California North Coast Offshore Wind Studies

Port Infrastructure Assessment Report

This report was prepared by Aaron Porter and Shane Phillips of The Mott MacDonald Group. It is part of the *California North Coast Offshore Wind Studies* collection, edited by Mark Severy, Zachary Alva, Gregory Chapman, Maia Cheli, Tanya Garcia, Christina Ortega, Nicole Salas, Amin Younes, James Zoellick, & Arne Jacobson, and published by the Schatz Energy Research Center in December 2020.

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Schatz Energy Research Center
Humboldt State University
Arcata, CA 95521 | (707) 826-4345

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Executive Summary

The Humboldt Bay Offshore Wind Port Infrastructure Assessment Report was initiated by the California Ocean Protection Council to evaluate the need and opportunities for improving port infrastructure (Navigation & Marine Terminal) to support the floating offshore wind (floating OSW) industry. This report is part of the North Coast Offshore Wind Study led by the Schatz Energy Research Center (SERC) at Humboldt State University. The purpose of this assessment is to:

- Develop conceptual-level port infrastructure requirements for supporting small (~50–150 megawatts (MW)) and large (~1800 MW) floating OSW installations.
- Identify capabilities and gaps of the existing port infrastructure.
- Develop recommendations for port infrastructure upgrades.
- Develop opinions of associated planning-level construction cost estimates.

This study addressed the following requirements when considering both the conceptual small and large wind farms:

- Evaluate the capability of existing marine terminals within Humboldt Bay and the need for upgrades or new terminals in order to unload offshore wind farm materials and components, store and stage materials, support assembly, support fabrication, and provide a base for operations and maintenance.
- Evaluate the capability of the Federal Navigation Channels (FNC) and other in-water areas within and in the vicinity of Humboldt Bay to support safe and efficient assembly of the offshore wind farm and assess the need for potential geometric or operational modifications to the FNC.

Marine terminal improvements: There is no existing marine terminal in Humboldt Bay that can support floating OSW assembly, substructure fabrication, or O&M activities without investment. A screening assessment was conducted and identified the Redwood Marine Terminal (RMT), areas I and II as the likely locations for an offshore wind marine terminal (see Figure 10). Conceptual engineering was conducted to assess infrastructure upgrades to create a marine terminal (consisting of yard, wharf, and berth, as shown in Figure 1) that would support both small- and large-scale projects:

- New high-capacity (~4,000 to 6,000 psf) wharf structure designed to accommodate sea-level rise. Small OSW projects would likely require a similar size footprint as the existing wharf at RMT 1. Large OSW projects will require a larger footprint than the existing wharf at RMT I.
- Berth dredging is likely required in areas outside the extents of prior capital or maintenance dredging activities.
- Yard ground improvement and surfacing over a large area of RMT I & II with connection to utilities and road transportation system.
- O&M vessel wharf or pier, moorage floats, and potentially a helipad.

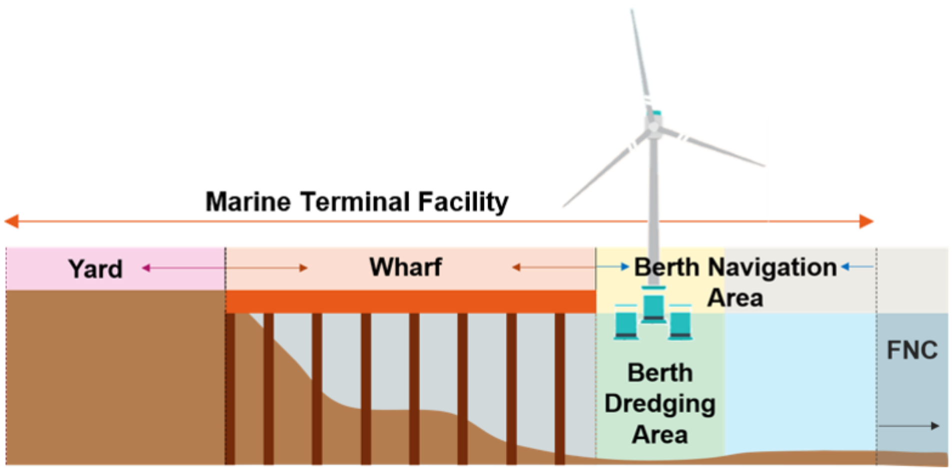


Figure 1 – Schematic showing various elements of a marine terminal facility

Navigation infrastructure improvements: The existing navigation infrastructure can support assembly activities; but throughput and geometry of the floating wind devices (thus, wind turbine power generation per unit) may be constrained without modifications to the Federal Navigation Channel (FNC). The need for upgrades was found to be related to specifics on device geometry, which varies by technology. The following upgrades may be required for large projects, but that depends on device geometry, so further analysis is required to confirm need and extent:

- Localized widening of the FNC at the entrance to Humboldt Bay (Entrance Channel)
- Widening of the North and Samoa FNCs
- Localized dredging for wet-storage and staging areas to support installation project throughput

Capital costs: Costs for port infrastructure upgrades will vary, depending on the size of the OSW project, annual throughput requirements, results of future site investigations, and other project-specific requirements. Planning-level costs for assembly, O&M navigation, and marine terminal facilities were developed based on assumptions and schematic-level designs:

- Small scale OSW project assembly and O&M, ~ $50–110 million.
- Large scale OSW project assembly and O&M, ~ $130–310 million.
- Floating substructure fabrication (yard, berth, wharf), ~ $50–100 million (if required).

Operations: Capital improvements and limitations on operations are connected. The infrastructure assessment considered the following operations:

- A modification of the maintenance dredging schedule or frequency of dredging for the FNC Entrance Channel at the entrance of Humboldt Bay to provide design water depths for a greater portion of the year would result in increased efficiency and safety of the buildout of small and large offshore wind farms and requires coordination with United States Army Corps of Engineers (USACE).
- Assembly and installation activities are likely to be limited to favorable weather months, which could result in a deployment and installation window of six months or fewer.
- A large (1800MW) offshore wind farm project could take 3–6+ years for assembly and installation.
- Winter wave climate could result in extra planning for O&M activities.
- Dredging of new wider berths to support OSW could increase the maintenance dredging needs of the new berths, outside the FNC.
- A new wharf would likely meet operational requirements of other industries and when nolonger in use as an assembly wharf would have the capability of serving other industries.

Infrastructure buildout schedule: Building out port facilities to support small projects would likely take 3–6 years. Port facilities to support large projects would likely take 5–7 years. If the FNC requires modification, the lead time of 5–7+ years for full assessment and approval could be the limiting factor for construction.

Next steps: Further site investigation, analysis, and design development will need to be conducted to refine the design concepts and cost estimates. Key elements include:

- A refinement of the existing bridge simulation model of Humboldt Bay is required to refine navigation constraints for device towing in the Entrance Channel and the Inner Channel.
- Floating foundation (deadship) tow plans should be developed in coordination with local US Coast Guard (USCG) unit.
- An operability assessment should be conducted to refine throughput capabilities and to identify constraining elements.
- A study to assess changes in aids to navigation (ATONs) will likely be required and requires coordination with the USCG through the Waterways Analysis and Management System (WAMS).
- Further investigation will need to be conducted during the preliminary design phase to optimize the finished elevation for a new wharf/yard with consideration for sea-level rise (SLR), stormwater, flooding and type of structure.
- A Navigation Risk Assessment would be required by the USCG. Early engagement with the local USCG is highly encouraged.
- Wharf and berth orientation and location need to be refined based on a detailed coastal engineering analysis to consider maintenance dredging needs.
- A detailed Navigation Safety Risk Assessment (NSRA) should be completed to evaluate impact to navigation for any waterfront facility added, modified, and removed.
- Floating foundation anchorage and staging area orientation and location need to be refined based on maintenance dredging needs, wave exposure, and other environmental conditions[1].
- Wave analysis is needed to aid in siting of the O&M vessel base within the Bay to determine suitable locations for a small craft harbor, in accordance with industry guidance.

[1] Anchorage modifications or establishment is a USCG District Eleven authority under 33CFR109.05.

- Conduct outreach with regulatory authorities, users, developers, UASCE, to help refine criteria and inform feasibility assessment work.
- An extensive subsurface investigation and report is needed prior to refinement of the wharf structure design.
- Environmental, geotechnical, and land/hydrographic surveying within the area of the project area incorporated into the planning and engineering design work.
- Studies to develop quantitative risk parameters, and adaptation or mitigation strategies to increase the resiliency of port infrastructure.
- A detailed port planning/throughput study with specific goals for development of alternatives.

Glossary

Term	Definition
Air Draft	Vertical distance measured from the device/vessel waterline to the highest point on the device/vessel.
Anchors	Secures the mooring lines to the seafloor. May be embedded, grouted, gravity or other type of anchors.
AHV	Anchor Handling Vessel or Tug - tug boat used for tow-in and tow-out of assembled floating offshore wind turbines.
Assembled Device	A fully assembled floating offshore wind turbine, including substructure and WTG. Also referred to as “device loaded w/ WTG.”
Assembly	Refers to construction of floating offshore wind turbine at an Assembly Facility by connecting various fabricated components (substructure, tower, nacelle, blades, etc.).
Assembly Berth	Purpose-built berth for assembly of offshore wind devices.
Assembly Facility/Assembly Terminal	Marine terminal facility that will be utilized during assembly of the offshore wind turbine, prior to tow-out to the installation location; can facilitate wind turbine assembly and component delivery.
Ballasting	In reference to a floating offshore wind turbine, ballasting refers to filling tanks in the foundation with water to increase device draft and provide greater stability.
Ballasting Area	A designated area with sufficient depth for ballasting of WTG device.
Beam	The width of a device/vessel.
Berth	Designated location where a device/vessel may be moored. For overwater structures, the berth is the part of a wharf or pier where people, equipment, and components are moved to and from vessels or devices (see Assembly Berth and Vessel Berth).
Berth Dredging Area	Area that is dredged to provide sufficient depth for moored vessels/devices at the berth for all water levels.
Berth Navigation Area	Area encompassing the berth and the area adjacent to the berth required for marine terminal navigation and maneuvering.
Blades	React to wind so that they rotate the rotor. Blades are considered part of the rotor.
CFR	Code of Federal Regulations
Class 1 Rail	Railway served by one of the seven largest freight carriers in the U.S. (i.e., BNSF, Union Pacific)
COG	Center of gravity
Component	A piece of the assembled WTG device (E.g., blade, nacelle, tower).
Crane Vessel	A vessel fitted with a heavy lift crane for lifting (but not transporting) heavy loads.
CTV	Crew Transfer Vessel – vessels that support the transfer of crew members and light supplies for day trips between a port facility and the offshore wind farm for operation, inspection, and maintenance activities.
Deck Barge	A flat barge used for transporting large/heavy loads.
Deepwater Port	A port able to accommodate Panamax size vessels.
Device A	Example floating wind turbine geometry; Device A represents the larger end of the range of device geometries considered. 300 ft. beam, 36 ft. transit draft. See Table 2.

Device B	Example floating wind turbine geometry; Device B represents the smaller end of the range of device geometries considered. 200 ft. beam, 25 ft. transit draft. See Table 2.
Dockside	Used to describe activities occurring in the water, adjacent to the berth.
Downtime	Period when pre-construction or construction activities are not able to proceed as scheduled due to unfavorable or unsafe environmental conditions (wind speed, wave height, channel sedimentation, etc.).
Draft	Submerged depth of the device/vessel.
Dry Dock	A structure able to contain a ship and to be drained or lifted so as to leave the ship free of water with all parts of the hull accessible. May be floating (floating dry dock) or land-based (graving dock).
Entrance Channel	Refers to the Bar and Entrance Channel FNC that provides passage between Humboldt Bay and the Pacific Ocean.
Export Cable	The AC power cable(s) that transmit power from the offshore wind farm to the grid.
Fabrication	Manufacturing of offshore wind turbine components and substructures.
Fabrication Facility	Marine terminal facility that will be utilized to fabricate offshore wind substructures or other components; can facilitate fabrication and float-off of devices.
Feeder Barge	Barge that transports equipment and components from port facilities to an offshore installation site.
Fixed Foundation	Refers to non-floating offshore wind foundation, example is the offshore wind farms presently operating in Europe.
Float-off	Transfer of substructure from dry to wet (floating) conditions. Sometimes referred to as launching.
FNC	Federal Navigation Channel – Navigation channel that is managed and maintained by the USACE.
Freeboard	Height of vessel deck height above the water line
Gantry Crane	Crane mounted on top of a frame that straddles the item to be lifted.
HBHRCD	Humboldt Bay Harbor Recreation and Conservation District (The Harbor District)
Heavy Lift Vessels	Vessels designed to transport very large loads. Some are fitted with cranes for conducting heavy lifts.
Hub	Part of the rotor and connects the wind turbine blades to the nacelle.
Humboldt Call Area	A BOEM Call Area identified west of Humboldt Bay (approximately 20-30 nautical miles offshore).
Inner Channel	Refers to the FNCs within North and South Humboldt Bay (North Bay Channel, Fields Landing Channel, Samoa Channel and Eureka Channel) that are generally protected from oceanic swell.
Installation	Refers to anchoring assembled devices to the seabed at the offshore wind farm location and connection to electrical infrastructure.
Landfall	Landfall refers to the portion of cable installation where a subsea cable is brought on shore for transition to upland routing or injection into a substation.
Large Commercial Scale	Buildout scenario where offshore wind farm generates >1.8GW of power.
LOA	Length Overall – length (longest dimension) of a device/vessel.

Loaded with WTG	A fully assembled floating offshore wind turbine, including substructure and WTG. Also referred to as "assembled device."
Marine Rail	Rail system extending from upland into the water used for lowering and raising devices/vessels between water and land.
Marine Terminal	Consists of the Yard, Wharf, and Berth
Metocean Conditions	Wind, wave, ocean current, and tide conditions.
Mooring Lines	Lines which secure the device to anchors located on the seafloor.
Notional Cape Mendocino Area	Hypothetical wind farm area offshore Cape Mendocino for investigative purposes. This notional wind array area is not representative of a BOEM Call Area.
Ocean Landfall	Location where export cable makes landfall on the ocean side of the South Spit or North Spit.
Nacelle	Sits on top of the tower and is connected to the rotor. Houses mechanical components.
O&M	Operation and Maintenance
Offshore Floating Wind	Wind turbines supported by floating foundations located offshore of the coastline.
OSW	Offshore Wind
Port	Consists of navigation and marine terminal infrastructure
Pier	Overwater structure that is usually perpendicular to shore.
Pilot Scale	Built-out scenario in which offshore wind farm generates ~50MW of power.
Power Rating	Nameplate capacity rating. The maximum potential power output of the turbine generator at the time of installation.
Rotor	Consists of blades fixed to the hub.
Secondary Rail	Consists of Class 2 or Class 3 rail. May include short-line branches.
Semi-Submersible Foundation	A floating wind turbine foundation which is partially submerged in the water with a traditional mooring line system.
Semi-Submersible Heavy Lift Vessels	Self-propelled, oceangoing vessels designed to transport very large loads, with submersible capabilities for loading/offloading.
Semi-Submersible Heavy Lift Barge	Oceangoing barge (not self-propelled) designed to transport very large loads, with submersible capabilities for loading/offloading.
Semi-Submersible Dockside Barge	Semi-submersible, not self-propelled, barges/platforms that can be used to lower substructures into the water at a port facility.
SERC	Schatz Energy Research Center at Humboldt State University
Shiplift	System designed for vertically lifting and lowering vessels/floating devices out of ad into the water.
Slipway	Dredged waterway used for transferring devices/vessels between land and water.
Side-channels	Navigable channel that is not part of a Federal Navigation Project, and therefore is not federally maintained.
Small Commercial Scale	Buildout scenario where offshore wind farm generates ~150MW of power.
SOV	Service Offshore Vessel – oceangoing vessel that supports multi-day offshore operation and maintenance at a wind farm.

SPMT	Self-Propelled Modular Trailer – vehicle used for transporting very large or heavy loads fitted with lots of wheels for load distribution.
Staging Area	Upland staging area is an area dedicated to temporarily storing components prior to and during assembly. A Staging Area below MLLW is an area for temporary storing assembled offshore wind turbines prior to tow-out through the Entrance Channel.
Storage Area	Upland area dedicated to temporarily storing components. Not necessarily harborside.
Substation	Electrical infrastructure that converts between high voltage and low voltage currents to enable electrical generation, transmission, and distribution. Substations can be located offshore or on land.
Substructure	Floating wind turbine foundation
Submarine or Subsea Cable	Cable routed below MLLW.
Support Tug	Ocean or Harbor tugs that provide support for navigation of vessels or other floating devices. Support tugs may be used in conjunction with AHVs for tow-in and tow-out of floating devices.
Tension Leg Platform	Floating wind-turbine foundation, anchored to seafloor with tension lines.
Tow-in/Tow-out	Transport of assembled floating offshore wind turbine between the port facility and the offshore wind farm.
Tower	This is the support column for wind turbine.
Trim	The difference in draft between the front and back of a device/vessel.
UKC	Under Keel Clearance – distance between the bottom of a device/vessel and the sea bed. It is the difference between the water depth and the device/vessel draft.
USCG	United States Coast Guard
USEPA	United States Environmental Protection Agency
Vessel Berth	Purpose-built berth for component delivery and vessel moorage.
WAMS	Waterways Analysis and Management System
Wet Storage Area	Area for temporary storage of floating substructures or assembled devices in the vicinity of the Assembly Facility.
Wharf	Overwater structure that is usually parallel with the shoreline and can be “open” (pile-or column supported) or “closed” (solid fill).
Wind Turbine Generator (WTG)	Wind turbine unit, consisting of the nacelle, blades, and tower. Does not include substructure.
WTIV	Wind Turbine Installation Vessel – specialty vessel with jack-up and lifting capabilities to assist with installation (fixed-foundation) or assembly activities.
Yard	Upland part of marine terminal.

1 Introduction

Mott MacDonald prepared this report for Schatz Energy Research Center (SERC) at Humboldt State University and the State of California Natural Resources Agency, Ocean Protection Council to assess port infrastructure capabilities and upgrades needed in Humboldt Bay to support the buildout of floating offshore wind (floating OSW) farms off the North Coast of California (North Coast). This report is part of the North Coast Offshore Wind Study led by SERC, which assesses the potential for OSW energy generation along the North Coast. Figure 2 shows the North Coast Offshore Wind Study area. Humboldt Bay is California's northernmost deep-water shipping port and the only North Coast port potentially able to support floating offshore wind farms in the North Coast region.

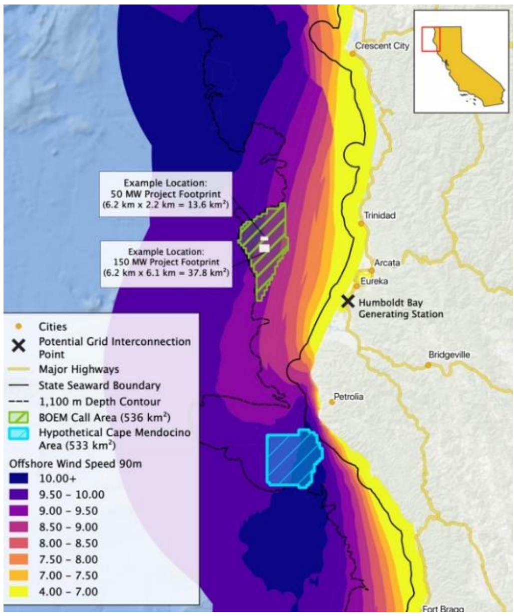


Figure 2 – Assumed project offshore wind farm location and size

Historically, Humboldt Bay's port infrastructure facilities were developed to serve the forest products industries. Prior studies showed that Humboldt Bay can likely provide build-out support facilities for the offshore wind industry; however, additional evaluations of the nature and extent of port upgrades were needed (Porter and Philips, 2016). The purpose of this assessment was to develop conceptual-level port infrastructure requirements for small (~50-150MW) and large (~1800MW) floating OSW installations, identify capability gaps in existing port infrastructure, develop recommendations for port infrastructure upgrades, and develop opinions of associated planning-level construction costs. The information presented in this report is not intended to be a detailed evaluation; but rather, a pre-feasibility-level assessment of upgrades likely required to support the floating OSW industry. Understanding the infrastructure upgrades will inform strategies for near- and long-term planning in the study area.

Figure 3 – Overview of Humboldt Bay and Entrance Channel (date unknown)

1.1 Assessment Background

The floating offshore wind industry is in the early stages of development, with no large-scale floating offshore wind energy farms deployed globally. The offshore wind energy market in Europe is well developed; currently, it relies on shallower water, fixed foundation installations (Porter and Phillips, 2016). Unlike the existing fixed foundation offshore wind industry, floating OSW turbines are likely to be assembled at port, in light of sea state conditions and equipment limitations. While this reduces the vessel fleet requirements (that is, no large jack-up vessels), the port facility must provide adequate infrastructure to assemble the turbine on site, such as a heavy-duty crane, an assembly area, a deep draft berth, and a high capacity wharf (Carbon Trust, 2019).

Small-scale floating OSW demonstration projects have generated electricity but are not yet installed on a large commercial scale in the U.S. or elsewhere. In addition, future floating OSW deployments will be larger in size than the existing ones, which have had relatively minimal logistical constraints (Carbon Trust, 2019). Thus, there is limited existing industry on which to base evaluation criteria directly for this study; instead, criteria must be developed based on existing information, similar industries, industry outreach, and assumed device characteristics based on best available current industry information.

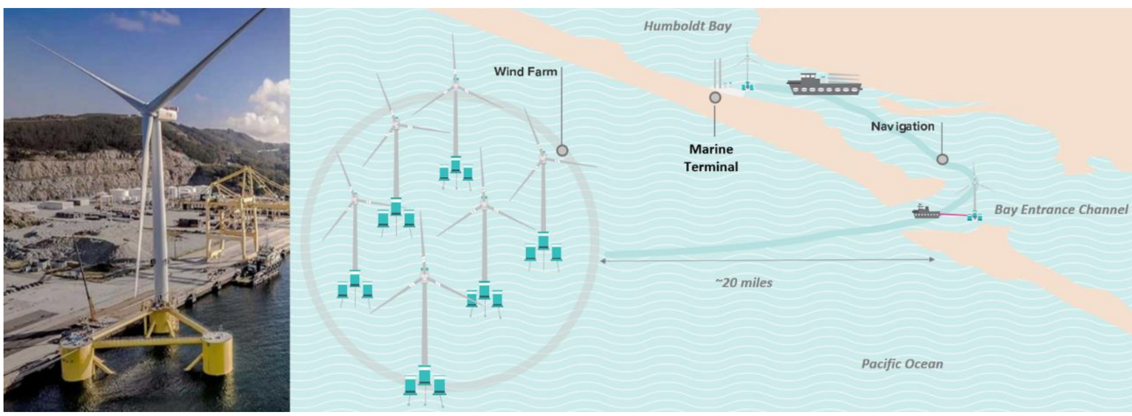


Figure 4 – (Left) Example of floating OSW device at a wharf; (Right) schematic showing a port facility supporting delivery of turbine components, turbine assembly, and assembled device tow-out

Source: (Left) Principle Power

Criteria were developed to evaluate existing navigation and port[2] infrastructure at a planning-level, identify where upgrades may be needed, and develop design concepts to meet the assessment criteria. Refinements in criteria will be needed as projects develop, and different projects will have project-specific criteria. The criteria developed for this study are intended to provide a basis for planning-level assessment and were developed based on a review of literature and similar industries, developer interviews, concept-level engineering analysis, review of standards and engineering/safety guidelines, and through interviews with marine transport specialists and construction contractors.

The components and final assembled devices are very large structures (Figure 4) that depend heavily upon the adequacy of the port infrastructure (marine navigation and marine terminal facilities) to execute an offshore floating wind farm installation. Port infrastructure supporting the assembly and installation of a floating OSW farm must be able to support a range of activities, including but not limited to: vessel delivery and offload or fabrication of the wind turbine components such as the blade, tower, and nacelle), storage of the components, delivery or fabrication and float-

[2] Port facility – consisting of the wharf (overwater structure parallel with shoreline) and the yard (upland part of a marine terminal).

off of the floating substructure, assembly of the wind turbine generator (WTG) components to the substructure, and tow-out of the assembled device (as shown in Figure 4). Different sized wind farm buildout scenarios have different requirements relative to these activities, and this assessment of facilities considers all buildout scenarios.

