RE-IMAGINING THE STANLEY PARK SEAWALL:
AN EXPLORATION OF LIVING SHORELINE ALTERNATIVES

Prepared by:
Brontë Mutukistna
Sustainability Scholar, August 2022

Prepared for:
Francisca Olaya Nieto, Environmental Planner
Environmental Planning and Sustainability, Vancouver Board of Parks and Recreation

ACKNOWLEDGMENTS

The author would first like to begin by acknowledging their position as a settler on the unceded territories of the xʷməθkʷəy̓əm (Musqueam), Sḵwx̱wú7mesh (Squamish), and səlilwətaɬ (Tsleil-Waututh) Nations. This report explores the shoreline of the site now known as Stanley Park. Since time immemorial, Coast Salish peoples have stewarded the land and cared for its shoreline, nurturing the place where the land meets the sea and harvesting the bounty along the coast. This report honours the past, present, and continued stewardship and advocacy of the shoreline by the Coast Salish peoples and recognizes that Indigenous knowledge and wisdom will be the foundation of a resilient and sustainable living shoreline.

I would like to thank Francisca Olaya Nieto, Environmental Planner at the Vancouver Board of Parks and Recreation, for her support and mentorship. I am truly grateful for her commitment, generosity, and encouragement throughout this project. I would also like to thank Chad Townsend, Senior Planner at the Vancouver Board of Parks and Recreation, who offered his time, support, and guidance. Thank you to all whom I sought direction and counsel from, faculty at UBC and the members of the Environmental Planning and Sustainability team, your perspectives have been invaluable and have helped shape this project.

This report was produced as part of the Greenest City or Healthy City Scholars Program,
a partnership between the City of Vancouver and the University of British Columbia,
in support of the Greenest City Action Plan and the Healthy City Strategy.

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.

The following are official partners and sponsors of the
Greenest City or Healthy City Scholars Program:

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report examines the Stanley Park seawall, an 8.8km recreational pathway that wraps around the entirety of the park's perimeter. Stated by author Sean Kheraj (2013) in *Inventing Stanley Park: An Environmental History*, "The construction of the seawall was a battle against nature and an effort to stall processes that had been at work for thousands of years before there was a Stanley Park" (p. 13). Coastal shore systems have been at odds with the seawall since the beginning of its construction in 1917. Routine repairs and fixes to degrading sections of the wall are commonplace as the seawall experiences the erosive forces of the ocean tides. The seawall doesn't just receive impacts from coastal systems, but in turn responds with even more destructive force. The seawall has significantly altered the shoreline, exacerbating erosion, disrupting nutrient flow between marine and terrestrial environments, and virtually removing all intertidal habitat. The once gradual fine sediment and rocky intertidal ecosystems along Stanley Park's western edge have been transformed to a landscape filled with large boulders and fine sediment that lack marine diversity (BIEMP FREMP, 2014, as cited in Canning, 2017).

The seawall not only creates a divide between land and sea, but also between people and the coast. Ranging from 0.5 to 4m in height, the seawall places users above the marine environment, forcing park visitors to observe rather than engage with the coastline. This physical separation reinforces an understanding, for park visitors, of a divide between the terrestrial and aquatic environments that opposes the important relationship between these two habitats.

The recent storm events in November 2021 and January 2022 shed light on the structural instability of the seawall, and its susceptibility to flooding and wave-induced impacts. As reparations to build a stronger and better wall remain to be the short-term solution, increasing sea level rise and storms events question the seawall's ability to withstand the destructive forces of climate change.

The financial and environmental costs of the seawall present an opportunity to re-envision what a more resilient and environmentally sustainable coastal pathway may look like. This document explores opportunities for a living shoreline alternative to the existing seawall, with the primary goal of developing a high-level, conceptual, nature-based coastal pathway that better supports park visitors, climate resiliency, and the intertidal habitat around the park. Presented in the following report is an inventory of the existing biophysical and environmental conditions of the park's shoreline that is then used to characterize the park's foreshore into different segments. This is followed by an analysis of the impacts of armoured shorelines on the intertidal zone, including coastal squeeze, scouring, and fragmentation. Existing coastal pathway projects in the Pacific Northwest and abroad are examined. These case studies were sought out for their relevance to the various conditions around Stanley Park's shoreline, helping to inform design strategies and opportunities unique to the different intertidal substrates and coastal processes around the park.

Two plans, the *Coastal Adaptation Plan* and the *Stanley Park Comprehensive Plan* (in progress) helped to identify value criteria that would inform design strategies. *The Coastal Adaptation Plan* first developed for the Fraser River Foreshore identified 7 community values for coastal projects, 6 of which are considered in this report (City of Vancouver, 2018). Currently, the Vancouver Park Board and the Musqueam, Squamish, and Tsleil-Waututh (MST) First Nations are developing the *Stanley Park Comprehensive Plan*, an outline

for a 100-year vision of the park (VPB, 2018). While the plan is in progress, this report aims to support the intentions and values of the comprehensive plan.

Stanley Park holds strong cultural significance amongst the Musqueam, Squamish, and Tsleil-Waututh (MST) Nations, where Coast Salish peoples have lived and stewarded the shorelines of Stanley Park since time immemorial. Indigenous settlements were located near the park's shoreline making use of the waters for harvesting natural resources such as clams, mussels, and cockles. This Sustainability Scholar report was not done in consultation with the MST and recognizes the need to develop design strategies with the Nations. The intent of this report is not to provide a solution to the existing seawall, but rather to begin to re-think what the Stanley Park seawall could be. Given that design proposals were not developed alongside the MST, Indigenous approaches to living shorelines were not explicitly explored, however, opportunities for telling the unwritten narratives and history of the park through education were a key consideration in the design process.

The analysis of the park's foreshore, living shoreline case studies, and value criteria all informed the selection of three areas in the park for potential design opportunities: X̱wáýx̱way, Third Beach, and the rocky intertidal areas between Third Beach and Prospect Point. The three areas were chosen for their potential to support a nature-based coastal pathway that protects the shoreline, increases intertidal habitat, and creates meaningful experiences between park visitors and the shoreline.

The unique setting of Stanley Park provides an opportunity to drastically transform the park's hardened shoreline to a resilient and ecologically-rich coastline. Unlike other parts along Vancouver's seawall that are centered in developed areas of the city, Stanley Park's lack of infrastructure and built form allow for a living shoreline approach that can take many forms. Recent storms events and sea level rise have shed light on the long-term viability of the seawall, and have prompted a need for change. The design proposals in this report aim to inspire and initiate further dialogue on an alternate future for the Stanley Park seawall - one that works in synergy with coastal processes rather than against them.

PROJECT BACKGROUND

INTRODUCTION

The Stanley Park seawall is often synonymous with Vancouver. Beginning construction in 1917 to prevent the erosion of the park, the seawall is an iconic 8.8km pathway that wraps around the park and provides uninterrupted access to Vancouver's shoreline. The seawall is a treasured recreational path frequented by Vancouverites and visitors around the world, however, with increasing storm events and sea level rise, the viability of the seawall is threatened.

On January 7th, 2022, Vancouver was hit by yet another powerful storm with fierce winds and high tides striking the Stanley Park seawall. The wall faced countless battery, washing away sections of the seawall and littering the shoreline with broken pieces of concrete and rubble. The damage sustained by the seawall is not unfamiliar. In 2012 and 2015, sections along the seawall were once again closed following large storm events and rising sea levels. The increasing frequency of extreme weather events and the consequential need for repairs and maintenance question the long-term viability of the seawall in its current form.

Beyond the financial and material burden, armoured shorelines such as seawalls have been shown to reduce marine biodiversity. A study undertaken by Gittman et al. (2016) noted, "Seawalls supported 23% lower biodiversity and 45% fewer organisms than natural shorelines" (p. 763). The intertidal zone plays a critical role for marine and terrestrial species, providing food and shelter for many organisms. The loss of intertidal habitat could result in more widespread effects to the larger marine and terrestrial food web. The foreshore not only supports marine habitat but provides an abundance of ecosystem services including flood protection, stormwater filtration, and carbon storage. These services are all but lost with the construction of seawalls, as armoured shorelines alter wave energy and reflection, resulting in greater erosion, disturbance to littoral transport, and the reduction of shoreline vegetation, preventing the natural ability for the shoreline to mitigate flooding.

The seawall not only creates a divide between land and sea, but also between people and the coast. Ranging from 0.5 to 4m in height, the seawall places users above the marine environment. With steep, inaccessible steps that appear infrequently along the shoreline, park visitors observe rather than engage with the coastline. An important aspect of this project is to better connect people to the shoreline and foster a greater understanding of the marine environment. In doing so, design proposals work with coastal processes, allowing for variations of public access depending on tide levels and flooding. The adaptability of the designs help visitors to engage with the dynamic nature of the shoreline and better understand the marine environment as a place that may not always be accessible.

Currently, the Vancouver Park Board and the Musqueam, Squamish, and Tsleil-Waututh (MST) Nations are developing the *Stanley Park Comprehensive Plan*, an outline for a 100-year vision of the park (VBP, 2018). While the plan is in progress, this report is operating under the knowledge that the three Nations will play an integral role in any ongoing and future developments in Stanley Park.

It is clear there is a need for alternative measures to protect Stanley Park's coastline. Examining the social, ecological, and technical complexities of the seawall reveal the need for a multifunctional landscape that will protect the shoreline from erosion, increase intertidal habitat, and support meaningful experiences between park visitors and the foreshore. Living shorelines have the capacity to provide physical protection while supporting biological diversity along coastlines. Faced with increasing storm events and sea level rise, a critical change is needed to protect Stanley Park's shoreline. Coastal adaptation measures are a necessary must to ensure there is a future for both ecology and people on Stanley Park's shores.

SCOPE

Re-envisioning the seawall is no small task. The intent of this project is not to provide an all encompassing solution, but to imagine new possibilities for the seawall as a nature-based pathway. The key deliverable of the project is a high-level, conceptual design alternative to the existing seawall. Limited by time constraints, consultation with the MST was not within the scope of the project, nor was any form of engagement with community and relevant stakeholders, or a feasibility study. An important objective of this project was the inclusion of visual aids to communicate potential design opportunities. Images, drawings, and visualizations are presented throughout the report to help describe findings, concepts, and designs, and to show a vision of a more restorative and ecologically-rich shoreline.

STANLEY PARK FORESHORE

BIOPHYSICAL CONDITIONS

Context

Stanley Park is situated in the Lower Mainland of British Columbia (Figure 1). The park is a 1000-acre forested peninsula that sits north of Vancouver's downtown core jutting into the Burrard Inlet. With shorelines on all three sides, the park's sea and shores provide vital habitat for migrating birds along the Pacific Flyway and marine mammals travelling to and from spawning areas (SPES, 2010). The peninsula's nearshore is an important source of shelter and food for water birds, terrestrial species, and marine organisms. Not only critical to wildlife, Stanley Park's shoreline is a popular tourist destination for locals and visitors of Vancouver, offering breathtaking views, wildlife sightings, and an accessible route along the coastline. The seawall forms the perimeter of the park, providing an uninterrupted 8.8km pathway along the water for pedestrians and cyclists. The abundance of nature in such a dense and urban setting, has made Stanley Park named one of the top city parks in the world (Hallinan, 2017).

Figure 1: Context plan

Currents

As pictured in Figure 2, tidal currents during flood durations move from west to east and enter through the Strait of Georgia hitting Stanley Park's western edge (Thomson, 1981). The flood currents are then separated recirculating at English Bay and passing through the First Narrows with increasing speed into the Inner Harbour. Along the shoreline in English Bay, tidal flows recirculate with an opposite direction to the main flow at a slower rate, while currents passing through the First Narrows move with increasing speed (Wu, 2019). During ebb periods, tidal flows are directed out of Burrard Inlet. The park's western edge is characterized by high wave energy with tidal flows of lower magnitude to the south and of greater strength to the north, subjecting the park's northwestern edge to increased coastal erosion and impacts from storm surges. As the currents move through the Inner Harbour towards the Indian Arm, they become weaker making Stanley Park's eastern edge subject to less coastal erosion and effects from extreme weather events (Wu, 2019).

Waves and Winds

With the Coastal Mountains to the north, Burrard Inlet is sheltered from wind. The predominant winds move from east to west and have little impact on ocean currents (Thomson, 1981). Easterly winds are more frequent in winter months; however, the average speed of westerlies exceed easterly winds for all months of the year and are strongest in January. While winds in the Burrard Inlet are generally insignificant, extreme westerly winds can occur and have a great impact on the Outer Harbour, where large waves are generated from strong winds in the Strait of Georgia. Waves induced by wind are weak within the Inner Harbour, where vessel generated waves become more significant given the considerable use of this area for commercial transport. While local winds may not have much impact on waves in the Burrard Inlet, waves induced from storm events have a considerable effect on Stanley Park's western shoreline.

Tides/Water Levels

Understanding changes in water levels along Stanley Park is critical in designing a shoreline that engages with the existing conditions of the site and influxes of the tide. Extreme high tide in the Burrard Inlet is measured at 5.6m with a mean water level of 3.1m (Thomson, 1981). Low tide occurs primarily in the evening during winter, and during the daytime in the spring. This makes intertidal species more exposed to summer heat with low tide occurring more frequently in the daytime in summer months.

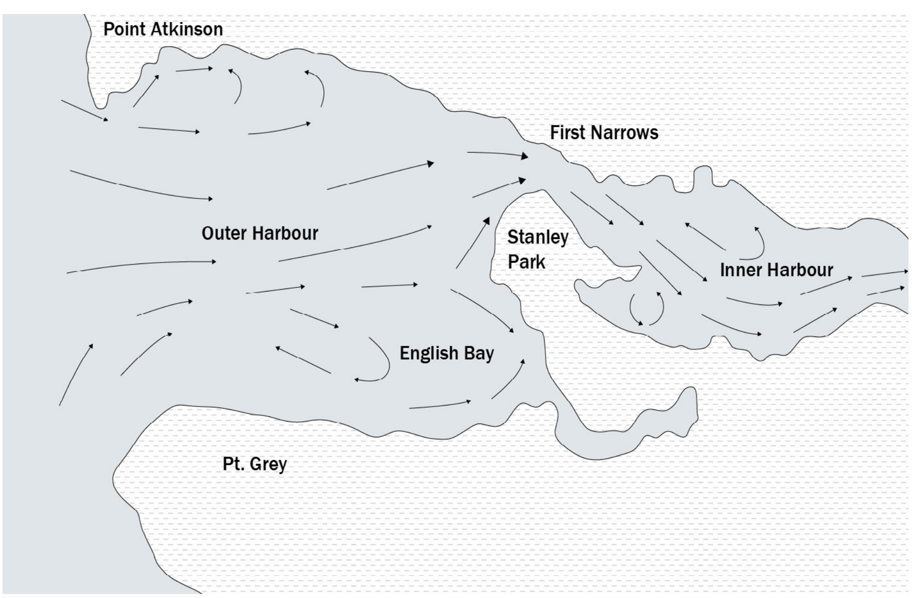


Figure 2: Currents during flood period, image adapted from Thomson, (1981).

Sediment Transport

Studies on sediment transport around Stanley Park's nearshore are limited, however information exists on the movement of sediment along Burrard Inlet that help to inform conditions around the park. Flows and sediment transport in the Burrard Inlet are tide-dominated where the impact from wind, waves, and freshwater discharge are relatively weak (Meijers, 2021). Along with the tides, the geometry of the inlet governs the movement of sediment. A study undertaken at Delft University of Technology by Meijers (2021), noted that current velocities in the Burrard Inlet vary, where the tidal flows accelerate rapidly in the First Narrows due to the narrow constriction of the channel. The morphology of the park's northern shore causes sediment concentrations to be directed away from the First Narrows during both ebb and flood periods. As such, little sediment is collected at the park's northern shore. Rather, sediment is pushed into the Inner Harbour during flood periods, collecting along the eastern edge of the park and forming sand pockets from Brockton to Prospect Point. Results from the study indicate the potential for sediment to reach the Burrard Inlet from the Fraser River. During periods of high westerly waves, sediment may be transported from Point Grey to the shorelines of the park's southwestern edge near Second Beach (Figure 3).

This study focuses on sediment patterns in the Burrard Inlet, with particular attention to the Tsleil-Waututh Nation reserve east of Stanley Park. Understanding the movement of sediment along Stanley Park's shores is critical to inform appropriate shoreline design. Transport patterns can give insight into areas of accretion and erosion, and potential sources of sediment that can feed eroding shorelines.

