

Pier Pressure:
Addressing Ecological Opportunities of Nearshore Infrastructure in
Lake Washington's Union Bay

Krista D. Doersch

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

University of Washington
2020

Committee:

Nancy Rottle

Ken Yocom

Program Authorized to Offer Degree:
Landscape Architecture

©Copyright 2020

Krista D. Doersch

University of Washington

Abstract

Pier Pressure:
Addressing Ecological Opportunities of Nearshore Infrastructure in
Lake Washington's Union Bay

Krista D. Doersch

Chair of the Supervisory Committee:

Nancy Rottle

Landscape Architecture

Along much of Seattle's freshwater shorelines, seemingly isolated problems like erosion and shading are compounded and repeated by docks, piers, and houseboats. This results in a much bigger ecological problem: the erasure of the critical nearshore habitat that supports all life in the lake. What innovations in nearshore infrastructure design can provide multifunctional benefits for people and the environment? This design thesis considers the existing conditions of five representative zones along the University of Washington's waterfront. Insights from restoration ecologists, engineers, local experts, and trends in aquatic infrastructure inform the design of this urban site. Pier Pressure proposes holistic solutions through a systems approach that enhances built interventions through ecological design.

Keywords: ecological design, overwater structures, nearshore lake habitat, shoreline armoring, UW waterfront, aquatic recreation



PIER PRESSURE

ADDRESSING ECOLOGICAL OPPORTUNITIES
OF NEARSHORE INFRASTRUCTURE
IN LAKE WASHINGTON'S UNION BAY

KRISTA DOERSCH
MASTER OF LANDSCAPE ARCHITECTURE THESIS
2020

UNIVERSITY OF WASHINGTON
COLLEGE OF BUILT ENVIRONMENTS



ACKNOWLEDGMENT

I would like to express my deepest appreciation to my thesis committee members, Nancy Rottle and Ken Yocom, for your guidance, dedication, and patience through this thesis adventure. You pulled me out of many rabbit holes and were able to make sense of my disparate ideas, thank you. I'm also extremely grateful to Brooke Sullivan for reminding me to focus on what matters and how to keep it simple. To the whole UW//LA department, thank you for your enduring support.

A big, heartfelt thank you to Nicole Klein and UW Recreation for being a champion for me and for the future of the ASUW Shell House. You

gave me so many opportunities to see the site from different perspectives. Your help added the necessary depth to my exploration.

This work would not have been possible without the support of my family and friends, thank you. The weekly zoom calls with the Well Built Women were especially important. Many thanks also to the many reviewers whose insights guided my thinking.

Finally, I would like to acknowledge that this project is sited on the traditional land of the first people of Seattle. I honor with gratitude the Duwamish People, past and present, as well as the land itself.

*Kayaking in a
restoration area in
Union Bay*



SUMMARY

Along much of Seattle's freshwater shorelines, seemingly isolated problems like erosion and shading are compounded and repeated by docks, piers, and houseboats. This results in a much bigger ecological problem: the erasure of the critical nearshore habitat that supports all life in the lake. What innovations in nearshore infrastructure design can provide multifunctional benefits for people and the environment?

This design thesis considers the existing conditions of five representative zones along the University of Washington's waterfront. Insights from restoration ecologists, engineers, local experts, and trends in aquatic infrastructure inform the design of this urban site. Pier Pressure proposes holistic solutions through a systems approach that enhances built interventions through ecological design.

Houseboats on Portage Bay which compound problems like erosion and shading

KEYWORDS

Ecological design, overwater structures, nearshore lake habitat, shoreline armoring, UW waterfront, aquatic recreation



TABLE OF CONTENTS

ACKNOWLEDGMENTS & SUMMARY	iii
CRITICAL STANCE A WATER-LAND RELATIONSHIP	1
HISTORICAL BACKGROUND WATER & WOOD	7
ECOLOGICAL BACKGROUND LENTIC ECOLOGY	33
SITE CONTEXT PIER PRESSURE	51
DESIGN CONCEPT CONSTRUCTIVE INTERFERENCE	79
CONCLUSION REFLECT & REFRACT	101
BIBLIOGRAPHY	107

All photographs
are by the author
and under CC
BY-NC-SA, unless
otherwise noted.

*The water's surface
as seen from below*



CRITICAL STANCE

A WATER-LAND RELATIONSHIP

“The ‘landscape cyborg’—a hybrid of human and nonhuman natural processes, of the mechanical and the organic—can occupy the conceptual space between oppositional pairs such as man-made and natural, man and nature, engineering and natural processes.”

Elizabeth Meyer, *The Expanded Field of Landscape Architecture*

Water has always been, and will always be, a defining characteristic of the Seattle region. From the dependable gray drizzle, to the mighty waterfalls of the Cascades, to the cold, clear waters of the Salish Sea, in one way or another, we are all here because of the water. As oceanographer Dr. Sylvia Earle famously said, “No water, no life, no blue, no green” (Earle 2013).

Not only is water a core requirement for survival, there is also a magnetism that draws us to where land meets water: to explore the eddy of a creek, experience the awe of a vast horizon, or the power of a crashing wave. In Union Bay, generations of paddlers have felt the bounce of the boat, joy of sunshine on their faces, and solace in hearing the “plink” of a turtle diving. We see the intrinsic value of connecting

*Union Bay in
a spring rain*

to water reflected in the soaring market prices of waterfront property. Yet, there is a pattern of developing the shorelines of Seattle's lakes and Puget Sound, much of which has encroached out onto the water's surface. Like plants competing for light, docks, marinas, and houseboats stretch out and blanket the shallows. Hydrology has been altered through great feats of engineering; but in the creation of the cuts and locks, rivers have been channeled and wetlands effaced. Despite all of the alterations, resilient species give us both hope for the future and also a false sense of security of present conditions.

Environmental externalities, like clean air and water, should not be at odds with shoreline development. The value of ecosystem services, such as filtering toxins from water or sequestering carbon, should not be underestimated because even in urban environments humans depend on them. We should aspire to live on lakes that are clean enough for recreational activities, healthy habitat, and emergency water supply. If the expected lifespan of a dock on a lake is fifty years, then in a boat town like Seattle, we have a responsibility to innovate and adapt with every structure that touches the water. What if we didn't have to compromise or value-engineer? It is with this idealism that I am analyzing the area just above and just below the water's surface, exploring trends in aquatic infrastructure

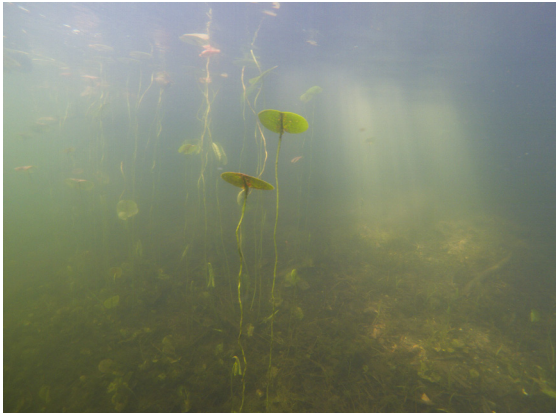
design, and proposing a holistic, systems-approach waterfront design for the University of Washington's (UW) Seattle campus.

Any work on the UW waterfront needs to be grounded in an understanding of the historical context. Geologically, the lakes and hills were carved by glaciers. Anthropologically, it has long been an important site for the Duwamish People. Ecologically, the lowering of Lake Washington was a "natural" disaster for the nearshore lake habitat. Aquatically, the water quality has fluctuated dramatically due to the rapid industrialization and urbanization of Seattle.

As I write this, in the spring of 2020, the pandemic COVID-19 has altered nearly every aspect of our way of life. From this perspective the water in our lakes seems more similar to the air we breathe: they support life and carry nearly invisible pathogens simultaneously. We have become intimately familiar with the idea that the seemingly empty air around us fills with pollen, and now the potential lethal threat of carrying the SARS-CoV-2 virus from one person to another. Without belittling the gravity of the current pandemic, let's acknowledge the lethal power of things we can't see with the naked eye. A comparable story has played out in our waterways for several generations; our

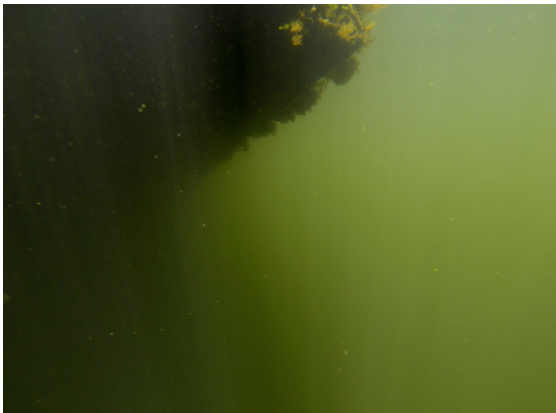


A submerged stump in the shallows along the UW shoreline



Left: naturally dappled lighting through a willow tree (although, with invasive water lily, Nymphaea odorata)

Below: shading under docks in Union Bay



actions can have consequences for vulnerable populations—although not always human—somewhere down the line. Take Chinook salmon as an example: a keystone species in the Pacific Northwest, a longtime staple of the human diet, an emblem of the majesty of the mountains meeting the Pacific, and a threatened species due to habitat loss and other human activity (NOAA Fisheries 2020).

Sadly, none of this is a revelation; in 1962, Rachel Carson wrote in *Silent Spring*, “We poison the caddis flies in a stream and the salmon runs dwindle and die. We poison the gnats in a lake and the poison travels from link to link of the food chain and soon the birds of the lake margins become its victims” (Carson 1962). Looking forward, how can we leave this place better than when we found it?

As is often the case in landscape architecture, I am pulling from the insights of restoration ecologists, engineers, and local experts to amalgamate a solution from trends in aquatic infrastructure design for this urban site. Aquatic infrastructure includes overwater and in-water structures such as docks, piers, retaining walls, houseboats, boat moorings, etc. (WSDE 2017). The goal of this research is not to challenge urban development, but rather to question

how it has happened and to ask how we can use human made structures to the ecosystem’s advantage. In that sense, this research is about connecting human and ecological systems in a mutually restorative way. Seattle and Washington State enforce strict regulations pertaining to development along shorelines. However, regulation at times stifles innovation when prescriptive measures don’t leave room for experimentation. This research looks beyond constraints from current regulations to seek opportunities and demonstrate design arguments based on ecological principles. We can no longer afford to sacrifice our natural environment for our built environment. The guiding research questions are:

- What innovations in nearshore infrastructure design can provide multifunctional benefits for people and the environment?
- How can aquatic design shift our view of the water’s surface, such that it is seen not as a barrier, but rather as an opportunity to bridge two environments?
- How can the UW shoreline be redesigned to bolster ecosystem services?



HISTORICAL BACKGROUND

WOOD & WATER

“Water is everywhere before it is somewhere. It is in rain before it is in rivers, it soaks before it gathers, it blurs before it clarifies.”

Anuradha Mathur and Dilip da Cunha, *Design In the Terrain of Water*

Landscapes are defined along both spatial and temporal dimensions. People learn from past natural or human-made marks, instill current ideology and priorities into our surroundings, and have the potential to improve future conditions. Change over time is a common denominator of every biotic or abiotic component in an ecosystem.

The idea of “restoration” in a landscape is often criticized for emphasizing going back to what was before, when the best “before” is debatable. But ecological restoration is about restoring function, not replicating former conditions. To restore function in a natural system, we must understand what was, consider existing components, and articulate what necessary functions are missing.

GEOLOGIC FORMATION

The Pacific Northwest is a region of mountains and sea; where temperate rainforests meet kelp forests. The abrupt rise of ranges like the Olympic Mountains or the Cascade Mountains is due to the underlying tectonic activity of the Cascadia subduction zone—as are our earthquakes and volcanoes. The Juan de Fuca plate, composed of oceanic crust, is wedging under the North American plate. Over millions of years, the uplift has brought rock formed on the seafloor to the tops of some of our mountains, and immense heat and pressure have erupted into other volcanic peaks. In fact, the mountains surrounding the Puget Sound are still rising (Kruckeberg 1991).

In more recent geologic history, approximately 15,000 years ago, the Cordilleran Ice Sheet advanced southward, carving the lower reach of the Puget Sound by pushing sediment out of its path. Several thousand years later, the glaciers retreated, depositing more sediment that had been trapped within the icy rivers. Deviant geology, deep lakes, and alpine glaciers remain as relics. Lake Washington's floor has a base of blue clay left by a glacier. The clay is covered in a layer of compacted ash from the eruption of Glacier Peak roughly 12,000 years ago, that in turn is covered in

a layer of diatomaceous sediment from the lake's planktonic life forms (McDonald 1979). A postglacial story is also written in the sediment of lakes through pollen profiles that indicate past vegetation, and therefore past climate. Spruce and pine signify cooler epochs, while Douglas fir indicates a warmer climate (Kruckeberg 1991). After the latest glacier retreated, streams and rivers have continued to persistently carve the landscape.

The natural hydrology of Lake Washington and Lake Union were separate watersheds. Water flowed into Lake Washington from Lake Sammamish as well as smaller streams, such as Ravenna Creek from Green Lake. Lake Washington's outflow was the Black River at its southern extent, which was joined by the Cedar River to meet the Duwamish River, which flows into Elliott Bay of Puget Sound. Lake Union's watershed was much smaller, and drained out through Shilshole Creek into Salmon Bay of Puget Sound. Today, the Lake Washington Ship Canal connects the two lakes, such that Lake Washington no longer connects to the Duwamish River. What was once an outflow at the southern extent is now an inflow from the redirected Cedar River. The current watershed is the Lake Washington-Cedar-Sammamish Watershed (WRIA 8).



Portion of McKee's 1894 Correct Road Map of Seattle and Vicinity. Notice the railroad, wetlands, and southern isthmus canal.
Museum of History & Industry, Seattle (MOHI), 2019.3.12

PEOPLE OF A LARGE LAKE

The first known peoples to inhabit the area around Lakes Washington and Union over multiple generations were named hah-choo-AHBSH in Lushootseed, or people of “a large lake” with direct familial ties to the Duwamish Tribe (“Chesheeahud — Duwamish Tribe” n.d.). The Duwamish (Dxʷdəwʔabš) are one of the tribes comprising the Coast Salish-speaking Peoples, who have walked the mountains, fished the rivers, and canoed on the lakes for many centuries.

According to tribal historian Thomas R. Speer, many traditional Duwamish longhouses existed in this region although ninety-four were burned to the ground by settlers by 1900 (Blecha 2009). One site of longhouses was on tleelh-chus or “little island” in southwest Lake Washington, or what is now called Pritchard Island. Just as indigenous peoples had recognized the island’s and surrounding marsh’s natural value, in 1903, the Olmsted Brothers noted it as a “most important landscape feature” and recommended it be set aside for recreation purposes (Wilma 2001).

Another collection of longhouses was on and around Swa’tsugwL, or “carry a canoe”, the isthmus between Lake Union and Lake Washington’s Union Bay (Becker 2013). There

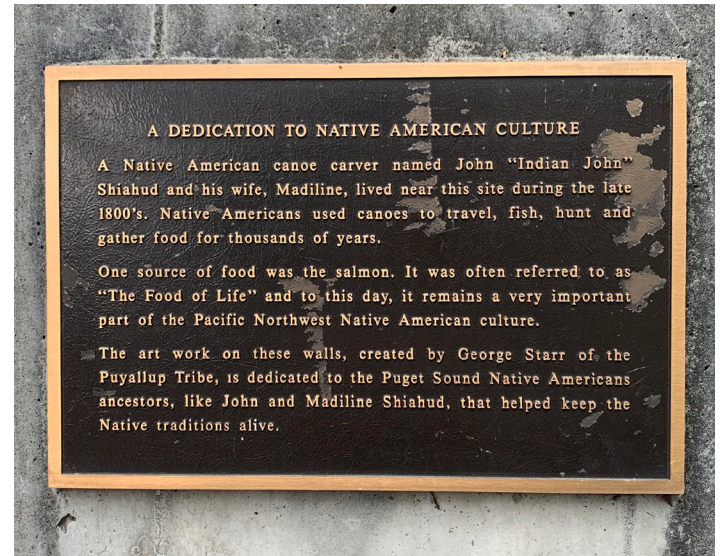
were two trails across the isthmus, a northern one at the present day Montlake Cut and a southern one along the present day SR 520; both would later serve as the templates for settlers to connect the lakes. An anthropological study in 2006 confirmed the importance of the portage and the edges of Union Bay and Portage Bay where marshes supported “abundant natural resources, including plants, birds, mammals, and fish” to indigenous peoples’ lifestyles (Becker 2013).

Lushootseed names indicate there was a fishtrap where Ravenna Creek joins Union Bay as well as the cultural significance of Foster Island as a burial ground, Stitici, “where the dead were placed in boxes tied up in the branches of trees” (McDonald 1979; “Chesheeahud — Duwamish Tribe” n.d.). Accounts from early settlers also remarked that the lakes were surrounded by valuable fir, spruce, and cedar trees; other observations noted reeds and edible wapatoes along the edges, as well as fish, beavers, and “other water denizens” (McDonald 1979).

One Duwamish chief, Chesheeahud, served as a travel guide throughout the lakes for the early settlers, including David Denny who is considered one of the founders of Seattle. Chesheeahud’s village, called hikw’al’al or “Big House”, was on the southern shore of



Chesheeahud and others in a Coast Salish canoe, ca. 1885
Museum of History & Industry, Seattle (MOHAI), SHS 2228



Plaque at E Shelby St commemorating Chesheeahud's homestead



Portage Bay in the foreground with the isthmus to Union Bay visible on the right, 1909
University of Washington Libraries, Special Collections, SEA1666

Union Bay and may have included a longhouse used as a potlatch house, a place where inter-tribal communities would gather (Ott 2012). Chesheeahud—also called Old Tom or Lake Union John—was “given” land on Portage Bay by Denny on which he had a cabin and potato patch (Thrush 2007). As Seattle grew, Chesheeahud and his wife, “Madeline”, were the last Duwamish family to live on Lake Union, circumventing a 1860’s ordinance banning native people within Seattle limits by renouncing any tribal affiliation (Lange and Tate 1998; “Coast Salish People & Languages” n.d.).

Chesheeahud moved to the Suquamish Reservation after his wife died in the early 1900s, in part because the natural resources of the lakes, like trout, were disappearing; Chesheeahud remarked “too much house now— all gone” (“Chesheeahud — Duwamish Tribe” n.d.; Thrush 2007). Today the multi-use recreation trail loop around Lake Union is named in Chesheeahud’s honor and there is a plaque near the site of his homestead at the E Shelby St street end park in Montlake.

EUROAMERICAN ARRIVAL

Once EuroAmericans arrived, displacement of indigenous peoples and development of the settlement happened quickly. The first settler to

lay eyes on Lake Washington was Isaac Ebey in 1850. He canoed up the Duwamish River to the now non-existent Black River that flowed out of the southern end of the lake (McDonald 1979). Separately from Ebey, the Denny party arrived at Alki Beach in 1851, Henry Yesler built a sawmill by 1852, and the “Town of Seattle” became official on the east shore of Elliott Bay in 1853 (Crowley 1998).

Meanwhile, coal had been discovered in present day Renton, and several coal mining outfits were established. In 1854, a sawmill near the junction of the Black and Cedar Rivers was the first alteration to Lake Washington’s hydrology. It was a six foot dam that seemed to change the direction of the Black River’s flow; however, the mill proved too difficult to reach to be of much use and was burned down in an altercation with native tribesmen (McDonald 1979). That same year, pioneer Thomas Mercer named Lake Union because he was confident it would eventually join Lake Washington directly to Puget Sound (Ott 2012). Soon other names derived from Lushootseed were replaced as indigenous peoples and culture were pushed off of their ancestral lands (Blecha 2010).

In the decades that followed, more homesteaders arrived and an elaborate but cumbersome system of barges and rails allowed

for the transport of coal to Seattle. In 1861, Harvey Pike obtained a deed to the isthmus between Lakes Washington and Union and had a vision of creating a canal under present day SR520, along one of the original portage trails. When he couldn't build it himself, he granted a concession to build a road between the lakes until a canal could be completed (McDonald 1979).

By 1867, the Army Corps of Engineers was also looking for possible routes to more directly connect Lake Washington to Elliott Bay since the marshes of the Black and Cedar Rivers and the meandering of the Duwamish River did not make them suitable for large transport or Navy ships. During those early surveys, Colonel Thomas Handbury observed that Lake Washington was seven feet higher than Lake Union and that the water level fluctuates over five feet throughout the seasons. McDonald notes that Handbury “found the water, though fresh and soft, not sufficiently pure for drinking because it seemed impregnated with minute particles of decaying vegetable matter and animal life” (McDonald 1979, 25).

In 1870, the isthmus was sold to the Lake Washington Canal Company, as progress was already being made to build a canal between Lake Union and Salmon Bay along Shilshole Creek. In 1885, Chinese immigrant laborers were

hired to dig what was known as the Montlake Ditch along Pike's originally envisioned path. The chute was only wide enough to sluice logs—and to “shoot the chute” in a canoe—and managed the different lake levels with a locks system (Ott 2012).

The railroads developed even more quickly than the canal plans and the Seattle, Lake Shore & Eastern Railway reached Woodinville in 1887, providing a more convenient mode of transportation for coal. Today's Burke-Gilman trail is what was then the railway and is named for two of the original investors (Cipalla 2019). The railway was built along Union Bay's edge, which highlights how much marsh area has been lost to the development of UW's parking lots and the University Village shopping center. The railway also connected the homesteads at Laurelhurst and allowed pioneer Henry Yesler to build another sawmill along the north shore of Union Bay, which allowed the little town of Yesler to be formed (McDonald 1979).

Due to the construction of the railway and the need for lumber downtown, much of the forest that many early settlers found remarkable was razed. The grove in the Ravenna ravine was one of the only places where old growth Douglas Fir were initially spared because it was too steep to easily deforest. The ravine, carved



Vegetation in Union Bay around the Montlake Ditch, ca. 1900
Museum of History & Industry, Seattle (MOHAI), SHS 1129



The wooden locks of the Montlake Ditch, ca. 1890
University of Washington Libraries, Special Collections, SEA1101



View into Union Bay from the Montlake Ditch, ca. 1911
Museum of History & Industry, Seattle (MOHAI), PEMCO Webster & Stevens Collection, 1983.10.9159

by Ravenna Creek, which historically drained Green Lake into Union Bay, was opened as a private big tree park in 1887 (Blecha 2011).

UNIVERSITY OF WASHINGTON MOVES TO UNION BAY

In 1861, The Territorial University of Washington was founded in its original location which is now downtown Seattle and is commemorated by University Street. While the first decades were challenging, by 1891 a committee of the Washington State House and Senate had a vision for the University that required more acreage, away from the distraction of the city. The present day site was chosen by the University President, Thomas Milton Gatch, because he specifically sought a site on Union Bay. The state legislature authorized the purchase and an architectural competition was underway by 1893 (UW Libraries Exhibition 1995).

The original campus plans by William Boone sited the academic buildings facing Union Bay; however, his plan was considered extravagant and was never built. Construction on Denny Hall began in 1894 without clear campus plans, and so A. H. Fuller's campus plan sited several other buildings around an oval oriented to Denny Hall. As the Olmsted Brothers finished a Seattle parks plan in 1903, they were asked to develop a new

campus plan and were hired again in 1906 to develop the Alaska-Yukon-Pacific Exposition (AYPE) on the University campus. The AYP Exposition plan laid out Rainier Vista and Geyser Basin, which is now Drumheller fountain.

The world came to Seattle at the AYPE over the summer of 1909, attracting nearly 3.7 million visitors (Cohen 2015). Arriving at the AYPE by boat was also accommodated with docks on both Lake Washington and Lake Union. Campus had two boathouses; the Associated Students of the University of Washington (ASUW) Boat House floating on Union Bay—different from the extant ASUW Shell House—and the US Life Saving exhibition that remained for several years on the shore of Portage Bay. It was used as the Varsity Boat Club where the men's rowing team slept, ate, and stored boats until 1919.

WATER AS A RESOURCE

As Seattle's population increased, so did the demand for water. The fire of 1889 underscored the need for a dependable water supply, so pump stations that pulled water from Lake Washington into reservoirs were enlarged. Water was also diverted from the Cedar River for the city's supply and into Lake Washington, which severed a healthy salmon run (Kingle 2007).

The Fair that will be Ready



Looking West on Yukon Avenue.



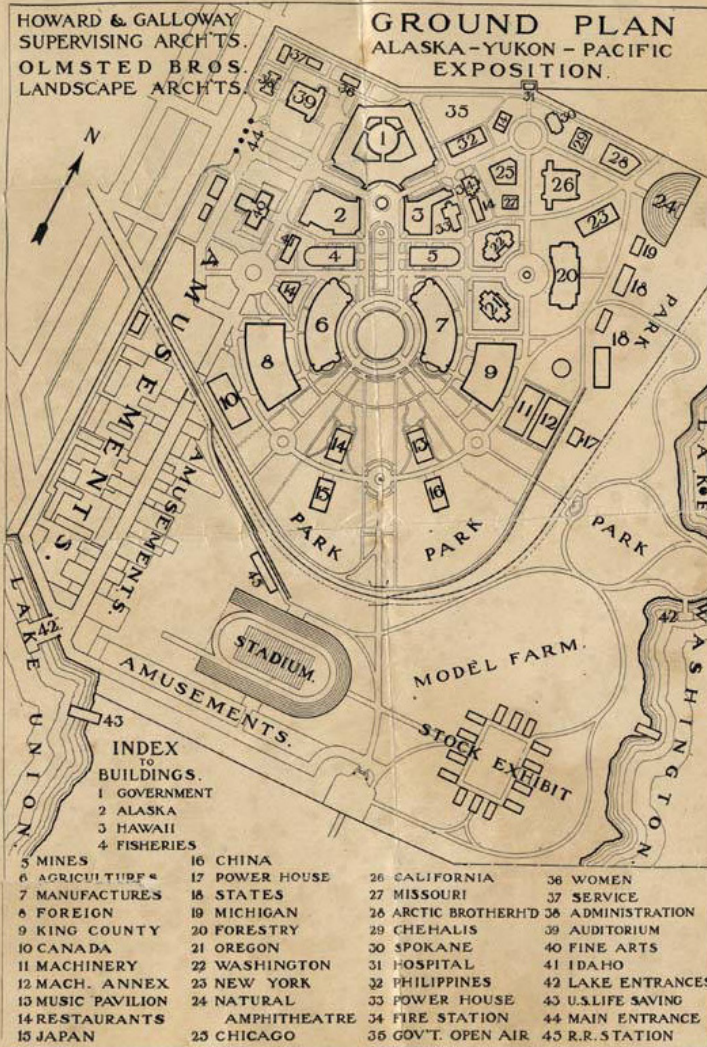
Auditorium; permanent steel and brick; to revert to the University of Washington. Completed December, 1908.



View from Manufacturers' Building across Cascades and Geyser Basin. All buildings completed.



End View of Manufacturers' Building. Completed in July, 1908.



View of Lake Washington and the Cascade Mountains.



Fireproof and permanent; to revert to the University of Washington. Completed January, 1909.



Oregon State Building. Completed September, 1908.



California State Building. Completed January, 1909.

Alaska-Yukon-Pacific
Exposition advertisement
with ground plan, ca. 1909
Museum of History & Industry,
Seattle (MOHA), 2019.3.45

The World's Most Beautiful Exposition
Seattle---June 1 to October 16, 1909



Excavating the canal, 1913

University of Washington Libraries, Special Collections, 2381



Construction of the Montlake Cut, 1914

Seattle Municipal Archives, 390



Coffer dam to Lake Union is removed, 1916

Museum of History & Industry, Seattle (MOHAI), 15277



Looking east at the completed Montlake Cut with lake levels even, 1922

University of Washington Libraries, Special Collections, CUR1469

Soon, water contamination became a problem, despite early warnings from experts. A 1901 report by Professor James Parkinson shared his observations of increased organic matter in Lake Washington due to sewage and commercial activity. He suggested pumping sewage out to Elliott Bay or expect contamination to increase. In 1907 Seattle was hit with a Typhoid epidemic of over 500 cases. The Mayor insisted the outbreak was not related to the city's water supply, but cases were later directly linked to two instances of using lake water to fill low reservoirs (McDonald 1979). Water quality continued to decline for several decades until sewage management was updated.

