# Amphibious City:
# Sustainable Adaptations to Sea Level Rise in Seattle's Interbay Area

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A dissertation submitted in a partial fulfillment of
the requirements for the degree of
Master of Landscape Architecture

University of Washington
2016

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Program Authorized to Offer Degree:
Department of Landscape Architecture

University of Washington

**Abstract**

Amphibious City: Sustainable Adaptations to Sea Level Rise in Seattle's Interbay Area

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Sea-level rise poses major challenges to coastal land uses, and therefore to urban design processes. The project is intended to create an innovative, sustainable and workable urban design plan. In the Seattle Interbay Area, the water along Seattle's Puget Sound shoreline has risen by more than 6 inches during the past century (Climate Impacts Group,2013). Climate change is expected to accelerate rising sea levels during the next century. Mean projections indicate that Seattle will experience 7 inches of sea-level rise by 2050, and 24 inches by 2100 (GGLO Design, 2015). While chronic inundation is a concern, sea-level rise impacts will first be noticed episodically with more frequent tidal flooding events.

As a result, there is a need to inspire creative thinking on how to integrate existing and future built environments with predicted coastal processes. I intended to provide coastal communities design concepts and ideas that create shoreline communities that address coastal hazards and preserve and enhance coastal resources. The project seeks to find the balancing point between people and nature, which is when sea level rise, how to survive because of flooding in the next hundred years. The design solution is an embodiment of cultural representation and technology of stormwater management in order to achieve ecological and social resilience which is life, produce and ecology.

ACKNOWLEDGEMENTS

I would like to thank my advisor, Professor Jeffrey Hou , for his help and encouragement in this work. He has been so supportive and thoughtful, and always willing to offer generous assistance and insightful guidance to help me understand concepts and generate ideas for the completion of this thesis. He is not merely an academic advisor, but an intellectual mentor and a friend to me as well. I would also like to thank my reading committee, Iain Robertson for his time and expertise.

Special thanks to my husband, Stan Chen, for his constant support in my academic and personal life. His encouragement, patience and compassion were so significant for the completion of this thesis. I would like to thank our parents as well, who have always believed in my academic abilities and supported me with passion, care and love.

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## CHAPTER 1: INTRODUCTION

Sea-level rise poses major challenges to coastal land uses, and therefore to urban design processes. This project is intended to create an innovative, sustainable and workable urban design plan.

Sea level rise is like storm surge in slow motion—an inexorable, decade-by-decade phenomenon that never creates a sense of immediate crisis. Impacts from sea level rise are forces that already contribute to coastal flooding, such as storm surge. When these forces are superimposed on higher sea levels, the result will be short-term, extremely high water levels that can inflict damage to areas that were not previously at risk.

In the Seattle Interbay Area, the water along Seattle's Puget Sound shoreline has risen by more than 6 inches during the past century (Climate Impacts Group,2013). Climate change is expected to accelerate rising sea levels during the next century. Mean projections indicate that Seattle will experience 7 inches of sea-level rise by 2050, and 24 inches by 2100 (GGLO Design, 2015). While chronic inundation is a concern, sea-level rise impacts will first be noticed episodically with more frequent tidal flooding events.

Increasing rates of sea level rise caused by global warming are expected to lead to permanent inundation, episodic flooding, beach erosion and saline intrusion in lowlying coastal areas. How do we keep Interbay safe in the face of future extreme weather events and sea-level rise? How can we make cities less vulnerable to water extremes, urban heat and population growth? And what can we do to improve the water quality and quality of life in the region? What can we do to make "bay life" safer, healthier, more fun, and more accessible?

These are the questions I address in Living with the Interbay, our comprehensive regional resiliency plan for Seattle’s Interbay. The goal of the plan is to make the communities around the Interbay more resilient in the face of future extreme weather events and sea level rise, but also strengthen what makes living near the bays great in the first place.

As a result, there is a need to inspire creative thinking on how to integrate existing and future built environments with predicted coastal processes. I intended to provide coastal communities design concepts and ideas that create shoreline communities that address coastal hazards and preserve and enhance coastal resources. The project seeks to find the balancing point between people and nature, which is when sea level rise, how to survive because of flooding in the next hundred years. The design solution is an embodiment of cultural representation and technology of stormwater management in order to achieve ecological and social resilience which is life, produce and ecology.

## 1.1. Background

Interbay is a neighborhood in Seattle, Washington in the United States consisting of the valley between Queen Anne Hill on the east and Magnolia on the west, plus filled-in areas of Smith Cove and Salmon Bay. Interbay is an industrial/retail/office area between the Magnolia and Queen Anne areas. Fifteenth Ave West is the main commercial street in this area. There are 70% industrial area such as light manufacturing complexes, a railroad yard, fenced off storage yards, marine industries, clustered retail stores, and the Interbay Golf Center are among the many varied uses located here.

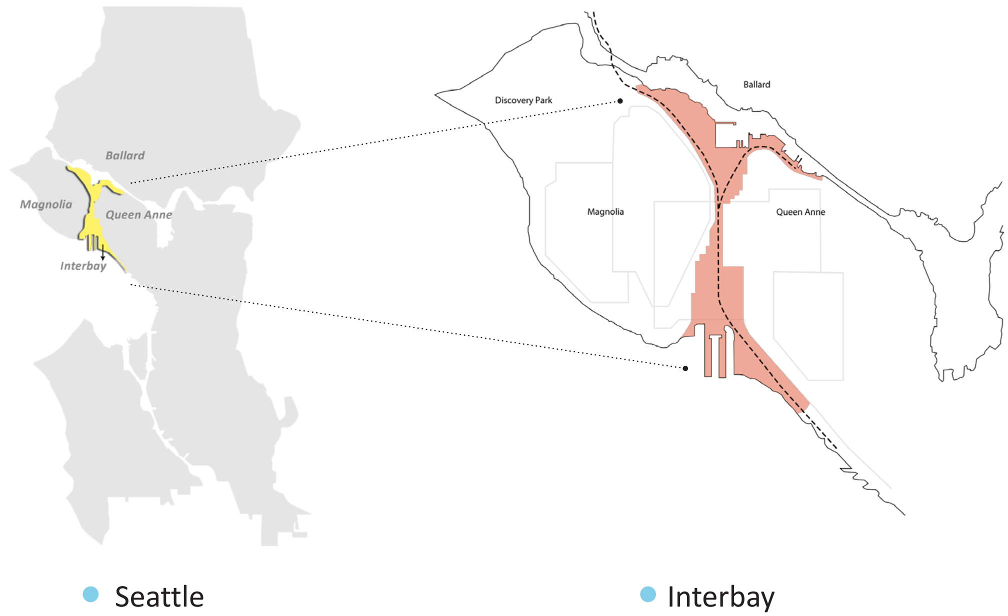



Figure 1. Locations

Figure 2. North of Interbay

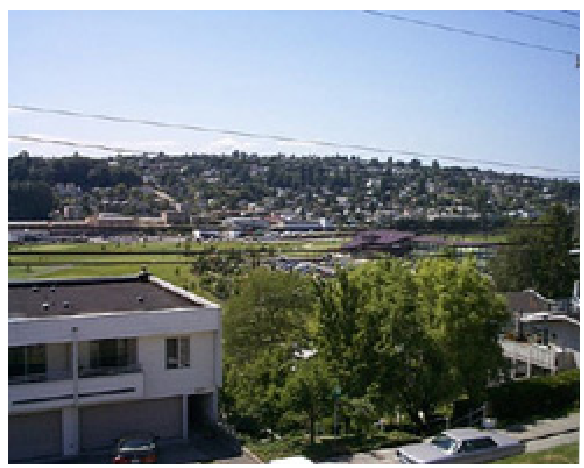


Figure 3. Middle of Interbay

Figure 4. South of Interbay

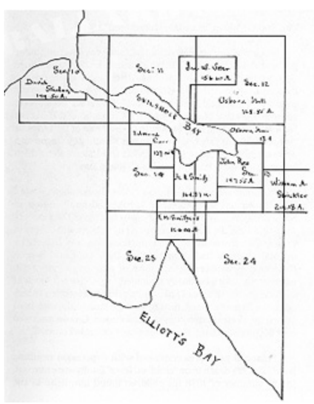

Figure 5. Opportunity of Interbay

**1.2. History**

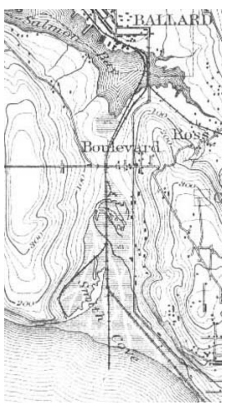
The ship canal project began in 1911 and was officially completed in 1934. Prior to construction of the Lake Washington Ship Canal, otherwise known as the Salmon Bay Waterway, water used to exit Lake Washington via the Black River which flowed from the south end of Lake Washington into the Duwamish River (Robert C,1961).

As early as 1854, there was discussion of building a navigable connection between Lake Washington and Puget Sound for the purpose of transporting logs, milled lumber, and fishing vessels. Thirteen years later, the United States Navy endorsed a canal project, which included a plan for building a naval shipyard on Lake Washington. In 1891 the US Army Corps of Engineers started planning the project. Some preliminary work was begun in 1906, and work began in earnest five years later. The delays in canal planning and construction resulted in the U.S. Navy building the Puget Sound Naval Shipyard in Bremerton, Washington, which is located across the Sound from Seattle.

1853




1894




1900

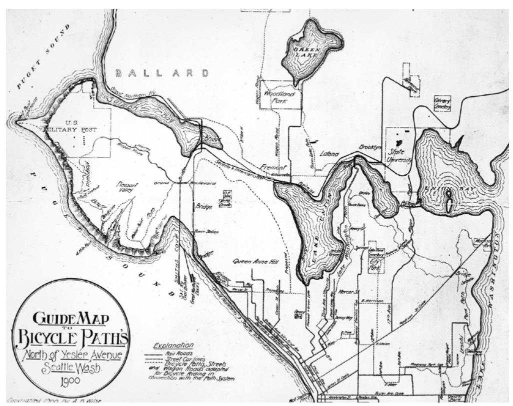



Figure 6. Ballard and Interbay

*Photo Source: Seattle Public Library*

Pier 91, Smith Cove, Seattle, 1947

*Interbay was a marshy area between Salmon Bay and Smith's Cove.*

Getting to Ballard can take time. 100 years ago, its fishing and lumber industries stayed connected to the world by rail and by sea. In 1892, the Great Northern Railway came to Seattle from the north, down the shore of Puget Sound, across Salmon Bay and Interbay, to Seattle.

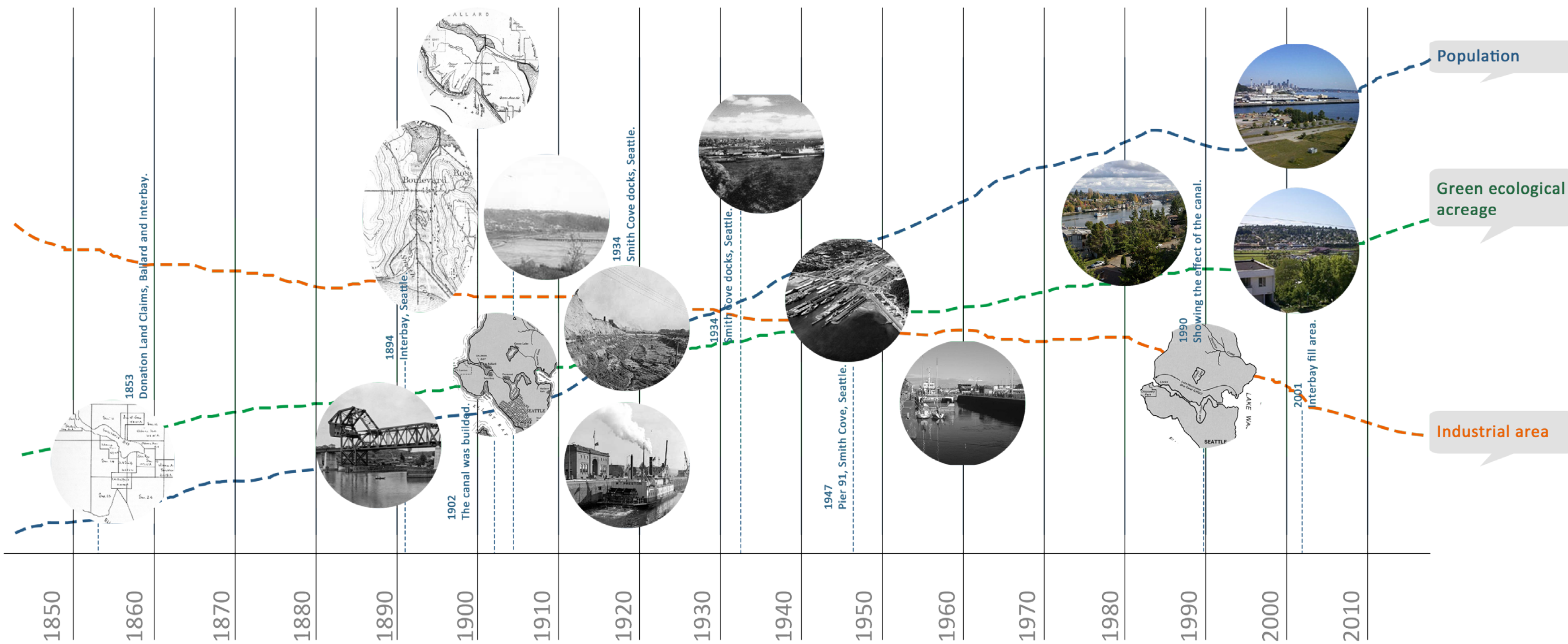
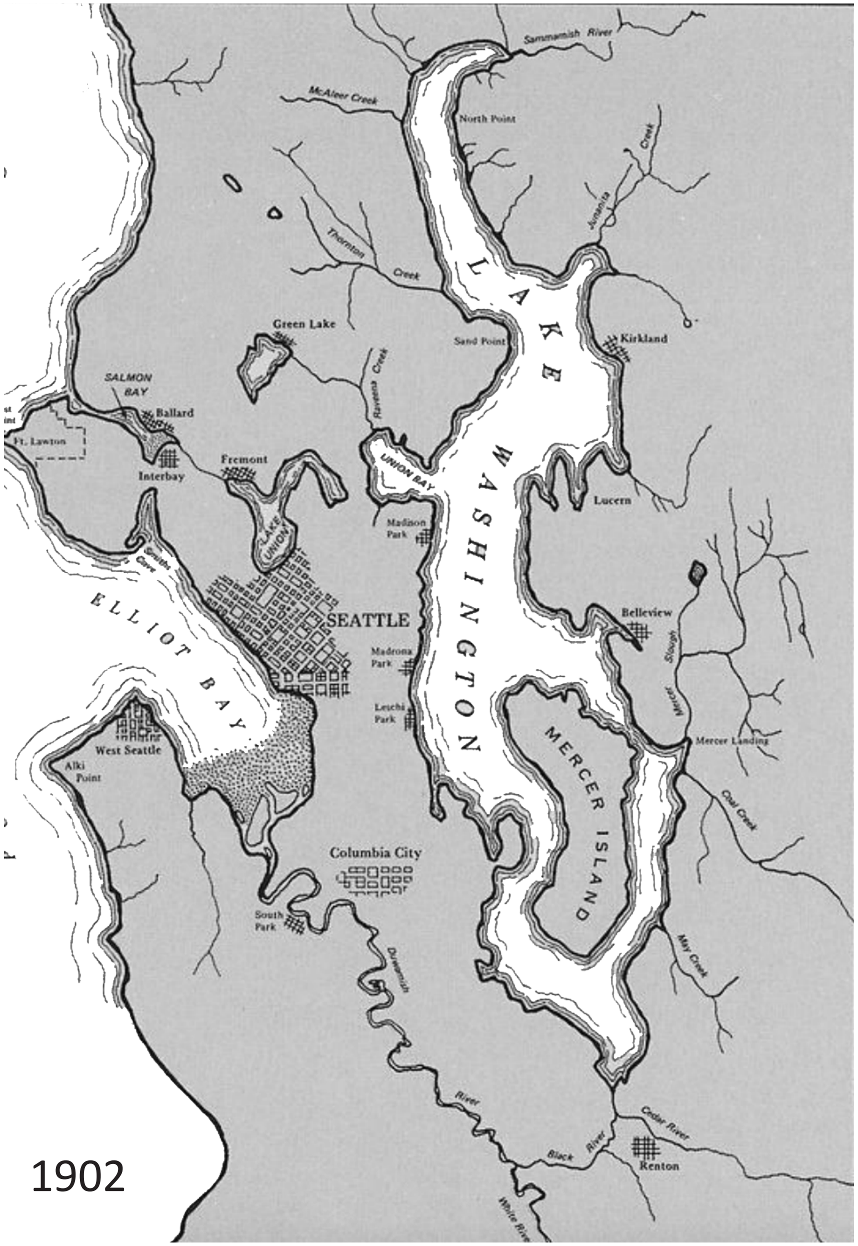



Figure 7. History of Interbay Timeline



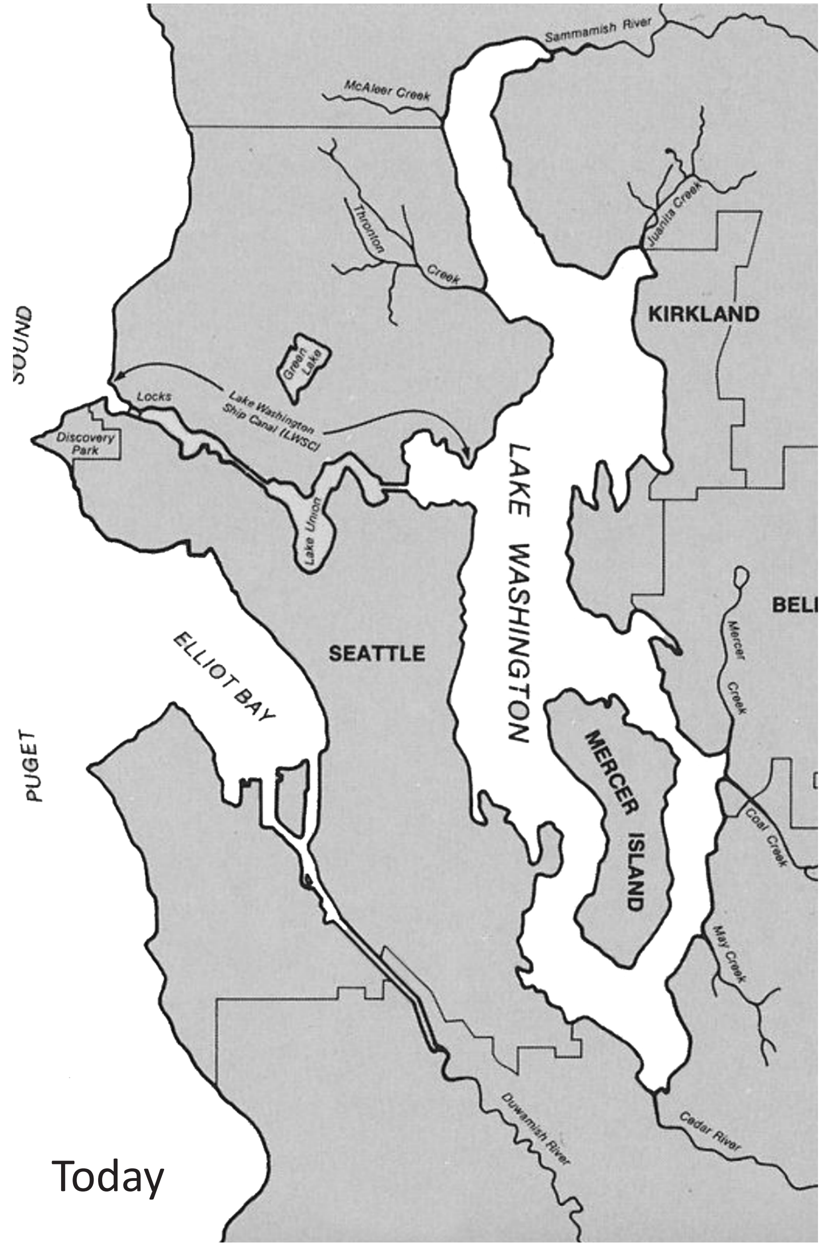




Figure 8. 1902 Map of waterways in Seattle Interbay Tide Flats

Figure 9. Map of waterways today

The two image is intended to be contrasted to the different waterway changes in Interbay.

