California North Coast Offshore Wind Studies

Port Infrastructure Assessment Report Appendices

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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Disclaimer

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About the Schatz Energy Research Center

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APPENDICES

The following appendices offer an extensive amount of invaluable technical information that served as the foundation for the development of the Port Infrastructure Assessment Report.

The appendices present the key findings from technical assessments of the main topic areas. These areas include navigation, substructure handling operations, nearby port facilities, metocean conditions, port screening for various activities, O&M requirements, vessel database, and sea-level rise and tsunami vulnerabilities. Most of the appendices are in slide presentation format. Presentations were given by Mott MacDonald periodically to share the results of the assessment work with the project team and ensure the project objectives were being met.

Appendix A Navigation
This appendix is divided into three sections.

- Appendix A-1 Navigation - Entrance Channel presents an assessment of the opportunities and challenges related to the navigation of the Humboldt Bay entrance channel. Identified challenges include limitations with the existing entrance channel geometry, additional dredging, dredging frequency, component delivery, and the tow-in and tow-out of the wind turbine generators during the installation and the operations and maintenance phases.
- Appendix A-2 Navigation - Inner Channel addresses the same opportunities and challenges as the previous section, but for the inner channel.
- Appendix A-3, Navigation – Wet Storage, Staging, and Ballasting provides an assessment of the wet storage, staging area, and ballasting area. The objective, criteria and assumptions, concept depth requirements, site conditions, depth assessments, and outcomes and next steps for this work is presented.

Appendix B Wharf and Yard
Appendix B consists of a capabilities and gap assessment of the assembly facilities, including the berth, wharf, and yard. The necessary renovations for a pilot/small-commercial and large commercial scale project at RMTI and RMTII are explored as well as requirements for the berth, wharf, and yard that would need to be constructed at each site.

Appendix C Substructure Delivery and Float-Off
Appendix C assesses the options for transferring the fabricated substructures to the water for the wind turbine generator assembly. Both the pilot/small-commercial and large commercial scale scenarios were assessed. The assessment specifies the potentially required vessels, barges, and channel depths, for both scenarios which includes importing the fabricated components from elsewhere and fabricating the components in Humboldt.

Appendix D Nearby Port Facilities
Appendix D consists of a memorandum that summarizes conditions for existing ports in Oregon/Northern California, the SF bay, and Southern California and also assesses how these facilities may provide services to the offshore wind industry relative to Humboldt County.

Appendix E Metocean Conditions
Appendix E contains a memorandum that documents an abbreviated assessment of metocean conditions in the vicinity of the Humboldt Offshore Windfarm and associated facilities. The water levels, wind speed and direction, and details on waves and extreme ocean events are included.

Appendix F Port Screening
Appendix F presents the results of a screening assessment of a range of existing marine terminals in Humboldt Bay to determine if they are likely suitable to serve as an assembly, fabrication, and major repair facility, and/or an O&M facility. The screening criteria included yard area, air draft, and navigation impacts.

Appendix G Operations and Maintenance
Appendix G presents the potential O&M requirements for the various build-out scenarios in order to determine the needs of associated port infrastructure. The facility requirements are based on windfarm size, windfarm distance, vessel requirements, and the number and types of vessels to perform the work.

Appendix H Vessel Database
Appendix H evaluates the ranges of dimensions for various categories of vessels that support floating offshore wind based on prototype review and engagement with industry specialists. For each category of vessel, a range of design dimensions (length, beam, and draft) were developed for use in navigation and port infrastructure assessments.

Appendix I Sea-Level Rise, Climate Change, and Tsunami Vulnerability
Appendix I presents a conceptual-level assessment that was conducted to evaluate potential effects 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 build-out of OSW infrastructure and providing a framework for quantitative risk assessments and adaptive planning studies. The best available science was reviewed to document the hazards and climate change parameters the infrastructure may be exposed to. Infrastructure and system vulnerability have been assessed as a combination of exposure to the hazards/processes, sensitivity to the hazard/process, and ability to adapt to the hazard/process.

Note: The following appendices can be read using available reader software such as Adobe Acrobat Reader; however, the content has not been optimized for accessibility and alternative text is not available for the figures and tables presented in this document.

Appendix A-1 Navigation - Entrance Channel

This appendix presents an assessment of the opportunities and challenges related to the navigation of the Humboldt Bay entrance channel. Identified challenges include limitations with the existing entrance channel geometry, additional dredging, dredging frequency, component delivery, and the tow-in and tow-out of the wind turbine generators during the installation and the operations and maintenance phases.

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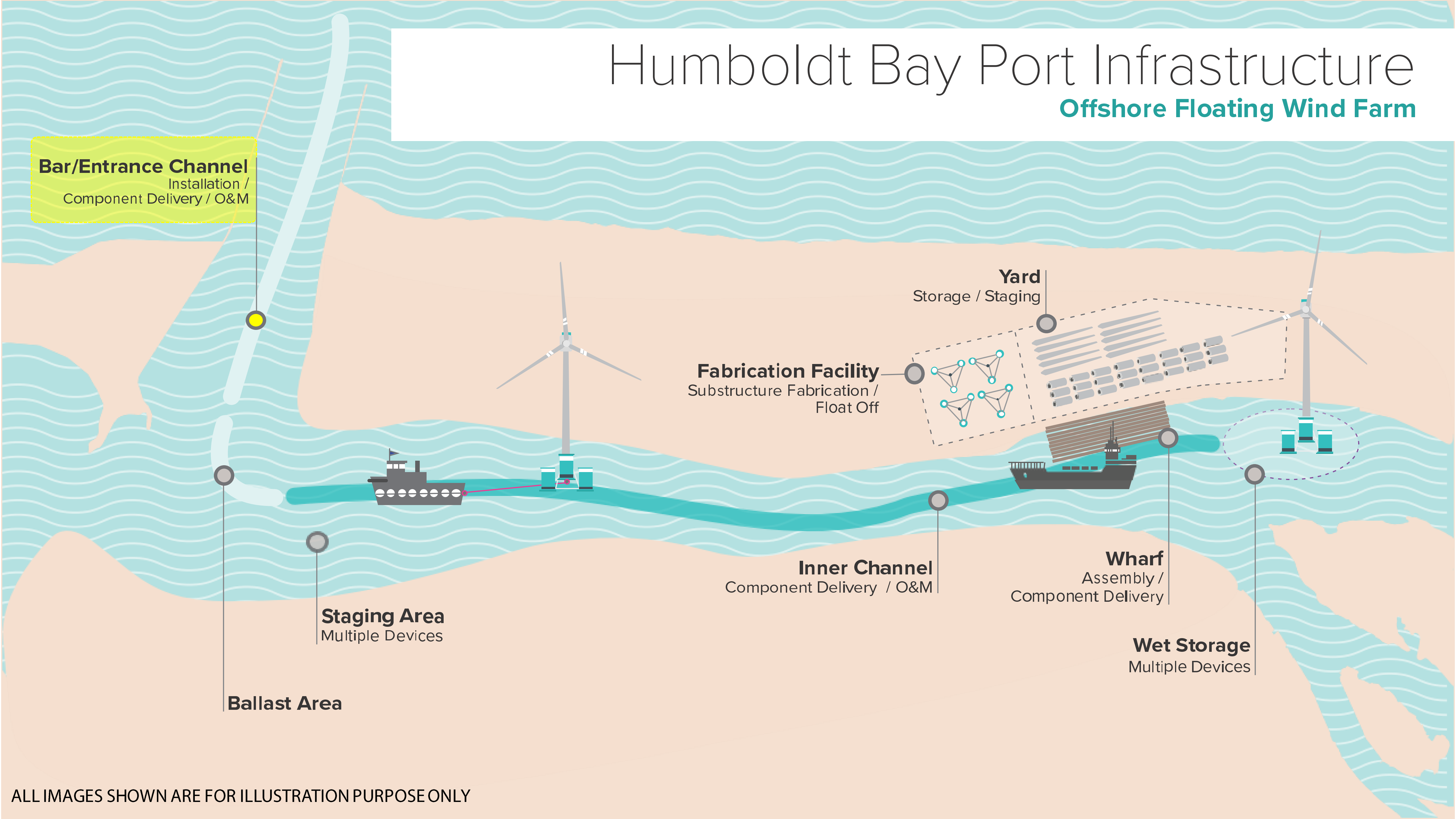
Appendix A-1: Entrance Channel Assessment

Humboldt Offshore Wind Study

Humboldt Bay Port Infrastructure

Offshore Floating Wind Farm



ALL IMAGES SHOWN ARE FOR ILLUSTRATION PURPOSE ONLY

Appendix A-1 Entrance Channel Assessment Outline

- Objective
- Criteria & Assumptions
- Site Conditions
- Downtime Considerations
- Channel Geometry Assessment
- Outcomes & Next Steps

Objective

Identify challenges relative to

- Limitations of existing Entrance Channel geometry,
- The need for potential modifications to channel geometry,
- Additional dredging areas, and
- Increased dredging frequency

to meet needs for following activities :

- Component delivery
- tow-out of wind turbine generators (WTGs) for installation
- Tow-in of WTGs for maintenance

Criteria & Assumptions

Vessel Criteria – Historic & Current Use

Current use

- Navigation channel designed for
  - Vessels for import/export of wood and timber products
  - Fuel barges delivering petroleum

Pax Silvia (Woodchip Carrier)

Source: USACE San Francisco District. 1994. Draft Feasibility Report and Environmental Impact Statement/Report for Navigation Improvements; Humboldt Harbor and Bay (Deepening)

The following presents vessel dimensions by commodity carried, which are comparable to the largest vessels currently using Humboldt Harbor:

Commodity	DWT	Length(ft)	Max. Draft	Beam
Woodchips	46,595	675	37	100
	45,762	639	36	106
Particle Board	45,252	656	38	100
Pulp	45,065	658	38	101
Logs	36,138	622	36	91
	25,357	524	34	83
Petroleum	40,631	658	35	100
	40,631	658	35	102

Vessels for which the existing navigation channel was designed to accommodate.

Navigation Criteria – Historic & Current Use

- USACE 1995 Feasibility Study for Navigation Improvements, Humboldt Harbor and Bay
- Outer Channel:

Squat	2ft
Trim	1ft
Maneuverability	2ft (Safety Clearance)
Wave Conditions	10ft

UKC: 15ft

- At time of channel deepening, Humboldt Bar Pilots restricted navigation through entrance to max. 10ft wave heights (Hs).
- Takeaways:
  - There is a linkage between maximum wave height for navigation & underkeel clearance (UKC) requirements.
  - Channel designed to accommodate winter conditions at all water levels for maximum vessel draft of 38ft.
  - Floating wind substructures response to wave action may be different than vessels -> UKC requirements may differ (higher or lower)

Design Device/Vessel – Future Use (OSW)

- The design vessels considered for potential future use to support the erection and operation & maintenance of an offshore wind farm were determined in the vessel prototype analysis (see Appendix H).
- The controlling vessel/device activity for determining navigation requirements for the Entrance Channel are:
- Tow-in and tow-out of the assembled device, and
- Component/substructure delivery via heavy lift vessel.

Device or Vessel	Dimension
	Beam
Device A	300ft.
Device B	200ft.
Heavy Lift Vessel	140-170ft
	Draft
Device A: Substructure Only Loaded w/ WTG	 28 ft. 36 ft.
Device B: Substructure Only Loaded w/ WTG	 20 ft. 25 ft.
Component Delivery/ Heavy Lift Vessel	28-35 ft.


Tug boats towing out assembled WTG Device


Bokalift 1 specialty heavy lift vessel transporting fixed WTG foundations


Device A (Loaded w/ WTG) Representative of larger substructure geometry


Device B (Loaded w/ WTG) Representative of smaller substructure geometry

Navigation Assessment Criteria

- Various methods (PIANC, USACE) were reviewed to develop criteria for channel dimension requirements at a pre-feasibility level to accommodate the design vessel/device.
- Criteria for navigational requirements were established with consideration for:

- PIANC 2014 *Harbour Approach Channels Design Guidelines* (Report nº 121 – 2014)
- USACE Engineering Manual 1110-2-1613 - *Navigation Channel Design*
- Correspondence with the Humboldt Bay Bar Pilots
- Feasibility Report and Environmental Impact Statement for Navigation Improvements (Humboldt Bay Harbor Recreation & Conservation District and USACE, 1994-1995)
- Humboldt Harbor Safety Committee Guidelines
- Prototype projects assessing the navigability of specialty, deep-draft devices

Navigation Assessment Criteria

Key Considerations

- Key considerations in determining the required channel dimensions for the design vessel include:

- Vessel dimensions & maneuverability
- Motion due to waves, currents, and winds
- Trim, ballasting (tow out COG & blades)
- Channel bottom type & topography
- Downtime restrictions
  - Environmental conditions, entrance channel sedimentation, etc.

REQUIRED WIDTH

Source: PIANC (2014)

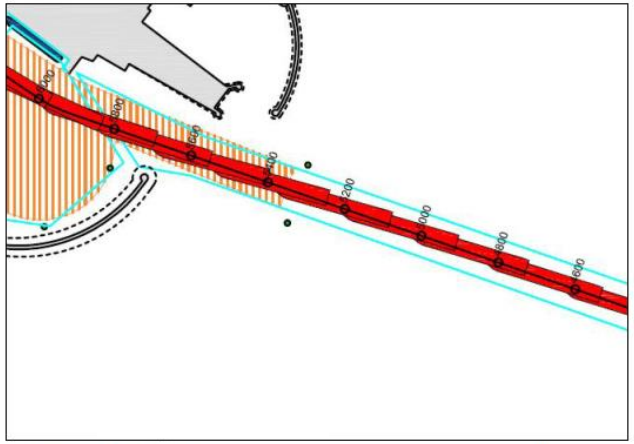


Figure 3.5: Ship course under strong wind conditions

Source: PIANC (2014)

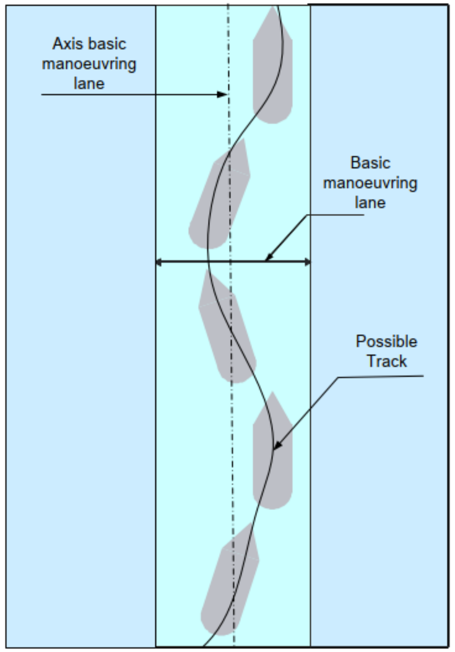
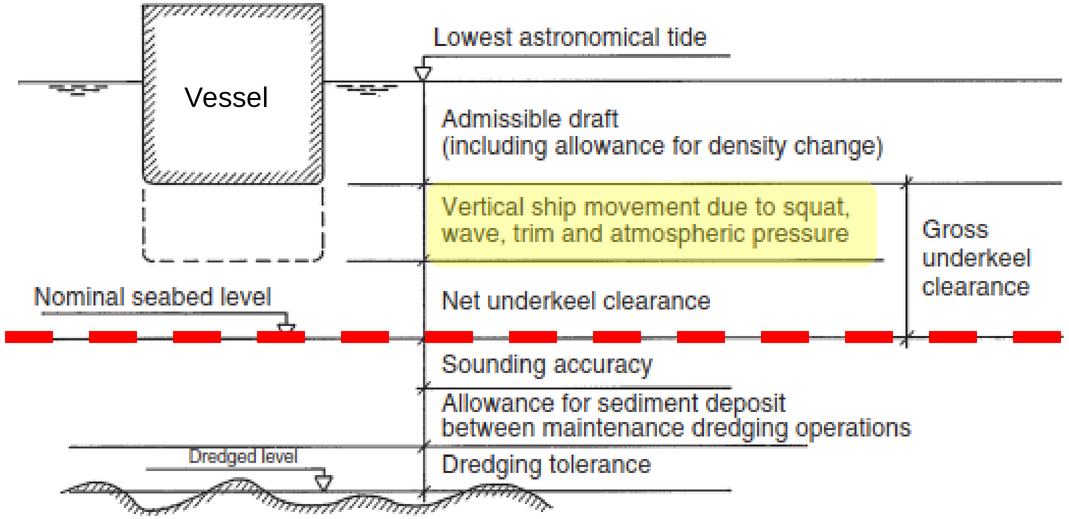


Figure 3.4: Basic manoeuvring lane

REQUIRED DEPTH



Navigation Assessment Criteria

Maneuverability & Device Motion – WTG devices

- The maneuverability of WTG Devices is different than that for vessels and typical tug-barge combinations that operate under their own power.
- WTG Devices are unique in their response to towing and tidal currents, wind, and waves at various locations along the Entrance Channel.
- Additional contingency or a safety factor should be provided for tow operation for a unique device, versus a vessel under its own power due to the unpredictability of the system.
- Navigation operations will need to be assessed using finalized device geometry and operational limits.

Navigation Assessment Criteria

Assumptions

Very high level concept assessment criteria developed for this study. Actual channel depth and width requirements need to be considered on a case-by-case basis for each WTG device.

Channel Depth

- UKC for single or small number of events is different than commercial navigation channel requirements.
- UKC requirements for WTG devices may be different than for vessels of same draft due to unique geometry.
- Lower end → favorable/ideal environmental conditions, stable device
- Higher end → less favorable environmental conditions or less stable device

Channel Width:

- 2.5-3.5X the width of the device/vessel assessed to be potential range of channel width required.
- Lower end → favorable/ideal environmental conditions, good maneuverability
- Higher end → less favorable environmental conditions, poor maneuverability

*Required UKC will be greater for tow-out in heavy (>2m) wave climate or for specific devices.

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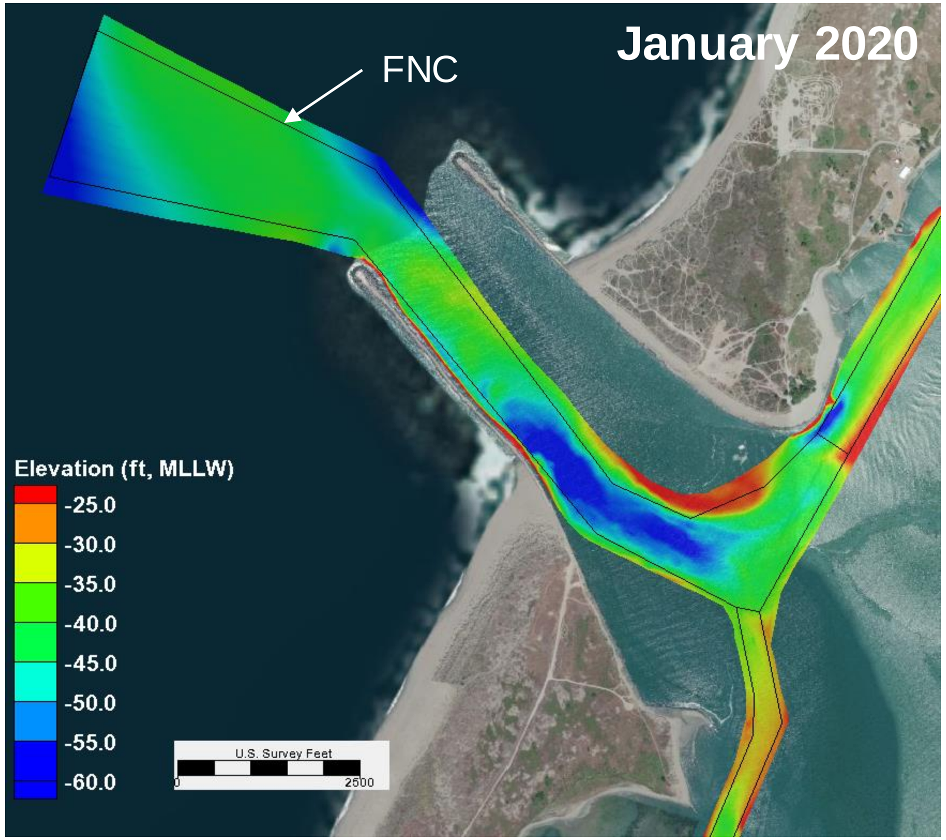
Site Conditions

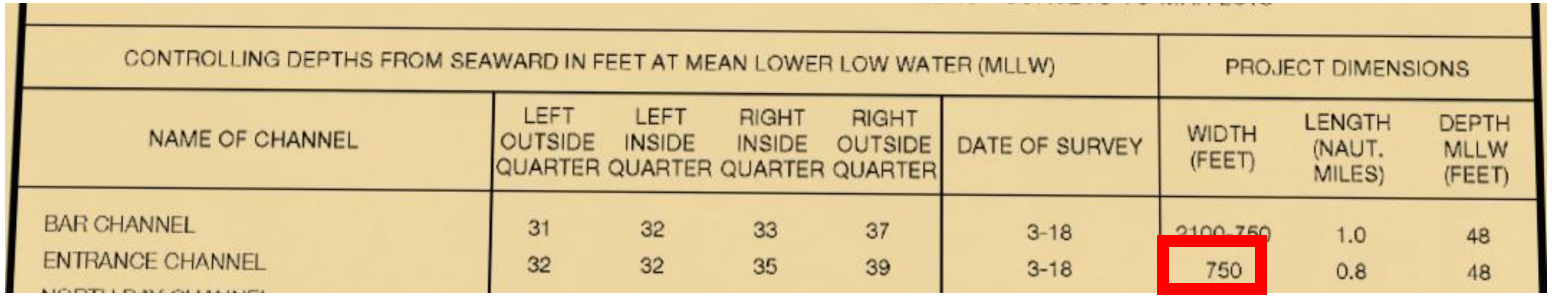
Entrance Channel Geometry & Elevation Data

- Entrance Channel & Bar are Federal Navigation Channels (FNCs)
- Authorized Depth: 48ft MLLW
- Authorized Width: assumed 600ft (see next slide)
- Existing Elevation Data
- Various USACE Bar & Entrance Channel Condition Surveys from 2012-2020 were used to assess typical bed elevations for the Entrance Channel and Bar.
  - Source: https://www.spn.usace.army.mil/Missions/Surveys-Studies-Strategy/Hydro-Survey/Humboldt-Bay-Channel/

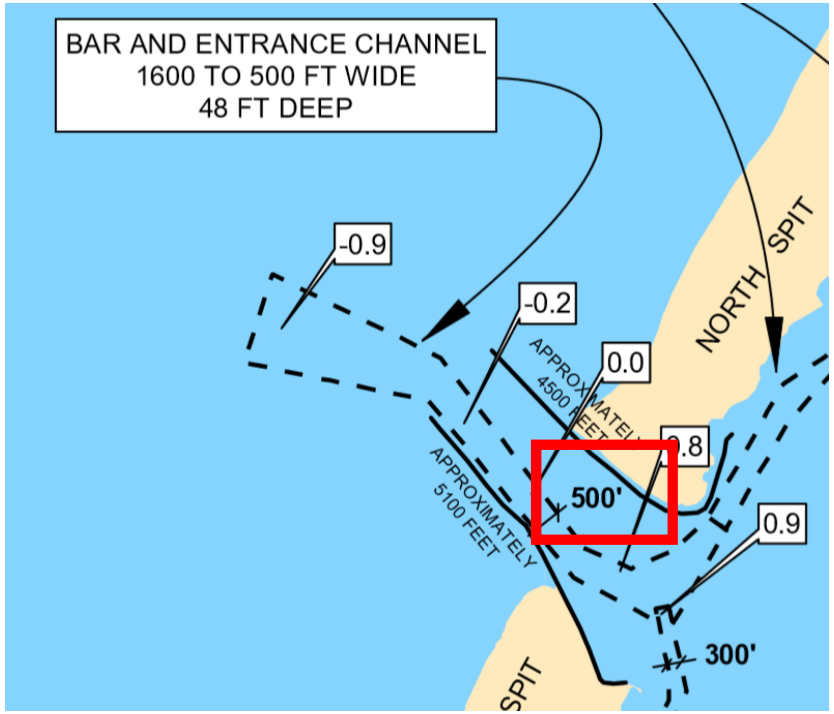


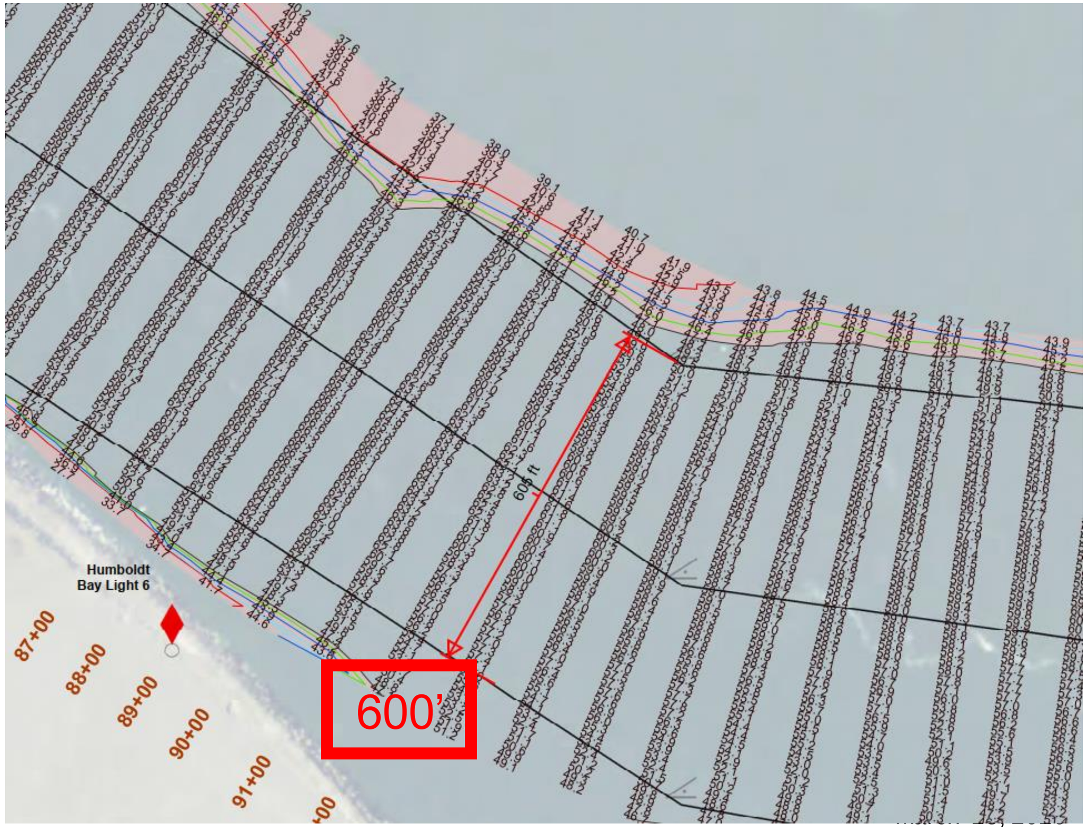
Entrance Channel Limiting Width - Literature Varies

Some variation. 600ft minimum used for this assessment Based on USACE survey figures (right)



CONTROLLING DEPTHS FROM SEAWARD IN FEET AT MEAN LOWER LOW WATER (MLLW)						PROJECT DIMENSIONS		
NAME OF CHANNEL	LEFT OUTSIDE QUARTER	LEFT INSIDE QUARTER	RIGHT INSIDE QUARTER	RIGHT OUTSIDE QUARTER	DATE OF SURVEY	WIDTH (FEET)	LENGTH (NAUT. MILES)	DEPTH MLLW (FEET)
BAR CHANNEL	31	32	33	37	3-18	2100-750	1.0	48
ENTRANCE CHANNEL	32	32	35	39	3-18	750	0.8	48





Entrance Channel Conditions & Current Guidelines

- Harbor Safety Committee Guidelines
- Environmental conditions (large swell, strong winds, fog, haze) often adversely affect transit in the entrance channel.
- Significant shoaling can occur quickly, making navigation difficult. Shoaling is more likely in the winter.
- Deep-draft vessels are usually taken in and out through Entrance Channel at high tide.
- No designated anchorage areas exist in Humboldt Bay.

- Humboldt Bar Pilots
- The bar pilots impose navigation restrictions when oceanic swell exceeds a certain height.
- Currently, navigation is suspended through the Entrance Channel for Hs ≥13ft.

Water Levels

- The tidal character in Humboldt Bay is mixed semi-diurnal (two high tides each day of varying magnitudes) with a marked spring-neap variation.

Source: NOAA Station 9418767, North Spit CA

Datum	Value	Description
MHHW	6.85ft	Mean Higher High Water
MHW	6.14ft	Mean High Water
MSL	3.70ft	Mean Sea Level
MLLW	0.00ft	Mean Lower Low Water
LAT	-2.39ft	Lowest Astronomical Tide

Downtime Considerations

Wind & Wave Condition Considerations

- Winds, wave heights are larger during the fall/winter/spring season than during the summer
- Elevated risk of downtime* outside summer conditions for:
- Crossing the bar in Entrance Channel**
- Open ocean towing
- Installation of device
- Towing through the entrance channel may not occur, or downtime will likely be increased, for fall/winter/spring relative to summer conditions

*see Appendix E MetOcean Conditions

	Downtime Risk Assessment	
Activity	**Summer (May-Sept)**	**Winter (Oct-April)**
Install of Tower and Nacelle		
Install of Blades		
Outer Channel Towing		
Open Ocean Transit Towing		
Installation of Device		
Dynamic Cable Install		

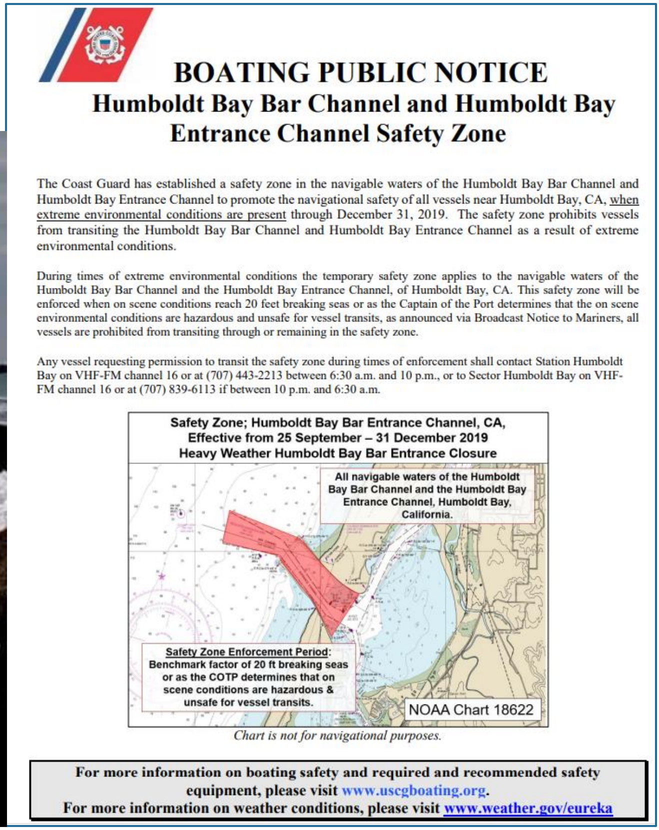
Few Operational Restrictions	*Some Operational Restrictions*
Operational Restrictions Common	*Operational Restrictions May Require Additional Planning*

**Offshore buoy indicate 2m or greater significant wave height have ~35% occurrence in summer. Nearshore modeling needed to transform waves to entrance channel

Wave Conditions - Entrance Channel Closures

- The Coast Guard establishes Safety Zones in the Humboldt Bar and Entrance Channel during winter months to restrict navigation during periods of high swell.
- Entrance Channel closures were enforced multiple times between 2018-present during stormy winter conditions.

Entrance to Humboldt Bay Closed – Feb 2019
Source: US Coast Guard



BOATING PUBLIC NOTICE

Humboldt Bay Bar Channel and Humboldt Bay Entrance Channel Safety Zone

The Coast Guard has established a safety zone in the navigable waters of the Humboldt Bay Bar Channel and Humboldt Bay Entrance Channel to promote the navigational safety of all vessels near Humboldt Bay, CA, when extreme environmental conditions are present through December 31, 2019. The safety zone prohibits vessels from transiting the Humboldt Bay Bar Channel and Humboldt Bay Entrance Channel as a result of extreme environmental conditions.

During times of extreme environmental conditions the temporary safety zone applies to the navigable waters of the Humboldt Bay Bar Channel and the Humboldt Bay Entrance Channel, of Humboldt Bay, CA. This safety zone will be enforced when on scene conditions reach 20 feet breaking seas or as the Captain of the Port determines that the on scene environmental conditions are hazardous and unsafe for vessel transits, as announced via Broadcast Notice to Mariners, all vessels are prohibited from transiting through or remaining in the safety zone.

Any vessel requesting permission to transit the safety zone during times of enforcement shall contact Station Humboldt Bay on VHF-FM channel 16 or at (707) 443-2213 between 6:30 a.m. and 10 p.m., or to Sector Humboldt Bay on VHF-FM channel 16 or at (707) 839-6113 if between 10 p.m. and 6:30 a.m.

Safety Zone; Humboldt Bay Bar Entrance Channel, CA, Effective from 25 September – 31 December 2019 Heavy Weather Humboldt Bay Bar Entrance Closure

All navigable waters of the Humboldt Bay Bar Channel and the Humboldt Bay Entrance Channel, Humboldt Bay, California.

Safety Zone Enforcement Period: Benchmark factor of 20 ft breaking seas or as the COTP determines that on scene conditions are hazardous & unsafe for vessel transits.

NOAA Chart 18622

Chart is not for navigational purposes.

For more information on boating safety and required and recommended safety equipment, please visit www.uscgboating.org.
For more information on weather conditions, please visit www.weather.gov/eureka

Entrance Channel Safety Zone Notice
Source: Humboldt Harbor Safety Committee

Entrance Channel Draft Restrictions

Recent Draft Restrictions due to Entrance Channel Shoaling (non-comprehensive list):

- Winter 2016-2017
  - Draft Restriction >28.5ft
- Winter 2017-2018
  - Draft Restriction >28ft
- Winter 2018-2019
  - Draft Restriction >21ft
- Winter 2019-2020
  - Draft Restriction >34ft

HANK SIMS / THURSDAY, FEB. 21, 2019 @ 3:17 P.M. / EMERGENCIES

'Life-Threatening' Emergency on Humboldt Bay as Harbor Entrance Silts Up; Commercial Shipping Closed Down; Local Agencies Petitioning Feds for Early Dredging

Source: Local Coast Outpost

Dredging urgently needed - but Harbor District lacks authority to declare emergency; fuel shipments not affected

Dan Squier, Eureka Times-Standard In The News Last Updated: 10 June 2019

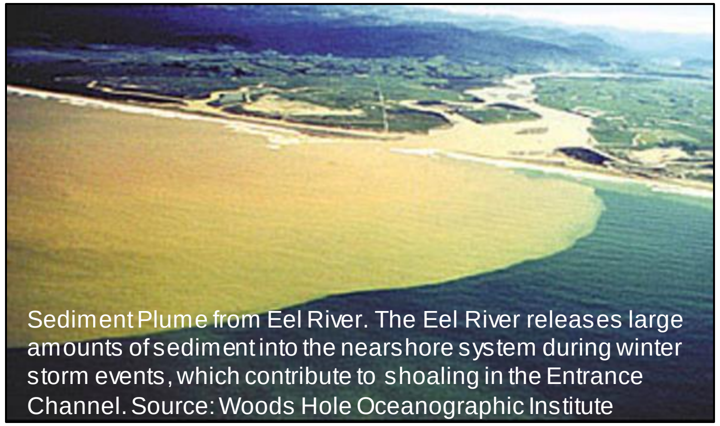
Source: Humboldt Baykeeper

the group, contracted by the Army Corps of Engineers. He said there was a restriction saying service vessels coming into the bay could not exceed a maximum draft of 28 feet. Since the recent dredging, those restrictions have been lifted and a full vessel, with maximum 38 feet draft, can now cruise into the bay.

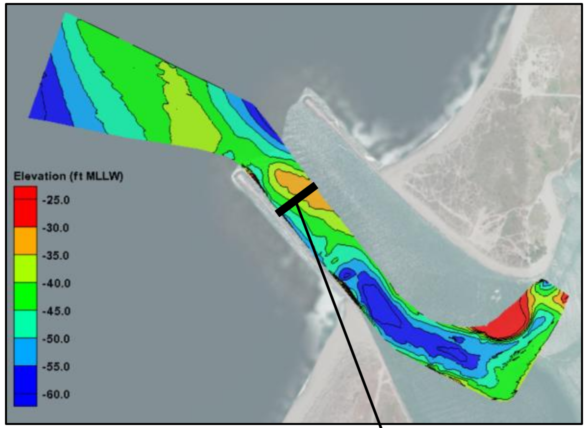
Source: KRCR News July, 2018

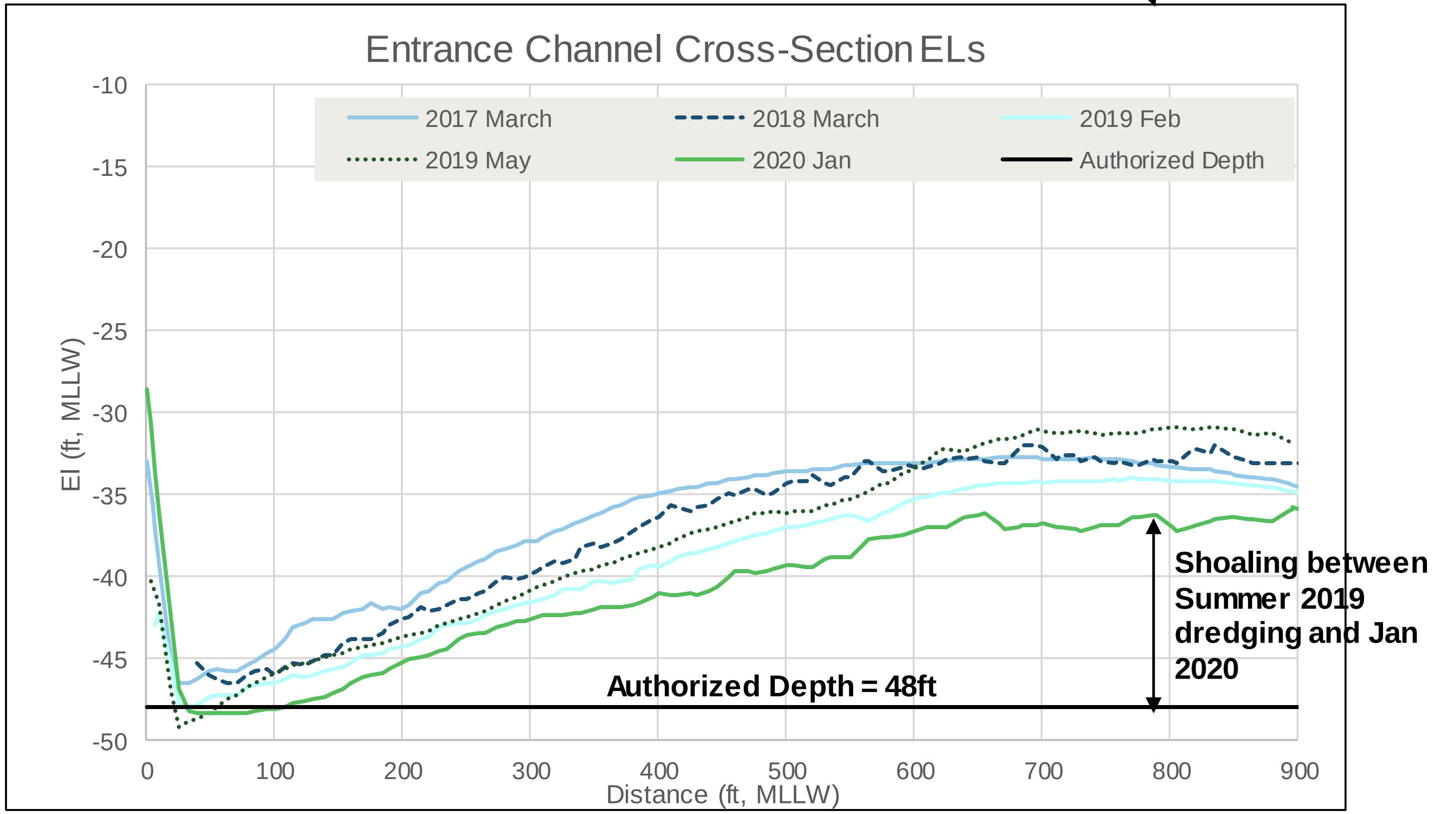
Entrance Channel Shoaling

- Winter storm washout from Eel River can result in significant shoaling (up to 14 ft in one storm event) in the Entrance Channel, making it un-safe for deeper draft vessels.
- Data from recent years shows depths in Entrance Channel can be reduced to -31 to -36ft MLLW.



Sediment Plume from Eel River. The Eel River releases large amounts of sediment into the nearshore system during winter storm events, which contribute to shoaling in the Entrance Channel. Source: Woods Hole Oceanographic Institute





Data from USACE hydrographic condition surveys.

Maintenance Dredging

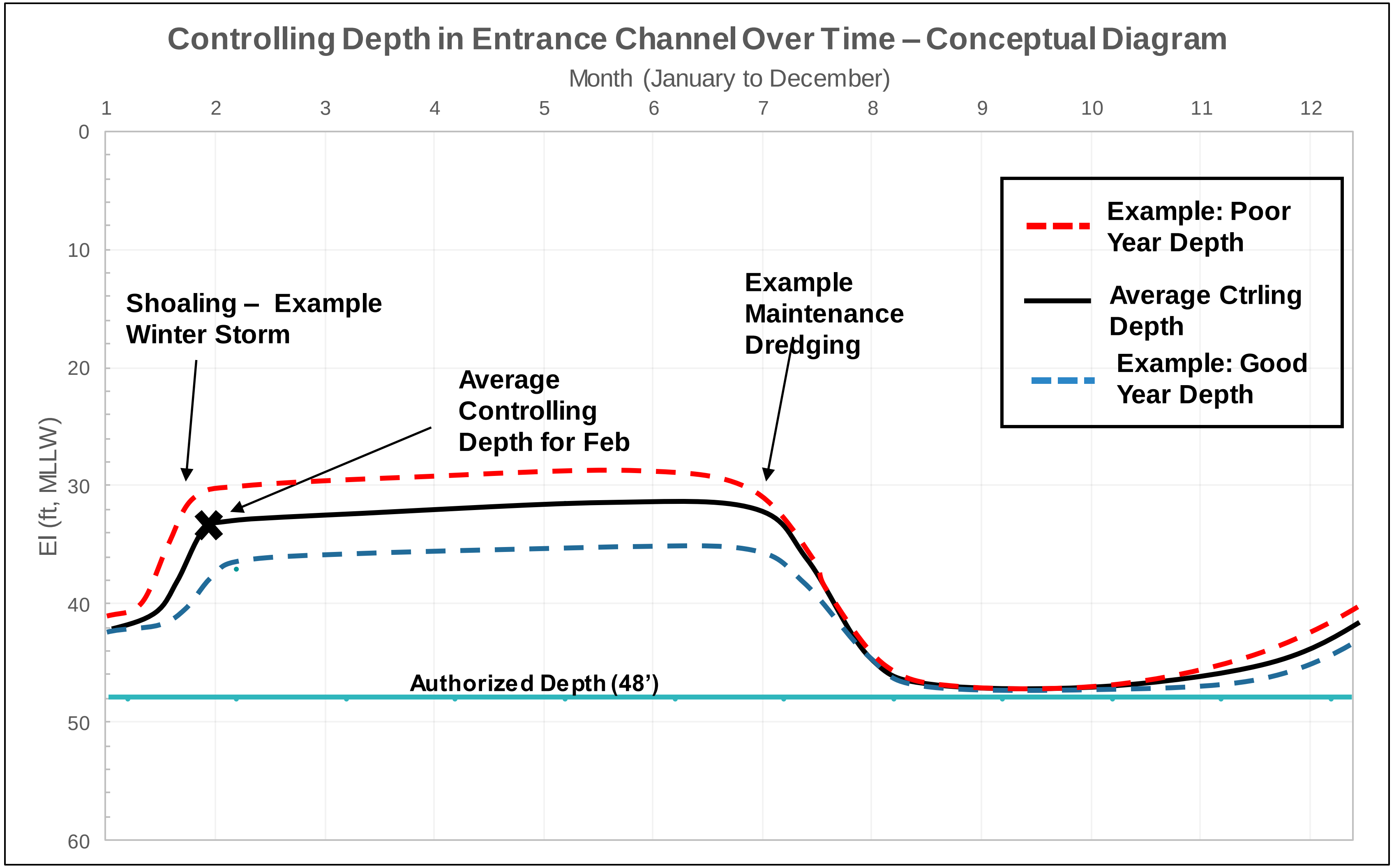
- USACE maintains the Entrance Channel annually to provide safe passage for vessels.
- Annually, approximately 1 million cubic yards of sediment is removed from the Entrance Channel during summer months.
- Temporary draft restrictions have been implemented during the winter in recent years on vessels seeking passage through the Entrance Channel until maintenance dredging can be conducted once the dredging window opens in the summer.

Hopper dredge removing sediment from Humboldt Entrance Channel. Source: *Dredging Today*

Entrance Channel Controlling Depth

Historical Entrance Channel elevations from 2012-present were assessed to characterize depths.

The controlling depth is about 10-20ft shallower than the authorized depth for approx. half of the year.



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Entrance Channel Assessment

Parametric Geometric Assessment

For the design vessel and device geometries, potential concept channel dimensions (width and depth) for safe navigation were estimated.

Legend:	Estimated Need Exceeds FNC Dimension	Estimated Need May Exceed FNC Dimension	Estimated Need Likely Within FNC Dimension

Device or Vessel	Dimension	Limiting FNC Dimension	Concept Channel Geometry Requirements – Assessed at MLLW	Concept Channel Geometry Requirements – Assessed at MHW
	Beam	Width	Concept Channel Width Req.	Concept Channel Width Req.
Device A (Large)	300ft.	600 ft.		
Device B (Small)	200ft.	600 ft.		
Heavy-Lift Vessel	140-170ft	600ft.		
	Draft	Depth	Concept Channel Depth Req.	Concept Channel Depth Req.
Device A (Large) Loaded w/ WTG	36 ft.	48 ft. MLLW		
Device B (Small) Loaded w/ WTG	25 ft.	48 ft. MLLW		
Heavy-Lift Vessel	28-35 ft.	48 ft. MLLW		

Notes:

- ***Does not consider sedimentation.***
- ***Concept analysis only based on desktop level guidance - Assumes wave heights at entrance less than 6 feet.***

Concept Channel Geometry Limitations

Concept limits of maximum device/vessel dimensions that can safely navigate were estimated.

Channel Dimension	Concept Device Geometry Limitations - MLLW	Concept Device Geometry Limitations - MHW
Exist. Width	Beam	Beam
600 ft.	~200-250 ft.	-
Exist. Authorized Depth	Draft	Draft
48 ft. MLLW	36-40 ft.	42-46 ft.
Example Shoaled Depths	Draft	Draft
38 ft. MLLW (10 feet of shoaling)	~26-30 ft.	~32-36 ft.
28 ft. MLLW (20 feet of shoaling)	~16-20 ft.	~22-26 ft.

