TACOMA TIDEFLATS

AGENDA

DATE AND TIME: January 14, 2021, 2:00 PM to 4:00 PM
LOCATION: Please click the link below to join the webinar:

https://us02web.zoom.us/j/87250903372?pwd=OEhlTENNcEpaeS9EdTlUM2hXY0dPQT09

By Telephone:
(253) 215-8782
Webinar ID: 872 5090 3372
Passcode: 276518

A. Approval of Agenda

B. Communication Items
1. Tideflats Advisory Group: Zoom and public participation
2. Project status and schedule

C. Discussion Items
1. Climate Change Vulnerability -- Discussion

   Description: Moffatt & Nichol to present key findings and implications of the baseline climate change vulnerability assessment for discussion with the Steering Committee.

D. Upcoming Agendas (subject to change):
1. March 11: Joint Steering Committee/Tideflats Advisory Group presentation: Key Baseline Report Findings

E. Other Items of Interest

F. Adjournment

G. Attachments
- DRAFT Climate Vulnerability Assessment (Moffatt & Nichol)
- Upcoming schedule of meetings

TACOMA TIDEFLATS

SUBAREA PLAN & EIS

DRAFT CLIMATE VULNERABILITY ASSESSMENT
DECEMBER 2020

moffatt & nichol

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DOCUMENT VERIFICATION

Client	BERK Consulting
Project name	Tacoma Tideflats Subarea Plan and EIS
Document title	Climate Vulnerability Assessment
Document sub-title	–
Status	Partial Submission – Flooding Analysis
Date	12/18/2020
Project number	11077
File reference	Q:\SEA\11077\11 Coastal\Report\20201218 Partial Sub to BERK\Tacoma Tideflats - Draft Climate Vulnerability_Rev01.docx

Revision	Description	Issued by	Date	Checked	Approved By
00	Partial Submission – Baseline Report	JT	11/18/2020	YN	YN
01	Partial Submission – Flooding Analysis	JT	12/18/2020	YN/MJ	YN

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This study is qualified in its entirety by, and should be considered in light of, these limitations, conditions and considerations.

CONTENTS

EXHIBITS

KEY TAKEAWAYS

1 INTRODUCTION

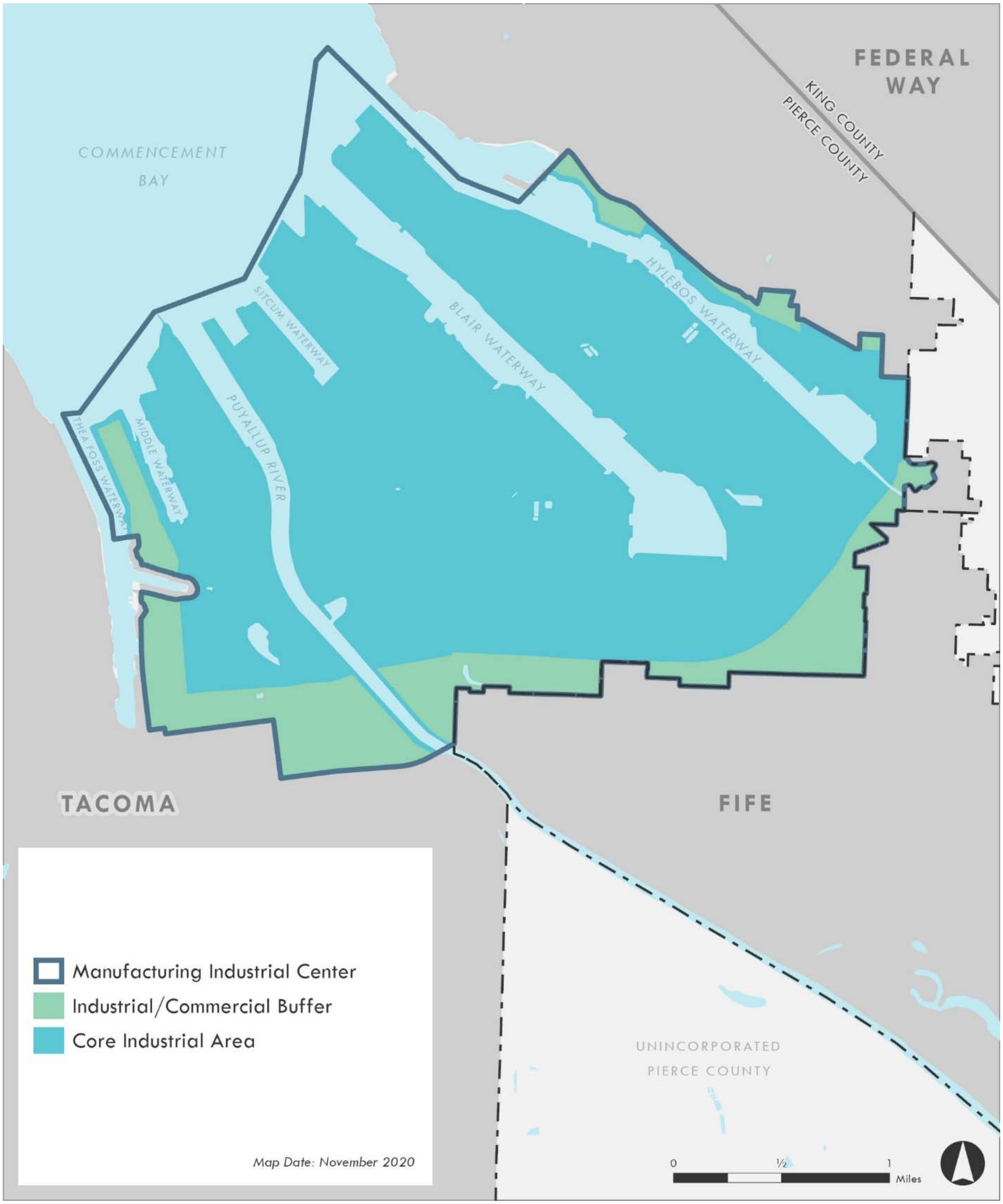
The Tacoma Tideflats and adjacent areas are of great significance to Tacoma, the Puyallup Tribe, the Port of Tacoma, Pierce County, Fife, and the entire region and State for reasons of heritage, environment, economics, employment, and the preservation, protection and enhancement of natural and cultural resources. The Tacoma Tideflats area is one of nine designated Manufacturing Industrial Centers in the Puget Sound Regional Council's regional development plan, VISION 2040. The State Growth Management Act requires that local comprehensive plans comply with VISION 2040, and directs local jurisdictions having one or more regionally designated centers to prepare a subarea plan for each such center.

Subarea planning (SAP) allows for the establishment of a shared, long-term vision, and a more coordinated approach to development, environmental review, and strategic capital investments in a focused area. Completion of a subarea plan will support the ongoing eligibility for and prioritization of transportation funding in the Port of Tacoma Manufacturing/Industrial Center, see Exhibit 1-1 for study area boundary.

Moffatt and Nichol (M&N) has conducted this climate vulnerability assessment as part of the Tacoma Tideflats SAP to support and inform evaluation of alternatives identified by the project team. The goal of this assessment is to inform hazard mitigation solutions within the study area that meet the needs of resources and infrastructure over their lifetime, being functional in the present and adaptable through time or protected in a way where future adaptation is not required. Specific objectives of this assessment include:

- Identification of key assets and infrastructure within the study area
- Identification of hazards of concern
- Identification of thresholds where the hazards impact key resources and infrastructure
- Evaluation of risk, based on the probability of these thresholds occurring
- Prioritization of adaptation and protection strategies according to risk tolerance and temporal horizon of coastal resources and infrastructure

Exhibit 1-1 Study Area Boundary for the Tacoma Tideflats Subarea Plan



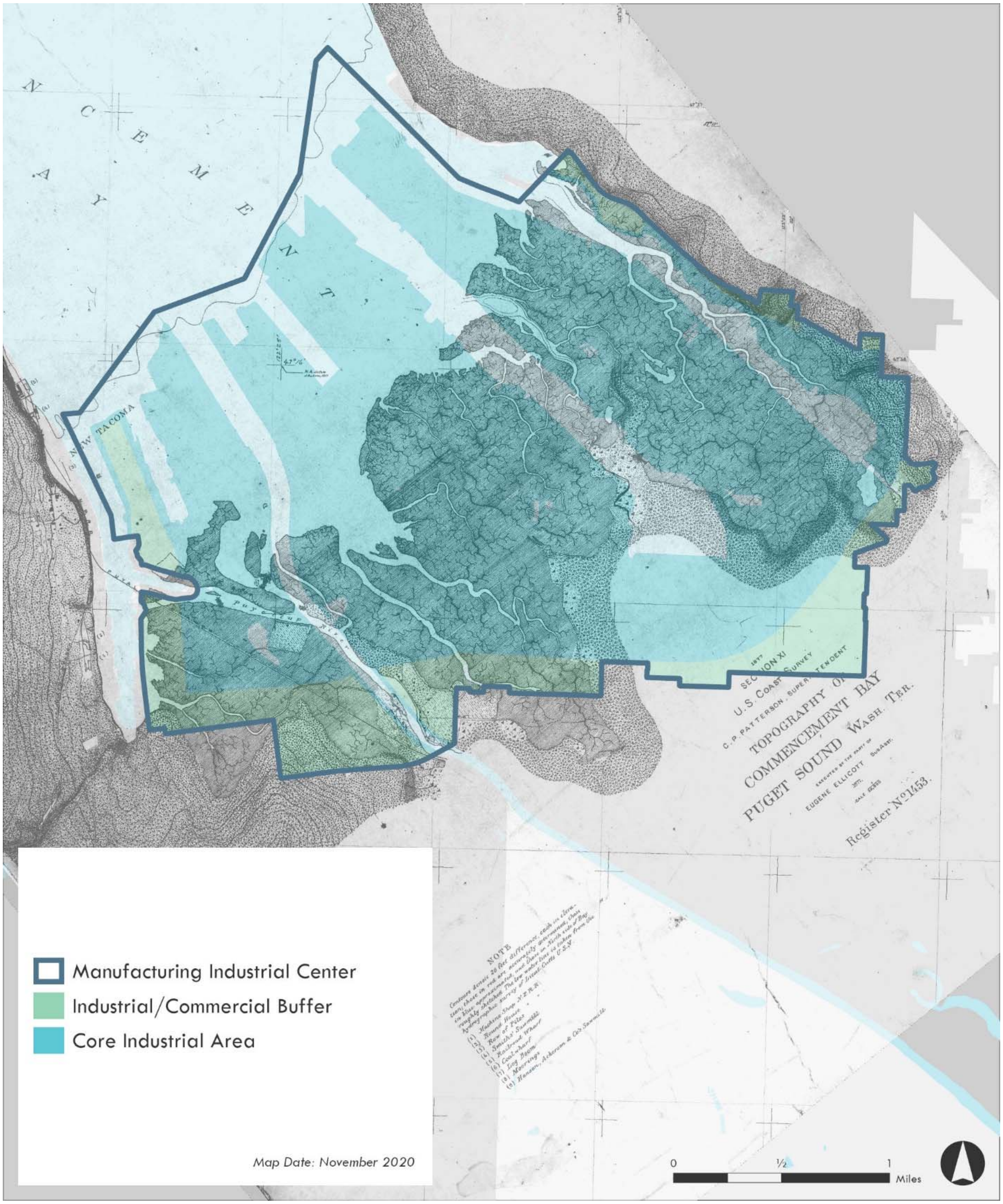
Study Area Setting

The Tacoma Tideflats study area is centered in the Manufacturing Industrial Center outlined in Exhibit 1-1, including the core industrial area as well as the industrial/commercial buffer. The study area lies in the interior of Commencement Bay, a small embayment within the larger Puget Sound. The Tideflats area is currently largely defined by development associated with the Port of Tacoma. Prior to development, the area contained large areas of wetlands and intertidal habitat where local waterways, such as the Puyallup River, emptied into coastal waters. The current industrial area, which extends beyond historic natural shorelines, was established through fill placement to increase shoreline elevations and allow for increased industrial use. This shift in shoreline position is illustrated in Exhibit 1-2. The majority of fill has been placed in areas bordering the Puyallup River and Blair Waterway, with several fill placement events approaching or exceeding 1 million cubic yards of material in the 1950s and 1960s (Hart-Crowser and Associates, Inc., 1974).

Shorelines within the study area extend across Shoreline Districts S8 – S12, as defined within the City of Tacoma Shoreline Master Program. The study area lies at the end of the low-lying Puyallup River floodplain as the river discharges into Commencement Bay, delivering sediment and forming deltas at the mouth of the river. The study area is bordered on either side by steep coastal bluffs that transition to upland plateaus. Topography within and surrounding the study area is shown in greater detail in Exhibit 1-3. Several coastal waterways extend inland within the study area in addition to the Puyallup River, including the Thea Foss Waterway, Middle Waterway, Sitcum Waterway, Blair Waterway, and Hylebos Waterway, accounting for approximately 20 miles of marine shoreline.

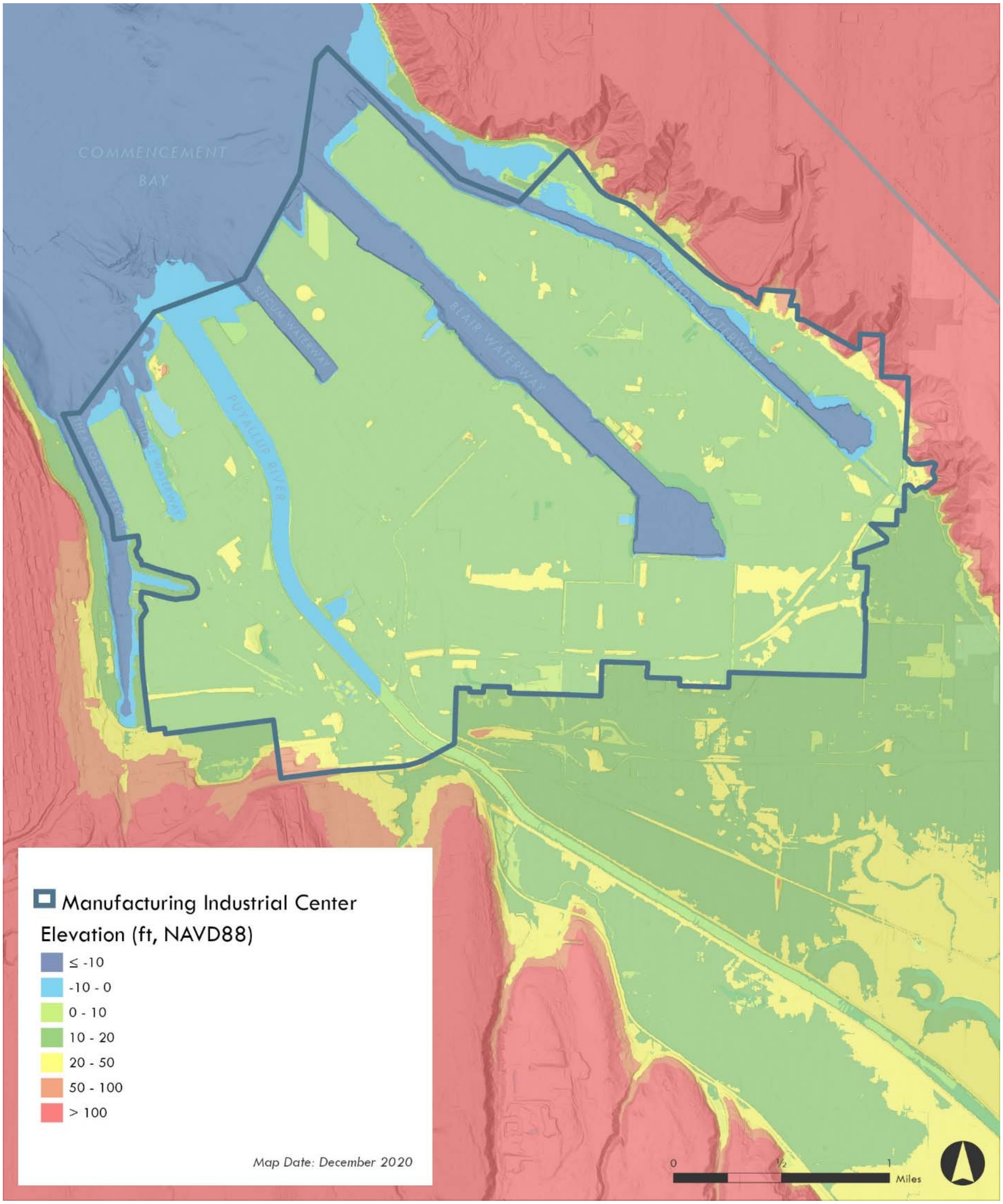
Much of the coastal shoreline within the study area has undergone significant structural alterations as a result of Port of Tacoma development, housing shipping terminals, heavy and light industrial use, and commercial use. Areas of the Thea Foss Waterway have also been developed as a mixed-use neighborhood. Approximately 70% of the shoreline now has some form of armoring, including concrete and wooden bulkheads as well as pile-supported over-water structures. Small areas of wetlands, mudflats, and intertidal habitat are also present on the border of select tidal zones and local waterways. These coastal protection structures have altered natural coastal processes over time by both increasing wave energy at the toe of armored areas and restricting sediment deposition from upland sources but have been effective at reducing erosion hazards within the study area. Landslide hazards are also limited directly within the study area, but slumping or slope failure along surrounding bluffs such as those bordering Marine View Dr may impact study area waterways and coastal environments.

