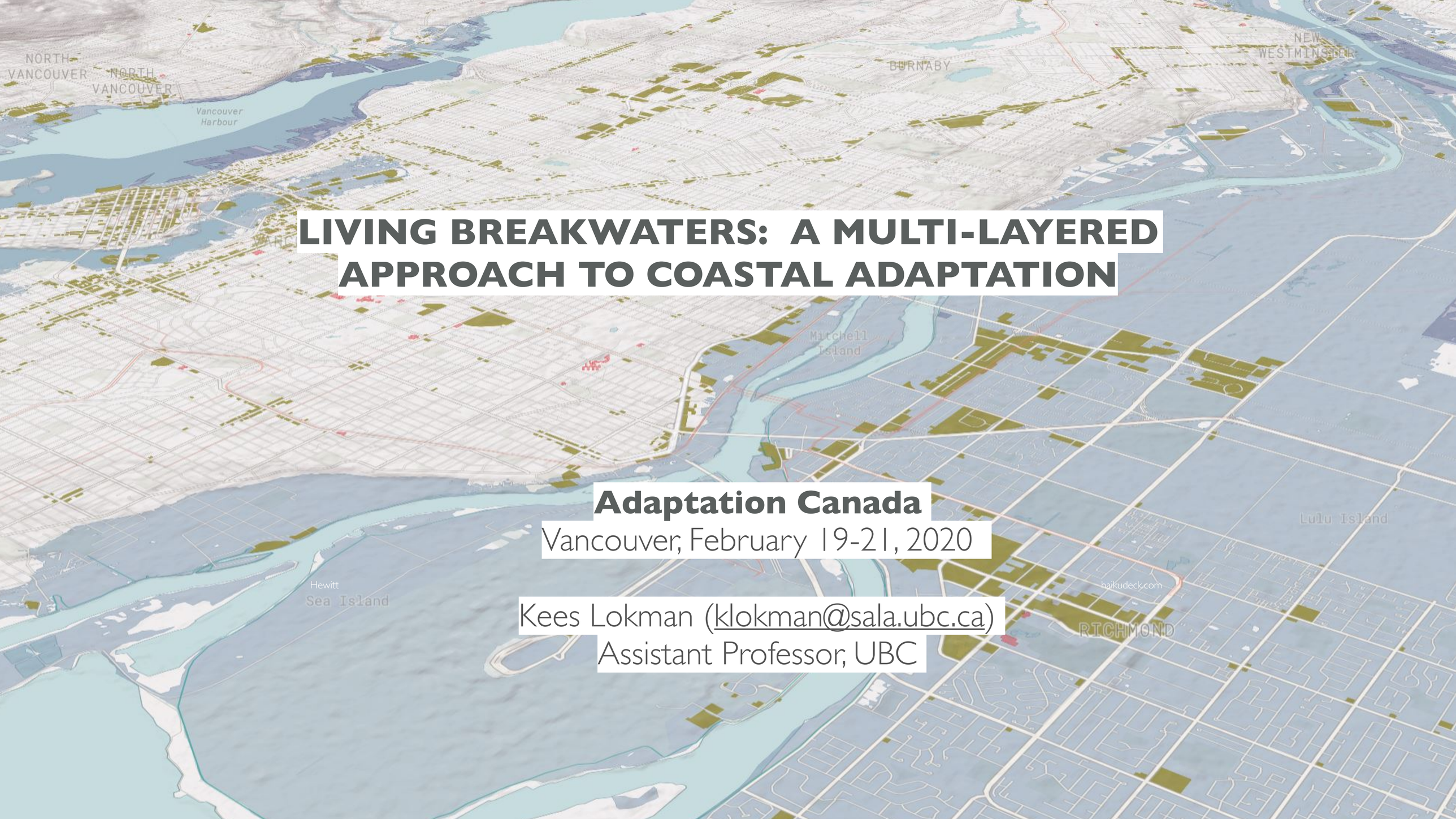

LIVING BREAKWATERS: A MULTI-LAYERED APPROACH TO COASTAL ADAPTATION

Adaptation Canada

Vancouver, February 19-21, 2020

Kees Lokman (klokman@sala.ubc.ca)
Assistant Professor, UBC

OUTLINE

- Project Overview
- Coastal Adaptation Platform
  - Interactive map browser
  - Time-based narratives
  - Adaptation strategies
- Point Grey Cliffs
  - Modeling marine conditions
  - Plant geography & potential for slope stabilization
  - Social, economic, legislative, & environmental assessment

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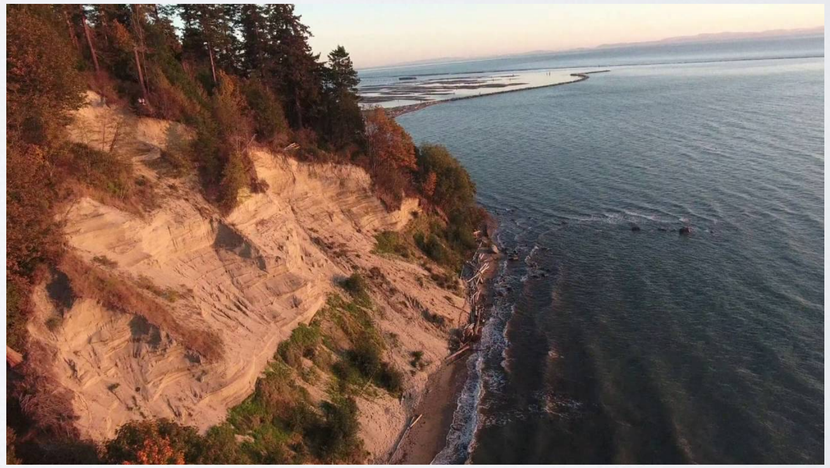
THE LIVING BREAKWATERS PROJECT

- Funded by Natural Resources Canada

  (May 2018 - December 2020)

- 2 overarching objectives
  - to advance the ***adaptation knowledge*** in the region and beyond, and
  - to ***develop solutions*** for erosion of the Point Grey cliffs.



Boyes

Coastal Risks in The Fraser Delta

102
Species at Risk of Extinction

Impact Livelihood 11 FN Communities

(in Metro Vancouver)

>238,000 people directly impacted

(based on present day flood event)

Source: Fraser Basin Council

Agricultural losses ~$690M

(based on short-duration present day flood event)

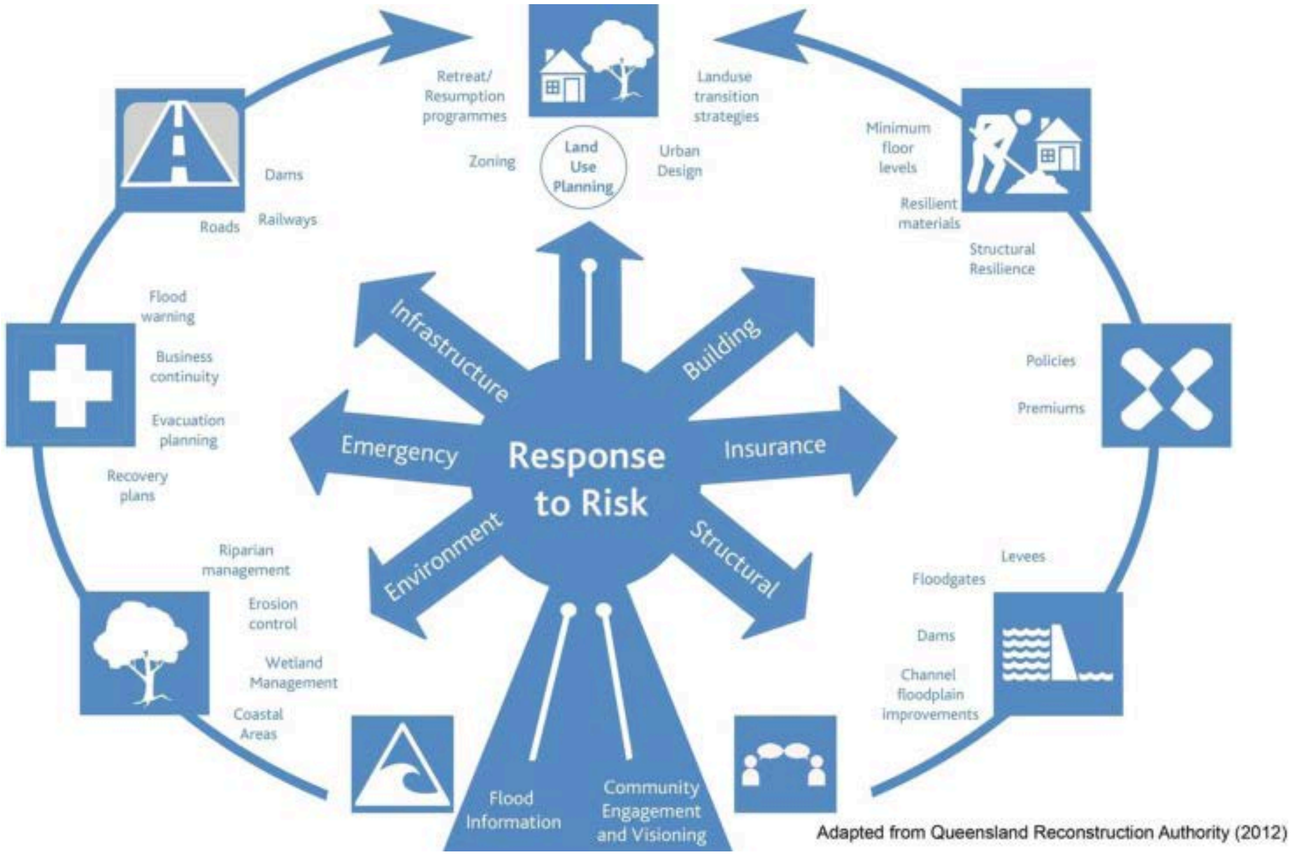
Source: Fraser Basin Council

Economic losses ~$20-23B

(based on present day flood event)

Source: Fraser Basin Council

Multifaceted Issue



Adapted from Queensland Reconstruction Authority (2012)

- Flood Control
- Land Use Planning
- Urban Design
- Emergency Management
- Spatial Justice
- Subsidence
- Salinization
- Coastal Habitat Squeeze
- Insurance
- Governance
- Real Estate Development
- Geotechnical Engineering
- Infrastructure Systems