1.2 Assessment Approach

This report evaluates the capacity of Humboldt Bay's infrastructure to support floating OSW by:

- Documenting existing marine terminal and navigation infrastructure.
- Developing upgrade requirements for the marine terminal and navigation infrastructure.
- Assessing existing navigation and marine terminal infrastructure capabilities and constraints, while identifying any necessary upgrades.

This report provides a high-level summary of the assessment methodology, engineering assessments, conceptual engineering design schematics, and cost/schedule considerations. The following chapters summarize the report's findings and technical appendices provide additional details:

- 2 Basis of Assessment outlines the wind farm buildout scenarios, assumptions, environmental conditions, and uses/purposes of port infrastructure (e.g., manufacturing, assembly, operations and maintenance), as well as the assumptions that provided the basis and framework for this assessment.
- 3 Literature and Prototype Review Summary synthesizes information coming from several related industries that was instrumental in developing criteria for this assessment.
- 4 Port Facility Activity and Site Screening Assessment describes how the assessment focused on Humboldt Bay, while providing context for the port's facilities by comparing them to facilities elsewhere in California and Oregon.
- 5 Navigation Infrastructure: shows how adequate navigation infrastructure is necessary for a successful project, regardless of the level of investment in the marine terminal facility. Because navigation is critical to all floating OSW port operations, it was evaluated first, so the results would inform the entire report. The conceptual assessment of navigation facilities considered a range of vessels and device types and geometries[3] in order to develop opinions regarding existing capabilities and to determine what upgrades might be needed to support floating OSW activities.
- 6 Marine Terminal Infrastructure outlines marine terminal facility infrastructure requirements (yard, wharf, and berth), documents gaps in the capabilities of the screened assessment sites, and identifies potential upgrades. Design schematics were developed to a level sufficient for a planning study and to support opinions about the cost for upgrades.
- 7 Operations and Maintenance addresses preventive maintenance, minor corrections, and major corrective repairs. Maintenance and minor repairs will occur at the wind farm, whereas major repairs are likely to be conducted in port. O&M facilities have fewer restrictions than assembly sites, and example locations in Humboldt Bay have been assessed at a conceptual level.
- 8 Construction Cost Estimates and Schedule Considerations provides a likely magnitude for planning-level construction costs and an implementation schedule for use in long-term planning activities. Projected costs are sensitive to site investigations and site logistics that have not yet been evaluated.

[3] Geometry range assumptions validated based on interviews with developers.

- 9 Climate Change Assessment - Summary contains a conceptual-level vulnerability assessment that evaluates the potential impact of climate change, including tsunamis, on OSW infrastructure in the Humboldt Bay region. Appendix I provides a summary of this assessment and a detailed memorandum.
- 10 Conclusions summarizes key chapter-level findings for Pilot/Small-Scale Commercial and Large-Scale Commercial OSW installation scenarios in the Humboldt Bay region and presents conclusions and next steps.
- Data and References include the data sources utilized to develop the report, and literature references.
- Technical Appendices include:
  - Appendix A – Navigation
    - 1. Entrance Channel
    - 2. Inner Channel
    - 3. Wet-storage, Staging, and Ballasting
  - Appendix B – Wharf and Yard
  - Appendix C – Substructure Delivery and Float-Off
  - Appendix D – Nearby Port Facilities
  - Appendix E – Metocean Conditions
  - Appendix F – Port Screening Assessment
  - Appendix G – Operations and Maintenance
  - Appendix H – Vessel Database
  - Appendix I – Sea-Level Rise, Climate Change, and Tsunami Vulnerability

2 Basis of Assessment

The following elements comprise a framework for evaluating existing conditions and developing concepts for potential upgrades.

2.1 Floating OSW Farm Device Deployment and Operational Requirements

2.1.1 Wind Farm Buildout Scenarios

Wind farm locations and sizes are described in North Coast Offshore Wind Study: Offshore Wind Scenario Description (SERC, 2019) and summarized below for reference within this document. Port infrastructure requirements have been assessed differently for the different wind farm buildout sizes[4]. The Pilot and Small-Commercial Scale scenarios developed by SERC have been combined, because requirements for these two scenarios are likely similar. Note that no single existing wind farm is as large as the Large-Commercial Scale buildout scenario.

- Pilot Scale: 48 MW
- Small Commercial-Scale: 144 MW
- Large Commercial-Scale: 1836 MW

2.1.2 Wind Farm Components

Wind farm components requiring assembly, fabrication, installation, and maintenance are based on the assumptions in Offshore Wind Scenario Description (SERC, 2019). The following terms were referenced for development of the navigation and port infrastructure assessments.

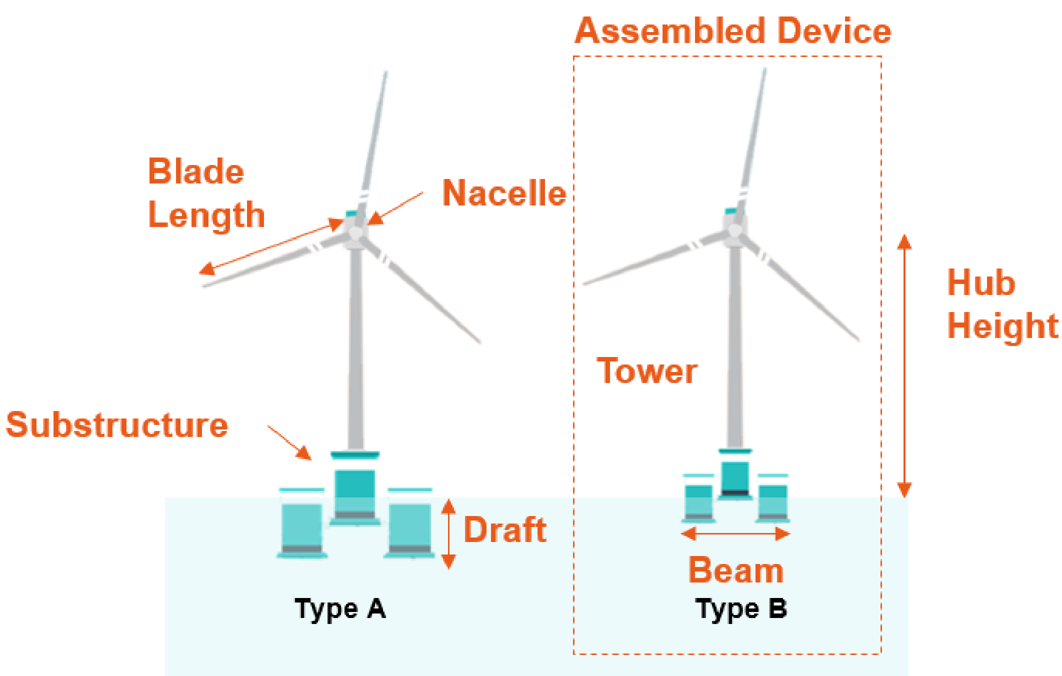


Figure 5 – Definitions: Substructure and WTG geometry

[4] All wind farm scenarios are assumed to use 12 MW turbines.

2.1.2.1 Wind Turbine Generator (WTG)

Component sizes: WTG component sizes are outlined in Offshore Wind Scenario Description (SERC, 2019). Table 1 provides a summary. These parameters were used to evaluate crane requirements.

2.1.2.2 Substructures

Type: The default substructure technology is semi-submersible, as defined in the Offshore Wind Scenario Description (SERC, 2019).

Material: This assessment does not specify between steel and concrete substructures.

Geometry: Floating OSW substructures have been parameterized with the simplified geometry in Table 2. The parameters are not specific to any design and are intended to reasonably bracket the range of substructure size likely to be deployed in this region. The actual substructure size may be between Type A and Type B geometries. It could also be greater or smaller, in some cases.

Table 1 – Study Component Sizes

Turbine Rating	Hub Height	Blade Length	Nacelle Weight	Tower Weight
12 MW	400-500 ft.	~300-330 ft.	600-800 tons	3 Pieces, 200-315 tons

Table 2 – Parameterized Substructure Characteristics

Parameterized Structure	Beam	Dry Weight[5]	Draft – Substructure Only	Draft – Assembled Device	Draft – Ballasted Device
Type A	300 ft.	4000-7000 tons	28 ft.	36 ft.	60 ft.
Type B	200 ft.	4000-7000 tons	20 ft.	25 ft.	45 ft.

2.1.3 Uses and Purpose of Navigation and Port Infrastructure

The assumed activities associated with floating OSW installation and use affect navigation and port infrastructure requirements. This section provides a general outline of assumed activities and the associated uses and purposes of infrastructure for all buildout scenarios[6]. The assumed activities are for the conceptual assessment only. Specific projects and technologies may have different needs and should be individually assessed. Figure 6 shows an example of a device fabricated and assembled in port, then towed to the installation location.

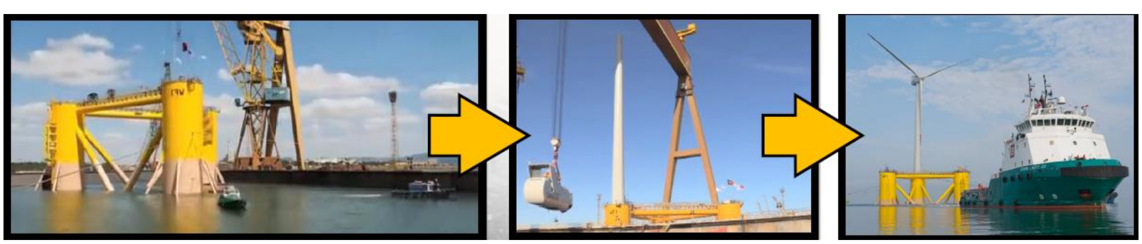


Figure 6 – Example of device float-off, assembly, and tow-out
(Source: Principle Power)

[5] There may be significant differences in weight between concrete and steel substructures. These values have been selected as a potential weight, to be used for the assessment. They are not specific to any technology.

[6] Anchor and mooring system installation and port infrastructure requirements were not assessed as part of this report. They may require additional study.

2.1.3.1 Navigation Infrastructure

Navigation infrastructure is assessed for the following activities:

- Manufacturing facilities
  - The manufacturing of OSW system components is assumed to be completed offsite and delivered to the Humboldt Assembly Facility via marine transport, because of the large size of the components and the lack of rail access to the port (see 4 Port Facility Activity and Site Screening Assessment).
  - Year-round vessel delivery of WTG components to Humboldt Bay (see Figure 7).
  - Substructure delivery, float-off, and maneuvering.
- Assembled device deployment
  - Device tow-out directly to site or to a staging area for temporary holding.
  - Wet-storage (anchorage) of substructure or assembled devices.
  - Ballasting of assembled devices.
  - Assembled device hookup and installation at site.
- Operations and maintenance
  - Tow-in and de-ballasting of devices for major repairs.
  - O&M crew transfer vessel and offshore service vessel transport.

Figure 7 – Example component delivery vessel, Vestvind

Source: https://www.allaboutshipping.co.uk/2017/06/27/united-wind-logistics-develops-and-realises-transport-concept-for-mhi-vestas-v164-wind-turbines/

A conceptual vessel database was developed for the activities above to aid in assessment of port infrastructure. Assumptions about vessel characteristics were developed to bracket the assessment, as shown in Table 3.

Table 3 – Parameterized Vessel Characteristics[7]

Vessel Category	Length (LAO)	Beam	Light Load Draft	Transit Draft	Ballasted Draft
Existing – Pax Silvia	656 ft.	106 ft.	-	28 ft.	
Device Type A w/ WTG	300 ft.	300 ft.	25-30 ft.	36 ft.	60 ft.
Device Type B w/ WTG	200 ft.	200 ft.	18-25 ft.	25 ft.	45 ft.
Component Delivery Vessels	400 ft – 650 ft.	80-140 ft.	15 ft.	20-35 ft.	
Specialty Heavy Lift Vessels	500-800 ft.	140ft-170+ft.		28-35 ft.	
Example Semi-Submersible Barge	500 ft.	125 ft.	5 ft.		40-48 ft.
Example Semi-Submersible Vessel	525 -900 ft.	150-230 ft	20 ft.		63-100 ft.
Crane Vessel	350 ft.	160 ft.	10 ft.	10 ft.	
Crew Transfer Vessel	65-100 ft	22-30 ft.		5-10 ft.	
Service Offshore Vessel	150-400 ft.	50-80 ft.		16-30 ft.	

[7] Not all vessels assessed are included in this table. Details in Appendix H.

2.1.3.2 Marine Terminal Infrastructure

Marine terminal infrastructure was assessed for the following activities:

- Manufacturing facilities
  - Manufacturing of components onsite was not part of the criteria for upland area requirements.
- Assembled device deployment[8]
  - WTG component delivery vessel berthing and offload.
  - WTG component staging, storage, and laydown areas to support device assembly.
  - Assembly of the WTG device at the wharf with large crane.
- Operations and maintenance
  - High-capacity wharf and deep draft berth for major repairs (e.g., blade).
  - O&M crew transfer vessel and offshore service vessel berths.

2.2 Port and Navigation Infrastructure Elements Assessed

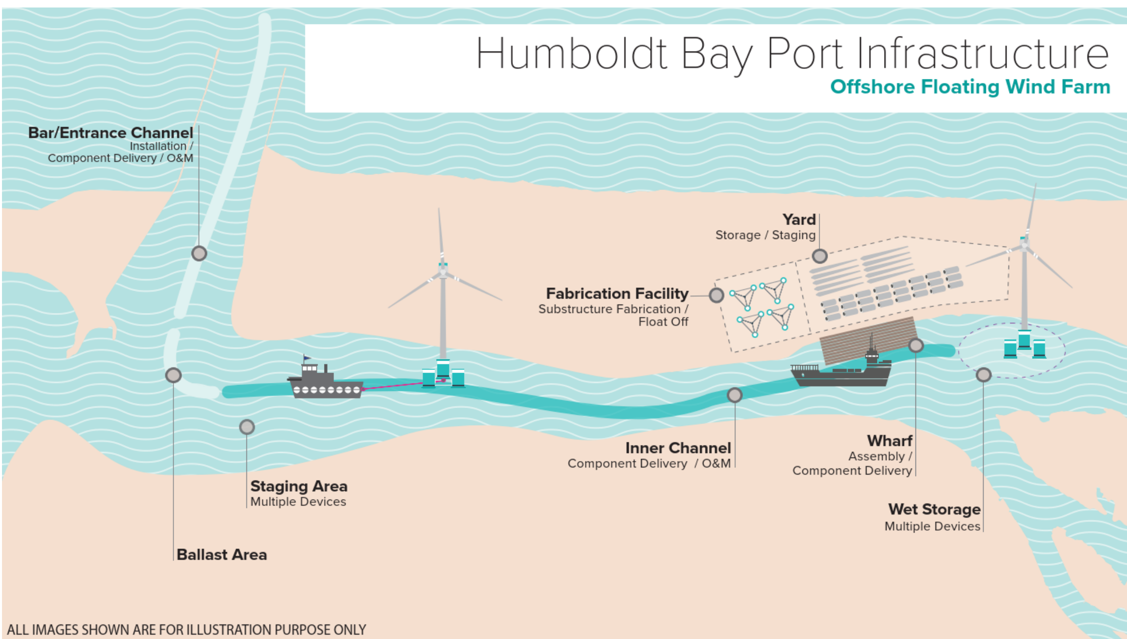


Figure 8 – Navigation and port features supporting floating OSW buildout

Port infrastructure needed to support floating OSW buildout includes the following critical elements, as shown in Figure 8:

- **Federal Navigation Channel (FNC):** Project areas that are federally managed by the United States Army Corps of Engineers (USACE). Depths are maintained by the USACE, with the local sponsor Humboldt Bay Harbor Recreation and Conservation District (HBHRCD or the Harbor District). There are limitations on changes to channel depth or width in these areas. The FNC has been parameterized as two areas:
  - **Bar/Entrance Channel:** The entrance to the harbor. The authorized depth of the FNC is 48ft MLLW. All delivered project vessels and assembled devices transit through this

[8] Pre-installation activities, such as surveys, anchoring, subsea cable installation.

location. Conditions at the entrance are variable and can affect throughput of vessels and WTG devices.

- **Inner Channel:** Protected navigation channel within Humboldt Bay that links the entrance of the bay to the Assembly Facility. The authorized depth of the FNC is 38ft MLLW. Component delivery vessels, installation support vessels, and WTG devices transit this channel.

- **Assembly Facility:** On-shore and nearshore facility supporting component delivery vessel berthing, storage of components, and assembly. As shown in Figure 9, the Assembly Facility includes:
  - **Yard:** Upland part of a marine terminal supporting assembly, which is utilized for storage of components, office space, etc.
  - **Wharf:** Overwater structure that is usually parallel with the shoreline and can be “open” (pile-or column supported) or “closed” (solid fill).
  - **Berth:** Designated location where a vessel may be moored. For overwater structures, the berth is the part of a wharf or pier where people, equipment, and components are moved to and from vessels or devices.
  - **Berth dredging area:** The area that is dredged to provide sufficient depth for moored vessels/devices at the berth, for all water levels.
  - **Berth navigation area:** The area encompassing the berth and the area adjacent to the berth required for marine terminal navigation and maneuvering of the devices or vessels.

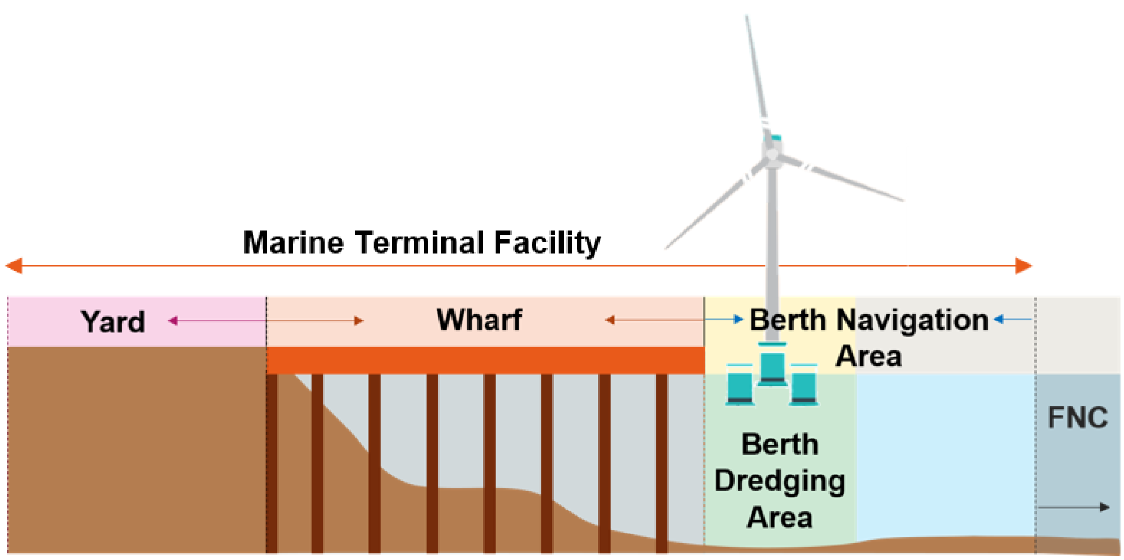


Figure 9 – Definitions: Assembly marine terminal facility port infrastructure

- **Fabrication yard:** Area used for fabrication floating substructures. A wharf and berth are also needed for substructure float-off.

- **In-water storage/staging:** Portions of the bay may be used to support wet-storage, staging, and ballasting of devices to support assembly and installation activities.
  - **Wet-storage:** Area near the assembly location that allows for in-water storage of substructures or assembled devices, so that assembly or fabrication throughput is not

affected by downtime due to environmental conditions at sea or in the Entrance Channel.

- **Staging area:** In-water area located near the Entrance Channel, where assembled devices may be temporarily stored to take advantage of favorable weather windows for tow-out.
- **Ballast area:** Deep, in-water area where devices may be ballasted down closer to or to the installed draft. Ballasting within a protected bay is preferred to ballasting at-sea, to minimize risk and cost.

2.3 Area of Study

The area of study includes both public and private facilities[9] within Humboldt Bay. Figure 10 shows the marine terminal and navigation facilities assessed.

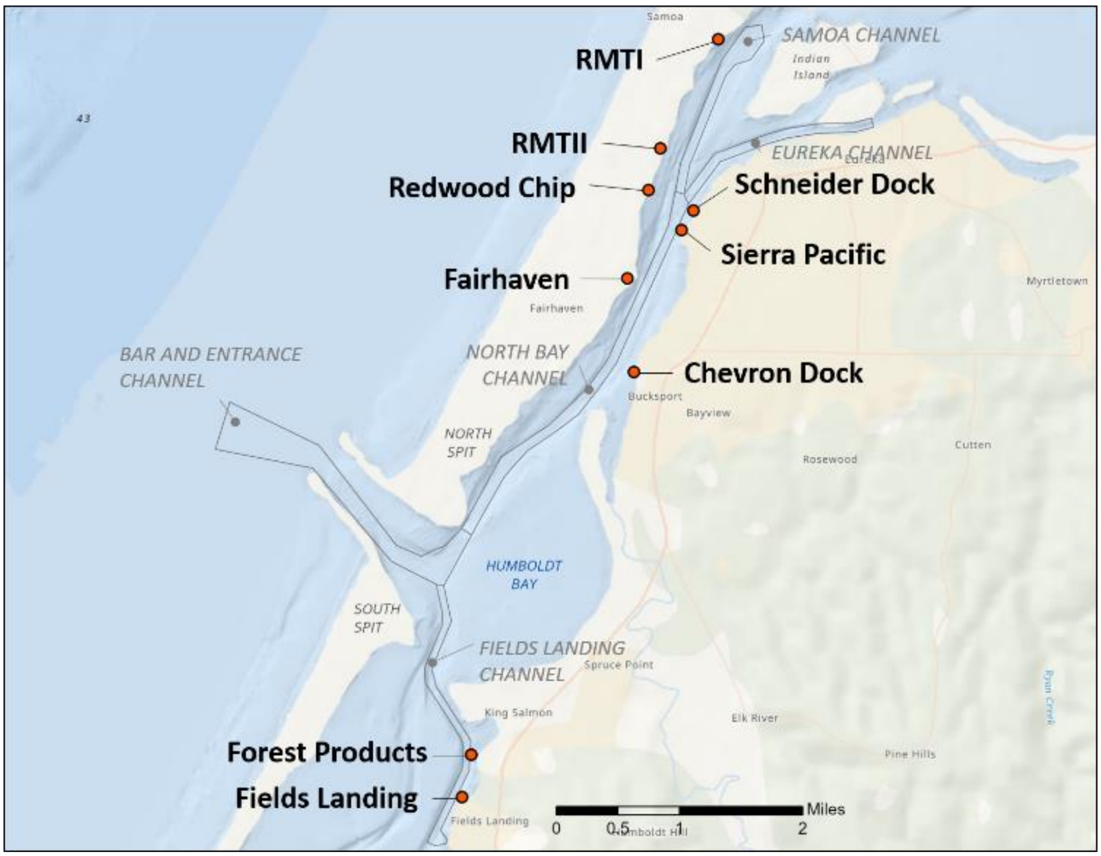


Figure 10 – Assessed port infrastructure (marine terminal and navigation infrastructure)

[9] Limited review of privately held lands. Public outreach not part of this assessment.