Exhibit 1-2 Comparison of Historic and Present Shoreline Within Commencement Bay



Source: (U.S. Coast Survey, 1877)

Exhibit 1-3 Study Area Topography and Bathymetry



Source: USGS Coastal National Elevation Database (Danielson, et al., 2016)

1.1 Past Climate Vulnerability Assessments

Prior climate vulnerability assessments covering the study area include the 2016 Tacoma Climate Change Resilience Study (City of Tacoma, 2016) and the 2016 Climate Change Impact Assessment and Adaptation Options report (Puyallup Tribe of Indians, 2016). Each of these reports examined a number of climate drivers and potential future changes in the region including shifts in air temperature, precipitation patterns, flood events, temperature of local waterbodies, landslides, wind events, shifts in ocean chemistry, wildfires, and sea level rise (SLR). These studies examined impacts across environmental, social, and built systems, identifying potential next steps and adaptation approaches to mitigate potential impacts. Key findings for the Tideflats area from these studies include the following:

Infrastructure

- Wastewater systems such as the Central Wastewater Treatment Plant, pump stations, and gravity conveyances could experience impacts due to higher sea levels and increased Puyallup River flooding.
- Surface water infrastructure that is tidally influenced will experience backwater effects as sea level rises and increased flow rates due to increased precipitation. Pump stations may experience impacts under conservative SLR projections for 2100.
- Puyallup River levees will be exposed to increased flooding due to hydrologic changes, SLR, and sediment deposition. Impacts largely dependent on current levee freeboard and condition.
- Transportation infrastructure throughout the Tideflats area is exposed to SLR, with low elevation roads being highly vulnerable.

Natural Systems

- Marine ecosystems and intertidal habitats, which exist in narrow elevation ranges and rely on complex nearshore processes, are likely to experience impacts due to increased frequency and duration of inundation caused by SLR.
- Puyallup River is likely to experience impacts due to increases in contributing basin size, hydrology, and sediment load with potentially limited adaptation options due to history of alteration.

This Climate Vulnerability Assessment will build upon these findings by focusing specifically on relevant hazards and impacts within the study area and leveraging any updates to best available science on climate hazards.

2 DATA, ASSETS, RESOURCES

Information on available data, assets, and resources used to inform the Climate Vulnerability Assessment are listed in Exhibit 2-1. Jurisdiction boundaries and land use within the study area are illustrated in Exhibit 2-2. The study area is primarily defined by the Manufacturing Industrial Center that surrounds the Port of Tacoma. Industrial land use makes up the vast majority of the area, save for shoreline buffer areas and small areas of parks and open space. The Puyallup Reservation Boundary also passes across the study area, approximately covering the southeastern half of the Tideflats. The study area is surrounded by a mix of open space, residential, commercial, and regional growth centers.

Transportation resources are presented in Exhibit 2-3. Major highways within and surrounding the study area include I-5 and I-705. State Route 509 and its associated bikeway also run along the southern boundary of the study area. Railways and roadways are present throughout industrial areas along with trails along the Puyallup River and Thea Foss Waterway.

Environmental resources within the study area are detailed in Exhibit 2-4. Major hydrologic features within the Tideflats include the Puyallup River, coastal waterways, and their associated floodplains that make up the majority of the current 100-year floodplain boundary. Surrounding creeks that feed into these larger waterbodies include Hylebos Creek, Wapato Creek, and Clear Creek. Small wetland areas are also sparsely distributed throughout the study area, becoming more common just outside the northeast boundary of the Tideflats.

Infrastructure for water and power utilities is presented in Exhibits 2-5 to 2-7. Stormwater, water, and sewer infrastructure within the study area are presented in Exhibit 2-5 and Exhibit 2-6. Each of these water utility systems extend across the study area. Stormwater outfalls, including tide gates, are located along each of the waterways within the Tideflats along with a mix of pipes and ditch systems for conveyance. The sole sewer outfall within the study area is located offshore in Commencement Bay between the Sitcum Waterway and the Blair Waterway. Sewer conveyance infrastructure largely runs alongside water infrastructure save for the pipes leading to this outfall. The Central Wastewater Treatment Plant is located in the southwestern portion of the Tideflats. Water pump systems are located in the northeastern corner of the study area along the Hylebos Waterway. Power utility infrastructure, presented in Exhibit 2-7, also extends across the study area, with substations and generators concentrated in areas east of the Puyallup River.

Tribal assets within the study area are presented in Exhibit 2-8. Ecological resources include the Gog-le-hi-te wetlands, a brackish wetland environment along the Puyallup River, and the Place of Circling waters, another brackish wetland environment within the Hylebos Watershed. Cultural sites include the Puyallup Tribal Ceremonial Grounds and dxʷɬalilali, also known as “a place to come ashore”. Tribal facilities within the study area include the Riverboat Property, the Chinook Marina and Shellfish Department, and the Youngsville Tribal Community.

Exhibit 2-1 Inventory of Data Layers Used in the Climate Vulnerability Assessment

Type	Data Layer	Source
Boundaries	City Boundaries	Pierce County GIS Database
	County Boundaries	Washington DNR GIS Database
	Port Parcel Boundaries	Port of Tacoma GIS
	Port Terminals	Port of Tacoma GIS
	Public Access Areas	Port of Tacoma GIS
	Tacoma Land Use Zones	Tacoma GIS Database
	Puyallup Reservation Boundary	Washington Geospatial Open Data Portal
	Manufacturing Industrial Center	Map Template (Tacoma GIS Database)
Transportation	Highways and Roadways	Map Template (Pierce County GIS)
	Railways	Map Template
	Bikeways	Tacoma GIS Database
	Trails	Tacoma GIS Database
	Healthcare Facility	MN Digitization Based on Google Maps Data
Environmental	Waterbodies	USGS National Hydrography Dataset
	Creeks and Channels	Pierce County GIS Database
	Wetlands	Port of Tacoma GIS
	Vegetation Management Areas	Port of Tacoma GIS
	100-Year Floodplain Boundary	FEMA National Flood Hazard Layer
	Puyallup River Levees	MN Digitization Based on 2019 Pierce County HIRA
Utilities Infrastructure	Stormwater Lines	Port of Tacoma GIS
	Stormwater Outfalls, including Tide Gates	Port of Tacoma GIS
	Stormwater Treatment Systems	Port of Tacoma GIS
	Wastewater Lines	Port of Tacoma GIS
	Wastewater Outfalls	Port of Tacoma GIS
	Wastewater Treatment Plant	M&N Digitization Based on Google Maps Data
	Water Lines	Port of Tacoma GIS
	Water Pumps	Port of Tacoma GIS
	Power Lines	Port of Tacoma GIS
	Power Generators	Port of Tacoma GIS
	Power Substations	Port of Tacoma GIS
Tribal	Tribal Ecological Resources	Tribal Staff
	Tribal Cultural Sites	Tribal Staff
	Tribal Facilities	Tribal Staff