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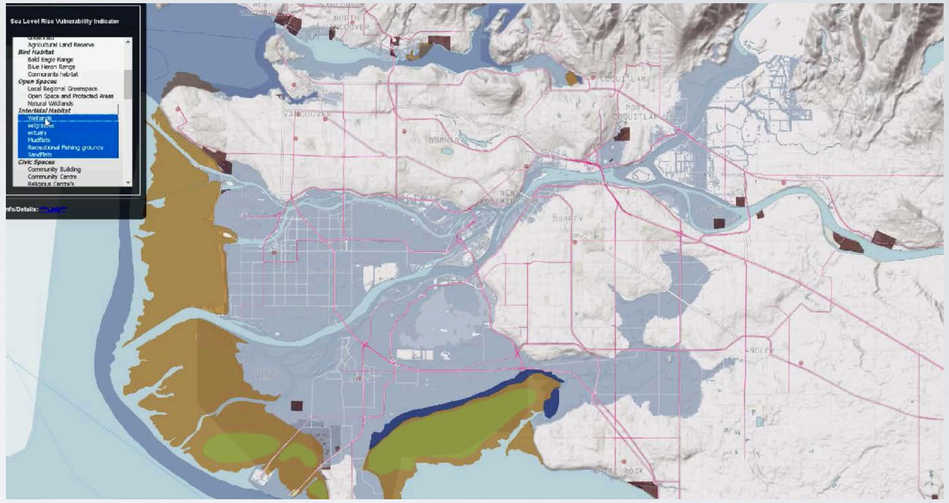
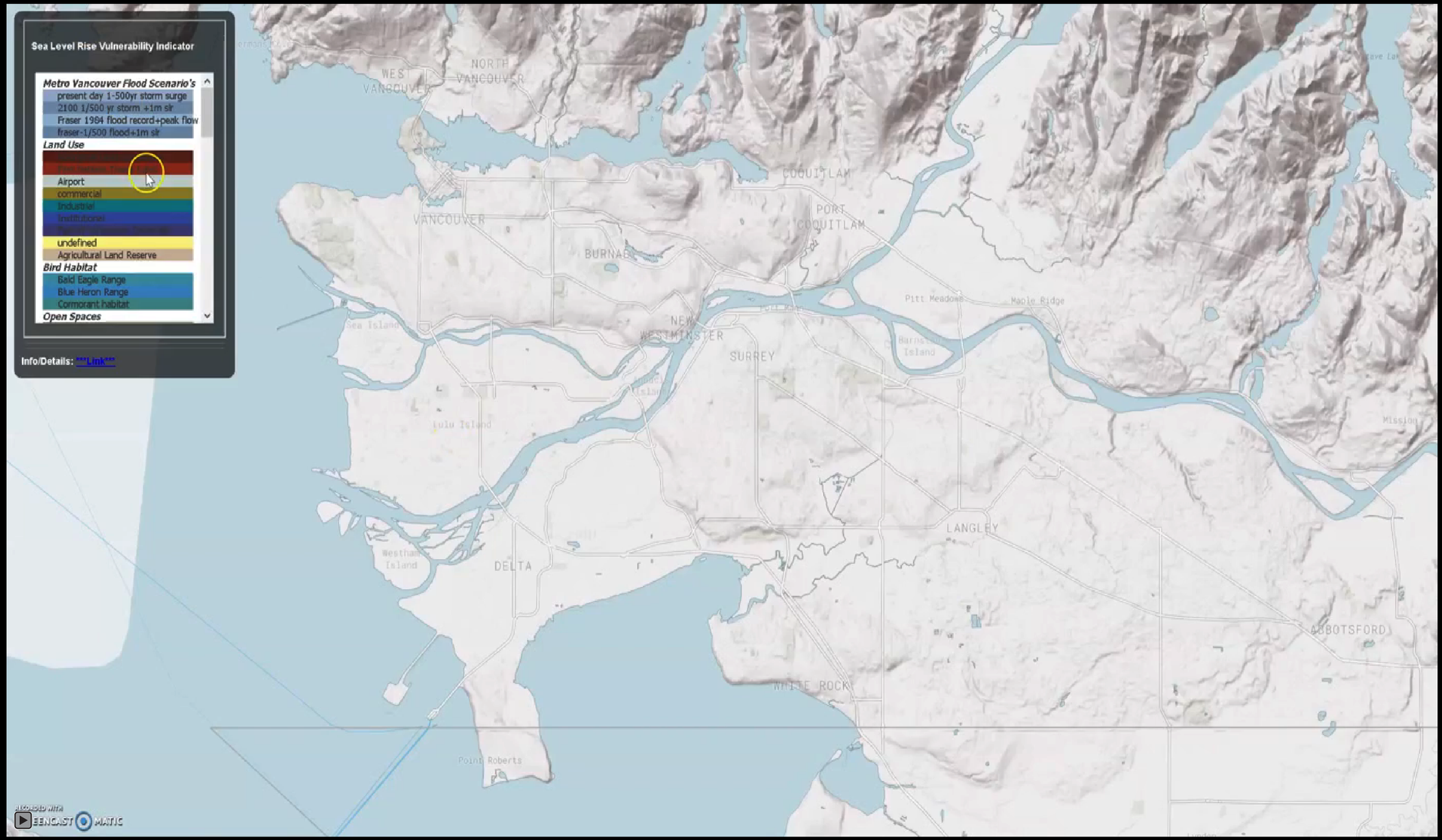
1. INTERACTIVE WEB BROWSER

- Highlights different flood scenarios
- Shows the areas under risk (flood plains, infrastructures, institutional buildings, impervious areas, etc.)
- Shows different vulnerability areas (social, built environment, ecological vulnerability)
- Provides an option to download data/maps



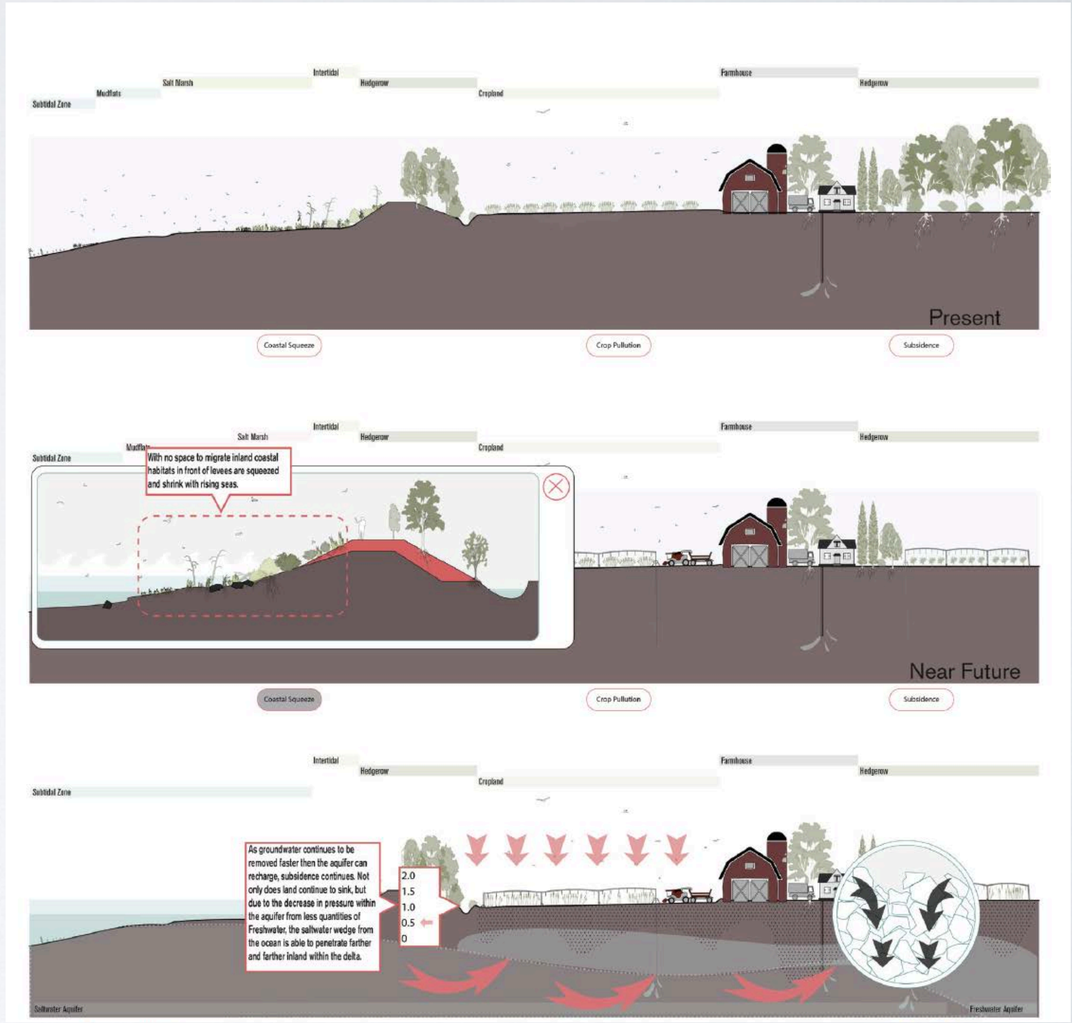

Sea Level Rise Vulnerability Indicator
Metro Vancouver Flood Scenario's
present day 1-500yr storm surge
2100 1/500 yr storm +1m slr
Fraser 1984 flood record+peak flow
fraser-1/500 flood+1m slr
Land Use
Airport
commercial
Industrial
undefined
Agricultural Land Reserve
Bird Habitat
Bald Eagle Range
Blue Heron Range
Cormorant Habitat
Open Spaces
Info/Details: ***Link***
WEST VANCOUVER
NORTH VANCOUVER
VANCOUVER
COQUITLAM
PORT COQUITLAM
BURNABY
NEW WESTMINSTER
SURREY
Pitt Meadows
Maple Ridge
Sea Island
Lulu Island
Mission
LANGLEY
DELTA
ABBOTSFORD
WHITE ROCK
Point Roberts

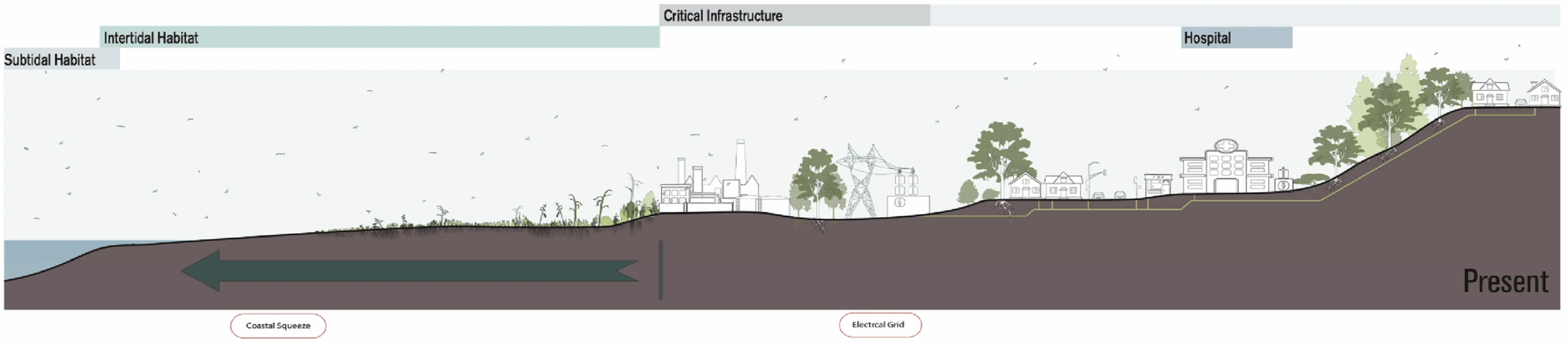
II. TIME-BASED NARRATIVES

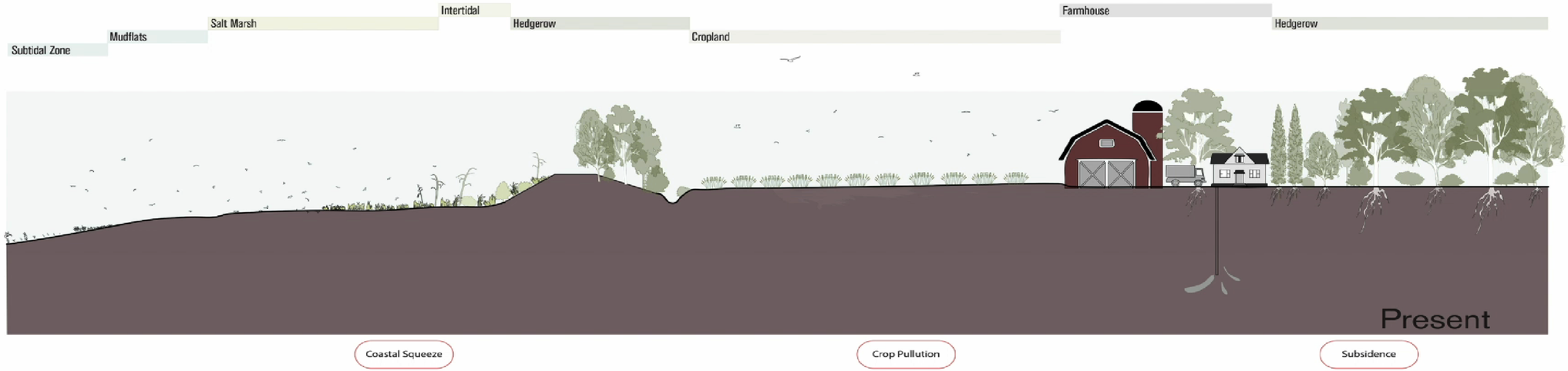
- Provides detailed information on areas/ timelines/progress or cascading impacts of a selected issue

