Appendix I
Sea Level Rise Considerations

Memorandum

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From:	Aaron Patterson (M&N)
Date:	April 20, 2016
Subject:	Terminal 5 Sea Level Rise Considerations
Project:	Terminal 5 Cargo Wharf Rehabilitation, Berth Deepening and Improvements

1.0 INTRODUCTION

Moffatt & Nichol (M&N) has been retained by the Port of Seattle (Port) to provide design support services, including support for the State Environmental Policy Act (SEPA) review for the Terminal 5 (T5) Cargo Wharf Rehabilitation, Berth Deepening and Improvements Project (the Project). Part of this effort includes assessing the potential for project-related short-term and long-term impacts due to rising sea levels in the Puget Sound.

This memorandum describes existing sea levels in the study area, observed sea level rise during the 20th Century, projected sea level rise during the 21st Century, and what potential changes to the Project alternatives might occur. Measures to avoid, minimize, or compensate for potential adverse effects are identified. Information is provided in a format that can be incorporated into the Project's in-development Environmental Impact Statement (EIS) as a separate chapter or as part of other existing EIS sections.

2.0 STUDY AREA

The study area for sea level rise includes the southern edge of Elliott Bay into the Duwamish River West Waterway and the existing T5 wharf (Figure 1).

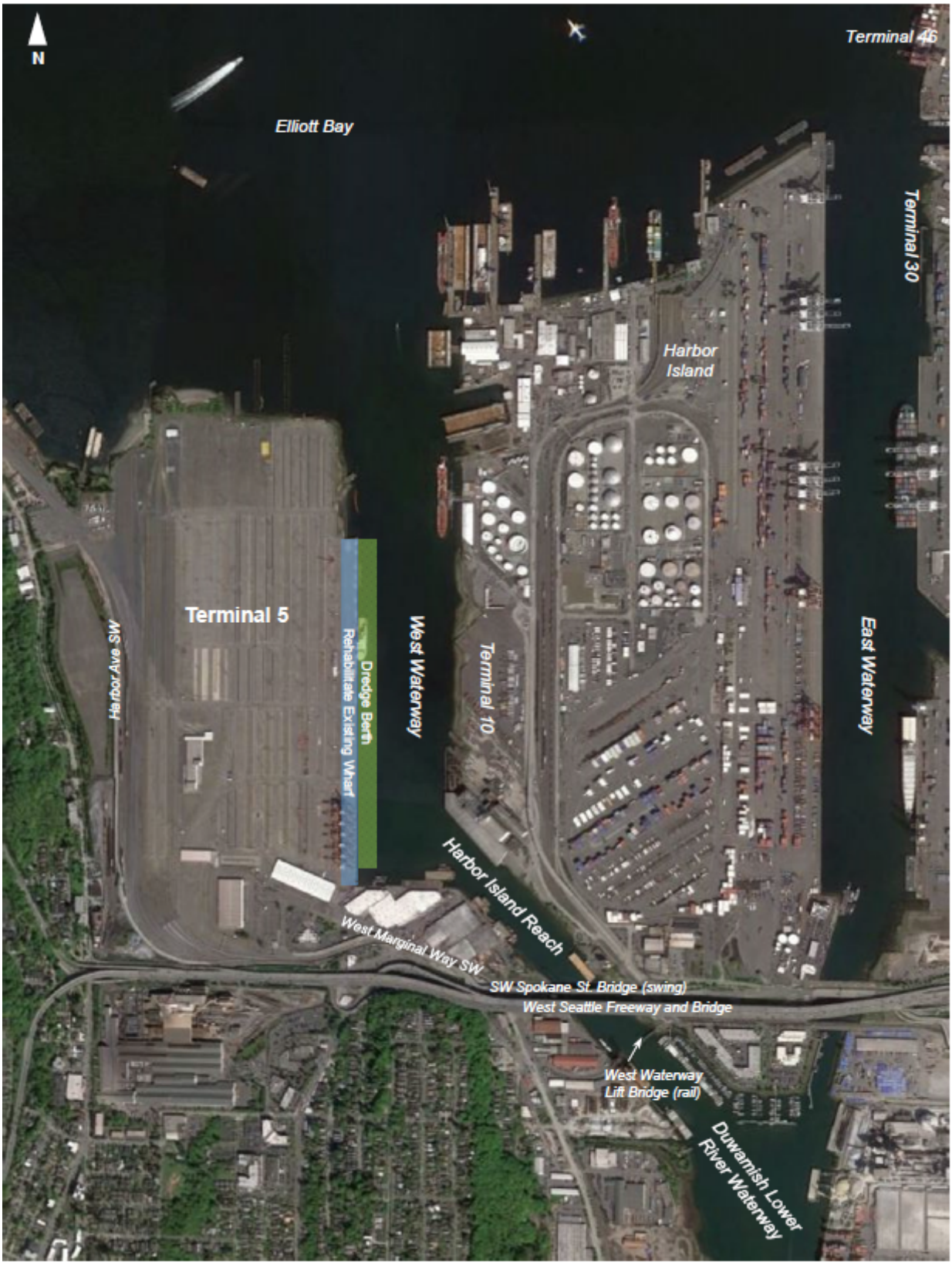

Figure 1: Port of Seattle Terminal 5 on the Duwamish River

2.1 Existing Terminal 5 Facility

T5 is located on the west side of the Duwamish River West Waterway and includes the existing marine cargo facility, approximately 197 acres of existing upland, and 19 acres of existing cargo pier, and berth in the west margin of the waterway, adjacent to the terminal upland cargo marshalling area. The existing T5 wharf is approximately 2,900 feet long. The existing top of wharf elevation is approximately 18.60 feet Mean Lower Low Water (MLLW).

2.1.1 Existing Sea Levels

