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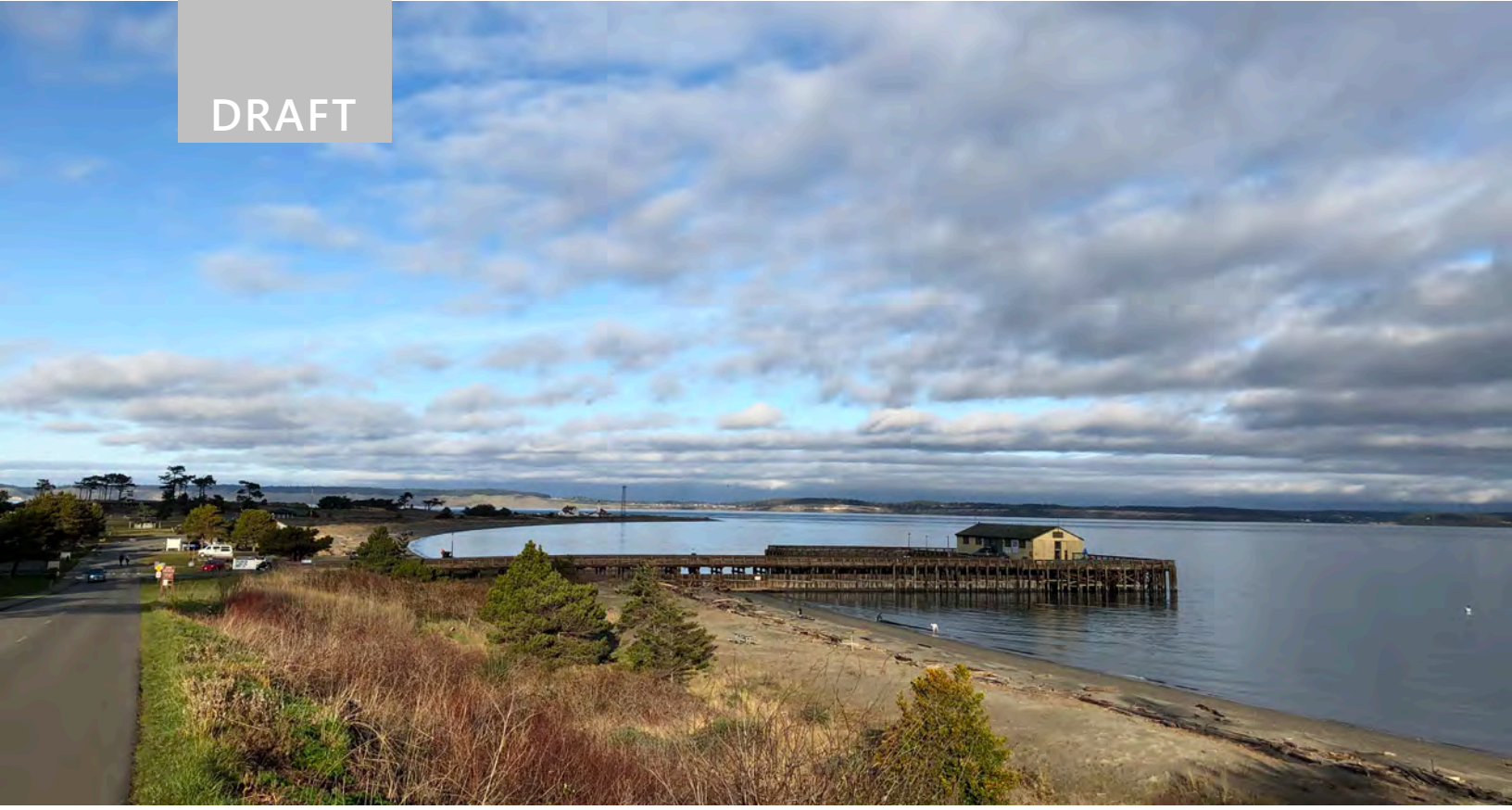

March 2019
Fort Worden Historical State Park – Marine Facilities Consultant Services Project

ANCHOR QEA

Appendix A
Preliminary Coastal Processes Evaluation
Task 3 Background Information Gathering and Technical Evaluations

Prepared for Washington State Parks and Recreation Commission

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Preliminary Coastal Processes Evaluation
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Prepared for
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ABBREVIATIONS

FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
Fort Worden	Fort Worden Historical State Park
HAT	highest astronomical tide
MHHW	mean higher high water
MLLW	mean lower low water
MSC	Fort Worden Marine Science Center
NOAA	National Oceanic and Atmospheric Administration
Project	Fort Worden Historical State Park – Marine Facilities Consultant Services Project
RCP	Representative Concentration Pathway
State Parks	Washington State Parks and Recreation Commission
T-sheets	United States Coast & Geodetic Survey topographic sheets
UWCIG	University of Washington Climate Impacts Group

1 Project Overview

The Washington State Parks and Recreation Commission (State Parks) seeks to develop a unified development scheme for the marine area (Project) at Fort Worden Historical State Park (Fort Worden). The first phase of the Project is a predesign phase focused on identifying the preferred location for a new boat launch facility and identifying a preferred strategy for the rehabilitation, removal, or removal and replacement of the pier (see Figure 3 in the main body of the Background Information Gathering and Technical Evaluations report).

The existing boat launch facility is in poor condition, and its current configuration as a gangway and float has become a maintenance issue for State Parks. The boat launch disrupts the natural shoreline littoral process, and sand continually builds up on the structure, requiring regular maintenance. State Parks would like to replace the boat launch facility with an elevated boat launch ramp structure, to allow littoral processes to recover and avoid future maintenance issues.

The existing pier structure is in satisfactory condition, based on the recent Facility Condition Assessment Report (Sitts & Hill 2016). The Project will consider whether to rehabilitate the pier in place, remove and not replace the pier, or to remove and replace the pier and shift its location north to a former location; there are remnant in-water piles associated with a historic pier located north of the existing pier. The MSC building is located at the terminus of the pier and is managed by the Fort Worden Marine Science Center (MSC); this building has historic status that will need to be considered. There are preliminary plans (as a separate project, with separate funding) to relocate the MSC program to a new building in an upland location.

2 Purpose of Preliminary Coastal Evaluation

As part of the predesign phase of work, Anchor QEA conducted an initial coastal evaluation of the marine area shoreline (see Figure 2 in the main body of the Background Information Gathering and Technical Evaluations report) to identify existing coastal processes at the Project site. This information will be used to inform the conceptual alternatives evaluation and additional coastal engineering design evaluation, which will be completed as part of the overall Project.

Specific work completed as part of the initial coastal processes evaluation includes the following:

- Compiled and reviewed current and historical information about the Project area shoreline, such as current and historical aerial photos, LiDAR data, existing topographic or bathymetric surveys, and United States Coast & Geodetic Survey topographic sheets (T-sheets).
- Compiled historical, long-term met-ocean data near the site, including winds, tides, waves, and Federal Emergency Management Agency (FEMA) flood map information for the Project shoreline.
- Developed wind statistics for prevailing wave directions ("everyday" conditions) and storm events (2- through 100-year return period wind speeds from various directions) through evaluating long-term wind data. The wind statistics were used to predict storm wave conditions for the same return periods and directions.
- Review predicted sea level rise estimates for Fort Worden, as outlined in the vulnerability assessment developed by the University of Washington Climate Impacts Group (UWCIG), in partnership with State Parks (UWCIG 2017). Anchor QEA will also review the recent (July 2018) UWCIG and Washington Sea Grant (in partnership with many others) that provides the most up-to-date sea level rise estimates for the Puget Sound region.
- Compiled maintenance information from State Parks staff regarding excavation of material from the boat ramp.
- Conducted a targeted topographic and bathymetric survey of the Project shoreline (see Section 4.1 of the main body of the Background Information Gathering and Technical Evaluations report).

Additional coastal engineering evaluation will be conducted for this Project as part of the alternatives evaluation, including a site reconnaissance, targeted wave modeling, estimates of longshore drift rates, and development of specific coastal engineering design criteria for proposed project elements.

3 Coastal Setting

3.1 Overview

The shoreline at Fort Worden is located north of Port Townsend, Washington, on the western shore of Admiralty Inlet, leading from the Strait of Juan de Fuca to the Puget Sound (see Figure 1 in the Background Information Gathering and Technical Evaluations). The shoreline is exposed to wind-waves from the northeast, east, and southeast across the inlet. Tidal currents offshore of the site through the strait can reach 6 knots.

The beach slope above mean lower low water (MLLW) is relatively constant along the entire project shore, based on beach topography and offshore bathymetry collected as part of this work (see Section 4 and Figure 3 of main body of the Background Information Gathering and Technical Evaluations report). Slopes below MLLW down to approximately -35 feet MLLW are relatively mild near the existing pier and boat launch and become steeper north of the boat launch. Offshore of the -35-foot MLLW contour, slopes are mild and consistent along the length of the project shoreline, with water depths reaching approximately 50 feet (at MLLW), approximately 500 feet offshore.