- Graphically rich, preferably dynamic presentation

- 5-8 narratives total (utilities/ infrastructure, ecosystem health, agriculture, urban development, cultural/ heritage)

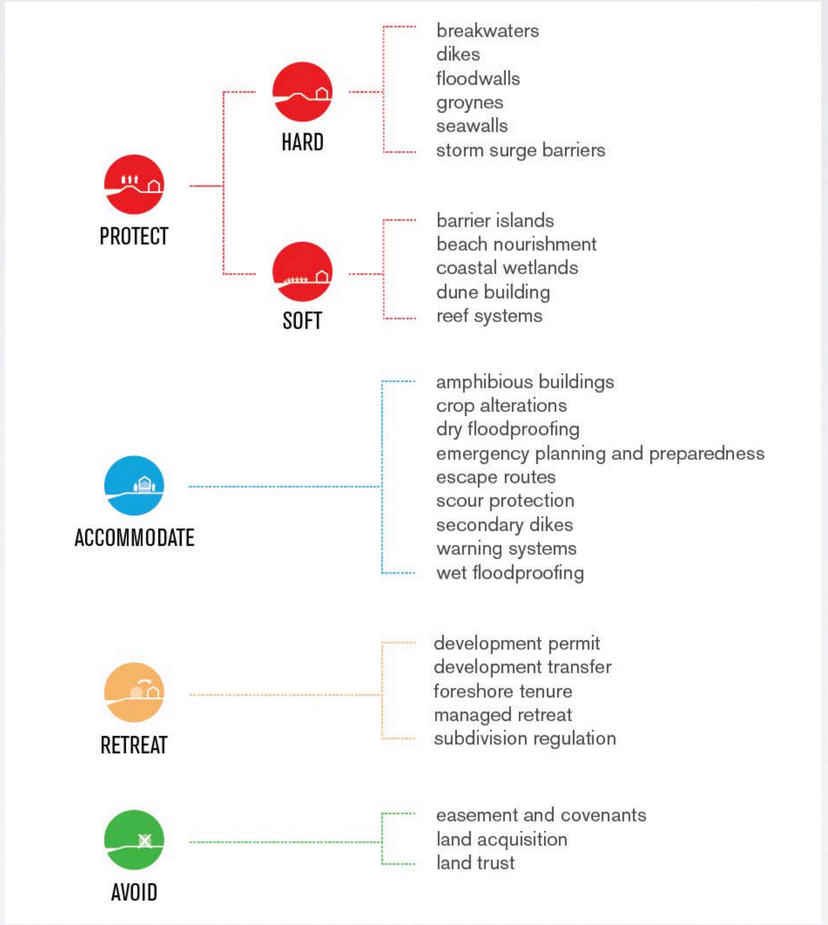


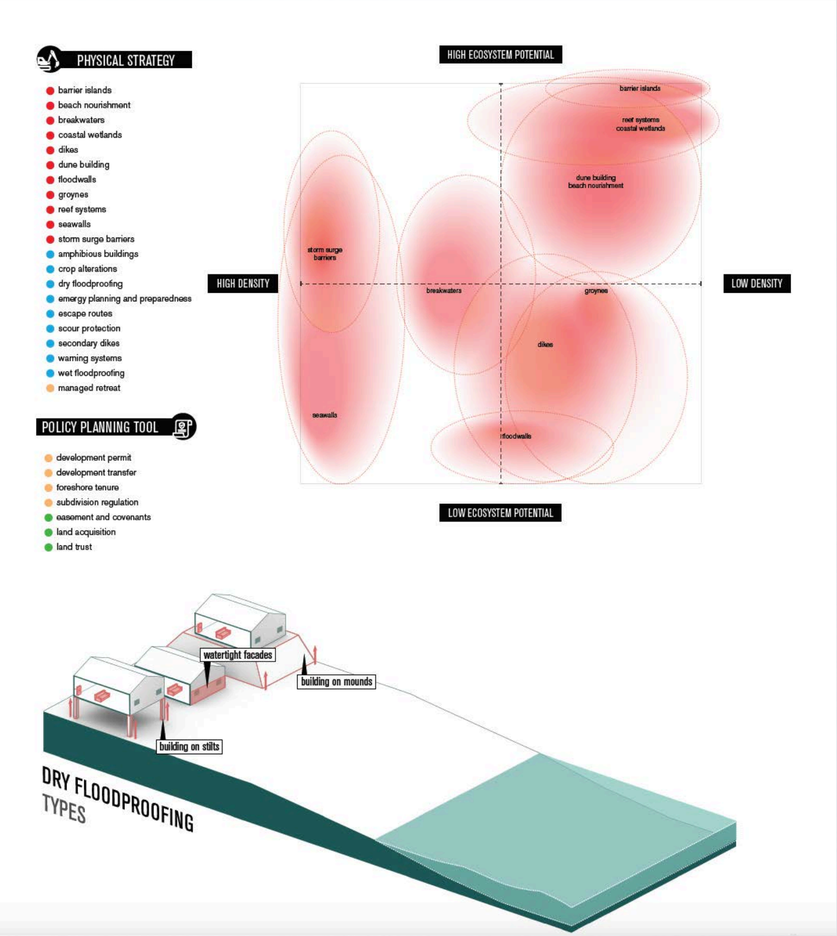

Critical Infrastructure
Intertidal Habitat
Hospital
Subtidal Habitat
Present
Coastal Squeeze
Electrcal Grid

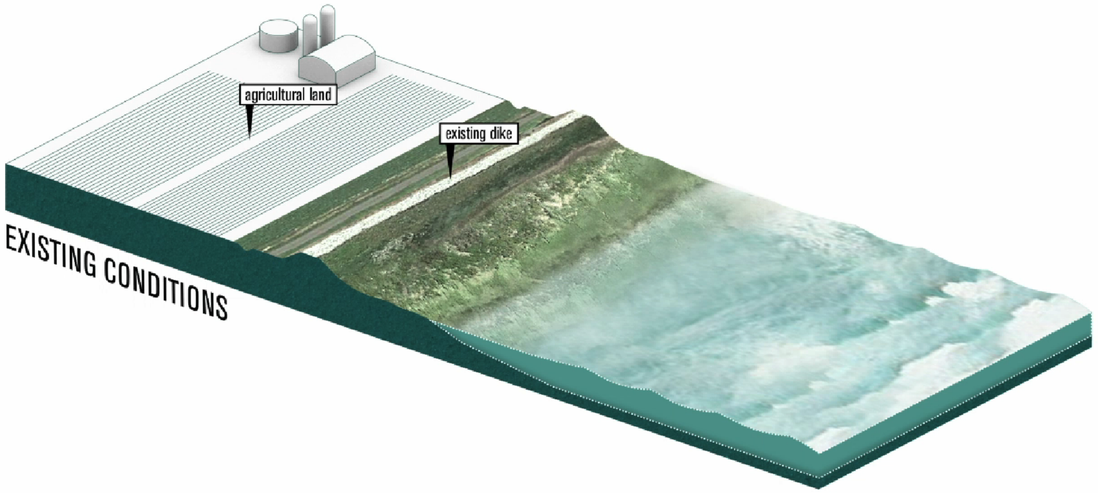

Subtidal Zone
Mudflats
Salt Marsh
Intertidal
Hedgerow
Cropland
Farmhouse
Hedgerow
Present
Coastal Squeeze
Crop Pullution
Subsidence

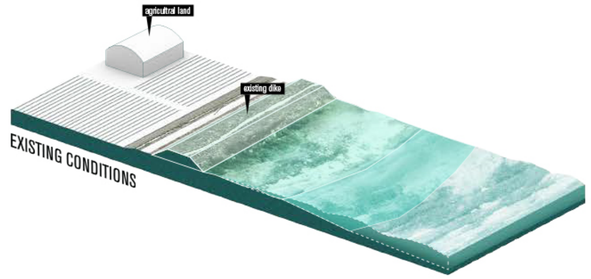
III. ADAPTATION STRATEGIES

- ~25 different strategies with embedded with links and information on costs, permitting, case studies. etc.






agricultural land
existing dike
EXISTING CONDITIONS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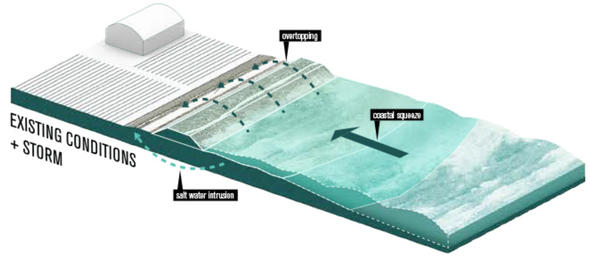
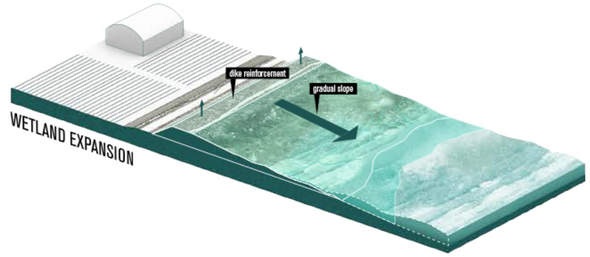
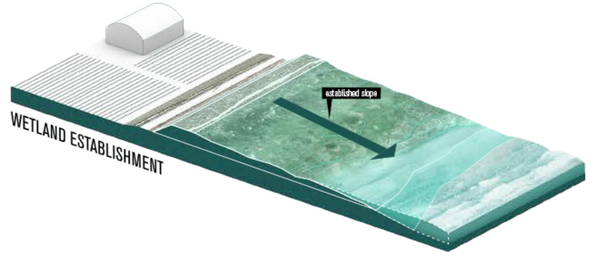
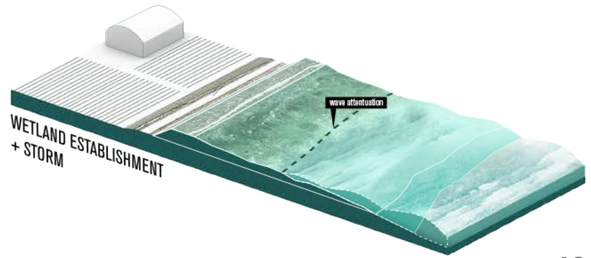