2.4 Metocean Conditions

Metocean conditions (e.g., wind, wave, tides) can result in downtime for component delivery, assembly, installation, and maintenance activities; therefore, they were assessed as part of the larger system. Appendix E includes wind, wave, tidal current, and water level conditions, based on an abbreviated review of available data. The wave climate off the coast of northern California is characterized by ocean swell and extreme wave heights during storm conditions. It has been reported that environmental conditions (large swell, strong winds, fog, haze) often adversely affect transit in the Entrance Channel. The data in Appendix E are intended to indicate potential conditions near the assessment areas; however, site-specific conditions (such as locations within the entrance channel) will vary. A summary of applicable conditions follow:

- Waves
  - Wind speeds and wave heights are larger during the fall/winter/spring seasons than during the summer.
  - OSW farm: exposed to Pacific Ocean swell.
  - Entrance Channel: exposed to Pacific Ocean swell and local wind waves.
  - Inner Channel: protected from Pacific Ocean swell; subject to local wind waves.
- Tidal currents
  - Entrance Channel: up to 3-3.5 knots, with horizontal circulation patterns.
  - Inner Channel: up to ~1.7 knots.
- Water levels
  - Tide range of 6.86 ft. between mean higher high water (MHHW) and mean lower low water (MLLW).
  - Highest observed tide: 9.88 ft. MLLW

2.5 Geologic Conditions

Publicly available information was reviewed to develop an understanding of the geologic site conditions. Borings are not available at a majority of the sites assessed; thus, requiring assumptions and qualitative interpretation of available information. Based on the information reviewed, the following assumed conditions have been developed:

- Offshore are numerous faults, including the Cascadia Megathrust fault line.
- In general, the project study area is potentially susceptible to liquefaction hazards in the top 10–15 feet of sediment (consisting of loose sands). This material is unfavorable for supporting heavy loading requirements.
- Below this layer, the material becomes denser and less susceptible to liquefaction. This material is more favorable for supporting heavy loading requirements.
- Section 6 Marine Terminal Infrastructure provides applicable site-specific assumptions.

2.6 Notable Data/Information Gaps

The following were identified as data gaps in our assessment[10]:

- **Geotechnical**: Site-specific borings at marine terminal facility assessment sites affect structure type.
- **Bathymetry and topography**: High-resolution, recent bathymetry outside the FNC affects dredging need and volume.
- **Metocean:**
  - Wind-waves at marine terminal locations could affect suitability and need for breakwaters.
  - Ocean swell propagation within the harbor entrance affects suitability of ballasting and staging areas.
- **Geomorphological**: Historical sedimentation patterns and rates were not reviewed and may affect berth location.
- **Vessels**: Future, specialized assembly, float-off, and installation vessels may be developed, which could affect the results of this study.

2.7 Regulatory Considerations

Detailed regulatory assessment is not part of this scope of work, but the following qualitative regulatory considerations have been included at a conceptual level:

- In-water work window
  - The in-water work window can affect construction length and must be considered.
  - It is understood that the limiting window is July 1st – Oct 15th; but it is assumed that construction outside the window will be allowed with mitigation actions.
- Habitat
  - Construction should avoid disturbing eelgrass beds, if possible. Few mitigation options have been reported available within the bay.
- Jones Act
  - Component and substructure delivery vessels from can be foreign flagged if the origin is an international location. Vessels transporting equipment or components from a US Port to another US Port or facility must be US flagged.
  - Tugboats, crew vessels, supply vessels, and other installation assist vessels must be US flagged and inspected by the USCG but are assumed to be available (Porter and Phillips, 2016).
- Coastal dependent industrial (CDI) use zoned land
  - The supply of CDI exceeds projected long-term demand by 600+ acres (BST Associates, 2018) and is therefore not considered a limiting aspect of this assessment.
- Site contamination
  - Not assessed in this study, but it should be noted that the area between RMTI and RMTII is part of the USEPA Brownfield Site Assessment Program.
- Port Operations
  - A project of this magnitude would likely require approval by the USCG through the Ports and Waterways Safety Act.
- Local ordinances

[10] New data collection may have been conducted since the time of report development.

- Lighting restrictions not known.
- Local guidance on noise levels (Humboldt County General Plan Update, Chapter 13).
- A Coastal Development Permit will be required from the Coastal Commission
- A permit from the HBHRCD will be required for construction within Humboldt Bay.

2.8 Overland Transport Connections

Road and rail connections are typically used as part of the port connection network. The following constitutes part of the assessment basis:

- Rail access
  - Active Class 1, 2, or 3 rail access do not currently exist. Based on prior studies conducted for the Harbor District (BST, 2013), rail access could involve an investment of ~$1 billion and was not recommended. This assessment assumes rail access is not planned for future development.
- Road access
  - Per coordination with the Harbor District, it is understood that roadway improvements may be conducted, if needed on the Samoa Peninsula, following the Samoa Industrial Waterfront Preliminary Transportation Access Plan (LACO, 2013). Other sites may require roadway access assessment studies.
  - Highway road access limits outside the project study area were not assessed in consideration of the OSW components sizes. The Port is served by Highway 299 from the east and Highway 101 from the north and south. Highway 299 can accommodate Class I trucks and Highway 101 from the south can accommodate Class I trucks, except for a narrow 10 mile stretch. However, it is assumed that because of the size and weight of the components, transport of assembled nacelles, tower sections, and blades is not likely to occur by truck.

2.9 Project Assumptions

The following assumptions underpin execution of this assessment and were coordinated with SERC.

- Port infrastructure upgrades to be based on the pre-feasibility assessment level.
- Assessment based on observations, prior project experience, interviews, and available facility documents.
- Technology developments may allow for differences in WTG and substructure designs and additional efficiencies in assembly, deployment, and maintenance, other than those reported in this document (based on existing technology and assumptions confirmed with developers, only).
- Construction cost estimates provided at planning level only. They have not been developed based on application of potential requirements to specific locations.
- Navigation assessment conducted at conceptual level only. Device-specific maneuverability and other operational details not included.
- Exclusions:
  - Design drawings are not part of this work.
  - Potential upgrades to ports/harbors outside Humboldt not developed.
  - New data collection has not been conducted specifically for this report.
  - Numerical metocean or vessel modeling are not part of this study.

- Detailed condition assessments, inspections, surveys, and detailed structural analysis are not part of this work.
- Bathymetry data is from available information only. The digital elevation model (DEM) data is not intended to represent a specific date. Recent data (April 2020) is available for within the USACE FNC channel and has been used, but depths are subject to change.
- De-commissioning not assessed within this study.
- Anchoring and mooring installation not assessed as part of this study.
- Dredge disposal is not assessed as part of this study. Open water disposal is assumed at the Humboldt Open Ocean Disposal Site (HOODS), approximately 3 miles off the coast of Humboldt Bay.

2.10 Guidelines and Standards

The following guidelines and standards have been referenced as part of this assessment:

- Harbour Approach Channels Design Guidelines (PIANC, 2014)
- Hydraulic Design of Deep-Draft Navigation Projects (USACE, 2006)
- USACE – Historical feasibility and design documents for Humboldt Bay (various)
- Port Designer's Handbook (Thoresen, 2003)
- Humboldt Harbor Safety Committee Regulations

3 Literature and Prototype Review Summary

Without an existing floating offshore wind commercial industry, review of existing literature and similar industries becomes an important factor in developing requirements for port and navigation infrastructure. This chapter synthesizes information from several related industries and reports, including a review of fixed foundation offshore floating wind requirements, load out (float-out) of gravity base foundations, and lessons from the Oil and Gas industry. Specifically, the following studies provide additional details and are recommended as further reading.

- Joint Industry Project for Floating Wind (Carbon Trust, 2019)
- NYSERDA Assessment of Port Infrastructure Phase 1 and Phase 2 (2017, 2018)
- Offshore Wind Industry Review of Gravity Based Structures (Carbon Trust, 2015)

This synthesis highlights key points from studies, guidelines, and prototype port facilities relevant to this assessment. This review is not intended to be comprehensive, as many new studies are on-going, and floating OSW project development is rapidly accelerating. This review does not summarize developer interviews, because those contain confidential information.

The following relate to general project scope, navigation, assembly yard, wharf, substructure fabrication and float-off, equipment requirements, and O&M.

3.1 General

- No existing large-scale floating OSW farms. The largest floating offshore wind farm, located in Scotland, is five units that use a substructure technology unlikely to be suitable for installation at Humboldt Bay because of the draft requirements for tow-out (Spar, 180-foot water depths required).
- Unlike for fixed OSW farms, limited studies have been conducted and few project examples built to support Large Commercial-Scale floating OSW farms.
- Future floating OSW farms will likely be required to support bigger wind turbine generator (WTG) components than existing deployments.

3.2 Navigation

- Serial installation during winter may be challenging because of downtime risks at sea, leading to an accumulation of foundations that are built and need to be delivered during summer.
- Thorough analysis of navigation and construction site limitations is needed. Wet storage of multiple units is likely to be a key element in maintaining sufficient throughput rates.

3.3 Assembly Yard

- With higher risk of downtime due to weather or other restrictions, a greater area is required for storage of WTG components being staged for assembly.
- Extensive planning and logistics are needed in order to link production to weather windows and plan yard size accordingly.
- Storage/staging yards at ports supporting large commercial wind farms can be 100 acres or greater (though they may support multiple projects).
- Existing ports in Europe have been re-configured to store components for multiple wind farms. Port of Esjberg, Denmark, is an example, with components for 100 turbines stored on 100+ acres.
- Minimum WTG staging land area for large commercial scale appears to be ~ 30–50 acres (8 MW devices) but could be as large as 100 acres depending on navigation downtime risks.

- Bearing pressure for storage of components within the yard is 1200–4000 psf+. Lower bearing capacity is required if using self-propelled modular transporters (SPMT). Higher capacity means more flexibility.

3.4 Assembly Wharf Areas

- Wharf length for WTG component loading/offloading, ~ 500–650 feet.
- Bearing capacity to support crawler crane access areas, 3000–6000 psf.

3.5 Substructure Fabrication and Float-off

- Serial production will likely be required for fabrication of substructures. With less serialization or parallel serial lines of assembly, dry and wet storage requirements increase.
- To support large-commercial scale projects, fabrication of substructures may need to be spread over multiple locations.
- Yard dimensions to support fabrication of substructures could be reduced with 24/7 operations.
- Load-out challenges include the long lead time to develop a facility, setting up space with a high bearing capacity, and having enough draft and area for marine operations, including wet-storage.
- A number of options for float-off are available for OSW, based on a review of gravity-based foundations (GBF) and floating OSW:
  - Lifted solutions requiring a crane, such as a heavy lift-vessel or gantry crane
  - Rolled or skidded solutions, such as a slipway (marine railway)
  - Buoyant solutions, such as a floating drydock or land-based graving dock
  - Dry-docks, which are unlikely cost effective because capital costs are very high and serial production is limited when loading out multiple units at once
  - Assembly upland with load-out to water by SPMT and barge, which is likely the most cost-effective method
- Specific considerations for concrete substructure fabrication:
  - Yard costs for concrete foundation fabrication, which may require a batch plant, could be $10–100 million.
  - Humboldt County has extensive sources of high-quality gravel that could be used as concrete aggregate.

3.6 Equipment

- Limited options for cranes that can meet lift requirements. Re-purposing of jack-up vessels is an option to consider.
- There are limited options for lifting a substructure into the water from a delivery vessel. A purpose-built system would need to be designed to lift from shore.

3.7 O&M

- No consensus exists yet on the most cost-effective way to conduct large-scale repairs. Disconnect and tow to port may be difficult in practice and is not proven in large numbers.
- Floating structure heavy lift operations at sea may be preferable in the future but have not yet been developed. (Note that prospects for use may differ in the Pacific from Europe because of differences in ocean swell height and period).

Source: XYHT Magazine

Figure 12 – Example of submersible barge float-off of concrete caissons

A

B

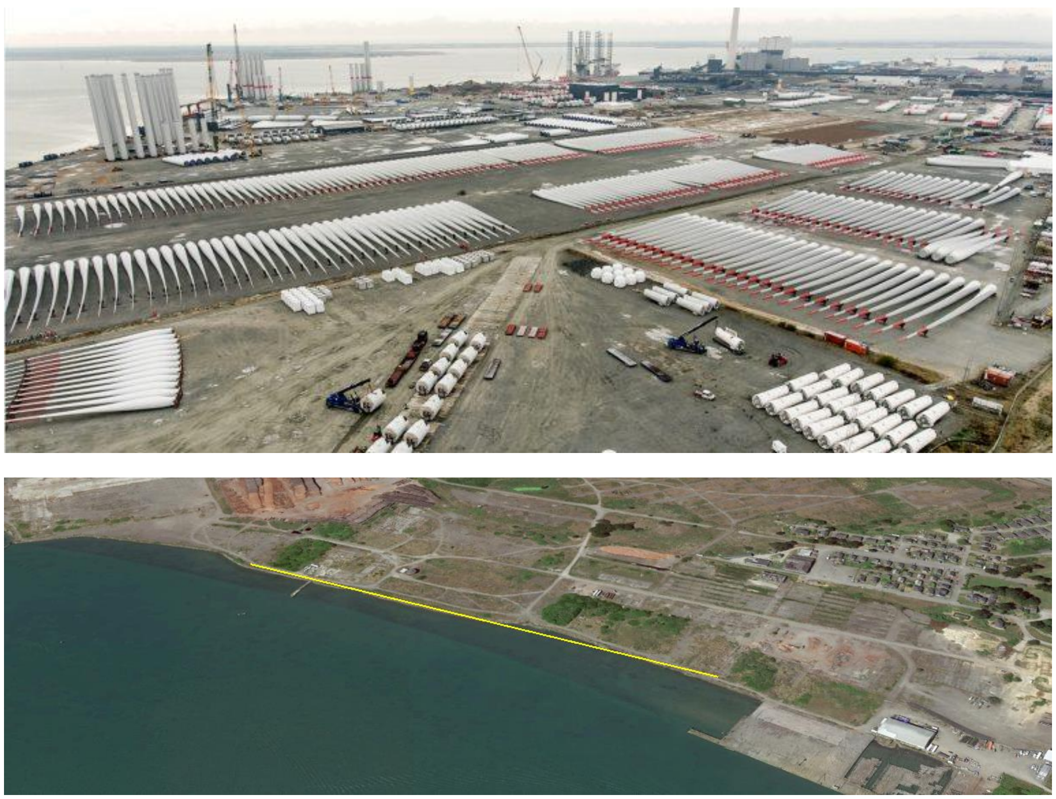


Figure 13 – (A) Example yard: ~100 turbines, Port of Esbjerg; (B) Area south of RMTI. The yellow line is approximately the same length as the storage area at the Port of Esbjerg.

In Figure 13, total storage area at the Port of Esbjerg is greater than 100 acres. Note that the length of the storage area shown is about 2,000 feet or approximately the distance between no-name dock and RMT I.

4 Port Facility Activity and Site Screening Assessments

Screening assessments were conducted to focus the infrastructure study on specific project activities and locations within Humboldt Bay, and to review nearby harbors relative to supporting potential installation activity support needs.

4.1 Nearby Harbors

A review of existing nearby port facilities and how they may support project activities relative to the North Coast was conducted. The majority of the assessment information is excerpted from BOEM 2016-011 (Porter and Phillips, 2016). Additional information is included in Appendix D.

4.1.1 General

Ports on the Pacific West Coast have various levels of existing and potential capabilities for supporting OSW. However, no single port facility currently has the infrastructure to allow for complete fabrication, construction, and assembly of OSW technology at one location. Humboldt Bay is the only deep draft harbor between San Francisco Bay, California and Coos Bay, Oregon and the only deep draft facility without air draft restriction between Southern California and Coos Bay. Commercial-scale development will most likely use a network of ports to provide fabrication and assembly support, considering the air draft restrictions and variable manufacturing capabilities along the US West Coast.

4.1.2 Unrestricted Air Draft Ports

The Port of Coos Bay is located 95 miles north of the Oregon-California border and is the largest deep-draft port between San Francisco and Washington State. It could potentially support assembly of floating OSW units, after upgrades and investment in infrastructure. The distance from Coos Bay to the Humboldt Call Area is approximately 175 miles, as opposed to ~20 miles between the call area and Humboldt Bay. Other port facilities farther from the wind farm location could potentially support assembly, but logistics would need a more detailed assessment (such as, Los Angeles, Long Beach, Hueneme, Astoria, Grays Harbor, and Puget Sound).

4.1.3 Air Draft Restricted Ports

Ports in San Francisco Bay and Inland Columbia River Ports are good candidates for supporting manufacturing and fabrication of OSW technology, but cannot support OSW assembly without novel turbine assembly methods because of air draft restrictions.

4.1.4 Assessment

If commercially viable, harbors in Oregon or Northern or Southern California may be able to house manufacturing facilities needed to support assembly in Humboldt Bay. Coos Bay could potentially support assembly for a floating wind farm in the study areas but would likely require investment. Mobilization from ports further away would likely require designing marine transport logistics to accommodate higher wave conditions, as safe harbor is not available along the route.

4.2 Humboldt Bay

A screening assessment for facilities within Humboldt Bay was conducted and focused on specific activities and locations. The screening assessment included:

- Port Buildout Screening Assessment: Screening of floating OSW supply chain activities for application within Humboldt Bay (versus those to be conducted offsite).
- Port Facility Screening Assessment: Screening of potential OSW facility locations within Humboldt Bay, relative to primary criteria for each type of port facility.

Table 4 – Humboldt Bay Port Buildout Screening Assessment. Supply chain elements in green are likely to be conducted in Humboldt Bay and are primary focuses of this assessment.

Supply Chain Element	Activities	Application within Assessment – All Scenarios
Assembly and major repairs	WTG components are assembled to the floating substructure. Receive and store WTG components. Storage and staging of mooring and anchoring system. Major repairs, such as blade replacement.	Required for Pilot/Small-Commercial and Large-Commercial scales. Primary focus area of assessment.
Operations and Maintenance	Long-term operations support. Crew transfer vessel base. Store replacement parts.	Pilot/Small-Commercial and Large-Commercial scales. Primary focus area of assessment.
Substructure fabrication	Fabricate, paint, and float off substructure.	May or may not be developed for Pilot/Small-Commercial and Large-Commercial scales. Not focus of assessment.
WTG manufacturing	Original equipment manufacturer (OEM) manufactures and exports WTG components, such as blade, nacelle, towers.	Assumed primarily delivered to the assembly area via marine transport only, due to the large size of the components, lack of rail access to the region. Also, assumed that a larger pipeline needed than 1.8 GW. Facility does need to be able to receive and store WTG components. Not included in assessment.
Offshore substation manufacturing	Specialized manufacturing of high voltage equipment. Load-out and delivery of floating substation.	Assumed not to be required for Pilot/Small-Commercial scale. Large Commercial-Scale assumed to be fabricated elsewhere, due to supply chain limitations in region and pipeline requirements. Not included in assessment.
Cable manufacturing	Specialized manufacturing and testing of subsea cables. Cable laying vessel assumed to be mobilized to region for installation	Assumed to be fabricated elsewhere, due to supply chain limitations in region and pipeline requirements. Not included in assessment.
Mooring and anchors manufacturing	Specialized manufacturing and testing of mooring systems. Storage and staging of anchors and mooring lines.	Assumed to be fabricated elsewhere due to supply chain limitations in region and pipeline requirements. Anchors may require staging at marine terminal, which could require further analysis. Not included in assessment.

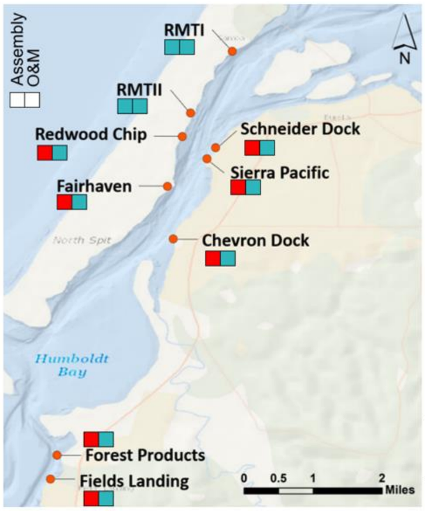
Based on the Port Buildout Screening Assessment shown in Table 4, two classifications of port facilities were identified for primary focus:

- Facility requiring large-scale infrastructure (Assembly and Major Repairs)
- Small craft harbor facility with upland warehouse and offices (O&M vessel base)

The sites were assessed relative to primary criteria, including:

- Available upland space for the yard (minimum 25 acres)
- Air draft restrictions
- Interferences with navigation infrastructure

Figure 14 summarizes the results of the screening assessment, indicating areas around RMT I and RMT II are potentially feasible for assembly and major repairs, while the remaining areas are more suitable for the O&M vessel base. The limiting factors are the available upland space (minimum of 25+ acres) and impacts to navigation infrastructure (major nearshore dredging or a significant change in FNC dimensions). Appendix F provides details of the screening assessment.



Site	Assembly, Fabrication, Major Repairs		O&M Vessel Base	
Criteria	Pilot/Small-Scale	Large Commercial	Pilot/Small-Scale	Large Commercial
RMT 1				
RMT 2				
Redwood Chip				
Schneider Dock				
Sierra Pacific				
Fairhaven				
Forest Products				
Fields Landing				

Teal - Meets primary criteria; upgrades may be needed.

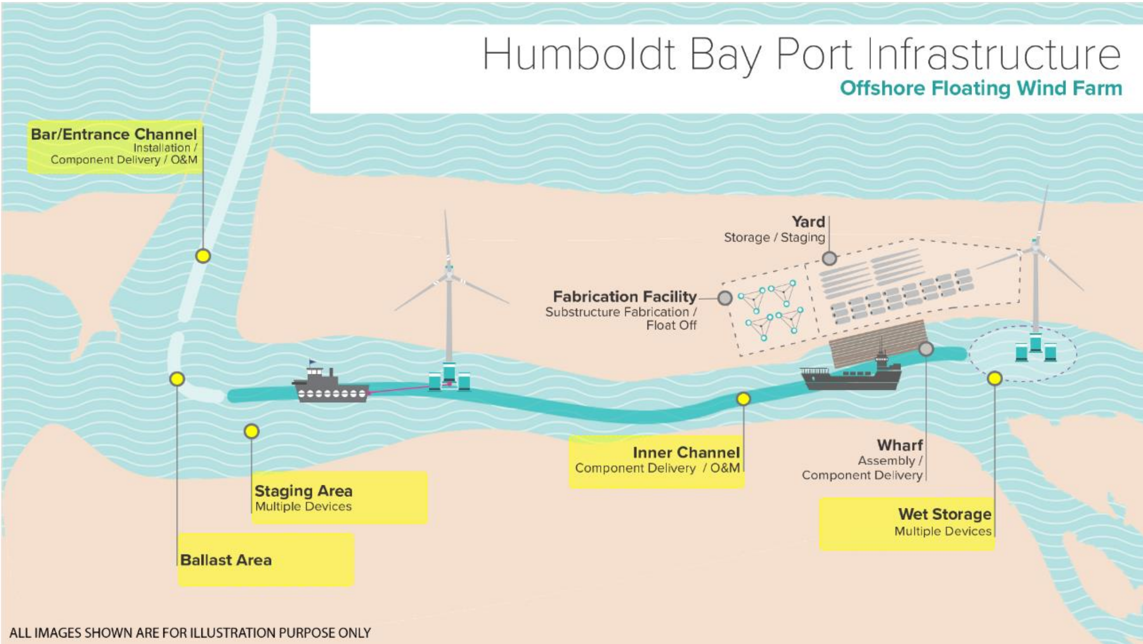
Red - Does not meet primary criteria, or major mitigation would be required.

Figure 14 – Humboldt Bay Port Facility Screening Assessment results

4.3 Screening Conclusions

- Humboldt Bay is verified as the nearest port that can support assembly and installation of an OSW farm in the study areas.
- Screened assessment activities at Humboldt Bay include Assembly, Operations and Maintenance, and potentially substructure fabrication.
- Project support of substructure fabrication, WTG manufacturing, or other project activities that are not limited by air draft may be conducted at air draft-restricted port facilities in California or along the US West Coast.
- Within Humboldt Bay, the Assembly Facility is likely to be located at the RMT I/RMT II area for both the Pilot/Small Commercial and Large Commercial scale implementations. Therefore, this is the only area to be assessed for assembly and large repair activities.
- The O&M vessel base can be located at a number of sites within Humboldt Bay Harbor.