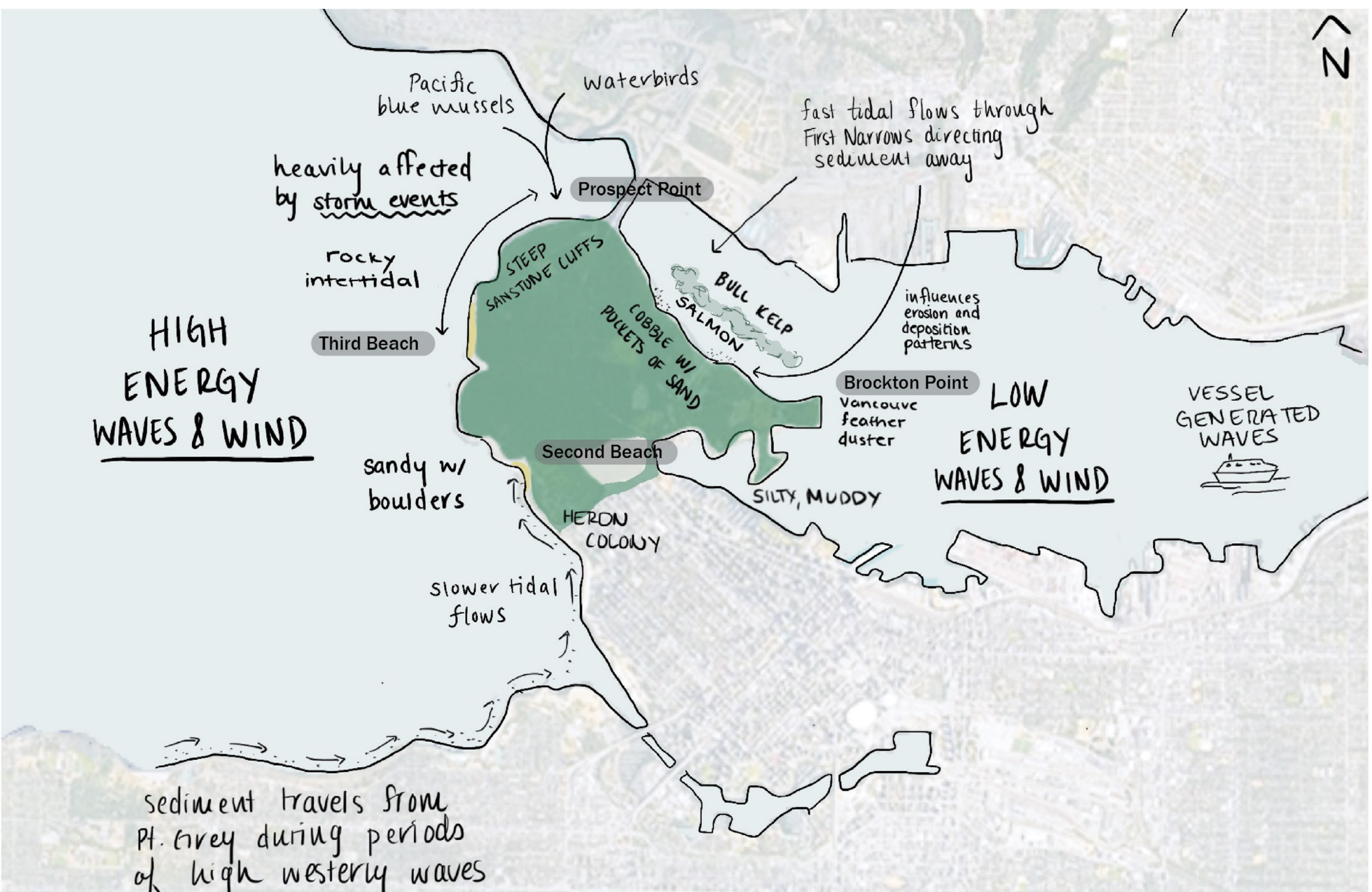


Figure 3: Coastal processes along Stanley Park's shoreline.

INTERTIDAL ECOSYSTEMS

The Intertidal Zone

The intertidal zone is defined by the space between low and high tide, connecting the terrestrial and marine environments. Subject to tidal cycles, species living in the intertidal zone undergo a variety of conditions as they are submerged in water during high tide and left exposed during low tide. These environmental parameters result in species that have adapted to both wet and dry conditions. Organisms living in the park's foreshore live in a delicate balance of exposure and inundation, and are adapted to specific levels of solar radiation, air temperature, ocean salinity, and wave action. Impacts to these factors can greatly influence the health of intertidal species. With growing changes in the environment from increasing sea level rise, storm surges, and heat waves, the fragile balance of the intertidal zone is threatened.

Along Stanley Park, the foreshore takes many forms including, rocky, cobble, and sandy substrates. These varying substrate compositions are influenced by coastal processes and energy inputs, determining the plant and marine communities that populate the intertidal ecosystem. The park's foreshore supports diverse organisms including Pacific blue mussels, Vancouver feather duster, and 7 species of Pacific salmon (KWL, 2017). This biodiversity provides vital food and spawning habitat for migrating and resident birds and fish. Beyond the ecological value of the intertidal zone, the foreshore provides important ecosystem services supporting the livability of our planet including, carbon storage, nutrient cycling, stormwater filtration, and protection from waves and erosion.

Figure 4: Sea star, photography by Jean Giroux, (2022).

The intertidal zone is integral for the health of the marine and terrestrial environment, as well as the well-being of Vancouverites. However, increasing anthropocentric impacts of climate change and the creation of the seawall has severely altered the intertidal zone, threatening this vital ecosystem. Currently, the intertidal zone lacks the diversity it once had. Stanley Park's shoreline was once characterized by rocky, sandy, and mudflat ecosystems that have all been virtually removed or altered, leaving large boulders that provide little habitat diversity and ecosystem services. The following section discusses the current species located along the park's shoreline, highlighting the importance of mitigating any more damage to the intertidal zone for the well-being of nearshore species.

Fish

Numerous reports indicate that Stanley Park's foreshore is likely used for rearing and migration by all 7 species of Pacific salmon, including chinook, sockeye, coho, chum, pink, steelhead, and cutthroat trout (KWL, 2017). Important locations for salmon habitat include the kelp forests along the eastern edge of Stanley Park. Juvenile salmon use Burrard Inlet's nearshore during spring and summer. Pacific sand lance and surf smelt utilize both pebble and sand beaches for spawning and are found along the beaches of the Outer Harbour, including Second and Third Beach. Shellfish such as Pacific blue mussels are found along Stanley Park's rocky shoreline between Prospect Point and Siwash Rock (Figure 3). These beds of mussels are commonly found clinging to bedrock, boulders, and cobble habitat, and provide food for water birds.

Birds

Stanley Park is situated within the English Bay & Burrard Inlet Important Bird Area (IBA) due to the large concentration of overwintering waterbirds located in the region. The park's intertidal and subtidal zones are critical habitats for globally significant numbers of Barrow's goldeneye, surf scoter, and Western grebe that winter in the Burrard Inlet and depart in the spring and summer (SPES, 2010). Waterbirds use the park's intertidal areas for foraging where there are Pacific blue mussels, forage fish, and marine organisms. A study examining wintering waterbirds along Stanley Park's shoreline noted an overall decrease in abundance and peak numbers of most birds from 2001/2002 to 2010/2011 (Worcester, 2013). The decrease in birds in the park indicate the need to conserve shoreline habitat that provide critical feeding and resting spots. In addition, the Great Blue Heron is a species at risk that is frequently observed on Stanley Park's shoreline. The park is home to one of the largest urban heron colonies in North America, nesting at their current location near Beach Avenue since 2001 (KWL, 2017). This species of heron does not migrate and is present yearlong in the park. During breeding season, the intertidal areas are critical for foraging, where herons feed on shellfish and small fish in the foreshore. Particularly, the park's western shoreline is a valuable feeding habitat for herons as the rocky intertidal zone is comprised of Pacific blue mussels.

Figure 5: Cormorants, photograph by Veronica Dudarev, (2020).

Figure 6: Intertidal vegetation, photography by Brontë Mutukistna (2022).

Vegetation

The vegetation in the intertidal zone along the perimeter of the park is composed of various algae. Sea lettuce and wrack seaweed are most found along the entirety of the park's intertidal areas with lower populations of Turkish towel and green algae found along the eastern side at X̱wáýx̱way and Figurehead Point (KWL, 2017). From Brockton Point to the Lionsgate Bridge, there are bands of kelp forests in the subtidal areas (Figure 3). Bull kelp supports forage fish such as Pacific herring, Pacific sandlance, and juvenile salmonids, and also protects the coastline by buffering waves. Additionally, the endemic Vancouver feather duster is found in the intertidal and subtidal areas along Brockton Point.

SOCIAL AND CULTURAL SETTING

Cultural

For over thousands of years, the Musqueam, Squamish, and Tsleil- Waututh First Nations lived in Stanley Park. The park was home to several settlements for which Coast Salish peoples resided and was the site of one of the largest Indigenous settlements in the Lower Mainland (Kheraj, 2013). The park's coastline was of incredible importance to First Nation communities' diet and trade. The intertidal zone was a place for harvesting natural resources such as clams, crabs, mussels, and cockles (Taft *et al*., 2022). The value of the intertidal zone for resources to First Nations communities is best understood by the common saying, "*when the tide is out, the table was set*." Beyond providing food and sustenance, the foreshore has considerable cultural importance. Many spiritual practices and ceremonies are held along the shore, where the intertidal zone is a transitional space between the land and sea, acting as the interface between the physical and spiritual realms.

Tourism and Recreation

Stanley Park is one of the most popular tourist attractions in Vancouver, with approximately 8 million visitors each year (Stanley Park, n.d.). The seawall is the most frequented space in the urban park where a majority of people accessing Stanley Park visit the seawall. The seawall path is a heavily recreated route and is used by pedestrians, cyclists, and rollerbladers alike. The park holds various walking/running events including the BMO Vancouver Marathon and the 'First Half' Half Marathon. The park's unique proximity to downtown Vancouver provides city dwellers and visitors with a coastal path distinct from the bustle of the city center. This low barrier access to the coastline makes the Stanley Park seawall a key destination in the city. Offering recreational, mental, and physical benefits, the seawall is a unique public space in Vancouver, and maintaining the path's value to the public is important.

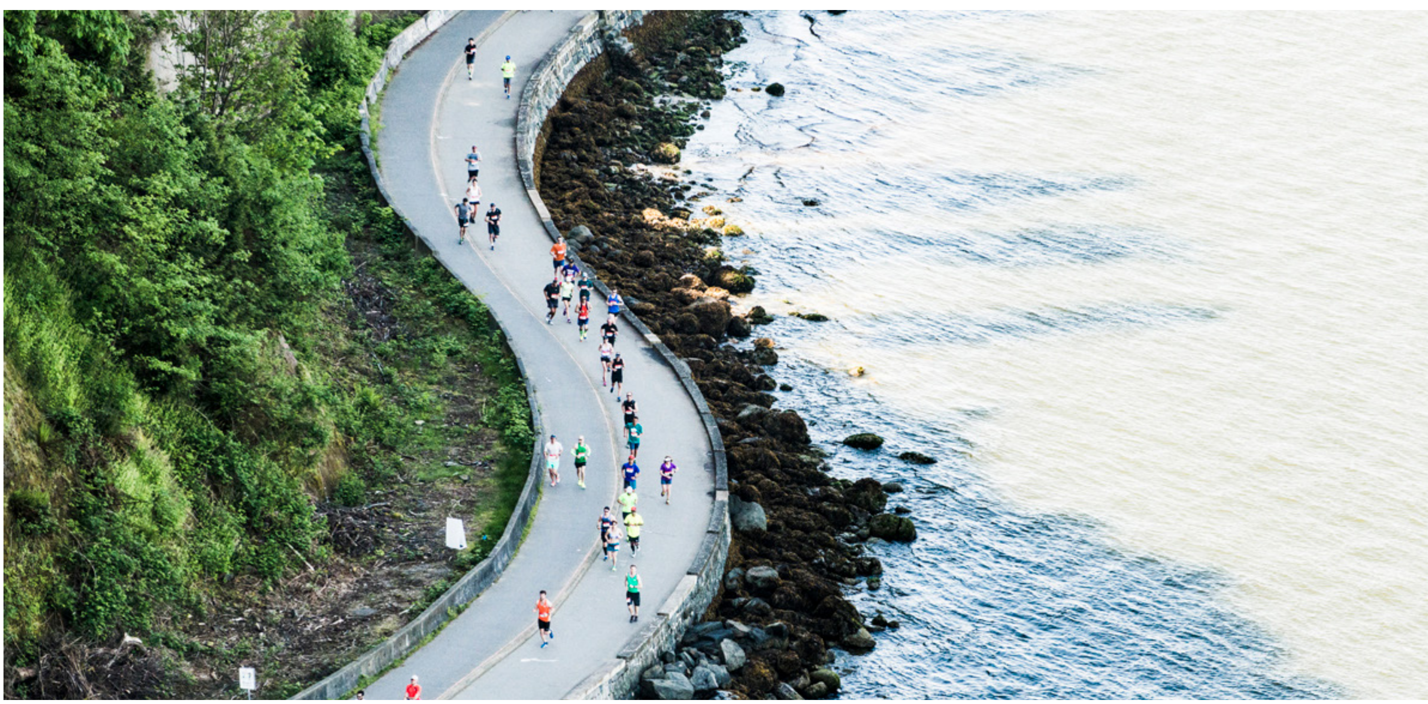


Figure 7: Seawall during the BMO Vancouver Marathon, BMO Vancouver Marathon, (n.d.)

CHARACTERIZING STANLEY PARK

Stanley Park's shoreline wraps around the perimeter of the park and is exposed to a variety of wind, wave, and coastal processes that shape the intertidal substrates, aquatic life, and vegetation present. The following section characterizes the park into 4 distinct areas based on similar biophysical and environmental conditions.

A1 - Coal Harbour

High Tide: seawall **Low Tide:** 20-100m offshore

Key species: juvenile salmon, crabs, and shellfish

Intertidal habitat: mudflat, sandy, gravel

Coal Harbour marks the eastern entrance of Stanley Park. Marinas are located in the harbour where numerous small boats are docked. Coal Harbour is sheltered from wave action lending to relatively still water and a sandy/gravel intertidal substrate. The weak tidal exchange allows for greater sedimentation forming muddy and silty areas along the shoreline. The erratic boulders along the shoreline provide habitat diversity (SPES, 2010).

A2 - Brockton Point to Prospect Point

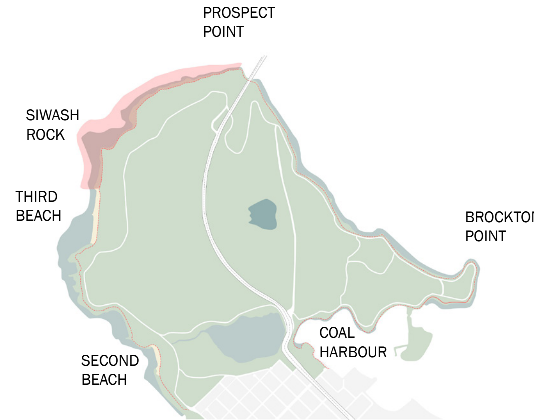
High Tide: seawall **Low Tide:** 10-50m offshore

Key species: Red Irish lord, sailfin sculpin, Pacific herring, red sea urchin, Vancouver feather duster, bull kelp

Intertidal habitat: gravel, cobble, boulder

The shoreline between Brockton Point and Prospect Point varies between bedrock, boulders, and cobble substrates with pockets of sand deposits. The nearshore is heavily influenced by tidal currents in the First Narrows, creating erosion and deposition patterns (KWL, 2017). Tidal flows along this section enable greater species diversity in the intertidal and subtidal zones, as currents reduce sedimentation drawing in nutrients and food for species (SPES, 2010). Large bands of bull kelp reside in the subtidal zone acting as important habitat for invertebrates, fish, and marine mammals, including Pacific herring, Pacific sandlance, and salmon species. The mix of cobble and boulder are important rearing and spawning habitat for fish, such as red Irish lord and sailfin sculpin. Brockton Point was found to have the highest species diversity, where sponges and tunicates were found, along with the endemic Vancouver feather duster that occupies the lower intertidal and subtidal habitats off of Brockton Point (SPES, 2010).

A3 - Prospect Point to Third Beach



High Tide: seawall **Low Tide:** 10-50m offshore

Key species: Pacific Blue mussels, Barrow's goldeneye, surf scoter

Intertidal habitat: boulders, bedrock

This region is characterized by steep sandstone cliffs with 40% slopes adjacent to the pedestrian and cyclist path (SPES, 2010). The instability of the cliffs can cause debris slides forcing the Vancouver Park Board to routinely close this section of the wall to undertake slope stabilization measures. The high tide line falls on the seawall with an intertidal zone that steeply slopes seaward. Situated on the park's western edge, this section is exposed to greater winds and wave activity resulting in an intertidal substrate that is primarily composed of exposed boulders and bedrock. Pacific blue mussels cling to boulders and provide food for wintering birds and ducks, such as Barrow's goldeneye and surf scoter. Siwash Rock is a critical feeding and resting area for water birds including seabirds, gulls, and cormorants. Extreme storm events have heavily affected this section of the park's shoreline, with large magnitude waves and wind severely damaging seawall infrastructure. The need for persistent large-scale maintenance and repairs are of concern.

A4 - Third Beach to English Bay

Key species: Marine invertebrates, gulls, cormorants, sea ducks, sanderlings, black turnstones

Intertidal habitat: sand, bedrock, boulders

The intertidal zone from Third Beach to Second Beach is comprised of sandy beaches with intermittent rocky areas, exposed bedrock, and erratic boulders. Bordering both Second and Third Beach are rocky shores with boulders that provide feeding and resting areas for water birds and shorebirds. The sandy substrate provides habitat for marine invertebrates, such as California softshell-clam and green (or yellow) shore crab found in Second Beach, and purple mahogany-clam and Dungeness crab found in Third Beach (SPES, 2010). The beaches in this section of the park serve a large recreational purpose for park visitors. The foreshore areas are often occupied by people, leaving intertidal habitat and the species that forage there exposed to human disruption.

Second and Third Beach are subject to wave erosion and are decreasing in size. In 1963, sand was pumped onto Second Beach only to be removed by wave action causing the beach to recede by 18m. Third Beach underwent a similar scenario, where after having sand pumped, the beach receded 30m from 1966 to 1988 (SPES, 2010). The gradual erosion of the beach is a concern given its value to the public for recreation.