overtopping
coastal squeeze
EXISTING CONDITIONS
+ STORM
salt water intrusion


dike reinforcement
gradual slope
WETLAND EXPANSION


established slope
WETLAND ESTABLISHMENT


wave attenuation
WETLAND ESTABLISHMENT
+ STORM

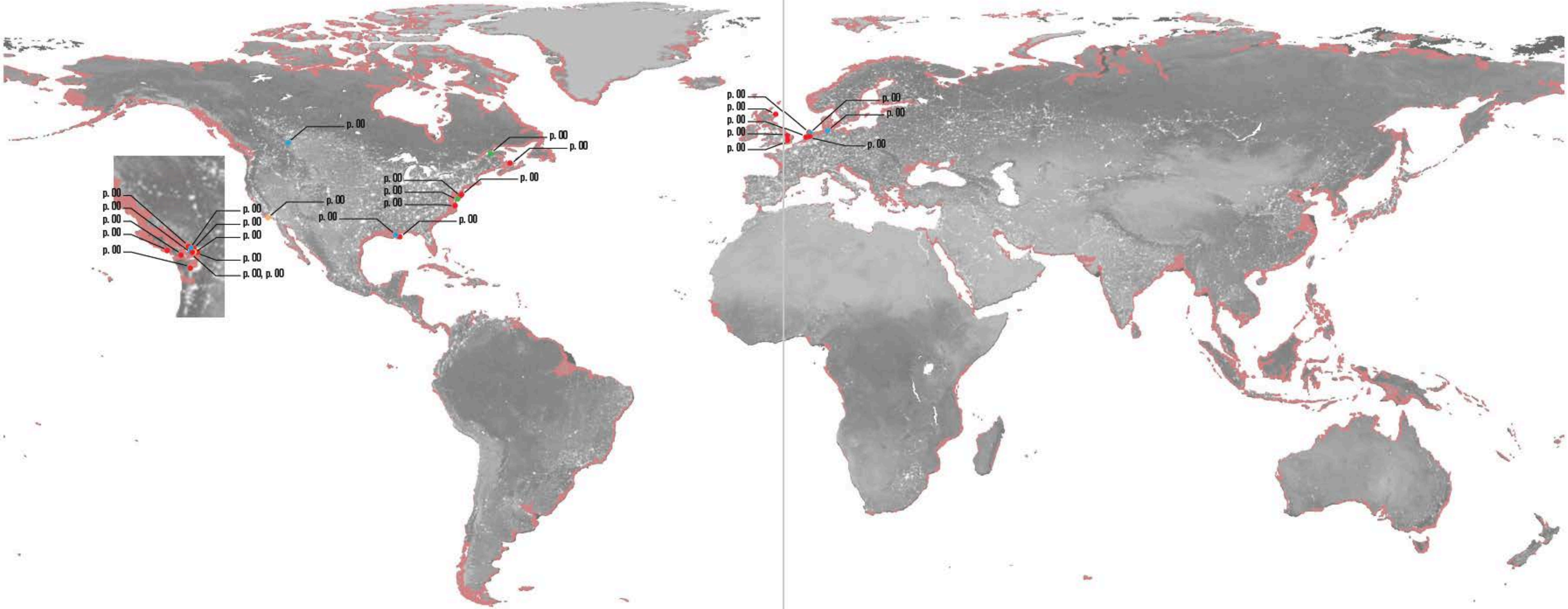


Fig. # Global case study map

Beach Nourishment

T A CC FC P

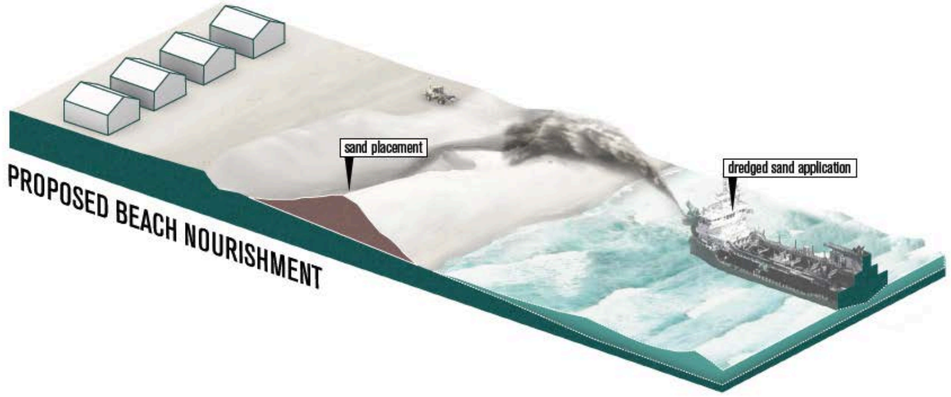


Fig. # Visualization of a beach nourishment

PROTECT

OVERVIEW

Beach nourishment is the process of adding beach sediment material to prevent shoreline erosion due to natural wave action.

This strategy is a repetitive process of mitigation that requires on-going maintenance programs to help fund re-nourishment.[1] Beach sediment is usually sourced from off-shore dredging and pumped onto the beach area where it is dispersed naturally or by machine, therefore stabilizing the eroded beach, increasing beach elevation, and area. Wave energy is dissipated as it runs up on the beach, the larger the beach area, the more energy is dissipated.[2]

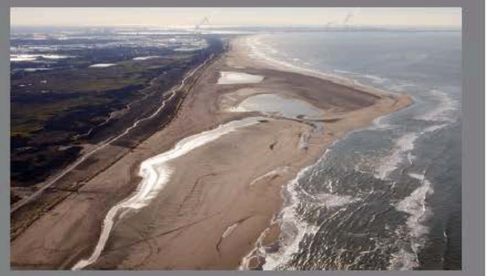
Types
- land-based
- dredging

Benefits
- increased beach area and elevation
- wave attentuation/dissipation
- cliff stabilization and enhancement
- sediment material is provided as sacrificial element against coastal erosion

Challenges
- requires on-going maintenance program to help fund re-nourishment
- cost of implementation due to supply limitations
- affect the productivity of intertidal areas

SAND ENGINE
The Hague, The Netherlands

The Sand Motor (or Sand Engine) is a unique beach nourishment experiement with the goal of replenishing the Dutch coast in a more sustainable and natural way. In 2011, the hook shaped peninsula was created which extends 1 km into the sea and 2 km wide where it joins the shore.[3] The idea was that the sand would be naturally spread over time towards the north and partially towards the south.[4] It can be seen from current day aerial photos that the hook shaped peninsula has taken shape over time and the sand has spread along the north and south as expected. The project is a great example of working with nature by using the coastal processes as a way of rebuilding the beach.



Project Details
- €81,000,000
- 2011
- 1,280,000 m^2
- 21.5 million m^3 of sand

Project Details
- ongoing
- 1980-present
- 6400 m^2
- ~10,000 m^3 of sand/yr

PARLEE BEACH NOURISHMENT
Pointe-Du-Chene NB, Canada

The beach nourishment program at Parlee Beach is part of an ongoing management program that uses a portion of the park entrance fee as funding for re-nourishment.[5] The volume of sand that is added to the beach varies from year to year which requires yearly assessment to monitor the amount of sand lost from storm damage.[6] As with most beach nourishment programs the source and match of beach sediment is a challenge, however, with the Parlee Beach Noruishment Program the source of material is obtained through land-based processes where the sand is collected north of the beach.[7] Because the sand shares the same characteristics as the beach sand, it functions similarly and retains the same aesthetics.

PROTECT

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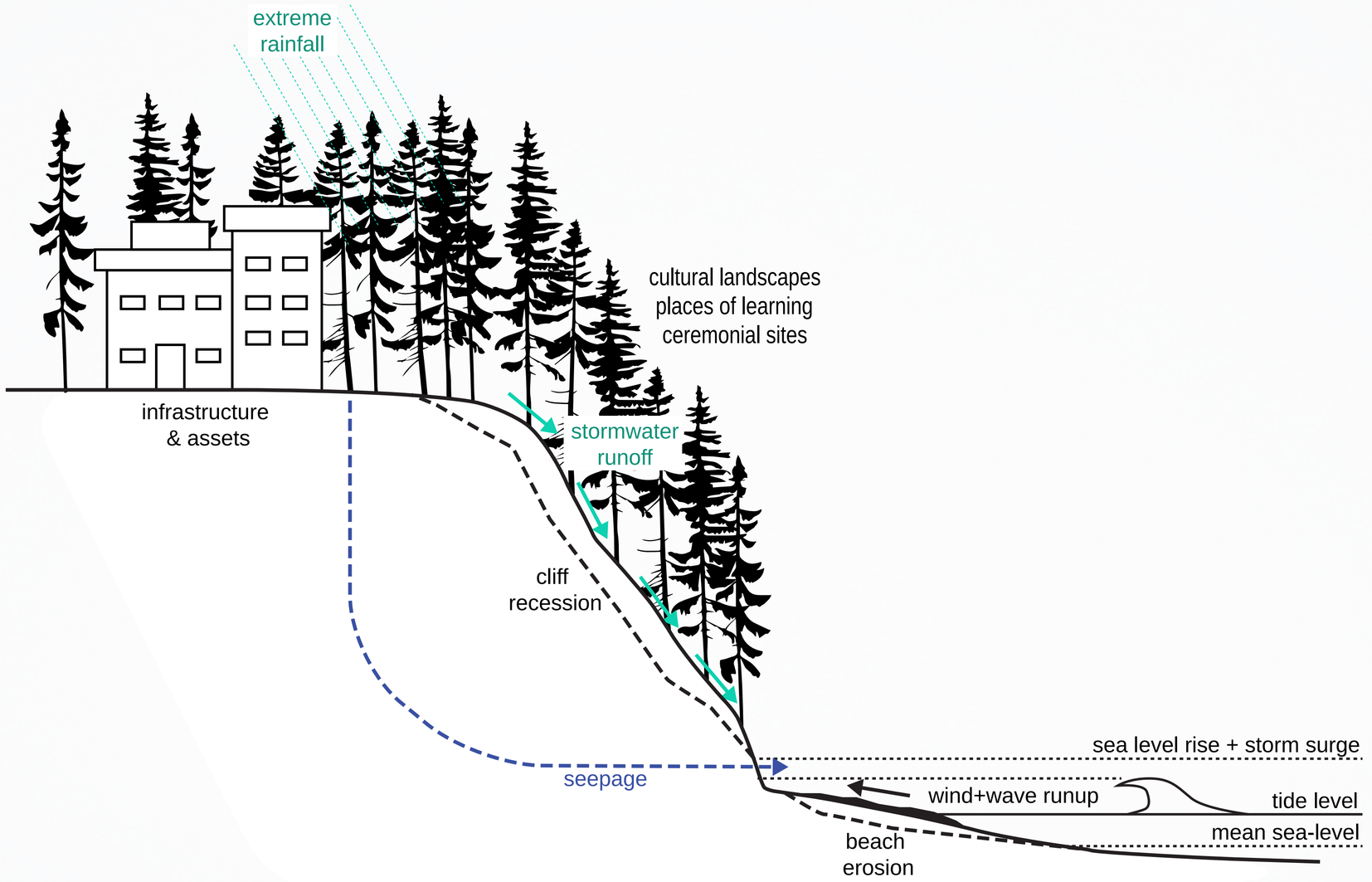
  - Understanding Values