5 Navigation Infrastructure



5.1 Introduction

Navigation infrastructure is intended to provide a safe, efficient, environmentally sound, and cost-effective waterway for ships and other vessels to access the harbor. Unlike wharf and yard, where criteria are developed and then infrastructure constructed, navigation facilities can be more difficult to change. Challenges implementing modifications of existing navigation infrastructure can be more difficult to resolve, because of permitting and engineering requirements associated with upland port infrastructure upgrades. Therefore, the assessment considered the existing navigation facilities first, rather than defining what is needed and modifying the channels to meet these requirements. The principal questions asked concerning the existing navigation infrastructure and whether it can support either small- or large-scale floating OSW projects include:

- Is dredging of the Entrance Channel needed?
- Is dredging of the Inner Channel needed?
- Is dredging needed for wet-storage and staging areas?
- Is dredging needed at the berth adjacent to the wharf?
- Can devices be ballasted within Humboldt Bay to minimize offshore operations?
- Are changes to maintenance dredging at the Entrance Channel needed?

5.1.1 Background

Risk and uncertainty analysis is a critical component of deep draft navigation project planning, design, and operations. Figure 15 summarizes the factors considered when assessing the feasibility of using the existing navigation infrastructure for a new purpose or the need to modify it.

Factors include:

- Environmental risks: wind, cross current, swell.
- Waterway system dimension: depth, width, alignment, length, transit time duration.
- Vessel safety: under keel clearance, maneuverability, bottom type.
- Vessel traffic uncertainty: type of vessel and corresponding maneuverability, range of vessel types, and their corresponding navigation characteristics.
- Waterway system maintenance uncertainty: schedule, frequency, and timing for dredging to provide the necessary navigable depths.
- Shoaling/sedimentation uncertainty: navigation facility sedimentation patterns with respect to location, degree, and timing.
- Fleet forecast and vessel operation: vessel and device type, size and maneuverability, characteristic certainty for the industry a port facility is being developed. Emerging industries, such as floating OSW, are less defined and constantly evolving to marketplace conditions, thereby presenting a higher risk for evaluation of navigation requirements.

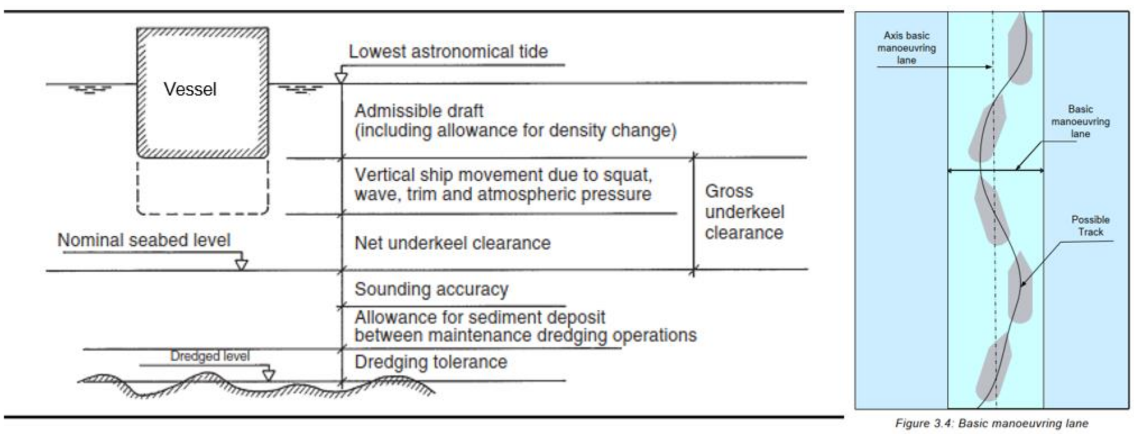


Figure 15 – Navigation and maneuverability considerations (Left: Depth, Right: Width)

Channel geometry may impose limitations on times and durations when the channel can be used safely for various device geometries and vessels; however, an adequate level of safety should be maintained for all navigation activities. The economic analysis is a trade-off between investment, availability, and efficiency, and not between investment and risk, because recommended safety requirements must always be maintained (PIANC, 2014).

5.1.2 Approach

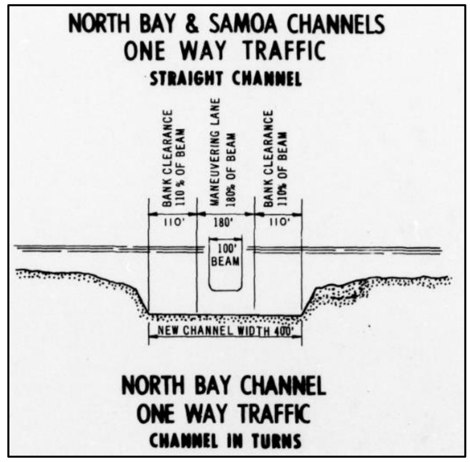
The conceptual-level navigation assessment was conducted to evaluate the capabilities and challenges of supporting the following activities:

- Component delivery
- Storage, staging, and ballasting of wind turbine generator (WTG) units
- Tow-out of WTG units for installation
- Tow-in of WTG units for maintenance

The assessment was conducted by developing a background of navigation infrastructure, documenting applicable criteria, developing an overview of metocean conditions and how they affect navigation throughput, assessing limitations of the existing FNC system for project transport requirements, and assessing potential storage/staging/ballasting activities.

5.2 Existing Conditions

Navigation infrastructure within Humboldt Bay includes the FNCs managed by USACE, as well as the USACE-managed North and South jetties, which keep the entrance open. The FNC system consists of a series of channels with different dimensions, tabulated in Table 5. The channel dimensions were developed by USACE based on the types of vessels historically accessing different areas of the bay and the safety clearances needed to support transport, considering the metocean conditions. Figure 16 shows an example of these dimensions for the North Bay and Samoa Channels. These dimensions can typically accommodate Panama Canal-class (Panamax) vessels. At present, the navigation infrastructure is used for import of petroleum delivered to the Chevron fuel dock, export of wood/timber products, commercial fishing, and recreational uses.



The USACE conducts annual maintenance of the FNC within Humboldt Bay. Usually heavy shoaling of the federal channels occurs after annual maintenance dredging, resulting in deep-draft-vessel operating restrictions that adversely affect commerce and limit the Bay's use as a harbor of refuge. Any improvement or modernization of these channels, such as deepening, requires a local sponsor. HBHRCD has participated as the local sponsor in two federally authorized navigation channel-deepening projects with USACE. Outside of the FNCs, the Harbor District is also responsible for completing periodic maintenance dredging on Harbor District facilities.

Table 5 – Authorized FNC Project Dimensions

Segment	Authorized Width (ft.)	Authorized Depth (ft.)
Bar	~750-1600	48
Entrance	~600-750	48
North Bay	400	38
Samoa	400	38
Fields Landing	300	26
Eureka	300	26

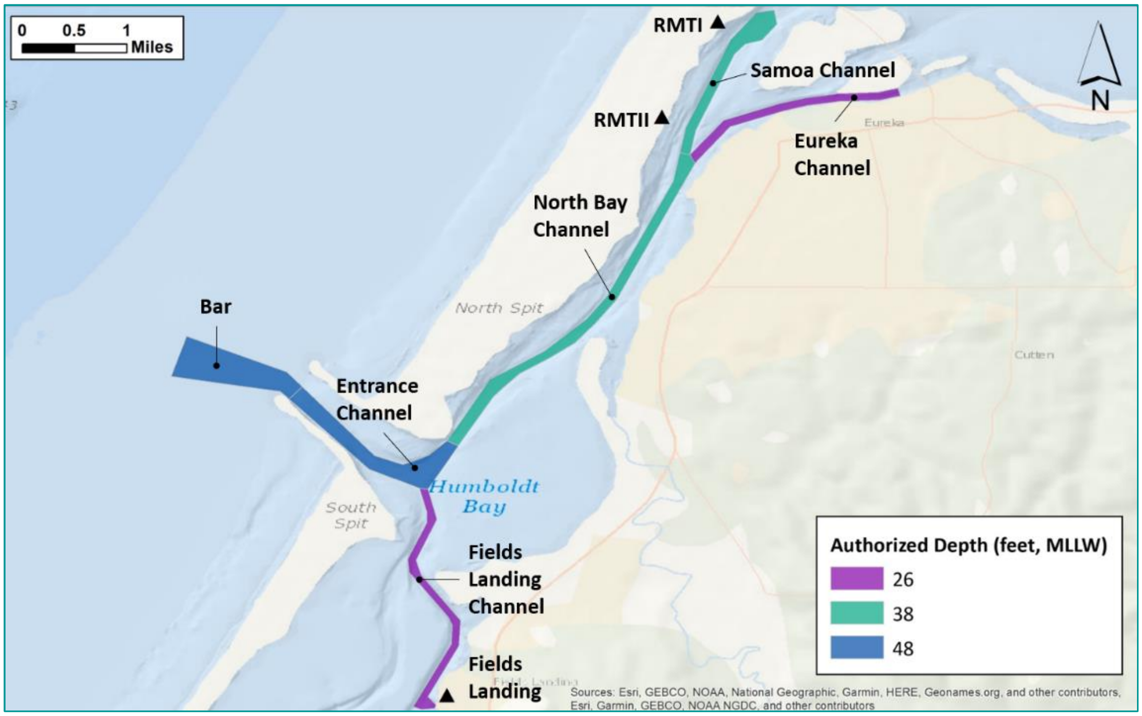


Figure 17 – USACE Federal Navigation Channel authorized depths in Humboldt Bay

Historically, the FNC supported higher transport volumes and vessel calls than at present, as shown in Table 6. From the 1950s to the 1990s, Humboldt Bay supported two pulp mills and regularly exported lumber and raw logs. The port remained open year-round with a higher level of vessel traffic. Based on conceptual-level vessel traffic projections, during OSW buildout, the number of annual vessel calls (including device tow-out) would potentially increase to historical vessel traffic levels. Dredging of the Entrance Channel was conducted more often than at present, to support the volume of cargo vessel calls year-round. At present, permits allow for dredging of the navigation channel between March and November. Typically, the USACE dredge *Yaquina* dredges Humboldt Bay in April; the *Yaquina* can achieve dredge depths of 38ft. In July, the West Coast dredge comes to Humboldt Bay and deepens the navigation channels to the federally authorized depths.

Table 6 – Historical Vessel Calls (2005-2017). Source: BST Associates, 2018

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2104	2015	2016	2017
Vessel Calls	154	155	106	69	54	56	78	66	54	53	42	63	48

The Harbor Safety Committee of the Humboldt Bay Area (HSC) is responsible for navigation considerations within the bay, including anchorage, channel design plans, competition, and when tugs must accompany tankers. Committee members include the USCG, the USACE, and the HBHRCD. Key guidelines from the HSC include:

- Navigation guidelines
  - Vessels are usually taken in and out of the entrance at high tide if there is swell on the bar because of shoaling in the Entrance Channel.
  - The Entrance Channel is regularly monitored for shoaling from December to March after large storms.
  - In case of tsunami, vessels in the harbor try to reach deep water at sea.
  - No vessel traffic service (VTS)[11]
  - USCG will be a participating agency in the approval process of standards of floating OSW to minimize impact to navigation[12].
  - USCG will conduct a Waterways Analysis Management System (WAMS) study to ensure that changes to navigation in Humboldt Bay maximize waterway passage and mitigate navigational risks. This review process may take up to 5 years.

- Anchorage
  - No designated anchorages exist within the bay. Anchorage is at a captain's discretion.
  - The HBHRCD approves all anchorages over 72 hours in Humboldt Bay.
  - Anchorage not currently allowed in the navigation channel.

5.3 Navigation Assessment Criteria

5.3.1 Vessels

A database of potential vessels to be used to support WTG tow-out activities has been developed in Appendix H. A comparison of vessels that could be used for the project versus present vessel use (e.g., *Pax Silva*) indicates:

- Geometry of WTG devices differs from that affecting historical vessel use. WTG devices are significantly wider but have a similar draft. Conceptual assessment of feasibility is required.
- Component delivery vessel and specialty heavy-lift vessels are similar to historical vessel use. No feasibility assessment required.

5.3.2 Assessment Methodology

Various methods (for example, PIANC, 2014 and USACE, 2006) were reviewed to develop criteria for channel dimension requirements at a pre-feasibility level to accommodate the design vessel/device. Considerations included metocean conditions, channel shoaling risk, and vessel maneuverability. The assessment also included discussions with developers, marine contractors, local guidance documents, and discussions with a representative from the Humboldt Bay Bar Pilots Association. The range of potential substructure geometries (Type A and Type B) was used to

[11] United States Coast Guard, "The purpose of VTS is to provide active monitoring and navigational advice for vessels in particularly confined and busy waterways."

[12] Through the Navigation and Vessel Inspection Circular (NVIC) NO. 01-19, Guidance on the Coast Guard's Roles and Responsibilities for Offshore Renewable Energy Installations (OREI).

develop a qualitative opinion on existing navigation infrastructure capabilities and required upgrades, based on a quantitative analysis.

5.4 Assessment Criteria Considerations

Site conditions affecting navigation downtime include metocean conditions and channel shoaling events. Downtime at sea or in the channel can affect the decision to conduct navigation improvements, changes to maintenance schedules, or investments in port infrastructure to offset the risk.

5.4.1 Metocean Downtime

Operational requirements for a range of activities at the entrance and offshore at the wind farm were developed and cross-referenced with site conditions for the summer and fall/winter/spring seasons (combined). Based on this assessment, there is an elevated risk of downtime outside summer conditions for:

- Crossing the bar and Entrance Channel
- Open-ocean towing
- Installing the device

Therefore, towing through the Entrance Channel may not occur or downtime will likely be increased during the fall/winter/spring season, as opposed to summer.

5.4.2 Channel Shoaling and Dredging

Channel shoaling can reduce the effective depth or width of the navigation channels, and thus reduce the metocean conditions in which navigation would occur at a similarly safe level relative to project conditions, as described in 5.4.1 Metocean Downtime. USACE maintains the Entrance Channel annually, which can include the removal of approximately one million cubic yards of material each year in order to keep the channel open. Data from recent surveys (2017–2020) indicates that depths in the Entrance Channel can be reduced to -31–36 ft. MLLW or around 15 feet less than the authorized dredge depth, in the winter following maintenance dredging. The channel shoaling events have resulted in draft restrictions on vessels with drafts greater than 21–34 ft. for high-tide conditions during the winter periods between 2016–2020. Historically (from the 1950s-1960s), the channel was maintained to reduce the duration and frequency of draft restrictions. Figure 18 illustrates conceptually how channel depth changes over time, showing an example winter shoaling event and an early summer maintenance dredge event.

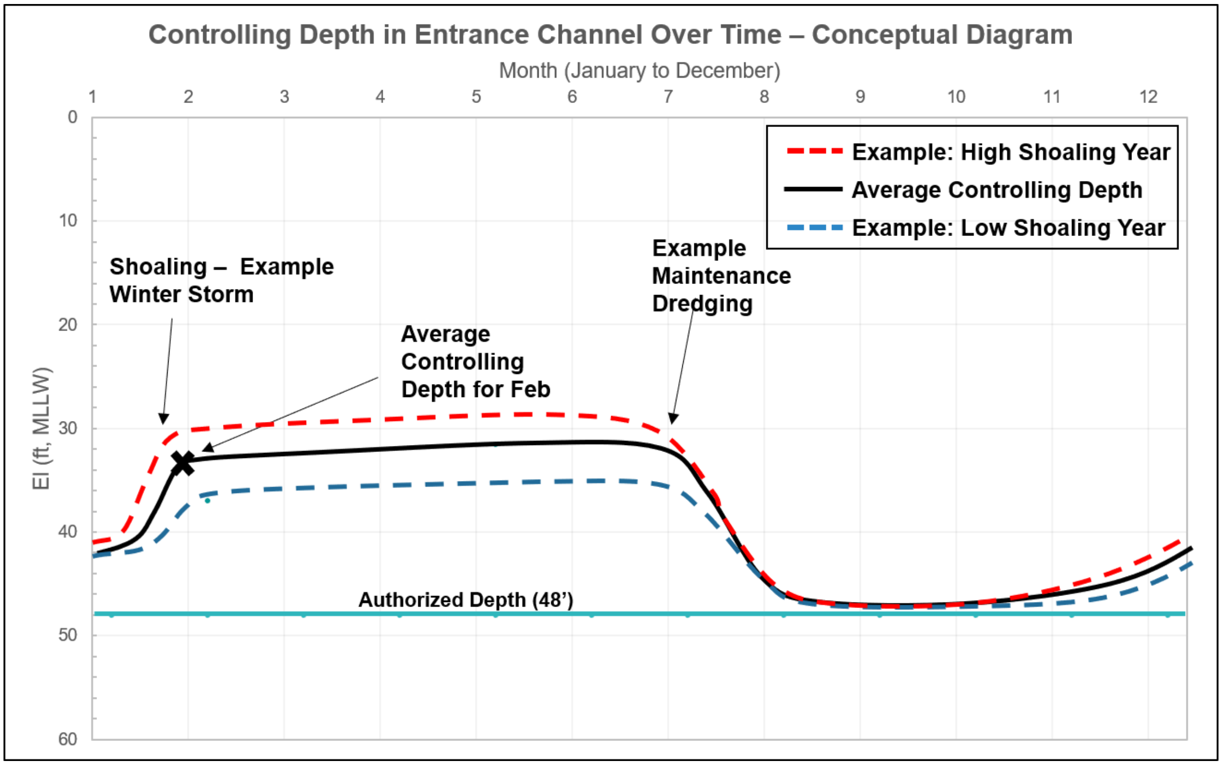


Figure 18 – Concept controlling depth for the Entrance Channel[13]

The Inner Channel (North Bay and Samoa Turning Basin) requires minimal annual dredging to maintain the authorized depth.

5.4.3 Required Channel Geometry

Concept navigation criteria have been developed for this study. Actual channel depth and width requirements need to be considered on a case-by-case basis for each WTG device design.

Table 7 summarizes estimated conceptual channel geometry requirements for device Type A and Type B (the different device geometries are summarized in Figure 5 and Table 2). Concept depth varies, depending on water level (low end at MHW, high end at MLLW); concept width varies with maneuverability and environmental conditions during the tow. Generally, channel dimensions need

[13] Actual dredge schedules may vary. Figure intended for visualization purposes only.

to be larger for commercial navigation (many vessels/devices) than for a single or small number of events utilizing the same substructure dimensions to maintain throughput.

Table 7 – Conceptual Navigation Requirements for Assembled Devices

Device or Vessel	Beam	Draft	Concept Channel Width Req.	Concept Channel Depth Req.[14]
			Entrance Channel	
Device A (Large)	300 ft.	36 ft.	750–1,050 ft.	38–48 ft. MLLW
Device B (Small)	200 ft.	25 ft.	500–700 ft.	27–37 ft. MLLW
Inner Channel			***Inner Channel***	
Device A (Large)	300 ft.	36 ft.	450–700 ft.	35–44 ft. MLLW
Device B (Small)	200 ft.	25 ft.	300–500 ft.	24–34 ft. MLLW

5.5 Assessment Results Summary

This section summarizes the results of the conceptual assessment detailed in Appendix A, for the Entrance Channel, Inner Channel, and wet-storage/staging/ballasting areas.

5.5.1 Entrance Channel

5.5.1.1 General Constraints

- The larger the device, the more ideal the conditions must be to cross the bar (tides, waves, winds, currents, shoals), and towing may be limited to certain tidal water levels and wave conditions.
- Due to the unique geometry of WTG floating foundations, the development of floating foundation (deadship) tow plans should be developed in coordination with local USCG unit.
- Wave conditions on the US Pacific Coast may result in limits on months that installation or major repairs can be conducted.
- Width
  - The maximum assembled device substructure beam that can safely navigate through the narrowest portion of the Entrance Channel is likely less than 300 ft.
  - Component delivery vessels can likely navigate safely when the channel is dredged to or near authorized geometry. These vessels are similar in size to existing vessel use.
- Depth
  - The authorized FNC depth is sufficient to conduct some level of ballasting, depending on the device. If dredged to the authorized depth, the maximum device draft for tow-out may be ~45-50 ft. (towed at MHW), pending USCG approval.
  - Ability to tow out while ballasted could be affected by channel shoaling events, depending on season.
  - If the channel shoals are similar to recent historical trends, the maximum device draft may be ~ 22 ft. for winter transport in high shoaling years, and ~ 36 ft. for mild shoaling years (towed at MHW), depending on allowable wave conditions and throughput requirements.
  - Applying the recent dredging schedule (the FNC entrance channel typically is dredged to authorized depth in July), WTG tow-out could be sensitive to shoaling events and could be

[14] Concept channel depth requirements depend on tide level, tow speed, and foundation specific details.

restricted for a significant portion of the year. Figure 19 shows an example device tow timing restriction.

- Component delivery vessels may be limited to certain times of year, based on draft restrictions in recent years (2016–2019), depending on the level of shoaling and whether the current maintenance dredging schedule is maintained.

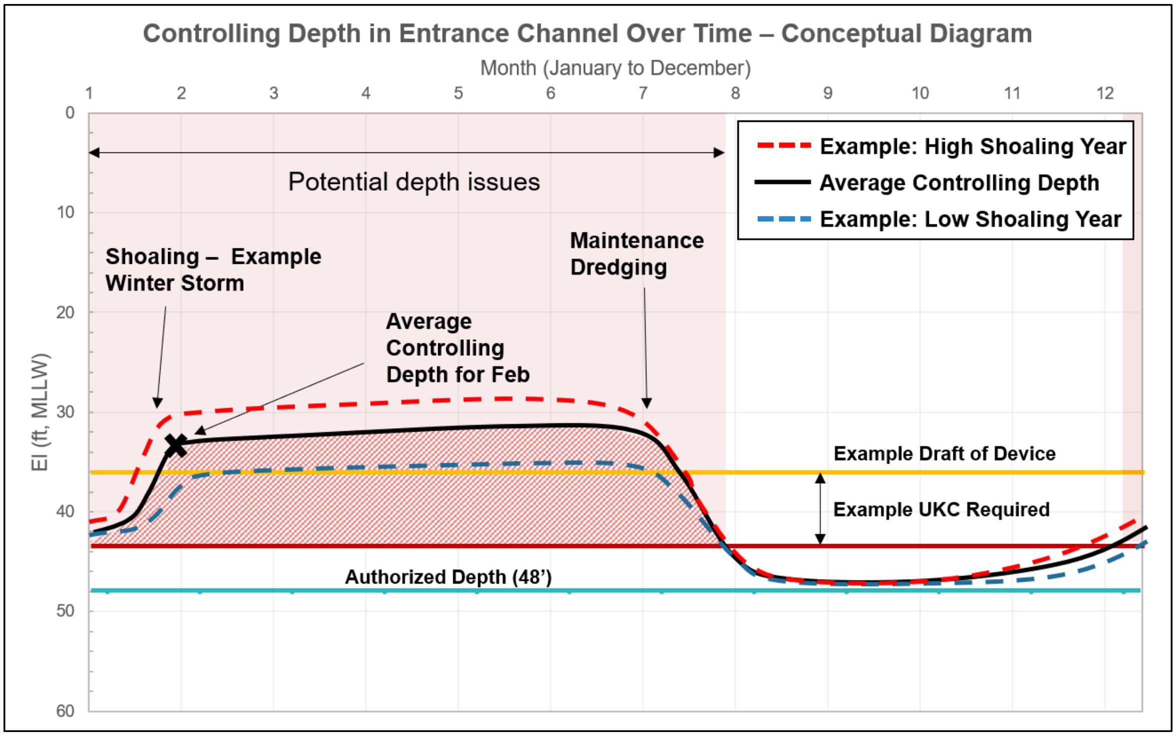


Figure 19 – Example of downtime due to controlling depth[15]

5.5.1.2 Pilot/Small Commercial Scale

- Modifications to the Federal Navigation Channel (FNC) entrance geometry not likely required for pilot/small-commercial projects, but the size of the device may be limited to less than a 300-foot beam.