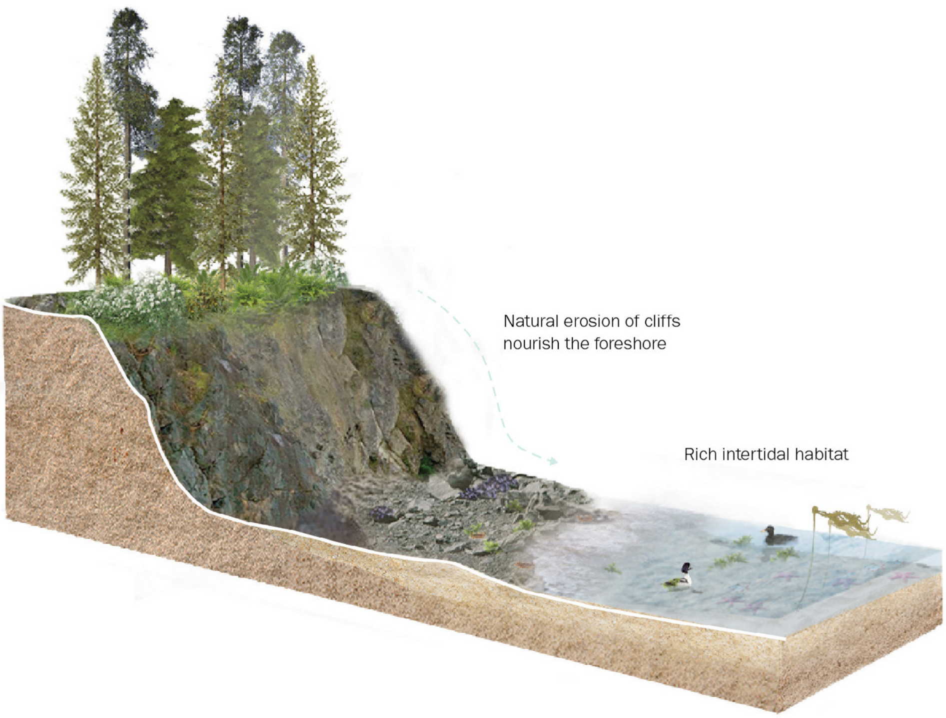
IMPACTS TO STANLEY PARK’S FORESHORE

THE SEAWALL

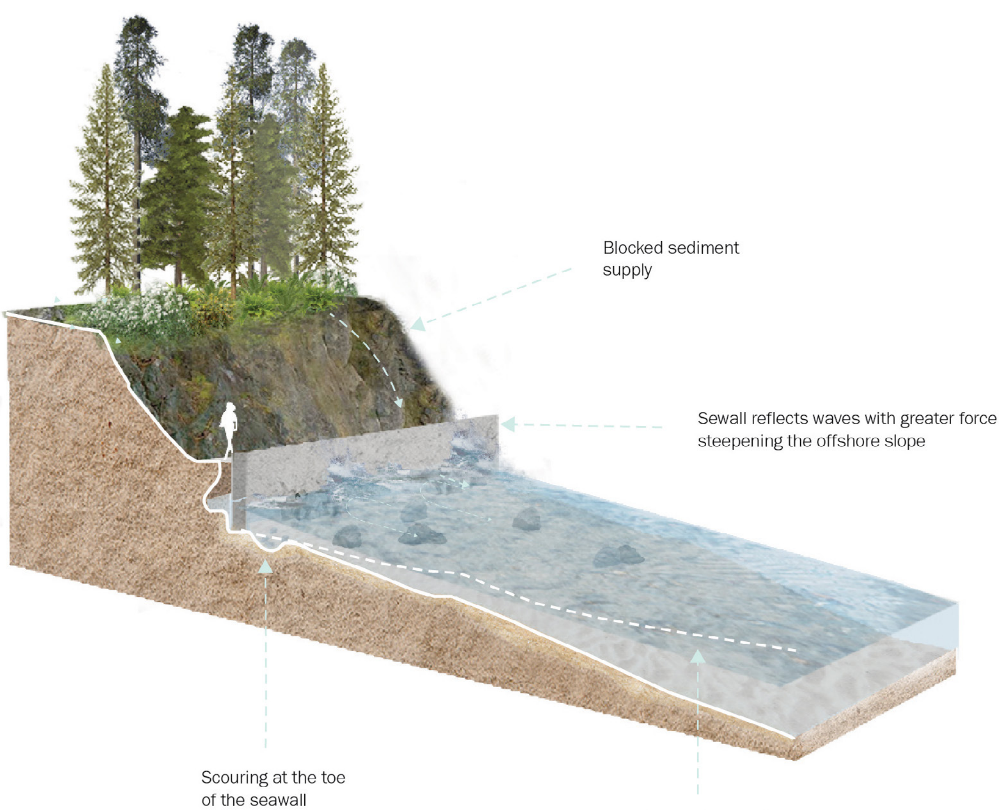
“The construction of the seawall was a battle against nature and an effort to stall processes that had been at work for thousands of years before there was a Stanley Park” (Kheraj, 2013, p. 13).

The seawall is a near-vertical stonewall made of rock and mortar, and backfilled with varying materials including rock, broken concrete, and gravel. The height of the seawall along Stanley Park varies from 0.5m to 4.0m and spans 8.8km around the park (KWL, 2017). Beginning construction in 1917, the seawall was originally built to prevent coastal erosion, but the wall’s path has now become one of Vancouver’s most popular tourist attractions. While the seawall provides recreational benefits and uninterrupted coastal access, the armouring of the shoreline has severe repercussions on nearshore habitats and worsens resilience to rising sea levels and storm events by limiting the natural ability of the shoreline to mitigate flooding and erosion.

The seawall has endured years of battery from waves, storm surges, and debris causing costly reparations. Beyond the financial burden in maintaining the wall, seawalls severely disturb coastal processes and remove highly biodiverse intertidal habitat. Impacts from seawalls to the foreshore include fragmentation, disruption of sedimentation processes, coastal squeeze, and increased scouring (Figure 8). As the number of extreme weather events and sea level rise increase, the intertidal zone continues to deteriorate and the need for major repairs following storms continue to grow. The ramifications of the seawall necessitate a long-term solution to support and protect the viability of Stanley Park’s shoreline for both ecology and people.



Before Seawall



After Seawall

Figure 8: Impacts of the seawall

Fragmentation

The connectivity between the intertidal zone and upland areas are critical for nutrient flow that support a healthy and functioning ecosystem. Seawalls interrupt the natural process of shoreline erosion whereby terrestrial substrates nourish the foreshore (SPES, 2010). This connection is fragmented when shorelines are armoured as seawalls prevent landward erosion contributing to the loss of the intertidal zone. The lack of sediment availability along the shoreline in turn disrupts longshore drift, a process that supplies sediment along the coastline (SCBC, 2003). With deficiencies in the supply of sediment, material fails to be transported along the coastline heavily affecting down current habitats.

Scour

While seawalls protect areas upland from erosion, hardened shorelines in fact accelerate processes of erosion on the seaward side. Vertical seawalls reflect incoming waves with greater intensity subsequently eroding and deepening the nearshore. This process, known as scouring, occurs when incoming wave energy is directed downward with force towards the seabed, resulting in a hole at the foot of the wall (Figure 9). Scouring contributes to the structural instability of the seawall and requires routine maintenance to avoid seawall failure. This process additionally undercuts the living root mass of the vegetated seabed, reducing and eliminating intertidal habitat (Curren *et al.*, 2010). Rozas (1987) noted that the deepening of waters adjacent to hardened structures allow larger fish to access previously shallow rearing areas, enabling them to feed on small and juvenile fish. This process transforms the characteristics and dynamics of the intertidal zone, affecting the species that reside in the foreshore and subsequently the waterbirds and predators that rely on the intertidal zone for sustenance.

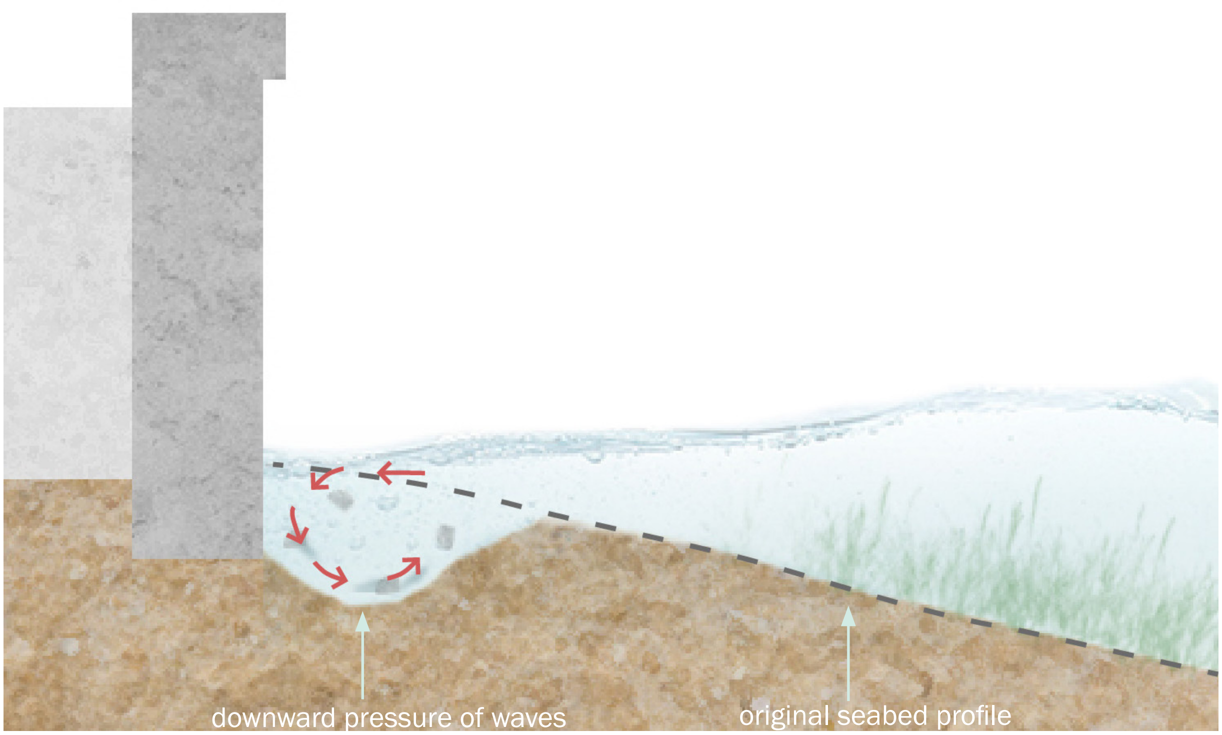


Figure 9: Scouring

Coastal Squeeze

Coastal squeeze is a consequence of built seawalls along the coastline and rising sea levels. With sea level rise, intertidal areas retreat further upland; however, fixed shoreline structures prevent the intertidal zone from moving landward causing the shortening of the foreshore (Hilke *et al*., 2020). The level of impact of coastal squeeze is dependent on the placement of the seawall where structures built further from the high tide line provide greater ability for the intertidal zone to move landward. The majority of the Stanley Park seawall is built at the existing high tide line. With the limited ability to move landward, the intertidal zone will be completely inundated, transforming the conditions of the nearshore and subsequently removing intertidal habitats and the ecosystem services they provide.

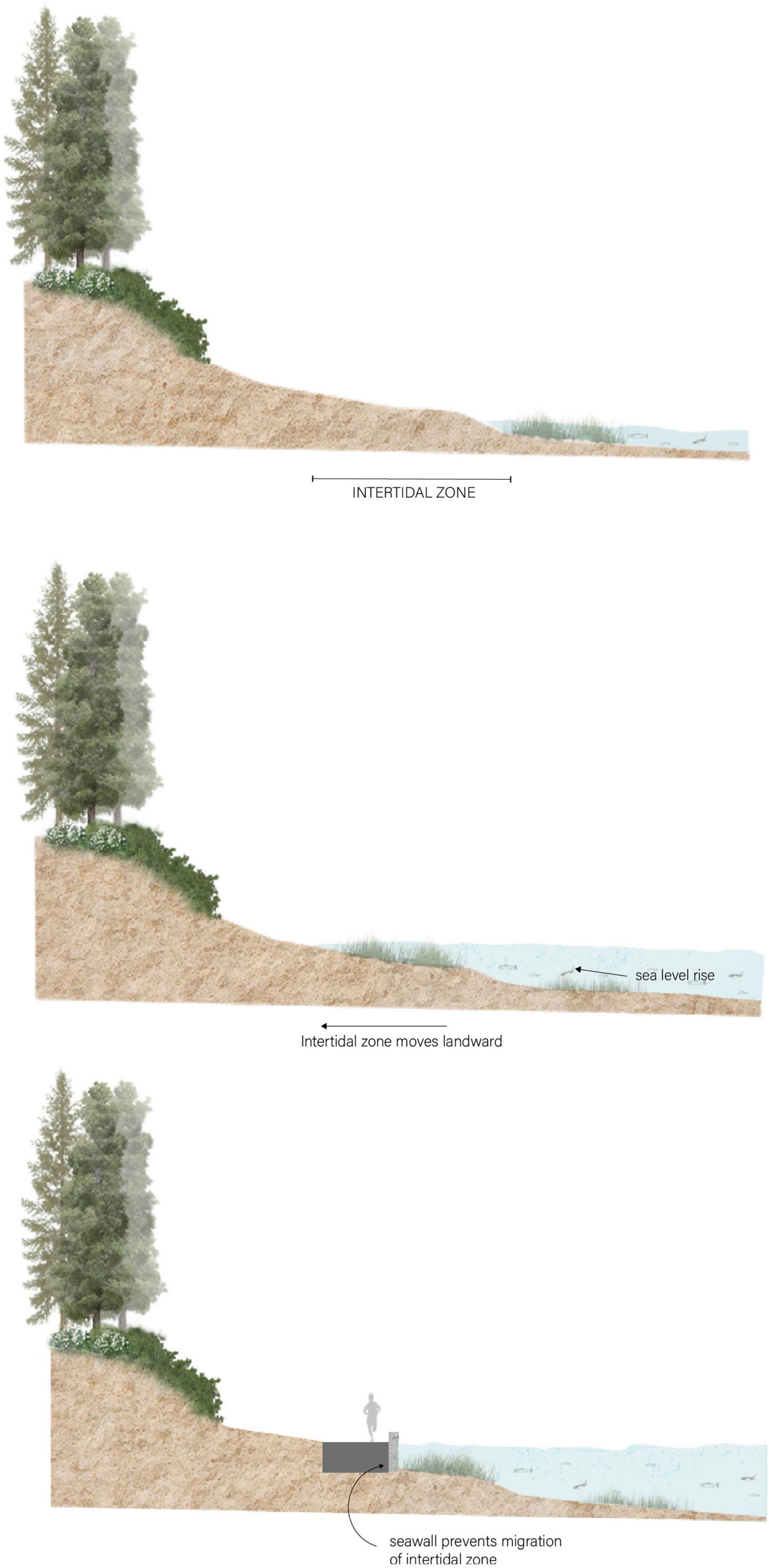


Figure 10: Coastal Squeeze

STORM SURGE

Extreme windstorms have considerable effect on Stanley Park's western shoreline. During winter months, Vancouver regularly experiences storm events which cause large waves to reach the shore. Storm surges shift the seawater above normal levels causing coastal flooding. When coinciding with King Tides, these events cause drastic impacts to the shoreline and the communities nearby. This was demonstrated in the storm event in January 2022, where winds of up to 70km/hr coincided with a King Tide, creating massive waves that battered the seawall and caused the destruction and closure of the wall (VPB, 2022). This isn't the first time the seawall has undergone impacts from storm surges. In 2012 and 2015, the seawall was closed for repairs following storm events in the winter. Extreme storm events are expected to increase with climate change, indicating the need for a shoreline that better protects coastal assets.

Figure 11: Waves hitting the seawall, photograph by Colin Knowles, (2013).

SEA LEVEL RISE

With global temperatures increasing, ocean waters have begun to expand, and glaciers and ice caps have melted increasing the volume of water in oceans. This increase has led to greater erosion of shorelines, flooding of coastal areas, and more intense storm surges. The impacts of sea level rise have already reached Vancouver's shoreline. To date, water levels have risen 3.7cm, and are projected to rise 1m by 2100 (City of Vancouver, 2018). Impacts to Stanley Park from sea level rise are numerous. As previously discussed, coastal squeeze and the loss of the foreshore are a major consequence of increase water levels. Additionally, sea level rise heightens the magnitude of storm surges. Greater water levels increase the baseline elevation of waves, therefore during large storm events, waves will have greater depths and magnitudes allowing the waves to reach further landward and lead to increase flooding (Climate Signals, n.d.). With predicted increases in storm events, the impacts of sea level rise are a major concern for the viability of Vancouver's shoreline.

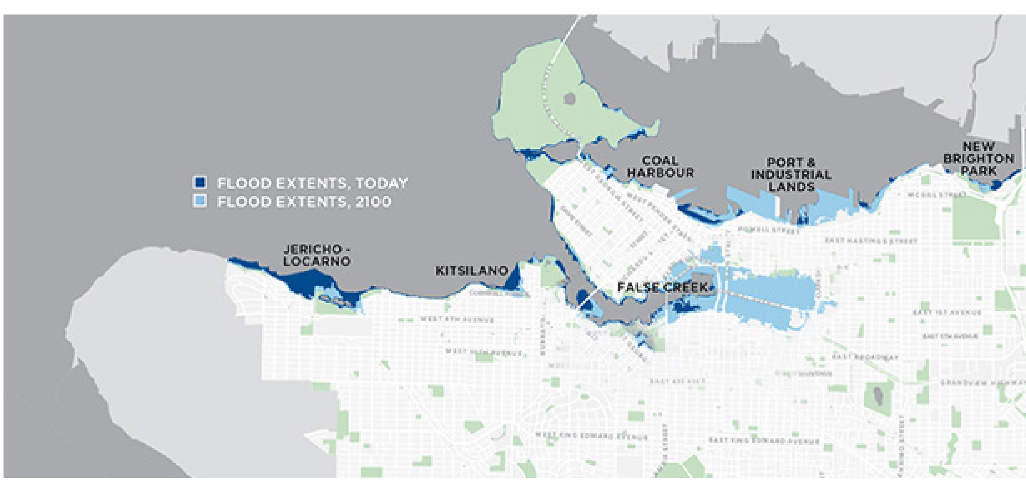


Figure 12: City of Vancouver, Flood Map (2018)

HEAT WAVE

Heat waves have considerably impacted the intertidal zone. On June 28th 2021, record high temperatures paired with an extreme low tide left intertidal species exposed to intolerable heat, killing around 10 billion marine organisms on the coast of British Columbia (Cruickshank, 2022). Unlike areas in the outer coast, Vancouver's location subjects the city and Stanley Park to low tides that occur later in the day. On June 28th, low tide occurred in the early afternoon, exposing the park's foreshore during the hottest part of the day (Bauman, 2022). While mussels can endure temperatures up to 30°C for short periods of time, the temperatures during the heat dome were recorded up to 40°C in Vancouver (Migdal, 2021). The loss of bivalves and particularly mussels can greatly impact the marine food web, where mussels are a source of food for many aquatic species including waterbirds and sea stars. Additionally, bivalves play an important role in filtering seawater (Kim, 2021). The loss of mussels from excessive heat could lead to changes in water quality affecting access to light for plants living in the ocean, consequently stunting their growth. The long term impacts of heat waves are dependent on how often they occur. With predictions of increased frequency and intensity of heat waves, intertidal zones are greatly threatened.