MAKING THE MONTLAKE CUT

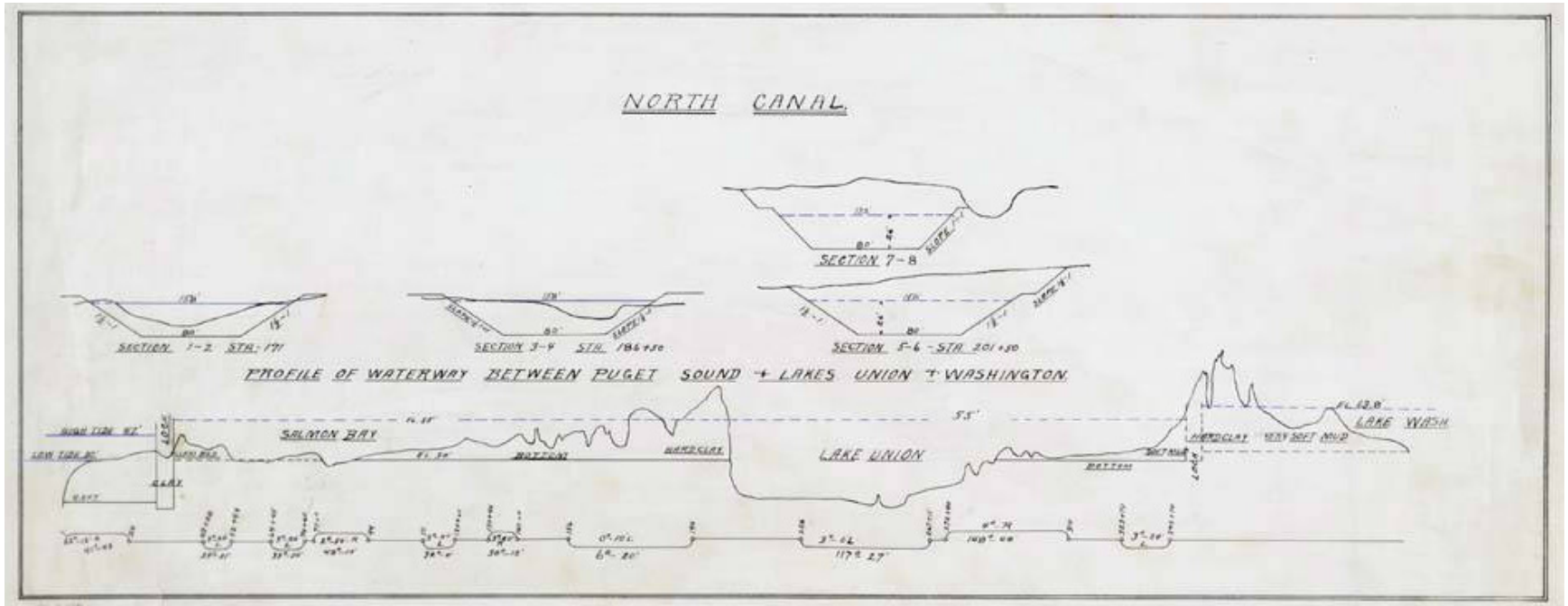
Soon after the AYPE, construction began in earnest to create the Lake Washington Ship Canal as demand for transporting lumber from inland to the Sound increased. There were three major engineering feats along the new waterway. East to west, they are the Montlake Cut, the Fremont Cut, and the Government Locks. Most of the Fremont Cut had been excavated by Chinese laborers in the 1880's along what had been Shilshole Creek and directly connected Lake Union and Salmon Bay (Ott 2012). It included a small, wooden dam, lock, and spillway to control the water level of the lake (Baar 2016).

In 1906, Major Hiram M. Chittenden was brought in to oversee the construction of the Government Locks—that would later be named after him but are locally known as the Ballard Locks—to allow large vessels to pass between the Sound and the lakes. He advocated for a masonry structure with two locks, and also removed earlier plans to include a lock in Montlake. In 1909, the Army Corps of Engineers began digging the Montlake Cut between Lake Union and Lake Washington, just north of the original Montlake Ditch. Meanwhile, Chittenden secured funding for his vision of the Government Locks through a River and Harbor Act and construction began in 1911 (Williams 2017).

Both projects progressed in parallel although the Montlake Cut had several issues. The initial canal did open in 1910 but was deemed too small, so construction began anew in 1912. There was vocal opposition to the lowering of Lake Washington due to the omission of Montlake locks, but the plans were not changed. The coffer dam to Lake Union was first removed in 1913; however, the south face was slumping and the walls had to be redone. Another attempt to open the canal in 1914 also didn't last long when the wall continued to fail and needed additional concrete work (Williams 2017). During the summer of 1916, both the Government Locks and the Montlake Cut were



Postcard showing the anticipated future of Portage Bay and the Montlake Cut, ca. 1912
University of Washington Libraries, Special Collections, SEA1718



Sections of the Lake Washington Ship Canal, highlighting the difference in lake levels, ca. 1911
Museum of History & Industry, Seattle (MOHI), 2019.3.50

finished, and the Lake Washington Ship Canal was almost ready for boats.

While the project was hugely beneficial to maritime industry, the nine foot drop in Lake Washington's water level devastated nearshore habitat by shifting the narrow band of shallow water conditions (Kling 2007). Water was released slowly to protect houseboats and docks in Portage Bay, but even over several months, the rate was too fast for much of the vegetation to survive. The lowering did expose rows of wooden posts at the indigenous town of Little Canoe Channel, which were the remains of a fishing weir. Stone hearths also resurfaced along the shoreline. Unfortunately, the EuroAmerican settlers considered their rapid changes to be improvements towards a goal of restoring nature; "rather than evoke the importance of such places to indigenous people, these unearthings only confirmed the naturalness of the engineering marvels that revealed and then obliterated them" (Thrush 2007, 96).

It wasn't until October of 1916 that the Montlake Cut, which became commonly known as the Cut, was fully opened to boat traffic and the grand opening was celebrated on July 4th, 1917. The new water level was lower than the natural drainage level of the Black River, so it and

the marshlands were left high and dry (Williams 2017). Duwamish descendent Joseph Mosese told a local historian how "the waters just went down, down, until our landing and canoes stood dry and there was no Black River at all. There were pools, of course, and the struggling fish trapped in them. People came from miles around, laughing and hollering and stuffing fish into gunny sacks" (Thrush 2007, 97). Union Bay became the new outlet for Lake Washington and a pinch point in the Lake Washington-Cedar-Sammamish watershed. As historian Coll Thrush concludes in *Native Seattle*, "in reordering the landscape for urban utility, Seattle's Changers had dramatically reduced the utility—and habitability—of that landscape for indigenous people" (Thrush 2007, 97).

The newly exposed shoreline also created confusion as to who owned the land. Many land owners sued over property damage or access due to changing water levels (Kling 2007). It was impossible to draw a definitive line along the shore to separate private from public, so it was hard to track the legality of shoreline alterations. In *Emerald City*, historian Matthew Kling describes that "with each subsequent 'improvement'—a filled estuary here, a new waterway there—the economy and the physical environment both grew more erratic" (Kling 2007, 72).



Beached houseboat in Lake Union after a dam failure, 1914. Note the shallow dock and decimated lake bottom.
Museum of History & Industry, Seattle (MOHA), 1983.10.9810.2

LIVING ON THE WATER

Beginning in the early 1880's, houseboats were already becoming part of the landscape in Seattle's waterways. Communities appeared all over the region—along Madison Park, Leschi, and Union Bay on Lake Washington, Portage Bay and the rest of Lake Union, Salmon Bay and the Elliott Bay Waterfront on Puget Sound, Harbor Island and the Duwamish River—in part because there was no zoning on the water.

There was a socioeconomic divide between houseboat communities: those that were lavish summer abodes and those that were low-cost living. The majority were structures that belonged to seasonal workers from either the timber or fishing industries who lived on boats or in makeshift floating shacks. By 1902, it was reported that there were nearly 1,000 houseboaters in Seattle. A small subset of “amphibious homes” spanning the shore from Union Bay to Madison Park were reported to be “as comfortable as the modern homes in fashionable residential sections” in 1909 (Blecha 2010, n.p.).

The major threat to floating communities was always storms; however, attempts were repeatedly made to remove them through zoning or health codes (Blecha 2010). Floating communities were often blamed for more of

their fair share of sewage entering the lake; since before 1938, all of the city's raw sewage still entered the nearest water body (Klingler 2007). A historic photograph highlights the early ecological damage that was a direct result of these structures, crowding out the once lush nearshore habitat. In 1914 muskrats caused a dam to fail and drain Lake Union by about ten feet. The photo of beached houseboats highlights how little emergent vegetation remained (Klingler 2007). It is estimated that in 1945 there were approximately 2,500 houseboats located on the shorelines of Seattle; today, there are roughly 480 units, excluding liveaboard boats, mostly restricted to the shores of Lake Union, Portage Bay, and Salmon Bay (Blecha 2010).

UNIVERSITY OF WASHINGTON REPRESENTING AMERICA

When the United States joined World War I in 1917, the UW campus became a hub of war efforts. A base hospital and naval training camp stood on the southern shore of campus, where the UW hospital and stadiums now stand. Wartime efforts led to the creation of UW's ROTC program and necessitated a switch from the semester system to the quarter system we still use today, but the only building that remains is the ASUW Shell House (UW Libraries Exhibition n.d.). The structure is one of only two remaining

timber-frame Navy seaplane hangars in the United States (Berger 2019). It was completed in 1918, just before the war ended, and was only used for instructional seaplanes for a short time. When the camp disbanded, ten buildings were going to be used by the University, including the Shell House, which is said to have sold for one dollar (BOLA 2018; Willman 2019). The cavernous structure, with expansive doors opening onto Union Bay was ideal for the UW Men's rowing team, so they moved from the AYPE Coast Guard building to the east end of the Cut (Cohen 2015).

The story of Washington Rowing's time in the Shell House is written in the best selling book, *The Boys in the Boat*, by Daniel James Brown. Rowing was a well established sport in England and had a significant foothold on the East Coast, but few crews were competing on the West Coast—Stanford and the University of California (Berkeley) were the only “local” competition (Brown 2013). Despite the hard sell, UW coach Hiram Conibear was able to convince English boatbuilder Goerge Pocock and his brother to set up shop in Seattle in 1913 in another AYPE building, the Tokyo Tea Room.

During the war, the Pocock brothers went to work for Boeing, building seaplane pontoons but returned to UW to set up shop in the back

of the ASUW Shell House in 1922 (Cohen 2015). Just as the Duwamish used western red cedar to build canoes, Pocock revolutionized rowing shell building with cedar. Today the brand, Pocock Racing Shells, still produces some of the fastest shells in the sport, and the Pocock legacy in Seattle remains strong through a rowing club and foundation.

It was Pocock who built Husky Clipper, the racing shell that the famous “Boys of ‘36”, who trained out of the ASUW Shell House, used to win Olympic gold at Hitler's 1936 games outside of Berlin (Brown 2013). Washington Rowing built the new Conibear shell house, near the former site of the ASUW Boat House in 1949, and the old Shell House became known as the Canoe House because it was used for boat rental and storage (BOLA 2018). Modifications were made in the “straightforward, utilitarian” structure over the years, including Pocock's garret, various windows, a locker room, and an internal apartment (National Park Service 1975).

The naval history, rowing fame, and threat of demolition for a new Waterfront Activities Center resulted in the ASUW Shell House being listed on the National Register of Historic Places in 1975, and the City of Seattle Designated Landmarks in 2018 (Sodt 2018; National Park Service n.d.). The Lake Washington Ship Canal



ASUW Boat House (white roof) with other floating structures, ca. 1916
 University of Washington Libraries, Special Collections, UWC1856



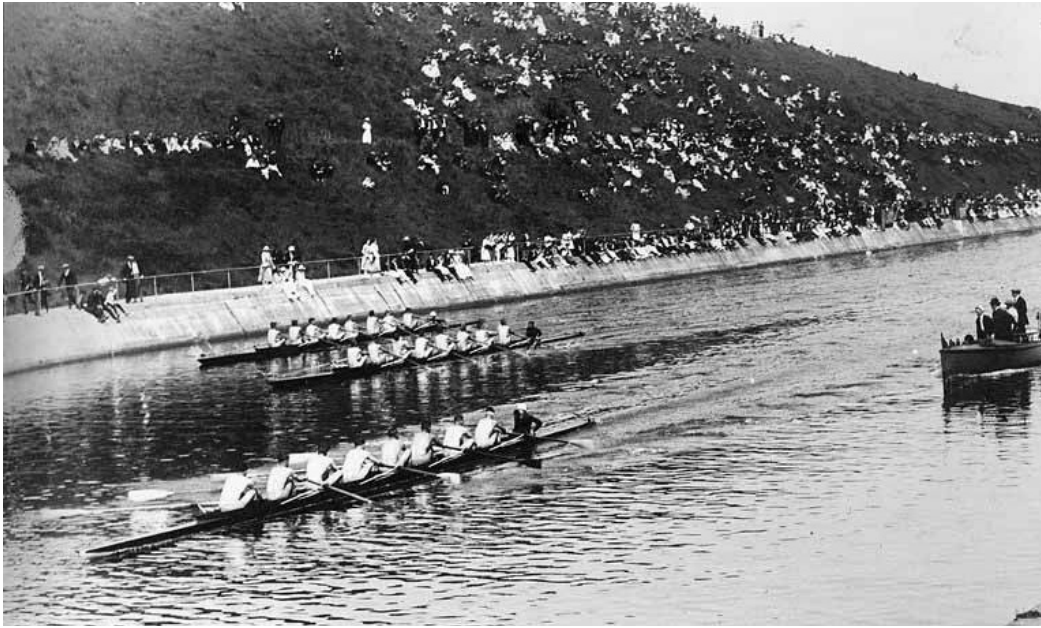
Varsity Boat Club on Portage Bay, 1909
 UW Rowing History



UW rowers on the dock of the ASUW Shell House in 1939
 Museum of History & Industry, Seattle (MOHA), 1986.5.15874.1



ASUW Shell House, ca. 1923
 University of Washington Libraries, Special Collections, UWC3635



Regatta in the Montlake Cut, ca. 1922

University of Washington Libraries, Special Collections, UWC1873



Montlake Cut on Opening Day, ca. 1959

Museum of History & Industry, Seattle (MOHAI), 1986.5.14384.2

and Hiram M. Chittenden Locks are also listed on the National Register; and the Montlake Cut and Montlake Bridge are on the City of Seattle Designated Landmarks List (National Park Service n.d.; City of Seattle n.d.). The Waterfront Activities Center (WAC) was built in 1975 in its current location, northeast of the Shell House. UW Recreation is currently leading a restoration project of the Shell House to honor its history and give more of the UW community access to the space. Washington Rowing is still celebrated in the Cut each spring with the Opening Day regatta and boat parade, which draws thousands of spectators to the final 500 meters of the race course.

URBANIZATION AND ENVIRONMENTALISM

In the decades following the Second World War, urbanization in Seattle continued at a steady pace. The Lake Washington Ship Canal had succeeded in bringing marine industry into the lakes, especially in Lake Union where many dry docks and shipyards had access to the water out of the way of ocean wind and waves. There were plenty of significant, industrial points of pollution: coal gasification on Lake Union, cement factories on the Duwamish River, the Montlake Dump in Union Bay, and so on. Transportation networks were growing through

the city and across the lakes, encouraging the growth of Seattle's suburban population, which contributed a significant amount of sewage into the waterways.

It was not until 1958 that the Municipality of Metropolitan Seattle (Metro) was created to address the obvious decade long decline of water quality in the lakes (Kling 2007). At its inception, Metro was to use taxpayer money to oversee regional sewer, transit, zoning, and parks; but the amount of power given to a regional authority remained contentious. Metro's early approach to the water quality problem was to sacrifice the Duwamish River to restore the ecological and recreational value of Lake Washington. The urban intellectual elitism met opposition, but in the end the Duwamish River did become the sewage outfall for the city, and the salmon and indigenous people that fished them bore the consequences while Lake Washington improved; this is another example of what was becoming a pattern for environmental efforts directly causing environmental injustice (Kling 2007).

MANAGEMENT AND MITIGATION

In 1972, Washington passed the Shoreline Management Act (SMA) with the overarching goal being "to prevent the inherent harm in an

uncoordinated and piecemeal development of the state’s shorelines” (WSDE 2020, n.p.). The SMA defines the role of the Washington State Department of Ecology (WSDE) in overseeing local programs and requires counties, cities, and towns with shorelines to create Shoreline Master Programs.

Shorelines include all marine waters; streams, river, and lakes above defined sizes; 200 feet upland of these waters; wetlands, river deltas, and 100-year floodplains of these waters. There are also “shorelines of statewide significance,” which include Lake Washington and Lake Sammamish and their wetlands. The policies of the SMA cover shoreline use, environmental protection, and public access. Preferred shoreline uses are outlined, which tend to favor water-oriented uses and public access. Allowed uses are required to consider and mitigate adverse impacts to land, vegetation, wildlife, and aquatic habitats. There is also language about preserving “natural character” and “aesthetics of the shoreline” (WSDE 2020, n.p.). Additionally, the SMA includes the Public Trust Doctrine, which is a common law stating that the water below the ordinary high water mark is owned by the citizens of Washington; however, it does not allow trespassing on private land to access water bodies.

Implemented in 1977, the Seattle Shoreline Master Plan was updated in 1987 and again most recently in 2015, establishing guidelines for permitting and management (Blecha 2010). Seattle’s Shoreline District includes the Duwamish River, the Ship Canal, Lake Union, Lake Washington, Green Lake, and Puget Sound, their wetlands, floodplains, and all land within 200 feet (City of Seattle 2020). Surrounding cities in the watershed have their own plans, as well as the King County Shoreline Master Program for unincorporated areas. Plans are periodically reviewed and updated with the Washington Department of Ecology. The impetus for SMA and these plans was the recognition that a tragedy of the commons was unfolding. The WSDE permitting manual stipulates that the cumulative impacts of projects must be considered in the conditional use permit evaluation process, which encourages foresight and planning (WSDE 2019).

Major changes to the Seattle Shoreline Master Plan in 2015 ranged from semantics to new ordinances. A notable change for the houseboat community is the implementation of a City-issued identification number to ensure new moorages aren’t added and that no floating homes discharge wastewater into the lakes. New standards for modifications, including vegetation and impervious surfaces were implemented, as



Aerial view of campus, the Montlake Cut, and Union Bay, 1937
University of Washington Libraries, Special Collections, SEA2330



Construction of the Evergreen Point Floating Bridge in Union Bay, 1962
Museum of History & Industry, Seattle (MOHAI), John Vallentyne Photographs, 2009.23.101

well as a ban on synthetic fertilizers. Ecological restoration and mitigation must now be sited as close as possible to the site of impact (City of Seattle 2020).

The biggest shoreline alteration in Union Bay since the dredging of the Cut was the addition of State Route 520 along the southern edge in 1963, notably, before the Shoreline Management Act. Despite vocal, local opposition, the Evergreen Point Bridge's (SR520) western end bisected the UW Arboretum and cut through two historic districts in the Montlake neighborhood to connect to I-5. At the time of its construction, ecological mitigation was not required, nor was the indigenous cultural significance of Foster Island acknowledged and protected.

As the original floating bridge aged and no longer met seismic standards, a new bridge was constructed and opened in 2016. The replacement bridge followed the same route but did have to adhere to modern standards and regulations according to the Shoreline Master Plan. Areas under the overpasses have been planted and several sections of UW shoreline have ongoing restoration efforts as mitigation

for the construction of the bridge (WSDOT 2011). Sustainable construction practices were employed to try to minimize the impacts of the building process and materials (WSDOT n.d.).

FUTURE OF THE UW SHORELINE

In 2019, the UW released an updated campus master plan calling for a prioritization of more green open spaces on campus ("University of Washington: 2019 Seattle Campus Plan" 2019). As part of this vision for a network of vistas, a request for proposals for a West and South campus green, as well as a Continuous Waterfront Trail concept, was posted in early 2020 (UW Facilities: Planning and Landscape Architecture 2020). As of this writing, the selected landscape architecture firm has not yet been announced. In conversation with UW campus landscape architect, Kristine Kenney, she described her office's vision for the shoreline surrounding the Waterfront Activities Center to be a destination distinct from the rest of the shoreline, to once again bring together views and access to the water, and to be a place to celebrate, especially on race day (Kenney 2020).



ECOLOGICAL BACKGROUND

LENTIC ECOLOGY

“Marginal habitats are not ecological wastelands... The role of manmade habitats in urbanized coastal environments is essential to elucidate if we are to design and manage these habitats in a way that maximizes returns of the ecosystem services we highly value.”

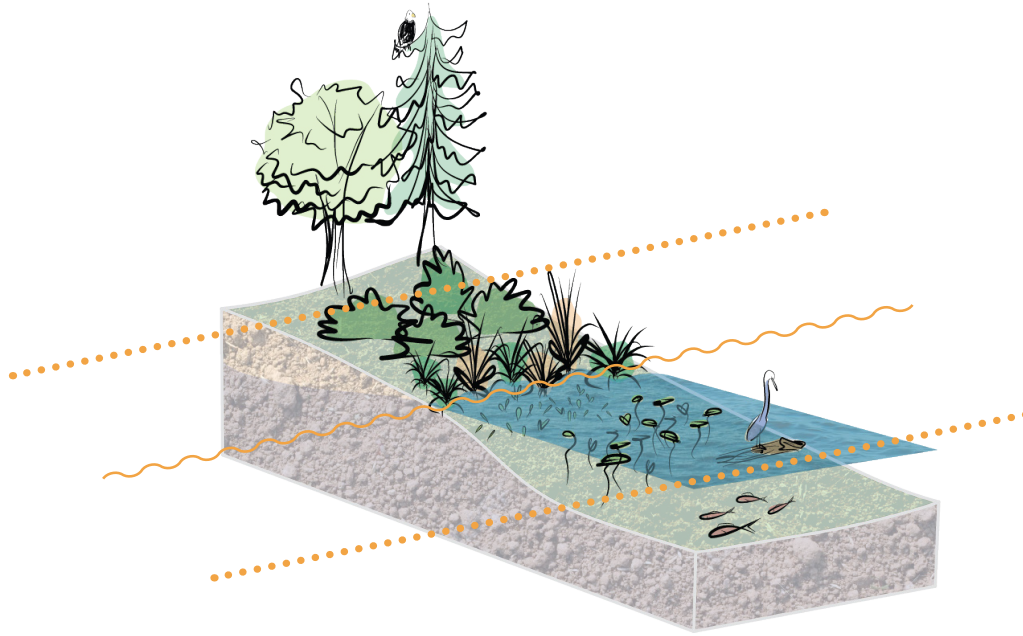
Layman et al., 2014

The visible shoreline is a mere sliver of the interface between terra and aqua; the benthic zone is a vast area where many essential organisms can be found. In urban water bodies the benthic sediment has become contaminated by run off from industry and everyday life. For example, of 11 sites tested near Gas Works Park in Lake Union in 2003, all of them had toxin levels

above the clean up criteria (Jack 2003). A survey of 30 lakes in the greater Seattle region found that the type of shoreline development plays a larger role than the amount of development, ie. small areas of poorly designed development have a disproportionate negative impact on the entire system (Moore et al. 2003).

*Native Yellow water-lily
(Nuphar polysepala) in
Union Bay*

*Nearshore ecotone
spanning both above and
below the shoreline*



NEARSHORE HABITAT

While Seattle's hydrologic engineering has been impressive, the ecological consequences are also formidable. Overwater structures have broken up the natural habitat that increases biodiversity and supports healthy lakes. Development is linked to eutrophication, a state of excess nutrients in a waterbody that leads to increased plant biomass, which eventually dies and the process of decomposition leads to a lack of oxygen in the water (Cerco, Noel, and Kim 2006). Eutrophication, and the hypoxic conditions it creates, underscores the importance of balance in biogeochemical cycles. As Seattle

continues to grow and develop its fresh and saltwater shorelines, design innovations can play a larger role in mitigating anthropogenic changes through ecological enhancements.

In lake ecosystems, the built environment has the biggest impact on nearshore habitat, or the ecotone along the shoreline. The actual waterline fluctuates seasonally, rising in the rainy season and falling in the dry season. The water level of Lake Washington and Lake Union system is unique in that it is controlled at the Hiram M. Chittenden Locks and does not

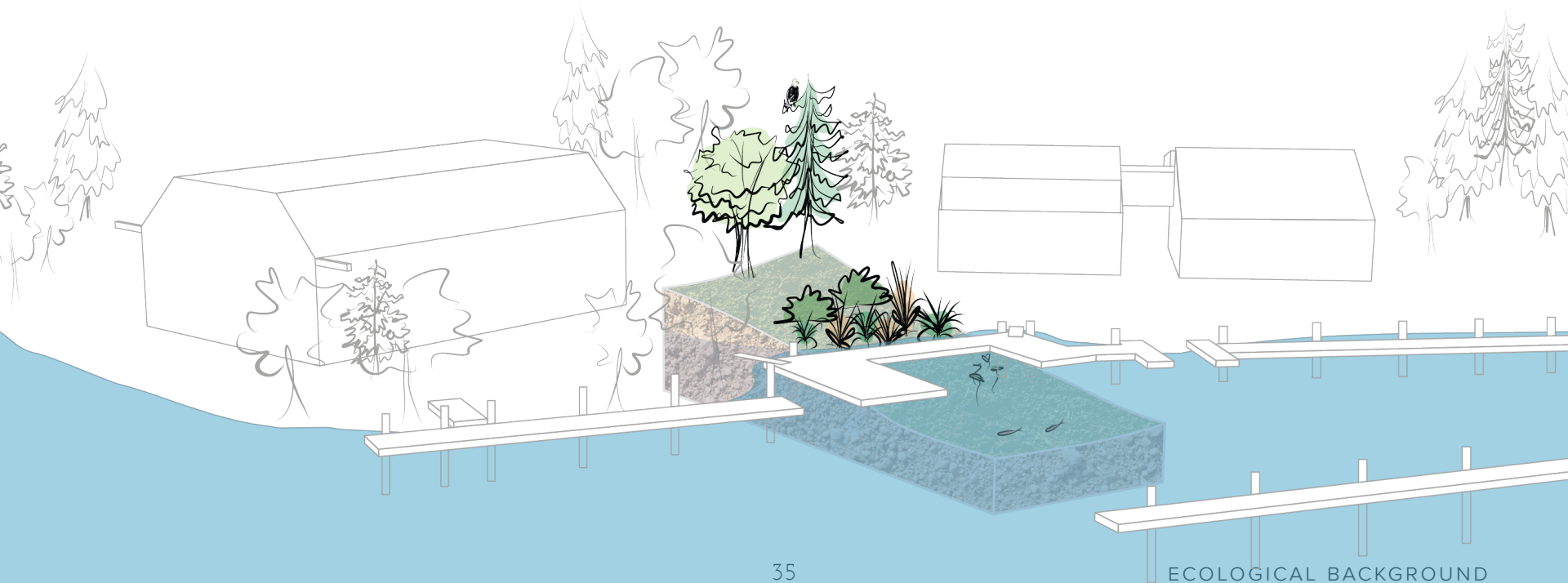
align with natural seasonal fluctuation. Water managers begin to fill the lakes in February to reach the target high water mark of 18.75 feet (North American Vertical Datum of 1988) by June in order to “meet increased summer water use, providing water necessary for fish passage, navigation and salinity control” (Dowell 2018, n.p.).

Nearshore habitat encompasses upland and shallow water zones along the waterline. It is distinct as a zone because of the dependence of its flora and fauna on water, substrate, and light. Its bordering terrestrial zone lacks the level of water inundation, while open water

lacks the combination of substrate and light. The nearshore waters of lakes are key habitat for a disproportionate amount of life in lakes. Therefore, localized pollution from shoreline development can rapidly diminish the health of the entire lake system. As discussed by biologist Craig Layman and colleagues, “marginal habitats are not ecological wastelands” (Layman et al. 2014).

A healthy nearshore habitat has diversity in structure and composition, so by building homogeneous structures, human activity is limiting the potential for success. Abiotic components, like dead trees, offer important

Docks divide and suppress nearshore habitats



resources for birds, insects, and other plants both above and below the surface of the water.

The potential for ecological improvements to be integrated into shoreline infrastructure is gaining traction. It is also worth noting that “even though freshwater represents a tiny proportion of the global landscape, it is arguably the most valuable and sought-after resource on earth” (Moore et al. 2003). The benefits of healthy habitat also impact the economy, supporting fisheries and neighboring property values (NOAA Fisheries 2019).

Economic implications of deteriorating salmon runs are a big driver in conversation in the Pacific Northwest. An interdisciplinary team from universities in the United Kingdom also demonstrate the economic argument for ecological enhancements along shorelines in the face of increasing storm intensity and urbanization (Naylor et al. 2018). In areas where increased flooding or sea level rise is expected, ecological preparation will protect communities. In areas where water quality is a concern, increasing the substrate for filter feeders can improve matters (Thom, Williams, and Diefenderfer 2005).

Interestingly, there is some discussion of whether the invasive, freshwater Asiatic clam (*Corbicula spp.*) which can be found in water bodies all over North America, including Union Bay, could be beneficial in contaminated areas because of its tolerance for toxins and ability to efficiently filter water (Kramer-Wilt 2008); but, there are broader concerns of the establishment and spread of the clams on biodiversity in lakes.