UNDERSTANDING FACTORS CAUSING CLIFF EROSION



A MULTI-LAYERED APPROACH TO COASTAL ADAPTATION

Literature review

Historical events and coastal interventions

Modeling marine conditions

Plant geography

Social, economic, legislative, environmental assessment

Understanding place

Stakeholder engagement

Adaptation strategies

Potential implementation strategies

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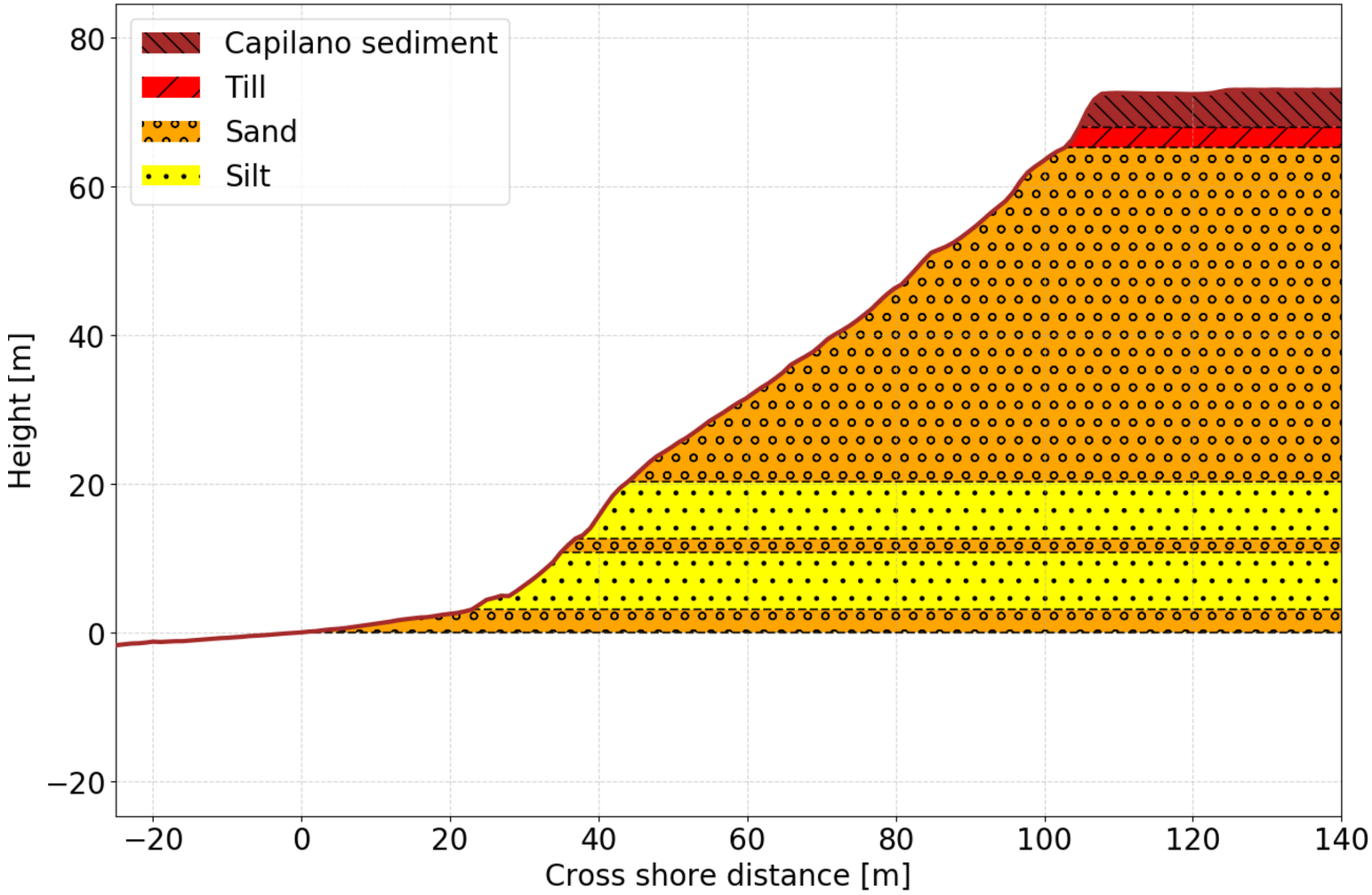
Potential implementation strategies

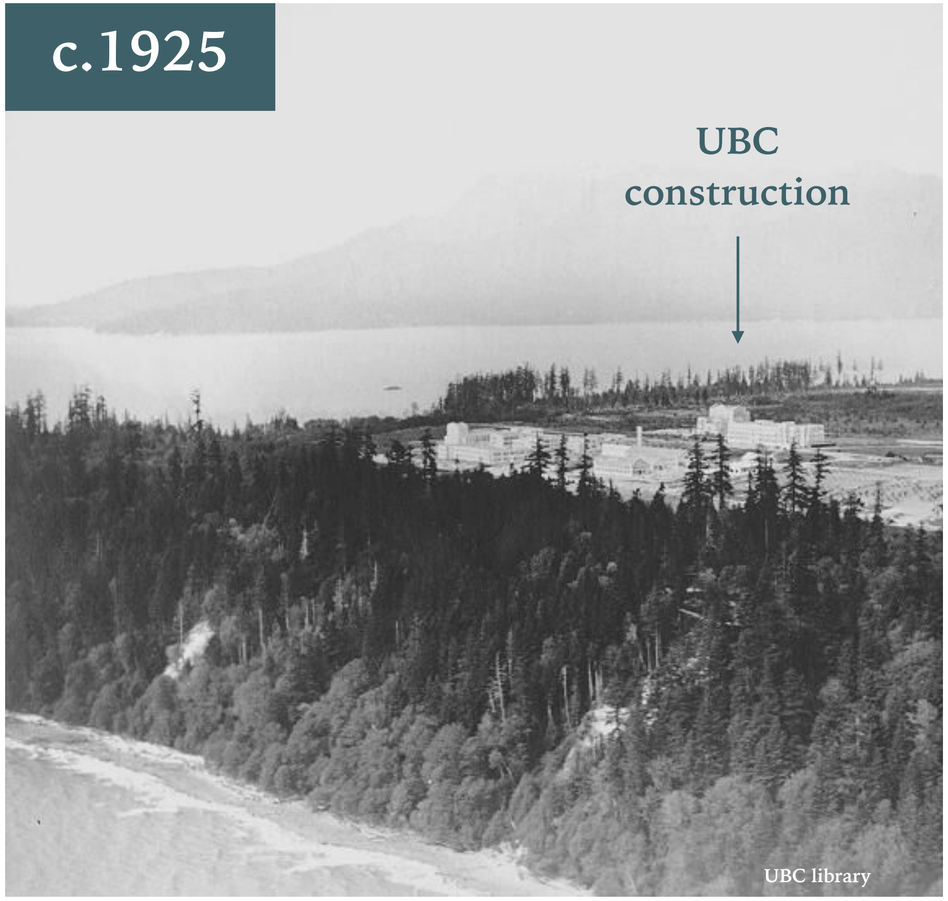
POINT GREY CLIFFS

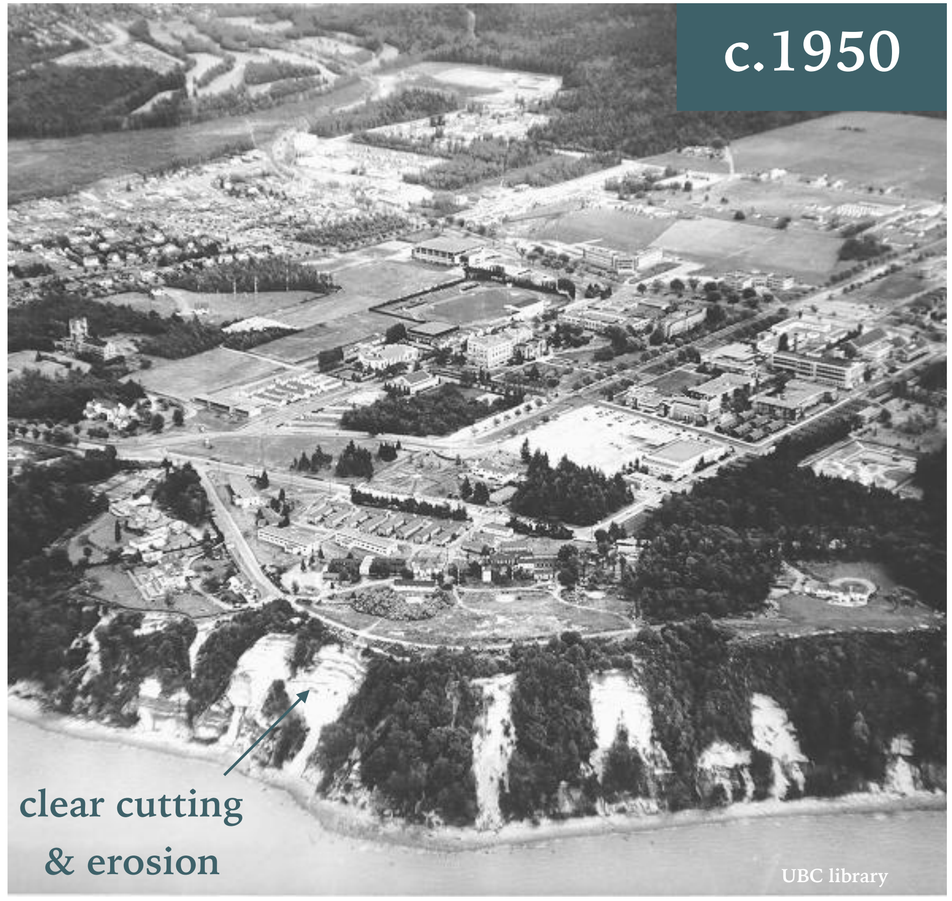
POINT GREY CLIFFS



Piteau Associates (2002)