Figure 13: Mussels, crabs, and sea stars that perished during the heat wave in June 2021, photograph by Chris Harley, (2021).

LIVING SHORELINES

ABOUT LIVING SHORELINES

Coastal shores are dynamic ecosystems that are constantly evolving. Wind, waves, and natural forces continuously transform shorelines as they respond to their environmental conditions. It is these very processes that protect the coastline from impacts of flooding and storms. However, the armouring of Stanley Park's coastline directly hinders these natural processes. The negative impacts along with the financial costs of armoured shorelines have led to many coastal cities and towns across North America and around the globe to implement living shoreline strategies. Not dissimilar to Vancouver, these places are faced with increasing sea levels and more extreme storms that have led to the reduction of intertidal biodiversity, increased flooding, and damage to infrastructure. Living shorelines are a nature-based solution that protect eroding coastlines whilst supporting intertidal ecosystems. This alternative to hardened infrastructure incorporates plants, sands, and other natural materials to restore coastal systems and enhance habitat diversity while stabilizing the coastline (NOAA, 2015). With a living shoreline approach the terrestrial and marine environments are reconnected supporting a healthy functioning ecosystem and natural coastal processes.

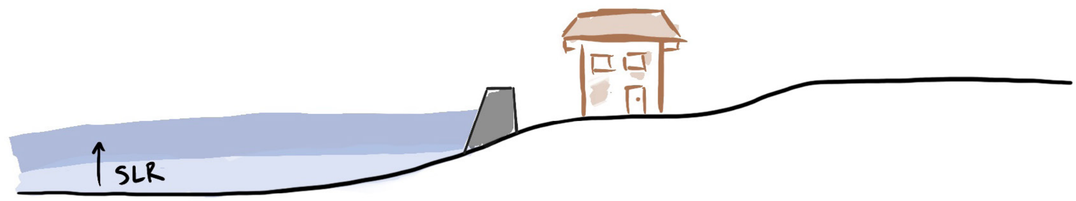
The most appropriate shoreline technique employed is dependent on site-specific conditions including, but not limited to, wave energy, tidal changes, intertidal substrate, and sea level rise (SCBC, 2003). Softer techniques, such as vegetation, sills, driftwood, and beach nourishment are more suitable for areas with small waves, gentle slopes, and sheltered coasts (SAGE, 2015). Whereas harder techniques, such as breakwaters, groins, and seawalls are more typical for areas characterized by large waves, steep slopes, and open coastal areas (Figure 15). Stanley Park's foreshore has a variety coastal conditions, from rocky shores with crashing waves to calm waters with muddy substrates. This diversity allows for a range of living shoreline designs. There are three common approaches to living shorelines: protect, accommodate, and retreat (Figure 16).

Figure 14: Salt marsh - soft living shoreline approach, photograph by Robert Isdell, (2021).

Figure 15: Rock groin - hard shoreline approach, photograph by Bob Bowie, (2019).

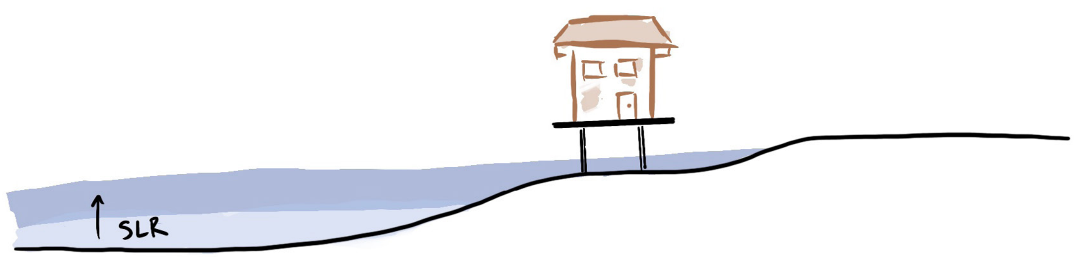
Protect

The placement of infrastructure to protect assets from coastal flooding and erosion. This technique ensures existing assets remain in place by employing hard shoreline strategies, such as seawalls, groins, revetments, and levees in between the development and the sea.



Accommodate

Existing infrastructure and future designs adapt to sea level rise and flooding. Strategies include: raised infrastructure, projects that withstand temporary inundation, and floating structures.



Retreat

The relocation of existing developments and assets out of areas at risk of flooding and sea level rise. The establishment of coastal setbacks for future developments. At risk areas are then naturalized.

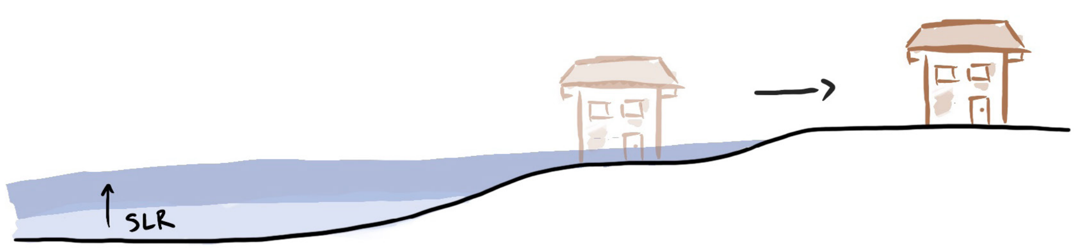


Figure 16: Living shoreline approaches: protect, accommodate, and retreat.

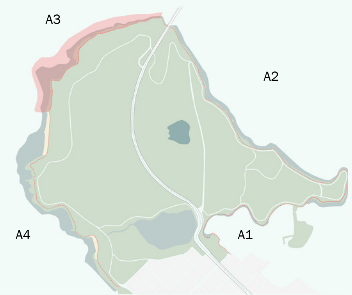
Promenade Aldilonda

Location: Bastia, Corsica, France

Setting: Mediterranean, exposed rocky cliffs

Program: recreation, flood protection **Design Elements:** elevated pathway

Opportunities in Stanley Park: A3 **Approach:** accommodate



Designed by Dietmar Feichtinger Architectes and Buzzo Spinelli Architecture, the promenade Aldilonda is a 450m long pedestrian and cyclist walkway that wraps around the rocky coastline at the base of the Citadelle in Bastia. Nestled into the rock, the promenade sits 5 meters above sea level, bringing visitors over the Mediterranean and providing a rare sense of immersion between the cliffs and the sea (Dietmar Feichtinger Architectes, 2021). The softly curved pathway contrasts the sharp cliffs, yet the construction seamlessly blends into the landscape. The reddish hue of the Corten steel railings mirror the natural colouring of the iron-rich rock and the Citadelle's architecture (Novakovic, 2021). The structure is designed to withstand wave exposure and flooding. The Corten steel railings are spaced at 110mm apart and perforated metal grates are placed around the cliff wall, allowing water to naturally flow through the structure during periods of flooding (Dietmar Feichtinger Architectes, 2021). These design elements reduce the force of the water onto the structure and soften the reflection of the waves back onto the ocean floor.

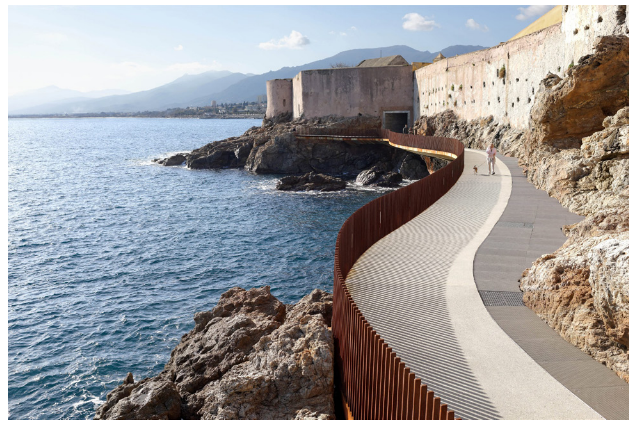


Figure 17 (top) & 18 (bottom): Pathway nestled into rock face, photograph by David Boureau, (2021).

Carrs Bush Park

Location: Sydney, Australia **Setting:** estuary, bay

Program: flood protection, recreation

Design Elements: rock pools, salt marsh, rocky intertidal habitat, mudflat

Opportunities in Stanley Park: A1, A2, A3 **Approach:** protect

Carss Bush Park is located within the Georges River estuary in New South Wales, Australia. The project encourages park visitors to reconnect with the shoreline through immersive and recreational spaces. Similar to Vancouver, the park's seawall has experienced impacts from King Tides and storm surges leading to erosion and structural failures (Heath, 2017). This project applies an engineering-based approach to foreshore design, with the goal of creating a shoreline that supports coastal ecosystems whilst maintaining the structural integrity of the coastline. The combination of technical approaches with natural processes has allowed for novel ideas for shoreline design. A number of techniques were applied along the park, including rock pools, salt marsh benches, and mudflats. The different approaches has allowed for diverse intertidal habitat, supporting an abundance of species and ecological communities. Rather than removing seawall infrastructure, sections of the park incorporate the seawall into the design. Constructed rock pools are built into the seawall, supporting the structural integrity of the wall itself and the wall's capacity to weather storms. The artificial rock pools mimic natural features to retain water during low tide, and provide habitat for aquatic species (Figure 19). In addition, the constructed salt marsh bench was designed with the use of the seawall. The seawall infrastructure acts as a tidal barrier enabling salt marsh establishment and growth (Figure 20). This park demonstrates the capacity of ecoengineering approaches to protect landward assets whilst supporting biological diversity and restoring ecosystem services.

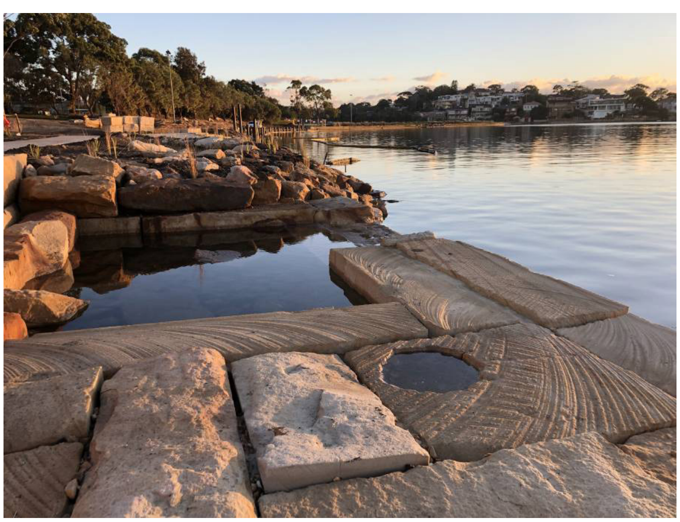


Figure 19: Constructed rock pools, The Leader, (n.d.).

Figure 20: Constructed salt marsh, NSW Department of primary Industries (2017).

Yanweizhou Park

Location: Jinhua, China **Setting:** riparian wetland

Program: recreation, habitat restoration, flood protection

Design Elements: terraced vegetated embankment

Opportunities in Stanley Park: A1, A2, A3, A4 **Approach:** accommodate

Located at the mouth of 3 rivers, Yanweizhou Park is a 26-hectare wetland park designed by Turenscape. Situated in Jinhua, an area prone to annual flooding due to its monsoon climate, the park was previously surrounded by a concrete flood wall that exacerbated annual flooding and destroyed the dynamic wetland ecosystem (Landezine, 2015). Turenscape's design aimed to remove the ecologically destructive wall whilst still providing flood protection. The flood wall is replaced with a terraced, vegetated embankment that absorbs and slows down floodwater (Hobson, 2015). Rather than working against natural flooding, the design uses the nutrients from the floodwater to support the growth of vegetation, lending to a landscape that requires no fertilization or irrigation. The terrace additionally filters stormwater from the pavement before entering the river (Figure 21). A 5-metre-wide bridge crosses over the two rivers, connecting the southern and northern city districts and linking the city with the park (Landezine, 2015). The bridge is elevated above the 200-year flood level allowing year-round pedestrian access, whilst other sections of the park are temporarily submerged. A network of pathways and boardwalks connect visitors with riparian vegetation (Figure 23).

Figure 21 (top): Vegetated terrace, Turenscape, (2015). Figure 22 (middle): Flood-adapted, elevated boardwalk, Turenscape, (2015). Figure 23 (bottom): Aerial view of park during dry season, Turenscape, (2015).

Tied Deck at Pier26

Location: Hudson River, New York City **Setting:** post-industrial, waterfront

Program: recreation, education, habitat restoration, flood protection

Design Elements: salt marsh, tide pools

Opportunities in Stanley Park: A1, A2 **Approach:** protect, accommodate

The Tide Deck is located on the edge of Pier 26 and sits 800 feet out into the water over the Hudson River in New York City. The project is composed of an engineered rocky salt marsh and is intended to connect visitors with the rich ecology of the Hudson River Estuary and support marine biodiversity.

Walkways split the deck into two different levels. The first walkway is in line with the original pier's edge and sits above the water, providing people with views of the Hudson River and the city's skyline (Olin, 2020). The second deck sits below, hovering over a manmade salt marsh, planted with native shrubs and grasses, and is surrounded by granite boulders (Brandon, 2020). The native marsh plantings, including smooth cordgrass, are used to stabilize soil and control coastal erosion (Hudson River Park, n.d.). The rocky boulders along the edge of the salt marsh are designed to break incoming waves and boat wakes (Brandon, 2020). Shallow holes are dug into the boulders, creating tidal pools for marine organisms, helping to support biological diversity (Figure 24).

An important element of this project is its educational objectives. The design of the project engages with tidal changes, where the landscape transforms along with the tide levels. During low tide, the salt marsh and boulders are exposed, and tour groups and classes can access the bottom walkway (Brandon, 2020). During high tide, the salt marsh is submerged, and visitors can only observe the tops of the tallest boulders from the upper walkway (Figure 25). Visitors see the impacts of the changing tides throughout the day, educating the public on the dynamic coastal processes of the Hudson River Estuary.

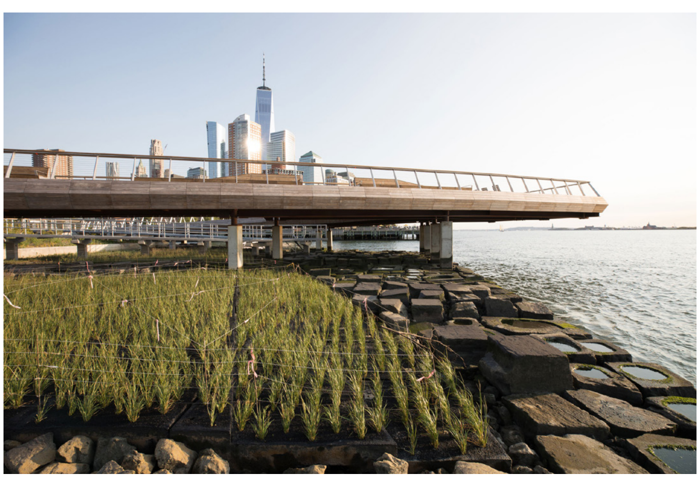


Figure 24: Tide deck during low tide, Hudson River PK, (n.d.).

Figure 25: Tide deck during high tide, Hudson River PK, (n.d.).

Hunter's Point South Park

Location: New York, USA **Setting:** estuary, bay

Program: flood protection, habitat restoration, education, recreation

Design Elements: salt marsh **Opportunities in Stanley Park:** A1, A2

Approach: protect, accommodate

Hunter's Point South Park transforms 11 acres of abandoned industrial land into a vibrant and multifunctional urban waterfront that supports climate resiliency and urban recreation. The park engages with anticipated sea level rise and increases in flooding events by constructing a salt marsh lined with rip-rap along the park's edge. The marsh provides multiple benefits, serving as a flood buffer, preventing shoreline erosion, and supporting native species of flora and fauna (Hunters Point Parks, 2020). To prevent scenarios of wave overtopping from storm events, the project is designed to allow storm surges to enter into the park. During periods of increased water levels, stormwater is gently absorbed and released by the tidal marsh (Sinopoli, 2019). This inundation of the marsh is also observed by visitors during high tide and can be seen exposed during low tide (Figure 26 & 27). The transformation of the space in symbiosis with tidal fluctuations provides different and unique experiences for park visitors. Rip-rap composed of large and angular stones line the park (Figure 28). The rip-rap protects the park from erosion, deflects impacts from storm waves, and prevents sediment from settling, enabling the shoreline to remain clean and clear. Beyond the coastal protection measures, the park incorporates a 9-metre-high viewing platform that cantilevers over the tidal marsh, providing views of Manhattan and the river. Bike paths and walkways wind through the grassland, with benches dotted throughout the park.

Figure 26: Marsh during low tide, Hunter's Point Parks, (n.d.).

Figure 27: Marsh during high tide, photography by Weiss Manfredi, (n.d.).

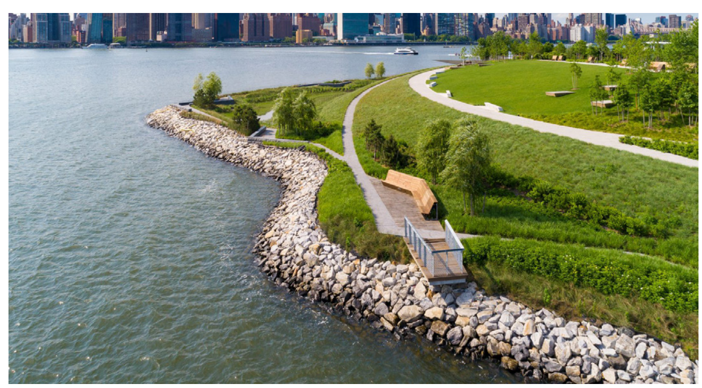


Figure 28: Rip-rap along park's edge, photograph by Bill Tatham, (2018).