Despite improvements to the municipal systems in recent decades, polluted runoff and sewage discharge still take a toll on the water quality throughout our watersheds. Currently, if you walk along the Lake Washington Waterside Trail, you will see a sign warning of the sewage overflow outfall and, soon thereafter, another sign with a warning about which fish are toxic due to chemical pollution. Urban development has removed the natural systems that helped mitigate water quality problems: marshes and wetlands. Nearshore habitat is essential for an entire lake ecosystem’s primary productivity, refuge, mating, and feeding and can easily be damaged by localized pollution (Hampton et al. 2011)



Water quality warning signs on Union Bay

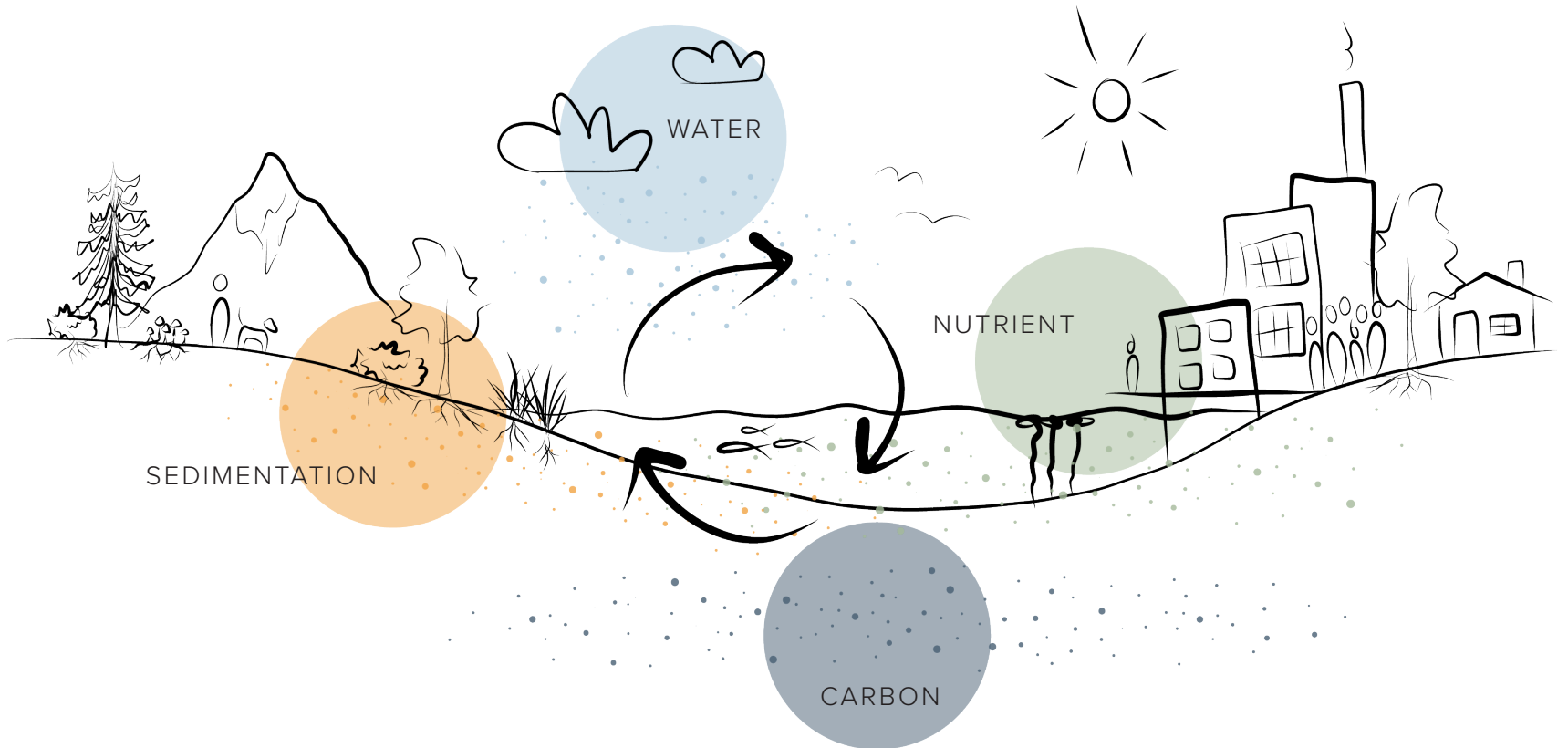
BIOGEOCHEMICAL CYCLES

To understand the impacts of overwater structures in lakes, we must first define the biogeochemical cycles and processes that drive these ecosystems and understand the influence of human actions within them. The importance of light, water, carbon, nutrients, and sediments are equally important in the water as they are on land.

Natural cycles encompass every ecosystem, including human made conditions

Landscape architecture has only occasionally delved deeply into underwater

scapes—Living Breakwaters, dive parks, and floating wetlands being notable examples—but as a field, it is uniquely poised to design more resilient shorelines. As with terrestrial projects, designing to ensure that organisms have the tools to rebuild is dependent on balancing the human impact on biogeochemical cycles. To consider water in a design, means to consider it above ground, in the ground, and in water bodies.



WATER

Most of us are familiar with the details of the water cycle—precipitation, evaporation, perspiration, and respiration—in our daily lives, but we may not always consider that the transition of water from one physical state to another is all part of one cycle. It is also easy to lose sight of the fact that while much of the planet is covered in water, very little is fresh water that is readily available for living organisms (Moore et al. 2003). Water is an essential component for life, and it is finite.

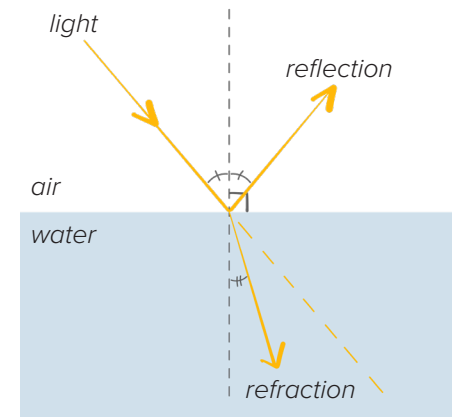
Lakes play a key role in the hydrologic cycle as freshwater reservoirs because they support lentic flora and fauna, as well as many other organisms in their vicinity. In Seattle some of the most drastic changes in the local water cycle are the alterations to how water flows through the watershed in order to support humans through transportation, industry, emergency water supply, and emergency wastewater system. The dredging of the Ship Canal completely changed the movement of water through the lake and bay, redefining which species could thrive (Klinge 2007).

Within lakes in temperate climates, there is also seasonal stratification through the water column. During summer months, water near the surface warms and creates a less dense

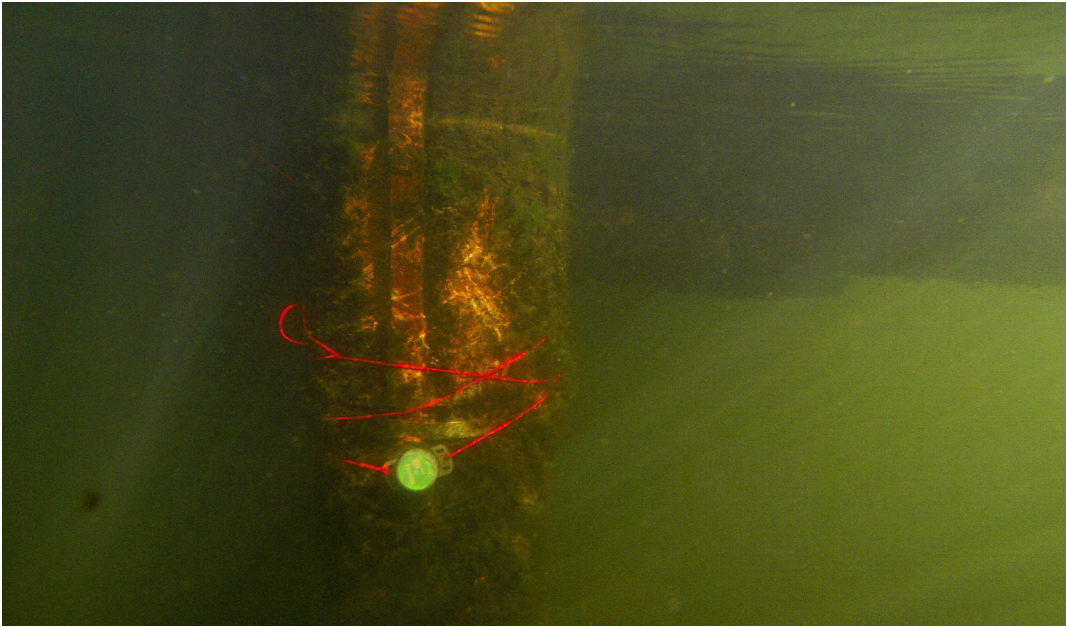
upper layer called the epilimnion. This is the zone that light reaches and has the most primary productivity. The turnover of lakes also regulates temperature and helps distribute dissolved oxygen on a seasonal basis (Davis, Storer, and Zisette 2007).

Light, temperature, and water chemistry are all factors that dictate whether a given species can survive there or not. Changes to any individual factor has the potential to cause die offs. Overwater structures increase human access to the water, but they can also affect the microhydrology around pilings as well as change light and temperature conditions (Dyson and Yocom 2015). On land, the impervious parking lots and ramps that often accompany docks and piers also redirect drainage on surfaces and increase polluted runoff directly into water bodies.

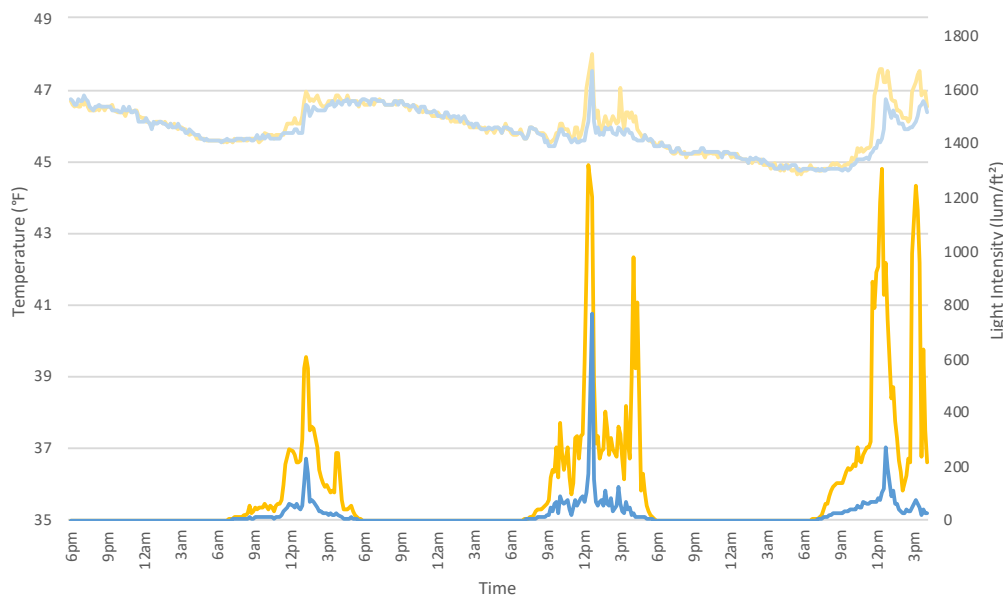
When light waves traveling through the air hit the surface of the water they reflect and/or refract, depending on the angle of travel. We experience reflection as glare and refraction when objects appear to bend in water. Movement of the water's surface constantly changes the angle of light and creates the dappled rays captured in underwater photos. This natural dappling is obstructed by overwater structures, especially floating docks.



Light interactions at the surface of the water



Sensors tied to piling to compare tree and dock shading



Light (lower) and temperature (upper) data collected in dappled tree shade (yellow) and under the public UW dock (blue)

To understand the impact of shading, I deployed two light meters on the public dock at UW on February 21, 2020 for three days of monitoring. The sensors were tied to a piling, 8 inches underwater, with one facing west under the dappled light of a willow (*Salix spp.*) and the other facing east under the shadow of the dock. The sensors recorded temperature and light intensity. While east and west lighting are not perfectly comparable, the data from noon each day shows that light intensity is 2-5 times higher in the willow shade than the dock shade. There was also greater fluctuation in temperature in the dappled shade. Docks shift the conditions in the water column enough that species with narrow habitat tolerance can no longer survive, while more opportunistic or invasive species are successful.

CARBON

The carbon cycle functions on several time scales: rapid carbon exchange takes place through breathing and eating, seasonal fluctuations are linked to growing seasons, and long term cycling occurs in geologic processes. Carbon exists in the air as carbon dioxide (CO_2), dissolved in water as bicarbonate (HCO_3^-), and it exists as many other carbon compounds in all living organisms. Photosynthesis and cellular respiration are the processes by which

plants and animals convert carbon between these various states. For example, an apple tree converts carbon dioxide into organic compounds, such as sugars. When one eats an apple, sugar is broken down to use as energy and carbon dioxide is released as a byproduct. In lake systems, phytoplankton and aquatic vegetation are the basis of the food web and key to carbon cycling. Overwater structures that shade out emergent vegetation not only limit habitat structure, but disrupt carbon cycling.

Carbon is also an important element released during the process of decaying. Over geologic periods of time, sediment that includes carbon from decomposition turns to rock, which is no longer immediately available for living things, but it eventually continues to cycle. Depending on the season and other factors, lakes can act as both carbon sources and sinks (Reed et al. 2018). A key finding from a 2011 study was that rivers, lakes, and wetlands are much more than transit for carbon; rather, about two thirds of the carbon that enters the watershed is outgassed to the atmosphere and buried in the geosphere on the way to the ocean (Aufdenkampe et al. 2011). More site specific data would be needed to understand the balance of carbon cycling in the Lake Washington Basin, but we can infer that the decrease in vegetation due to structures makes it likely that less carbon is being absorbed.

NUTRIENT: NITROGEN & PHOSPHORUS

Without the proper nutrients, the primary producers that support all animal life cannot thrive. Typically phosphorus and nitrogen are limiting factors in natural systems. Areas with dense animal activity, like cities and agriculture, increase the amount of nitrogen and phosphorus available. In addition to pathogens, sewage is especially detrimental to lake systems because it causes eutrophication, the state of excess primary productivity. While there are temporary benefits, eventually excess nutrients lead to a boom and bust cycle between eutrophication and hypoxic conditions. Seattle has a combined sewer system which has several overflow outfalls that result in raw sewage dumping into the lakes in heavy rain events; one such outfall is in the Montlake Cut.

To prevent the combined system from overflowing, the best strategy is to find other ways to manage stormwater before it enters the waterways. One upland strategy is to use rain gardens, or bioretention cells, to treat stormwater. Rain gardens not only slow the rate of water flowing off of impervious surfaces, but also they can be planted to promote biofiltration of pollutants often found in runoff, like heavy metals. Naturally, wetlands play an important role as a buffer in nearshore habitat, so in areas

Species in the Lake Washington basin are interconnected through land, air, and water cycles

INTERCONNECTED FLORA & FAUNA



raptors



humans



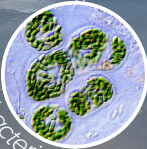
insects



emergent vegetation



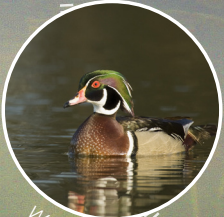
mammals



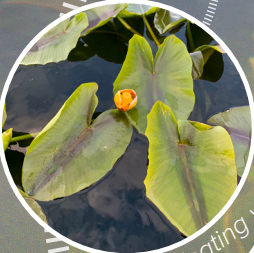
cyanobacteria



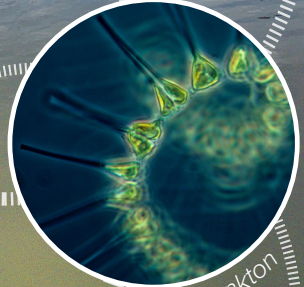
reptiles



waterfowl



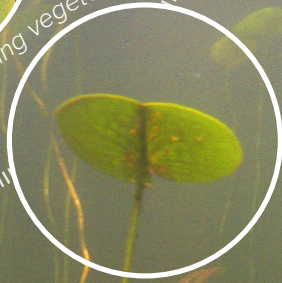
rooted floating vegetation



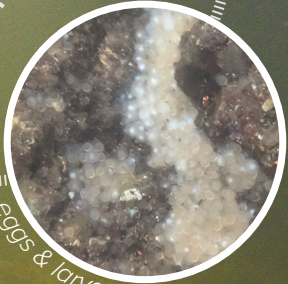
phytoplankton



fishes



submergent vegetation



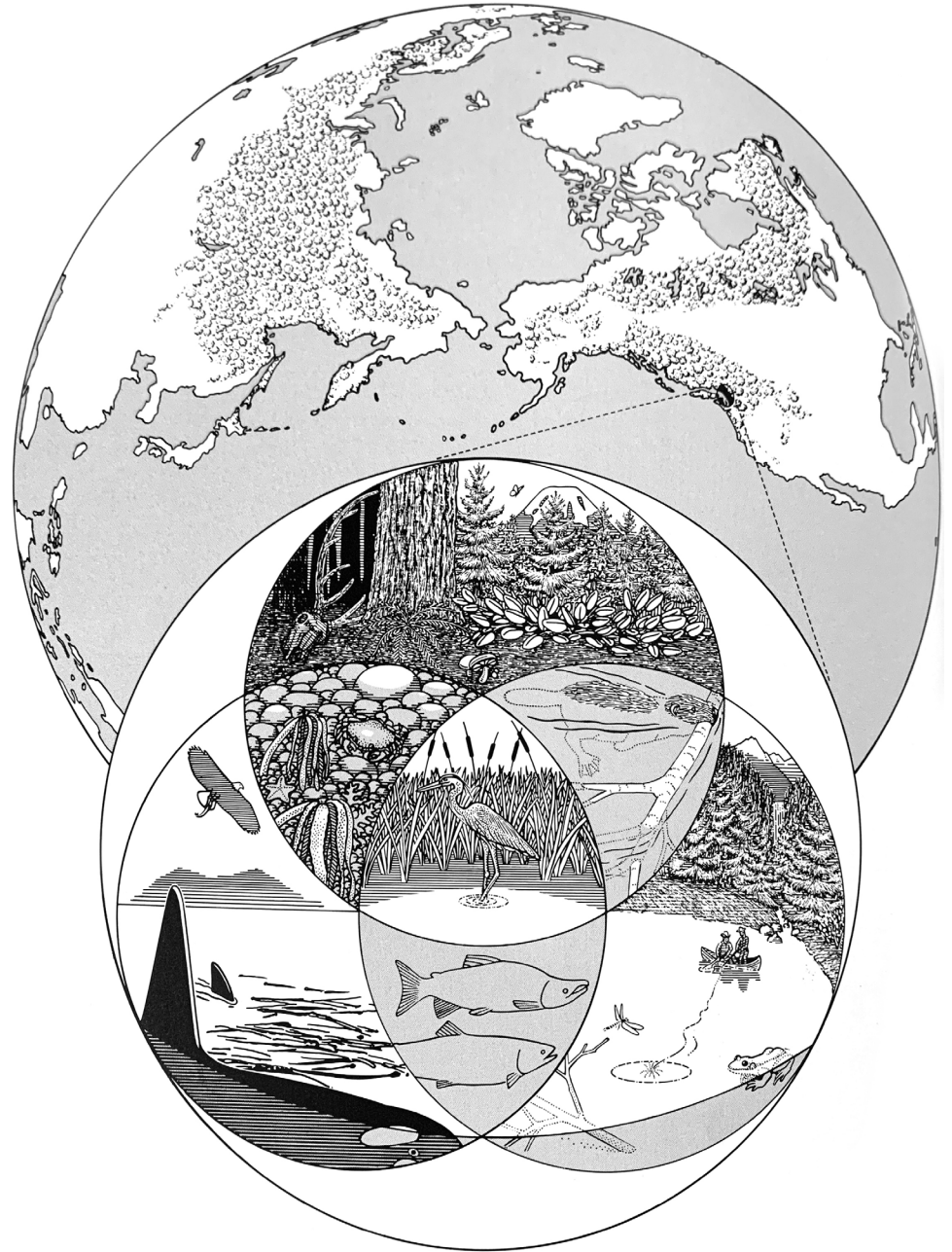
eggs & larvae

where wetlands are no longer possible, rain gardens can recreate lost ecosystem services.

SEDIMENTATION

Weathering of mountains naturally releases sediment and minerals back into the ecosystem. Streams and rivers carry new sediment into lakes and the ocean. New sediment is important to replace sediment that has been washed away from shorelines by erosion. When development creates bulkheads, channels, and piped streams, sediment flow can be disrupted. When Ravenna Creek was the outflow from Green Lake, it would have likely been the primary sediment input into Union Bay. The present day watershed and flow of Ravenna Creek is only a fraction of what it was historically.

Daily boat traffic in the Lake Washington Ship Canal creates nearly constant wake energy which has necessitated bulkheads along much of its length. Because of the erosion from boat wakes, the canal is also dredged to maintain a depth greater than 30 feet—five times the average depth of Union Bay. Aquatic infrastructure can also affect sediment flow by controlling erosion and strategically encouraging accumulation. This is typical in marine systems where jetties are used to build beaches, but the same principles can be used in any current.



SPECIES INTERACTIONS

The Puget basin is home to many ecosystems with myriad microclimates. While not as vast as the Salish Sea or as humbling as evergreen forests, nearshore habitats are a crucial intersection for species. It is notable that cattails and willows along a water channel are highlighted on the cover of Arthur Kruckeberg's *The Natural History of Puget Sound Country*; not an orca, not a forest, and not a salmon (Kruckeberg 1991). These charismatic megafauna—and megaflora—are certainly important and worth protecting throughout the Pacific Northwest, but they are peripheral to the story of nearshore habitat in Union Bay.

While salmon were historically and are currently present, their journey through Union Bay is complex. The pre-Montlake Cut salmon migration route into Union Bay would have been up the Duwamish River to the Black River and up through Lake Washington. Now, the Lake Washington Ship Canal—including a fish ladder at the locks—is a pinch point for the entire WRIA 8 watershed, including the Cedar River which was redirected into Lake Washington.

There are six species from the Salmonidae family in the Lake Washington basin and a dozen other fish species that likely interact with

salmonids (Tabor et al. 2004). Chinook salmon, (*Oncorhynchus tshawytscha*) is of interest because it is listed as threatened and protected under the Endangered Species Act. Coho salmon (*Oncorhynchus kisutch*) and Sockeye salmon (*Oncorhynchus nerka*) also travel through the basin.

The largest run of Chinook is in the Cedar River and both Chinook and coho are propagated at the Issaquah State Hatchery, which is upstream of Lake Sammamish (Tabor et al. 2002). Salmonids use the Union Bay reach as a migration corridor to and from natal streams, typically passing in less than a day (Celedonia et al. 2008). Studies have found that juvenile Chinook will use overhanging vegetation but rarely go under overwater structures (Tabor et al. 2011). Beneficial shallow littoral habitat should be considered in the Lake Washington Ship Canal, but further studies to understand influential factors at specific sites such as temperature and water clarity are needed (Celedonia et al. 2008; City of Seattle 2001).

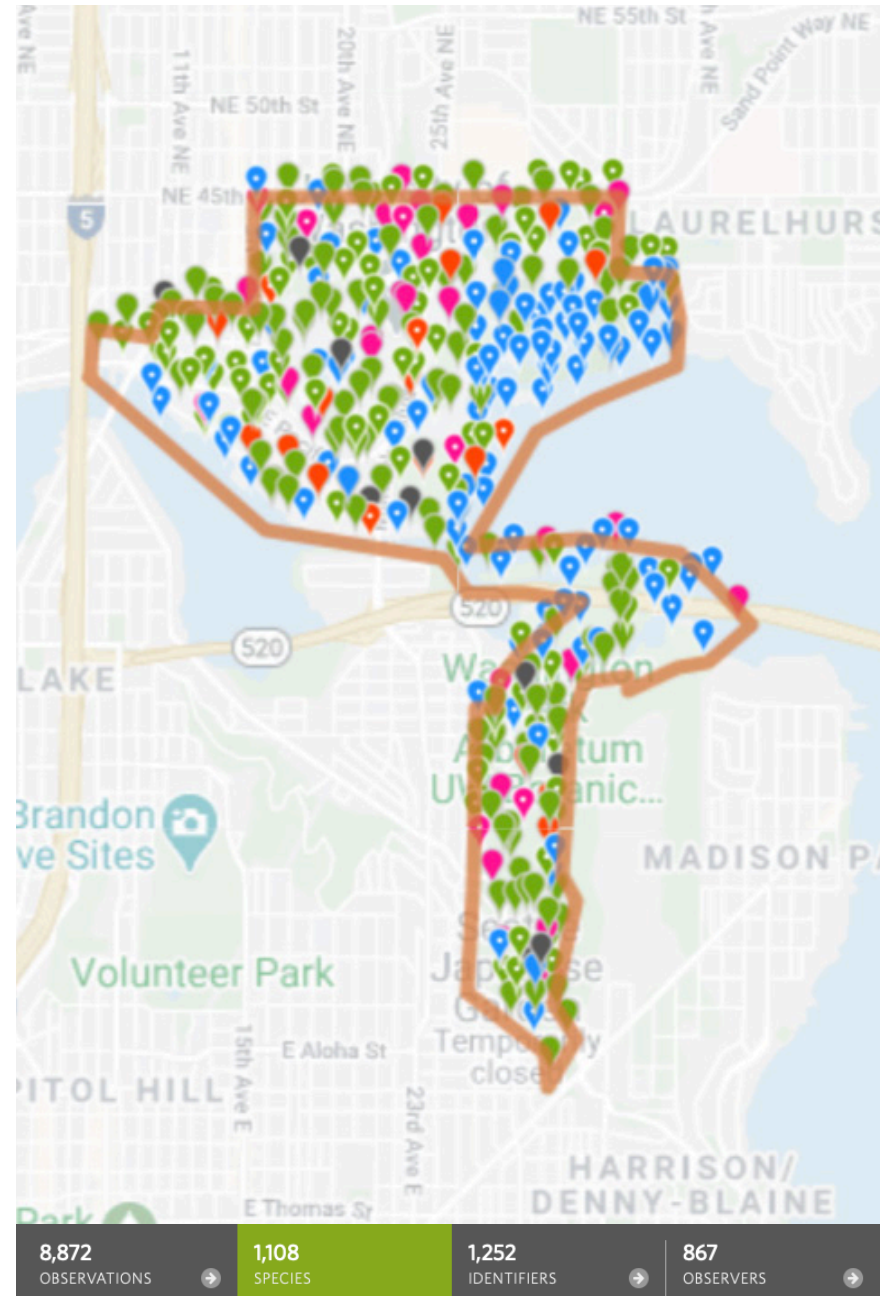
The ecological venn diagram by Michael Emerson highlights several of the other key characters found in Seattle where land meets freshwater: cattails, cedar, frogs, dragonflies,

*The web of relatedness
of land, water, and living
things—major ecosystems
in the Puget basin*
Diagram by Michael Emerson

beavers, eagles, herons, and of course people. Spanning across trophic levels—energy flow between producers, consumers, and decomposers—these species all play a role in continuing local biogeochemical cycles.

Many native species have been resilient in Union Bay, with populations surviving through the hydrologic and urbanization changes. On the citizen science identification platform, iNaturalist, 867 observers have contributed 8,872 verified observations of 1,108 species on the University of Washington Seattle campus as of June 2020 (“Observations · iNaturalist” n.d.). There is bias in observations since often the mundane or common is not documented. For example, the iNaturalist dataset does not indicate Himalayan blackberry as commonly observed, but in reality it is ubiquitous.

The interconnectedness of native species, including emergent vegetation, invertebrates, and birds, helps to maintain checks and balances in the nearshore ecosystem. Some species also alter the environment, such as North American beavers (*Castor canadensis*) which build large lodges in moving water. While their removal of trees is sometimes undesirable, their dams help build new pools and wetlands which create more habitat for birds, insects, and fish.



iNaturalist observations of flora and fauna on the UW Seattle campus



Water striders (Aquarius remigis) eat mosquito larvae
Chris Rurik



Amber snails (Succinea spp.) live in damp habitats and eat decaying plants



Peamouth (Mylocheilus caurinus) fish eggs in rock crevices at the Montlake Cut



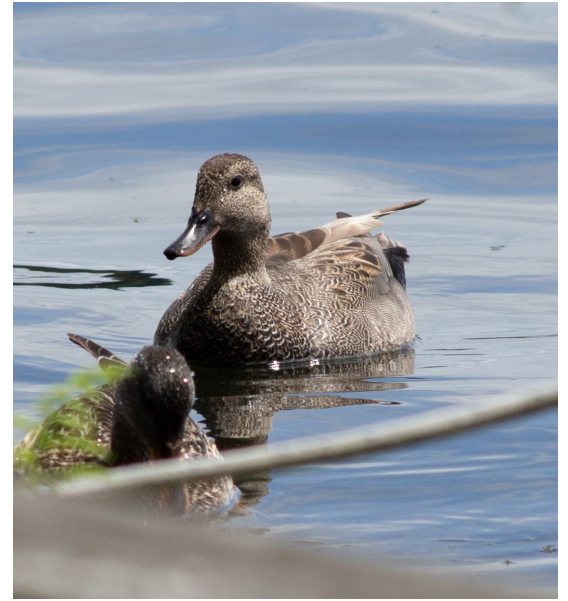
Shadow darners (Aeshna umbrosa) eat insects and depend on wetlands to reproduce



Bald eagle (*Haliaeetus leucocephalus*)



Caspian tern (*Hydroprogne caspia*)



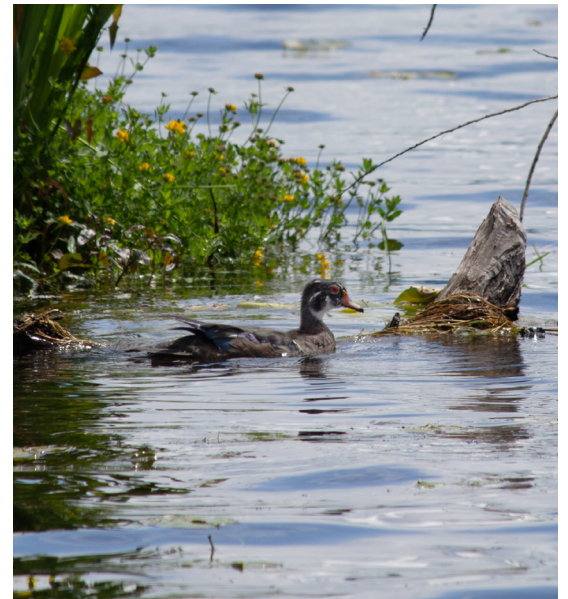
Gadwall (*Mareca strepera*)



Osprey (*Pandion haliaetus*)



Gull (*Laridae* family)



Wood duck (*Aix sponsa*)

In addition to resident species, migratory species also depend on shorelines. Over 200 species of birds have been identified at the Union Bay Natural Area, many of which are migratory (“Union Bay Natural Area” 2015). Typically, many other non-aquatic animals like coyotes and raccoons also depend on streams and lakes for water.

