Duwamish Valley Sea Level Rise Adaptation Strategy: Task 1

Opportunities & Barriers for Community Resilience

DRAFT May 2023

INTRODUCTION

Purpose

The Duwamish Valley is a close-knit environmental justice community that is bound together by intimate social and cultural ties. It is centered around the Duwamish River. The area has always been vulnerable to tidal flooding from the river. With ongoing global climate change, existing flooding issues in the Duwamish Valley will be made worse by sea level rise over the next 100 years. Flooding is just one of multiple hazards posed by climate change in the Duwamish Valley. This memo describes existing and future flood risks and related climate hazards. It then outlines barriers and opportunities to community resilience that will inform the design of possible sea level rise adaptation strategies.

Community resilience is a community's ability to use their assets to improve the health of individuals, organizations, and businesses and to withstand, adapt to, and recover from adversity. The 2018 Duwamish Valley Action Plan directs the City of Seattle to identify and implement community resilience actions specific to the Duwamish Valley, including a strong focus on sea level rise and flooding. The Action Plan establishes that strategies to address flooding must also provide multiple benefits for community resilience while actively fighting displacement and gentrification and advancing racial equity outcomes.

The Duwamish Valley Sea Level Rise Adaptation Strategy is based on the premise that historically impacted marginalized communities must hold power in the process of building infrastructure to protect the Duwamish Valley from sea level rise. The resulting adaptation strategies and infrastructure should actively protect existing residents and businesses to remain and prosper in place while advancing racial equity outcomes for the community.

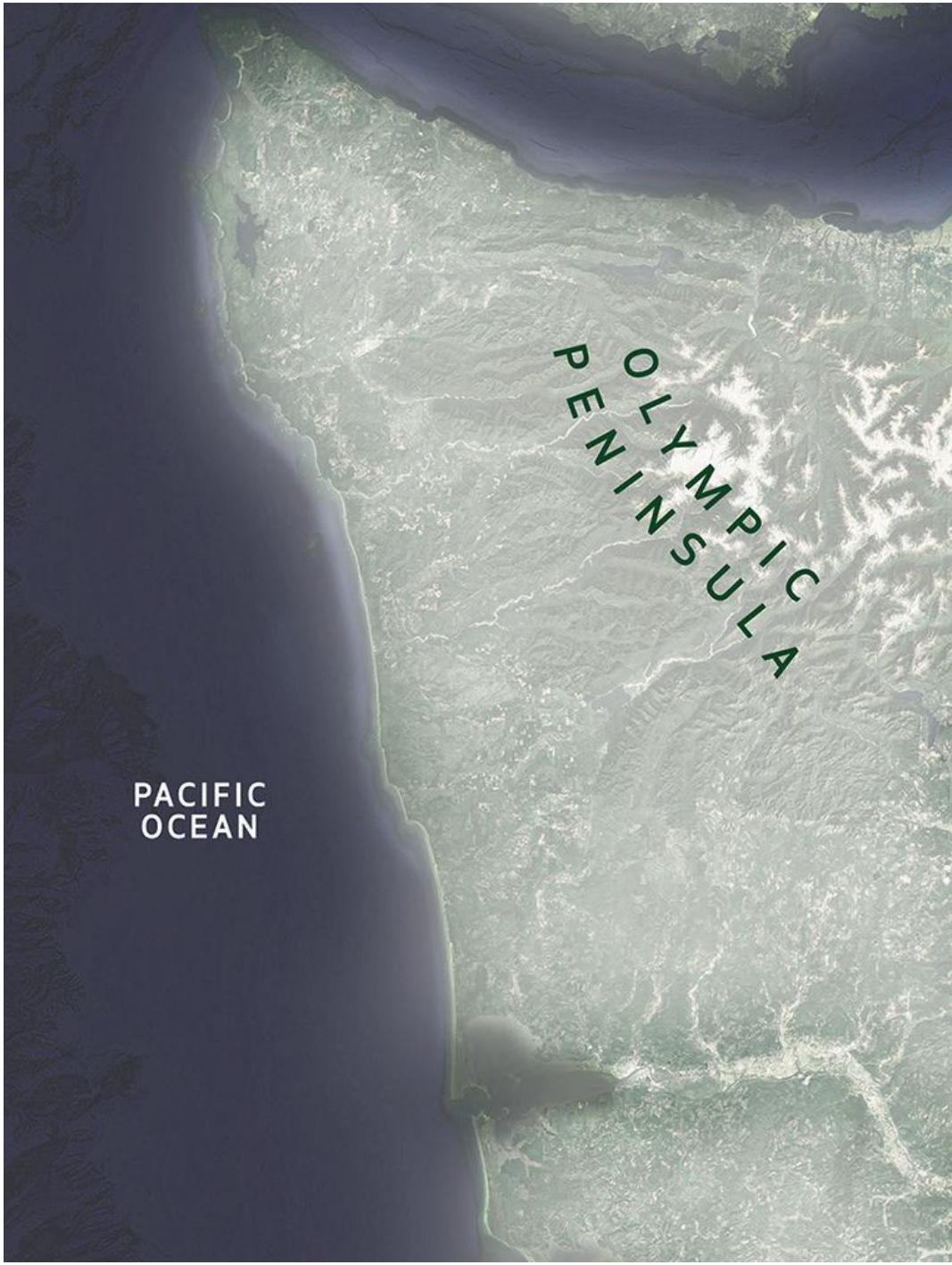


Figure 1. Map of the Duwamish River estuary sub-watershed within the Puget Sound and Salish Sea region.


SALISH SEA
PUGET SOUND
CASCADE RANGE
LAKE CHELAN
KING COUNTY
DUWAMISH ESTUARY SUB-WATERSHED
UPPER GREEN RIVER SUB-WATERSHED
COLUMBIA RIVER
LOWER GREEN RIVER SUB-WATERSHED
MIDDLE GREEN RIVER SUB-WATERSHED
BLOWOUT MOUNTAIN
MT RAINIER

Green-Duwamish River System

The Green-Duwamish River runs from Blowout Mountain in the Cascade Range, through forests, fields, and urbanized areas, and into the Puget Sound. This project's study area is located within the area with the highest need for salmon habitat as shown in Figure 2.

Project Study Area

The Duwamish Valley Sea Level Rise Adaptation Strategy focuses on the flood-impacted urban neighborhoods of South Park and Georgetown, located along the industrialized area of the Duwamish River. These areas were historically the homeland of the Duwamish People, where the river meandered through a floodplain with mudflats and forest. With Euro-American immigrant settlement, these floodplains were filled and the river straightened over time for use as an industrial waterway. The Duwamish People still inhabit this place today.

The South Park and Georgetown neighborhoods are more racially diverse than the City of Seattle as a whole; and they are impacted by environmental racism. A 2013 Cumulative Health Impact Assessment, conducted with local communities, found that average life expectancy in South Park and Georgetown is eight years shorter than the county average. Health issues like heart disease, asthma, lung cancer, diabetes, and stroke are also more common in these neighborhoods than the county average. Though many of Seattle's most marginalized communities reside in this flood-impacted area, they have not seen signifcant investment in flood protection.

Figure 3 shows the historic path of the river overlaid with its current channel. South Park is vulnerable to severe **coastal flooding**, while Georgetown is mostly impacted by stormwater-related **urban flooding**. These neighborhoods will be the most impacted by sea level rise-related coastal flooding in Seattle in the coming decades.

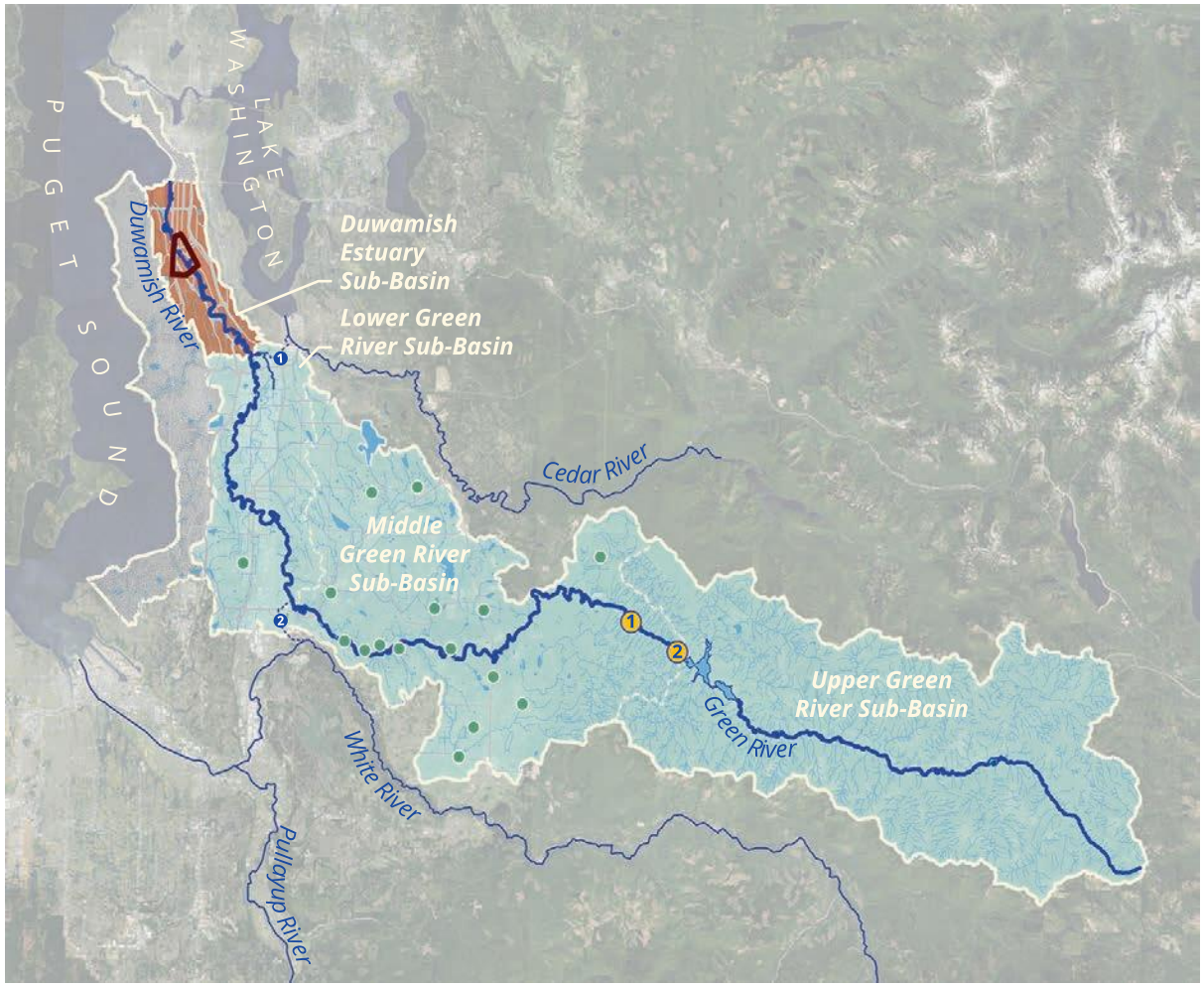


Figure 2. Green-Duwamish River Watershed

Legend

- *Green River Watershed*
- *Critical Salmon Habitat (Duwamish Estuary)*
- *Study Area*
- *Upstream Habitat and Acquired Open Space*
- *Historic Connections to Green-Duwamish River*
- *Historic Black River*
- *Historic White River*
- *Tacoma Headworks Diversion Dam*
- *Howard Hanson Dam*