Exhibit 2-2 Jurisdictional Boundaries and Land Use within the Study Area

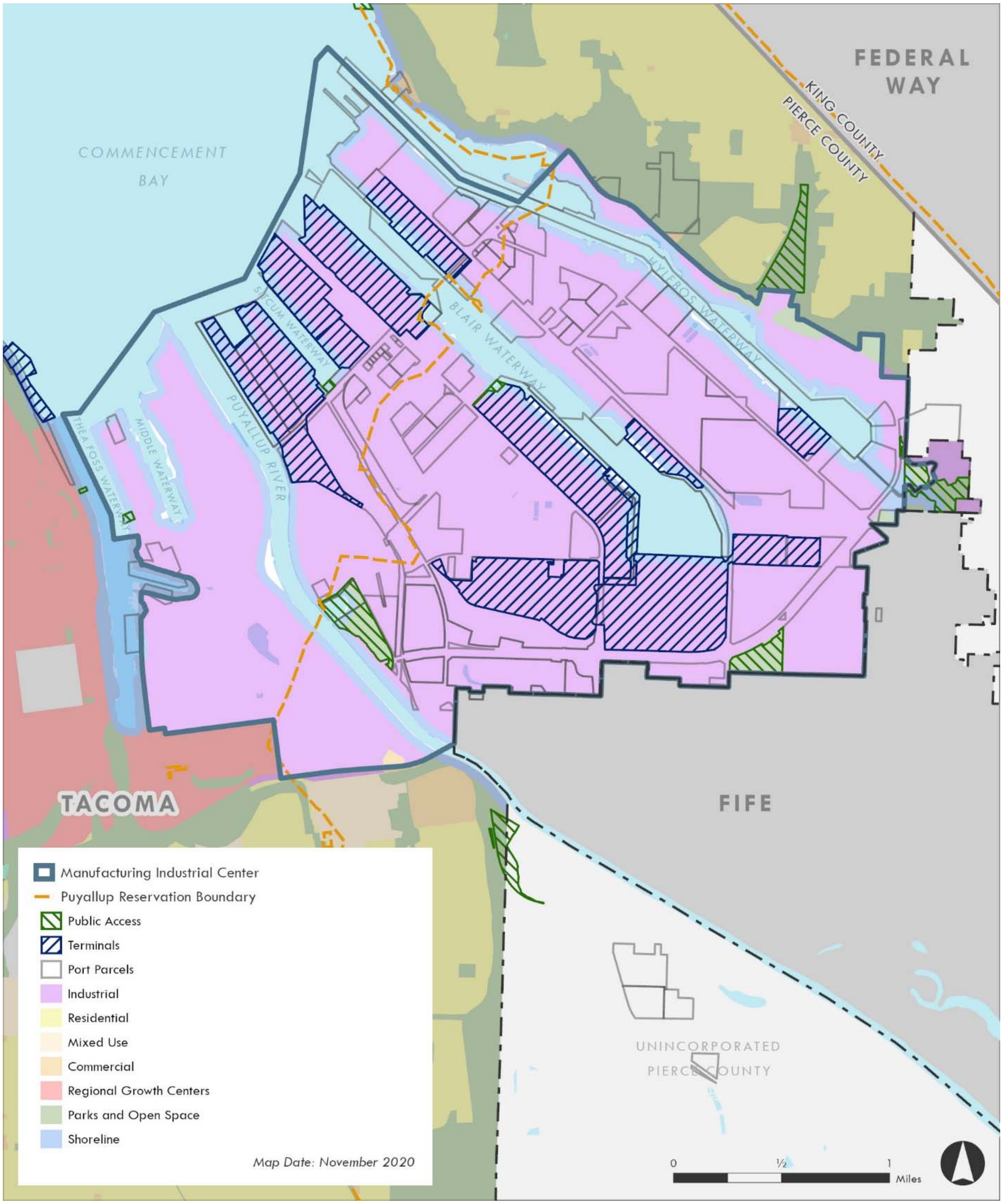


Exhibit 2-3 Transportation Assets within the Study Area

Exhibit 2-4 Environmental Resources within the Study Area

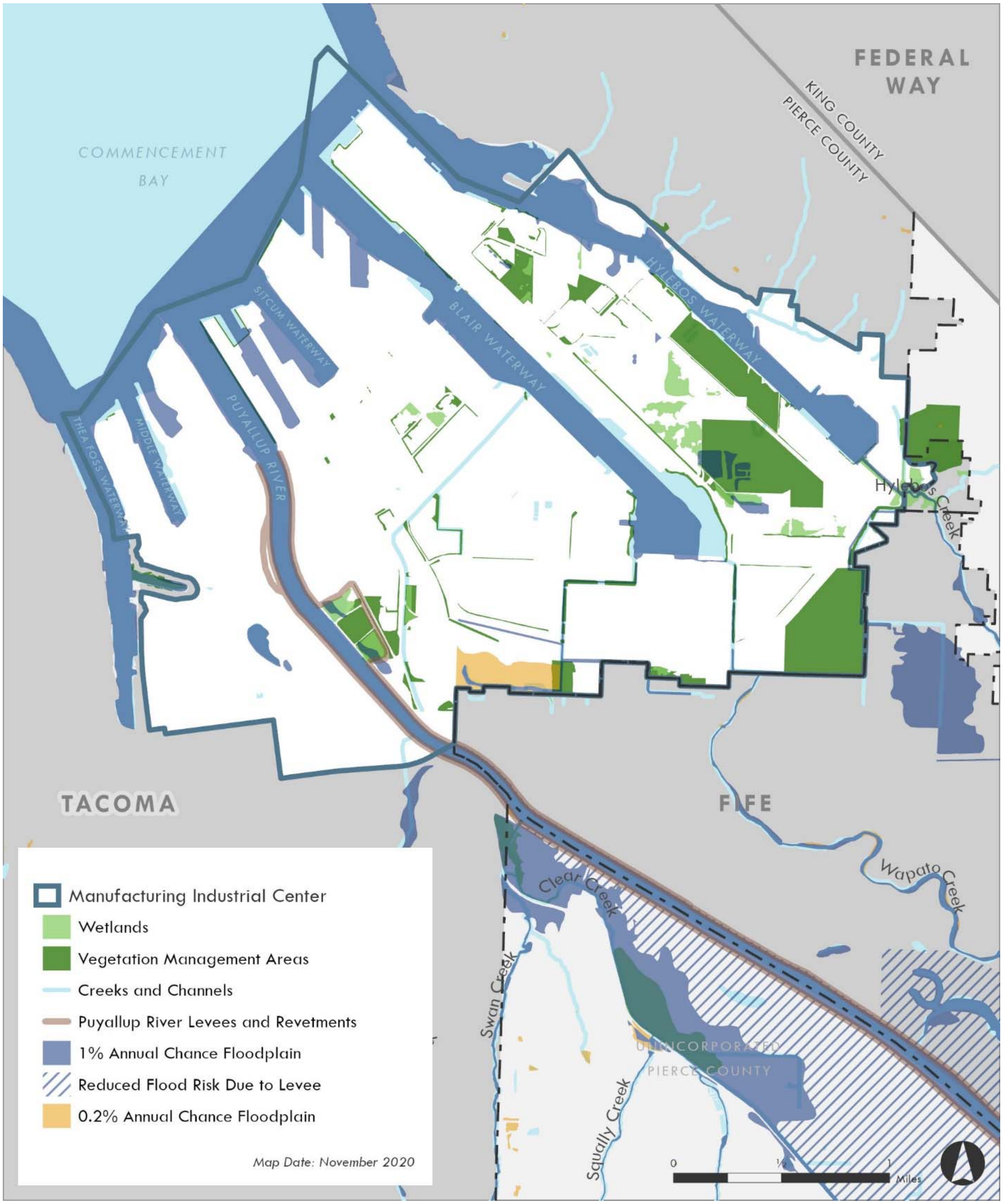


Exhibit 2-5 Stormwater Resources within the Study Area

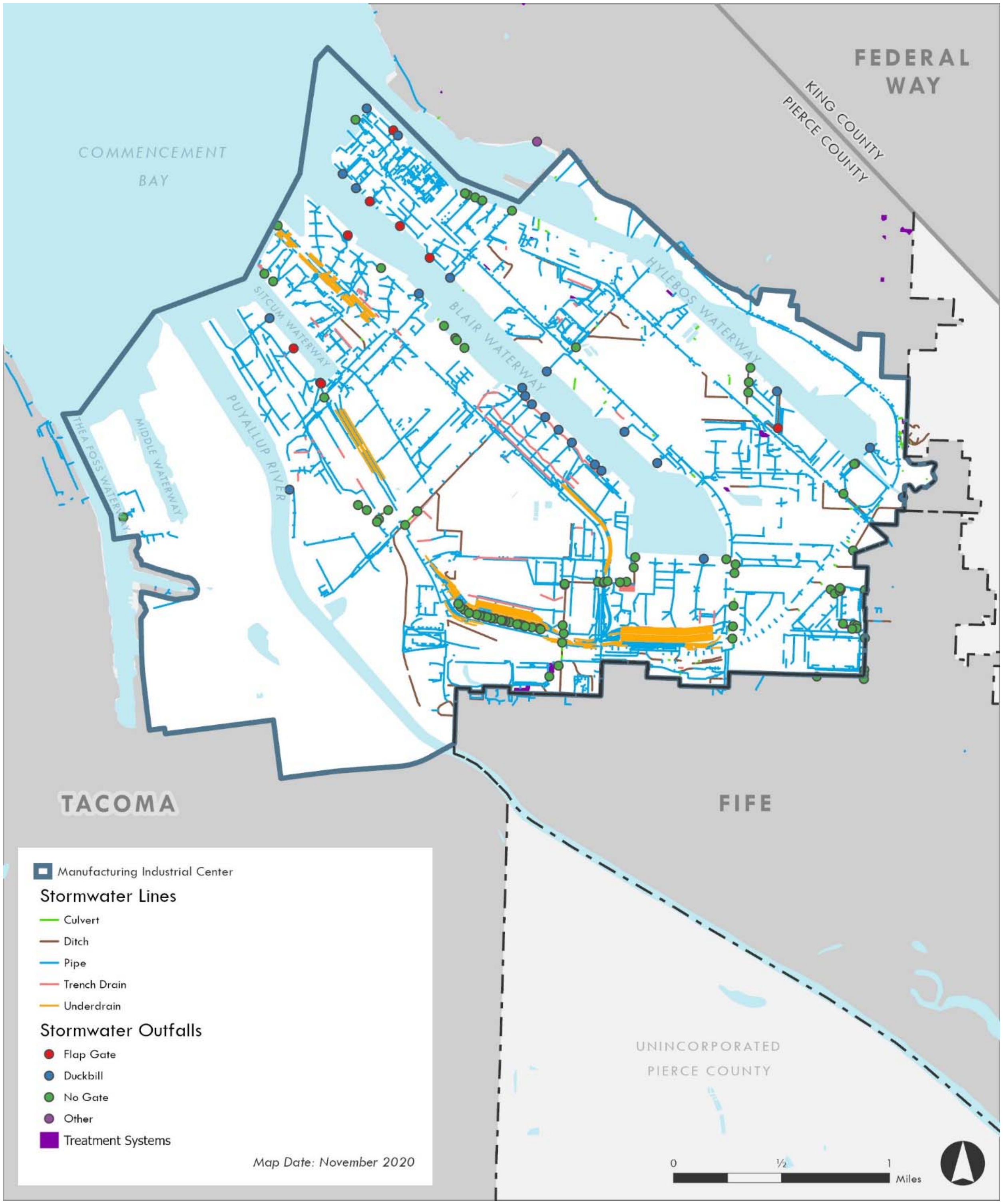


Exhibit 2-6 Sewer and Water Resources within the Study Area

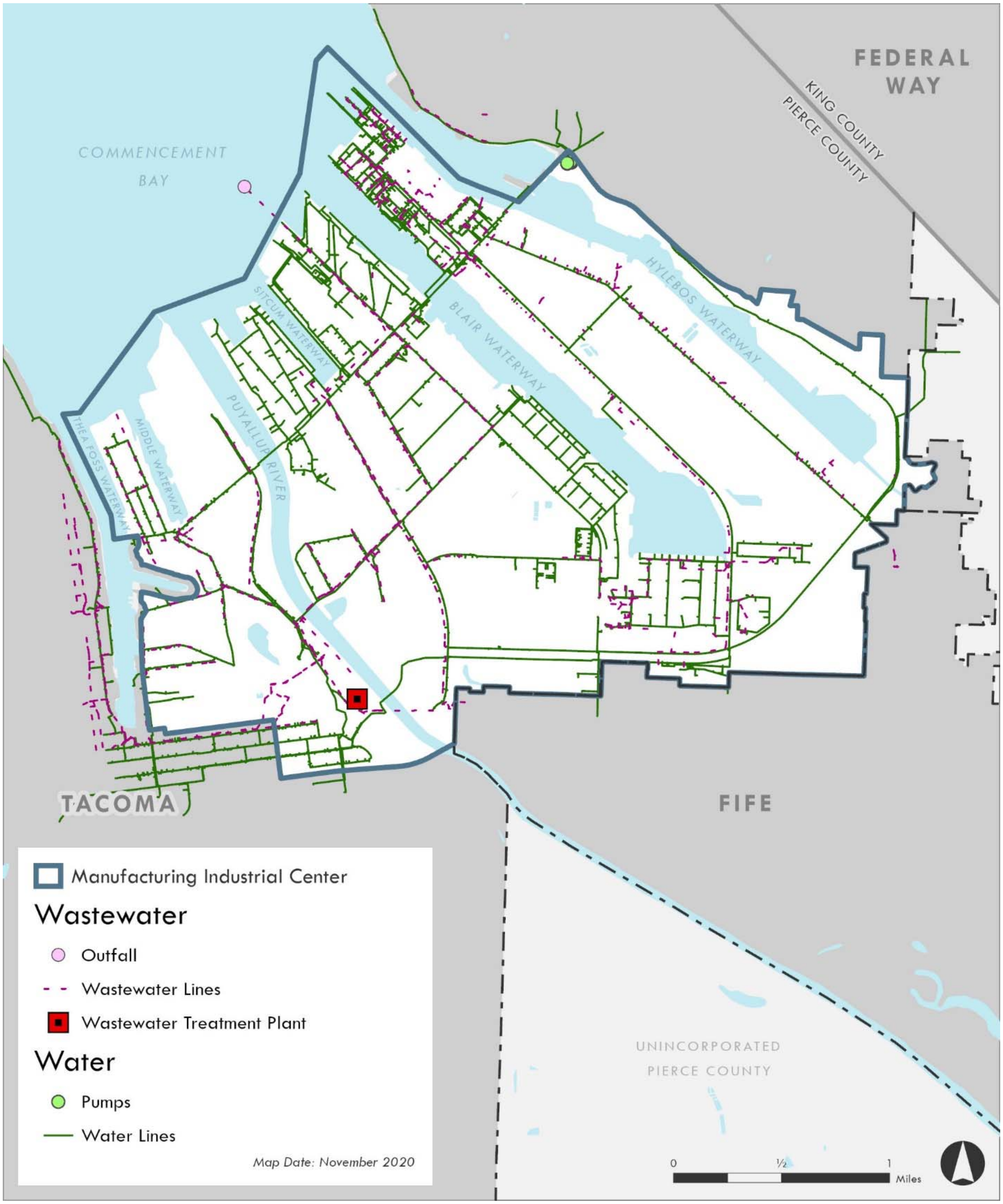


Exhibit 2-7 Power Utility Resources within the Study Area

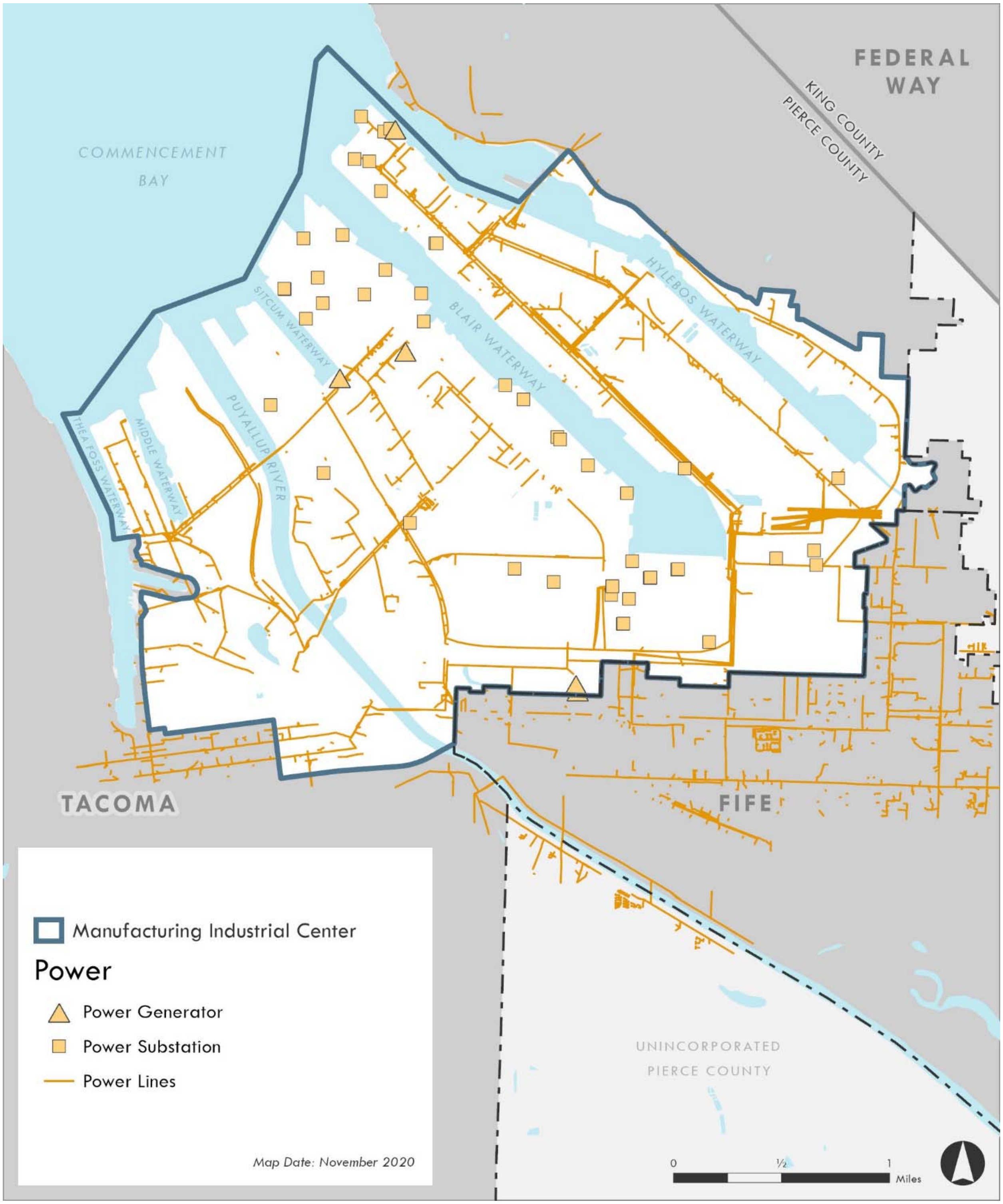
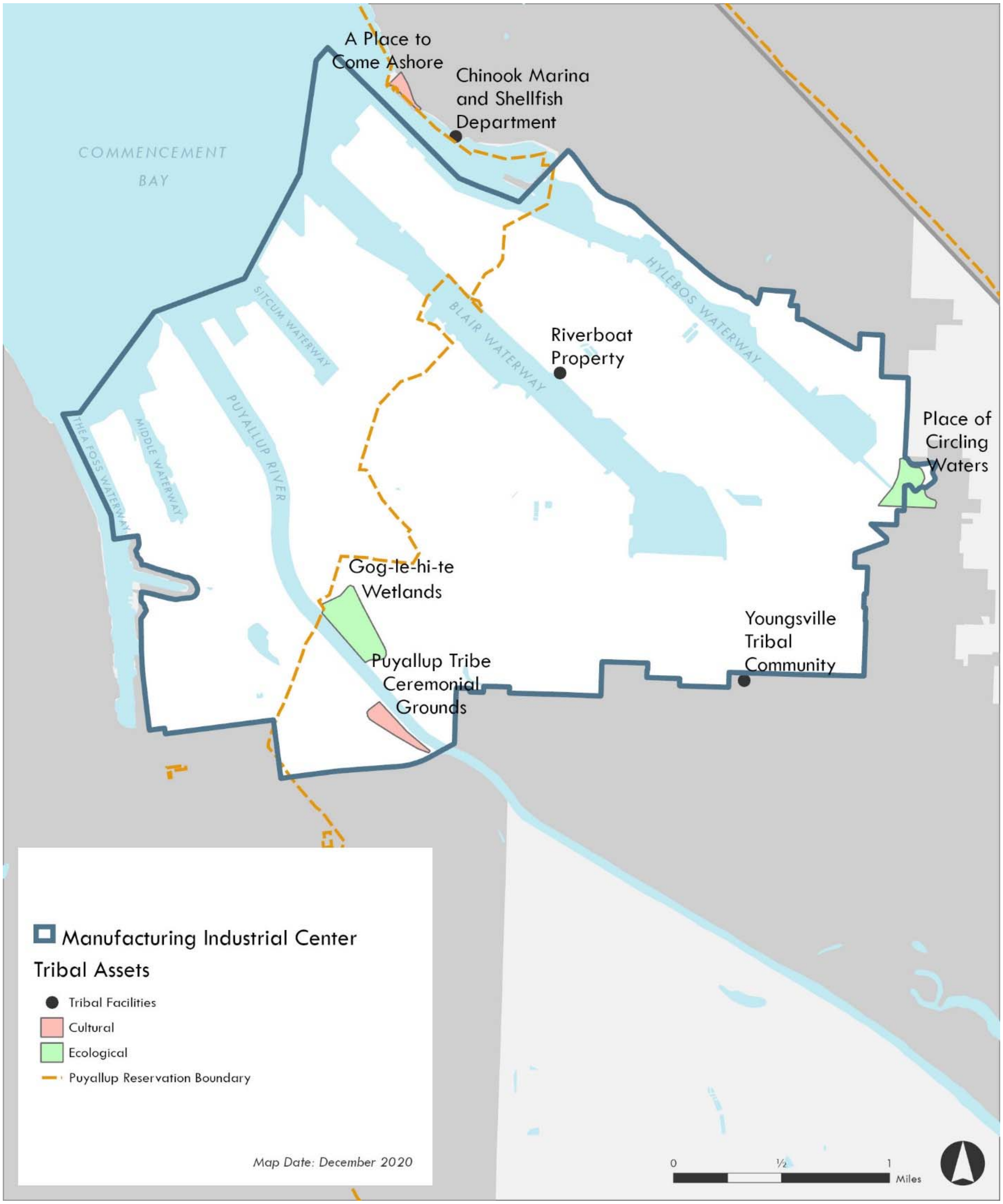


Exhibit 2-8 Tribal Assets within the Study Area



3 NATURAL HAZARDS

Resources and infrastructure within the Tacoma Tideflats are exposed to a variety of natural hazards due to the relatively low elevation of the area and proximity to the shoreline. Based on previous climate vulnerability assessments, three primary hazards were identified as the focus of this study: coastal flooding, fluvial flooding, and landslides. Within this section each of these hazards is described both in terms of current conditions and potential futures changes due to climate drivers such as shifts in air temperature, precipitation patterns, and sea level rise.

3.1 Coastal Flooding

Current Conditions

Coastal flooding within the study area is a product of both tidal water elevations and wave action. Tides within Puget Sound are semidiurnal, characterized by two low waters and two high waters each lunar day, an approximately 25-hour time period. The National Oceanographic and Atmospheric Administration (NOAA) operates tide stations throughout the Sound and the larger Washington shoreline. The Tacoma, WA tide station (Station 9446484), located within Commencement Bay, provides water level data within the study area dating back to 1996. Data from this station represents the most relevant source of water level information for the study and can be used to characterize variability in existing water levels, illustrated in Exhibit 3-1.

Astronomical tides account for the most significant amount of variability in the total water level. Typical daily tides range from mean lower low water (MLLW) to mean higher high water (MHHW), a tidal range of about 11.8 feet (ft). During spring tides, which occur twice per lunar month, the tide range increases further due to the additive gravitational forces caused by alignment of the sun and moon. During neap tides, which also occur twice per lunar month, the forces of the sun and moon partially cancel out, resulting in a smaller tide range. The largest spring tides of the year, which occur in the winter and summer, are sometimes referred to as "King" tides and can result in high tides that are approximately 1.5 ft higher than normal MHHW levels.

Ocean water levels typically vary within predictable ranges; however, it is not uncommon to experience sea level anomalies, such as El Niño, that can significantly increase the predicted water level above the normally occurring astronomical tide. These events can increase the predicted tides over the course of several days to several months. Storm surge from events such as extratropical cyclones can also affect water levels within Puget Sound. The strong winds and low atmospheric pressure caused by storms can increase water levels by as much as 2.6 ft (0.8 m) in Commencement Bay (Yang, Wang, & Castrucci, 2019).