The biggest threats to species in Union Bay are habitat loss, pollution, and invasive species. As previously discussed, urbanization has caused habitat loss and pollution. Invasive flora and fauna are typically introduced through boat ballast or nearby gardens and ponds. Invasive

A school of fish (unlikely that they are salmon, given the season) demonstrably swimming around a dock shadow



species pose a threat through either competition or predation. In addition to creating favorable conditions for native species, shoreline design must also consciously not create habitat for invasive species.

One well-documented salmonid predator is the invasive smallmouth bass (*Micropterus dolomieu*). Smallmouth bass wait in shaded areas to ambush their prey and unfortunately their habitat preference overlaps considerably with that of salmon. Their abundance in Lake Washington is positively correlated with the amount of cobble and they travel around macrophages, much like salmon (Celedonia et al. 2008; Fresh et al. 2003). However, SCUBA surveys along the Lake Washington Ship Canal found that 72% of smallmouth bass found were within 2 m of an overwater structure, with a preference for large docks with many pilings (Fresh et al. 2003). Another study found that in South Lake Union, 50% of the diet of smallmouth bass was salmonid smolts (Tabor et al. 2004). These findings have increased concern about overwater structures and influenced updates to the Shoreline Master Plan.

Professor Kern Ewing revised the Union Bay Natural Area Shoreline Management Plan in 2010 with an update on invasive species control strategies. In the 1990s, bio-control was



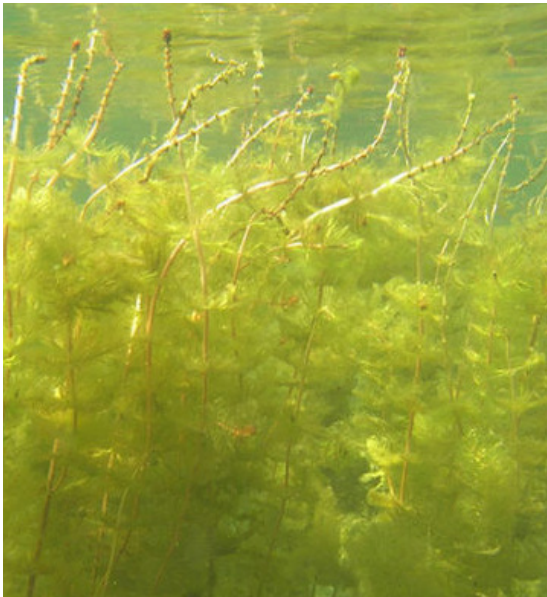
A great blue heron (Ardea herodias) grabs what appears to be a smallmouth bass (Micropterus dolomieu). The heron made a failed attempt to hunt from the dock, but was successful from a floating log.



Himalayan blackberry (*Rubus armeniacus*)



Yellow flag iris (*Iris pseudacorus*)
WA Noxious Weed Control Board



Eurasian water milfoil (*Myriophyllum spicatum*)
WA Noxious Weed Control Board



Reed canary grass (*Phalaris arundinacea*)
WA Noxious Weed Control Board

used to remove purple loosestrife (*Lythrum salicaria*) through the introduction of *Gallerucella* beetles. Himalayan blackberry (*Rubus armeniacus*) has spread rapidly and is the focus of most current restoration efforts (Ewing 2010).

King County has compiled a list of 17 invasive aquatic plant species of local concern from the Washington State Noxious Weed List. Included are several species that are found along the UW shoreline, including yellow flag iris (*Iris pseudacorus*), Eurasian water milfoil (*Myriophyllum spicatum*), and reed canary grass (*Phalaris arundinacea*) which are known to create large stands of monocultures and outcompete native vegetation (Shaw and Messick, n.d.)

SITE CONTEXT
PIER PRESSURE

“Nature has introduced great variety into the landscape, but man has displayed a passion for simplifying it. Thus he undoes the built-in checks and balances by which nature holds the species within bounds.”

Rachel Carson, *Silent Spring*

People are incredibly good at problem solving, but we are primarily motivated by self preservation, economic gain, and then sometimes the greater good. Often, we are caught in a positive feedback cycle: we justify the necessity of actions because short-term benefits outweigh long-term damage, and when the long-term damage is evident, we maintain

status quo because it is “grandfathered in”. Overwater structures are a prime example of this reinforcing cycle. What began with maritime businesses and seasonal floating shacks a century ago has expanded to include permanent boat storage, buildings on stilts, and luxury houseboat communities, all at the expense of the nearshore ecosystem.

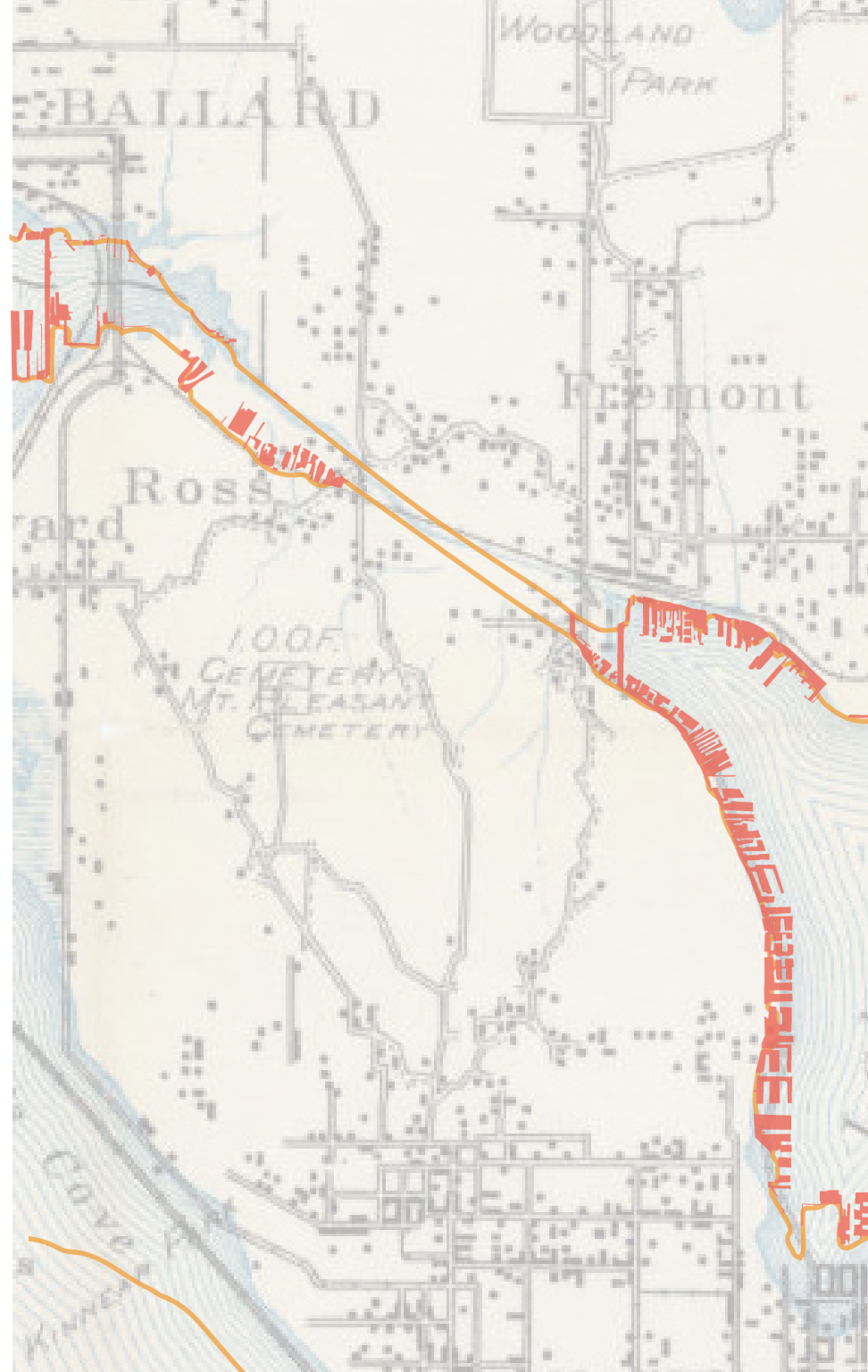
*Harsh shadow cast
by a UW dock*

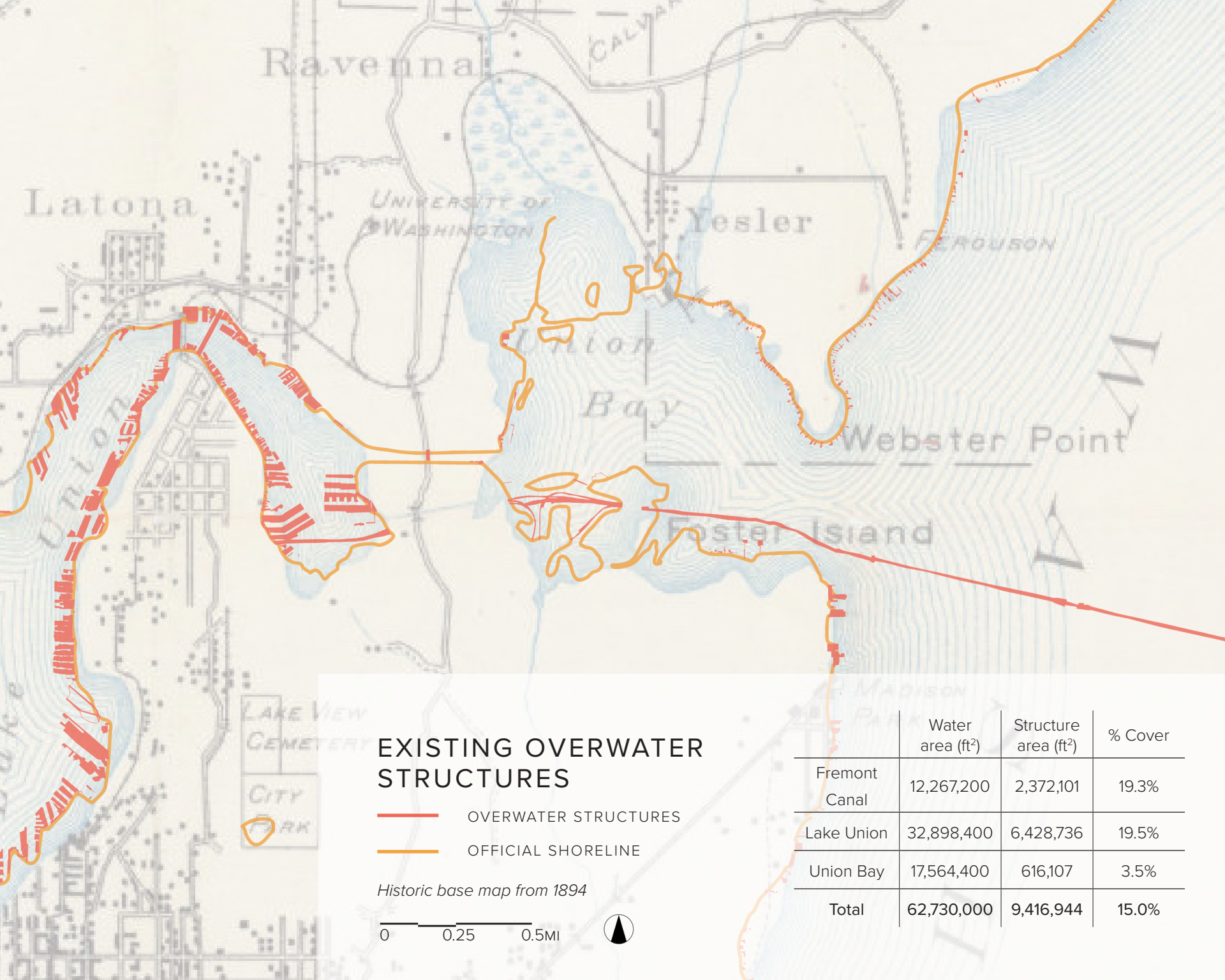
OVERWATER STRUCTURES

Currently, an average of 15% of the surface area of the lakes and canals that comprise the Lake Washington Ship Canal have overwater structures, according to GIS data from the Washington Department of Natural Resources. These docks, piers, house boats, and boat houses are nearly all connected to land so coverage is almost exclusively in areas that would otherwise be nearshore habitat.

Private docks on Lake Washington have a much smaller footprint than commercial and private structures on Lake Union, but they are still numerous. In contrast, Union Bay has very few structures due to the protection of the University of Washington's Arboretum and Union Bay Natural Area shorelines. Union Bay is an opportunity for refuge for migratory species, especially for fish that must navigate a gauntlet of human made conditions out to sea.

Existing conditions highlight the need for ecological services to be overlaid onto nearshore infrastructure.





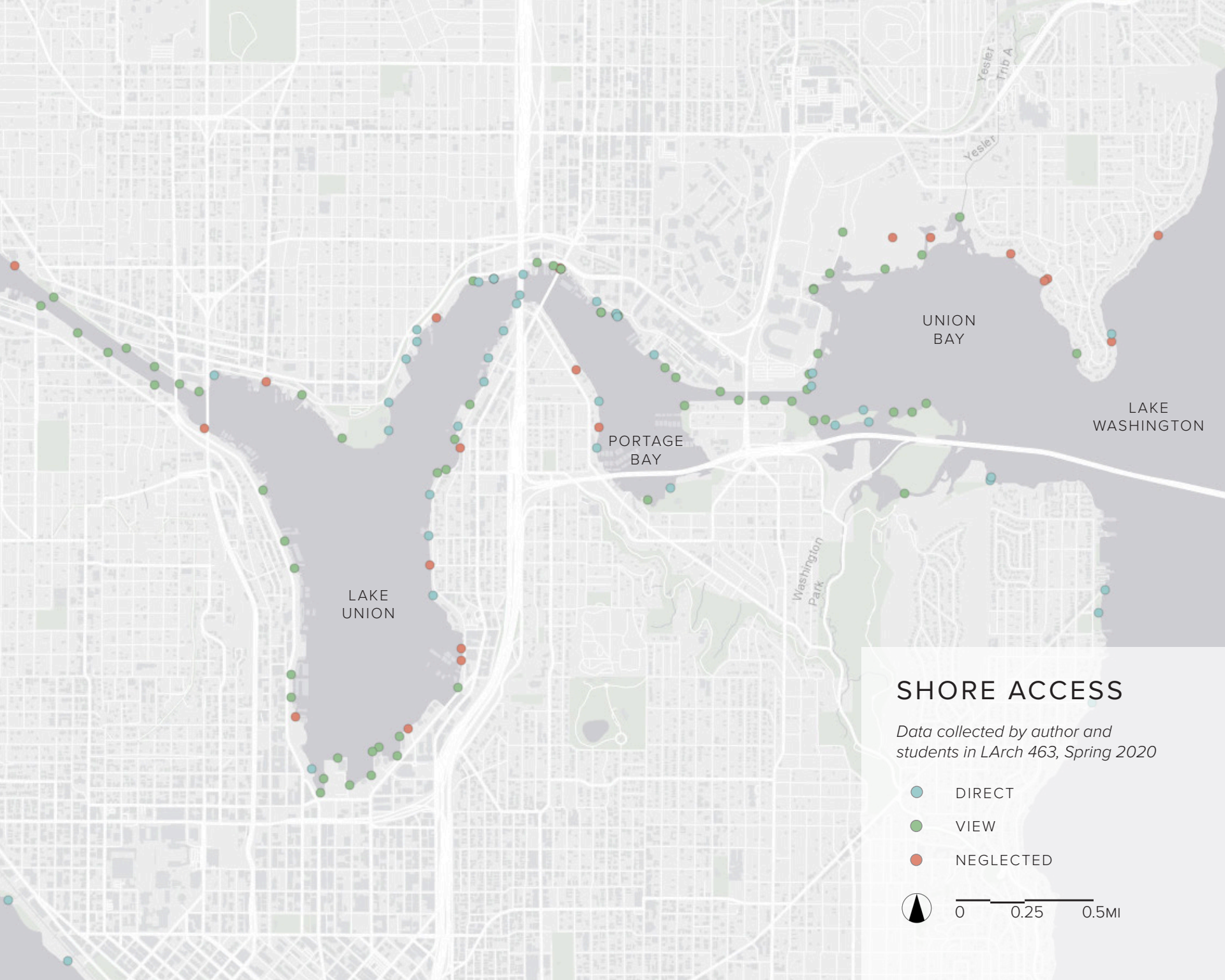
EXISTING OVERWATER STRUCTURES

- OVERWATER STRUCTURES
- OFFICIAL SHORELINE

Historic base map from 1894



	Water area (ft ²)	Structure area (ft ²)	% Cover
Fremont Canal	12,267,200	2,372,101	19.3%
Lake Union	32,898,400	6,428,736	19.5%
Union Bay	17,564,400	616,107	3.5%
Total	62,730,000	9,416,944	15.0%



UNION BAY

LAKE WASHINGTON

PORTAGE BAY

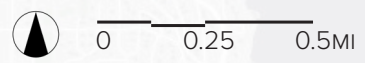
LAKE UNION

Washington Park

SHORE ACCESS

Data collected by author and students in LArch 463, Spring 2020

-  DIRECT
-  VIEW
-  NEGLECTED

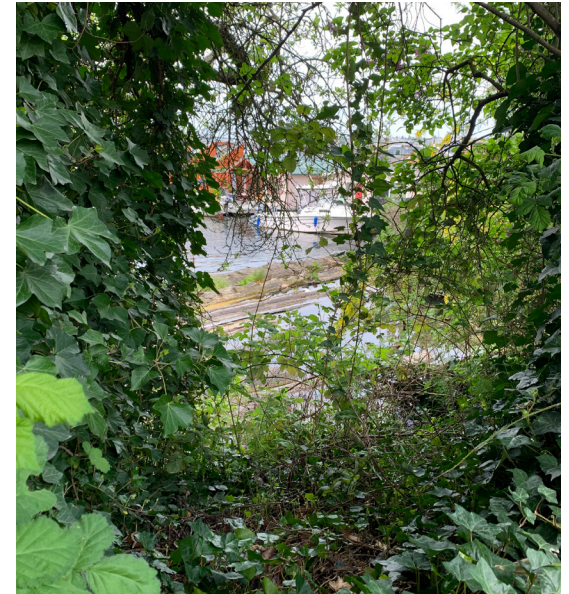




DIRECT ACCESS



VIEW ONLY



NEGLECTED

SEATTLE'S SHORE ACCESS

If you walk along the shore of Lake Union today, you are likely on a road with businesses between you and the wall that is the water's edge. Or perhaps you can see the water, but there are half a dozen houseboats before you can find a clear view across the lake. City programs, like the Shoreline Street Ends, are working to increase the amount of public shore access. However, currently the majority of these access points offer no ecological benefits,

and many don't even offer human benefits.

The Shoreline Street End program became official in 1996 when a city resolution officially recognized any street end terminating in the water as a right of way; neighboring private landowners could no longer usurp the space (City of Seattle n.d.). Seattle has the opportunity to build up a network of nearshore habitat in the same way that pollinator pathways are designed on land.

SHORELINE RESTORATION BEST PRACTICES

In accordance with the Shoreline Management Act and Shoreline Master Plan, the City of Seattle has created the Green Shorelines Guidebook which proposes ecological alternatives to bulkheads. The best alternative to bulkheads on Lake Washington is a rocky beach with vegetation. Plants anchor the sediment, provide food and habitat, and offer ecosystem services

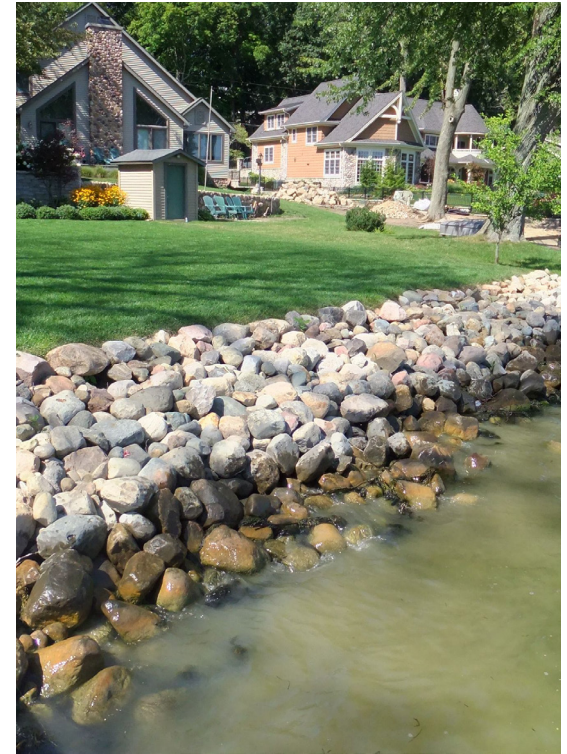
like filtration (LaClergue et al. n.d.). Many current bulkheads create a wall where there should have been a natural slope into the water. By recreating the slope, wave energy naturally dissipates and the property is just as protected. In areas where the slope is steep or erosion is expected, set back bulkheads offer some compromise.



BEACHES AND VEGETATION



SET BACK BULKHEADS



SLOPE BIOENGINEERING

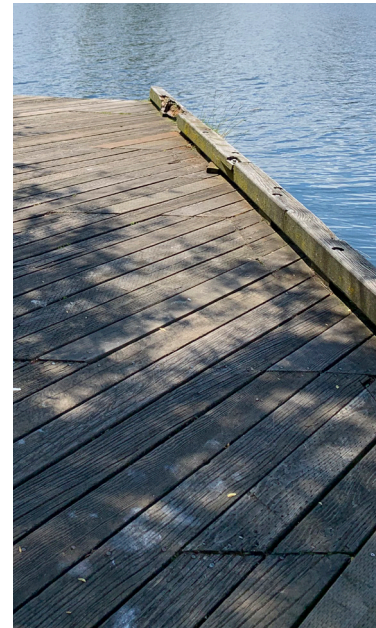


The challenge through the Lake Washington ship canal is not only bulkheads, but extensive overwater structures

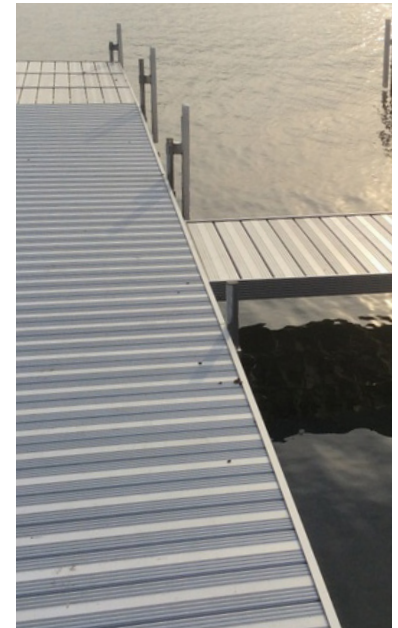
OVERWATER STRUCTURE MATERIALITY

There are many factors to consider in dock and piling materiality. First, we must consider the conditions in which the dock will be used, including weather, wave action, type of boat, etc. These factors will determine the buoyancy needed and, thus, narrow the list of suitable materials. Another important factor is the life cycle of the material in production, in the water, and after decommission. One key component of the life cycle assessment is the material's effect on the environment and can be complicated by treatments needed to withstand the elements; for example, wooden docks are often treated with chemicals to extend their life spans. Wooden docks are also often made with styrofoam flotation, which is known to degrade and break off; therefore, the entire structure needs to be analyzed.

One priority in dock design is to allow light through to the water below the structure. This can best be done either by building elevated docks, or using a grated surface. Grating is appropriate for ramps, but when grating is encouraged for floating dock surfaces, the large, opaque floats beneath them actually end up defeating the purpose of letting light through. Material and form should be considered together to create the best, minimal overwater solution.



WOOD



ALUMINUM

PROS

renewable
biodegradable
surface stays cool

long life span
lightweight

CONS

shorter life span
chemically treated

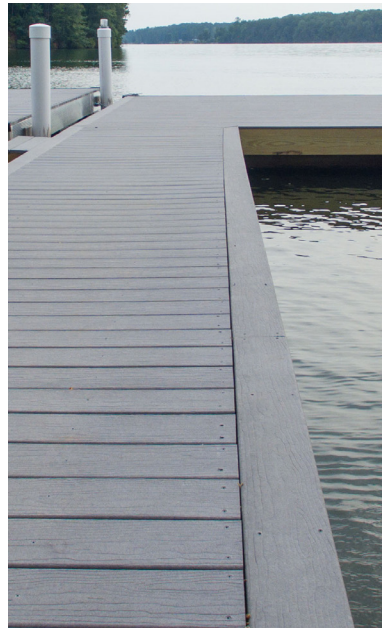
surface gets hot
slippery without traction/
sharp with traction



PLASTIC

long life span
lightweight
easily assembled/can be seasonal

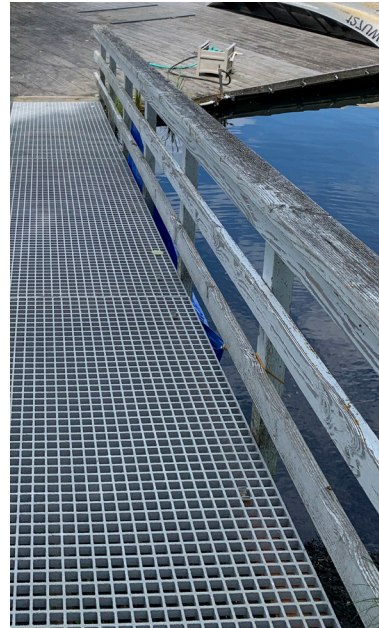
non biodegradable
slippery



COMPOSITE

recycled materials
long life span

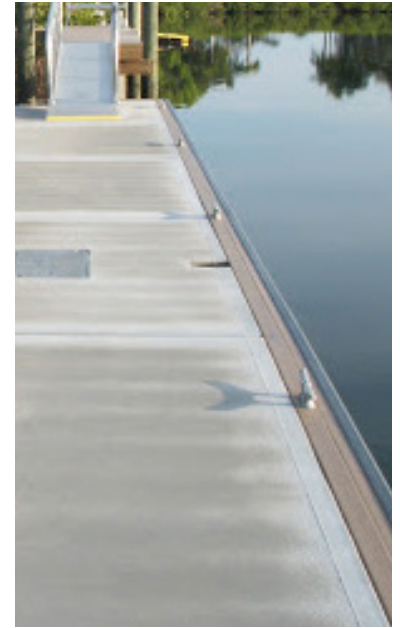
non biodegradable



COMPOSITE GRATE

allows light through
recycled materials
long life span

non biodegradable



CONCRETE

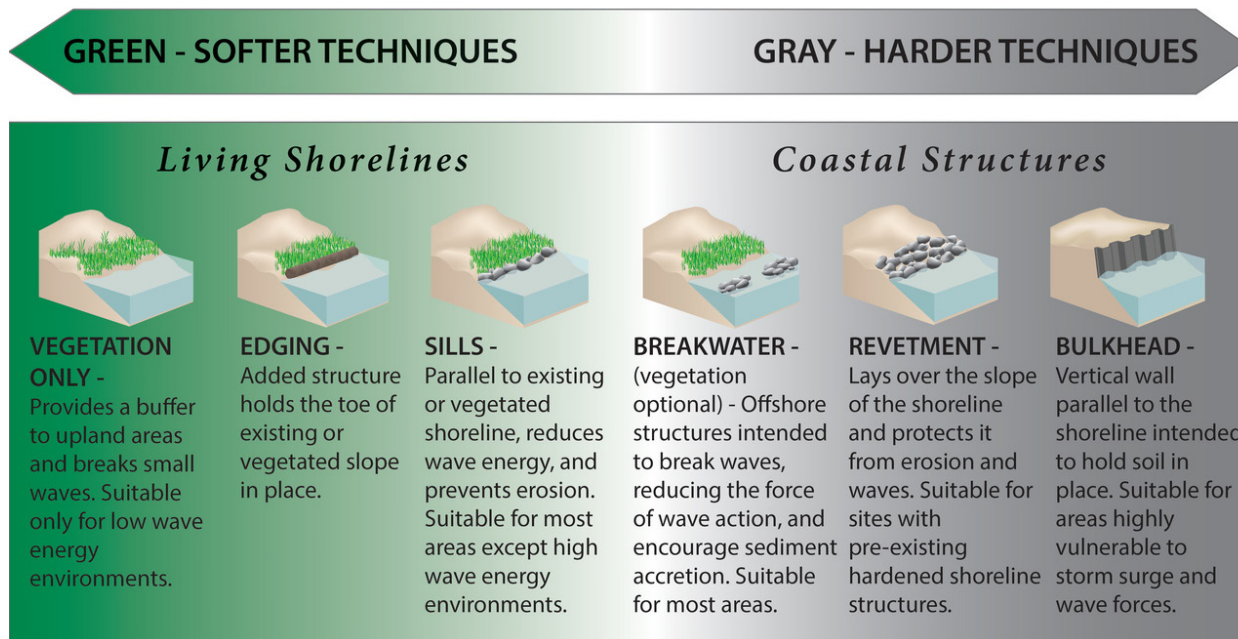
long life span
stable in waves

non biodegradable
styrofoam core
depth of structure

DESIGNING SHORELINES

The idea of ecological design has gained popularity in recent decades, which has included innovation along marine coasts for living shorelines; however, less research has focused on aquatic infrastructure improvements. In their 2015 article on ecosystem enhancements for urban waterfronts, Dyson and Yocom noted that “overall, docks and overwater structures remain in need of creative ecological design efforts to address altered water flow, shading, and habitat structure.”