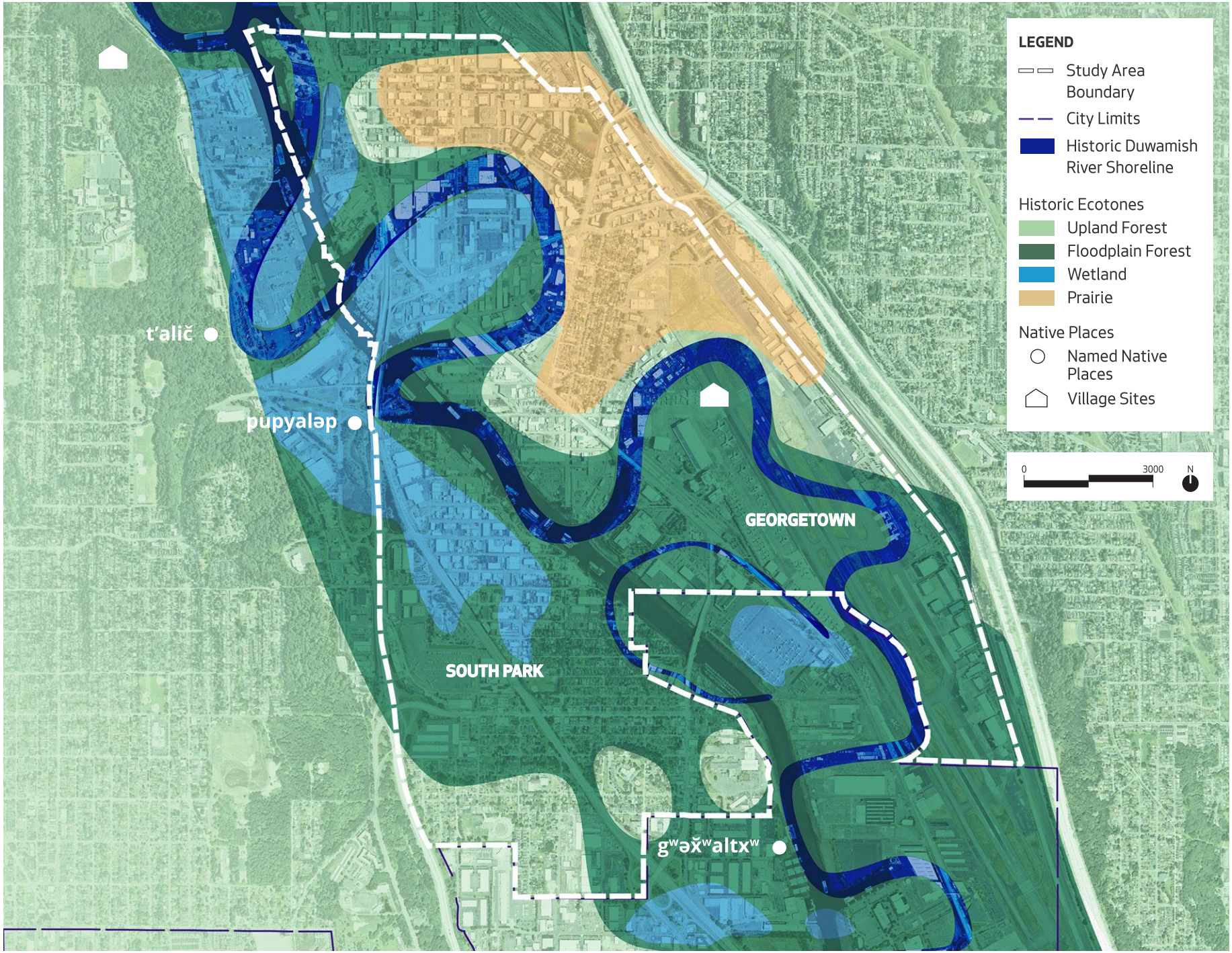
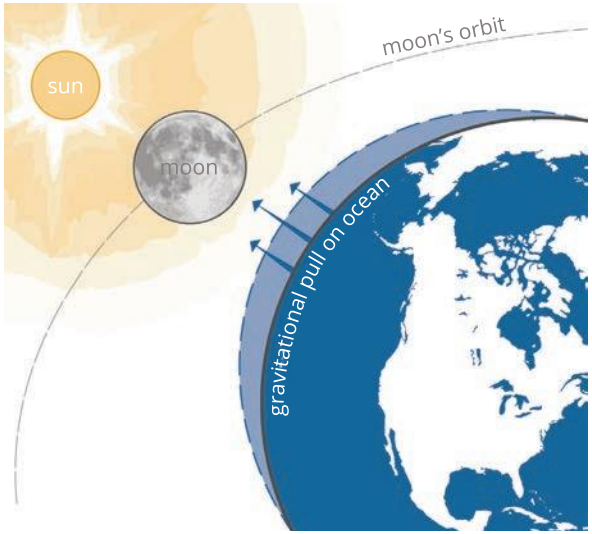


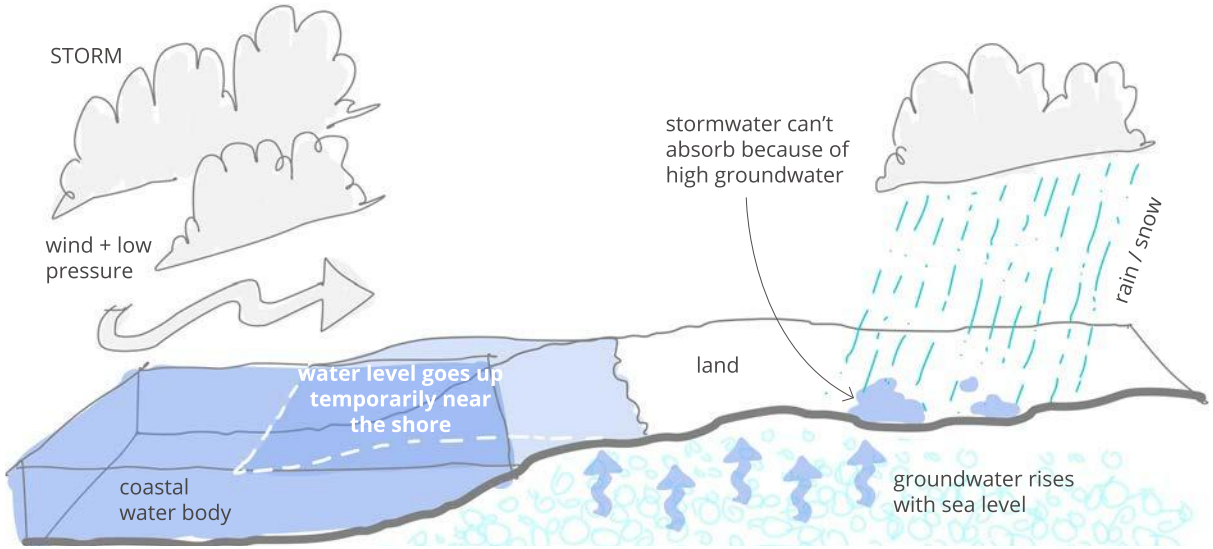
Figure 3. Study area for the Duwamish Valley Sea Level Rise Adaptation Strategy overlaid with the historic path of the Duwamish River, historic ecotones, and place-names from pre-colonial settlement in the Lushootseed language (based on the Waterlines Project)

CAUSES OF FLOODING

Coastal Inundation

The Duwamish Valley, especially the South Park neighborhood, is vulnerable to flooding from **coastal inundation**, which is the covering of normally dry land with coastal water. This is typically caused by high tide and storm surge conditions. **Coastal inundation is being made worse by sea level rise from climate change.**





High Tide Flooding

As Earth orbits the sun, and the moon orbits Earth, the sun and moon create gravitational pull on the earth's oceans. This causes the ocean's tides to rise and fall each day. The highest tides, called "king tides", occur during winter when the earth is closest to the sun. During winter, when the earth, sun, and moon align, this creates a strong pull on the oceans. The Duwamish River is close enough to the ocean that its water levels are influenced by the changing tide. High tide flooding occurs when the land at the river's edge is lower than the height of the tide and water spills over the riverbank.

Storm Surge Flooding

Storm surge is when a storm over the ocean creates strong winds and low atmospheric pressure. This makes the local sea level go up temporarily during the storm. When the local sea level goes up, the Duwamish River's water also rises.

Groundwater & Stormwater

Other factors that can make coastal inundation worse include high groundwater and stormwater. Groundwater is water that exists in saturated zones beneath the ground, and it tends to rise up with the tide in areas close to the shore. Groundwater in the Duwamish Valley is high, about one to eight feet below the ground in the South Park Neighborhood. Stormwater is caused by direct runoff from precipitation and snow melt, and occurs during and after storm events. When heavy rain and snow fall, very high groundwater could stop this stormwater from absorbing into the ground, which can add to the impacts of coastal flooding.

December 2022 Flood Event

On December 27th, 2022, a king tide combined with storm surge to create an historic flood event. Water levels were much higher than predicted tides, and created the highest recorded flood in 31 years. This unexpectedly high flood was mostly due to storm surge from a low pressure storm system moving over the Puget Sound area.

The highest water level recorded during the flood was about 12 feet and 11 inches (NAVD88) along Riverside Drive in South Park. See Figure 4 illustrating the NAVD88 measurement system and some relative typical tidal elevations. The December 2022 flood was more than nine inches higher than the National Weather Service's measure for "major flooding" in this location[1].

Water overtopped the riverbanks first at the lowest points along the bank in South Park, including the intersections of 5th Ave. S and S Fontanelle St. and S Riverside St. and S Austin St. As the water rose higher, higher elevation areas of the bank began to overflow, including the intersection of S Riverside Dr. and S 7th Ave. and the intersection of S 8th Ave. and S Portland St. In addition to flooding coming over the riverbanks, families and businesses in South Park may have experienced sewer overflows inside homes and buildings as the high river water pushed backward into combined sewer and stormwater pipes. Street flooding from stormwater was also observed in low-lying areas in Georgetown.

The devastating flood displaced 13 families living in South Park and impacted multiple industrial properties. This tragic event makes action on flood protection more urgent than ever. As climate change continues, sea levels will rise. Without protection from sea level rise, disasters like the December 27th, 2022 flood will impact the Duwamish Valley community more frequently.

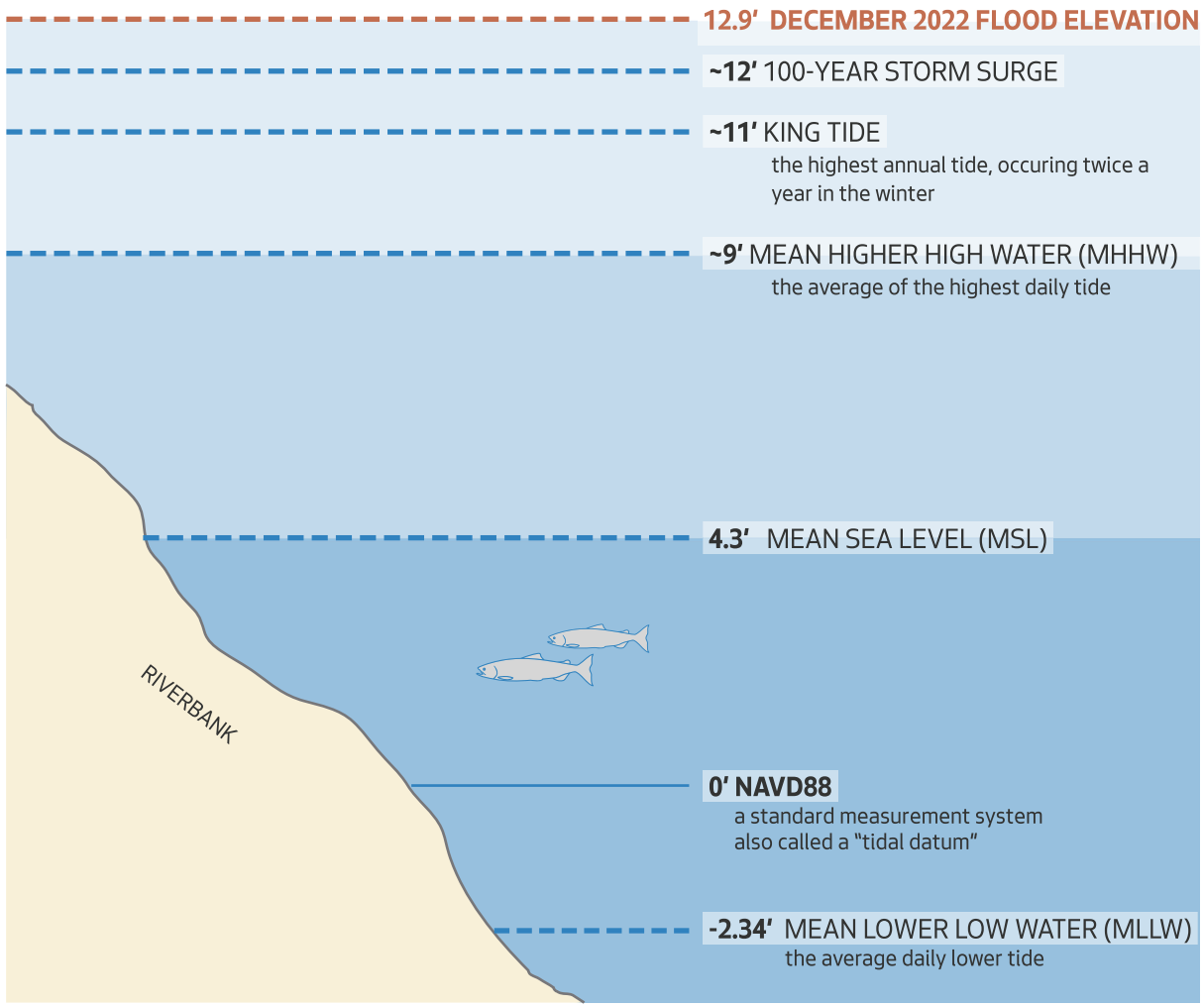


Figure 4. When describing the height of observed and projected flooding, this study uses a reference system called the North American Vertical Datum of 1988, or "NAVD88". The diagram shows other tidal elevations measured in NAVD88, the typical amount of water rise attributed King Tide and Storm Surge, and the elevation of the December 2022 flood.