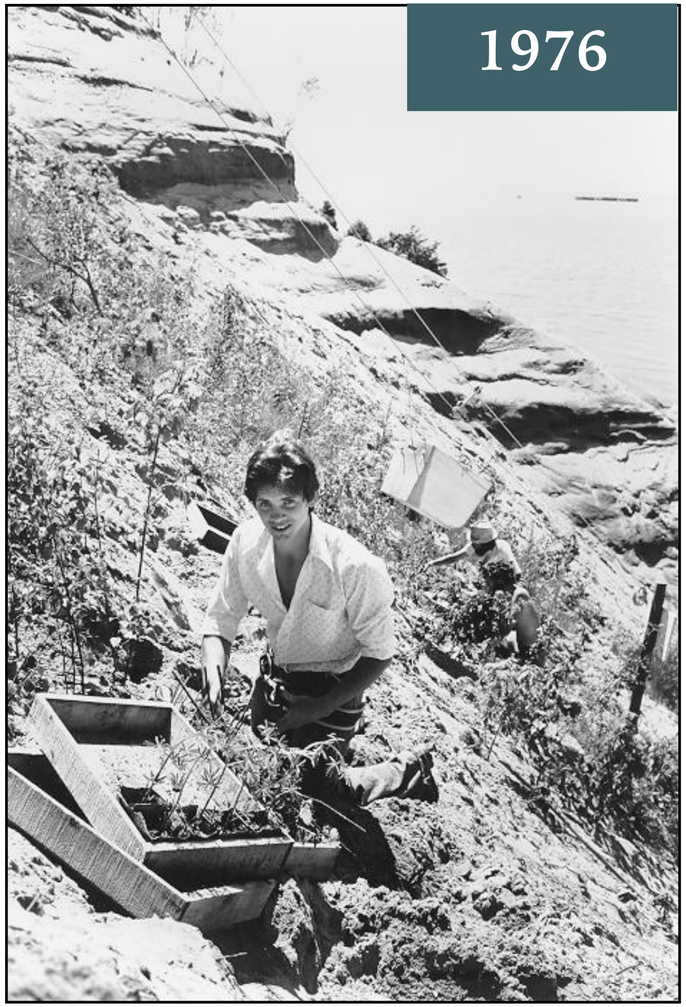
POINT GREY CLIFFS





2 APPROACHES (NATURAL)

UBC library

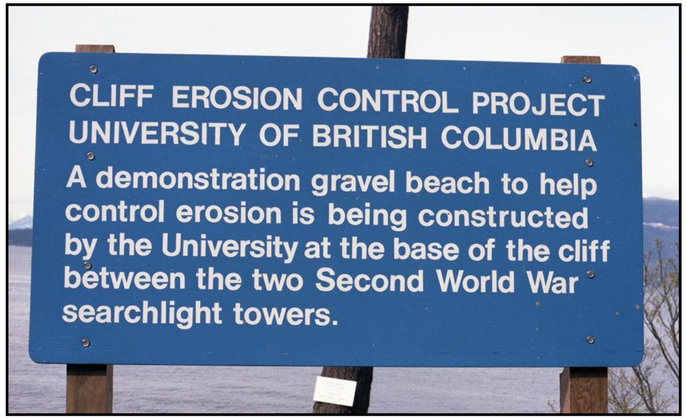


UBC library

2 APPROACHES (ENGINEERED)

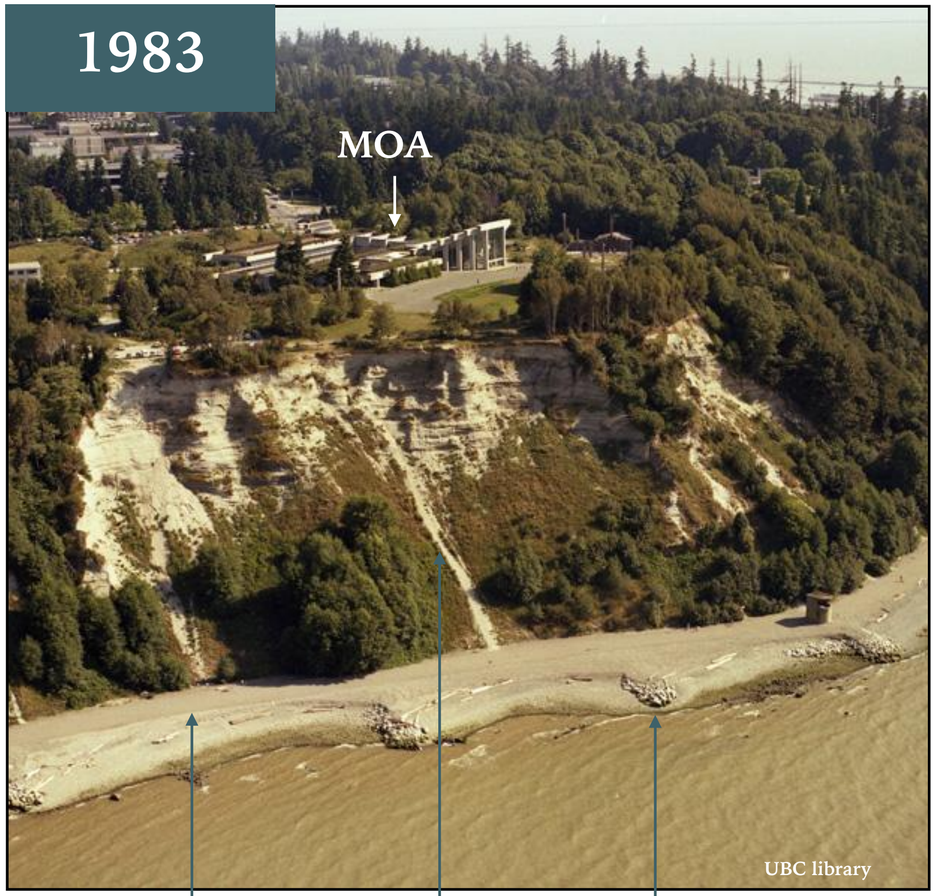
1981

UBC library



UBC library

POINT GREY CLIFFS



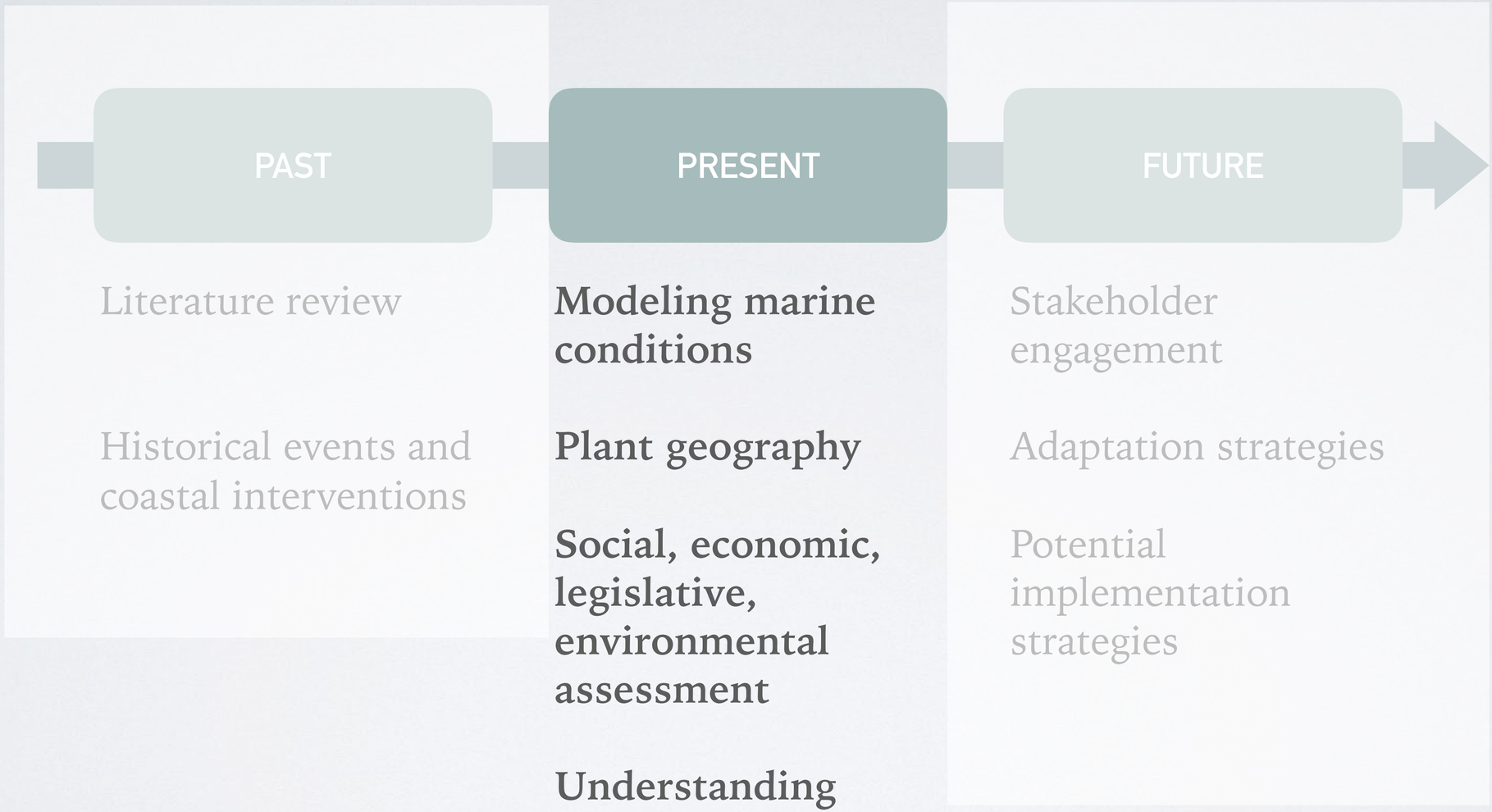
Gravel

Replanting

Berms

Landslides

A MULTI-LAYERED APPROACH TO COASTAL ADAPTATION



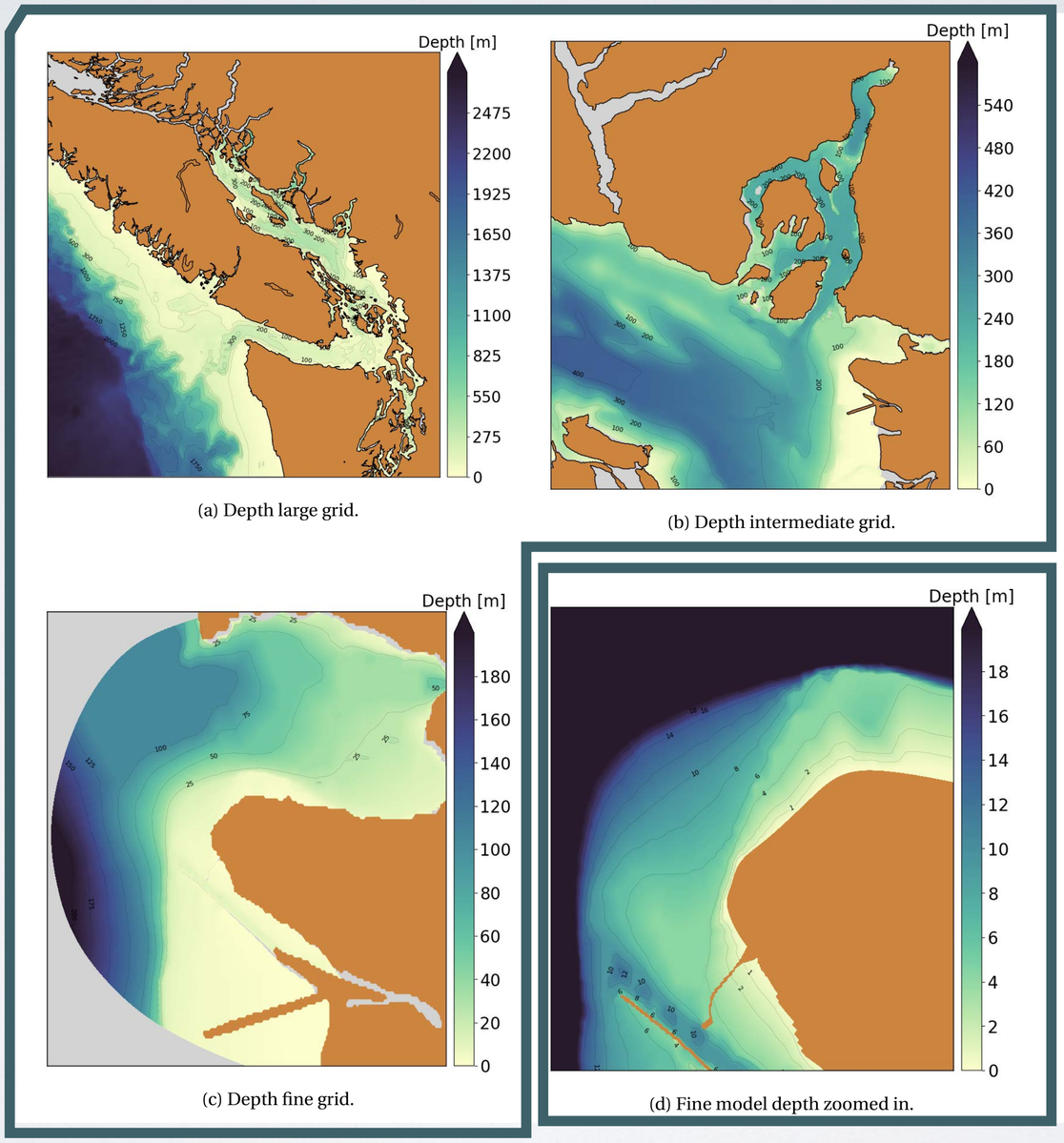
I. MODELING MARINE CONDITIONS

- Tidal characteristics
- Wind & waves
- Storm surges
- Fraser River
- Human Interventions (marine works & dredging)
- Conceptual sediment budgets

Scenario ID	Period	Tidal range	River discharge	Wind/waves
1	Aug. - Apr.	Normal	Non-freshet	WNW
2	Aug. - Apr.	Normal	Non-freshet	ESE
3	Aug. - Apr.	Normal	Non-freshet	Eastern storm (5 years RP)
4	May - Jul.	Normal	Freshet	Western storm (5 years RP)
5	May - Jul.	Normal	Freshet	WNW
6	May - Jul.	Normal	Freshet	ESE

I. MODELING MARINE CONDITIONS

3 computational grids



(a) Depth large grid.