Exhibit 3-1 Tidal Datums for NOAA Station 9446484 in Tacoma, WA

Datum	Description	Value (ft, NAVD88)
MHHW	Mean Higher-High Water	9.39
MHW	Mean High Water	8.51
MTL	Mean Tide Level	4.48
MSL	Mean Sea Level	4.45
DTL	Mean Diurnal Tide Level	3.50
MLW	Mean Low Water	0.45
MLLW	Mean Lower-Low Water	-2.39
NAVD88	North American Vertical Datum of 1988	0.00
MN	Mean Range of Tide	8.06
GT	Great Diurnal Range	11.77
Max Tide	Highest Observed Tide	12.48
Max Tide Date and Time	Highest Observed Tide Date and Time	12/17/2012 16:12
Min Tide	Lowest Observed Tide	-7.12
Min Tide Date and Time	Lowest Observed Tide Date and Time	11/26/2007 07:06

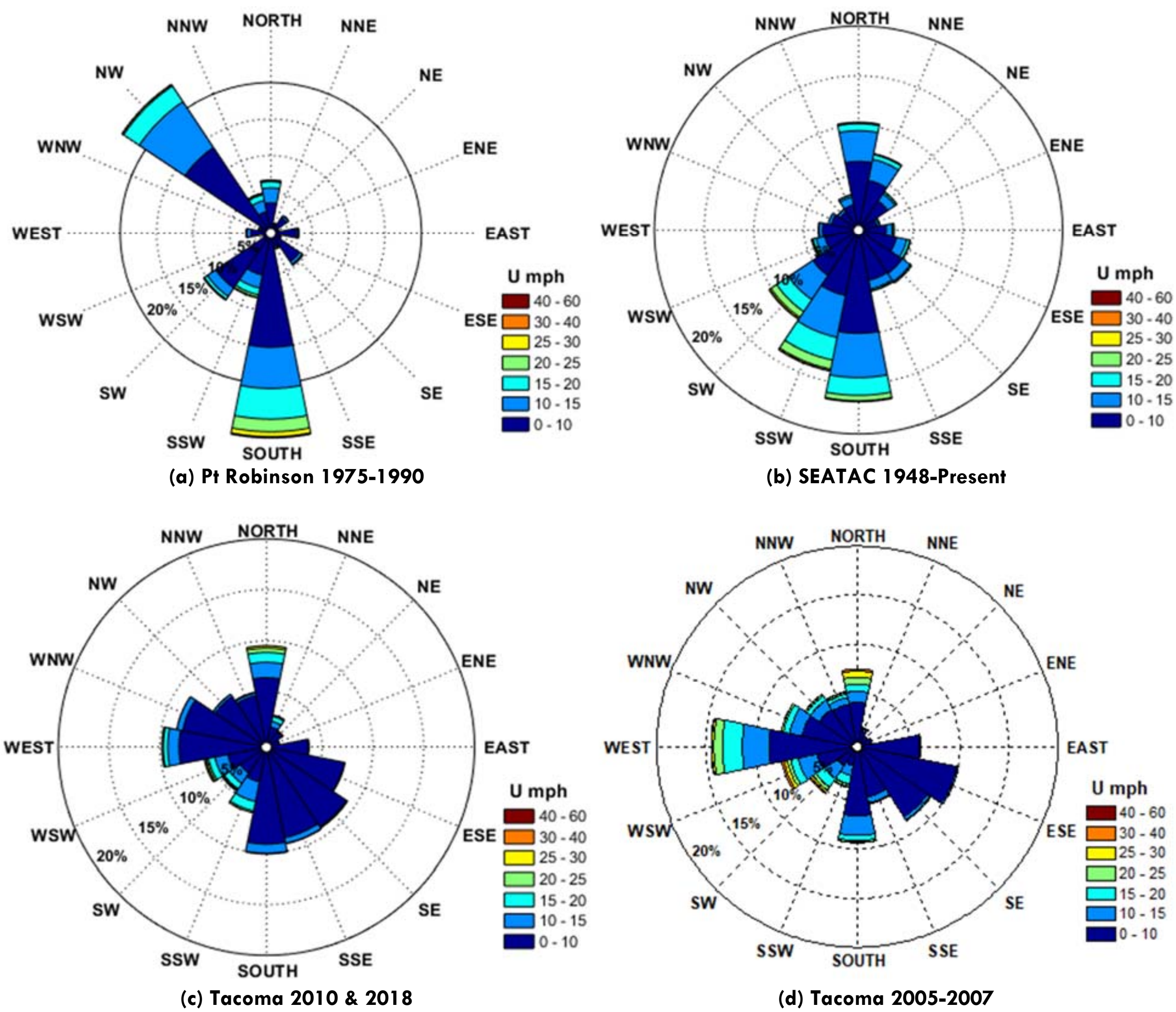
Source: NOAA Center for Operational Oceanographic Products and Services https://tidesandcurrents.noaa.gov

The study area is sheltered from open ocean wave energy due to its location on the interior of Commencement Bay. The primary sources of wave energy at the study site are locally generated wind waves and boat wake. Wave energy generated within Commencement Bay has the potential to increase water levels along the shoreline due to wave runup, the upward surge of wave energy that occurs as waves reach the shoreline.

Wind waves present the most significant source of wave energy along the study site and have the potential to increase water levels along exposed segments of the shoreline during strong wind events. Wind wave heights within the study area depend on both the wind direction and fetch length relative to the study site. Average annual local wind speed and direction data measured at nearby meteorological stations is presented in Exhibit 3-2, showing a dominant southerly wind direction that is unlikely to impact the study area. The Browns Point headland protects the majority of the study area from northerly wind-driven waves. Winds from the northwest, which would most directly impact the study area, are among the least frequent, and are further limited by relatively small 5-mile fetch distance across the bay.

Though wind wave energy may be limited within the study area, potential impacts still warrant consideration. Exposure to wind wave energy is not uniform throughout the study area and will depend on factors such as shoreline orientation and the presence of coastal protection structures. Segments of the shoreline oriented towards the northwest would be exposed to more wind wave energy, while the interior of waterways such as the Blair Waterway would experience diminished wave impacts. The majority of the shoreline within the study area is also exposed to wakes generated by boating activity, as large vessels frequently enter and exit the study area as part of Port activities. Passing vessel waves are a function of water depth, vessel size, speed, and distance from the source.

Exhibit 3-2 Wind Speed and Direction for nearby Meteorological Stations



Source: NOAA National Center for Environmental Information https://gis.ncdc.noaa.gov/maps/ncei/

Future Projections

Prior Climate Vulnerability Assessments relied on a National Research Council (NRC) report (National Research Council, 2012) for SLR projections across different emissions scenarios utilizing the upper end of the projections presented in Exhibit 3-3. SLR science remains an evolving field as our understanding of climate processes improves, and projections are periodically updated to reflect improvements in global, national, and regional modeling efforts.

The current best-available SLR science for the State of Washington is based on a recent University of Washington (UW) Climate Impacts Group Report (Miller, et al., 2018). All SLR projections within this study are based on projections for the Commencement Bay area under the high-emissions Representative Concentration Pathways (RCPs) 'RCP8.5' global warming scenario, which is based on a high, "business as usual" carbon emissions future. The high-emissions projections are recommended for use in climate resilience planning based on current emissions trends.

The UW SLR Guidance provides multiple probabilistic SLR projections for a given time horizon, ranging from lower, less conservative values (high probability) to higher, more conservative values (low probability). Projections are presented in terms of relative sea level rise (RSLR), incorporating both the projected increase in water elevation and projected vertical land movement (VLM) within the study area. These RSLR projections and associated exceedance probabilities from 2030 to 2100 are presented in Exhibit 3-4. Within this study these probabilistic projections are intended to inform a decision-making process rather than assign an estimate of the exact rate or timing of RSLR based on an individual scenario or projection, allowing for the use of different RSLR projections based on both design life and acceptable levels of risk tolerance for various resources and infrastructure within the study area.

Exhibit 3-3 NRC 2012 SLR Projections for Washington, Oregon, and Northern California

Year	Sea Level Rise Projection Range (Inches)
2030	-2 to +9
2050	-1 to +19
2100	+4 to +56

Source: (National Research Council, 2012)

Exhibit 3-4 Projected RSLR Magnitudes (ft) and Associated Probabilities For Each Time Horizon

Time Period	83% - 17%	50%	10%	5%	1%	0.1%
2030	0.3 – 0.6	0.5	0.6	0.7	0.7	0.9
2040	0.5 – 0.8	0.7	0.9	1.0	1.1	1.5
2050	0.7 – 1.2	0.9	1.2	1.4	1.6	2.2
2060	0.9 – 1.5	1.2	1.6	1.7	2.1	3.2
2070	1.1 – 1.9	1.5	2.0	2.2	2.8	4.4
2080	1.4 – 2.3	1.8	2.5	2.8	3.5	5.7
2090	1.6 – 2.8	2.1	3.0	3.3	4.3	7.1
2100	1.9 – 3.3	2.5	3.6	4.0	5.3	8.8

Source: (Miller, et al., 2018)

3.2 Fluvial Flooding

Fluvial flood hazards occur when flood waters overtop a river's channel bank or flood control structure, such as a levee, and extend into the surrounding floodplain. The primary fluvial flood hazard within the study area occurs along the lower Puyallup River as it passes through the study area and empties into Commencement Bay. Although levees have been constructed along the banks of the lower Puyallup River, flood hazards remain due to the potential for overtopping, breaching, or other events that would result in partial or complete failure of the levee system.

Current Conditions

The full extent of the Puyallup River watershed drains approximately 1,040 square miles, flowing from Mount Rainier glaciers to Commencement Bay. The lower portion of the river, which extends from Commencement Bay upstream to the confluence with the White River, has been straightened over time with a combination of levees and revetments for flood control purposes. Mud Mountain Dam, located upstream on the White River tributary, provides additional flood control for the lower portions of the Puyallup River by storing up to 106,000 acre-feet of water (Pierce County Emergency Management, 2019b).

The lower Puyallup River experienced major flood events in 1917, 1933, 1965, 1977, 1986, 1990, 1996, 2006, and 2009. The largest flood on record since construction of the Mud Mountain Dam was associated with a river flow of 48,200 cubic feet per second (cfs) (Exhibit 3-5). This 2009 flood event was approximately equivalent to a 100-year event in the lower Puyallup River based on current flood frequency flow estimates (Pierce County Emergency Management, 2019b). Moderate flooding also occurred along the lower Puyallup in November 2014 and October, November, and December 2015. Current calculations for the 10-year, 50-year, 100-year, and 500-year recurrence interval flood events are 41,000, 46,000, 48,000, and 63,000 cfs, respectively. Any flows in excess of 45,000 cfs on the lower Puyallup River are considered severe, with significant flooding expected (Pierce County Emergency Management, 2019b).

Exhibit 3-5 Historic Flood Events in the Lower Puyallup River at USGS 12101500 Puyallup River at Puyallup, WA

Water Year	Date	Stream Flow (cfs)
1934	December 10, 1933	57,000
2009	January 8, 2009	48,200*
1996	February 9. 1996	46,700*
1990	January 9, 1990	44,800*
1987	November 24, 1986	43,800*
1991	November 24, 1990	41,900*

1965	January 29, 1965	41,500*
1978	December 2, 1977	40,600*
1918	December 18, 1917	40,500
2016	December 9, 2015	39,800*
2007	November 7, 2006	39,700*
1935	October 25, 1934	39,500
1933	November 13, 1932	37,800
1956	December 12, 1955	37,600*
1984	January 25, 1984	37,100*

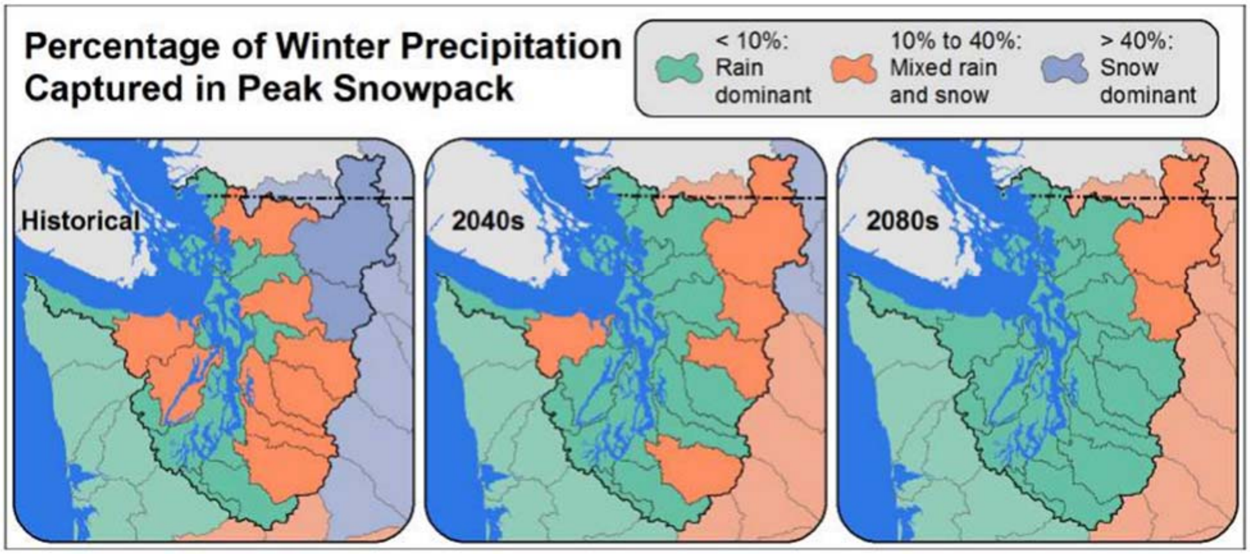
Source: (Pierce County Emergency Management, 2019b)
*Post Mud Mountain Dam

While a history of flooding exists along the Lower Puyallup River, flood hazards have yet to become widespread within the study area. Flood exposure under the 1% annual chance (100-year) flood event is limited to select low-lying areas primarily due to the protection provided by the Puyallup River levee and revetment system (Exhibit 2-4). The primary asset at risk within the existing 1% annual chance floodplain is the Central Wastewater Treatment Plant (Exhibit 2-6). A capital improvement project was undertaken to address this risk, involving construction of a floodwall around the plant and installation of an emergency pump station inside the plant, completed in 2015 (Pierce County Public Works and Utilities, 2018).

Future Projections

Future changes in fluvial flood patterns within the Puyallup watershed are influenced by a number of factors, including projections of decreased snowpack, ongoing shifts in precipitation from snow to rain, earlier streamflow timing, and increases in extreme precipitation events and extreme streamflow events (Mauger, et al., 2015). Projected snowpack decline is driven by warming air temperatures in the region, causing snow to both accumulate less in winter and melt more rapidly in spring and summer. Snowpack in the region is projected to decline by as much as 55% by 2080 under a high greenhouse gas emissions scenario (Mauger, et al., 2015; Hamlet, et al., 2013). This shift to rain-dominant watersheds over time is illustrated in Exhibit 3-6. Increased precipitation within reginal watersheds is projected to cause increased streamflow volumes in winter and decreases in spring and summer. Only slight changes in total streamflow are projected, with peak streamflow occurring two to six weeks earlier on average across the region (Mauger, et al., 2015; Hamlet, et al., 2013).

Exhibit 3-6 Shifts to Rain-Dominant Conditions in Puget Sound Watersheds



Source: (Mauger, et al., 2015; Hamlet, et al., 2013)

Total annual precipitation within the Pacific Northwest is projected to increase slightly as a result of climate change in the region. An increase in year-to-year variability of total precipitation is also projected (Rupp, Abatzoglou, & Mote, 2016). Projected increases in precipitation for the Puget Sound region are primarily seen in fall, winter, and spring months, with projected increases by 2050 ranging from +2% to +11% on average (Mauger, et al., 2015). Though total annual precipitation is projected to increase, summer precipitation is projected to decline for the Puget Sound region. Climate models project a decline in summer precipitation of 22% on average (Mauger, et al., 2015).

In addition to changes in annual and seasonal precipitation patterns, extreme rainfall events are projected to become more common in the region (Kossin, et al., 2017). This increase in extreme rainfall events is largely driven by a projected increase in the frequency and intensity of "atmospheric rivers," narrow streams of moisture transport that occur within and across midlatitudes and account for 30%-40% of annual precipitation along the U.S. West Coast. A visualization of this phenomenon is provided in Exhibit 3-8. Recent modeling efforts have quantified these potential changes in short-duration precipitation events within the Puget Sound Region (Mauger, et al., 2018). These results are summarized in Exhibit 3-7.