The project shoreline is characterized by net littoral drift (movement of sediment parallel to shore) from south to north. To the south of the project shoreline are unarmored feeder bluffs, which provide a continuing source of sediment to the project site. The existing pier at the site inhibits littoral drift but does not interrupt it completely. Littoral drift continues north of the pier and results in sediment accumulation on the boat launch. The breakwater/groin north of the boat launch protects the launch from waves from the north and northeast significantly inhibits littoral drift. It does not completely interrupt littoral drift, because littoral drift can occur anywhere within the breaking wave zone. At lower tides, the breaking wave zone would include areas offshore of the end of the breakwater/groin, allowing littoral drift to continue north around the end of that structure. However, steeper beach slopes below MLLW north of the breakwater/groin imply that the impacts to littoral drift are also having a significant impact to sediment supply and beach shape north of the structure.

In addition to littoral drift processes, shoreline erosion (movement of sediment offshore) due to storm events is an ongoing problem at the park, and predicted sea level rise and predicted changes to storm frequency and intensity are expected to increase shoreline erosion at the site. These future processes will also increase the impacts of existing structures to littoral drift processes and increase potential for damage to these existing structures due to storms.

3.2 Historic Shoreline: T-Sheets

The T-sheet for the site is shown on Figure 1, below. This figure represents shoreline conditions at the site in the late 1800s. Figure 1 shows an overlay of the T-sheet with a current aerial photograph of the site. Overall, there appears to be little change to the shoreline location at the project shoreline

since the late 1800s. This is likely due to the sediment source (i.e., feeder bluff) that is still located to the south of the site and the lack of development and armoring of both feeder bluffs to the south and the project shoreline itself.

Figure 1
Existing Conditions Compared to Historic T-Sheet (T-582)

http://riverhistory.ess.washington.edu/tsheets/j_t0582.html

3.3 Tidal Information: Water Levels

Tidal data for the area was taken from the National Oceanic and Atmospheric Administration (NOAA) Tides and Currents database, tidal station 9444900, Port Townsend, Washington (NOAA 2018).

Table 1
Tidal Datums: Port Townsend NOAA Station No. 9444900

Tidal Datum	Elevation Relative to MLLW at Gage Location (feet)
Highest Astronomical Tide	10
Mean Higher High Water	8.5
Mean High Water	7.8
Mean Sea Level	5.0
NGVD29	4.8
Mean Low Water	2.5
NAVD88	1.1
Mean Lower Low Water	0.0
Lowest Astronomical Tide	-4.0

Notes:
NAVD88: North American Vertical Datum of 1988
NGVD29: National Geodetic Vertical Datum of 1929