Olympic Sculpture Park

Location: Seattle, USA **Setting:** post-industrial, waterfront

Program: recreation, habitat restoration, flood protection

Design Elements: habitat bench, pocket park

Opportunities in Stanley Park: A2, A4 **Approach:** protect, accommodate

Olympic Sculpture Park is a 9-acre transformation of a contaminated, post-industrial waterfront. The project involved the restoration of the shoreline to support salmon habitat and connect visitors to the waterfront. Existing rip-rap that armoured the shoreline was replaced by a pocket beach populated with native dunegrass and riparian vegetation. The beach works to support public recreation while stabilizing the shoreline. Additionally, a habitat bench was placed in the shallow subtidal zone. The bench is made of angular well-packed sediment making it invulnerable to movement (Toft *et al.*, 2013). The structure builds a more gradual slope along the ocean floor creating a shallow water environment for juvenile salmon and other aquatic species (LAF, n.d.). Studies following the construction of the pocket beach and habitat bench saw an increase in nearshore fishes and invertebrates (Toft *et al*., 2013). Olympic Sculpture Park highlights landscape design that allows for both people and aquatic species to thrive, where an estimated 400,000 people have visited the park per year with at least a third of visitors accessing the pocket beach.

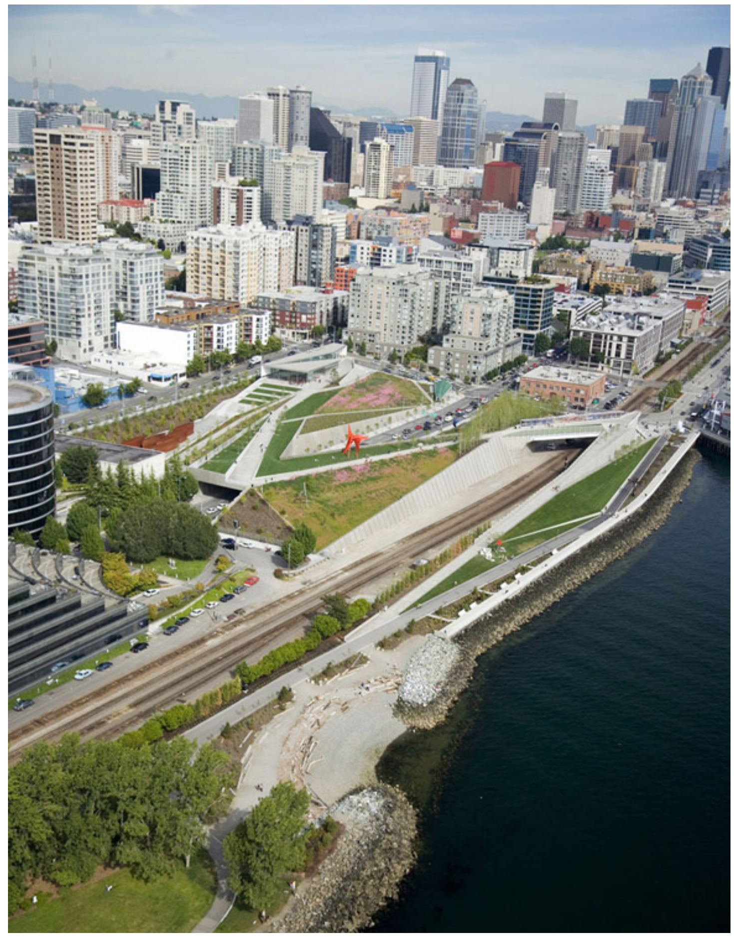


Figure 30: Aerial view of park, photograph by Andrew Buchanan (2011).

Figure 29: Pocket beach, photograph by Lydia Heard (2011).

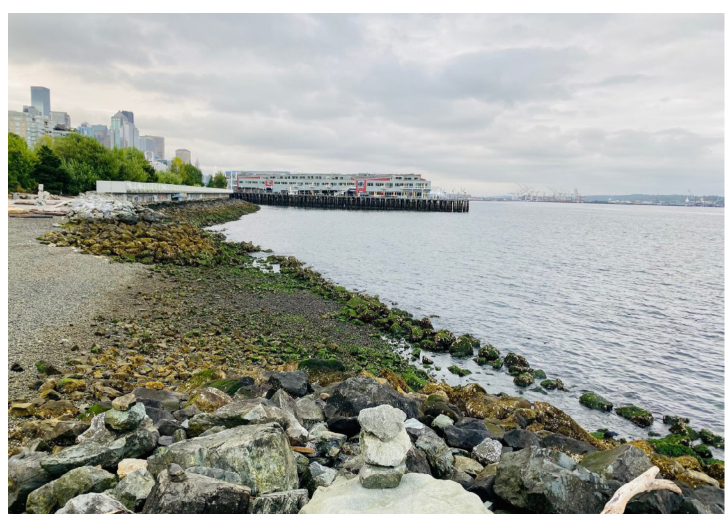


Figure 31: Habitat bench, photograph by Joe Finn (2021).

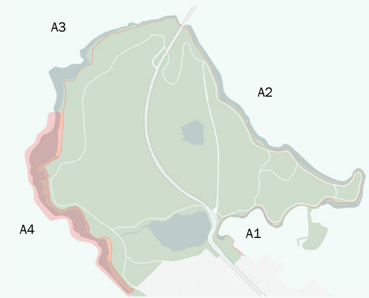
Surfers' Point Managed Shoreline Retreat Project

Location: Ventura, California **Setting:** open coast, river mouth delta

Program: recreation, flood protection, habitat restoration

Design Elements: vegetated dunes, cobble berm, backshore infrastructure

Opportunities in Stanley Park: A4 **Approach:** retreat



Surfers' Point is a managed retreat and restoration project. In 1989, a bike path, roadway, and parking lot were installed in the backshore to create greater public accessibility to the shoreline (Judge *et al.*, 2018). The infrastructure was eroded shortly after in 1992, causing the collapse of portions of the bike path and parking. Rather than build a seawall, the City of Ventura decided to move the parking, bike path, and roadway landward. The realignment of public infrastructure allowed for the natural migration of the shore towards the land, supporting intertidal ecosystems and natural ecological processes. By shifting the bike path, roadway, and parking away from the shoreline, the beach was widened enabling additional space in the backshore for natural vegetated dunes (Figure 32). The dunes allowed for the dissipation of waves, contrary to a seawall construction, and helped mitigate impacts of storm surges and flooding. The project has withstood El Niño storms, both accommodating and preventing erosion, indicating the success of the living shoreline application. This project achieves both ecological and recreational objectives by maintaining beach access for cyclists and pedestrians whilst enhancing the shoreline and its resilience to adverse weather events.

Figure 32: Vegetated dunes, ESA (n.d.).

Shinnecock Indian Reservation Coastal Habitat Restoration

Location: Shinnecock Reservation, Southampton NY

Setting: Eroding beach, archaeological significance

Design Elements: Eelgrass restoration, salt marsh, upland restoration

Program: flood protection, habitat restoration

Opportunities in SP: A1, A2, A4 **Approach:** protect

The Shinnecock Restoration project looks to restore ecological diversity and strengthen the natural resilience of the shoreline. Located along the eastern shore of Shinnecock Bay in Southampton, New York, the shoreline was hit hard by Superstorm Sandy which led to the loss of fish and wildlife habitat and the degradation of the shoreline (Varanasi, 2019). Beyond impacts from storm events, the shoreline has been shrinking with rising tide levels which have toppled trees 20 to 30 feet from the shore (Diaz, 2019). Next to the beach lie ancestral burial grounds, and with increasing sea level rise and storm surges, residents began to fear the tides would swallow a critical part of Shinnecock identity. In response, this living shoreline approach aimed to protect the coastline, rather than retreat. The project combats future sea level rise and storms through wave attenuation and sediment trapping. A series of efforts to revitalize the coastline were employed, including beach nourishment and restoration, constructed oyster reefs, eelgrass meadow restoration, salt marsh plantings, restoration of the upland habitat, and the restoration of tidal flows (CCE, 2017). Boulders are placed to break wave action, and grasses sit behind to retain soil and sand from being pulled back out to sea. A key role of this project was to offer a short-term solution, buying time for larger, more comprehensive planning efforts such as managed retreat and relocation (Diaz, 2019). This project outlines the urgency of the living shoreline projects to protect the coastline from immediate impacts of storms and sea level rise.

Figure 33: Cordgrass plantings to prevent beach erosion, photograph by Anuradha Varanasi, (2019).

Figure 34: An aerial view of the oyster reefs during low-tide, photograph by Matthew Ballard (n.d.).

Maplewood Marine Restoration Project

Location: Maplewood Basin, North Vancouver

Setting: post-industrial, waterfront

Program: restoration, culture, habitat enhancement

Design Elements: subtidal rock reef, eelgrass, & intertidal flat habitat

Opportunities in Stanley Park: A1, A2 **Approach:** retreat

In the 1800s, the Maplewood Basin was once composed of intertidal flats that provided rich habitat for waterfowl, fish, and shellfish. In the 20th century, however, European colonization transformed the marine tidal flat to support the logging industry, dredging the intertidal and upland areas for log sorting and storage operations (Kirk & Co. Consulting Ltd, 2018). Currently, the site sits within a deep basin (up to nine metres deep) due to its dredging. The site was chosen due to its poor habitat quality and based on input from Indigenous groups. Maplewood Basin was additionally identified as a restoration priority by the Tsleil-Waututh Nation.

The Vancouver Fraser Port Authority delivered the project through its Habitat Enhancement Program, with the intentions of maintaining a balance between a functioning environment and future development for port operations. The objectives of the restoration project were to enhance 7 acres of low-value marine habitat by creating three habitats: a subtidal rock reef, eelgrass beds, and an intertidal flat. In order to re-create these habitats, the design raises the elevation of the sea floor to support intertidal flat and shallow subtidal eelgrass. Around 125,000 eelgrass shoots were planted creating a 1.5-hectare eelgrass bed. The planning and implementation of the eelgrass transplant was done in tandem with the Port Authority and Indigenous groups, with the goal of increasing the understanding of future restoration opportunities. The overall enhancement of the basin is anticipated to benefit fish, invertebrates, and wildlife, including salmon, Dungeness crab, waterfowl, and wading birds. This project was developed with the involvement of Indigenous groups and centered on acknowledging the cultural importance and value of the Maplewood Basin to Indigenous peoples.

Figure 35 (top): Dungeness crab, unknown (n.d.). Figure 36 (bottom): Aerial view of Maplewood Marine Restoration Project, Port of Vancouver (n.d.).

VALUE CRITERIA

DEFINING VALUE CRITERIA

Stanley Park's coastline holds multiple recreational, cultural, social, and ecological benefits. The multi-faceted role of the park in supporting different needs and stakeholders indicates the importance of critically examining and integrating these different priorities when developing design opportunities for the park. The goals and intentions for the design proposals in this report are informed by the *Coastal Adaptation Plan* and the *Stanley Park Comprehensive Plan*.

The Coastal Adaptation Plan

The *Coastal Adaptation Plan* is a participatory, structured, values-based planning effort to address sea level rise and identify coastal adaptation options that consider the priorities of the community (City of Vancouver, 2018). Two areas in Vancouver – the Fraser River Foreshore and False Creek – served to identify the community values that can help inform future coastal planning work. The value-based criteria were first developed through public engagement as part of the Fraser River Foreshore project in 2018. This process engaged almost 1,400 residents, business owners, and other stakeholders through which seven community values were identified. The Fraser River Foreshore consultation process went on to inform the Coastal Adaptation Plan in False Creek, whereby participants confirmed the applicability of the same seven community values. The commonality of the seven values across shoreline projects in Vancouver indicate the potential for these themes to be applied to design implementations along Stanley Park's shoreline. Of the seven values, six were included in this report. The definitions and applicability of the values are further discussed in Appendix I.

The Stanley Park Comprehensive Plan

The Vancouver Park Board and the Musqueam, Squamish, and Tsleil-Waututh (MST) First Nations are currently developing the *Stanley Park Comprehensive Plan* that outlines a 100-year vision for the park that brings together park design, programming, and management (VPB, 2018). The plan will provide a united and holistic vision of Stanley Park and will be a result of the collaboration between the Park Board, the Nations, and the community. While the plan is still in progress, this report is operating under the knowledge that the three Nations will play an integral role in any ongoing and future developments in Stanley Park. The MST hold significant wisdom and knowledge having stewarded and protected the park's shoreline since time immemorial. This Sustainability Scholar report was not completed in consultation with the MST and recognizes the need to develop design strategies in tandem with the Nations. The intent of this report is not to provide a solution to the existing seawall, but rather to begin to re-think what the Stanley Park seawall could be. Given that design proposals were not developed alongside the Nations, Indigenous approaches to living shorelines were not fully explored, however, opportunities for telling the unwritten narratives and history of the park through education were a key consideration in the design process.

DESIGN PROPOSALS

SITE SELECTION

The sections along the park's shoreline that were selected to be further explored and developed for a design proposal were shaped by the initial findings on the conditions of the park's foreshore, the knowledge gained from living shoreline case studies, and value criteria informed by the *Coastal Adaptation Plan* and the *Stanley Park Comprehensive Plan*.

After balancing all four of these parameters, the following areas were chosen due to their feasibility and potential to showcase a coastal pathway that protects the shoreline, increases intertidal biodiversity, and provides opportunities to meaningfully engage visitors with the park's marine environment. Below are additional key issues that were considered when choosing the sites:

+ Sections with major existing problems (seawall damage, erosion).

+ Environmentally degraded sections, in need of greater intertidal habitat .

+ Potential for education on marine environments.

+ Potential to support knowledge building of Indigenous culture and history.

+ Opportunity to showcase different living shoreline approaches.

Three sites were chosen based on the parameters above: X̱wáýx̱way, Third Beach, and the rocky intertidal areas between Third Beach and Prospect Point.

KEY PROJECT GOALS

The following are project goals that span across each site.

+ Protection from storm events and sea level rise.

+ Increase intertidal habitat.

+ Engage park users with intertidal and marine ecosystems.

X̲WÁÝX̲WAY

SITE BACKGROUND

X̲wáýx̲way is located at present day Lumberman's Arch and was the largest Indigenous settlement in the Lower Mainland. The site is located on the eastern side of the park and is sheltered from the open ocean. This region experiences less impacts from storm waves allowing for a sandy/muddy intertidal substrate. X̲wáýx̲way was once a mudflat and was rich with clams, mussels, and cockles harvested by Indigenous communities. Much of the bivalves that once littered the beach are gone with construction of the seawall. Currently, a splash park is located at the site providing recreational play for children.

SITE SELECTION

+ Restoring bivalve habitat, an important cultural resource for Indigenous Peoples.
+ Current park design fails to reflect the historical and cultural relevance of the site to the Musqueam, Squamish and Tsleil-Waututh First Nations, prompting a need to create a more informative and educational space.
+ Important area for salmon migration and shallow water fish species.

KEY SITE CONDITIONS

+ Muddy, sandy substrate
+ Low wave energy
+ Important cultural significance to MST
+ Existing splash park, recreational play

SPECIES

+ Clams, mussels, aquatic worms
+ Salmon
+ Bull kelp

KEY CONSIDERATIONS

+ Restore previous intertidal conditions to support bivalves (clams, mussels, and cockles).
+ Support education of Indigenous culture and history.
+ Support migrating salmon and fish species.

Figure 37: Existing site

POTENTIAL DESIGN APPROACHES

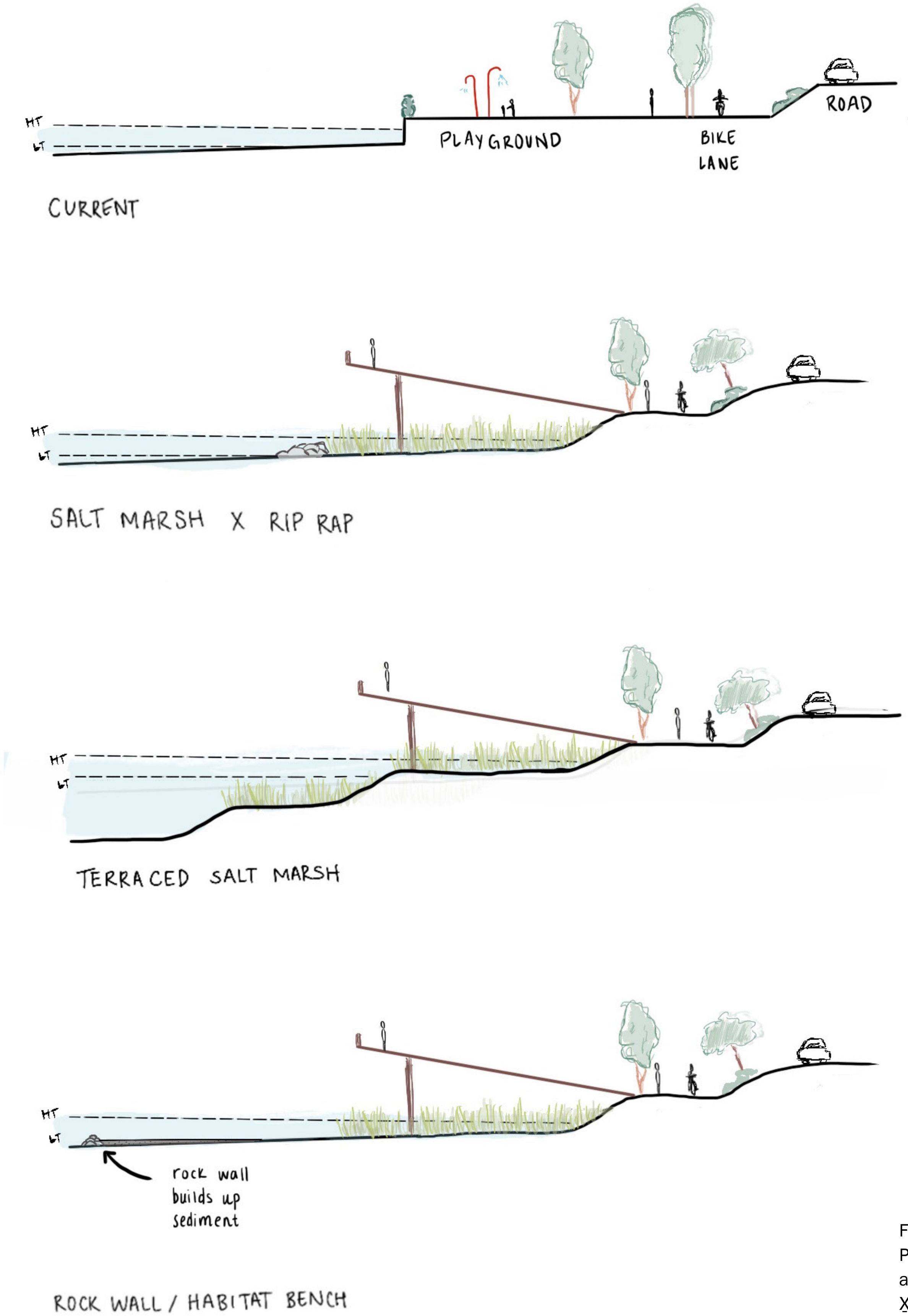


Figure 38: Potential design approaches to X̱wáýx̱way

DESIGN PROPOSAL

Figure 39: Proposed site plan

DESIGN OPPORTUNITIES

+ Drawing from traditional Coast Salish clam gardens, an engineered rock wall reduces wave energy and traps sediment, creating a more gradual seabed profile that provides habitat for intertidal bivalve species that once populated the site's shores. The rock wall also creates a suitable environment for salmon and shallow water fish species.