The National Oceanic and Atmospheric Administration (NOAA) developed a framework called Habitat Blueprint to “improve habitat conditions that support fisheries, coastal communities, and marine life, and provide environmental, economic, and cultural benefits” (NOAA Habitat Blueprint n.d.). NOAA has created tools and guiding principles to encourage the use of living shorelines as well as working towards policy changes. While focused on marine shorelines, in a comparison of common living shorelines to hard stabilization techniques, there



Soft to hard shoreline technique continuum
Diagram from NOAA

is a notable lack of incorporating vegetation into harder techniques. Opportunities to incorporate ecosystem services are being missed. Layering hard and soft is especially relevant to urban freshwater systems that don't have as harsh weather conditions as marine waterfronts, but do have space constraints. An analogy in urban landscapes is street trees; we know they won't reach their full potential, but they still add significant social and ecological benefits.

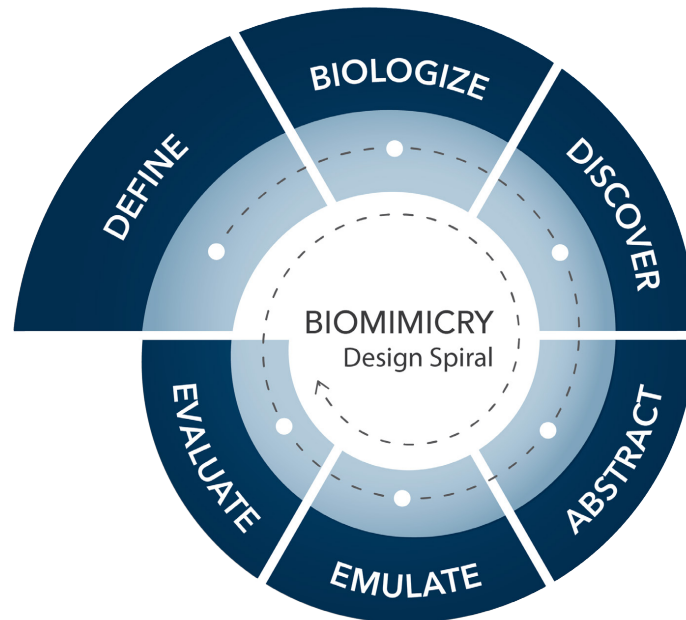
Enhancing ecosystem services is not synonymous with biomimicry although both are strategies within ecological design. Enhancing ecosystem services is accomplished by creating

conditions for natural processes to thrive, like restoring wetlands in order to filter pollutants. Biomimicry means to learn from processes and forms in nature and to apply them in a different way, like the shape of a mosquito's mouth informing medical needle design. Biomimicry is based on understanding the relationship between form and function in nature and creatively applying them to new problems. Some of the design strategies observable in nature are to use waste as a resource, cooperate to fully use a habitat, and optimize rather than maximize (Beatley 2011). Strategies such as these allow for broader exploration of nature inspired solutions, which is crucial in landscapes that have been so altered that native ecological functions are no longer supported. In areas where human made impacts will remain, biomimicry can be a tool for design thinking.

The Biomimicry Institute is a non-profit organization that encourages the use of nature's design lessons through design challenges and resources. The Biomimicry Design Spiral, developed by Carl Hastrich, considers the design process through nature's lens and is intended as a framework to generate innovative and sustainable design solutions (DeLuca 2016). Biomimicry can help tackle shoreline problems that are too complex for classic restoration.

Biomimicry Design Spiral
Diagram from Biomimicry Institute Toolkit

- DEFINE**
Challenge
- BIOLOGIZE**
Function & Context
- DISCOVER**
Biological Strategies
- ABSTRACT**
Design Strategies
- EMULATE**
Nature's Lessons
- EVALUATE**
Fit and Functionality



PRECEDENT STUDIES

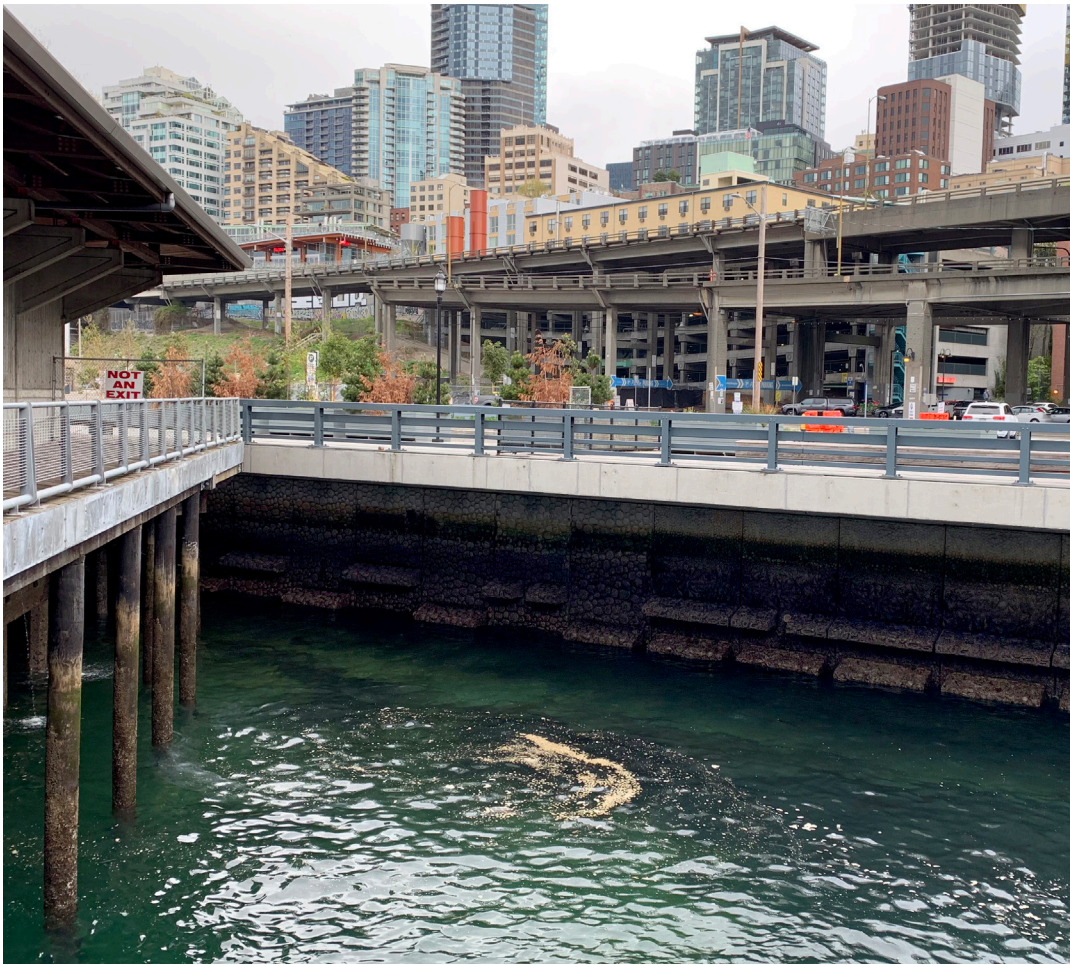
These best practices and innovative ecological design strategies are showcased in built projects all over the world. I have been inspired by both underwater and above water restoration projects, land art, and public spaces.

Locally, shoreline restoration projects are being implemented along the Lake Washington Ship Canal. One example is Portage Bay Park which is currently under construction in the spring of 2020 and is nestled into the UW Seattle campus. This City of Seattle park is designed by Walker Macy on a newly restored

stretch of shoreline that was previously the site of a police station. The removal of the building allowed space for a gradual slope into the water with a low, recessed bulkhead that doubles as seating. Terraced lawns step onto a rocky shore such that the park is equally enjoyable for a lunch break or launching a kayak. A short pier creates a viewpoint and provides ADA access over the water. Sections of the shore also use anchored logs and emergent vegetation to bolster the nearshore habitat. I was able to visit by paddle board and there was already a Great Blue Heron preening on the shore.



New Portage Bay Park shoreline in progress



Seattle Seawall shelves and texture is visible when the tide is out

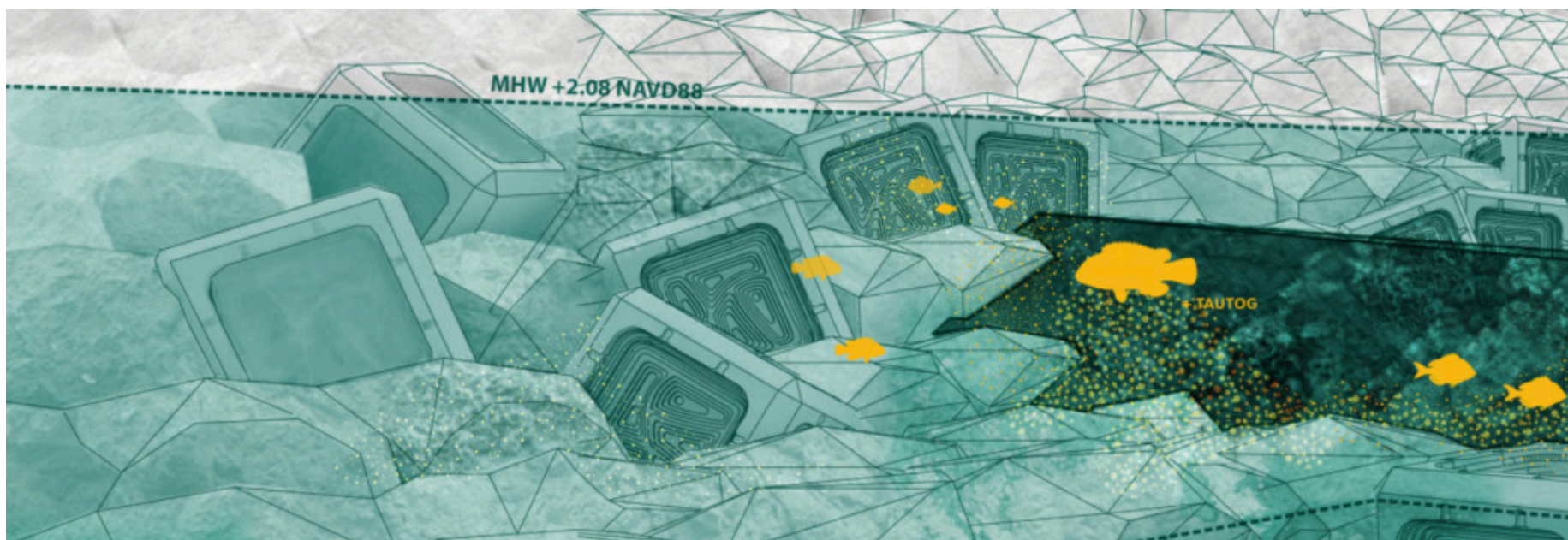
Biomimicry is often utilized in marine systems to reestablish lost habitat, from small scale reef balls to urban waterfronts. The Seattle Seawall protects downtown from coastal hazards, is part of an active waterfront, and is a popular tourist attraction. With many necessary functions and stakeholders, it is laudable that the design for the 2017 reconstruction prioritized ecosystem services. The big design moves focused on creating microhabitats and reducing the impacts of shading, two key factors typical of many shorelines. Through in situ pilot projects, the new structure includes a shelf to create shallow water conditions, textured “pillows” that encourage benthic invertebrate communities to establish, and glass bricks in the cantilevered sidewalk to allow sunlight in (Dyson and Yocom 2015). The passage specifically benefits migrating salmon by creating a corridor with the right food, all under a bustling, urban waterfront.

One challenge this seawall project is facing is that the glass bricks are breaking and becoming more opaque through wear and tear than anticipated. To maintain safe pedestrian circulation, sections are covered with boards, thus, shading out the structures below. Subsequent phases of the waterfront project, being designed by James Corner Field Operations, may have to address this problem while designing the rest of the streetscape.

SCAPE is a leader in ecological infrastructure and emphasizes reviving site systems in their design approach. Their concept of Oyster-tecture directly harnesses ecosystem services as a design building block to clean water and create habitat (SCAPE 2009). This concept is being implemented in Living Breakwaters, a project to restore a stretch of shore on Staten Island in New York that was severely damaged in Hurricane Sandy. Elements of restoration and education are included in the project through partnerships with local organizations, inviting community involvement. Carefully considered materials and forms create the conditions for native species to thrive and humans to benefit.

The firm emphasizes the need to “cohabitat”, or really to share space with other species (SCAPE n.d.). Upcoming SCAPE projects apply these same ideas to river and dune ecosystems.

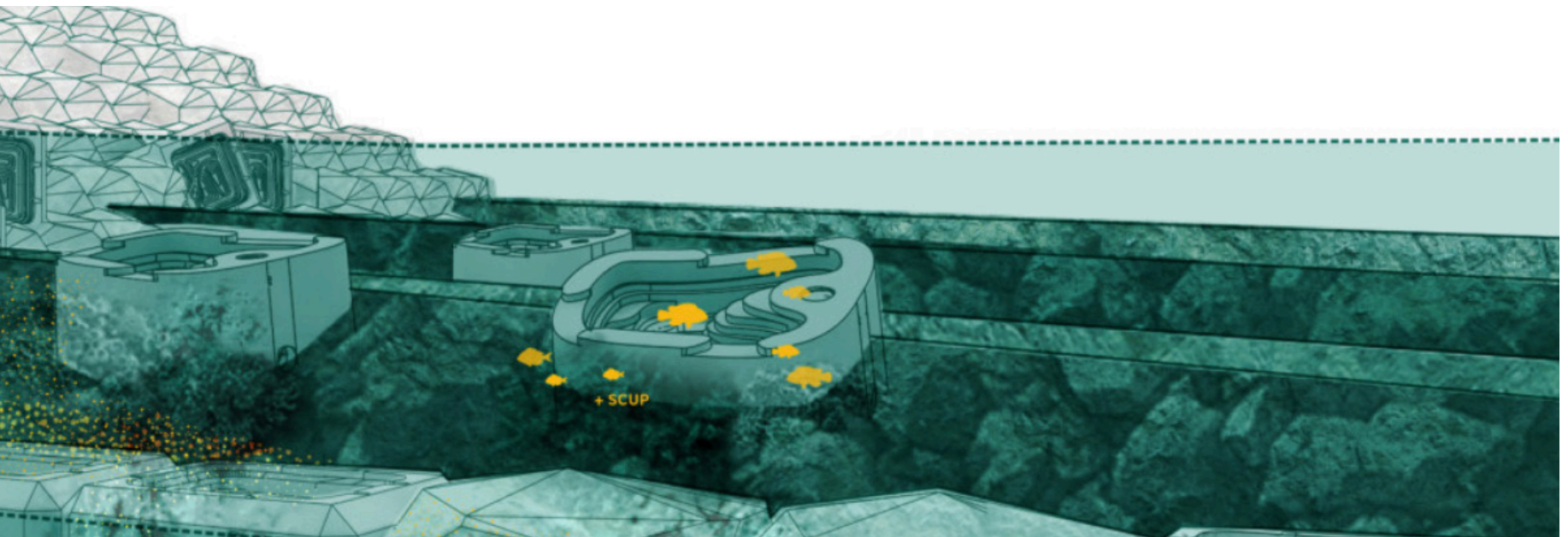
A key component of the Living Breakwaters is artificial tide pools, created with precast concrete. The leading manufacturer of environmentally sensitive concrete is EConcrete, which has developed a system of tide pools, mats, and blocks with a proprietary bio-enhancing admix to reduce the CO₂ footprint of the product. When I contacted them, their team of marine biologists had not yet tested their products in freshwater environments (Perkol-Finkel 2020).





*Right: Precast concrete tide pools
create textured surface area for
benthic marine life*
ECONcrete

*Below: Living Breakwaters diagram
of designed microhabitats*
SCAPE



Another approach to building foundations that encourage natural growth is with underwater sculptures, like the work of Jason deCaires Taylor. He took the simple concept of “reef balls”, which are often employed by conservationists to create surface area for coral to grow, and added a poignant message through the form of his sculptures. Mostly depicting people, the figures are posed as social commentary “indicative of the daily actions of humanity, living above the waves, often oblivious to the impact each of their actions can have on the environment” (Taylor n.d.). The underwater realm offers viewers a different reality while the marine organisms complete the sculptures.

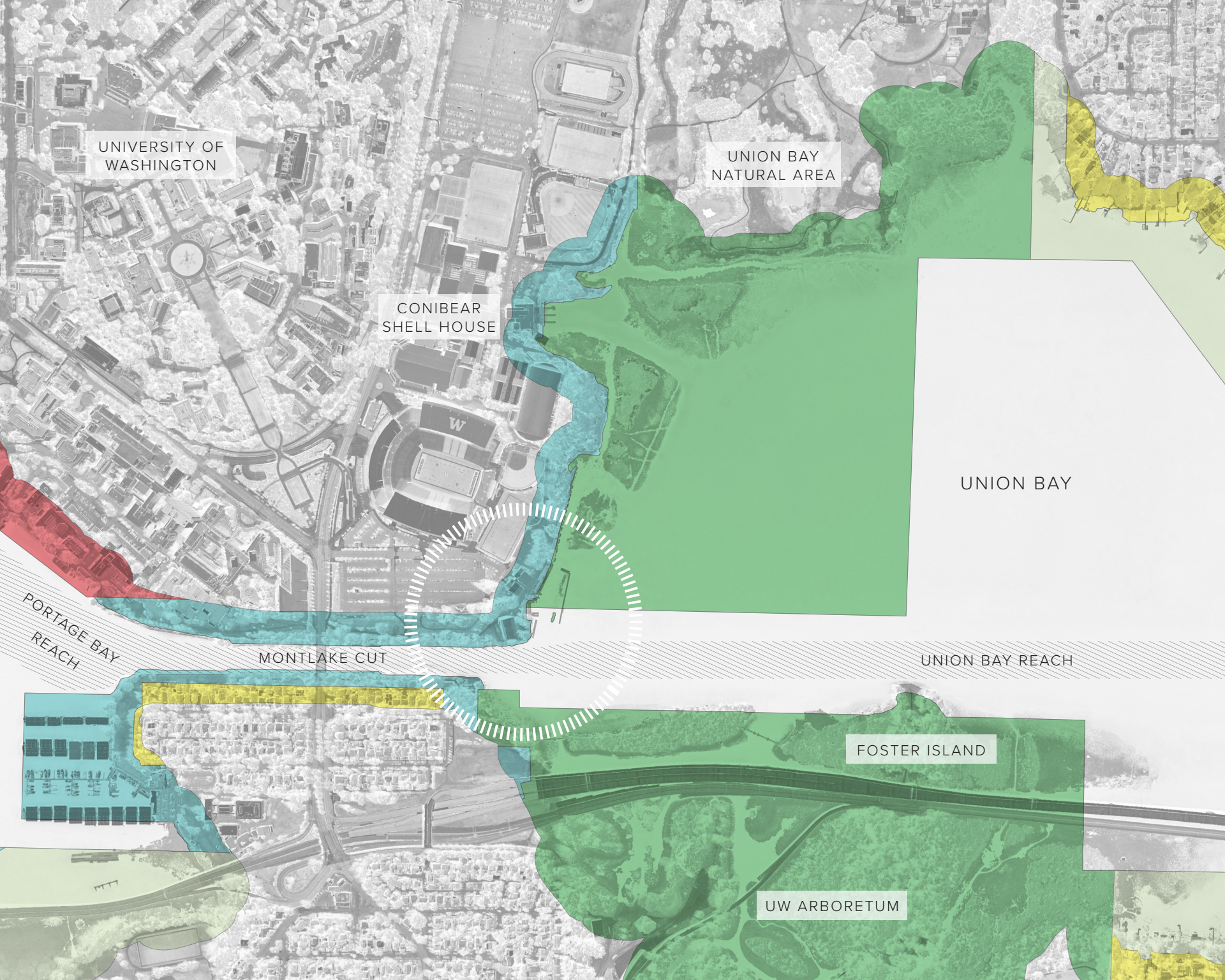
This thesis’ focus on dock design was also inspired by several harbor bath projects in Copenhagen that have created public space in the water. Each swimming area is unique but also striking and functional like so much of Scandinavian design. The harbor baths include diving towers, artificial beaches, slides, and even one that is directly accessible by bike. Ecological impact does not seem to be a key design consideration in their overwater structures; however, “eco-efficient technology” in urban systems, like stormwater and sewage management, has transformed their harbor into a thriving aquatic environment (City of Copenhagen n.d.)



Vicissitudes underwater exhibit combines art with coral reef restoration
Jason deCaires Taylor



Kalvebod Waves extends the sidewalk out over Copenhagen's harbor and includes a kayak slide, play structures, and seating



UNIVERSITY OF WASHINGTON

UNION BAY NATURAL AREA

CONIBEAR SHELL HOUSE

UNION BAY

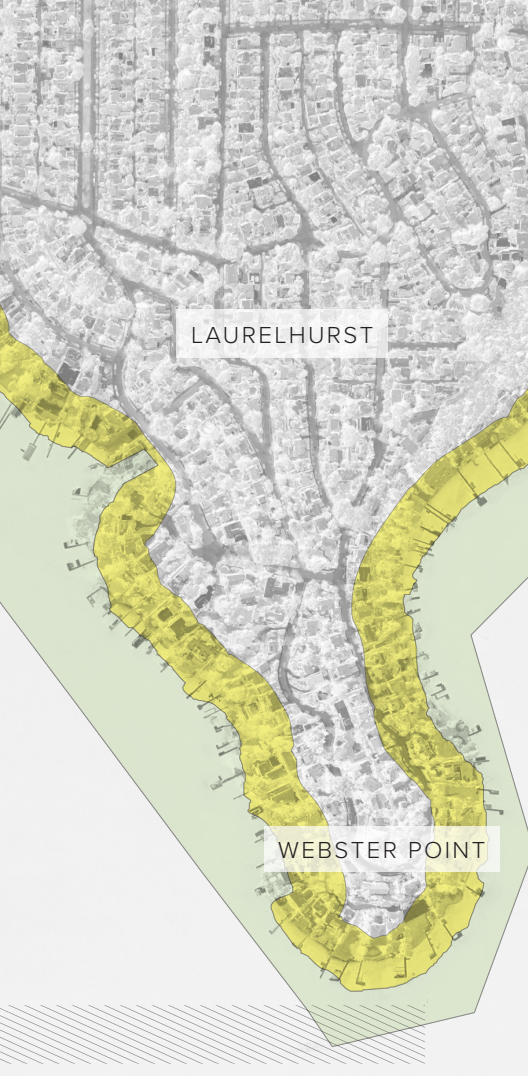
PORTAGE BAY REACH

MONTLAKE CUT

UNION BAY REACH

FOSTER ISLAND

UW ARBORETUM



UW SHORELINE CONTEXT

The University of Washington Seattle Campus includes approximately two miles of shoreline, shared between Lake Union’s Portage Bay and Lake Washington’s Union Bay. The two water bodies are connected by the Montlake Cut which is part of the Lake Washington Ship Canal. In many ways, the Montlake Cut is the villain in this story, since the depth and flow of water make typical wetland restoration impossible on this site.

The UW shoreline is classified into either Urban Commercial, Conservancy Management, and Conservancy Preservation as defined by the City of Seattle Shoreline Master Program in accordance with the Washington State Department of Ecology Shoreline Management Act (WSDE 2020). The site for this thesis falls into Conservancy Management while the existing wetland islands are within Conservancy Preservation. Any development on this site would need to follow regulations associated with these designations, including limits on overwater structures, impermeable surface, a shoreline buffer zone, mitigation, tree protection, etc. This proposal applies the same ecological principles used to inform the Shoreline Master Plan; however, as an exercise in innovation, it does not strictly adhere to the regulations.

The northern section of Union Bay is the UW Arboretum’s Union Bay Natural Area where restoration practices are tested on an area that was historically marshland, then used as a city landfill, and now is a nature preserve. The northeast shore is private residential in the Laurelhurst neighborhood, an affluent community where most waterfront properties have their own docks. The mouth of Union Bay to Lake Washington is to the west, between Webster Point in Laurelhurst and the Madison Park neighborhood. The southern edge is also primarily managed by the UW Arboretum with a network of trails, with the notable disruption caused by the woven overpasses of SR 520. The popular Arboretum Waterfront Trail, consisting of a concrete floating dock system, which connects Montlake to Foster Island is currently being updated by local firm, Anchor QEA.

Stormwater drains from the stadium parking lots and surrounding sports fields into Union Bay. Wastewater from the buildings flow into the combined sewer system; there are nearby Combined Sewer Overflows (CSO) from the University in Portage Bay and from the Montlake neighborhood at the entrance to the Cut.

There are multiple destinations and cultural

landmarks in the vicinity that have varying levels of consideration in the Campus Master Plan. Notable locations include the Link Light Rail Station, Husky Stadium, the ASUW Shell House, and the Waterfront Activities Center. The Husky Climbing Rock is a bouldering destination beloved by the climbing community. Built in the 1970's, the easily accessible concrete walls are unique among urban, outdoor climbing spots.

Hidden in a grove of trees and overgrown grasses is a 1992 sculpture by Christy Rupp entitled Rollback Bench. The work was commissioned by the State of Washington Art in Public Places Program to mark 20 years of endangered species legislation during a time when the Endangered Species Act was being challenged. Rupp describes that “the actual sculpture was a cement couch in the shape of a dam. You can sit in the sculpture and reflect on your position in the debate, while two large stainless steel salmon try to get by the obstruction you have become” (Rupp 2005, n.p.).

There is the Story of North Island totem pole from Waterfall, Alaska at the entrance to the Cut in East Montlake Park. Originally carved in 1937 by Haida Chief John Dewey Wallace for a salmon cannery, it mysteriously disappeared and “resurfaced” in Seattle and was restored and erected on this site in 1983 (Childress 2013). While not representative of local traditions, it serves as an important reminder of indigenous history.



Husky Climbing Rock

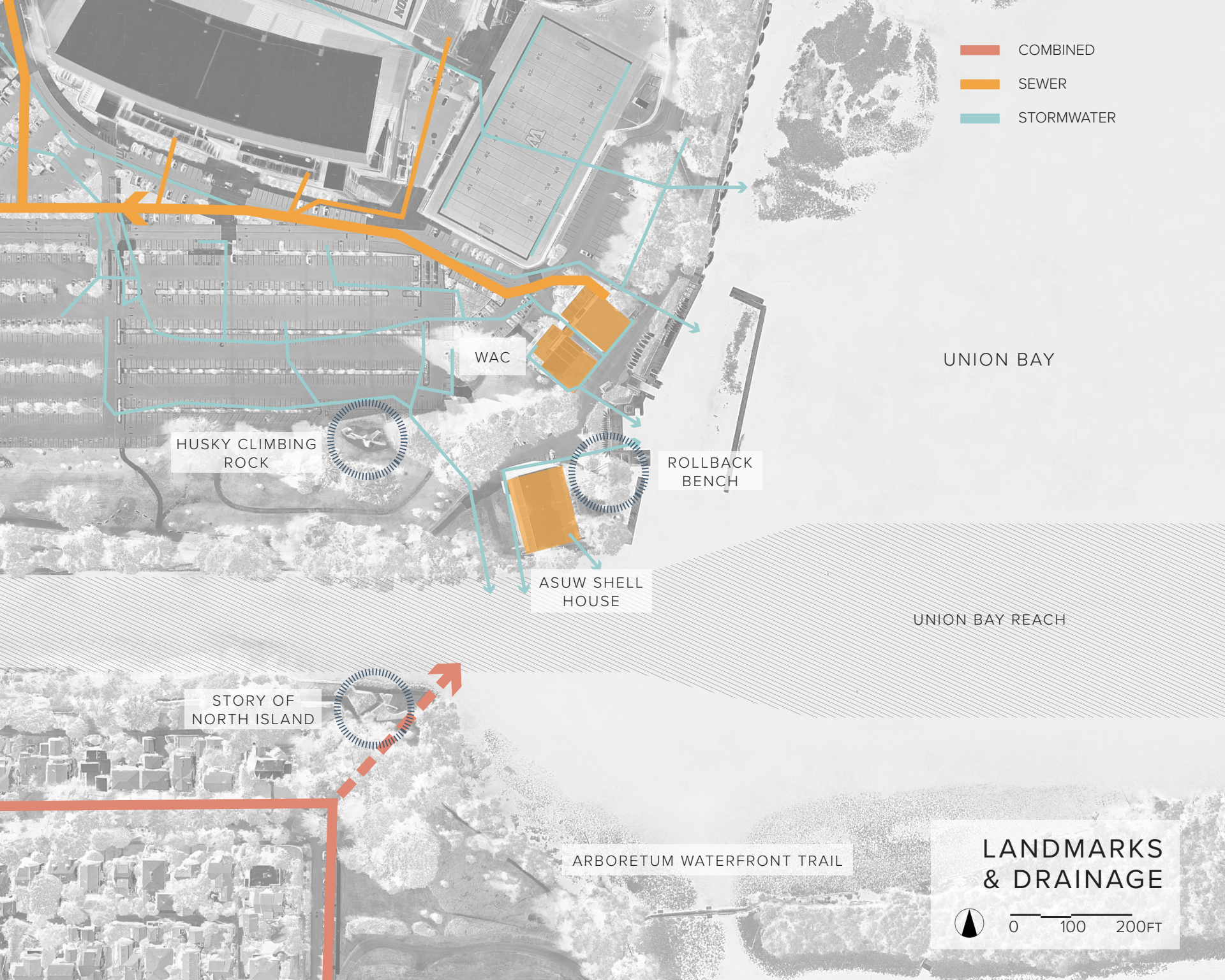


Rollback Bench



Story of North Island totem pole

- COMBINED
- SEWER
- STORMWATER



HUSKY CLIMBING ROCK

WAC

ROLLBACK BENCH

ASUW SHELL HOUSE

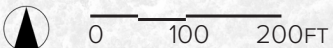
STORY OF NORTH ISLAND

ARBORETUM WATERFRONT TRAIL

UNION BAY

UNION BAY REACH

LANDMARKS & DRAINAGE



EXISTING PROGRAMMING

The ASUW Shell House is listed on the National Register of Historic Places and is recognized for its Naval construction as a wood frame seaplane hangar. It also housed the UW rowing team that won gold at the 1936 Olympics as well as the workshop of renowned boat builder, George Pocock. This structure, and the visceral connection to the water one feels within it, is what drew me to this site.

As a rower, I learned about the Shell House from the best selling book, *The Boys in the Boat*, and when I chose to attend UW in 2017, I was excited to see where the action happened. I was disappointed to find that it was being used for private boat storage and only occasionally open for tours. Luckily, the rowing club stored its boats inside, so I was one of roughly a dozen team members who used it daily.

In 2018, a restoration project for the building was taking off, with a vision to reprogram the space. I was able to participate in a design charrette and started helping with fundraising events. With a focus on honoring the Naval, rowing, and UW history of the building, the scope of the restoration project did not include the surrounding landscape. This thesis responds to the grandeur of the hangar doors and anticipates future activation of the Shell House for student use and events.



ASUW Shell House with rowing team, 1939
Museum of History & Industry, Seattle (MOHAI), 1986.5.15874.1



ASUW Shell House, 2020

The other building on site is the Waterfront Activities Center (WAC). The WAC is open to the public for canoe and kayak rentals through UW Recreation. The WAC also houses UWild's Gear Garage where members of the UW community can rent wilderness gear, like camping equipment, skis, etc. There are also four UW clubs that have access: Union Bay Rowing Club (UBRC), Washington Yacht Club, University Kayak Club, and UW Concrete Canoe Team. Currently, the primary use of the building and dock space is boat storage.

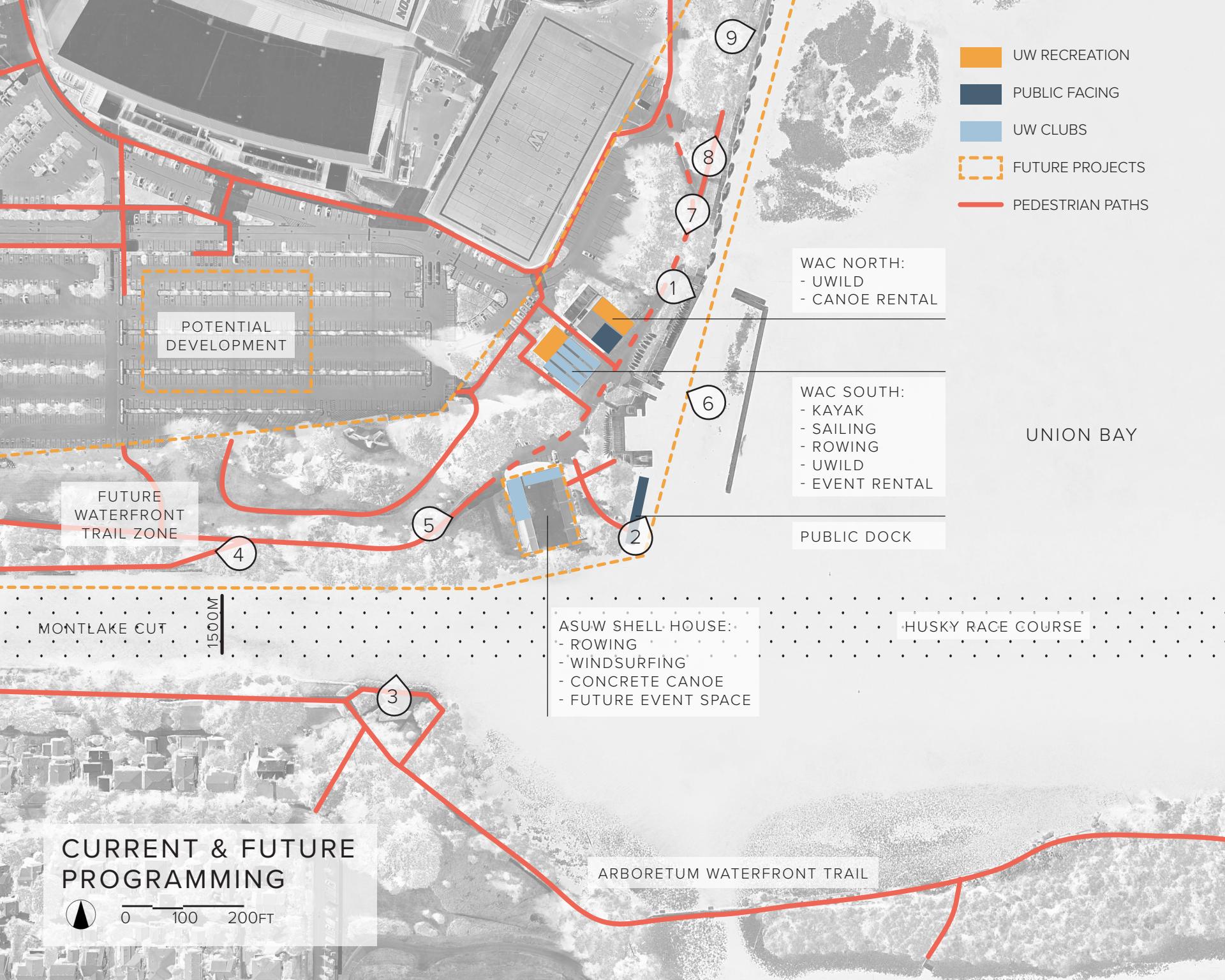
On football game days, "Husky Harbor" is a popular destination for "sailgating" and the

docks provide quick access to the stadium. The biggest day of the year along the UW shoreline is Opening Day on the first Saturday in May. Festivities include a rowing regatta and a boat parade to celebrate the opening of boating season. Spectators perch along the Cut, while boats raft up to log booms along the race course.

On sunny days, students and the public enjoy use of the southernmost dock, which is the only one without restricted access. The boat ramp and other docks have plastic chains and signs asking people to stay off. There are trails frequented by runners and birders connecting to both ends of the site.



Existing shoreline and docks, looking southeast. The Shell House and WAC are visible in the far right.



- UW RECREATION
- PUBLIC FACING
- UW CLUBS
- FUTURE PROJECTS
- PEDESTRIAN PATHS

POTENTIAL DEVELOPMENT

FUTURE WATERFRONT TRAIL ZONE

WAC NORTH:
- UWILD
- CANOE RENTAL

WAC SOUTH:
- KAYAK
- SAILING
- ROWING
- UWILD
- EVENT RENTAL

PUBLIC DOCK

UNION BAY

MONTLAKE CUT

1500M

ASUW SHELL HOUSE:
- ROWING
- WINDSURFING
- CONCRETE CANOE
- FUTURE EVENT SPACE

HUSKY RACE COURSE

CURRENT & FUTURE PROGRAMMING



ARBORETUM WATERFRONT TRAIL

- 9
- 8
- 7
- 1
- 6
- 5
- 2
- 4
- 3

2



Existing docks, looking northeast. Webster Point and Foster Point frame the mouth of Union Bay to Lake Washington on the right.

3



Montlake Cut and the ASUW Shell House from East Montlake Park, looking northeast.

4



Desire paths along the terraces of the Montlake Cut with ad hoc railing

6



The WAC, boat ramp, and current docks used for boat storage, GOOGLE

5



Trails become a gravel road along the underutilized area west of the Shell House

7



Paved road is the only trail along most of the WAC shoreline

8



Dead end trail towards north sailing docks

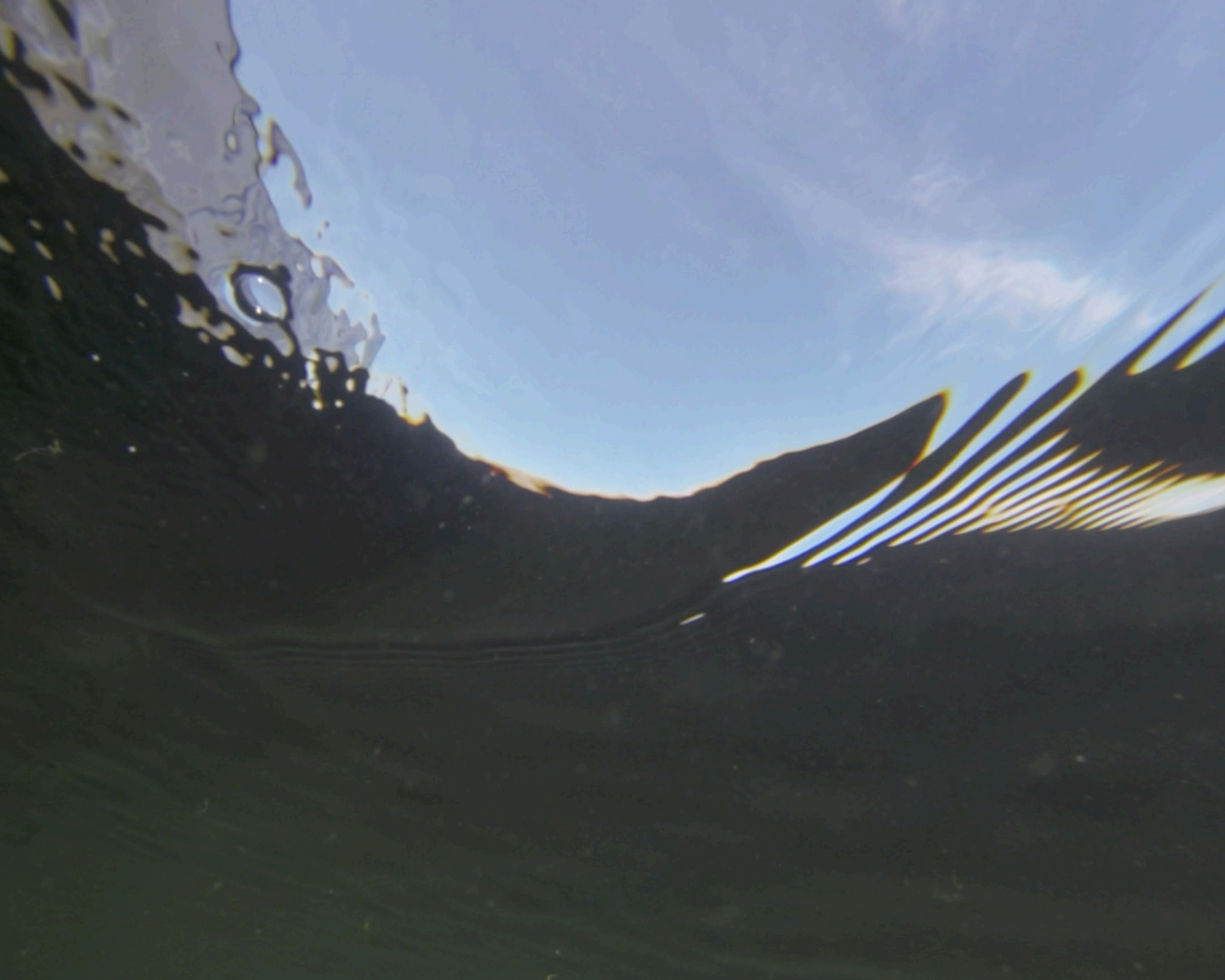
9



Resilient wildlife use the islands just beyond the docks

However, there is no clear circulation through its core. From the Montlake Bridge, a wood chip path turns to gravel and then pavement along the WAC waterfront. While signs indicate this is the East Campus Bike path, the changes in terrain are not suited well to road bikes. When coming from the Link Light Rail station or the Burke Gilman Trail, pedestrians and bikers can cross through the stadium parking lot but there is no clear wayfinding to the WAC or shore.

The Campus Master Plan includes the potential for development in the current parking lot and improvements to the entire shoreline. In early 2020 the University posted a request for proposals for a Continuous Waterfront Trail design concept to be included in bids for the West and South Campus Greens. These projects are all part of the University's vision for more significant open spaces on campus. Combined with the ASUW Shell House restoration project, the University has a tremendous opportunity to increase ecological productivity while improving human access to a significant stretch of shoreline.



DESIGN CONCEPT

CONSTRUCTIVE INTERFERENCE

“A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise.”

Aldo Leopold, *A Sand County Almanac*

Human made problems can be remedied with human made solutions that are inspired by nature. The strategies in this proposal are inspired by the predictability of wave interference. Constructive interference is when two waves align and the resulting wave is amplified. If two waves are perfectly opposite, they cancel each other out in destructive interference. This is true

for light, sound, water, etc. By combining an understanding of biogeochemical cycles and how they are interrupted in urban settings, we can design to amplify ecosystem services while canceling out the built environment’s negative impacts. Thus, nearshore infrastructure that is often part of the problem can become part of the solution for improving lentic ecosystems.

Light pattern from the bow wave of a canoe



REARRANGED
STORAGE

ROCKY
BEACH

REORIENTED
DOCKS

BIORETENTION
CELLS

VEGETATED
ARMORING



A combination of restoration and biomimicry respond to the specific conditions along the UW shoreline. By considering the existing landscape and anticipating the impacts of natural cycles and human use, nearshore infrastructure can benefit people and the environment, simultaneously.

The first strategy is to tackle stormwater before it drains into the lake. Bioretention cells, or rain gardens, can reintroduce the function of wetlands, especially in this area just below the stadium's surface parking lots. The planting design would utilize native species and create a garden space to compliment the event space inside the buildings.

Secondly, erosion due to boat wakes diminishes the shore at the mouth of the Montlake Cut. Wave energy also causes sedimentation in the Cut which then needs to be dredged. A modular, vegetated armoring system can serve as a compromise between a naturalistic and engineered approach, with additional co-

benefits. Acting like planter beds underwater, this strategy encourages emergent vegetation which provides habitat, improves water quality, and controls sediment. Where armoring is not needed, a rocky beach serves as a boat launch for hand powered crafts and an opportunity to dip one's toes in the water.

The third intervention is a new dock arrangement that minimizes the impact on nearshore habitat by following best practices for overwater structures. They are designed for the most common uses, like pedestrian access and small boats, while also being able to accommodate large boats. The docks are oriented along sightlines and wave angles to create a protected cove for novice paddlers. Boat storage is also made more efficient through stacking and mooring.

Together, these strategies create a system that treats stormwater, increases habitat, and creates more opportunities for recreation.

SITE PLAN



0 50 100FT



PORTAGE BAY

UNIVERSITY OF WASHINGTON

MONTLAKE CUT

SITE DESIGN

RESTORATION

UNION BAY

SITE ZONES 

EXISTING ZONES

There are currently five typical shoreline conditions on site: wall armoring, rock armoring, active shore, static shore, and restoration. The entire shore has been altered, although there is a discernible gradient of increasing vegetation and biodiversity from south to north.

The Montlake Cut, characterized by wall armoring, is owned by the state of Washington but controlled by the US Army Corps of Engineers through an easement. UW has been granted consent to use, maintain, operate, and repair “in-place structures” within 100 feet of the shoreline, which includes the retaining wall and part of the ASUW Shell House. This proposal does not address the existing wall armoring in detail but rather includes strategies to mitigate its impact in neighboring zones.

West of the Shell House is an underutilized lawn that has been used for parking or boat storage in the past. The shoreline is characterized by rock armoring although significant erosion in some areas has exposed roots and what appears to be a layer of asphalt rubble. The shore is overgrown with invasive Himalayan blackberry that block both water views and access. There are several “exceptional trees”, per the City of Seattle’s tree protection code (City of Seattle 2008).

The shoreline of Husky Harbor, or the waterfront area around the WAC, is defined by the docks that run parallel to shore. The existing, primarily invasive, vegetation creates a visual and physical barrier to the water. This is the most actively used zone; however, water access is only from the docks.

Behind the stadium is a narrow stand of trees between the road and shore. A dock runs parallel to shore that is approximately 300 feet long in an average depth of 4 feet of water. It is currently used to tie up 18 sailboats, which creates a static shore condition. The dock tends to trap litter and create an area of largely stagnant water; however, there are healthy willows and naturally fallen woody debris. Beyond the dock, several islands and natural floating wetlands provide refuge for birds and other aquatic life.

The northernmost zone is a restoration site as a mitigation for the construction of SR 520 through wetlands at the southern edge of Union Bay. There is no trail access through the brush or near the shoreline. This area is best accessed by boat where there are beaver dams and bird boxes that create opportunities for wildlife viewing. There continue to be problems with invasive species and so the restoration effort is still ongoing.

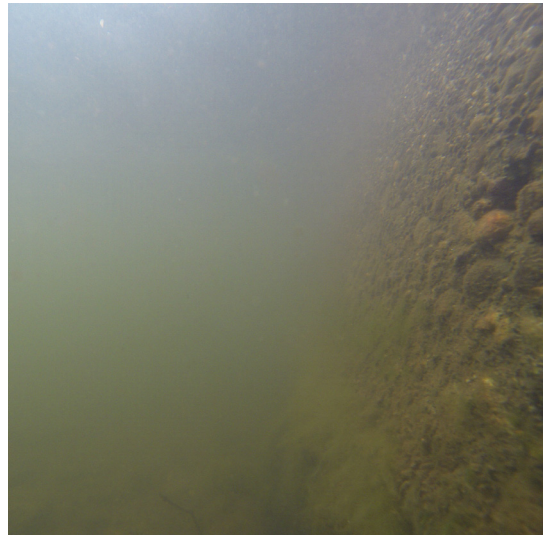
EXISTING CONDITIONS

The existing shoreline is a gradient of hard to soft conditions in response to the level of wave action. The wall is in good shape; however, the reflection of boat wakes causes a bathtub effect that is hazardous to small boats. The rock armoring around the point has not prevented erosion from boat wakes, so the shore is stabilized by roots. The parallel docks cut off the shore from the normal lake circulation. The islands just beyond the docks provide an example of the site's potential to recover.

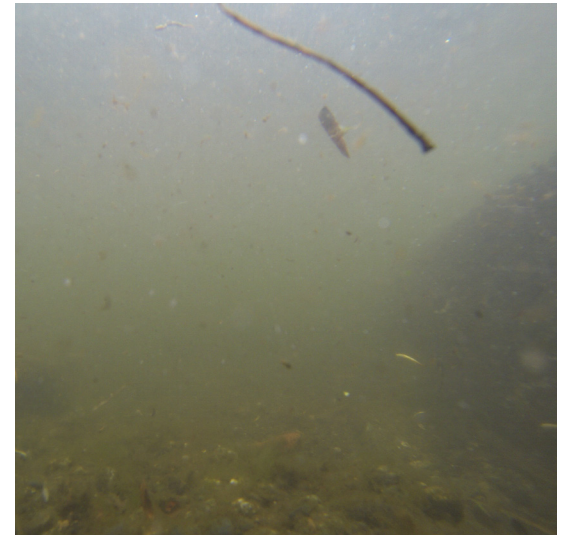
Underwater, the lake sediment is also a gradient. There are larger rocks at the mouth of the Cut and soft bottom with detritus towards the north. While waves and movement stir up sediment that clouds the water, it typically settles when the water is still. Seasonal algae can also reduce water clarity.



HARD



WALL ARMORING



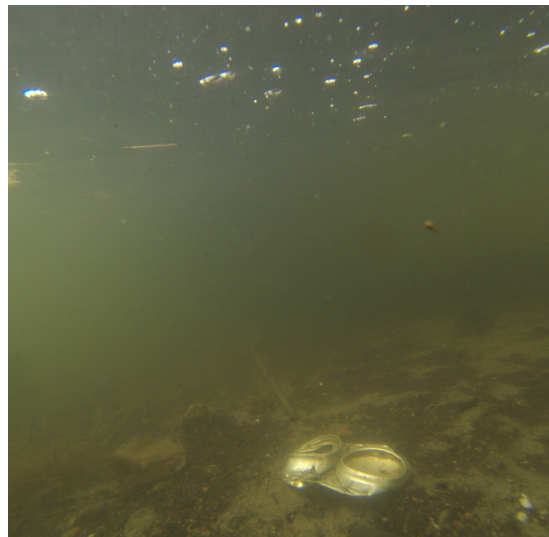
ROCK ARMORING



SOFT



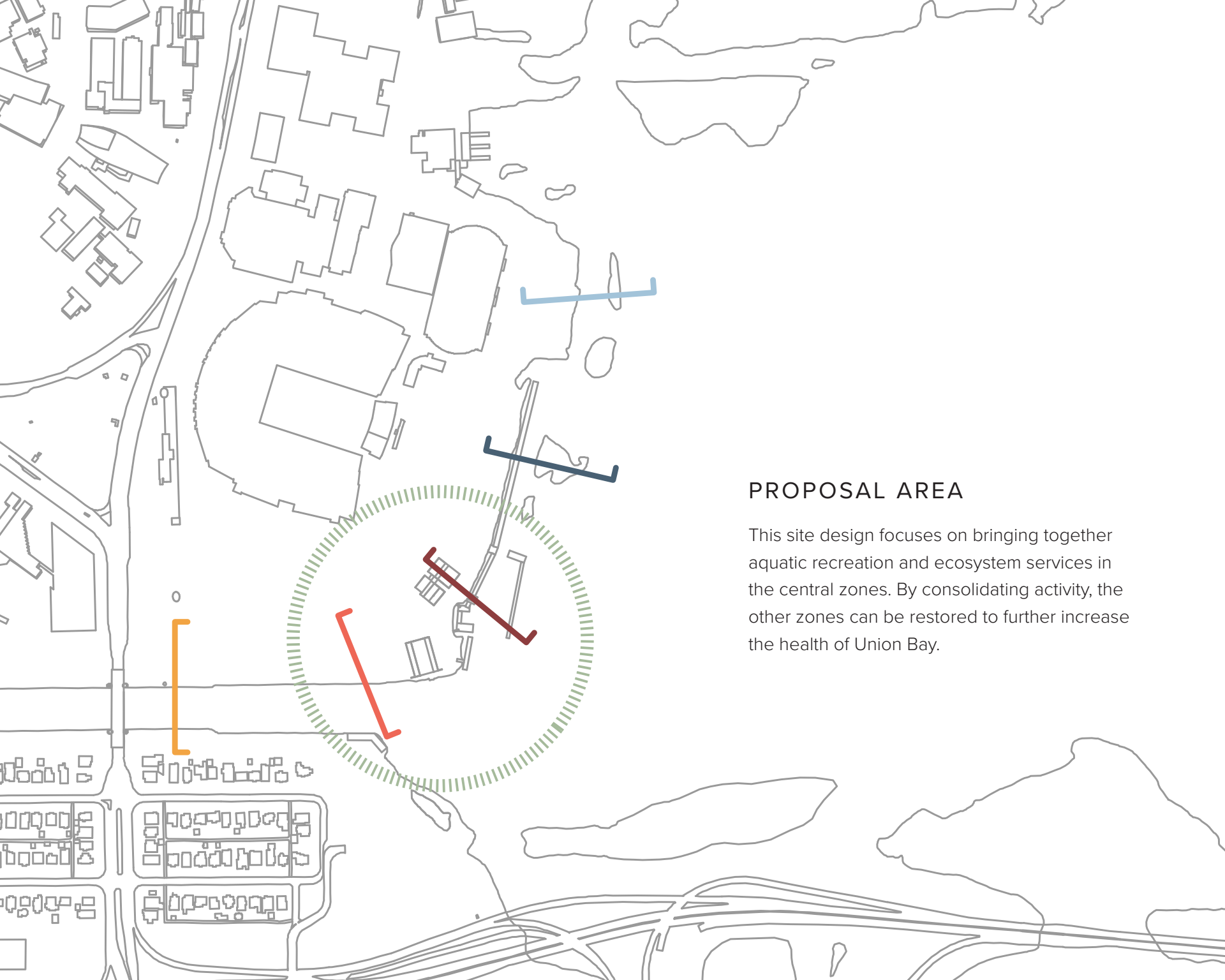
ACTIVE SHORE



STATIC SHORE



RESTORATION



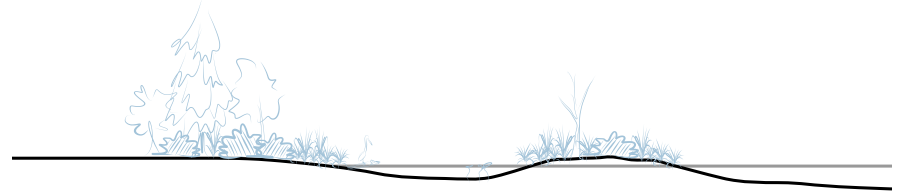
PROPOSAL AREA

This site design focuses on bringing together aquatic recreation and ecosystem services in the central zones. By consolidating activity, the other zones can be restored to further increase the health of Union Bay.

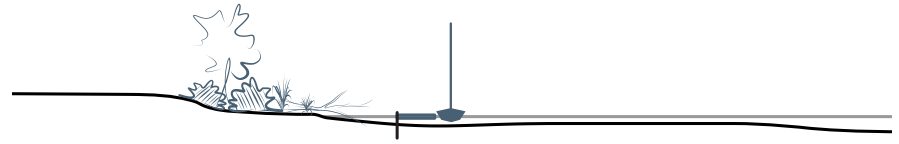
EXISTING ZONES

SECTIONS

RESTORATION



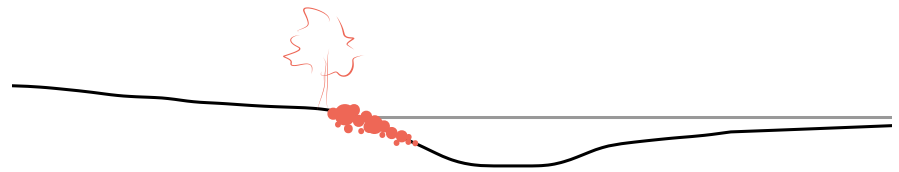
STATIC SHORE



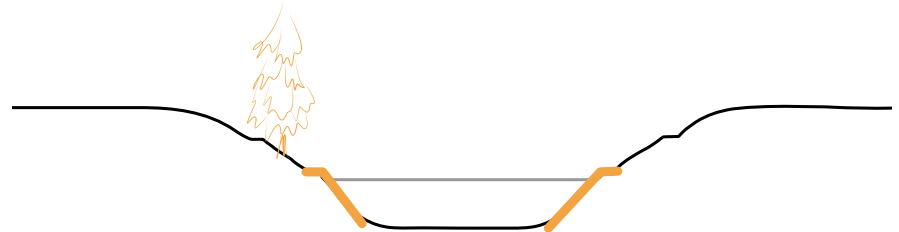
ACTIVE SHORE



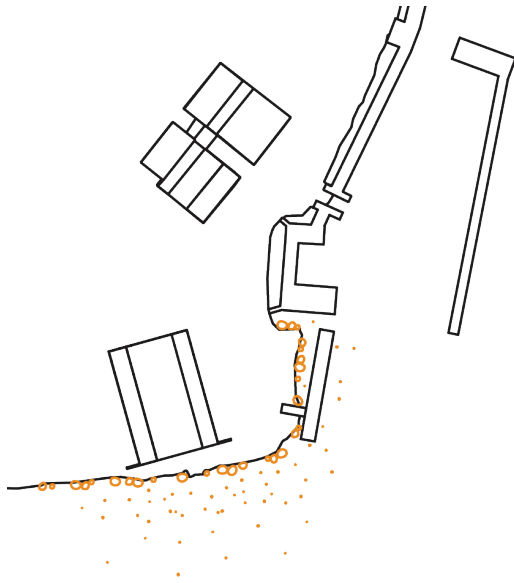
ROCK ARMORING



WALL ARMORING

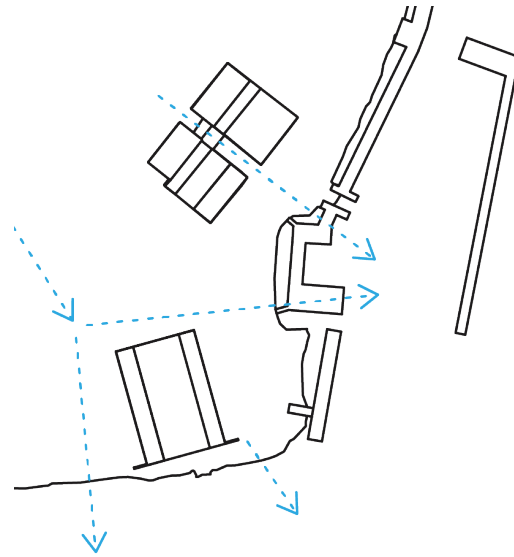


KEY PROBLEMS



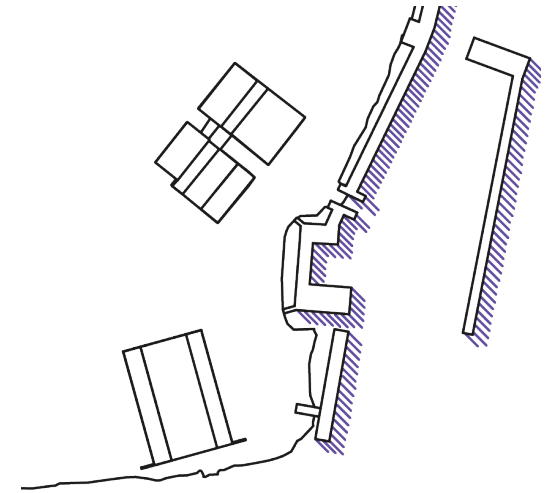
EROSION

Erosion along this shoreline is primarily caused by boat wakes. Water flowing out through the Cut can also contribute to scouring.



STORMWATER

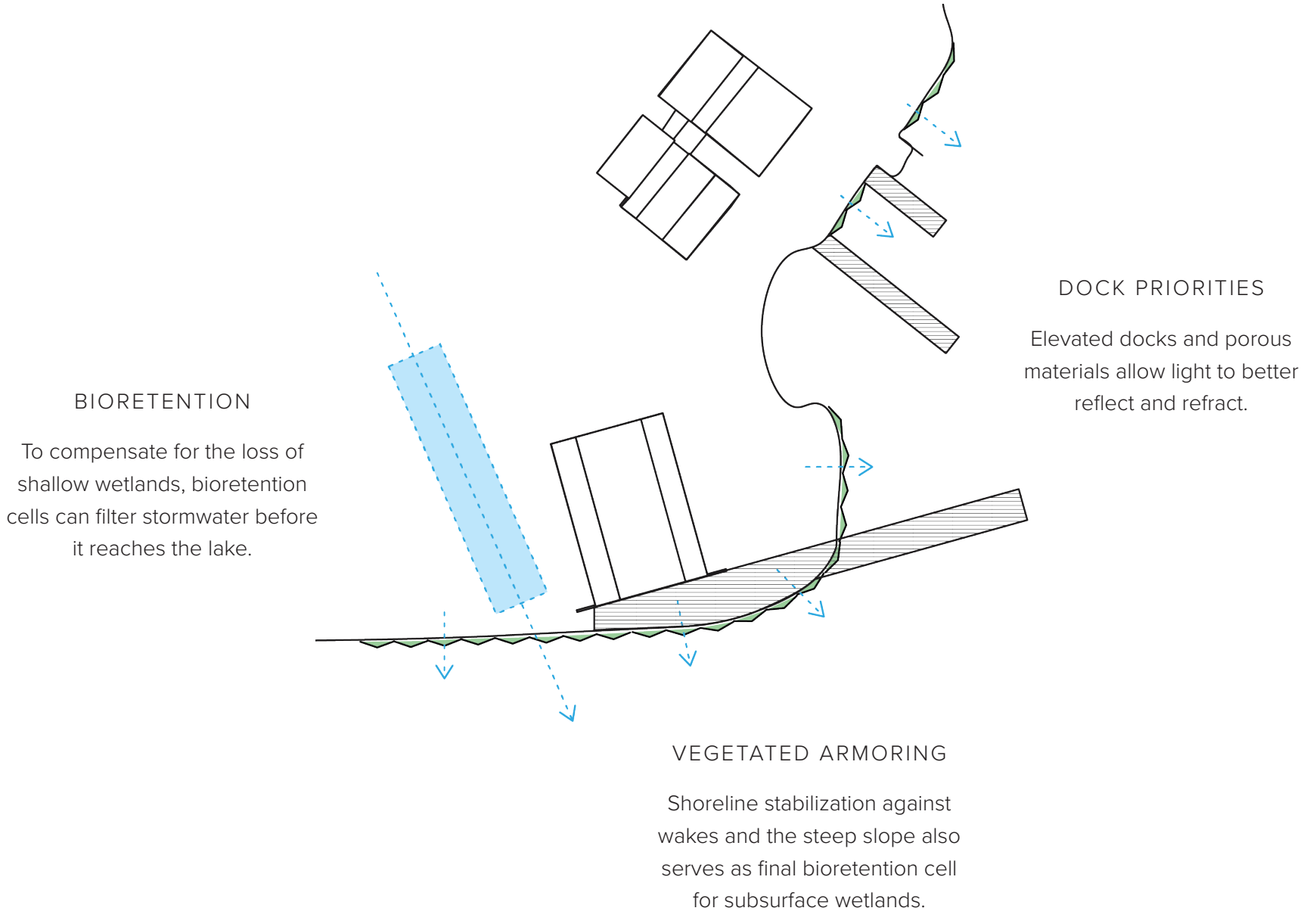
Polluted water from the large hospital and stadium parking lots to the north drain directly into Union Bay.



SHADING

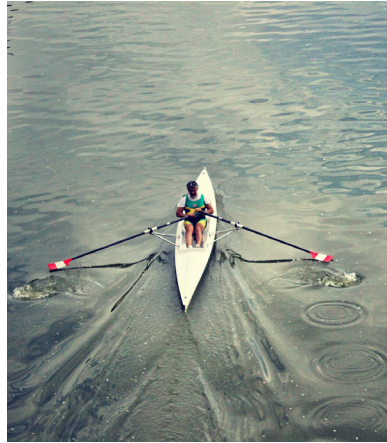
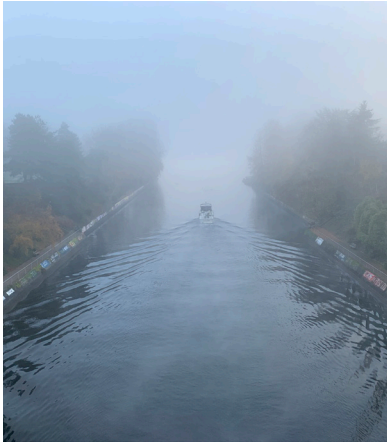
Floating docks cause severe shading, especially in shallow water. The current parallel configuration exacerbates the problem.

PROPOSED STRATEGIES



KELVIN WAKE PATTERN

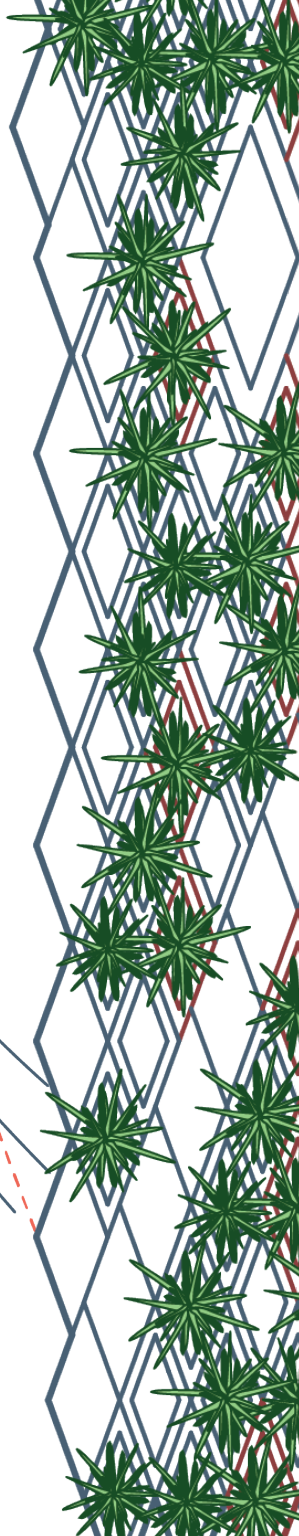
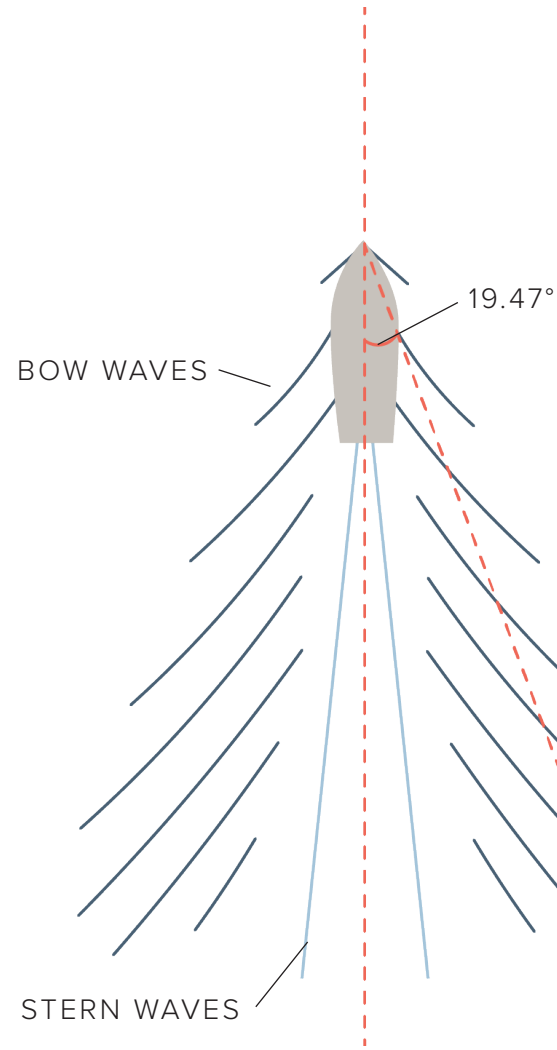
A vessel traveling through water will create a predictable wake pattern, with an angle of 19.47 degrees from the direction of travel. There are a few exceptions, but with the consistent depth, direction, and low speed, we can expect this to hold true in the Cut.



pixabay.com

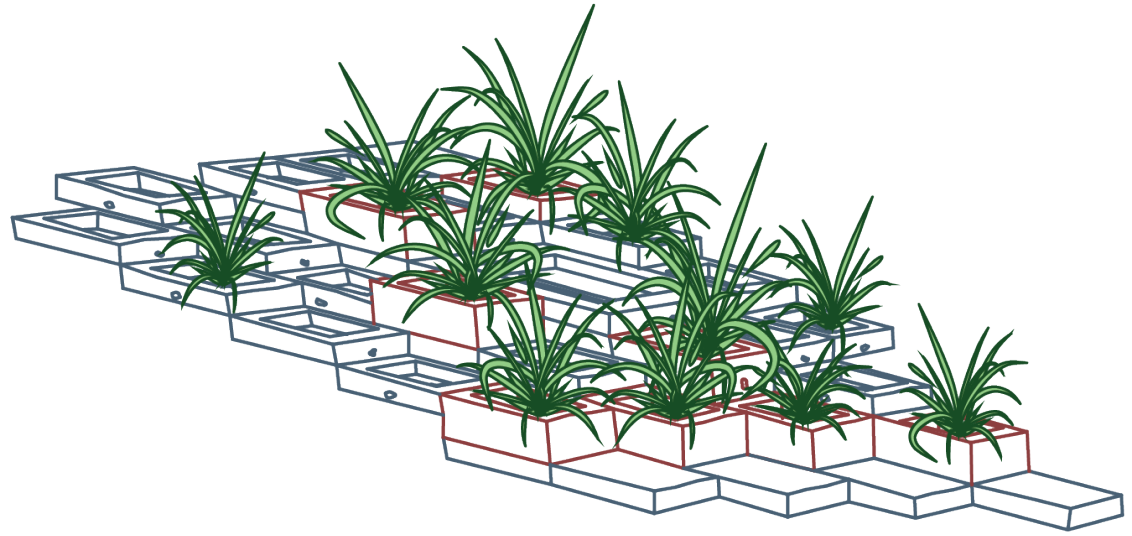


pixabay.com



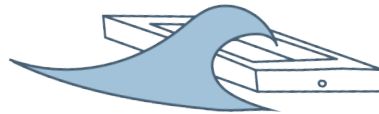
VEGETATED ARMORING

Knowing the wake angle, the shoreline can be designed to dissipate wake energy and prevent erosion. This modular system would be customized throughout the site to best protect the shore while also creating access to the water. Through stacking, the armoring width can be expanded or contracted to create sloping. Varied combinations would increase the shoreline texture and provide for diversity in habitat. Three primary components are presented here, but there is the potential to add more variations that introduce play, sculpture, or sound into the landscape.



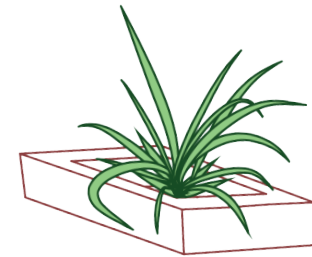
STEP

for direct water access, uses only the angle to dissipate waves



CATCH

to decrease wake reflection, bigger waves splash into the catch basin and drain slowly



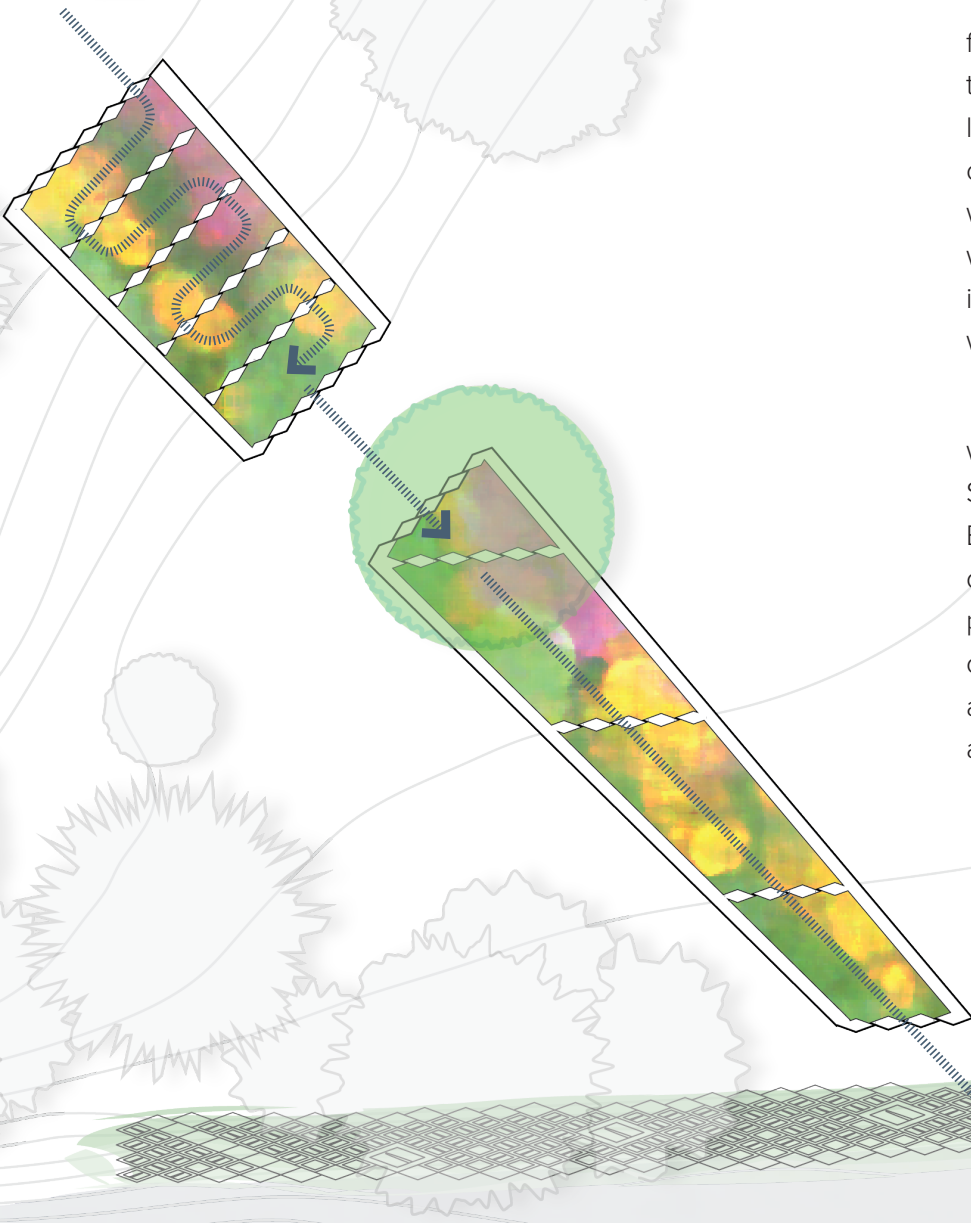
BUFFER

to create habitat and soften the shore, the movement of vegetation scatters wake energy

BIORETENTION

The rain garden captures polluted runoff from the extensive surface parking lots just to the north, which currently drain directly into the lake. The existing retaining wall is failing, but could be replaced with biofiltration terraces that would slow the runoff and function like a native wetland. The final cascade would be integrated into the vegetated armoring to resurface the water cycle that is currently buried in pipes.

Beyond function, the form of the rain garden would define the edge of the west lawn of the Shell House and guide visitors to the water. Events could flow between the indoor and outdoor space, with the bioretention cell walls providing casual seating. Native species would comprise the planting palette, anchored with a tree at the threshold between the waterfront area and trails





Wikimedia Commons: public domain

RED ALDER
Alnus rubra



sevenoaksnativenursery.com

SMALL-FRUITED BULRUSH
Scirpus microcarpus



sevenoaksnativenursery.com

SLENDER RUSH
Juncus tenuis



sevenoaksnativenursery.com

COMMON CATTAIL
Typha latifolia



sevenoaksnativenursery.com

CAMAS
Camassia quamash



Wikimedia Commons: Bouba

ARROWHEAD
Sagittaria latifolia



pixabay.com

Beach launch



ez-dock.com

Low dock



castlecraft.com

Boat storage racks



pixabay.com

Boat mooring

DOCK PRIORITIES

The primary consideration for overwater structures is to minimize shading. Common strategies include:

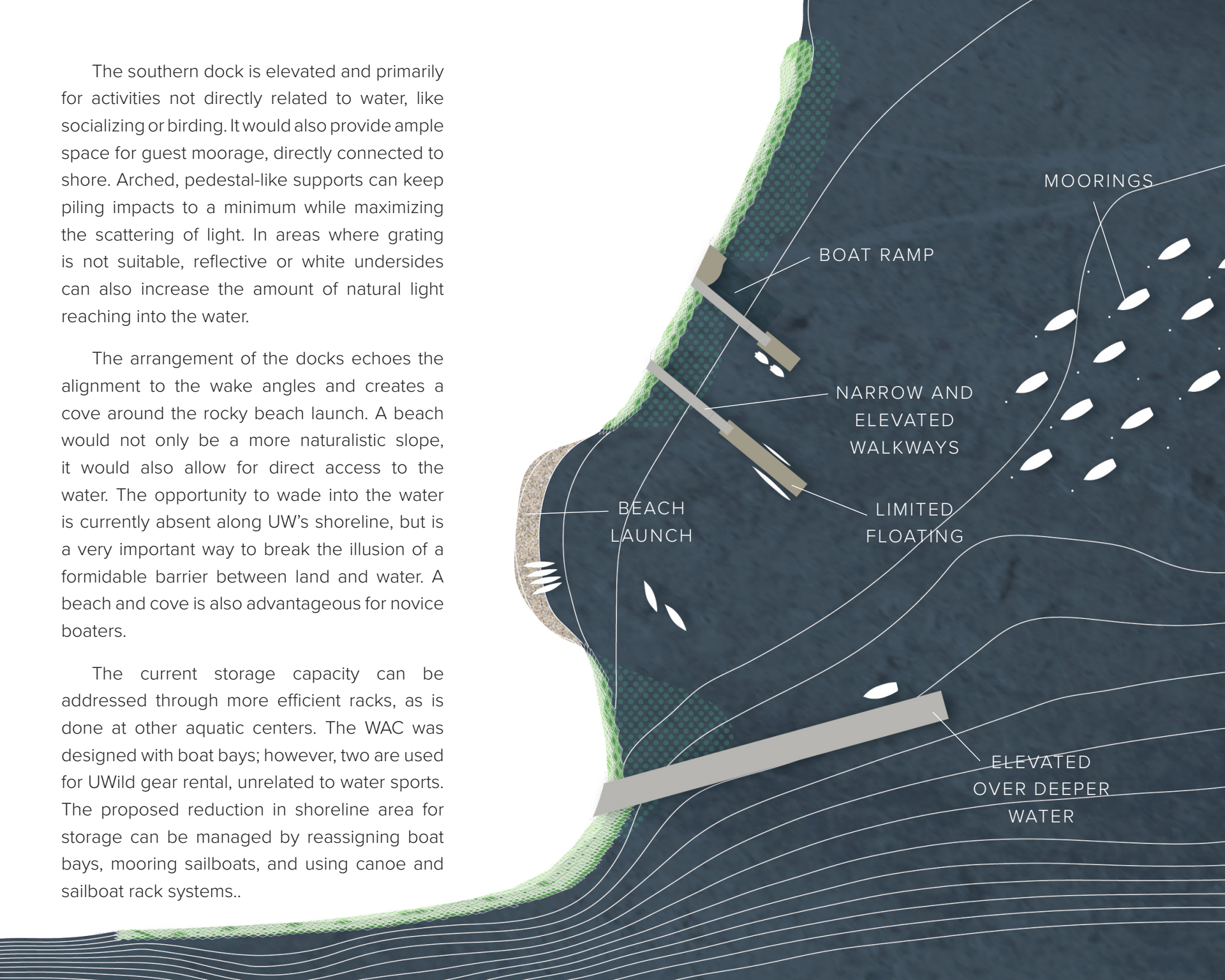
- consider if a dock is necessary
- elevate docks in order to allow for more natural reflection and refraction at the water's surface
- maximize grated surfaces to allow dappled light through
- use the most narrow form for the site's needs
- reach towards deeper water

The three docks proposed each have tailored forms and functions. The northernmost dock would serve as a tie up for the boat ramp as well as permanent docking of the WAC safety launches. The second dock would be for launching small boats, like rowing shells or kayaks and would float low in the water. The floating platforms of both of these docks would have the smallest necessary surface area, be accessed by grated, elevated walkways, and float over at least 4 feet of water. By minimizing the shadow of the dock, nearshore emergent vegetation will be able to establish without interfering with aquatic recreation.

The southern dock is elevated and primarily for activities not directly related to water, like socializing or birding. It would also provide ample space for guest moorage, directly connected to shore. Arched, pedestal-like supports can keep piling impacts to a minimum while maximizing the scattering of light. In areas where grating is not suitable, reflective or white undersides can also increase the amount of natural light reaching into the water.

The arrangement of the docks echoes the alignment to the wake angles and creates a cove around the rocky beach launch. A beach would not only be a more naturalistic slope, it would also allow for direct access to the water. The opportunity to wade into the water is currently absent along UW's shoreline, but is a very important way to break the illusion of a formidable barrier between land and water. A beach and cove is also advantageous for novice boaters.

The current storage capacity can be addressed through more efficient racks, as is done at other aquatic centers. The WAC was designed with boat bays; however, two are used for UWild gear rental, unrelated to water sports. The proposed reduction in shoreline area for storage can be managed by reassigning boat bays, mooring sailboats, and using canoe and sailboat rack systems..



CREATING FAVORABLE CONDITIONS

A holistic approach that combines upland and in-water strategies mimics the functions of a natural wetland. Restoring favorable conditions will allow native flora and fauna to establish and continue to provide the ecosystem services that define this region. Everything in an ecosystem is connected, so we can use the implications of one intervention to close the loop on another. While the design focuses on a segment of the shoreline, improvements there will affect the rest of the bay.

Water chemistry and temperature are two main factors that determine if species can survive in an environment. The bioretention cells treat one major source of pollution and would be part of a network of regional stormwater treatment on campus.

Cleaner water leads to clearer water; when nutrient inputs are balanced, phytoplankton don't have the resources to cause harmful blooms. Suspended sediments also cloud water when wave action is strong or artificially steep slopes lead to erosion. The orientation of nearshore infrastructure can stabilize banks and create beneficial accumulation.

In order to protect the historic ASUW Shell

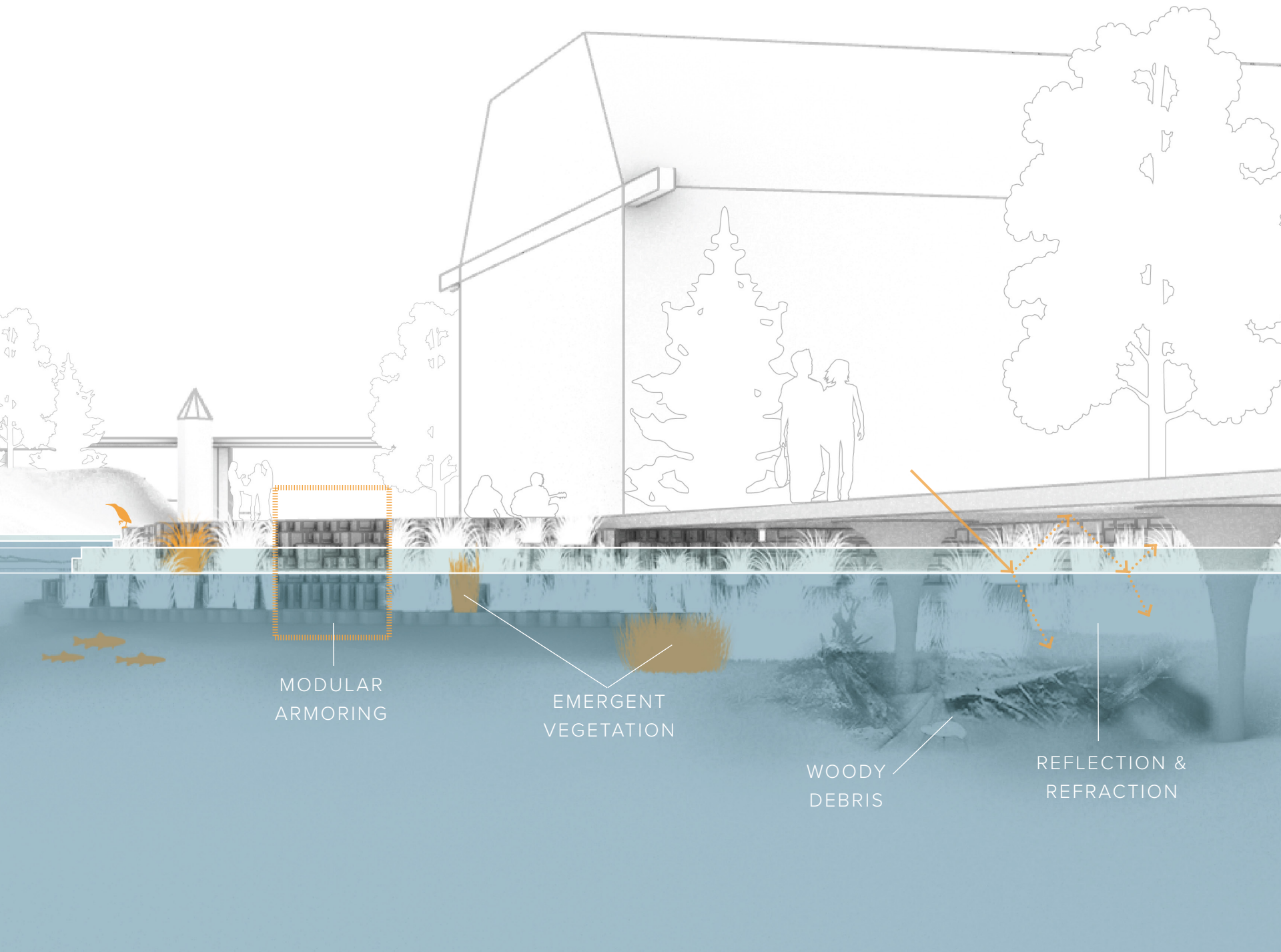
House and maintain the integrity of the Montlake Cut, some armoring is necessary on this site. By layering vegetation into the structure it will both dampen wave energy from boat wakes and create a more resilient shoreline in the face of the engineered water levels. Primary producers are the base of the food web, so if they are incorporated into the entire shoreline, we can expect herbivores and carnivores to follow.

A key factor in the success of aquatic vegetation is light intensity. The way light both reflects off of the surface of the water and refracts into the water differentiates overwater structures from elevated infrastructure on land. The shape and materiality of docks can be used to angle light to areas that would otherwise be shaded. Increasing light is also beneficial for reducing habitat for invasive predators, like smallmouth bass.

Favorable habitat for native species also improves conditions for humans through recreational or educational opportunities. This site is at the nexus of many layers of history, ecology, and activity. As an intersection of interests, the UW shoreline can be a tool for personal discoveries and building campus community.



MEAN HIGH WATER ———
LOW WATER ———



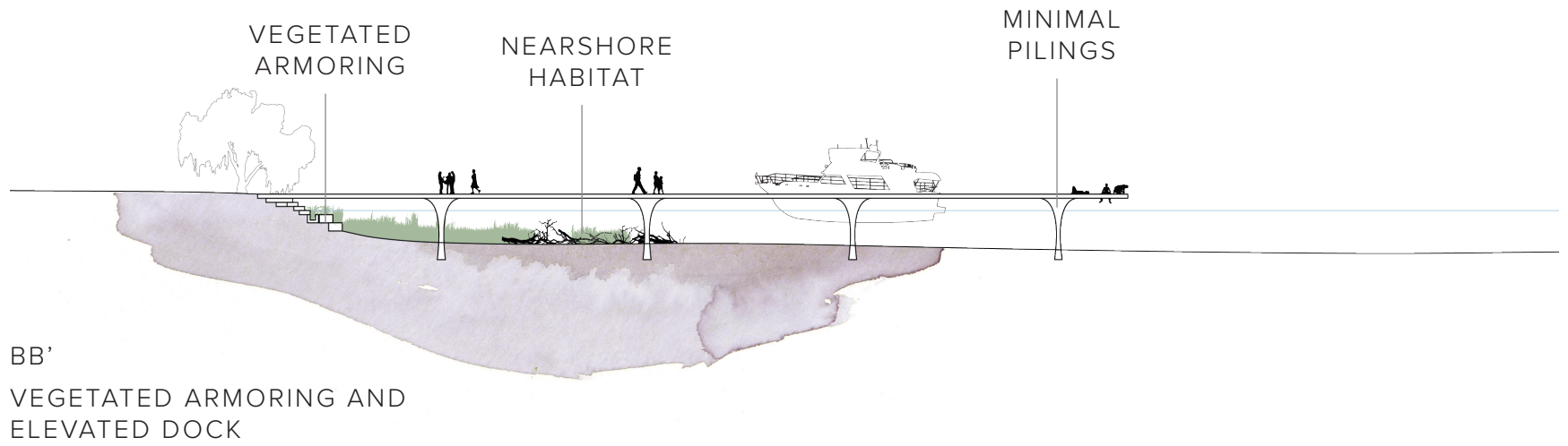
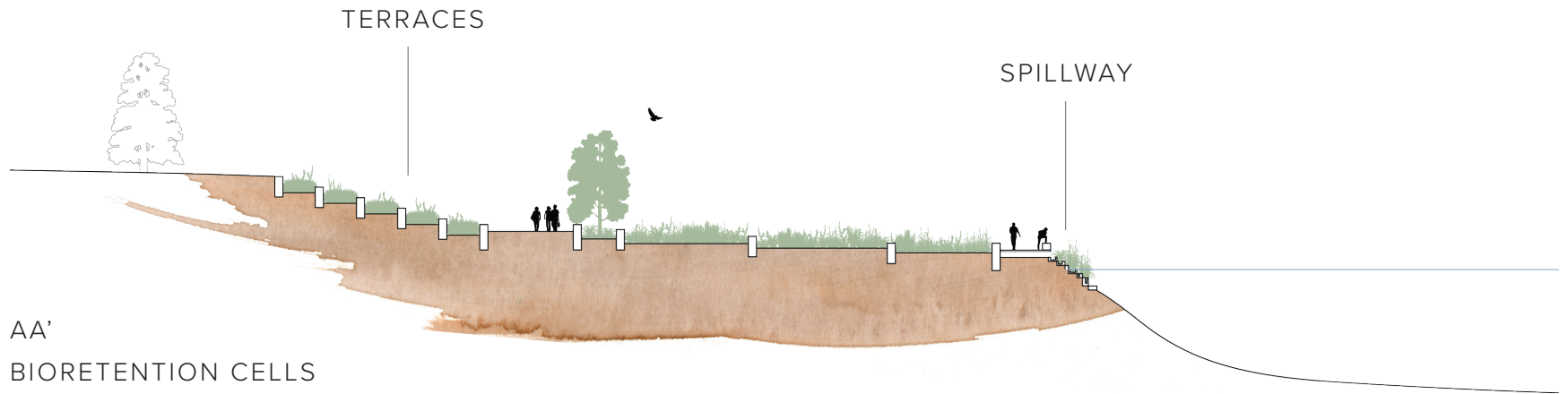
MODULAR
ARMORING

EMERGENT
VEGETATION

WOODY
DEBRIS

REFLECTION &
REFRACTION

SECTIONS



0 20 40FT



SHALLOW HABITAT

RECREATION

SEDIMENT CONTROL

EROSION CONTROL

BIOREMEDIATION

HARNESSING ECOSYSTEM SERVICES





CONCLUSION

REFLECT & REFRACT

“The ecological truism that we can never merely do one thing”

Arthur Kruckeberg, *The Natural History of Puget Sound Country*

Most of my time on this site has been in the early morning hours, watching the sunrise over the Cascades while rowing in calm waters. I grew up rowing on harbors, rivers, and estuaries where we navigated primarily by natural landmarks: “follow the shore”, “turn at the island”, “stop at the point”. Foster Point is the only natural landmark my club uses in Seattle. Otherwise, we “line up with the houseboats”, “stop at the Oceanography ships”, “aim for the middle tower”. What at first seemed jarring,

quickly became the norm, and I accepted the new jargon; I adapted.

We have all adapted to the urban shoreline such that it fades into the background. Not until new stretches are opened up to the water, like the Portage Bay Park, do we question what was there before, blocking our access. So, while rules and regulations aim to curb detrimental changes, we need to keep thinking critically and look for opportunities for positive

change. The momentum of implementing green infrastructure and urban ecology can reach beyond buildings and streets. Our shorelines need layered solutions that combine restoration and engineering not just side by side, but instead are intertwined. I began this process by considering:

- What innovations in nearshore infrastructure design can provide multifunctional benefits for people and the environment?
- How can aquatic design shift our view of the water's surface, such that it is seen not as a barrier, but rather as an opportunity to bridge two environments?
- How can the UW shoreline be redesigned to bolster ecosystem services?

I focused on wake energy, stormwater, and shading along the UW shoreline, which are common problems throughout the Lake Washington basin, but there are many other opportunities to rethink the underwater landscape. My design concept uses biomimicry to create strong but soft shorelines through vegetated armoring and diverse shore conditions while supporting ecosystem services like biofiltration.

I also embrace the philosophy that we should design as little as possible, but as much as necessary when creating overwater structures. By understanding microhabitats and human uses, the UW shoreline can be tailored to protect existing landmarks while restoring greater ecological function. My research exposed other considerations that should be explored further, including how to better use the surface area of pilings; how to not only deflect wake energy, but collect it; and how to get more efficient buoyancy.

I remain hopeful that social and economic pressure will continue to spur innovative design solutions through supporting ecosystem services and biomimicry. As with green buildings, there needs to be a shift in thinking about how aquatic infrastructure can become a component of the ecosystem. As I was exploring the street end parks in Montlake, I happened to pass a SCUBA diver getting ready to inspect a houseboat. I took the opportunity to ask him what the ecological impact of overwater structures is in his opinion, and he laughed and suggested that I not ask any houseboat owners; he was going in assuming he would find deteriorating styrofoam floats.

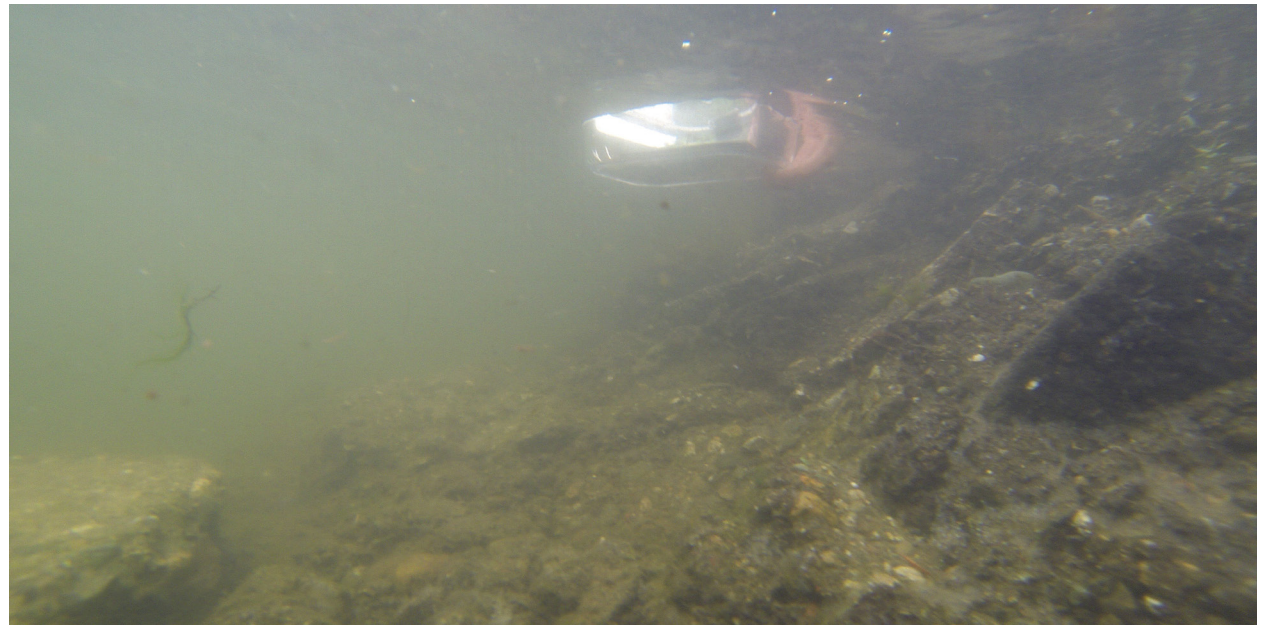
If every overwater structure were to become part of a network of planned microhabitats, ecological function could be restored without

removing human development. This is the advantage of a modular approach; by identifying typical conditions, design concepts and principles can be outlined to guide site-specific solutions.

I would have also liked to continue to explore not only how to bridge designs across the water's surface, but also how to give people more of a view into the lentic world. The Exploratorium in San Francisco has a series of outdoor interactive exhibits along public piers designed as "experiments in noticing and understanding" (Richards et al. 2010). They help one to answer "I wonder..." questions right there

on the shoreline, which I think is an important element for building a connection to a place through experience and understanding.

While I primarily used a GoPro camera to get a view underwater, some of my most impactful moments on site were where I used a clear tupperware as a viewfinder to look through the glare of the surface of the water. I was able to float along and happen upon new vegetation, fish eggs, or the invasive clams. Spending time on site without the intention of working on this project was also really informative. While out for an afternoon jog, I realized just how many boat wakes roll under the Waterfront Activity



*Looking through my DIY
viewfinder*

Center docks on a sunny day and I witnessed the constructive interference of wakes that truly resembled Maya Lin's Wavefield land art series ("Maya Lin Studio" 1995).

I find land art to be fascinating and admire how bold the interventions can be. At times, I have struggled to reconcile my restoration focus with big design moves. In future iterations of this UW shoreline design, I think there is room for more radical approaches that still address ecological function. Vegetated armoring is one small step in that direction that I hope could be the building blocks for more thought-provoking interventions.

It is often said in design education that just because you can do something, doesn't mean you should. Throughout this process, I have often thought this is good advice for anyone applying for a dock permit. But, I also had to remind myself to focus my design when my ideas got stretched so thin they began to resemble the Stirling engine of shorelines—efficient but theoretical. A goal of this project was to offer ambitious solutions as the university begins to update buildings and infrastructure at the shoreline. A key next step is adapting idealistic ideas to regulatory and financial constraints.

On a recent visit to the site, a young girl asked me what I was taking pictures of in the

water, and I told her I wanted to see what was living down there and asked her if she had seen any fish. Her babysitter asked her if she thought we could find starfish here, and she chuckled a "no". They kept chatting and then asked me how much salt water comes into Lake Washington. In my most engaging, former marine science instructor voice, I explained how water is always flowing out through the Cut, and there is a special salt gate at the Ballard Locks. I explained that it's crazy that saltwater and freshwater don't actually mix right away because the saltwater is heavier, and then I was promptly corrected. The girl said in an innocent, matter-of-fact tone, "that's actually not crazy. If I add salt to water I would expect it to be heavier than just water." With my faith in the future of humanity restored, I realized she was using the same logic I had: if you break down the components of a system, you can make predictions about how conditions can change.

The UW shoreline can be analyzed through many lenses, and I look forward to witnessing how this site continues to evolve. It has great potential to be a place for stories, students, and wildlife to thrive. This process has given me a great appreciation for deep site analysis and reevaluating the role and obligations of landscape architecture in water.



Rowers in the Montlake Cut at sunrise



BIBLIOGRAPHY

All photographs are by the author and under CC BY-NC-SA, unless otherwise noted.

Aufdenkampe, Anthony K., Emilio Mayorga, Peter A. Raymond, John M. Melack, Scott C. Doney, Simone R. Alin, Rolf E. Aalto, and Kyungsoo Yoo. 2011. "Riverine Coupling of Biogeochemical Cycles between Land, Oceans, and Atmosphere." *Frontiers in Ecology and the Environment* 9 (1): 53–60. <https://doi.org/10.1890/100014>.

Baar, Joe. 2016. "Inside Passage: Making the Cut: The Locks by the Numbers." *Inside Passage: The Blog of the Puget Sound Maritime Historical Society* (blog). April 25, 2016. <http://psmhsinsidepassage.blogspot.com/2016/04/making-cut-locks-by-numbers.html>.

Beatley, Timothy. 2011. *Biophilic Cities: Integrating Nature Into Urban Design and Planning*. Washington, DC: Island Press.

Becker, Paula. 2013. "Seattle Neighborhoods: Montlake -- Thumbnail History." January 29, 2013. <https://www.historylink.org/File/10170>.

Berger, Knute. 2019. "The New ASUW Shell House Will Pay Homage to Its History Through a Restoration." *Seattle Magazine*. September 20, 2019. <https://www.seattlemag.com/knute-berger->

column/new-asuw-shell-house-will-pay-homage-its-history-through-restoration.

- Blecha, Peter. 2009. "Seattle's Duwamish Tribe Celebrates New Longhouse and Cultural Center on January 3, 2009. - HistoryLink.Org." January 14, 2009. <https://www.historylink.org/File/8894>.
- . 2010. "Seattle's Historic Houseboats." August 12, 2010. <https://www.historylink.org/File/9507>.
- . 2011. "Ravenna Park (Seattle)." January 23, 2011. <https://www.historylink.org/File/9559>.
- BOLA. 2018. "Landmark Nomination University of Washington Canoe House Seattle."
- Brown, Daniel James. 2013. *The Boys in the Boat : Nine Americans and Their Epic Quest for Gold at the 1936 Berlin Olympics*. New York: Viking.
- Carson, Rachel. 1962. *Silent Spring*. Boston: Houghton Mifflin.
- Celedonia, Mark, Roger Tabor, Scott Sanders, Dan Lantz, and Ian Grettenberger. 2008. *Movement and Habitat Use of Chinook Salmon Smolts and Two Predatory Fishes in Lake Washington and the Lake Washington Ship Canal: 2004-2005 Acoustic Tracking Studies*.
- Cerco, Carl F., Mark R. Noel, and Sung-Chan Kim. 2006. "Three-Dimensional Management Model for Lake Washington, Part II: Eutrophication Modeling and Skill Assessment." *Lake and Reservoir Management* 22 (2): 115–31. <https://doi.org/10.1080/07438140609353889>.
- Childress, Tamara. 2013. "Restoration of the 'Story of North Island' Totem Pole." 2013. <https://artbeat.seattle.gov/2013/08/16/restoration-of-the-story-of-north-island-totem-pole/>.
- "Chesheehud — Duwamish Tribe." n.d. Accessed May 5, 2020. <https://www.duwamishtribe.org/cheshiahud>.
- Cipalla, Rita. 2019. "The Original 12.1-Mile Stretch of the Burke-Gilman Trail, Seattle." July 11, 2019. <https://www.historylink.org/File/20809>.
- City of Copenhagen. n.d. "The Port of Copenhagen – from a Heavily Polluted Industrial Port to a Clean and Thriving Aquatic Environment." Danish Ministry of the Environment. Accessed June 10, 2020. https://eng.ecoinnovation.dk/media/mst/8051440/Havn_baggrundsartikel_print.pdf.
- City of Seattle. 2001. "Seattle's Urban Blueprint for Habitat Protection and Restoration." https://www.seattle.gov/util/cs/groups/public/@spu/@conservation/documents/webcontent/spu01_002700.pdf.
- . 2008. "Tree Protection Code - SDCI | Seattle.Gov." 2008. <http://www.seattle.gov/sdci/codes/>

codes-we-enforce-(a-z)/tree-protection-code.

- . 2020. “Shoreline Master Program - SDCI | Seattle.Gov.” 2020. [https://www.seattle.gov/sdci/codes/codes-we-enforce-\(a-z\)/shoreline-master-program](https://www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/shoreline-master-program).
- . n.d. “Landmarks List - Neighborhoods | Seattle.Gov.” Accessed June 12, 2020a. <https://www.seattle.gov/neighborhoods/programs-and-services/historic-preservation/landmarks/landmark-list>.
- . n.d. “Shoreline Street Ends - Transportation | Seattle.Gov.” Accessed June 14, 2020b. <https://www.seattle.gov/transportation/projects-and-programs/programs/public-space-management-programs/shoreline-street-ends#programbackground>.
- “Coast Salish People & Languages.” n.d. Burke Museum. Accessed June 11, 2020. <https://www.burkemuseum.org/collections-and-research/culture/contemporary-culture/coast-salish-art/coast-salish-people>.
- Cohen, Eric. 2015. “The History of the Varsity Boat Club.” Washington Rowing. 2015. <https://washingtonrowing.com/history/history-of-the-varsity-boat-club/>.
- Crowley, Walt. 1998. “Seattle -- A Brief History of Its Founding.” August 31, 1998. <https://www.historylink.org/File/303>.
- Davis, Joanne, Bob Storer, and Rob Zisette. 2007. “The Washington Lake Book: A Handbook for Lake Users.” Washington State Department of Ecology.
- DeLuca, Denise. 2016. “The Power of the Biomimicry Design Spiral.” Biomimicry Institute. June 14, 2016. <https://biomimicry.org/biomimicry-design-spiral/>.
- Dowell, Bill. 2018. “Corps of Engineers Begins Lake Washington Annual Summer Refill > Seattle District > Seattle District News Releases.” February 8, 2018. <https://www.nws.usace.army.mil/Media/News-Releases/Article/1436351/corps-of-engineers-begins-lake-washington-annual-summer-refill/>.
- Dyson, Karen, and Ken Yocom. 2015. “Ecological Design for Urban Waterfronts.” *Urban Ecosystems* 18 (1): 189–208. <https://doi.org/10.1007/s11252-014-0385-9>.
- Earle, Sylvia. 2013. “No Blue, No Green.” Mission Blue (blog). April 22, 2013. <https://mission-blue.org/2013/04/no-blue-no-green/>.
- Ewing, Kern. 2010. “Union Bay Natural Area and Shoreline Management Guidelines.” University of

Washington Botanic Gardens.

- Fresh, Kurt, Donald Rothaus, Karl Mueller, and Christopher Waldbillig. 2003. "Habitat Utilization by Smallmouth Bass in the Littoral Zones of Lake Washington and Lake Union/Ship Canal." Washington Department of Fish and Wildlife.
- Hampton, Stephanie E., Steven C. Fradkin, Peter R. Leavitt, and Elizabeth E. Rosenberger. 2011. "Disproportionate Importance of Nearshore Habitat for the Food Web of a Deep Oligotrophic Lake." *Marine and Freshwater Research* 62 (4): 350–58. <https://doi.org/10.1071/MF10229>.
- Jack, R. 2003. "Sediment Toxicity Near Gas Works Park, Lake Union, Seattle," 37.
- Kenney, Kristine. 2020. Zoom call with author, April 9 2020.
- Klingbe, Matthew. 2007. *Emerald City. An Environmental History of Seattle*. Yale University Press. <https://www.jstor.org/stable/j.ctt1npgd8.1>.
- Kramer-Wilt, Errin. 2008. "Corbicula Fluminea (O. F. Müller, 1774) – Asian Clam," 16.
- Kruckeberg, Arthur R. 1991. *The Natural History of Puget Sound Country*. Weyerhaeuser Environmental Book. Seattle: University of Washington Press.
- LaClergue, Dave, Margaret Glowacki, Miles Mayhew, and Holly McCracken. n.d. "Green Shorelines: Bulkhead Alternatives for a Healthier Lake Washington." Accessed May 22, 2020. https://www.govlink.org/watersheds/8/action/greenshorelines/Green_Shorelines_SecondEdweb.pdf.
- Lange, Greg, and Cassandra Tate. 1998. "Legislature Incorporates the Town of Seattle for the First Time on January 14, 1865. - HistoryLink.Org." November 4, 1998. <https://www.historylink.org/File/168>.
- Layman, Craig A., Zachary R. Jud, Stephanie K. Archer, and David Riera. 2014. "Provision of Ecosystem Services by Human-Made Structures in a Highly Impacted Estuary." *Environmental Research Letters* 9 (4): 044009. <https://doi.org/10.1088/1748-9326/9/4/044009>.
- Leopold, Aldo. 1968. *A Sand County Almanac*. American Museum of Natural History. London, etc.: Oxford University Press.
- Mathur, Anuradha, Cunha, Dilip da, and University of Pennsylvania. School of Design. 2014. *Design in the Terrain of Water*. First edition. United States] : [Philadelphia, Pennsylvania]: Applied Research + Design Publishing ; University of Pennsylvania School of Design.
- "Maya Lin Studio." 1995. 1995. <http://www.mayalin.com/>.

- McDonald, Lucile Saunders. 1979. *The Lake Washington Story : A Pictorial History*. 1st ed. Seattle: Superior Pub. Co.
- Meyer, Elizabeth. 1997. "The Expanded Field of Landscape Architecture." In *Ecological Design and Planning*, edited by George F. Thompson and Frederick R. Steiner. New York: John Wiley & Sons, Inc. 45–79.
- Moore, Jonathan W., Daniel E. Schindler, Mark D. Scheuerell, Danielle Smith, and Jonathan Frodge. 2003. "Lake Eutrophication at the Urban Fringe, Seattle Region, USA." *AMBIO: A Journal of the Human Environment* 32 (1): 13–18. <https://doi.org/10.1579/0044-7447-32.1.13>.
- National Park Service. 1975. "Naval Military Hangar--University Shell House_07/01/1975."
- . n.d. "National Register Database and Research - National Register of Historic Places (U.S. National Park Service)." Accessed June 12, 2020. <https://www.nps.gov/subjects/nationalregister/database-research.htm>.
- Naylor, L., M. A. Coombes, H. Kippen, B. Horton, T. Gardiner, M. R. Cordell, J. Simm, and G. J. C. Underwood. 2018. *Developing a Business Case for Greening Hard Coastal and Estuarine Infrastructure: Preliminary Results*. Institute of Civil Engineers. <https://ora.ox.ac.uk/objects/uuid:a1ebda20-f03d-4e2e-a777-818bb1be9f65>.
- NOAA Fisheries. 2019. "Habitat Conservation | NOAA Fisheries." September 10, 2019. <https://www.fisheries.noaa.gov/topic/habitat-conservation>.
- . 2020. "Chinook Salmon (Protected) | NOAA Fisheries." NOAA. West Coast. May 1, 2020. <https://www.fisheries.noaa.gov/species/chinook-salmon-protected>.
- NOAA Habitat Blueprint. n.d. "About Habitat Blueprint." NOAA Habitat Blueprint. Accessed June 18, 2020. <https://www.habitatblueprint.noaa.gov/about-the-habitat-blueprint/>.
- "Observations · INaturalist." n.d. INaturalist. Accessed June 19, 2020. https://www.inaturalist.org/observations?place_id=51098&view=species.
- Ott, Jennifer. 2012. "Montlake Cut (Seattle)." December 30, 2012. <https://www.historylink.org/File/10221>.
- Perkol-Finkel, Shimrit. 2020. "Email with Author, February 5 2020," February 5, 2020.
- Reed, David E., Hilary A. Dugan, Amelia L. Flannery, and Ankur R. Desai. 2018. "Carbon Sink and Source Dynamics of a Eutrophic Deep Lake Using Multiple Flux Observations over Multiple

- Years.” *Limnology and Oceanography Letters* 3 (3): 285–92. <https://doi.org/10.1002/lol2.10075>.
- Richards, Peter G, Thomas C Rockwell, Exploratorium (Organization), and APE Team. 2010. *Outdoor Exploratorium: Experiments in Noticing and Understanding*. San Francisco: Exploratorium.
- Rupp, Christy. 2005. “The Single-Celled Artist.” *Satya Magazine*, May 2005. <http://christyrupp.com/lowgo-single-celled-artist/>.
- SCAPE. 2009. “Oyster-Tecture.” SCAPE. 2009. <https://www.scapestudio.com/projects/oyster-ecture/>.
- . n.d. “Ideas.” SCAPE. Accessed June 22, 2020. <https://www.scapestudio.com/ideas/>.
- Shaw, Sarah, and Katie Messick. n.d. “Water Weeds: Guide to Aquatic Weeds in King County.” King County Noxious Weed Control Program.
- Sodt, Sarah. 2018. “University of Washington Canoe House / ASUW Shell House / US Naval Training Hangar Report on Designation.”
- Tabor, Roger A, Mark T Celedonia, Francine Mejia, Rich M Piaskowski, David L Low, U S Fish, and Brian Footen. 2004. “Predation of Juvenile Chinook Salmon by Predatory Fishes in Three Areas of the Lake Washington Basin.”
- Tabor, Roger A., Kurt L. Fresh, Richard M. Piaskowski, Howard A. Gearns, and Daniel B. Hayes. 2011. “Habitat Use by Juvenile Chinook Salmon in the Nearshore Areas of Lake Washington: Effects of Depth, Lakeshore Development, Substrate, and Vegetation.” *North American Journal of Fisheries Management* 31 (4): 700–713. <https://doi.org/10.1080/02755947.2011.611424>.
- Tabor, Roger A., Julie A. Scheurer, Howard A. Gearns, Eric P. Bixler, U. S. Fish, Wildlife Service, Western Washington Fish, and Wildlife Office. 2002. “Nearshore Habitat Use by Juvenile Chinook Salmon in Lentic Systems of the Lake Washington Basin.”
- Taylor, Jason deCaires. n.d. “Overview.” *Underwater Sculpture by Jason DeCaires Taylor*. Accessed June 11, 2020. <https://www.underwatersculpture.com/about/overview/>.
- Thom, R. M., G. W. Williams, and H. L. Diefenderfer. 2005. “Balancing the Need to Develop Coastal Areas with the Desire for an Ecologically Functioning Coastal Environment: Is Net Ecosystem Improvement Possible?” *Restoration Ecology* 13 (1): 193–203. <https://doi.org/10.1111/j.1526-100X.2005.00024.x>.
- Thrush, Coll-Peter. 2007. *Native Seattle : Histories from the Crossing-over Place*. Weyerhaeuser

- Environmental Book. Seattle, Wash. : Chesham: University of Washington Press ; Combined Academic [distributor].
- “Union Bay Natural Area.” 2015. University of Washington Botanic Gardens (blog). March 18, 2015. <https://botanicgardens.uw.edu/center-for-urban-horticulture/visit/union-bay-natural-area/>.
- “University of Washington: 2019 Seattle Campus Plan.” 2019.
- UW Facilities: Planning and Landscape Architecture. 2020. “RFP: West Campus Green, South Campus Green & Continuous Waterfront Trail.”
- UW Libraries Exhibition. 1995. “II. The Decision to Move to a New Campus — UW Libraries.” 1995. <https://www.lib.washington.edu/specialcollections/collections/exhibits/site/decision>.
- . n.d. “WWI Exhibit: President Suzzallo and the State Council of Defense.” Accessed June 12, 2020. <https://content.lib.washington.edu/exhibits/WWI/campus.html>.
- Williams, David. 2017. “Lake Washington Ship Canal (Seattle).” February 5, 2017. <https://www.historylink.org/File/1444>.
- Willman, Judy Rantz. 2019. “Century-Old ASUW Shell House Is Where the ‘Boys in the Boat’ Became a Team.” UW Magazine — University of Washington Magazine (blog). 2019. <https://magazine.washington.edu/feature/where-it-all-began-rowing/>.
- Wilma, David. 2001. “Pritchard Island.” March 20, 2001. <https://www.historylink.org/File/3119>.
- WSDE. 2017. “Shoreline Master Program Handbook, Chapter 12 Piers, Docks and Overwater Structures.”
- . 2019. “Shoreline Permitting Manual Guidance for Local Governments.”
- . 2020. “Shoreline Management Act - Washington State Department of Ecology.” 2020. <https://ecology.wa.gov/Water-Shorelines/Shoreline-coastal-management/Shoreline-coastal-planning/Shoreline-Management-Act-SMA>.
- WSDOT. 2011. “SR520 Wetland Mitigation Plan: 5.2 Union Bay Natural Area Mitigation Site.” Washington State Department of Transportation. http://www.seattleaudubon.org/sas/Portals/0/Conservation/Regional/WSDOT%202011_SR520%20Wetland%20Mitigation%20Plan_UBNA%20section.pdf.
- . n.d. “SR520 History - 1946 - 1965 - Neighborhood Development - Engineering - SR520 Bridge Construction.” Accessed June 13, 2020. <http://520history.org/1956-Present/EvergreenPtBridge/BridgeConstruction.htm>.