*Photo Source: U.S. Government Printing Office Pamphlet 1999-791-887: "Lake Washington Ship Canal and Hiram M. Chittenden Locks", p. 3.*

### 1.3. Conceptual Framework

This study begins with an estimation of river level rise in the Interbay and its floodplain, taking into account the causes of urban storm surge within the City of Seattle, as a study sample site. Given current civil engineering solutions and ecological factors, this study provides an alternative operational framework to evaluate the sustainability of solutions to urban flooding at levels estimated for the next 100 years.

Based upon my analysis of the three selected work by theorist-practitioners, I was able to find a way to consider the landscape in different dimensions: architecture space, industrial area and coasts area. The site synthesis presented three major issues and opportunities for the Interbay site: walkability, disconnection to its people and context, and linkages to surrounding park systems to form a network of ecological infrastructure. These design priorities became the facilitators between theory and real world problems.

This study proposes a sustainable urbanism design model including building designs to confront urban flooding in Interbay while accommodating ecological and social activities in this historical city center. The structure of the research undertaken is shown in the diagram below (Figure 10).

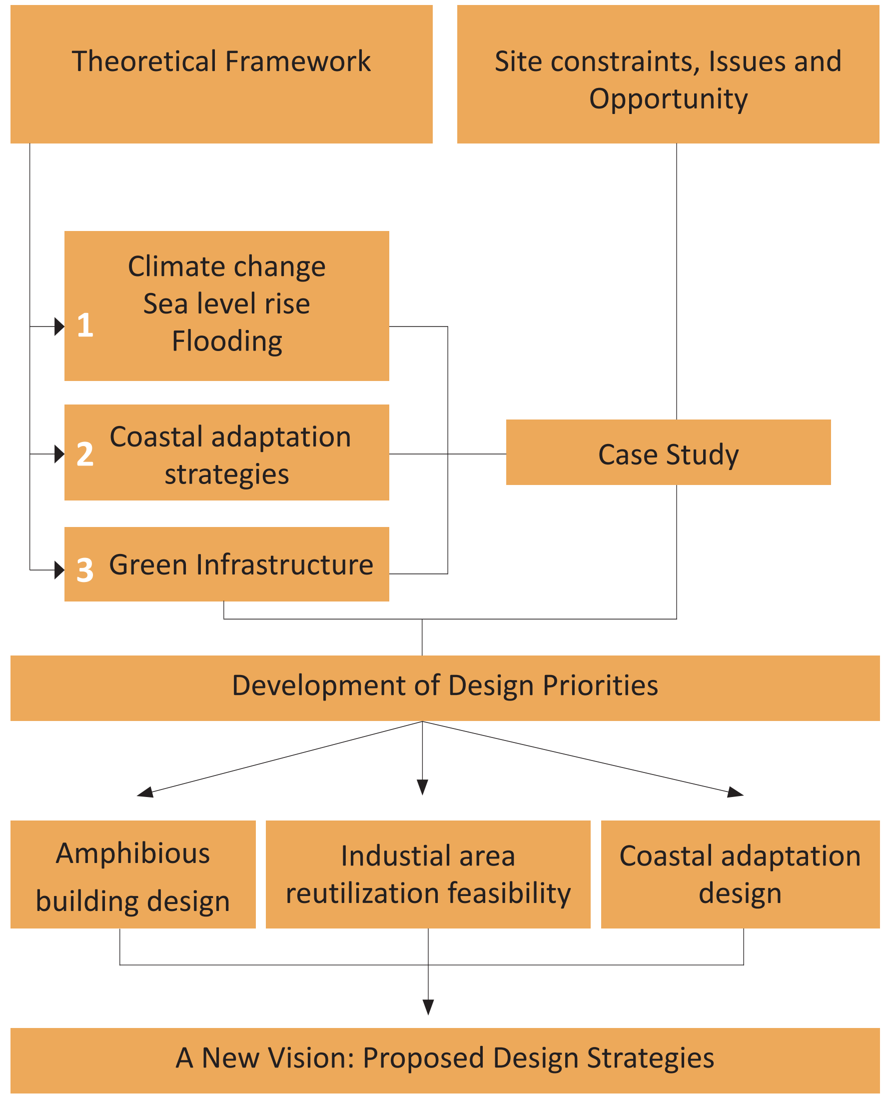



Figure 10. Thesis Structure Diagram

# CHAPTER 2: LITERATURE REVIEW AND CASE STUDIES

This chapter reviews the scientific literature and synthesizes global sea level rise projections and impacts, then narrows in scope to focus on Interbay in Seattle.

Characteristics of the Interbay coast make it unique in planning and adapting to sea level rise, including the coastal communities and salt marshes. Coastal management literature suggests methods that coastal communities might consider to adapt to coastal hazards using varying strategies such as accommodation, protection, and retreat (IPCC Working Group III, 1990). These scientific findings and adaptation strategies gleaned from this chapter will provide grounding as subsequent chapters move toward a site design that incorporates rising sea levels into the design process.

## 2.1. Global Sea Level Rise

Over the past fifty years, the rate of global sea level rise has increased from 1.8mm per year to 3.1mm per year. Scientists predict that the rate of change will continue to accelerate over the next century(IPCC, Climate Change, 2007). Future sea level rise projections are defined through a scientific analysis of how humans' actions are manipulating the climate and, in turn, natural earth processes. This section examines the ways climate change affects global sea level rise through thermal expansion and melting ice sheets(Martin Vermeer, 2009).

Sea level rise is predicted to impact the built and natural environments of the coast in significant ways. Some impacts of a rising sea level are permanent inundation, more frequent temporary flooding, higher storm surges, erosion, and intrusion of salt water. When coupled with the prediction that climate change will bring more intense and frequent storms and thus high winds and storm surges, damage to coastal communities will only increase.

Inundation in natural areas will cause inland migration of intertidal and upland natural
environments, such as marshes, tidal flats, and dunes (Craft et al., 2009). While these habitats are naturally equipped to deal with change and disturbance, without adequate space for these features to migrate these environments could be fractured or lost all together. Hard coastal defenses such as sea walls or levees prevent the habitat from migrating, leading to devastating loss of species and habitat as well as loss of vital ecosystem services such as storm surge buffering, nutrient cycling, and water quality provided by these habitats (Craft et al., 2009).

| Climate Change Prediction | Impacts associated with change | Potential effects on society and built and natural environments |
|---|---|---|
| Sea level rise | • Higher high tides cause temporary and permanent inundation<br>• Increased shoreline erosion<br>• Saltwater intrusion | • More frequent temporary flooding and permanent inundation of low lying land<br>• Flooding of critical infrastructure<br>• Loss of transportation accessibility during inundation events<br>• Loss of economic industries, especially natural resource-based, such as agriculture, fisheries, forestry<br>• Mobilization of contaminants at flooded sites<br>• Increased shoreline erosion<br>• Habitat and vegetation migration<br>• Salinity damage to built structures and infrastructure, both above and below ground<br>• Increased salinity of estuaries and aquifers contaminates drinking water sources |

Table 1: Sea Level Rise Impacts (NOAA Tides, 2012)

The study included a detailed analysis of the projected sea level rise. The following findings from the Seattle Government Climate Change Center are summarized as follows:

1. The mean sea level rise along the Interbay in Seattle coast is projected to rise from 7 to 24 inches by the year 2100.

2. A 24 inches sea level rise will put 320,000 people at risk of a 100 year flood event, given today's population. The current 100 year high tide peak would become a 10 year high tide peak, causing more frequent risks of inundation.

3. A wide range of critical infrastructure, such as roads, golf course, schools, wastewater treatment plants, and more will be at increased risk of inundation in a 100 year flood event.

**2.2. Coastal Adaptation Strategies**

In light of these projections of sea level rise and its impacts, it is critical that coastal areas prepare to adapt to a "new normal" of higher sea levels, higher tides, and increased flooding.

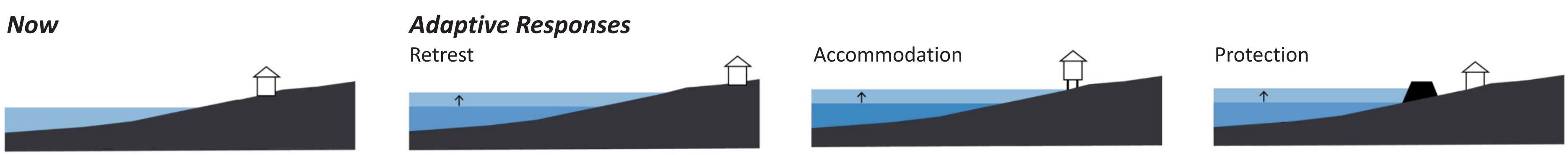



Figure 11. Diagram of coastal adaptation responses to sea level rise: retreat, accommodation and protection(adapted from IPCC Working Group III, 1990).

By recognizing the risks, uncertainties and vulnerabilities that a coastal community faces in the future, communities can plan their own response and develop their own direction for growth in the future. By combining a strategy of coastal management that combines hard and soft infrastructures, accommodation, and retreat, communities can alter their built and natural environments to attain a resilient future.

Design professions such as landscape architecture are poised to lead these discussions and develop creative solutions to these apocalyptic problems. New and innovative strategies in the planning and design fields will help to address these unprecedented changes to our modern society.

Despite the fact that specific climate change predictions are considered uncertain, it is nevertheless a fact that measures must be taken in the Seattle Interbay Area to guard against, or to take advantage and adapt to, flooding and high water levels.

## Coastal Vulnerability to Sea Level Rise

Several studies have examined the vulnerability of coastal areas to sea level rise (Gornitz, 1990). Vulnerability is defined as the degree to which a natural or social system is at risk to damages or losses due to natural phenomenon. Vulnerability can be discussed as a function of exposure (i.e. duration or intensity of change), sensitivity (i.e. extent to which a system will respond to change) and adaptive capacity (i.e. extent to which a system can moderate or take advantage of change). In this characterization, a vulnerable coastal area is susceptible to the effects, and incapable to adapting to, even modest increases in sea level.

Gornitz (1990) constructed a coastal hazards database to assess the vulnerability of the U.S. West Coast to the impacts of sea level rise. The database integrated seven variables known to influence the vulnerability of coastal areas to the impacts of sea level rise. These variables included elevation, coastal rock type, geomorphology, relative sea level rise, erosion and accretion, tidal ranges and wave heights (Gornitz, 1990).

Accelerated sea level rise, driven by global climate change, will continue to affect the Elliott coast through permanent inundation, episodic flooding, beach erosion and increased saline intrusion of low-lying areas. As a result, a wide range of impacts on socioeconomic and natural systems is anticipated, including increased damage of property and infrastructure, declines in coastal bird and wildlife populations and the contamination of groundwater supplies. The past and current affect of sea level rise on the Seattle coast are apparent. Base on these theories, proposed that the final waterfront design is likely to include a combination of perched beach, headland, salt marsh, boardwalk, walkway, and bikeway, as well as convenience parking, retail, and hotel/dining experiences.

### 2.3. Green Infrastructure Defined

Green infrastructure is a term that is appearing more and more frequently in discussions of sustainability across the United States (Center for Watershed Protection, 2009). Green infrastructure has become a popular stormwater management tool as a growing number of practitioners are applying its techniques to site designs, and long-term monitoring results are contributing to research quantifying its benefits (Calkins, 2012).

The profile of green infrastructure for urban stormwater management has also been raised, as major metropolitan cities such as Philadelphia, Chicago, New York, Seattle, and Portland adopt comprehensive green infrastructure plans in order to meet water management goals in urban areas.

Green infrastructure shares many characteristics to other terms used in coastal adaptation, climate change, and hazard literature. Terms such as soft protection, soft infrastructure, soft coastal engineering, and living shoreline are commonly used in coastal literature (Grannis, 2011). While these names might differ from “green infrastructure” they all stem from the same philosophy - using natural materials and natural processes to perform ecological services. One definition of soft coastal protection highlights these similarities, defining it as, “projects that replenish or mimic natural buffers, such as beach nourishment, living shorelines, or wetlands restoration” (Grannis, 2011).

There are many types of green infrastructure, depending on the scale at which it is being used. The types range from small-scale site design features, commonly called Low Impact Development (LID) techniques, to landscape conservation agendas (Center for Watershed Protection, 2009). A compiled list of green infrastructure techniques and practices is found in Table2.

| Green Infrastructure Type | Examples |
|---|---|
| Low Impact Development Techniques | • Natural areas<br>• Riparian buffers<br>• Land conservation<br>• Cluster Building<br>• Reduced impervious area<br>• Site assessment and design |
| Low Impact Development Practices | • Bioretention<br>• Bioswales<br>• Stormwater wetlands<br>• Stormwater ponds<br>• Constructed wetlands<br>• Rainwater harvesting<br>• Green roofs<br>• Permeable pavement<br>• Filtration practices (sand or vegetated filter strips)<br>• Infiltration practices (infiltration basins & trenches) |
| Coastal Green Infrastructure Practices/ Restoration | • Sand dunes<br>• Salt marshes<br>• Wetlands<br>• Organism-based habitats (oyster reefs, oyster beds, mussel beds)<br>• Submerged aquatic vegetation |

Table 2: Green infrastructure types (adapted from Center for Watershed Protection, 2009).

**Green Infrastructure as a Climate Change Adaptation Strategy**

Green infrastructure is increasingly mentioned in the climate change literature as a method for both mitigating greenhouse gas emissions and adapting to the realities of climate change. Studies are concluding that green infrastructure, by increasing green space and natural land cover, can help manage flooding, temper the urban heat island effect, provide cleaner air and water, and increase human health through increased recreational opportunities and interaction with nature (Gill, 2007).

In the policy statements of national associations of landscape architects, such as the American Society of Landscape Architects (ASLA) and The Landscape Institute in the United Kingdom, the organizations advocate for the use of green infrastructure as a climate change mitigation and adaptation technique (ASLA 2008; The Landscape Institute, 2008).

Therefore, green infrastructure is a possible solution that can help adapt our urban infrastructure to be more resilient to disturbances due to climate change.

The following section describes some of the unique challenges and possible benefits of applying green infrastructure to manage and adapt to sea level rise and flooding under uncertain future scenarios. The discussion focuses on using a green infrastructure approach to coastal adaptation to sea level rise that other strategies such as adaptability and resilience.

**Adaptability and Resilience**

By working "with nature's capacity to absorb and control impacts," green infrastructure has the potential to provide systems that are adaptable and flexible to uncertain future conditions (Odefey et al., 2012, p.147). With the large levels of uncertainty regarding the exact rate and height of sea level rise, a flexible and adaptable approach is one method to design in the present but be prepared for future conditions.

Green infrastructure is a spatially flexible approach to design that can be used at multiple scales. This flexibility may prove especially beneficial considering the uncertain future conditions of sea level rise. A green infrastructure approach can be used at multiple scales from a large landscape scale to a site scale (Benedict & McMahon, 2006).

Resilience theory is one way that adaptability might be approached. Resilience is defined as, "the ability of a system to absorb disturbance and still retain its basic function and structure" (Walker & Salt, 2006, p.62). Resilience has been championed as a new paradigm of design thinking that adopts lessons from nature and ecosystem services to mitigate impacts of flooding, extreme weather and climate change (Watson & Adams, 2010).

The design strategies will utilizing green infrastructure including bio-swales, wetlands, permeable paving, green roofs, and rainwater harvesting. In addition to providing solutions to buffer and absorb flooding and coastal habitat, the proposed infrastructure will provide living machines or turbines to cleanse urban storm water and reduce urban heat as well as collect energy.

### 2.4. Conclusion for Literature Review

1. ***Sea level rise*** - As sea levels rise and chronic flooding becomes the new normal. How to moving to more flexible, resilient solutions. The concept of designing with bay is the strategy of allowing defined areas to flood or contain water in order to prevent damage to other areas. Solutions to address rising sea levels should provide opportunities to improve our environment and our relationship with the city.

2. ***Coastal Adaptation Planning*** - Understanding how extreme urban flooding in the City of Seattle Interbay could be caused by sea rise, storm surge, and extreme precipitation, the limitations of current hard-only solutions - not to mention the ecological damage caused by the latter, should be apparent. Therefore, solutions should address improved resiliency and ecological benefits including enhanced biodiversity.

3. ***Green infrastructure*** - Reestablishment of habitat depends on restoration and management of wetlands and the development of infrastructure. Therefore, green space as new type of urban infrastructure in high-density urban settings could promote urban ecological health by providing potential space for urban habitats, recreational space, and living amenities in a sustainable manner.

In Seattle, today's emergency response to coastal flooding means people need to develop effective short-term strategies for protecting their properties from saltwater intrusion. With extensive resources on emergency response available elsewhere, this thesis largely focuses on longer-term preparedness measures.


Figure 12. Diagram of design with Interbay principles.

## 2.5. Case Studies

### 1. Greater New Orleans Urban Water Plan
### New Orleans, Louisana

The Greater New Orleans Urban Water Plan addresses the need to plan across political boundaries. Large-scale issues such as sea level rise call for regional decision making. Boston and surrounding communities will need to plan regionally to address flood risks without making them worse for others. In addition, land subsidence, although less dramatic in Boston than in Louisiana, is a real issue for Boston, especially for neighborhoods built on former tidelands.

Greater New Orleans links America's heartland and the Mississippi River Valley to the Gulf of Mexico and the rest of the world.
It is a vital center of commerce and culture, and is positioned to become a global leader in water management and climate adaptation as well.