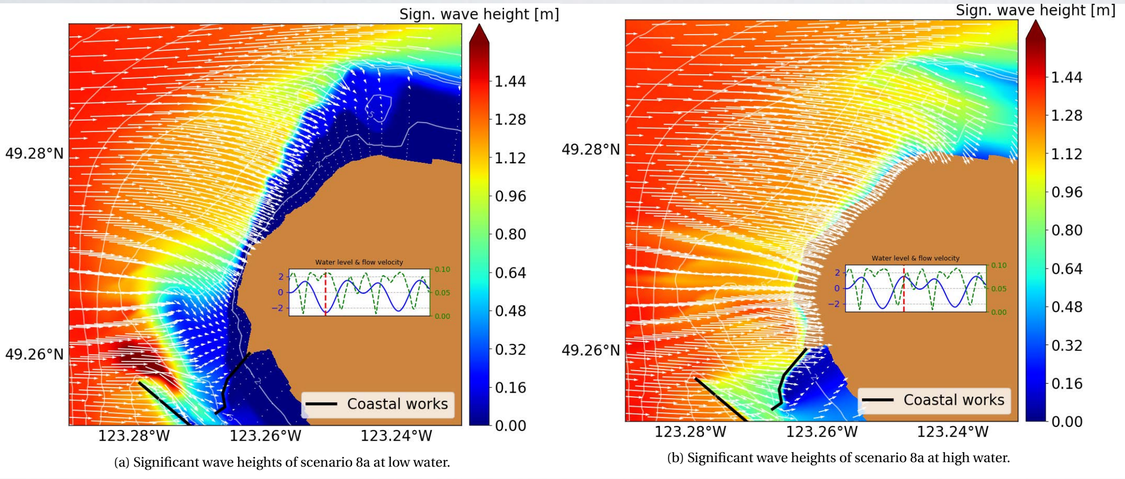
(b) Depth intermediate grid.

(c) Depth fine grid.

(d) Fine model depth zoomed in.

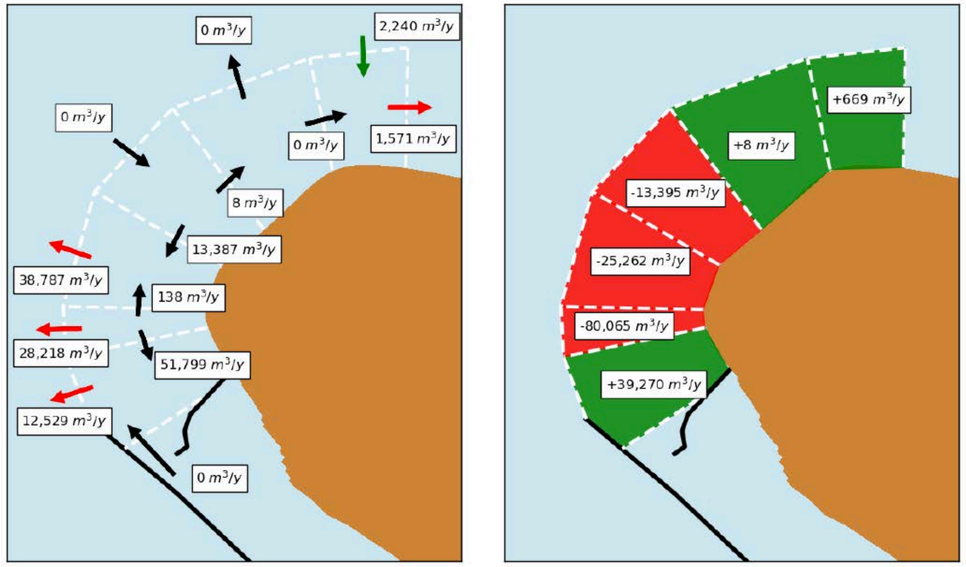
Close-up of the finest grid

I. MODELING MARINE CONDITIONS



(a) Significant wave heights of scenario 8a at low water.

(b) Significant wave heights of scenario 8a at high water.



(a) Transport between SUs.

(b) SU budgets.

Figure 6.11: Sediment transport and budget over the different SU along Wreck Beach.

Causes of marine erosion

- Direct wave attack & wave run-up during high tide and storm events
- Long shore sediment transport by tides and waves.
- Deficit of sediment input to the coastal system.
- Sea level rise

PLANT GEOGRAPHY AND POTENTIAL FOR SLOPE STABILIZATION

- Density and types of the plant understory and canopy impacting Cliff's surface erosion.

II. PLANT GEOGRAPHY + POTENTIAL FOR SLOPE STABILIZATION

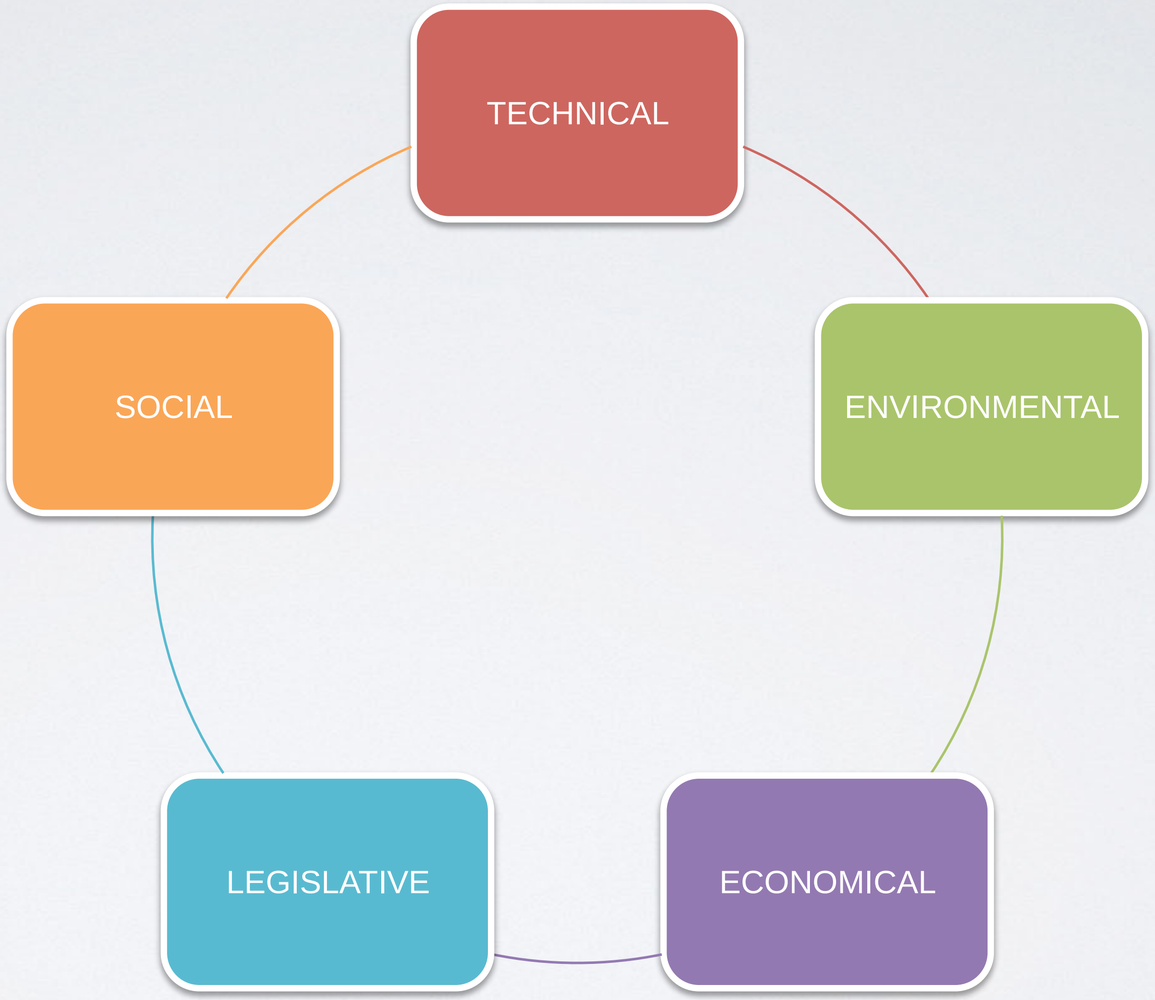
Candidates to stabilize the soil along the cliffs

- *Big-Leaf Maple* and *Red Alder* for canopy
- *Sword Fern* and native *Rubus* species (*Trailing Blackberry*) for understory

Other findings

- *Western Red Hemlock*, *Douglas Fir* and *Western Red Cedar* show relatively low abundance, indicating they either failed to establish or failed to reproduce

III. SOCIAL, ECONOMIC, LEGISLATIVE & ENVIRONMENTAL ASSESSMENT



III. SOCIAL, ECONOMIC, LEGISLATIVE & ENVIRONMENTAL ASSESSMENT

Musqueam FN

Port of Vancouver

DFO

Province of BC

Metro Vancouver

City of Vancouver

UBC Campus Planning

Univ. Endowment L.