5.5.1.3 Large Commercial Scale

- FNC deepening is unlikely required, but towing will likely be limited to certain water levels, depending on the measured depth in the channel, device ballasting needs, and wave conditions.
- Depending on the device, localized widening of the FNC Entrance Channel may need to be conducted to increase weather window opportunities and maintain throughput. This would require coordinating long-term planning with USACE and other stakeholders. If not conducted, more wet-storage and vessel support, or upland storage area may be required to maintain throughput.

[15] Actual dredge schedules may vary. Figure intended for visualization purposes only.

- A change in FNC maintenance dredging schedule/frequency may be required to support component delivery vessels, otherwise increased upland infrastructure investments will likely be required (additional wharf, etc.).
- If existing FNC geometry is not modified, substructure geometry may be smaller than substructures used for Pilot/Small Commercial scale, to increase weather windows to meet the higher yearly throughput requirements.

5.5.2 Inner Channel

5.5.2.1 General Constraints

- Width
  - Without good navigation support and favorable environmental conditions, tow-out may not be considered safe for either the small or large assembled devices.
  - The maximum vessel/device beam that can safely navigate through the existing Inner Channel (400 ft. authorized width) is likely between 200–270 ft.
  - Safety concerns for larger devices could be mitigated by widening the channel.
  - Component delivery vessels are likely to be able to navigate, because their requirements are similar to those for existing vessel use.
- Depth
  - The maximum assembled device draft that can safely navigate through the existing Inner Channel (at an authorized depth of -38 ft. MLLW), is likely between 33–37 ft., as if towed at MSL, and 35–39 ft. if towed at MHW.

5.5.2.2 Pilot/Small Commercial Scale

- Modifications to the inner FNC geometry is not likely for Pilot/Small Commercial scale projects, but safe navigation may be possible if towing is restricted to favorable environmental conditions and/or the beam of the device is limited.

5.5.2.3 Large-Commercial Scale

- FNC deepening is unlikely to be required if towing along the channel is timed with high tides, depending on the device geometry.
- To accommodate the larger end of devices, the FNC would likely need to be widened. The initial dredge volume magnitude would be similar to the dredging required at the Entrance Channel annually.
- The volume of dredging would vary along the channel due to the shape of the natural waterway driven by tidal hydraulics, as shown in Figure 20. Maintenance dredging requirements would need to be assessed separately.
- If modification of FNC geometry is needed, even within localized areas, this would require coordinating long-term planning with the USACE and other stakeholders.

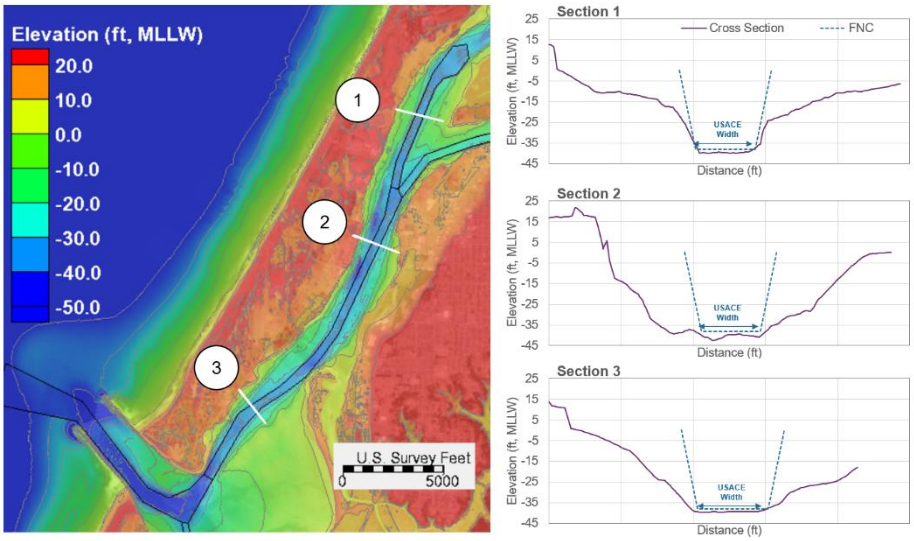


Figure 20 – Example Inner Channel cross sections and existing FNC geometry (Samoa Channel, Section 1; North Channel, Sections 2 and 3)

5.5.3 Storage, Staging, and Ballasting Assessment

Figure 21 – Schematic showing concepts for wet storage, staging, and ballasting areas.

- Wet-storage and staging areas are likely required to accommodate risk of installation downtime due to either conditions within the Federal Navigation Channel (FNC) or wave conditions at sea affecting installation.
- Wet-storage of unassembled devices near RMT I appears to be possible with no or limited dredging. The number will depend on mooring schemes and device geometry, but conceptual-level review indicates 2–4+ devices are likely possible within areas shown in Figure 22. A fairway needs to be maintained in this area for other vessel traffic.
- Limited wet-storage of assembled devices near RMT I is likely feasible without dredging for the low end of device drafts. To accommodate a wider range of devices dredging would need to be conducted.
- If staging is acceptable within the FNC near the entrance during the Pilot/Small Commercial scale buildout, dredging is likely not required, as indicated in Figure 23.
- A limited number of devices (1–3) may potentially be staged outside the FNC near the entrance without dredging for the low range of device drafts assessed.
- For the larger end of devices, dredging outside the FNC would likely be required to support a staging area.

- The assembled device will require ballasting. Ballasting inside Humboldt Bay is likely preferred, to reduce at-sea operations; however, interference with other vessel traffic should be minimized, if possible.
- If allowed, some ballasting may be possible at high water levels within the FNC near the entrance (little-to-no shoaling), but the existing FNC cannot facilitate the fully ballasted draft of a larger floating WTG device without deepening.
- Dredging would be required for ballasting activities outside the FNC.

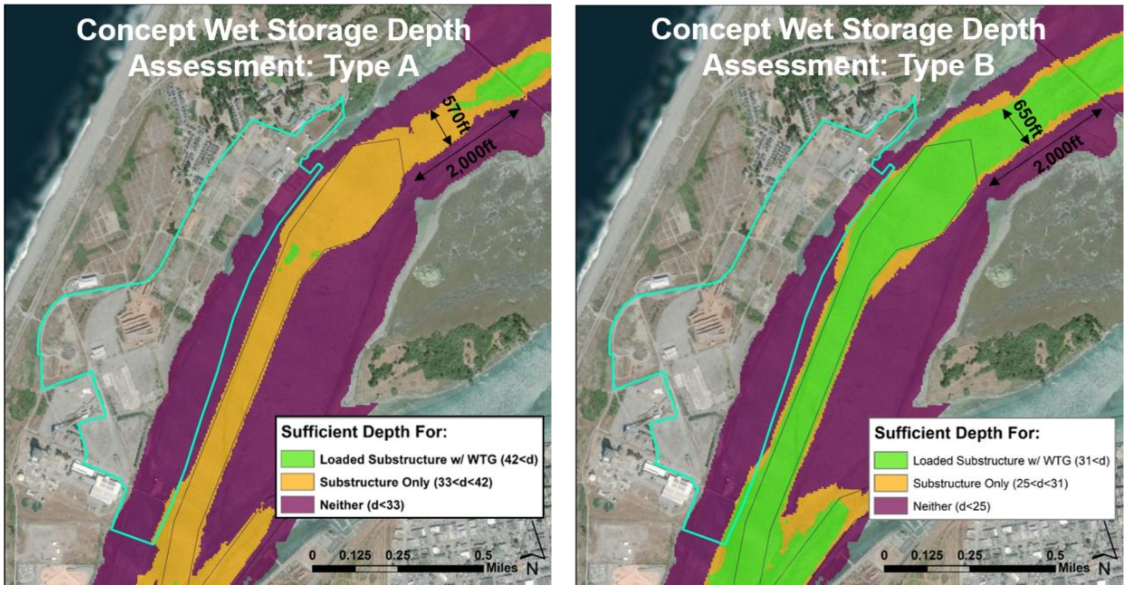


Figure 22 – Wet-storage assessment near RMT I and II for transit draft (green) and light loaded (no WTG) substructures (left: Type A; right: Type B)

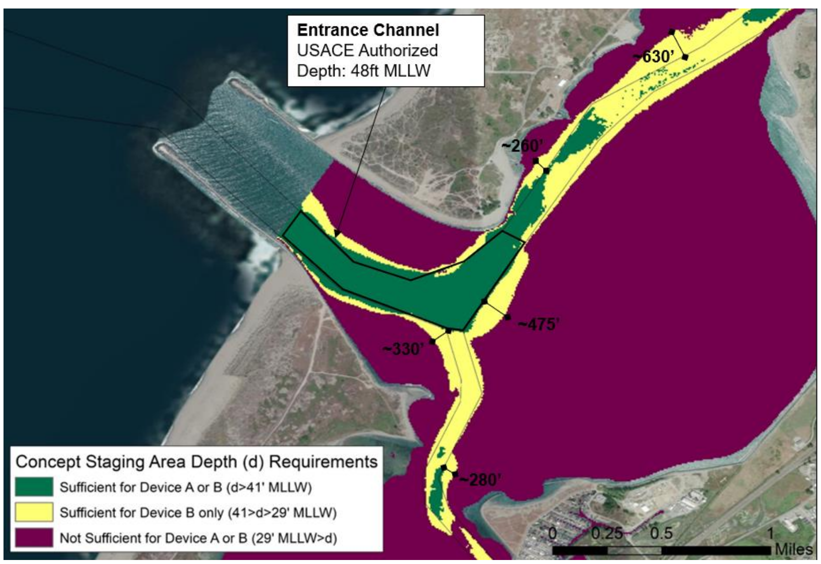
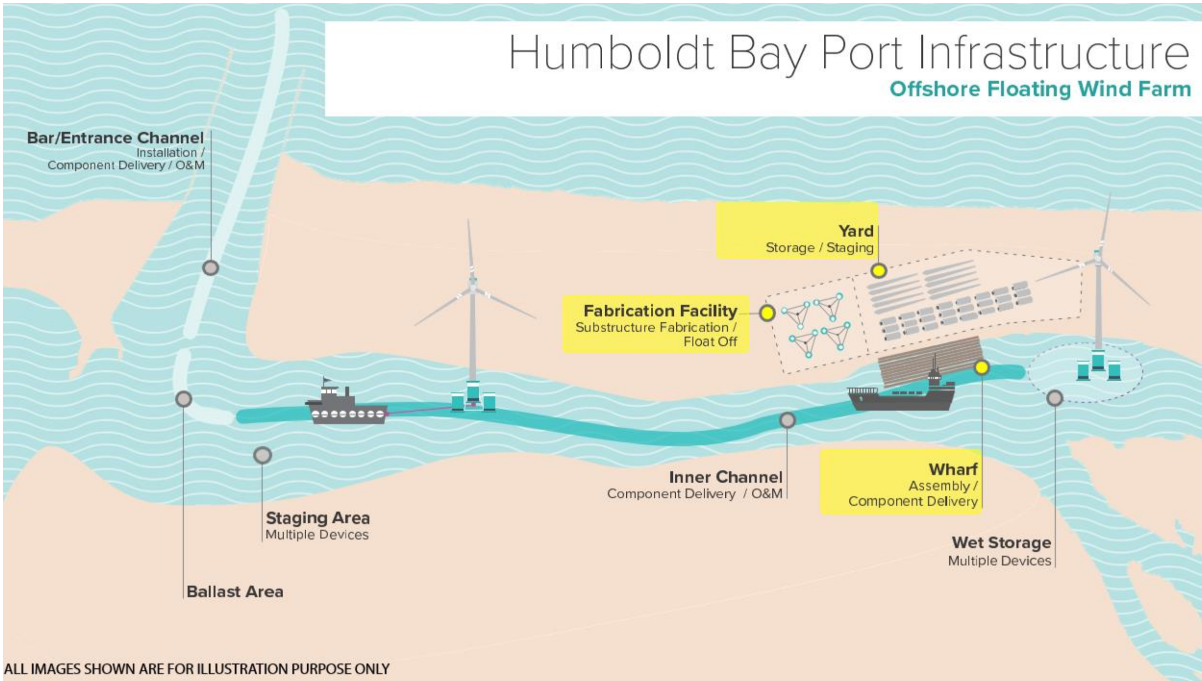


Figure 23 – Staging area assessment near Entrance Channel for smaller devices (yellow: type B) and larger devices (green: type A)

5.5.4 Summary

Overall, the existing navigation infrastructure appears to be able to support component delivery, tow-out of assembled devices, and O&M activities, with some potential restrictions on device size and seasonal activities. Changes in navigation infrastructure for the Pilot/Small Commercial scale are unlikely, and substructures will likely need to be designed within geometric limitations that allow for safe transport while meeting yearly throughput requirements. Improvements in channel geometry may or may not be required for the higher-throughput Large Commercial scale buildout, depending on the device details and throughput requirements.

6 Marine Terminal Infrastructure



6.1 Introduction

Marine Terminal infrastructure (yard, wharf, berth) requirements for supporting floating OSW assembly and fabrication have been assessed at a conceptual level to identify any required upgrades. The assessment was based on similar industry and literature review, project vessels, project activities, discussions with developers and contractors, available geotechnical and site elevation information, and conceptual engineering design. Based on the screening assessment (see 4 Port Facility Activity and Site Screening Assessment), assembly, O&M, and substructure fabrication activities have been assessed. Details of this assessment are located in Appendix B and Appendix C.

The focus of this chapter is assembly activities. Assembly facilities must have the capability to store, maneuver, and attach turbine components to the foundation, as well as handle the import of constructed components. Substructure fabrication facilities must have the capability to receive and store materials, fabricate and store substructures over a large area, and float off (launch) the substructures to the waters of the bay from the upland fabrication yard. Section 7 Operations and Maintenance addresses O&M.

Marine Terminal requirement criteria will differ for each buildout scenario and substructure technology, as the functions and vessel requirements differ. Because the industry is young and deployment technologies and methodologies are still in development, the requirements presented in this chapter are intended only as a review of likely port facility requirements, based on available data and technology. Technology yet to be developed that is device or project specific cannot be estimated or included in the study. Specific projects with specific needs may differ from the criteria presented in this report; these needs would be analyzed in more detail as part of future project planning.

This chapter presents existing conditions, results of a conceptual-engineering assessment for assembly and fabrication facilities, and conceptual engineering design schematics and considerations. Section 8 Construction Cost Estimates and Schedule Considerations addresses construction costs and the buildout schedule.

6.2 Existing Conditions

Overall, significant land is potentially available; but there are currently a limited high-capacity infrastructure and limited overland interstate highway connections (Highway 299). BST Associates (BST, 2019) conducted a Maritime Industrial Use Market Study that indicated the industries most likely to grow in demand as coastal-dependent industries are local marine cargo, commercial fishing, mariculture, marine research, and recreational boating. Future use may also include increased cruise ship visits (up to 10 per season), aggregate export from local quarries, and exporting shellfish seed and larvae. BST notes that a single marine purpose terminal of approximately 40 acres could support most of the projected growth in marine cargo.

RMT I and RMT II areas were screened as the likely location for an Assembly Facility. Assumed facility limits were coordinated with HBHRCD and are shown in Figure 24. The upland portion is the area for potential use as a yard (Yard Assessment Area). The overwater portion is the area for potential use as a wharf (Wharf Assessment Area).

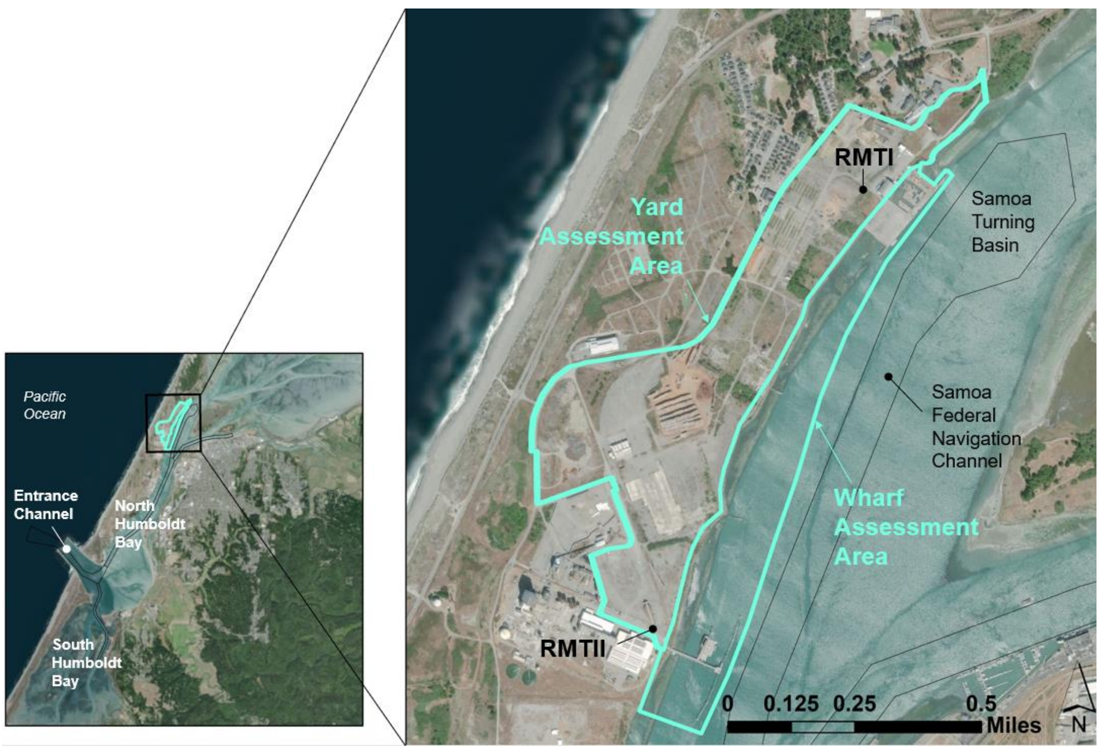


Figure 24: Assumed primary project area extents, per coordination with Harbor District

Figure 25 – Existing RMT I timber wharf structure

Table 8 – Existing Conditions at RMT I/RMT II

Element	RMT I	RMT II
Dockside Depths	<28-34 ft.	<36 ft.
Wharf Geometry	340' (width) x 840' (length)	No wharf. Pier only
Wharf Elevation	~10ft. MLLW	~17 ft. MLLW
Wharf Live Load Capacity	Original Condition: <800pdf Current Condition: Critical. See Figure 25.	No wharf
Yard Area	60 acres	90 acres
Yard Elevation	~10.5ft. MLLW	~20 ft. MLLW
Yard Ground Conditions	Mixed tarmac areas with shallow layer of low-capacity loose sand	20 existing tarmac
Utilities	Limited utility service	60 kv electric. Industrial water
Current Use	Commercial fishing, aquaponics research, fish processing	Aquaculture
Roadway Connection Functional Classification	Local	Local
Zoning	Industrial/Coastal Dependent Use	–

6.3 Assembly Facility Assessment Summary

Assembly facilities have been assessed for buildout of Pilot/Small Commercial and Large Commercial scale at the RMT I/RMT II area. This section presents a summary of criteria and a gap assessment pertaining to existing conditions. Section 8 Construction Cost Estimates and Schedule Considerations provides an example schematic wharf and berth layouts.

6.3.1 Assessment Criteria

Concept marine terminal criteria have been developed for this study. They are summarized in Table 9 and their values follow this narrative:

- Wharf geometry
  - For a smaller, multi-purpose terminal, a berth length at least 15% greater than the largest vessel length should be planned.

  - Additional length for device assembly operation and mooring will be needed beyond the length of the vessel berth.
  - Marginal wharves are preferred over mooring dolphins, to allow unloading equipment (cranes) access to entire length of vessel.
  - Apron width, not less than 150 ft.
- Wharf live load capacity
  - May be variable depending on specific uses along the wharf.
  - Wind turbine generator (WTG) component delivery, SPMT movement (as shown in Figure 26) and, laydown live load will be different than assembly utilizing crawler cranes or ring cranes.
- Wharf deck elevation
  - A new wharf and yard facility service life will be on the order of 50 years and will need to take into consideration SLR. Increasing the finished elevation for a new wharf/yard from the existing facilities will be needed to ensure the facility remains outside the future flood zone and reduces the risk of increased maintenance and flooding.
  - For purposes of this Port infrastructure assessment, it was determined that the minimum finished elevation of the wharf/yard facility would likely need to be increased to somewhere in the range of El 11.5 ft. to 12.5 ft.
  - To optimize the finished elevation for a new wharf and yard, further investigation should be conducted during preliminary design to account for SLR, stormwater, flood risk, and the type of wharf structure.
- Berth dredging area
  - The length of the dredged area at the berth areas should be at least 1.25 x longest vessel with tug assistance (greater without tug assist).
  - Depth of the dredged area should provide sufficient under keel clearance (UKC) at the design low water level to preclude contact with the bed, considering vessel or device motion.
- Substructure delivery[16]
  - Simultaneous transport of several units by semi-submersible barge or self-propelled vessels may be required.
  - Depth needs to be provided for semi-submersible barge or vessel to ballast down to a depth that the substructures can be floated off.
- Number of berths
  - Should be sufficient to meet project throughput requirements for assembly and component delivery. Likely that 2-3 berths will be required. If risk of vessel or device towing downtime is high, more berths may be required to provide the same throughput.
  - Pilot/Small Commercial scale can likely use a single, multi-purpose berth since seasonal throughput is lower.
  - Large Commercial scale may require simultaneous component delivery and WTG assembly to support serial production. Depending on throughput, yard size, and year-round navigation availability in the Entrance Channel, shared use of a multi-purpose berth may be possible, which could reduce wharf length requirements.

[16] Details in Appendix C.

- Yard
  - Per Carbon Trust (2019), with higher risk of downtime due to weather or other restrictions, a greater area is required for storage of WTG components to be staged for assembly. Extensive planning and logistics are needed in order to link production to weather windows and plan yard size accordingly.
  - Size of yard needs to be sufficient to store components and provide fairways for transport of components. Size of storage yard is greater if risk of downtime is high.
  - Surface treatment may include reinforced concrete or crushed rock.
  - Yard elevation should be consistent with wharf deck elevation.
- Utilities
  - Utility systems will be required for both the ports operation and for the moored vessel. These will include potable water to the berth and non-potable water to the wharf for fire protection.
  - Electrical service to the wharf for equipment operation and lighting and to the berth for shore power.
  - Refueling options would be a consideration if marine vessel bunkering were not available if needed.

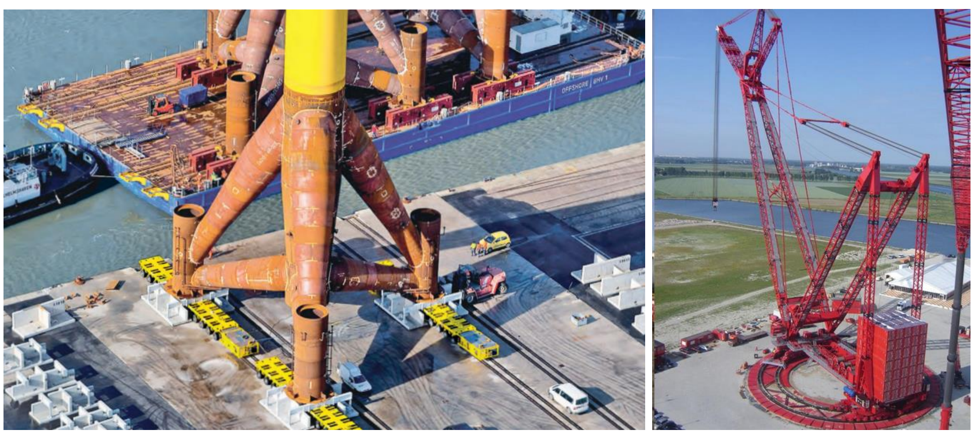


Figure 26 – Example operations requiring high-capacity wharf; SPMT offloading a steel foundation (left) and large ring crane with counterweights (right)

Sources: Scheuerle Spmt Self-Propelled Modular Transporters and Mammoet

Figure 27 – Example wharf layouts minimizing over-water coverage

Table 9 – Assessment criteria: Assembly Terminal (berth, wharf, yard)

Element	Pilot/Small Commercial	Large-Scale Commercial
Berths	1 multi-purpose berth – if yard is sized appropriately	2-3 berths (assembly and component delivery vessel)
Min. Berth Depth – Multi-Purpose	32-40 ft. MLLW	Similar
Min. Berth Depth – Vessel Berth	32-40 ft. MLLW	Similar
Min. Berth Depth – Assembly	29-40 ft. MLLW	Similar
	32-45 ft. MLLW	Similar
Wharf Live Load Capacity – Component Delivery and Storage	2,000-4,000 psf	Similar
Wharf Live Load Capacity – Assembly	4,000-6,000 psf	Similar
Wharf Length	650-1000 ft.	1,100 – 2,100 ft.
Wharf Width	150-300 ft.	Similar
Minimum Wharf and Yard Elevation	12-14 ft. MLLW	Similar
Assembly Yard Size	25-40 acres	60-100 acres
Yard surface treatment	2,000-4,000 psf	Similar
Utilities	Water/wastewater, electricity, internet	Similar
Land Use and Facilities	24 hr. operations may be required – Construction noise and lighting Office space, restrooms, parking	24 hr. operations likely be required – Construction noise and lighting Office space, restrooms, parking
Roadway Connection Functional Classification	Major Collector	Major Collector

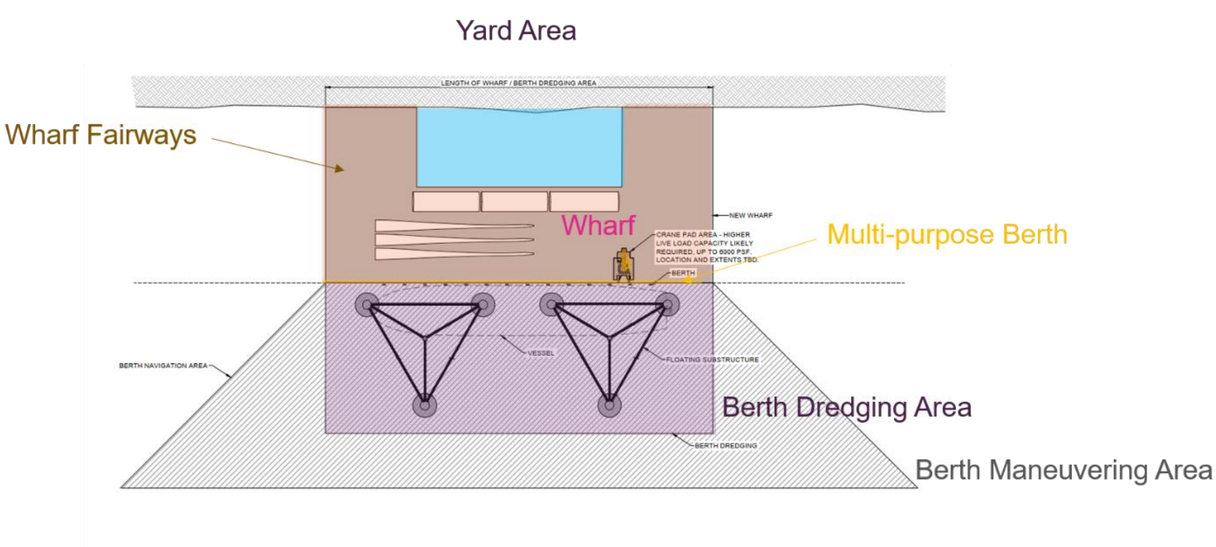


Figure 28 – Example Pilot/Small Commercial scale wharf to support assembly (multi-purpose berth)

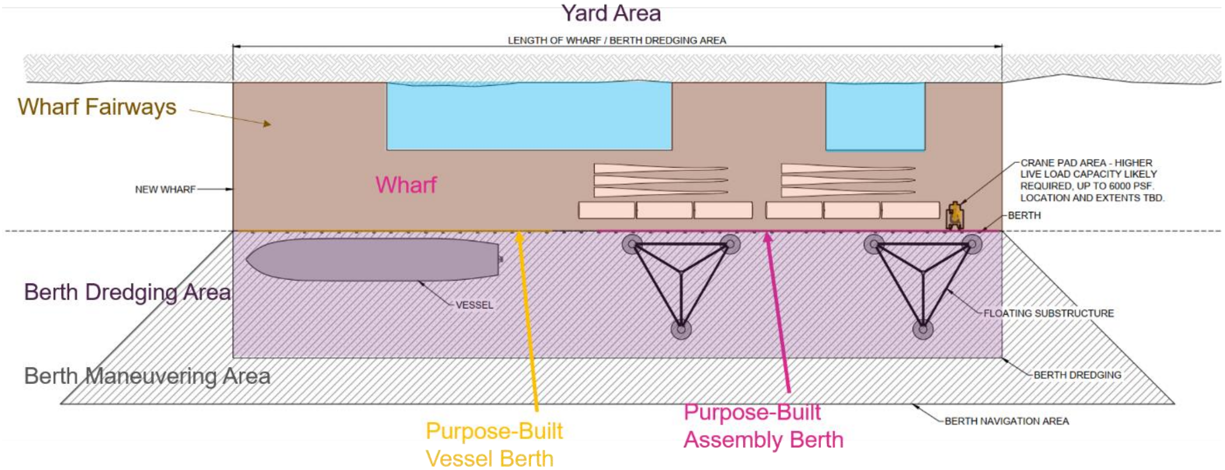


Figure 29 – Example Large Commercial wharf to support assembly (exclusive-use berth)

6.3.2 Gap Assessment – Assembly

Existing capabilities/conditions of the RMT I/RMT II area in Table 8 were contrasted with the assessment criteria to conduct a gap assessment. Results of the gap assessment are included in Table 10. The gap assessment indicates that upland port infrastructure upgrades are required for all scenarios, with the magnitude of the gap increasing for the Large Commercial-Scale scenario. Results of this assessment have been used to develop the conceptual engineering design assessment and costs of upgrades.

Table 10 – Gap Assessment - Assembly Marine Terminal

Element	Pilot/Small Commercial	Large Commercial
Assembly and Vessel Berths	Localized Dredging Required.	New Dredging Required. Timber pile removal required.
Substructure Delivery	FNC Turning Basin may be sufficient depth. Larger classes of submersible barges/vessels would require deepening.	FNC Turning Basin may be sufficient depth. Larger classes of submersible barges/vessels would require deepening.
Wharf Geometry	May be similar in size to historical RMT I wharf. RMT II pier not sufficient for transport of components.	Longer than historical RMT I wharf length
Wharf Location	New berth line of wharf likely landward of existing berth lines (RMT I and RMT II).	New berth line of wharf likely landward of existing berth lines (RMT I and RMT II)
Wharf Type	Change in wharf structure type required.	Similar
Minimum Wharf and Yard Elevation	Higher elevation than existing RMT I. RMT II Yard elevation sufficient.	Higher than existing RMT I. RMT II Yard elevation sufficient.
Assembly Yard Size	RMT I or RMT II sufficient	Total area of RMT I and RMT II sufficient, but no area of contiguous elevation available within the primary project area extents for 100 acres which is currently approximately flat.
Yard surface treatment	Ground improvement and grading required.	Similar
Utilities	Site utilities required. Utility connection upgrades may be required.	Similar
Land Use and Facilities	Noise and lighting studies may be conducted to determine mitigation methods.	Similar
Roadway Connection	Roadway improvements likely required (LAC0, 2013)	Similar

6.4 Fabrication Facility and Float-Off Assessment

A substructure fabrication facility is likely to include, at a minimum, a fabrication yard, a paint area, and a float-off system/launching point to transfer the substructures from the upland yard to a floating condition. Details of fabrication facilities would likely be very specific to the substructure material type (e.g., concrete versus steel) and have specific logistical requirements. Therefore a high-level assessment was conducted for planning-level commentary as part of this assessment. No gap assessment was conducted.

As outlined in the literature review, fabrication float-off challenges can include long lead time to develop a facility, space with high bearing capacity to set up, a launching/float-off system developed, and have enough draft and area for marine operations, including wet-storage (Carbon Trust, 2015). To meet assembly-line needs, fabrication of substructures may need to be spread over multiple locations, and therefore, fabrication may or may not occur in Humboldt Bay.

Based on literature review and industry engagement, a semi-submersible dockside barge (or similar type system) is a likely float-off method (details in Appendix C). Other float-off/launching systems are likely possible (such as gantry crane or dry-dock), but appear to likely be greater cost, require more excavation/dredging, or haven’t been proven at this scale. Pilot/Small-Commercial-scale projects may consider fabrication of the substructure directly on a semi-submersible barge, but this approach may not allow for serial production, or may require a longer wharf structure.

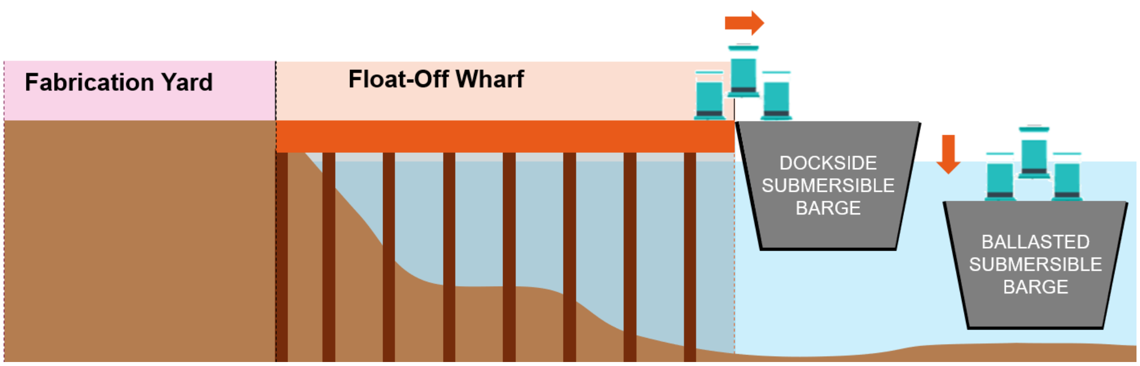


Figure 30 – Example Float-Off Wharf and Berth w/ Submersible Barge

6.4.1 Fabrication Facility Assessment Criteria

A facility in the RMT area would likely have similar requirements as the Assembly Facility, with some specific criteria differences.

- Wharf:
  - A wharf with sufficient bearing capacity and width will be required to transfer the fabricated substructure onto the barge/floating dry-dock type system at a berth.
  - A berth may require an exclusive use, with float-off every few days to meet throughput requirements.
  - Live Load capacity needs to be coordinated with equipment used to transport the substructures via SPMT.
- Wharf Deck Elevation
  - For the dockside semi-submersible barge option the wharf deck elevation and barge need to be able to be aligned with barge ballasting at various water levels to allow for roll-on of the substructure onto the barge via SPMT.

  - Deck elevation must also consider the physical constraints of a semi-submersible barge system (e.g., maximum freeboard), and may be limited in height.
- Berth Dredging Depth
  - The fabrication berth would need to be able to accommodate ballasting of the submersible barge at appropriate water levels.
- Yard
  - Serial production is likely required for fabrication of substructures. With less serialization or without parallel serial lines of assembly, dry and wet storage requirements increase.
  - Concrete substructure fabrication will likely require a concrete batch plant.

Table 11 – Fabrication Facility Assessment Criteria

Element	Pilot/Small Commercial	Large-Scale Commercial
Berths	May share berth at multi-purpose assembly wharf	Exclusive-use berth likely required.
Min. Berth Depth – Float-off	29-40 ft. MLLW	Similar
Wharf Live Load Capacity – Float-off	4,000-6,000 psf	Similar
Wharf Length	~300 ft.+	Similar
Wharf Width	Varies depending on location	Similar
Minimum Wharf and Yard Elevation – Flooding and overtopping	12-14 ft. MLLW	Similar
Wharf Elevation for semi-submersible barge float-off	TBD based on specific devices and vessels	Similar
Fabrication Yard Size	20+ acres	20-40 acres
Yard surface treatment	4,000-6,000 psf Reinforced concrete or crushed rock	Similar

6.4.2 Abbreviated Fabrication Facility Gap Assessment Results

- If fabrication occurs at Humboldt additional facility upgrades are likely required in addition the assembly port upgrades, depending on buildout size.
- Fabrication of substructures for the large-commercial would likely require an exclusive use facility, and therefore an additional, or longer, wharf structure relative to existing conditions and the assembly facility needs.
- Fabrication at the Pilot/Small-scale may possibly use the same multi-purpose berth as assembly, if throughput and wet or dry storage allows, but would require more studies of logistics and timing.
- Fabrication yard ground improvements are likely required to provide adequate bearing capacity.
- A lower yard/wharf elevation may be desired for float-off so that the substructures may be rolled onto the semi-sub barge at a greater range of water levels. This may indicate RMT I would be a preferred location for this activity, depending on project details.
- Nearshore berth dredging would likely be required.

6.5 Conceptual Engineering Design Considerations – Assembly

Schematic level wharf designs and example wharf and berth layouts have been developed based on the assessment criteria and gap assessment. The following outlines the considerations for development of the schematic level layouts and cross-sections.

6.5.1 Wharf Structure

Final Selection of a preferred structure type of wharf is highly dependent on the soil conditions, seismic criteria, current and future berth requirements, service life, and magnitude and type of loading. Prior design studies used both closed fill and open pile structures. Open pile-supported, closed solid fill type or combination thereof are likely types of wharf that could be used for meeting the operational needs for the project. Examples are shown in Figure 31 and are described below:

- Open Pile
  - An anchored bulkhead would be required along the landward edge of the open pile wharf to provide a transition from overwater wharf to landslide yard.
  - Structure material types would likely be either prestressed concrete or coated steel pile supporting a combination of precast and cast in place reinforced concrete caps, beams and slabs.
  - Larger diameter piles would need to be driven deep enough to provide the required pier capacity, as well as withstand soil settlement and downdrag due to liquefaction.
  - To anticipate the expected liquefaction results, piles should be designed with no skin friction zone where the loose sands and gravels are encountered in the proposed borings.
- Closed Fill
  - Slab supported on structural fill and potentially smaller diameter piles
  - Bulkhead facing the bay could be a combination of steel pile wall embedded into bearing soil and filled with concrete and fill.
  - The fill soils would provide bracing for the piles and additional capacity through this zone, as well as reduce concerns related to liquefaction.
  - Placing and compacting fill will reduce the settlement of existing soil due to liquefaction. However, the construction area must be exposed to the existing bed level (mudline) and kept dry by dewatering until completion of construction.
  - Use of a load relieving platform is likely needed for a solid type structure within the areas of higher live loads such as the crane operations.

6.5.2 Wharf/Berth Geometry

- Consideration for future larger class of vessels should be made to provide flexibility for future modification
- Over-water coverage may be minimized with application of access piers, as shown in the examples in Figure 27.

6.5.3 Wharf Location and Berth Dredging

- Exact positioning will be dependent on the site conditions such as bathymetry, intertidal habitat, side slope stability requirements to dredged berth depth, maintenance dredging requirements, and construction costs.
- The wharf and berth areas likely need to be oriented and located so that the berthed devices and vessels do not interfere with the FNC Turning Basin.

- The wharf and berth locations also should not be located too far landward, as dredging volume increases the further landward the wharf and berth is located.
- Conceptual layout application conducted to the RMT I and RMT II sites to assess potential geometric constraints[17] is shown in Figure 33 and Figure 34.

6.5.4 Yard Improvements

- Grading may be required due to ground elevation differences. Example of ground elevation differences across areas near RMT I are shown in Figure 32 relative to a consistent yard elevation of 12 ft. MLLW.
- Site improvement methods including soil improvement techniques (such as stone columns, pile supports, or grouting) are often employed for port yards with high load capacity requirements.
- Base course (subbase improvements and base courses) requirements will need to be determined based on the subgrade condition (to be determined from a geotechnical field investigation) and the required traffic and storage area loading.

6.5.5 Demolition and Site Preparation

- At a minimum, timber pile removal will be required for installation of new wharf structure.
- The cost and duration of pile-removal depends on whether the removal is subject to environmental requirements (e.g., full extraction) or is only functional requirement to facilitate the construction of the new wharf.

[17] Wharf may be located between RMT I and RMT II, locations selected as existing terminals.

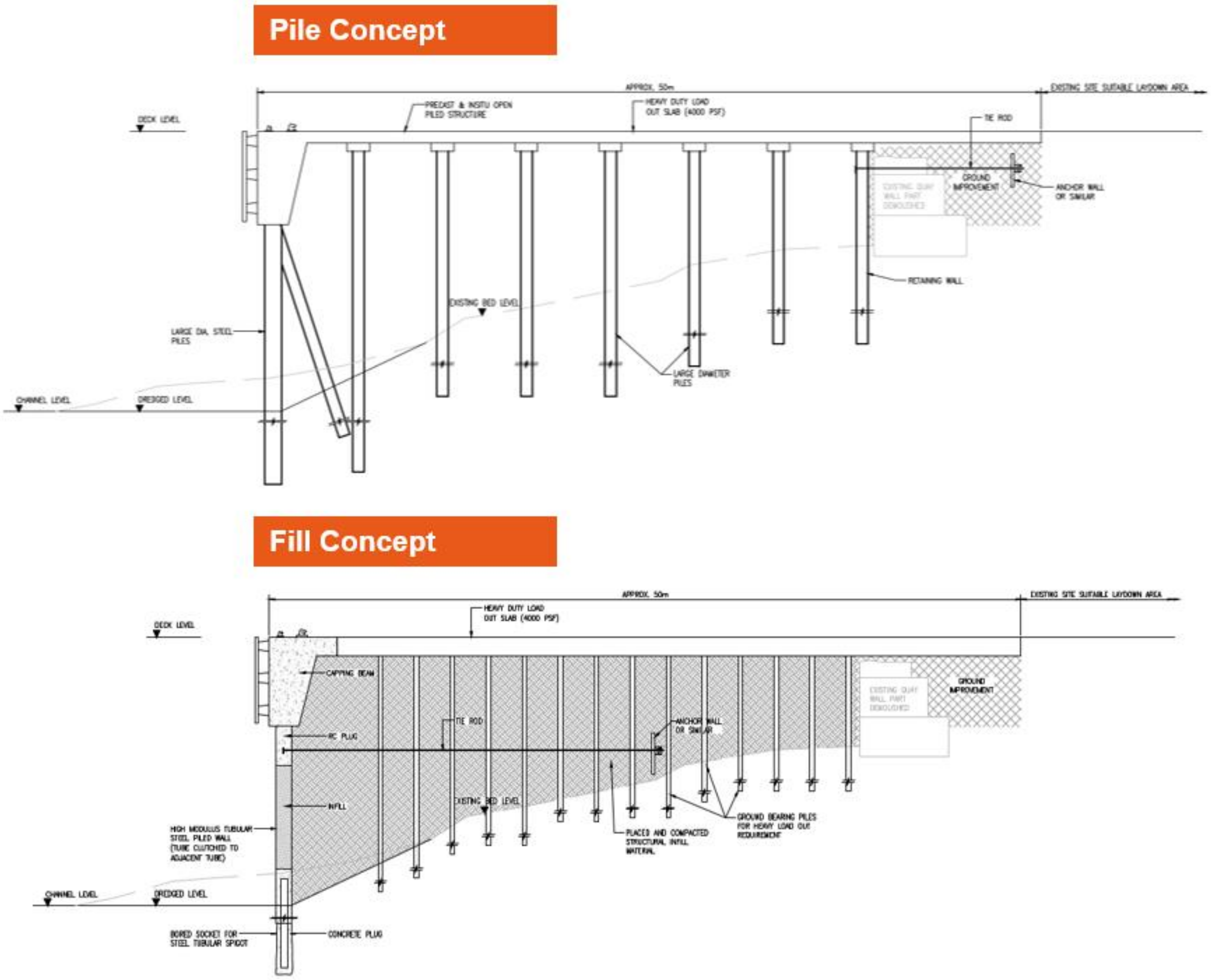


Figure 31 – Example Open Pile (top) and Closed Fill (bottom) Concepts

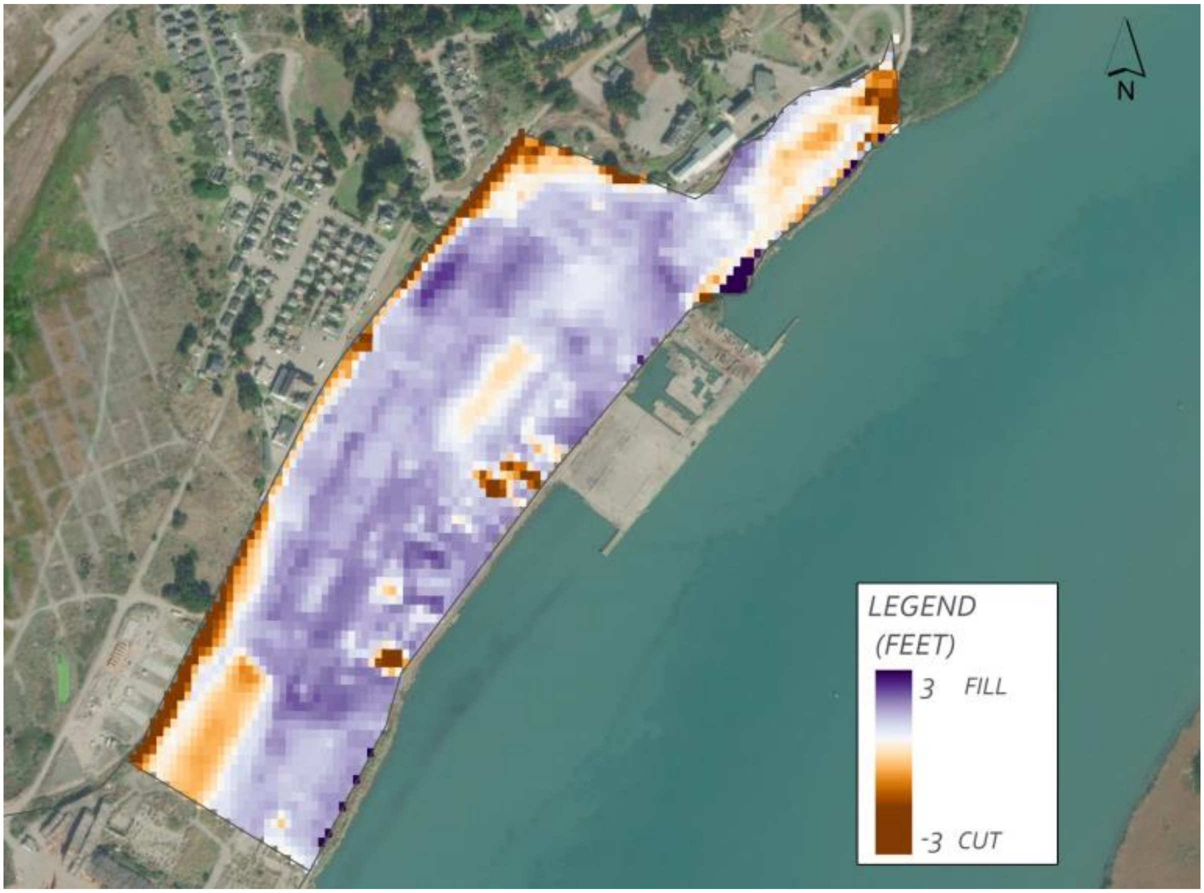


Figure 32 – Example Fill and Cut Depth – 12 ft. MLLW Yard at RMT I

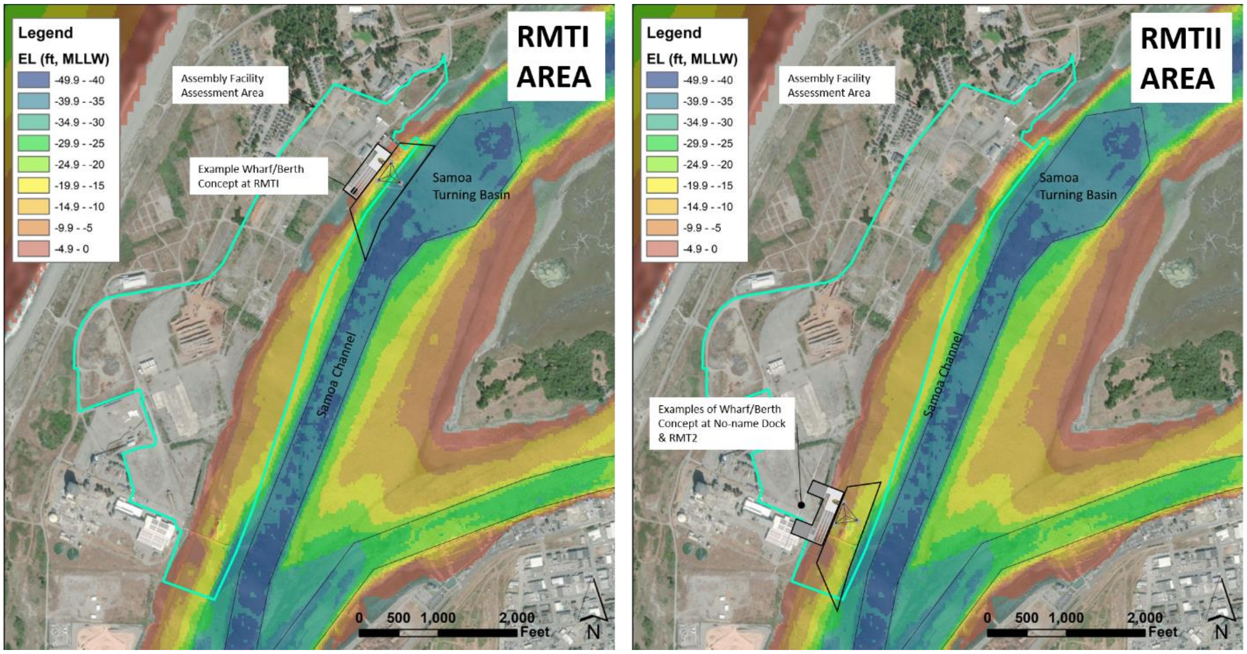


Figure 33 – Example Pilot/Small-Commercial Scale Wharf Location, Orientation, and Berth Dredging Outlines. Overlaid on site elevation data (blue = deeper water, red = shallower water. Dredging volume increases when wharf is located further from blue areas.