3.4 Wind Data

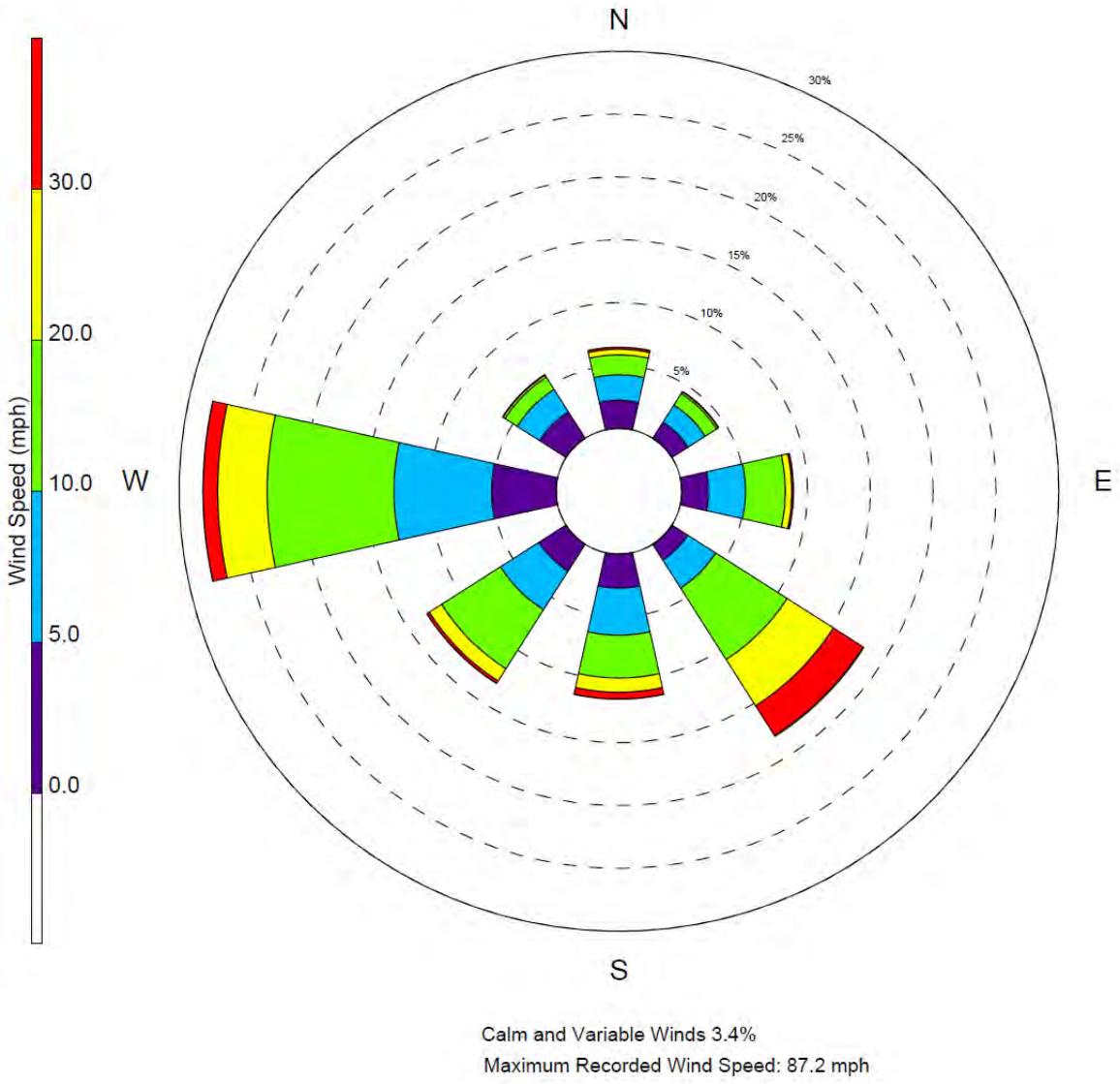
Wind data from Smith Island Lighthouse, located north of Fort Worden in the Strait of Juan de Fuca, were used in the coastal environment evaluation. Data from 1975 to 2018 were used to develop extreme wind conditions for the project site; full wind distribution is shown on Figure 2, below. The results of the extreme wind analysis are shown in Table 2.

Table 2
Smith Island Extreme Wind Speeds*

Direction	10-year	50-year	100-year
Northeast (22 to 67 degrees)	18.6	24.5	27.0
East (67 to 112 degrees)	20.9	30.6	35.2
Southeast (112 to 157 degrees)	31.1	38.4	41.5

Note:
*Wind speeds represent 2-minute average wind speeds, in miles per hour.

Figure 2
Smith Island Wind Rose



Wind data from Smith Island Lighthouse, from 1975 to 2018

3.5 Hindcast Wind-Waves

The extreme wind data, as outlined in Table 2, were used in a wave hindcast analysis to estimate potential wave heights at Fort Worden. The 2-minute windspeeds were adjusted to 15-minute windspeeds and analyzed using the Automated Coastal Engineering System Wave Prediction module (Leenknecht et al. 1992). Table 3 outlines the results of the wave hindcast analysis.

Table 3
Hindcast Extreme Waves

Direction	Fetch (miles)	10-year Wave Height (feet) Period (seconds)		50-year Wave Height (feet) Period (seconds)		100-year Wave Height (feet) Period (seconds)	
Northeast (22 to 67 degrees)	4.4	0.9	1.9	1.3	2.2	1.5	2.3
East (67 to 112 degrees)	7.2	1.3	2.3	2.1	2.8	2.3	3.0
Southeast (112 to 157 degrees)	7.9	2.0	2.8	2.5	3.1	2.8	3.2

Note:
Wave heights based on 15-minute sustained wind speeds.

3.6 FEMA 100-Year Flood Elevation

The latest FEMA Flood Insurance Study (FIS) for the area is pending effectiveness June 2019. The FIS states that the 100-year still water elevation at 11.7 feet North American Vertical Datum of 1988 for Admiralty Inlet. No information is available from FEMA for the 100-year wave conditions at or near the site; therefore, predictions of the 100-year wave conditions shown in Table 4 will be assumed for the project shoreline.

3.7 Sea Level Rise

The Washington Coastal Resilience Project published the Projected Sea Level Rise for Washington State (Miller et al. 2018), with the latest sea level rise projections. The projections analyzed two different greenhouse gas scenarios (Representative Concentration Pathway [RCP] 4.5 and RCP 8.5) for various chances of likelihood and up to the year 2150.