Existing tidal datums for the Project are provided in the following table, relative to MLLW and based on the 1983 – 2001 epoch (NOAA/NOS 2012). NOAA Station 9447130 is located near Coleman Dock in downtown Seattle.

Table 2-1. Tidal datum and vertical datum relationships in feet relative to MLLW at NOAA Station 9447130, Seattle, WA

Datum	Elevation (feet, MLLW)
Extreme High Water	14.48
Mean Higher High Water	11.36
Mean High Water	10.49
Mean Low Water	2.83
Mean Lower Low Water	0.00
Extreme Low Water	-5.04

3.0 SEA LEVEL RISE

Sea level rise is the relative increase in mean sea level, primarily caused by two processes: additional water in the ocean from glacial and land-based ice sheet melt, and thermal expansion of ocean waters due to warmer sea temperatures (Adelsman and Ekrem 2012). Sea level rise is a global occurrence, however, observed sea level rise varies by location due to changes in land elevation and wind.

3.1.1 Observed Sea Level Rise

On a global scale, oceans have risen approximately eight inches from 1900 to 2009. In Washington, sea level rise has varied due to variations in land elevation changes. Subduction of the Juan de Fuca plate has resulted in the Olympic Peninsula rising approximately 0.08 inches a year, while the Puget Sound has subsided at an equal rate (Adelsman and Ekrem 2012). Sea level rise in Seattle, as measured by the Seattle tide gauge, has risen by 8.6 inches over the same time span.

3.1.2 Projected Sea Level Rise

Climate projections for the Pacific Northwest (PNW) are available from the Climate Impacts Group at the University of Washington (Mauger et al. 2015). The climate projections indicate that the Puget Sound is likely to experience the following effects over the next 50 to 100 years:

- Increased temperature leading to more frequent extreme heat events, worsened air quality, and glacial melting.
- Sea-level rise, coastal erosion, and salt water intrusion.
- Changes in the volume and timing of precipitation resulting in reduced snow pack, increased erosion, and more frequent and severe flooding.
- Ecological effects of a changing climate including the spread of disease, altered plant and animal habitats, and negative impacts on human health and well-being.