1. Correspondence with National Weather Service, January 2023

Temporary Protection Measures

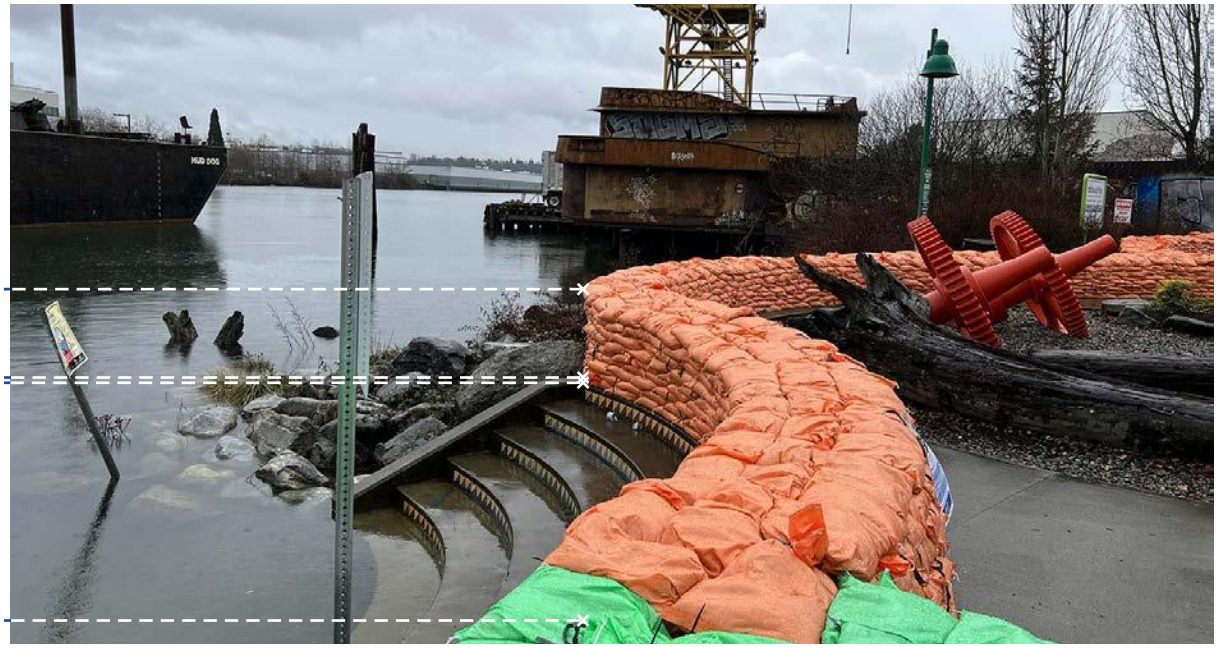
Because another king tide was expected in early February 2023, soon after the December 2022 flooding event, Seattle Public Utilities and other City departments mobilized quickly to install temporary protection for the South Park neighborhood. A "wall" of sandbags and jersey barriers was placed in a continuous line along the riverbank to keep water from overtopping at low points into the northern industrial and residential areas of South Park.

Although the flood elevation was just under 13 feet NAVD88 on December 27th, 2022, the temporary berms were built up to around 15 feet NAVD88 as a precaution. **This is approximately the expected flood elevation in a king tide and storm surge in 2100 with sea level rise. The temporary protection provides a visual example of the elevation of future floods, and therefore the elevation needed to protect the neighborhoods from future coastal flooding with the impacts expected from sea level rise.**

Flood protection infrastructure usually needs to be built higher than the elevation of the expected flood water level. For example, the Federal Emergency Management Agency, FEMA, encourages communities to build at least one foot above expected flood elevation. This additional height is called "freeboard".

Photo looking east on S. Holden St. of high tide and storm surge flooding on the morning of December 27th, 2022.

Photo looking west on S. Chicago Street during the flood. Credit: Port of Seattle



After the December 27th, 2022 flood receded, SPU installed a temporary sandbag berm in low places along the riverbank to protect the community in case of another winter king tide and storm surge. The approximate height of this berm (15 feet NAVD88) is the elevation of expected king tide and storm surge flooding in 2100 with sea level rise. Therefore, protection from flooding in 2100 would need to be about a foot higher than this to ensure full protection.

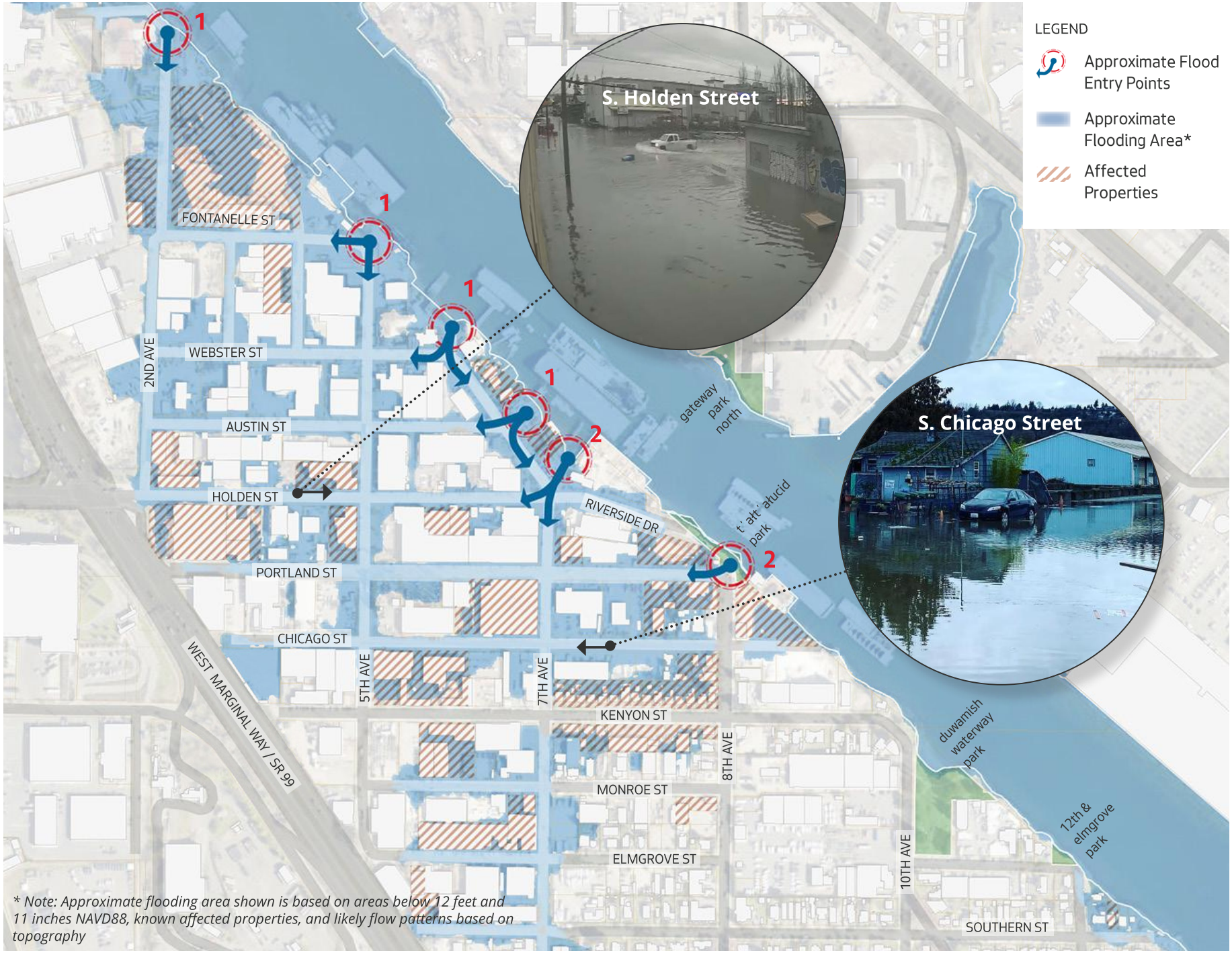


Figure 5. Approximate impacts of December 27th, 2022 flood event, with flood entry points numbered in the order that water overtopped the banks

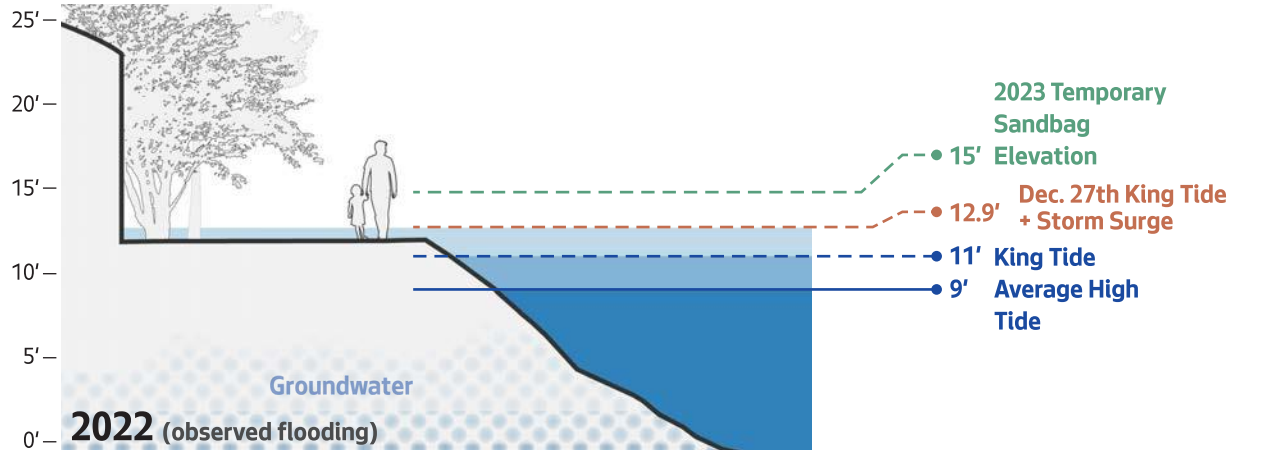
Sea Level Rise (SLR)

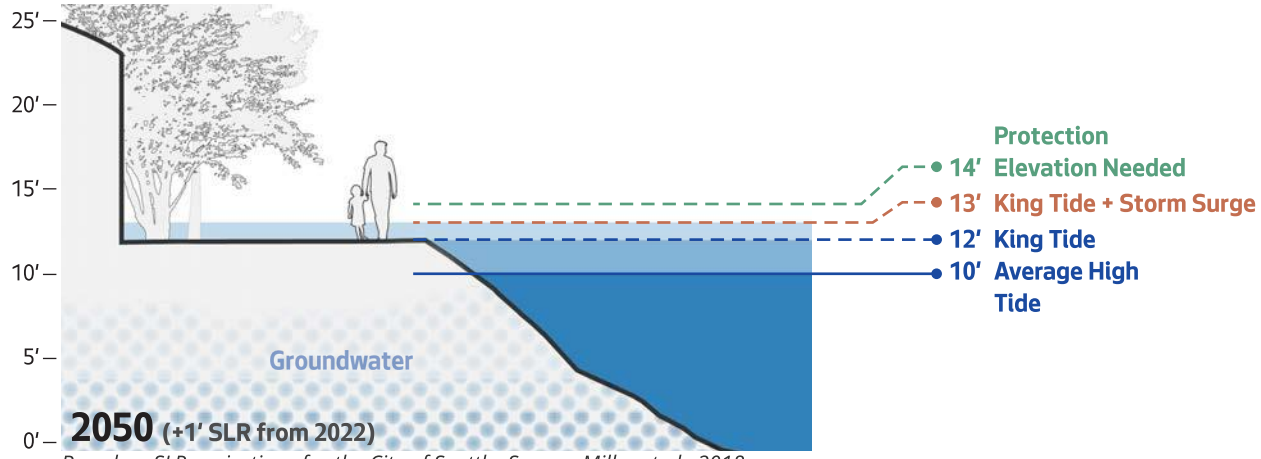
Climate change is causing global sea levels to rise in two ways. First, glaciers and ice sheets worldwide are melting and adding water to the ocean. Second, the volume of the ocean is expanding as the water warms. Sea level rise will make high tides higher over time, creating worse and more frequent flooding in the Duwamish Valley.

A 2018 study of SLR projections for the State of Washington found that if global greenhouse gas emissions remain high, Seattle may experience about one foot of SLR by 2050 and about three feet of SLR by 2100. This means that by 2100, the Duwamish Valley could experience flooding in low areas during many high tides. Much more severe flooding could happen multiple times per year during king tides and storm surges.

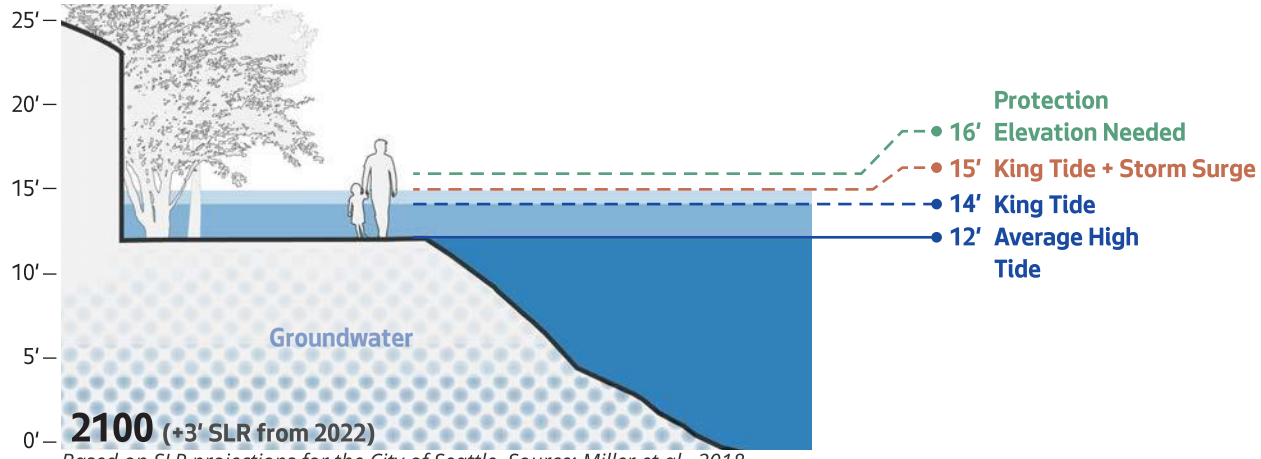
The diagrams at right show flood elevations projected from the different kinds of coastal flooding over time. The December 27th, 2022 flood reached 12 feet and 11 inches. In 2050, a similar level of flooding could happen much more frequently. By 2100, daily high tides could cause flooding, and flood elevations of up to 15 feet could occur if there is a storm surge during a king tide. The ground is shown at 12 feet, which is the average elevation of the riverbank in South Park today. But because the riverbank elevation varies from 10.5 feet at the lowest point to 15 feet at the highest, the river will flood the banks faster and more frequently in some places than others. In addition, groundwater tends to rise along with sea level. This could make stormwater flooding worse in low lying areas farther away from the bank.

The map in Figure 7 shows the approximate areas that could be impacted during the highest flood elevation projected with SLR by 2050 and 2100.





Based on SLR projections for the City of Seattle. Source: Miller et al., 2018.



Based on SLR projections for the City of Seattle. Source: Miller et al., 2018.

Figure 6: Flood water heights based on SLR projections for the City of Seattle. Source: Miller et al., 2018.
Notes: A "king tide" is an annual high tide that occurs approximately three times per year.
Average High Tide refers to Mean Higher High Water (MHHW).
Elevations are shown in North American Vertical Datum of 1988 (NAVD88)

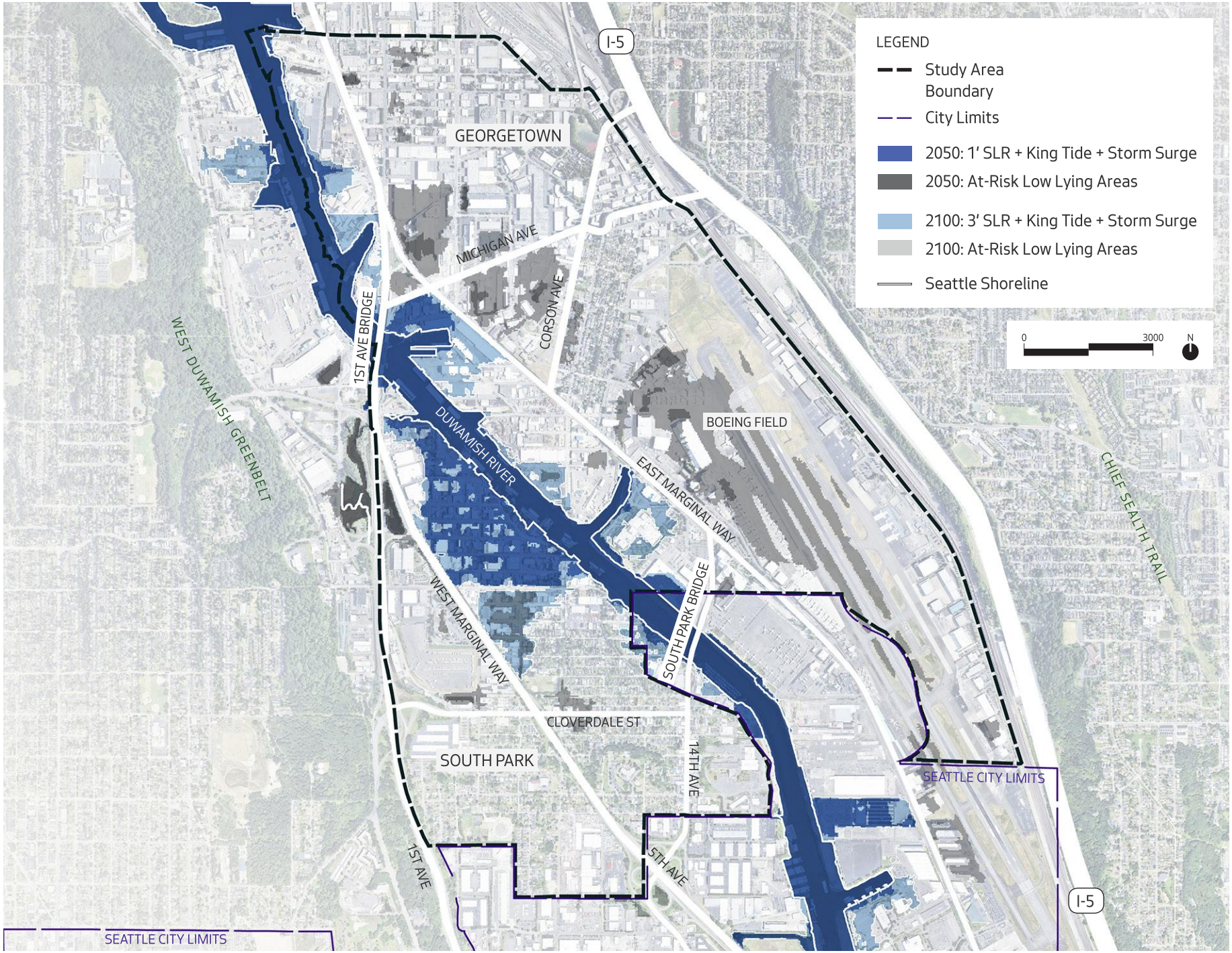


Figure 6: Flood impacts expected with king tide, storm surge, and sea level rise in 2050 and 2100. Based on SLR projections for the City of Seattle. Source: Miller et al., 2018.

Urban Flooding

While some areas of the Georgetown neighborhood shoreline will be impacted by coastal inundation, the neighborhood is mostly impacted by stormwater-related **urban flooding**. Urban flooding is caused by heavy rainfall that overwhelms local stormwater drainage pipe capacity. Climate change and SLR could make urban flooding issues worse over time.

The flooding issues in Georgetown are a little more varied and complex than in the South Park neighborhood, largely due to the fact that there are multiple outfalls into the Duwamish River in Georgetown, and the different types of drainage systems, shown at right.

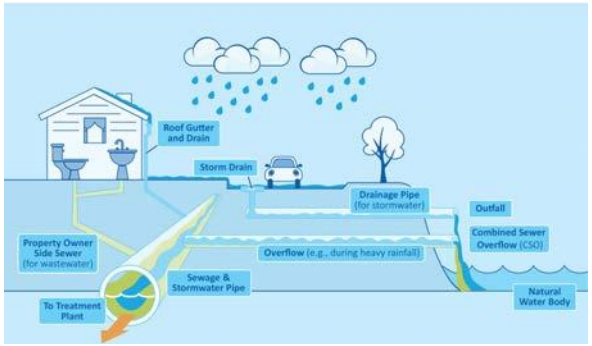
The different types of flooding issues in Georgetown, and how SLR and climate change can impact them, include:

- Lack of drainage infrastructure, resulting in localized flooding (for example, big puddles on the side of the road). This type of flooding is caused by low spots that are missing catch basins and pipes to collect and convey the stormwater. SLR won't have an impact on this type of flooding, but climate change is expected to increase the intensity of rainfall, which could result in more frequent localized flooding. Solutions to this type of flooding typically involve installing the missing infrastructure – catch basins, pipes, green infrastructure, etc.
- Lack of capacity in the drainage system, resulting in stormwater (and / or combined sewage, depending on the type of drainage system) backing up onto the street or into homes and businesses. This type of flooding can be caused by a variety of factors – for example, the catch basin might be clogged, the pipe in the street might be too small, or the Duwamish River might be high (which reduces the capacity of the drainage system). How often this type of flooding happens depends on the type of drainage system. In areas with combined sewers it typically only occurs during large storms, but in separate or partially separated areas it could happen during smaller storms as well. SLR and climate change will increase the frequency and intensity of these types of flooding events. Solutions to this type of flooding typically includes installing backflow preventors on the ends of outfall pipes and side sewers, increasing pipe sizes, or building pump stations.
- Coastal inundation (i.e. flooding) in lower-lying areas near the shoreline due to high tides and storm surge, resulting in river water flooding properties. SLR will increase the frequency and intensity of this flooding, and the solutions typically involve building a barrier (like a berm or floodwall) to hold back the river water, raising the elevation of buildings, or some combination of strategies.

COMBINED SEWER SYSTEM

SEPARATED SEWER SYSTEM

PARTIALLY SEPARATED SEWER SYSTEM



These diagrams show how combined, separated, and partially separated sewer systems work. Source: SPU Shape Our Water

DO HIGHER RIVER LEVELS CAUSE URBAN FLOODING IN GEORGETOWN?

Tide Conditions ↓ / Weather Conditions →	NO RAINFALL	LOW TO MEDIUM RAINFALL	MAJOR RAINFALL
NORMAL TIDE	No Impact	No Impact	No Impact (Overflows to River)
VERY HIGH TIDE	No Impact	No Impact	Yes (Worse Urban Flooding)

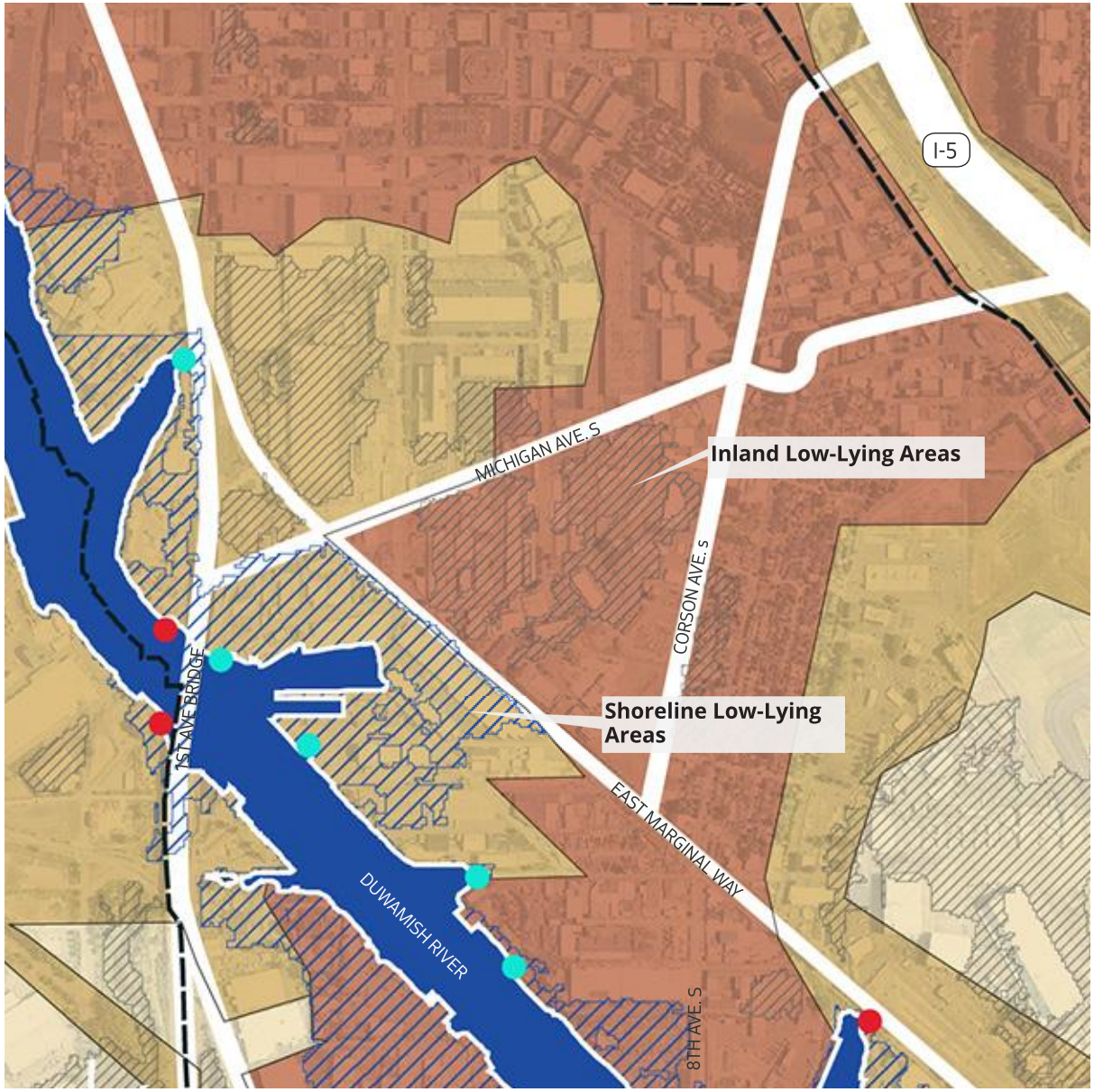


Figure 7: Map of Georgetown area sewer / stormwater basin areas and outfalls to the river, along with areas under 15' in elevation (the projected flood elevation of a king tide with storm surge by 2100).

LEGEND

- Study Area Boundary
- City Limits

Drainage Basins

- Combined Sewer System
- Partially Separated Sewer System
- Separated Sewer System

Outfalls

- Combined Sewer Outfall
- Stormwater Outfall

- Seattle Shoreline
- 2100: 3' SLR + King Tide + Storm Surge
- 2100: At-Risk Low Lying Areas

Example of urban flooding that could be caused by drainage backups or inadequate local stormwater drainage infrastructure.

Georgetown and South Park will experience flooding impacts from SLR differently over time, and it is important to recognize the many other potential hazards to the Duwamish Valley community that can compound or intersect with the impacts of these types of flooding.

The City of Seattle's All Hazards Mitigation Plan and Preparing for Climate Change Strategy Report outline several hazards related to climate change and other disasters that impact the Duwamish Valley.

Climate and Weather Risks

Extreme Heat & Air Quality

With climate change, Seattle will see increasing average annual temperatures and more frequent extreme heat events. Both South Park and Georgetown are disproportionately impacted by heat island effect because they lack tree canopy and because many homes and businesses may not be equipped with air conditioning systems.

Outdoor air quality is worsened by extreme heat, both from increased ozone levels and smoke from wildfires. Over time, buildings that have been damaged by floods can develop mold issues and worsen indoor air quality which damages the health of residents and workers.

Drier Summers, Wetter Winters

Climate change will also make summers and winters more intense, with more intense rainstorm events in the winter and longer periods of dry weather in the summer. More intense and frequent winter rainstorms could make coastal flooding more frequent if these storm systems create storm surges and strong winds. Heavier rain events will make urban flooding more severe. On the other hand, longer, drier summers can damage the health of urban trees, making it difficult to maintain beneficial tree canopy. Drought conditions and lower stream levels can also increase the concentration of pollution that enters the river, which harms fish, wildlife, and people.

Other Disasters

Earthquake & Tsunami

A major earthquake would be the most damaging single natural disaster to strike Seattle. The Duwamish Valley is within the Seattle Fault Zone and a liquefaction zone, which means that soil would temporarily behave like liquid under buildings during a major earthquake. Depending on design, flood protection infrastructure could help to stabilize soil against earthquake movement, though this would make the infrastructure more expensive.

A strong earthquake could also create a tsunami. The first impact of a tsunami on the Duwamish Valley would be water rapidly draining out of the river channel toward Elliott Bay before the tsunami wave reflected off the north side of the bay and inundated Harbor Island. The South Park and Georgetown neighborhoods would then experience a surge in water levels upriver from the wave.[2]

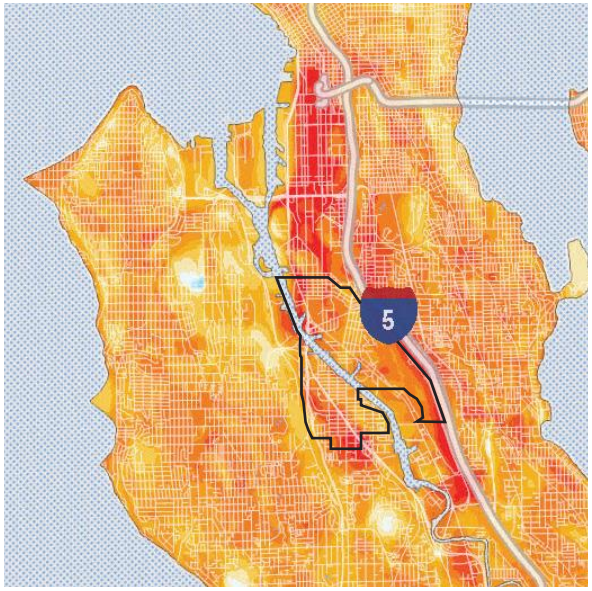
Landslide

The West Duwamish Greenbelt area, located across Highway 99 from the South Park neighborhood, is at risk for landslides. An earthquake could trigger landslides, and landslide risk could also increase with more intense rain events due to climate change. While a landslide might not damage homes or businesses in South Park, it could impact road transportation to and from the area.

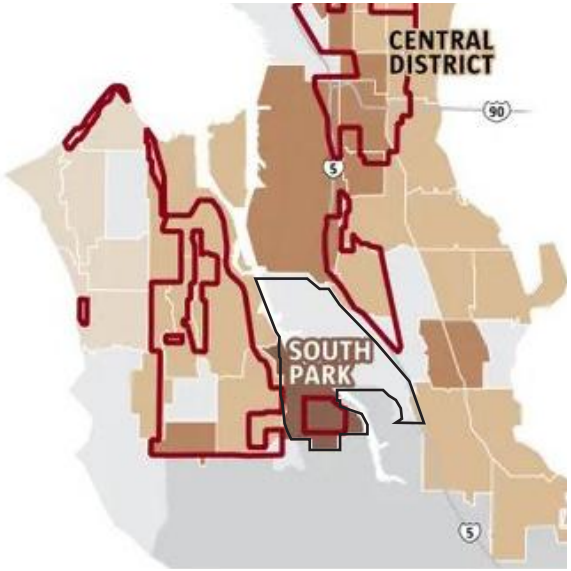
Lahar & Volcanic Sediment

If Mt. Rainier erupted, or if there was a major earthquake, a mixture of sediment and debris would flow down the valleys toward lower areas. This flow is called a "lahar". A lahar could reach the Duwamish Valley depending on what obstacles it meets along the way. But even if did not reach the Duwamish Valley, erosion and sediment would wash down from upriver that could impact water levels in the days following an eruption.

2. Dolcimascolo et al., 2022, Tsunami hazard maps of the Puget Sound and adjacent waters—Model results from an extended L1 Mw 9.0 Cascadia subduction zone megathrust earthquake scenario: Washington Geological Survey Map Series 2021-01



During heat events, the Duwamish Valley stays hotter in the evening due to many paved surfaces and lack of shade trees. (Source: King County)



The Duwamish Valley area has higher levels of Nitrous Dioxide air pollution than surrounding areas in Seattle, and this correlates with racist redlining practices conducted in the 1930s. (Source: Seattle Times, Emily M. Eng)

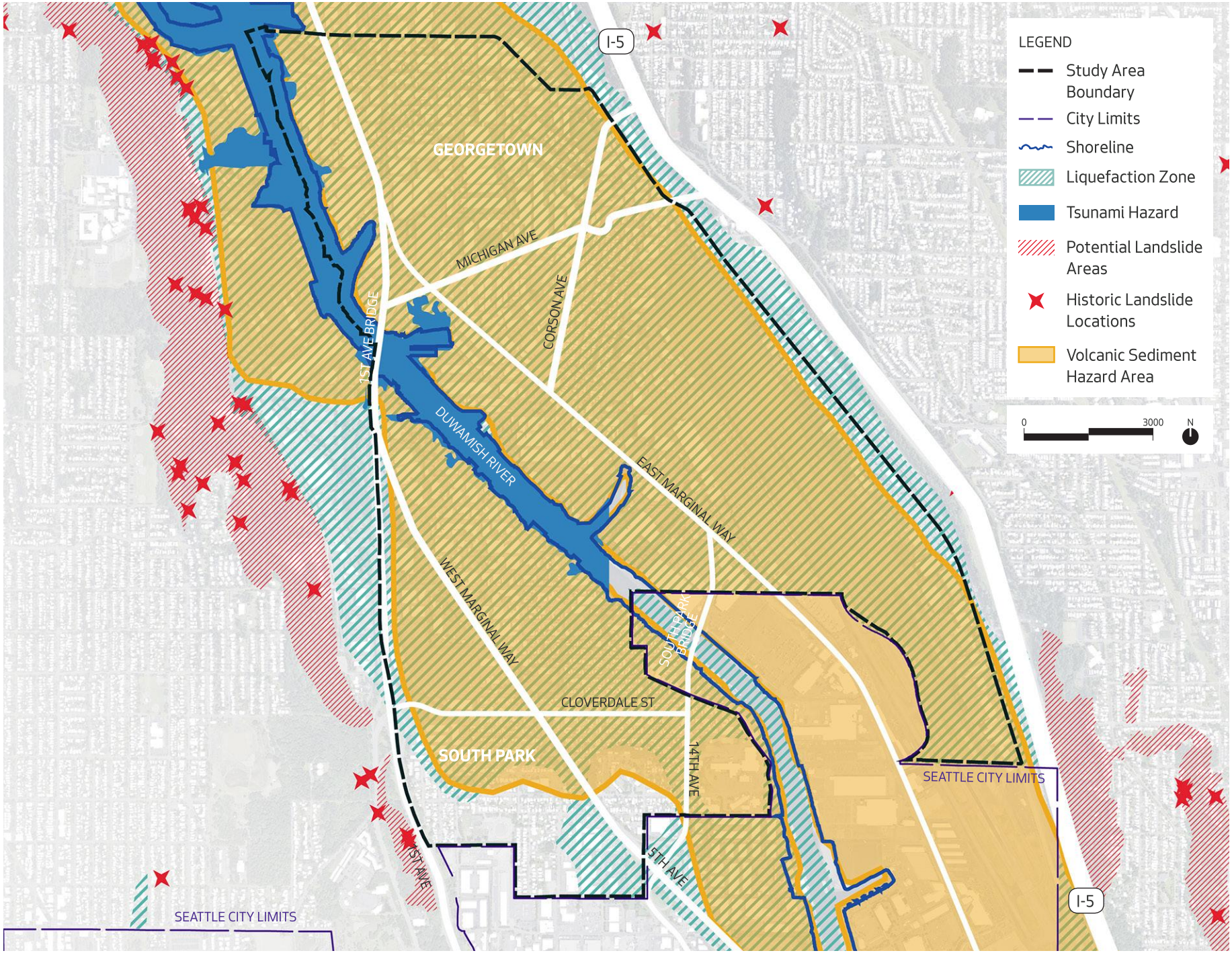


Figure 8: Liquefaction, lahar, and landslide risks.

BARRIERS & OPPORTUNITIES FOR COMMUNITY RESILIENCE

To create community resilience in the face of coastal flooding and related hazards, sea level rise (SLR) infrastructure can be designed to provide multiple benefits and protections. SLR infrastructure could include hard protection strategies (like walls or berms), soft protection strategies (like restored habitat and green spaces at the shoreline), and retrofitting strategies (like pumps or raised roads). Through a combination of strategies, SLR infrastructure can protect the neighborhoods from coastal flooding while also helping with urban stormwater flooding and other related hazards.

The 2018 Duwamish Valley Action Plan identified seven priority areas for advancing equitable development, environmental justice, and anti-displacement:

- Healthy Environment
- Parks & Open Spaces
- Community Capacity
- Mobility and Transportation
- Economic Opportunity
- Affordable Housing
- Public Safety

There are specific site-based opportunities and challenges within each of these priority areas when protecting the community from flooding. The following barriers and opportunities will inform the design of SLR infrastructure.

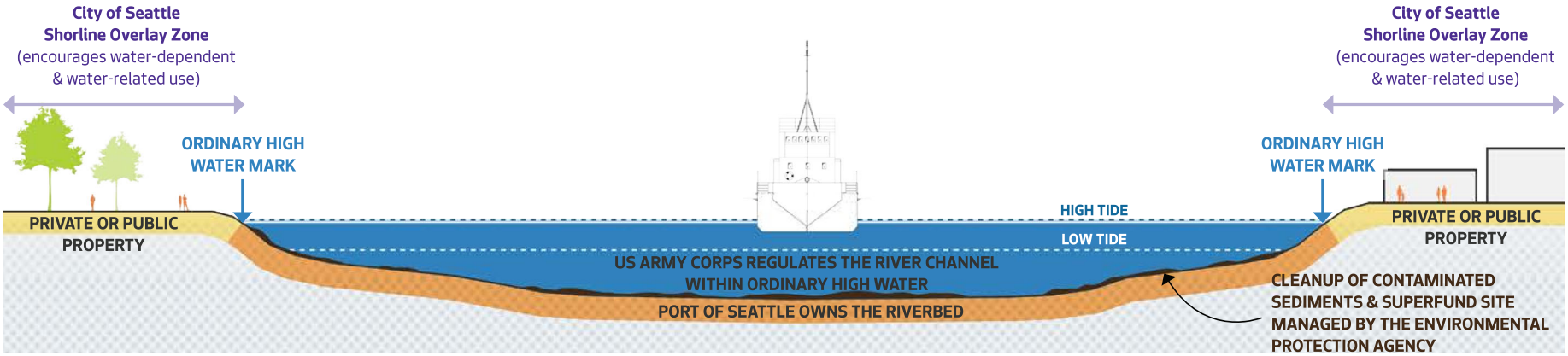
Healthy Environment

Shoreline Conditions

The shoreline environment is mostly designated as Urban Industrial in the City's Shoreline Master Program, which is meant to provide for water-dependent and water-related industrial uses on larger lots. Currently, many but not all property uses along the waterfront are water-dependent or water-related. Additionally, many sites are known or suspected to be contaminated. While some shoreline properties are publicly owned, many are privately owned by different landholders. The Port of Seattle owns the bed of the river, and any construction activity in the water past the Ordinary High Water Mark requires permits from the US Army Corps of Engineers. In order to provide comprehensive protection from SLR along the shoreline that provides multiple community benefits, public agencies will need to coordinate with numerous property owners and the community.

SLR Adaptation Opportunities:

- Protect shoreline parcels for ongoing maritime or other uses
- Attract / create green jobs
- Public access / views / recreation
- Habitat restoration



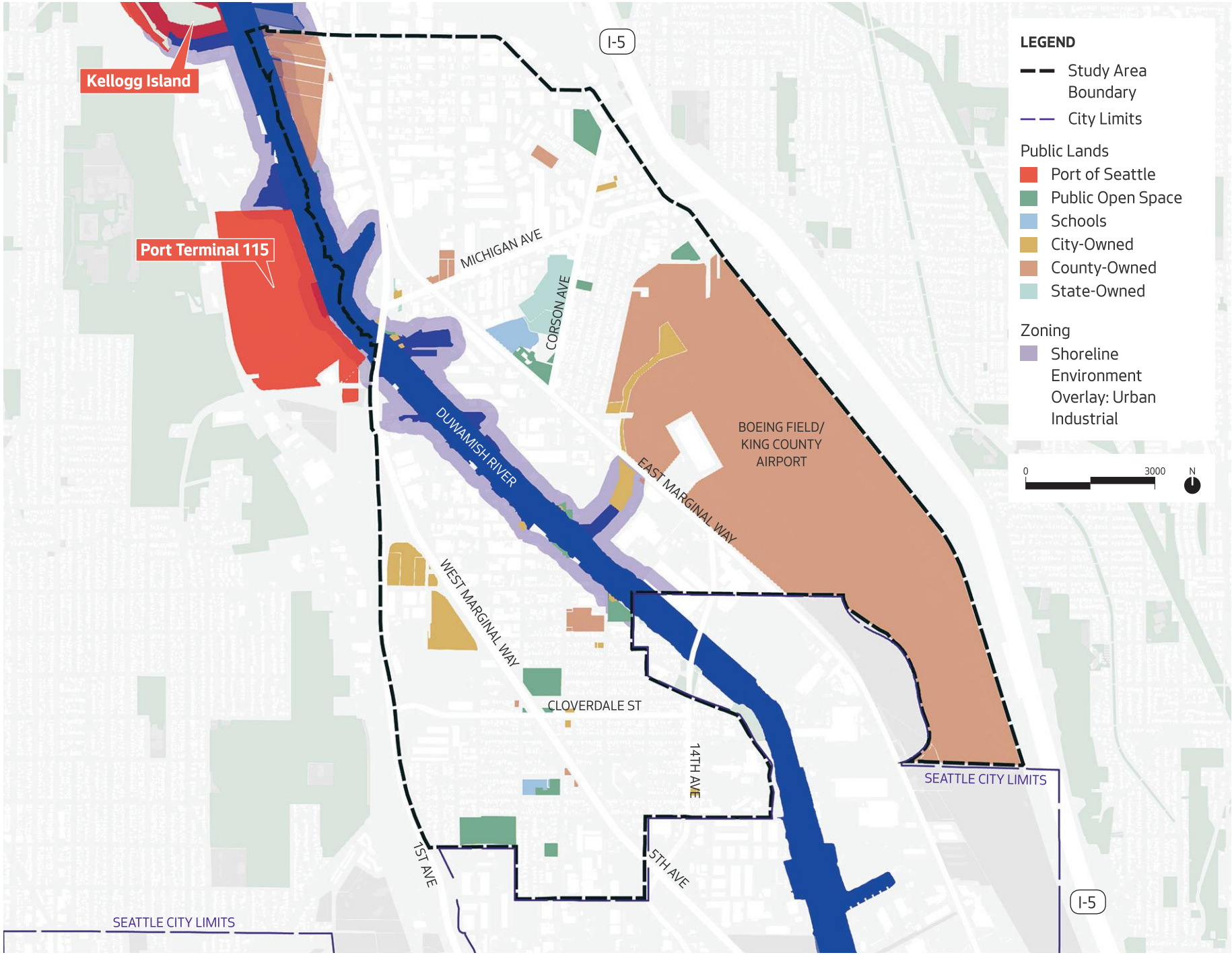


Figure 9: Shoreline Environment Overlay and public ownership.

Habitat and Ecosystem

Historically, the Duwamish estuary was a robust ecosystem, home to expansive tideflats, wetlands, marshes, forests, and prairies that supported countless fish, wildlife, and plants as well as the Duwamish People (see Figure 3 Historic Ecotones). An estuary for the Green River, the Lower Duwamish is a brackish environment that has been dramatically transformed by the last 140 years of development, dredging, and filling.

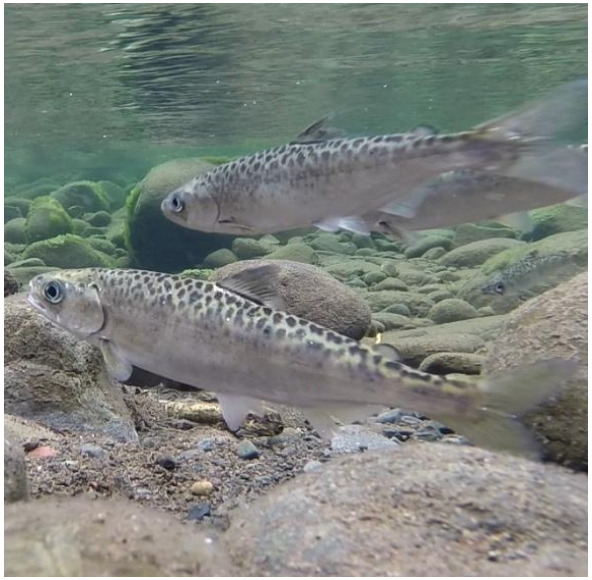
The Duwamish Blueprint: Salmon Habitat in the Duwamish Transition Zone, identifies the river extents within our Project Area as necessary habitat for keystone salmonid species, specifically critical for migrating juvenile Chinook salmon that depend on "transition habitat" as they transition from being freshwater fish to saltwater fish. And that the historic loss, degradation, and fragmentation of this habitat is a "limiting habitat factor for the Chinook populations of the watershed" at large.

Since the 1980s, habitat restoration has been supported by community groups and more recently with funding and requirements associated to superfund cleanup. Many of these efforts have focused on the critical creation of salmon habitat, including intertidal mudflats and marsh, the addition of large woody debris, and healthy riparian areas that provide shade, edible organisms, and areas of slow water for fish to rest.

Still, remaining shoreline armoring has reduced the functionality of most of the intertidal habitat. Continued restoration work and habitat management is needed to re-establish a vibrant ecosystem within the Lower Duwamish, bolstered by healthy and native plant and wildlife species that rely on and support one another. By pairing gray and green infrastructure, sea level rise adaptation strategies can incorporate natural systems to support this effort.

SLR Adaptation Opportunities:

- In general, incorporate natural systems and habitat into required flood mitigating gray infrastructure to allow for a more holistic and healthier balance of the future built environment and ecosystem.
- Work with WRIA9 to include habitat opportunities in the Green/Duwamish and Central Puget Sound Watershed Salmon Habitat Plan.
- Prioritize tree planting and improved shoreline banks. Work to incorporate habitat function within any shoreline infrastructure.
- Make room for large (>2 acres) intertidal mudflats for migrating juvenile salmon; brackish areas near streams are best.
- Incorporate removal of fish barriers to stream habitat with any adjacent SLR mitigation.
- Vary elevations and slope banks gradually to support adaptation of habitat to sea level rise.
- Incorporate green infrastructure solutions such as bi-valve shellfish habitat or floating islands to support the mitigation of toxicity levels in the estuary.
- Pair Green Stormwater Infrastructure (GSI) with any necessary "interior drainage" mitigation for stormwater that collects on the land side along SLR infrastructure.
- Provide GSI and plant trees throughout the watershed to help mitigate stormwater stress on drainage systems that will be become more easily overwhelmed by both an increase in heavy rain events and by higher river levels.
- Incorporate connected, native pollinator pathways within and between public improvements.
- Provide pollinator and bird habitat to support the health and biodiversity of the Duwamish estuary ecosystem.
- Plan for habitat maintenance with associated funding, job creation, and coalition support.



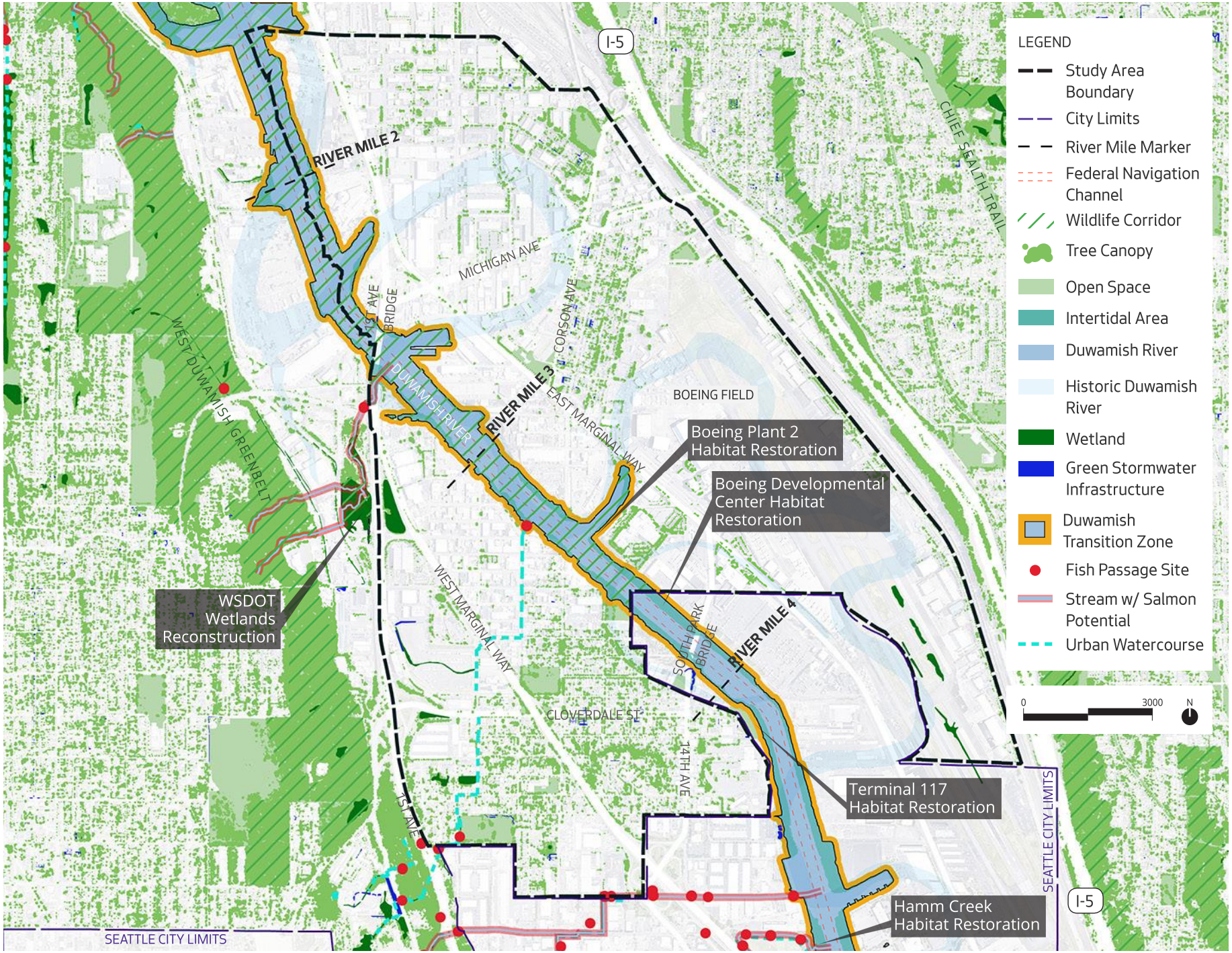


Figure 10: Existing Habitat, Recent Restoration Efforts, and The Duwamish Transition zone, the area most critical for migrating juvenile salmonids

Land Use, Land Cover & Drainage

Due to the dominance of industrial land uses and streets, much of the land in the study area is paved or impervious, and some of these areas may have contaminated soils and/or groundwater. Tree canopy is also missing in the industrial areas. The industrial areas of South Park and Georgetown are low-lying, so that rainwater tends to pool in the low places. Because of the amount of impervious or paved surfaces in the study area, pooling rainwater cannot always absorb into the ground. All of these issues contribute to urban flooding, which can make coastal flooding impacts more severe when the water overtops the banks. Additionally, sewer pipes are connected with stormwater pipes in some locations, called combined sewer overflows (CSOs). When rainfall volumes are high, stormwater can mix with sewage before it enters the Duwamish River. Similarly, when the river is high, it can enter these combined pipes and cause sewers to back up in homes and businesses.

Seattle Public Utilities and King County Wastewater Treatment Division are currently planning and building infrastructure in both South Park and Georgetown to help with stormwater issues, including SPU's South Park Stormwater Pump Station and the King County Georgetown Wet Weather Treatment Facility. These improvements will help with urban stormwater flooding and improve water quality before it enters the river. However, they will not stop river water from spilling over low areas of the banks (primarily in South Park, but also in some industrial portions of Georgetown) due to high tides and sea level rise.

Private development also plays a role in reducing stormwater impacts. As the City updates its comprehensive plan, it may designate much of the Duwamish Valley area as a new Maritime, Manufacturing, and Logistics land use, with the intent to strengthen established economic clusters and expand equitable access to jobs, including union jobs, in businesses that depend on access to water and other supporting infrastructure.

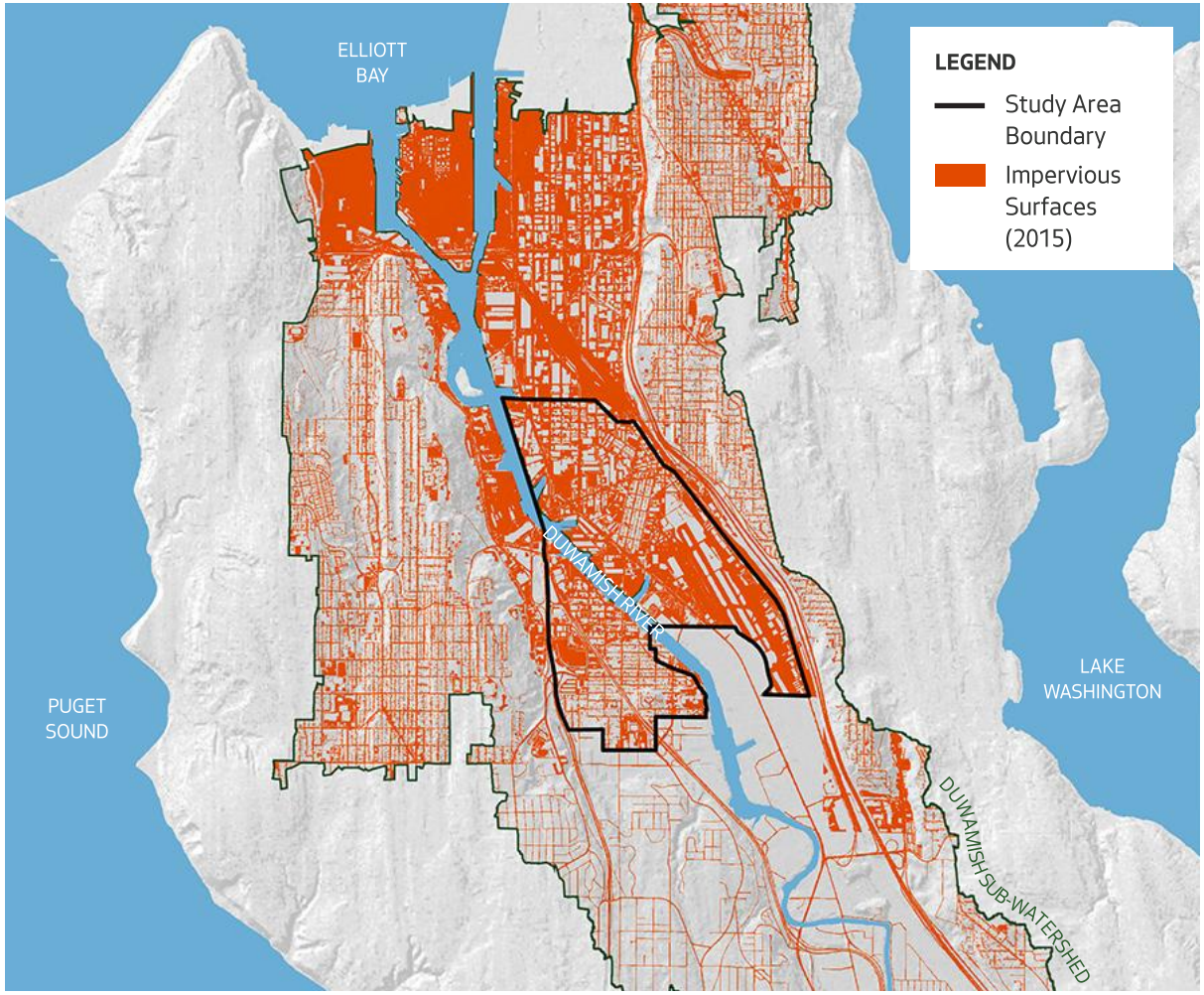


Figure 11. Mapped impervious surfaces within Duwamish Subwatershed (SPU, 2015; data not complete outside of City of Seattle)

<u>SLR Adaptation Opportunities:</u>

- Green infrastructure, tree planting, and enhanced landscaping in and near areas impacted by flooding and where gaps in tree canopy exist
- Jobs in design, installation, and maintenance of green infrastructure, living shorelines, and trees
- Improved air quality, reduced urban heat, and habitat for wildlife and insects
- Creative and place-based approaches to shoreline land uses that are resilient to Sea Level Rise and provide multiple community benefits
- Incorporate pervious paving solutions in lieu of impermeable concrete sidewalks, asphalt roads etc.

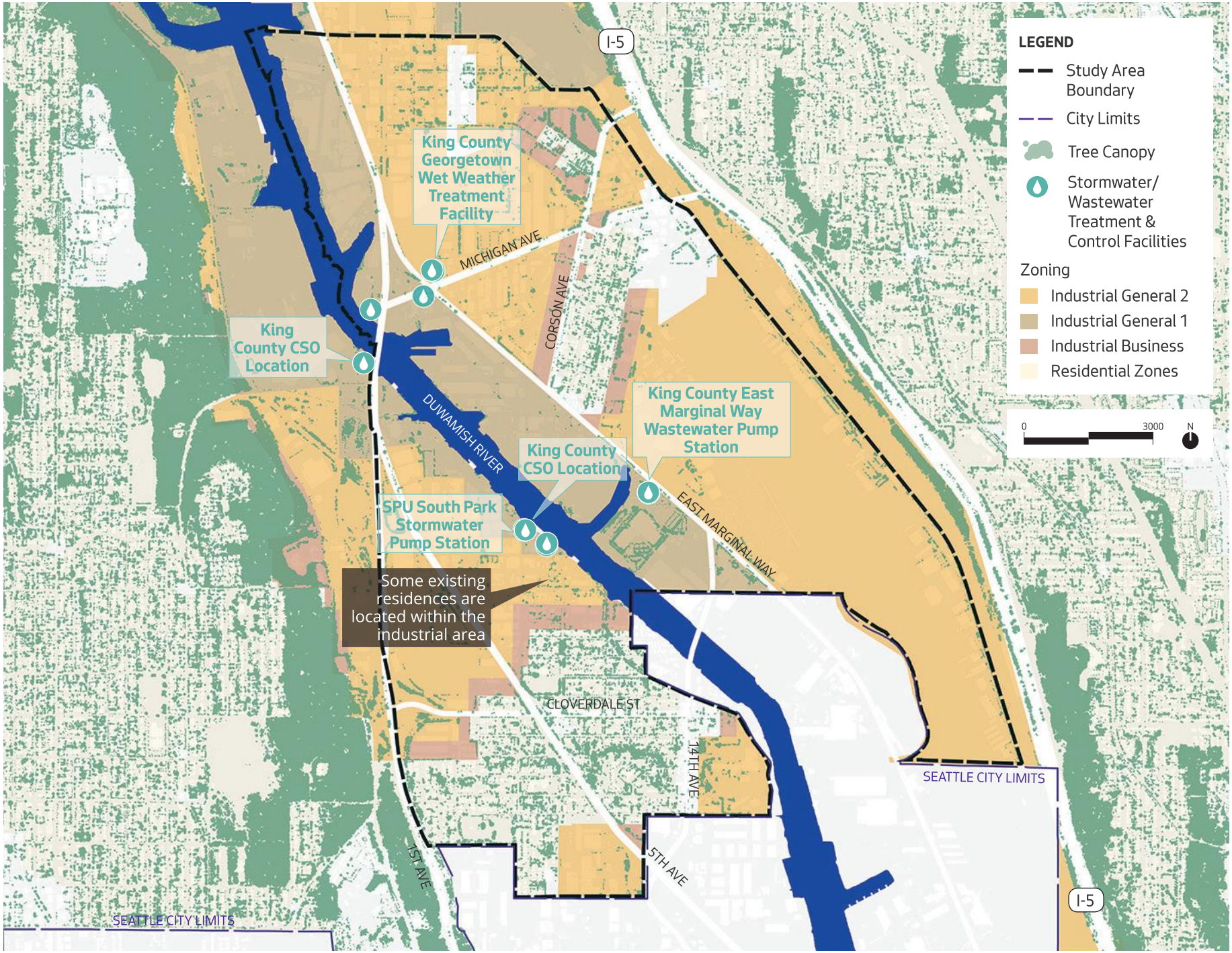


Figure 12. Zoning, tree canopy, and stormwater/wastewater treatment and control facilities

Pollution & Contamination

Over the last century, industrial and urban use have polluted the Duwamish River and the lands surrounding it. In 2001, the federal Environmental Protection Agency designated the Lower Duwamish Waterway as a Superfund Site, leading to specific cleanup actions over time. Community leaders and volunteers have been holding the EPA and local responsible parties to a high standard of cleanup and challenging cleanup efforts to go beyond the minimum to create a truly healthy and livable environment in the Duwamish Valley over the long term. A 2013 Health Impact Assessment, conducted with local communities including participation from the Duwamish and Suquamish Tribes, established the critical importance of a high standard of cleanup and the opportunity for the Duwamish River cleanup to become a national example of a healthy and sustainable coexistence of industry, Tribes, and community.

Today, known and suspected contaminated sites in the Duwamish Valley continue to impact the health of local communities, fish, and wildlife. As the sea level rises, contaminated soil and groundwater could be flooded and cause pollutants to spread further. Figure 12 shows flood-impacted areas in 2100 overlaid with known or suspected contaminated sites.

Contamination may present a barrier to building resilient infrastructure. It is likely that the sites for SLR infrastructure will have contaminated soil and/or groundwater. This can create challenges for public acquisition of land to build infrastructure due to the liability and cost to clean up contamination. Any excavation and construction activities at these locations could trigger clean-up requirements, which can be time-consuming and expensive.

SLR Adaptation Opportunities:

- High standard of cleanup of contaminated land along the river
- Strengthened controls on pollution sources, ensuring that ongoing and future uses do not pollute the land or the river
- Reinvesting penalties for pollution into local community benefits
- Job opportunities in construction, maintenance, monitoring
- Contributing to a healthy and sustainable coexistence of industry, Tribes, and community

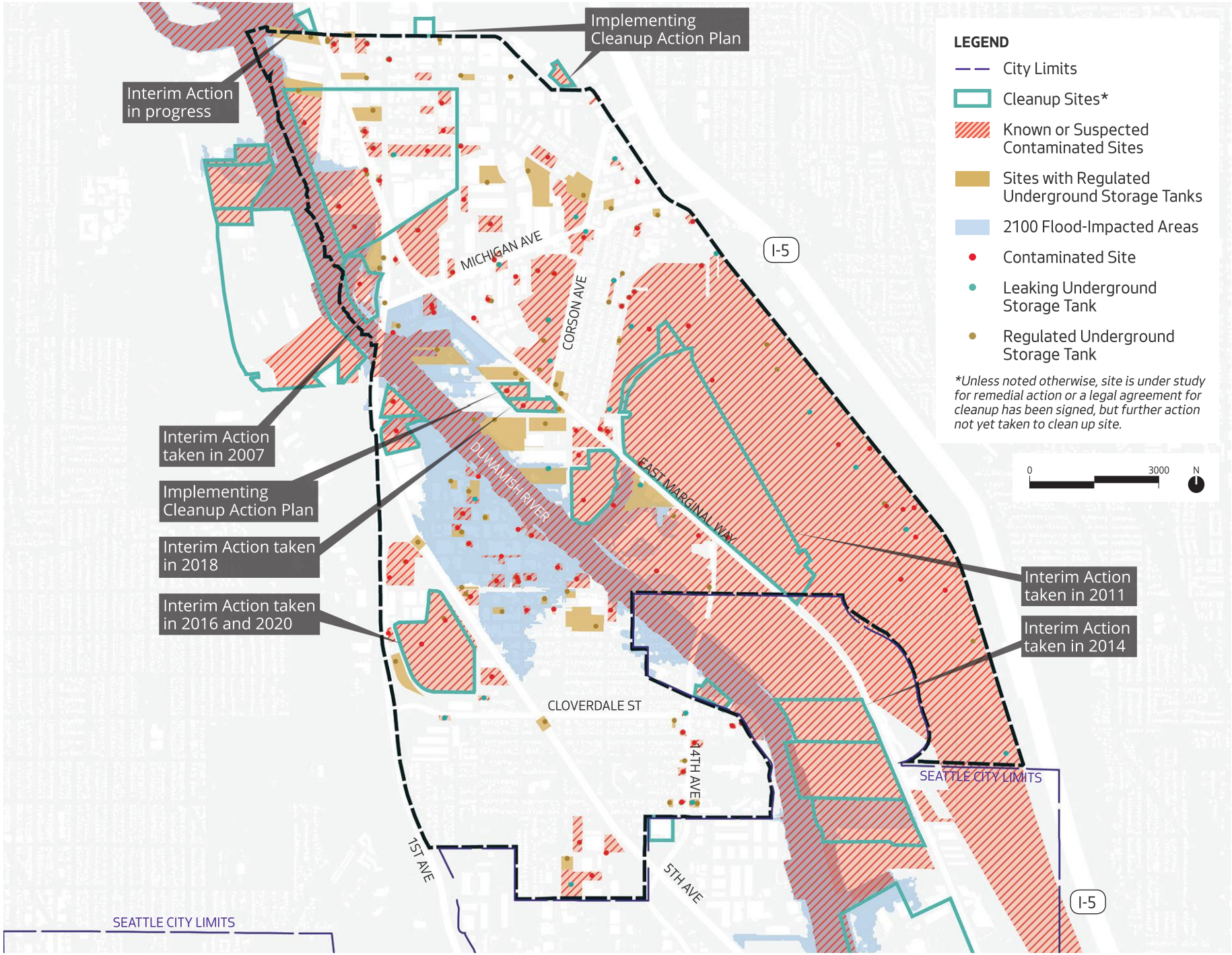


Figure 13. Known and suspected contamination in the Duwamish Valley, and cleanup actions taken

Parks & Open Spaces

The South Park and Georgetown neighborhoods both lack parks and greenspaces when compared to the rest of Seattle. Community desires for improved greenspace and bicycle and pedestrian connections are outlined in the South Park Green Space Vision Plan, the Georgetown Green Space Vision Framework, and the Duwamish Valley Action Plan. New parks, like the Duwamish Waterway Park and Shoreline Park/ t'ałt'ałucid Park, have advanced the community's vision. As further steps, the City is currently working on developing the Unity Electric site as a public space in South Park, improving the pedestrian environment of 8th Avenue in Georgetown, and creating a public space and museum at the Georgetown Steam Plant. However, the northern areas of South Park and Georgetown still lack green space. And some existing public spaces have been improved by the local community but need more supportive public investment.

SLR Adaptation Opportunities:

- Create new public green space near the shoreline and in neighborhoods
- Combine green infrastructure with pedestrian/ bike connections between parks and destinations

Mobility, Transportation & Safety

Truck traffic in industrial areas of the valley is essential for manufacturing, industrial, and maritime transport, and it presents safety and air quality issues for pedestrians and cyclists in South Park and Georgetown. In addition, the neighborhoods lack a complete and safe network of comfortable, low-stress bicycling and walking routes, and the two neighborhoods are disconnected.

SLR Adaptation Opportunities:

- Walking and biking infrastructure along shoreline and potential for light watercraft connections between neighborhoods
- Improving drainage and creating green streets
- Integration of infrastructure to facilitate water dependent and related industrial uses (e.g. docks, cranes, mooring dolphins) and industrial freight access

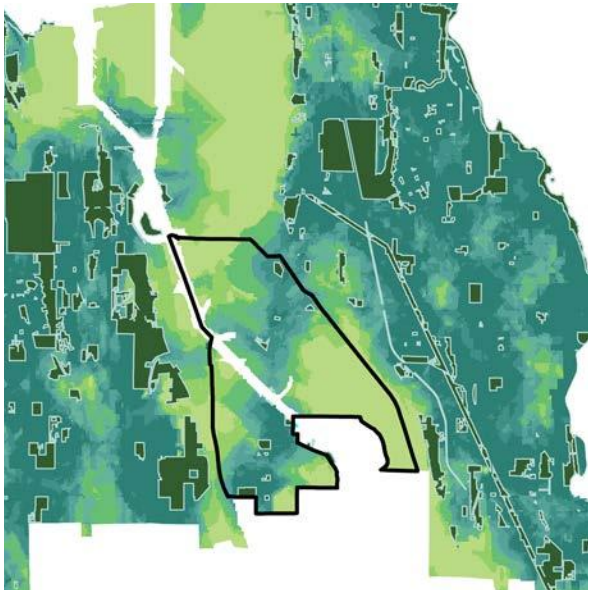
Community Capacity, Jobs, and Housing

South Park and Georgetown currently contain some of the most affordable housing prices in the city, which means that displacement pressures are increasing. With the citywide affordability and houselessness crisis, the public spaces in these neighborhoods are sometimes the only places for houseless community members to take refuge. Though the Duwamish Manufacturing and Industrial Center hosts about 40% of industrial jobs in Seattle, there is a need for more localized employment. Almost half of employed residents in the area work outside of their neighborhood (the Duwamish Valley Action Plan noted that 43% of working residents in South Park and 49% in Georgetown have more than a 30 minute commute to work). Additionally, the Duwamish Valley communities have historically experienced a lack of investment in schools and other public resources. Without significant investment in affordable housing, community resources, and local living wage jobs, the pressures of gentrification will continue to increase.

The Duwamish Valley Action Plan noted opportunities to fight displacement by establishing cultural anchors, connecting to community-controlled spaces, reducing poverty, and increasing local access to jobs and contracts, affordable housing, and affordable space for community-serving organizations. The Duwamish Valley Resilience District can become a model for supporting community prosperity in place, and SLR adaptation infrastructure can support this.

SLR Adaptation Opportunities:

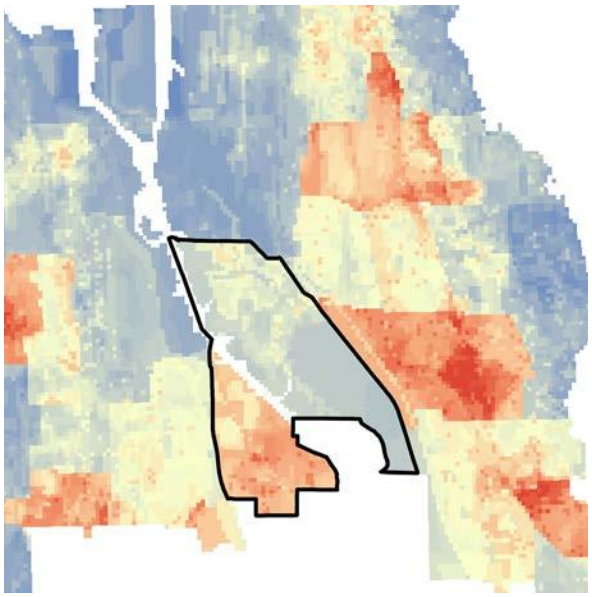
- Support local access to jobs and contracts for design, construction, and maintenance
- Capture financial benefits of public investment in infrastructure and reinvest within the neighborhoods
- Create a hub for resilience and climate adaptation related jobs



Public Space Priority Areas (OPCD Outside Citywide Initiative, 2016)

HIGH NEED

LOW NEED



Displacement Risk Index (Preliminary; OPCD Comprehensive Plan Update, 2022)

HIGH

LOW

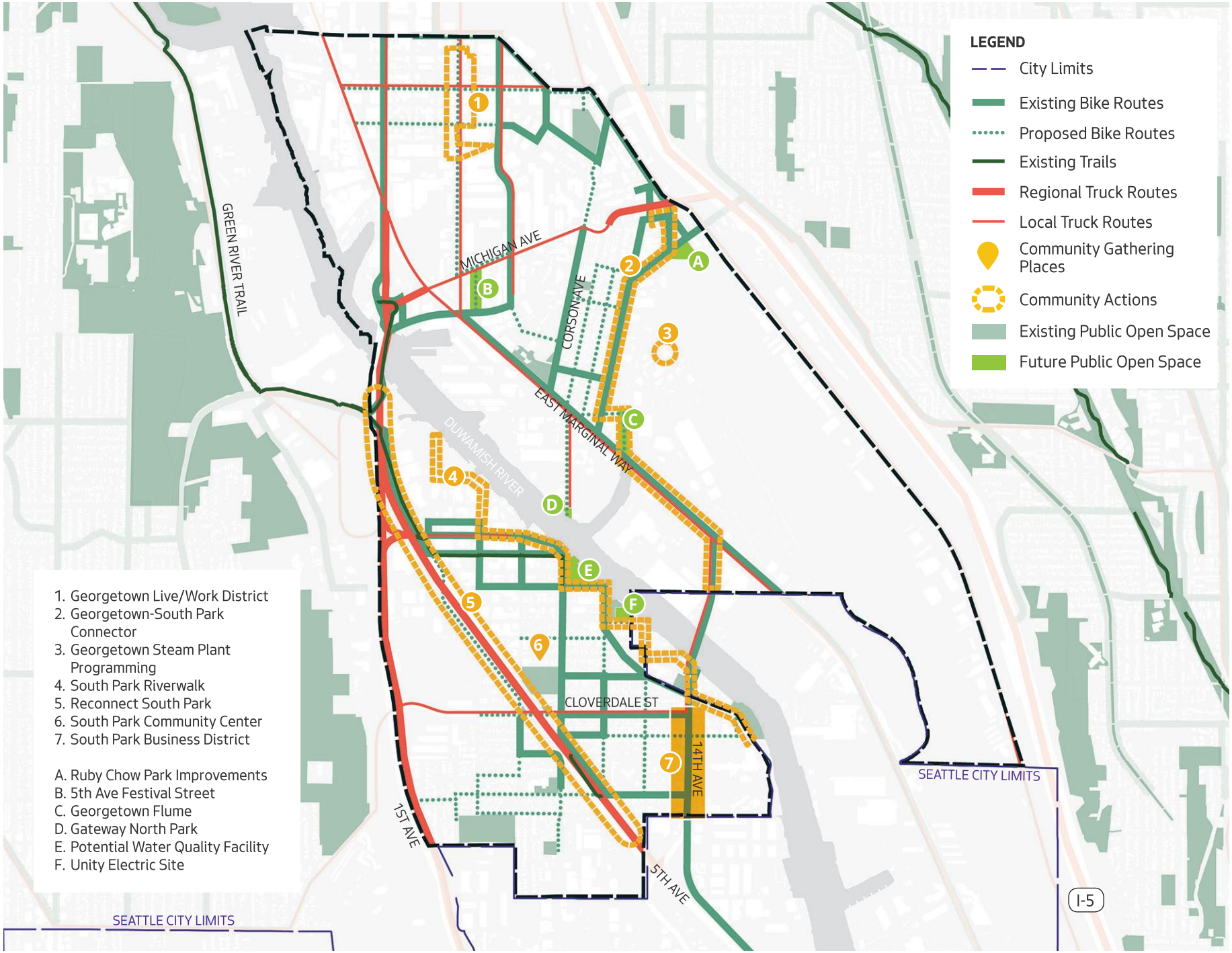


Figure 14: Community-defined actions for gathering spaces and mobility

TECHNICAL CONSIDERATIONS

The design of SLR infrastructure presents an opportunity to protect the Duwamish Valley against flooding while achieving multiple community priorities and advancing racial equity outcomes. In order to design this infrastructure, however, it is important to understand the technical considerations that will influence design and construction. The Duwamish Valley Sea Level Rise Adaptation Strategy will conduct high-level conceptual design of infrastructure scenarios. Based on the preferred concept, future, more detailed design study will be needed in order to build SLR infrastructure. The following technical information will be important to consider.

Contaminated Soils and Groundwater

It is highly likely that the sites where SLR infrastructure will be sited will have contaminated soil and / or groundwater. Any excavation and construction activities at these locations could trigger clean-up requirements, which can be time-consuming and expensive. However, the removal of contamination would benefit the community and environment.

For conceptual design:

- This phase should include large contingency in cost estimates to account for potential contamination.

For detailed design:

- Information will be needed on documented contamination. Site-specific assessments of potential environmental contamination will be needed once preferred locations / sites are selected.

Groundwater & Geotechnical Conditions

The depth and flow direction of groundwater in the South Park and Georgetown neighborhoods is not currently known. Groundwater can impact the design and cost of SLR infrastructure for several reasons. Depth of groundwater will impact the type and size of foundations and footings. Flow direction of groundwater will impact whether pumping of groundwater around the SLR infrastructure is needed. SLR infrastructure keeps the river water in the river, but could also prevent groundwater from draining by gravity into the river. And the relationship between tide and groundwater also needs to be understood to determine whether groundwater will need to be pumped out from behind SLR infrastructure.

Geotechnical conditions also impact the needed size and resulting cost of SLR infrastructure. Geotechnical conditions at the likely locations of SLR infrastructure are not currently known, but are likely to be poor because the Duwamish River valley consists primarily of imported fill when the river was channelized.

For conceptual design:

- This phase will rely on readily-available groundwater and geotechnical information, and incorporate these considerations into design and cost estimating.

For detailed design:

- Geotechnical exploration and a groundwater model will be needed to understand the impact of proposed SLR infrastructure.

Liquifiable Soils & Earthquake Risk

Stabilization of SLR infrastructure against lateral movement during an earthquake could be very expensive, but could provide a benefit to the neighborhood more broadly by reducing potential earthquake damage. SLR infrastructure could be built without stabilization against lateral movement – some options would perform better during an earthquake than other options.

For conceptual design:

- This phase will include contingency for lateral stabilization and use earthquake resilience as a criterion when comparing infrastructure options.

For detailed design:

- Decisions should be made about whether to include lateral stabilization.

Timeline for SLR Inundation

One of the key design criteria for SLR infrastructure is how high it needs to be, which is based on the desired level of protection from flooding. The City of Seattle has adopted SLR projections of 3 feet of SLR, 2 feet of King Tide, and 1 foot of storm surge by 2100, totaling a potential floodwater height of 6' above MHHW for South Park and Georgetown SLR infrastructure.

The timing of SLR will dictate what infrastructure is needed where and by when. Initial efforts will be focused on addressing low spots that are impacted by near-term SLR and current flooding patterns.

For conceptual design:

- Alternatives will be developed based on the level of flooding protection needed for SLR projections of 3' by 2100. The alternatives can be framed in terms of near-term (within ~10 years), medium-term (by 2050) and long-term (by 2100). Near-term flood protection infrastructure may be designed for medium and/or long-term SLR projections in order to provide protection against major flood events as early as possible.
- This phase will identify low spots and flooding pathways based on readily available data such as NOAA's SLR datasets.
- This phase will explore modular design strategies that can easily be made higher.

For detailed design and future processes:

- Future analyses could conduct a benefit-cost analysis on various SLR conditions.
- Update SLR projections and resulting design criteria as SLR continues to advance and future projections are refined through scientific advances.
- Confirm or model actual flow paths for flooding – where does flooding start and how does it progress?

Permitting Requirements

Constructing SLR infrastructure will require many permits, many of which will take a long time to acquire and will constrain construction windows. Early identification of permits will aid in establishing a realistic construction timeline.

For conceptual design:

- Include contingency in schedule and cost estimates for permit acquisition.

For detailed design:

- Develop a preliminary permit matrix based on the recommended option.

Property Ownership & Use

The area of South Park where SLR infrastructure is likely to be sited consists of many different parcels with different owners, and land in the river is owned by the Port of Seattle. Additionally, it will be important to continue to accommodate water-dependent and water-related uses in this area. Implementation of SLR infrastructure will require coordination with numerous property owners and the community, and potentially require property acquisition of riverfront parcels.

For conceptual design:

- Include contingency in schedule and cost estimates for property acquisition.
- Map out property ownership.

For detailed design:

- Identify property acquisition needs and property owner engagement needs.