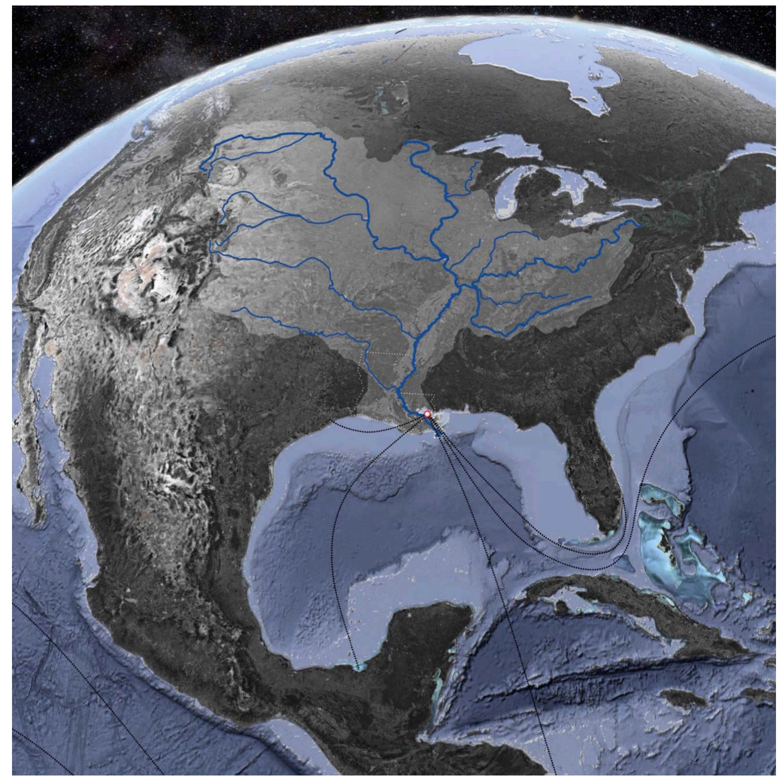


Figure 13. A Map of Greater New Orleans

*Photo Source: Waggonner, Ball Architects. (2013). Greater New Orleans Urban Water Plan.*

The Challenge

New Orleans' current flood control strategy relies on highly-engineered infrastructure that moves water out of the city as quickly as possible. This system allows extensive development within a below-grade floodplain and prevents groundwater replenishment, leading to increased subsidence of land and exacerbating the city's risk of flooding.

Levees currently around the city separate residents from the surrounding water bodies — including Lake Pontchartrain, Lake Borgne, the Mississippi River, and the Gulf of Mexico. Most stormwater is managed via unseen underground pumps. In order to protect from future devastating floods, New Orleans' challenge is to make room for water physically and culturally.

Figure 14. Greater New Orleans Urban Water PlanNew Orleans, Louisana
*Photo Source: LSU Coastal Sustainability Studio | The Greater New Orleans Urban Water Plan*

THE PROCESS

The Greater New Orleans Urban Water Plan, released in September 2013, identifies a 50-year, phased regional strategy incorporating intelligent retrofits and urban design strategies for flood resilience. It was the product of a two- year collaboration among the City of New Orleans, the State of Louisiana, Waggonner & Ball Architects, and the Royal Netherlands Embassy. The Urban Water Plan strives to be a regional planning example for other coastal cities.

The plan shifts the city's focus from hard, engineered stormwater management strategies to dynamic, adaptive solutions that address the relationship between flooding and subsidence. It calls for making space for water within the greater region using bio-swales, retrofitted canals, new canals, and ponds to hold and absorb water. Absorbent landscapes and natural systems control the first wave of stormwater. Pumping stations are activated as a last resort.

THE RESULTS

The plan advocates for regional cooperation to support both the economic and cultural future of Greater New Orleans. It will be integrated with the Louisiana 2012 Coastal Master Plan and the existing levee system to create a greener, more resilient New Orleans region.

Figure 15. A Vision of Greater New Orleans

*Photo Source: Waggonner, Ball Architects. (2013). Greater New Orleans Urban Water Plan.*

## 2. Buffalo Bayou Promenade
### Houston, Texas

Buffalo Bayou Promenade designed by SWA Group. This project was created under challenging urban conditions, overhead freeways and utilities, steep slopes, limited access and critical flood elevations(Figure16).

The Master Plan transforms the formerly neglected bayou system of downtown Houston into 23 acres of new parkland with extensive bike trails and pedestrian connections to the downtown area(Figure17).

Designers created a safety pedestrian system and bikeway for people under freeways and bridges, and provided some recreation area for activities and events. In order to provide a safe pedestrian environment at night for people, designers used special event lighting in this park.


Figure 16. Buffalo Bayou Promenade site map

*Photo Source: http://www.asla.org/2009awards/104.html*

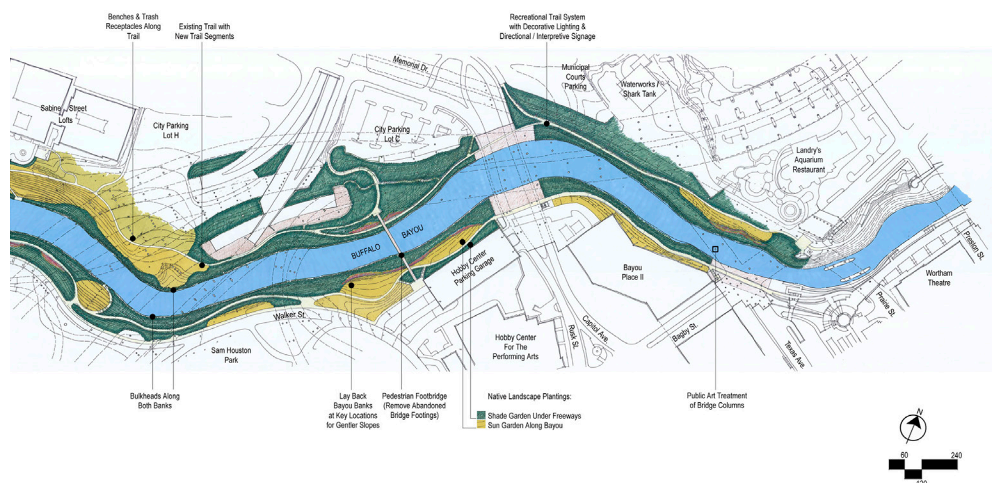



Figure 17. Buffalo Bayou Promenade Master Plan

*Photo Source: http://www.asla.org/2009awards/images/largescale/104_00.jpg*

Because Buffalo Bayou is the principal drainage system for much of Houston, the design team had to treat the waterway and its banks with special care. Gabion edge treatments allow for safety and visual clarity. The stepped design provides water egress at any point while allowing floating storm debris to pass through. The gabion cages, utilized over 14,000 tons of recycled crushed concrete. The open gabion cages also allow tree roots and riparian ground covers to form a natural edge while providing a porous foundation for the riparian benthic community. Native and naturalized riparian plants were chosen for their deep-rooted ability to control erosion and sustain the future hydrologic actions of the bayou.

Comparing the Arroyo Seco Confluence with the Buffalo Bayou Promenade project, I can find that their sites are located under the highway and bridges, and their environments are complex. In the Arroyo Seco Confluence project, we should primarily consider the Arroyo Seco's function of the drainage channel, should control flooding. In addition, we should make better use of the limited land which is located under freeways and bridges for providing a safety pedestrian system and bikeway and creating recreational areas for people, should rebuild the ecological riverbank with native and local plants for restoring the river, and use landscape lighting to provide a safe environment at night for people.

Figure 18. Buffalo Bayou is the principal drainage system

*Photo Source: https://www.asla.org/2009awards/104.html*

Figure 19. Buffalo Bayou is the principal drainage system

*Photo Source: https://www.asla.org/2009awards/104.html*

### 3. Guadalupe River Project
### San Jose, California

The Guadalupe River is truly the heart of San Jose, linking various corners of the downtown and connecting the city to the region through a network of trails. Fish have returned, breeding, migrating and spawning in the channel. Birds, mammals and amphibians find habitat in the vegetation along the river's edge. And humans who enjoy the stimulation of urban life can also find moments for quiet reflection in the park's plazas and gardens (H Graem, 2012).

- Providing access for people either at points to the river or along banks.
- Developing open spaces so that people can gather along its banks and enjoy the rare resource of a natural river in a vital urban area.
- Using gabion wall system and terraces for protecting the bank.
- Building pedestrian way and bikeway along the river.

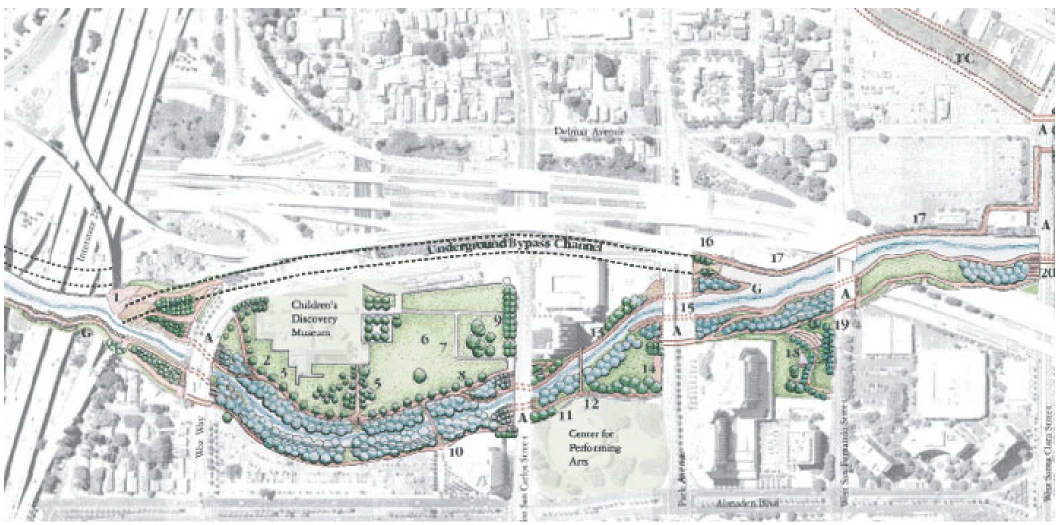



Figure 20. Overall plan

*Photo Source: http://visions2200.com/EnvironmentWaterFlow.*

Similarly, the channelized channel can be widened and deepened for expanding floodplain and increasing flood capacity with using gabion wall system and terraces for protecting the riverbank. And riverwalk, pedestrian way and bicycle way can be also built along the riverbank for providing the access for people.

This project included planting native vegetation and trees along an existing channel and creating a meandering low-flow channel. It is referred to as a flood protection measure. The restored riparian zone can then be narrower, since it will only need to contain sufficient capacity for flood waters within the determined volume. Although not fully natural riparian landscape, the created environment shown, it is a decided improvement over the much larger concrete channel originally proposed here for flood control purposes.

Figure 21. Gabion wall system and terraces for protecting the riverbank

*Photo Source: http://visions2200.com/EnvironmentWaterFlow.*

**4. The Thames Estuary 2100 Plan**
**London, England**

The Thames Estuary is located at the junction of the North Sea and the River Thames, with tidal fluctuations as high as 22 feet. Like so many other coastal communities, for centuries London has relied on flood barriers. In addition to sea level rise, the region faces aging flood defenses, land subsidence, changing socio-economics, and low public awareness of flood risks.

In 2002, the UK Environment Agency began its work on the Thames Estuary 2100 Plan (TE2100). The plan sought to manage coastal flooding risks through "technically-realistic, adaptable, environmentally-sustainable, economically-feasible, and socially- and politically- acceptable" means. The TE2100 plan was the first flood management plan in the United Kingdom to be defined by climate change instead of economic goals and political boundaries. It is a process- based plan with area boundaries defined by flood risks, not municipal borders.

Figure 22. Thames estuary

*Photo Source: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/322061/LIT7540_43858f.pdf*

## THE PROCESS

The plan defines 23 policy units (locations) in the estuary that share common flood characteristics.Risk assessments and recommendations were developed for three time horizons: short-term (2010–2035), medium-term (2035–2050), and long-term (2050–2100). The plan builds on the best science today and integrates a recurring process of decision-making based on new information. It calls for monitoring 10 key indicators to alert decision-makers to changing conditions. Significant changes in these indicators trigger further action.52 The plan will be updated every decade, or more often if water levels rise more quickly than expected.

## THE RESULTS

TE2100 is a national flood management strategy for the Thames Estuary. It directs future floodplain management, provides key information to local governments, and helps build knowledge and capacity within the region. The Environment Agency's leadership on the TE2100 plan institutionalized the planning process and elevated the platform of flooding risk to a national level.

**5. Room For The River Waal**
**Nijmegen, The Netherlands**

In the Netherlands, many major rivers are contained by high dikes while residents live on sinking, but habitable, land behind the dikes. Nijmegen, the oldest city in Holland, celebrated its 2,000th anniversary in 2005. It is located next to a sharp bend in the Waal River that creates a dangerous bottleneck in the river and makes the city particularly susceptible to flooding. In 1993 and again in 1995, extreme rainfall events forced approximately 250,00055 Dutch residents to evacuate riverside communities, including Nijmegen.

Although the dikes held floodwaters back, the close calls alarmed the Dutch government. They realized if existing dikes failed, resulting damage would be worsened by water filling the sunken land behind the dikes.

THE PROCESS

The Dutch government initiated the Ruimte voor de Rivier ("Room for the River") program, targeting almost 40 locations across the country. The program looks to expand rivers' capacity to hold increased volumes of water during intense storm events. In Nijmegen, Room for the River Waal involves relocating the Waal dike in Lent and constructing a secondary channel within the floodplain. These measures create a new elevated island in the Waal that includes residential, recreational, and cultural development.

Figure 23. In the process, it is also creating an island for recreation as well as prime property that can be developed into a new heart of the city.

*Photo Source: http://citiscope.org/story/2015/dutch-city-makes-room-its-river-and-new-identity*

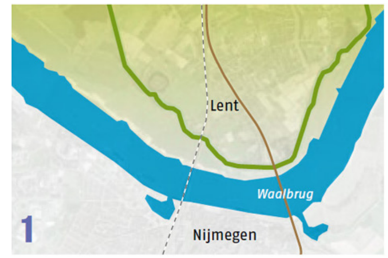
THE RESULTS

The new island is expected to attract more development to the city's center. Social benefits include new bridges connecting residential neighborhoods, a green dike for pedestrians and cyclists, and new restaurants and shops along the waterfront. When plans are completed, the ancient city of Nijmegen will span the new channel.

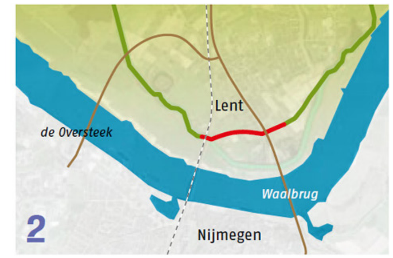
**6. Conclusion**

This chapter has given a brief case studies of urban design development. Those five case investigated the applicability of the design principles urban developed. I studies the different ways when sea level rise, how to design, and focus on fully fledged urban strategies for a vulnerable coastal site that are finely tuned to the ecological and hydrologic dynamics in play, including the effects of storm surge and sea-level rise.

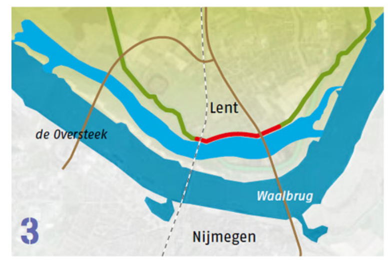
These sections set the stage for a more in-depth look at the approach to the preservation of urban design and green infrastructure within each redevelopment project. The case studies are arranged chronologically, based on the time planning for redevelopment was started in order to reveal evolution in the approach to sea level rise heritage.



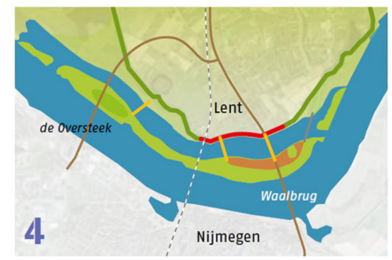
The initial situation with the existing dike.



The dike was moved 350 meters inland.



An ancillary channel is to be dug in order to Bridges across the ancillary channel. give the river more room. This will create an elongated island.



Bridges across the ancillary channel.

Figure 24. The river flows from east to west (right to left).

*Photo Source: http://citiscope.org/story/2015/dutch-city-makes-room-its-river-and-new-identity*

Interbay is located in the city of Seattle, WA, in the neighborhood of Ballard on the north, Magnolia on the west and Queen Anne Hill on the east, plus filled-in areas of Smith Cove and Salmon Bay.

It is a small and protected industrial harbor off of Puget Sound. Salmon Bay continues east to become part of the Lake Washington Ship Canal, established in 1917 by the Army Corp of Engineers. The ship canal was established as part of the Government Locks to enhance commercial and industrial uses of Salmon Bay and to connect it with the fresh water bodies of Lake Washington and Lake Union ( Warren,2005). Within the Interbay, a industrial historic core and had been established to preserve.

The Interbay industrial area effectively severs most of the possible green connections between the Queen Anne Boulevard system and the Magnolia open space network. However, land use patterns in Interbay are shifting. The Port of Seattle, with huge holdings in the area, is currently considering future development in the southern half of Interbay.


Figure 25. Site studies area.

The Interbay is currently planning to replace the Magnolia Bridge, the gateway to the Magnolia boulevard system. These changes create the opportunity to provide trail and linear park connections linking Queen Anne and Magnolia as well as between Salmon Bay and the City's waterfront. The alignment and design of the Magnolia Bridge will be especially important in establishing a strong sense of continuity between the historic Olmsted Boulevard systems on Queen Anne and Magnolia.

The Seattle Interbay are three roadway connections from the Magnolia community, of over 20,000 residents, to the rest of Seattle (City of Seattle, Department of Planning and Development, 2012). As the southernmost of the three connections, the Magnolia Bridge is the most direct route for much of south and west Magnolia to downtown Seattle and the regional freeway system.


Figure 26. The Ballard Interbay Northend Manufacturing and Industrial Center (BINMIC).

*Photo Source: Seattle: City of Seattle, Department of Planning and Development,(2012).*

### 3.1. Ballard-Interbay Northend Manufacturing and Industrial Center (BINMIC)

Ballard's thriving urban industrial centre has been made successful largely due to its creation as one of two Seattle Manufacturing and Industrial Centers (MICs). The City designated Ballard as part of the BINMIC in 1994 through the adoption of its Comprehensive Plan, Toward a Sustainable Seattle. Comprising approximately 843 acres of waterfront and upland property northwest of downtown Seattle, the BINMIC was established to ensure that adequate accessible industrial land is available to promote a diversified employment base and sustain Seattle's contribution to regional high-wage job growth (PSRC, 2002)

BINMIC's centre spans from Elliot Bay to Salmon Bay, and includes some of the city's most productive working waterfront, wharfs, shipyards and rail yards. The BINMIC encompasses an area in Ballard which parallels the shore of Salmon Bay from the Locks to 3rd NW Ave and includes much of the industrial zoned land in Ballard.

To preserve jobs and industrial lands; and to provide recreational spaces that connect important public amenities and open spaces. The Ballard Interbay Northend Manufacturing and Industrial Center (BINMIC) is a community based organization addressing commercial /industrial issues including:

1. Preserving Industrial Land
2. Locate bike trails away from BINMIC
3. Drainage Improvements

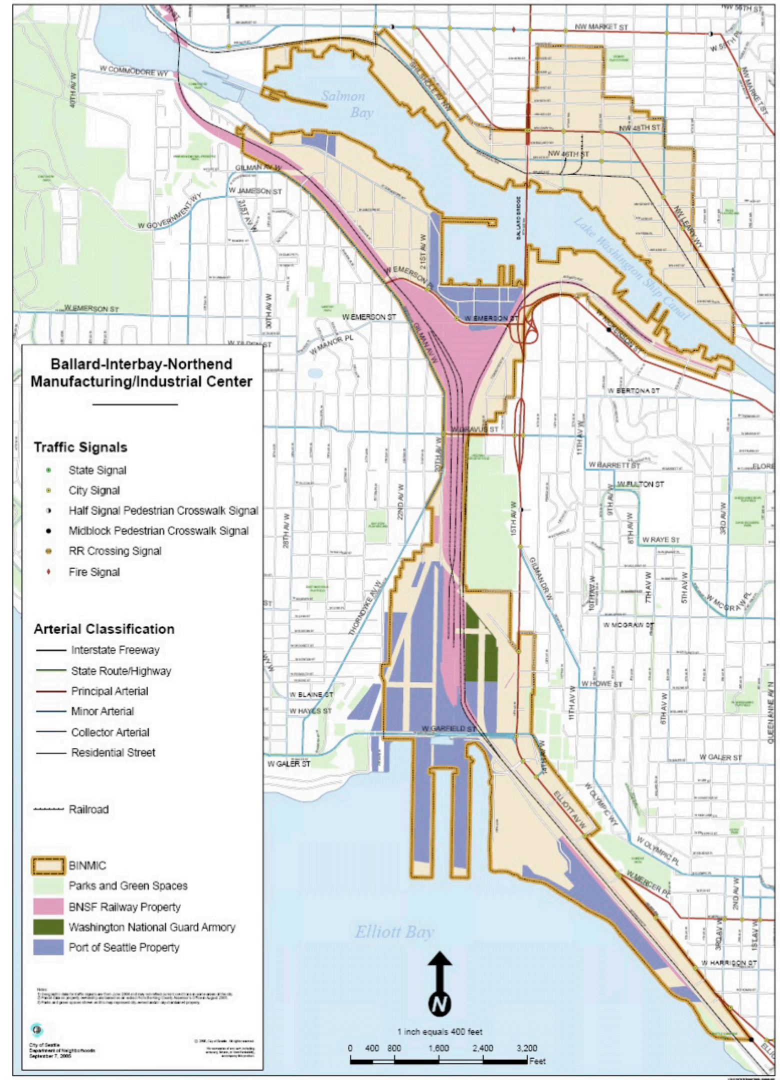



Figure 27. The Ballard Interbay Northend Manufacturing and Industrial Center (BINMIC) land use map .

*Photo Source: City of Seattle DPD.*

### 3.2. History of Salmon Bay

Interbay area is developed with residential, commercial, industrial, institutional, public uses, and streets/highways. Ballard celebrate its heritage by preserving elements of the fishing and maritime industry along the Ship Canal, integrated with other green industry, bio- business, and public open space.

In the early 1900's, Salmon Bay was an important fishing waterway as it was one of the inland salmon migration routes from Puget Sound. Salmon bay and ships symbolize Ballard's marine heritage and it was come together at the Ballard Locks. The Locks have never served the salmon well because not mimic the natural functions of an estuary such as mixing salt water and freshwater, protecting sea bound fish with shallow water, modulating water temperatures, and providing abundant food.

In the future, I think that keeping one of the most historically important pieces of the neighborhood, especially economically viable. Present industrial and fishing zones along salmon bay will be infilled with public greenspaces that also serve as green machine filtration units to create an eco-processing buffer zone to preserve the water quality of the canal.

Figure 28. Salmon bay in 1887 and 1903.

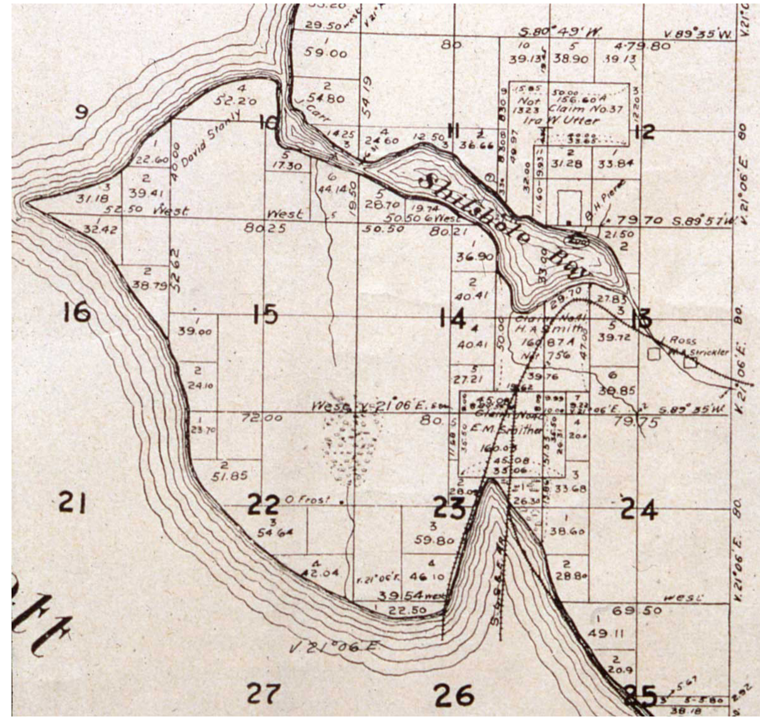


Figure 29. Salmon Bay and Magnolia – as the federal surveyors first drew it in the late 1850s.

*Photo Source: City of Seattle DPD.*

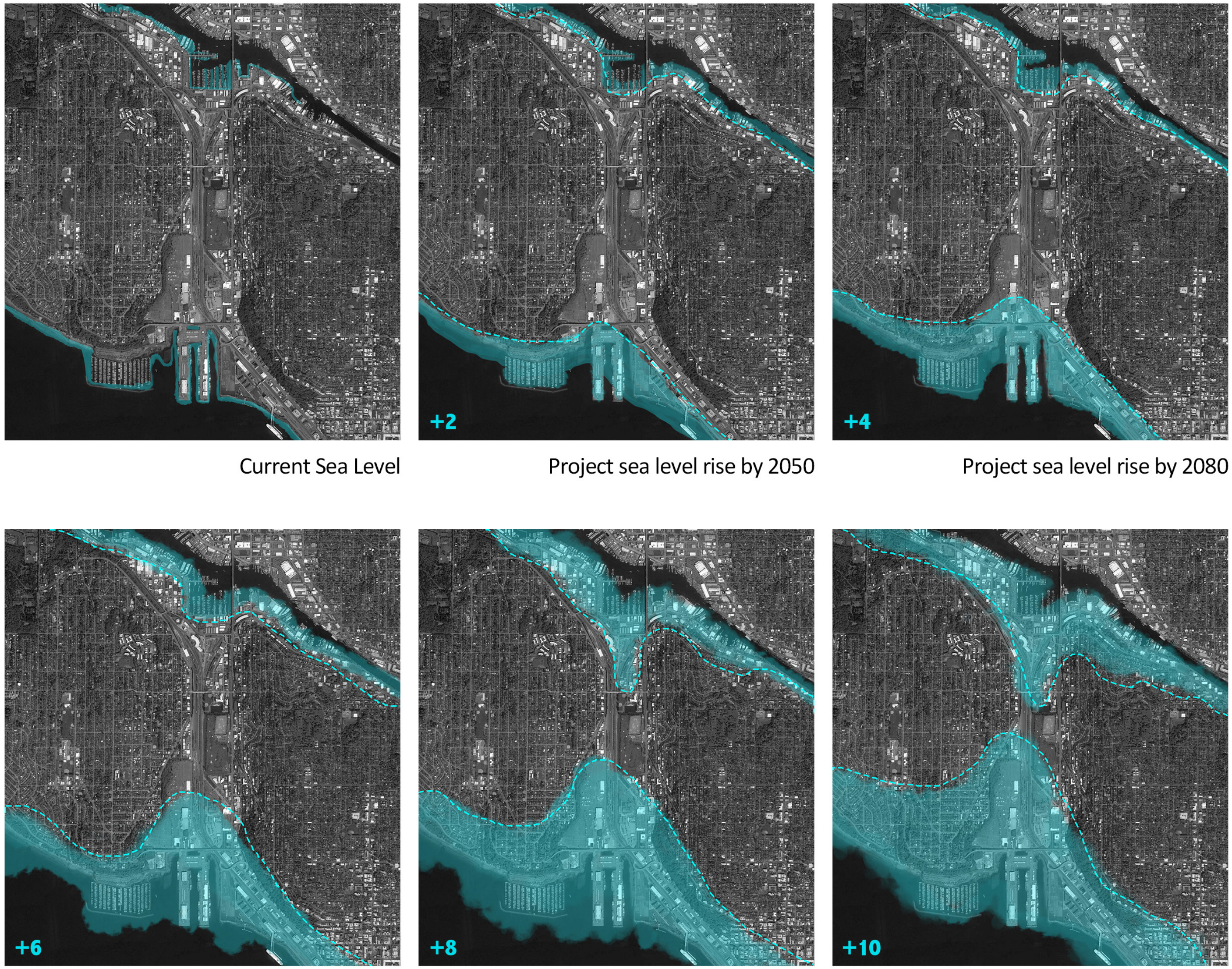
### 3.3. High Flood Risk

Section explored the problem of how flood protection could be designed for the sea level rise of Interbay of Seattle. The flood protection that keeps Seattle dry during extreme weather events will only serve this purpose for a small percentage of its lifetime. It is essential that it be designed as an improvement to the city's coastline, which can be enjoyed by citizens on a daily basis. To make this work, flood protection features must become part of the life of the city.

In the Seattle Interbay Area, the water along Seattle's Puget Sound shoreline has risen by more than 6 inches during the past century. Climate change is expected to accelerate rising sea levels during the next century. Mean projections indicate that Seattle will experience 7 inches of sea-level rise by 2050, and 24 inches by 2100 (GGLO Design, 2015). While chronic inundation is a concern, sea-level rise impacts will first be noticed episodically with more frequent tidal flooding events.

Figure 30. The simulation allows wetland area in south Interbay. Flood protection features must become part of the life of the city.

## High Flood Risk




Current Sea Level

Project sea level rise by 2050

Project sea level rise by 2080

Project sea level rise by 2100

Project sea level rise with a 100-year flood

Project sea level rise with a 500-year flood

Figure 31. High flood risk in Interbay

### 3.4. System Analysis - Green Space

In my investigated, I found three types of open space around the Interbay: 1) passive; 2) active; and 3) scenic. Passive landscape is defined as a space that provides opportunities for less intensive recreation, i.e. strolling, seating, people-watching and dog-walking. Active landscape is for formal recreational and cultural events, i.e. active sports and events including soccer, basketball and music concerts. Scenic landscape is greenery or landscaping that provides very little recreational opportunities and is mostly used for ornamental decoration and often put in places that are highly inaccessible but easy to be viewed i.e. slopes, highway underpasses.

Furthermore, just only one corridor Magnolia and queen Anne. Many of these streets are separated by roads and buildings. Geographically, salmon bay offers a central location that has the potential to connect the parks and establish a more systematic network of green infrastructure. This new green infrastructure has the potential to provide ecological functions such as stormwater filtration, food production, biodiversity and energy saving.

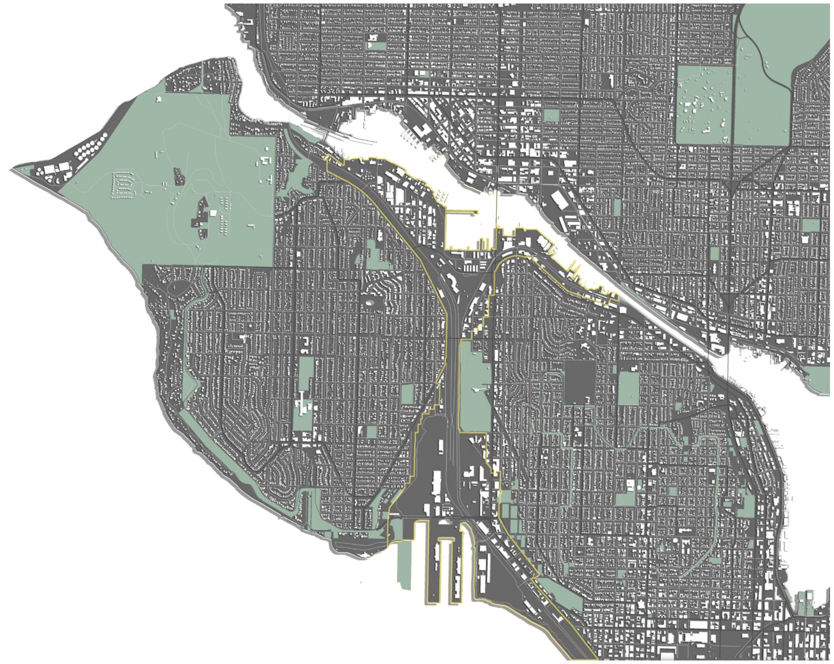


Figure 31. Existing site of green space

| Problem | Solution |
| --- | --- |
| Natural land cover is limited to small, fragmented patches dispersed throughout the area. | • Incorporate green infrastructure.<br>• Foster urban agriculture.<br>• Increase and improve habitat within the urban network. |

Table 3: Green space problem and solutions.

**Transportation System**

The circulation network for the Interbay includes a system of multi-modal pedestrian-friendly streets, sidewalks, transit routes and bike paths which will reconnect the City of Seattle's Interbay. The street network is one of the most important components.

Throughout the Interbay area, the circulation system will encourage people to access and enjoy new community parks, walkways, open space and restored Interbay.  Connectivity – Connections between the Magnolia and Queen Anne neighborhoods by extending the existing street grid. New view corridors, and access points, allowing safe transport over the bluff and an active railroad in the future.

Local traffic – Magnolia is isolated from the rest of the city due to the presence of rail infrastructure in the Interbay area.
Pedestrian environment – Create a walkable environment, with design adjustments to accommodate a comfortable blend of opportunities for people moving on foot, and using bikes, transit, commercial and personal vehicles.

| Problem | Solution |
|---|---|
| Natural land cover is limited to small, fragmented patches dispersed throughout the area. | • Incorporate green infrastructure.<br>• Develop multi-modal greenways (functioning for both people and habitat).<br>• Create community gathering spaces.<br>• Increase local access to open space.<br>• Transform Interbay's identity |

Table 4: Transportation problem and solutions.

Figure 32. Existing site of transportation

## Soils

Modified Land (Mc and Mf)

The term "modified land" is used to describe surficial geologic conditions that have been "modified" by human activities such as, but not limited to: cutting (Mc), filling (Mf), grading, leveling, sluicing, and shoreline protection.

Alluvium (Ha)

Alluvial soils were transported and deposited by water in streams, rivers, and creeks. They are typically comprised of silt and fine to medium sand, but the size of the particles in a particular deposit depends on the velocity of the water at the time of deposition.

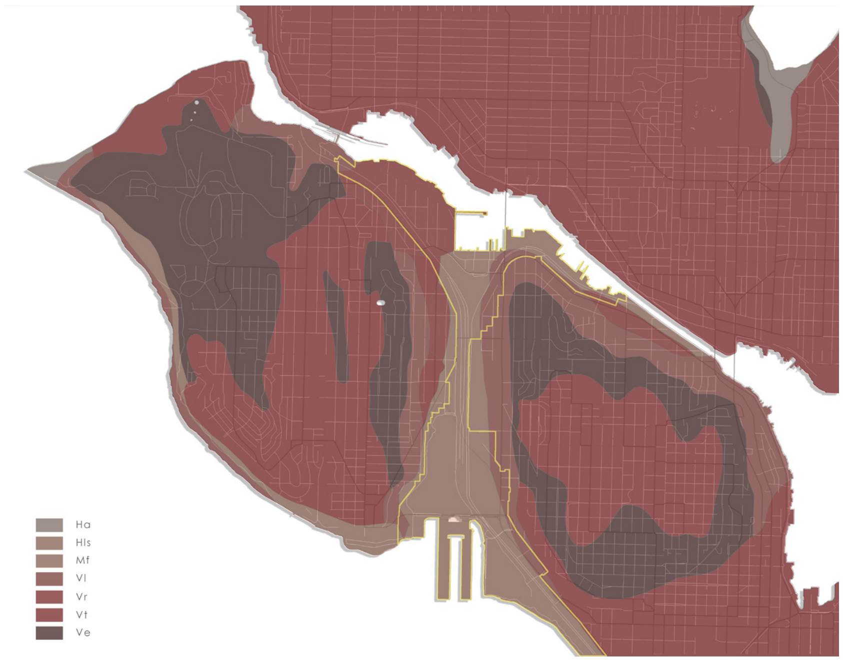



Figure 33. Existing site of soils

Recessional Outwash (Vr)

Recessional outwash was deposited by meltwater streams emanating from retreating glaciers during the last episode of glaciation.

Glacial Till (Vt)

Glacial till typically consists of a heterogeneous mix of gravelly sand with scattered cobbles and boulders in a clay/silt matrix.

Advance Outwash (Ve)

Glacial advance outwash soils were deposited by meltwater streams emanating from advancing glaciers. Advance outwash is similar in composition to recessional outwash, except it has been glacially over-ridden.

**Land use**

Industrial uses 70% industrial area, such as clothes, glasses. Interbay covers just over 407 acres – 100 acres in communication, utility, and transportation uses reflecting the port and rail activities, nearly 100 acres in warehouse facilities, and just over 60 acres in manufacturing activities. 32% of the area is in public or railroad ownership.

**Contours**

• Flat valley floor.
• Topographic between corridor and adjacent neighborhoods.

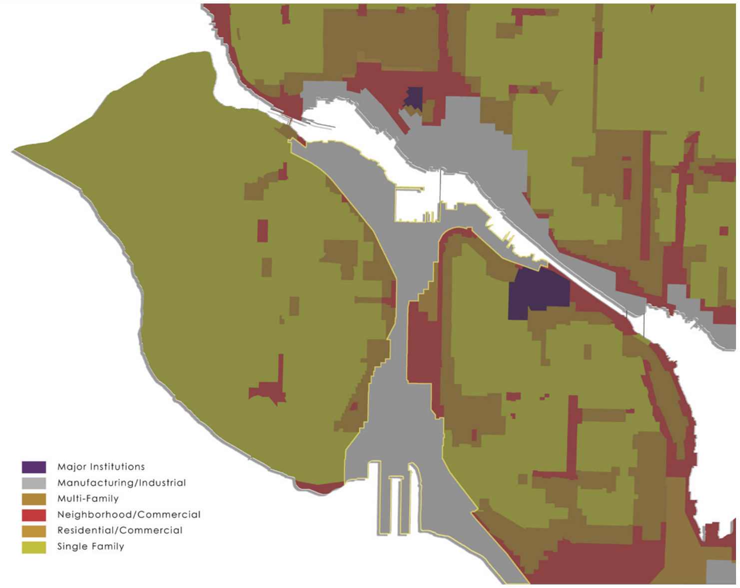



Figure 34. Existing site of landuse

Figure 35. Existing site of contours

### 3.5. Vision

When climate change and temperature rise, it is not only effect natural but also change human activities. Design proposals of this project are to re-transform the Interbay from a channelized and single-functional channel to multi-functional corridor of significant natural and cultural value, to reuse stormwater and improve ecological environment of the Interbay, to create green infrastructures which place an emphasis on balancing the restoration of habitat and watershed with the accessibility and recreation for people within the maze of pre-existing infrastructure, to create a synergy that elevates an urban riverfront landscape to a thriving and harmonious balance of complex systems, and to regenerate for developing to bring new life and investment to nearby urban settlements.

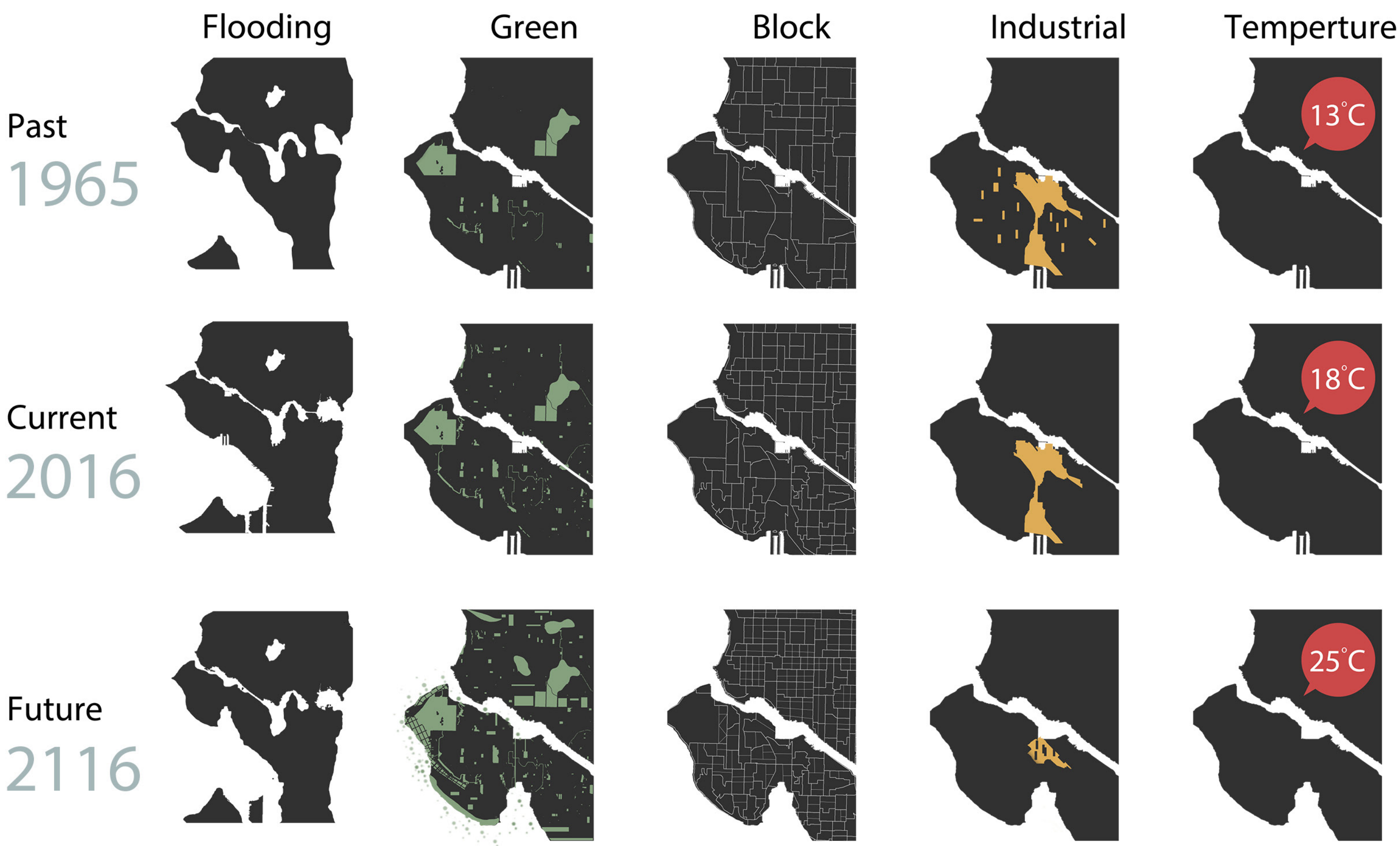



Figure 36. Analysis of Interbay area.

# FUTURE

# ?

## CHAPTER 4: DESIGN PROCESS

### 4.1. Design Concept

The design of the site specifically addresses the goal of applying green infrastructure at a site scale to help increase sustainability and resilience to coastal climate change impacts of sea level rise and flooding.  This thesis applies the findings and discussions on sea level rise and green infrastructure in Interbay, including community, park and coastal. Congregate, Connect, Cleanse is a design response to the vision to form a cohesive landscape that creates values through social, ecological means along the Interbay area of Seattle.


Figure 37. Design concept diagram

As the bay is restored for natural habitats and a place of learning, it also creates an opportunity for an iconic architectural element that captures the imagination of this park system, as well as affords a spectacular view.

By increasing awareness and connection to nature, this Green River Corridor project can begin to heal the riverfront. The ecological services of this park system in the environs of the Estuary shall include: storm-water/sea-water treatment strategies in the form of salt marshes, constructed wetlands, and vernal ponds.

Groves of trees act as screens along the paths to break up spaces and provide natural habitat. Other ecological services would include food production, plant selection to maximize bio-diversity, and the creation of wildlife habitats.

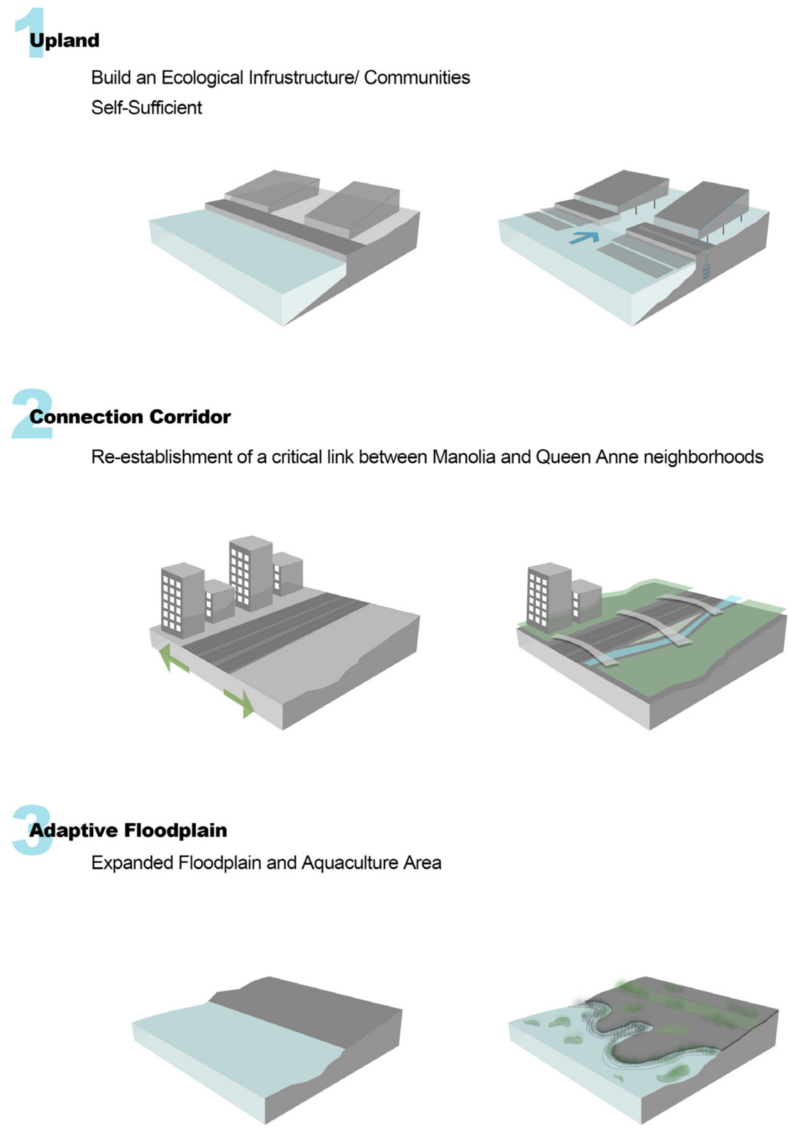



Figure 38. Concept diagram-1

**Congregate - Community: Upland**

• 20-50 years- Let It Raise • 50-100years- Let It Flood

Commercial Developments / Propose high density residential, commercial and mixed-use buildings along the bay as the solution for the expanding of Interbay and the increasing population. Community area provide two element. Firstly, to minimize the use of energy through passive design measures and, secondly, to maximize the use of sustainable and renewable energy sources.

**Connect - Park: connection corridor**

A plan to redevelop the river as a critical ecological, industrial, and cultural resource for the city.

Let Us Go – Create Connection / Reconnecting the site to cities.

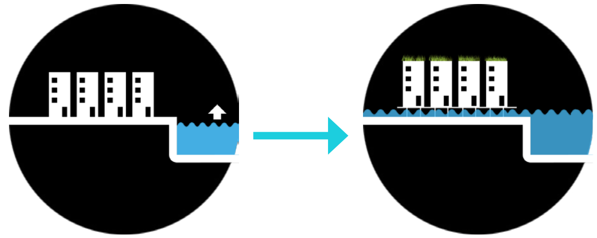
three main bridges are proposed on the bay and the railroad which connects Magnolia and Queen anne to form a complete trail system, making the bay more accessible to public. I do not broken the industrial area pattern. But, adding participative design to supply two concepts, which is food productive and fabrication produce.

**Cleanse - Coastal: adaptation floodplain**

Let It Grow – Wetland Restoration, Urban Agriculture and Reforestation.

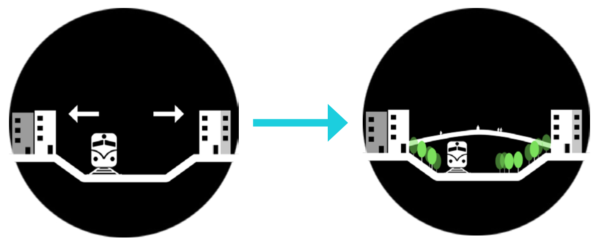
The proposed ecological framework will adapt to the site condition over time. Bringing back wetlands that clean and improve overall water quality while providing refuge for animal species. Promoting Urban Agriculture in the neighborhood will establish healthy and sustainable food access to populations in needed.

## Community: Upland



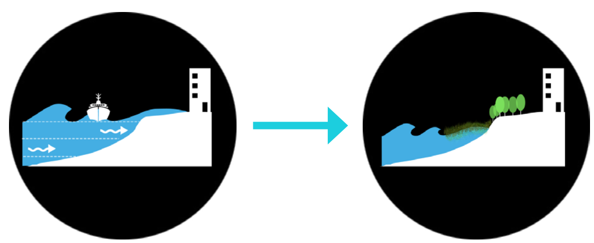
Build an Ecological Infrastructure/
Communities. Self-Sufficient

## Park: Connection Corridor



Re-establishment of a critical link between
Magnolia and Queen Anne neighborhoods

## Coasts: Adaptive Floodplain



Expanded Floodplain and Wetland,
Aquaculture Area

Figure 39. Concept diagram-2

## 4.2. Design Strategy - Program

This is not simply a park plan. Rather, it is a strategy for transforming the larger urban fabric, and the everyday lives of locals and visitors alike. It does so by tapping into larger systems—infrastructural and ecological—and by extending its physical reach across the Ballard, Magnolia and Queen Anne into outlying neighborhoods.

The strategy is flexible, and therefore sustainable: environmentally, urbanistically, and economically.  Importantly, it is a 50- to 100-year plan, a series of parks and neighborhoods for the next generation of Seattle people. In this way, the various proposals contained herein will help guide these places' gradual transformation, making for new kinds of parks and public infrastructures, for new working ecologies and landscapes and city fabrics that will come to revitalize Seattle for decades to come.

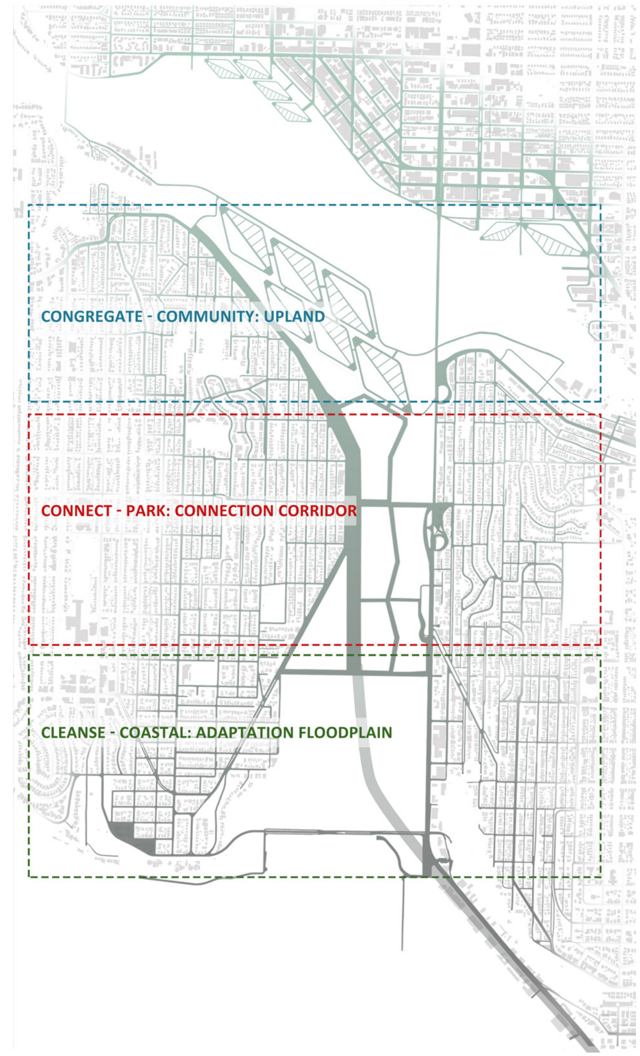



Figure 40. Program diagram

**Mobility**

Pedestrian and bikeway system will be created along the Salmon bay. In the flood period, riverwalk in the low water level will be covered by bay water.

The Interbay-park area can become one of the major green-blue parkways of Seattle , providing significant public spaces with recreational and educational opportunities for both residents and visitors. Programming includes baseball fields, tennis and basketball courts, playgrounds, a track, community gardens, farmer's market, possibly even a museum, and small-scale housing development. Pathways can be developed for pedestrians, cyclists, in-line skaters, and runners.

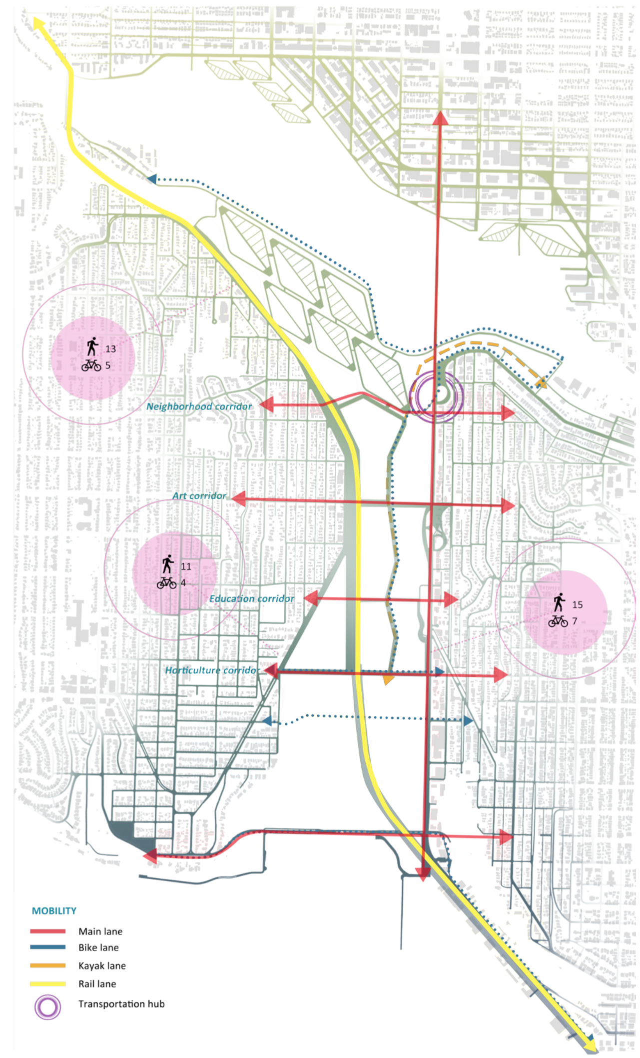


Figure 41. Molility diagram

## Water

The backbone of the program is the creation of a new ecosystem, a stormwater cleansing system that connects the existing open space to Interbay and creates values. The proposed stormwater cleansing system intents to link Elliott with the regional open space program to form a ecological network.

The proposed stormwater cleansing system will serve three major purposes:
1. Reduce stormwater surge and improve the quality water quality
2. Reintroduce biodiversity and habitat communities
3. Provide opportunities to increase human interaction with ecology by creating different types of spaces that promote recreation activity (jogging path along the wetland), passive activity (seating facility and overlook decks),and interaction (water path).

The program features three types of spaces: neighborhood, public and education. The intent of these spaces is to facilitate outdoor learning experience in sustainability and ecology. The new ecosystem can not fully function in an urban setting like Salmon bay without systematic and efficient circulation system.

The new proposed non- motorist circulation network addresses different user groups: bikers, joggers and pedestrians. The active circulation system of bike and jogging trails is separated from pedestrian circulation to minimize potential conflicts between the two user groups.


Figure 42. Water diagram

## Habitat

Engaging hybrid, systematic approaches to dealing with storm water runoff, river surge, and sea rise collectively in Interbay, this thesis set up a study and design model for urban flood prevention and urban refinement adaptive strategies without eliminating existing civil engineering solutions. Combining soft and hard solutions makes possible more environmental and sustainable solutions. Soft solutions can find their home on or adjacent to hard solutions to meet a collective goal of sustaining beauty for the city in the future and providing more amenities for people. Water is treated not as an enemy but as a welcome friend, transforming the character of the city.

Ecosystem is a system formed by interaction of living and non-living organisms. Ecosystem provides critical services and functions to our society include air purification, water cleansing, recreation, cultural implications, food and resources. By introducing a new ecosystem to the site area that connects Salmon bay with existing open space programs, it will strengthen the ecological network in the area and hence the overall ecosystem services and functions.

The wetlands of the South Interbay are a major urban biodiversity reservoir in the Seattle. Documented species include more than 260 species of birds, 22 mammals, more than 51 species of fishes and bees and 420 species of plants. Wetlands make up 340 acres of the South Interbay and include brackish and freshwater marshes.  Because of small height differences there are plentiful transition areas between low (wet) and high (more dry) habitats as well as salt and freshwater habitats. These create a great potential for biodiversity.

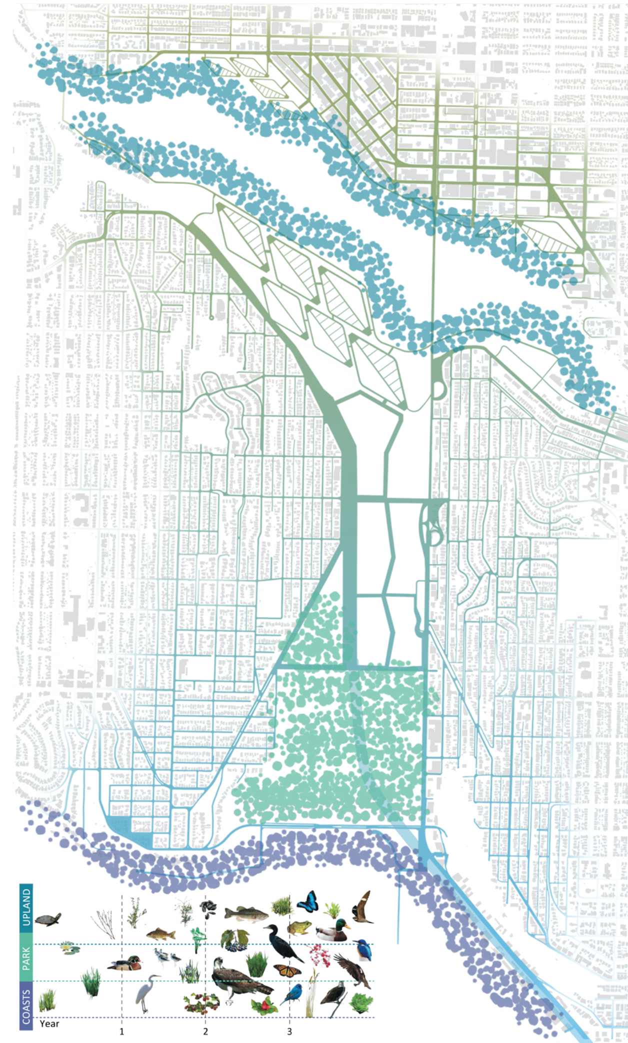


Figure 43. Habitat diagram

### 4.3. Deaign Evolution

A strategy for transforming the larger urban fabric, and the everyday lives of locals and visitors alike. It does so by tapping into larger systems— infrastructural and ecological—and by extending its physical reach across the Ballard, Magnolia and Queen Anne into outlying neighborhoods. It is a strategy for transforming the larger urban fabric,and it is flexible, and therefore sustainable: environmentally, urbanistically, and economically.

The design evolution are sea level rise different phases, a 20- to 100-year plan, a series of communities, parks and coastal area for the next generation of Seattle people. In this way, the various proposals contained herein will help guide these places' gradual transformation, making for new kinds of parks and public infrastructures, for new working ecologies and landscapes and city fabrics that will come to revitalize Seattle for decades to come.

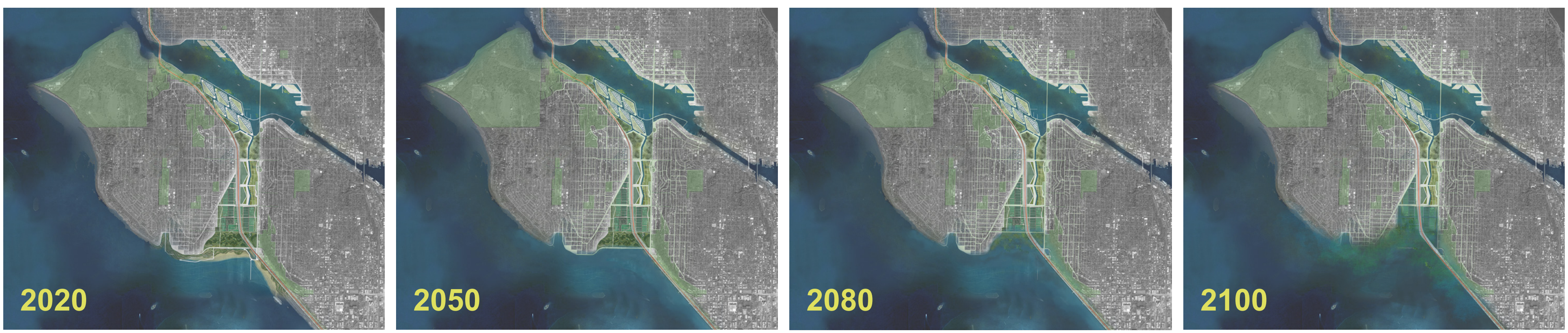



Figure 44. Design evolution

The design of the site attempts to create a framework of green infrastructure that can accommodate and facilitate the adaptation of rising water levels and vegetation shifts predicted with sea level rise.  The ecological function of the bioswales could improve the ability of the site to be resilient to small disturbances (i.e. a low level of sea level rise).  The design is meant to be a conceptual intervention into the landscape that could help bring resiliency and function to the site.

The buildings on site could be designed to accommodate raising the structures and occasional flooding. And structures such as the kayak and canoe storage facility could be designed as open to the air and would accommodate occasional flooding.
Simple structures such as the day use pavilion and kiosks could be designed to be elevated at a later date, as threats of rising waters become more apparent.

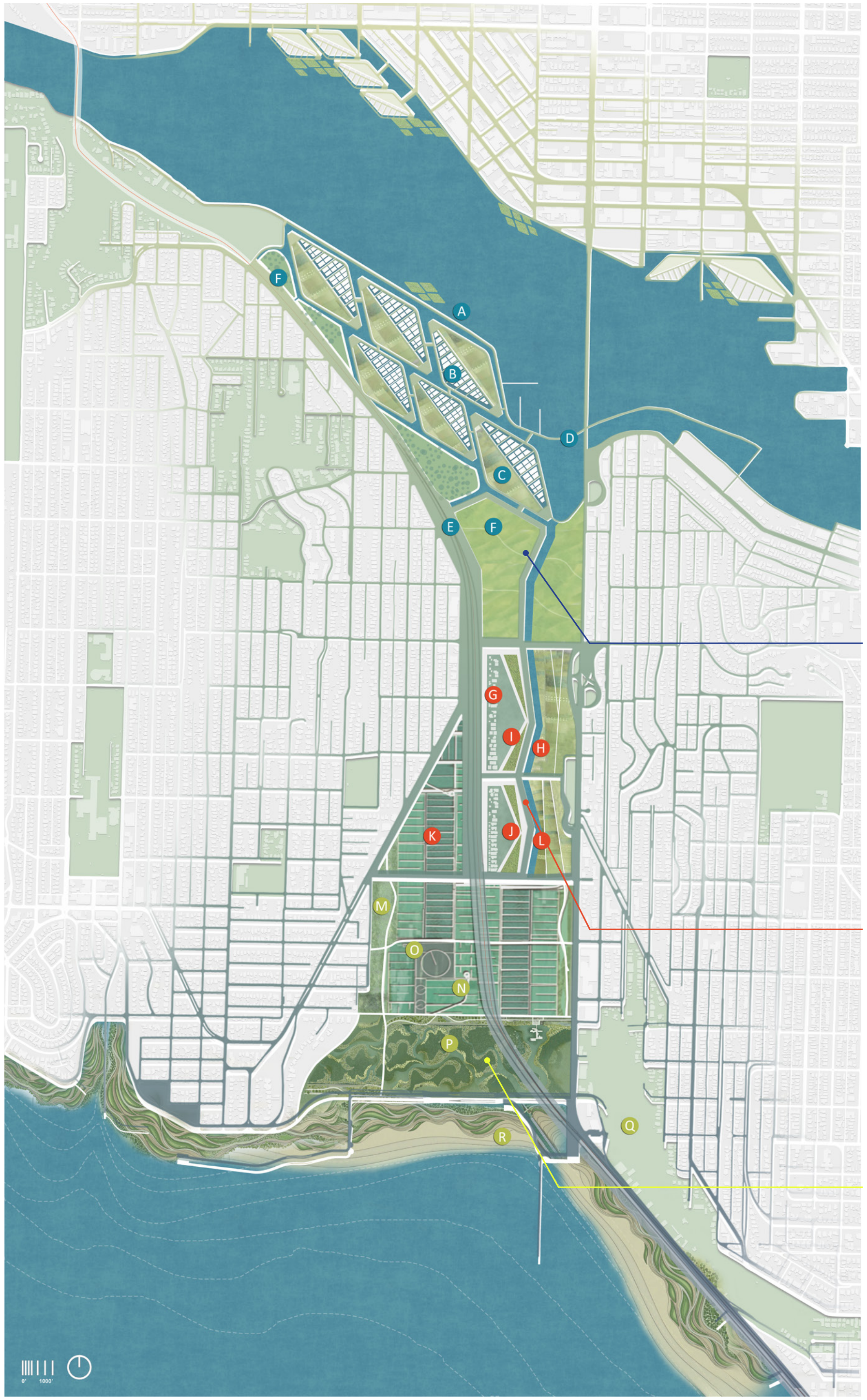
The process of coastal retreat would also be set in motion by this design. First, the vulnerable populations living in vulnerable housing would be relocated already into safe, accessible housing on higher ground, removing the risk of having residents on the site.

Secondly, the system of bioswales begins to enable a trajectory of ecological restoration back to a more natural state. The swales would provide conduits for water to migrate, similar in function to natural salt marshes.

### 4.4. Overall - Amphibious City

This scheme for the site seeks to create a landscape and building which add amenity to the neighborhood and create space which does not merely improve the water management of the area but the quality of life as well for those who live in the development, the bayview, and the city.

The project focuses on the design of strategic relationships between larger social, natural, civic and ecologies. Physical concepts for the three parts which is high density community, park and coast area. The site proposes a set of creative, inter related design initiatives that function at multiple scales.



**COMMUNITY: UPLAND HIGH DENSITY URBAN EDGE**

- A Salmon bay area wetlands
- B Mixed-use residential
- C Community garden
- D Bike path
- E Rail line
- F Recreational park

**PARK: CONNECTION CORRIDOR**

- G Industrial area
- H Aquatic gardens
- I Bike station
- J Farmers market
- K Urban agriculture area
- L Kayak

**COASTS: ADAPTIVE FLOODPLAIN**

- M Urban farm and greenhouses
- N Wetland Eco-lab park/overlook terrace
- O Tree nursery factory
- P Wetland machine
- Q Energy forest
- R Beach park

Figure 45. Design overall plan

## Design Topography

The study of these design priorities at various scales created a scope which helped inform specific design strategies to address current site issues and opportunities. It also helped me understand the relationship between different parameters at different scales.

The design topography is base on the currently topo, the site specific demonstration sites create anchors at strategic locations along the Interbay that establish the foundation for a vision for the Seattle that will support the region's neighborhoods that are rich with cultural and ethnic diversity, artistic production, and multi-scaled industrial business served by freeway, rail, and barge.

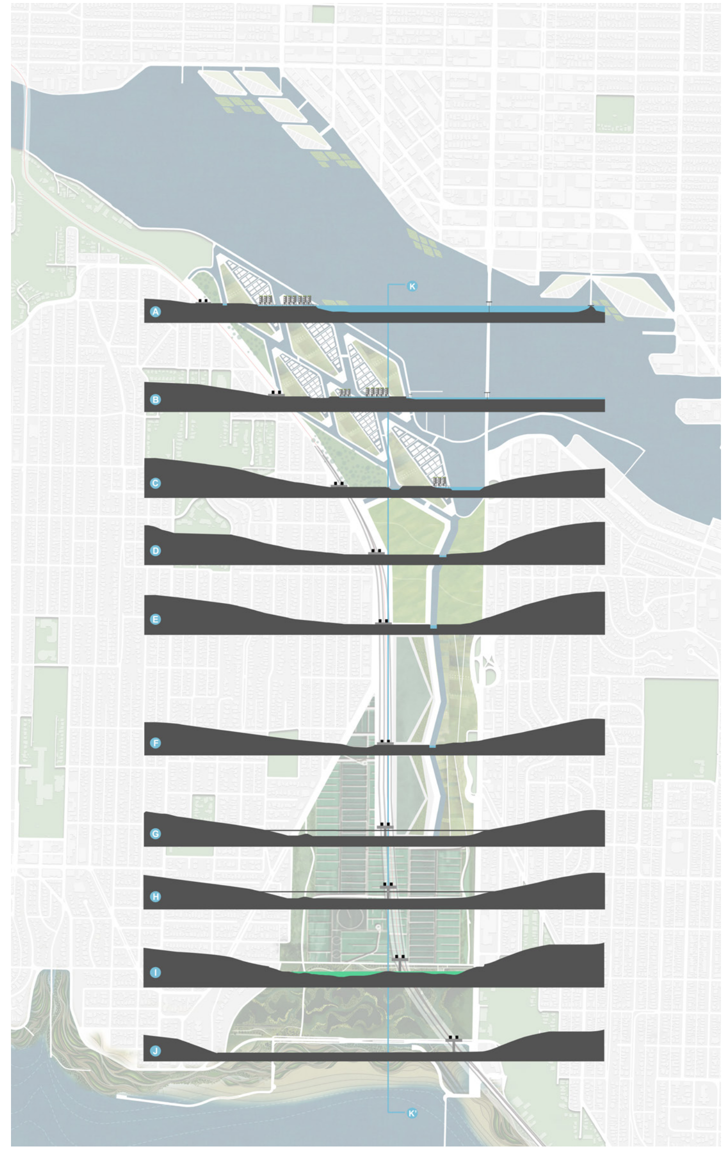


Figure 46. Design topography

## 4.5. Detail: Congregate - Community

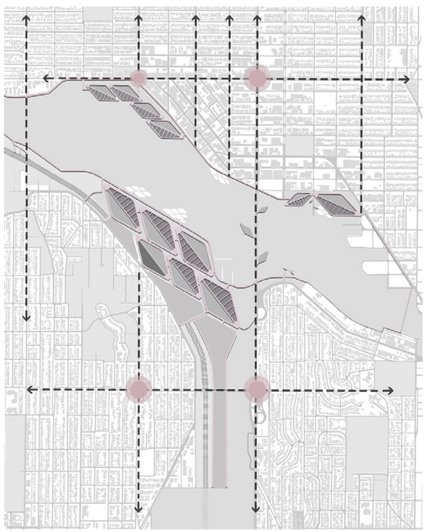
The site plan creates a gradient of spaces designed for bay ecology and people. Higher density housing is mixed with small-scale commercial and retail use at the middle portion of the site, bay-side canal and linear park create a lively neighborhood destination for culture, and arts programming.


Figure 47. High density community view

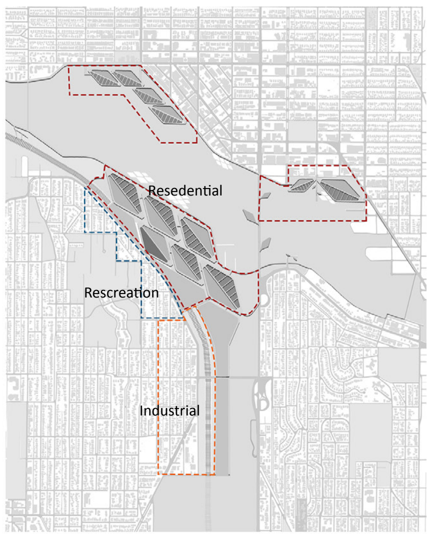
## Design program

Community area is very much a working landscape, one that cleans the site—and the city - as it grows. It supports a full range of social and recreational activities, and ecological life: nesting sites, skating canals, fields for flying kites, vibrant meadow habitats.

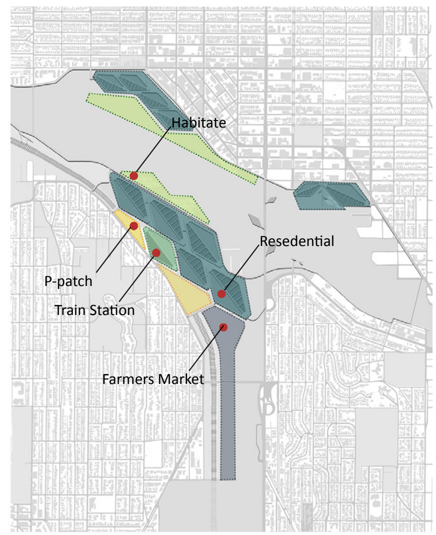
Extension



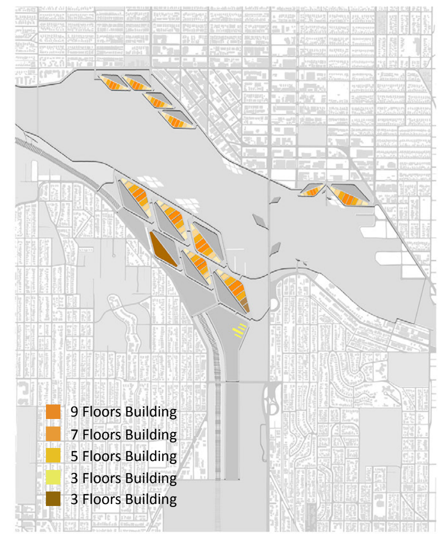
Program



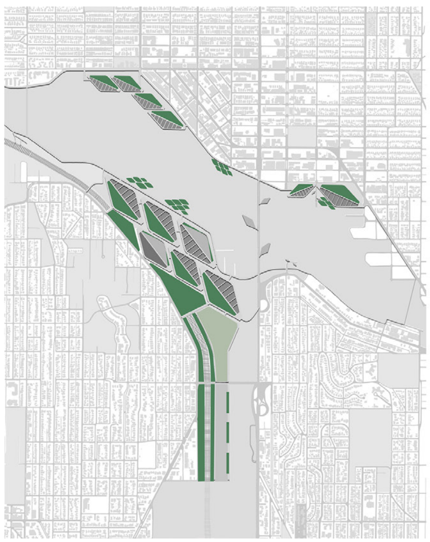

Configuration




Building Heights

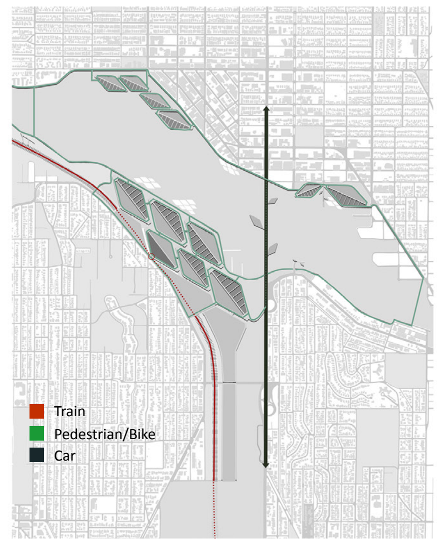


Green Network



Drainge System

Circulation




Mutificational Landscape

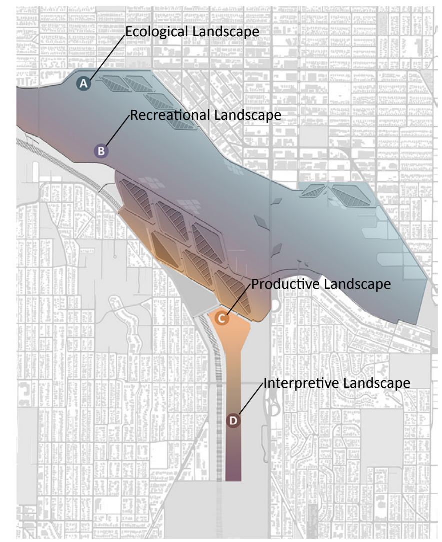



Figure 48. Community area program

**Community overall strategy**

The overall strategy for sustainability takes its starting point in the LEED Neighborhood Development rating system. This will ensure a thorough process and create an area residents can be proud of, while making it an exemplary neighborhood for future developments in flood prone areas around the world.

For optimal sustainability the site and buildings should be designed, firstly, to minimize the use of energy through passive design measures and, secondly, to maximize the use of sustainable and renewable energy sources.

| | |
|---|---|
| RESIDENTIAL - Low to Medium Density | |
| RESIDENTIAL - Medium to High Density | 500-600 units |
| MIXED USE - Arts, Commercial & Residential | 100,00 SF |
| COMMERCIAL | |
| CULTURE & COMMUNITY / INSTITUTIONAL | 80,00 SF |
| WATER AREAS | 3.5 Acres |
| RECREATION | 6.5 Acres |
| NATURE PRESERVE | 35 Acres |

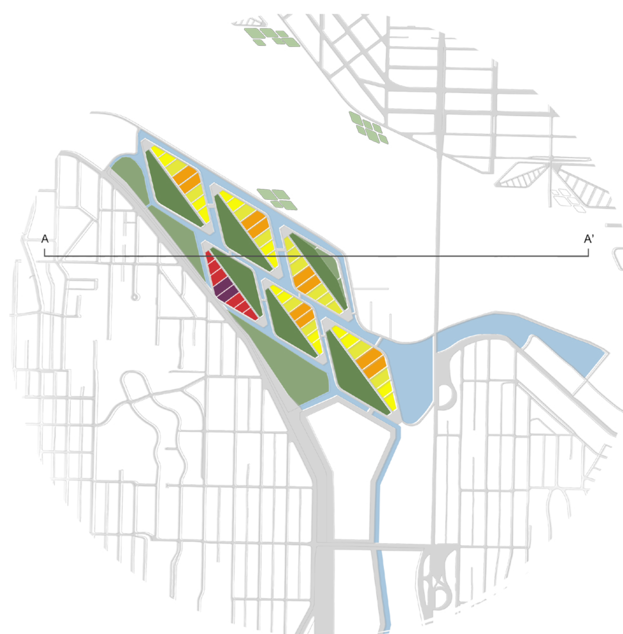



Figure 49. Landuse of community area

Seattle sunshine time is very short, so take advantage of the sunshine slanting roof elements allow easy access to the interior. In front of each community the open public space provide agriculture and production.

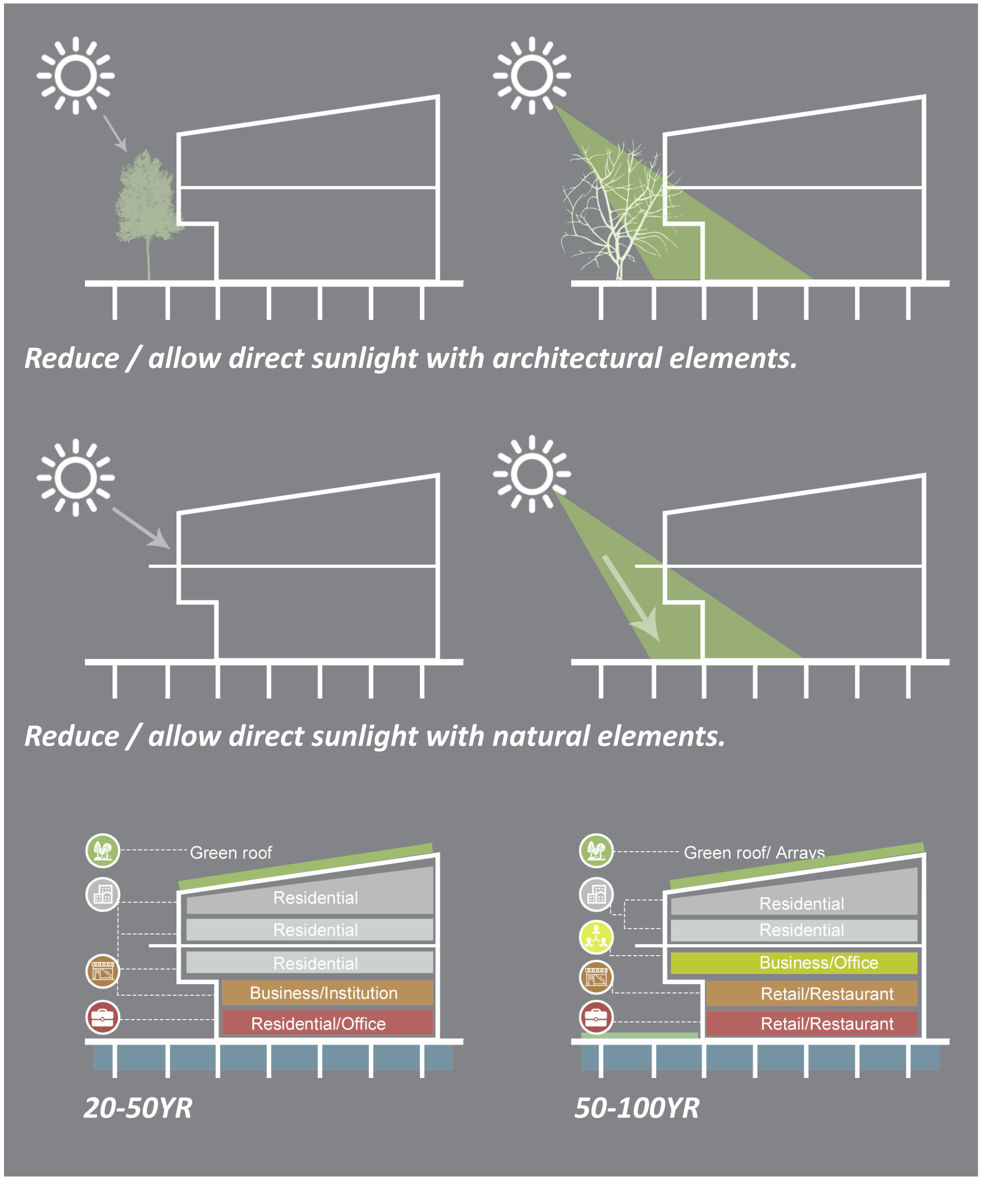



Figure 50. Building concept diagram-1

The building is made out of timber and sits within a steel barge. The reason for timber construction is that wood is a light building material.  A steel barge is used due to its low corrosive rate in salt water and is not harmful to the water on which it floats.

To ensure necessary ballast and waterproofing, concrete slabs are inserted on top of Expanded Polyeurethane Foam blocks inside the barge. The wooden structure on a concrete foundation within a steel barge gives the house a low center of gravity, which promotes stability.

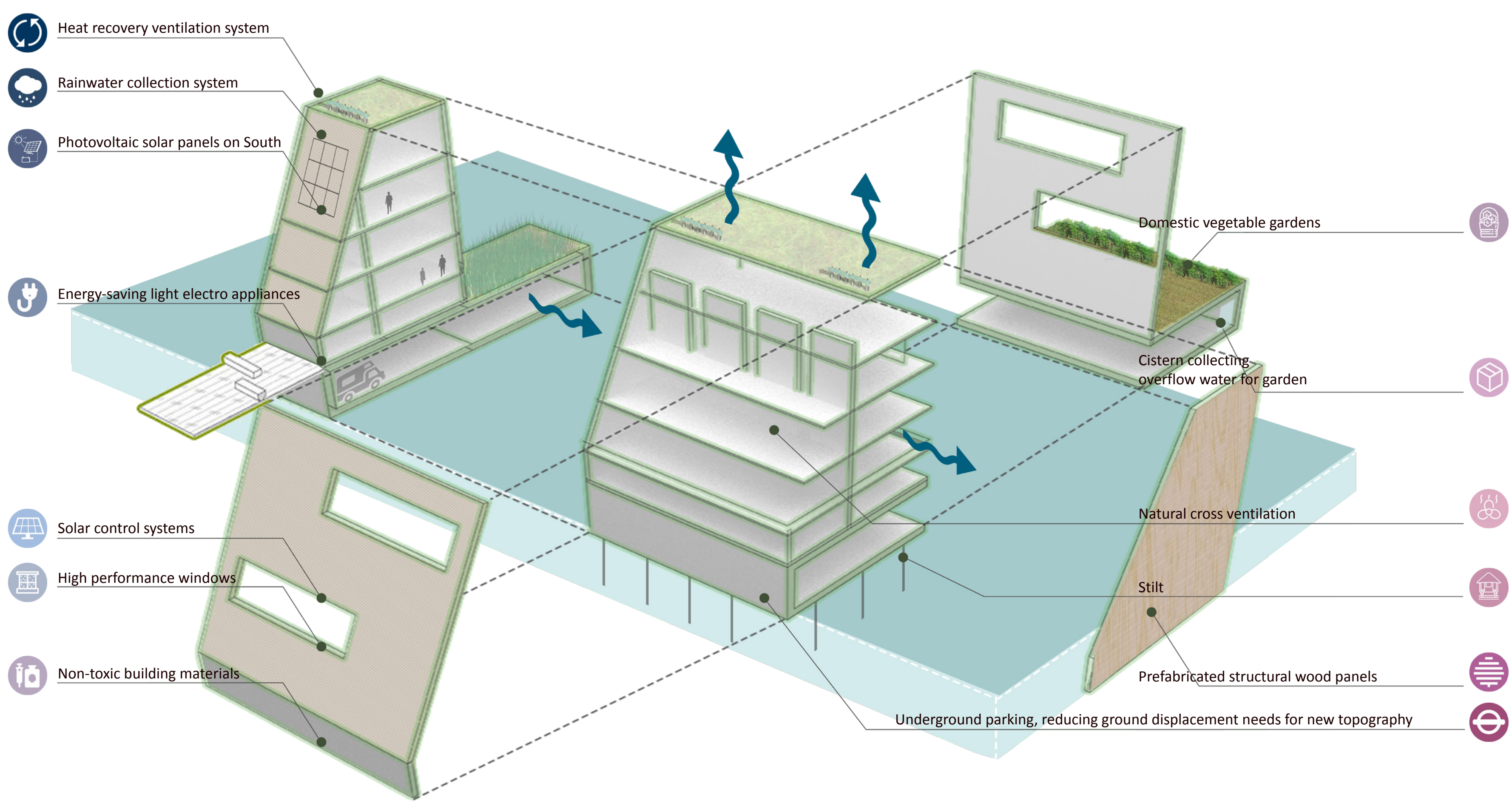



Figure 51. Building concept diagram-2

Figure 52. Amphibious city - Building view

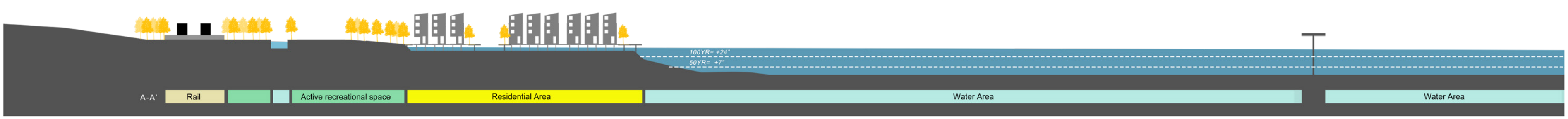



Figure 53. Amphibious city section

## Welcome to the new lifestyle of the Resilient bay

Among the new residential communities, the flagship is a flooding neighborhood.

I envision a truly 21st Century lifestyle adapted to the local climate. The neighborhood will be built with the most innovative on-site infrastructures for water, waste, and energy. Residents can work in the surrounding biotech, art, and education corridors or commute by bicycle or streetcar from Ballard to Interbay. Community gardens, tree nurseries, and biofuel farms will occupy remediated sites. Citizens will be engaged in the cycles of production, learning more about where their food, energy, and other landscape resources come from.


Figure 54. Sustainable building

**Connect - Park: connection corridor**

Let Us Go – Create Connection / Reconnecting the site to cities.
three main bridges are proposed on the bay and the railroad which connects Magnolia and Queen anne to form a complete trail system, making the bay more accessible to public. I do not broken the industrial area pattern. But, adding participative design to supply two concepts, which is food productive and fabrication produce.


Figure 55. The park view

**Create Connection/ Industrial strategy**

It is combines public open space with the emerging tendency of urban food production and the ecological balance. The main goals were to the industrial area, to promote the practice of agriculture and to provide recreation. Citizens will be engaged in the cycles of production, learning more about where their food, energy, and other landscape resources come from.

Productive urban agricultural lands have replaced an area once home to heavy industry.

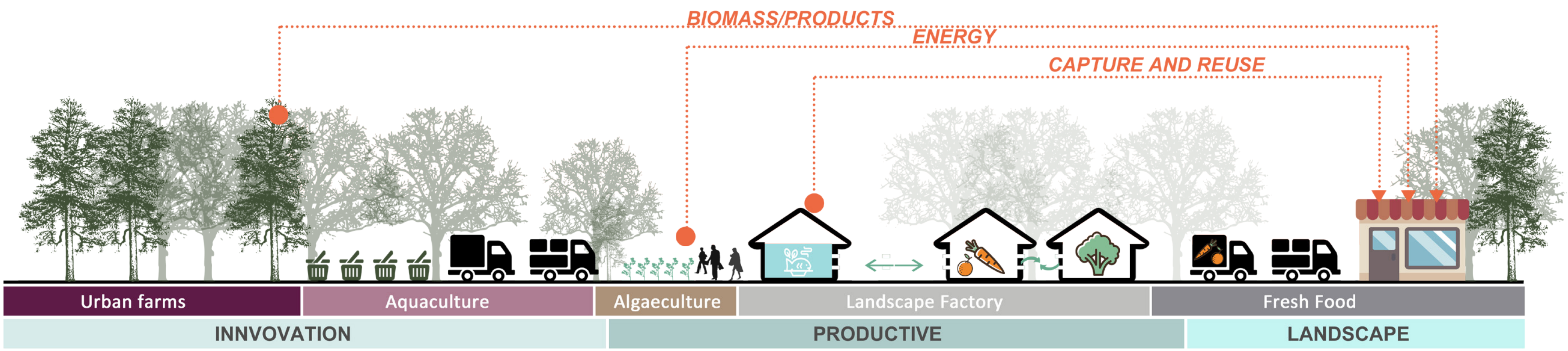



Figure 56. Industrial area diagram-1

The design concept for Eco-productive Park combines public open space with the emerging tendency of urban food production and the ecological balance. The main goals were to restore the river habitat, to promote the practice of agriculture and to provide recreation. Many allotments for horticulture set the design of the space and offer color and texture in the wide central area of the park.

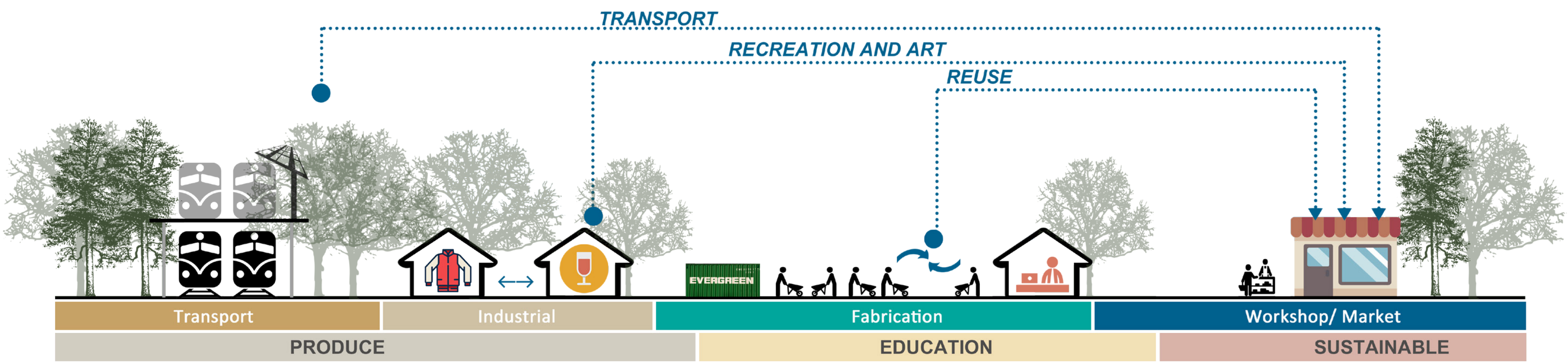



Figure 57. Industrial area diagram-2

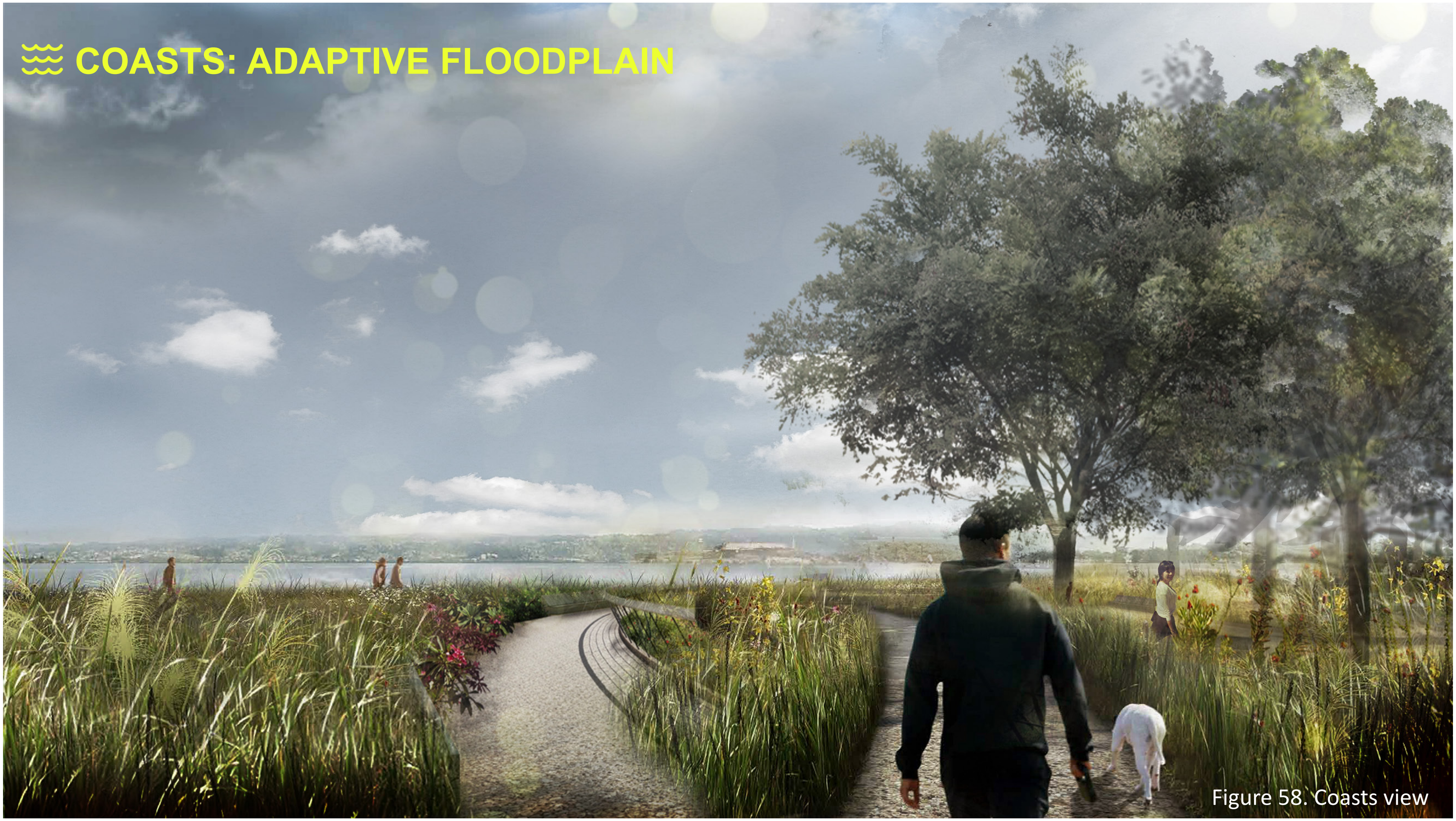


Figure 58. Coasts view

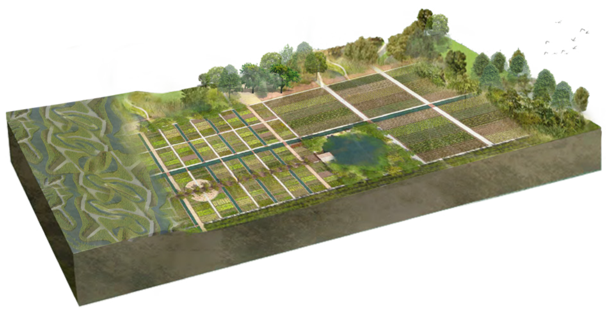
**Cleanse - Coastal: adaptation floodplain**

Let It Grow – Wetland Restoration, Urban Agriculture and Reforestation.
The proposed ecological framework will adapt to the site condition over time. Bringing back wetlands that clean and improve overall water quality while providing refuge for animal species. Promoting Urban Agriculture in the neighborhood will establish healthy and sustainable food access to populations in needed.

Each studied type presented a different way of understanding the relationship between ecology and human activity. Whereas some typologies focused more on providing seating opportunities that provoke an appreciation of nature and its services, other typologies stressed more on creating a scenic and aesthetics promenade.

Aquatic gardens/ Kayak area

Urban agriculture area



Coasts: Adaptive Floodplain - Beach park

Figure 59. Different type of design models

**Stormwater and urban ecology wetland system**

Restoration of habitats is proposed as part of this design. Islands for wet prairie and riparian habitat will be built from recycled demolition materials and organics from the soil factory. The River will once again be a safe haven for migrating birds and other wildlife.

A water-cleansing system structures the area. Rain washes particles of soil, grit, and other materials off streets, beach and roofs in nearby neighborhoods. This stormwater is intercepted by a sedimentation chamber and periodically emptied; clean extracts of the sediment can be used in shoreline and island building. Wetlands of nutrient-tolerant species receive the stormwater next, removing fine sediment and pollutants; here indigenous wet meadow species such as sedges, cordgrass, blue-joint and wildflowers would thrive.

Plants here are able to root in water and withstand flooding: arrowhead, bur-reed, aquatic sedges, bulrush, and other marsh plants. Water then flows into the riffle stream and bivalve bed. All along are native plants, naturalized soils, and insect life which provide organic matter to the stream, forming the base of the food chain.

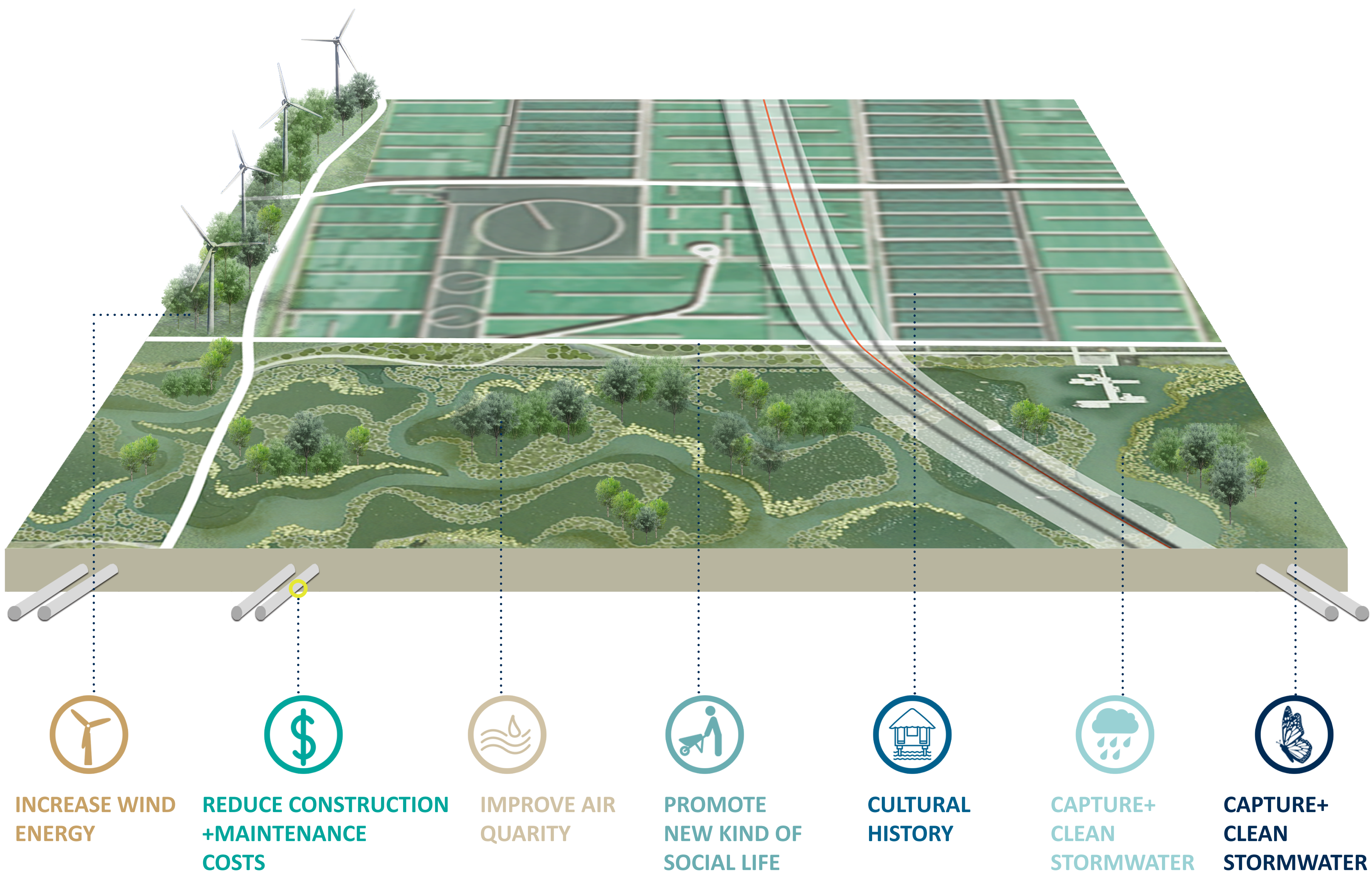



Figure 60. Stormwater and urban ecology wetland system

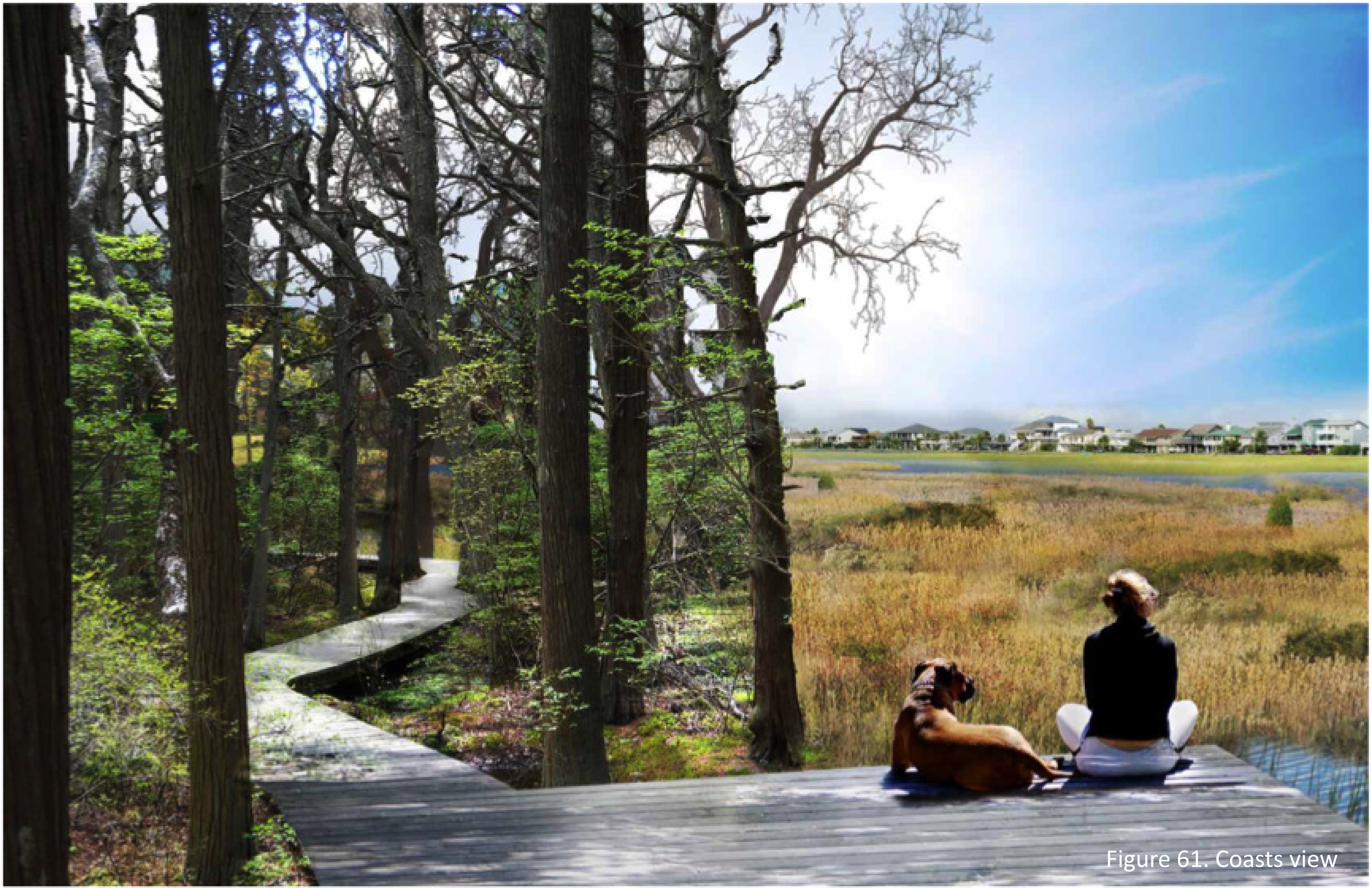


Figure 61. Coasts view

Within the coasts protected areas, existing green spaces can be used as storm water buffers. Fresh water marshes offer fluctuating water levels, forests offer soil infiltration capacity. It is important to integrate a more natural storm water catchment system with recreational functions so communities can enjoy the spatial benefits.

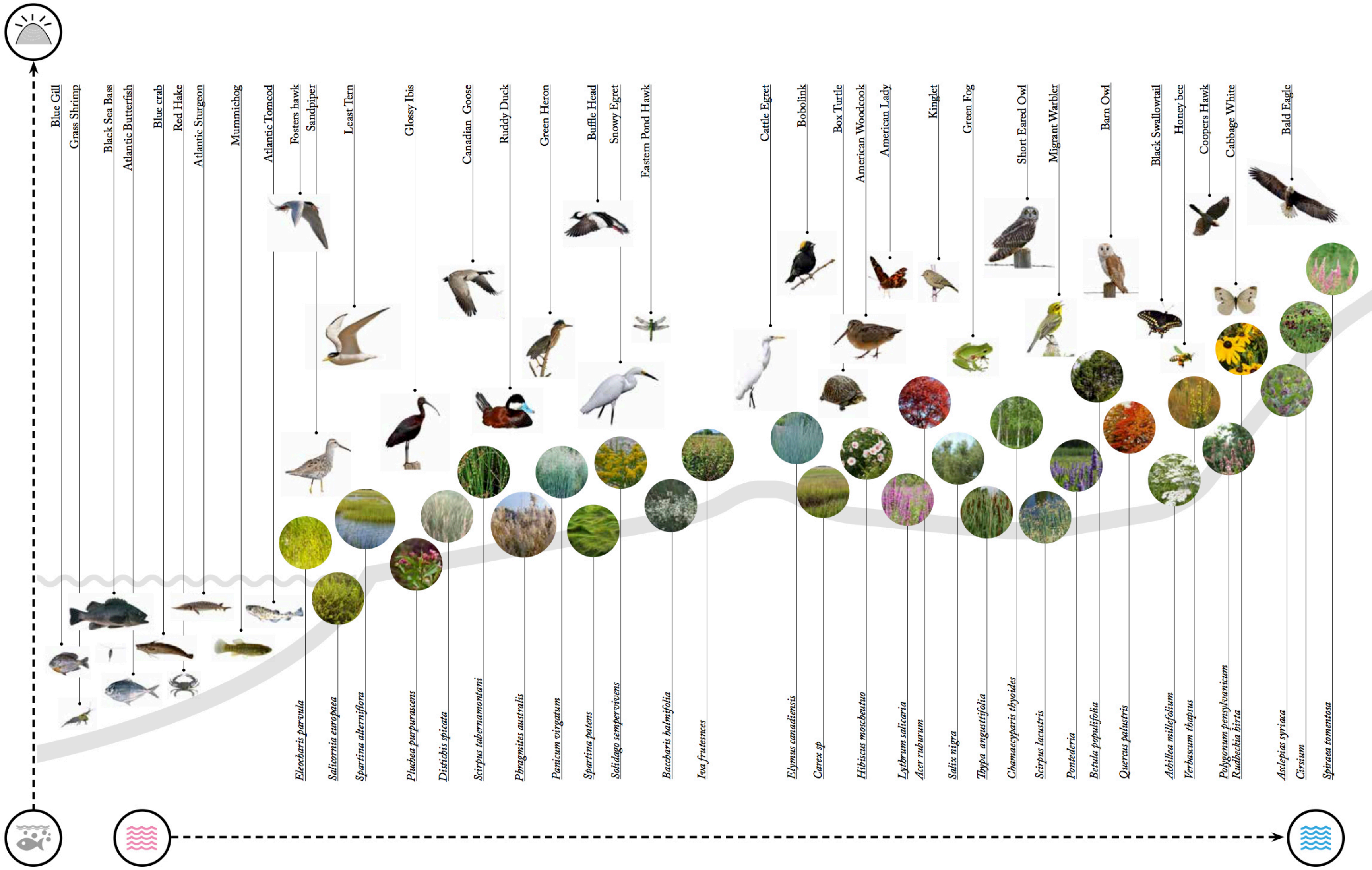



Figure 62. Biodiversity system

# CHAPTER 5: CONCLUSION

With global predictions of climate change and sea level rise threatening the future of US coastal areas, planning and design solutions that protect and adapt our coastal communities from rising waters are rapidly becoming a necessity. Green infrastructure practices such as wetland restoration, bioswales, green roofs, and rainwater harvesting/reuse are some strategies that could be implemented in coastal regions that would provide benefits to stormwater management today and sea level rise management in the future.

This thesis has used the methods of literature review, precedent design study, inventory, analysis, and design application to answer the research questions provided in the Chapter 1 of this thesis. The thesis has shown that green infrastructure can be a viable adaptation strategy for coastal sea level rise adaptation planning. By working with, rather than against, natural systems, materials and processes, green infrastructure can assist in buffering capacity for increased storm surge and rising water levels.

This thesis identifies the potential for reutilization of the Interbay, and the importance of planning for resilience to future changes. The design application inventory provides an example of site-specific inventory of sea level rise impacts. And lastly, the design of the Interbay is one example of how green infrastructure practices can be applied to a coastal site and how the landscape can reveal subtle changes to topography and hydrology as water levels rise and vegetation shifts through time.

Further scientific research is needed to define the exact quantification of the capacity of green infrastructure to protect against rising water levels and increases salinity. In the mean time, green infrastructure can be a cost-effective way to make small, incremental changes to increase future resilience in coastal communities. By working with nature's services, green infrastructure might provide some level of protection, while also benefiting ecological and community health.

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