Sea levels are projected to rise over the coming century, with a wide range of possible future amounts, depending on the rate of global greenhouse gas (GHG) emissions. Globally, sea level is projected to increase by 11 to 38 inches between 2000 and 2100, depending on the amount of GHG emission. Between 2000 and 2100, relative sea level in Seattle is projected to rise between 4 and 56 inches. The Climate Impact Group has provided a middle estimate of sea level rise for the latitude of Seattle of +24 inches by 2100, relative to 2000 (Mauger et al. 2015).

The Port of Seattle is developing a draft climate change adaptation plan to address projected rates of sea level rise at Port facilities. The draft adaptation plan notes that the longest design life that the Port assigns to an asset is 50 years and the most likely amount of sea level rise that an asset will experience over the next 50 years is about nine inches (Port of Seattle 2015).

4.0 PROJECT DESCRIPTION

Three alternatives are being considered as part of the Project EIS and are described in brief detail below. Alternative 1, the No Action Alternative, provides a baseline of conditions for comparison when discussing the action alternatives.

- ***Alternative 1 or No Action Alternative.***

  The No Action Alternative assumes that no improvements will be made to the existing site other than minor alterations, routine maintenance and repair work. No changes to the cargo pier, existing berth or wharf, potable water lines, sewer, or site elevations and grades are proposed. Stormwater treatment facilities will be installed to aid the facility in achieving Department of Ecology Industrial Stormwater Permit compliance.

- ***Alternative 2: Wharf improvements, increased cargo-handling efficiency and volume.***

  Alternative 2 proposes to rehabilitate the existing T5 container cargo pier to support larger container cranes. The rehabilitation includes upgrades to the existing apron area and crane rails to support the large container cranes. Upgrades to the apron will not include changes to apron or upland surface elevations. Slope stabilization measures under the wharf will be implemented with apron upgrades, to maintain the existing slope stability.

  The extent of utilities work, other than associated with electrical is limited. Stormwater treatment facilities will be installed to aid the facility in achieving Department of Ecology Industrial Stormwater Permit compliance. Minimal excavation is proposed for trenching of utilities and site preparation work and the new crane beam.

- ***Alternative 3: Wharf improvements, relocate buildings, densify rail yard, optimized cargo-handling efficiency and volume.***

  In-water and over-water construction including berth deepening, and upland construction activities will be the same as described for Alternative 2, including upgrades to the apron and slope stabilization measures, to maintain the existing slope stability.

The majority of the stormwater collection system will be reconfigured to accommodate the new terminal stacking system. Existing outfalls will be maintained where possible. A stormwater management plan and potential treatment facilities will be installed to aid the facility in achieving Department of Ecology Industrial Stormwater Permit compliance.

Excavation will be required for trenching of utilities and site preparation work and the new crane beams. Utility excavations are expected to be up to 10 feet below ground surface, and dewatering may be required to accommodate construction.

5.0 POTENTIAL IMPACTS TO THE PROJECT

Inundation from rising sea levels could challenge the capacity of storm drains and treatment facilities. Rising sea levels could inundate or disrupt numerous nearshore facilities due to flooding caused by the increased elevation of receiving water bodies. Drainage facilities may need to be enlarged to provide storage for additional stormwater volumes that may result from water backing up due to sea level rise.

Sea-level rise impacts could potentially include changes to shoreline slope stability due to changes in tidal flux and wave action and higher frequency of flooding; higher ground water elevations which may affect pavement and foundation performance, settlement, subsurface utilities and berthing functionality.

The SEPA Implementation Working Group (IWG) has developed recommendations to ensure that consideration of climate change is included in SEPA review (IWG 2008). Analysis of the environmental impacts of a given proposal and its vulnerability to climate change effects, including sea level rise, is required.

The Port of Seattle's DRAFT Climate Change Adaption Plan (Port of Seattle 2015) also addresses anticipated climate change vulnerabilities of Port and adjacent facilities and how major capital projects should be designed to account for resiliency, including sea level rise. The Port focuses on adaptation measures that would be required prior to 2065 and combines it with their overall philosophy of adaptive management and business planning. Typical adaptation measures prescribed by the Port include improvements to terminal stormwater conveyance, treatment, and drainage systems along with necessary modifications to power supply.