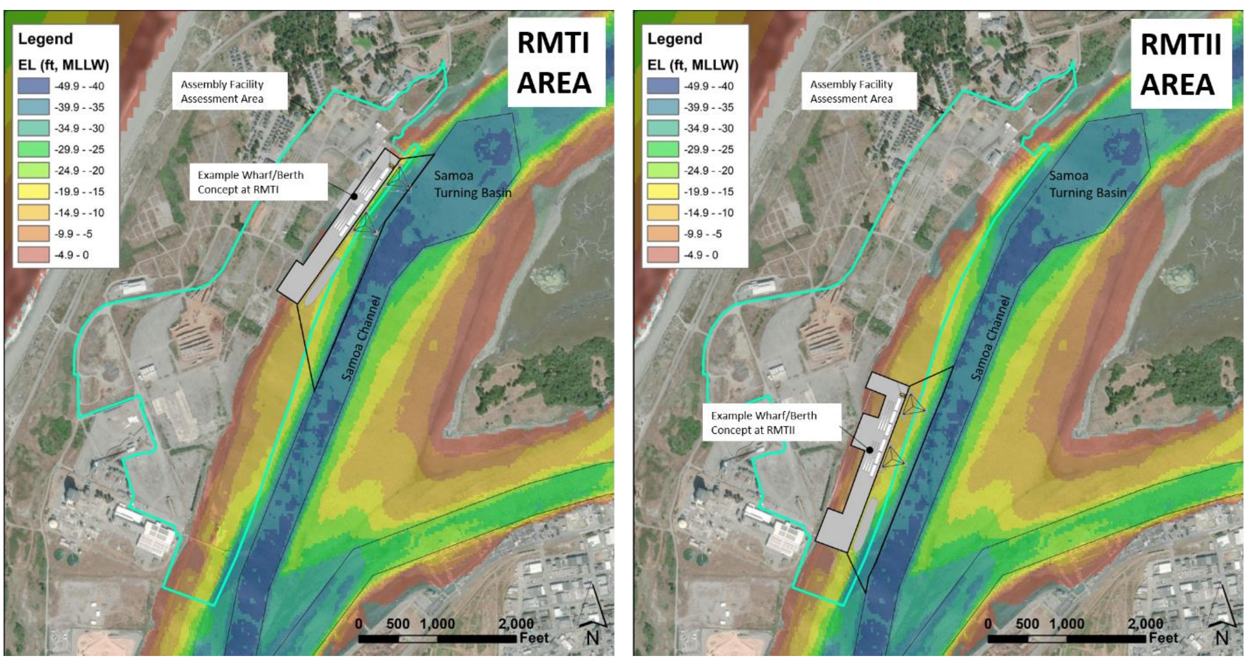
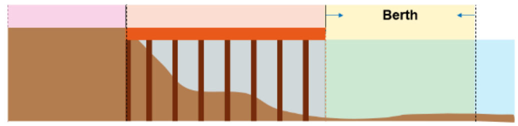


Figure 34 – Example Large-Commercial Scale Wharf Location, Orientation, and Berth Dredging Outlines. Overlaid on site elevation data (blue = deeper water, red = shallower water. Dredging volume increases when wharf is located further from blue areas.

6.6 Marine Terminal Results Summary

6.6.1 Berth



6.6.1.1 General Constraints

- Water depth at the berth may need be deeper than the existing FNC Samoa Channel to accommodate the larger end of devices at all water levels.

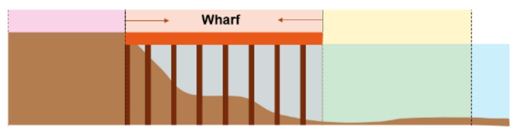
6.6.1.2 Pilot/Small-Commercial 

- 1 multi-purpose berth may be sufficient.
- Dredging is likely required, shoreward of existing extents of historical dredging.

6.6.1.3 Large-Commercial 

- Multiple berths likely required, including an exclusive-use component delivery berth. Berth may be multi-purpose if all components can be delivered throughout the winter (not currently guaranteed with existing shoaling and maintenance dredging schedule).
- The dredging area required is larger than the historical dredge areas of RMT I/RMT II.
- Nearshore dredging could potentially be reduced if the FNC is relocated to the East

6.6.2 Wharf



6.6.2.1 General Constraints

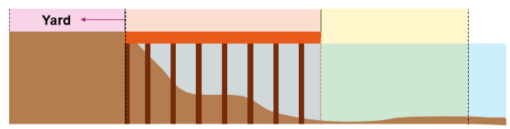
- The existing wharves at RMT I and RMT II were not designed for high capacity loads and would need replacement, both in its current condition, and if rehabilitated.
- The structure type may possibly be either open pile supported or closed fill and is dependent on site-specific geotechnical information not yet available.
- The wharf elevation would likely need to be 1-2 feet higher than the existing RMT I.

6.6.2.2 Pilot/Small-Commercial 

- If located at RMT I, the outer edge of the wharf may need to be landward of outer edge of the existing wharf.
- Structure over-water area may potentially be reduced with moving the wharf closer to the shoreline, but would require additional nearshore dredging.
- If fabrication occurs onsite, the wharf length may need to be longer than the existing RMT I wharf.
- New wharf may be designed to be approximately similar size of footprint of the existing wharf at RMT I.

6.6.2.3 Large-Commercial

- The required length of the new wharf structure will likely significantly exceed that of the existing RMT I wharf.
- A multi-berth wharf can likely be located and oriented to minimize conflicts with the FNC and USACE turning basin but will require nearshore dredging. At RMT I, access pier fairways may not be required due to proximity of wharf to yard.
- If fabrication is conducted on site, an additional exclusive-use berth may be required for launching the substructures.
- Overwater coverage may be reduced if the structure is moved inland, which also may improve transport logistics but would require significant new nearshore dredging. This tradeoff requires further analysis.



6.6.3 Yard

6.6.3.1 General Constraints

- Ground improvement is likely required. New surface may potentially be concrete or crushed stone.
- Material import for grading may or may not be required depending on the ground improvement and surface treatment options.
- There may need to be considerations for lighting and noise considering residential areas.
- Utility upgrades likely required, and roadway upgrades may be required (LACO, 2013)

6.6.3.2 Pilot/Small-Commercial

- The RMT I/RMT II area provides sufficient area for an upland Assembly Facility and if required, a Fabrication Facility.

6.6.3.3 Large-Commercial

- Sufficient upland area is available within the Yard Assembly Area to support an Assembly Port facility and Fabrication facility, though details on fabrication layout are not yet developed.
- Total area likely required for assembly and fabrication at large commercial scale is up to 140 acres – total available acreage in study area is 160 acres. Therefore, the total available area is likely sufficient for these activities.
- Grading challenges are present due to the differential in elevations across the site between RMT I and RMT II. SPMTs, the vehicles used to move the heavy equipment, can operate on a gradient, but further site and use specific assessments are needed.

6.6.4 Other Users

6.6.4.1 Pilot/Small-Commercial

- RMT I/RMT II area would provide enough remaining area for full buildout of other maritime growth users (assumed to be maximum of approximately 40 acres).
- The multi-purpose terminal would exceed the length, live load capacity, and berth depth need of the other potential growth industries in the area (e.g., mariculture, commercial fishing, aggregate export, etc.).

- When in use for OSW activities, the facility would likely require exclusive use. After the floating OSW buildout, the only facility that would require exclusive use is the O&M vessel base which may or may not be located at the RMT I/RMT II multi-purpose high-capacity wharf.
- Port-generated noise should be considered within the port area, residential and other noise sensitive neighboring areas, and areas between the port area source and the noise sensitive areas.
- A detailed Navigation Safety Risk Assessment (NSRA) should be completed to evaluate impact to navigation for any waterfront facility added, modified, and removed. The study would consider the size, scope, and vessel traffic impacts of the new facility.

6.6.4.2 Large-Commercial

- Depending on total available industrial land area RMT I/RMT II area may or may not provide enough remaining area for full potential of other maritime growth users (assumed to be maximum of approximately 40 acres), if buildout includes a fabrication yard.

7 Operations and Maintenance

7.1 Introduction and Background

O&M facilities are required to support preventative maintenance and minor corrections, and also major corrective repairs. Maintenance and minor repairs (such as replacement of small parts or substructure inspection) will occur at the wind farm, whereas major repairs (such as blade repairs) are likely to be conducted in port. The port facilities needed to support O&M are dependent on a combination of wind farm size, distance, and strategy of the contractor executing the Service and Maintenance Agreement (SMA).

Figure 35 - O&M CTV (top), Heli-support (middle), and SOV (Bottom)

The SMA contractor will likely propose their own repair approach, but two conceptual strategies have been developed for use in this port assessment. Strategies potentially include either an onshore-based strategy or an offshore-based strategy. The onshore-based strategy may consist of a fleet of small crew transfer vessels (CTVs), with helicopter support. An offshore-based strategy may consist of one or multiple Service Operation Vessels (SOVs), as well as a smaller fleet of CTVs and helicopter support. A summary of potential transport equipment needs is included in Table 12. The exact number of vessels and helicopter support units may change as additional technology and vessels are developed.

Table 12 – Operations and Maintenance Transport Units

Strategy Wind farm Size	Example Onshore, Small	Example Onshore, Large	Example Offshore, Large
CTVs	1-2	8-10	2-4
Helicopters	-	1-2	1-2
SOVs	-	-	1-3

7.2 Operations and Maintenance Assessment Criteria

Conceptual Operations and Maintenance Assessment Criteria are provided in Appendix G. Key criteria used in the evaluation are the following, and are summarized in Table 13.

- Yard Area
  - 2-10 acres to include space for warehouse, parking, offices, security, etc.
- Wharf Live Load:
  - 500-1000 psf for movements of goods and people. Moorage floats do not require the same loading requirements.
- Berth Length
  - CTV - Length required is dependent on the strategy developed by the SMA, but would likely be between 450-900 ft. Length may be split between various vessel slips.
  - SOV - Length required is dependent on the strategy developed by the SMA, but likely would be at least 300-600 ft.

- Wave Exposure
  - Small craft – such as CTVs are more sensitive to wave action than larger vessels. A protected harbor is needed, and a siting assessment including wave modeling would need to be completed for a quantitative assessment.

7.3 Operations and Maintenance Assessment

Assessment includes the screened sites which could potentially support an O&M vessel base and is based on the criteria in Section 7.2.

7.3.1 General

- Fewer restrictions than assembly and fabrication sites
- With present technology, major repairs will require the device to be towed to a wharf in the harbor (likely the assembly berth), and major repairs likely to be limited to summer conditions.
- Some timing limitations on crew access to the wind farm should be planned for due to offshore wave conditions
- A summary of the assessment is included in Table 13 relative to the criteria in Section 7.2.
- More analysis is needed to detail vessel and transport needs. Number of vessels was developed only to the level needed for assessing navigation and marine terminal infrastructure at a conceptual-level, and should not be used as a planning tool.

7.3.2 Pilot/Small-Commercial Scale

- Strategy may potentially consist of 1-2 CTVs. SOV likely not required.
- Numerous potential options throughout the bay, but additional investigation is needed to confirm if wave criteria can be met without a breakwater.
- CTV floating dock berths likely consist of a set of floats accessed via gangway; does not require deep draft access.
- Additional siting analysis is needed to determine if existing facilities can be re-configured to support CTV berths.
- Wave exposure needs to be assessed for siting of CTV harbor. More exposed sites may require a breakwater.

7.3.3 Large-Commercial Scale

- Strategy may potentially be:
  - Onshore support system option may consist of CTVs and may require helicopter support
  - Offshore support system option may consist of SOVs, CTVs, and 1-2 helicopters
- Requires more infrastructure than the small/pilot-scale due to increased support of at-sea operations. May require 10 CTV berths, or multiple deep draft berths for SOVs.
- No existing facility appears capable to support large-scale CTV or SOV base without upgrades.
- SOV berth less likely to require a breakwater due to size of vessel
- If O&M base is in South Bay, the Field's Landing FNC geometry may limit SOV vessel specifications (e.g., draft).

7.3.4 Other Users

- If a breakwater is constructed to provide a protected harbor for CTV base, other small craft vessel slips could be constructed if the breakwater is sized and designed for additional needs.

Table 13 – Conceptual O&M Facility Assessment[18]

Site	Yard Area	Live Load on Wharf	SOV Berth Length	CVT Pier/Floats	CTV Wave Exposure
RMT 1					
RMT 2					
Schneider Dock					
Fields Landing					
Sierra Pacific					
Redwood					
Fairhaven					
Forest Products					
Woodley Island					

Facility Likely Meets Criteria

Facility May Meets Criteria or Minor Upgrades Needed

Facility Upgrades Needed

Facility is Likely Unable to Meet Criteria

[18] Other locations in Humboldt Bay may be feasible, assessment was not intended to be exhaustive of all potential options.

8 Construction Cost Estimates and Schedule Considerations

8.1 Construction Costs

An opinion of planning-level (pre-feasibility) construction costs for port infrastructure upgrades was developed for assembly and O&M facilities. Planning-level costs for Pilot/Small-Commercial Scale are provided in Table 14, and costs for the Large-Commercial scale are provided in Table 15. Costs were developed aligning with a Class 5 level estimate of the American Association of Cost Estimating (AACE) – Cost Estimate Classification System, typically used for concept screening. The estimates were developed based on prior project experience, contractor outreach, literature review, and conceptual-level engineering analysis, and do not include warehouses, offices, utilities, land acquisition, parking, security[19].The following assumptions were made to develop the construction cost estimates, but could vary greatly based on developer specific needs:

- Pilot/Small-Commercial
  - New 800 ft. long wharf
  - Yard ground improvements and surface treatments (50-75% of area assumed – 20 total acres)
  - Berth dredging to FNC depth
  - Operations and maintenance use CTVs at floating dock
- Large-Commercial
  - New 1,600 ft. long wharf
  - Yard ground improvements and surface treatments (50-75% of area assumed - 60 total acres)
  - Berth dredging to FNC depth
  - Navigation Channel Modifications (assumed to be a moderate level of channel widening)
  - Wet-storage dredging
  - Operations and maintenance use CTVs at floating dock and fixed pier or wharf for SOV

Table 14 – Pilot/Small-Commercial Scale Planning-Level Construction Cost Estimate

	Cost
Mobilization	$ 4,000,000
Demolition	$ 1,000,000
Wharf	$ 54,000,000
Yard Ground Improvements and Surface	$ 14,000,000
Berth Dredging	$ 2,000,000
O&M In-water facilities	$ 1,000,000
Contingency (+/- 40%)	$ 30,000,000
Range (Pilot/Small-Commercial Scale)	$ $50,000,000 - 110,000,000

[19] Costs do not include optional fabrication facility as those costs would be very specific to the type of substructure and logistical requirements. Placeholder costs assumed to be $50-100 million.

Table 15 – Large-Commercial Scale Planning-Level Construction Cost Estimate

		Cost
Mobilization	$	10,000,000
Demolition	$	1,000,000
Wharf	$	140,000,000
Yard Ground Improvements and Surface	$	42,000,000
Berth Dredging	$	3,000,000
Navigation Channel Modifications	$	9,000,000
Anchorage Dredging	$	3,000,000
O&M In-water facilities	$	6,000,000
Contingency (+/-40%)	$	90,000,000
Range (Large Commercial-Scale)		$130,000,00 - 310,000,000

8.2 Construction Schedule Considerations

Construction schedule considerations have been developed for the port and navigation infrastructure upgrades. Typical activities required are listed below. Note that most of activities can be conducted in parallel to minimize schedule and in-water construction windows. The total estimated buildout from project initiation is estimated to be 3-6 years for Pilot/Small-Commercial, and 5-7 years for Large-Commercial, dependent on the availability to work outside the typical in-water construction window for Humboldt Bay.

- Preliminary Design and Permitting – design drawings and permit approval
- Final Design and Bidding – construction level design and procurement
- Assembly Wharf Demolition – pile removal and upland site demolition
- Assembly Wharf Construction – all piles installed first considering in-water work windows to minimize in-water and over-water construction
- Assembly Berth/Side-Channel Dredging – for vessel access to berths
- Wet-storage Area Dredging – for storage of substructures
- Staging Area Dredging – if required for staging assembled units
- Assembly Crane Procurement and Assembly – may require overseas procurement
- Assembly Yard grading and ground improvements – less sensitive to in-water work windows
- O&M vessel berth/wharf construction – may consist of floats or fixed pier in water
- Navigation Channel Modifications – may require long-lead times up to 5-7 years

9 Climate Change Assessment - Summary

A conceptual-level assessment was conducted to evaluate potential effect of climate change and tsunamis, and associated vulnerability of potential offshore wind (OSW) and port infrastructure in the Humboldt Bay region. The vulnerability assessment is intended to be used for planning a buildout of OSW infrastructure and providing a framework for quantitative risk assessments and adaptive planning studies. The best available science, including Humboldt Bay specific guidance documents, was reviewed to document the hazards and climate change parameters the infrastructure may be exposed to. Infrastructure and system vulnerability has been assessed as a combination of exposure to the hazards/processes, sensitivity to the hazard/process, and ability to adapt to the hazard/process.

Hazards and climate related processes were selected based on review of existing literature and for their potential effect on the OSW infrastructure. Climate-related processes included wind, currents, storminess, sea-level rise (SLR), fire, precipitation/streamflow, and fog[20]. Infrastructure was divided into four main elements to conduct the vulnerability assessment:

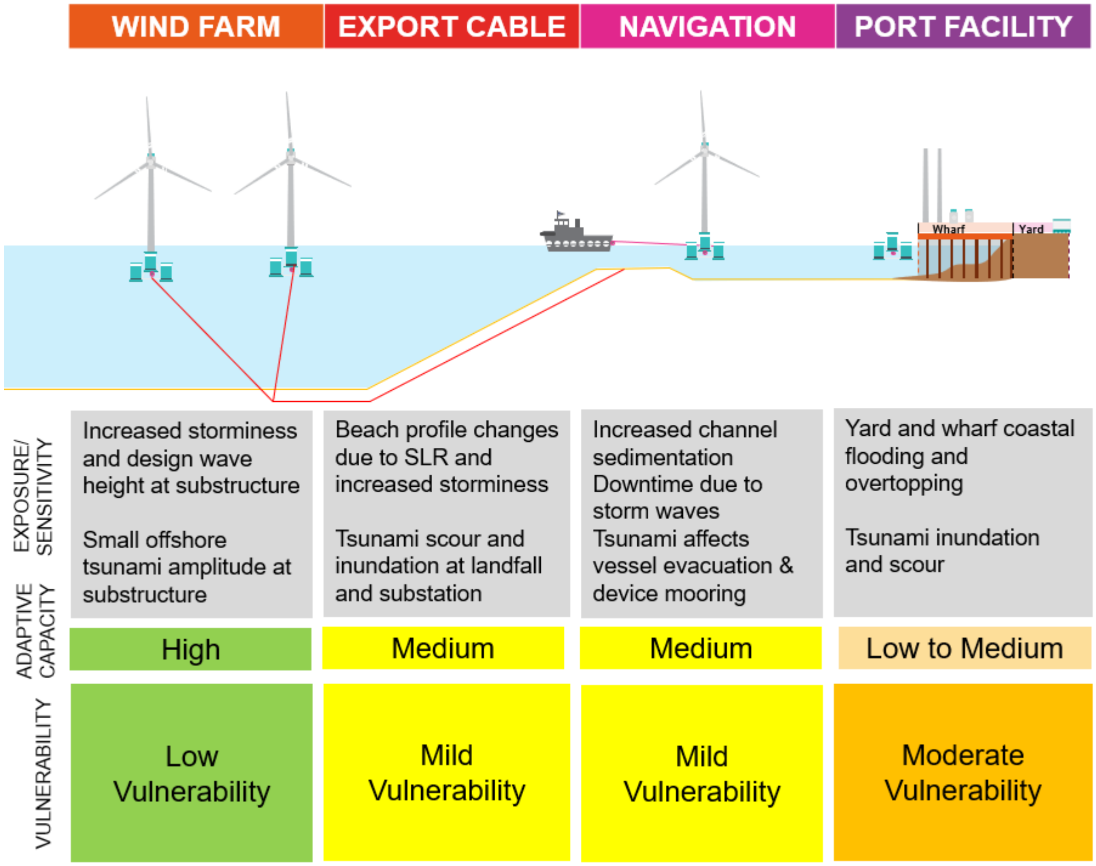
- Offshore wind farm (turbine, anchoring, mooring lines, and inter-array cables),
- Export cable infrastructure to Humboldt Bay (subsea routing, landfall, upland routing, and substation),
- Navigation (both offshore and within Humboldt Bay), and
- Port facilities (wharf and yard).

The existing hazards and potential changes in climate-related processes were applied to each of these infrastructure elements to qualitatively assess the vulnerability of each of the four main project infrastructure elements. A summary of the application of the hazards and climate-related processes is summarized in Appendix I. Future studies need to be conducted to develop quantitative risk parameters, and adaptation or mitigation strategies to increase the capacity of these elements to absorb the hazards and climate change parameters and maintain function (resiliency), if possible.

Offshore Wind Farm. The offshore wind farm appears to be at a low vulnerability level. The offshore tsunami amplitude is small, and changes in wind and wave storminess may be able to be incorporated into design.

Export Cable. The export cable, more specifically the landfall, appears to be mildly vulnerable. The landfall could be sensitive to changes in beach profile in response to SLR (increasing risk of cable infrastructure de-burial and exposure) and scour due to tsunami inundation over the spit features where landfall is likely to be made. Coastal engineering studies for the landfall design and siting of the onshore substation should incorporate SLR, quantify the effects, and include a planning assessment to protect against unacceptable risks.

[20] This assessment included the current state of the science with regards climate change, the climate change parameters should be revisited in future studies as the understanding of climate change and SLR processes are rapidly evolving.