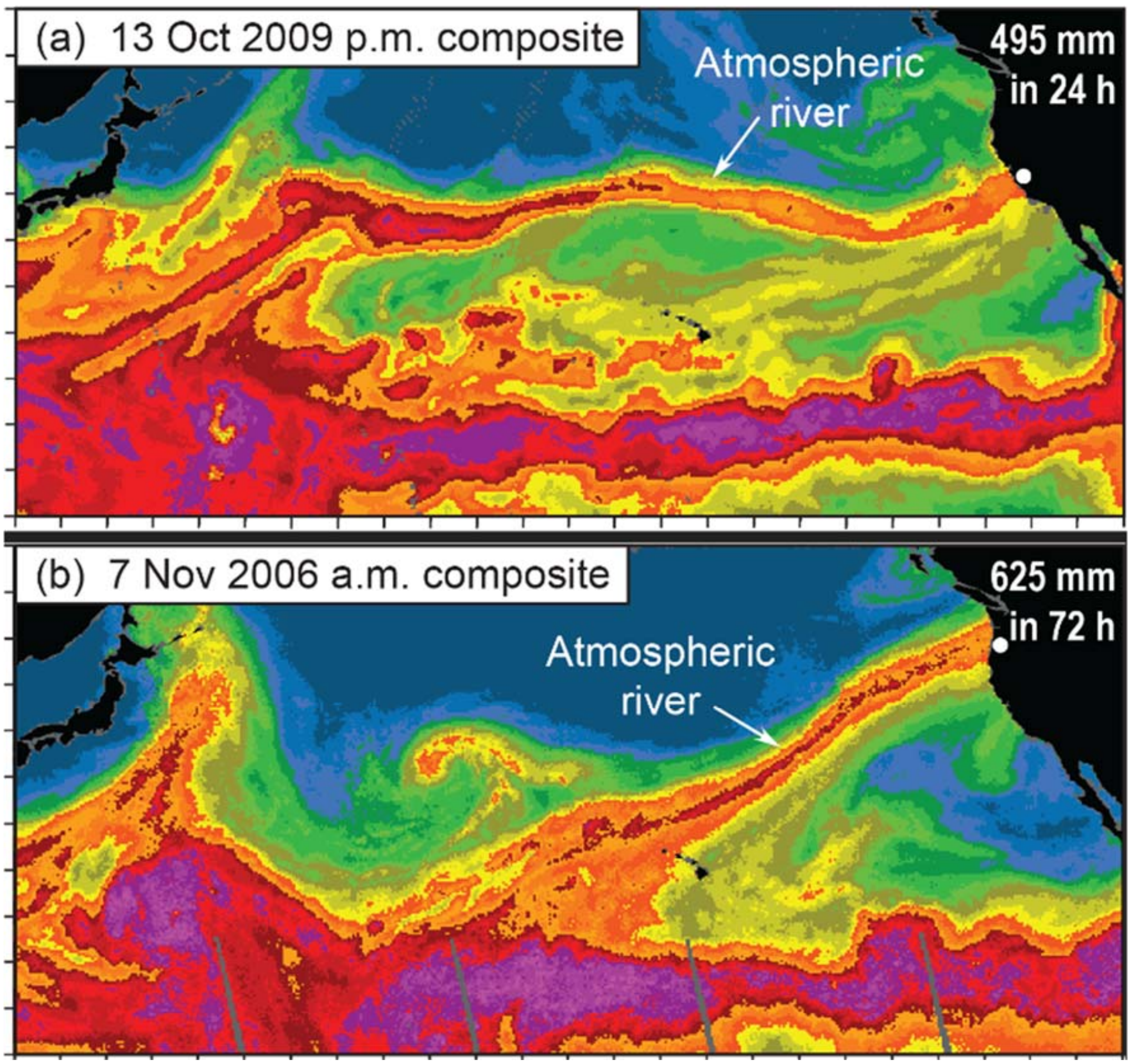
Exhibit 3-7 Projected Changes in 1-Hour Precipitation Statistics for the Seattle/Tacoma Rain Gauge for the 2080s Relative to 1970-1999

Precipitation Event	Annual	Winter	Spring	Summer	Fall
2-Year	+32%	+32%	+8%	-4%	+49%
5-Year	+35%	+42%	+10%	+6%	+65%

Precipitation Event	Annual	Winter	Spring	Summer	Fall
10-Year	+41%	+48%	+10%	+9%	+70%
25-Year	+53%	+57%	+11%	+10%	+73%
50-Year	+65%	+64%	+12%	+9%	+73%
100-Year	+80%	+70%	+12%	+8%	+72%
Total Annual	+6%	+18%	+15%	-45%	+7%

Source: (Mauger, et al., 2018)

Exhibit 3-8 Example of an Atmospheric River Transporting Moisture to the U.S. West Coast



Source: (Kossin, et al., 2017)

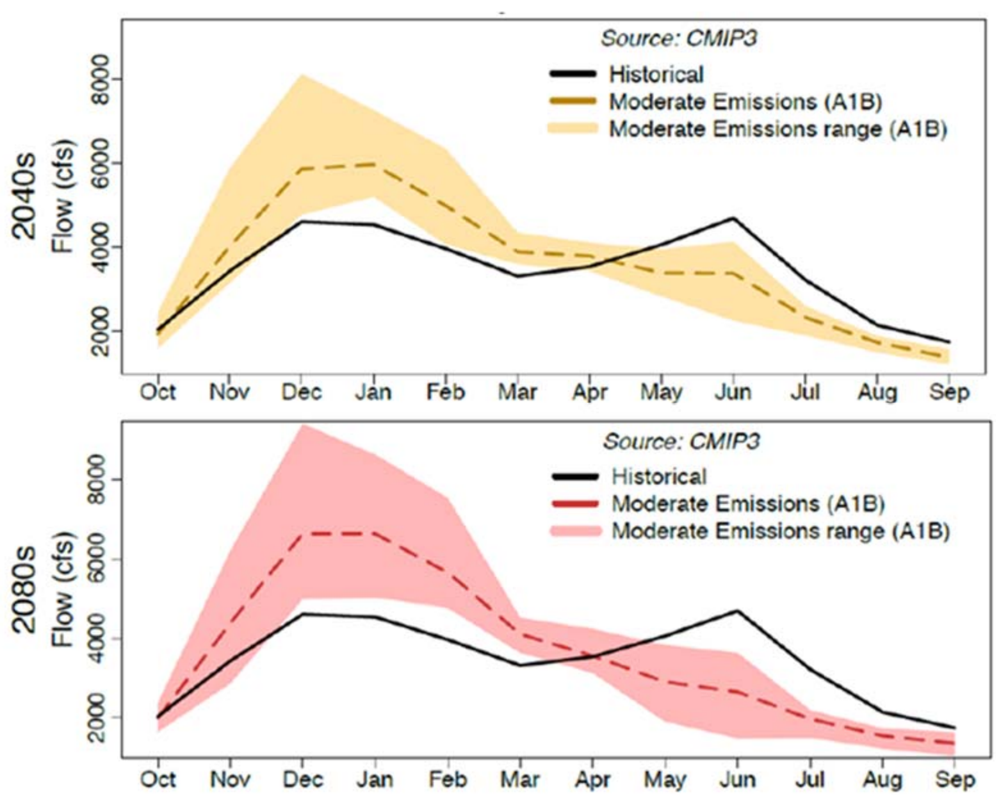
Snowpack decline and increases in extreme rainfall events are projected to contribute to shifts in streamflow timing and increases in flood risk within the Puyallup watershed. Even without accounting for increases in heavy rainfall or SLR, peak river flows are projected to increase by 18% to 55% across the region by 2080 due to expansion of drainage basins with snowpack decline (Mauger, et al., 2015). Shifts in flood and streamflow conditions for the Puyallup River are summarized in Exhibit 3-9 and illustrated in Exhibit 3-10. SLR and extreme precipitation events are likely to further exacerbate these impacts, especially in areas such as the Tideflats where higher tides will make it more difficult for flood waters to drain into Commencement Bay.

Exhibit 3-9 Projected Changes in Streamflow for the Puyallup River by 2080 Under a Moderate Greenhouse Gas Emissions Scenario

Watershed Impact	Projected Change for Puyallup River
Peak Streamflow Timing	-18 Days (-30 Days to -9 Days)
100-Year Event Streamflow	+37% (+10% to +88%)
Summer Minimum Streamflow	-27% (-39% to -16%)

Source: (Mauger, et al., 2015; Hamlet, et al., 2013)

Exhibit 3-10 Projected Shifts in Monthly Streamflow for the Puyallup River



Source: (Pierce County Emergency Management, 2019a)

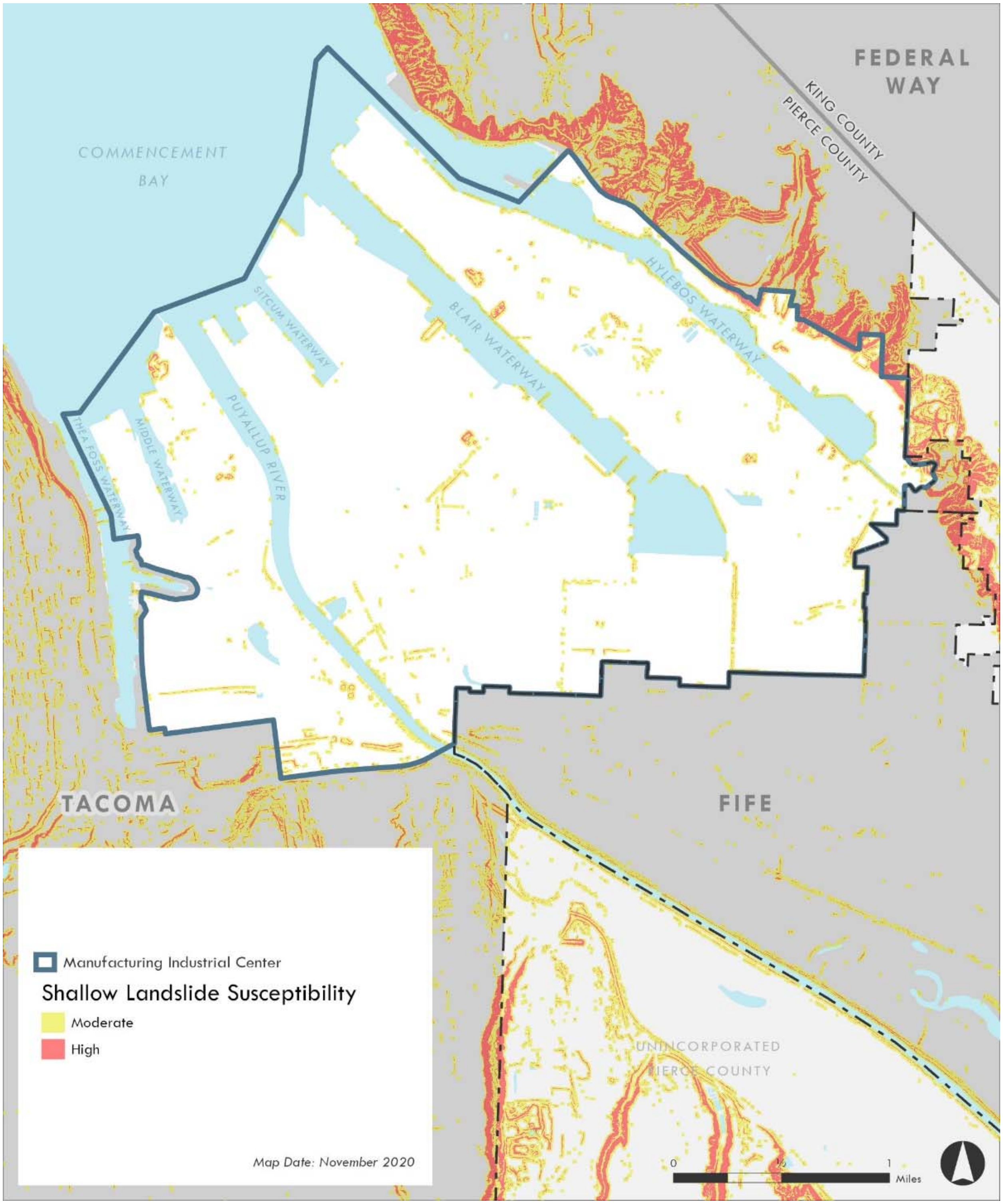
3.3 Landslides

Landslides occur when the weight of a mass of rock, soil, and vegetation becomes greater than the holding strength of soil along a slope. Landslide risk can be influenced by a number of factors, including soil compositions, slope steepness, precipitation patterns, and land use. Shallow landslides, the most common form of landslide hazard, are typically associated with short, intense rain events that destabilize the soil surface. Shallow landslides can also occur along steep marine bluffs, often in areas where vegetation has been removed (Pierce County Emergency Management, 2019c). Slower-moving, deep landslides are larger in scale, usually a result of reactivations of pre-historic failures after high levels of precipitation over the course of months to years.

Current Conditions

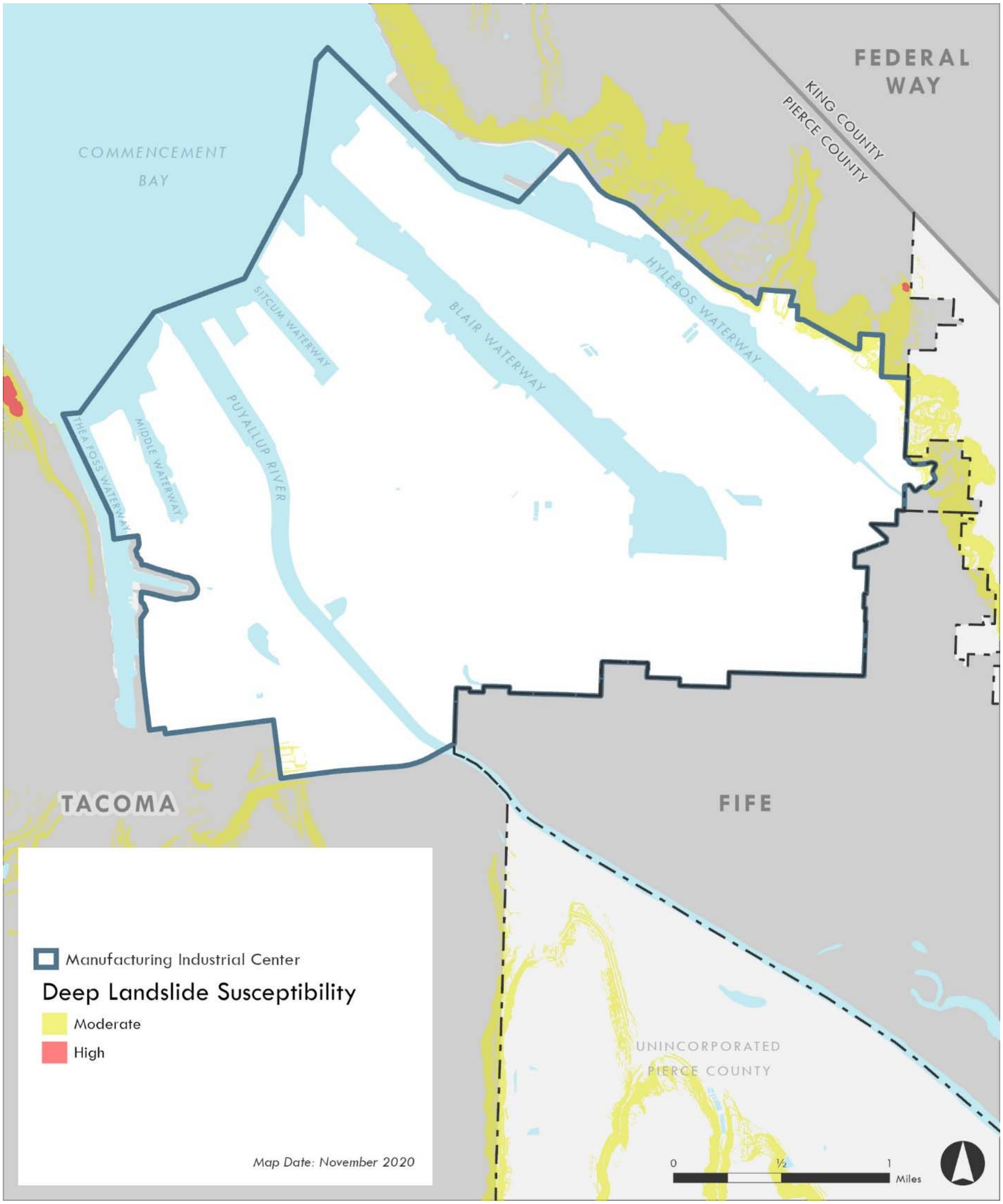
Areas currently susceptible to shallow and deep landslides within and surrounding the Tideflats are illustrated in Exhibit 3-11 and Exhibit 3-12, respectively.

Exhibit 3-11 Shallow Landslide Susceptibility Within and Surrounding the Tideflats Area



Source: Washington Department of Natural Resources Landslide Inventory Mapping, Pierce County 2017

Exhibit 3-12 Deep Landslide Susceptibility Within and Surrounding the Tideflats Area



Source: Washington Department of Natural Resources Landslide Inventory Mapping, Pierce County 2017

Future Projections

Increased air temperature, frequency and intensity of extreme precipitation events, and RSLR can all potentially influence landslide hazards within the study area (Mauger, et al., 2015). Temperature increases can increase rates of soil breakdown and also increase the potential for wildfires that can increase rates of erosion and sediment transport. Heavy rains can have a similar impact, increasing soil water content and making landslides more likely. RSLR can also increase rates of erosion within coastal areas. While these climate-related factors may influence future landslide hazards within the study area, there is limited information on regional trends in landslide hazards, especially in relation to climate change (Mauger, et al., 2015).

Thus, while projections for other climate drivers such as precipitation and RSLR indicate a likely increase in landslide hazards, a quantitative projection is less clear and will likely be heavily influenced by changes in land use patterns within the study area over time. Increased landslide hazards are also most likely to be seen in areas where landslides are currently a hazard, potentially impacting coastal habitats and wetlands located within the study area.

4 HAZARD ANALYSIS – COASTAL FLOODING

4.1 Methodology

Future coastal flood hazards driven by rising sea levels were evaluated under a daily high tide condition (MHHW) across five RSLR projection scenarios ranging from 1ft to 5ft, with and without an extreme (1% annual chance exceedance) riverine flow. The potential timing of these projection scenarios are listed in Exhibit 4-1. The 1ft RSLR scenario is the most relevant scenario over the 20-year planning horizon of the study, having a 5% chance of being exceeded by 2040 (Miller, et al., 2018). The 2ft RSLR scenario has a minimal (<0.1% chance) chance of being exceeded by 2040 (Miller, et al., 2018). Though highly unlikely, this scenario could potentially be used for planning efforts dealing with highly vulnerable infrastructure where flood impacts would have significant consequences.