5.1 Alternative 1

Increased sea levels could result in changes in tidal flux and wave action along the wharf. The existing rock-stabilized slope extends the length of the wharf from the existing bulkhead wall to below the intertidal zone. Increases in tidal flux and wave action may result in additional erosion and shoreline degradation in areas where the riprap may not be sufficiently sized. Slope stability improvements are not proposed under Alternative 1.

Higher groundwater elevations may coincide with higher sea levels affecting T5 pavement subgrades, building and structure foundations, and settlement. Compromised pavement subgrades, foundations, and settlement may lead to reductions in terminal operations and increased levels of maintenance and repair.

Increasing the elevation of a water body that receives runoff from a stormwater system can affect the hydraulic performance of the stormwater system. If the elevation of a receiving water body is increased, water may begin to encroach up the end of the pipe, reducing the overall system capacity. With a reduced capacity, existing systems may become inundated and not be able to convey the design flows for that system, which leads to localized upland flooding during periods of higher tidal cycles and large storm events. This could occur at T5 under the No Action Alternative. Localized flooding could then adversely impact terminal operations.

5.2 Alternative 2

Slope stability improvements are not proposed in Alternative 2. Increased wave action due to increased sea levels may result in shoreline degradation in areas where the existing riprap, under the wharf or along the north shoreline of the site, may not be sufficiently sized.

Similar to Alternative 1, higher groundwater elevations may compromise pavement subgrades, foundations, and settlement, which may lead to reductions in terminal operation efficiencies and increased maintenance and repair efforts.

Inundation of existing subsurface utilities may occur under Alternative 2 and could lead to localized upland flooding during periods of higher tidal cycles. Stormwater treatment facilities constructed under Alternative 2 would be installed at elevations that accommodate the existing elevations of the stormwater system and may not account for increased water levels in the receiving water body.

5.3 Alternative 3

Similar to Alternatives 1 and 2, slope stability improvements are not proposed in Alternative 3. Increased wave action due to increased sea levels may result in shoreline degradation in areas where the existing riprap may not be sufficiently sized.

The majority of the stormwater collection system will be reconfigured to accommodate the new terminal stacking system. As part of the reconfiguration, existing outfalls will be maintained where possible and the conveyance system elevations may be adjusted, where upland elevations allow. Raising the conveyance system elevations could minimize potential flooding due to projected increases in sea level.

5.4 Potential Mitigation Measures

It is important to note that the project is proposed on an existing site, with existing rail, vehicle, and vessel access and support infrastructure already in place. Continued use of and connectivity to existing infrastructure are critical design considerations. The proposed opportunities for Alternatives 2 and 3 present ideas that could be implemented now as a part of this project, or at a later date in an adaptive management strategy to minimize sea level rise risks and maintain terminal efficient operations:

- Replacement of the fender system could incorporate design to account for some sea level rise. The existing fender system could be replaced with a panelized fender system that could accommodate vessels berthing during higher tidal elevations and increased sea levels.
- The installation of backflow prevention devices (flap gates) could prevent saltwater from backing up into the enclosed drainage system of T5.
- The installation of larger diameter storm system piping, modification of existing outfalls, and/or installation of new outfalls could provide additional system capacity and prevent overtopping during high tidal events.
- The majority of the pavement in the container yard will be removed and replaced as part of Alternative 3. The subgrade of the replaced pavement could be designed to accommodate increased groundwater elevations.

Compared to the Alternative 1 and Alternative 2, Alternative 3 will most likely provide the most opportunities to accommodate sea level rise in design.

5.5 Significant Unavoidable Adverse Impacts

Under all alternatives the existing elevation of the wharf deck will not be increased. As sea levels rise, increased tidal flux and wave action will result in waves overtopping the wharf during storm events at

higher tide cycles. Although rebuilding of the outer wharf deck under Alternative 2 and Alternative 3 would allow for the elevation of the outer portion to be raised to account for higher tidal elevations, the inner portion of the terminal would remain at the existing elevation and would result in grade changes that are not suitable for containerized port facilities.

6.0 REFERENCES

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