+ The salt marsh absorbs wave energy and traps sediment stabilizing the shoreline. Salt marshes also sequester carbon and provide nursery habitat and refuge for juvenile salmon.

+ At high tide, the path through the salt marsh is submerged while the elevated walkway provides an accessible coastal pathway year-round. The paths are influenced by tide levels and engages visitors with the dynamic processes of coastal systems and the intertidal zone.

+ Netted playground elements allow park users to look below at the intertidal zone, observing species and bivalves, educating users on culturally important resources for Indigenous communities. Potential to pair this with informative signage to pass on knowledge of the significance of this site for the MST Nations.

+ The bike path is elevated and located on a berm providing protection during high tide.

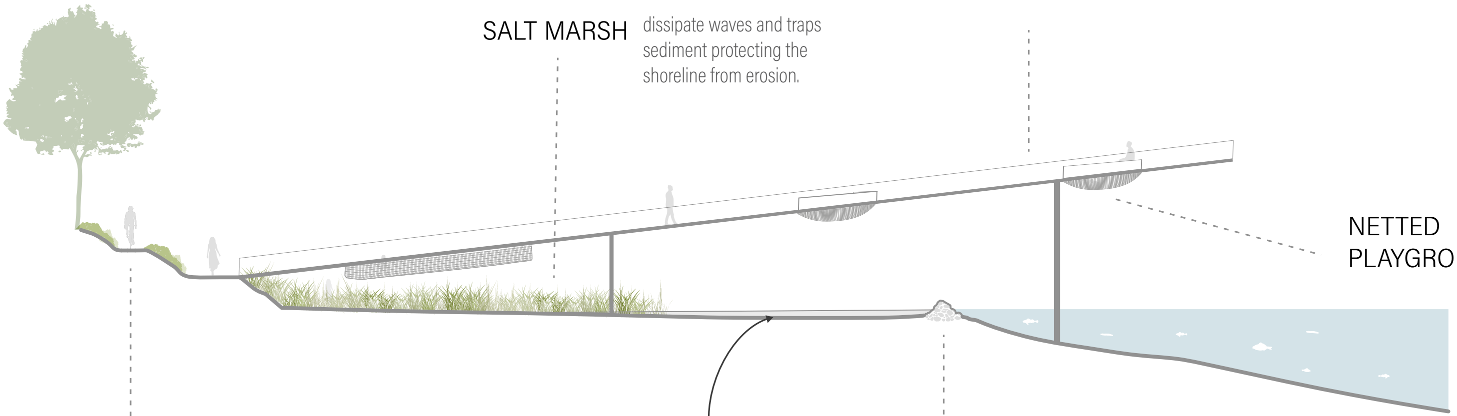


Figure 40: Proposed section

Rock Wall

+ Informed by clam gardens, a traditional Indigenous mariculture technique.

+ Traps sand on landward side that flattens the seabed, creating shallow water habitat suitable for salmon and larvae.

+ Creates habitat that supports the accumulation of bivalves.

+ Dissipates oncoming waves.

Figure 41: Netted playground supports educational play

Figure 42: Site during high tide

Figure 43: Site during low tide

THIRD BEACH

SITE BACKGROUND

Third Beach is a popular recreation spot for park visitors. The beach is located on the western side of the park receiving the full force of westerly waves. Storm surges and wave induced erosion have contributed to the gradual recession of the beach. In 1966, Third Beach was nourished with sand but by 1988, the beach had receded by 30m (SPES, 2010). Rock headlands are positioned at each end of the beach helping to contain sand along the foreshore by preventing the northward transport of sediment. A sandstone reef juts into the ocean in the center of the beach. The reef is a popular resting spot for waterbirds, as well as park visitors during low tide.

Site Selection

+ The beach is an important recreation spot for park visitors. With the beach's gradual recession, it is observed to be a valuable park asset to preserve.

+ Third Beach has little intertidal biodiversity and is in need of infrastructure to increase intertidal habitat.

KEY SITE CONDITIONS

+ Sandy substrate
+ Strong westerly waves
+ Steep sandstone cliffs
+ Recreational beach

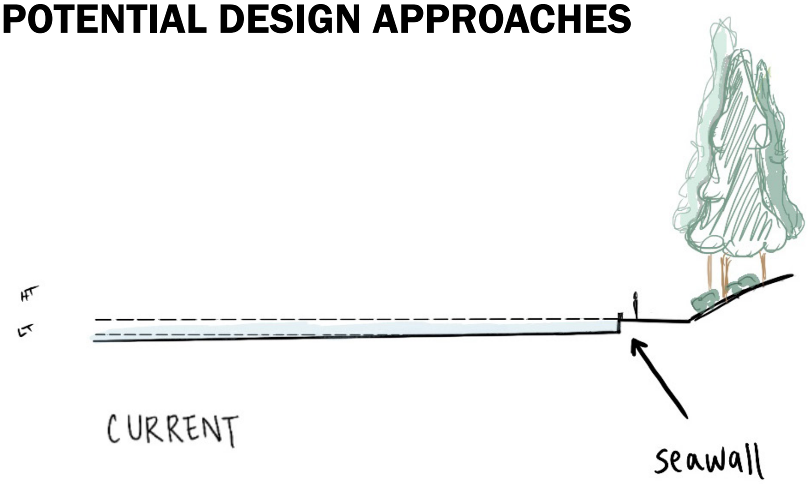
SPECIES

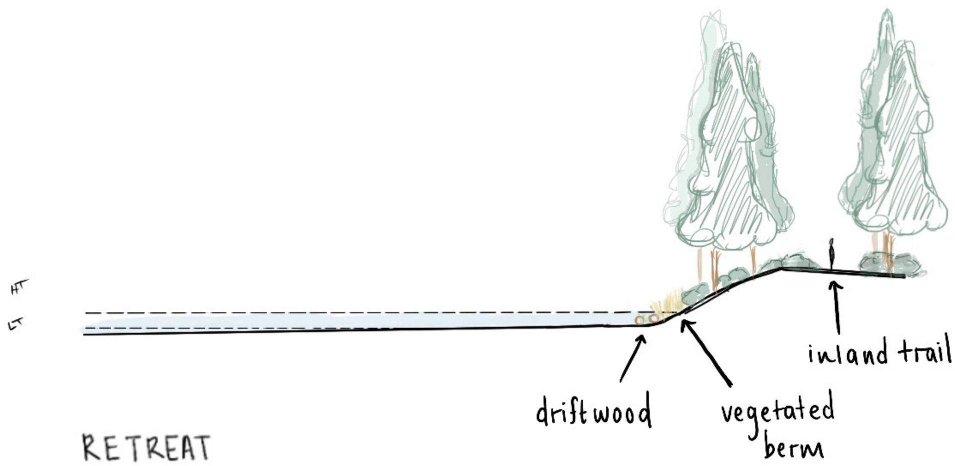
+ Surf smelt and sand lance spawning
+ Dungeness crab
+ Barrow's goldeneye
+ Clam and cockle species

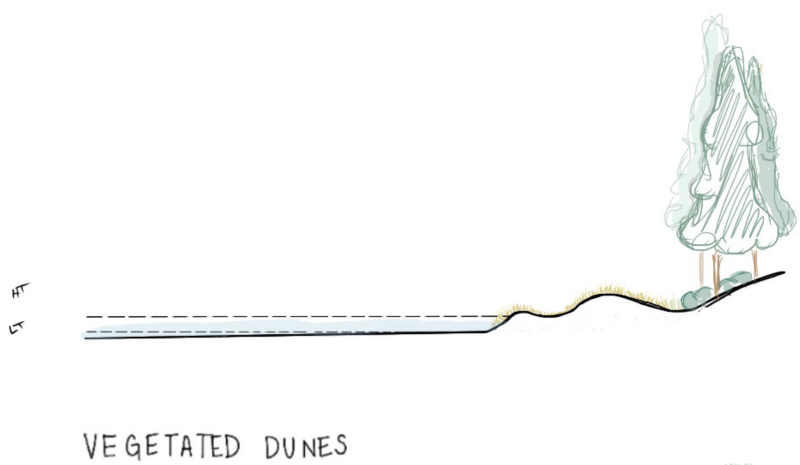
KEY CONSIDERATIONS

+ Prevent beach erosion
+ Wave attenuation
+ Increase intertidal habitat
+ Support recreational opportunities
+ Support knowledge building of Indigenous culture and history

POTENTIAL DESIGN APPROACHES







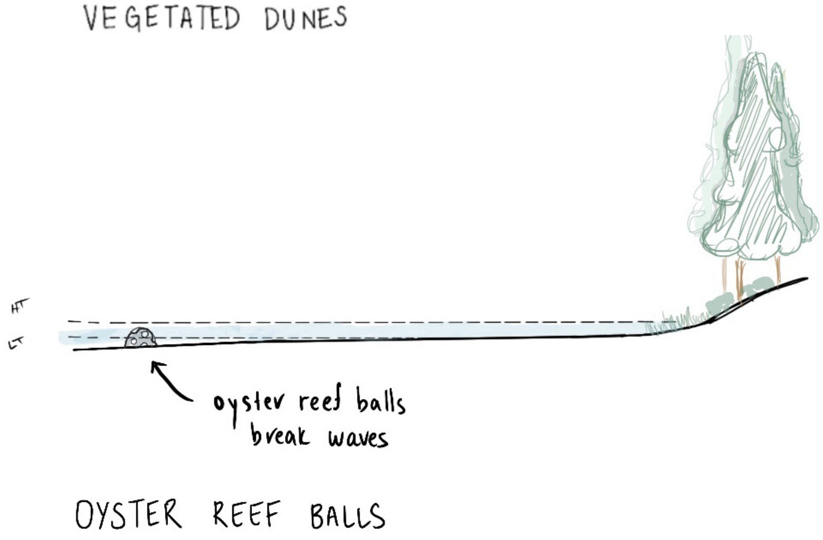


Figure 44: Design approaches to Third Beach

DESIGN PROPOSAL

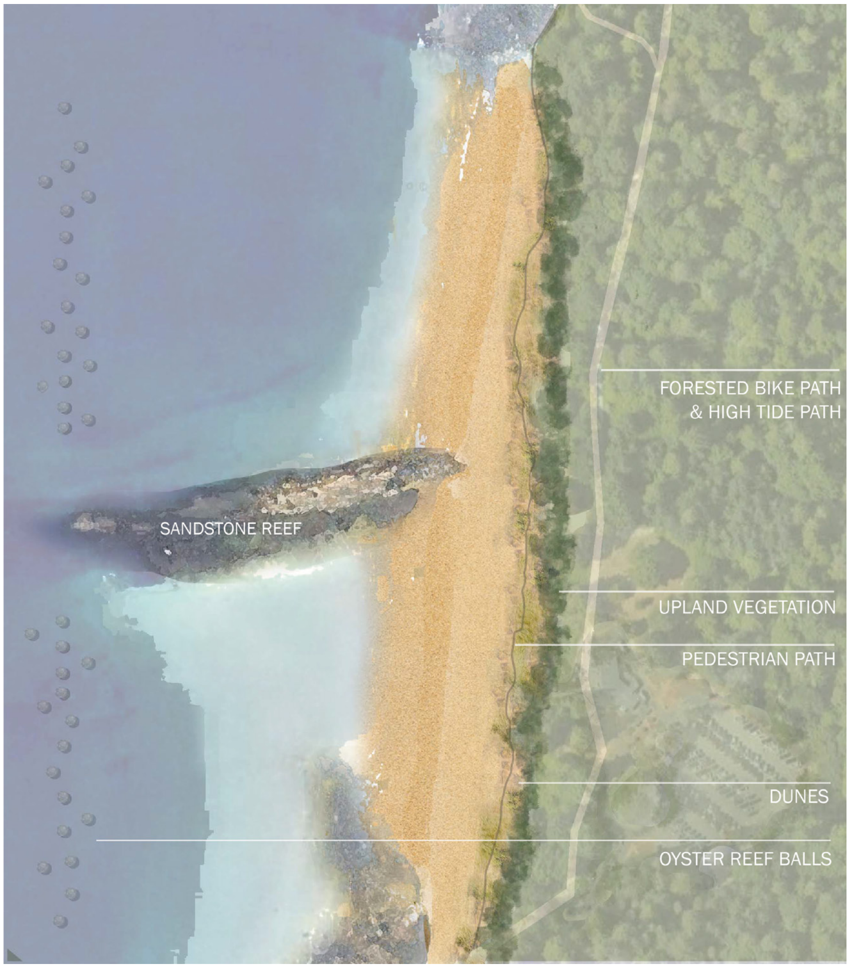
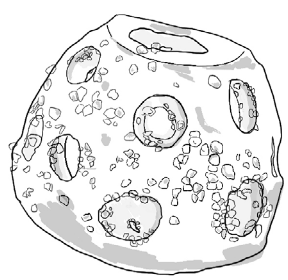


Figure 45: Proposed site plan



+ Dissipates oncoming wave energy

+ Supports fish ad shellfish populations, colonization of oysters

+ Supports the growth of marine plants (algae and seaweed)

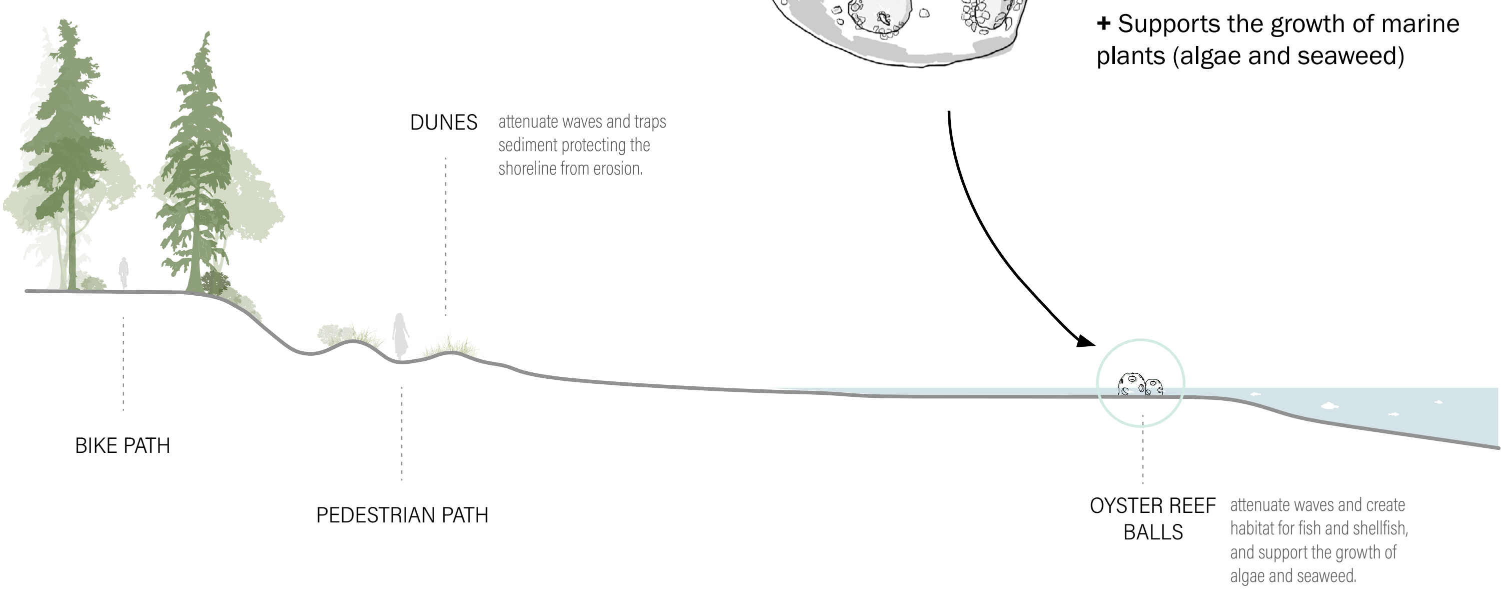


Figure 46: Proposed section

Figure 47: Existing

Figure 48: Proposed

DESIGN OPPORTUNITIES

+ Dunes replace the seawall providing a natural barrier to waves. Native dunegrasses and plants stabilize and retain sand reducing the erosion and recession of the beach.

+ A forested path upland is widened for year round cyclist use and high tide pedestrian use.

+ Oyster reef balls located in the subtidal zone reduce wave energy, support oyster habitat, and the growth of marine plants including algae that support primary production.

+ Opportunity to include educational signage on the importance of the shoreline along Third Beach to MST Nations for harvesting marine resources.