The 3ft and greater RSLR scenarios extend beyond the 2040 time horizon and can be used to inform long-term resource and/or infrastructure planning. These higher, long-term RSLR scenarios can also be used to identify any critical flood risk thresholds within the study area.

Exhibit 4-1: Potential Timing of 1ft to 5ft RSLR Scenarios

RSLR Scenario	50% Exceedance Chance	10% Exceedance Chance	5% Exceedance Chance	1% Exceedance Chance	0.1% Exceedance Chance
1ft	2050-2060	2040-2050	2040	2030-2040	2030
2ft	2080-2090	2070	2060-2070	2050-2060	2040-2050
3ft	2100+	2090	2080-2090	2070-2080	2050-2060
4ft	2100+	2100+	2100	2080-2090	2060-2070
5ft	2100+	2100+	2100+	2090-2100	2070-2080

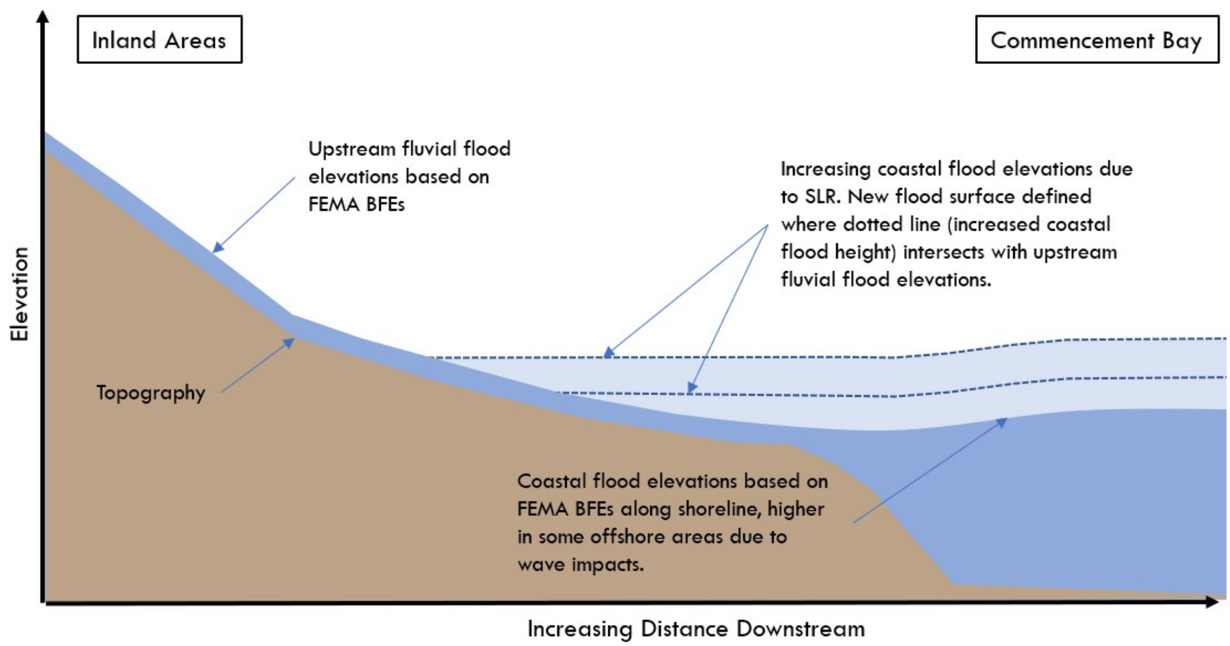
Source: Developed based on Miller et al. 2018

Coastal flooding was evaluated using two methods:

- Without Riverine Flooding: A bathtub flood hazard modelling approach, in which a constant tidal elevation is applied over an area, was used to evaluate potential flooding under MHHW conditions for each increment of RSLR. For areas below MHHW, under each RSLR scenario, connections to either the shoreline or other water bodies were checked based on intersection with the NOAA Continually Updated Shoreline Product or hydrology centerline data made available through the Pierce County GIS database. Bathymetry and topography data for the study area were obtained through the USGS Coastal National Elevation Database (CoNED) (Danielson, et al., 2016).

- With Riverine Flooding: A modified bathtub approach was used to evaluate coastal flood hazards for a 1% annual chance flood event to account for variable flood depths along the coast and flooding upstream within rivers. In place of a constant flood elevation, coastal and fluvial flood surfaces were created based on publicly available FEMA Base Flood Elevation (BFE) data. For each increment of RSLR, the coastal flood surface was raised, and a new overall flood surface was defined based on where the elevated coastal flood surface met upstream fluvial flood elevations. This process is visualized in Exhibit 4-2: Cross-Section View.

Exhibit 4-2: Cross-Section View of 1% Annual Chance Riverine-Coastal Flood Hazard Analysis Methodology



Limitations

Coastal flood hazard modelling is based solely on the topography within the study area and publicly available flood elevation, shoreline, and hydrology centerline data. While the CoNED topography used within this study is based on high-resolution 1m LiDAR data, the topography surface may not precisely resolve the elevation of narrow features such as levees or flood walls. Flooding within the study area can also be limited by the volume of water conveyed through a particular hydrologic connection over a period of time such as the peak of a tide cycle. Though these limitations are present, these flood hazard modeling remain suitable for the planning-level hazard assessment provided in this study.

4.2 Results

Coastal Flooding

20-Year Planning Horizon Scenarios

Coastal flood hazards within the study area are limited under MHHW conditions with 1ft RSLR. Flood projections are primarily restricted to shallow flooding along low-lying areas bordering channels that feed into the Hylebos Waterway and Blair Waterway (Exhibit 4-3). These flood projections increase slightly in terms of depth and extent with 2ft of RSLR but remain limited to these areas bordering the Manufacturing Industrial Center (Exhibit 4-4).

Long-term Planning Horizon Scenarios

With 3ft of RSLR shallow flooding begins to appear along low-lying portions of the Hylebos Waterway, extending into select parking and industrial use areas (Exhibit 4-5). The 4ft RSLR scenario represents a significant threshold for flood impacts under normal tidal elevations (Exhibit 4-6). In addition to increased flood projections in areas impacted under previous scenarios, significant areas between the Thea Foss Waterway and Puyallup River are projected to become inundated under this scenario. Flooding in this area stems from projected overtopping in southern portions of the Thea Foss Waterway and Middle Waterway, with floodwaters then travelling along low-lying rail and roadways to other areas.

Similar flood impacts are projected in the eastern portion of the study area between the Blair Waterway and Hylebos Waterway with 4ft RSLR, where overtopping along the shoreline and drainage channels cause flood projections to become widespread. Flooding also begins to emerge along drainage channels in the central portion of the study area under the 4ft RSLR scenario. Tidal inundation is projected to become widespread throughout the study area with 5ft of RSLR, covering greater areas in the eastern and western portions of the study area and increasing significantly in central areas between the Puyallup River and Blair Waterway (Exhibit 4-7).

Coastal + Riverine Flooding

20-Year Planning Horizon Scenarios

Under current conditions flood projections for a 1% annual chance event are largely limited to low-lying areas bordering drainage channels in the southern and southeastern portions of the Industrial Center (Exhibit 4-8). Flooding is also projected in select areas between the Blair Waterway and Hylebos Waterway.

With 1ft of RSLR, flood projections are seen in low-lying areas between the Thea Foss Waterway and Puyallup River, originating from overtopping at the southern end of the Thea Foss Waterway (Exhibit 4-9). Shallow flooding also become more widespread along drainage channels in the southern and southeastern portions of the study area, particularly between the Blair Waterway and Hylebos Waterway.

The 2ft SLR scenario represents a potential impact threshold for the study area under 1% annual chance flood conditions. Flooding becomes widespread throughout the study area under this scenario, with notable increases along southern and southeastern drainage channels and areas between the Blair Waterway and Hylebos Waterway (Exhibit 4-10). Flood extents also increase significantly in areas between the Puyallup River and Blair Waterway under this scenario.

Long-term Planning Horizon Scenarios

With 3ft and greater RSLR the majority of the study area is projected to flood under 1% annual chance flood conditions with the exception of select areas along the eastern and southern shorelines of the Blair Waterway (Exhibit 4-11). Incremental increases in projected flood depth and extent are seen between 3ft (Exhibit 4-11), 4ft (Exhibit 4-12), and 5ft (Exhibit 4-13) RSLR scenarios, but flooding is projected to largely remain within the same areas with no significant thresholds between each scenario.