WIND FARM
EXPORT CABLE
NAVIGATION
PORT FACILITY
Wharf
Yard
EXPOSURE/ SENSITIVITY
Increased storminess and design wave height at substructure
Small offshore tsunami amplitude at substructure
Beach profile changes due to SLR and increased storminess
Tsunami scour and inundation at landfall and substation
Increased channel sedimentation
Downtime due to storm waves
Tsunami affects vessel evacuation & device mooring
Yard and wharf coastal flooding and overtopping
Tsunami inundation and scour
ADAPTIVE CAPACITY
High
Medium
Medium
Low to Medium
VULNERABILITY
Low Vulnerability
Mild Vulnerability
Mild Vulnerability
Moderate Vulnerability

10 Conclusions

10.1 General assessment conclusions

Port infrastructure elements in Humboldt Bay have various levels of existing potential suitability to support offshore wind installation and assembly, substructure fabrication, and O&M activities. However, there is no existing marine terminal in Humboldt Bay that can support these activities without investment. Industry needs can likely be met with various levels of investment for the Pilot/Small-Commercial and Large-Commercial buildout scenarios.

A screening assessment was conducted and identified the RMT I and II areas as the likely location for an offshore wind marine terminal. The existing navigation infrastructure can likely support assembly activities, but the size of the floating substructures may be constrained without upgrades to the FNC. O&M facilities will require some investment, but the existing site imposes fewer restrictions on O&M activity than on assembly activities. The O&M facility could likely be co-located with an assembly facility at RMT I or II, or there are numerous options for siting an O&M facility within the bay. The Humboldt area is unlikely to support OEM manufacturing due to a number of factors, including supply chain connections.

The following outlines the marine terminal and navigation infrastructure improvements that are recommended to meet industry needs, the planning-level costs associated with these upgrades, and schedule considerations. A summary of assessment findings that influenced these recommendations are provided at the end of this section in Table 17.

Marine Terminal Improvements: Conceptual engineering was conducted to assess the likely infrastructure upgrades required for a marine terminal for both small and large-scale projects:

- New high-capacity wharf structure designed to accommodate sea-level rise. Small OSW projects would likely require a similar footprint as the footprint of the existing wharf at RMT 1. Large OSW projects will require a larger footprint than the existing wharf at RMT I.
- Berth dredging is likely required in areas outside the extents of prior capital or maintenance dredging activities.
- Yard ground improvement and surfacing over a large area of RMT I & II is required.
- New O&M vessel wharf or pier, moorage floats, and potentially a helipad are required.

Navigation infrastructure Improvements: The existing navigation infrastructure can support assembly activities, but the throughput and geometry of the floating wind devices (and therefore wind turbine power generation per unit), may be constrained without modifications to the FNC. The need for upgrades was found to be related to specifics on device geometry, which varies by technology. The following upgrades may be required for large projects, depending on device geometry. Further analysis is needed to confirm the need and extents of these upgrades:

- Localized widening of the FNC at the entrance to Humboldt Bay (Entrance Channel).
- Widening of the North and Samoa FNCs.
- Localized dredging for wet-storage and staging areas to support project installation throughput.

Construction Cost: An opinion of planning-level (pre-feasibility) construction costs for port infrastructure upgrades was developed for assembly and O&M facilities. The construction cost of navigation and port infrastructure upgrades needed to support assembly and O&M is dependent on the OSW buildout scenario and the floating OSW substructure details. Construction cost for the Pilot/Small-commercial scale projects is likely in the range of $50-110 million. Construction cost for the Large-Commercial Scale port and navigation improvements may be in the range of $130-310 million. Construction costs of the two scales are not intended to be additive and may be phased, resulting in cost efficiencies for the larger buildout. These costs do not include development of a fabrication facility yard and wharf, which could result in an additional $50-100 million.

Schedule Considerations: Buildout duration for Large-Commercial Scale port and navigation infrastructure upgrades (including engineering design, permitting, bidding, demolition, and construction of a new facility) could be on the order of 5-7 years. Buildout for facilities supporting Pilot/Small-Scale projects could require 4-6 years. If modification of the FNC is needed, the lead time for that process (5-7+ years) could be the limiting factor for construction. Construction may be required outside the typical in-water work window within Humboldt Bay to meet this schedule.

Wind farm installation activities are likely to be limited to favorable weather months. A Pilot/Small-Commercial Scale win farm may be able to be installed in 1-2 years. A Large-Commercial Scale wind farm could take 3-6+ years for installation, depending on device geometry and navigation improvements.

10.2 Navigation Conclusions

The navigation infrastructure at Humboldt Bay provides deep draft vessels access to marine terminal facilities within the bay without air-draft restrictions and can likely support OSW build-out. However, there are a number of constraints that became evident during the course of the assessment. The constraints summarized in Figure 37 should be addressed in more detail prior to development of marine terminal facilities and represent the conclusions below:

- Operations in the Entrance Channel are more limited by metocean conditions and channel shoaling, with some limitations based on existing channel geometry. Inner Channel operations more limited by existing geometry, as it was designed for narrower vessels in calm conditions, rather than wide substructures.
- Inner Channel is more likely to be the limiting constraint for the size of device towed out. Without increasing the width of the channel, device width limitations may be between 200-270 ft., depending on more detailed maneuverability analysis.
- Pilot/Small-Commercial scale projects being developed for Humboldt Bay should include maneuverability assessments early on in project planning to reduce risk of throughput constraints or future substructure device modifications.
- The depths and conditions in Humboldt Bay are likely sufficient for component and substructure delivery, but the delivery vessel and method selection needs to be carefully planned and assessed.
- Device wet-storage, component yard storage size requirements, and Entrance Channel conditions are closely related for both component delivery and assembled device tow-out. Earlier or more frequent dredging of the Entrance Channel would likely reduce the yard size required for storage of the components. A localized increase in width of the FNC at the entrance would likely reduce the need for wet-storage and in-water staging areas, depending on device geometry.
- Due to the metocean conditions in the region, it is likely that installation and major maintenance activities will be limited to favorable seasons (such as late spring, summer, and early fall), similar to other OSW projects world-wide.
- To conduct minor repairs in the winter, advancements in crew transfer technologies to accommodate larger wave limits may be required; otherwise, a larger vessel fleet may be needed to accommodate smaller weather windows.

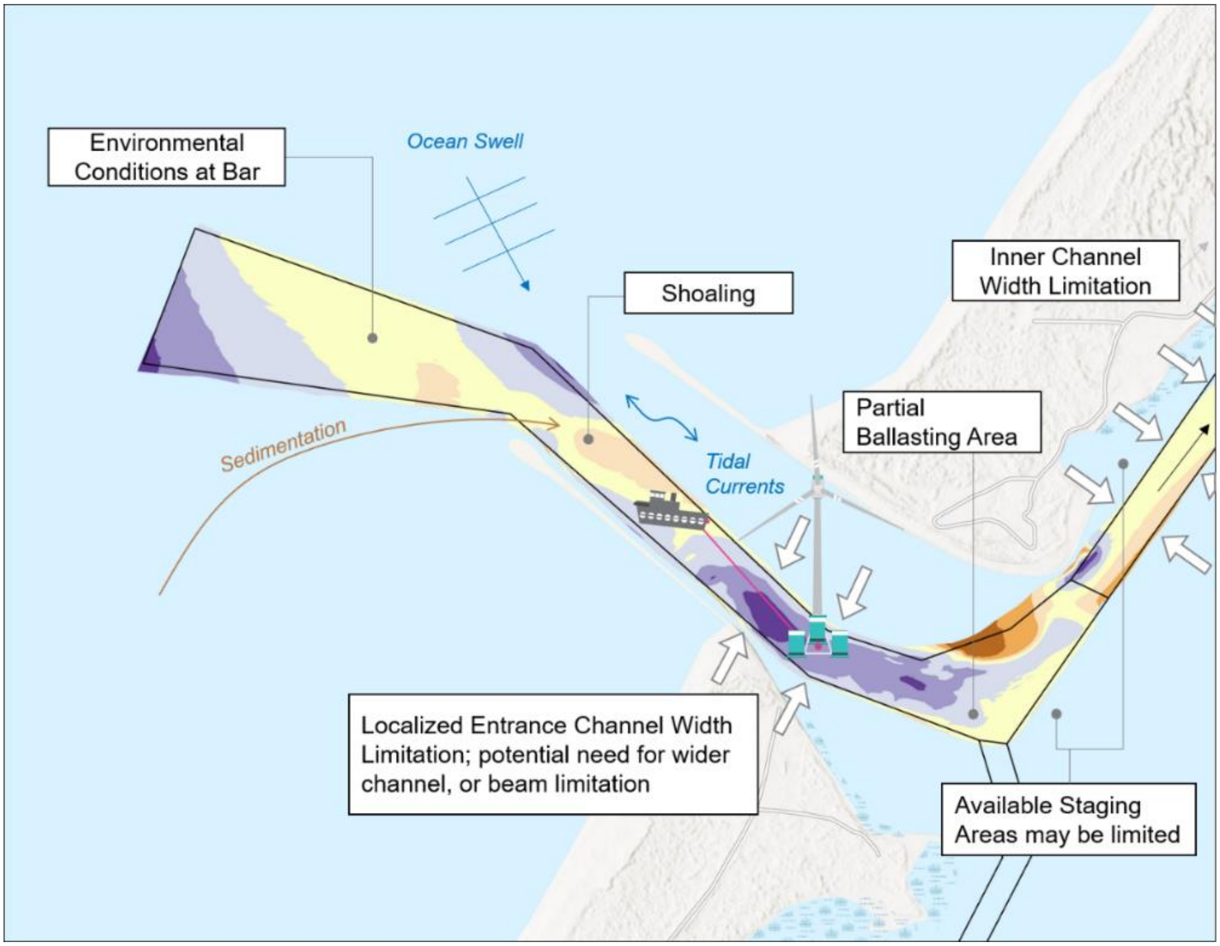


Figure 37 – Navigation Conclusions Summary Schematic

10.3 Marine Terminal Infrastructure Conclusions

Marine terminal infrastructure investments required to support OSW buildout include considerations of the following:

- The existing wharf and yard at RMT I/RMT II was purpose-built to support the timber industry with substantially lower live load requirements, and if rehabilitated to a new condition, would not be sufficient to support the necessary assembly activities such as component delivery, component storage and transport, or heavy-duty cranes.
- A new assembly wharf at RMT I/II could potentially be phased with the Pilot/Small Commercial buildout to the Large Commercial scale size/length, if designed appropriately.
- Based on review of limited available geotechnical investigation information, it appears either an open pile supported or closed fill supported wharf may be feasible, but additional investigations are needed to confirm.
- Increasing the finished elevation for a new wharf/yard at RMT I will be needed to ensure the facility remains outside the future flood zone and reduces the risk of increased maintenance and flooding.
- The finished elevation of the RMT I wharf/yard facility would need to be increased to somewhere in the range of 1.5-2.5 feet; whereas, the yard elevations at RMT I are likely sufficient

- There is not a clear “best choice” for the areas between RMT I and RMT II areas for assembly and fabrication facility layouts. There are benefits and risks for each site, as outlined in Table 16, and other factors may influence where wharf development occurs in this area, which could be RMT I, RMT II, or between the existing facilities.
- The yard areas at RMT II may require less construction if used for storage or fabrication, but the wharf area at RMT I may be preferable for development of a wharf and berth dredging. However, the two areas are at different elevations. If both areas are used for the Large-Commercial scale buildout, the connectivity between the sites requires further assessment.
- Projects utilizing Humboldt Bay as an assembly port will likely use a port network to support assembly activities (manufacturing and fabrication).

Table 16 – RMT I and RMT II Comparison

Facility	Benefits	Risks
RMT I	Potentially limited new overwater coverage for Pilot/Small-Commercial scale. Less impact on mapped eelgrass beds. Adjacent to turning basin.	Low-lying area, is vulnerable to SLR. Site grading may be required.
RMT II	Yard is significantly less vulnerable to SLR. Located further from residential areas	Higher volume of berth dredging likely required. May be more challenging to float-off substructure at high elevation.

Table 17 – Assessment Finding Summary Table

Location	Key Activities & Considerations	Key Constraints	Key Findings
Open Ocean	Assembled device tow-out. Major repairs tow-in. Crew transfer	Average winter wave conditions exceed existing typical limits for device towing, installation, and crew transfer.	Some timing limitations on crew access to the wind farm should be planned for due to offshore wave conditions. Seasonal major repair windows likely.
Outer Channel	Assembled device tow-out. Major repairs tow-in. Component vessel delivery	Channel width during large-scale tow-out. Seasonal channel shoaling and maintenance dredging frequency. Frequency of harsh metocean conditions.	Existing channel can likely accommodate deployment for a range of substructures sizes, but throughput and size of substructures may be limited. Modification of channel may be needed for large-commercial deployment. Increase in maintenance dredging frequency may be required for year-round component delivery.
Inner Channel	Assembled device tow-out. Major repairs tow-in. Component vessel delivery/	Inner Channel width of 400ft. Inner Channel depth of 38ft.	Without good navigation support, and favorable environmental conditions tow-out may not be considered safe. Channel widening may be required for large-commercial scale deployments. Tow-out likely limited to high-tide.
Wharf and Berth	Component Delivery Device assembly Foundation float-off and/or delivery	Existing structures Nearshore water depth Eelgrass FNC alignment	New wharf needed – Pilot-scale size similar to RMT I, large-commercial will be larger and likely encroach on eelgrass. Location of wharf likely landward of existing wharf line to minimize conflict with FNC, resulting in additional dredging. Wharf elevation likely elevated relative to existing to mitigate coastal flood risk, at present conditions and with SLR.
Yard	Component storage Substructure fabrication	Variable elevations. Flood zone at RMT 1. Low capacity near surface sediment likely.	The total area is likely sufficient to support assembly, fabrication and O&M activities. Due to elevation differentials on site, significant grading or differentiation of activities may be required. RMT I likely requires an increase in ground elevations. Ground improvement likely required.
Wet-Storage and Staging	Storage of fabricated substructures and assembled devices awaiting tow-out. Ballasting activities.	Regulations on anchorage in FNC. Depths inside and outside the FNC. Channel shoaling.	Wet-storage of unassembled devices likely requires limited to no dredging. Wet storage of assembled devices likely requires new dredging. Staging area near the entrance may be able to accommodate smaller devices w/out dredging. Full ballasting of devices may or may not be possible, depending on draft, and Entrance Channel shoaling rate.
Operations and Maintenance Base	Crew transfer vessel – small craft harbor. Berthing of SOV fixed wharf or pier. Offices and storage.	Offshore wave conditions Distance to wind farm Berth length (SOV) CTV wave conditions	O&M facilities require investment, but at a lower level than assembly and fabrication facilities. Additional siting analysis is needed to determine if existing facilities can be re-configured to support CTV berths. A breakwater may be required.
Estimated Conceptual Construction Cost	Wharf, yard, berth, and navigation channel	Unknowns include subsurface conditions, specific foundation geometry	Small: $50-110 million Large: $130-310 million

10.4 Next Steps

The following next steps are not intended to be comprehensive for development of an offshore wind farm, but are key analyses or investigations recommended based on the outcomes of this assessment:

- Further investigation will need to be conducted during the preliminary design phase to optimize the finished elevation for a new wharf/yard with consideration for SLR, stormwater, flooding and type of structure.
- Wharf and berth orientation and location need to be refined based on a detailed coastal engineering analysis to consider maintenance dredging needs.
- The elevation of a new wharf and yard needs to be refined with consideration for SLR, stormwater, flooding risk, and wharf structure type.
- Anchorage and staging area orientation and location need to be refined based on a detailed coastal engineering analysis to consider maintenance dredging needs, wave exposure, and other environmental conditions.
- Wave analysis is needed to aid in siting of the O&M vessel base to determine suitable locations for a small craft harbor, in accordance with industry guidance.
- Conduct outreach with regulatory authorities, users, developers, UASCE, to help refine criteria and inform feasibility assessment work.
- Environmental, geotechnical, and land/hydrographic surveying within the area of the project area for use in the planning and engineering design work.
- Site-specific liquefaction analysis should be performed to determine the effects of seismic events on the proposed foundation and site grading concepts.
- Ground improvement can be estimated more with site-specific settlement analysis.
- Full bridge simulations should be conducted by modifying the existing bridge simulation model of Humboldt Bay to refine the navigation requirements.
- Tow plans for the floating foundations should be developed in coordination with USCG.
- A Navigation Risk Assessment should be conducted (as required by the USCG) to assess and mitigate potential impacts to navigation from a new port facility.
- A detailed port planning study and development of how the key development areas will be integrated with each other, including existing and proposed services/utilities/transport routes and grading of the layouts.
- Aids to Navigation (ATONs) considering floating OSW may require further assessment in coordination with the USCG's WAMs tool.
- Future studies should be conducted to develop quantitative risk parameters and adaptation or mitigation strategies to increase the resiliency of port infrastructure.
- Operability assessment should be conducted to confirm throughput and aid in identifying limited infrastructure.

Data and References

Data Source	Name	Date Published
Elevation Data		
Humboldt Harbor District	Bathy DEM (1m) North	2005
Humboldt Harbor District	Bathy DEM (1m) South	2005
Humboldt Harbor District	DEM fusion project	2005
NOAA	Eureka 1/3 arc-second DEM	2009
NOAA	Northern California 36 arc-second Coastal DEM	2018
USACE	Hydrographic Survey Data	2010-2020
Misc. GIS Data		
Humboldt Harbor District	Parcels	2019
NOAA	NOAA Nautical Chart 18662	2016
State of California Geoportal	California Population Density Estimate 2011	2011
MarineCadastre	Ocean Reports Tool	2019
CA Offshore Wind Energy Gateway	CA Offshore Wind Energy Maps	Various
Schatz Energy Center GIS	*OffshoreWindStudy.gpkg*	2019
CA Department of Fish and Wildlife	Eelgrass Distribution	2016
Port of Humboldt Bay - Existing		
BST Associates	Humboldt Bay Maritime Industrial Use Study Final Report	2018
USACE	Environmental Assessment and Draft FONSI Humboldt Harbor and Bay Operations and Maintenance Dredging	2017
Northern Hydrology & Engineering	Sampling and Analysis Plan, Humboldt Bay Harbor Recreation and Conservation District and City of Eureka Sediment Characterization for 2016-2021 Maintenance Dredging	2015
Humboldt State University (Humboldt State Environmental Management and Protection Planning Option Senior Practicum 2016)	Shoreline Protection Options for Humboldt Bay	2016
LACO Associates	Samoa Industrial Waterfront Access Plan	2013
SHN, CH2M, HEMPHILL Water Engineering	Infrastructure Needs and Reuse on Samoa Peninsula, RMTII	2016
BST Associates	Humboldt Bay Alternative Rail Corridor Concept level Construction Cost and Revenue Analysis Final Report	2013
USACE	Humboldt Bay, California, Entrance Channel, Data review (Costa, Glatzel)	2002
Humboldt Bay Harbor Recreation, & Conservation District	Website: humboldtbay.org	Accessed 2019
Port Infrastructure		
NREL; Beider et al	A Spatial Economic Cost Reduction Pathway Analysis for US Offshore Wind Energy Development from 2015-2030	2016
Porter and Phillips, prepared for BOEM	Determining the Infrastructure Needs to Support Offshore Floating Wind and Marine Hydrokinetic Facilities on the Pacific West	2016

	Coast and Hawaii.	
BVG, prepared for the State of Virginia	Virginia offshore wind port readiness evaluation Report 1: An evaluation of 10 Virginia ports	2015
NYSERDA	NYSERDA Assessment of Ports and Infrastructure	2017, 2018
Massachusetts Clean Energy Center	MA Clean Energy Center Offshore Wind Ports & Infrastructure Assessment	2017
Navigant; prepared for DOE	US Offshore Wind Manufacturing and Supply Chain Development	2013
Pacific Northwest National Laboratory; Copping and Grear	Humpback Whale Encounter with Offshore Wind Mooring Lines and Inter-Array Cables	2018
American Jobs Project	California Offshore Wind Project: A Vision for Industry Growth	2019
Hydrodynamics		
Prepared by Northern Hydrology and Engineering. Prepared for State Coastal Conservancy and Coastal Ecosystems Institute of N. CA	Humboldt Bay: SLR, Hydrodynamic Modeling, and Inundation Vulnerability Mapping	2015
Nathan Classen (Thesis)	Modeling Wave-current interaction in the vicinity of Humboldt Bay, CA	2003
USACE	CMS application - forecasting approach for NWS, Eureka, CA	2010
Moffatt & Nichol, prepared for CA Coastal Sediment Management Workgroup	Eureka Littoral Cell, Coastal Regional Sediment Management Plan	2017
SLR	*Note: Additional references in Appendix I*	
Prepared by Northern Hydrology and Engineering. Prepared for State Coastal Conservancy and Coastal Ecosystems Institute of N. CA	Humboldt Bay: SLR, Hydrodynamic Modeling, and Inundation Vulnerability Mapping	2015
Prepared by Northern Hydrology and Engineering. Prepared for State Coastal Conservancy and Coastal Ecosystems Institute of N. CA	SLR in Humboldt Bay Region	2018
Aldaron Laird Trinity Associates. Funded by CA Coastal Conservancy, Sponsored by Coastal Ecosystems Institute of N. CA.	Humboldt Bay SLR Adaptation Planning Project: Phase II report	2015
Aldaron Laird Trinity Associates. Prepared for State Coastal Conservancy	Humboldt Bay Shoreline Inventory, Mapping, and SLR Vulnerability Assessment	2013
Geology		
McCrory P. (USGS)	Upper plate contraction north of the migrating Mendocino triple junction, northern CA: Implications of partitioning of strain	2000
Fisch Drilling	Well Completion Report – WCR2008-004344	2018
Pacific Gas & Electric Company	Humboldt Bay ISFSI Safety Analysis Report	2005
Pacific Affiliates Consulting Engineers, Inc.	Environmental Impact Report for Samoa Terminal Reconstruction	1994
USACE	Navigation Channel Feasibility Report	1976
SHN Engineers & Geologists	Geologic Hazard Evaluation and Soils Engineering Report, Samoa Peninsula Wastewater Project	2018
PG & E	Humboldt Bay ISFSI Safety Analysis Report: Seismic Hazard Assessment for Humboldt Bay ISFSI Project	2002

SHN Consulting Engineers and Geologists	Interviews with site geology experts	2020
Environmental		
Merkel & Associates; US EPA; Humboldt Bay Harbor Recreation & Conservation District	Humboldt Bay Eelgrass Comprehensive Management Plan	2017
Humboldt Bay Harbor, Recreation, & Conservation District	Eelgrass Distribution Map	2009; updated 2016
CA Dept of Fish and Game	Dungeness Crab Report	2012
History		
Orville, Sloan, Shimizu	Design and construction of Humboldt Jetties 1880 to 1975	1976
USACE	Design Memorandum No. 1, Navigation Channel Improvements: Humboldt Harbor and Bay, California	1976
Environmental Impact Reports (EIRs)		
AECOM/Humboldt County	Humboldt Wind Energy Project EIR	2018
HB Harbor Recreation and Conservation District	EIR for Samoa Terminal Reconstruction	1994
Humboldt Wind Energy Project	Draft Environmental Impact Report: Humboldt Wind Energy Project	2019
Floating Offshore Wind		
Carbon Trust	Floating Offshore Wind: Market and Technology Review	Jun-15
NREL	Oregon Offshore Wind Site Feasibility and Cost Study	Oct-19
Carbon Trust	Floating Wind Joint Industry Project - summary report phase 1	2019
Carbon Trust	Offshore wind industry review of Gravity Based Structures	2015
Noise		
Humboldt County	Humboldt County General Plan Update - Chapter 13 "Noise"	Adopted Oct 23, 2017
Humboldt County	Humboldt County General Plan Revised Draft EIR Section 3.6 - Noise	
California State University (Tang-Hung Nguyen & I-Hung Khoo)	Noise Mapping of Container Terminals at the Port of Los Angeles METRANS Project 11-26	Apr-13
NoME Ports	Good practice guide on Port Area Noise Mapping and Management	