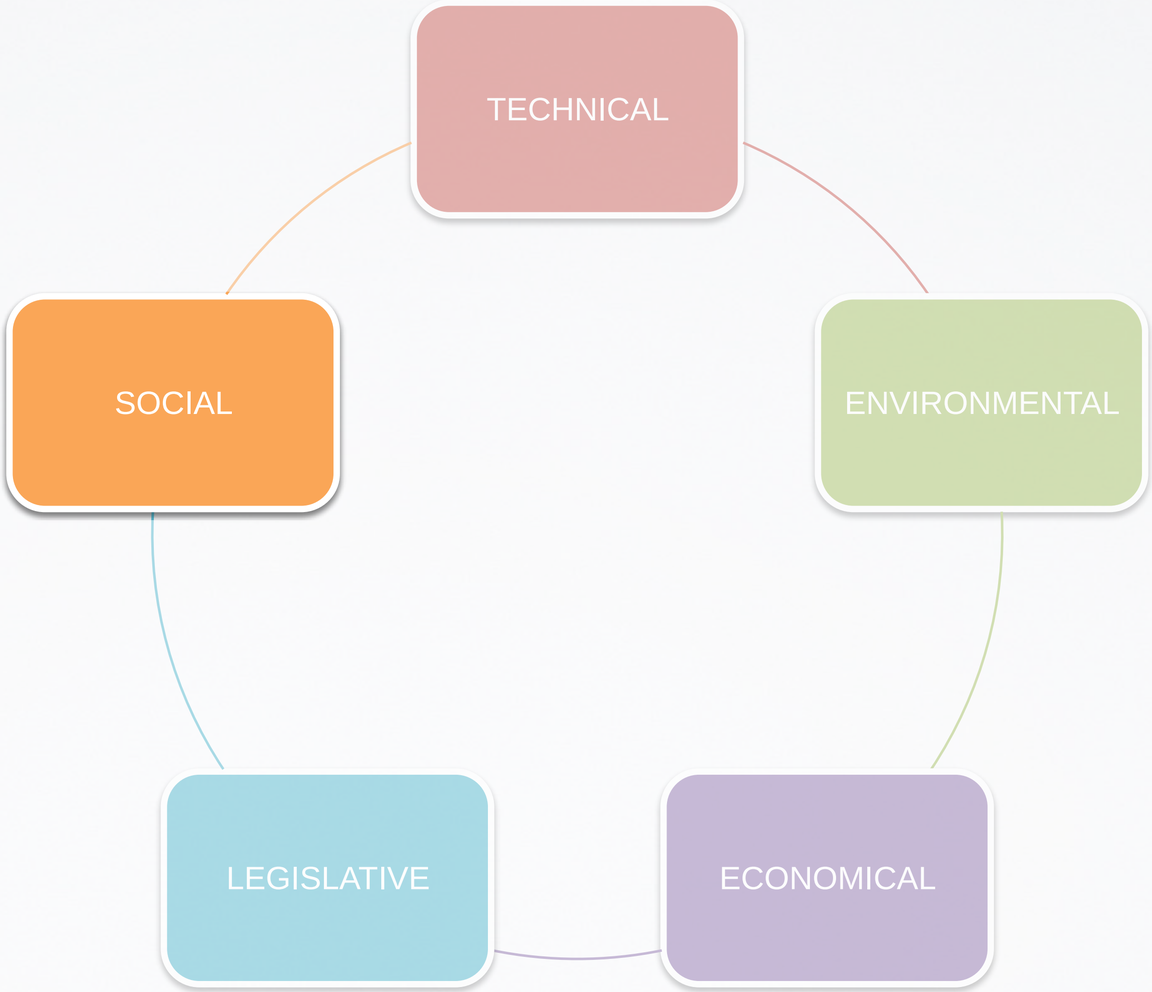
Private owners

Pacific Spirit Park

UBC community

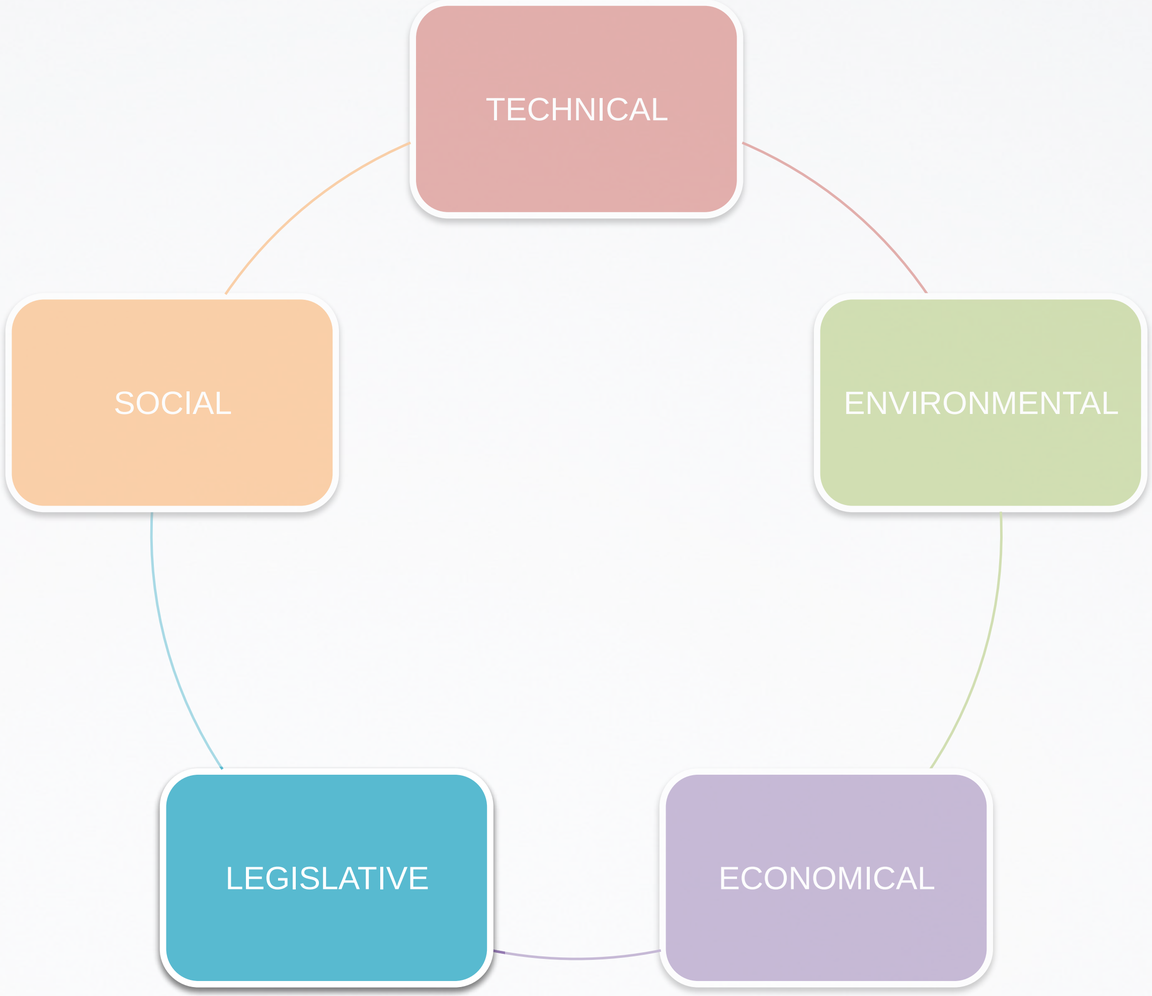
Tourists

7 NGOs



III. SOCIAL, ECONOMIC, LEGISLATIVE & ENVIRONMENTAL ASSESSMENT

- Fisheries Act
- Species at Risk Act
- Navigable Waters Act
- Environmental Protection Act
- Migratory Birds Convection Act
- Canada Marine Act
- Land Act
- Wildlife act
- Guidelines for Management of Coastal Flood Hazard
- Sea Dike Guidelines 2010
- Riparian Rights and Public Foreshore Use
- Land Use, Building and Community
- Official Community Plan
- Land Use 2015

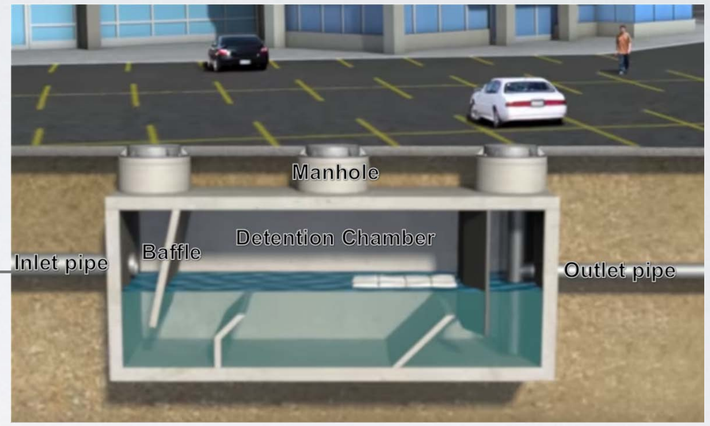


III. SOCIAL, ECONOMIC, LEGISLATIVE & ENVIRONMENTAL ASSESSMENT

Do nothing

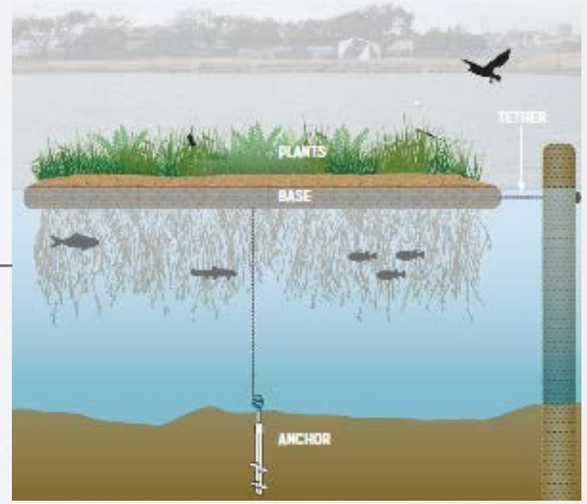
Subaerial

1. Revegetation
2. Stormwater detention facility
3. Inter-aquifer drainage wells



Marine

1. Rip-rap and rock revetment
2. Engineered beach & floating wetlands
3. Clam gardens



III. SOCIAL, ECONOMIC, LEGISLATIVE & ENVIRONMENTAL ASSESSMENT

Concept	Technical	Environmental	Economical	Legislative	Social
Do Nothing	- Non intervention - Erosion will continue as business as usual	- Habitat will disappear as the cliff erodes - Probably new habitats will be formed	- Lost of campus land - Lost of infrastructure: buildings, roads and sewer	- Without intervention no permission is needed	- Community affected by the lost of land and cultural heritage
Rip-rap and rock revetment	- Effective protection of the toe - Does not solve the problem of sediment budget	- Reduction of the available habitat - It is recommendable carrying the most nuisance activities during winter reduce the loss of species	-Minimum maintenance - Total estimated cost is around 210 MM CAD	- Needs to meet the jurisdictional demands of UBC, BC and Canada's government	- Change of the aesthetic landscape - Beach may be not suitable for pedestrians
Engineered beach and floating wetlands	- It copes with problems of marine erosion and sediment budget - Lack of studies to ensure level of effectiveness	- Alteration of the habitat due to coverage of (new type) sand and increase of turbidity - Floating islands give a new habitat but can generate a dead zone behind -Resilient solution that can be adaptable to SLR	-Maintenance of floating wetlands and beach must be considered - Total estimated cost is around 180 MM CAD	-Federal, provincial and local jurisdictional demands must be fulfilled	- Change of the aesthetic landscape - Increase of available recreational beach
Clam gardens and submerged breakwater	-Does not solve the problem of sediment budget - Lack of studies to ensure level of effectiveness	- Alteration of habitat from beach to clam garden - Low water quality can impact in clamps contamination (not suitable for human consumption) - Increase of habitat for clams and other species -Resilient solution that can be adaptable to SLR	-Maintenance of clam gardens must be considered - Total estimated cost is around 35 MM CAD	-Provincial and local jurisdictional demands must be fulfilled	- Change of the aesthetic landscape -First Nations cultural heritage
Subaerial	- Cliff stability is aim through revegetation. Efficiency is not certain - High speed flow over the cliff is avoid through an underground stormwater detention facility -Inter-aquifer drainage wells reduce thus seepage erosion. Best location is difficult to be determined	- Revegetation provides new habitats expanding the existing wildlife population - The stormwater detention removes contaminants improving water quality - The drainage wells can influence the quality and quantity of ground water (i.e oxidation of dissolved metals)	-Maintenance vegetation must be considered - Total estimated cost is around 7.5 MM CAD	- The three approaches are in UBC land thus must be approved mainly by UBC - Storm water detention facility and drainage wells plans must follow BC guidelines	-Revegetation adds aesthetic value - Storm water facility reduces nuisances due to flooding - Revegetation and drainage wells increase safety for cliff's visitors

III. SOCIAL, ECONOMIC, LEGISLATIVE & ENVIRONMENTAL ASSESSMENT

Comparison suggests

- Hard marine approaches
  - work well to *stop the waves*
  - do not solve *the sediment deficit* problems
  - *Negative economic* and *environmental* impacts
- Soft/hybrid approaches
  - high *uncertainty* as there is no precedent in this region
  - supply *more sediment*
  - have more *environmental, social* and *economic benefits*
  - possible *regulatory complications*
- *Access* to cliff presents practical challenges

NEXT STEPS — UNDERSTANDING VALUES AND PERSPECTIVES

FINAL REMARKS

- Provide an online platform that advances adaptation knowledge in the region and beyond
- Provide information on adaptation strategies and adaptation resources
- Case study to examine different factors contributing to erosion
- Identify tangible & intangible assets at risk
- Bring people together to discuss different values and perspectives on adaptation
- Lead to more informed, involved & meaningful decisions (hopefully)

THANK YOU / QUESTIONS ?

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