Notes:

- ***Assumes 1-way traffic***
- ***Adverse conditions or differences in geometry drastically affect assessment.***
- ***Concept analysis only based on desktop level guidance***

Width

The maximum vessel/device beam that can safely navigate through the constriction in Entrance Channel is likely around 200-250ft.

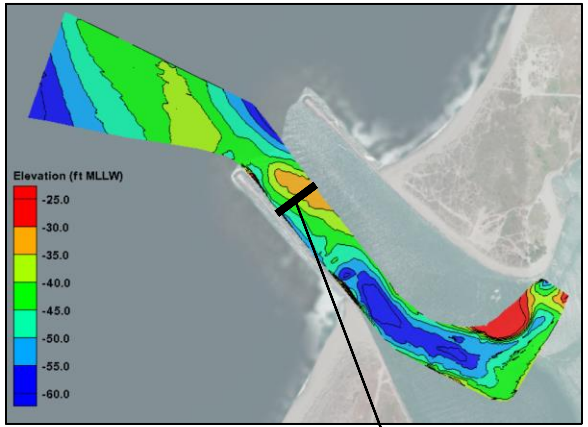
Draft

- *At the Authorized Depth of 48ft.*
  - The maximum device draft is estimated to be ~ 42-46ft. (towed at MHW).

With Winter shoaling - variable depth ~28-38ft.

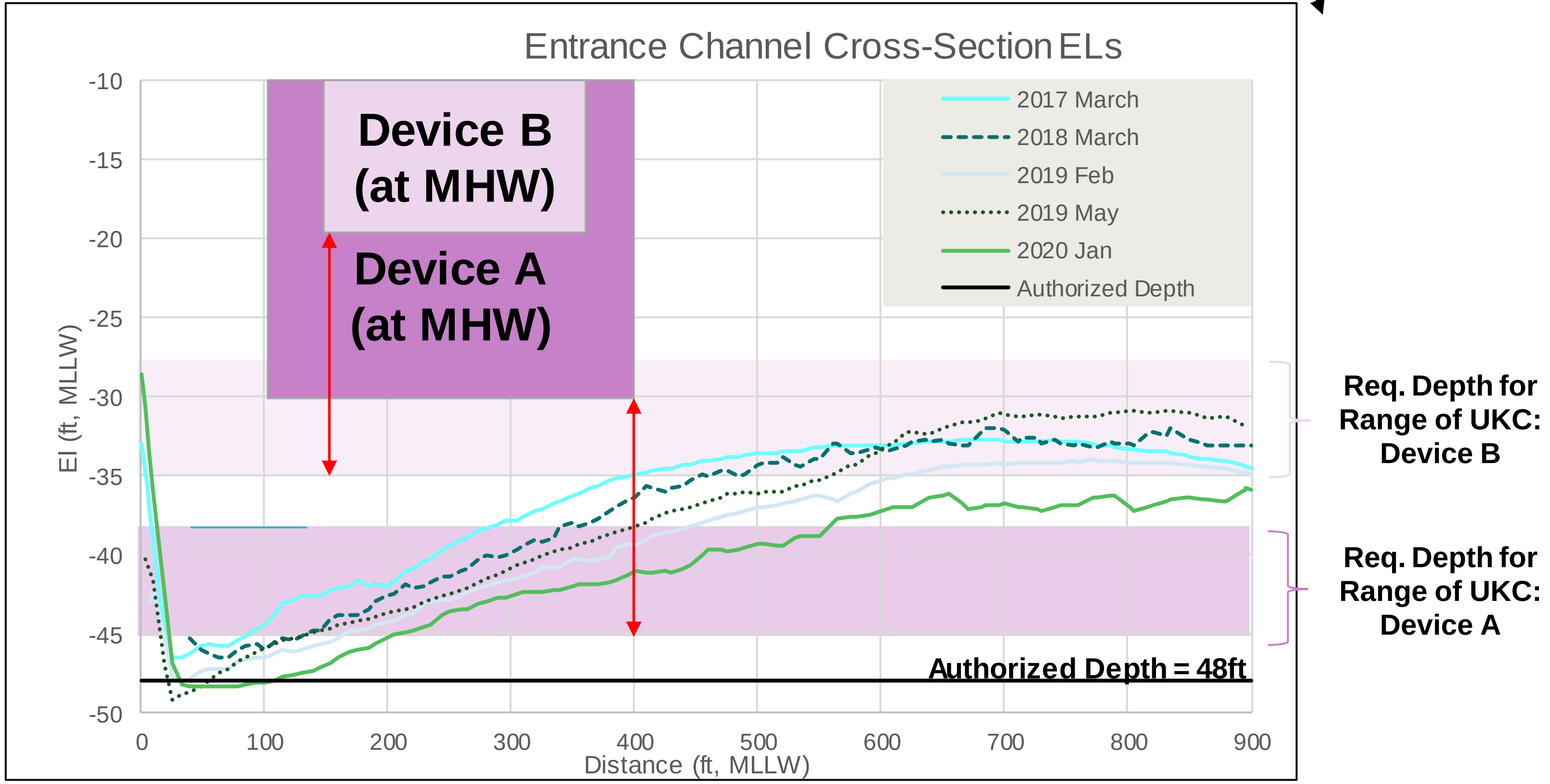
  - The maximum device draft is estimated to be ~ 22ft. for high shoaling years, and ~ 36ft. for mild shoaling years (towed at MHW), depending on level of shoaling

Entrance Channel Shoaling



Depth are shallower than the required depths to provide sufficient UKC for devices across the width of the Entrance Channel

Shoaling tends to impact the north side of the channel more severely than the south side.

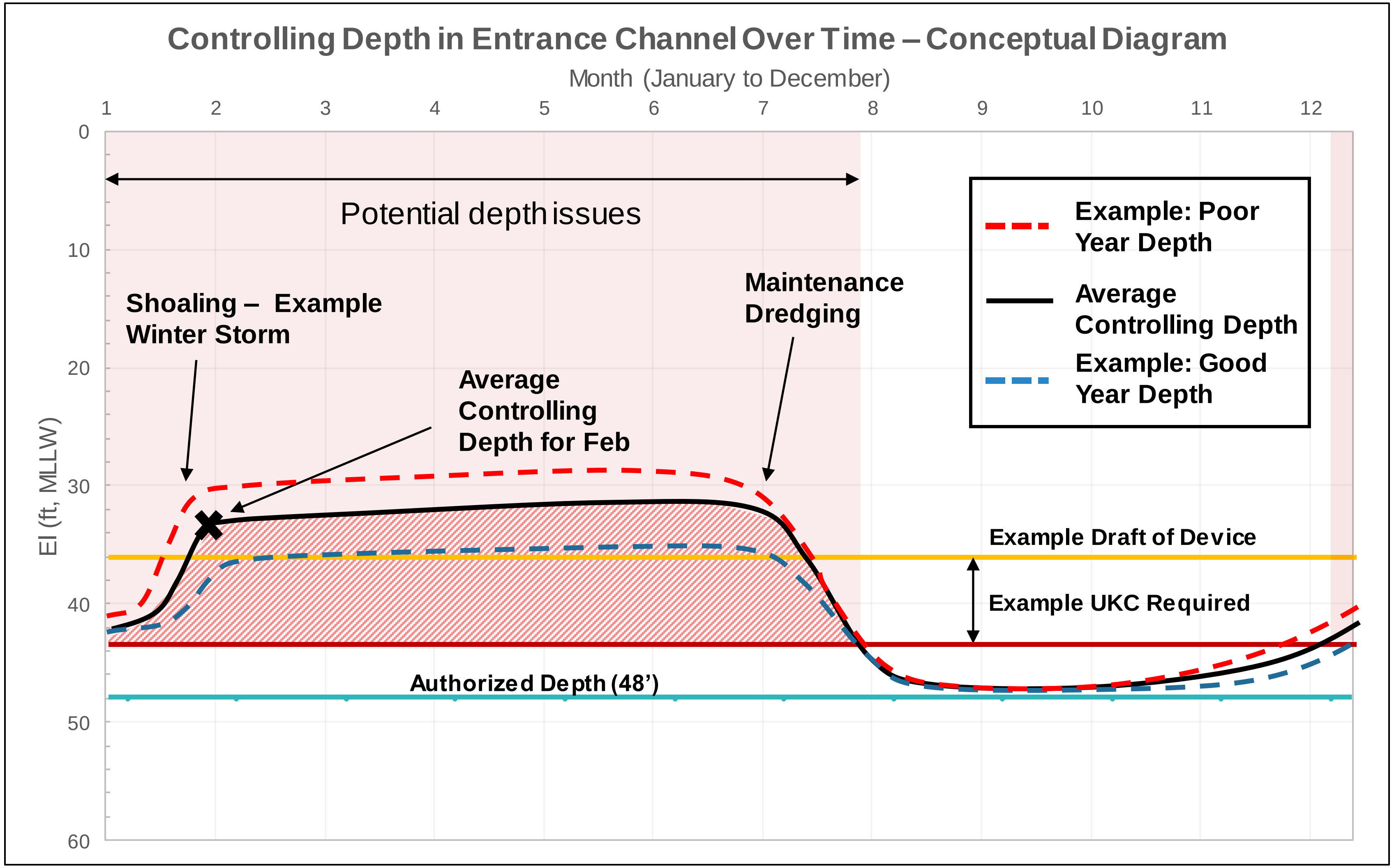


Data from USACE hydrographic condition surveys.

Entrance Channel Controlling Depth – Downtime Implications

Applying the recent dredging schedule, WTG tow-out may be restricted for more than half the year

Component delivery vessels may be limited to certain times of year based on draft restrictions in recent years (2016-2020)



Outcomes

Outcomes

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 device may be limited to less than 300 feet beam.
- The authorized FNC depth is sufficient to conduct some level of ballasting, depending on device. Ballasted draft may be limited to around 45-50 ft. for tow-out in good conditions.
- The larger the device the more ideal the conditions will need to be to cross the bar (tides, waves, winds, currents, shoals), and towing may be limited to certain tidal water levels and wave conditions.
- Ability to tow-out while ballasted could be affected by channel shoaling events, depending on season.
- Wave conditions on the US Pacific West Coast may result in limits on months that installation or major repairs can be conducted.

Outcomes

Large Commercial Scale

- FNC deepening is unlikely to be required, but towing likely to 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. This would require coordinating long-term planning with the USACE and other stakeholders. If not conducted, more wet-storage and vessel support, or upland storage area may be required to maintain throughput.
- A change in FNC maintenance dredging schedule/frequency may be required to support component delivery vessels, otherwise increased upland infrastructure investments likely required (additional wharf, etc.).
- If existing FNC geometry is not modified, WTG device geometry may need to be reduced relative Pilot/Small-Commercial scale, to meet the higher yearly throughput requirements.

Appendix A-2 Navigation - Inner Channel

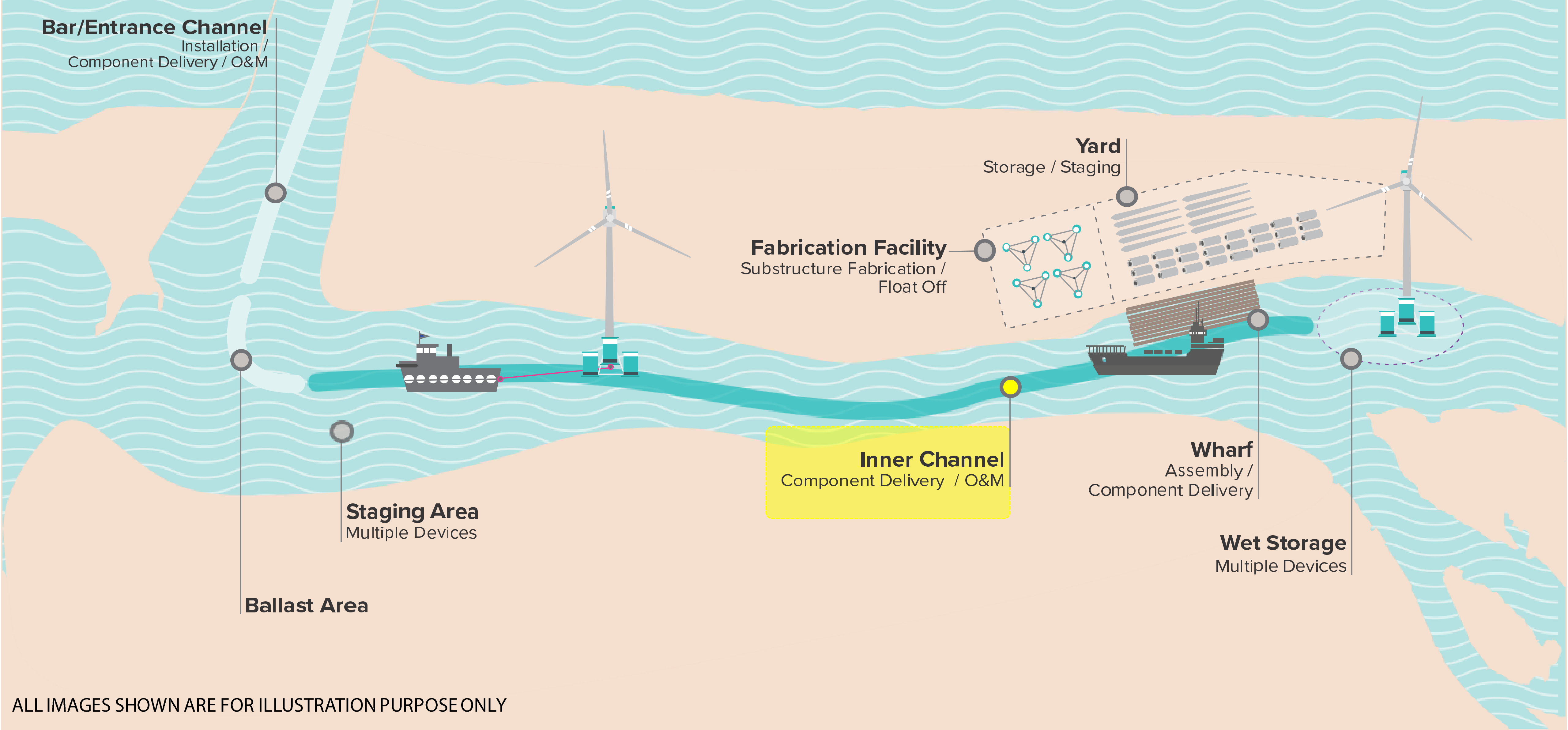
This appendix presents an assessment of the opportunities and challenges related to the navigation of the Humboldt Bay inner channel. Identified challenges include limitations with the existing entrance channel geometry, additional dredging, dredging frequency, component delivery, and the tow-in and tow-out of the wind turbine generators during the installation and the operations and maintenance phases.

Appendix A-2: Inner Channel Assessment

Humboldt Offshore Wind Study

Humboldt Bay Port Infrastructure

Offshore Floating Wind Farm



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Appendix A-2 Inner Channel Assessment Outline

- Objective
- Criteria & Assumptions
- Site Conditions
- Channel Geometry Assessment
- Outcomes & Next Steps

Objective

Identify challenges relative to

- Limitations of existing Inner Channel geometry,
- The need for potential modifications to channel geometry,
- Additional dredging areas, and
- Increased dredging frequency

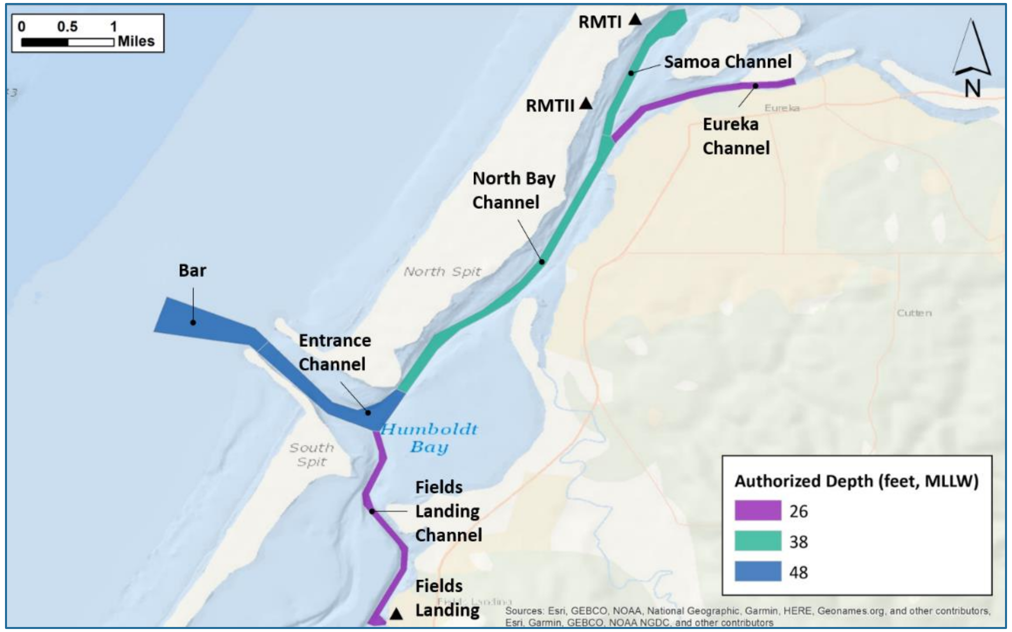
to meet needs for following activities :

- Component delivery
- Tow-out of wind turbine generators (WTGs) for installation
- Tow-in of WTGs for maintenance

Criteria & Assumptions

Inner Channel Screening

- Inner Channel
- The Inner Channel provides passage between the Entrance Channel and the Offshore Wind (OSW) Port Facility.
- In the Screening Assessment (see Appendix F), port facilities along the Eureka and Fields Landing channels were ruled out due to upland land availability and land use concerns. RMTI and RMTII were identified as preferred potential port facilities.
- The Inner Channel considered in this assessment therefore consists of the North Bay and Samoa Federal Navigation Channels (FNCs)



Design Vessels – Historic & Current Use

- Current use
- Navigation channel used for import of petroleum delivered to Chevron fuel dock, and export of wood/timber products.

Pax Silvia (Woodchip Carrier)

Source: USACE San Francisco District. 1994. Draft Feasibility Report and Environmental Impact Statement/Report for Navigation Improvements; Humboldt Harbor and Bay (Deepening)

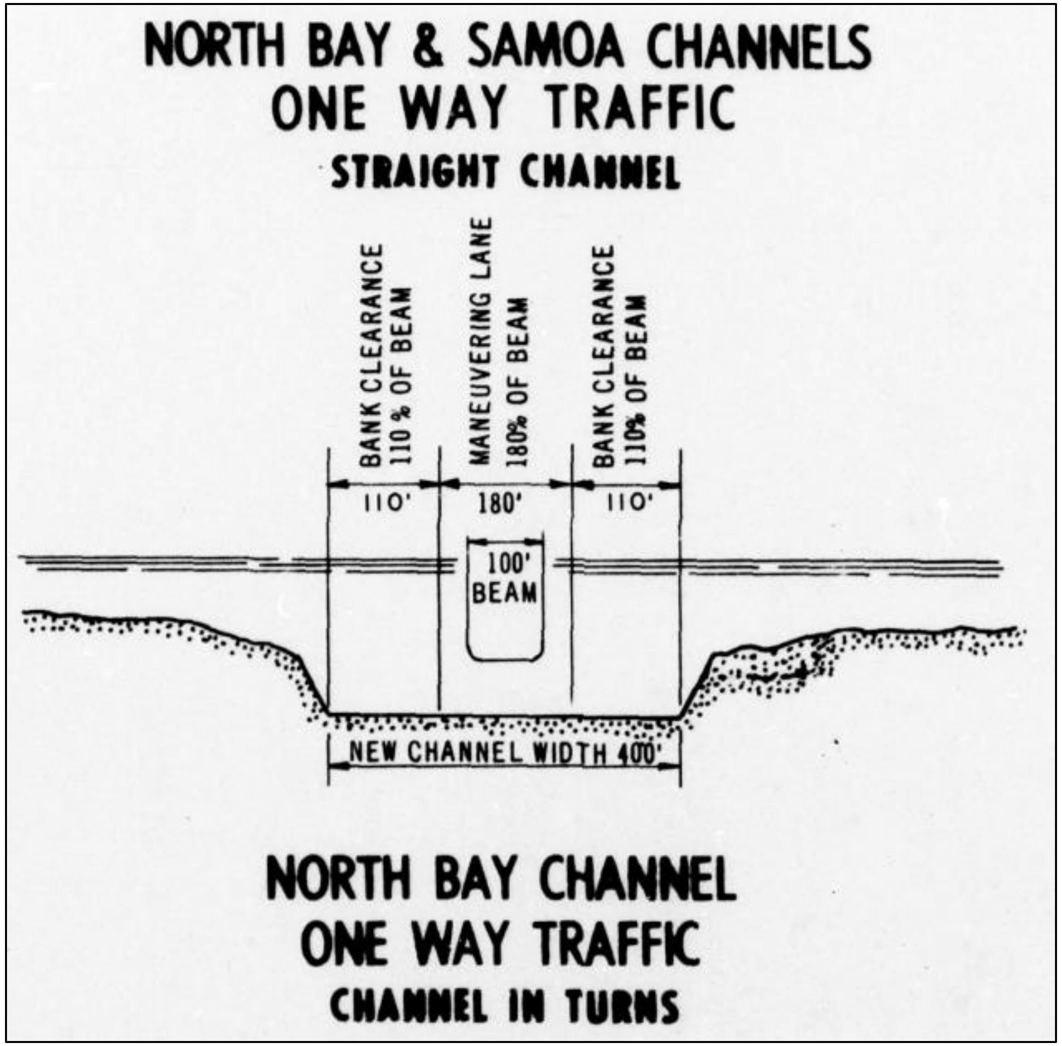
The following presents vessel dimensions by commodity carried, which are comparable to the largest vessels currently using Humboldt Harbor:

Commodity	DWT	Length(ft)	Max. Draft	Beam
Woodchips	46,595	675	37	100
	45,762	639	36	106
Particle Board	45,252	656	38	100
Pulp	45,065	658	38	101
Logs	36,138	622	36	91
	25,357	524	34	83
Petroleum	40,631	658	35	100
	40,631	658	35	102

Panamax class size vessels for which the existing navigation channel was designed to accommodate.

Navigation Width Criteria – Historic & Current Use

- The authorized width of the existing Inner Channel is based on USACE criteria of 4X the vessel beam, for a design beam of 100ft.
- This criteria is dependent on bottom and bank clearances, traffic frequency, and wave/wind/current conditions.
- The maneuvering lane criteria was 1.8X the design vessel beam.



USACE Navigation Channel Feasibility Report (1976)

Navigation Depth Criteria – Historic & Current Use

- USACE 1995 Feasibility Study for Navigation Improvements, Humboldt Harbor and Bay
- Inner Channel:

Squat	2ft
Trim	1ft
Maneuverability	2ft (Safety Clearance)

Recommended UKC: 5ft

- Humboldt Harbor Safety Committee
- The 2-ft UKC required by the Safety Committee for vessels may be consistent with the safety clearance utilized by USACE for design of the channel.

- Existing guidance was developed for vessels, not specialty WTG devices.
- WTG devices are unique in their response to towing and currents, wind, and waves, and the maneuverability of WTG devices is different than that for typical vessels.
- As such, additional contingency for a safety factor should be provided for tow operation for a unique device, versus a vessel under its own power.

Design Device/Vessel – Future Use (OSW)

- The design vessels considered for potential future use to support the assembly and operation & maintenance of an offshore wind farm were outlined in the Vessel database (see Appendix H).
- The controlling vessel/device activity for determining navigation requirements for the Inner Channel are:
- Tow-in and tow-out of the assembled device, and
- Component/substructure delivery via heavy lift vessel.

Device or Vessel	Dimension
	Beam
Device A	300ft.
Device B	200ft.
Heavy Lift Vessel	140-170ft
	Draft
Device A:	
Substructure Only	28 ft.
Loaded w/ WTG	36 ft.
Device B:	
Substructure Only	20 ft.
Loaded w/ WTG	25 ft.
Heavy Lift Vessel	28-35 ft.


Tug boats towing out assembled WTG Device


Bokalift 1 specialty heavy lift vessel transporting fixed WTG foundations


Device A (Loaded w/ WTG) Representative of larger substructure geometry


Device B (Loaded w/ WTG) Representative of smaller substructure geometry

Navigation Assessment Criteria

- Various methods (PIANC, USACE) were reviewed to develop criteria for channel dimension requirements at a pre-feasibility level to accommodate the design device/vessel.

- Criteria for navigational requirements were established with consideration for:

- PIANC 2014 *Harbour Approach Channels Design Guidelines* (Report nº 121 – 2014)
- USACE Engineering Manual 1110-2-1613 - *Navigation Channel Design*
- Correspondence with the Humboldt Bay Bar Pilots
- Feasibility Report and Environmental Impact Statement for Navigation Improvements (Humboldt Bay Harbor Recreation & Conservation District and USACE, (1994-1995)
- Humboldt Harbor Safety Committee Guidelines
- Prototype projects assessing the navigability of specialty, deep-draft devices
- Engagement with Marine Transport Specialists

Navigation Assessment Criteria

Key Considerations

Key considerations in determining the required channel dimensions for the design vessel include:

- Vessel dimensions & maneuverability
- Motion due to waves, currents, and winds
- Trim, ballasting (tow out COG & blades)
- Channel bottom type & topography
- Downtime restrictions
  - Restricted (navigable channel at high tide only) vs. unrestricted (navigable channel at all times)

REQUIRED WIDTH

Source: PIANC (2014)

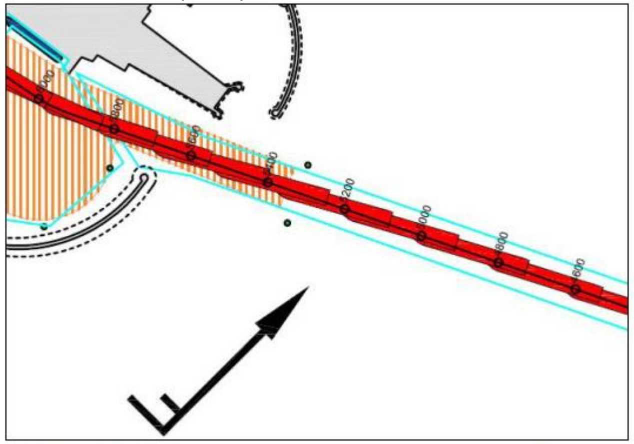


Figure 3.5: Ship course under strong wind conditions

Source: PIANC (2014)

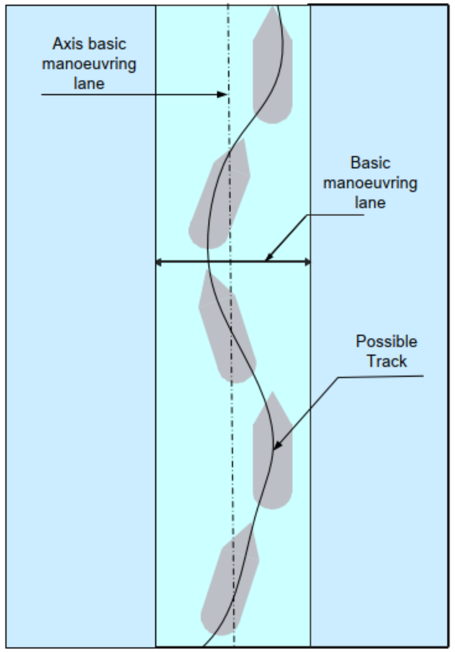
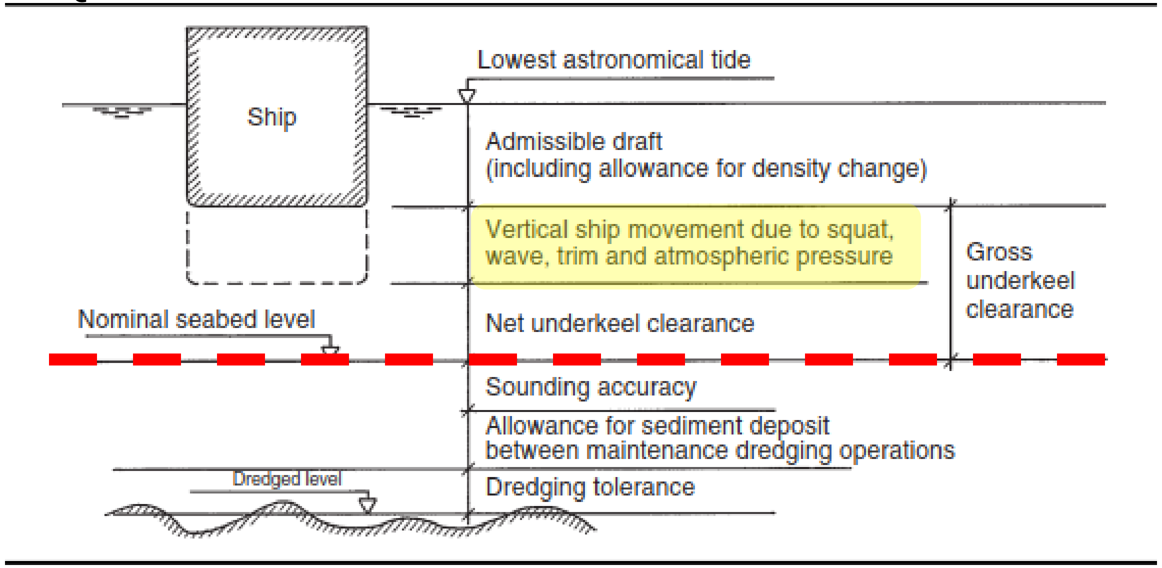


Figure 3.4: Basic manoeuvring lane

REQUIRED DEPTH



Navigation Assessment Criteria

Assumptions

Very high level concept assessment criteria developed for this study. Actual channel depth and width requirements need to be considered on a case-by-case basis for each WTG device.

Channel Depth

- UKC for single or small number of events is different than commercial navigation channel requirements.
- 5-9+ feet of UKC assessed to be potential range of UKC required. May be less or greater based on specific devices and operational limits.
- Lower end → favorable/ideal environmental conditions, stable device
- Higher end → less favorable environmental conditions or less stable device

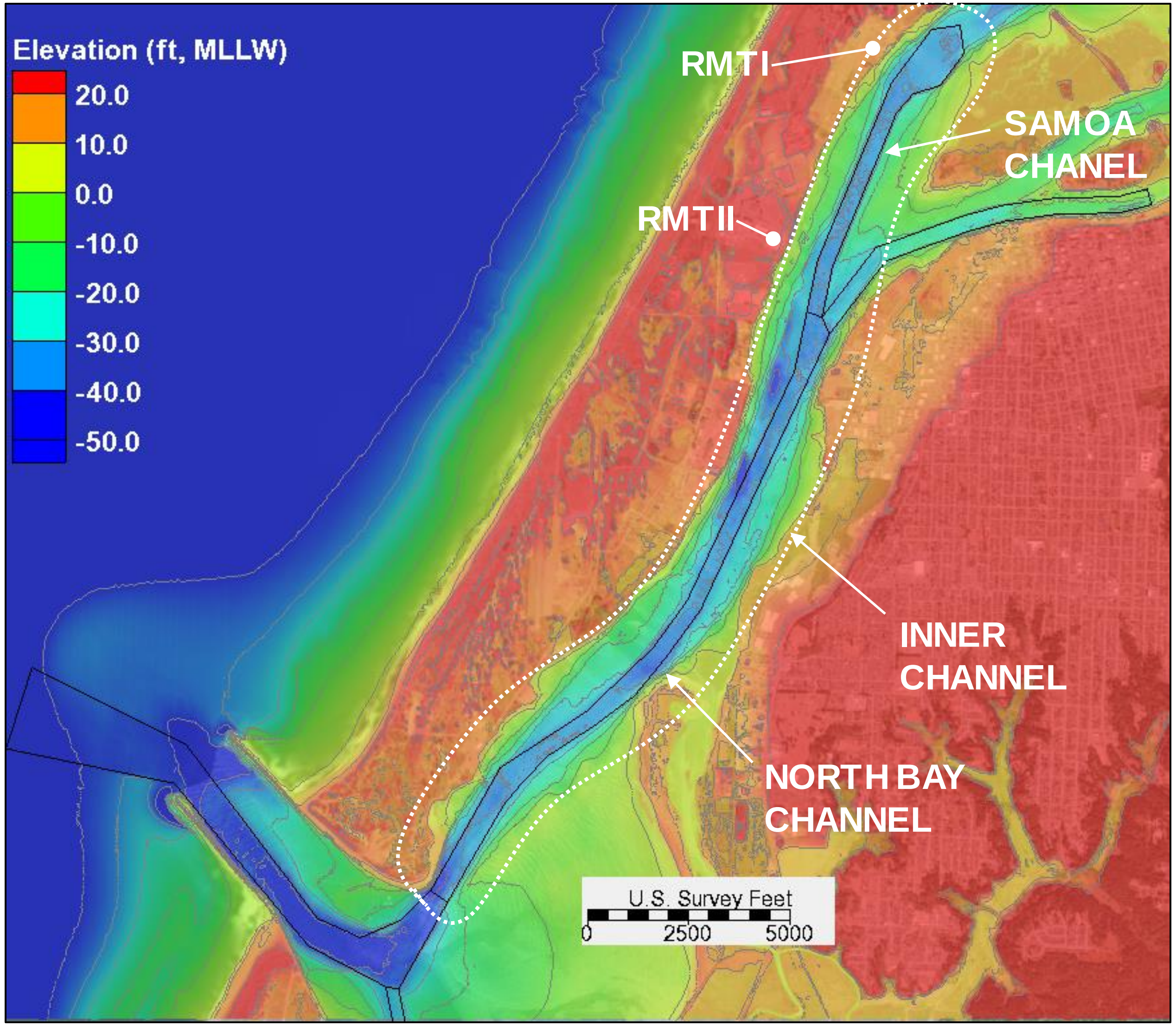
Channel Width:

- 1.5-2.5X the width of the device/vessel assessed to be potential range of channel width required.
- Lower end → favorable/ideal environmental conditions, good maneuverability
- Higher end → less favorable environmental conditions, poor maneuverability

Site Conditions

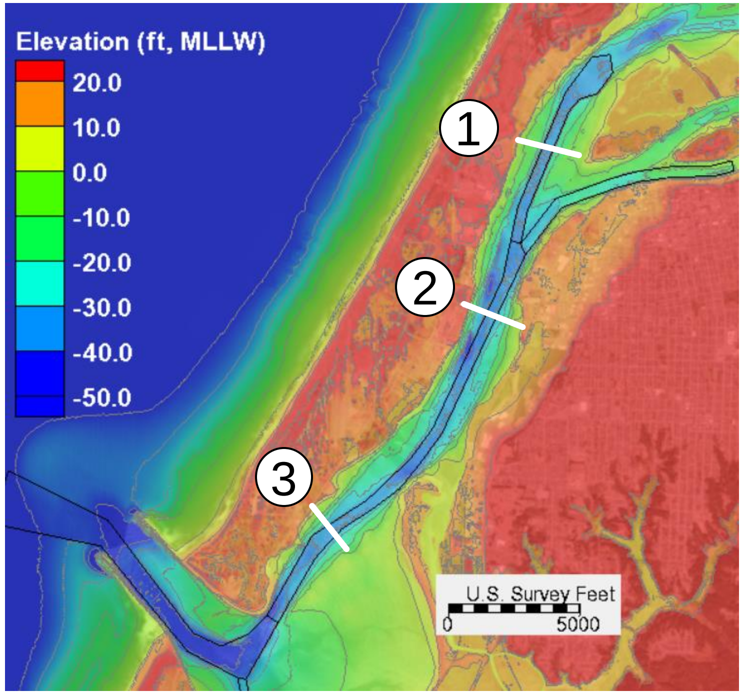
Inner Channel Geometry & Elevation Data

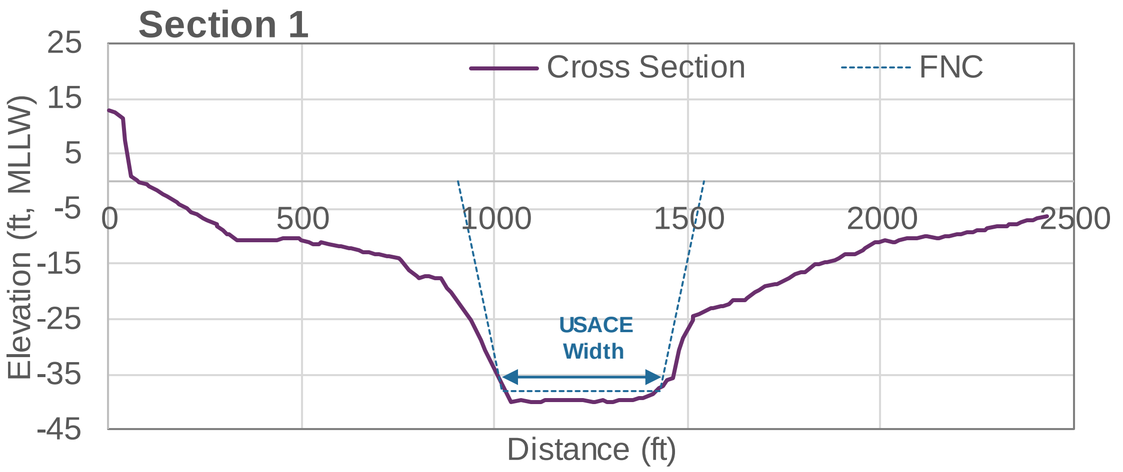
- North Bay and Samoa Channel Geometry
- Authorized Depth: 38ft MLLW
- Authorized Width: 400ft
- Existing Elevation Data
- NOAA Eureka Digital Elevation Model (DEM) (2009), 1/3 arc second
  - Note: more recent survey data from USACE condition surveys is available within the Navigation Channel. USACE data from January 2020 was compared at a high level to the Eureka DEM elevations within the annually maintained navigation channel, and elevations were similar.

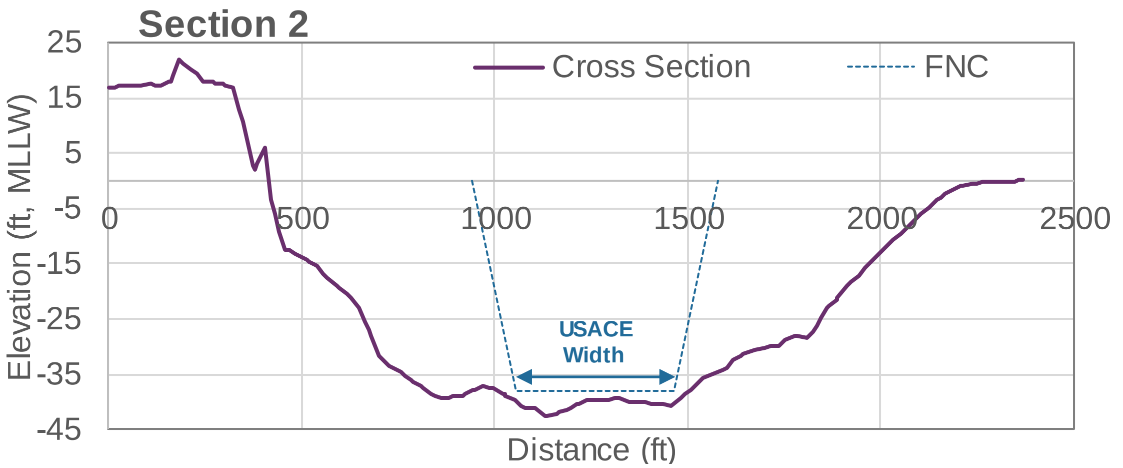


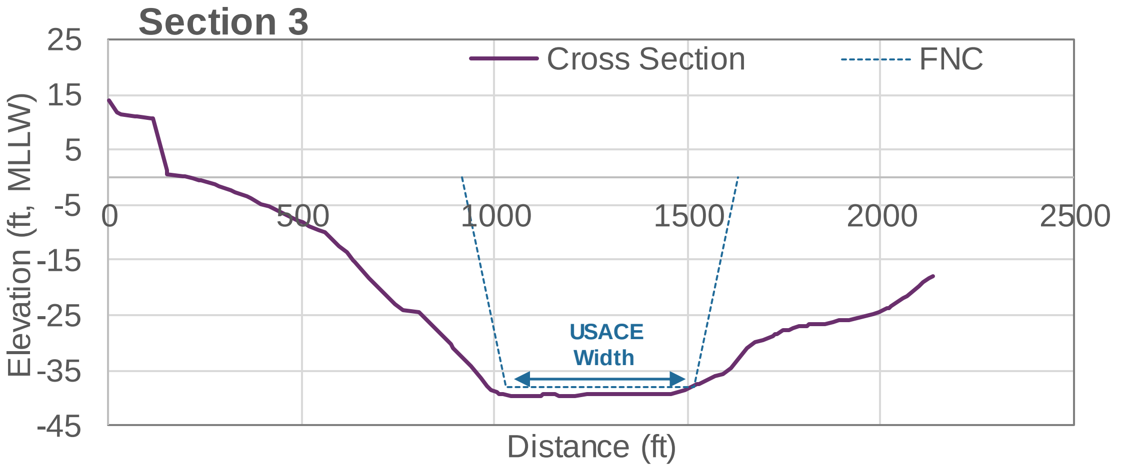
Bathymetry

- Cross sections through the Inner Channel show that the natural morphology of the channel is wider than the Authorized USACE channel width in some places.



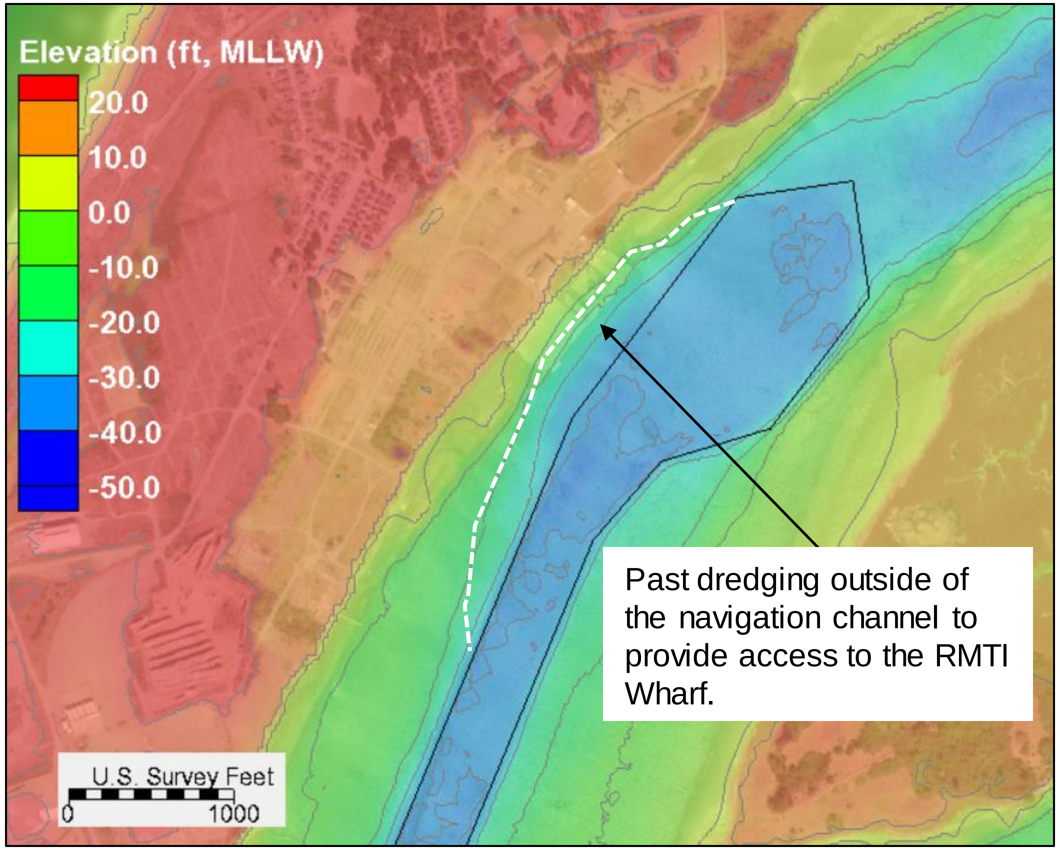






Maintenance Dredging

- Annual maintenance dredging is conducted within the Federal Navigation Channels (FNCs) during the dredging window in the summer.
- Annually, approximately 120,000cy of sediment is removed from North Bay and Samoa Turning Basin (EPA, 2019).
- In the past, dredging outside the FNCs has been conducted periodically as needed to provide access to active berths (e.g. RMTI).



Water Levels

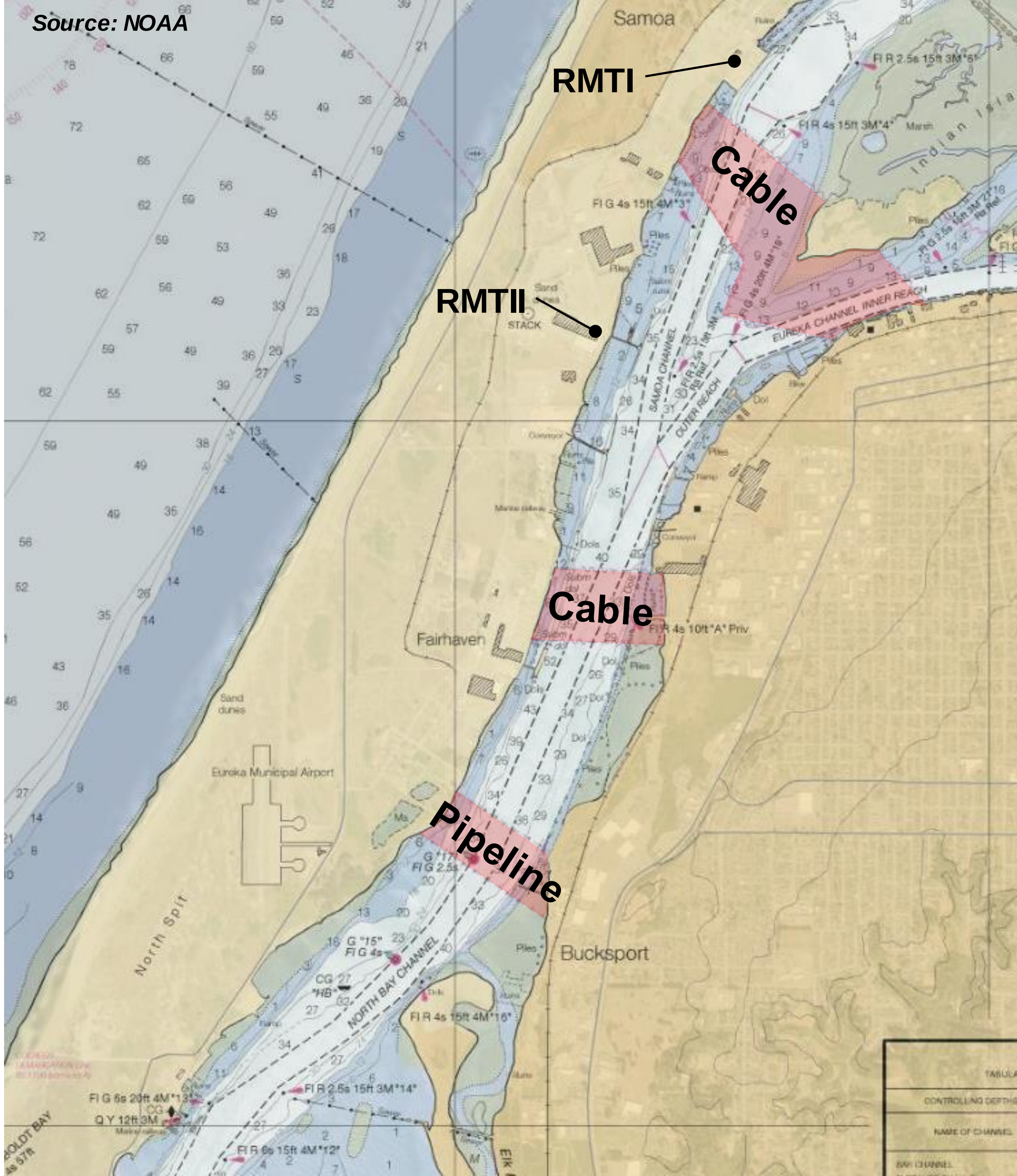
- The tidal character in Humboldt Bay is mixed semi-diurnal (two high tides each day of varying magnitudes) with a marked spring-neap variation.
- Current practice is that deeper draft vessels pass through the Entrance Channel at high tide.