Exhibit 4-3: Coastal Flood Hazards, MHHW + 1ft RSLR

Exhibit 4-4: Coastal Flood Hazards, MHHW + 2ft RSLR

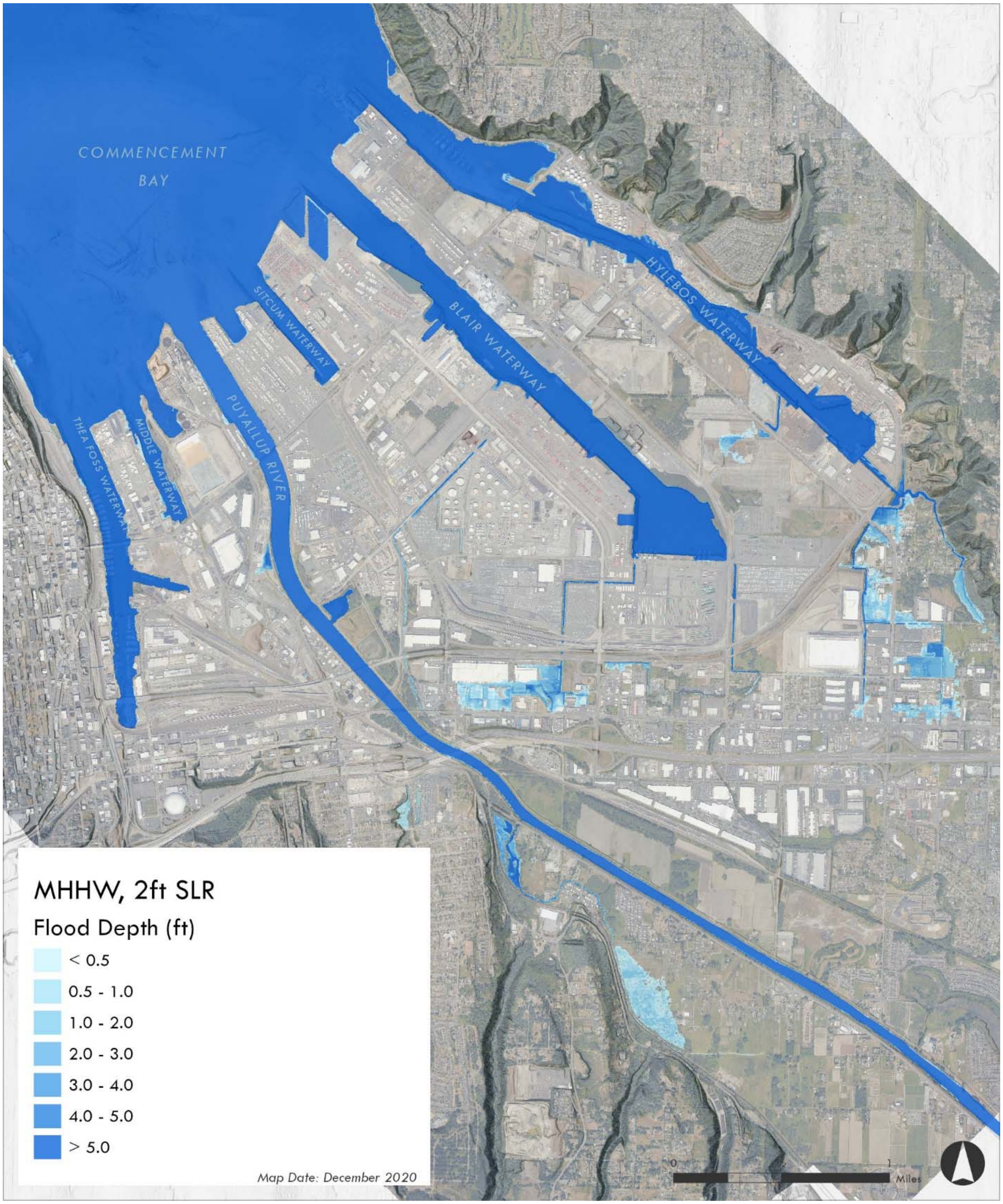


Exhibit 4-5: Coastal Flood Hazards, MHHW + 3ft RSLR

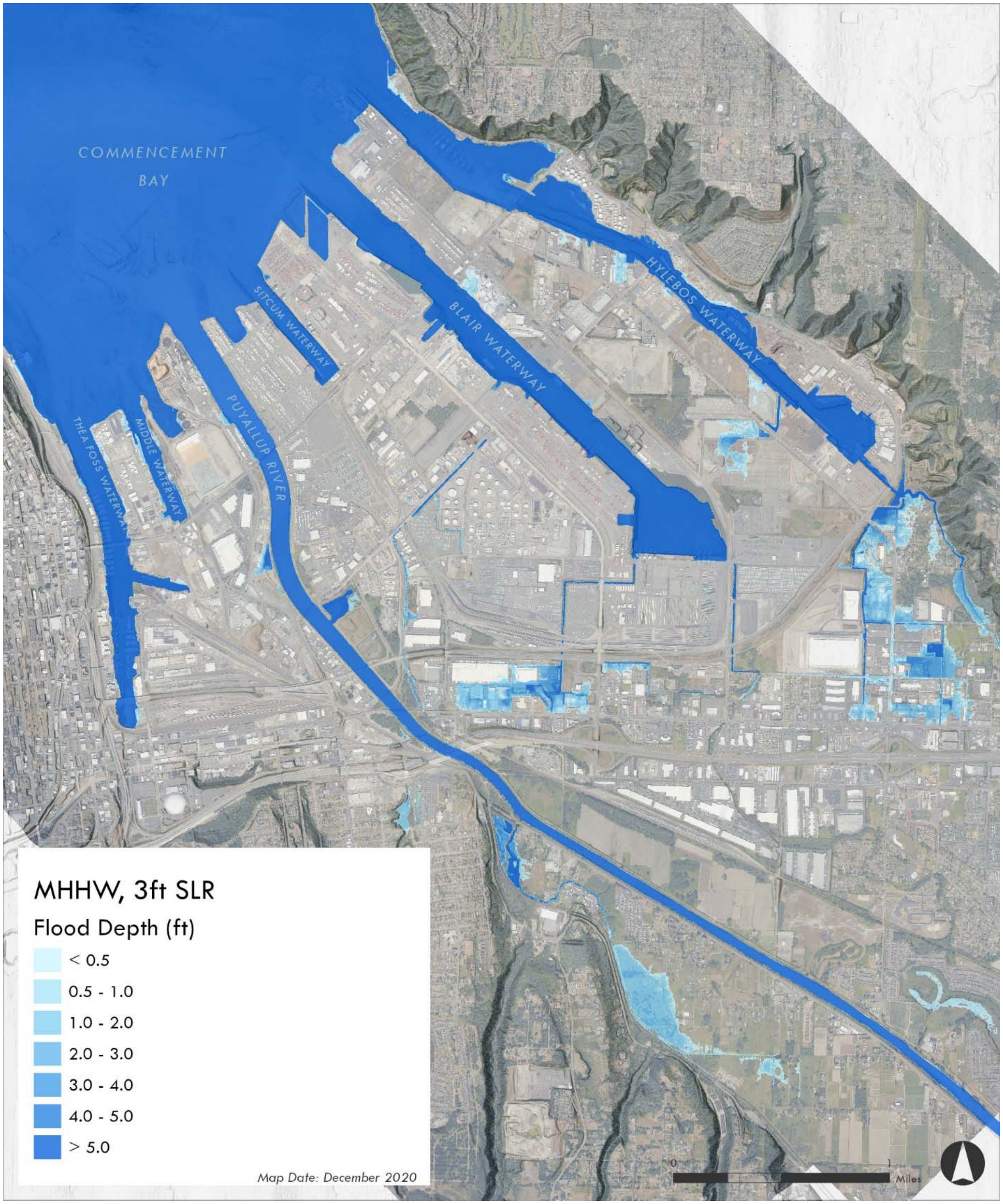


Exhibit 4-6: Coastal Flood Hazards, MHHW + 4ft RSLR

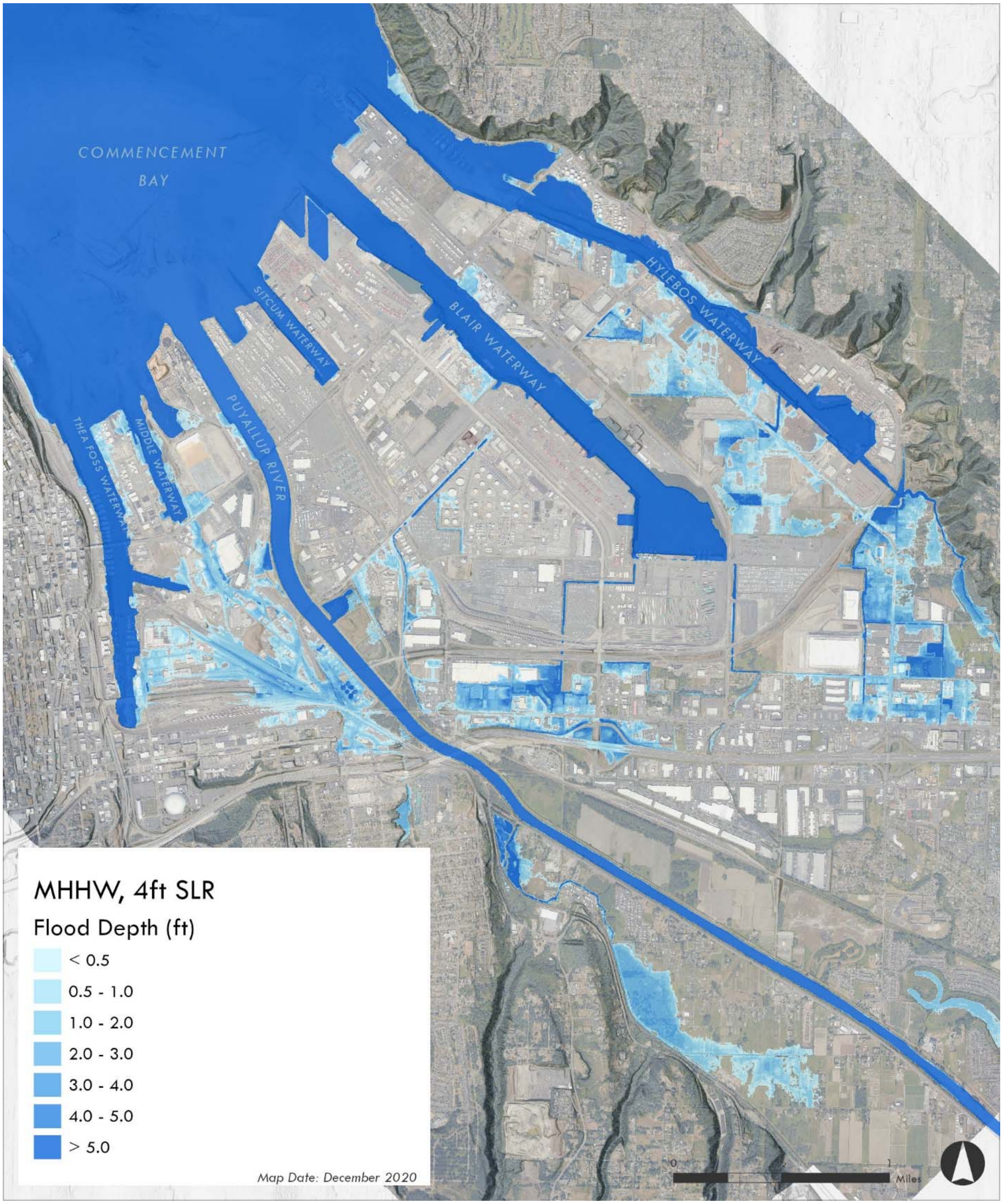


Exhibit 4-7: Coastal Flood Hazards, MHHW + 5ft RSLR

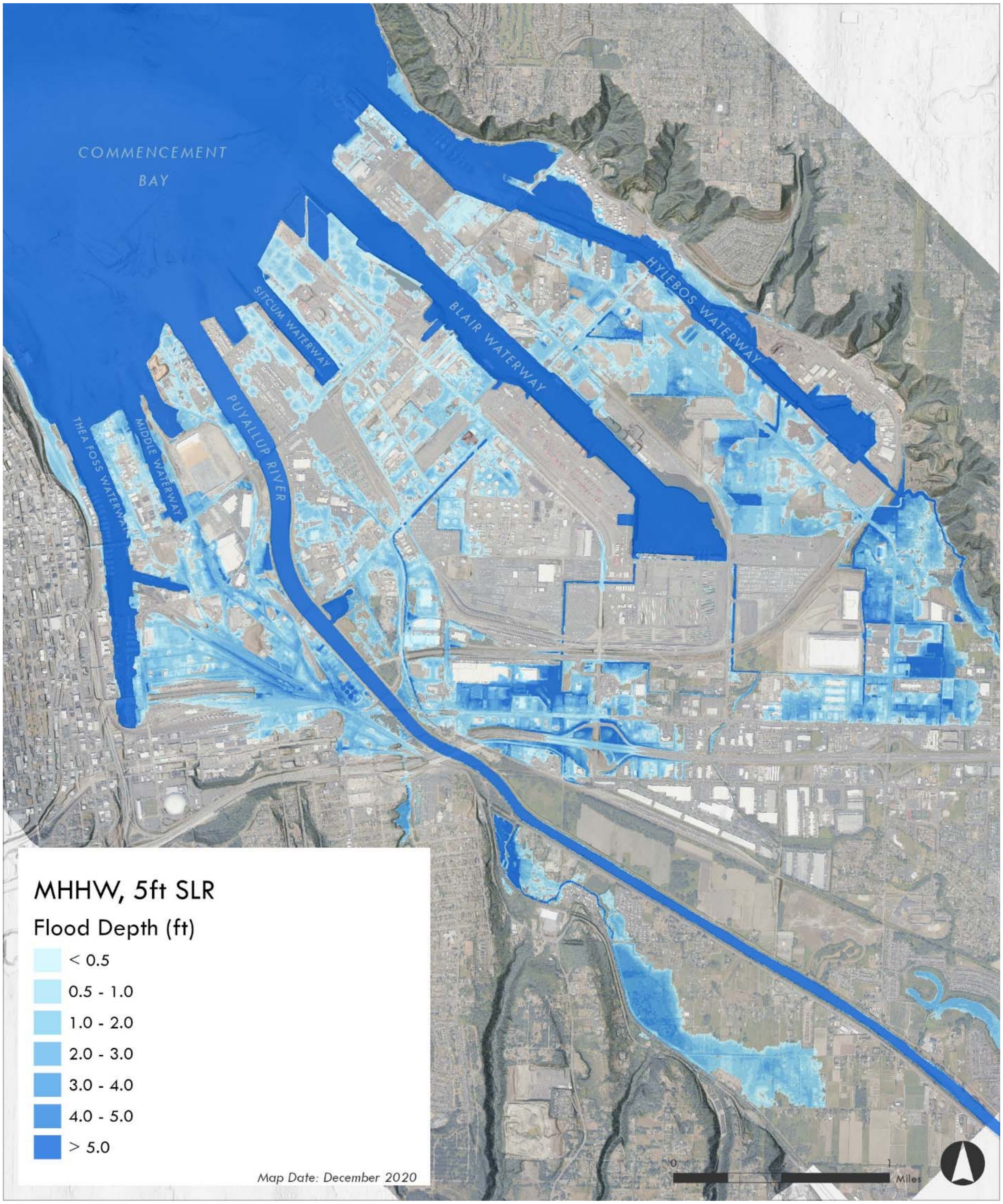


Exhibit 4-8: Coastal Flood Hazards, BFE + 0ft RSLR

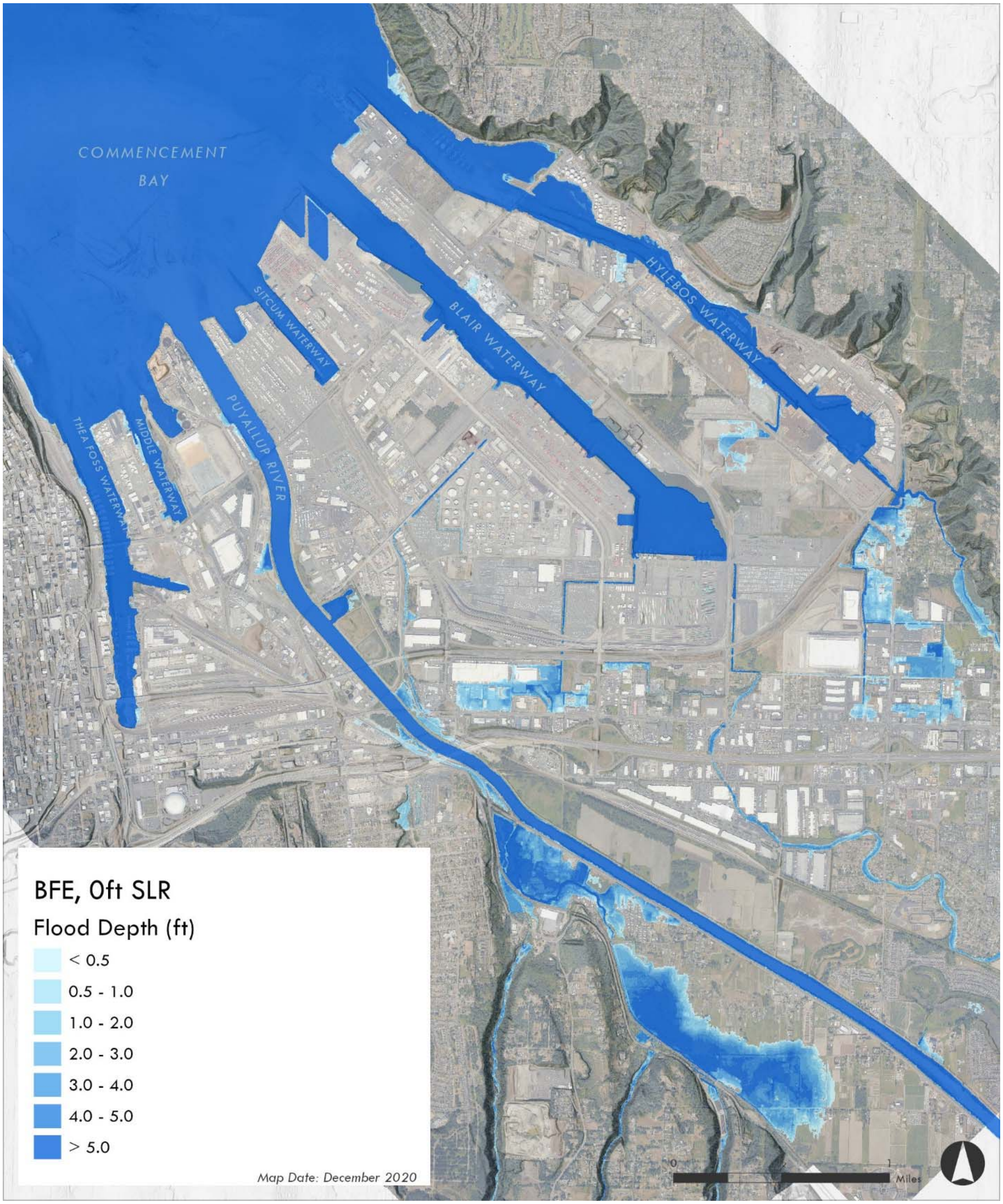


Exhibit 4-9: Coastal Flood Hazards, BFE + 1ft RSLR

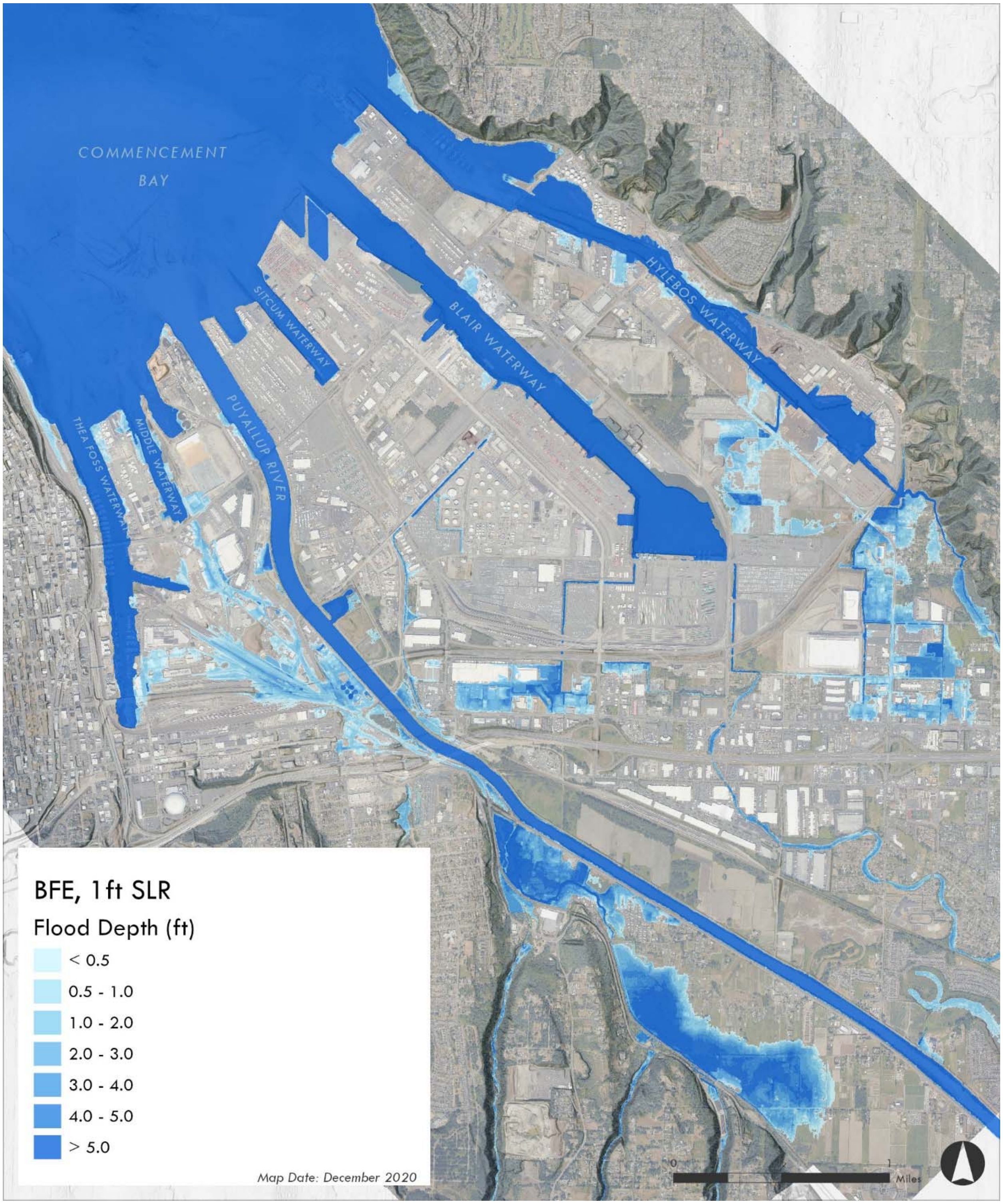


Exhibit 4-10: Coastal Flood Hazards, BFE + 2ft RSLR

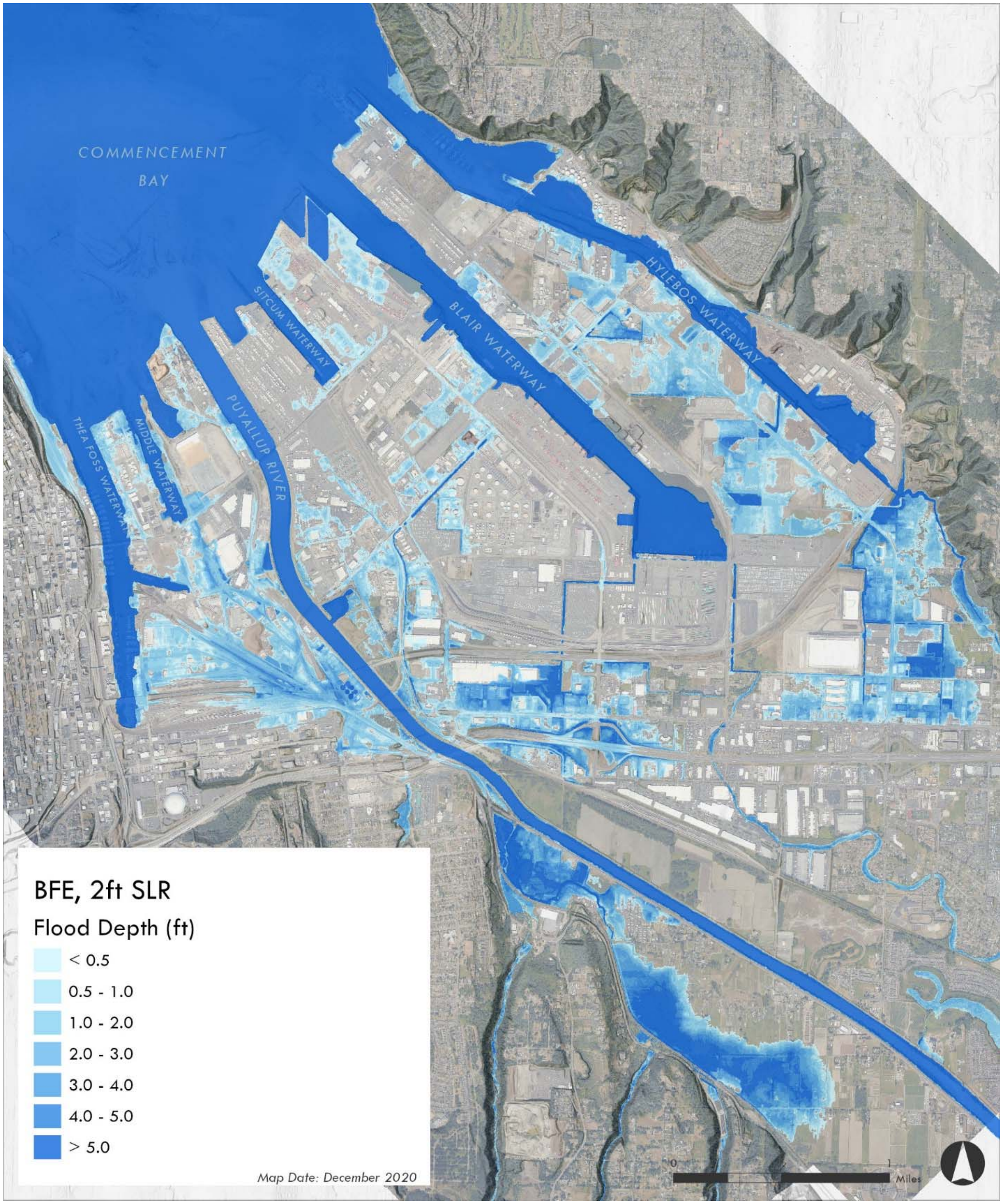


Exhibit 4-11: Coastal Flood Hazards, BFE + 3ft RSLR

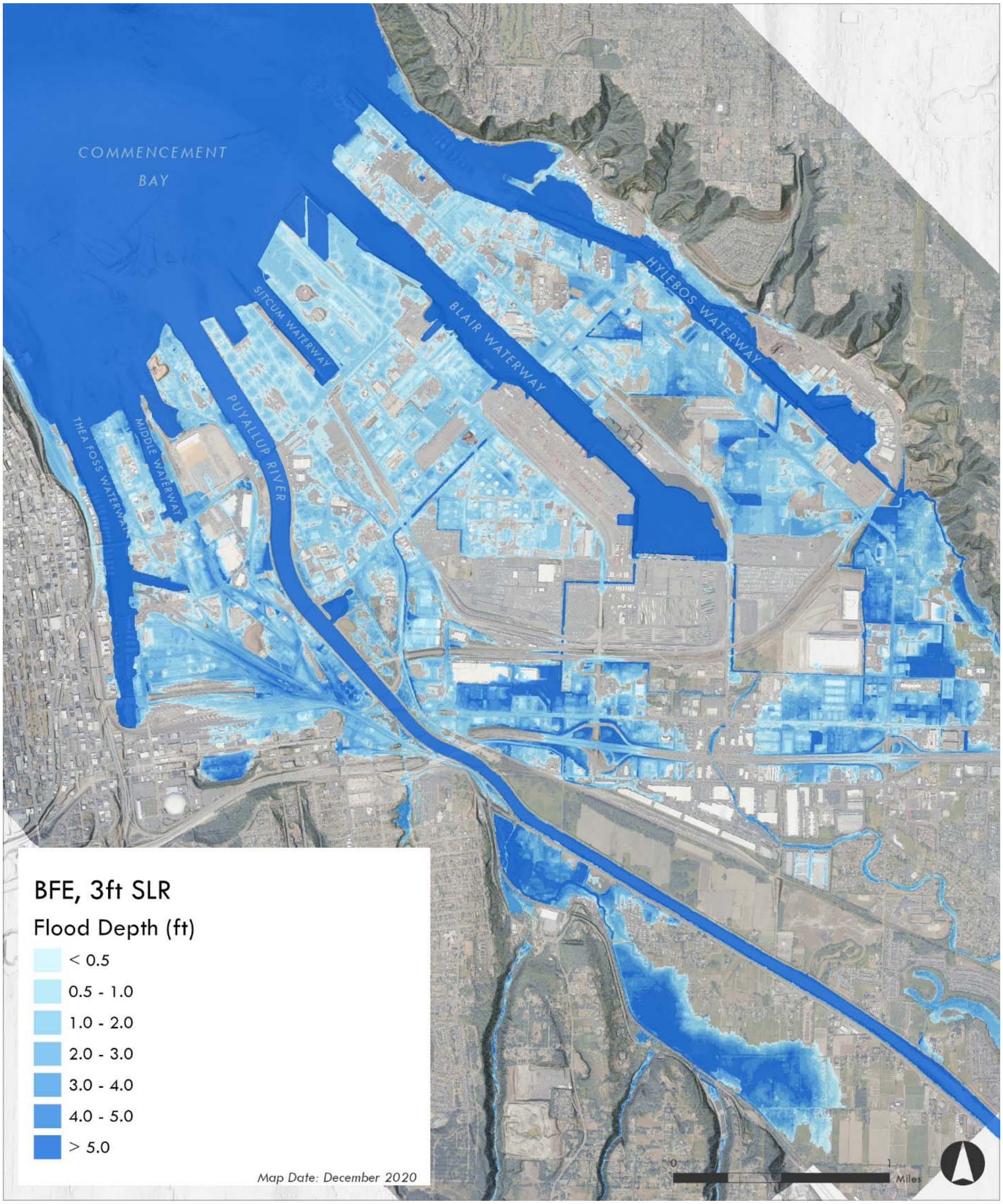


Exhibit 4-12: Coastal Flood Hazards, BFE + 4ft RSLR

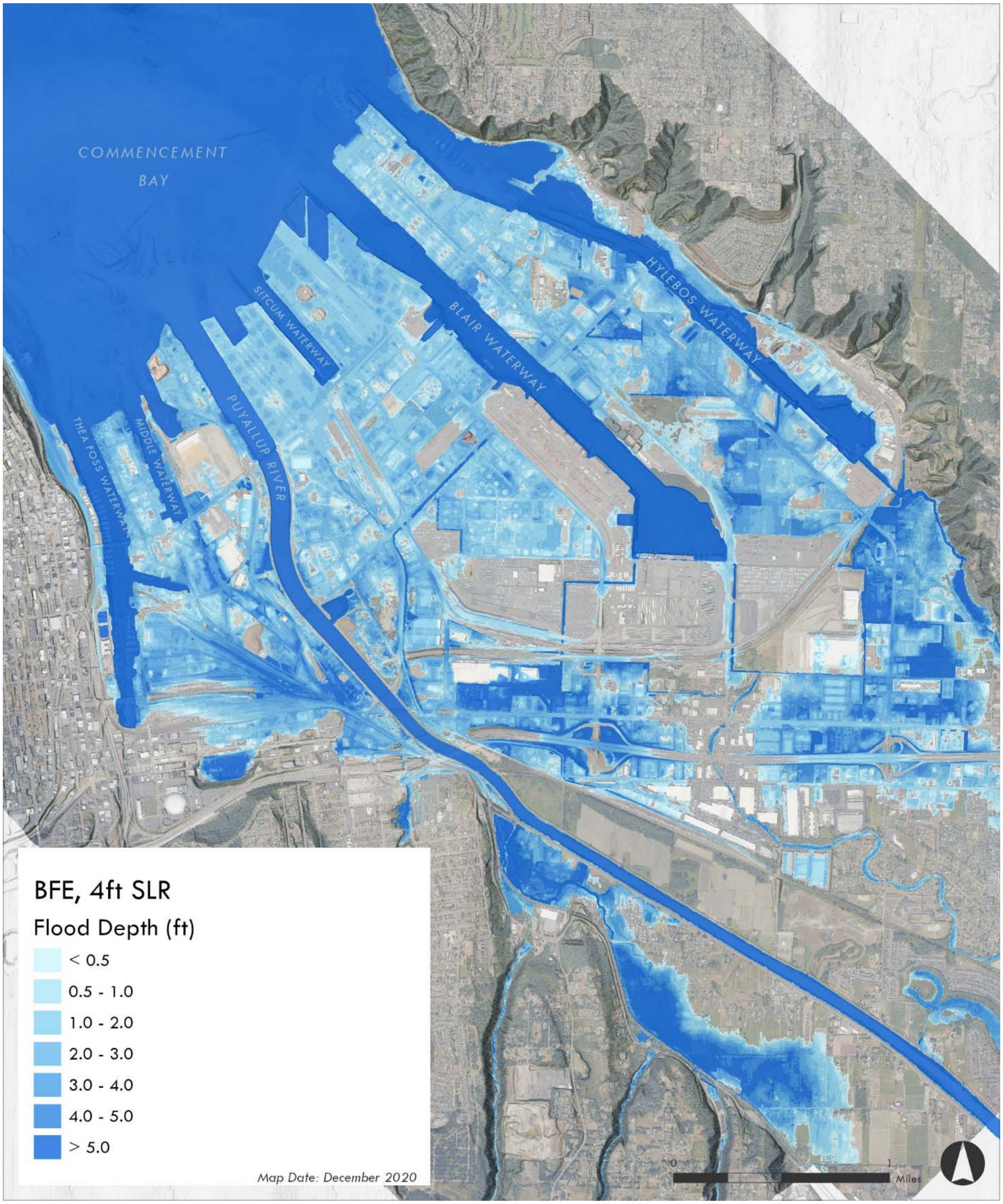
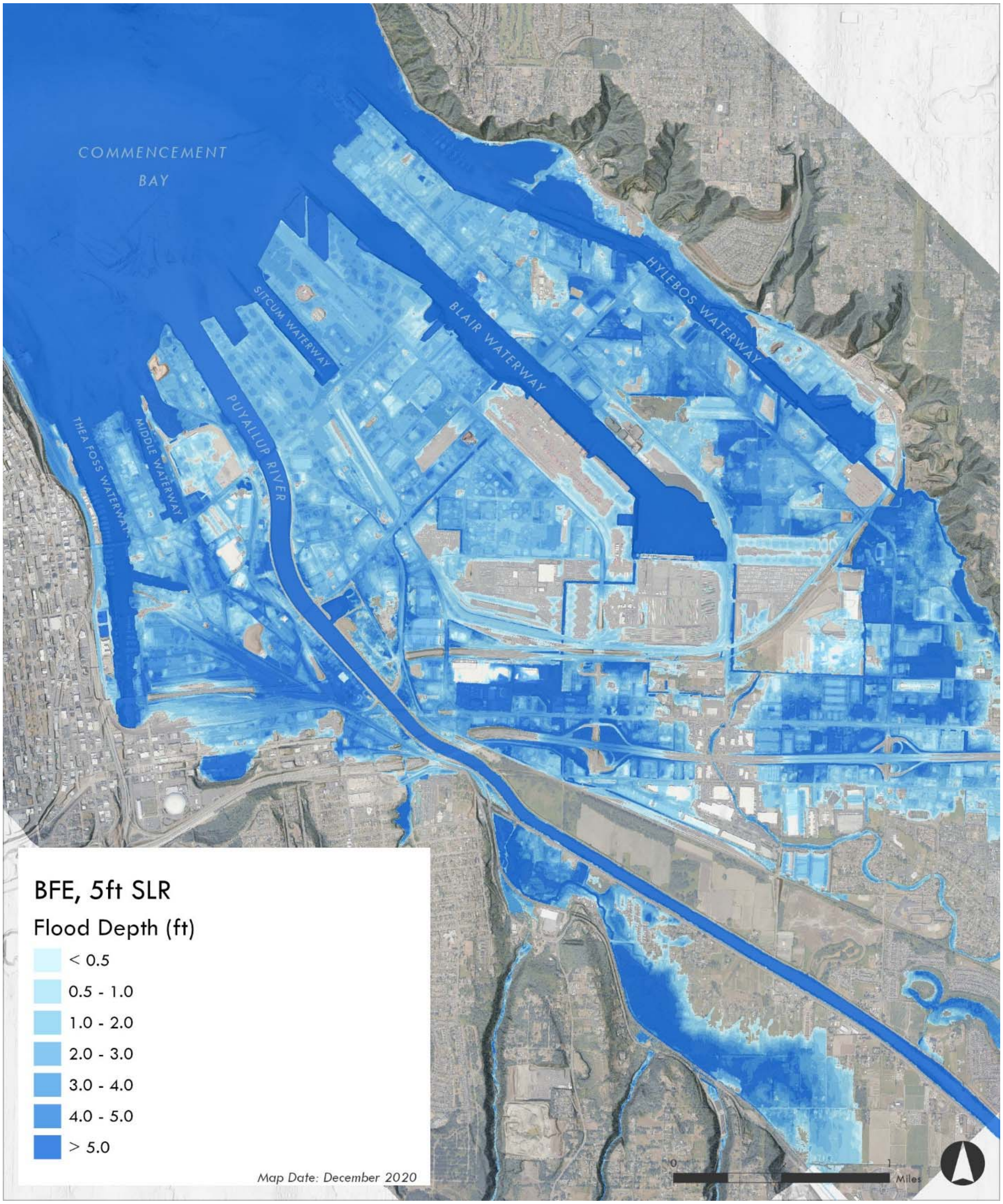


Exhibit 4-13: Coastal Flood Hazards, BFE + 5ft RSLR



5 CLIMATE VULNERABILITY ASSESSMENT

A critical component in climate resiliency planning is an assessment of the vulnerability of different resources and infrastructure assets within the study area. The vulnerability of a resource or asset is defined within this study as a product of three components: exposure, sensitivity, and adaptive capacity (Snover, et al., 2007), defined below.

- **Exposure** is the degree to which a system or asset is exposed to climate hazards.
- **Sensitivity** is the degree an asset would be impaired by the impacts of climate hazards. Systems that are greatly impaired by small changes in climate hazards have a high sensitivity, while systems that are minimally impaired by the same small change in climate hazards have a low sensitivity.
- **Adaptive capacity** is the ability of an asset to respond to climate hazards, to moderate potential damages, to take advantage of opportunities, and to cope with the consequences. This does not mean that the system must look the same as before the impact, but it must provide comparable services and functions with minimum disruption or additional cost.

The vulnerability of a resource increases as sensitivity and hazard exposure increase. Adaptive capacity is inversely related to vulnerability in that as the adaptive capacity increases, the vulnerability decreases. In the context of SLR adaptation, resources with low vulnerability may utilize less conservative SLR projections for planning purposes due to their ability to adapt or experience relatively small consequences of SLR hazard impacts, whereas higher, more conservative SLR projections may be appropriate