THIRD BEACH TO PROSPECT POINT

SITE BACKGROUND

The section between Third Beach and Prospect Point is characterized by strong wind and waves resulting in an intertidal zone composed of large boulders and a rocky intertidal substrate. Due to wind and wave exposure, this portion of the wall has suffered the most damage during storm events which has led to closures of the seawall for reparations. Located on the landward side are steep sandstone cliffs that are easily eroded with wave impact and stormwater runoff. The proximity between the water and cliffs limit the seawall to a very narrow path that wraps around the perimeter of the cliff. Boulders along this section are covered in barnacles and Pacific blue mussels. The area is frequented by waterbirds, including Great Blue Herons.

SITE SELECTION

+ This site is frequently impacted by extreme storm events causing damage to the seawall.
+ Rocky intertidal areas are uncommon for living shoreline projects prompting novel approaches.
+ Important resting and foraging site for waterbirds and shorebirds.

KEY SITE CONDITIONS

+ High wave energy
+ Rocky substrate
+ Sandstone cliffs landward

SPECIES

+ Pacific blue mussels
+ Waterbirds: Barrow’s goldeneye, surf scoter, Great Blue Herons

KEY CONSIDERATIONS

+ Wave attenuation and storm protection
+ Limit damage to seawall re-design
+ Enhance rocky intertidal species

Figure 49: Existing site conditions

POTENTIAL DESIGN APPROACHES

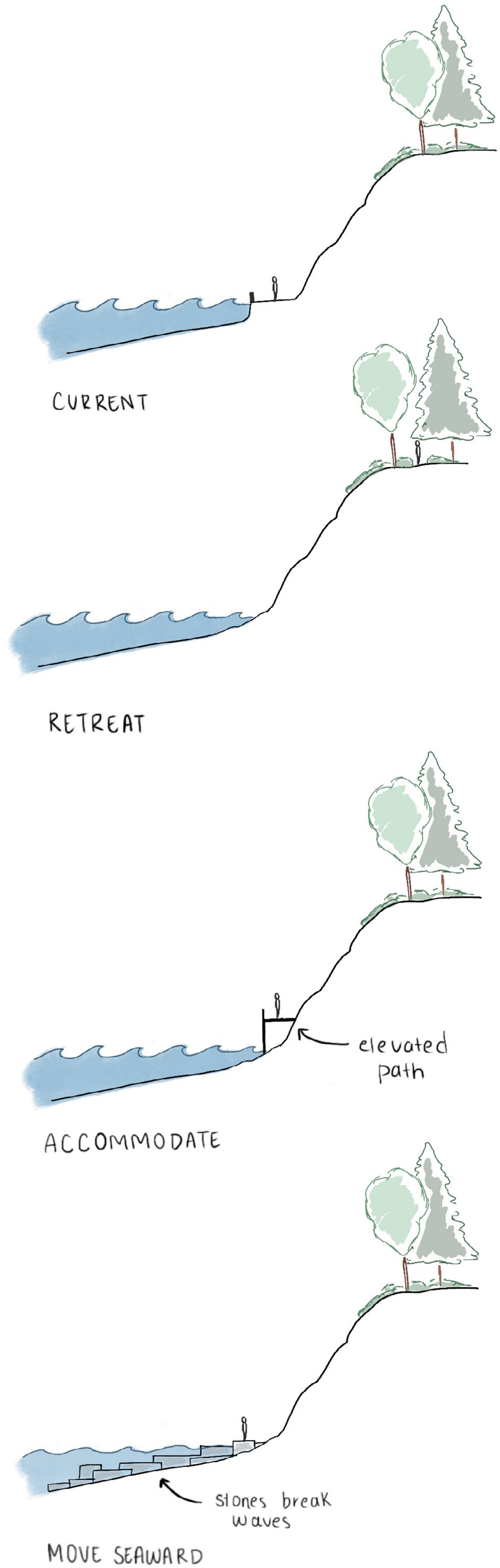


Figure 50: Potential design approaches to rocky intertidal areas between Third Beach and Prospect Point

DESIGN PROPOSAL

Figure 51: Proposed site plan

DESIGN OPPORTUNITIES

+ Sandstone blocks create a gradual seaward slope that has a greater horizontal grade than the previous vertical seawall, softening impacts from storm waves and providing coastal protection.

+ Different sized and elevated sandstone blocks create tidal pools at different water levels and create shady areas to protect intertidal species from the sun during low tide. The crevices in the sandstone blocks also retain water during low tide, providing habitat and refuge for marine species.

+ Accessible tidal pools encourage park visitors to explore marine biodiversity during low tide.

+ An elevated walkway wraps around cliffs that provides a coastal pathway year-round during extreme high tide events and an alternate path if maintenance is needed for sandstone infrastructure below.

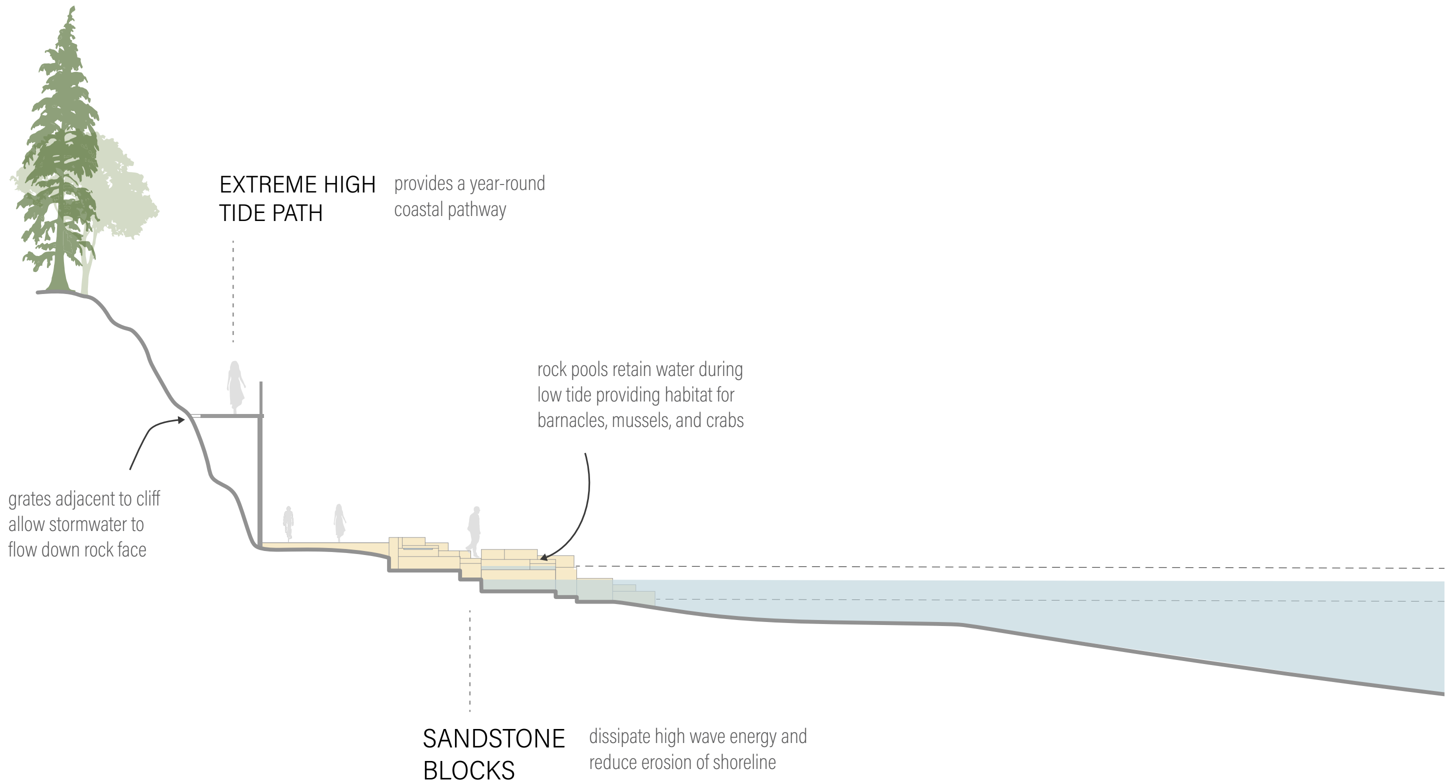
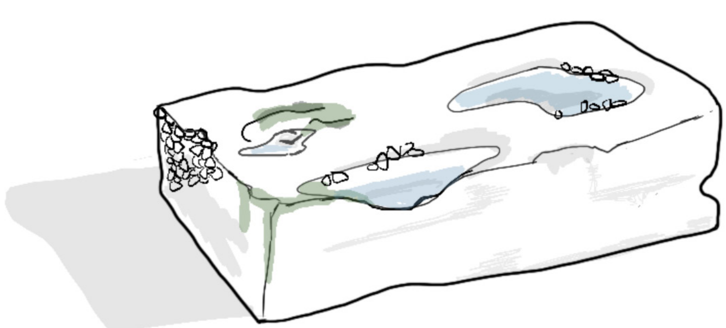


Figure 52: Proposed section

Sandstone Blocks



+ Crevices in stone blocks retain water during low tide, providing shelter and supporting the colonization of rocky intertidal species.

+ Sandstone blocks create shade for intertidal species to seek refuge from extreme heat during low tide.

+ Blocks act as an intermediary between ocean waves and sandstone cliffs, dissipating waves, stabilizing the shoreline and preventing the erosion of the cliffs.

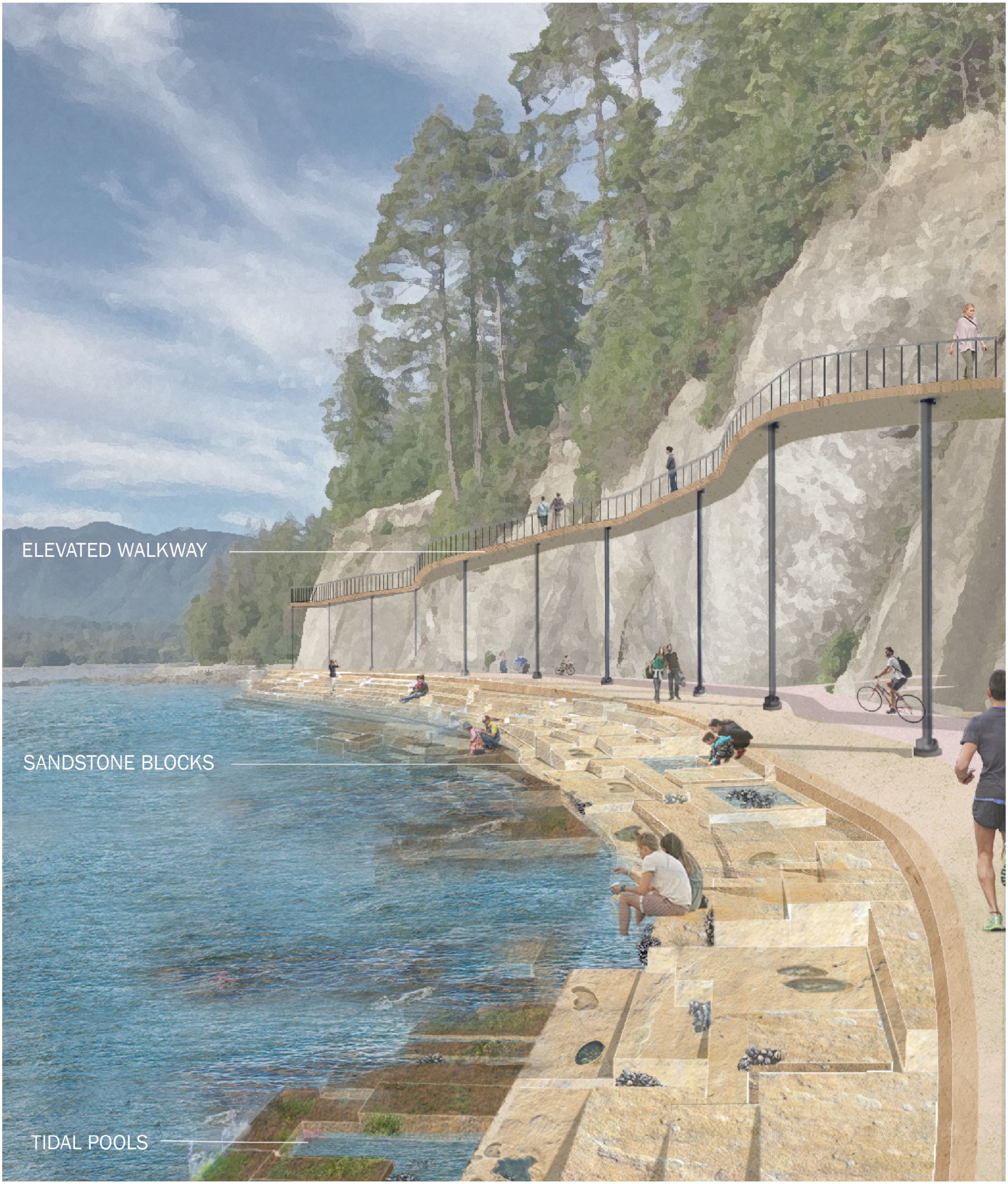


Figure 53: Concept of proposed design

CONCLUSION

NEXT STEPS

Before moving forward with a living shoreline design, studies must be undertaken on the current biophysical and environmental conditions of the park's shoreline. While this report outlines a general description of important factors to consider, there is a considerable gap in tangible baseline data on coastal processes, specifically around Stanley Park's shores. Field studies and analysis were out of the scope of this project, however collecting site-specific data, including sediment transport, wave characteristics, bathymetry, fetch, and other factors for each section of the park, is essential to determine the appropriate living shoreline approach. Alongside ecosystem services that were considered throughout the ideation process, such as biodiversity, recreation, aesthetics, flood control, and climate resilience among other factors, the social, cultural, economic, and engineering factors of a seawall re-design must be fully explored and incorporated. Any changes to the seawall will further affect a number of stakeholders. The identification of relevant stakeholders along with a meaningful engagement process will be an important next step before, during, and after the design process.

Time constraints prevented the opportunity to develop design proposals in collaboration with the Musqueam, Squamish, and Tsleil-Waututh First Nations. Any future developments of Stanley Park's shoreline should be informed by the MST. Considerations for a living shoreline coastal pathway should be included in the *Stanley Park Comprehensive Plan*.

CONCLUSION

The unique setting of Stanley Park provides an opportunity to drastically transform the park's shoreline from hard armouring to a resilient and ecologically-rich coastline. Unlike other parts along Vancouver's seawall that are centered in developed areas of the city, Stanley Park's lack of infrastructure and built form allow for a living shoreline approach that can take many forms. Recent storms and sea level rise have shed light on the long-term viability of the seawall, presenting an opportunity to make a change for a better designed coastal pathway. The design proposals in this report aim to inspire and initiate further dialogue on an alternate future for the Stanley Park seawall - one that works in synergy with coastal processes, creates habitat for biodiversity, and meaningfully engages people with the shoreline.

APPENDIX I

APPENDIX I

Coastal Adaptation Plan: Defining Value Criteria

Recreation

Recreation refers to the opportunity for outdoor physical activity and play, it encompasses both active and passive activities, including walking, running, cycling, swimming, reading, and sunbathing. Recreation is important for both physical and mental health, supporting the City of Vancouver's *Healthy City Strategy* and *VanPlay*.

Stanley Park: The seawall is a critical recreational feature along the park's shoreline for Vancouver residents and visitors. The continuous loop around the park's coastline is a major attraction of the park and an important space for recreation. The path is heavily recreated by pedestrians, cyclists, and skaters, and seating is located all along the seawall for resting and relaxation. The park holds many walking/running events including the BMO Vancouver Marathon and the 'First Half' Half Marathon. Third Beach and Second Beach are located along the park's foreshore and are important recreational spaces. An outdoor pool is located at Second Beach that offers spaces for families and more active lap swimmers. Located at the east end of the park, known as Lumberman's Arch, is a splash park. The playground is a popular spot for children visiting the seawall.

The design approach should aim to maintain and enhance recreational opportunities afforded to park visitors.

Environment

Environment refers to the ecosystems, habitats, and species occupying the site. The environment provides an abundance of ecosystem services that support human survival on the planet, from purifying the air, nutrient cycling, the provisioning of food, and regulating the climate. Healthy ecosystems also provide cultural, aesthetic, and recreational services, where access to nature is associated with improved mental and physical well-being.

Stanley Park: The upland, intertidal, and subtidal zones are filled with rich biodiversity. The range of intertidal substrate along the coastline from sandy, cobble, to rocky intertidal zones allow for a variety of species to populate the park's shoreline. The foreshore provides critical rearing habitat for all 5 species of salmon, foraging spaces for waterbirds, and spawning habitat for fish. The seawall fragments the connection between the marine and terrestrial environments, damaging the intertidal zone and obstructing natural coastal processes that support biodiversity.

The design approach must take into account the existing intertidal species along the park's shores and the negative impact of armoured shorelines on intertidal biodiversity. Efforts must be made to increase the intertidal and subtidal zones.

Health and Safety

Health and safety refer to the physical and mental well-being of park visitors. This includes direct threats to physical safety that may cause injury or death as well as impacts to social and emotional well-being. When considering mental and physical health, this pertains to the equitable access to ecologically rich landscapes and providing opportunities for physical activity and recreation.

Stanley Park: This criterion pertains to threats to direct physical safety due to flooding and storm surge events along the seawall. In the case of mental and physical well-being, the routine closures of the seawall due to post-storm maintenance impact visitor access and the subsequent recreational and therapeutic benefits of the park's shoreline.

The design approach must mitigate any impacts to direct community safety. The design should engage with the inherent value of the seawall for mental and physical well-being as well as the short-term impacts of more park closures due to flooding and long-term viability of the seawall as a means of connecting people to nature.

Culture and Heritage

Culture and Heritage refers to the historical and cultural significance of a place, society, and people. This value criterion pertains to the practices, customs, and behaviours of a society that are passed down through generations.