The 50% probably of occurrence sea level rise predictions are presented in Table 4 for both greenhouse gas scenarios and the corresponding MHHW and HAT tidal elevations. The specific sea level rise estimates used to develop coastal engineering design criteria as part of the alternatives evaluation will be selected in coordination with Parks.

Table 4
Sea Level Rise

Year	RCP 4.5			RCP 8.5		
	Additional Feet	MHHW (feet, MLLW)	HAT (feet, MLLW)	Additional Feet	MHHW (feet, MLLW)	HAT (feet, MLLW)
2010	0.1	8.6	10.1	0.1	8.6	10.1
2020	0.2	8.7	10.2	0.2	8.7	10.2
2030	0.4	8.9	10.4	0.4	8.9	10.4

Year	RCP 4.5			RCP 8.5		
	Additional Feet	MHHW (feet, MLLW)	HAT (feet, MLLW)	Additional Feet	MHHW (feet, MLLW)	HAT (feet, MLLW)
2040	0.5	9	10.5	0.5	9	10.5
2050	0.7	9.2	10.7	0.8	9.3	10.8
2060	0.9	9.4	10.9	1	9.5	11
2070	1.1	9.6	11.1	1.3	9.8	11.3
2080	1.3	9.8	11.3	1.6	10.1	11.6
2090	1.5	10	11.5	1.9	10.4	11.9
2100	1.8	10.3	11.8	2.2	10.7	12.2
2110	2	10.5	12	2.4	10.9	12.4
2120	2.2	10.7	12.2	2.7	11.2	12.7
2130	2.4	10.9	12.4	3.1	11.6	13.1
2140	2.6	11.1	12.6	3.4	11.9	13.4
2150	2.8	11.3	12.8	3.7	12.2	13.7

Notes:
Sea level rise is additional feet relative to 1991 to 2009 average, and MHHW and HAT levels are based on current MLLW elevations.
HAT: highest astronomical tide
MHHW: mean higher high water

3.8 Sediment Transport

No direct sediment transport data are available for the project shoreline. The Geomorphology of Puget Sound Beaches report (Finlayson 2006) has the closest longshore drift rates to the project site, at Port Townsend marina, at 1,000 meters per year toward the west. While this location's transportation runs toward the west, the project site experiences a similar wave climate from south to north.

Some inferences can be made for the potential littoral transport rate based on State Parks data of excavation of sediment from the boat launch ramp. The amount removed from the boat ramp ranged from 7 to 53 cubic yards, with the time between removal ranging between 1 and 23 days. The daily average was then found to be approximately 10 cubic yards (approximately 7.5 cubic meters), which equates to approximately 3,400 cubic yards (2,600 cubic meters) per year. This estimate is based on only a few months of data in 2018, and should be considered an order of magnitude estimate of littoral drift rate at the site. This estimate also does not take into account transport over the entire beach profile (only the boat launch) or seasonal differences in drift rates (all data collected in fall/winter of 2018).

4 References

FEMA (Federal Emergency Management Agency), 2019. *Flood Insurance Study: Jefferson County, Washington.* Study number 53031CV000A. Effective: June 7, 2019.

Finlayson, David, 2006. *The Geomorphology of Puget Sound Beaches*. Puget Sound Nearshore Partnership Report No. 2006-02. Published by Washington Sea Grant Program, University of Washington, Seattle, Washington. Available at: http://pugetsoundnearshore.org.

Leenknecht, David A., A. Szuwalski, and A. Sherlock, 1992. *Automated Coastal Engineering System – Technical Reference*. September 1992.

Miller, I.M., Morgan, H., Mauger, G., Newton, T., Weldon, R., Schmidt, D., Welch, M., Grossman, E. 2018. *Projected Sea Level Rise for Washington State – A 2018 Assessment*. A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, Oregon State University, University of Washington, and US Geological Survey. Prepared for the Washington Coastal Resilience Project. July 2018.

NOAA (National Oceanic and Atmospheric Administration), 2018. Tides and Currents. Accessed: January 25, 2019. Available at: https://tidesandcurrents.noaa.gov/datums.html?id=9444900

Sitts & Hill, 2016. *Fort Worden Pier and Marine Center Facility Condition Assessment Report*. Prepared for Washington State Parks and Recreation Commission. December 2016.

UWCIG (University of Washington Climate Impacts Group), 2017. *Preparing Washington State Parks for Climate Change*. Prepared in partnership with Washington State Parks and Recreation Commission. June 2017.