Source: NOAA Station 9418767, North Spit CA

Datum	Value	Description
MHHW	6.85ft	Mean Higher High Water
MHW	6.14	Mean High Water
MSL	3.70ft	Mean Sea Level
MLLW	0.00ft	Mean Lower Low Water
LAT	-2.39ft	Lowest Astronomical Tide

Subsea Infrastructure

- Two submarine cable areas and one pipeline area are shown on NOAA nautical chart crossing the Inner Channel.

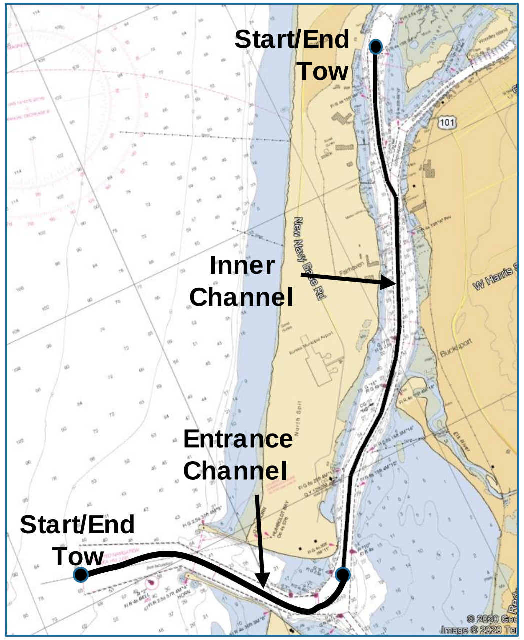


Pre-Feasibility Inner Channel Assessment

Approach – Parametric Geometric Assessment

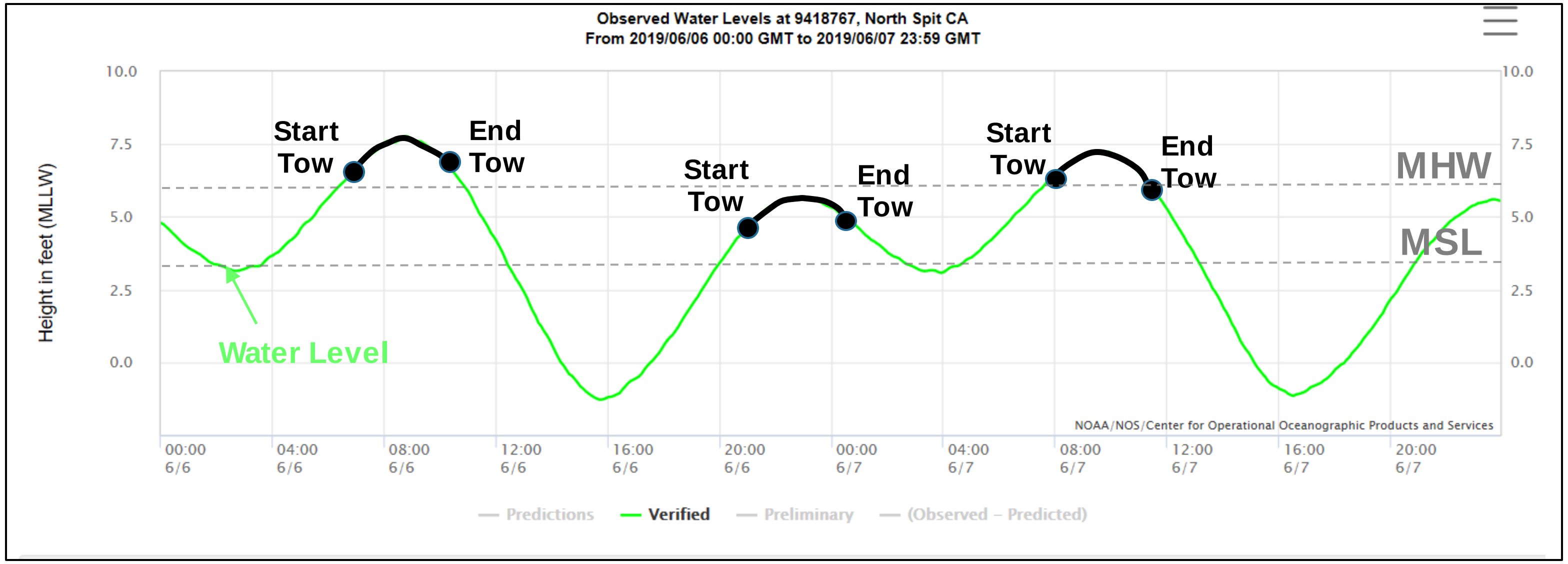
- Required depth was assessed at LAT for unrestricted water levels (e.g. tow-in and tow-out of WTG devices at any point in tidal cycle).
- For the range of design devices/vessels considered, it was determined that water level restrictions may be needed to facilitate navigation of deeper draft devices/vessels, unless the navigation channel is modified.
- A high level tow time assessment was conducted to see at what water levels tow-in and tow-out could be achieved.
- The estimated requirements for channel dimensions were assessed at these water levels to determine whether channel geometry modification would be needed to provide adequate throughput.

Tow-in/Tow-out Phasing



- A tow time assessment was conducted to compare the tow duration relative to the tidal cycle.
- It could take ~3-4 hours to tow an assembled WTG from RMTI through the Inner Channel and out through the Entrance Channel.
- Tow duration likely possible at MHW
- The Inner Channel would need to be linked to the tow-in and tow-out of devices through the Entrance Channel or potential staging areas.

Source: NOAA Station #9418767



Tow duration relative to an example tidal signal in Humboldt Bay.

Parametric Geometric Assessment

For the design vessel and device geometries, potential concept channel dimensions (width and depth) for safe navigation were estimated.

Legend: Estimated Need Exceeds FNC Dimension | Estimated Need May Exceed FNC Dimension | Estimated Need Likely Within FNC Dimension

Device or Vessel	Device Dimension	FNC Dimension	Concept Channel Geometry Requirements – Assessed at MLLW	Concept Channel Geometry Requirements – Assessed at MSL	Concept Channel Geometry Requirements – Assessed at MHW
	Beam	Width	Width		
Device A (Large)	300ft.	400 ft.			
Device B (Small)	200ft.	400 ft.			
Heavy Lift Vessel	140-170ft	400ft.			
	Draft	Depth			
Device A (Large) Loaded w/ WTG	36 ft.	38 ft. MLLW			
Device B (Small) Loaded w/ WTG	25 ft.	38 ft. MLLW			
Heavy Lift Vessel	28-35 ft.	38 ft. MLLW			

Notes:

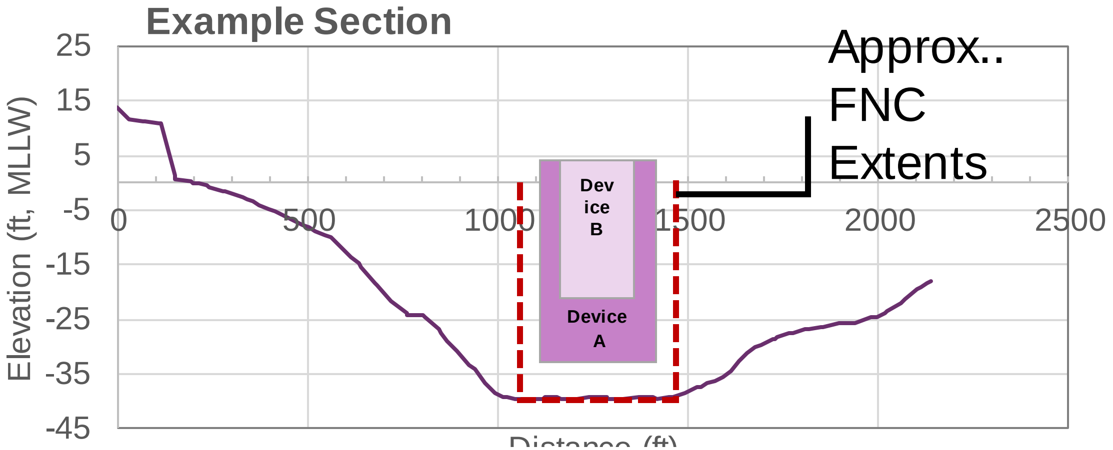
- ***Adverse conditions or differences in geometry drastically affect assessment; does not consider shoaling of channel.***
- ***Concept analysis only based on desktop level guidance.***

Concept Device Geometry Limitations

- For the existing Inner Channel geometry, the potential maximum device/vessel dimensions that can safely navigate were estimated based on the project criteria.
- Width
- The maximum vessel/device beam that can safely navigate through the existing inner channel (400ft width) is likely between 200-270ft.
- Depth
- The maximum vessel/device draft that can safely navigate through the existing inner channel (at a depth of -38ft MLLW), is likely between 33-37ft at MSL and 35-39ft at MHW.

Notes:

- ***Assumes 1-way traffic***
- ***Adverse conditions or differences in geometry drastically affect assessment***
- ***Concept analysis only based on desktop level guidance***



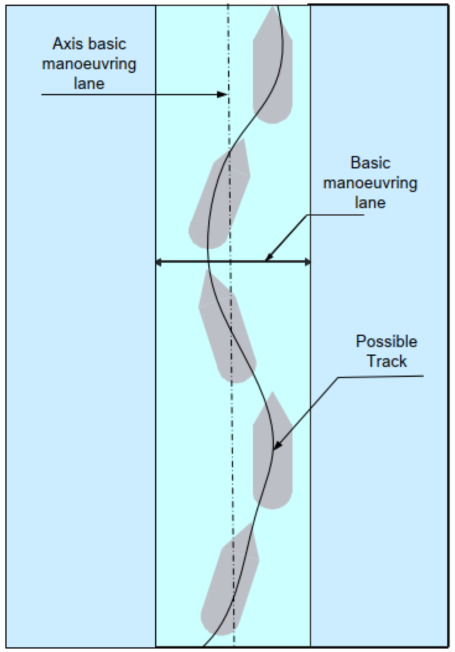
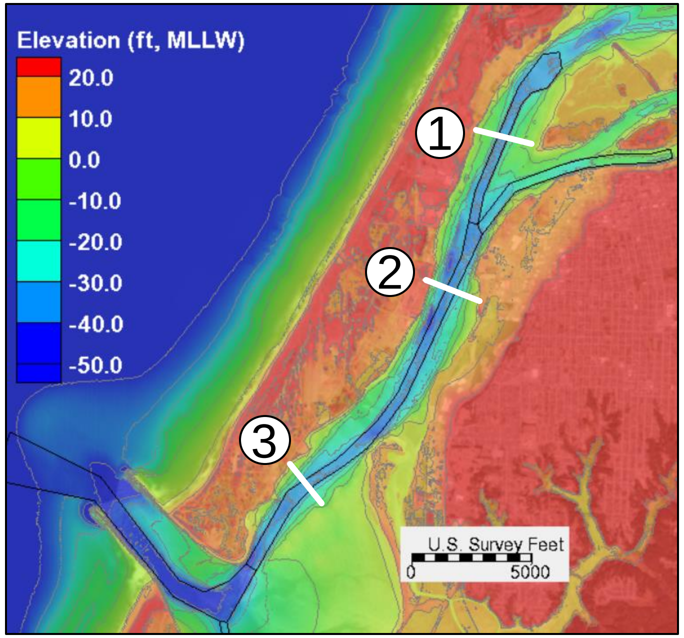
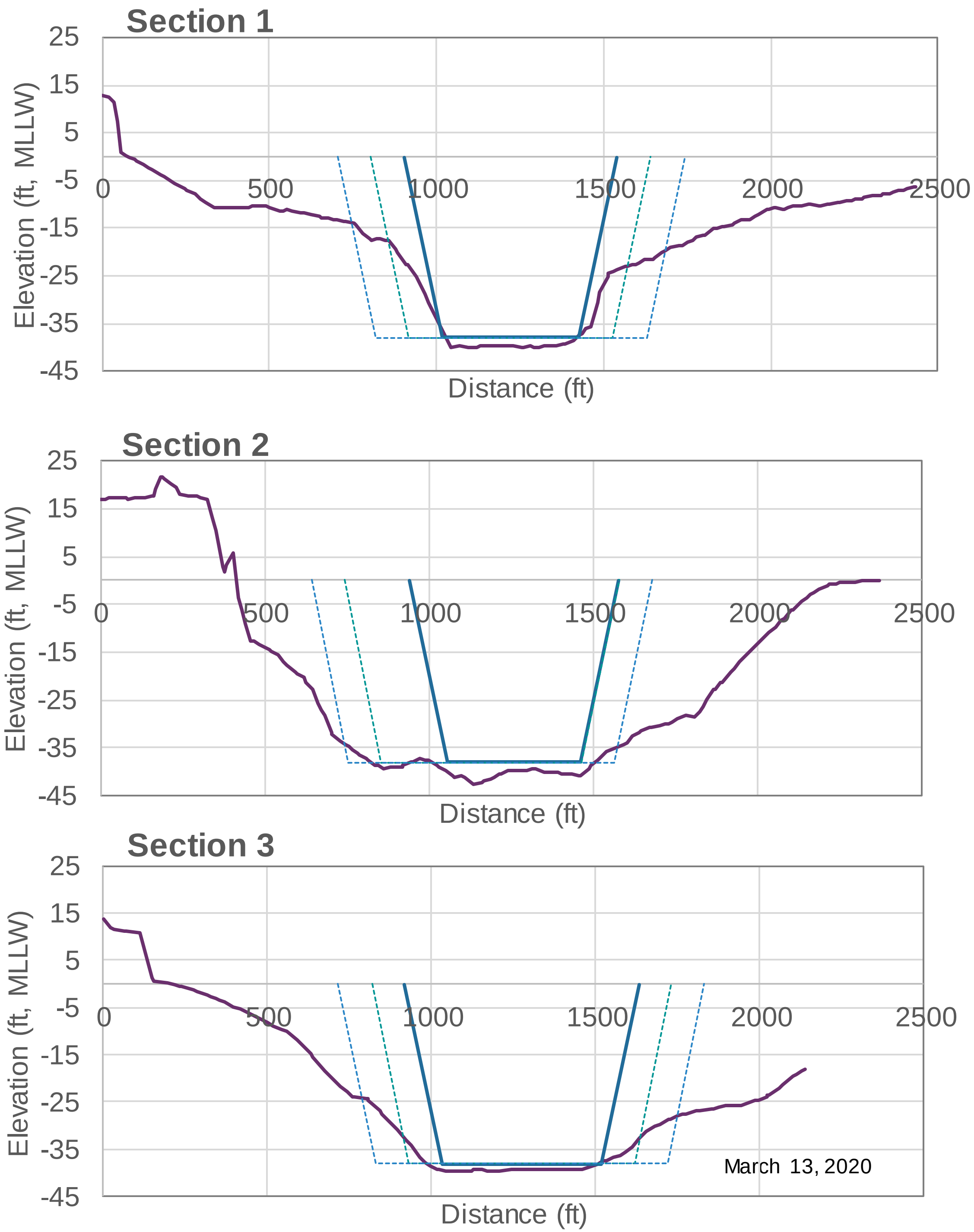


Figure 3.4: Basic manoeuvring lane

Channel Width Modification





- If dredging is required the amount of dredging required will vary by location– the natural channel is wider than the Authorized Width in some areas.
- A more recent bathymetric survey outside of the FNC is required to estimate dredging requirements for channel geometry modifications.

Outcomes

Outcomes

Assessment Scenarios

Pilot/Small-Commercial Scale

- Modifications to the inner Federal Navigation Channel (FNC) geometry not likely for pilot/small-commercial projects, but towing may be limited to favorable environmental conditions and the beam of the device may be limited
- At present channel width the limitations on device size may be between ~200-270ft.

Large Commercial Scale

- Without good navigation support, and favorable environmental conditions tow-out may not be considered safe for any devices. Safety an throughput concerns for devices could be mitigated by widening the channel.
- FNC deepening is unlikely to be required if towing along the channel is timed with high-tides, depending on device.
- 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 on a yearly basis.
- If modification of FNC geometry is needed, even within localized areas, this would require coordinating long-term planning with the USACE and other stakeholders.

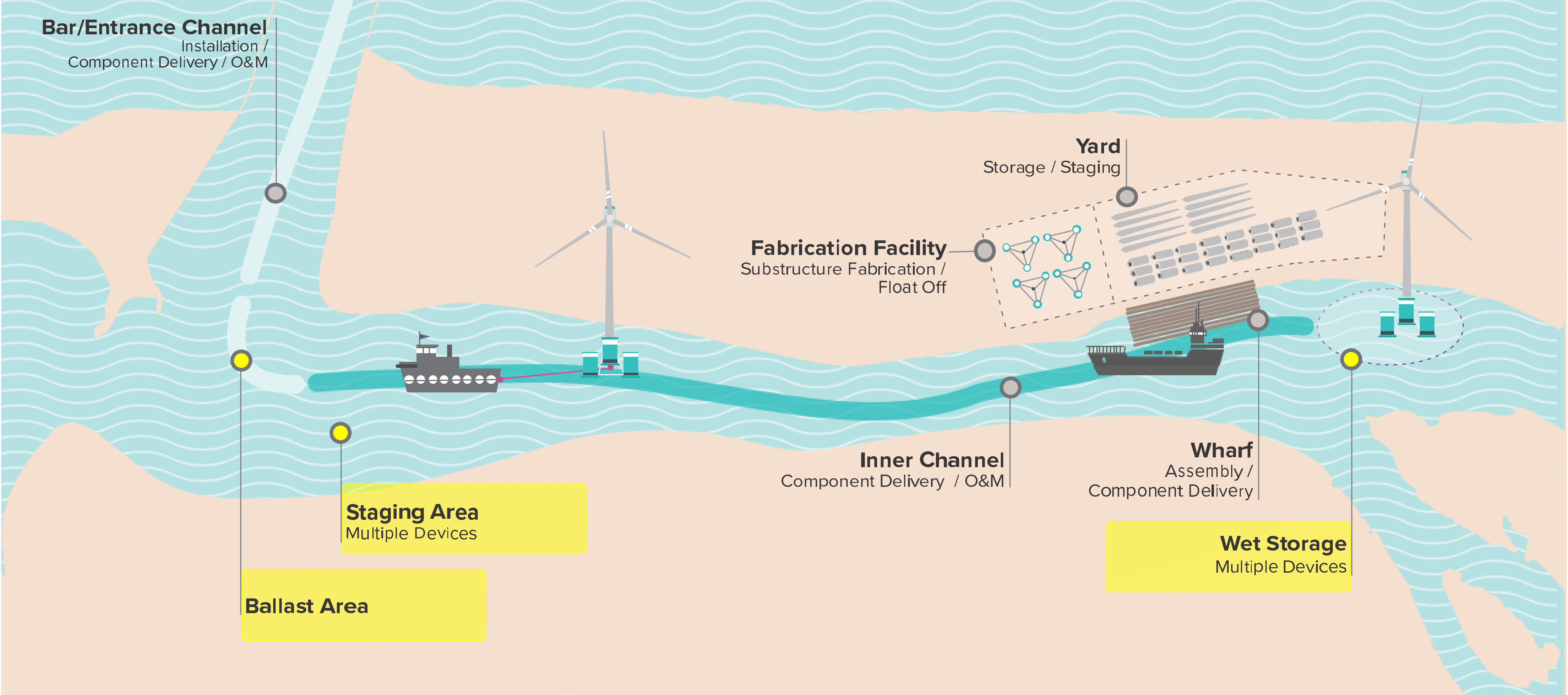
Appendix A-3 Navigation – Wet-Storage, Staging, and Ballasting

This appendix provides an assessment of the wet storage, staging area, and ballasting area. The objective, criteria and assumptions, concept depth requirements, site conditions, depth assessments, and outcomes and next steps for this work is presented.

Appendix A-3: Wet Storage, Staging, & Ballasting

Humboldt Bay Port Infrastructure

Offshore Floating Wind Farm



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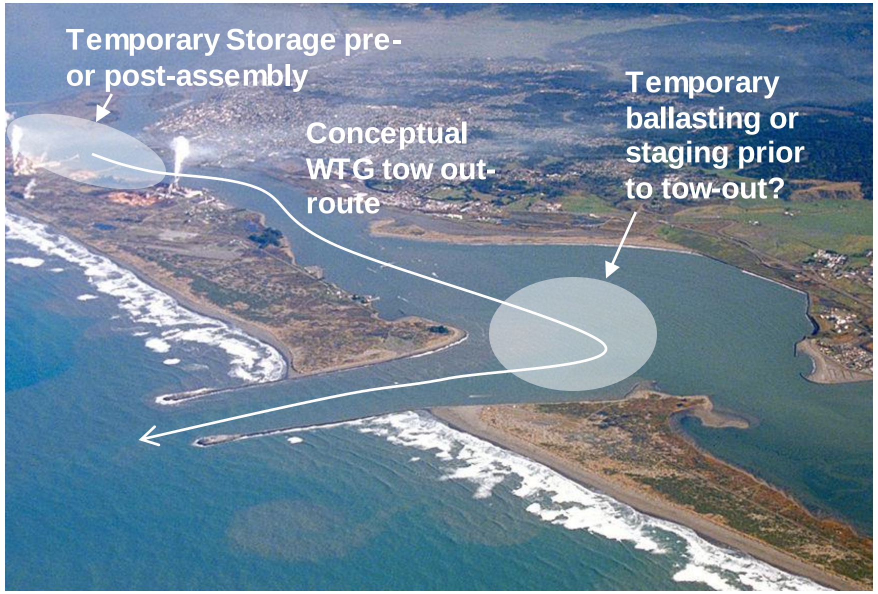
Appendix A-3: Staging & Ballast Areas Assessment Overview

- Objective
- Criteria & Assumptions
- Concept Depth Requirements
- Site Conditions
- Depth Assessments
- Outcomes & Next Steps

Objectives

- Develop criteria and requirements for wet storage, staging, and ballasting areas to support the following activities:
- Temporary storage of floating substructures (pre-assembly) or assembled WTGs (post-assembly);
- Temporary staging of assembled WTGs prior to tow-out to take advantage of favorable weather windows and tides; and
- Assembled device ballasting within sheltered waters to reduce at-sea activity requirements.
- Evaluate the possibility for Humboldt Bay to support these activities for given elevations and channel geometry.
- Determine potential modifications to navigation channel geometry or additional dredging that may be needed to support these activities for various buildout scenarios.



Terminology

<u>Wet Storage Area</u>: area for temporary storage of floating substructures or assembled WTG devices in the vicinity of the Assembly Facility.

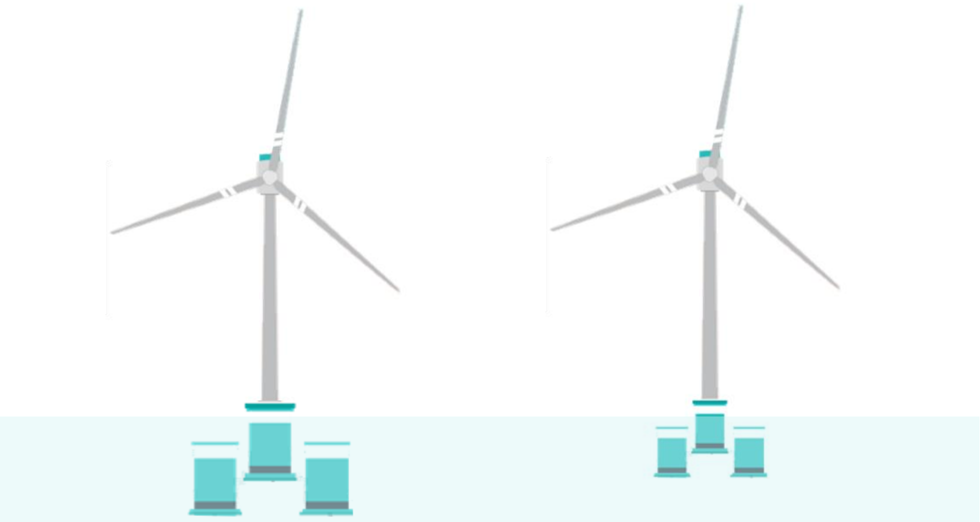
<u>Staging Area</u>: area for temporary storage of assembled WTGs prior to tow-out through the Entrance Channel.

<u>Ballasting Area</u>: designated area where WTG devices can be ballasted down (increase draft) prior to crossing the bar and de-ballast when towed-in for maintenance.

Criteria & Assumptions

Design Device Dimensions

The assumed range of device dimensions considered for assessing potential staging and ballasting areas within Humboldt Bay are shown in the table to the right.



Device A
Representative of larger substructure geometry

Device B
Representative of smaller substructure geometry

Note: geometries assumed for sensitivity analysis only, not intended to represent specific substructure designs.

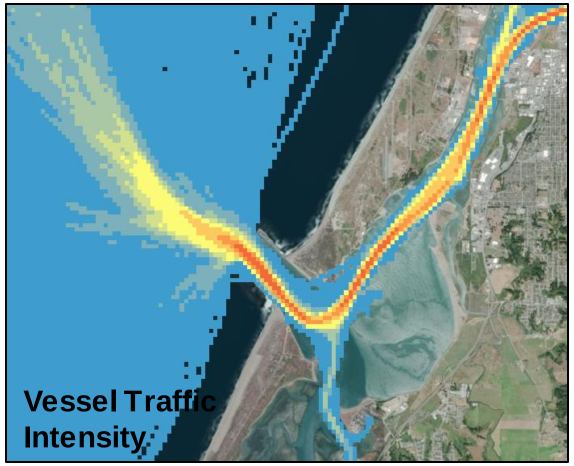
Device	Device Dimension
	Beam
Device A	300ft.
Device B	200ft.
	Length Overall (LOA)
Device A	300ft.
Device B	200ft.
	Draft
Device A:	
Substructure Only	28 ft.
Loaded w/ WTG	36 ft.
Fully Ballasted	60ft.
Device B:	
Substructure Only	20 ft.
Loaded w/ WTG	25 ft.
Fully Ballasted	45ft.

Assessment Criteria

Key considerations in evaluating potential storage, staging or ballasting areas include:

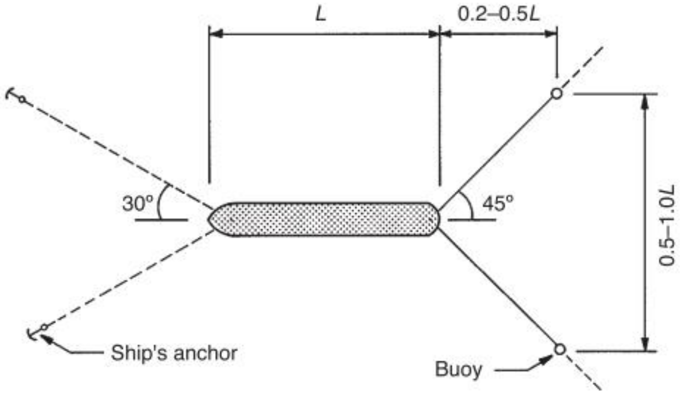
- Sufficient depth to accommodate device draft, device motion, and water level fluctuations for staging or ballasting activities.
- Sufficient area to accommodate ballasting or temporary storage/staging (device motion, maneuverability, navigation).
- Proximity to navigation channel or assembly facility.
- Interference with other vessel traffic.

INTERFERENCE WITH VESSEL ACTIVITY



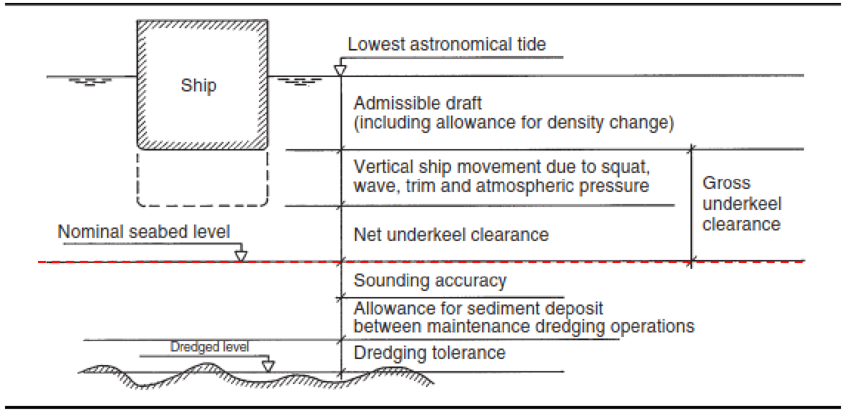
REQUIRED AREA

Source: Port Designer Handbook



METOCEAN CONDITIONS

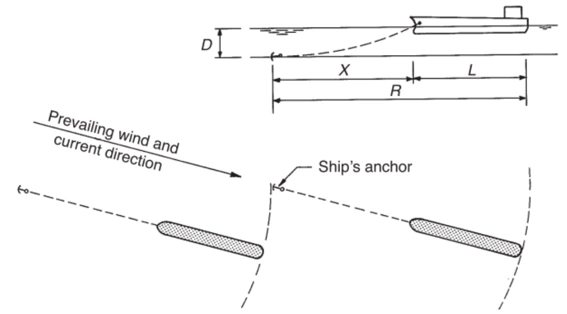
REQUIRED DEPTH



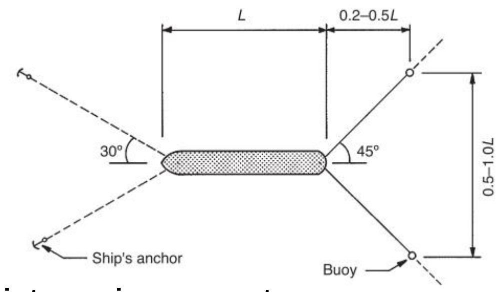
Temporary Anchoring

- Options for securing floating devices include:
- Single-Point Mooring
  - Not appropriate for use in WTG staging area in Humboldt Bay. Devices would move with tidal currents, and would therefore require more space (and dredging).
- Multiple-Point Mooring
  - It is assumed that WTG devices would be secured in the staging area via multi-point mooring.
- Mooring Dolphins
  - Dolphins could also be considered as an alternative for temporary staging of devices.

Source: Port Designer Handbook



Single-point (free-swinging) mooring concept



Multiple-point mooring concept

Wet Storage Area Assessment Criteria

- Assumptions
- Limited storage may be allowable within the Federal Navigation Channel (FNC), on a case-by-case basis.
- Temporary storage may occur inside or outside of the Inner Channel.
- Location
- Close proximity to the Assembly Facility is preferred.
- Not block navigation channels.
- Allow for passage of small and commercial-sized fishing vessels who need access north of the turning basin.
- Footprint
- Space requirements are likely 1.5-3X the size of the device to accommodate assembled device maneuverability/navigation and temporary storage.
- At a minimum, it is assumed that a 300'x300' to 500'x500' area is needed for each device.
- Depth
- Under Keel Clearance (UKC)
  - Assume 2-3ft of UKC is needed for temporary WTG storage, which is consistent with Humboldt Harbor Safety guidelines for vessels within the Bay.
  - WTG units respond differently to waves – final UKC requirements may differ.
- Water Levels
  - Staging area depth requirements should be assessed at Lowest Astronomical Tide (LAT), since devices may be stored for longer periods of time.

Staging Area Assessment Criteria

- ## Assumptions
- Pilot-Scale Scenario
  - Assumed that temporary staging may occur within the Entrance Channel.
- Large Commercial-Scale Scenario
  - Long-term staging area use should occur outside of the Entrance Channel.
- ## Location
- Staging area should be in close proximity to Entrance Channel.
- Staging area should be characterized by calm metocean conditions (protection from ocean swell, swift tidal currents, etc)
- Interference with other vessel traffic should be minimized

- ## Footprint
- Similar to wet storage area criteria; assumed that 1.5-3X the size of the device to accommodate assembled device maneuverability/navigation and temporary staging.
- At a minimum, it is assumed that a 300’x300’ to 500’x500’ area is needed for each device.
- ## Depth
- Under Keel Clearance (UKC)
  - Assume 2-3ft of UKC is needed for temporary WTG staging, which is consistent with Humboldt Harbor Safety guidelines for vessels within the Bay.
  - WTG units respond differently to waves – final UKC requirements may differ.
- Water Levels
  - Staging area depth requirements should be assessed at Lowest Astronomical Tide (LAT), since devices may be stored for longer periods of time.

Ballasting Area Assessment Criteria

- Assumptions
- Ballasting inside Humboldt Bay is preferred to reduce at-sea operations
- Limited ballasting operations may be allowable within the Federal Navigation Channel (FNC), on a case-by-case basis.
- Location
- Ballasting area should be in close proximity to Entrance Channel.
- Calm metocean conditions (protection from ocean swell, swift tidal currents, etc.) are preferred.
- Interference with other vessel traffic should be minimized, if possible.

- Timing
- Ballasting would occur prior tow-out (one device at a time).
- Depth
- Under Keel Clearance (UKC)
  - UKC requirements will vary based on wave exposure. May be less than required for tow-out if wave exposure is reduced.
  - WTG units respond differently than vessels to waves – final UKC requirements may differ.
- Water Levels
  - Assume ballasting operations would be conducted at MSL or MHW in accordance with the tow-out assessment conducted in Appendix A-1 Entrance Channel.
    - Note: MHHW is only 0.7ft above MHW; for this level of analysis, assessment results at MHHW would be similar to assessment at MHW.

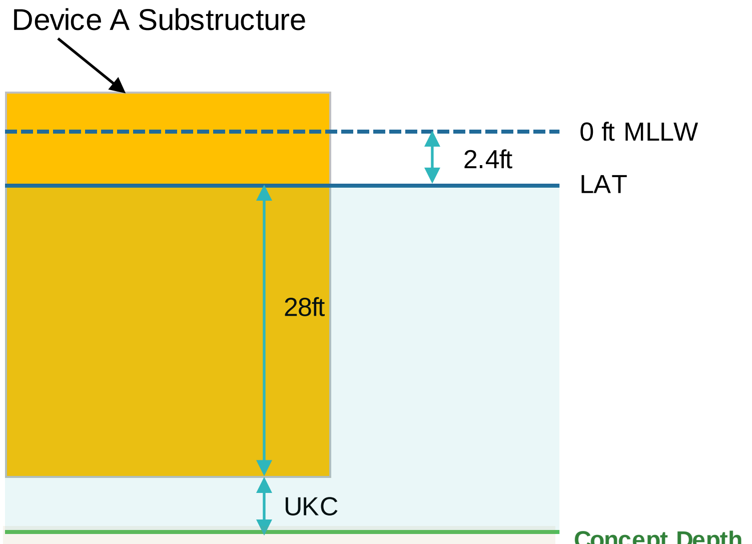
MOTT MACDONALD

Concept Depth Requirements

Wet Storage Assessment – Depth Requirements

Concept depth requirements were developed for temporary storage of substructures and loaded WTG devices.

Device (Scenario)	Device Draft	Concept Depth Requirements – All Tides (LAT)
Device A (Substructure only)	28 ft.	~34 ft. MLLW
Device B (Substructure only)	20 ft.	~26 ft. MLLW
Device A (Loaded w/ WTG)	36 ft.	~42 ft. MLLW
Device B (Loaded w/ WTG)	25 ft.	~31 ft. MLLW

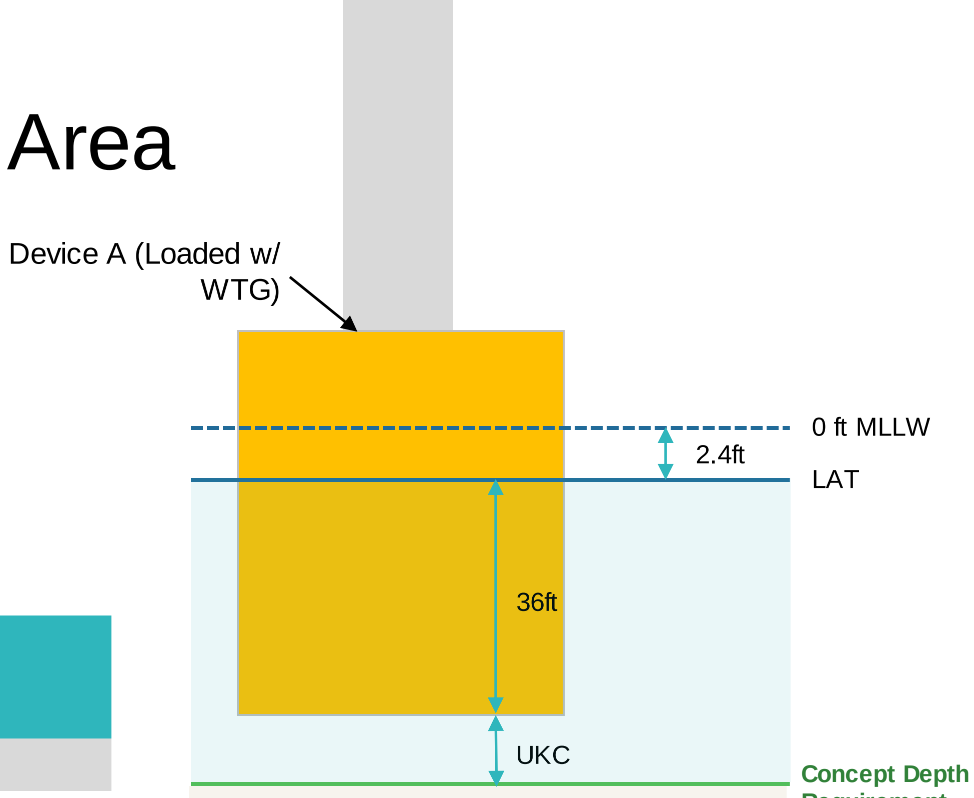


Wet Storage Area Depth Requirement schematic (not to scale)

Concept Depth Requirements – Staging Area

Concept depth requirements were developed for temporary staging of loaded WTG devices, prior to tow-out.

Dimension	Device Draft	Concept Staging Area Depth Requirements: WL = LAT
Draft – Device A (Loaded w/ WTG)	36 ft.	~41 ft. MLLW
Draft – Device B (Loaded w/ WTG)	25 ft.	~30 ft. MLLW

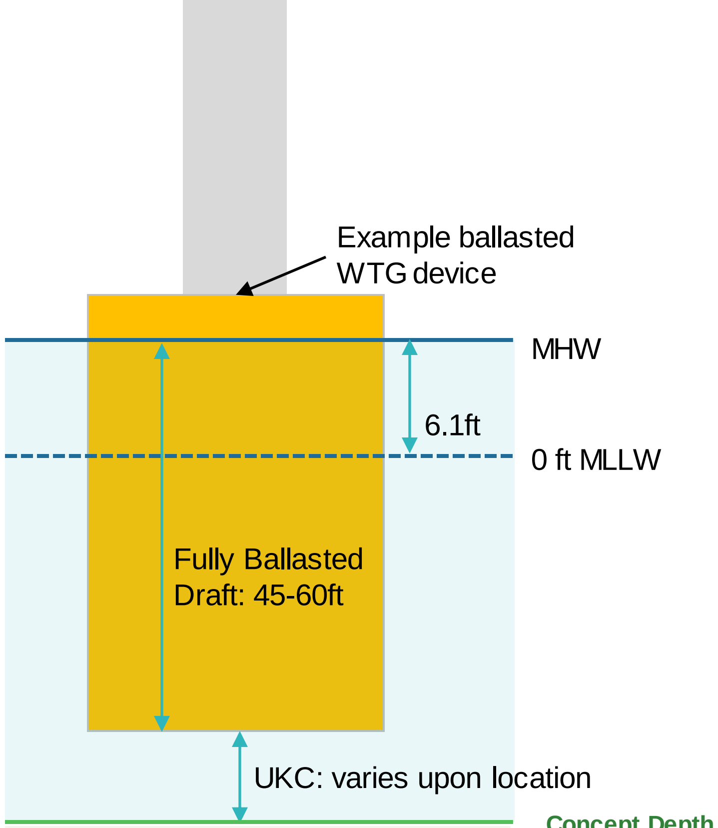


Concept Staging Area Depth Requirement Schematic (not to scale)

Concept Depth Requirements – Ballasting

Concept depth requirements were developed for ballasting of loaded WTG devices prior to tow-out (not including tow-out)

Device	Ballast Level	Device Draft	Concept Ballast Area Depth Requirements: WL = MLLW	Concept Ballast Area Depth Requirements: WL = MHW
A	50% Ballasted	48 ft.	52 to 58 ft. MLLW	46 to 52 ft. MLLW
A	Fully Ballasted	60 ft.	64 to 70 ft. MLLW	58 to 64 ft. MLLW
B	50% Ballasted	35 ft.	39 to 47 ft. MLLW	33 to 39 ft. MLLW
B	Fully Ballasted	45 ft.	49 to 55 ft. MLLW	43 to 49 ft. MLLW



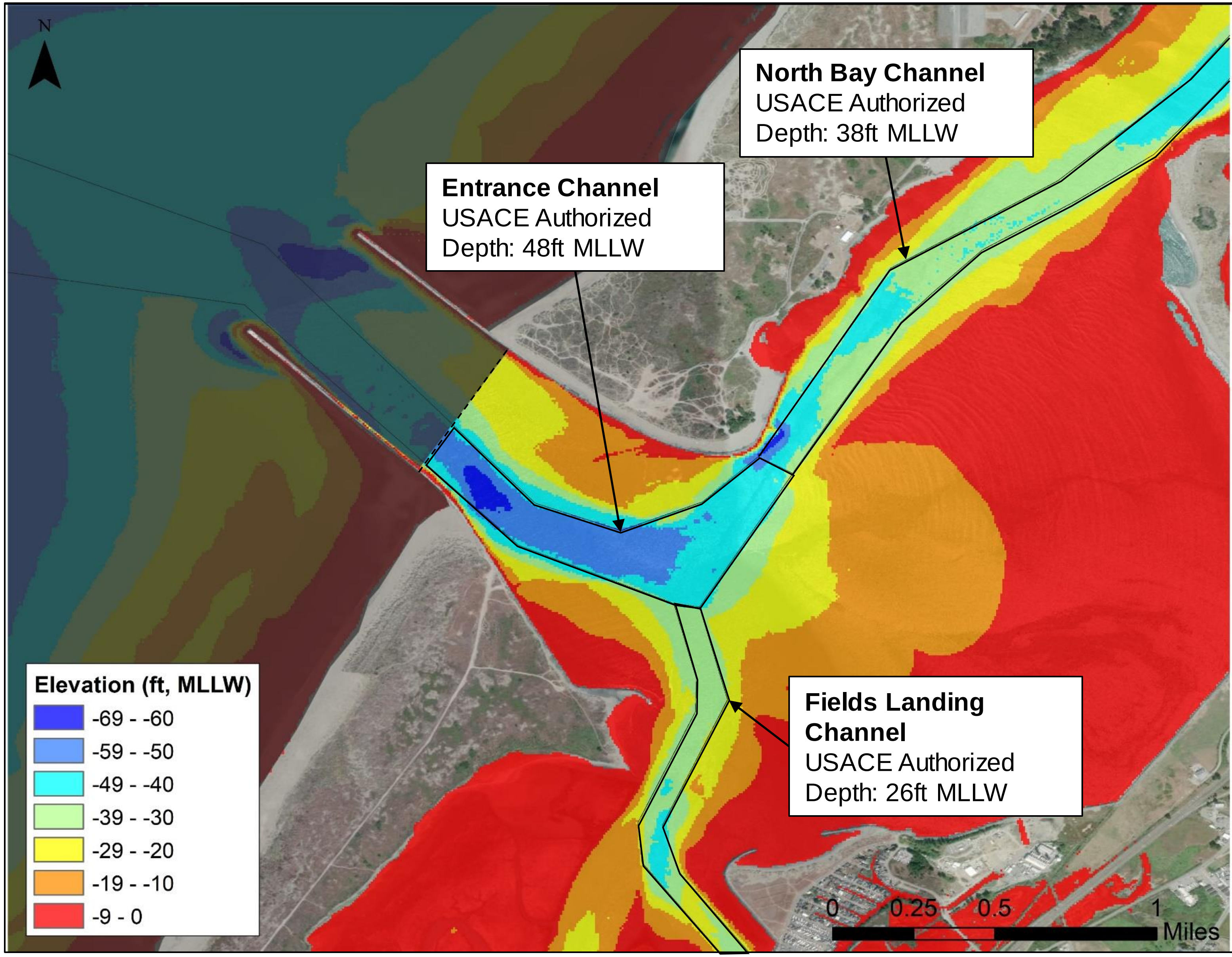
Ballasting Area Depth Requirement schematic (not to scale)

Site Conditions

Near Entrance Channel

Channel Geometry & Elevation Data near Entrance Channel

- Federal Navigation Channels
- Entrance Channel & Bar:
  - Authorized Depth: 48ft MLLW
  - Authorized Width: assumed 600ft
- North Bay Channel
  - Authorized Depth: 38ft MLLW
  - Authorized Width: 400ft
- Existing Elevation Data
- NOAA Eureka DEM (2009), 1/3 arc second
  - Note: USACE condition surveys within the Entrance Channel show that bathymetric conditions change monthly. The elevations shown represent a snapshot of elevations from the 2009 NOAA DEM (the most recent publicly available bathymetry data outside of the FNCs).

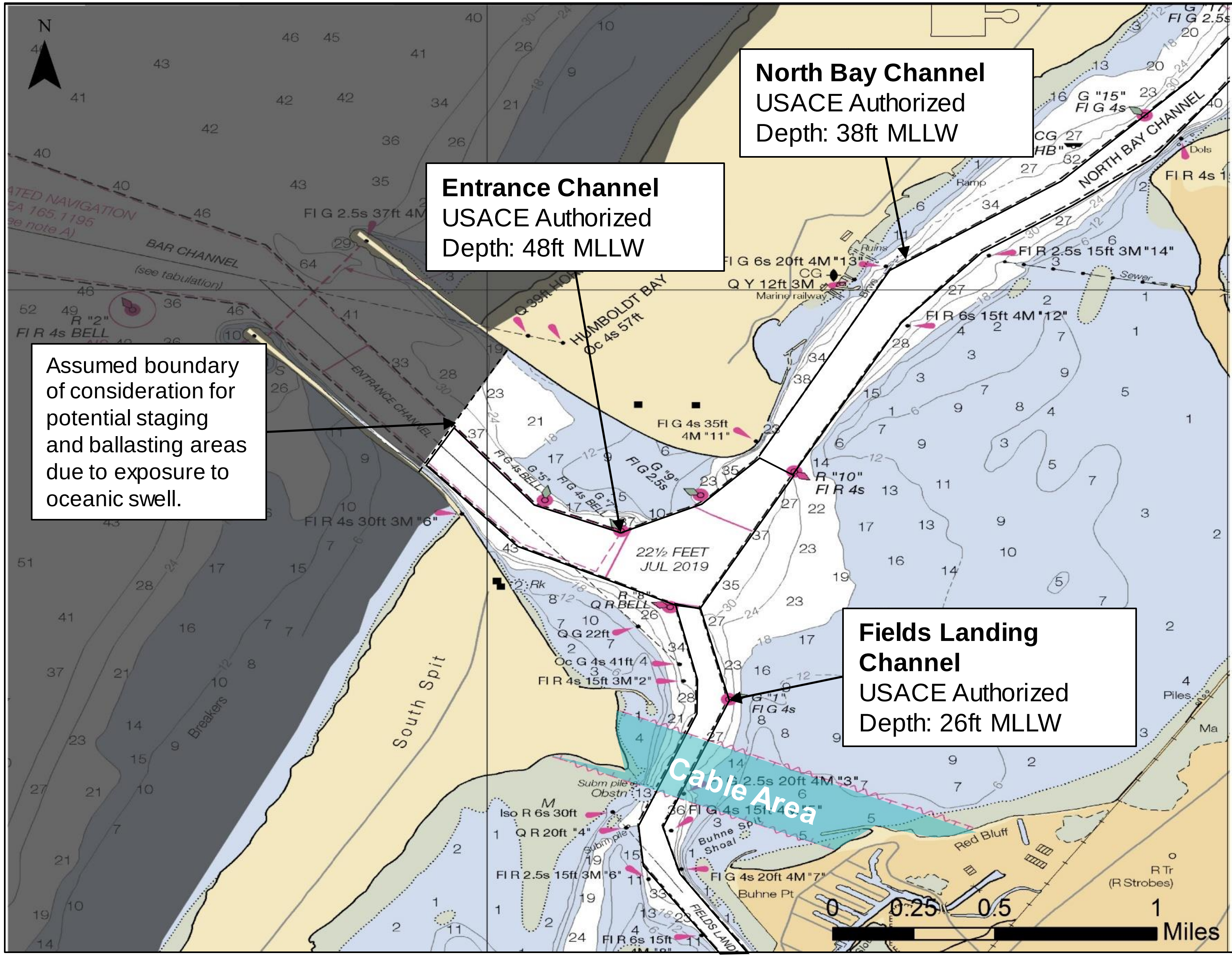


Subsea Infrastructure

Potential dredging obstructions

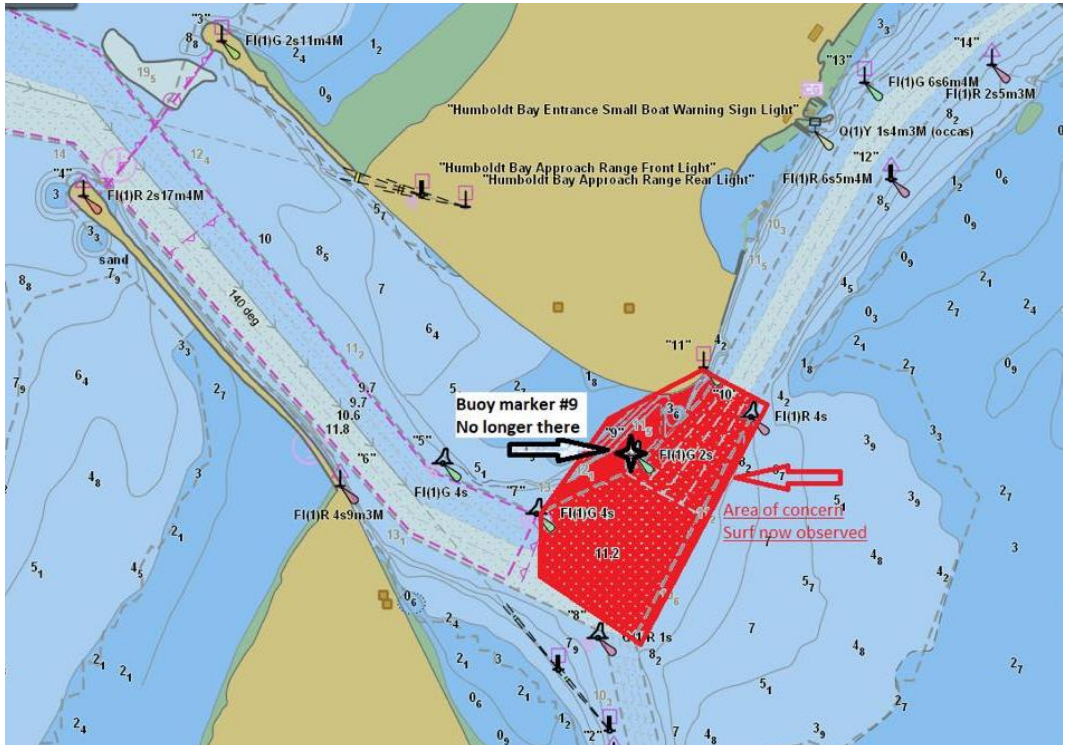
Submarine Cable

- A submarine cable is shown on NOAA nautical chart crossing the Fields Landing Channel from South Spit to Buhne Point.



Wave Conditions – Interior of Entrance Channel

- The interior part of the Entrance Channel is generally protected from oceanic swell
- In 2019, breaking waves were observed at the interior of the Entrance Channel.
- Further analysis is needed to assess the risk and impact of wave action to staging in this area.



Inner Humboldt Channel Surf Zones – breaking waves reported well into Humboldt Channel
Source: US Coast Guard – March 2019

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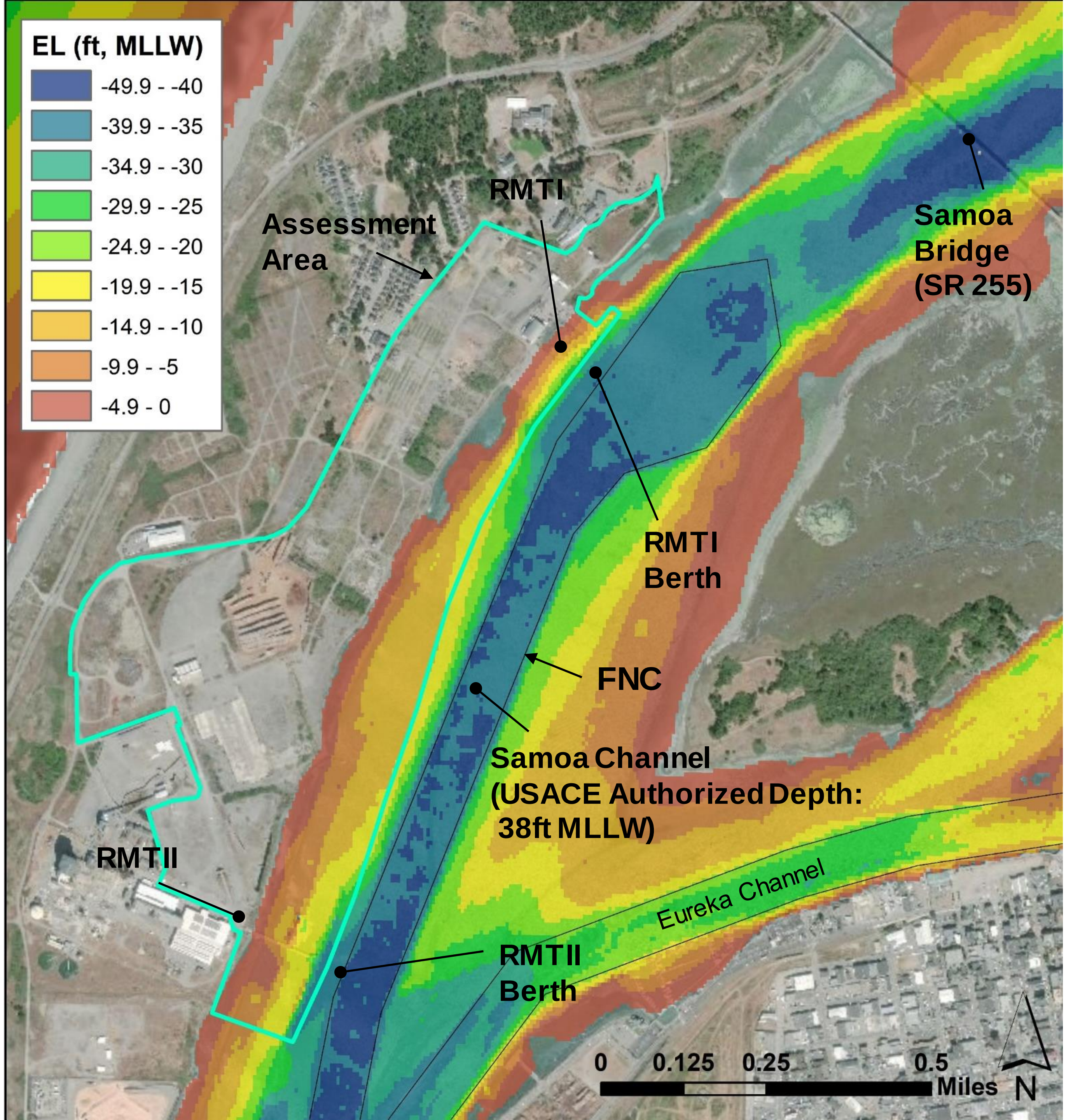
Site Conditions

Near Assembly Facility Assessment Area

Channel Geometry & Elevation Data near Assembly Facility

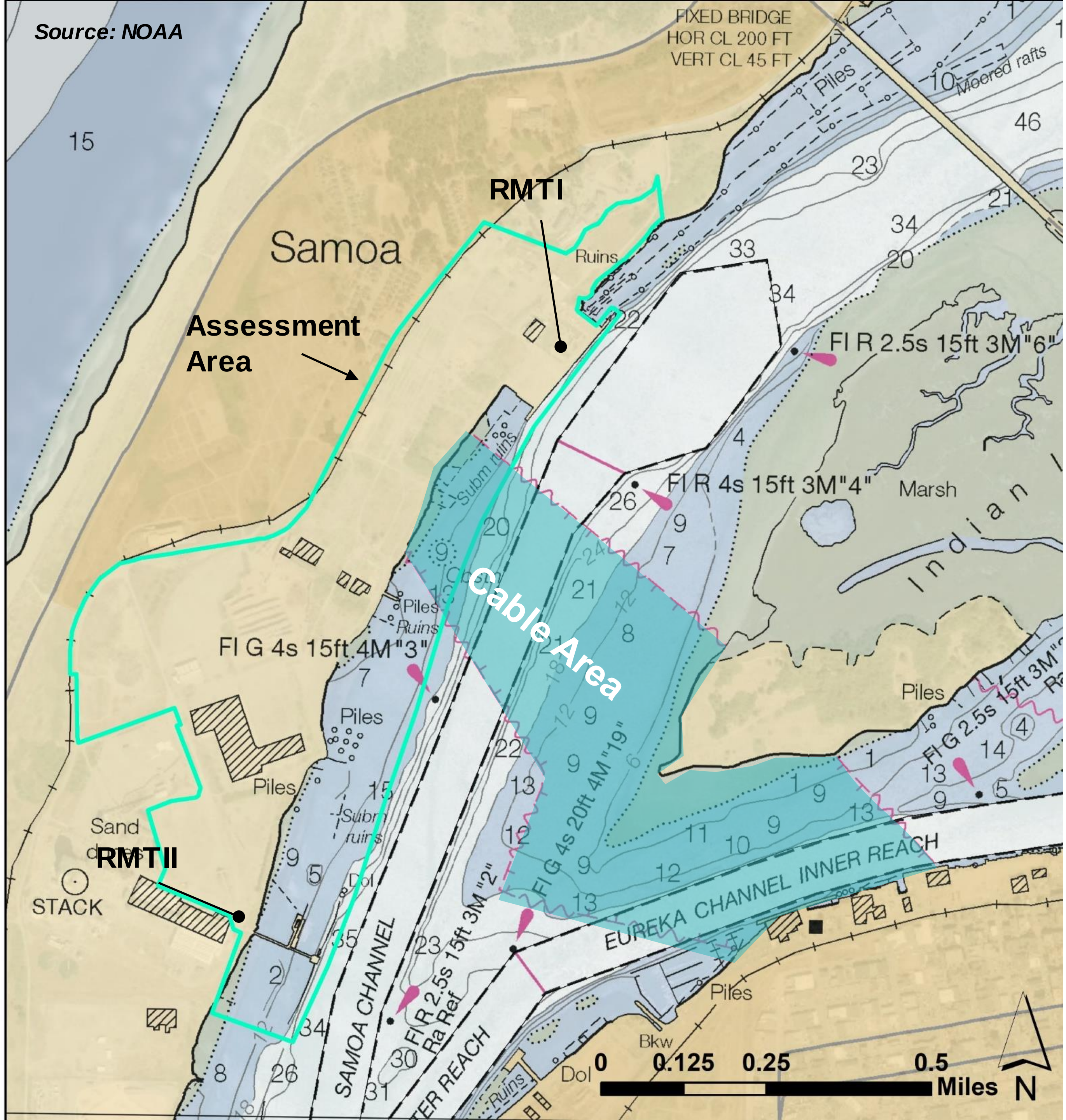
- Samoa Federal Navigation Channel (FNC):
- Authorized Depth: 38ft MLLW
- Authorized Width: 400ft
- Existing Elevation Data
- NOAA Eureka DEM (2009), 1/3 arc second



Subsea Infrastructure

Potential dredging obstructions

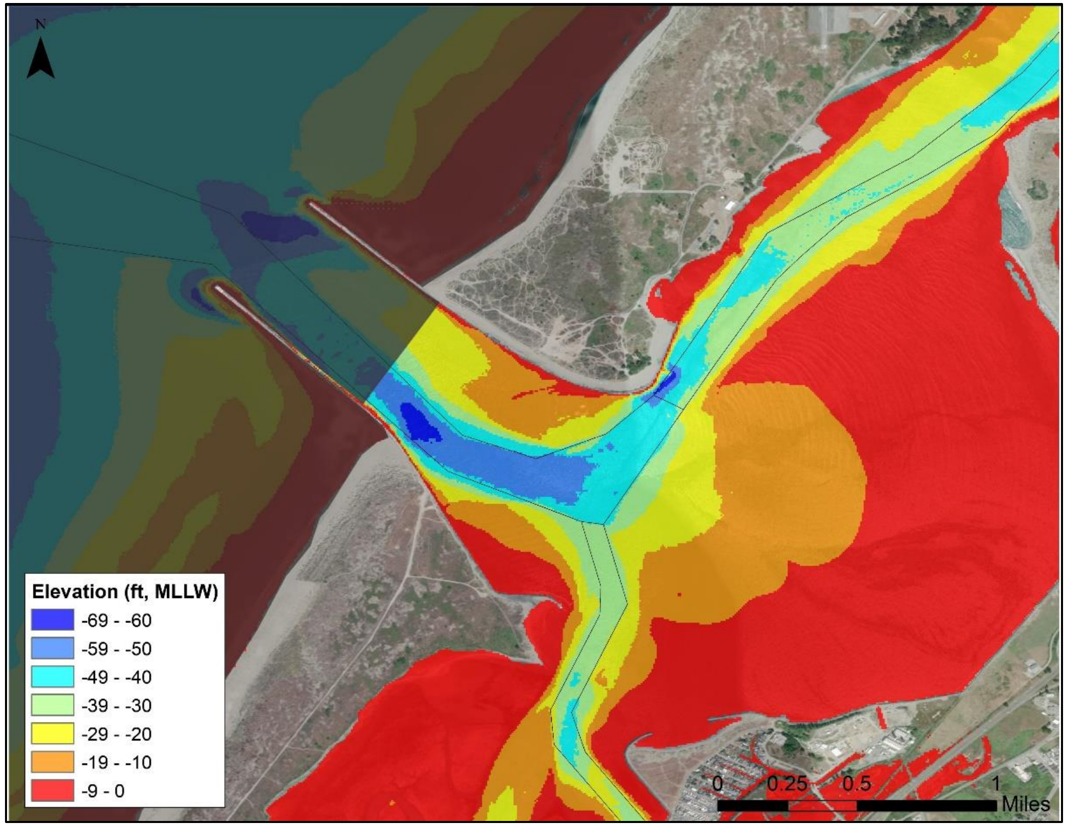
- **Submarine Cable**
- A submarine cable is shown on NOAA nautical chart crossing the Samoa and Eureka FNCs approximately 450ft south of RMTI.
- **Pile Field(s)**
- Piles and ruins from remnant structures are shown between RMTI and RMTII.



Concept Depth Assessments

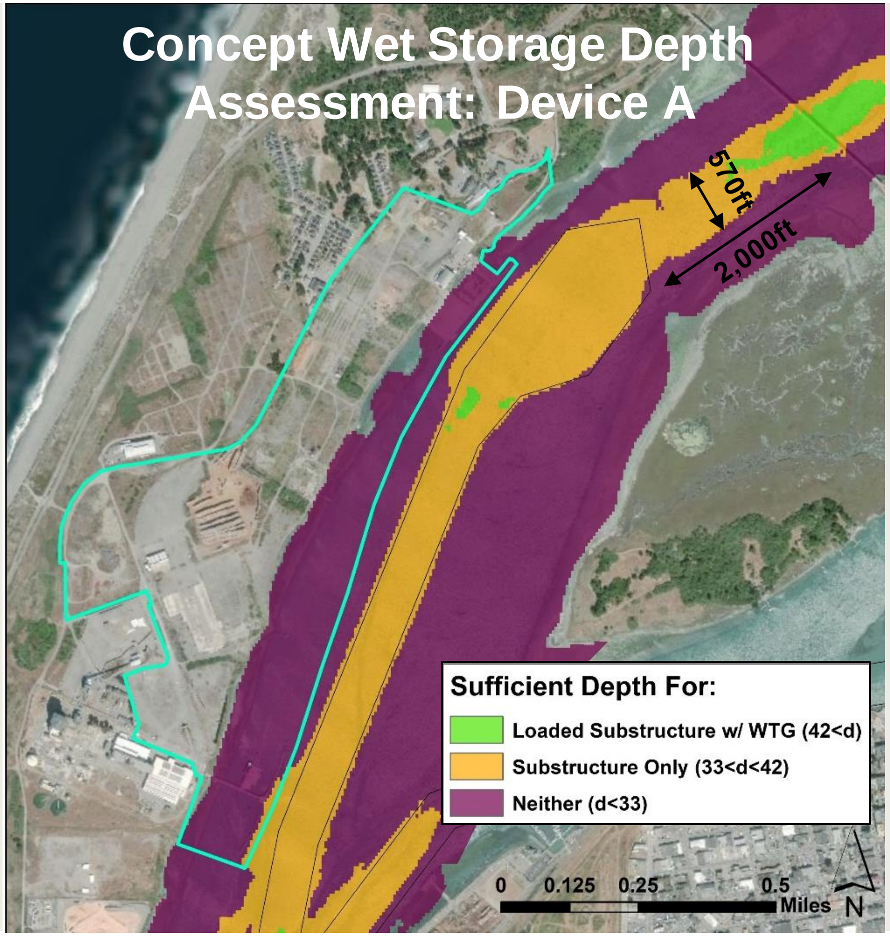
Concept Depth Assessments – Approach

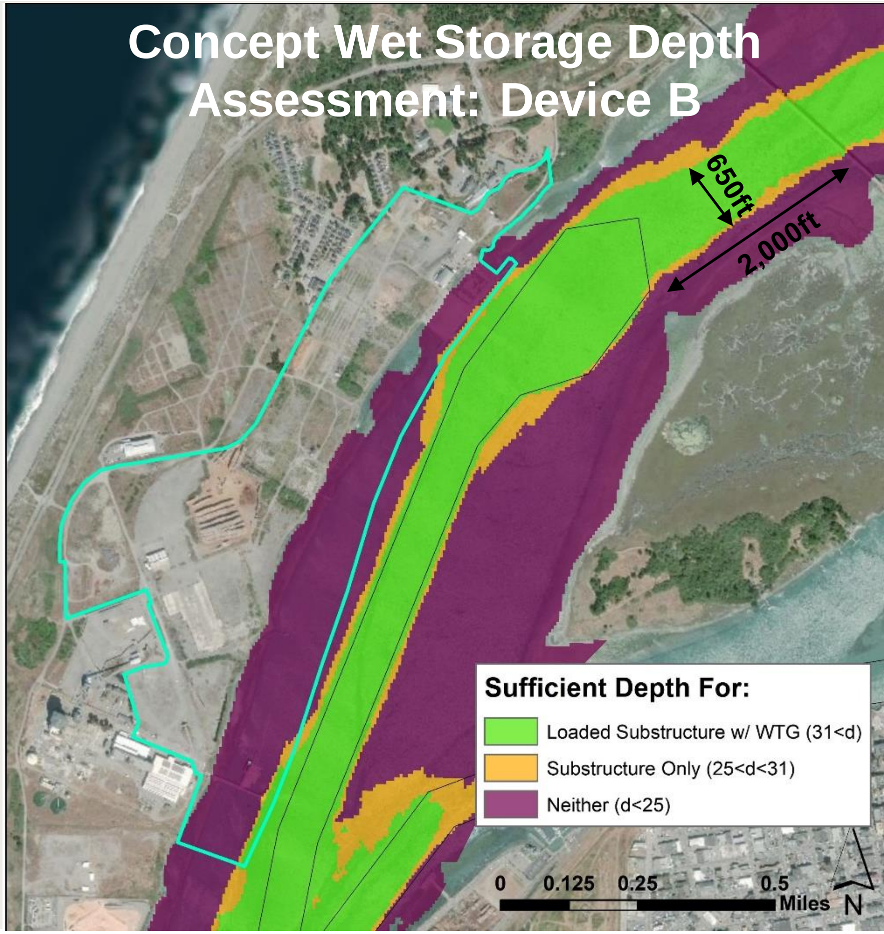
- Approach:
  - Concept Depth Requirements compared to existing depths in Humboldt Bay
  - Assess conditions within the FNC and outside the FNC
- Outcomes:
  - Estimate which activities can be conducted without dredging, and under what conditions dredging may be required.
- Data:
  - This assessment was conducted based on the NOAA (2009) Eureka Digital Elevation Model, and represents a snapshot of elevations in time. A more recent bathymetric survey, including areas outside of the navigation channel, is needed to refine this assessment.



Concept Wet Storage Depth Assessment

- Takeaways:
- Device A
  - There may be sufficient area and depth north of the Samoa Turning basin for temporary storage of 2-4+substructures, although dredging may be needed to provide sufficient area.
  - Dredging would be needed outside of the navigation channel to accommodate wet storage for assembled devices.
- Device B
  - There may be sufficient area and depth north of the Samoa Turning Basin for temporary storage of 2-4+substructures or assembled devices.

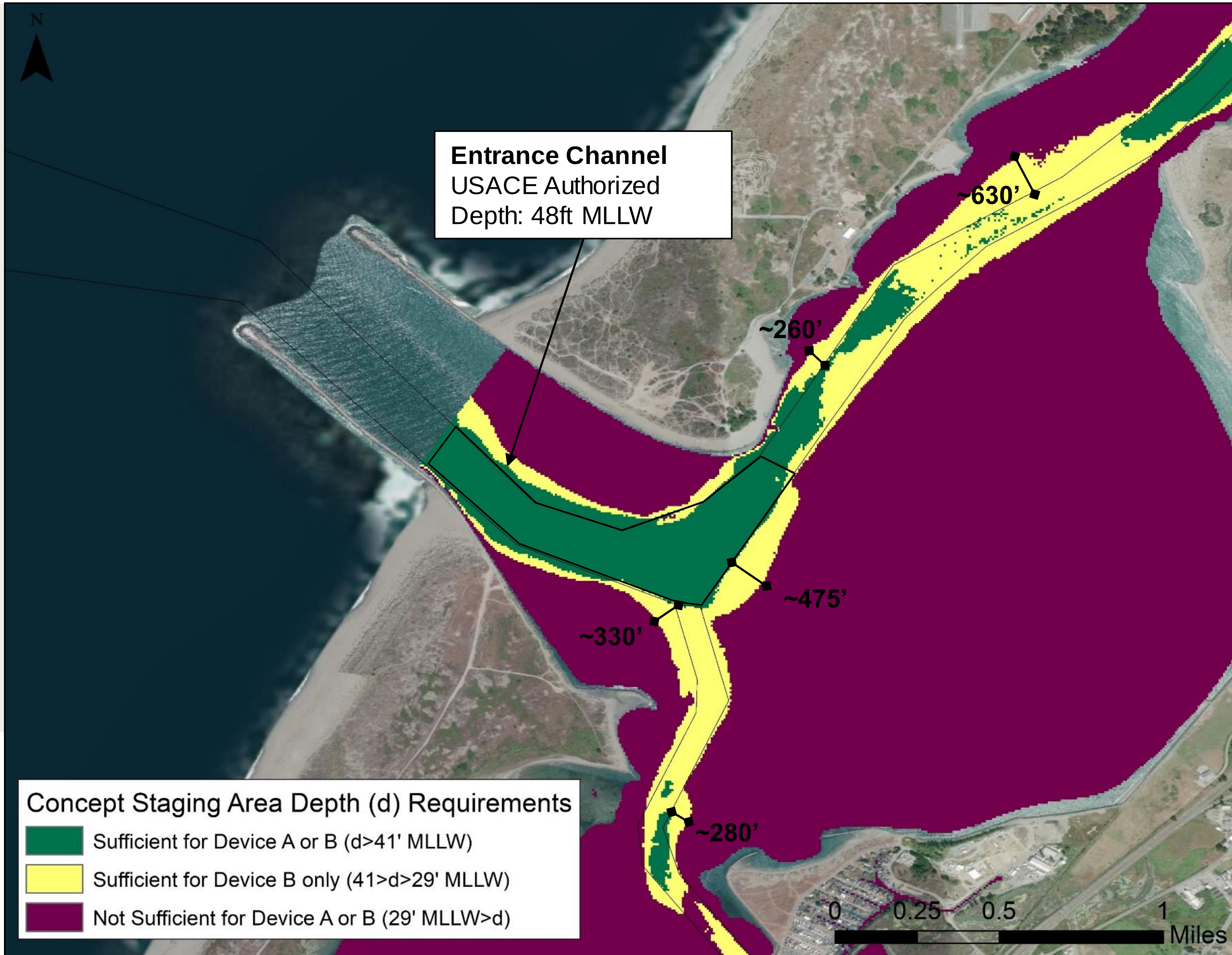




Staging Area Depth Assessment

- Takeaways:
- Pilot-Scale Scenario
  - Depths within the Entrance Channel are sufficient for staging of either Device A or Device B (not considering shoaling).
- Large Commercial-Scale Scenario
  - More recent hydrographic survey is needed to assess potential staging outside of the Federal Navigation Channels.
  - Based on available data, temporary staging of a limited number (1-3) of assembled WTGs outside of the navigation channel may be feasible for the smaller range of device geometries (Device B).
  - For the larger range of device geometries (Device A), dredging would be needed to stage devices outside of the Entrance Channel.

Note: assessment based on elevations from NOAA Eureka DEM (2009); does not consider shoaling.



Ballasting Area Depth Assessment

Legend: FNC Likely Not Sufficient | FNC Potentially Sufficient | FNC Likely Sufficient

Device	Ballast Level	Device Draft	Entrance Channel Authorized Channel Elevation*	Concept Channel Geometry Requirements – Assessed at MLLW	Concept Ballast Area Depth Requirements - (MHW)
A	50% Ballasted	48 ft.	-48 ft. MLLW		
A	Fully Ballasted	60 ft.	-48 ft. MLLW		
			-48 ft. MLLW		
B	50% Ballasted	35 ft.	-48 ft. MLLW		
B	Fully Ballasted	45 ft.	-48 ft. MLLW		

Note: This assessment compares the Concept Depth Requirements to the USACE Authorized Depth of the Entrance Channel and does not consider shoaling. The depth at the Entrance Channel is less than the authorized depth for a period of time each year due to shoaling and limitations on maintenance dredging schedule (see Appendix A-1 Entrance Channel for more details).

Takeaways:

- Device A: 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.
- Device B: Some ballasting may be at high water levels within the FNC near the entrance (little-to-no shoaling). Fully ballasting the smaller WTG device may be possible within the FNC for favorable environmental conditions (calm, no shoaling, high water levels).
- Dredging: To conduct ballasting activities outside the FNC dredging would be required.

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Outcomes & Next Steps

Outcomes

Pilot/Small-Commercial Scale

- 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 capabilities.
- Wet-storage of un-assembled devices near RMT1 appears to be possible with no, or limited dredging
- Limited wet-storage of assembled devices near RMT1 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.
- A limited number of devices may potentially be staged outside the FNC near the entrance without dredging for the low range of device drafts assessed. For other devices, dredging outside the FNC would be required to support a staging area.
- Dredging would be required for fixed location ballasting activities outside of the Entrance Channel.
- A coastal engineering analysis would be needed to optimize staging, storage, and ballasting locaitons relative to waves, currents, dredging volume, mooring requirements, and sedimentation.

Large Commercial Scale

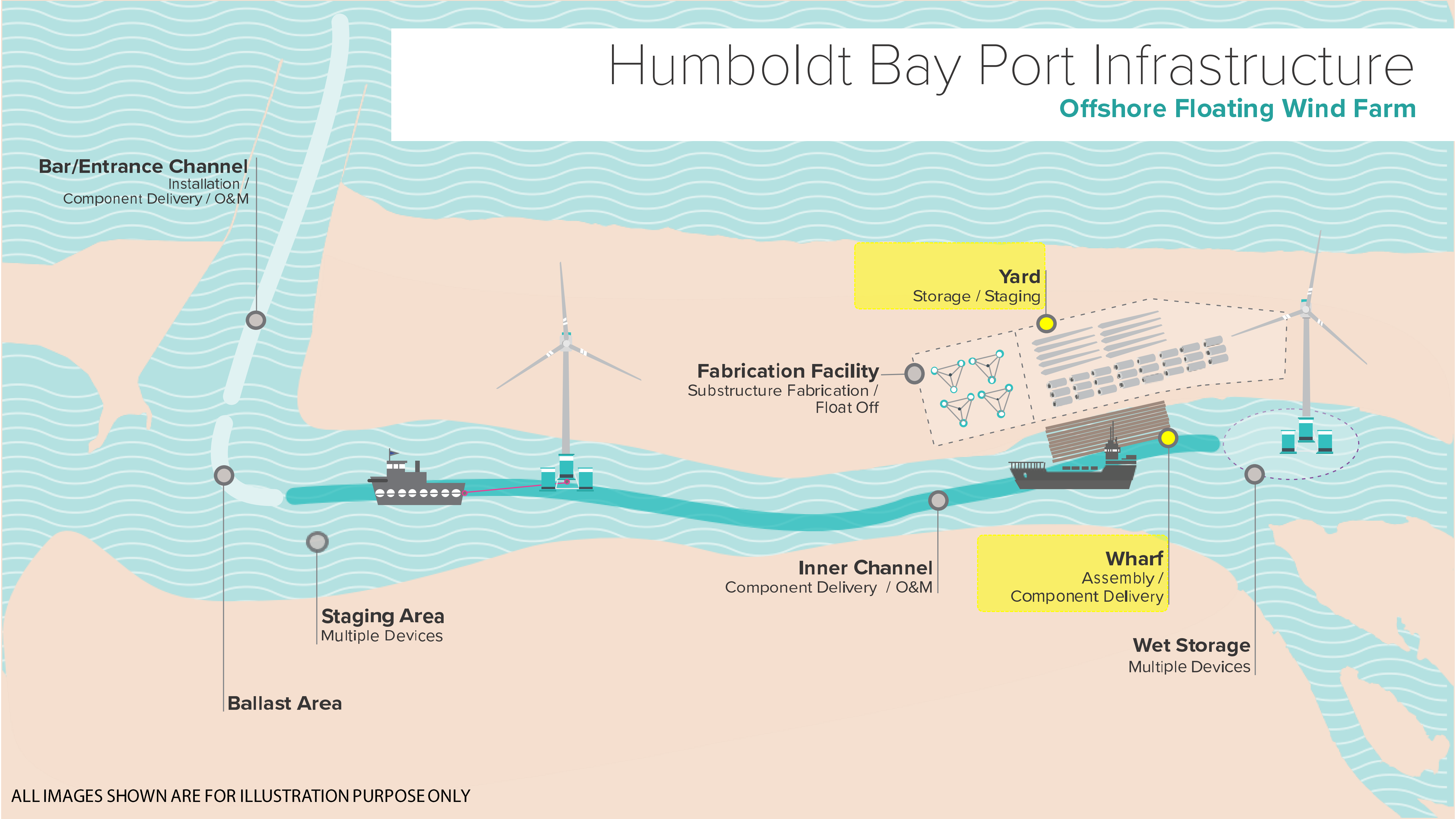
- Similar findings to Pilot/Small-Commercial Scale. However, wet-storage and staging areas may be larger to maintain throughput.

Appendix B Wharf and Yard

This appendix consists of a capabilities and gap assessment of the assembly facilities, including the berth, wharf, and yard. The necessary renovations for a pilot/small-commercial and large commercial scale project at RMTI and RMTII are explored as well as requirements for the berth, wharf, and yard that would need to be constructed at each site.

Apendix B: Wharf & Yard

Assembly Facility Capabilities & Gap Assessment



Humboldt Bay Port Infrastructure
Offshore Floating Wind Farm
Bar/Entrance Channel
Installation / Component Delivery / O&M
Yard
Storage / Staging
Fabrication Facility
Substructure Fabrication / Float Off
Inner Channel
Component Delivery / O&M
Wharf
Assembly / Component Delivery
Staging Area
Multiple Devices
Wet Storage
Multiple Devices
Ballast Area
ALL IMAGES SHOWN ARE FOR ILLUSTRATION PURPOSE ONLY

Primary Objectives

Berth

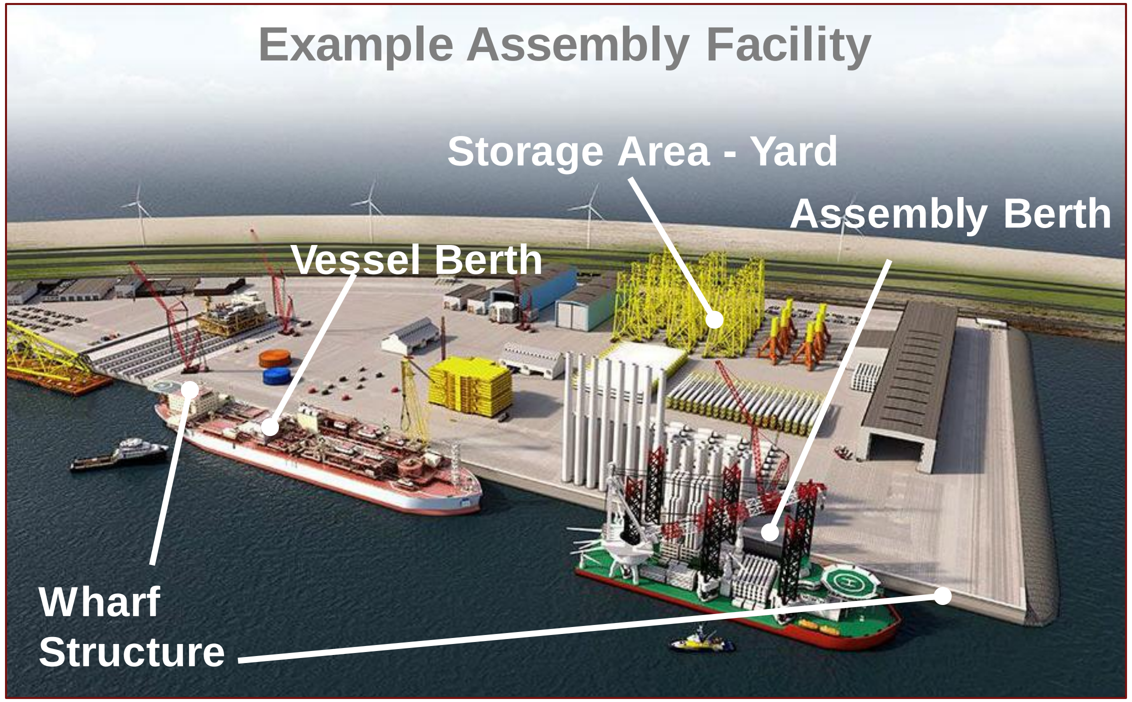
- Is any dredging required?
- Will the berth dredging exceed depth of FNC?
- What are the interferences/complexities associated with dredging?

Wharf

- Are existing wharf facilities sufficient?
- Do new facilities need to be larger than the existing facility footprint?
- What are the constraints for locating and orienting the wharf?

Yard

- Is the available area in the RMTI/RTMII sufficient to support assembly, fabrication, and O&M?
- Is ground improvement required for storage and movement of components?



Port of Rotterdam Offshore Center – Maasvlakte 2; Source: The Maritime Executive

Berth, Wharf & Yard Assessment Outline

Basis of Analysis

Geotechnical Conditions

Berth

- Conceptual Assessment Criteria
- Site Conditions and Gap Analysis

Wharf

- Conceptual Assessment Criteria
- Site Conditions and Gap Analysis

Wharf and Berth Layout Considerations

Yard

- Conceptual Assessment Criteria
- Site Conditions and Gap Analysis

Outcomes

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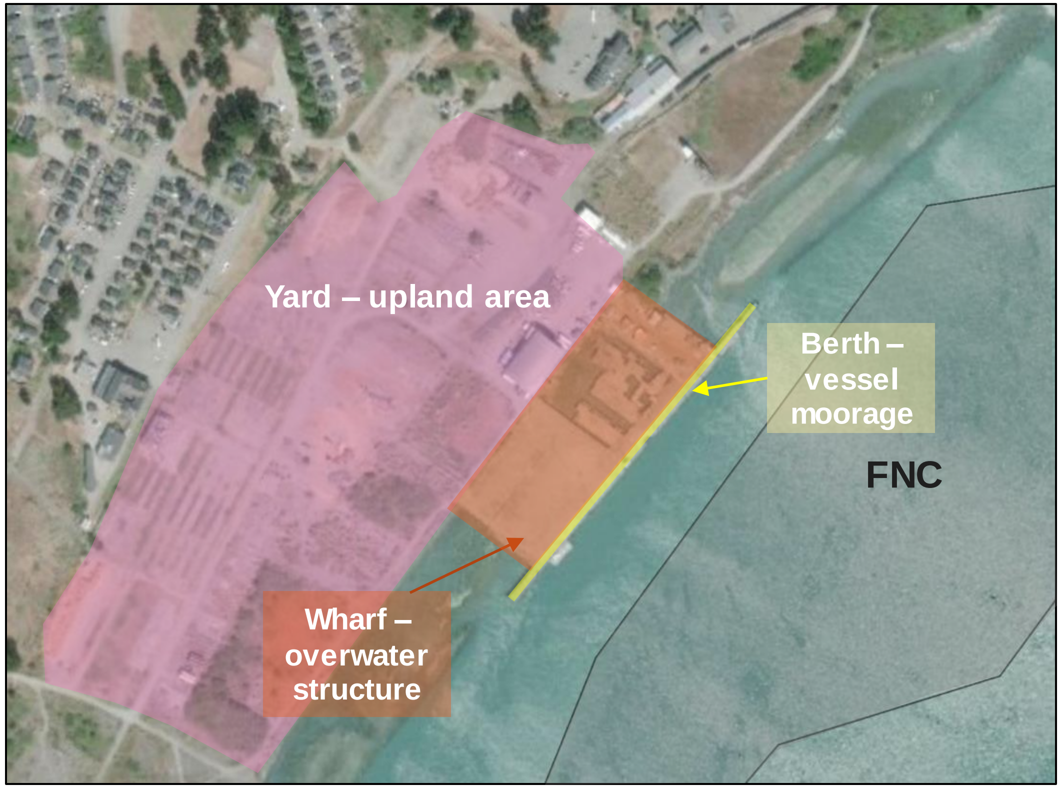
Basis of Analysis

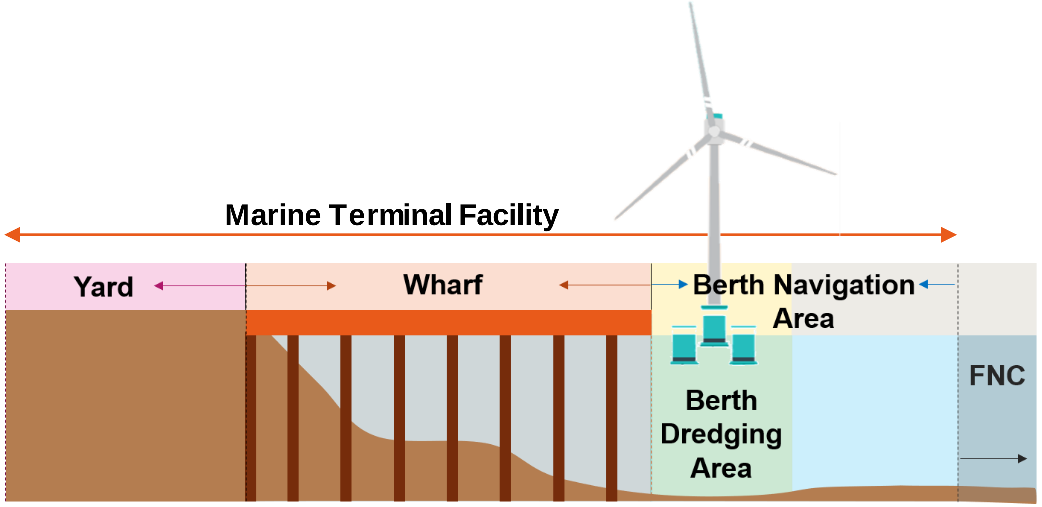
Terminology

The following terms are defined for use in this study as follows:

- **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.
- **Wharf:** overwater structure that is usually parallel with the shoreline, and can be "open" (pile-or column supported) or "closed" (solid fill).
- **Yard:** upland part of a marine terminal.

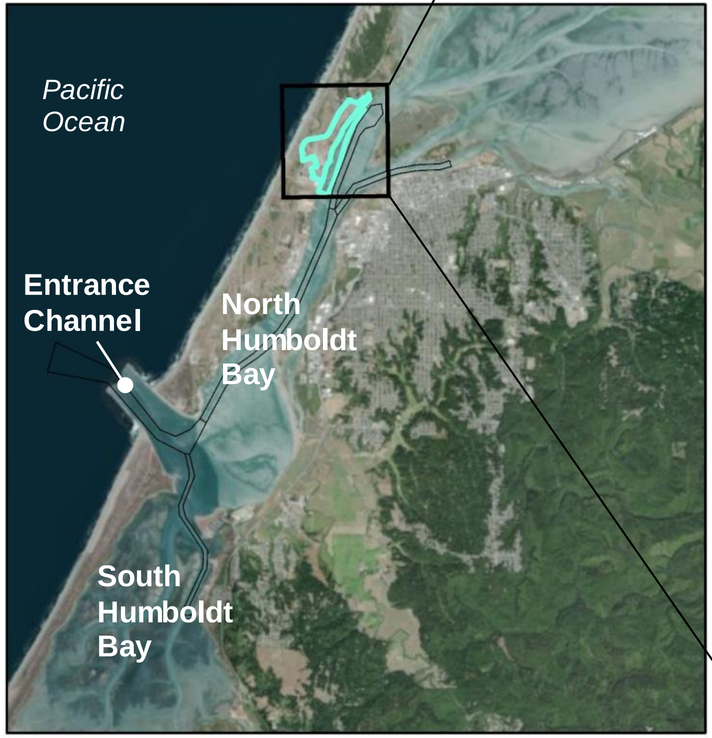
Terminology shown at Redwood Marine Terminal I (RMTI) as an example.

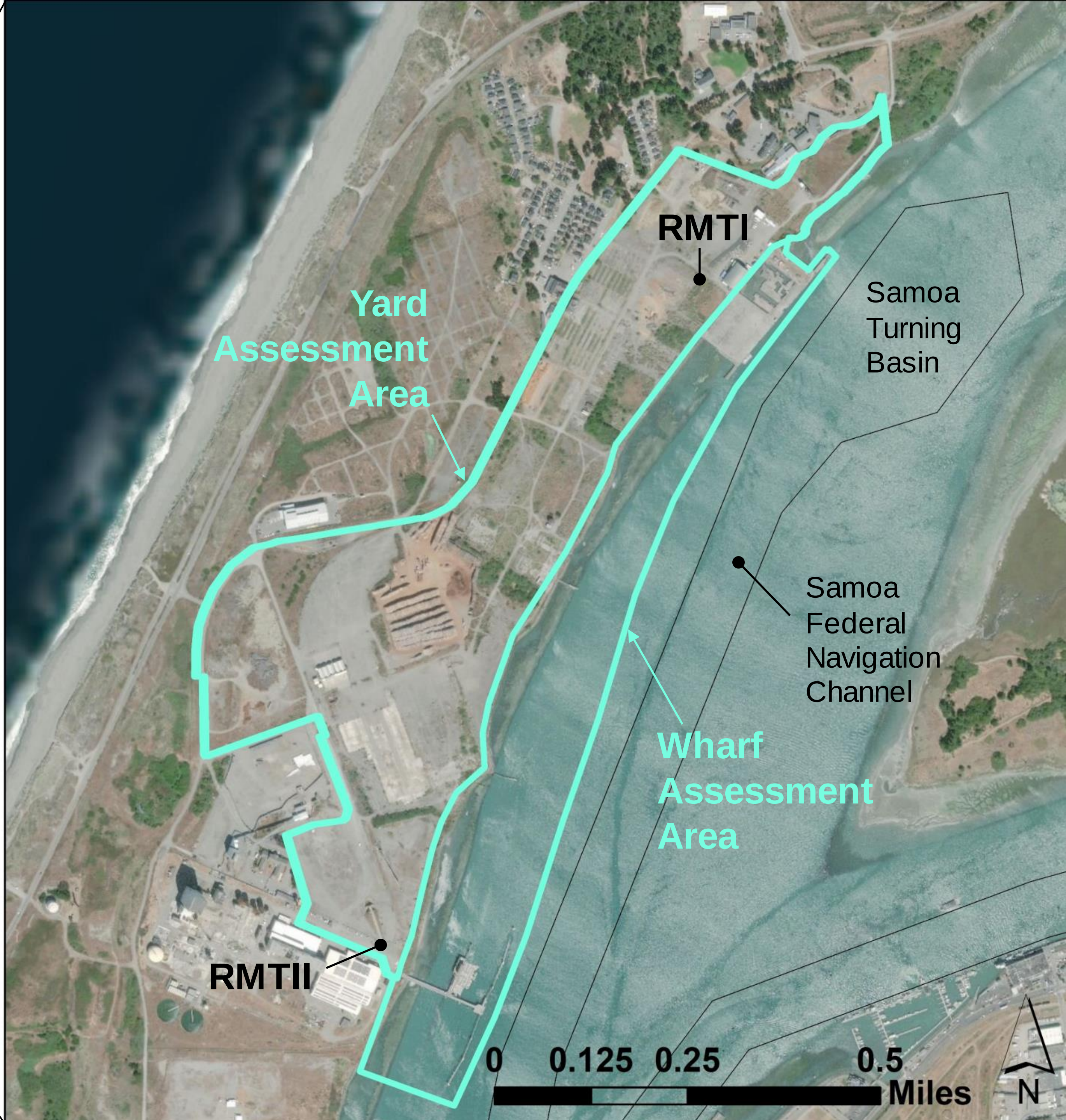




Assessment Area

- The Assessment Area represents the assumed extents of area for potential use as an Assembly Facility.
- 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).





Criteria Development

- Criteria for berth, wharf and yard requirements were developed with consideration for:

- Literature Review
  - State Offshore Wind Study Reports (New York, Massachusetts, Virginia)
  - PIANC Guidelines
  - BOEM Publications
  - Port Designer's Handbook
  - USACE Engineering Manuals
  - Humboldt Bay Harbor District Planning Study

- Interviews with floating offshore wind developers and researchers to confirm assumptions

- Prototype projects and industries

Geotechnical Conditions

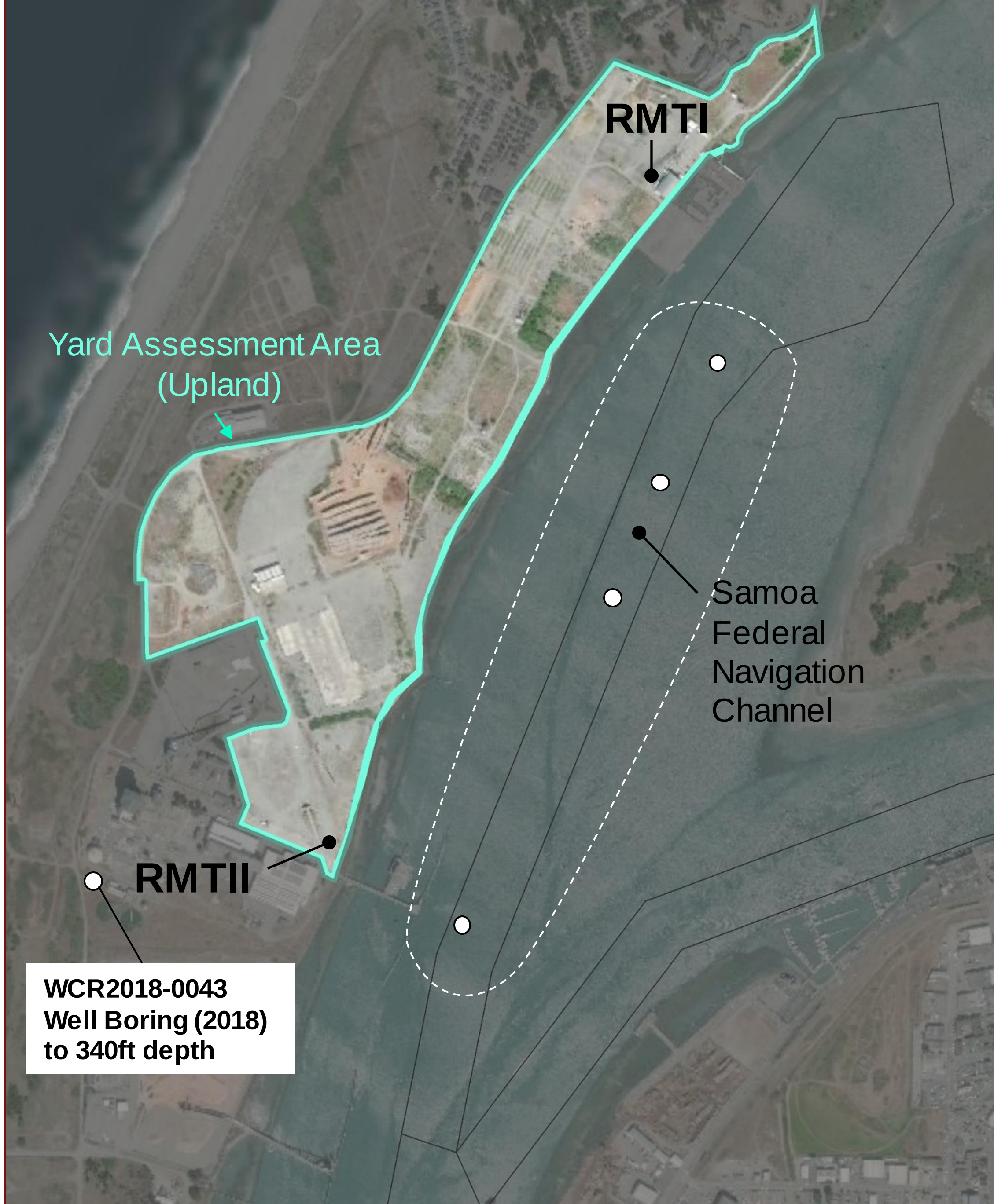
Desktop Review

Existing Geotechnical Conditions

Publicly available information was reviewed to develop an understanding of the geological site conditions.

- Well Completion Report - WCR2008-0043 (Humboldt County DHHS – Land Use Program, 2018)
- Humboldt Bay ISFSI Safety Analysis Report (2005)
- Environmental Impact Report for Samoa Terminal Reconstruction (Busch, 1994)
- Navigation Channel Feasibility Report (USACE, 1976)
- Geologic Hazard Evaluation and Soils Engineering Report, Samoa Peninsula Wastewater Project (SHN, 2018)
- Discussions with local experts (SHN)

Available Subsurface Data



Geotechnical Summary

Parameterized conditions – subject to investigation

- Wharf

  Prior designs included utilizing both open pile and closed solid fill wharf/pier structure concepts.

  Liquefaction likely negligible in load bearing soils.

  Foundation-bearing soils at the project site are primarily medium dense to very dense poorly graded fine to medium sands.

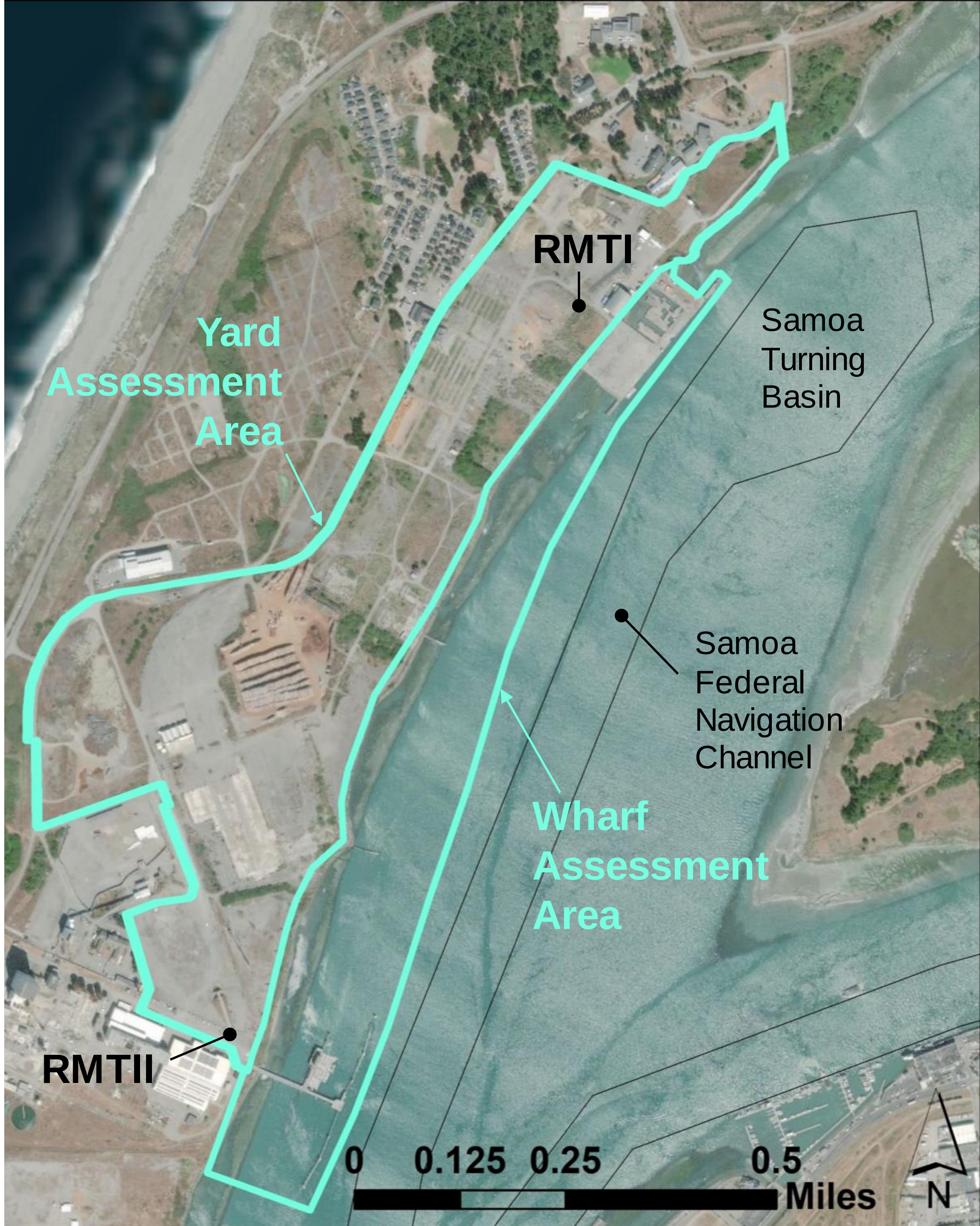
  Alternating layers of clay with silt and sand with gravel may be encountered below the existing mudline.

- Yard

  Native sediment likely includes 10-20ft depth of loose sands.

  Below 10-20 ft depth, dense material is likely. In dense material, liquefaction is likely negligible. Woody debris and shell material may be encountered.

Subsurface investigation study, with borings and potentially geophysical methods, needs to be conducted prior to conceptual engineering



Berth
Assessment Criteria

Introduction

Berth Considerations

Depth

Berth geometry to allow for under keel clearance below vessel/device at extreme low water.

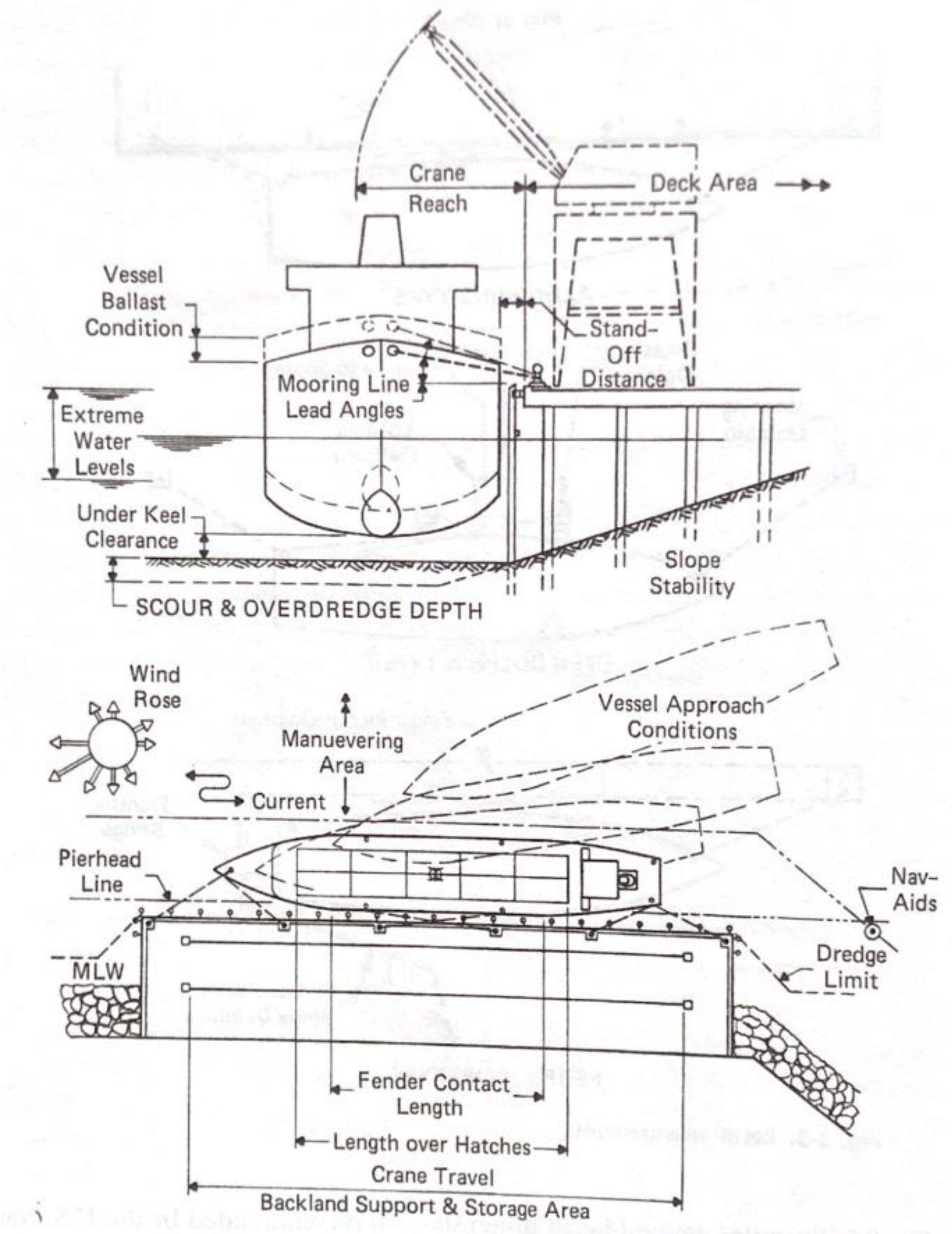
Maneuvering area depth may be shallower than berth depth, depending on water level requirements for approach.

Geometry

Length to provide for vessel/device mooring and loading/offloading.

Maneuvering area to accommodate vessel approach and device assembly.

Consider currents/winds.



Assumptions - Design Substructure Dimensions

- A range of floating offshore wind turbine substructure geometries was developed based on literature review, interviews with developers, and existing prototypes.
- Range is intended to bracket potential substructure geometries, from the smaller end (Device A) to the larger end (Device B) to help inform the assessment.

Device A
Representative of larger substructure geometry

Device B
Representative of smaller substructure geometry

Device	Substructure Dimension
	Beam/Length (LOA)
Device A	300ft.
Device B	200ft.
	Draft
Device A:	
Substructure Only	28 ft.
Loaded w/ WTG	36 ft.
Device B:	
Substructure Only	20 ft.
Loaded w/ WTG	25 ft.

Assumptions - Design Vessel Dimensions

- Assumed vessels to support assembly are documented in the Design Vessel Appendix (see Appendix I).
- Component delivery vessels (breakbulk carriers, barges, cargo vessels) and heavy lift vessels may deliver WTG components to the Assembly Facility, but the dimensions of heavy lift vessels will control for design.

Vessel	Vessel Dimension
	Beam
Component Delivery Vessel	80-140ft
Heavy Lift Vessel	140-170ft
	Length Overall (LOA)
Component Delivery Vessel	400-650ft
Heavy Lift Vessel	500-800ft
	Draft
Component Delivery Vessel	18-35ft
Heavy Lift Vessel	28-35ft

***Vestvind* Component Delivery Vessel**

***Bokalift 1* specialty heavy lift vessel transporting fixed WTG foundations**

Assumptions – Berth

The berth geometry should be sufficient to accommodate:

- An **Assembly Berth** for dockside turbine (WTG) assembly; and
- A **Vessel Berth** for component delivery and unloading.

Pilot-Scale Scenario

- One multipurpose berth will serve as both a Vessel Berth and an Assembly Berth.

Large Commercial-Scale Scenario

- Two purpose-built berths (one Vessel Berth and one Assembly Berth)
  - Simultaneous component delivery and WTG assembly to support serial production.
  - Depending on throughput, yard size, and year-round navigation availability in the Entrance Channel, a multi-purpose berth may be possible.

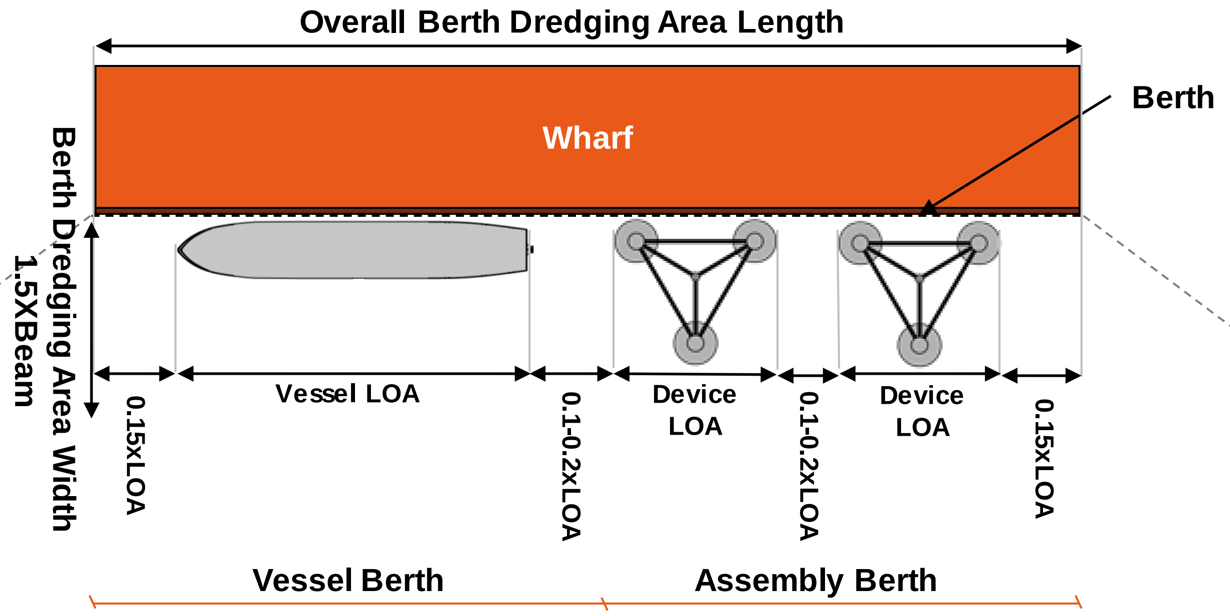
Assumptions – Berth Geometry

Berth Length

- Device and Vessel Spacing
  - 10-20% the length of the larger device/vessel, with a minimum spacing of 50ft.
- Berth Dredging Area Length
  - Extend 15% beyond the length of the design device or vessel.
  - *Note: the Wharf could be shorter relative to the length of the Berth Navigation Area with the use of mooring dolphins; to be determined in a later phase.*

Berth Navigation Area Width

- It is assumed that the Berth Navigation Area width should be a minimum of 1.5X the beam of the design device or vessel.

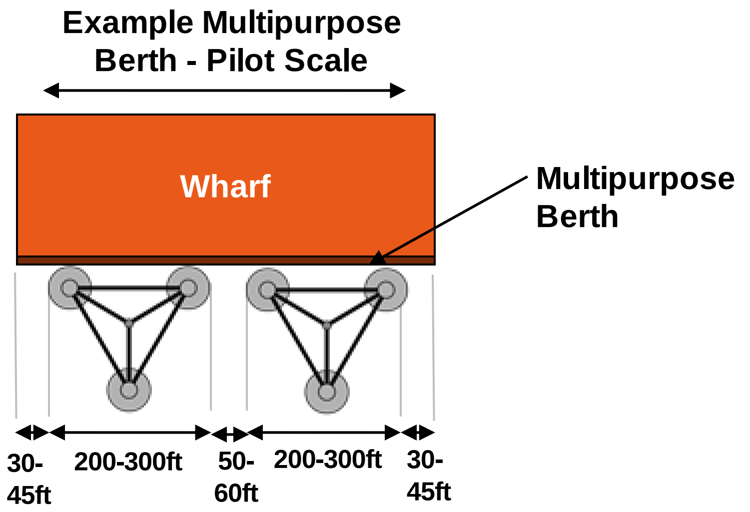


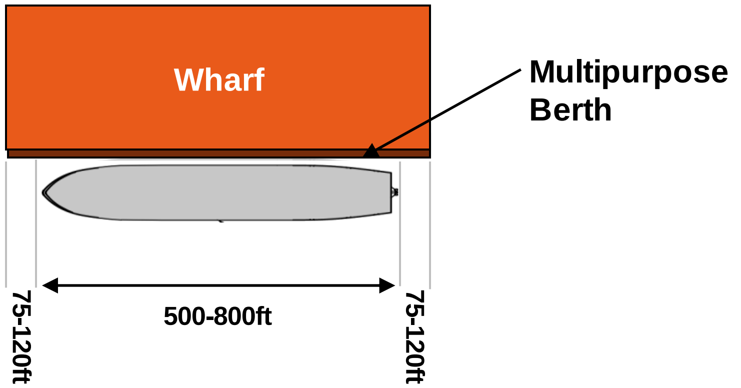
Schematic for Example Commercial Scale Wharf and Berth

Assessment Criteria – Berth Length

Pilot Scale Scenario

- Berth Length – Pilot Scale Scenario
- One multipurpose berth
  - The berth length must be sufficient for accommodating both component delivery and assembly activities.
  - Note: this assumption is only valid if all component delivery precedes assembly activities. Feasibility to be studied in a future phase.
- Berth Length
  - Simultaneous assembly of 2 WTGs is likely similar to Vessel Berth Length
- **Assumed Berth Length Criteria**
  - Assuming 2 WTGs assembled simultaneously:
    - Device A: 750ft to 1000ft
    - Device B: 650ft to 1000ft





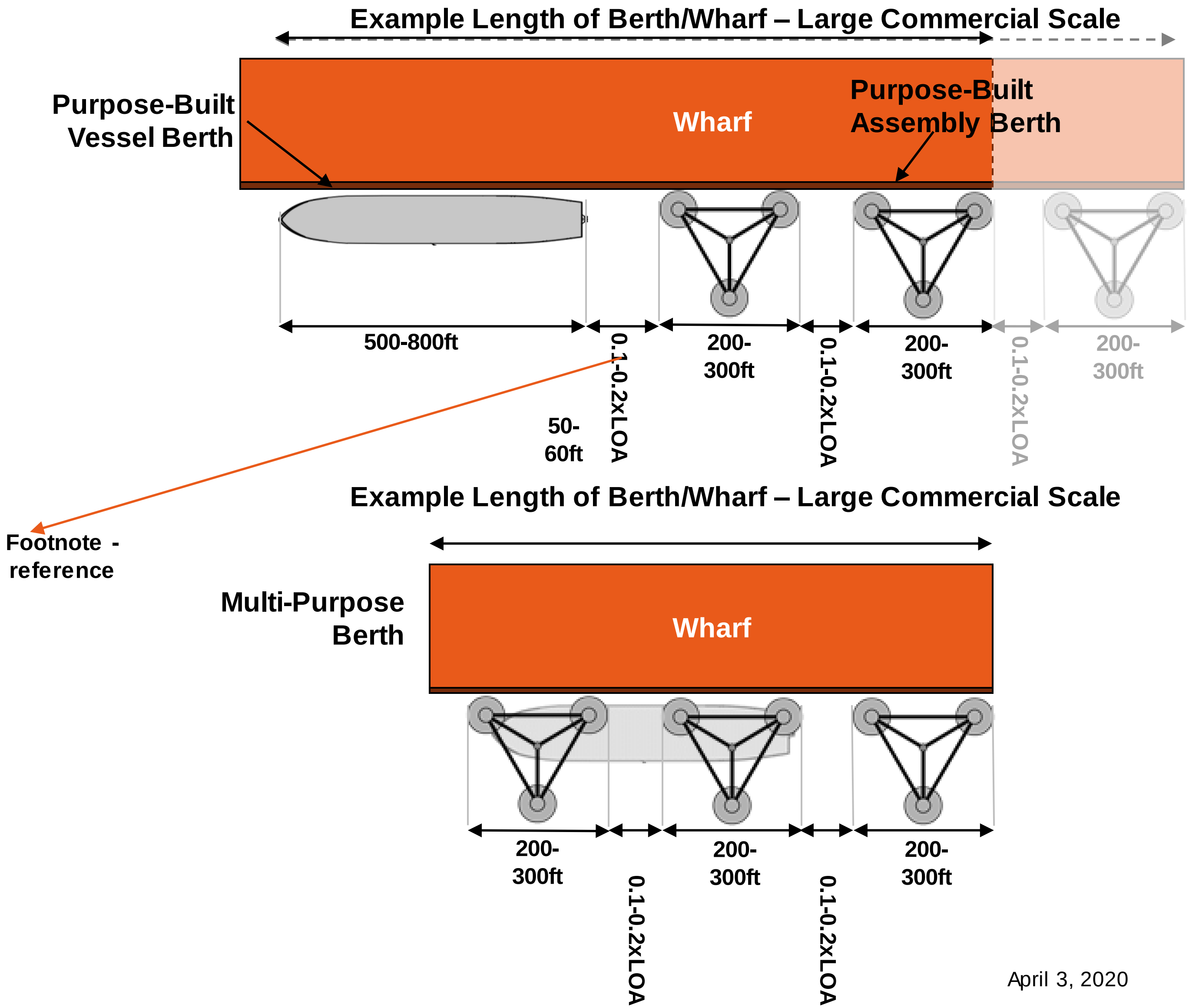
Takeaway:
Berth length likely between 650-1,000ft.

Assessment Criteria – Berth Length

Large Commercial-Scale Scenario

- Berth Length – Large Commercial-Scale Scenario
- **Assumed Berth Length Criteria**
  - Assuming 2 WTGs assembled simultaneously:
    - Device A: 1,350 to 1,800ft
    - Device B: 1,100 to 1,550ft
  - Assuming 3 WTGs assembled simultaneously:
    - Device A: 1,650 to 2,100ft
    - Device B: 1,350 to 1,800ft
  - Note: Length may be reduced if

Takeaway:
Berth length likely between 1,100-2,100ft, depending on # of devices and use of component delivery berth during assembly season



Assumptions – Berth Depth

- Under Keel Clearance (UKC)
- ~2-3ft of UKC for vessel and device moorage
- Water Levels
- The Berth Dredging Area
  - LAT, since vessels and WTG devices will be berthed for duration of construction season
- The Berth Navigation Area
  - Depth assumed to be similar to navigation channel depth for device maneuvering/tow-out (see Appendix A1 Inner Channel).

Assessment Criteria – Berth Dredging Area Depth

Design Vessel or Device	Device Draft	Concept Depth Requirements – All Tides (LAT)
VESSEL BERTH:		
Component Delivery Vessel	18-35ft.	22-40ft. MLLW
Heavy Lift Vessel	28-35ft.	32-40ft. MLLW
ASSEMBLY BERTH:		
Device A (Loaded w/ WTG)	36ft.	~40ft. MLLW
Device B (Loaded w/ WTG)	25ft.	~29ft. MLLW
Heavy Lift Vessel for Assembly Support	28-35ft.	32-40ft. MLLW

Note: This criteria was developed for the design vessel and devices for component delivery and device assembly activities. Berth Dredging Area depth requirements for fabrication or float-off are not addressed in this appendix (see Appendix C Float Off and Delivery).

Berth Conceptual Assessment Criteria Summary

Berth Dredging Area Criteria Summary

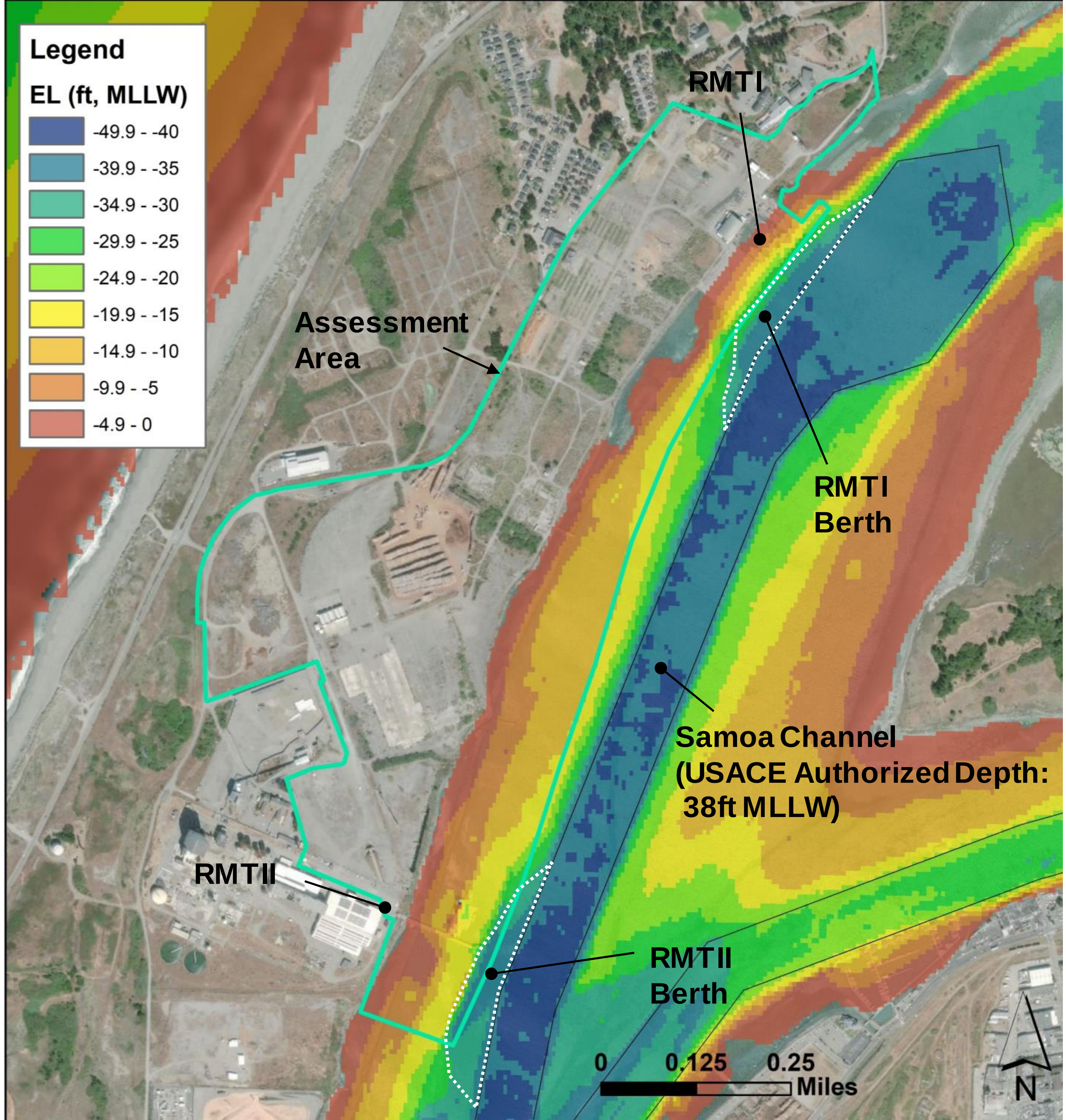
Element	Berth Criteria
Berth Length	Pilot Scale: 1 multipurpose berth 650ft to 1,000ft Large Commercial Scale: 2 purpose-built berths or multi-purpose berths 1,100ft to 2,100ft
Width of Berth Navigation Area	Pilot and Large Commercial Scales: 300- 450ft
Depth of Berth Dredging Area	Pilot Scale: 1 multipurpose berth ~32-40ft. MLLW Large Commercial Scale: Vessel Berth: ~32-40ft. MLLW Assembly Berth: ~29-40ft. MLLW

Note: the criteria summarized here was developed for an Assembly Port Facility (to support component delivery and WTG assembly). Criteria for a substructure fabrication facility is not addressed in this Appendix.

Berth Site Conditions & Gap Assessment

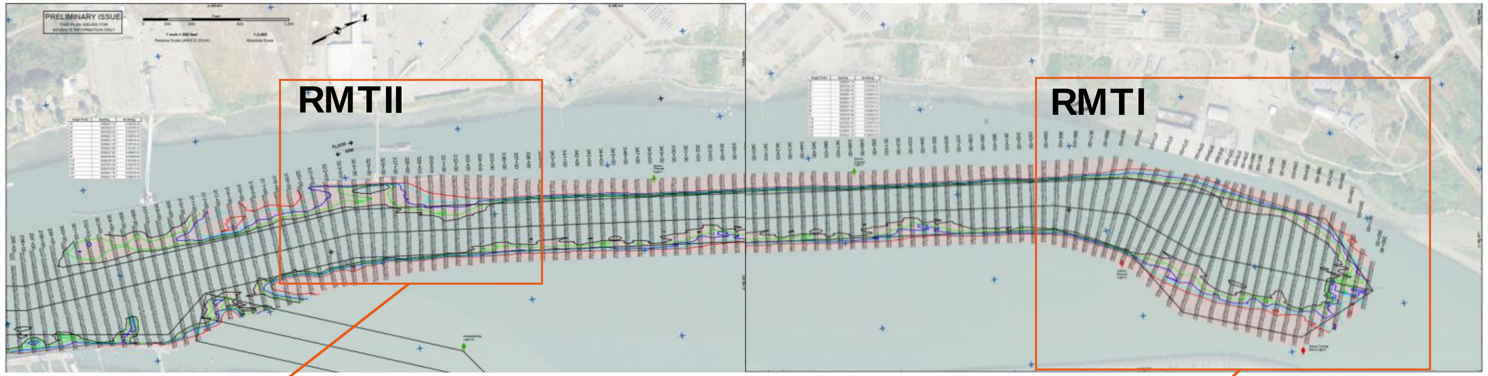
Existing Elevations

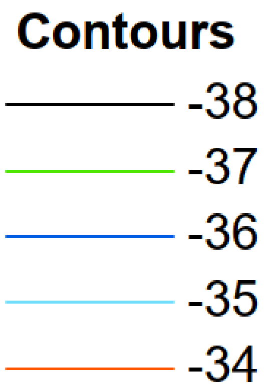
- Elevations shown represent NOAA Eureka DEM (2009).
- Presently depths ranging from 30-40ft MLLW at the RMTI and RMTII berth areas
- Dredging outside of the navigation channel was historically conducted on an “as-needed” basis at the RMTI and RMTII berth.
- Between RMTI and RMTII, the depths within the Assessment Area are shallower than 20ft MLLW.

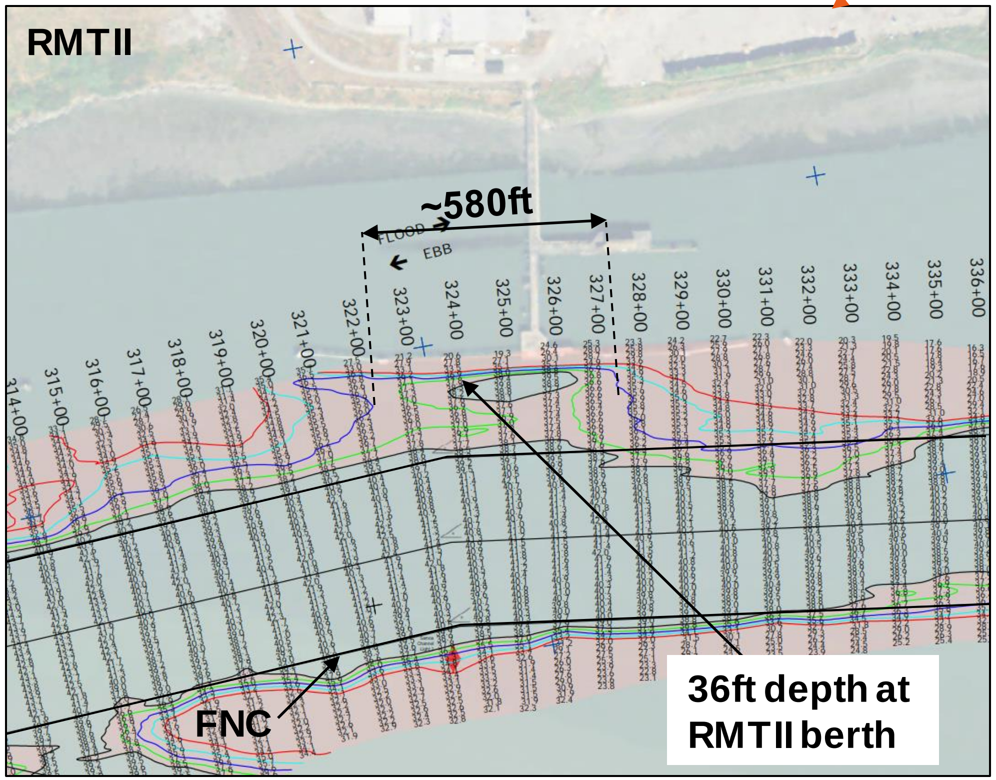


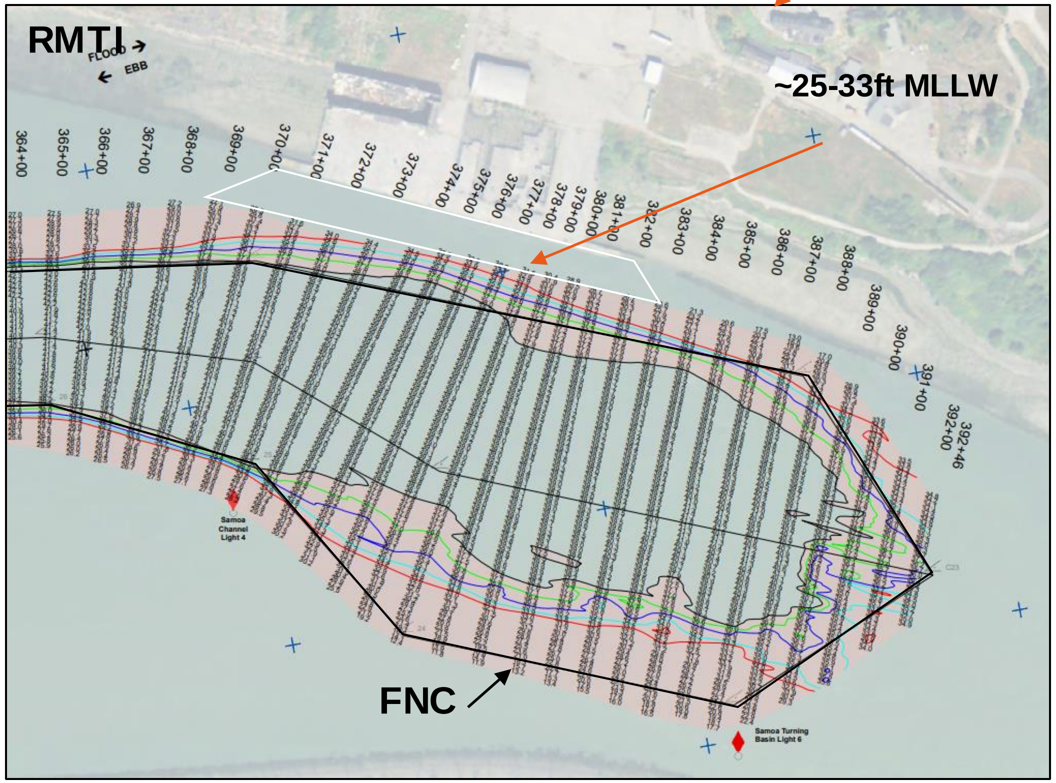
Existing Elevations – USACE April 2020 Condition Survey

Recent USACE Condition Survey data (focusing on the navigation channel), was checked for updated elevations in the Assessment Area, relative to the 2009 NOAA DEM.









Berth Dredging Area Depth Assessment – Outside FNC

For Component Delivery and WTG Assembly

Legend: Dredging Likely Required | Dredging May Be Required | Depth Likely Sufficient

Design Vessel or Device	Device Draft	Concept Depth Requirements: (LAT)	RMT I	RMT II	Between RMTI/RMT II
VESSEL BERTH:			Existing Depth ~ 25ft.	Existing Depth ~ 36ft.	Existing Depth <20ft.
Component Delivery Vessel	18-35ft.	22-40ft. MLLW			
Heavy Lift Vessel	28-35ft.	~32-40ft. MLLW			
ASSEMBLY BERTH:					
Device A (Loaded w/ WTG)	36ft.	~40ft. MLLW			
Device B (Loaded w/ WTG)	25ft.	~29ft. MLLW			
Heavy Lift Vessel	28-35ft.	~32-40ft. MLLW			

Takeaways:

- The existing depths at the existing berths are not sufficient for most berthing needs.
- At a minimum, maintenance dredging is likely for the vessel berth and assembly berth, and capital dredging may be required depending on final location.
- If a change in berth location from RMT I/RMT II more dredging volume is required than at existing berths.

Berth Dredging Area Depth Assessment – If Dredged to FNC Depth

For Component Delivery and WTG Assembly

Legend: Authorized Depth Likely Not Sufficient | Authorized Depth May be Sufficient | Authorized Depth Likely Sufficient

Design Vessel or Device	Device Draft	Concept Depth Requirements: (LAT)	FNC Depth
VESSEL BERTH:			Depth = 38ft. MLLW
Component Delivery Vessel	18-35ft.	22-40ft. MLLW	Authorized Depth Likely Sufficient
Heavy Lift Vessel	28-35ft.	~32-40ft. MLLW	Authorized Depth Likely Sufficient
ASSEMBLY BERTH			
Device A (Loaded w/ WTG)	36ft.	~40ft. MLLW	Authorized Depth Likely Not Sufficient
Device B (Loaded w/ WTG)	25ft.	~29ft. MLLW	Authorized Depth Likely Sufficient
Heavy Lift Vessel	28-35ft.	~32-40ft. MLLW	Authorized Depth Likely Sufficient

Takeaways:

- The authorized navigation channel depth (38ft MLLW) would likely be a sufficient depth for the vessel berth, unless the larger range of component delivery and heavy lift vessels are utilized.
- The authorized navigation channel depth (38ft MLLW) may be a sufficient depth for the assembly berth for the smaller range of device geometries considered (Device B). Dredging deeper the authorized channel depth would likely be needed for the larger range of device geometries considered (Device A).
- Maintenance dredging requirements should be assessed separately.

Berth Gap Assessment

Berth Criteria Summary

Element	Existing Conditions	Berth Criteria	Berth Gap Assessment
Geometry & Depth	**DEPTH** RMTI: • Shallower than 25-33ft MLLW, but a hydrographic survey is needed to confirm. RMTII: • ~36ft MLLW for a length of 580ft. **LENGTH** There is no consistently maintained berth dredging area within the Assessment Area.	**BERTH DREDGING AREA DEPTH** Pilot Scale: 1 multipurpose berth ~32-40ft. MLLW Large Commercial Scale: Vessel Berth: ~32-40ft. MLLW Assembly Berth: ~29-40ft. MLLW **LENGTH** Pilot Scale: 650ft to 1,000ft Large Commercial Scale: 1,100ft to 2,100ft	The existing RMT I/RMT II berth areas likely do not provide sufficient depths. At a minimum, maintenance dredging is required. **DEPTH** Pilot Scale Scenario • Dredging will be required. It may be required to a few feet below the FNC authorized depth. Large Commercial Scale Scenario • Vessel Berth: Dredging is likely needed. The type of vessel is likely available which would not require dredging deeper than the existing FNC depth. • Assembly Berth: Dredging will be required. It may be required to a few feet below the FNC authorized depth **LENGTH** Dredging outside of the navigation channel will be needed corresponding to berth lengths. Pilot scale may be within historical dredge prism depending on site planning needs. Large-Commercial will require new dredge areas.

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Wharf Assessment Criteria

Assumptions – Wharf

Location

The wharf geometry should be sufficient to accommodate:

- An **Assembly Berth for** dockside turbine (WTG) assembly; and
- A **Vessel Berth** for component delivery and unloading.

Location

- Replacement of the existing wharf is understood to be preferable to construction outside the existing wharf footprint for habitat considerations

Type

- Wharf structure should be able to accommodate high live loads to support component movements, assembly staging, and high-capacity cranes

Width

- The width of the high capacity wharf should be sufficient to accommodate component staging during WTG assembly and the loading/offloading of components.

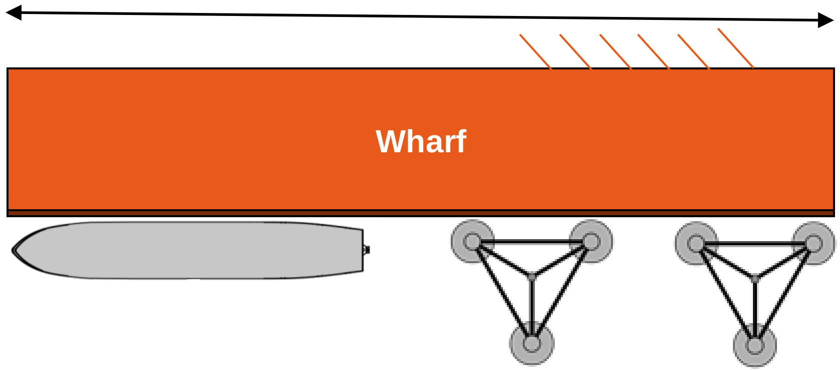

Example Vessel Berth

Example Assembly Berth
IDEOL

Assessment Criteria – Wharf Length

Assumptions

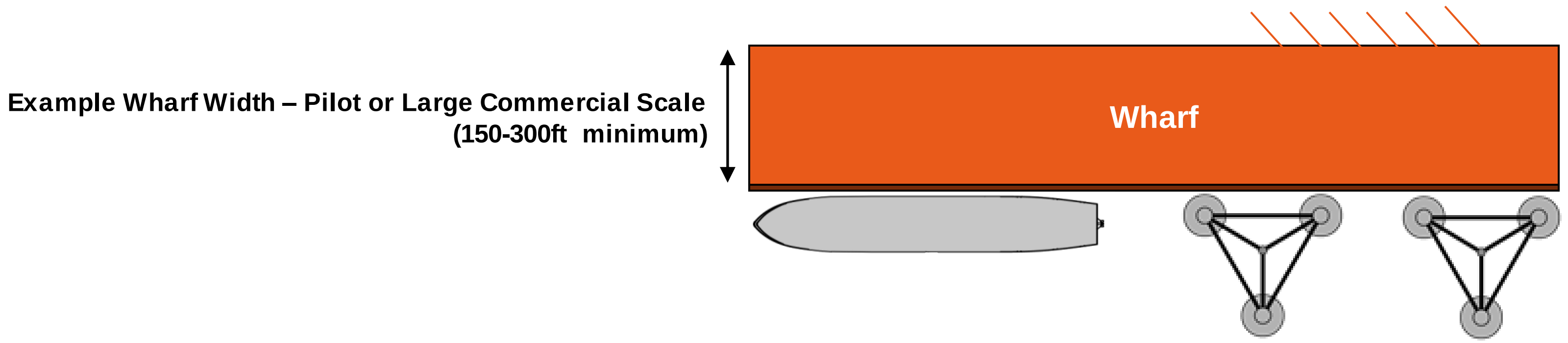
- For this level of pre-feasibility assessment, it is assumed that a marginal wharf extends along the length of the berth dredging area criteria developed in the previous section.
  - Pilot Scale: 650ft to 1,000ft
  - Large Commercial Scale: 1,100ft to 2,100ft
- Wharf length may be shorter relative to the berth length, with the use of mooring dolphins, but may affect offload flexibility.



Assessment Criteria –Wharf Width

Width

- Criteria developed based on literature review of developer interviews and prototype projects and Offshore Wind Port Infrastructure publications.
- Assumed wharf width criteria:
  - Minimum of 150-300ft of high capacity wharf is required for both pilot-scale and large-scale commercial scenarios. Exact width needs to be balanced with operator needs, cost, and habitat considerations.



Assessment Criteria –Wharf Elevation

Elevation Considerations

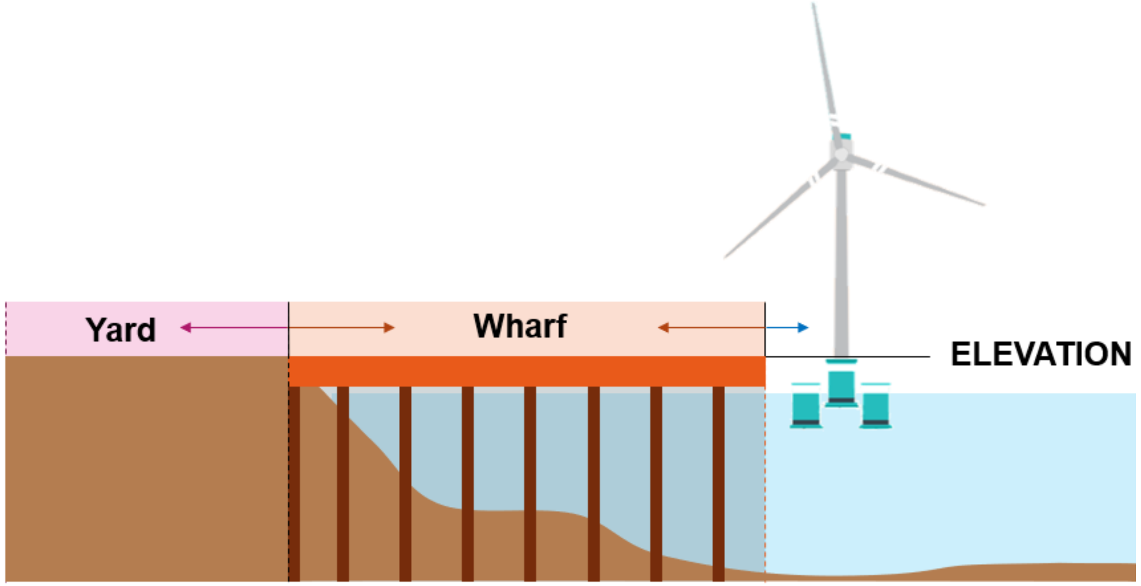
- Minimize overtopping and uplift forces
- Meet cargo handling requirements
- Consider SLR
- Connectivity to yard elevations

Assessment Criteria

- United Facilities Command (4-152-01 Design: Piers and Wharves (Guidelines)
- FEMA Base Flood Elevation + SLR

Minimum Wharf Elevation:

- ~12ft. MLLW
  - SLR Considerations - See Appendix I.



Assessment Criteria –Wharf Live Load Capacity

- Component Delivery (Vessel Berth): 3,000-4,000psf
  - Live load capacity for laydown and SPMT movement of different WTG components.
- WTG Assembly (Assembly Berth): 4,000-6,000psf
  - Live load capacity for laydown and movement of WTG components, and assembly crane.
    - The lower end of the range allows for unrestricted movement of self-propelled modular trailers (SPMTs)
    - The higher end of the range allows for fewer restrictions of movement of large crawler cranes such as Leibherr LR11350
    - Lower-rated live loads may potentially be used; however, load distribution strategies may restrict component movements.
    - Ring crane may be utilized to minimize space requirements, but doesn't allow for mobility

Wharf Conceptual Assessment Criteria Summary

Wharf Criteria Summary

Element	Wharf Criteria
Length	Pilot Scale: 1 multipurpose berth 650ft to 1,000ft Large Commercial Scale: 2 purpose-built berths or multi-purpose berths Device B: 1,100ft to 2,100ft
Width	Minimum 150-300ft of dockside width.
Elevation	~ 12-14ft. MLLW
Live Load Capacity	Component Delivery, Storage & Staging: 3000-4000psf WTG Assembly (heavy lifting operations, crane operation): 4000-6000psf
Other Design Considerations	• Overwater coverage of sensitive habitats should be minimized due to environmental considerations. • Wharf layout and location is linked to the Berth Area and should be designed with consideration for both upland logistics and marine terminal navigation.

Note: The criteria summarized here was developed for an Assembly Port Facility (to support component delivery and WTG assembly). Criteria for a substructure fabrication facility is not addressed in this Appendix.

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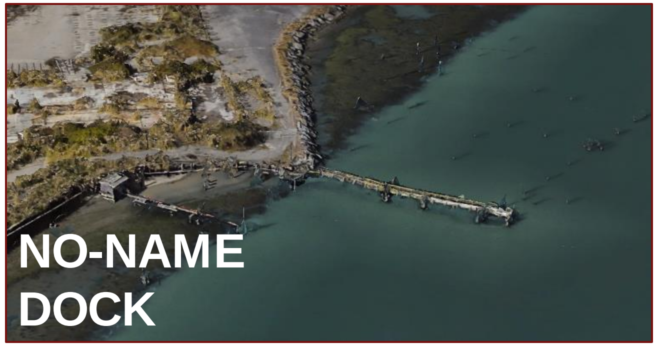
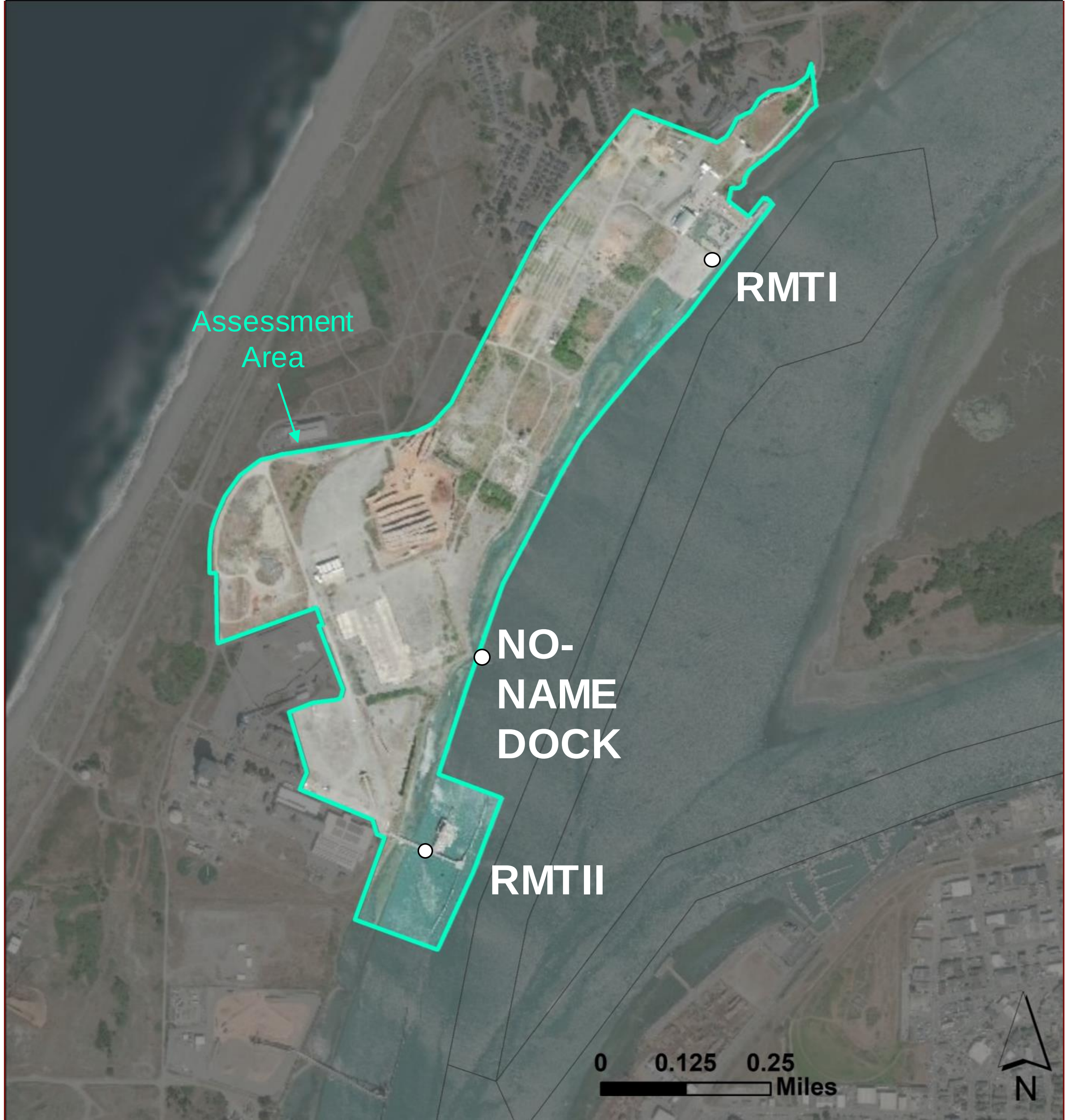
Wharf Site Conditions & Gap Assessment

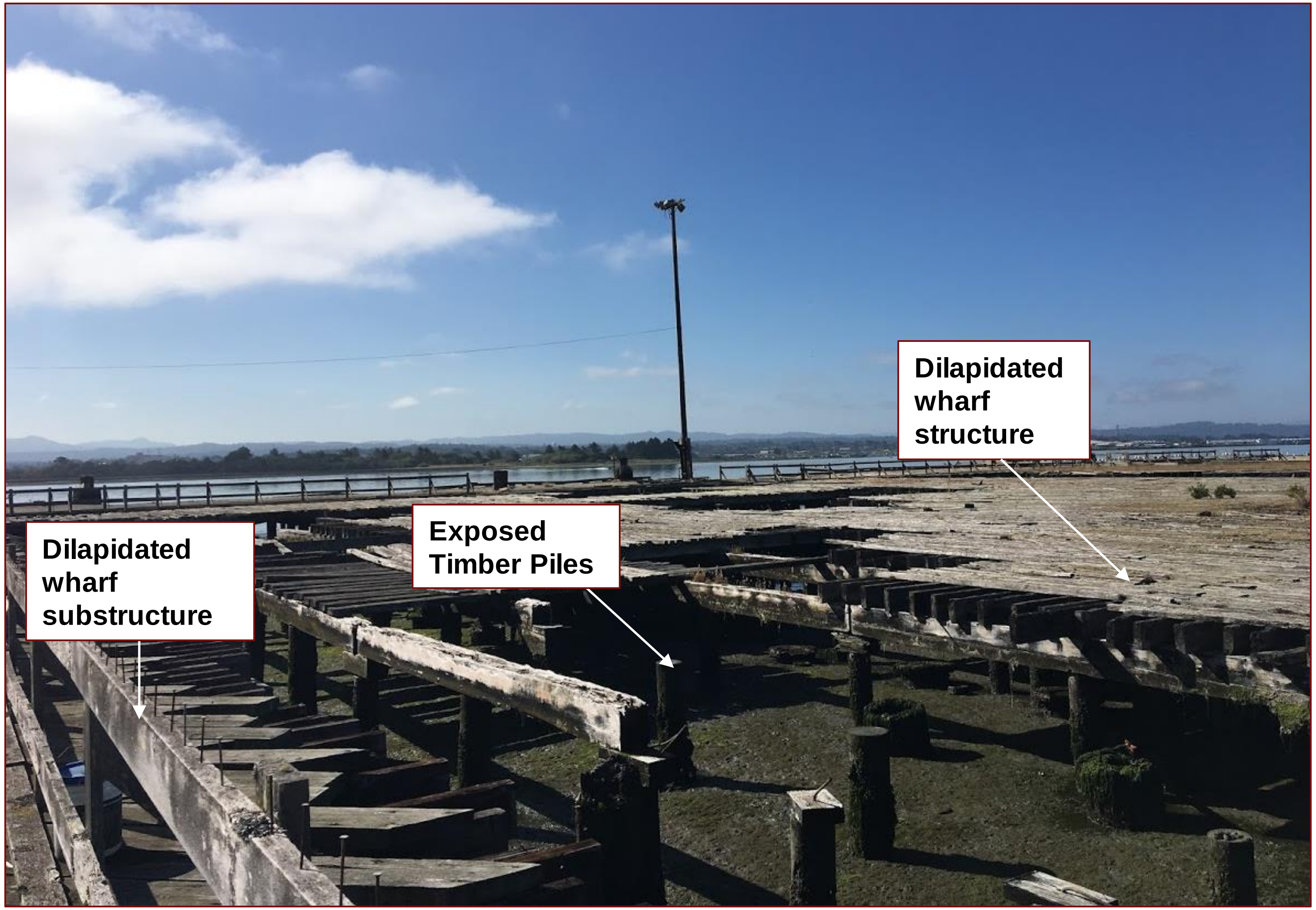
Existing Overwater Structures



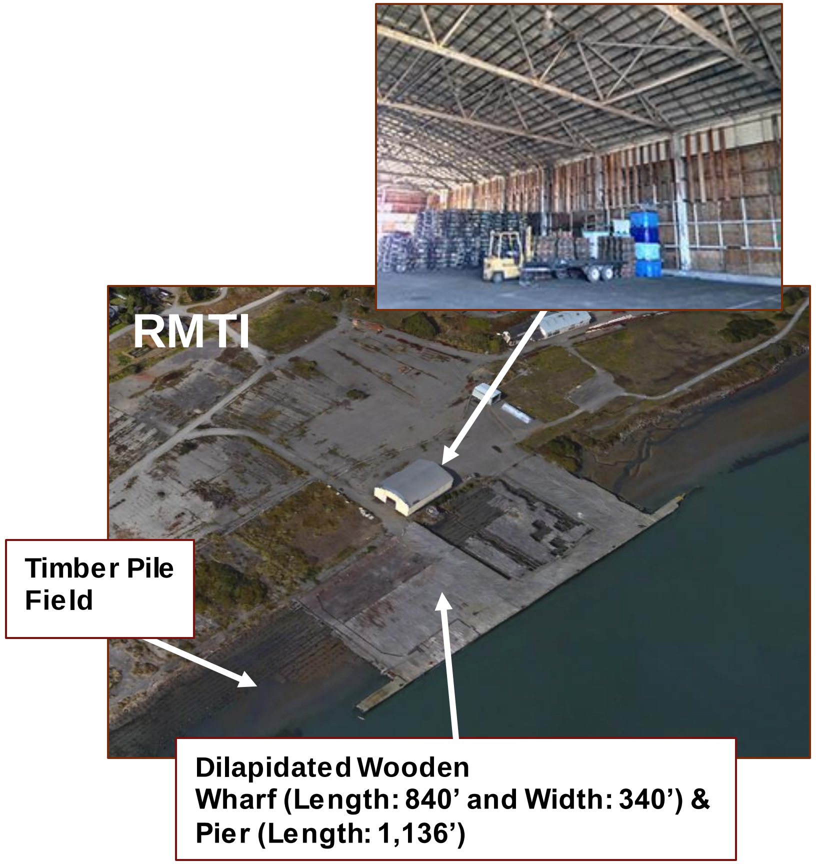


Existing Site Conditions – RMTI Wharf

RMTI Condition Assessment Rating = 1 *Critical*, based on criteria outlined in ASCE Waterfront Facilities Inspection and Assessment (ASCE Practice No. 130)



Source: Humboldt Harbor District



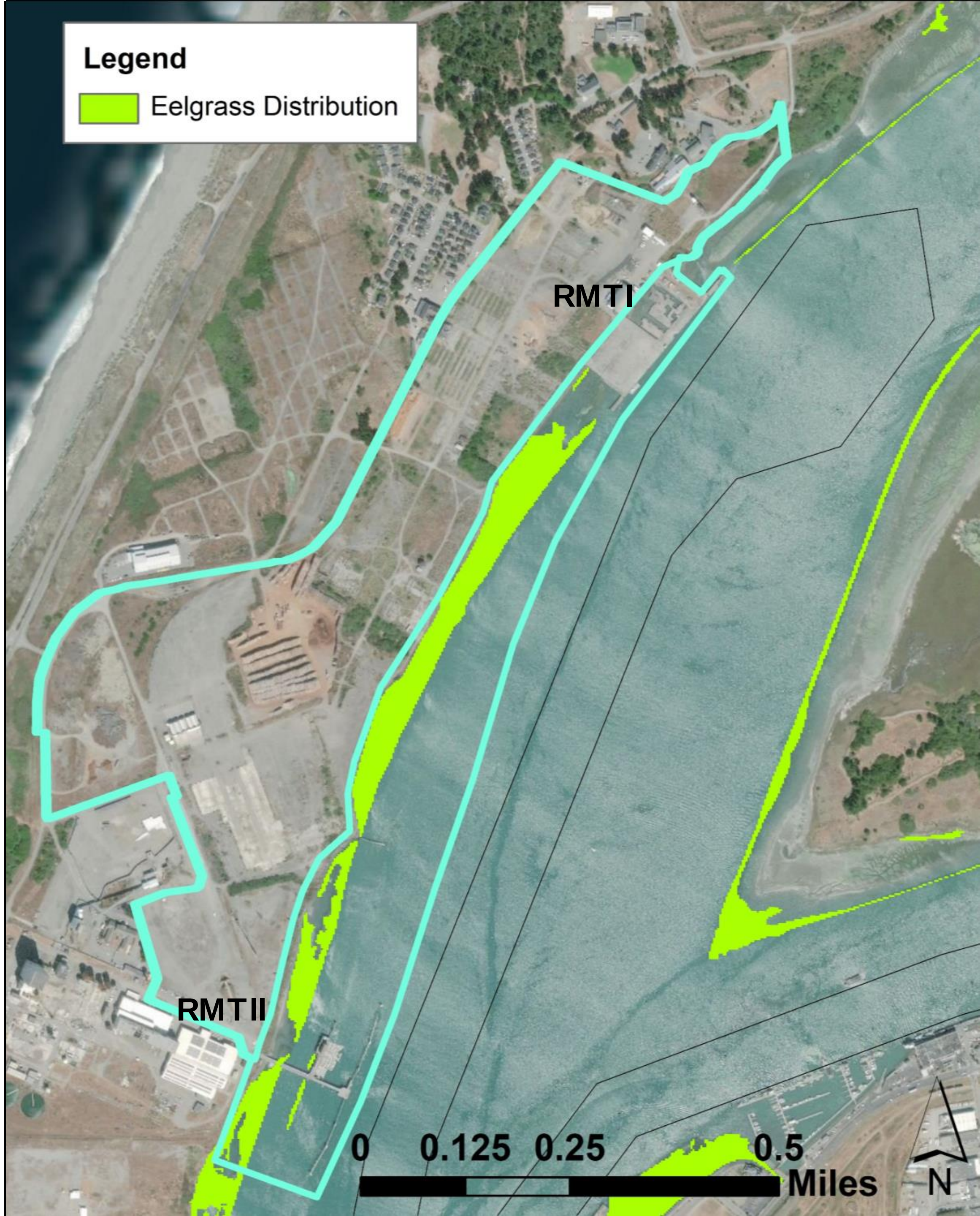
Existing Site Conditions – RMTII and No-Name Dock

Source: Humboldt Harbor District

- RMTII
- Vessel berth and narrow timber pier,
- No existing wharf structure.
- No-Name Dock
- Dilapidated timber pier; no existing wharf structure

Existing Site Conditions – Eelgrass

- Eelgrass beds are documented both north and south of the existing RMTI wharf (June 2009, Schlosser & Eicher, 2012)
- Presence appears to increase ~300ft south of the existing RMTI wharf.

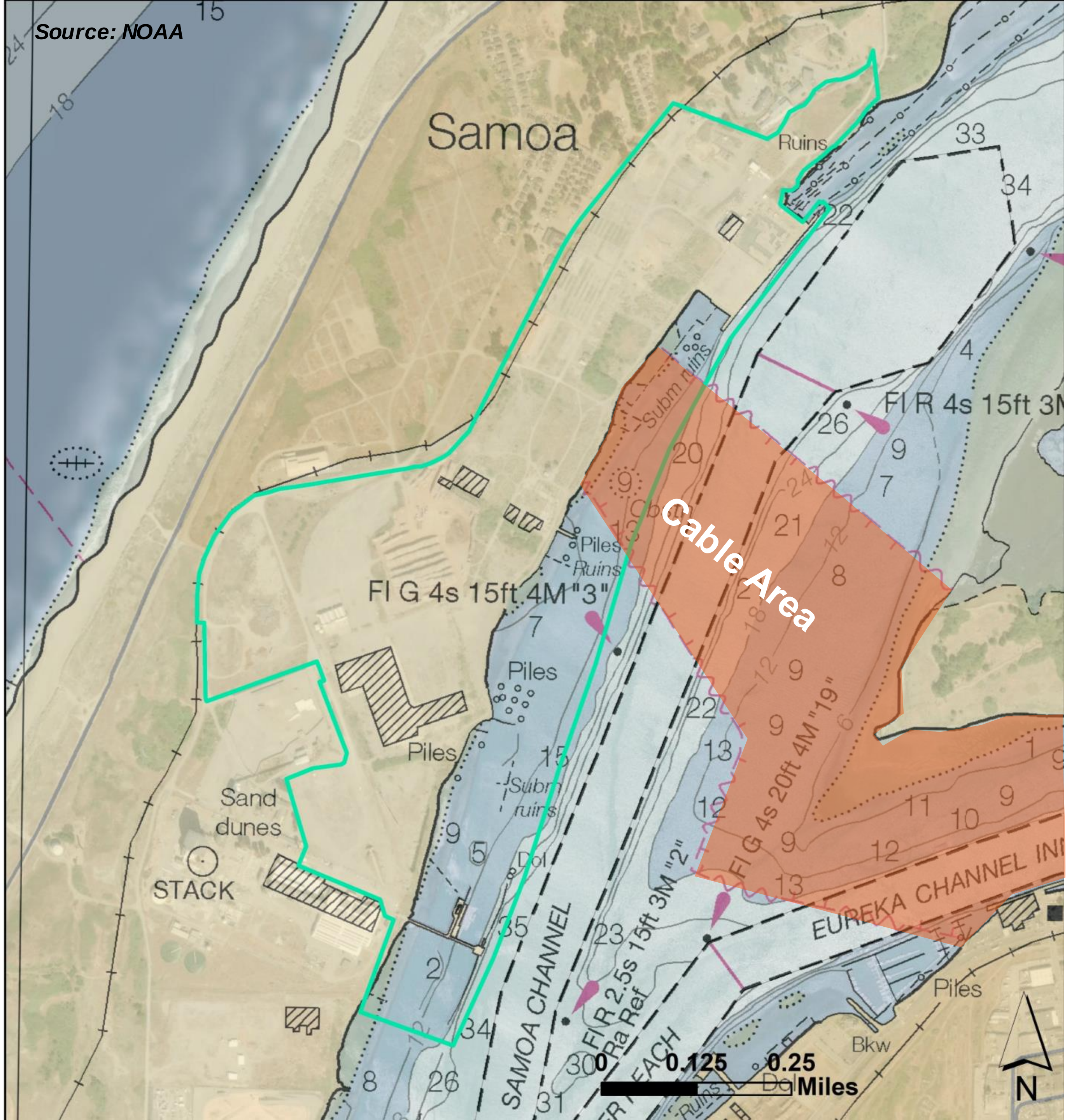


Eelgrass Data Source:
(Schlosser and Eicher, 2012)

Subsea Infrastructure

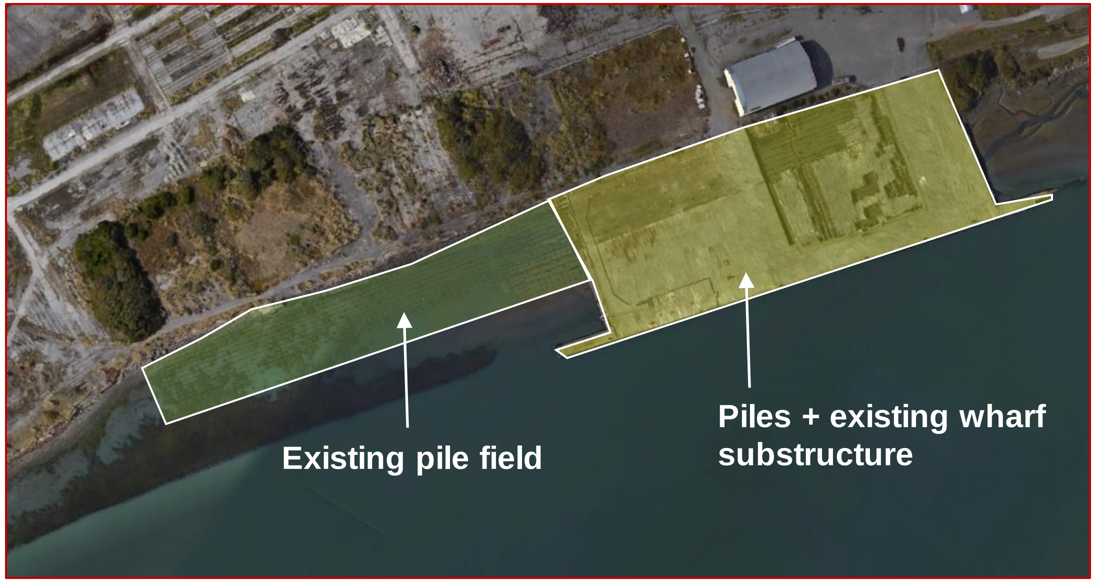
Potential dredging obstructions

A submarine cable is shown on NOAA nautical chart crossing the Samoa and Eureka FNCs approximately 450ft south of RMTI.



Existing Piles

Existing piles within the footprint of the new structure would need to be removed



Wharf Gap Assessment

Element	Existing Conditions	Wharf Criteria	Wharf Gap Assessment
Bearing Capacity	Bearing capacity of existing overwater structures is estimated to be <1000psf.	Component Delivery: 3000-4000 psf Component Storage & Staging: 3000-4000psf WTG Assembly: 4000-6000psf	The bearing capacity criteria is not met by the existing overwater structures A new high-capacity (3000-6000psf) wharf structure is needed. Type of structure TBD, depending on site specific existing geologic conditions
Elevation	RMT 1: ~10.5ft. MLLW RMT 2: ~ 17ft. MLLW	~12-14ft. MLLW	New wharf elevation will likely need to be 1.5-3.5 feet higher in elevation than the existing RMT1 timber wharf. RMT2 wharf elevation likely sufficient.
Geometry	The only existing wharf is at RMTI with approximate dimensions 340' (width) x 840' (length).	Length: Pilot Scale: 650ft to 1,000ft Large Commercial Scale: 1,100ft to 2,100ft Width: Minimum 150-300ft of dockside width.	Pilot-Scale Scenario • New wharf may be designed to be approximately similar size of footprint of the existing wharf at RMTI. Large-Scale Commercial Scenario • New wharf will be larger than the length of the existing RMTI wharf.

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Wharf & Berth Layout Considerations

Wharf & Berth Layout Considerations

The Berth Navigation Area is between the berth (at the Wharf's edge) and the navigation channel.

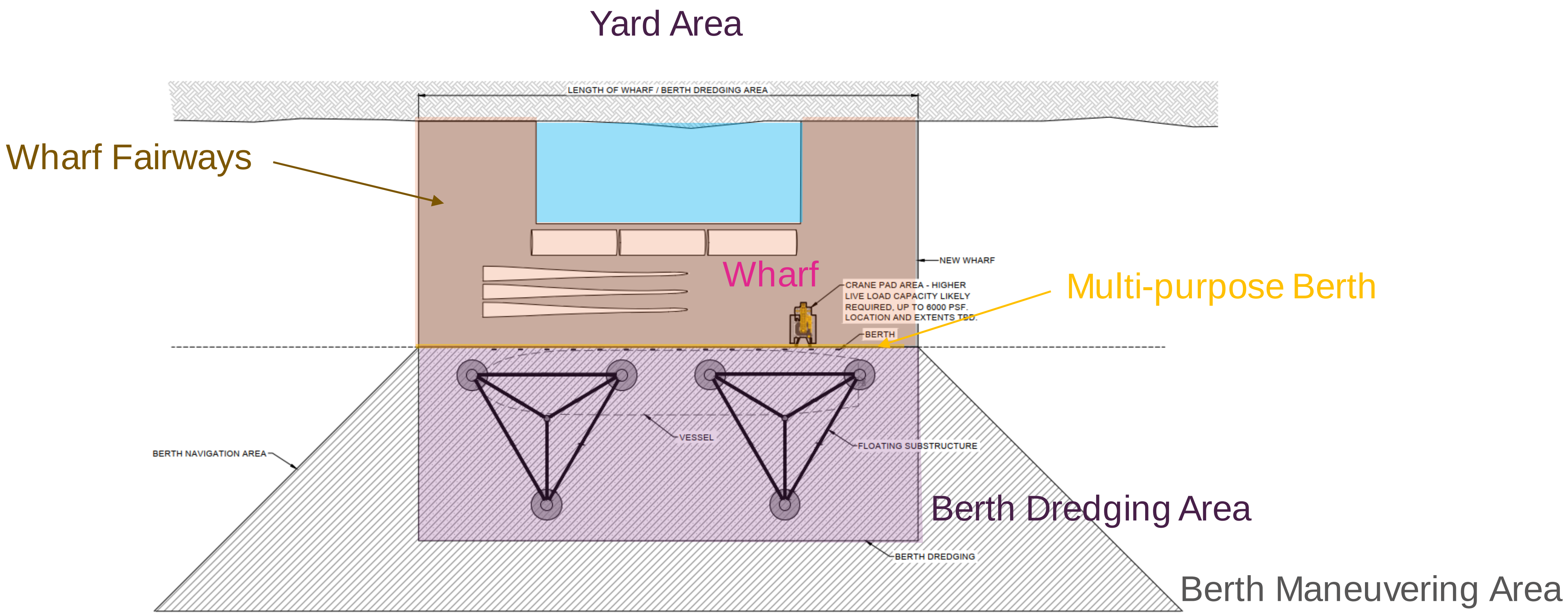
Location and Orientation of Wharf and Berth will likely consider the following:

- **FNC:** Sufficient offset from the navigation channel to reduce interference with Samoa Channel navigation and Turning Basin for substructures and vessels
- **Habitat Areas:** Reduce overwater coverage of environmentally sensitive areas (e.g. eelgrass)
- **Dredge Volume:** Minimize dredging requirements
- **Wharf Access:** Component transport to dockside area may prefer full width access, but fairways with habitat gaps between may be possible to minimize overwater coverage.

Following slides provide example locations and effect of considerations

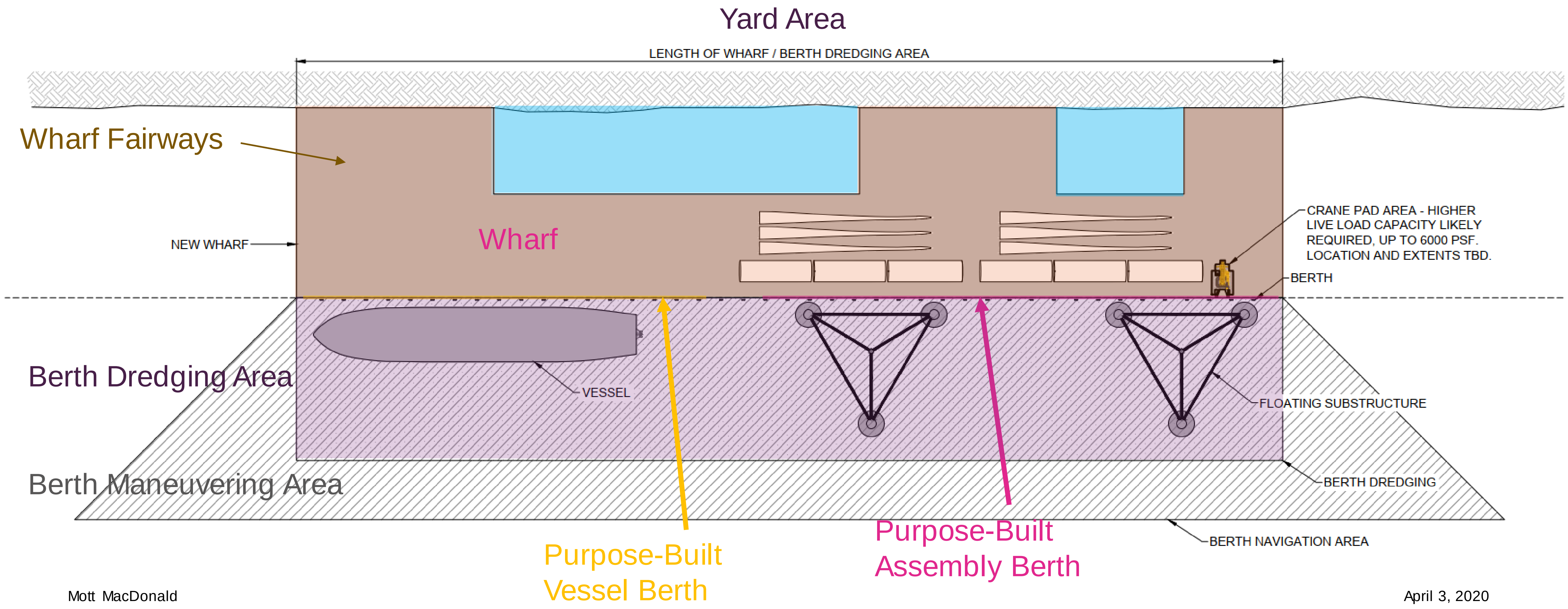
Pilot Scale Wharf & Terminal Dredging Concept

EXAMPLE



Large Commercial-Scale Wharf & Terminal Dredging Concept

EXAMPLE



Pilot Scale

RMT 1 Area

FNC Interference

- Wharf line landward of existing RMT1

Habitat Coverage

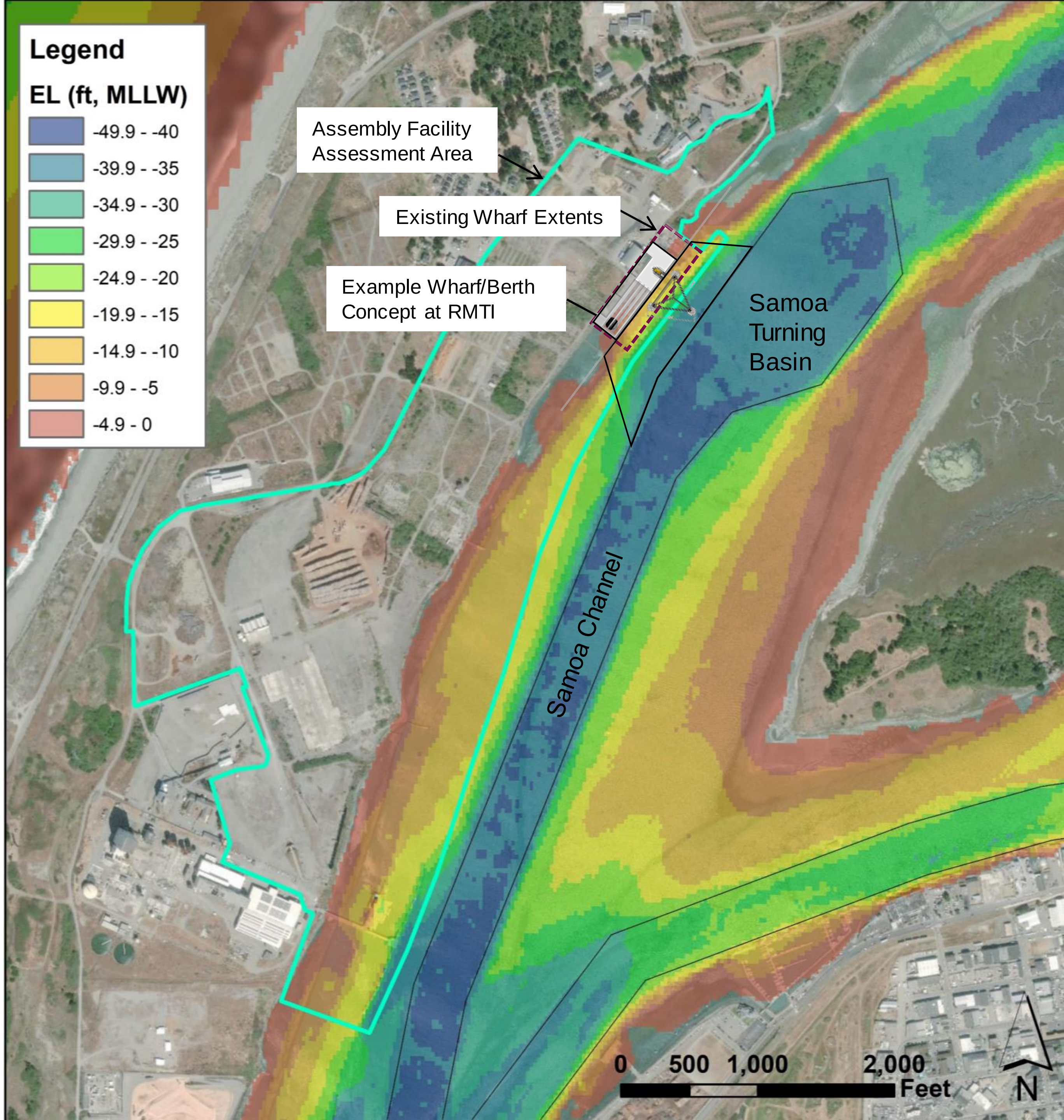
- Similar to existing

Dredge Areas

- Historical dredging minimizes new dredge area

Layout Takeaways:

- Berth dredging landwards of the existing RMTI wharf edge may be needed to reduce interference with the Samoa turning basin.



Pilot Scale

RMT II Area

FNC Interference

- Use of existing RMT2 would result in conflict with FNC – new wharf would need to be landward

Habitat Coverage

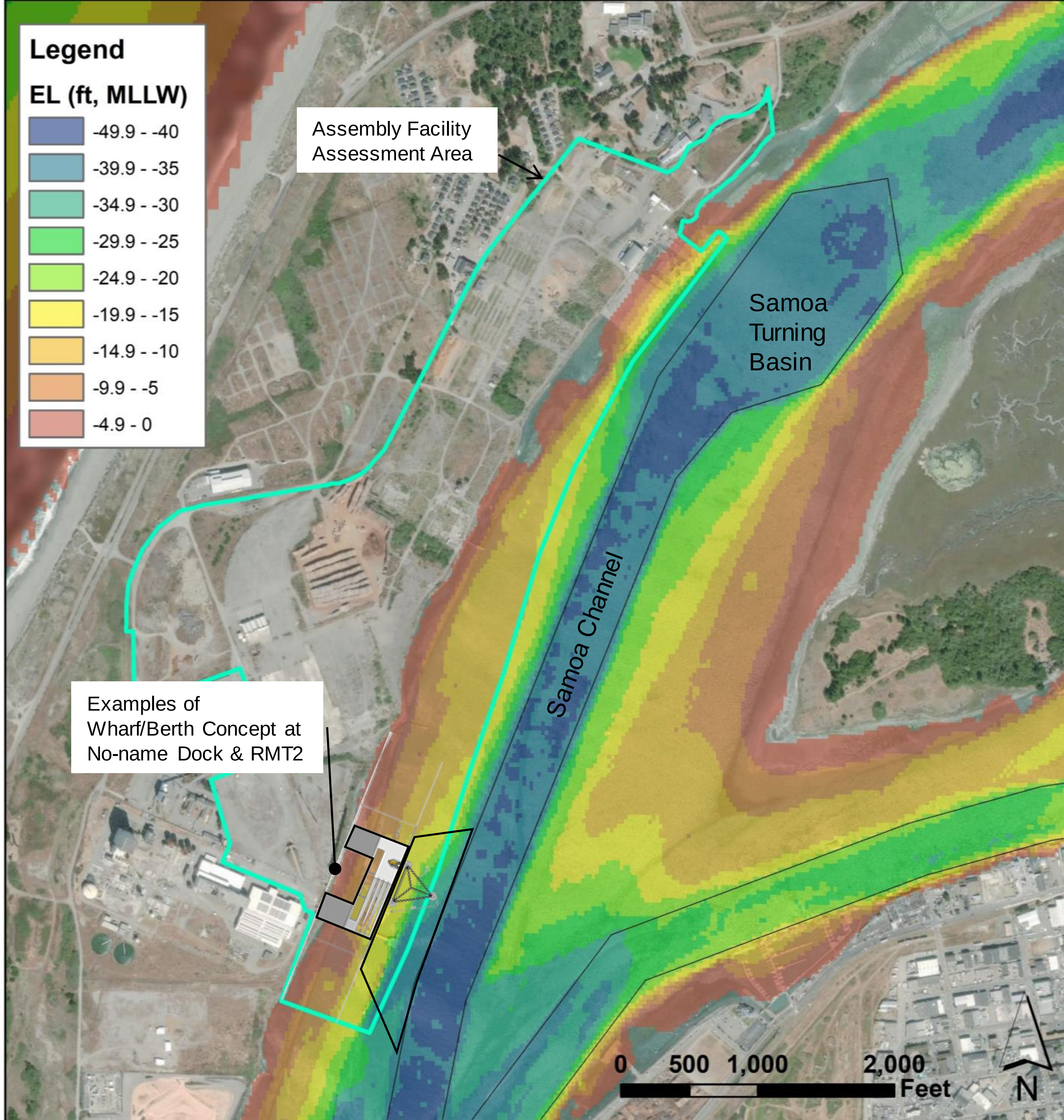
- No existing wharf – new overwater coverage required

Dredge Areas

- Limited historical dredging areas available

Layout Takeaways:

- Berth dredging required to avoid interferences with FNC (landward of existing RMTII berth)
- Higher dredge volume than at RMTI



Large Commercial Scale

RMT I Area

FNC Interference

- Orientation of Wharf may differ from RMT1 to avoid conflict with FNC

Habitat Coverage

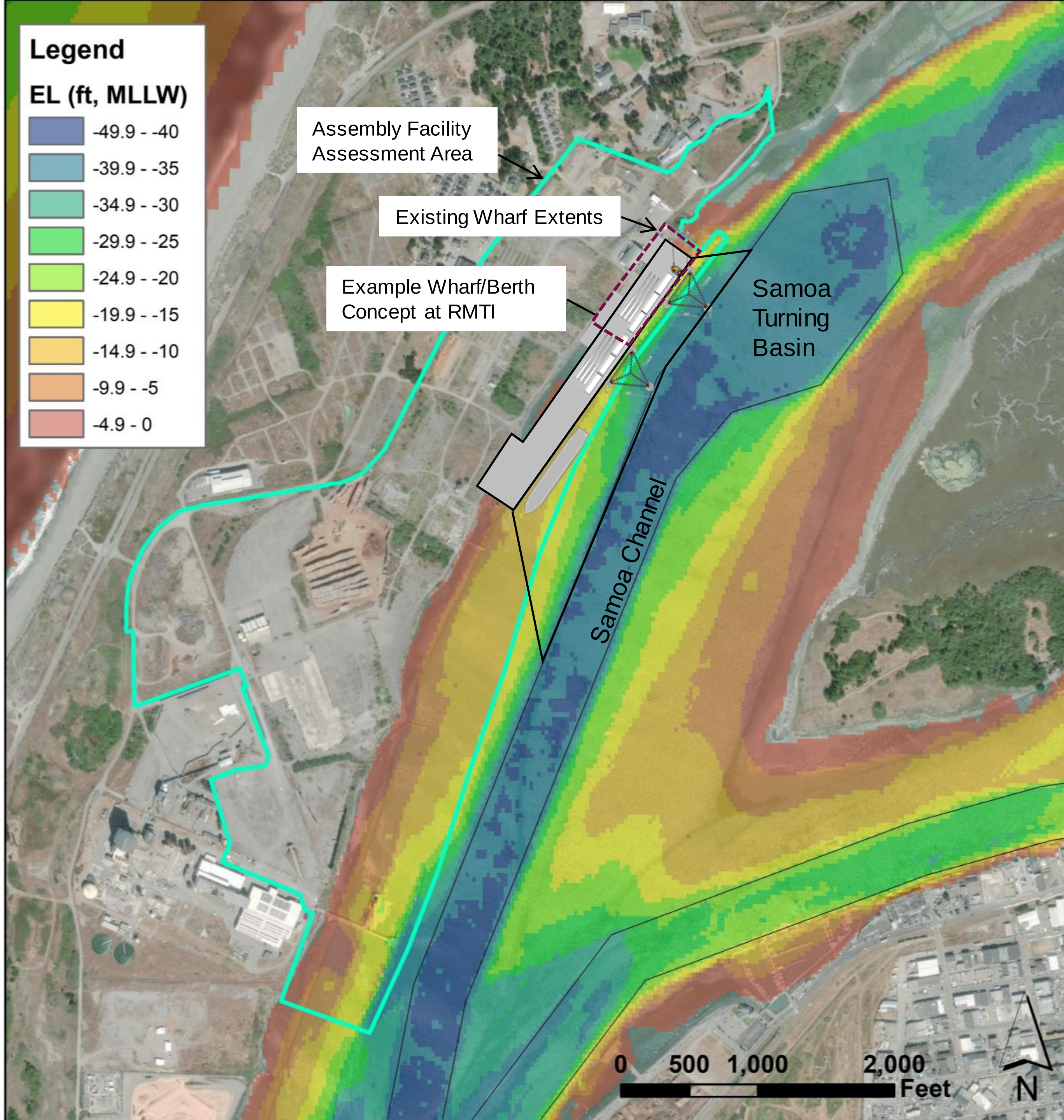
- New overwater coverage required

Dredge Areas

- Berth dredge area extends beyond historical

Layout Takeaways:

- Berth dredging landwards of the existing RMTI wharf edge may be needed. Berth dredging length along shoreline will extend into areas not previously dredged.
- If dredging at variable depths, deeper area may be located to the north to minimize dredge volume
- Fairways may not be required near RMT1 Wharf



Large Commercial Scale

RTM II Area

FNC Interference

- Seaward edge of wharf would be located inland of existing RMTII

Habitat Coverage

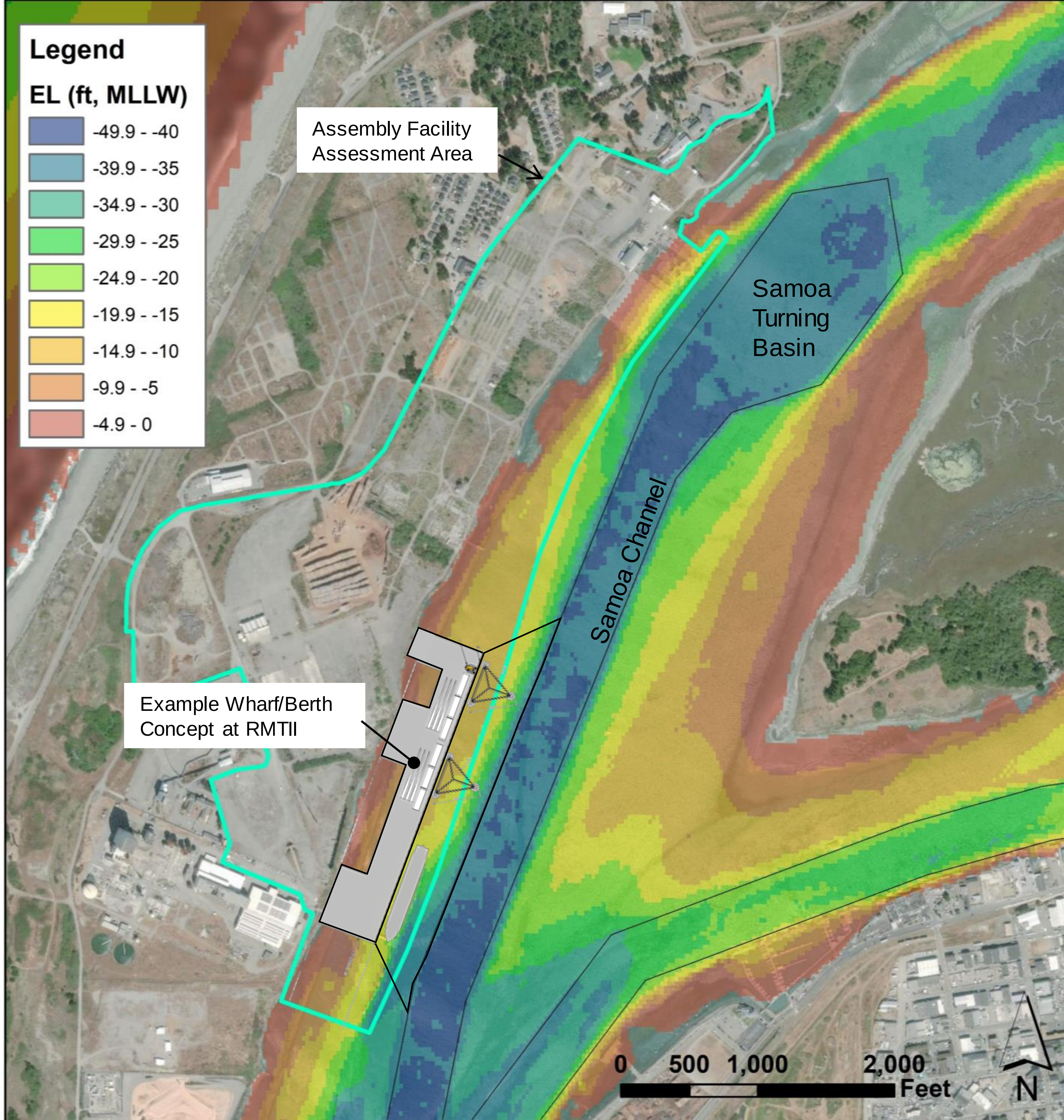
- New overwater coverage required, more than at RMTI

Dredge Areas

- Berth dredge area extends beyond historical

Layout Takeaways:

- Berth dredging required to avoid interferences with FNC (landward of existing RMTII berth)
- Higher dredge volume than at RMTI
- If dredging at variable depths, deeper area may be located to the north to minimize dredge volume



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Yard Assessment Criteria

Yard Conceptual Assessment Criteria

Functions

- Component storage,
- Component manipulation (pre-assembly),
- Component staging,
- Other miscellaneous upland facilities (office buildings, employee parking, etc).

Key Considerations

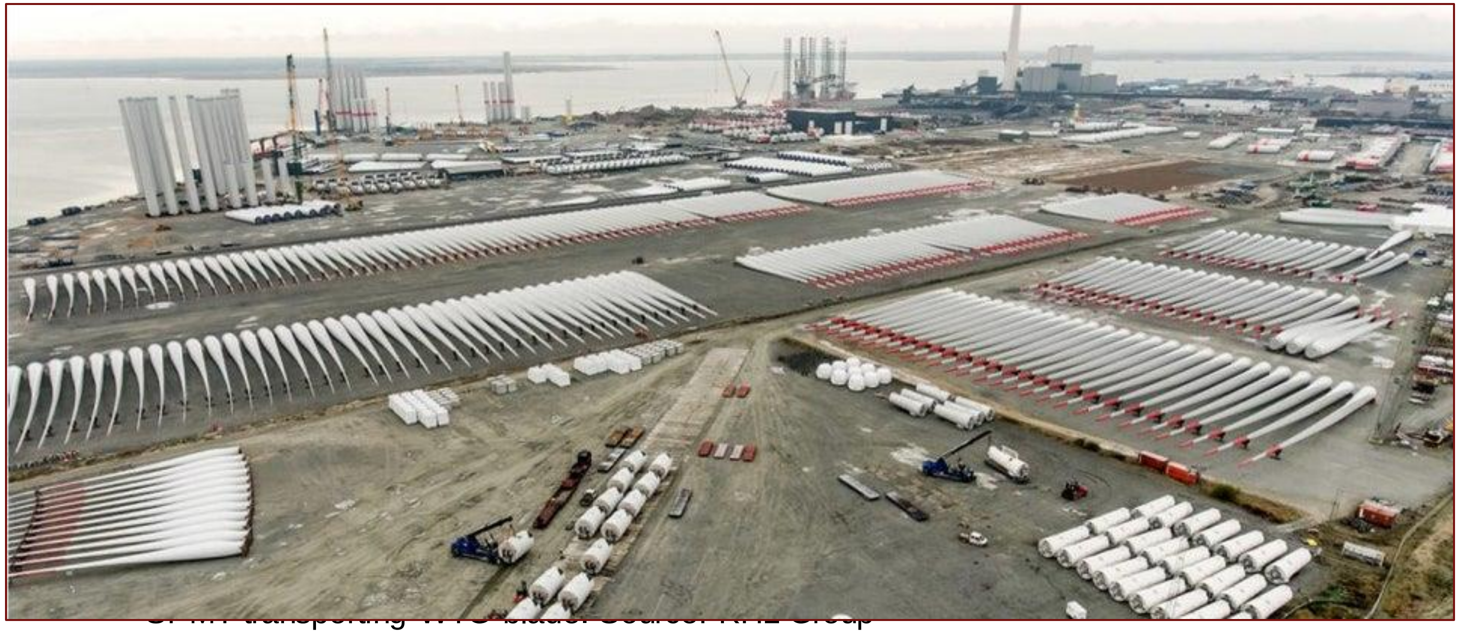
- High-capacity ground surface for storage and transport of components,
- Level ground surface for transport of components,
- Storage area size to accommodate potential limitations on crossing the bar in the Entrance Channel,
- Minimal risk of flooding.

Assessment Criteria – Yard Area

Assessment Criteria

- Pilot Scale Scenario: 25-40 acres
- Large Commercial Scale Scenario: 60-100 acres

Example of Yard Storage Area for WTG components at Port of Esberg, Denmark
Storage area approximately 2,000 feet in length



Assessment Criteria – Storage Area

Assessment Criteria

- Bearing Capacity: 2,000-4,000 psf for all scenarios. The required bearing capacity may be on the lower end of the range if storage is limited to individual pieces (non-assembled) and/or SPMTs are used for transporting components.
- Surface Type: Storage areas may potentially be either reinforced concrete or may be crushed rock

SPMT transporting WTG blade. Source: KHL Group

Assessment Criteria – Yard Services and Land-Use

Other Considerations

- Services & Utilities: the following are assumed to be requirements at the OSW port facility:
  - Communication, site access control, waste/sanitation management.
  - Potable water to the berth and non potable 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
- Facilities: office space, restrooms & staff parking availability.
- Land Use: 24-hour operations may be required. Noise levels may be at ~ 70-75dB

Night WTG assembly operations for EnBW HoHe See wind farm. Source: EnBW

Yard Assumed Criteria Summary

Yard Criteria Summary

Element	Yard Criteria
Area	Pilot Scale: 25-40 acres Large Commercial Scale: 60-100 acres
Elevation	Limited risk of flooding – Assumed to be outside FEMA Flood Hazard Zone (1% annual chance of inundation)
Bearing Capacity	2000-4000psf – concrete or crushed rock
Other Considerations	Services, Facilities & Utilities Land Use and Noise/Lighting

Note: The criteria summarized here was developed for an Assembly Facility (to support component delivery and WTG assembly). Criteria for a substructure fabrication facility is not addressed in this Appendix.

Yard Capabilities & Gap Assessment

Existing Upland Area

Upland Area

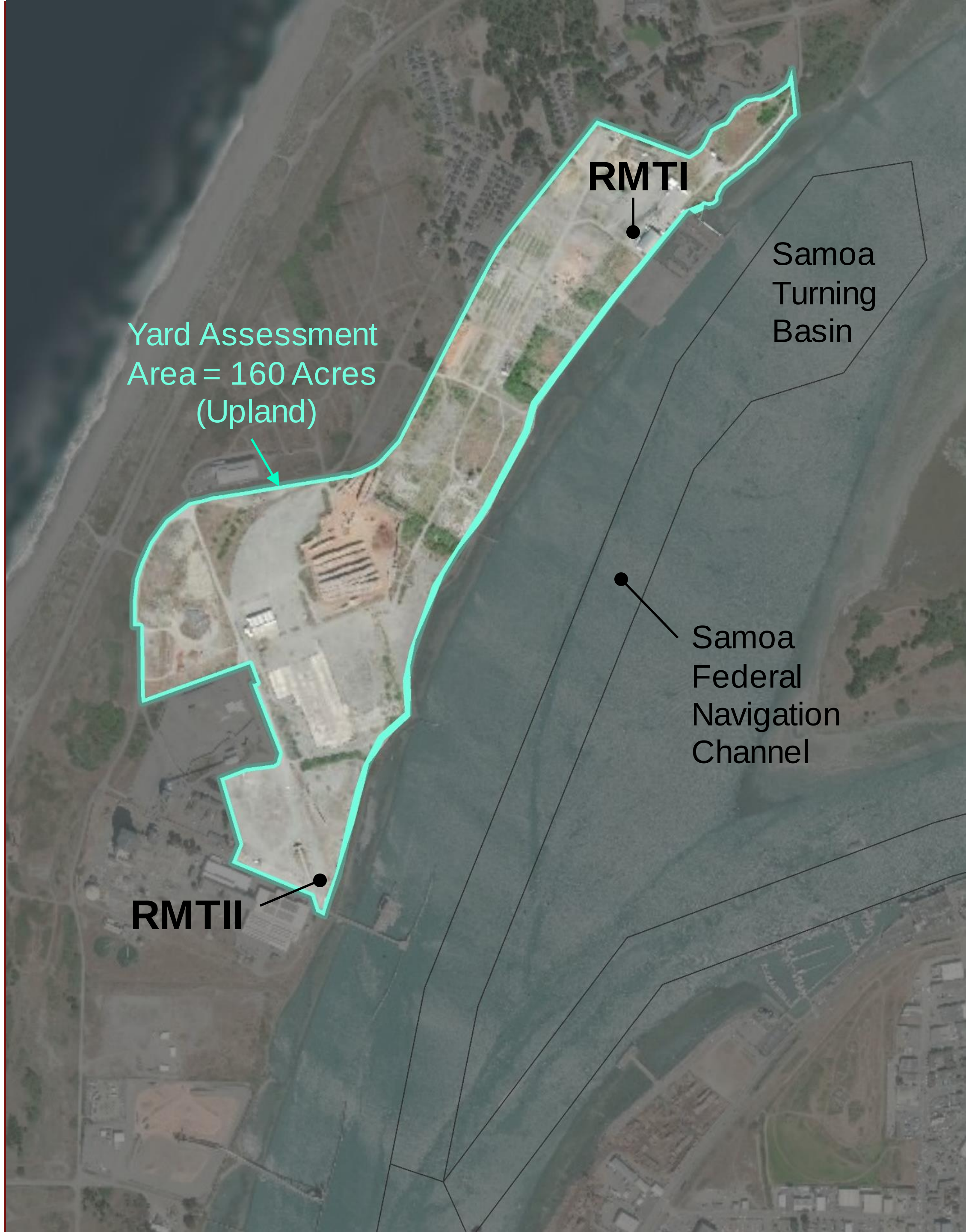
- Yard Assessment Area: 160 acres.
- Conditions: Existing warehouses, vacant lots, and vegetated areas.
- Site Elevations: Next slides

Land Use

- A residential neighborhood (Samoa) is located near RMTI. The remainder of the assessment area is bordered by vacant or industrial lots.

Geotechnical Conditions

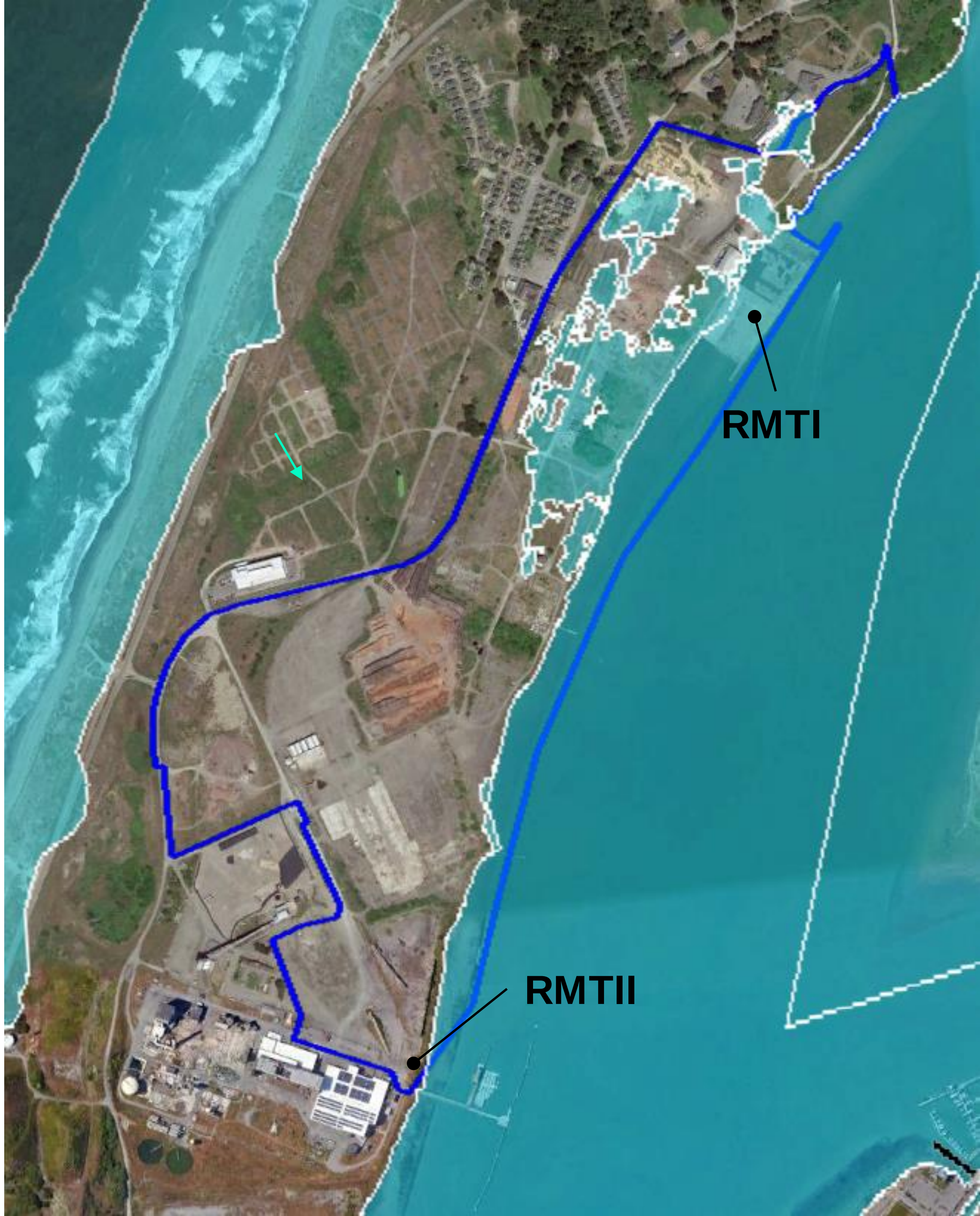
- Shallow layer of loose liquefiable sand (~10ft.)
- Dense sands with low liquefaction potential below ~10ft.
- Homes in area typically are pile supported
- Heavy structures in area historically slabs



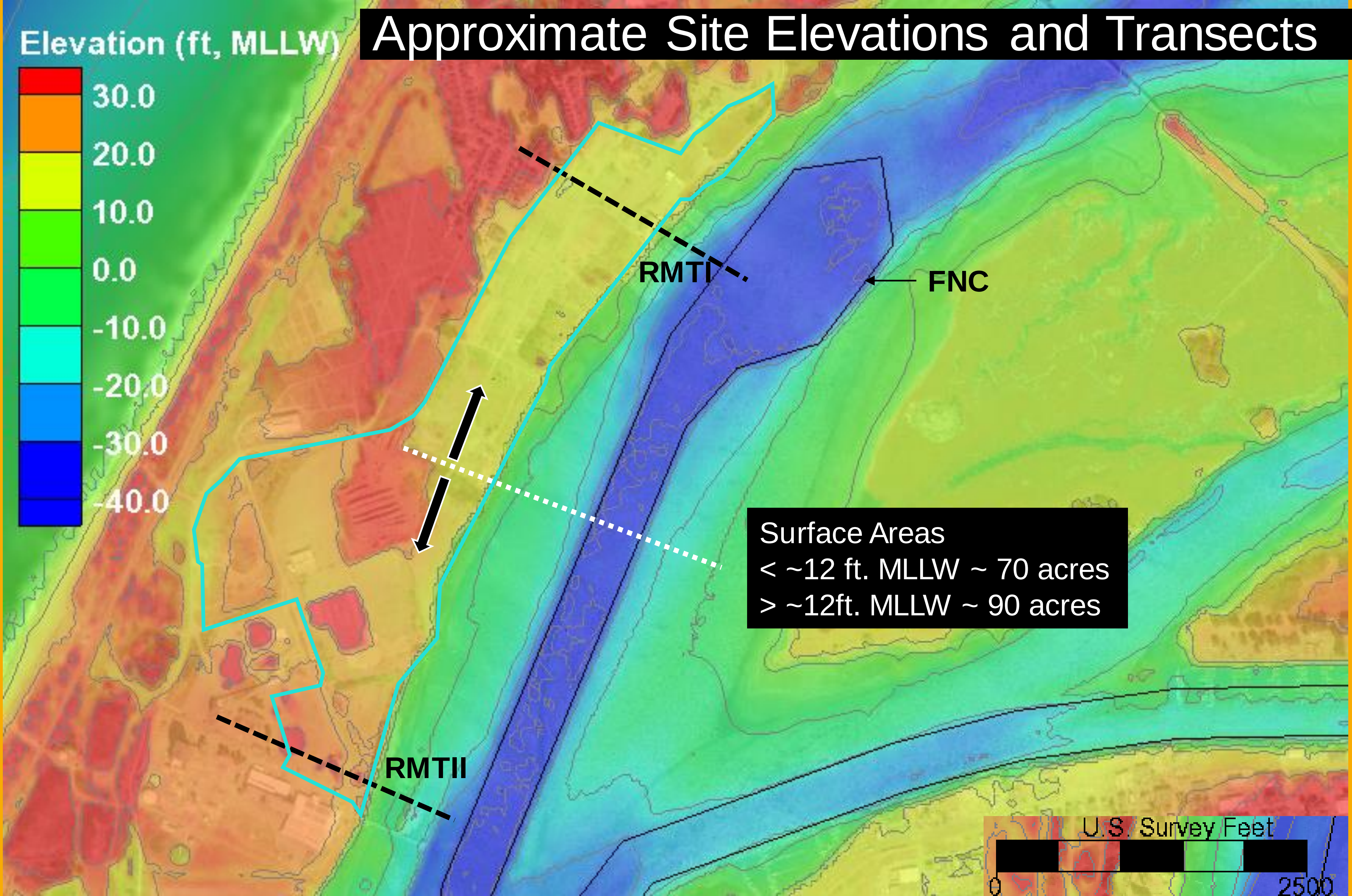
FEMA Flood Mapping

100-Year Flood Level

- 1% Chance of Flooding
- 10 ft. NAVD88



Approximate Site Elevations and Transects

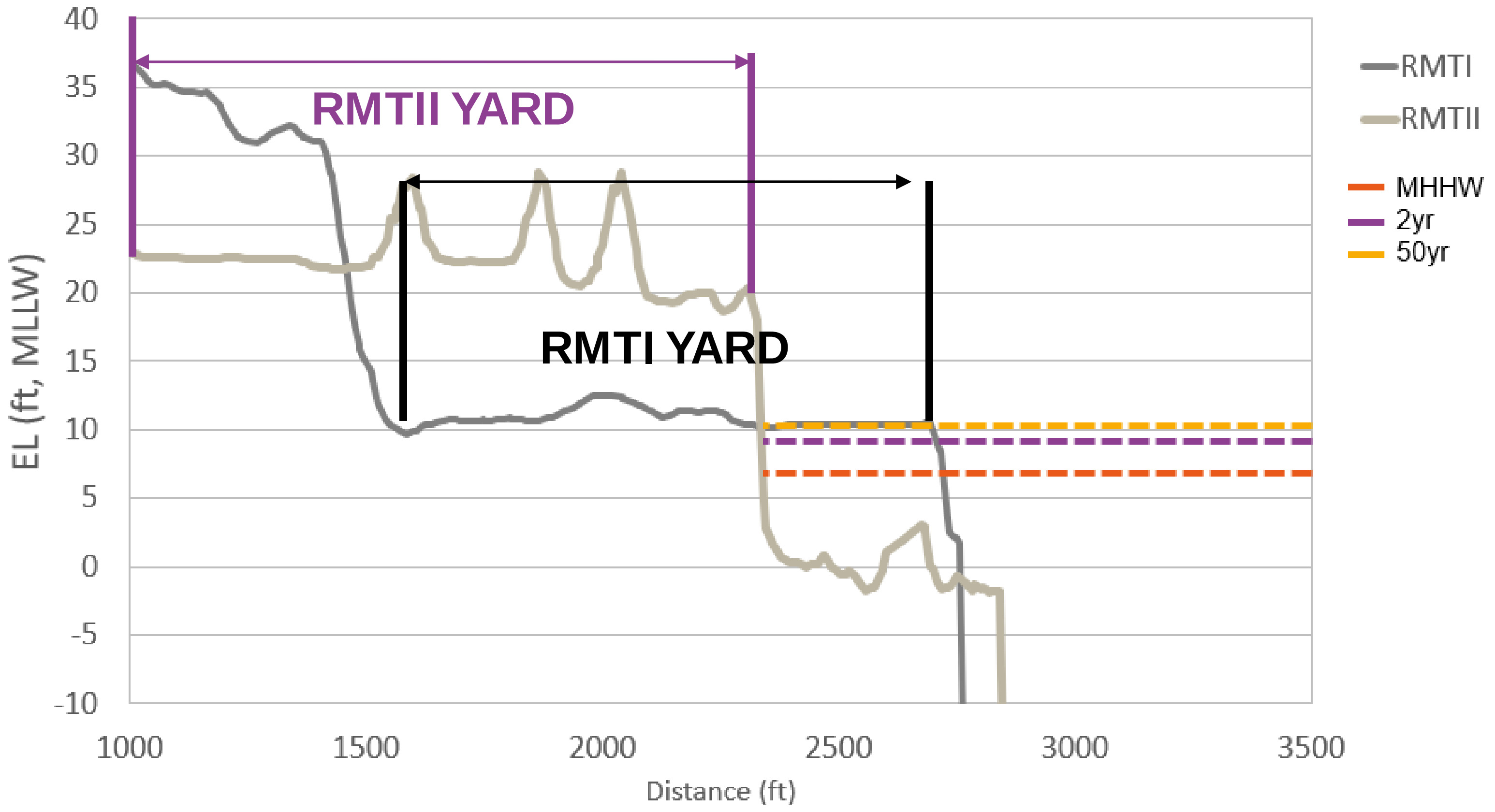


Yard Elevations

RMTII Yard is at a higher elevation than RMTI Yard by approximately 7-10 feet.

Localized flooding may occur at RMTI yard in the 50-year event.

See Appendix I for additional details regarding SLR.



Yard Gap Assessment

Element	Existing Conditions	Yard Criteria	Yard Gap Assessment
Area	160 Acres	Pilot Scale: 24-40 acres Large Commercial Scale: 60-100 acres	Sufficient upland area is available within the Yard Assembly Area to support an Assembly Port facility for either the pilot-scale or large commercial-scale build-out scenarios. No single area available with 100 acres, which is currently approximately flat. Some grading would be required. Within the study area there would likely be remaining space for other OSW uses (fabrication, O&M) or other marine dependent uses.
Bearing Capacity	Shallow layer of loose liquefiable sand (~10ft.) Dense sands with low liquefaction potential below ~10ft.	2000-4000psf	Ground improvement is likely required. Native near surface soils likely would not meet bearing capacity criteria for storage & staging areas. Grading may be required adjacent to RMTI to increase ground level relative to sea-level.
Elevation	Varies – Some areas within RMT1 within FEMA Flood Zone	Above FEMA Flood Hazard elevation (~10ft. MLLW)	Portions of RMTI require grading; may be combined with improvements to bearing capacity. Additional grading may be required to accommodate SLR.
Other Considerations	Some utilities service the site, but are not meant to support a large-scale facility	Services & Utilities: Communication, water, electrical, fuel storage, site access control waste/sanitation management. Facilities: Office space, restrooms & staff parking availability. Land Use: 24-hour operations more likely for large-commercial	Service & utility and facility upgrades will be needed to support Assembly Port operations. The layout of the marine facility should consider noise and lighting impacts if 24-hr operations are required.

Outcomes

Outcomes – Pilot/Small Commercial

Berth

- Water depth at the berth may need to be deeper than the existing FNC to accommodate the larger end of the devices, but likely sufficient for component delivery vessels.
- For smaller end of the devices some dredging is likely. Larger devices could require dredge depth deeper than FNC.

Wharf Structure

- The existing wharves at RMTI and RMTII were not designed for heavy-lift operations, and need replacement.
- The structure type may possibly be either open pile supported or closed fill, is dependent on site-specific geotechnical information not yet available.
- New wharf may be designed to be approximately similar size of footprint of the existing wharf at RMTI.
- The wharf deck elevation will likely need to be higher than the existing RMTI deck elevation.
- If fabrication occurs on site the wharf length may need to be longer than the existing RMTI wharf.
- If located at RMTI, the outer edge of the wharf likely needs to be landward of outer edge of the existing wharf.
- Structure over-water area may be reduced with additional nearshore dredging.

Yard

- The RMTI/RMTII area provides sufficient area for an upland Assembly Port Facility and if required, a Fabrication Facility.
- Ground improvement and grading is likely required. New surface may potentially be concrete or crushed stone.
- There may need to be considerations for lighting and noise considering local residential areas.
- Utility upgrades likely required.

Outcomes – Large Commercial

Berth

- Dredge depth requirements similar to the pilot/Small-Commercial Scale scenario.
- The dredging area required is larger than the historical dredge areas of RMT1/RMT2.

Wharf Structure

- Structure type would be similar to that in the pilot-scale scenario.
- The required length of the new wharf structure will likely significantly exceed that of the existing RMTI 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 the North end, access piers 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. Nearshore dredging could potentially be reduced if the FNC is relocated to the East. This tradeoff requires further analysis.

Yard

- Sufficient upland area is available within the Yard Assembly Area to support an Assembly Port facility and Fabrication facility, though details on fabrication layout not yet developed.
- No single area available with 100 acres which is currently approximately flat. Grading would be required to provide 100 acres of contiguous flat land.
- Ground improvement is likely required. New surface may potentially be reinforced concrete or crushed stone.
- Land use and utilities similar to Pilot/Small-Commercial Scale

Appendix C Substructure Delivery and Float-Off

This appendix assesses the options for transferring the fabricated substructures to the water for the wind turbine generator assembly. Both the pilot/small-commercial and large commercial scale scenarios were assessed. The assessment specifies the potentially required vessels, barges, and channel depths, for both scenarios which includes importing the fabricated components from elsewhere and fabricating the components in Humboldt.

Apendix C: Substructure Delivery and Float-Off

Basis of Analysis

Objective

Assess options for transfer of fabricated substructure to water for WTG assembly, in both pilot/small-commercial and large commercial scale scenarios.

Methodology

Cursory review of potential float-off systems based on literature review and prior project team experience. Assess relative to conditions in Humboldt Bay, and high-level assessment criteria.

Definitions

Float-off: Substructure transferred from dry to wet conditions.

Vessel Based Delivery: crane or semi-submersible vessel or barge lifts or sinks substructure into water; limited upland infrastructure.

Land Based Fabrication: substructure is transferred from land into water – lifted or sunken; area where substructure is fabricated.

Scenarios

- Pilot/Small Commercial Scale Buildout
  - Fabricated elsewhere – Limited landside support infrastructure – Vessel Based Delivery
- Large Commercial Scale Buildout
  - Fabricated at Humboldt – Float-off (launch) into Humboldt Bay – Land Based Fabrication
  - Fabricated elsewhere - Vessel Based Delivery or aided by wharf staging – similar to Pilot/Small Commercial Scale Assessment

Assessment Criteria

Pilot/Small Commercial Scale

Draft of vessel or barge/vessel combination with transport/lift capacity can navigate and offload in Bay

Does not require specialized landside infrastructure for offload of substructure

Fabrication may or may not take place at Humboldt Bay

Large Scale Commercial

Proven or prototype technology exists

Supports serial production

Minimizes significant nearshore dredging in area of eelgrass

Land Based – Substructure is transferred from land into water – lifted or sunken

CapEx considerations (OpEx considerations not included)

Fabrication may or may not take place at Humboldt Bay

Substructure, Vessel, and Barge Assumptions

Device	Draft (light)	Beam	Weight
Type A	28ft.	300ft.	5,000-8,000 tons
Type B	20ft.	200ft.	2,000-4,000 tons

Example Crane Vessel List (non-comprehensive)

Vessel/Crane	Max Lift Capacity*	Draft Range
Rambiz	3,300 MT	~10 ft.
Bokalift 1	3,000 MT	~28ft.
Asian Hercules 3	5,000 MT	~20ft.
Thialf	14,200 MT	43-104 ft
Aegnir	4,000 MT	30-36 ft.

Example Barge List

Vessel/Barge	Capacity	Draft	Depth
BOABARGE 29 Semi-Sub	Jackets up to 3,500 MT	~20 ft.	26ft.
Crowley 400L Deck/Launch Barge	~17,000 MT	~20 ft.	N/A

Actual lift capacity at radius of lift required for float off may be less, depending on device and crane

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Literature Review Summary

Float-Off

Carbon Trust

Two key documents

Offshore wind industry review of Gravity Based Structures - 2015

- Provides overview of float-off techniques for serial production

Floating Wind Joint Industry Project - summary report phase 1 - 2019

- Provides overview of challenges for serial production of floating offshore wind substructures and likely float-off techniques

Carbon Trust (2019) Literature Review – Floating Wind Fabrication Float off

Deployment to date has primarily consisted of 1-5 units in a pre-commercial application. Minimal logistical constraints for the size and number constructed so far.

Future farms will be bigger, and more numerous. All moorings, cabling will need to be completed within a restrictive time period and within weather windows.

Order of Assembly (semi-submersible):

Fabrication and assembly of substructure in countries with low personnel cost

Simultaneous transport of several units by semi-submersible barge or self-propelled vessels

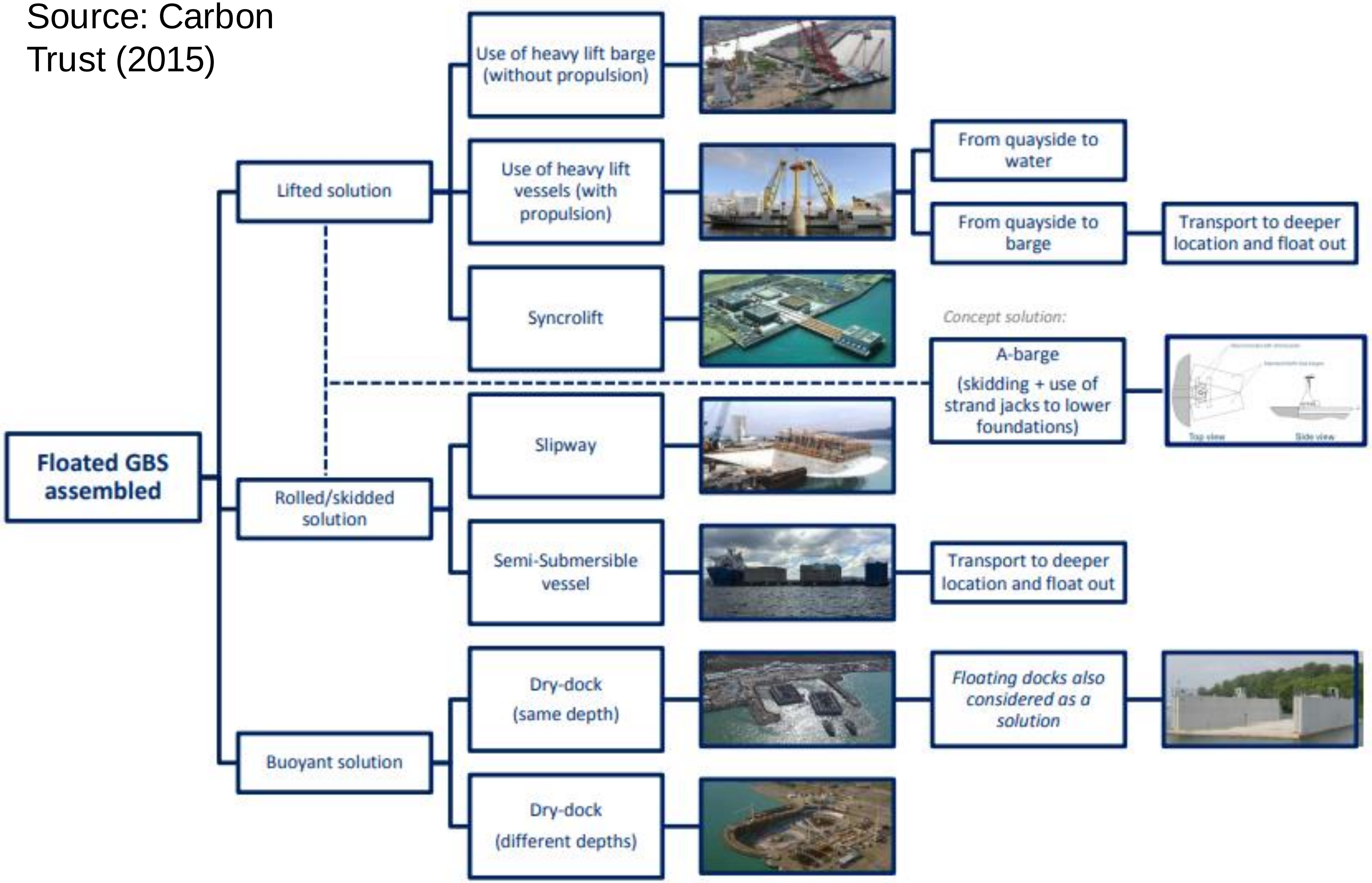
Vessel transport to port or to site for float-off

Dry-docks unlikely to be cost-effective. Units must be assembled simultaneously, rather than series.

To deliver 50 units in 200 days would require a fully assembled structure every 4 days. Assuming 1-2 weeks for fabrication of substructure that means 4 structures at a time in different stations.

Most practical and economical method would be to assemble dockside with load-out by trailer. Reduced crane needs.

Source: Carbon Trust (2015)



Gravity Base System Launching (Float-off) Options Lit Review

Substructure Delivery

Pilot/Small Scale-Commercial Scale Delivery

Potential options (not intended to be comprehensive, only developed for planning level)

Semi-Submersible Vessel

Substructures delivered on large self propelled semi-submersible vessel. Vessel ballasts down for substructure to float off.

Semi-Submersible Barge

Substructures delivered on semi-submersible barge. Barge ballasts down for substructure to float off.

Heavy Lift Vessel

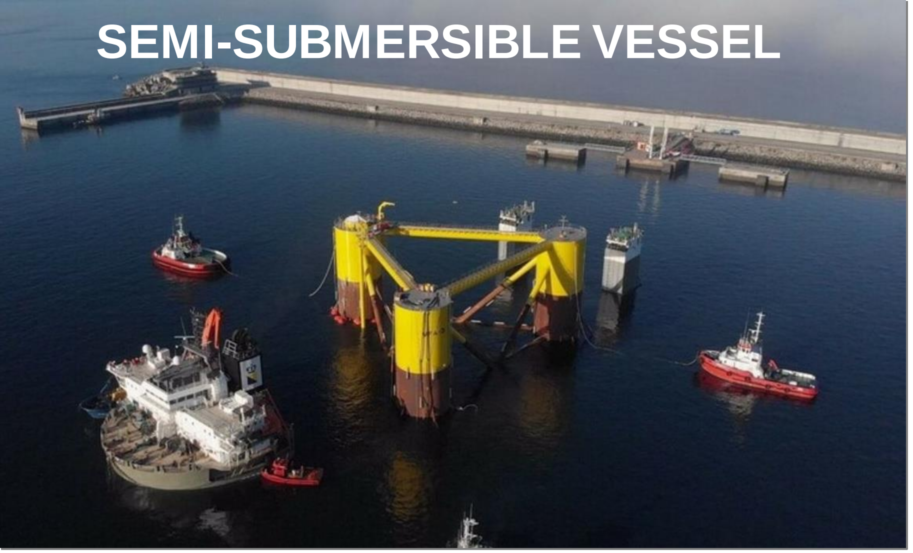
Substructures delivered on self-propelled vessel with crane large enough to offload substructure.

Deck Barge and Crane Vessel

Deck barges deliver substructures. Specialized crane vessel lifts substructures into water for tow to dockside assembly area.

Deck Barge to Dockside Semi-Submersible Barge System

Deck barges deliver substructures, which are transferred via self propelled modular transporter to a shallower draft semi-sub barge, which is not intended for ocean-going transport. Alternatively, if the substructure could be fabricated on the barge system dockside, upland facilities not required.



TRANSFER TO DOCKSIDE SEMI-SUBMERSIBLE BARGE (NON-OCEAN GOING)

Pilot/Small Commercial Scale – Assumed Float-Off Options

Berth Depth Assessment for Dockside Float-Off Concepts

Vessel	Vessel Draft	Berth Depth	Concept Depth Requirements - MSL	Concept Depth Requirements – MHW
Heavy Lift Vessel	35 ft.	38 ft.		
Crane Vessel	10ft.	38ft.		
Transfer to Semi-Sub Dockside Barge	32-40 ft.	38 ft.		
Semi-Submersible Heavy Lift Barge	40-48 ft.	38 ft.		
Semi-Submersible Heavy Lift Vessel	63 ft.	38 ft.		

Assessment: Delivery appears feasible considering possible vessel geometry**.** Depth at Humboldt Bay may not be sufficient for the larger end of semi-submersible ocean-going vessels for delivery of substructure. Larger semi-submersible barge may be possible if wave action allows for float-off in deep portion of existing navigation channel (48 ft. Authorized Depth), or a new "dredge pit"

Fabrication Float-Off

Large Commercial Scale – Fabrication Float-Off

Potential options (not intended to be comprehensive, only developed for planning level)

Semi-Submersible Dockside Barge+

Substructure transferred from upland via self propelled modular transporter to a shallower draft semi-sub barge located dockside.

Dockside Crane+

Substructures lifted by land-based crane or specialized crane vessel into the water, dockside to fabrication.

Marine Railway*

Substructures lowered via inclined rail system extending from upland elevations into the water.

Gantry Crane and Slipway*

Gantry crane on rails to lift substructure and place either into dredged slipway or extend gantry crane structure into deep water.

Dry Dock*

Structure that can be flooded or drained in which substructures are fabricated in, or lowered into, for float-off.

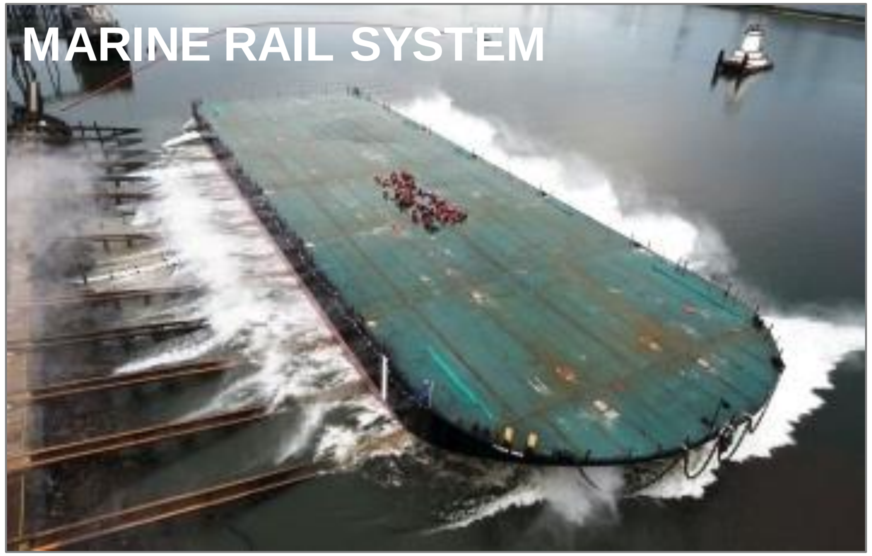
Shiplift*

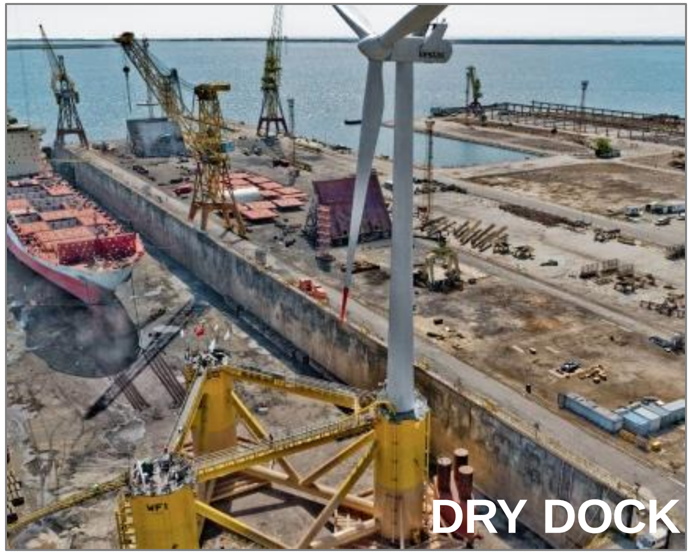
Lifting system to allow for one substructure to be lowered into water. Similar dredge requirements to gantry crane system

* Additional dredging requirement detail on following slides.

+ Additional dredging detail not provided, assumed no additional dredging required.

Substructure Float-Off Concepts – Fabrication Wharf





Dry Dock, Slipway, and Shiplift Dredging Example

Dry Dock Float-Off Concept Excavation and Dredging

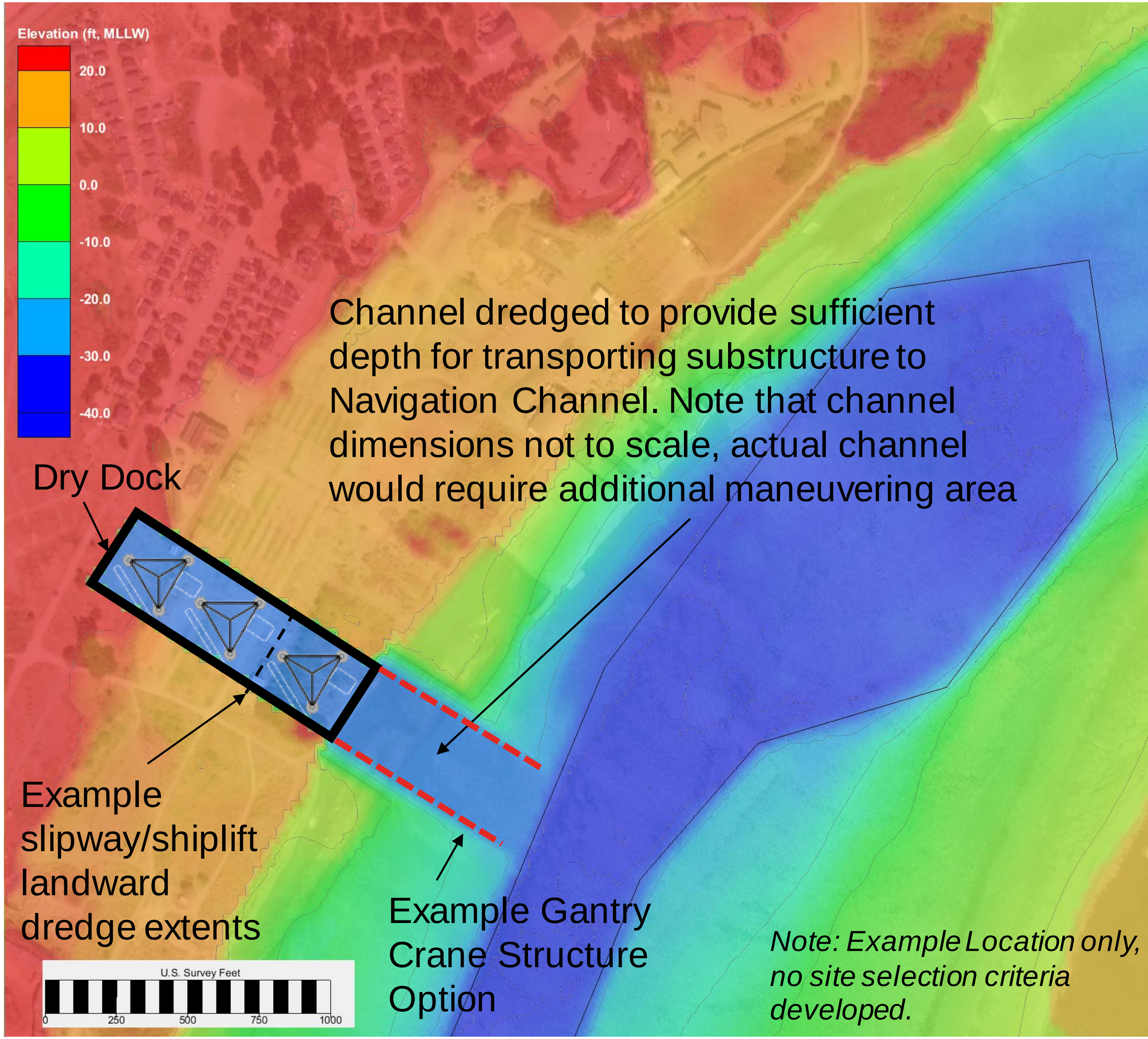
The example graving dock concept shown, would require a minimum of:

- Upland Excavation ~500,000CY
- Dredging* ~250,000+CY

Slipway and shiplift concepts – similar dredging requirements, w/less upland excavation.

Gantry crane support structure may extend seaward to minimize dredging

*Assuming 3H:1V side slopes



Large Commercial Scale – Fabrication Float-Off Assessment

Fabrication at Humboldt

Concept	Proven Technology At scale	Supports Serial Production	Minimizes Dredging	Minimizes CapEX
Semi-Submersible Dockside Barge	Yes	Yes	Yes	Yes
Marine Rail System	No	Yes	No	No
Dockside Crane Vessel	Yes (Oil & Gas industry)	No	Yes	No
Dry Dock	Yes	No	No	No
Gantry Crane and Slipway	Yes	Yes	No	No
Shiplift	Not known (200-300ft. Span)	Yes	No	No

Assessment: Semi-sub dockside barge (or similar type system) is likely float-off method. A wharf with sufficient bearing capacity and width will be required to transfer the fabricated substructure onto the barge-type system. The berth may require an exclusive use, with float-off every few days. Other float-off/launching systems are likely possible, but appear to either be likely greater cost, likely require more excavation/dredging, or haven't been proven at this scale. If fabricated offsite, similar findings to the pilot/small commercial scale assessment.

Outcomes

Pilot/Small Commercial-Scale

Delivery appears feasible considering possible vessel geometry and delivery options.

Depth at Humboldt Bay may not be sufficient for the larger end of semi-submersible ocean-going vessels for delivery of substructure. Larger semi-submersible barge options may be possible if wave action allows for float-off in deep portion of existing navigation channel (48 ft. Authorized Depth), or within a new “dredge pit.”

Large Commercial-Scale

Semi-sub dockside barge (or similar type system) is likely float-off method.

A wharf with sufficient bearing capacity and width will be required to transfer the fabricated substructure onto the barge-type system at a berth. The berth may require an exclusive use, with float-off every few days.

Other float-off/launching systems are likely possible, but likely appear to cost more, require more excavation/dredging, or haven’t been proven at this scale.

If fabricated offsite, findings are similar to those for vessel delivery in Pilot/Small Commercial-scale. Likely feasible, but size of vessel may be limited without either operating in Entrance Channel, or new dredging.

Appendix D Nearby Port Facilities

This appendix consists of a memorandum that summarizes conditions for existing ports in Oregon/Northern California, the SF bay, and Southern California and also assesses how these facilities may provide services to the offshore wind industry relative to Humboldt County.

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Appendix D
Nearby Port Facilities

Project:	North Coast Offshore Wind		
Our reference:	507100657		
Prepared by:	Aaron Porter	**Date:**	6-30-20

Information contained in this memorandum is summarized from Porter and Phillips (2016), and has been re-purposed for this assessment. Updates have not been conducted, and information within may be superseded by new facilities. The intent is to summarize approximate conditions for use in assessing how these facilities may provide services to the OSW industry relative to Humboldt Bay, and not to update the port facility characteristics database.

Regional Assessment Summary

1.1 Oregon/Northern California

Although there are deep draft ports in this region, there are no major international ports. The deep draft ports on the Oregon and Northern California Coasts without air draft restrictions are Astoria, Coos Bay, and Humboldt Bay. Coos Bay and Humboldt Bay have large protected harbors and land potentially available for development. Astoria is located just seaward of the Astoria-Megler Bridge and has several terminals. As compared to Coos Bay and Humboldt, Astoria has less land available with direct port access. Newport is a deep draft harbor and is the home for the NOAA Pacific Fleet as well as a commercial fishing harbor, but has limited land available.

The Coos Bay area has the largest population on the coast with approximately 26,000 people, and has land available for development. The horizontal clearance of 197 ft. at the rail bridge will likely preclude the fabrication and construction of OFW foundations to/from ports landward of the bridge due to the width restriction. The vertical clearance of 149 ft. at the Hwy. 101 Bridge will affect the fabrication and construction of OFW Foundations. Fabrication, construction, and assembly facilities would be best suited seaward of the bridges. Though privately held land is potentially available, commercial-scale facilities would most likely require land redevelopment for component storage and transport, as well as a new heavy load wharf. The proposed Jordan Cove project which proposes creation of a new slip with access to the navigation channel could also potentially serve as access for OFW construction and assembly. Required development is similar in scope to Humboldt Bay. The Lower Coos Bay Channel Modification project is planned, and would increase available navigable depths which would improve navigation conditions for OFW foundations

1.2 SF Bay

Air draft heights are limited to 220 ft. or less due to the Golden Gate Bridge, and other bridges crossing waterways, and therefore the Northern California ports are more likely suited to be potentially supporting OFW manufacturing and construction rather than assembly. Similar to Southern California, Northern California ports provide high volume cargo throughput and have few navigation restrictions. Ports in the bay are protected from Pacific Ocean swell waves and do not require breakwaters. The total amount of area at the Port of Oakland is very high, but is primarily used for container terminals currently.

Northern California has a network of ports which have characteristics that may be able to support future OFW Fabrication and Construction activities. A potential limitation of ports in the San Francisco Bay area is the present availability of developed upland areas which have direct quayside access for transport of the large OFW components. Ports such as Oakland have substantial upland area with marine access, and should it become available for a change in use, these areas would be a good candidate for OFW fabrication site. Overall, to support OFW fabrication requirements for multiple component types it is likely that at least some upland or terminal redevelopment is required, or marine terminal facilities will need to be built. The dry dock facilities may not be large enough to support all OFW technologies. The ports of Stockton and West Sacramento may be able to provide fabrication and construction services.

1.3 Southern California

Southern California is home to several large capacity ports including San Diego, Los Angeles and Long Beach. The port of San Diego is advantageous due to natural protection from ocean swell and a temperate climate suitable for year-round cargo shipments. The port has amble upland area including 135 acres of potential upland use, however some draft restrictions exist inland of the Coronado bridge.

The Port of Long beach and Port of Los Angeles are some of the busiest container ports in the world. The port of Los Angeles has the benefit of sheltered waters and existing breakbulk facilities. However OFW assembly will be difficult because of air draft restrictions near the existing breakbulk terminals. Additional OFW infrastructure development is likely required to support operations out of the port of Los Angeles. The Port of Long beach, located adjacent to the Port of Los Angeles is also a major container port with few navigation restrictions. The amount of traffic the port already receives limits the potential for OFW assembly/construction. If some of the land could be repurposed for supporting OFW, the Port of Long Beach already has in place much of the equipment/infrastructure to handle large OFW components.

2 Summary of Nearby Port Facilities

Table 1. Nearby Port Facilities

STATE	PORT	Nav. Depth (ft.)	Nav. Width (ft.)	Regional Height Limit (ft.)	Potential Upland Area w/Marine Access (acres)
California	Oakland	50	480	190	771
California	Richmond	38	500	220	130
California	San Francisco	38	600	190	76
California	Benicia	38	500	140	650
California	San Diego	42	600	No Limitation	135
California	Los Angeles	53	750	No Limitation	1600
California	Long Beach	76	600	No Limitation	1600
California	Hueneme	35	333	No Limitation	130
California	Morro Bay	18	250	No Limitation	1
Oregon	Coos Bay	37	300	No Limitation	1000

STATE	PORT	Nav. Depth (ft.)	Nav. Width (ft.)	Regional Height Limit (ft.)	Potential Upland Area (acres) w/Marine Access
Oregon	Newport	30	300	135	40
Oregon	Astoria	43	600	No Limitation	10

3 Facility Summaries

3.1 Port of San Francisco

Figure 1 – Port of San Francisco.

3.1.1 Existing Facilities

The Port of San Francisco, located in the City and County of San Francisco, lies on the western edge of the San Francisco Bay. The port has 145 acres of paved cargo staging area (Port of San Francisco 2016). It has six deepwater berths, covers 7.5 miles of waterfront, and has four gantry cranes. The port specializes in non-containerized cargo, which includes experience handling wind turbine components. The port is unable to develop container trade due to poor rail access, inability to move double-stack container trains due to tunnel height restrictions, and limited room for expansion. Major State Highway System routes serving the Port include US 101, I-80, I-580, I-680, I-880, SR-84, SR-92 (CalTrans 2016)

The Port is also known for having a large floating dry dock dedicated to ship repair (CalTrans 2016).The dry docks are operated by BAE systems, and have approximate dimensions of 530 ft. by 90 ft., and 900 ft. by 150 ft. Crane capacity at the dry dock is approximately 15 tons, and 60 tons, respectively. In addition to the floating dry docks, four full-service layberths, and small boat shops are located nearby.

The Pier 80 breakbulk terminal is 69 acres, with 1000 psf bearing capacity, 2,700 ft. lineal length, multiple 40 ton cranes, and a depth of 40 ft. MLLW. The Pier 94/96 breakbulk terminal has 3 berths, 2,450 feet of lineal length, 800 psf bearing load capacity, on dock rail access, a 40 ton crane, 15 acres of paved land, and a berth depth of 40 ft. MLLW. Behind Piers 90-94 there are approximately 23 acres of unimproved land which the port is planning to re-develop for new uses (Port of San Francisco 2016).

Table 2. San Francisco Key Characteristics

Characteristic	Strength	Potential Limitation
Harbor Location	Sheltered harbor	No direct access to Ocean
Navigation	38 ft. depth, 600 ft. width navigation channel.	-
Air Draft	-	Restricted by regional bridges
Upland Area	-	Limited available land available for redevelopment (~25 acres)
Crane	-	60 ton crane
Shipyard	900 ft. by 150ft dry dock	-
Road & Rail Access	-	No class 1 Rail
Quayside Facilities	Multiple deep draft berths 800-1000 psf load bearing capacity	-
Helipad	-	-
Workforce & Fabrication	Large workforce population to pull from	-
Other	Existing breakbulk cargo handling. Experience with wind turbine components.	-

3.2 Port of Oakland

Figure 2 – Port of Oakland.

3.2.1 Existing Facilities

Port of Oakland is the largest port in San Francisco Bay by volume, and is located on the east side of San Francisco Bay, approximately 16 nm. from BOEM waters, inland of the Golden Gate Bridge (220 ft. clearance). Because it is a major container port; most berths are designed for container cargo. The Port is dredged to a depth of 50 feet annually, and has 1300 acres of maritime area over seven marine terminals, and 20 deep water berths. The Union Pacific and BNSF railroad facilities are located adjacent to the marine terminal facilities. Presently the 18.5 acre, 700 ft. long, Berth 33 is available for lease (Port of Oakland 2016), and has previously handled breakbulk cargo (seaport.findthedata.com 2016). In February 2016, Ports America terminated their lease at the 200+ acre Outer Harbor Terminal. Oakland port officials also said they'd consider other uses for the soon-to-be-vacant terminal apart from container operations (Wall Street Journal 2016). There does not appear to be a helipad at the port or in the vicinity. The Left Coast Lifter crane barge had been used to construct the Bay Bridge, and is now located in New York State after being moored at Pier 7 at the Port of Oakland (Mercury News, 2013)

Table 3. Port of Oakland Key Characteristics

Characteristic	Strength	Potential Limitation
Harbor Location	Sheltered harbor	-
Navigation	50 ft. dredge depth, accommodates major container ships.	-
Air Draft	-	San Francisco Bay Bridge (190 ft.)
Upland Area	200 acres may be available for redevelopment.	Existing quayside area is limited and used primarily for container throughput.
Crane	-	Primarily container cranes
Shipyard	-	Significant dry docks not on site.
Road & Rail Access	Interstate Highway and Class 1 Rail	-
Quayside Facilities	Multiple deep draft berths	-
Helipad	-	-
Workforce & Fabrication	Large workforce population to pull from	Few shipbuilding and waterside manufacturing facilities.
Other	Potentially large (200+ acre) facility for repurpose from container use.	Historically a container port

3.3

3.4 Port of Richmond

Figure 3 – Port of Richmond.

3.4.1 Existing Facilities

The Port of Richmond is a deepwater port located approximately nine miles from the Golden Gate Bridge in Contra Costa County on the east shore of the San Francisco Bay at the end of Canal Boulevard in South Richmond. The port is accessible through the 38 ft. deep Richmond Harbor Channel. Currently, the port ranks #1 in liquid bulk and automobile tonnage among the five ports on the San Francisco Bay. The port has five city-owned terminals and ten privately owned terminals for handling bulk liquids, dry bulk materials, vehicle and break-bulk cargoes. The port does not handle containers (CalTrans 2016). The port has interstate highway access, shortline rail, and Class 1 rail Access. There are 5 public terminals and 10 private terminals over 200 acres, and 32 miles of shoreline. Pt. Potero Marine Terminal has approximately 130 acres of land, a concrete wharf and pier, multiple berths, two warehouses, and multiple graving docks (four docks measuring 575 ft. x 100 ft. and one dock measuring 750 ft. x 100 ft.). The graving docks are currently flooded.

Table 4. Port of Richmond Key Characteristics

Characteristic	Strength	Potential Limitation
Harbor Location	Protected Harbor	Not directly on ocean
Navigation	38 ft. Navigable Depth. Accommodates 500 ft. LOA vessels. 500 ft. wide Navigation Channel.	-
Air Draft	-	Air draft limited by Golden Gate Bridge
Upland Area	Potentially available land available for redevelopment (130 acres)	Much of available upland appears to be used for roll-on roll-off automobile cargo
Crane	-	55 ton breakbulk crane capacity.
Shipyard	Existing graving docks	Graving docks are presently flooded
Road & Rail Access	Interstate Highway and Class 1 Rail	-
Quayside Facilities	Existing breakbulk cargo handling	-
Helipad	Helipad in vicinity	-
Workforce & Fabrication	Large workforce population to pull from	-
Other	-	-

3.5 Port of Benicia

Figure 4 – Port of Benicia.

3.5.1 Existing Facilities

The private Port of Benicia is located in Solano County on the northern bank of the Carquinez Strait approximately 19 miles northeast of the Port of Oakland and 25 miles northeast of the Port of San Francisco. Cargo at the port is primarily automobiles, but it also handles break-bulk and other heavy lift cargo. The Port is accessed by a single 2,400 ft. long pier deep-water pier with three berths on a 38 ft. depth navigation channel. The port is located one mile from Interstate access. Union Pacific railroad operations provide on-terminal rail service. Marine operations cover 645 acres, and appears to be primarily auto staging. The Benicia Industrial Park is an additional 4,000 acres (CalTrans 2016). A number of private facilities are located across the Strait, including the C&H Sugar docks at Crockett, while other installations are located to the east at Pittsburgh and Antioch, one of the largest being the USS-POSCO complex at Pittsburgh which handles steel coils. (Pacmar 2015)

Table 5. Port of Benicia Key Characteristics

Characteristic	Strength	Potential Limitation
Harbor Location	Protected	Not directly on Pacific Ocean
Navigation	Deep wide natural channel. Accommodates 500 ft. LOA vessels..	-
Air Draft	-	140 ft. limited by bridges.
Upland Area	Appx. 650 acres with marine access.	Primarily auto staging .
Crane	-	Limited crane infrastructure.
Shipyard	-	-
Road & Rail Access	Interstate Highway, Class 1 Rail	-
Quayside Facilities	2,400 ft. long pier	Appx. 80 ft. wide pier
Helipad	-	-
Workforce & Fabrication	Large metropolitan population	-
Other	Large paved area exists	-

3.6 Port of San Diego

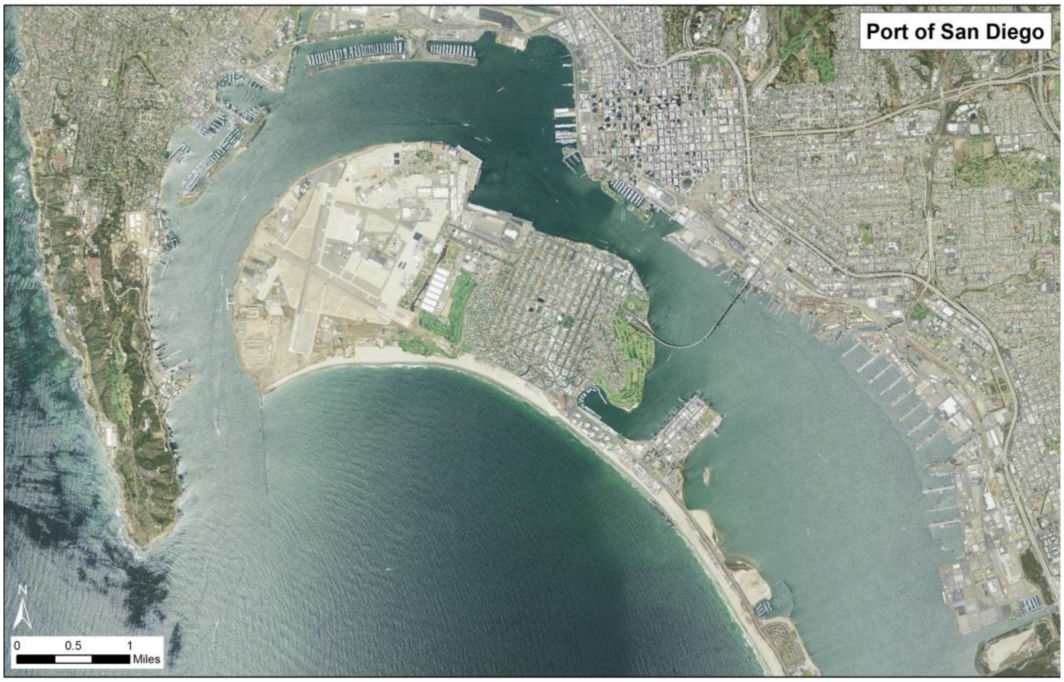


Figure 5 – Port of San Diego.

3.6.1 Existing Facilities

The Port of San Diego is a natural deep water harbor located approximately 96 miles southeast of Los Angeles and 10 miles north of the United States-Mexico border. San Diego Bay is protected from the Pacific Ocean by two peninsulas, and the area's temperate climate makes it conducive to year-round cargo handling. It contains a full service shipyard, and two ship repair yards. The port operates two primary cargo marine terminals, Tenth Avenue and National City and specializes in breakbulk cargo (CalTrans 2016). The Tenth Avenue Terminal has previously handled wind farm components such as hubs, blades, and nacelles. To support breakbulk cargo handling and staging the terminal has 25 acres of open space and a 100-ton mobile crane, as well as 24 hour operations. National City Marine Terminal is south of the Coronado Sand Diego Bay Bridge, which as a clearance of 200 ft. NASSCO General Dynamics and BAE Systems shipyards are also located inland of the bridge. Dry docks at the shipyards have a maximum width of approximately 175 ft., with a lift capability of 650 tons.

Table 6. San Diego Key Characteristics

Characteristic	Strength	Potential Limitation
Harbor Location	Sheltered harbor and near BOEM waters	
Navigation	Wide (600 ft) deep navigation channel (~42 ft.)	
Air Draft	Some facilities are seaward of Coronado bridge (~200 ft. clearance)	Shipyards are inland of Coronado bridge (~200 ft. clearance)
Upland Area	135 acres of potential port upland use.	Limited upland area not presently in use for new fabrication facilities with access to the water seaward of the Coronado Bridge.
Crane	650 ton shipyard crane	100 ton mobile crane
Shipyard	Large shipyard	Shipyard is primarily located inland of air draft restriction
Road & Rail Access	Highway access. Class 1 and Shortline Rail access.	
Quayside Facilities		Quayside clear area is limited due to proximity of buildings or existing uses.
Helipad	Airport located near seaport.	
Workforce & Fabrication	Significant manufacturing and shipbuilding capability. Large metropolitan population and manufacturing base.	
Other	Previous experience importing wind turbine components. 24 hour operations	

3.7 Port of Los Angeles

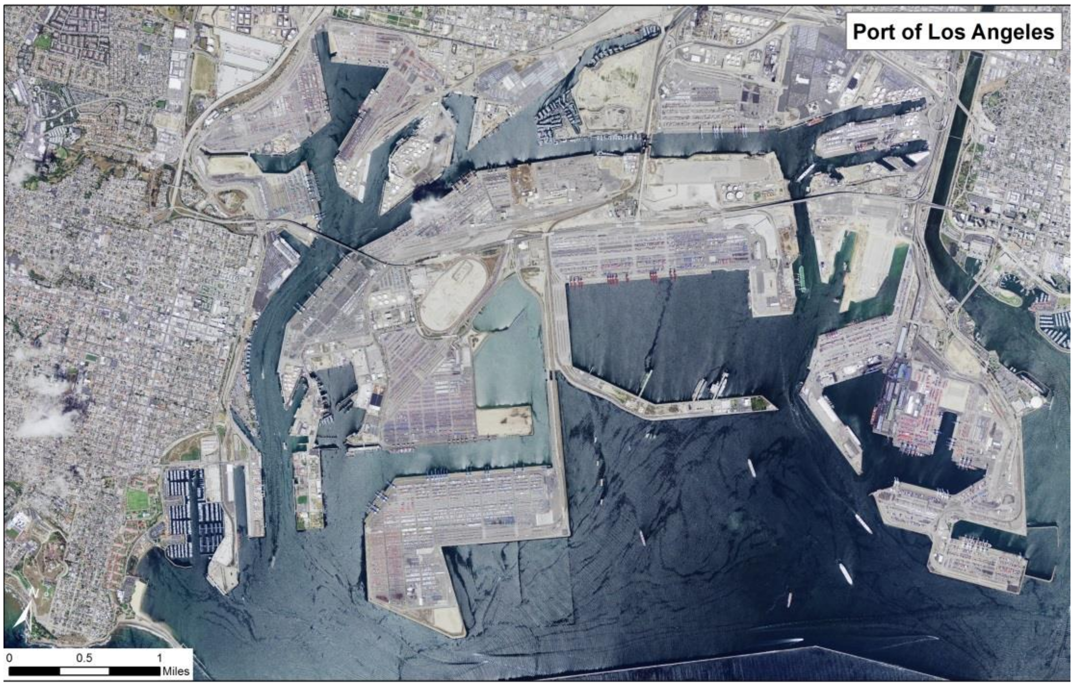


Figure 6 – Port of Los Angeles.

3.7.1 Existing Facilities

The Port of Los Angeles (POLA) is located on San Pedro Bay, 20 miles south of downtown Los Angeles (LA), at the south end of Interstate (I-) 110. The Port is the busiest container port in the U.S. (ranked 1st since 2000) and the 16th busiest container port in the world (CalTrans. 2016). The port has 23 cargo terminals, 270 berths, and 85 gantry cranes over an area of 1600 terminal acres. Of interest to OFW and MHK development, the port operates three (3) breakbulk terminals, with a total of seven (7) berths, and a total of 76 acres (POLA 2016). Existing crane capacity is approximately 45 tons. The Port does not have a major dry dock, though some ship repair facilities are in the area (e.g., Al Larson Boat Shop). The existing breakbulk terminals currently handle steel and are located landward of the Vincent Thomas Bridge, which has a clearance of 184 ft. Expansion of breakbulk facilities is included in the port master plan, but is primarily located inland of the bridge. The port has significant overland connections (Interstates, Class 1 rail, shoreline rail) as a result of the cargo volume handled.

Table 7. Los Angeles Key Characteristics

Characteristic	Strength	Potential Limitation
Harbor Location	Sheltered harbor and near BOEM waters	-
Navigation	Deep (53 ft.) and wide (750ft.) primary navigation channel	-
Air Draft	No regional restrictions	Some areas of the port which may be available are located inland to air draft restriction (184 ft.)
Upland Area	Appx. 1600 total acres	Limited upland area with direct access to the water seaward of the Vincent Thomas Bridge.
Crane	-	45 ton crane
Dry Dock	-	Some shipbuilding and waterside manufacturing facilities.
Road & Rail Access	Class 1 and Shortline Rail access, Interstate access.	-
Quayside Facilities	7 existing breakbulk berths	Quayside berth loading capacity not known.
Helipad	Helipad located at the port	-
Workforce & Fabrication	Large metropolitan population and manufacturing base.	-
Other	24 hour operations	-

3.8 Port of Long Beach

Figure 7 – Port of Long Beach Map.

3.8.1 Existing Facilities

The Port of Long Beach (Port) is located at the south end of the I-710 Freeway and approximately 25 miles south of downtown LA. It has one of the deepest harbors of any seaport in the world and handles approximately 5,000 vessel calls a year (CalTrans 2016). The port is located directly adjacent to the Port of Los Angeles. Five breakbulk terminals are located at the Port, two (Pier F, Pier T) of which are located seaward of the Gerald Desmond Bridge (clearance of 155 ft.). Existing breakbulk crane capacity is approximately 40 tons.

Table 3. Long Beach Key Characteristics

Characteristic	Strength	Potential Limitation
Harbor Location	Sheltered harbor and near BOEM waters	-
Navigation	One of the deepest harbors in the world (76 ft.)	-
Air Draft	Appx. 1600 total acres	Several terminals located inland of air draft restriction (155 ft.)
Upland Area	-	Limited undeveloped upland area for new fabrication facilities with access to the water.
Crane	-	40 ton crane
Shipyard	-	Minor shipbuilding and waterside manufacturing facilities.
Road & Rail Access	Interstate Highway and Class 1 rail	-
Quayside Facilities		-
Helipad	Located at Port	-
Workforce & Fabrication	Large metropolitan population and manufacturing base.	-
Other	Experience with wind turbine components	-

3.9 Port of Hueneme

Figure 8 – Port of Hueneme.

3.9.1 Existing Facilitates

Port of Hueneme is the only deep draft harbor between Los Angeles and San Francisco Bay. The Ports specializes in handling automobiles, produce, and bulk cargo. It also provides support services for the offshore oil industry. (CalTrans 2106). The port has 6 deep draft berths, which appear to be supported by concrete piles, and handles break bulk cargo at the south terminal. It is known as a handler of automobiles and fresh produce. The port has outdoor storage capacity of 50 acres, 165 acres of maritime operations, and 210 acres of industrial land. Shortline rail access is available at the port, but not direct to dock. The port can handle vessels up to 800 ft. in length. At present, it has approximately 130 acres up for commercial lease and 280 acres in additional private parcels. In 2013 Ports America, a terminal operator at the port purchased a LHM 420 mobile harbor crane with a maximum lifting capacity of 136 tones and a radius of approximately 150 ft. Existing cargo storage bearing capacity appears to be approximately 600 psf (findthedata 2015). Presently the navigation channel is maintained at 35 ft. mean lower low water (MLLW), and is planned for deepening to 40 ft.

Table 9. Hueneme Key Characteristics

Characteristic	Strength	Potential Limitation
Harbor Location	Sheltered harbor and direct ocean access	-
Navigation	-	35 ft. MLLW navigation depth
Air Draft	No air draft restrictions	-
Upland Area	Over 100+ acres of land available for lease	-
Crane	110+ ton crane	-
Shipyard	-	-
Road & Rail Access	Shortline Rail access	No direct highway access
Quayside Facilities	Multiple deep draft berths	Quayside berth loading capacity investigation may be required.
Helipad	Helipad located near the port	-
Workforce & Fabrication	Large metropolitan area to draw from	Few shipbuilding and waterside manufacturing facilities.
Other	Experience with wind turbine components	-

3.10 Port of Morro Bay

Figure 9 – Morro Bay.

3.10.1 Existing Facilities

The Port of Morro Bay is a small harbor located on the California coast, approximately 200 miles Northwest of Los Angeles. The harbor is home to a commercial fishing fleet and full-service marina with launch ramp. The port also provides a harbor patrol and Coast Guard station. There appears to be limited upland area available for staging operations. There is no crane or helipad infrastructure at the port.

Table 10. Morro Bay Key Characteristics

Characteristic	Strength	Potential Limitation
Harbor Location	Protected. Directly on Pacific Ocean	-
Navigation	Channel Depth = 18 ft. Channel Width = 250 ft.	-
Air Draft	No air draft	-
Upland Area	-	-
Crane	-	Limited crane infrastructure
Shipyard	-	-
Road & Rail Access	-	-
Quayside Facilities	-	-
Helipad	-	-
Workforce & Fabrication	-	-
Other	Coast Guard Station	Remote area

3.11 Port of Coos Bay

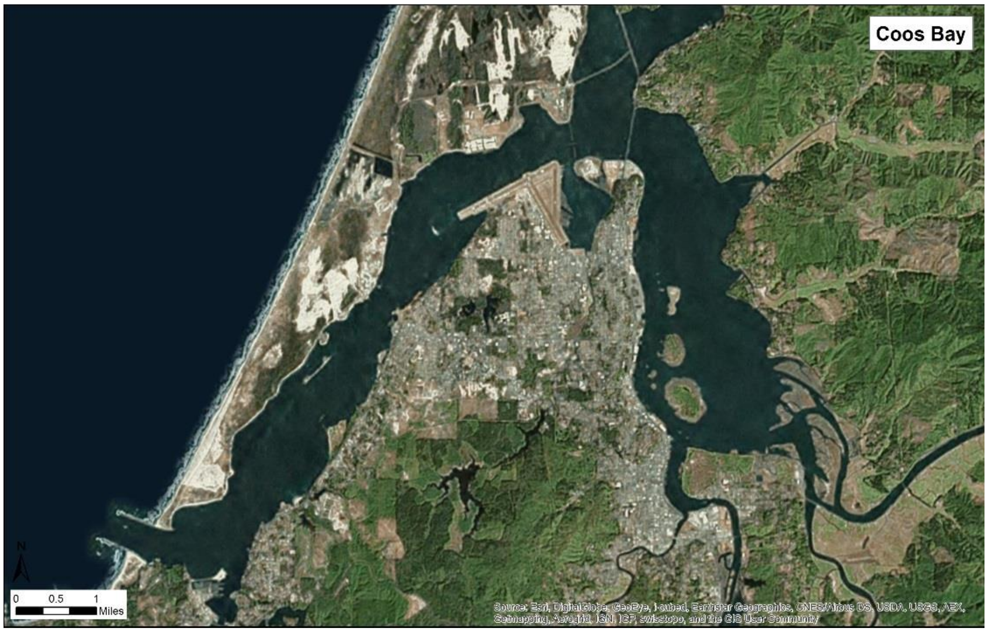


Figure 10 – Port of Coos Bay.

3.11.1 Existing Facilities

The Port of Coos Bay is located 95 miles north of the Oregon-California border and 18 miles from BOEM waters, is the largest deep-draft port between San Francisco and Washington State. Maintained by the USACE, the channel (37 ft. deep) is 1,150 ft. wide at the entrance mark, reducing to 700 ft. by Channel Mile 0, and further reducing to 300 ft. at Channel Mile 1. There is a horizontal clearance of 197 ft. at the railroad bridge spanning from Jordan Point to North Point (Channel Mile 9.2) and a vertical clearance restriction of 149 ft. at the U.S. 101 Bridge (Channel Mile 9.5). The Port owns more than 1,000 acres of land on the North Spit area of lower Coos Bay. Port jurisdiction currently includes seventeen terminals, five of which are located seaward of both bridges and their associated horizontal or vertical clearance restrictions. It appears that no crane infrastructure currently exists at the port. The port has access to U.S. Hwy 101 and Class 3 rail network. A rail spur runs down the west and west bank of the bay. Helipad infrastructure can be found nearby at the Southwest Oregon Regional Airport. Developed upland area appears to be available (~20 acres), primarily at the 5 port facilities seaward of the rail and Hwy. 101 bridges. The port currently services vessels on the order of 500 ft. in length. Shipyard facilities can be found nearby the port at Charleston Shipyard. The Jordan Cove project proposed on Coos River's North Spit in North Bend includes an application for a new access channel and marine slip. Southern Oregon Marine, Inc. operates a 40-hectare marine oriented construction and repair facility located 16 km upstream from the harbor entrance (Advanced Research, 2009). Port is considering the feasibility of developing a General Purpose Cargo Terminal. Such a terminal could be utilized by break bulk, project or similar cargos, and could also serve as a staging, assembly, and deployment area for offshore wind energy platforms.

Table 11. Port of Coos Bay Key Characteristics

Characteristic	Strength	Potential Limitation
Harbor Location	Sheltered harbor and near BOEM waters (13 miles).	-
Navigation	Deep-water draft port. Currently serves +500 ft. vessels – limited vessel navigation restrictions anticipated	The existing navigable depth (37 ft.) is less than the conceptual-level estimate for required depth for assembled Semi-sub and TLP tow out, though with favorable tides, (diurnal tide range of approximately 7.6 ft.), tow-out may be possible.
Air Draft	150 ft. 5 terminals without horizontal and vertical clearance restriction	Horizontal and vertical clearance restrictions at 12 of 17 terminals
Upland Area	Approximately 1000 acres of potential development area owned by the port.	Limited developed staging area available.
Crane	-	-
Shipyard	Ship repair services available nearby. include haul out services are available for vessels up to 60 tons	-
Road & Rail Access	Access to Hwy. 101 and Class 3 rail network	-
Quayside Facilities	-	
Helipad	-	No helipad located at the port
Workforce & Fabrication	Coos Bay is manufacturing hub for central/south Oregon coast. Southwestern Oregon Community College	-
Other	Potential development at Jordan Cove to support OFW.	-

3.12 Port of Newport

Figure 11 – Port of Newport

3.12.1 Existing Facilities

The Port of Newport, located in Yaquina Bay 113 miles south of the Columbia River Mouth, is one of three deep draft ports on the Oregon Coast. The port's Newport International Terminal primarily deals with fabrication of forest products. Ten (10) acres of industrial land is currently vacant and features utilities in addition to 30 acres of bulk cargo storage adjacent to the terminal. The cargo docks at the terminal are 1.5 miles from the ocean entrance. A 30-ton mobile crane is available for use at the terminal. The port also features a small port with both commercial and recreational marina facilities. With moorage for approximately 200 commercial fishing vessels, the commercial marina also features a 300 ft. service berth with 4 hoists (1-5 ton) and a 200 ft. floating dock for dockside vessel repair. Shipwright services are available on-site and marine supplies can be found nearby. Although no helipad facility is found at the port, one is located at the Newport Municipal Airport, less than 5 miles from the port.

Table 12. Port of Newport Key Characteristics

Characteristic	Strength	Potential Limitation
Harbor Location	Sheltered Harbor. Close to BOEM waters (5 miles).	-
Navigation	Channel Depth = 30 ft., Channel Width = 300 ft., Deep-draft berth	-
Air Draft	-	135 ft.
Upland Area	Upland staging area and possible development available (~40 acres).	-
Crane	30 tom mobile crane	-
Dry Dock	Shipwright on-site.	No dry-dock
Road & Rail Access	Access to Hwy. 101.	No rail access.
Quayside Facilities	-	-
Helipad	-	No Helipad on-site.
Workforce & Fabrication	-	Remote area
Other	-	-

3.13

3.14 Port of Astoria

Figure 12 – Port of Astoria

3.14.1 Existing Facilities

Located just upstream from the meeting of the Columbia River and Pacific Ocean, but seaward of any air draft restrictions (such as the Astoria Bridge), the Port of Astoria is a deep water draft port with three piers, servicing the cruise ship, commercial fishing, and lumber industries. The 7.35 acre Pier 1 supports Astoria Forest products (Pier 1 West), as well as port-of-call berthing for cruise ships (Pier 1 North). Pier 2 (13.2 acres) serves the bulk fishing fleet with 3 faces: North, East and West (2,990 ft. total length). Pier 3 is used as a debarking and storage facility for Astoria Forest products as well as upland storage for boat haul out and vessel storage. However, Pier 3 is not currently a deep water berth. It is planned to upgrade Pier 3 into a deep draft terminal. The port has access to highway, state road and Class 3 rail facilities. Permanent on-dock crane equipment doesn't current exist at any of the piers.

Table 13. Port of Astoria Key Characteristics

Characteristic	Strength	Potential Limitation
Harbor Location	Sheltered Harbor. Close to BOEM waters (15 miles).	-
Navigation	Channel Depth = 43 ft. Channel Width = 600 ft.. Deep-draft port	-
Air Draft	No air draft restrictions	-
Upland Area	-	Pier 1 – 7 acres Pier 2 – 13 acres
Crane	-	No permanent crane.
Dry Dock	-	-
Road & Rail Access	Hwy. and state road access. Class 3 rail.	-
Quayside Facilities	-	-
Helipad	Helipad nearby – Astoria regional airport.	No helipad on-site
Workforce & Fabrication	-	Remote Area
Other	-	-

Appendix E Metocean Conditions

This appendix contains a memorandum that documents an abbreviated assessment of metocean conditions in the vicinity of the Humboldt Offshore Windfarm and associated facilities. The water levels, wind speed and direction, and details on waves and extreme ocean events are included.

MOTT MACDONALD

Appendix E
Metocean Conditions

Project:	Humboldt Offshore Wind		
Our reference:	507100657	**Subject:**	MetOcean Conditions
Prepared by:	Aaron Porter, PE	**Date:**	June 5, 2020
Approved by:	Shane Phillips, PE	**Checked by:**	Michelle Gostic

This memo was developed to identify metocean conditions in the vicinity of the Humboldt Offshore Windfarm and associated facilities. This conceptual level assessment was conducted by reviewing publicly available metocean data, conducting literature review, and interviews with local authorities

1.1 Water Levels

Tides for the area are based on the tidal benchmark sheet for NOAA Station 9418767, North Spit, Humboldt Bay, CA (NOAA, 2011) and the analysis by Aldaron Laird Trinity Associates (ALTA, 2015). Tides are generally semidiurnal. However, ALTA (2015) notes that near Humboldt Bay, the two high tides are not equivalent; one is higher than the other. The same is true for the low tides. In addition to the datums typically used by NOAA, ALTA (2015) defines two additional datums – mean monthly maximum water (MMMW) and the mean annual maximum water (MAMW), which is indicative of the average "king tide" elevation. Tidal datum elevations are summarized in Table 12.

Table 1: Tidal Datums, NOAA Station 9418767, North Spit, Humboldt Bay, CA, 40.76670 deg. N, 124.21700 deg. W

DATUM	(feet MLLW)	(feet NAVD88)
HIGHEST OBSERVED WATER LEVEL (12/31/2005)	9.89	9.55
MEAN ANNUAL MAXIMUM WATER (MAMW)*	9.12	8.78
MEAN MONTHLY MAXIMUM WATER (MMMW)*	8.08	7.74
MEAN HIGHER HIGH WATER (MHHW)	6.86	6.52
MEAN HIGH WATER (MHW)	6.15	5.81
MEAN TIDE LEVEL (MTL)	3.70	3.37
MEAN SEA LEVEL (MSL)	3.70	3.37
NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD29)	3.69	3.36
MEAN LOW WATER (MLW)	1.26	0.92
NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88)	0.34	0.00
MEAN LOWER LOW WATER (MLLW)	0.00	-0.34
LOWEST OBSERVED WATER LEVEL (01/20/1988)	-2.90	-3.23

NOTE: *Value estimated by ALTA (2015). All other values taken from the NOAA (2011) tidal benchmark sheet.

1.2 Winds

Wind data provided in the memorandum near Humboldt Bay are based on the record at NOAA Station 9418767, North Spit, Humboldt Bay, CA, which extends from August 2008 to the present. The prevailing winds are from the north, followed by the south and southeast (see Figure 1). Northerly winds predominate between March and October. Between November and February, winds from the southeast bring in larg e storms with higher wind speeds. Average wind speeds are 7.0 mph between June and September and 9.3 mph during the remainder of the year (October through May). The probability of wind speed exceedance during the summer and the remainder of the year is presented in Figure 1.

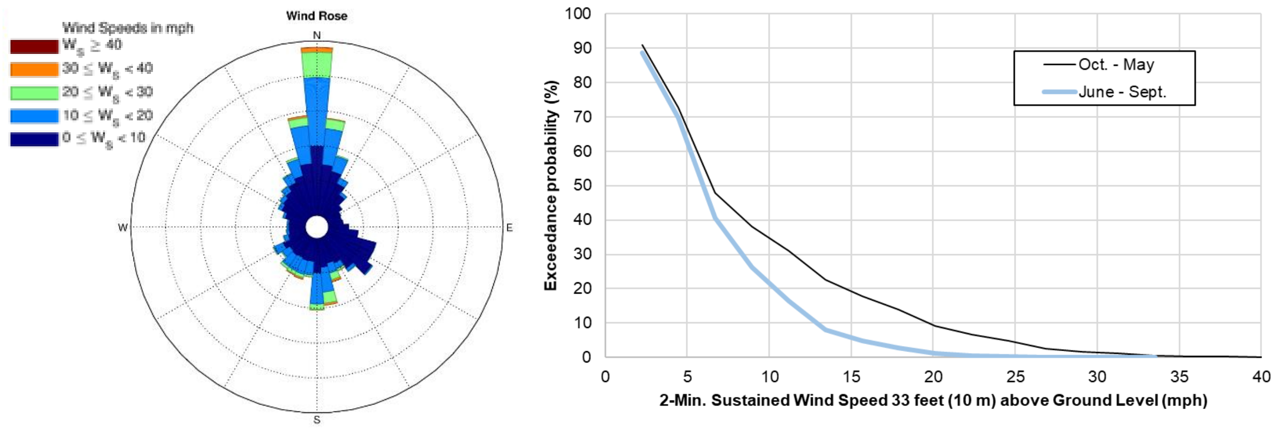


Figure 1: Wind rose at NOAA Station 9418767, North Spit, Humboldt Bay, CA (left panel) & Exceedance of winds at NOAA Station 9418767, North Spit, Humboldt Bay, CA (right panel)

1.3 Waves

Waves near Humboldt Bay are based on the record at Coastal Data Information Program Station 168 (40.89098 deg. N, 124.35660 deg. W, depth 394 feet), which extends from June 1, 2010 to the present. The prevailing waves are from the west-northwest and the northwest (Figure 1). Lower waves (< 7 feet) from the northwest are common between May and September (see Figure 2). During the rest of the year, waves tend to be higher, coming in from the west-northwest (see Figure 2). Extreme wave conditions are based on the longer record at NOAA Buoy 46022 (40.712 deg. N, 124.529 deg. W, depth 1,253 feet), which extends from January 18, 1982 to the present. Extreme wave statistics developed by Previsic and Berg (2010) are summarized in Table 2.

Table 2: Extreme Ocean Events near Eureka, CA (Previsic and Berg, 2010)

Percent	Return	Significant Wave Height (feet)		
Annual Chance	Period (years)	Max. Likelihood Estimate	95% Conf. Interval Lower Limit	95% Conf. Interval Upper Limit
2%	50	38.1	35.8	44.6
1%	100	39.0	36.7	47.5

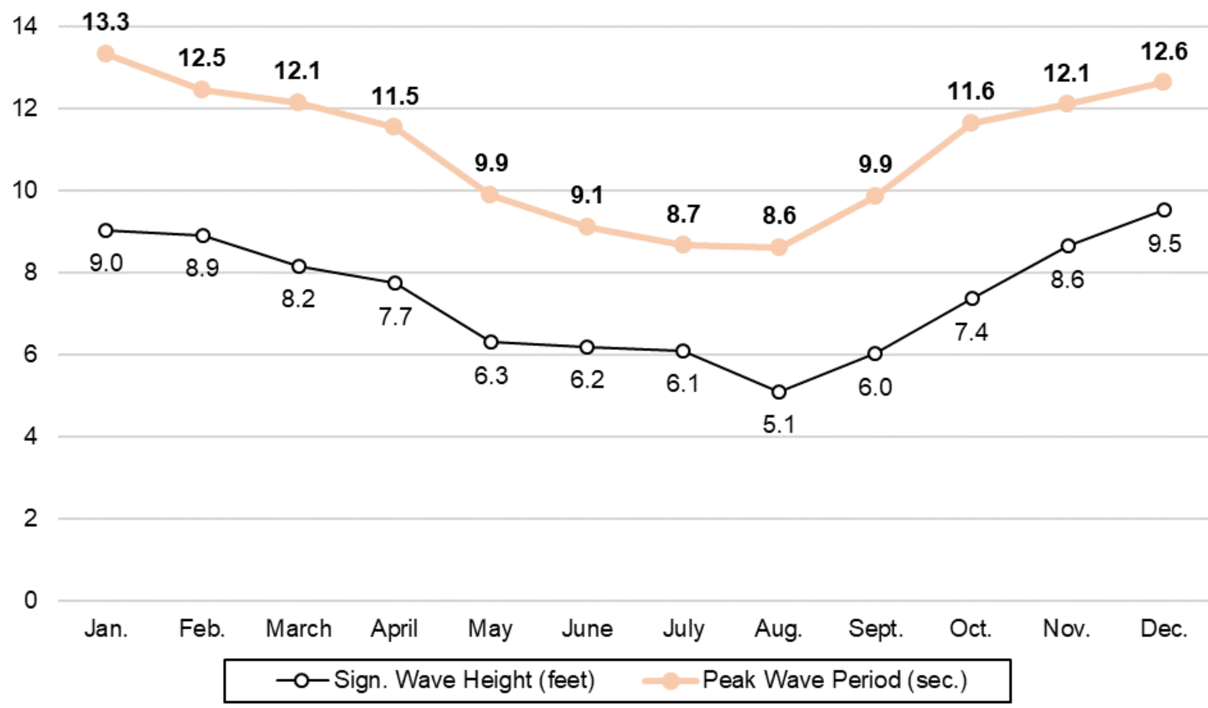


Figure 2: Monthly average waves at CDIP Buoy 168 (40.89098 deg. N, 124.35660 deg. W)

1.4 Currents

- Entrance:
  - Large shoal in entrance channel (seen in surveys) result of horizontal circulation patterns associated with ebb and flood currents
  - Strong entrance currents: average max flood (1.6 knots), average max ebb (2.0 knots)
  - Max flood (2.8 knots), max ebb (3.5 knots) also results in steeper waves making the entrance very hazardous to vessels during ebb tides
- Samoa Channel
  - Currents in Samoa Channel up to ~ 1.7 knots

2 References

Aldaron Laird Trinity Associates. Humboldt Bay SLR Adaptation Planning Project: Phase II report. 2015.

HB Harbor Recreation and Conservation District. EIR for Samoa Terminal Reconstruction. 1994.

Previsic, P. and Berg, .J. Wave Energy Resource and Site Characterization. RE Vision Consulting. 2010.

Appendix F Port Screening Assessment

This appendix presents the results of a screening assessment of a range of existing marine terminals in Humboldt Bay to determine if they are likely suitable to serve as an assembly, fabrication, and major repair facility, and/or an O&M facility. The screening criteria included yard area, air draft, and navigation impacts.

Appendix F: Port Screening Assessment

Primary Screening Assessment

Assembly Facility

1

Primary Criteria

- Yard Area
- Air Draft
- Navigation Interferences

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

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

Teal - Meets Primary Criteria – upgrades may be needed

Assembly Facility Screening

1

Primary Criteria

- Yard Area
- Air Draft
- Navigation Interferences

Site	Yard Area	Navigability	Air Draft
Criteria	25-100 acres	Limited/no effect.	No Limits
RMT 1			
RMT 2			
Schneider Dock			
Fields Landing			
Sierra Pacific			
Redwood			
Fairhaven			
Forest Products			

Red – Does not meet Primary Criteria without significant mitigation
Yellow – May meet Primary Criteria
Green - Meets Primary Criteria

O&M Facility Assessment Screening

1

Primary Criteria

- Yard Area

Site	Yard Area
Criteria	2-10 acres
RMT 1	Green
RMT 2	Green
Schneider Dock	Green
Fields Landing	Green
Sierra Pacific	Green
Redwood	Green
Fairhaven	Yellow
Forest Products	Green
Woodley Island	Yellow

Red – Does not meet Primary Criteria without significant mitigation
Yellow – May meet Primary Criteria
Green - Meets Primary Criteria

Appendix G Operations and Maintenance

This appendix presents the potential O&M requirements for the various build-out scenarios in order to determine the needs of associated port infrastructure. The facility requirements are based on windfarm size, windfarm distance, vessel requirements, and the number and types of vessels to perform the work.

Appendix G Operations and Maintenance

Introduction

Operations and maintenance requirements needed to be assessed for the various build-out scenarios in order to assess the port infrastructure requirements.

O&M can consist of minor repairs, preventative maintenance or major component replacement

Facility requirements are based on a combination of

- