Sea-Level Rise:
Re-imagining the Urban Edge

A preliminary investigation of the effect of future sea-level rise on the design of our built environment.

Olympia, Washington

by

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This thesis is submitted in partial satisfaction of the requirements for the degree of Master of Urban Design, Graduate Division of the University of California, Berkeley.

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Fall 2010

The thesis of Brenda Lorene Snyder, titled Sea-level Rise:
Re-imagining the Urban Edge, is approved:

Chair ______________________________ Date ______________

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University of California, Berkeley

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Dedicated to:

The Muddie Buddies, official and honorary: Annaroo, Edo, Jeff, Mish Mash, D$, Cliff, Lisa, Hugo and Alexis. I've cherished all of our *autrageous* moments together, every last one.

The ASUC Pottery Studio - for providing a very worthwhile distraction and the best ceramic education yet.

The City of Olympia – a jewel.

Acknowledgements

I am sincerely greatful to all of those who helped this thesis materialize: Committee members Louise Mozingo, Rob Thayer and Peter Bosselmann for their invaluable insight and gentle guidance; Andy Haub of the City of Olympia's Public Works Department for taking the time to share his perspective and feedback on the matter; Whitney Bowerman of the City of Olympia for providing much needed GIS data - more than once; Kari Qvigstad of the Port of Olympia for offering an essential view - and as family friends, she and husband Jeff Fishal, son and daughter Gabe and Annaliese for providing a warm welcome to the City of Olympia; John Kriken of SOM, whose tales of the world of Urban Design had me spellbound, thank you for your reassuring enthusiasm early on in the process; Karl Kullmann, whose fifteen minutes of insight had a lasting impression; Jeff Haltiner of Philip Williams & Associates for going above and beyond the Hydrology for Planners course, sharing his knowledge every step of the way. Last but not least a warm thanks to Stefan Pellegrini, for herding cats through the summer months, your patience and insight were endless.

Preface

The following thesis study explores alternative urban design strategies for urban areas facing inundation by sea water within the coming century due to sea-level rise (SLR). The effect of SLR on the vitality of shoreline built environments, the health of the intertidal zone, estuary habitats and accompanying natural processes were of primary concern, framing the problem as well as the solutions explored. Design solutions explored are contextually based. The thesis site, located within the city of Olympia, Washington, encompasses the area expected to be inundated with 50” of SLR.

Within this document proactive planned response by municipalities when faced with a gradual rise in sea-level is recognized as a significant opportunity to improve the relationship between built environments and the natural systems on which they depend. The design alternatives explored within this thesis work towards a long term vision of economic, social and environmental resilience, and provide municipalities with a flexible framework of ideas through which they may begin to envision a range of options of retreat, accommodation and protection as viable incremental solutions to predicted inundation.

Prior to discussion of site selection analysis and design solutions a broader framing of the issue is given through a short discussion of historic human settlement patterns, relationship with the sea and current sea-level rise predictions. Site selection and analysis of existing urban morphology then provide a detailed understanding of site relationships and use. Natural and social history of the region and municipality offer a better understanding of the site and how it came to be, while explanations of conventional methods of shoreline protection and alteration provide a clear understanding of the way in which urban shorelines are typically addressed. Several precedents which illustrate elements of proposed design solutions and current spatial planning strategies are discussed prior to the final design chapter and conclusion.

"…a healthy Puget Sound can be reached if we are willing to make significant improvements in the way we develop the land and our built environment, use our natural resources and dispose of our wastes. Saving Puget Sound requires changes in our behavior, and a willingness to restrict or modify those actions that cause serious harm to the Sound."

State of the Sound, 2007

1 Introduction

Detailed study of our oceans and the way in which they shape our environment have revealed a dynamic relationship between land, sea and atmosphere. It is now known that ocean temperatures determine climate and wind patterns which affect life on land. Recent concerns of global warming and resulting studies have lead to the discovery of a steady rise in sea-level; through a combination of acceleration of glacial melt (melting of the cryosphere) sustained by dynamic positive feedback loops and expansion of warming sea water (through a process of thermal expansion) (Mote et al., 2008)

Much of the World's human population is found concentrated along the ocean's shore, some estimate that over 2 billion people (37% of the global population) live within 100 km of a coastline. In the United States, 55–60% of the population lives in the 772 coastal counties of the Atlantic and Pacific coast lines.

Historically within sea-fairing societies the benefit of set tling near the ocean's edge exceeded the danger posed by natural disasters. Over time methods of protecting the built environment from storms, SLR and erosion were developed and adopted. A region of the world known for its historic struggle with inundation, The Netherlands, brings to light what many regions may face within the coming century.

1.1 Historic Deltas

Low lying deltas of the Rhine, Waal, Meuse and Scheldt rivers which now form The Netherlands once made up a vast area of grassland estuary attractive to groups of nomadic cattle herders. Natural levees found along these deltas became the first high ground for settlement. Sea-level rise following the last ice age prompted residents to protect their settlements through cutting sod from the surrounding landscape and layering it atop the original natural levees; raising their homes above high tide inundation. These town-islands became known as Terp meaning ‘village’ in Old Frisian.

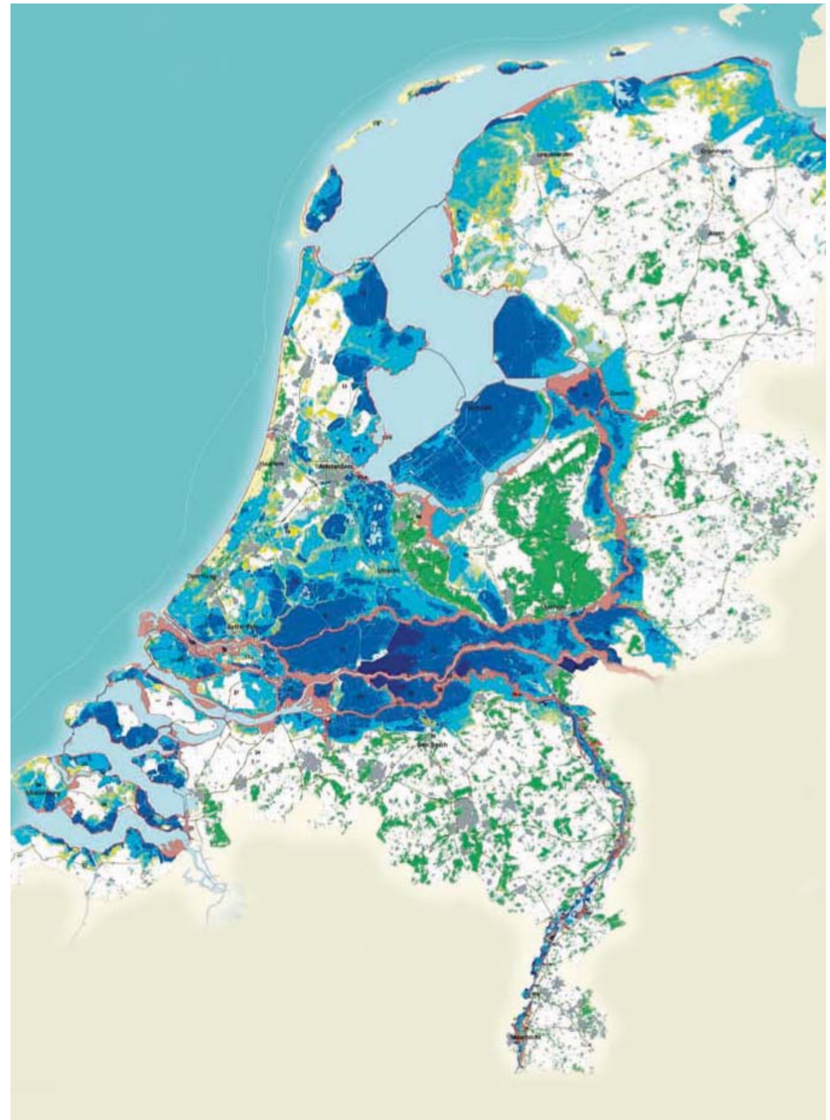


Figure 1.1 Area of land within the Netherlands bellow sea-level, dark blue being the lowest.
Source: National Water Plan 2009-2015, Dutch Central Government

The first Terp settlements were constructed around 500 BCE, speckling the landscape of the Northern Netherlands, Denmark and Germany. They numbered 1,200 within the northern Netherland provinces of Groningen and Friesland alone. By 1200 CE monks took on the task of constructing and managing dikes which connected Terp protecting the farmland within from tides. As technology began to play an increasingly important role, what was once an accommodation strategy by means of dwelling mounds evolved into a protection strategy through the creation of a network of dikes and drainage canals. The creation of flood management groups called water boards in the 13th century held each Dutch community accountable for upkeep of their own canals and protective dikes (VanKoningsveld et al. 2008).

Figure 1.2 Historic map of Terpen villages in the Northern Netherlands
Source: http://www.lancewadplan.org

Dikes as well as sea walls and revetments are just a few of the conventional methods used to protect both artificial and natural shorelines and the communities built along them. Despite investment and innovation hard engineering strategies can be vulnerable. For example, along the southern shore of The Netherlands the collapse of several dikes during the 1953 North Sea storm surge (5.6 meters above mean sea level) drowned over 1,800 residents. This national disaster spurred the creation of a large scale national program of public works titled Deltaworks which continues to protect the low lying regions of The Netherlands through extensive research and investment.

More recently Hurricane Katrina passed through the city of New Orleans along the southern shore of the United States on the morning of August 29th 2005. Through the breaching of the sea-dike system storm waters reached 10-19 km (6-12 miles) inland, eighty percent of the city was flooded total property damage was estimated at $81 billion and over 1,800 residents died. (Knabb et. al, 2006). Recently regions of the Netherlands and cities such as New Orleans have begun to explore alternatives to conventional hard engineering strategies of shoreline protection.

Given projections of acceleration of the rate of sea-level rise, the traditional strict protection strategy has come under strong debate. Working with nature, with a re-evaluation of an accommodation strategy in combination with a hard protection strategy, is now considered to be a sustainable alternative. This perspective requires a shift in approach toward one which is multi-disciplinary and holistic in nature (VanKoningsveld et al. 2008).

Comparititive Aproximate Qualitative and Quantitative Cost of SLR Urban Design Strategies

	Protection	Accommodation	Retreat	RAP Strategy
Implementation Cost	+ + +	+ + +	+ + +	+ + +
Maintenance Cost	+ + +	+ - -	- - -	+ - -
Public Safety Cost	+ + +	+ + -	- - -	- - -
Biodiversity Loss	+ + +	+ + -	- - -	+ - -
Maritime Commerce Loss	+ + +	+ - -	- - -	- - -
Resilience	- - -	+ + -	+ + +	+ + +
Change to ex. Urban Form	+ - -	+ + +	+ + +	+ + -

HIGH	MED-HIGH	MED-LOW	LOW
+ + +	+ + -	+ - -	- - -

Figure 1.3 SLR Urban Design Strategy Matrix

1.2 Sea-level Rise Predictions

A wide range of unknowns and variables make it difficult to accurately predict the rate and degree of future SLR. Reflecting this uncertainty estimates vary. A 2007 report from the

Figure 1.4 Downtown City of Olympia bridge with 17 foot tide January 2010

Intergovernmental Panel on Climate Change (IPCC) gave a range of 0.18m to 0.59m (7"-23") for SLR by the last decade of the twenty-first century, but these values explicitly exclude future rapid dynamic changes in ice flow which the IPCC deemed too uncertain to quantify. (IPCC, 2007)

A 2008 report prepared by University of Washington's Climate Impacts Group titled Sea-level Rise Scenarios for Washington State, estimates 1.28m (50") SLR for the Puget Sound basin by 2100. A document prepared by the National Wildlife Federation, Sea-level Rise and Coastal Habitats in the Pacific Northwest 2007, forecasts a rise of 0.69m-1.5m (27.3"-59.1") by 2100. While a study within the United Kingdom warns that although unlikely, rapid environmental changes could lead to a collapse of the West Antarctic ice sheet leading to a global rise in sea-level of 5m-6m (16.4'(197")-19.6'(235") over the course of 100 years (Tol et al. 2006).

Parallel to the concern for human life and damage to our built environment, concern exists for coastal habitats already taxed by conventional forms of human settlement The rate of SLR in the Pacific Northwest is projected to be faster than the global average and is likely to increase both the pace and extent of the erosion and nearshore habitat loss already affecting Puget Sound Shorelines. (NOAA, 2007)

1.3 A City at Risk

Study of the affect of sea-level rise within the Puget Sound Basin by the National Wildlife Federation and University of Washing ton's Climate Impacts Group identify the City of Olympia as one of the most vulnerable urban areas, in terms of SLR, within the Pacific Northwest. Hence the primary goal of this thesis is to demonstrate the implications of future SLR on the redevelopment of Olympia's urban waterfront.

Low areas of land which make up the Olympias Downtown, historic district and industrial area rest slightly above high tide. Downtown land elevations in relation to current sea-level are 1-3 feet above annual high tides. (City of Olympia, 2010) During extreme high tide events evidence of seawater caused backflow through storm water pipes into the city center has been found. In response a detailed study of Downtown storm drainage infrastructure has been preformed, with emphasis on updating the system to a simplified network of easily monitored outlets, and the decoupling of stormwater and sewage systems. The City of Olympia's work plan for 2010-2011 appropriates $75,000 toward the completion of a preliminary engineering analysis of potential shoreline sea walls/barriers for 50" of sea-level rise (Council Meeting, 2010).


Figure 1.5 Typical Natural Shoreline

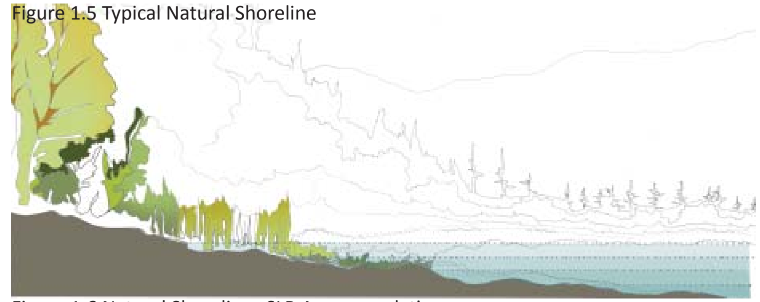


Figure 1.6 Natural Shorelines SLR Accommodation

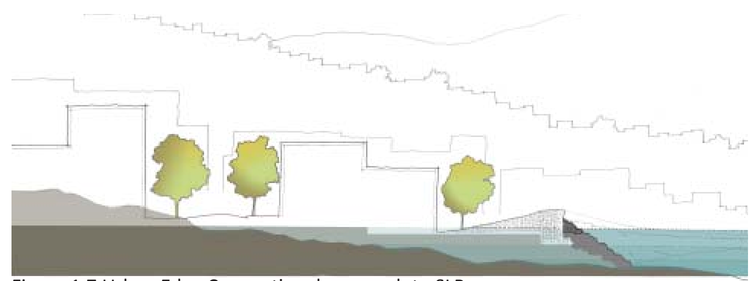


Figure 1.7 Urban Edge Conventional approach to SLR


Figure 1.8 Urban Edge Alternate Approach to SLR

Coastal modifications such as dikes and seawalls prevent the ability of habitats to migrate inland to accommodate for sea-level rise, and often provide a false sense of security for communities which live behind them. Therefore adopting a strategy solely of protection, although conventional, brings into play a number of future risks which municipalities may wish to avoid:

1) Along with the cost associated with implementing and maintaining protection of existing shorelines municipalities risk becoming liable in perpetuity for the protection of properties and lives located along the shore as sea-level rises and storm surge becomes more severe.

2) Through the construction of barriers which protect existing shorelines and in doing so prevent natural migration of aquatic and semi-aquatic habitats inland, municipalities risk losing their intertidal zone completely, along with species and livelihoods which depend on it.

3) Through the construction of a protective barrier along the existing shores edge municipalities risk creating a social and economic barrier, hindering public access to the water and disrupting maritime industry.

2 Site Selection and Analysis

The City of Olympia is located along the southern shore of Budd Inlet a fjord-like body of water which connects to the greater Puget Sound. The heart of the city lies on a small peninsula wedged between the mouth of Moxli Creek and the Deschutes River. Downtown Olympia, including the historic district comprises roughly 530 acres.

The city core has remained a relatively dense center with few opportunities for expansion; bound by the State Capitol Campus to the south, Capital Lake to the southwest, Budd Inlet to the north, steep topography to the east and west. This area represents the heart of Olympia, pedestrian access to the waterfront and the center of most major transportation links. The city has been constructed using a traditional grid pattern, streets running north-south and east-west, forming blocks approximately 250 -270 feet square, with a variety of uses and activities. A majority of street right-of-ways are 60 feet wide. One larger arterial Capitol Way S. running north-south is 80 feet wide. These

Figure 2.1 City of Olympia location within the greater Puget Sound

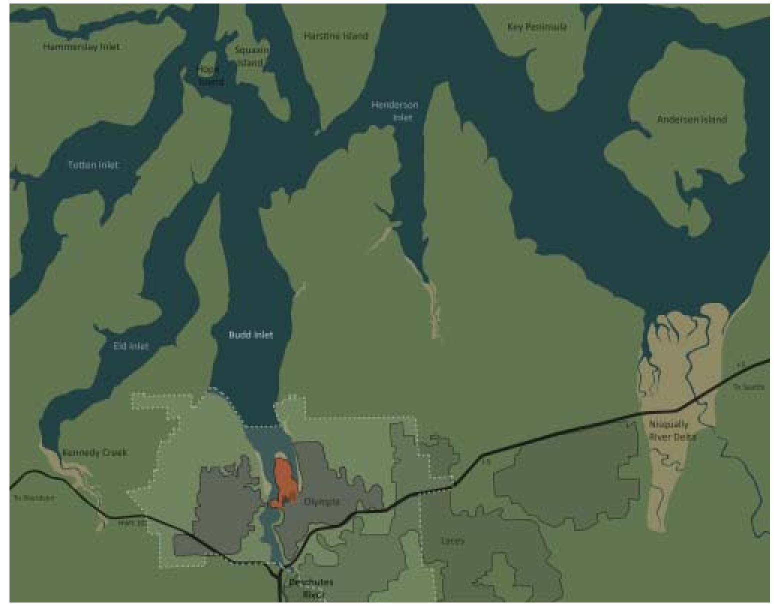


Figure 2.2 City of Olympia location within the South Puget Sound


Figure 2.3 City of Olympia areial view; Source: Google Earth

Figure 2.4 Aerial view of Downtown Olympia Source: Google Earth

Figure 2.5 Figure ground, historic district structures, 50” sea-level rise

Figure 2.6 Evolution of Olympia’s shorline, historic district boundary

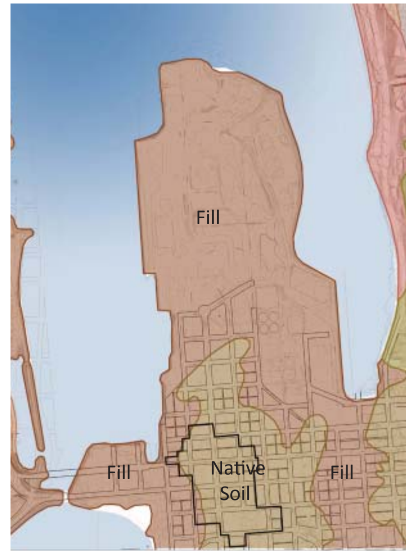


Figure 2.7 The extent of fill

Figure 2.8 Surface Parking shown in dark grey

dimensions include sidewalks often sheltered by building awnings, street trees and streetparking along either side (Comp. Plan, 1994). Underutilized parcels of land currently used for surface parking present future opportunities for urban infill surrounding the historic core.

2.1 Land Use

Olympia’s compact Downtown provides an attractive retail core, clearly defined town square, varied architectural styles. The State of Washington owns roughly two million square feet of office space on the Capital Campus, and owns or leases roughly 1.6 million more in Downtown. Olympia’s Downtown has recently attracted a strong influx of small specialty shops, boutiques, restaurants, and tourist-related activities. While not the

Figure 2.9 Historic district intersection of Washington St. SE and 5th Ave. SW

Figure 2.10 Historic district character

Figure 2.11 Olympia National Bank, 1915, 5th Ave. SW

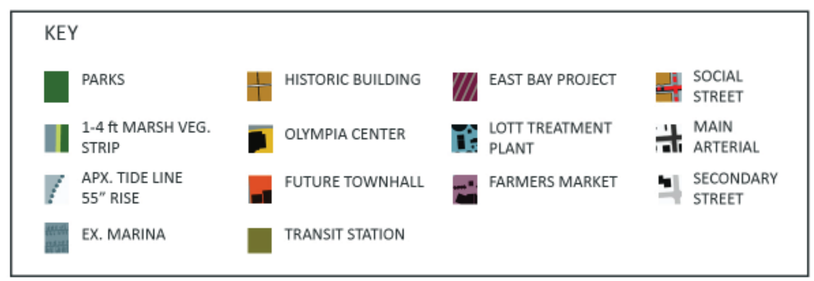
Figure 2.12 Historic district character

Figure 2.13 Historic district character

Figure 2.14 Diagram of significant structures, streets and open spaces

major retail center of the community, the urban core has strong employment in finance, insurance, real estate, wholesale trade, and miscellaneous services, as well as a significant level of retail trade. The major public facilities in Downtown Olympia include: Olympia City Hall, Old City Hall, the LOTT (Lacey, Olympia, Tumwater and Thurston County) Regional Wastewater Treatment Plant, the Farmers' Market, Olympia Timberland Regional Library, the Old State Capitol Building, the Federal Building, the Post Office, the Olympia Maintenance Center, the Washington Center for the Performing Arts, and the Olympia Center. (Comp. Plan, 1994)

Many second and third-story apartments Downtown accommodate a mostly low to moderate-income group. Additional housing, typically second-story apartments are found scattered



LOTT Clean Water Alliance

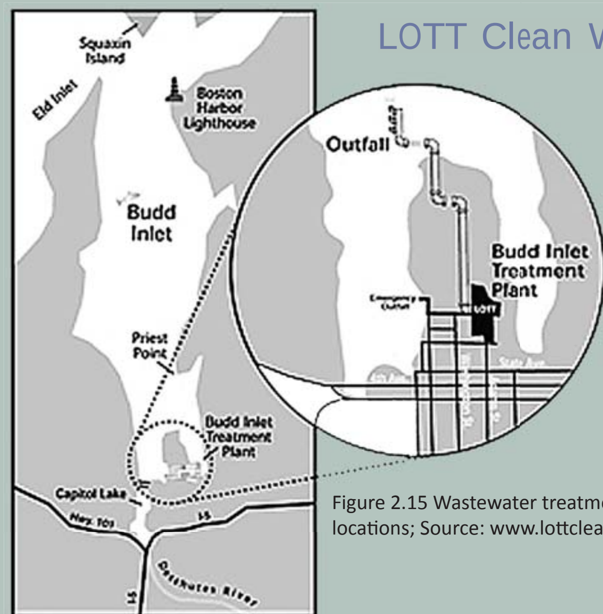


Figure 2.15 Wastewater treatment plant outfall locations; Source: www.lottcleanwater.org

LOTT Regional Wastewater Treatment Plant treats and average of 10 to 12 million gallons of wastewater per day. Advanced secondary treatment standards are used including nitrogen removal and ultraviolet disinfection. Among the many municipal treatment plants located along the Puget Sound LOTT is the only which employs biological nutrient removal. A majority of treated water is released into Budd Inlet. One million gallons of treated water are directed towards a reclaimed water filtration system; these gallons are then used within the downtown Olympia area for non potable uses such as irrigation.

LOTT has constructed one satellite reclaimed water plant in the adjacent city of Lacey and purchased property to build a second. These reclaimed water plants clean wastewater to Class A standards producing water which can be used for irrigation as well as commercial and industrial processes.

throughout Downtown. Currently 1,600 people live in more than 1,000 dwellings. Market studies have shown a demand for new housing development within the Downtown neighborhood which includes middle to upper income occupants if located in areas that offer high amenity (adjacent to parks, Percival Landing, shopping, attractive streets, and opportunity for views). (Comp. Plan, 1994)

According to the City of Olympia's comprehensive plan, over time most of the existing Doentown industrial uses, located to the north and east of the historic core, are expected to leave due to escalating land prices or the need for expansion. Port of Olympia international trade activity facilitated by the ocean terminal, located north of Olympia's Downtown neighborhood, is expected to continue.

2.2 Port Property

The Port of Olympia owns approximately two hundred acres of property along Budd Inlet. This land is located primarily

Figure 2.16 Port of Olympia, Port Plaza, looking south

Figure 2.17 Port of Olympia, Farmers Market Facility

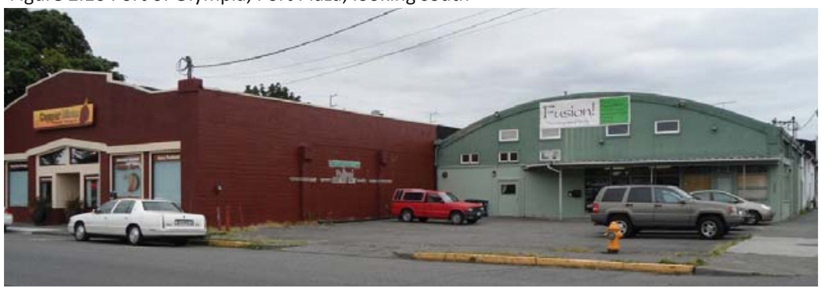


Figure 2.18 Warehouse structures, Olympia Ave. NW and Columbia St. NW

Figure 2.19 Warehouse structure, Thurston Ave. NW and Franklin St. NE

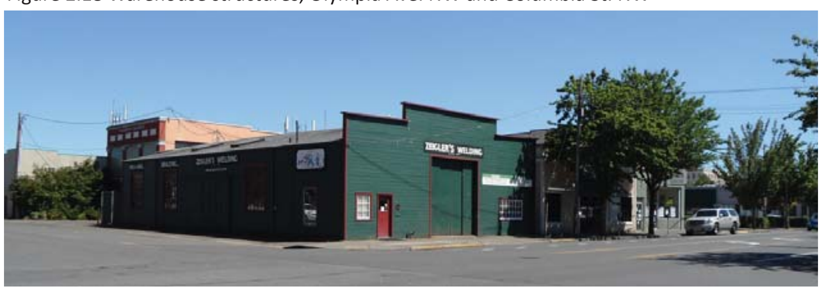


Figure 2.20 Industrial area character

Figure 2.21 Industrial area character

Figure 2.22 Industrial area character

Figure 2.23 Industrial area character

Figure 2.24 Looking south across Capitol Lake

Figure 2.25 Looking north along Percival Landing Park, West Bay

Figure 2.26 Looking south during high tide which overtops banks

Figure 2.27 The same vantage point at low tide

Figure 2.28 Edge condition along West Bay

Figure 2.29 Marinas along West Bay, looking south

on a constructed peninsula of fill extending northward from the downtown core (see figure 2.30) but also includes a strip of land along the western shore and a significant amount of surrounding tidelands. Equivalent to approximately 80 downtown city blocks the Port Peninsula facilitates mixed-use industrial, commercial, retail, and recreational activities.

The 1995 Municipal Comprehensive Plan includes a land use plan for the Port of Olympia's Budd Inlet properties. The districts identified within the plan are characterized with distinct purpose, intent, list of anticipated land uses and design requirements.

MARKET DISTRICT

The Market District located to the south of the Ocean Terminal is imagined as a vibrant public-oriented waterfront development, supporting a variety of uses and encouraging people to walk along the waterfront and shop. The farmer's market has become an important node of activity.

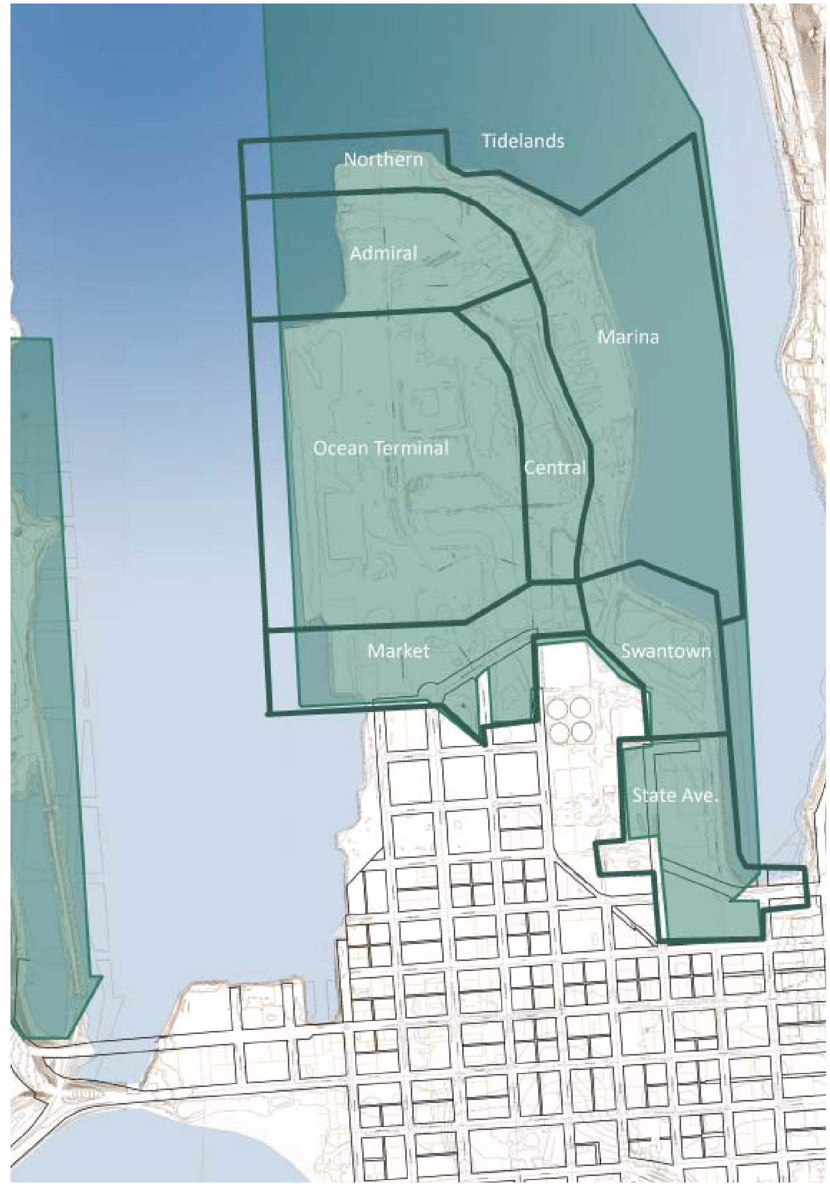


Figure 2.30 Port property districts

Cascade Pole Remediation Site

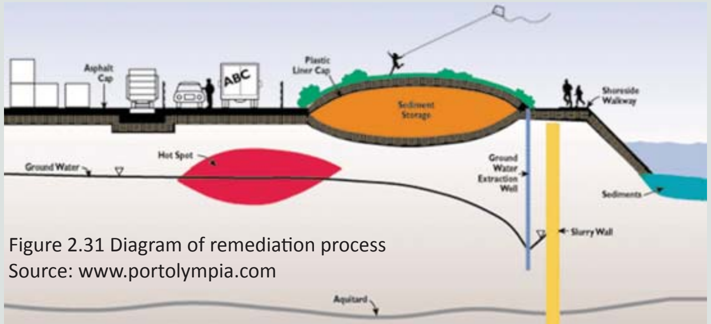


Figure 2.31 Diagram of remediation process
Source: www.portolympia.com

The 17-acre site, a former wood treatment facility owned and operated by Cascade Pole Company from 1957 to 1986 is currently undergoing remediation through a partnership between Washington State Department of Ecology and the Port of Olympia. Prior to Cascade Pole, multiple wood treating companies leased the land from the Port from 1939 to 1957. The companies used toxic chemicals such as creosote and pentachlorphenol (PCP) to preserve primarily railroad ties and utility poles. In the 1980's the site was determined a hazardous waste site. The following decade above ground structures were removed cleaned and disposed of, however waste material which had been dumped into the ground and off-shore sediments remained.

In 1992 and 1993 a sheet pile cutoff wall and contaminant collection trench were installed. A slurry wall along with the sheet pile wall block the spread of contaminants off the site. In adition, a ground water pump and treatment system was installe dto control the sread of contaminants from the uplands. The pump and treatment system sonsists of wells, which pump water from the ground to a treatment plant for removal of contaminents. The treated water is discharged via the LOTT treatment plant outfall. Over the first five-year period, 6,500 gallons of wood preserving product were captured by the remediation system. Offshore contaminated sediments were excavated in 2001. The toxic sediment storage cap currently functions as an asphalt parking lot.

OCEAN TERMINAL

The operation of the Ocean Terminal, planned to continue as a key business center for the Port, represents a majority of the industrial lands on the peninsula. Typical uses in this district include transshipment of goods by rail, truck and ship, warehousing, manufacturing, and distribution. A narrow shipping channel and turning basin dredged to 30 feet below mean lower low water located along the western portion of the inlet facilitates Freighter access to Port of Olympia facilities. Depths along the Port of Olympia pier reach 40 feet below mean lower low water, ten feet deeper than the remaining turning basin. A small channel, 13 feet bellow mean lower low water level exists along the eastern bay facilitating small commercial vessel access to existing marinas.

CENTRAL DISTRICT

The Central District to the east of the Ocean Terminal serves the Ocean Terminal with cargo storage, an area for export/import industries, other future industrial operations, and currently acts as a buffer between Marina and Port activities.

Figure 2.32 Looking north across the East Bay


Figure 2.33 Moxlie Creek pipe outlet at low tide, East Bay


Figure 2.34 East Bay at low tide looking south east

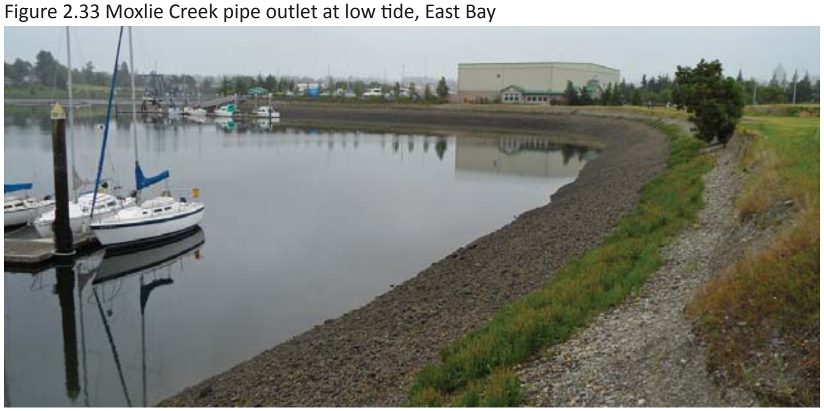


Figure 2.35 Strip of marsh vegetation, looking south, East Bay


Figure 2.36 Budd Inlet northern lookout across tidelands, Port Property

ADMIRAL DISTRICT

The Admiral district, north of the Ocean Terminal is an industrial scalelarge vessel (70-200 tons) haul-out and repair center which includes boat building and associated wholesale and retail sale.

NORTHERN DISTRICT

A mixed use commercial, office, and recreational area; a lookout marks the end of pedestrian access along the east shore of the peninsula, connecting Marina and Swantown districts. A visitor's marina is located adjacent to the Admiral District's large vessel marina.

TIDELANDS DISTRICT

The Tidelands District includes an alluvial fan which has naturally formed at the tip of Port Peninsula.

MARINA DISTRICT

East Bay Marina which offers moorage, boat launch, and support facilities - a 1,100 slip marina (at build-out) - developed for recreational and commercial use. Adjacent to uplands for marina-related services including commercial, retail, and limited office use.

SWANTOWN

Swantown, south of the Marina District is a 6-acre mixed-use marine center for boats under 70 tons. It includes vessel haul-out, repair, associated retail sales, and restaurant uses. Several gravel pads have been prepared along the eastern edge of the peninsula for anticipated construction.

STATE AVENUE DISTRICT

A project currently underway in the State Ave. district is the $18 million dollar East Bay Mixed Use Development. Plans for the 13.3 acre East Bay Development include a 27,000 square foot LEED Silver Children's Museum with outdoor learning center, Public Plaza, expansion of the waste water treatment plant, as well as seven mixed use office, retail, and residential buildings. Olympia's new town hall is planned for construction two blocks north of the East Bay Development.

3 Social History and History of the Built Environment

The creation story of the Squaxin Tribe of the South Puget Sound (sub-tribe, Steh-Chass of Budd Inlet watershed) begins with a great flood in which they tie their boats to the top of a mountain and are propelled by receding flood waters to their current location. Thousands of years prior to European contact and the arrival of American pioneers, native people of the Puget Sound began forming complex hierarchical societies.

Documentation of encounters between native tribes of the Northwest and Europeans began in 1774. By 1812 a strong trade relationship had developed between the societies. The spring of 1833 a trading post of the Hudson Bay Trading Company was established near Steilacoom. Well established trade relations with the Hudson Bay Trading Company and early American traders helped tribes within the Puget Sound defend their villages from raids of the war-like Haidahs of British Columbia, who swept down periodically from the north.

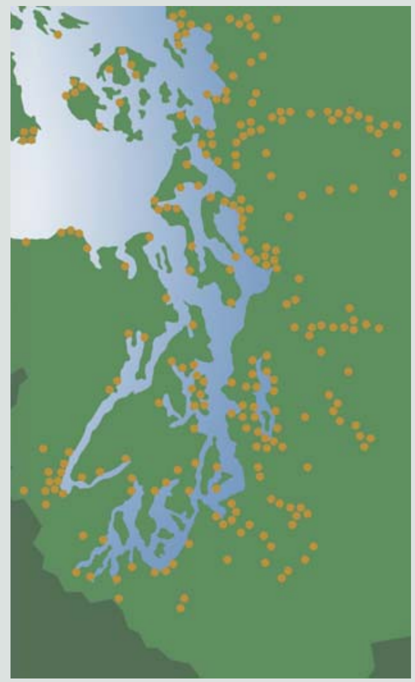
Figure 3.1 Native residence of the Puget Sound Basin; Source: Washington State Historical Society

3.1 American Migration

The Cowlitz Trail (northern branch of the Oregon Trail) became the primary land entrance to the Puget Sound Basin from Portland Oregon; shortly following its establishment the town of New Market (now Tumwater) was founded and two Americans, Edmund Sylvester a Maine fisherman and Levi Smith of Wisconsin traveled to the south shore of Budd Inlet. Each filed a claim of 320 acres under the Homestead Act. The claim of Smith

Native Communities of the Puget Sound

During the winter months native people of the region lived in stationary winter villages while during summer they traversed their territories with mobile summer structures. Northwest native societies were typically structured through the custom of Potlatch in which families would vie for prominence through the accumulation of material wealth which was then redistributed through ceremonies called Potlatch. Potlatch often spanned two weeks within which hundreds of guests gathered. The more a family was able to give away the more socially prestigious they became. By the mid-1770's smallpox along with influenza and malaria began to spread among native populations. It is estimated that by 1840 populations of Northwest tribes had diminished by sixtiy-five to ninty-five percent.



The Squaxin tribe was one of the first Native American tribes in the U.S. to enter into the Self Governance Demonstration Project with the federal government. They remain prominent stewards of Southern Puget Sound waterways.

Figure 3.2 Approximate density of permanent native villages within the Puget Sound Basin; Source: Info. gathered from coastsalishmap.org

Figure 3.3 Map of Olympia 1853; Source: Info gathered from Washington State Digital Map Library
Drawn by B.L.Snyder

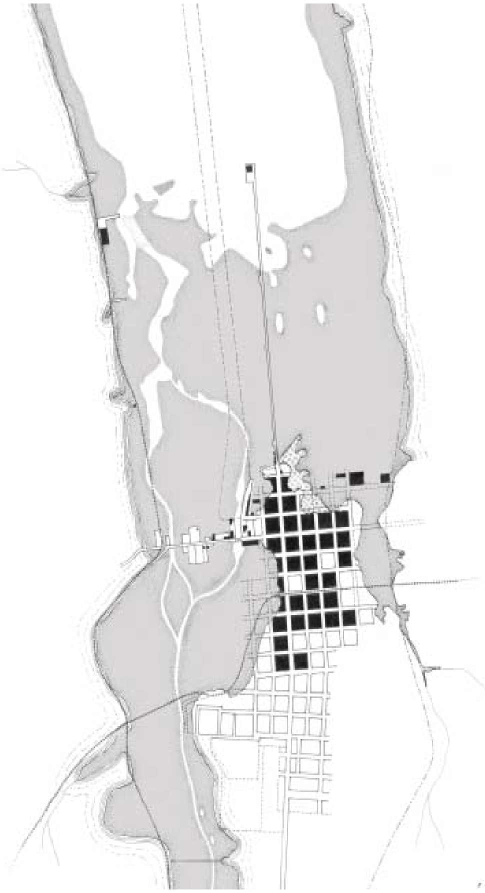


Figure 3.4 Map of Olympia 1865; Source: Info gathered from Washington State Digital Map Library. Drawn by B.L.Snyder

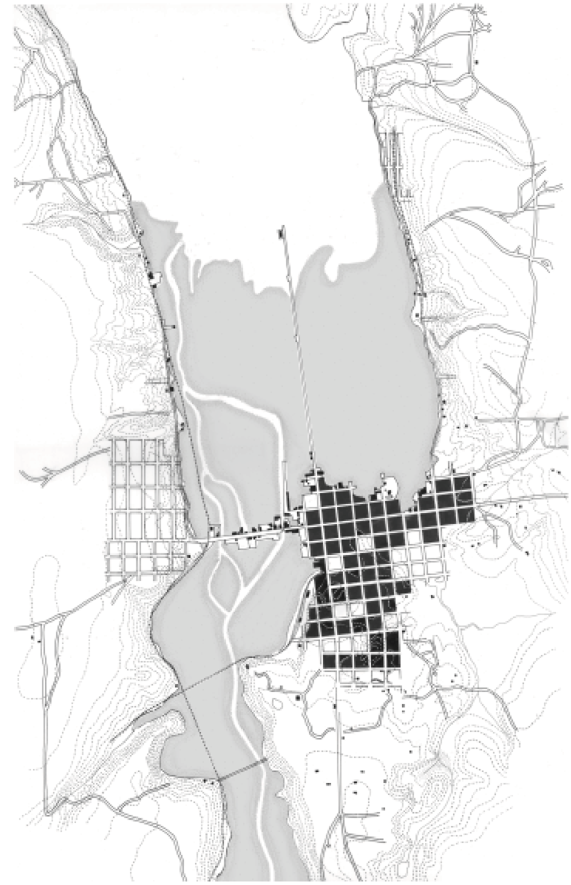


Figure 3.5 Map of Olympia 1876; Source: Info gathered from Washington State Digital Map Library
Drawn by B.L.Snyder

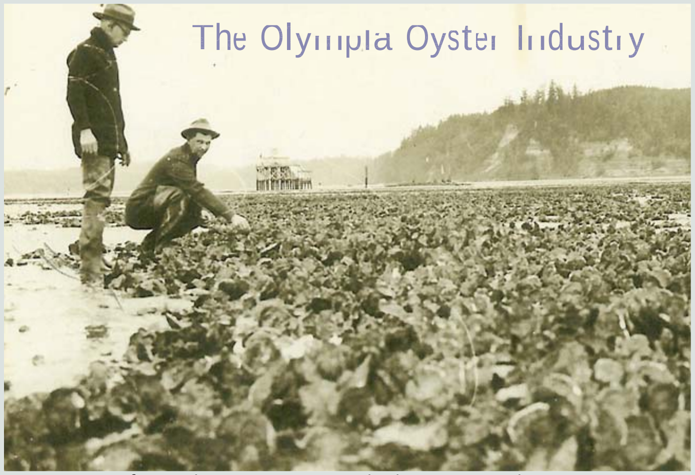


Figure 3.6 Pacific Northwest native oyster bed; Source: Washington State Historical Society

The first Oyster processing plant was built along Olympia's waterfront in 1893 following early commercial cultivation of the oyster in 1890. Becoming an early regional attraction the native Olympia Oyster (City of Olympia's namesake) carpeted the estuarine tidelands of Budd Inlet; commercial harvesting soon moved to other inlets of the Puget Sound. The decline of the Olympia oyster coincided with the influx of sulfite pulp mill waste water from area lumber processors.

In 1926 the Olympia Oyster Growers Association warned the Washington Department of Fisheries of the threat of a proposed pulp mill in Shelton. Oceanographic predictions were made that tidal current would transport sulfite waste throughout southern Puget Sound polluting oyster beds within a few days. Rapid decline of oyster health occurred following the opening of the mill. Harvesting reached a low point in 1955. A law suit led by the Olympia Oyster Company went through the United States District Court in Tacoma in 1959 but was dismissed due to limited scientific evidence. (Chasan 1981, Holt 2000) Recently the Olympia Oyster (Ostreola conchaphila) has made a significant reappearance with Puget Sound improved water quality.

included a small spit of shoreline (approximately two miles area) of upland tidal habitat adjacent to a river and creek, and the site of a native winter village, along the southern most shore of Budd Inlet. This winter village occupied by 250 to 300 tribal members was known among the locals as Cheet-woot or place of black bears. Budd Inlet, characterized by a highly productive estuarine zone was dense with oysters and other mollusks; a local staple food.

The homestead of Smith acquired by Edmund Sylvester following Smiths death in 1848 was platted by 1850. The name given to the new town was Olympia - named after prominent views of the Olympic Mountain Range to the Northwest. Soon after its founding Olympia was declared the Capital of Washington Territory. Settlements to the east and west of Olympia began to form. Edwin Marsh filed a claim which became known as Marshville to the west and John Swan filled a claim which became known as Swantown to the east, both settlements were later annexed to the City of Olympia.

By 1854 twenty wooden houses bordered the main road of Olympia while behind them and along adjacent shores were a number of Native lodges still occupied during the winter months by tribal members. The territories of the eight sub-tribes of the Squaxin including the Steh-Chass of Budd Inlet were reduced to a small south Puget Sound island (Squaxin Island) through the Treaty of Medicine Creek 1854. Civil unrest ensued through 1855 and 1856 as local tribes were stripped of their land rights and customary peaceful relations deteriorated.

Early Olympians quickly established water commerce through the purchasing of a ship, construction of a wharf and establishment of shipment of timber to San Francisco. Olympia's first wharf, Giddings Wharf, extended 300 feet out into the mudflats of Budd Inlet, and was dry at low tide. By 1888 the 300 foot Giddings Wharf dock was extended to 4,789 feet into the bay and became known as Olympia's Mile Warf. Early Budd Inlet industry included the Olympic Oyster Company, orchards, canneries and lumber mills.

Boats from Olympia ferried settlers throughout the Puget

Figure 3.7 The shanty town coined 'Little Hollywood', along the Deschutes River prior to the creation of Capitol Lake; Source: Washington State Historical Society

Sound, fueling a burgeoning timber industry. Regular steamer service was established via the U.S. Mail Steamer Traveler with service semi-weekly from Olympia via Steilacoom to Seattle. Until the Northern Pacific rail line was established in the 1870's boat was the primary mode of transport and settlement of the Puget Sound Basin.

The first significant dredging of a channel through the mud flats of Budd Inlet occurred in 1893 and 1894 by the Army Corps of Engineers who deposited the fill under the Fourth street Bridge and across the delta of Moxlie creek to the east which until then separated Swantown from downtown Olympia. The most extensive fill took place in 1910 and 1911 with the dredge of a deepwater shipping channel. Titled the Carlyon fill (after the mayor of the city) two million cubic yards of mud fill were confined behind bulkheads adding an area of 29 blocks of land to the original peninsula of the urban center. By 1922 the Port of Olympia was established and the capitol building constructed. Construction of Capitol Lake began in 1948 through the damming of the Deschutes River. The project, envisioned as a reflection pool for the capitol building, eliminated a growing shanty town along the western edge of Downtown and permanently hindered natural function of the Deschutes estuary.

3.2 A Capitol City

As other towns within the region grew Olympia felt a steady push to live up to its title as capitol. This often took the form of

Figure 3.8 Creation of the port peninsula, Carlyon Fill; Source: City of Olympia historic signage

civic improvements especially in the way of lodging and transportation for visiting legislators. As the city grew the recorded Sylvester Plat of 1870 regularized the size of the blocks, alleys and streets. A town-wide fire in 1882 encouraged many owners to rebuild with brick, these substantial new structures provided an anchor for the cross roads of the city at 4th and Main (now Capitol Way). Their design reflected the Victorian Era.

By 1889 Olympians implemented a horse-drawn street car, water system, gas street lights, and new water reservoir. The sidewalks were re-planked, then replaced by concrete in 1908 and lined with street trees. Olympians completed a narrow gauge spur railroad connecting to the mainline of the Northern Pacific which terminated at the west end of the west side bridge by 1878. Streets began to be paved with brick by 1910.

In 1919 the first large scale road building program in the state constructed highway 99 and 9 which ran through the center of downtown Olympia at 4th and Main (now Capitol Way). By the mid 1950's the interstate 5 corridor was constructed east of the downtown alleviating traffic congestion which often occurred at the intersection of highway 99 and 9 in Olympia's city center. Use of the automobile encouraged the creation of satellite commercial centers which led to decline of the historic urban core.

The Historic Preservation Program initiated in 1983 and subsequent naming of Olympia as a Washington Main Street City in 1984 and an All-American City in 1987 lead to considerable revitalization. The designated historic district is significant as it holds a concentration of early 20th century commercial architecture representing important style of the era such as Art Moderne, Mission Revival, Beaux Arts, Georgian Revival, Sullicanesque, Modern and Romanesque.

4 Natural History and Ecology of the Puget Sound Basin

The Puget Sound is a large complex estuary made up of glacier carved fjords covering an area of 2,330 km2 including 4,000 km of shoreline. Designated an "Estuary of National Significance" by the US EPA in 1988, it forms the southern portion of one of the world's largest inland seas, the Salish Sea, harboring multiple estuaries through which 140 billion cubic feet of fresh water flow per year. Present geographic character of the Puget Sound both terrain and bathometry reflect ice-age events of the recent past culminating 18,000 to 13,000 years ago.

During the late Pleistocene period of Fraser glaciation 20,000 years ago, a large glacier called the Vashon ice sheet spread from north to south. This large layer of ice grew to the depth of approximately 6,000 feet and extended a few miles south of present day Olympia. Dramatically carved channels of Puget Sound, and larger Georgia Basin, are attributed to the movement and melting of ice. In conjunction with ice-age events, Puget Sound's

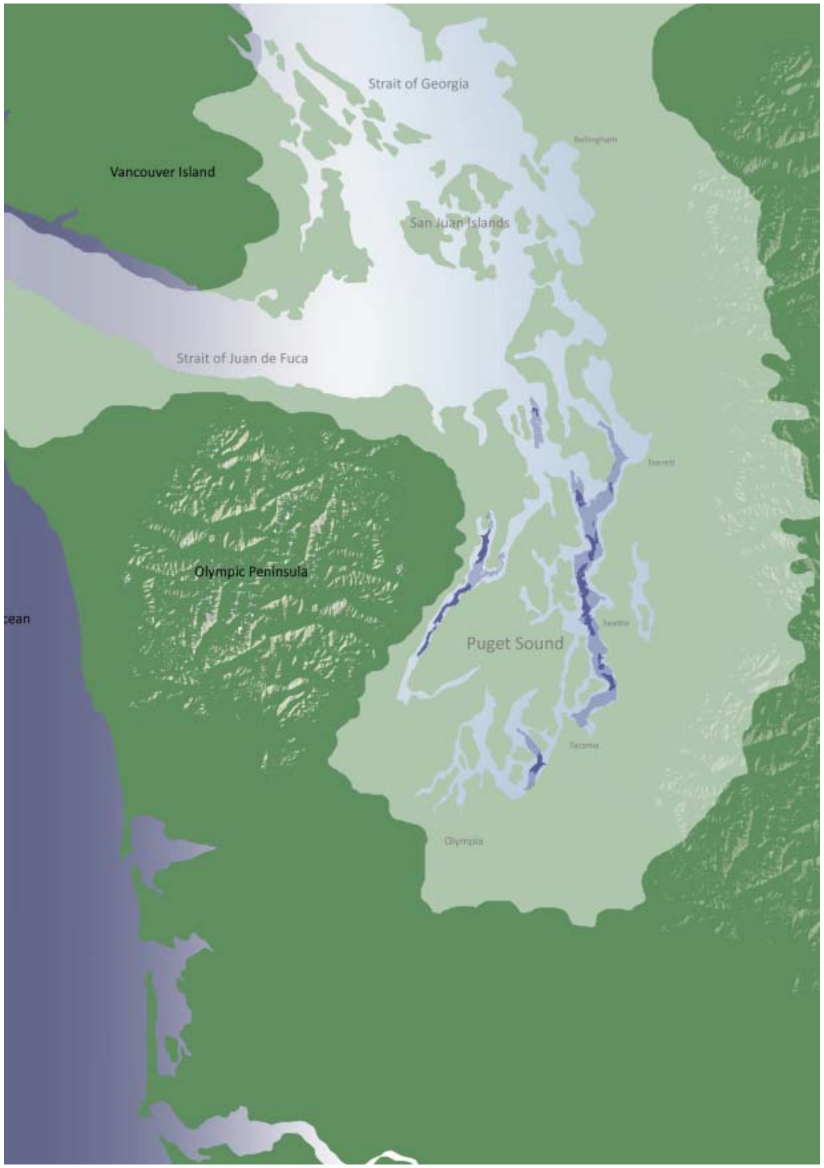


Figure 4.1 Extent of Vashon Glacier and location of the four Puget Sound basins
Source: Information gathered from *The Natural History of Puget Sound Country*. 1991.

Pacific Rim rests atop a subduction zone in which the Pacific oceanic plate sinks beneath the lighter North American and Juan de Fuca Plate. Subduction zone geological processes formed the Cascade Mountain Range to the east of Puget Sound and Olympic Mountain Range to the west.

Aside from river deltas precipitously sloping sides of Puget Sound allow for only a narrow fringe of vegetated intertidal habitat where light is able to penetrate (NOAA, 2007). The pelagic areas, the euphotic, or lighted, zone extends to about 20m in the relatively clear regions of the northern Puget Sound, and to 10m in the more turbid waters of the South Sound (NOAA, 2007). Geographical bathometry of the Puget Sound defines four basins: Central Puget Sound Basin, Whidbey Basin, South Puget Sound Basin, and Hood Canal Basin – the deepest being 930 feet. South Puget Sound depths are typically 300 feet. The basins are defined by several submarine dams or ridges called sills which prevent sediment, many organisms, and contaminants from readily leaving Puget Sound (NOAA, 2007).

The climate character of the Puget Sound is often described as maritime - mild and wet. Seventy-five percent of the regions precipitation falls as rain between the months of October and March. West of the Cascade Mountains low-lying valleys have a climate of winter rains, infrequent snow, dry summers, and mild temperatures year-round – winter snow seldom remains for more than a few days (NOAA, 2007). Semi-permanent high and low pressure cells which hover over the North Pacific Ocean propel maritime air in the direction of the Sound. From mid-October to early spring prevailing winds flow eastwardly from the Pacific bringing moisture laden air.

Significant variations are found within the tidal heights of Puget Sound. The southern Puget Sound basin is strongly influenced by tides due to the shallowness of the area. North at the gateway between the Sound and the Strait of Juan de Fuca the daily tidal range is 8 feet whereas the southern shore of the Sound near Olympia experiences a tidal range of 15 feet or more. When the sun and the moon are at a right angle to each other and the sun is nearest the equator, the daily extremes between high and low tides are at a minimum (called neap tides - March and September). When the sun, moon and earth align with each other their gravitational pull is at its greatest, the daily differences between high and low tides are at a maximum (called spring tides - June and December) (Weis et al. 2009).

Waves due to wind within the Puget Sound are not comparable to those found on the open ocean. By the time ocean swells reach the entrance to the Sound their amplitude has been so greatly decreased that they are of little consequence. The heights of waves within the Sound are limited by fetch - the strait line distance that the wind has to act on the water surface for the generation of waves. The largest waves recorded reached a height of eight feet. During storms four to six foot waves are characteristic.

4.1 Puget Sound Ecology

The Puget Sound Basin supports a human population of four million; expected to grow by two million within the next 20 years (NOAA, 2007). Over forty species of marine birds, mammals, fish, plants, and invertebrates found within the Puget Sound are currently listed as threatened, endangered or are candidates for state and federal endangered species lists.

Terrestrial-aquatic exchanges within the Puget Sound generally occur at two distinct interfaces between fresh water and saltwater environments: marine shorelines and river-mouth estuaries. Sub-tidal soft sediments, ranging from course sands to fine silts and clay, are the predominant sub-tidal substratum in Puget Sound. While a diverse array of large invertebrates – including snails, sea stars and sea cucumbers - live on the sediment surface, a rich variety of burrowing and tube-dwelling microscopic organisms dwell within the sediments – including marine worms, bivalves and snails, crustaceans, sea stars, sea urchins, sea cucumbers, and an assortment of other taxa. Communities of these sediment-dwelling organisms vary according to sediment type, water depth, and geographic location within the Puget Sound. They provide a rich food source for an abundance of bottom-feeding organisms, and serve as indicators of environmental quality (NOAA, 2007).

Puget Sound Water Quality

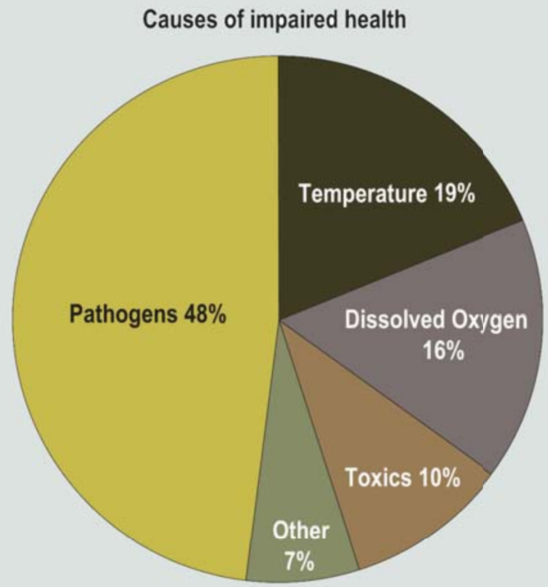


Figure 4.2 Puget Sound Pollutants;
Source: The State of the Sound 2007

Storm water runoff into Puget Sound was recently declared the most severe pollution problem in the region because it carries oil and grease from paved surfaces, fertilizers and pesticides from lawns, heavy metals from wear and tear on brakes and tires, and animal waste. (Weis et al. 2009) Unless trends in land use patterns are significantly modified to reduce their impacts, urbanization will continue to place increasing stresses on the land, natural resources, and biodiversity. Further losses or changes in habitat composition within the Puget Sound will have devastating consequences for the region's overall ecological and economic health. (NOAA, 2007)

Extensive development of Puget Sound coastal bluffs and shoreline has lead to the widespread use of engineered structures designed to protect upland properties, railroads, and roads. Shoreline armoring often interrupts sediment-transport processes leading to burial or starvation of beaches in specific locations, increased wave energy scour and changes to habitat types such as eelgrass meadows, mud flats and salt marsh. These modifications have increased dramatically since the 1970s with substantial deleterious effect on the ecosystem health of the Sound (NOAA, 2007).

Parallel to shoreline armoring, removal of the marine riparian forest corridor has reduced avail able habitat needed for the survival of species which travel regularly between terrestrial and saltwater environments or along shoreline corridors. When the narrow fringe of habitat along the Puget Sound shoreline is degraded or destroyed, the support system for numerous plants and animals is disproportionately removed (NOAA, 2007). Approximately 30% of the Puget Sound shoreline has been modified by humans, most intensely in the heavily populated regions of Puget Sound.

4.2 Salt Marsh Ecology

A slow accumulation of sediment formed the fully functioning salt marshes we study today. Sediments carried to estuaries from freshwater rivers and shorelines accumulated in areas which were flat and slow draining. Mats of microscopic bacteria and algae- formed, stabilizing the sediment upon which plants took root and sped up the process of accretion. A fully developed marsh includes water channels or creeks which form a network through the marsh. These channels form the primary link between estuary and land - tidal waters enter and exit the marsh through these channels.

Saltwater and freshwater marshes and sand and mud flats along estuaries were historically dominant parts of the Puget Sound landscape, providing critical habitat and transitional zones for young salmon and many other species of birds, fish and mammals (NOAA, 2007). An 1885 survey estimated approxi

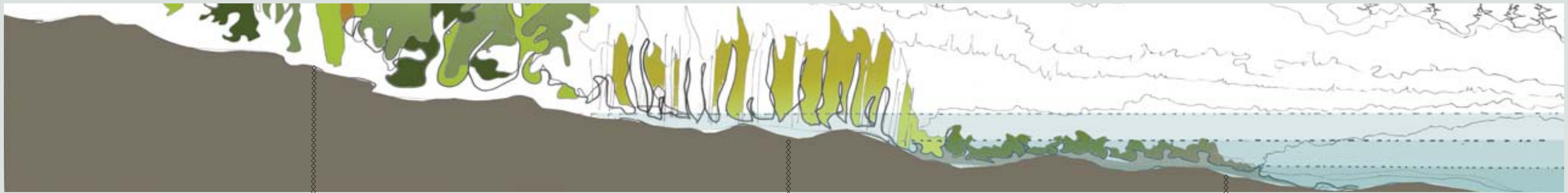


Figure 4.3 High, mid and low marsh flora diagram

High, Mid and Low Marsh Flora

of the Pacific Northwest

Jaumea (Jaumea carnosa)
Sea arrowgrass (Triglochin maritime)
Bushy shoregrass (Monanthochloe littoralis)
Bird's beak (Cordylanthus maritimus).
Salt grass (Distichlis spicata)

Three-cornered grass (Scirpus olneyi)
Saltgrass (Distichlis spicata)
Sea lavender (Limonium californicum)
Sea milkwort (Glaux maritime)
Sea plantain (Plantago maritime)
Gumplant (Grindelia stricta)
Dodder (Cuscuta salina)
Sand spurrey (Spergularia macrotheca and S. Canadensis)
Salt bush (Atriplex patula)
Salt rush (Juncus leseurii)

Pickleweed (Salicornia virginica)
Salt grass (Distichlis spicata)
Sea blite (Suaeda californica)
Lyngbye's sedge (Carex lingbyei)

mately 267 km2 (103 mi2) of tidal marsh and swamplands bordering Puget Sound. A comparison approximately 100 years later indicated that 54.6 km2 (21 mi2) remained – a decline of 80% Soundwide (NOAA, 2007).

Essential for the survival of many species of fish and shellfish who depend on the marsh for food and shelter, salt marsh are often called nurseries. Numerous species live either within, on or above marsh sediment. Plants provide shelter for spawning, and they protect juveniles of many different species of commercial and ecological importance.

Environmental conditions of marsh habitat vary greatly; salinity fluctuates depending on the phase in the tidal cycle and recent rainfall. The amount of dissolved oxygen as well as temperature varies throughout the year. Both flora and fauna must cope with these variations on a daily basis. A cross section of a typical marsh shows bands of different plant species occupying different elevations. Marsh areas at the lowest elevations that are submerged by all or most high tides are termed low marsh.

4.3 Budd Inlet Ecology

Budd Inlet is Puget Sound's southernmost marine water body; located several hundred miles inland from the Pacific Ocean. Approximately 85% of the South Puget Sound drainage basin is forested, 4% is urbanized and 7% is agriculture. When compared with other drainage basins within the Puget Sound Southern Puget Sound has the least amount of intertidal vegetation; salt marsh and green algae are the most common types. This area of the Puget Sound tends to be more sheltered and protected, consequently the area is slightly less saline than deeper and more exposed basins within the Puget Sound.

Approximately seven miles long, one mile wide at its mouth and two miles wide near its center; Budd Inlet holds approximately 0.01% of Puget Sound's water volume. The volume of water within the inlet varies greatly between high and low tides. On average the tide drains approximately 73% of the inner inlet's volume between highest and lowest tide levels.

Tide flats found within Budd Inlet are characterized by weak circulation, gradual slopes, and sandy or muddy sub-strate. They provide habitat for organisms in the detritus-based food webs that support most of the biomass in Puget Sound. Numer ous species of burrowing invertebrates and fish utilize these areas during some portion of their life cycle. Higher zones may have large populations of burrowing mud shrimp, clams, oysters, and a variety of snails and crabs. Microalgae (diatoms and other species) often cover the surface of such mudflats and are highly productive. Mud flats are also important forage areas for marine birds at low tide (NOAA, 2007).

Circulation features of Budd Inlet vary substantially. The West and East bay are very shallow. The two mile wide central portion of the inlet is characterized by gently sloping bathymetry; water depths generally being within 5m to 15m. A large underwater hill is also present, Olympia Shoals. Budd Inlet's water volume is comprised of approximately 75% oceanic input and 25% river input. The inlet's shallow character, dramatic tidal range and episodic river input produce a circulation that ranks it as one of the Sounds more active water bodies. Flushing times range from 1-700 days for Puget Sound inlets. Along this scale, Budd Inlet lies within the 8-12 day flushing range.

5 Physical Alterations of Shoreline

Natural shorelines have long been altered to accommodate human settlement patterns. Areas of salt marsh characterized by large expanses of flat wetland have been filled to create dry land for agricultural use or urban development. Within the Pacific Northwest about thirty percent of tidal wetlands remain. Shoreline protection takes the form of hard construction and armoring methods, soft methods such as beach nourishment, composite methods combining both hard and soft components, and non-structural activities that involve local zoning or land use regulations. Soft solutions do not necessarily imply unaltered natural protection; rather, they refer to a compliant method that can naturally deform and adjust over time in response to changing shore conditions (Thom et al. 1994).

Hard structures include bulkheads, zero-clearance bulkheads, seawalls, revetments, riprap, gabions, grout-filled bags, floating attenuators and breakwaters. These rigid installations are constructed with the purpose of deflecting and attenuating wave energy or to retain a failing area of shore. A majority are constructed at or behind the water's edge.

REVETMENTS

In some cases revetments are constructed and buried with native sized sediment; catering to aesthetics and shoreline access while providing the protection of a hard structure during a storm surge. Berm revetments use a thick layer of variable size stone, individual stones are mobile and the revetment is compliant and deformable depending on the wave environment. Wave action shapes the berm into a form which dissipates wave energy. Buried revetments are often designed to prevent shoreline erosion from storm waves until restoration of a shore or beach may occur. Occasionally large grout-filled bags are placed at the toe of bluffs forming revetments. Although they are able to be constructed within limited access areas, they are generally more susceptible to damage from waves than their rock counterparts due to inflexibility.

BREAKWATERS

Breakwaters and floating attenuators are barriers constructed in the water as a method of reducing wave action before it reaches the shore. Floating attenuators may be constructed of buoyant materials or shapes such as log bundles or rafts, hollow prisms, catamarans, buoyant panels, and flexible assemblies. They are advantageous when shore access is limited and fish migration is of concern; however they are not able to reduce the propagation of long-period waves

BULKHEADS

Historically bulkheads are the most common form of erosion protection used in the Puget Sound. They generally appear in one of three forms: cast-in-place vertical concrete walls, large rock walls or sheet style walls assembled from rows of planks, panels, or piles of timber, steal, or concrete. Bulkheads are intended to resist erosion and can be built to a height of 10 to 15 feet above the existing ground level. Massive gravity –held bulkheads built to resist severe wave action and prevent overtopping and land inundation are called seawalls. Seawalls have substantial mass and three dimensional forms intended to redirect wave action.

RIPRAP

Smaller sized material placed along an existing slope as armoring is called riprap, larger material placed in this same fashion is called a revetment.

GABIONS

Rectangular wire mesh baskets filled with rock are called gabions, stacked upon each other and set back accordingly. Live root plants may be installed along the gabion for future vegetative cover, and the porosity of the wall allows for good groundwater drainage.

An unintended drawback of hard structures is sediment at the base of the structure is lifted and carried away whenever the high tide washes against it. Consequently beach or marsh in front of the structure is lost and there is no allowance for habitat to move inland. As previously stated a normally sloping intertidal zone provides habitat for a variety of plants and animals, many of which use the shallow water as refuge against larger predators. Replacing the slope with a vertical hard structure removes habitat both adjacent to the structure and along neighboring properties through a change in hydrology and subsequent erosion (Weis et al. 2009).

Soft structures include sand fill, gravel fill, beach face dewatering, beach strand, shoreline vegetation, bluff vegetation, groundwater drainage, and slope regrading. In areas of calm water with infrequent waves of less than two feet small beach fills have been used to combat minor erosion. Varying sized matrial is used, typically sand or gravel at least as course as the native beach material. Larger material placed at a steeper slope is more resistant to wave attack. Effective beach fills possess an adequate cross-shore width which permits natural shape deformation and absorption of wave energy.

Puget Sound summers are generally characterized by long and shallow gentile waves. Summer beach face becomes only partially saturated as wave run-up easily percolates downward. As a result transport of sand is towards the shore and an accumulation of sand occurs. Frequent storms and short steep waves saturate winter beach face, lowering sediments resistance to motion, causing erosion. Beach face dewatering emulates summer beach face conditions through the removal of water from beach sediment, encouraging sediment retention throughout winter months - through pumping water out of perforated pipe buried in the beach.

Long interrupted stretches of artificially created beach called beach strands, act as dynamic wave energy absorbers. Designed to deform in both plan and section to accommodate varying wave conditions preventing upland erosion, beach strands can also be designed to act as feeder beaches; reintroducing sediment to an adjacent sediment-starved shoreline. Planting programs to establish shoreline vegetation can be an effective method of shoreline protection. Vegetation alone cannot prevent erosion from heavy wave action nor erosion of shoreline bluffs due to groundwater action. Groundwater drainage, slope regrading and bluff vegetation are common methods of steep slope stabilization .

6 Precedents

The effect of SLR on urban environments, as we now know them has yet to be dealt with. Human societies of the past were generally more attuned to their environments. Cities were constructed on hills, communities adapted out of necessity. The rigid protection strategies currently in place have yet to be tested by a significant rise in sea-level.

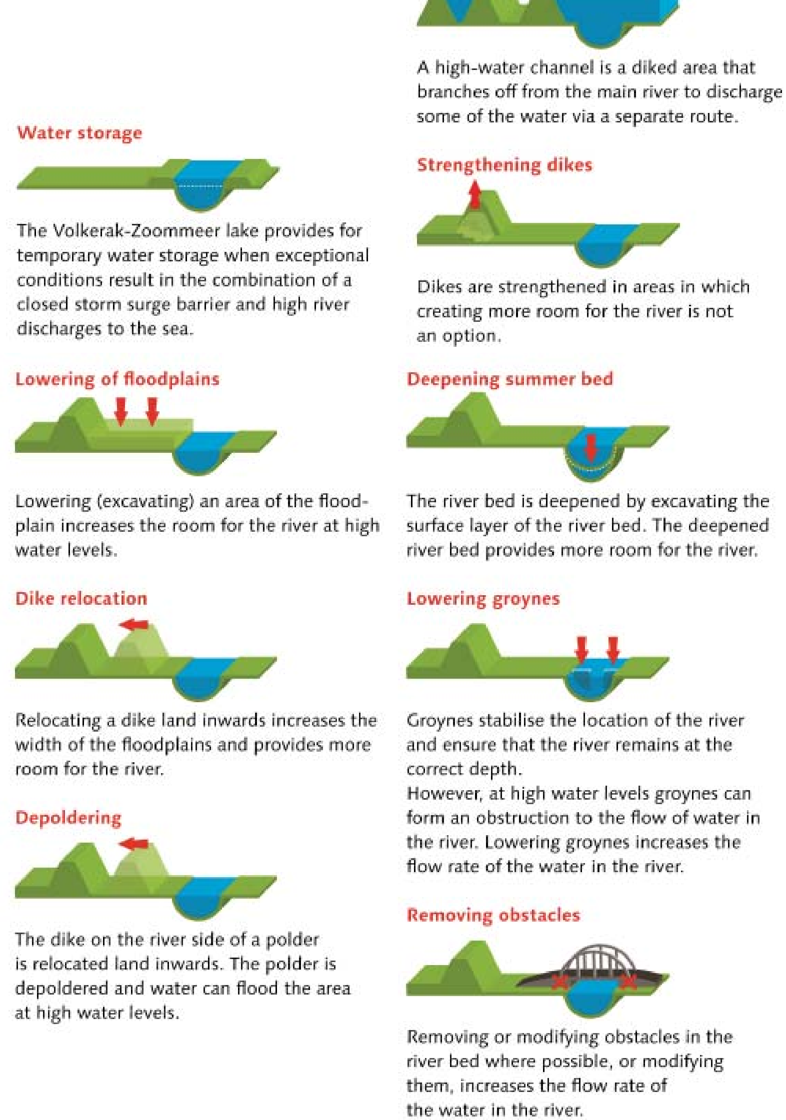
Due to the lack of precedents which provide an explicit example of urban evolution in response to SLR, the following precedents instead help to illustrate segments of the design proposed. A city peeling back areas of its existing infrastructure to accommodate a shifting intertidal zone is unheard of, but the restoration of estuarine systems through the removal of a dike is not. The implementation of a surface channel for a creek piped fifteen feet below ground to mitigate the pressure of rising tides on drainage infrastructure is not common place, but the creation of secondary surface channels for habitat purposes is. Therefore the following case studies begin to form a design tool kit.

6.1 Netherlands Sustainable Water Management, National Water Plan : Room for the River Program

River discharge within The Netherlands reached dangerously high levels in 1993 and 1995, prompting the evacuation of 250,000 people. In response a series of legislative initiatives were devised including The Netherlands first National Water Plan drafted for the 2009-2015 planning period. Acting as a framework vision based on the Water Act and Spatial Planning Act, this document brings to light the current need for investment in, and execution of, sustainable and 'climate-proof' water management measures for long term social, economic and environmental well being within The Netherlands.

A precursor to the National Water Plan was the Water Vision 2007, in which the Cabinet established a second Delta Committee - an advisory board for water policy within the next century and beyond. The Delta Act, formulated in 2009, regulates the legal basis of the Delta Program. The National Water Plan now provides further elaboration of the Delta Program - a

Figure 6.1 Room for the River Strategy Diagrams; Source: National Water Plan 2009-2015



comprehensive program aimed at the achievement of long term sustainable flood safety and sustainable fresh water supply. Key measures of the Delta Program have already begun to be implemened through Room for the River and Meuse Projects. The basic principle of sustainable water management within The Netherlands is to ‘go with the flow of natural processes where possible, offer resistance where necessary and seize opportunities to foster prosperity and well-being’. As stated by the National Water Plan 2009-20015, “If a sustainable and climate-proof water system is to be accomplished, water must play a more influential role than it has done so far in decisions regarding major tasks in the areas of urbanization, commerce, industry and agriculture, nature, landscape and leisure activities.”

A range of land uses have been identified for their compatibility with water management, namely leisure activities, nature reserves, agriculture, renewable energy production and housing. Area based approaches are becoming the standard for implementation of the Room for the River program, which means not only deciding what is needed from the perspective of the natural sys

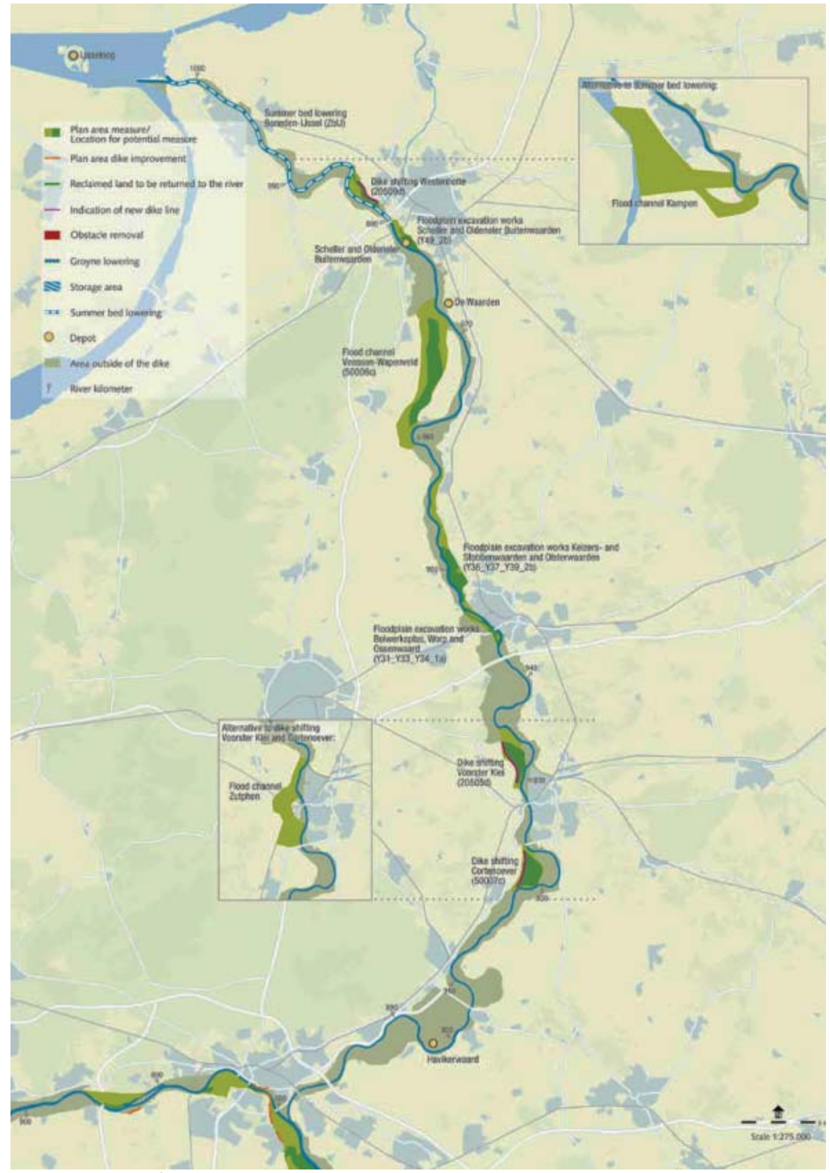


Figure 6.2 Room for the River Project Rivert Ijssel short term goals
Source: Spatial Planning Key Decision Room for the River, Approved decision

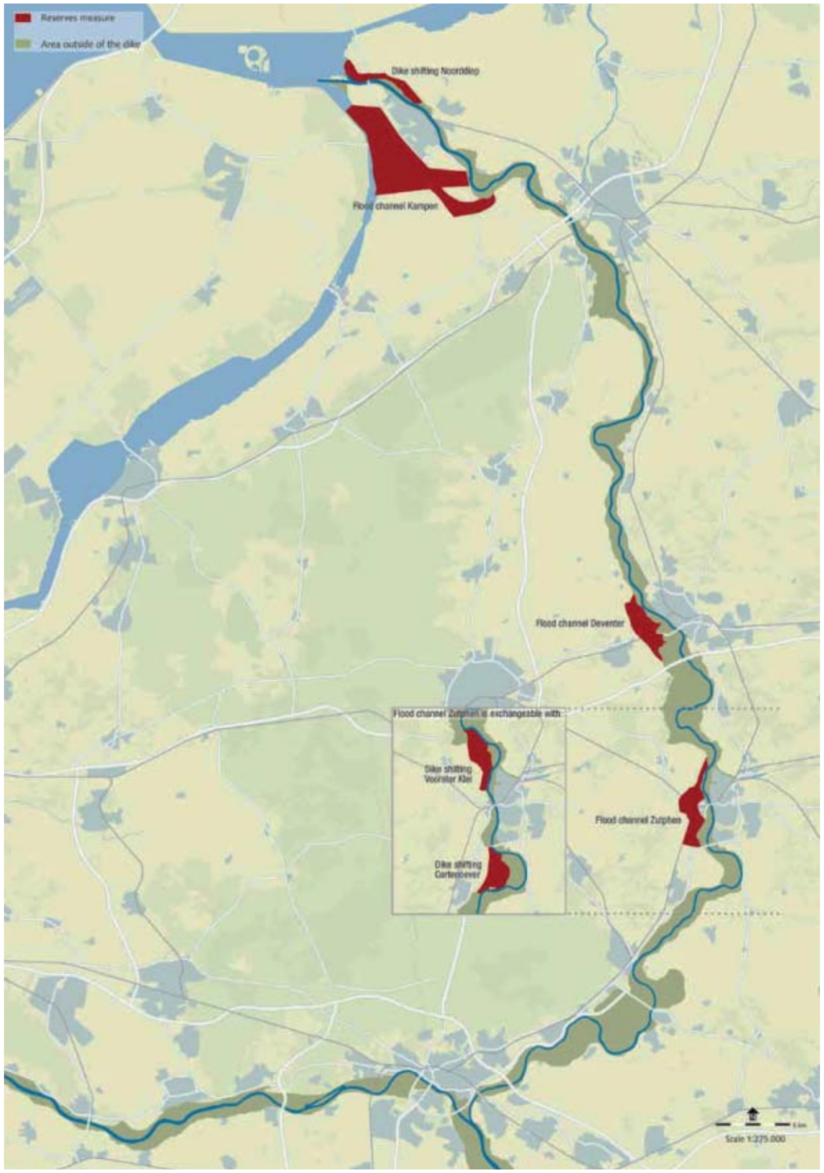
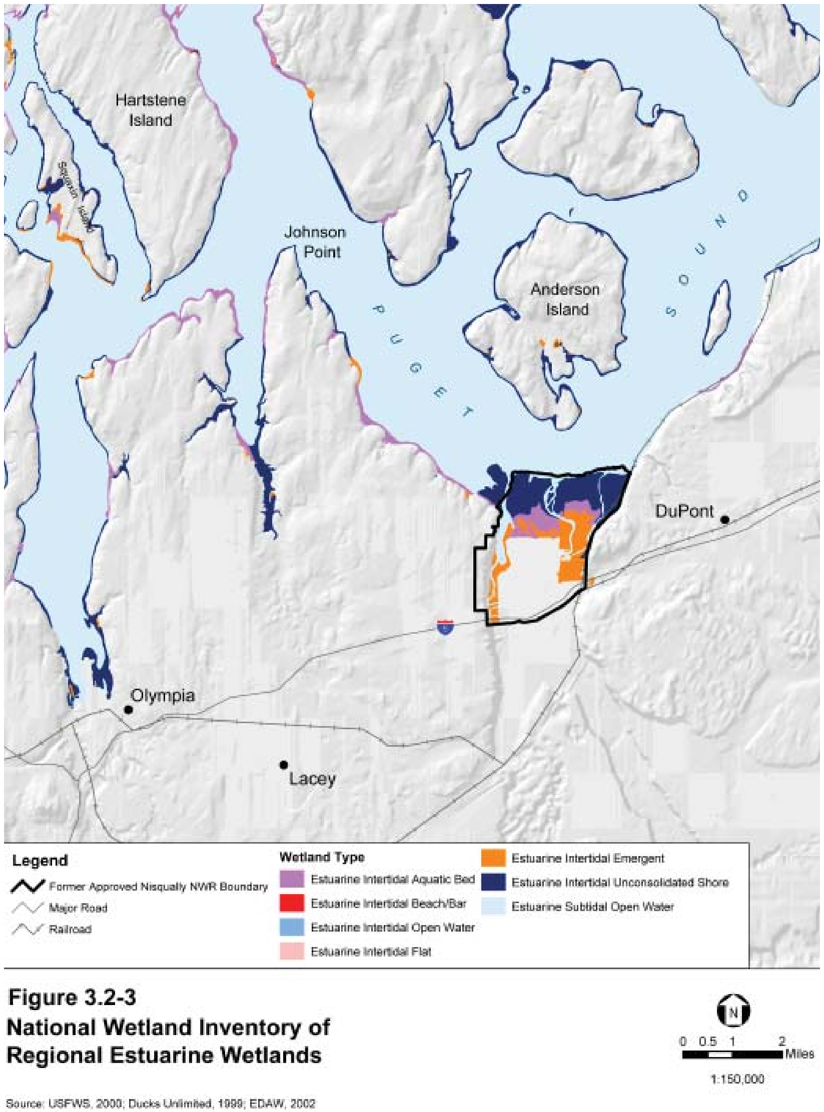


Figure 6.3 Room for the River Project Rivert Ijssel long term viison
Source: Spatial Planning Key Decision Room for the River, Approved decision

tem but, more specifically, working with all stakeholders to apply a development-geared approach. Room for the River and Meuse Projects put into practice the philosophy of sustainable water management through retaining and storing water before draining it and, moreover, by giving water more room. Strategic land acquisition and the formation of land banks which allow for future widening of river corridors are being set aside for long term goals of the projects. It is thought that the space set aside could be used in a multifunctional way, as temporary nature areas with possibilities for recreation or for agriculture and biomass production.

Seventeen partners - provinces, municipalities, water boards and Rijkswaterstaat are carrying out the plans – the Minister of Transport, Public Works and Water Management oversee the implementation of the program. Budget for the project is 2.3 billion euros for implementation of short term goals by 2015. Current maximum discharge capacities of the rivers are 15,000 m cubed per second, upon completion their discharge capacity will be 16,000 m cubed per second.

Figure 6.4 Nisqually Delta habitat context



6.2 Restoration of Tidal System

Nisqually Wildlife Refuge, South Puget Sound

Seattle attorney Alson L. Brown purchased 1,500 acres of Nisqually Delta land in 1904. Shortly after the purchase Brown Farm Dike a five and a half mile dike was constructed along the mouth of the Nisqually Delta creating hay fields and dairy pasture land. Through the building of the dike 1,000 acres of naturally functioning estuarine habitat were lost. Motivated by the concern of rapidly declining habitat Nisqually National Wildlife Refuge was established in 1974 by the Department of Fish and Wildlife. This sequestration of land set aside three thousand acres of salt and freshwater marshes, grasslands, riparian, and mixed forest habitats (including the original diked farmland) for the protection of migratory birds.

On November 11th 2009 following ten years of planning, a $12 million plan to restore the estuarine environment of the delta, Brown Farm Dike was removed, restoring tidal inundation to 308 ha of delta land. Over the past decade, the Refuge and close partners, including the Nisqually Tribe and Ducks Unlimited, have restored more than 35 km of the historic tidal slough systems and re-connected historic floodplains to Puget Sound, increasing potential salt marsh habitat in the southern reach of Puget Sound by fifty percent.

Along with 57 ha of wetlands restored by the Nisqually Indian Tribe, the Nisqually Delta represents the largest tidal marsh restoration project in the Pacific Northwest to assist in recovery of wildlife populations. New structures within the delta employ Low Impact Development (LID) techniques, in which all buildings and boardwalks are constructed using pin-pile foundations; eliminating the impact of excavation. Due to the mosaic of estuarine habitat, this large-scale restoration is expected to result in a considerable increase in regional ecological functions and services, representing one of the most significant advances to date towards the recovery of Puget Sound. The US Geological Survey is the lead scientific agency providing science support to document habitat development and ecosystem function with large-scale restoration.

Figure 6.5 Nisqually Delta change in habitat type

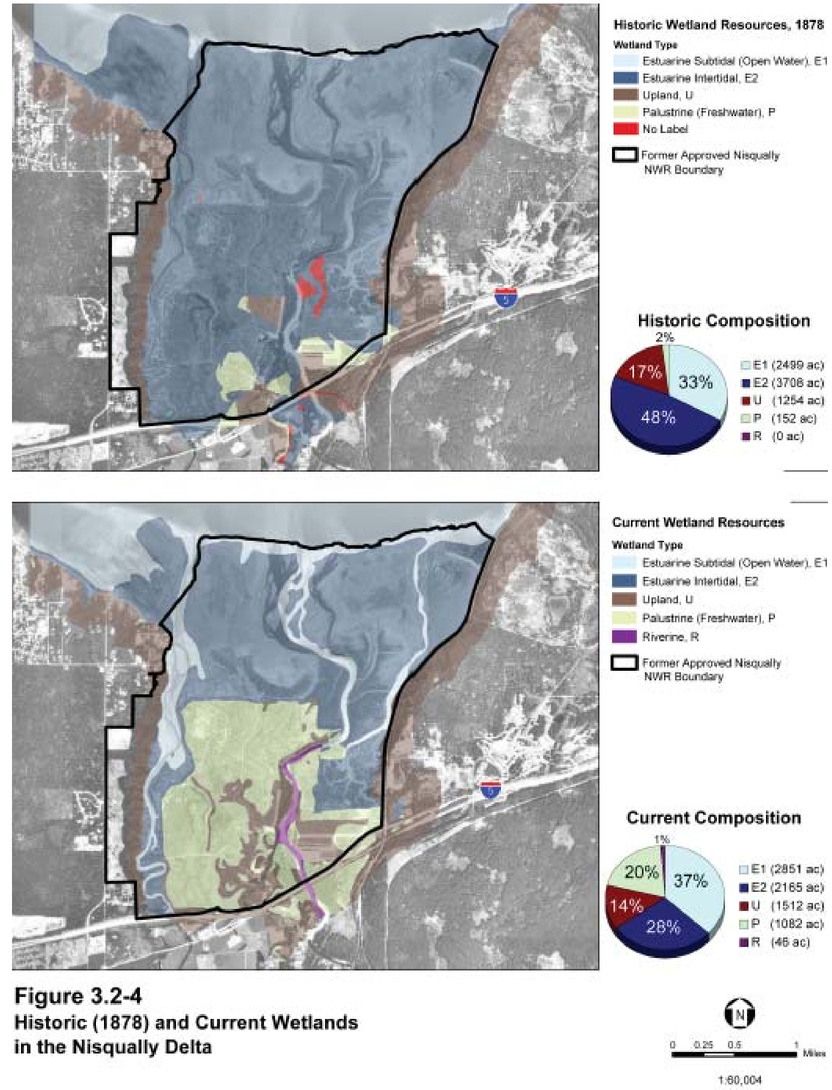


Figure 3.2-4
Historic (1878) and Current Wetlands in the Nisqually Delta

Source: USFWS, 2000; Ducks Unlimited, 1999; Tanner 1999; EDAW, 2002

Figure 6.6 Nisqually Delta current habitat types

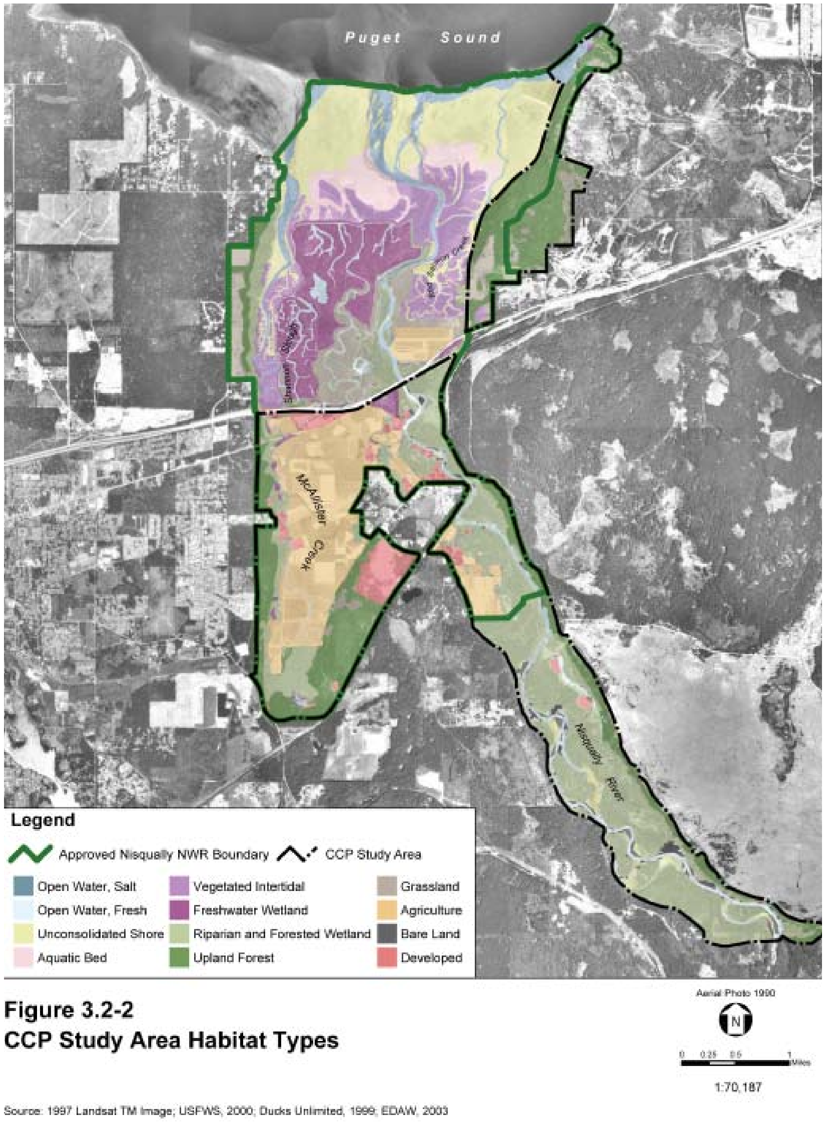



Figure 6.7 Nisqually Delta educational center


Figure 6.8 Nisqually Delta forested freshwater wetland


Figure 6.9 Low Impact Development Pier

6.3 Multifunctional Dike Concept, Delta Dike

Sustainable Water Management Approach, The Netherlands

One of the core values of The Netherlands sustainable water management approach for climate adaptation is boosting the strength and/or flexibility of systems. A water system is more robust when it makes use of or gives room to natural processes, as natural systems offer resistance to disruption themselves and possess a degree of resilience that allows them to continue to function after damage - recovering or adapting to altered circumstances. It has now been recognized that there is a substantial risk of over investment when designing for climate change, should climate change be less extreme than it is expected to be. To mitigate this potential risk of over investment the aim is to link adaptation objectives with multifunctional use.

One such strategy is conveyed through the concept of the Delta Dike: a protective earthwork which is constructed in such a robust way (through height, width or internal structure) that it is practically breach resistant. The surface of the dike would be

Figure 6.10 Delta Dike strategy conceptual section
Source: National Water Plan 2009-2015

used for housing, business, recreation, nature or in frastructure. It is believed that due to its multifunctional use a Delta Dike would be money well spent even if climate change is more mild than expected. The implementation of a Delta Dike is dependent on site conditions. Public support for the concept is strong; however space availability may be an issue. The concept is believed to offer significant opportunities for urban areas where space saving and improved physical quality can be achieved by accommodating infrastructure inside or on top of a dike.

6.4 Surface Channel Storm Water Network

Western Harbor, Bo01 Swedish Housing Exposition

Malmo, Sweden

The city of Malmo, supporting a population of approximately 280,000 residents, has begun to make a name for itself in the way of sustainability. Current municipal goals include climate neutrality by 2020. By 2030 the municipality plans to run on 100% renewable energy. The term sustainable development used within Malmo is defined in the UN report "Our Common Future", also known as the Bruntland Report, as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Three dimensions of societal development must cooperate for the long term success of sustainable development: social, economic and ecological dimensions.

The catalyst within Malmo for sustainable development was Bo01, the first Swedish housing exposition implemented in 2001 on an abandoned brown-field industrial site adjacent to the city center. Originally the project was planned for a more isolated site. Had the plan been carried out as intended Bo01s energy consumption would have been detached from existing urban infrastructure. When original site location plans fell through, using funds from the Government of Sweden, the City purchased land from car manufacturer, Saab, for $13 million. Due to its adjacency to the city center Bo01 has become an important example of the ability of new sustainable developments to be intricately linked to existing urban energy grids, as well as fully incorporated into existing spatial networks.

Calling on more than 20 architect-developer teams the overall urban design of the site was inspired by the intricacy of a fish net; a network of offset corridors and plazas, blocking strong Baltic seaside winds. The underlying goal of the development was to negate the commonly held belief that living sustainably was accomplished only through a significant measure of personal sacrifice and inconvenience. Bo01 set out to be the first of a series of projects planned for Malmo's Western Harbor which strove to create durable urban environments in which a sustainable lifestyle

Figure 6.11 Bo01 courtyard and Aqua-point network diagram
Source: Info gathered from www.malmo.se

Figure 6.12 Bo01 birds-eye view; Source: www.australiandesignreview.com

Figure 6.13 Bo01 plaza with Aqua-point feature; Source: www.flickr.com

for residents, would be effortless. Upon completion the district of Bo01 includes almost sixty different housing styles, eight-five percent being apartments and fifteen percent townhomes.

Due to the high cost of excavating and treating all contaminated soils on site, the site was treated moderately through the excavation and treatment of 3,500 m2 (11,482 sq. ft.) of contaminated soil. The site was then topped with 1.2 m of new soil and graded to create a subtle ridge line along the western edge of the site. Most of the sites storm water is gathered and fed through a series of treatment pools prior to being released into the eastern canal. Only during a strong storm surge does water drain toward the western edge of the site. Bo01 structures are designed with the use of a system of green-points, the green factor, ensuring natural elements are integrated with architectural design.

Many buildings utilize green roof technology, absorbing and slowly releasing storm water. Due to the toxic soils bellow, storm water is prevented from infiltrating, architects were encouraged to utilized storm water within the design of their sites com mon space. Storm water, collected from structures and impervious surfaces gathers by way of an intricate network of open runnels. These runnels feed treatment pools centered within the neighborhoods common areas. Storm water is treated aesthetically, trickling through a series of shallow open pools termed 'aqua points', the storm water then collects in final treatment basins along the eastern edge of the site prior to being released. During the summer months storm water is continually pumped back through the aqua points, creating an urban water feature year round.

6.5 Stormwater Management

Wetlands of Corte Madera and Palo Alto

The towns of Corte Madera and Palo Alto, located within San Francisco bay, were both developed on low lying areas of marshland. Present day flooding within the town of Corte Madera is caused by three sources: extreme high tides, storm water runoff and areas of substandard storm drainage infrastructure. Flood waters can reach depths of two to three feet, inundating a significant amount of urban area.

To protect the city from high tides a levee was built along the urban edge. Stormwater is piped through the levee to a catchment wetland. The wetland discharges to the bay via gravity or a monitored pump station. Gravity outflow from the wetland is controlled with an electronically controlled tide gate and culvert. The tide gate only opens when the interior water level is higher than that of the outlying bay. The city of Corte Matera advises its residents to protect their property against floods through the following methods: re-grade the lot to be higher than expected flood

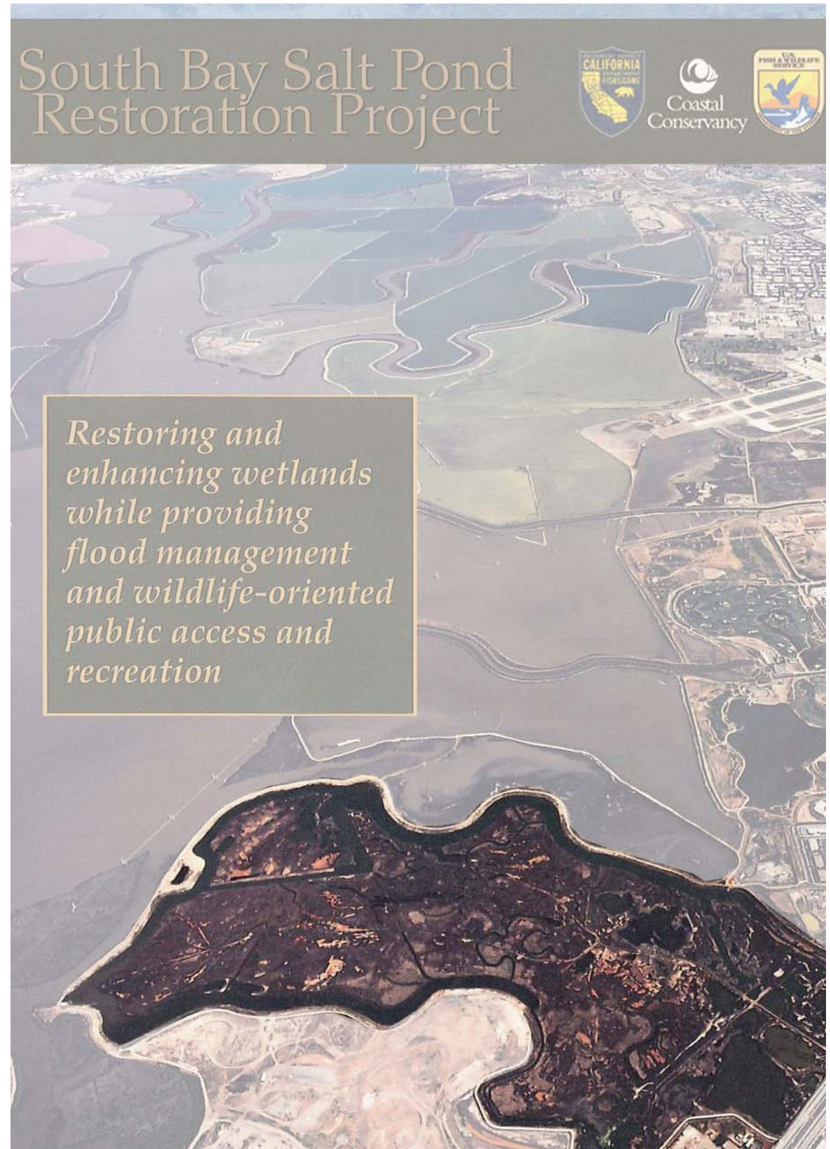


Figure 6.14 Palo Alto Flood Basin / Wetland Aerial
Source: South bay restoration brochure

Figure 6.15 Palo Alto Baylands (Flood Basin) Map; Source: baynature.org


Figure 6.17 Palo Alto Baylands (Flood Basin); Source: www.rhorii.com/PABaylands


Figure 6.18 Palo Alto Baylands (Flood Basin); Source: www.rhorii.com/PABaylands


Figure 6.16 Palo Alto Baylands (Flood Basin); Source: www.rhorii.com/PABaylands


Figure 6.19 Palo Alto Baylands; Source: www.rhorii.com/PABaylands

waters or construct and earthen berm, waterproof the walls of a structure and place watertight closures at the doorways, or raise the structures above flood levels.

All drainage from the town of Palo Alto is conveyed to a large flood basin which dually serves as a wetland. To maintain the marsh during non flood periods a slide/flap gate connects the basin to the bay via a culvert. Tidal inundation is prevented during flood periods as the basin fills up with flood waters. Along with storm water management the flood basin has become a popular outdoor recreation area and provides significant habitat along the North American bird migration flyway.

7 Urban Form Urban Function

Design RAP Strategy (Retreat, Accommodate, Protect) solutions and implementation strategies devised for predicted inundation would vary from city to city. Formation of site specific solutions and phasing processes would come about through collaboration between city officials, community groups, ecologists, hydrologists, engineers, planners, urban designers, lawyers and economists – and would reflect municipal priorities and values. For this thesis the assumption is made that when faced with sea-level rise, social, ecological and economical resilience remain core values for the City of Olympia, and therefore protection of its historic district, retention of its active water front and protection of its intertidal habitat become principal long-term goals.

Analysis of the urban fabric, namely identification of historic structures and areas of land most easily acquired by the municipality, set the groundwork for the following design proposal. Through mapping of parcels which are currently used as surface parking lots, existing alleyways, and public parks, areas of potential aquizition by the municipality were identified. Priority for protection was given to the most vital and most fragile areas of the city, namely the historic district,. These sets of information when overlaied with existing topography revieled and edge of underutilized parcels and park space along which it appeared reasonable to propose a line of protection. This line of protection takes the form of a large terraced earthwork wrapped around the historic core, at either end connecting to existing topography. The proposal was then divided into five zones within which strategies of protection, accommodation or retreat are employed. Parcels outlying this boundary are overtime designed to undergo varying degrees of inundation. The core principles again being:

(1) protect historic structures from sea and storm water inundation

(2) retain and strengthen the social and historic heart of the city

(3) facilitate an active waterfront

(4) accommodate migration of intertidal habitat

(5) restore natural processes

Figure 7.1 Underutilized Parcels and Open Space; Parking Lots (grey) Alleyways (orange) and Open space/park (green)


Figure 7.2 Underutilized Parcels, Open Space and Historic Structures


Figure 7.3 Historic Structures and Proposed Line of Protection

Figure 7.4 Proposed zones

Figure 7.5 Proposed habitat areas

Figure 7.6 Proposed intertidal zone

Figure 7.7 Proposed storm surge inundation

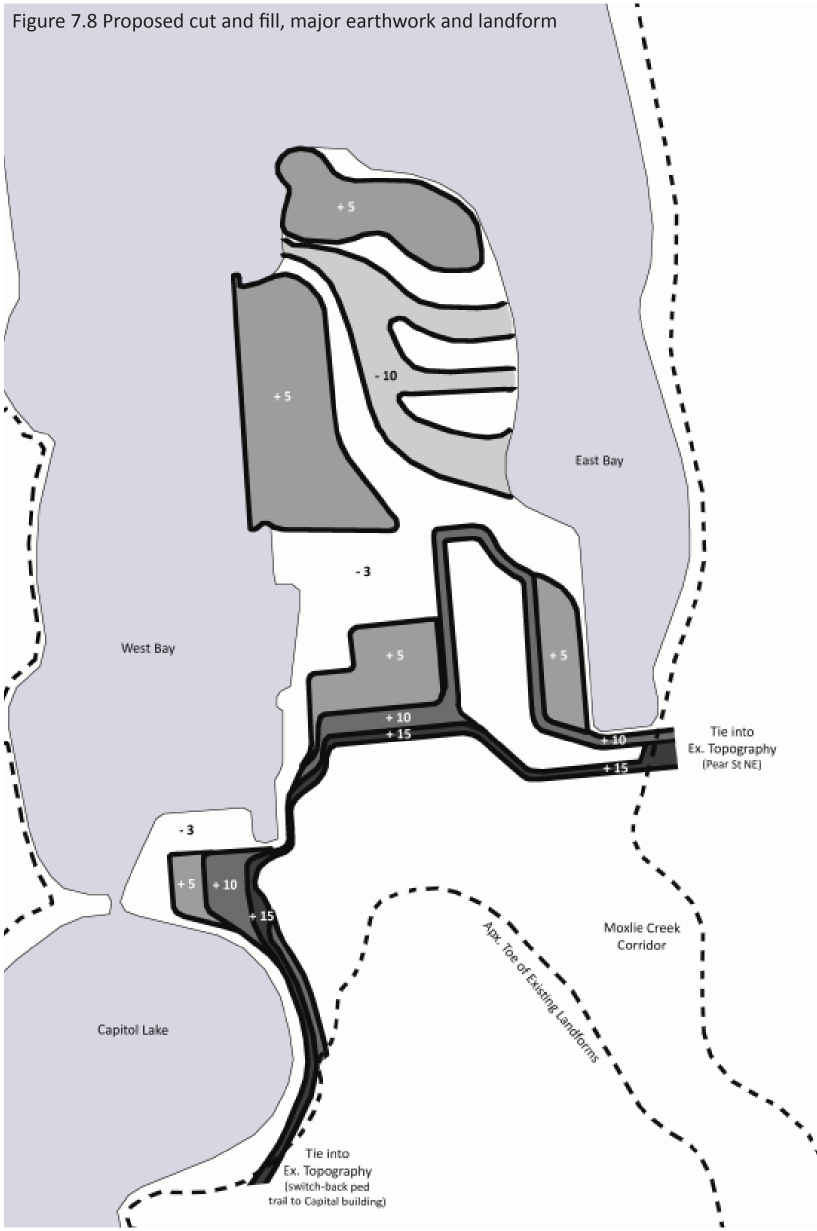


Figure 7.8 Proposed cut and fill, major earthwork and landform

Figure 7.9 Master plan

7.1 Depiction of Zones

Rather than relying on traditional forms of habitat restoration the following proposal explores methods of process-based restoration. Process-based restoration differs from traditional habitat restoration in that it restores processes that form and sustain habitats (e.g., sediment supply, nutrient supply, or river dynamics), rather than attempting to build specific habitat types (Sound Science, 2007). Restoration focusing on allowing the natural system to form and sustain habitats is the most sustainable and cost-effective approach to habitat restoration.

The zones described in detail below are broken down into five components: earthwork, infrastructure, structures, ecology and use. When it is recognized that multiple alternatives may exist for a component a short description is given of the alternates before reasoning behind the final proposal is provided.

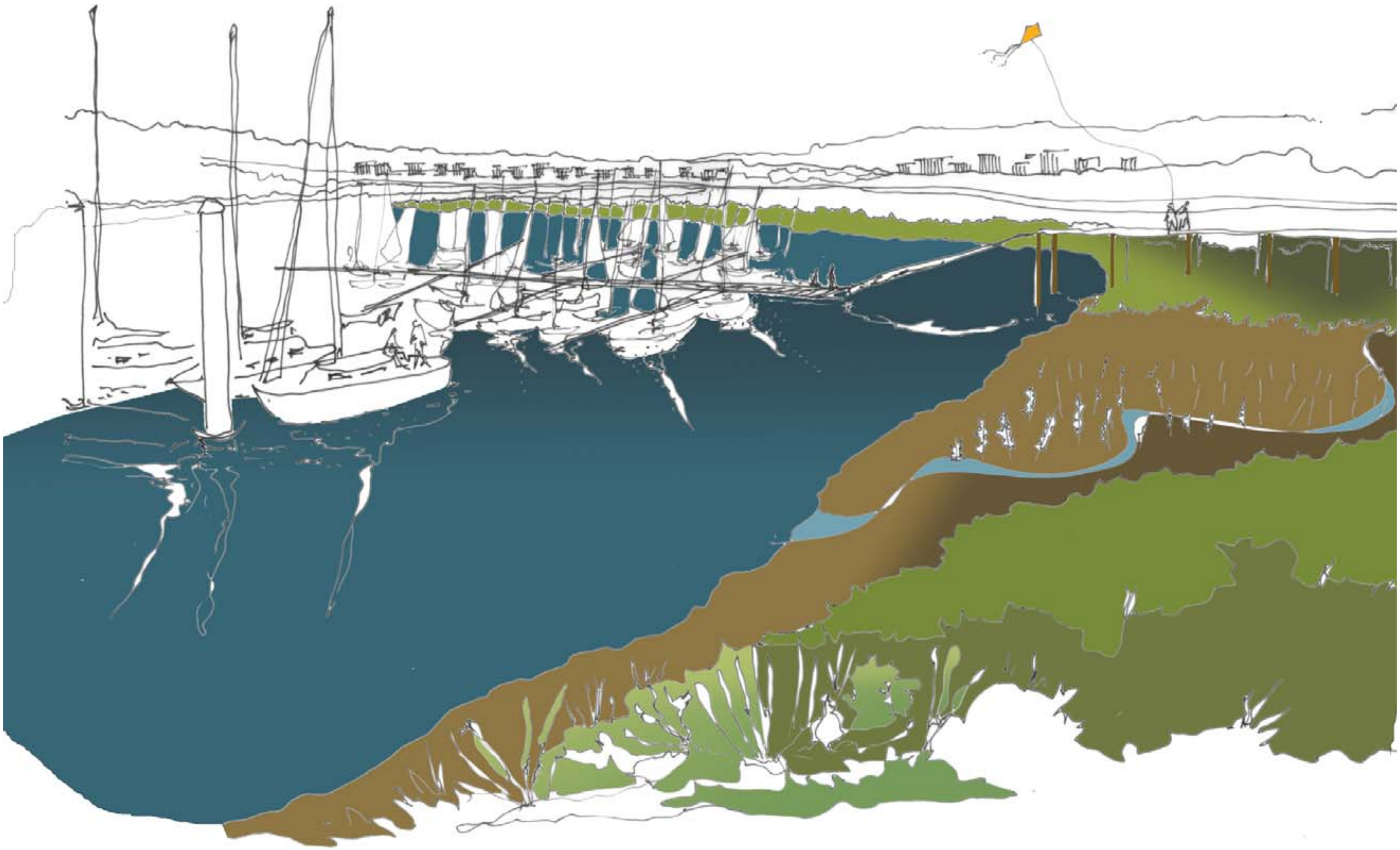


Figure 7.20 View from proposed marina pier, looking south-east along East Bay, marsh and oyster beds

ZONE ONE

Nearly all of the land within zone one is currently owned by the Port of Olympia. Primary export cargo is raw timber forested by Weyerhaeuser bound for Japan, China or Hong Kong. Primary import cargo is that which does not fit into cargo containers, an example being large propellers for wind turbines. In this way Port of Olympia's niche is of a specially items port. The following proposal assumes that the port is able to remain active while accommodating a rise in sea level. That through significant modification of its existing property it is able to retain and enhance existing maritime activity as well as establish new uses which strengthen its identity as a progressive port.

EARTHWORK

Alternate 1: Raise all port property through additional fill to protect against sea-level rise. Construction cost as well as destruction of the intertidal zone make this alternate undesirable.

Alternate 2: Allow all port property to undergo inundation. Core

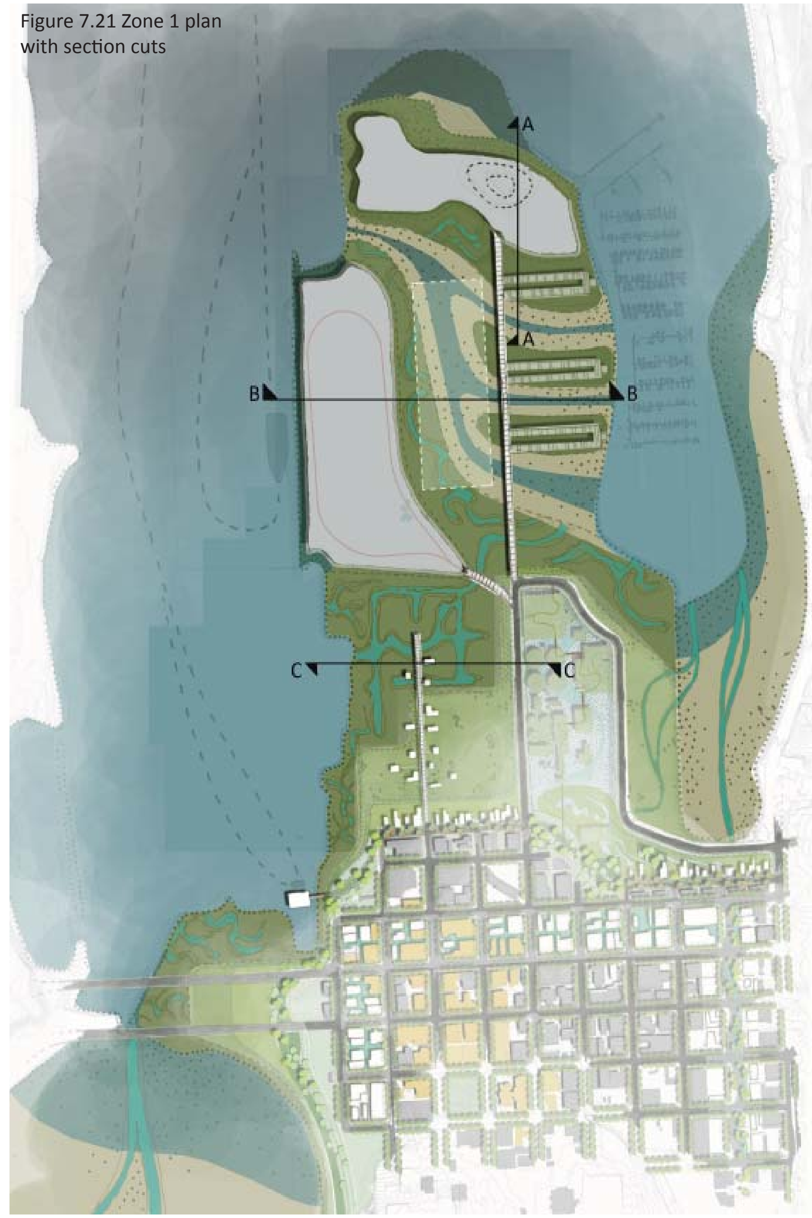


Figure 7.21 Zone 1 plan with section cuts

Figure 7.22 Zone 1 Section B

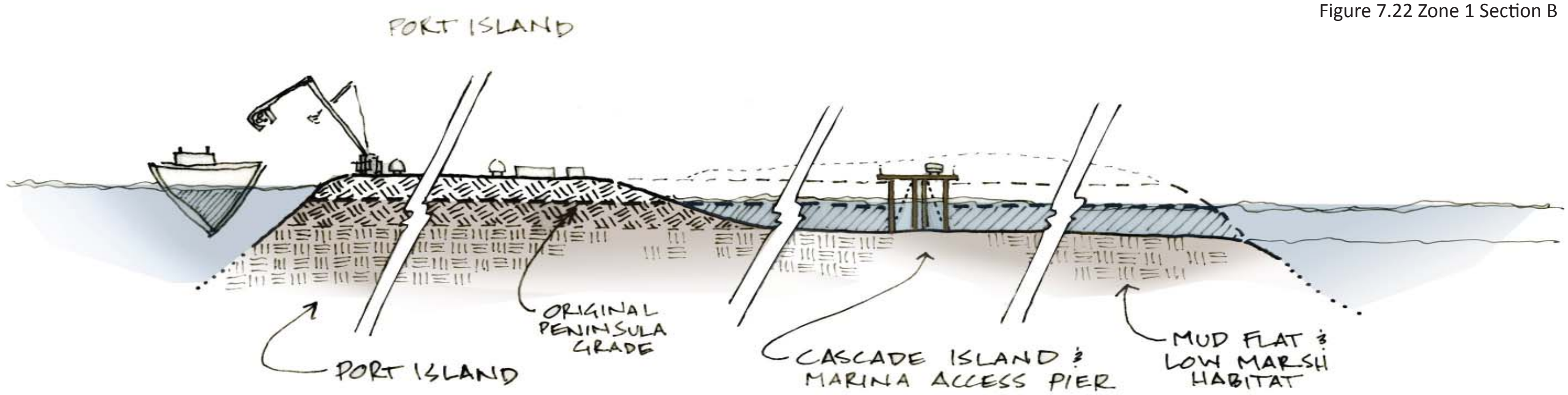
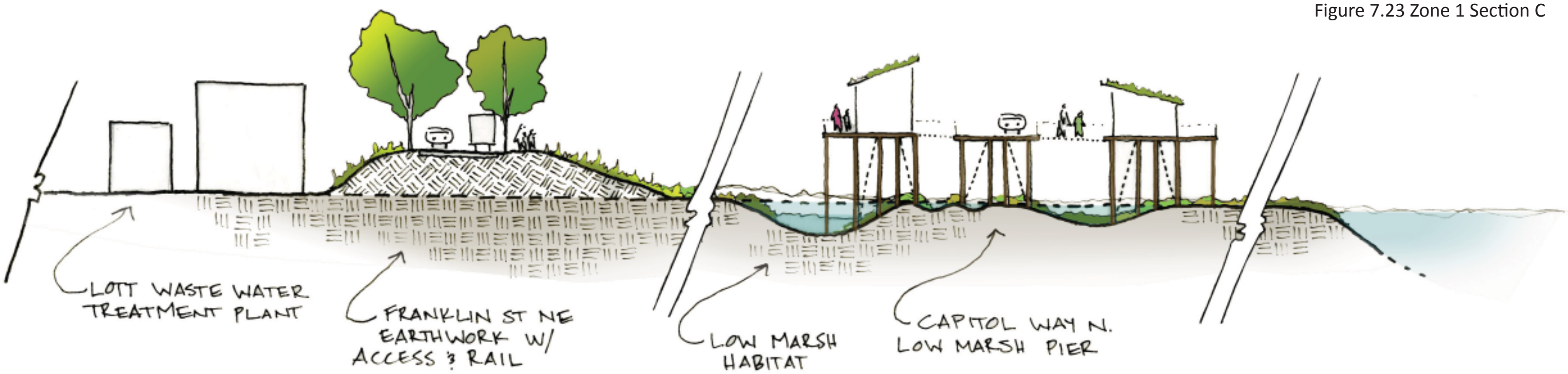


Figure 7.23 Zone 1 Section C

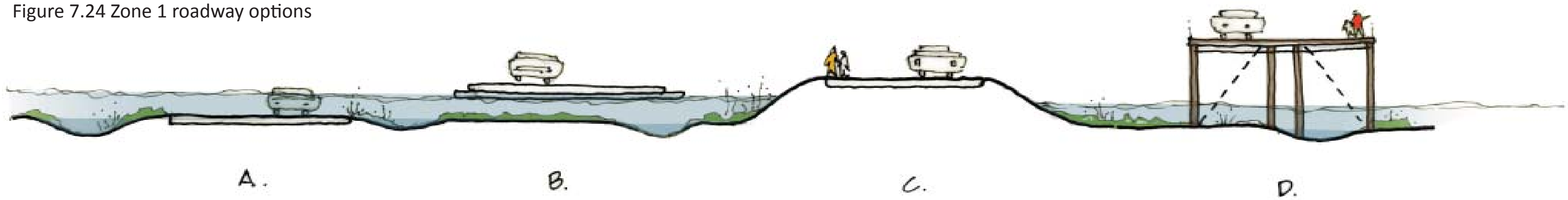


port activities such as rail dependent shipping, remediation of the Cascade Poll site, dry storage and boat building depend on dry land, therefore allowing all port property to be inundated would be economically detrimental.

Alternate 3: Establish sea walls or levees to protect existing shorelines of port property from inundation. Construction cost, maintenance cost as well as destruction of the intertidal zone make this alternate undesirable.

Proposal: Limited dry land dependent activities are retained through significant cut and fill. Large tidal channels cut through the western side of the peninsula, connecting through to the northwestern corner provide enough fill to raise land adjacent to

Figure 7.24 Zone 1 roadway options



the deep water channel, and at the tip of the peninsula – protecting existing dry land shipping activities and ongoing remediation of the Cascade Poll site.

INFRASTRUCTURE

Alternate 2: Repave roads with new flood resilient materials.

Alternate 3: Construct floating roads which are able to move up and down with tides.

Alternate 4: Elevate roads with earthwork.

Proposal: through the construction of elevated roads which extend from Franklin Street southeast and Capitol Way north. These access routes, piers utilizing low impact pin pile construction, are designed to allow tidal waters to pass below them freely.

STRUCTURES

Alternate 1: Retain existing structural footprints and retrofit lower floors to accommodate inundation.

Alternate 2: When rebuilding adjust finished floor elevation to a level which is above predicted inundation levels.

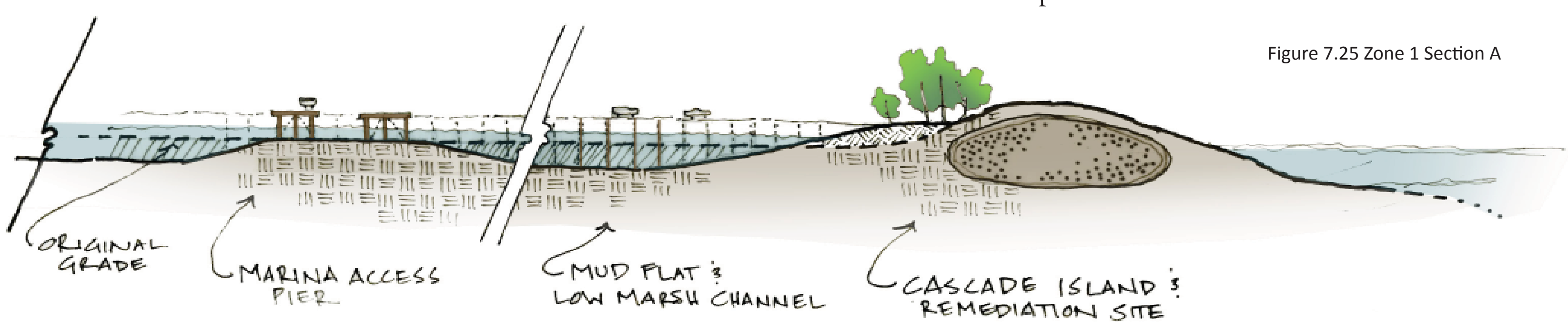
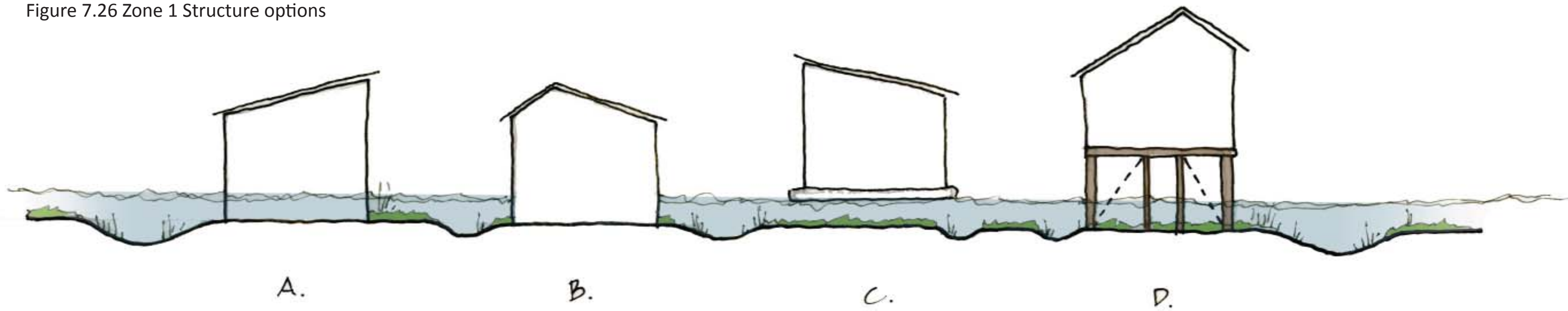


Figure 7.25 Zone 1 Section A

Figure 7.26 Zone 1 Structure options



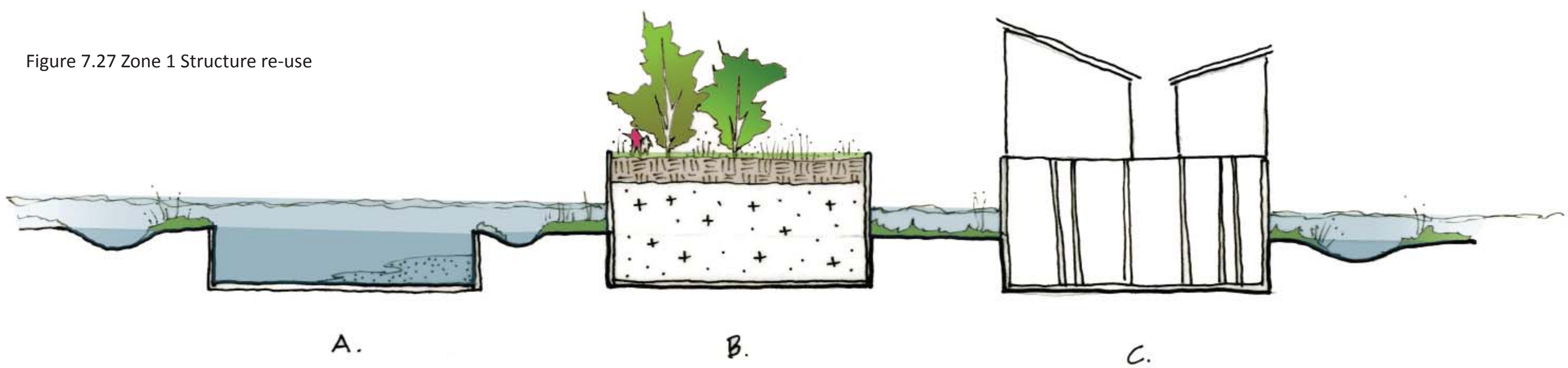
Alternate 3: Retrofit and reused existing structures, shifting the main floor to the second story.

Alternate 4: Demolish and rebuild using floating structures.

Alternate 5: Demolish existing structures and allow all ground to revert to low marsh habitat.

Proposal: Demolish, remove and recycle structural materials which are toxic or void of value for emergent low marsh habitat. For example wood, plastics and metals. Retain elements of structures, namely concrete footings and concrete basements which overtime may serve as tide pools and surfaces to which species of mollusks easily adhere. Removal of roofs and filling of remaining concrete walls create islands of higher habitat. New structures elevated and constructed on pin piles, by code are limited in their area and shadow cast, allowing enough light for low marsh habitat to dominate the ground plane.

Figure 7.27 Zone 1 Structure re-use



ECOLOGY

Following removal of impervious surfaces, allow all ground planes other than islands to be inundated regularly by tides allowing low marsh habitat to re-establish itself. Rehabilitation of existing soils may require small earthwork excavations which encourage a hierarchy of small tidal channels to form over time. Large excavated tidal channels along the eastern side of the peninsula will support mudflat habitat.

USE

Ocean liner facilities remain active, if needed large floating structures to the east of Port Island provide space for dry storage of goods. The northern island supports ongoing remediation of the Cascade Poll site as well as ship building, repair and dry storage, park and plaza space, and restaurant and banquet activity Linear docks along the eastern half of the peninsula provide parking and access to marinas. Excavated tidal channels passing through the peninsula from the east to the west support mudflat habitat; extensive oyster beds are seeded within this zone which help clean the waters of Budd Inlet. With improved prac tices in water quality these oyster beds over time provide opportunity for small commercial industry. Areas above the mudflats regularly inundated by tidal waters support extensive low marsh habitat and provide a unique opportunity for small footprint, low impact site specific business such as boutique hotels which provide small craft access and parking (e.g. canoes and kayaks), a small craft center and rental (e.g. canoes and kayaks), live/work studios, limited retail, outdoor tidally fed swimming pool and marsh bird sanctuary boardwalks. Habitat provided within this area allows species and livelihoods dependent on the intertidal zone remain intact.

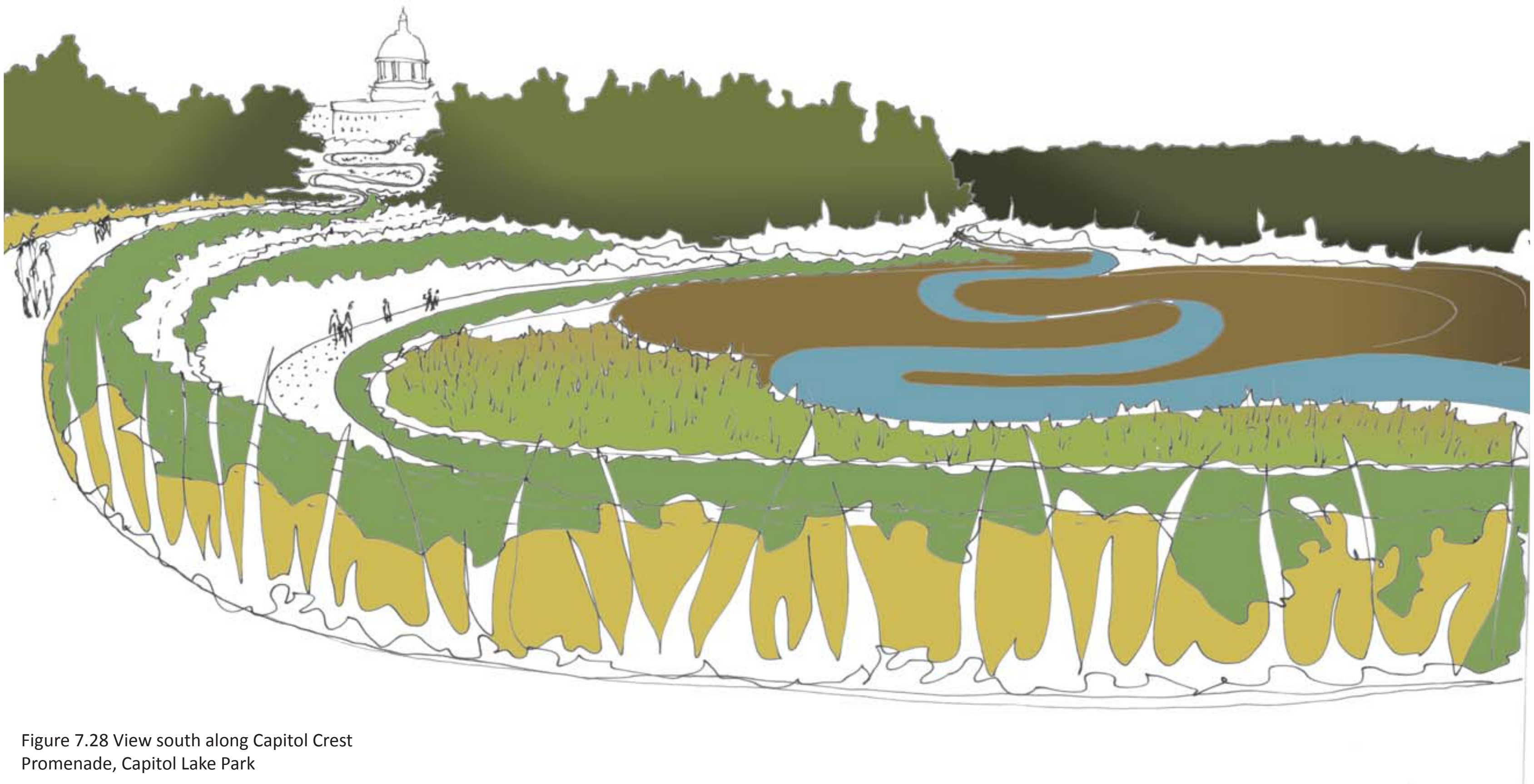


Figure 7.28 View south along Capitol Crest Promenade, Capitol Lake Park

Figure 7.29 Zone 2 and 3 plan with section cuts

ZONE TWO

Nearly all of the land within zone two is currently owned by private business, namely small industry. As with other properties which are to become part of the future line of protection, and as a result are due to experience significant grade change and/or inundation, land acquisition via contract may be the most reasonable approach. For example the municipality may offer to purchase land at its present value well into the future when property values begin to drop due to the threat of inundation. As tides rise the ownership of the parcels gradually turns over to the municipality.

EARTHWORK

Following the first five foot high berm of protection which allowes continued access and use of B and A Streets as well as Columbia St. NW, zone two acts as the first terraced protective buffer, the grade being raised uniformly five feet, gradually sloping down (no more than five percent slope) to the low marsh zone below and with the impliementation of zone three - filled

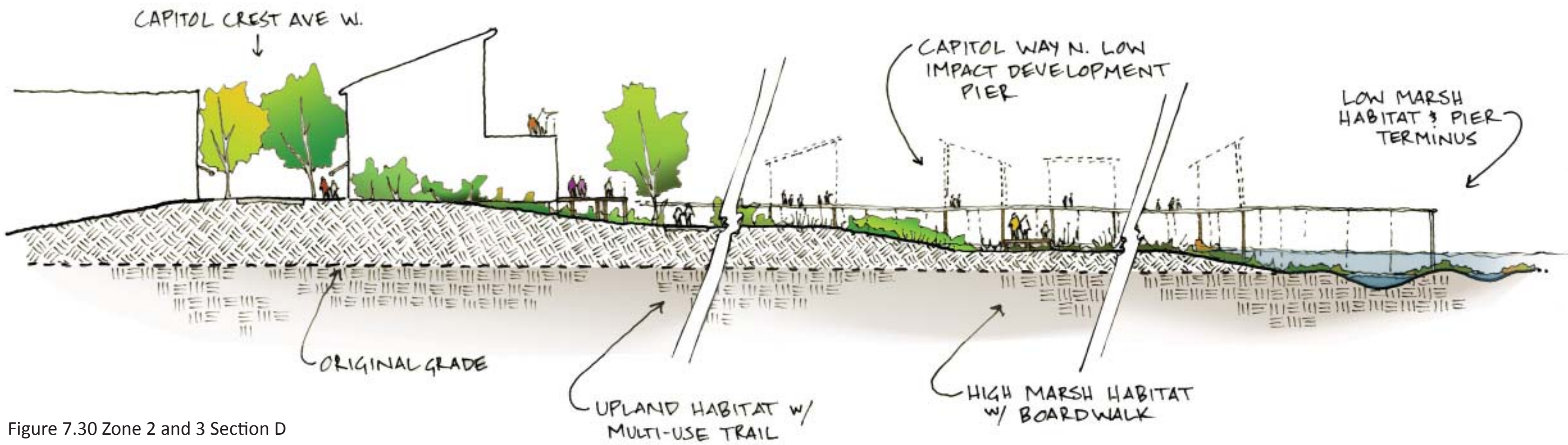


Figure 7.30 Zone 2 and 3 Section D

to Thurston Ave. NE. - between five and ten foot tall berms.

INFRASTRUCTURE

Access is limited and provided through the construction of elevated roads which extend from Franklin Street southeast and Capitol Way north, namely Low Marsh Pier. These access routes, piers using low impact pin pile construction, are designed to allow tidal waters to pass below them freely.

STRUCTURES

Demolish, remove and recycle structural materials which are toxic or void of value for high marsh habitat. For example wood, plastics and metals. Retain elements of structures, namely concrete footings, basements and walls which overtime may serve as tide pools or seasonal wetlands. Any new structures by code, float, or rest on pin-pile foundations restricting ground penetration which may compromise the stability of the earthwork. Structural footprints are limited, allowing enough light and surface area for high marsh habitat to dominate the ground plane.

Part of the proposed east bay development exists within this zone. Dependent on the expected life of the structures proposed plans could be modified to incorporate a five foot gain in elevation in preparation for the creation of a protective buffer. Lower floors could be designed with flood resistant materials.

ECOLOGY

Following removal of impervious surfaces and filling of designated area, zone two provides high marsh habitat.

USE

Along with limited low-impact development build-out supporting mixed use, zone two provides high marsh habitat and significant parklands.

ZONE THREE

Land within zone three is currently owned by private business, namely small industry and the waste water treatment plant LOTT Clean Water Alliance. As with other properties which are to become part of the future line of protection and as a result are expected to experience significant grade change and/or inundation, land acquisition of small parcels via contract as described for zone two may be the most reasonable approach. This proposal assumes that future changes in waste water treatment driven by climate change, new technologies and an increasing demand

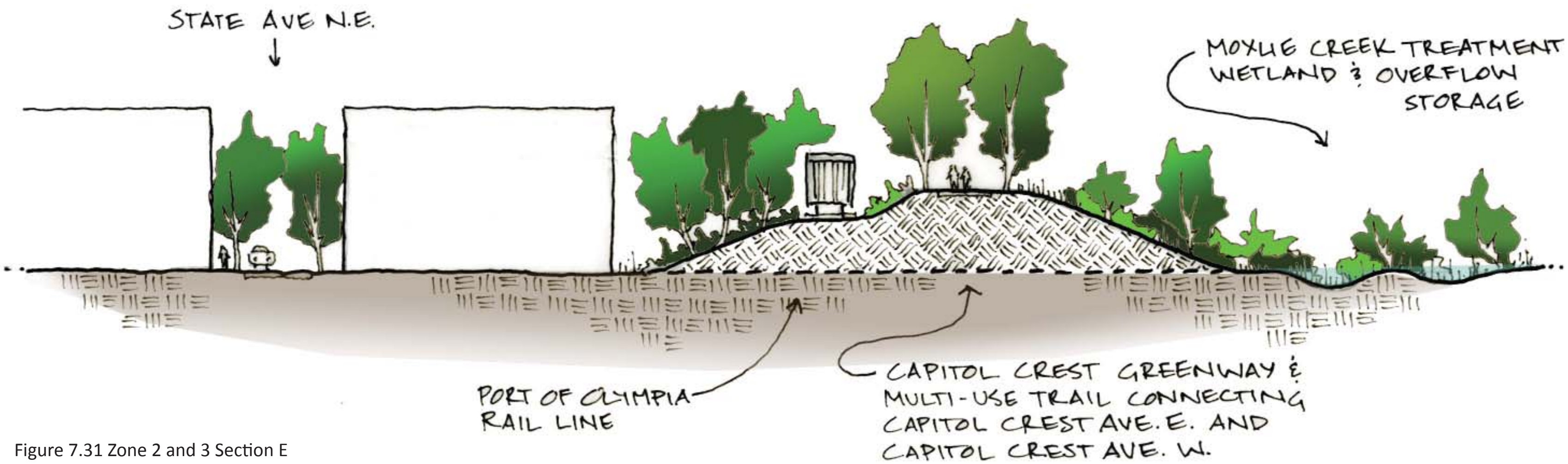


Figure 7.31 Zone 2 and 3 Section E

for reclaimed water will leave the existing wastewater treatment plant either obsolete or significantly reduced in scale. Within the Puget Sound Basin it is expected that winter runoff will increase, the amount of water stored as snowpack will decrease in the late spring, and snowmelt runoff will substantially decrease. This shift in the hydrograph will increase the competition for water resources, making it much more difficult to maintain in-stream flows for fish and to provide water for municipal uses (NOAA, 2007).

EARTHWORK

Following the second ten foot high berm of protection which allowed continued access and use of B and A Streets as well as Columbia St. NW, zone three acts as the second terraced protective buffer, the grade being raised uniformly 10 feet, gradually slopping down (no more than five percent slope) to the high marsh zone below. Allowing continued use of Thurston Ave. NE.

INFRASTRUCTURE

Access is limited and provided through the construction of elevated roads which extend from Franklin Street southeast and Capitol Way north. These access routes, piers using low impact pin pile construction, are designed to allow tidal waters to pass below them freely.

STRUCTURES

Demolish, remove and recycle structural materials which are toxic or void of value for high marsh habitat. For example wood, plastics and metals. Retain elements of structures, namely concrete footings and concrete basements which overtime may serve as tide pools or seasonal wetlands. Any new structures by code, float or are elevated on piles (depending on the stability of the earthwork). Structural footprints are limited, allowing enough light and surface area for upland habitat to dominate the ground plane.

ECOLOGY

Following removal of impervious surfaces and filling of designated area, zone three provides upland habitat.

USE

Along with limited low-impact development mixed use in nature, zone two provides upland habitat and significant parklands.

Figure 7.32 View west along Capitol Crest Ave. E

ZONE 4

Zone four marks the peak of the proposed earthwork. Land within zone four is currently owned by private business, namely small industry. Although the initial line of protection is made through the identification of public right of ways, parks and existing parking lots, as with other properties which are to become part of the future line of protection and as a result are expected to experience significant grade change and/or inundation, land acquisition of parcels via contract as described for zone two may be the most reasonable approach.

EARTHWORK

Following the third terrace of earthwork of protection reaching a height of ten feet, zone four acts as the final terraced protective buffer. The grade being raised uniformly fifteen feet, gradually slopes down through a series of terraced earthwork to Budd inlet, and on the opposing side (no more than five percent slope) to the historic district and commercial core. The crest of the earthwork is approximately sixty to one-hundred feet wide for most of its

Figure 7.33 Zone 4 plan with section cuts

length, and is able to facilitate a broad range of uses as well as provide desirable views towards the inlet and back toward the historic district.

INFRASTRUCTURE

Public access spans the length of the crest, creating a public promenade characterized by segments of active street and multi-use greenway - stretching from Pear St. (northeast) to the switch back trail which jogs up to the Capitol campus (southwest). Segments of promenade roadway - Capitol Crest Ave. E and Capitol Crest Ave. W – are small in scale; streets twenty-five to thirty feet wide preferably. Several roadways from the city core extend up to the top of the crest providing access to the Capitol Crest avenues, as well as providing access to piers. Regionally specific construction materials should be utilized, for example crushed oyster shells as aggregate for new sidewalks and pedestrian pathways.

STRUCTURES

Concrete forms of past structures within this zone are retained when suitable, namely concrete footings basements and walls

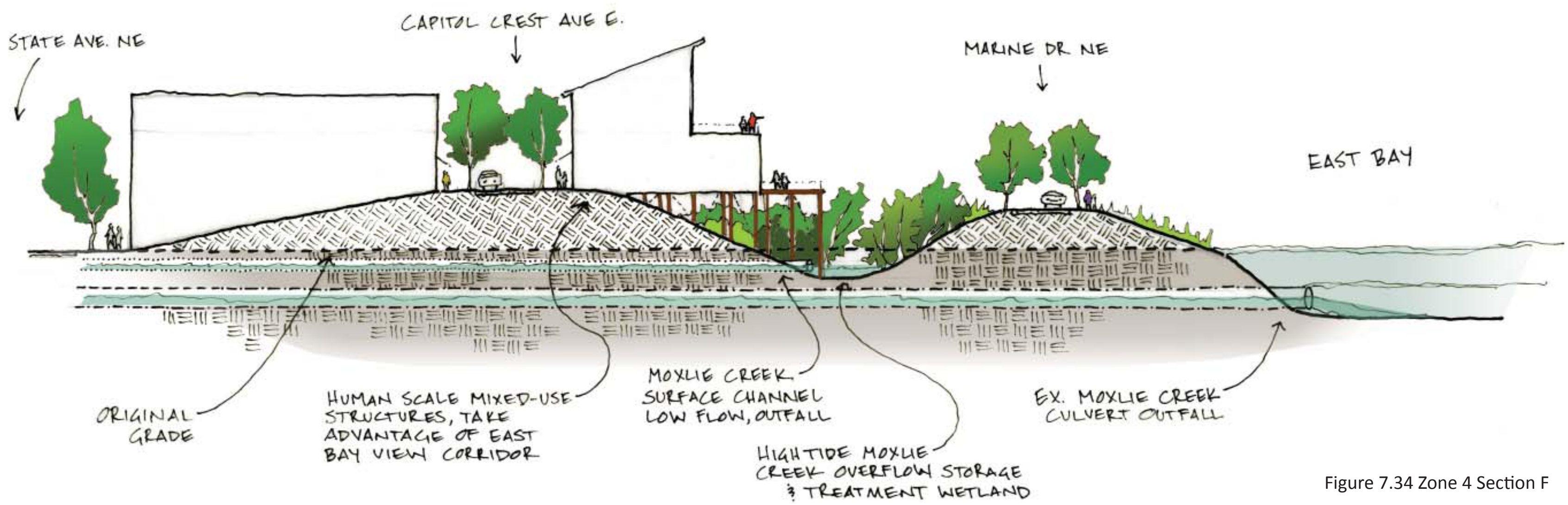


Figure 7.34 Zone 4 Section F

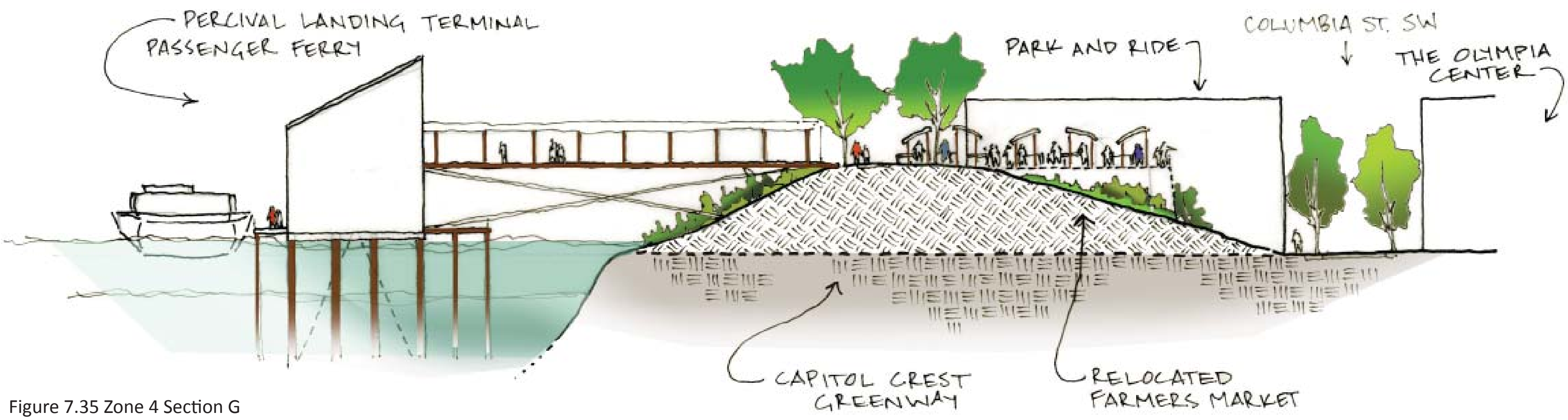


Figure 7.35 Zone 4 Section G

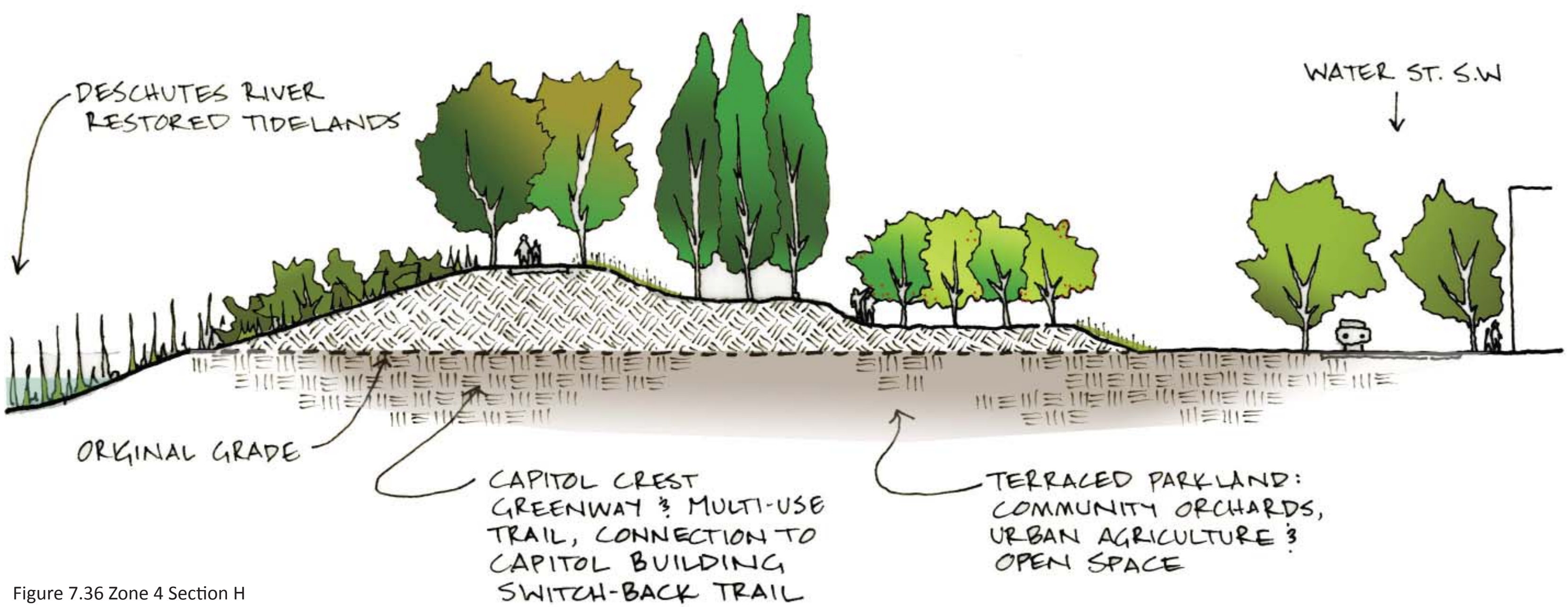


Figure 7.36 Zone 4 Section H

which when filled (provided they may be retrofit to take the load) serve as extensions of park along the promenade. New structures flank the proposed roadways, Capitol Crest Ave. E and Capitol Crest Ave. W. Due to their adjacency to the shoreline height restrictions along these roadways are put in place (one to two stories along the water side, three to four along the urban core) as well as spatial requirements to encourage framing of views rather than impediment of views. Structures which transition from the urban core to the top of the crest do so with lower floors fronting the city core along the south and second floors fronting the Crest Promenade along the north. Structures overlooking Budd Inlet are fine grained, seaside in nature, and create a strong relationship to the tidelands through framed views, decks and boardwalks.

ECOLOGY

Following removal of impervious surfaces and filling of designated area, zone three provides upland habitat.

USE

A wide range of uses are encouraged along the promenade, creating an active engaging environment. Lower floors of structures and their uses along Capitol Crest Avenues should activate the street - cafés, studios, workshops, boutiques, markets, and pubs, for example should create textured attractive streetscape. Above this active frontage is the opportunity for high end residential, taking advantage of shoreline and city views. The greenway portions of the promenade, along with multiuse trail provide opportunity for exploration and play directly linked with marshland trails and boardwalks. Functioning as linear parks they may facilitate community gardens, dog parks, playgrounds and sports facilities.

Figure 7.37 Aqua Block alleyway stormwater channel

ZONE 5

The social heart of Olympia, currently admired for its human scale, walkability and diversity is not only protected but strengthened by the cradling of the Capitol Crest Promenade. The daily exchanges made between the active edge, social heart and outlying water landscape are complementary and symbiotic in nature.

EARTHWORK AND INFRASTRUCTURE

Earthwork within the city center is minimal and sensitively done. The load once placed on existing storm water infrastructure (in the past a flood risk) is relieved through four methods: 1) the redesign of ten toe of slope city blocks, coined Aqua Blocks, to collect stormwater, storing it internally and conveying it toward two out fall locations, , 2) decreasing impervious surface through the implementation of vegetated roof tops, 3) the creation of a surface channel for Moxlie Creek (forming a dual system of bellow grade pipe and surface water conveyance, which prevents backing up and flooding of the creek during high tide storm surge events), and 4) creation of a treatment wetland (see zone 3).

Figure 7.38 Zone 5 Plan

Figure 7.39 Zone 5 plan in detail

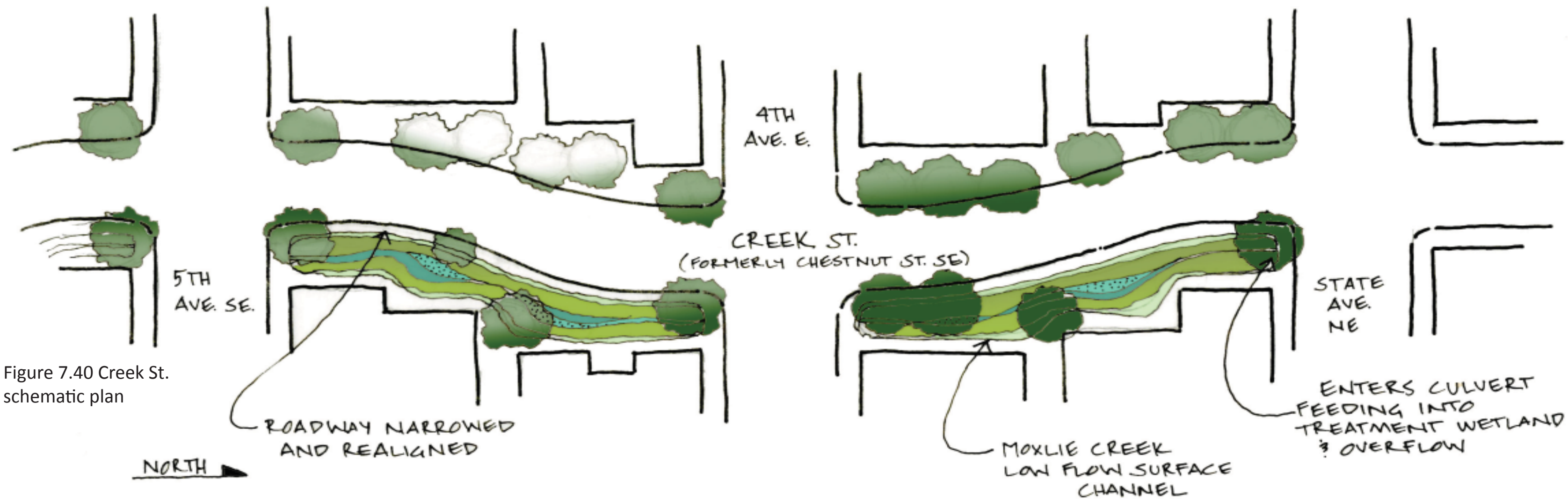


Figure 7.40 Creek St. schematic plan

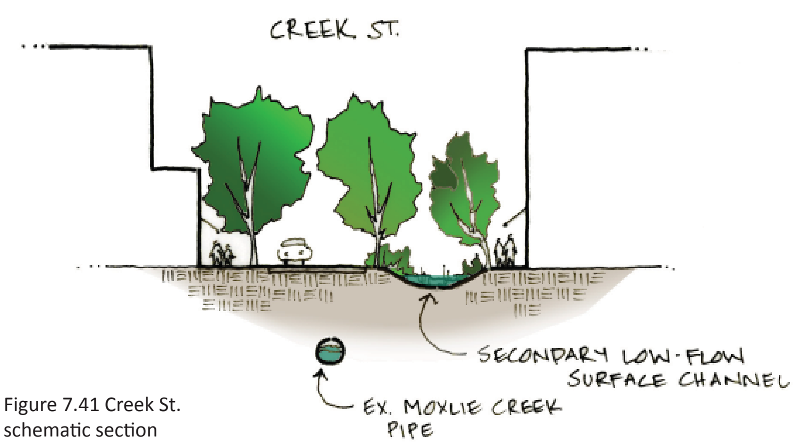


Figure 7.41 Creek St. schematic section

STRUCTURES AND USE

Parcels of land which were previously under-utilized (as surface parking) are redeveloped. Depending on the risk posed, new structures may be encouraged to utilize flood-proof materials for their lower floors. A higher density within the downtown core is achieved without sacrificing its identity, through conscientious architectural design reflective of place, and convenient connections to mass transit. Small industry remains within the downtown; however land use largely shifts toward mixed use with pockets of residential .

ECOLOGY

The urban core benefits ecologically through the implementation of vegetated roofs, creation of Moxlie Creek surface channel and the surface drainage network held within the aqua blocks.

Figure 7.42 Aqua Blocks conceptual plan and cross section

Figure 7.43 Conceptual phasing diagrams

As mentioned previously the rate, degree and timeframe of SLR is uncertain. Therefore solutions should be as flexible as possible in their approach. This proposal assumes a significant gradual rise in sea-level spanning several decades. Phasing explored set increments of twenty year time frames for each zone, slowing employing RAP strategies.

For example agreements would be made with parcel owners in zone one within the first twenty years, dictating acquisition by the city following significant sustained flooding. As tides rise and properties turn over, the first line of protection is implemented - a five foot high earthwork. Following completion of zone one and the first line of protection similar long standing agreements are made with those parcel owners in zone two. It is nearly impossible to predict the rate of change, therefore long term agreements are made with the worst case scenario in mind. As a result three lines of protection would be decided upon and implementation would occur incrementally, dictated by the need.

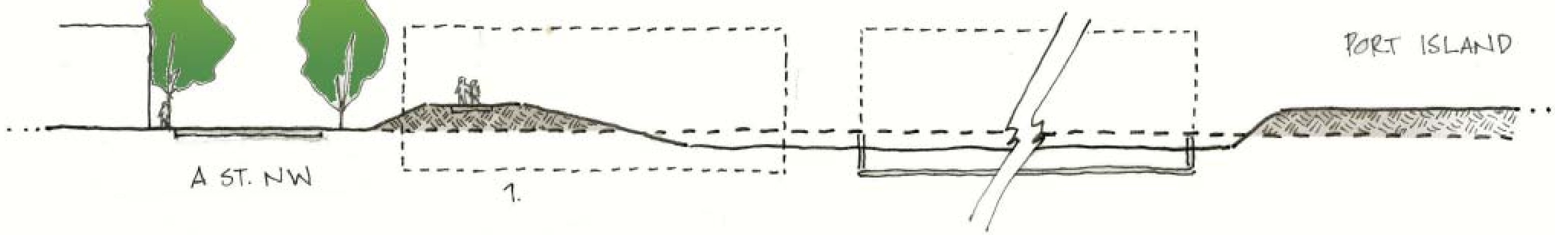


Figure 7.44 Conceptual phasing section 1: Having located first second and third (final) lines of protection, begin with implementation of first line of protection (five foot tall earthwork), allowing for continued use of A St. NW, remove impervious surfaces and toxic materials within zone one, construct earthwork protection incorporating multi-use trial, raise port property dependent on dry land use (rail dependent area and remediation site), slope to low marsh should be as gradual as possible, maximum five percent, to allow for habitat migration.

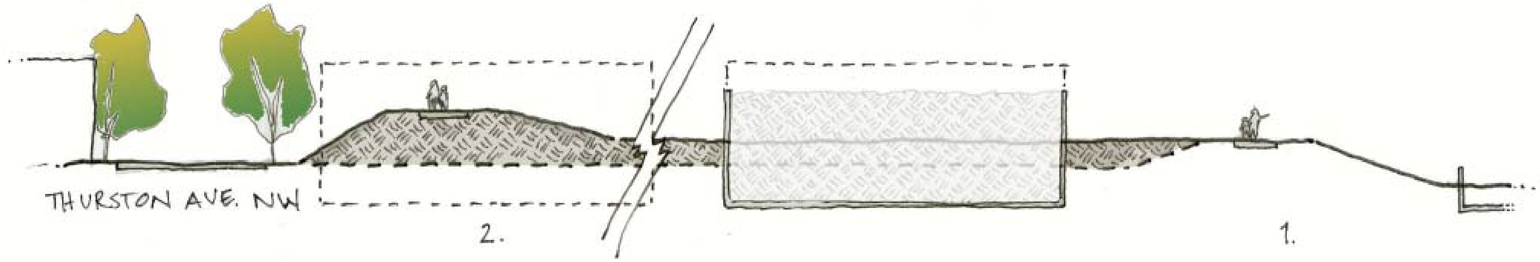


Figure 7.45 Conceptual phasing section 2: Implement second line of protection (ten foot tall earthwork), allowing for continued use of Thurston Ave. NW, remove impervious surfaces and toxic materials within zone two, construct earthwork incorporating multi-use trail, fill from first line of protection to second line - flush with first line of five feet (creating first terrace), construction may utilize deconstruction rubble as fill, slope to first terrace should be as gradual as possible, maximum five percent, to allow for habitat migration.

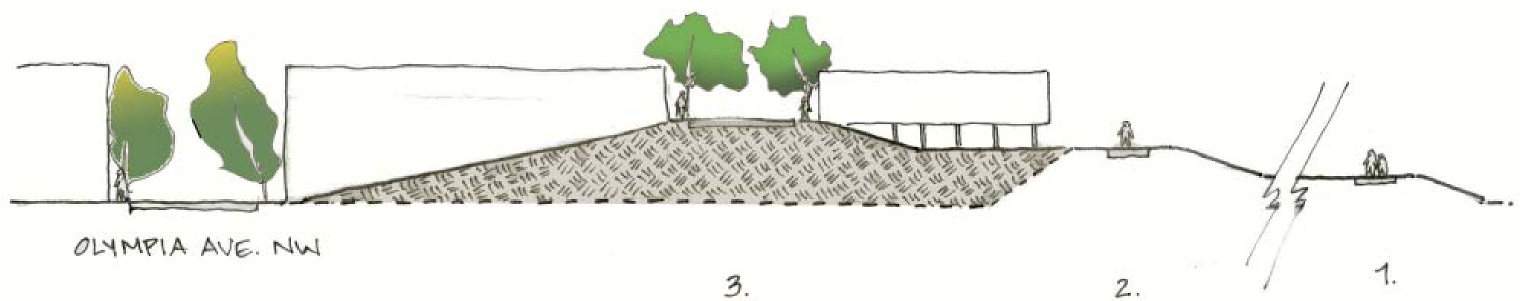


Figure 7.46 Conceptual phasing section 3: Implement final line of protection (fifteen foot tall earthwork), allowing for continued use of Olympia Ave. NW, remove impervious surfaces and toxic materials within zone three and four, construct earthwork incorporating segments of street and multi-use trail, fill from second line of protection to final line - flush with the second line of ten feet (creating the second terrace), construction may utilize deconstruction rubble or perhaps remediation of toxic sediments as fill..

7.2 Image of the City, Olympia 2110

Narrative, a (returning) visitors perspective

We arrived mid-day to Olympia, pulling our kayaks up onto the small float pad before ascending to the top of the pier. For the past thirty years my husband and have visited Olympia annually. We'll stay in the small boutique hotel located beside the pier which along with a small crafts center provides easy access and storage for people traveling by kayak along the shores of the Puget Sound.

Low Marsh Pier, which traces the path of Olympia's historic mile long wharf, is now known for its artist's community – commonly known as Artists Wharf. Many of the modestly sized structures flanking its length serve as live /work studios. I imagine the convenience of the nearby city center pared with the serene, retreat-like quality of the marsh provides an attractive milieu. The first Friday of every month Low Marsh Pier becomes the hub of Olympia's Art Walk. Being situated along the pier we'll be able to easily explore the backwaters of the marsh with our boats and paddle up the Deschutes River. At this time of year pickleweed carpeting the marsh glows with a rosey hue.

This afternoon, seeking a more urban atmosphere we walk south towards the city along the pier and soon intersect Capitol Crest Ave. W - a narrow cozy active street. Capitol Crest Ave. W is one segment of a lively public promenade stretching from the northeastern corner of Olympia's downtown to the Capitol Campus located to the southwest. Turning to the left we walk to the eastern end of the avenue, a T intersection with Franklin St. NE. Turning left again at this point would lead us toward a pier which serves Port and Cascade Island, major boat works and marina facilities as well as an expansive intertidal zone within which the native Olympia Oyster has re-established itself. Improvements in storm water quality, the function of Budd Inlet and clean maritime industry now allow public harvest of these Oyster beds. The Port of Olympia facilitates an annual oyster and maritime festival on Cascade Island.

We continue onward along a multi-use trail spanning a section of greenway. To the left we overlook the city's old waste

Figure 7.47 Walking rout of Olympia visitor

water treatment facility. Protected from rising tides with extensive earthwork its use slowly became obsolete as snow pack vanished and water scarcity became an issue. The term waste water is no longer used, as all municipal grey water is now recycled at a neighborhood scale; bio-solids are collected and fed to local cogeneration plants. The large concrete structures of the old treatment plant bellow have been filled, capped with top soil and vegetated. The site is now a popular public park. Visitors are free to traverse the structures through a series of elevated boardwalks. The ground bellow functions as a treatment wetland, during a storm surge as the water volume increases the structures become islands.

Up ahead we reach Capitol Crest Ave. E. a continuation of the popular street whose quaint shoreline character houses a variety of small format commercial businesses below and high end residential above. To our left we overlook sweeping framed views of the East Bay corridor. Concrete walls of structures previously occupying the site have been incorporated into the existing earth work. Filled fifteen feet to be flush with Capitol Crest Ave. E. they now function as parks jutting out to the north, providing a collection of unique viewpoints. We turn right onto the illustrious Creek St.; previously known as Chestnut St.

For years there was a community debate over whether or not the creek piped bellow, Moxlie Creek, should be day-lighted. As with many creek day-lighting projects cost was not the sole issue, the piped creek existed fifteen feet below grade; there was reasonable disagreement over what such a deep excavation of creek corridor would accomplish. When the City of Olympia was founded where we now stand now was not dry land. For many years the Moxlie Creek delta separated central Olympia from east Olympia (then known as Swantown). As the city grew Moxlie Creek delta was filled, the creek was placed in a pipe, and as a result its delta was artificially shifted approximately eight blocks to the north.

During the early 21st century as sea-level rise became a principal concern studies found that the pressure of a high tide in combination with expected sea-level rise and storm surge would in effect back up Moxlie creek; preventing its discharge and caus ing it to overtop it's banks significantly at the point at which it entered the pipe. In response to this concern the city devised a dual pipe and surface channel system. The pipe bellow grade has been retained to accommodate high flow waters able to outfall provided the tide is out. A secondary surface channel now runs along the surface accommodating low flows, which then feed into a treatment wetland once adjacent (and now a part of) the old LOTT treatment plant before it's outfall to East Bay. During a combined high tide and storm surge event this channel accommodates and conveys expected creek overflow to the treatment wetland, functioning as a storm surge storage facility before it's outfall to the East Bay at low tide.

Following the establishment of the surface channel Creek Street became a hot spot for re-development. Within walking distance of the historic district, it's adjacency to Plum Street provides easy access to main arterials, and yet because Creek Street itself is not a through street it's able to maintain a pleasant pedestrian friendly atmosphere, commercially active yet absent of heavy traffic. Unlike Capitol Crest streets with significant height restrictions, the Creek Street corridor is able to accommodate higher densities. It has become a prominent neighborhood within Olympia's Downtown core – attracting long term residents as well as visitors. As we stroll its length this afternoon a number of cafés and restaurants spill out with chairs and tables along broad tree shaded sidewalks perched beside Moxlie Creek.

After perusing Creek Street we turn right onto Legion Way SE, headed towards Olympia's historic town square, Sylvester Park. Significant growth has occurred within the downtown neighborhood over the past decades and Olympia has been able to manage this growth to its own benefit. Strategic infill has strengthened the continuity of its human scale walk-able blocks. Through thoughtful design and attentiveness to the scale and style of historic structures Olympia has been able to maintain and strengthen the character of livability it's become known for - a cozy yet lively village tucked away along the shores of the Puget Sound.

Turning right onto Capitol Way S. we walk down a gentle slope towards what have been coined the Aqua Blocks, which lie between 4th and State Avenue. Historically the downtown core faced periodic flooding by storm water runoff unable to be contained by the existing below grade storm drainage network. Due to limited space within existing right-of-ways to accommodate greater amounts of storm water runoff, as has often been accomplished through the implementation of surface channels (natural drainage systems), a series of blocks at the tow of the downtown slope were designed to accommodate storm water internally. Alley right-of-ways provide conveyance of storm water toward to two outfall points, Moxlie Creek surface channel to the east and Percival Landing to the west.

Redeveloped parcels within these blocks are required to devote fifteen to twenty percent of their lot to storm water detention and conveyance, forming a network when connected to the core alley conveyance channel. Along with the requirement of green roofs, developers are encouraged to incorporate detention basins creatively, integrated with architectural design and use. The Aqua Block pilot project spurred the zero emission movement within Olympia's Downtown. Due to its commitment to zero waste - subsequently a zero emission city, and recognizing that buildings were the largest single contributor of CO2 emissions (43%), the City of Olympia used the Aqua Block pilot project as a way to test the ability of a city to retrofit its urban environment, becoming climate neutral.

The Aqua Block project has now been fully implemented, spanning ten city blocks. Due to Olympia's willingness to take on such forward-looking projects, addressing climate change and urban sustainability head-on, it has become both a regional and global leader in the arena of urban evolution. Tourists as well as officials from other cities often travel to Olympia to better understand the ways in which their own cities could implement the redesign of systems, optimizing both urban and ecological environments.

Continuing along Capitol Way S. we reach Capitol Crest Ave. W. and its intersection with Low Marsh Pier. Turning to the right we discover enchanting framed views of the Olympic Mountain range to the North West which commercial businesses make use of with open decks. Above this lower commercial level are high end residential lofts. As we reach the eastern terminus of the avenue we continue on along the pedestrian promenade, named Olympic Point after its expansive views to the north of the Olympic Mountain Range. Nearing Percival Landing Park we stroll through the farmers market to our left, bustling with local farmers, crafts people and visitors. Their facility is opportunely located across from Percival Landing passenger ferry terminal; a ferry which in the coming days we'll board to exploring the greater Puget Sound.

Crossing 4th Ave. E. and 5th Ave. S.W. we over look Heritage Park to the left, whose fountain this afternoon has attracted a slew of delighted squealing children along with their families. The capitol building is the focal point to the south, perched above the Deschutes River estuary. Capitol Lake once located to right, created artificially with a dam, was long ago drained with the removal of the dam, restoring the rivers natural exchange with Budd Inlet. Ensuing sediment accumulation in the ports shipping channel was then dredged and utilized for the final stages of the Capitol Crest earthwork. Capitol Lake Park, a name reminiscent of the reflecting pond, encompasses the southern stretch of Capital Crest Promenade. To the left large terraces of earth step down to the city center, along their length public orchards and urban agricultural plots evoke the orchards once present in Olympia after which several of the streets to the east of the Downtown are named.

The terminus of Capitol Crest Promenade meets the switch back trail which jogs up the steep slope to the Washington Supreme Court Temple of Justice, behind which the domed capitol building stands. We've reached this vantage point as dusk falls across Budd Inlet; the silhouette of the Olympic Mountains in the distance awash with fading sunlight.

7 Conclusion

Throughout the past decade a growing awareness and then concern has arisen, first in regard to climate change, and then over specifics like SLR. At first discussion was had over how we could prevent climate change and accompanying sea-level rise by limiting CO2 emissions – the hope being to turn back climate change all together. Recent studies have suggested that although changing our present consumption patterns would be a positive and necessary step for the health of future generations, there's little if nothing at all we can do about the climate change currently underway. Glaciers are melting, the sea is expanding as it warms and those of us who are privileged enough to do so, have a choice to make.

Low lying communities may naturally perceive sea-level rise as a threat requiring a fight; while others view retreat as the only solution. Traditional hard engineering solutions may be a comforting prospect. However our knowledge of how and to what degree they interfere with natural processes, the overall health of our ecosystems and therefore our communities, should guide us in a different direction. Sea-level rise will test our ability to adapt. This challenge carries with it a significant prospect. Should sea-level rise be dealt with strategically, we may have the opportunity to re-shape our cities in a way arguably comparable to that of the industrial revolution or advent of the automobile, through our deliberate optimization of the relationship we share with natural systems.

The design alternatives explored within this thesis look toward a long term vision of economic, social and environmental resilience for shoreline built environments when faced with a gradual rise in sea-level. Within which combined strategies of retreat, accommodation and protection (RAP) have been explored. It is my sincere hope that this document, along with others like it begin to provide municipalities with a flexible framework of ideas though which they may begin to envision a range of options of retreat, accommodation and protection as viable incremental solutions; guiding them towards models of social, economic and environmental resilience.

References:

Macdonald, Keith. 1994. Shoreline armoring effects on physical coastal processes in Puget Sound, Washington. Coastal erosion management studies, v. 5. Olympia, Wash: Shorelands and Coastal Zone Management Program, Washington Dept. of Ecology.

Thom, Ronald M., David K. Shreffler, and Keith Macdonald. 1994. Shoreline armoring effects on coastal ecology and biological resources in Puget Sound, Washington. Coastal erosion management studies, v. 7. Olympia, Wash: Shorelands and Coastal Zone Management Program, Washington Dept. of Ecology.

United States. 2007. Sound science synthesizing ecological and socio-economic information about the Puget Sound ecosystem. [Washington, D.C.]: National Oceanic and Atmospheric Administration. http://purl.access.gpo.gov/GPO/LPS78091.

Newell, Gordon R. 1985. So fair a dwelling place: a history of Olympia and Thurston County, Washington. [Olympia, Wash.]: G.R. Newell.

Kruckeberg, Arthur R. 1991. The natural history of Puget Sound country. Seattle: University of Washington Press.

Weis, Judith S., and Carol A. Butler. 2009. Salt marshes: a natural and unnatural history. New Brunswick, N.J.: Rutgers University Press.

Multi-department Sea Level Rise Strategy Team. October 2010. "Proposed 2010-2011 Sea Level Rise Work Plan, City Council Meeting."

Lonsdale, K., T. Downing, R. Nicholls, D. Parker, A. Vafeidis, R. Dawson, and J. Hall. 2008. "Plausible responses to the threat of rapid sea-level rise in the Thames Estuary". Climatic Change. 91 (1-2): 1-2.

Tol, Richard S. J., Maria Bohn, Thomas E. Downing, Marie Laure Guillerminet, Eva Hizsnyik, Roger Kasperson, Kate Lonsdale, et al. 2006. "Adaptation to Five Metres of Sea Level Rise". Journal of Risk Research. 9 (5): 467-482.

Kirwan, M., and S. Temmerman. 2009. "Coastal marsh response to historical and future sea-level acceleration".

France, R. L. 2008. Handbook of regenerative landscape design. Integrative studies in water management and land development. Boca Raton: CRC Press.

VanKoningsveld, M., J.P.M. Mulder, M.J.F. Stive, L. VanDerValk, and A.W. VanDerWeck. 2008. "Living with Sea-Level Rise and Climate Change: A Case Study of the Netherlands". Journal of Coastal Research. 24 (2): 367-379.

Tol, Richard S.J., Richard J.T. Klein, and Robert J. Nicholls. 2008. "Towards Successful Adaptation to Sea-Level Rise along Europes Coasts". Journal of Coastal Research. 24 (2): 432-442.

Washington (State), and Puget Sound Action Team. 2007. The state of the Sound.

Coastal/Infrastructure Preparation/Adaptation Workgroup. 2007. Meeting #4 Summary Washington Climate Change.

City of Olympia. January 2010. "Sea Level Rise Response". PowerPoint presentation.

Olympia Community Planning and Development Department Advance Planning and Historic Preservation. July 1994. "Comprehensive Plan for Olympia and the Olympia Growth Area".

City of Olympia Historic Preservation Program. 2004. "Olympia Downtown Historic District, Listed on the Washington Heritage Register and the National Register of Historic Places". Brochure.

Loffredo, L., D. Schulz, and J. Wilkens. 2007. "Design parameters for coastal dikes".

City of Olympia and Olympia Heritage Commission. 2006. "Olympia Downtown Historic District Walking Tour".

Center for the Study of the Pacific Northwest University of Washington Department of History. "Indians and Europeans on the Northwest Coast, 1774–1812 A Curriculum Project for Washington State Schools".

Dutch central government. 2009. "National Water Plan, 2009-2015".

White, Jacqueline, Jennifer L Ruesink, and Alan C Trimble. 2009. "The nearly forgotten oyster: Ostrea lurida Carpenter 1864 (Olympia oyster) history and management in Washington state". Journal of Shellfish Research. 28 (1): 43.

U.S. Fish and Wildlife Service. 2005. Nisqually National Wildlife Refuge: final comprehensive conservation plan and environmental impact statement, Thurston and Pierce Counties, Washington. [Olympia, Wash.]: The Service.

LOTT Wastewater Management Partnership. August 1998. "Budd Inlet Scientific Study Final Report".

Couch, David, and Thomas J. Hassler. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) : olympia oyster. Vicksburg, MS: Coastal Ecology Group, Waterways Experiment Station, U.S. Army Corps of Engineers.

Olympia Public Works Department Water Resources. 2007. "Olympia's Response to the Challenge of Climate Change, Background Report and Preliminary Recommendations".

Dutch central government. December 2006. "Spatial Planning Key Decision Room for the River, Approved decision".

Thurston Regional Planning Council. 1993. "Section Eleven, Olympia Special Area Management Plan (SAMP), Olympia Urban Waterfront Plan."

Web References:

http://www.malmo.se/sustainablecity

http://www.squaxinisland.org/

http://nisquallydeltarestoration.org/

http://coastsalishmap.org/start_page.htm

http://www.ci.olympia.wa.us/

http://www.ecy.wa.gov/