Stanley Park: The park's foreshore has significant cultural and heritage value. Villages and settlements were located along the park's shoreline, including X̱wáýx̱way, one the largest Indigenous settlements in the Lower Mainland situated at present day Lumberman's Arch. The park is of incredible archaeological importance, as middens lay beneath the grounds of the park composed of shells and Indigenous remains. Uplands of the foreshore were used for habitation, and the intertidal zones were heavily used for harvesting clams and mussels. Traditional practices along the shoreline such as clam gardens and fish weirs were used along the park to harvest food. These practices were critical to control water flow and naturally protect the coastline from erosion.

Acknowledgment of Indigenous history in Stanley Park is very limited in the current park design. This project was not undertaken alongside the MST therefore explicit efforts to incorporate Indigenous knowledge to climate adaptation may not be included, however an effort must be made to highlight the cultural and value of the park's shoreline for Indigenous peoples. Furthermore, design efforts should work to support the education of the public on the histories of the foreshore and the forced removal of Indigenous communities from Stanley Park.

Local and Regional Economy

This criterion pertains to the economic value and assets associated with a region. This can include businesses, warehouses, and places of employment that may be located in the site, as well as the financial growth afforded to adjacent businesses and employment. Natural assets are beyond the scope of this project.

Stanley Park: Around 8 million people visit Stanley Park annually, while the City of Vancouver receives 11 million visitors each year. The revenues generated from visitors of Stanley Park are out of scope of the project, however, it is clear that the seawall is a major attraction in Vancouver and can be only assumed to generate considerable revenue for both in-park services (restaurants, parking, etc.) as well as businesses in near proximity to the park. While tourism may generate revenues, maintaining the seawall infrastructure is costly. Routine repairs over the years to maintain the stability of the wall have totaled over millions of dollars, where the most recent repair in 2018 cost the City 4.5 million dollars.

The design must recognize the tourism value of the seawall and the financial gain for in situ and out of park amenities. The proposal should minimize the need for costly repairs along the shoreline.

Communities, People & Homes

People, Communities & Homes addresses the impacts of coastal adaptation projects on housing, including the displacement of residents.

Stanley Park: While there are no present-day places of residence in the park, the park was once home to many Indigenous people who were forcefully removed during the construction of the park.

Design efforts should work to acknowledge the history of Indigenous dispossession.

Infrastructure & Transportation

Infrastructure and Transportation refer to transportation networks and facilities including energy facilities, telecommunications, water and wastewater infrastructure as well as transportation arteries including roads, bridges, and bike paths.

Stanley Park: Not applicable - major transportation routes and corridors are absent from the park's shoreline. The causeway runs through the park however it does not fall within the foreshore area. Critical infrastructure and lifeline services, if any, are beyond the scope of the project.

REFERENCES

REFERENCES

Bauman, M. (2022, July 7). *'It smelled like death': One year after the heat dome killed billions of marine animals, scientists watch for signs of life.* Capital Daily. https://www.capitaldaily.ca/news/it-smelled-like-death-one-year-after-the-heat-dome-killed-billions-of-marine-animals-scientists-watch-for-signs-of-life

Brandon, E. M. (2020, October 26). *How New York City Is Reclaiming Its Piers.* Smithsonian Magazine. https://www.smithsonianmag.com/innovation/how-new-york-city-is-reclaiming-its-piers-180976121/

Canning, A. (2017). *Walled Off: Re-Imagining the Stanley Park Coastline.* [Master's thesis, University of British Columbia].

Cornell Cooperative Extension of Suffolk County. (2019, July 26). *Coastal Habitat Restoration Project: Shinnecock Indian Reservation.* https://ccesuffolk.org/marine/habitat/coastal-habitat-restoration-project-shinnecock-indian-reservation

City of Vancouver (2018). *Coastal Adaptation Plan - Fraser River Foreshore*. Retrieved from https://vancouver.ca/files/cov/coastal-adaptation-plan-final-report.pdf

City of Vancouver. (2018). *Vancouver's Changing Shoreline: Preparing for Sea Level Rise.* Retrieved from https://vancouver.ca/files/cov/vancouvers-changing-shoreline.pdf-

Cruickshank, A. (2022, July 11). *B.C.'s sea life is bouncing back, slowly after the 2021 heat dome.* The Narwhal. https://thenarwhal.ca/heat-wave-bc-sealife-return/

Currin, C.A., Chappell, W.S., & Deaton, A. (2010). Developing alternative shoreline armoring strategies: the living shoreline approach in North Carolina. In: Shipman, H., Dethier, M., Gelfanbaum, G., Fresh, K.L., Dinicola, R.S. (Eds.), Puget Sound Shorelines and the Impacts of Armoring-proceedings: USGS Scientfic Investigations Report 2010-5254, pp. 92-102.

Diaz, C. (2019, September 16). *Long Island's Shinnecock Fight Sea Level Rise By Using Nature Itself.* Gothamist. https://gothamist.com/news/long-islands-shinnecock-fight-sea-level-rise-with-nature

Dietmar Feichtinger Architectes. (2021, December 2). *Aldilonda: The path becomes the destination.* Topos. https://toposmagazine.com/aldilonda-promenade/

Gittman, R.K., Scyphers, S. B., Smith, C.S., Neylan, I.P., & Grabowski, J.H. (2016). Ecological Consequences of Shore line Hardening: A Meta-Analysis. *BioScience 66*(9), 763-773. https://doi.org/10.1093%2Fbiosci%2Fbiw091

Hallinan, B. (2017, October 19). *Best City Parks in the World*. Condé Nast Traveler. https://www.cntraveler.com/gallery/best-city-parks-in-the-world

Heath, T. (2017). *Carss Bush Park environmentally friendly seawall – Stage 1.* NSW Department of Primary Industries. Retrieved from https://www.fishhabitatnetwork.com.au/application/third_party/ckfinder/userfiles/files/CASE%20STUDY%20-%20Carss%20Bush%20Park%20Environmentally%20Friendly%20Seawall.pdf

Hilke, C., Ritter, J., Ryan-Henry, J., Powell, E., Fuller, A., Stein, B.A., & Watson, B. (2020). *Softening Our Shorelines: Policy and Practice for Living Shorelines Along the Gulf and Atlantic Coasts.* Washington, DC: National Wildlife Federation.

Hobson, B. (2015, December 7). *Terraces of plants in Yanweizhou Park "controls floods in an ecological way". Dezeen.* https://www.dezeen.com/2015/12/07/terraces-of-plants-yanweizhou-park-control-floods-ecological-turenscape-landscape-architecture-china/

Judge, J., Newkirk, S., Leo, K., Heady, W., Hayden, M., Veloz, S., Cheng, T., Battalio, B., Ursell, T., and Small, M. 2017. *Case Studies of Natural Shoreline Infrastructure in Coastal California: A Component of Identification of Natural Infrastructure Options for Adapting to Sea Level Rise.* (California's Fourth Climate Change Assessment). The Nature Conservancy, Arlington, VA. 38 pp.

Kerr Wood Leidal Associates Ltd. (KWL) (2017). 2017-2018 Stanley Park and Enlgish Bay Seawall Repairs - Environmental Impact Assessment. Final report prepared for Vancouver Board of Parks and Recreation (File: 3598.001-300).

Kheraj, S. (2013). *Inventing Stanley Park.* UBC Press.

Kim, S. E. (2021, July 12). "*Pacific Northwest and Canada's Crushing Heat Wave Cooks Millions of Sea Creatures,"* Smithsonian Magazine. https://www.smithsonianmag.com/smart-news/pacific-northwest-and-canadas-crushing-heat-wave-cooks-millions-sea-creatures-180978143/

Kirk & Co. Consulting Ltd. (2018). *Consultation Summary Report – Maplewood Marine Restoration Project.* Retrieved from https://www.portvancouver.com/wp-content/uploads/2018/12/November-2018-Consultation-summary-report-Maplewood-Marine-Restoration-Project.pdf

Landscape Architecture Foundation. (n.d.). *Olympic Sculpture Park. Landscape Performance Series.* Retrieved on August 8, 2022, from https://www.landscapeperformance.org/case-study-briefs/olympic-sculpture-park#/sustainable-features

Meijers, C. (2021). *Sediment Transport Pathways in Burrard Inlet* [Master's thesis, Delft University of Technology]. Retrieved from http://resolver.tudelft.nl/uuid:ff2b7adf-6c8b-40b4-99e3-216395e890fa

Migdal, A. (2021, July 5). *More than a billion seashore animals may have cooked to death in B.C. heat wave, says UBC researcher.* CBC. https://www.cbc.ca/news/canada/british-columbia/intertidal-animals-ubc-research-1.6090774

National Oceanic Atmospheric Association (NOAA). (2015). Guidance for Considering the Use of Living Shorelines. https://www.habitatblueprint.noaa.gov/wp-content/uploads/2018/01/NOAA-Guidance-for-Considering-the-Use-of-Living-Shorelines_2015.pdf

Novakovic, S. (2021, April 29). *In Corsica, a Sinuous Promenade is Engineered to Withstand the Waves*. Azure. https://www.azuremagazine.com/article/in-corsica-a-sinuous-promenade-is-engineered-to-withstand-the-waves/

Olin. (n.d.). *Hudson River Park's Pier 26.* https://www.theolinstudio.com/pier-26

Pier 26 Tide Deck. (n.d.). Hudson River Pk. Retrieved August 9, 2022, from https://hudsonriverpark.org/activities/tide-deck/

Resilient Design Features. (2020, November 7). Hunters Point Parks Conservancy. https://www.hunterspointparks.org/resiliency

Rozas, L.P. (1987). *Submerged plant beds and tidal freshwater marshes - Nekton community structure and interactions*. [Ph.D. dissertation, University of Virginia].

SAGE. (2015). *Natural and Structural Measures for Shoreline Stabilization*. Retrieved from http://sagecoast.org/docs/SAGE_LivingShorelineBrochure_Print.pdf

Sinopoli, D. (2019, April 12). *The Climate-Resilient Hunter's Point South Park in New York*. Azure. https://www.azuremagazine.com/article/hunters-point-south-park-queens-resilience/

Stanley Park Ecology Society (2010). *State of the Park Report for the Ecological Integrity of Stanley Park.* Retrieved from https://stanleyparkecology.ca/wp-content/uploads/2021/07/SOPEI-Full-2010.pdf

Stewardship Centre for BC (SCBC). (2003). Coastal Shore Stewardship: A Guide for Planners, Builders and Developers on Canada's Pacific Coast. In Partner with the Province of British Columbia. Retrieved from http://stewardshipcentrebc.ca/PDF_docs/StewardshipSeries/Coastal.pdf

Storm Surge Increase. (n.d.). Climate Signals. Retrieved August 8, 2022, from https://www.climatesignals.org/climate-signals/storm-surge-increase#more

Taft, S., Oldford, G., Lilley, P.L., Oetterich, S.B., Morin, J., George, M., George, M., and Christensen, V. (2022). Reconstructing the pre-contact shoreline of Burrard Inlet (British Columbia, Canada) to quantify cumulative intertidal and subtidal area change from 1792 to 2020. *Fisheries Centre Research Report 30*(1) 48pp.

Thomson, R. E. (1981). Oceanography of the British Columbia Coast. Canadian Government Publishing Centre.

Toft, J.D., Ogston, A.S., Heerhartz, S.M., Cordell, J.R., & Flemer, E.E. (2013). Ecological response and physical stability of habitat enhancements along an urban armored shoreline. *Ecological Engineering 57*, 97-108. https://doi.org/10.1016/j.ecoleng.2013.04.022

Turenscape Landscape Architecture. (2015, March 24). *Yanweizhou Park in Jinhua City*. Landezine. https://landezine.com/a-resilient-landscape-yanweizhou-park-in-jinhua-city-by-turenscape/

Vancouver Board of Parks and Recreation. (2018). *Understanding Stanley Park: Developing a Comprehensive Plan.* https://parkboardmeetings.vancouver.ca/2018/20180416/REPORT-UnderstandingStanleyPark-DevelopingaComprehensivePlan-20180416.pdf

Vancouver Board of Parks and Recreation. (2022). *Extreme Weather Impacts & Damages - Safety, assessment and recovery plan. https://parkboardmeetings.vancouver.ca/2022/20220124/PRESENTATION-ExtremeWeatherImpactsDamages-20220124.pdf*

Vancouver Seawall. Destination Vancouver. Retrieved August 8th, 2022 from https://www.destinationvancouver.com/activities/stanley-park/seawall/

Varanasi, A. (2019, September 18). *The Tribe That Brought a Damaged Shoreline Back to Life.* Columbia Climate School. https://news.climate.columbia.edu/2019/09/18/shinnecock-coastal-habitat-restoration-project/

Worcester, R. (2013). Changes in the abundance of wintering waterbirds along the shoreline of Stanley Park, Vancouver, British Columbia, between 2001/2002 and 2010/2011. *British Columbia Birds 23,* 41-44. https://bcbirds.files.wordpress.com/2016/08/bcbirds_v23_p41_changes-in-abundance-wintering-waterbirds-stanley-park-vancouver-2001-2010.pdf

Wu, Y., Hannah, C., O'Flaherty-Sproul, M., MacAulay, P., & Shan, S. (2019). A modeling study on tides in the Port of Vancouver. *Anthropocene Coasts 2*(1), 101-125. http://dx.doi.org/10.1139/anc-2018-0008

IMAGES

Ballard, M. (n.d.). *An aerial view of the oyster reefs during low-tide*. [Photograph]. Shinnecock Environmental Department. https://news.climate.columbia.edu/2019/09/18/shinnecock-coastal-habitat-restoration-project/

BMO Vancouver Marathon. (n.d.). [Half marathon at Stanley Park Seawall]. Retrieved on August 8, 2022 from https://bmovanmarathon.ca/halfmarathon

Boureau, D. (2021). *The striking Corten steel railings nod to the "iron-rich Corsican coast.* Azure. https://www.azuremagazine.com/article/in-corsica-a-sinuous-promenade-is-engineered-to-withstand-the-waves/

Bowie, B. (2019). [Rock groin in Newport, USA]. Unsplash. https://unsplash.com/photos/32gzNFOvUcc

Buchannan, A. (2011). [Aerial view of Olympic Sculpture Park]. Landezine. https://landezine.com/seattle-landscape-architecture/

City of Vancouver (2018). *Vancouver's Coastal Floodplain Today and 2100.* [Diagram]. Vancouver's Changing Shoreline - Preparing for Sea Level Rise. https://vancouver.ca/files/cov/vancouvers-changing-shoreline.pdf

Dudarev, V. (2021). [Cormorants in Stanley Park]. Unsplash. https://unsplash.com/photos/IKW28_z2f3w

ESA. (n.d.). [Vegetated Dunes]. Retrieved on August 8, 2022 from https://esassoc.com/projects/surfers-point-shoreline-management/

Finn, J. (2021). [Habitat Bench]. SAMBlog. https://samblog.seattleartmuseum.org/2021/12/osp-environmental-restoration/

Giroux, J. (2022). [Sea Star found in Stanley Park]. Unsplash. https://unsplash.com/photos/EGVzaKhDd4A

Harley, C. (2021). *A dead sea star in West Vancouver, British Columbia. If extreme heat becomes too frequent, scientists warn, normally resilient species won't have time to recover.* [Photograph] The New York Times. https://www.nytimes.com/2021/07/09/climate/marine-heat-wave.html

Heard, L. (2011) [Pocket Beach]. Landezine. https://landezine.com/seattle-landscape-architecture/

Hudson River Park (n.d.). [Tide Deck during high tide]. Retrieved August 8, 2022, from https://hudsonriverpark.org/visit/events/event/park-tours-pier-26-tide-deck-4/

Hudson River Park (n.d.). [Tide Deck during low tide]. Retrieved August 8, 2022, from https://hudsonriverpark.org/activities/tide-deck/

Hunters Point Parks. (n.d.). [Salt marsh during low tide]. Retrieved on August 8, 2022 from https://www.hunterspointparks.org/resiliency

Isdell, R. (2021). *John's Point Living Shoreline.* [Photograph]. Flickr.

NSW Department of Primary Industries (2017). [Constructed salt marsh]. Retrieved on August 8, 2022 from https://www.fishhabitatnetwork.com.au/application/third_party/ckfinder/userfiles/files/CASE%20 STUDY%20-%20Carss%20Bush%20Park%20Environmentally%20Friendly%20Seawall.pdf

Port of Vancouver. (n.d.) [Aerial view of Maplewood Marine Restoration Project]. Retrieved on August 8, 2022 from https://www.portvancouver.com/news-and-media/news/eelgrass-transplanting-work-underway-at-maple-wood-marine-restoration-project/

Tatham, B. (2018). [Rip-rap around park's edge]. Dezeen. https://www.dezeen.com/2018/11/19/hunters-point-south-park-long-island-city-swa-balsley-weiss-manfredi/

The ACEC-BC Awards. (n.d.). [Dungeness crab]. Retrieved August 8, 2022 from https://acecbcawards.com/2022-awards/2022-natural-resource-habitat/maplewood-marine-restoration-project/

The Leader. (n.d). [Constructed rock pools]. Retrieved on August 8, 2022 from https://www.theleader.com.au/story/6403814/great-wall-of-carss-parks-marine-habitat-project/

Turenscape (2015). *Flood-adapted boardwalk*. Landezine. https://landezine.com/a-resilient-landscape-yanweizhou-park-in-jinhua-city-by-turenscape/

Turenscape (2015). *Beautiful terraced embankment*. Landezine. https://landezine.com/a-resilient-landscape-yanweizhou-park-in-jinhua-city-by-turenscape/

Turenscape (2015). [Aerial view of park during dry season]. Dezeen. https://www.dezeen.com/2015/12/07/terraces-of-plants-yanweizhou-park-control-floods-ecological-turenscape-landscape-architecture-china/

Varanasi, A. (2019). *The Shinnecock Indian Reservation's beach in Long Island,* New York [Photograph]. Columbia Climate School. https://news.climate.columbia.edu/2019/09/18/shinnecock-coastal-habitat-restoration-project/

Weiss Manfredi. (n.d.). [Marsh during high tide]. Retrieved on August 8, 2022, from https://www.weissmanfredi.com/projects/15-hunter-s-point-south-waterfront-park