for highly vulnerable resources. For example, Pebbly Beach Road has a high sensitivity because even minor damage from flooding or erosion can cause a significant disruption in service. The roadway has a low adaptive capacity to SLR in that it cannot easily be relocated or raised to cope with consequences; thus, it would be classified as a highly vulnerable asset. Conversely, the harbor moorings are highly exposed to coastal hazards, but have a low vulnerability to SLR because they are easily adaptable to increasing water levels and will maintain their function even with a significant rise in sea level.

Vulnerability assessment is currently being conducted and will be included in the next versions of this report.

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Tideflats Subarea Plan

Public and Advisory Groups Meetings: Working Schedule

2021

Tideflats Advisory Group (third Thursday of the month)	**Steering Committee** (second Thursday of the month)	**Community Meetings**
January 21 • Visioning exercise rehearsal • Meeting in a box support • Community kick-off update • Kick-off questions shortlist	**January 14** • Calendar check-in • Climate change resilience (Moffatt & Nichol)	
February 18 • Community kick-off feedback • Visioning/MEIB support, as needed • transmit draft baseline report (no presentation)	**February 11** • No Meeting • Written transmittal: Community kick off summary; draft baseline report; calendar update	**February 4 (pm)** Community Kick-off **February 24 (pm)** Big Picture Visioning **February 27 (Sat am)** Big Picture Visioning
March 11 • Joint TAG/SC meeting on baseline report, alternatives framework		**March 1-5** (date TBD) Focus Group **March 4 (am)** Closer Look Visioning **March 9 (pm)**

		Closer Look Visioning **March 31** (tentative) Community Visioning Workshop
April 15 • Visioning feedback[1] • Preliminary scenarios (input)	**April 8** • No meeting • Written transmittal: visioning update; draft baseline report; calendar update	
May 20 • No meeting	**May 13** • Visioning sessions debrief[2] • Preliminary direction for alternatives	
June 17 • EIS overview • Planning process • Schedule	**June 10** • Draft alternatives recommendation[3]	**Date TBD** Scoping meeting
July 15 • No meeting	**July 8** • Meeting if needed	
August 19 • Written transmittal: PC action	**August 12** • PC action • EIS/plan overview/schedule	
September 16 •	**September 9** •	
October 15 •	**October 8** •	
November 19	**November 12**	

•	•	
December 17 •	**December 10** •	

1 Follows week of 3/29 community meeting
2 Follows TAG debrief in April
3 Tacoma Planning Commission review to follow (7/7, 7/21)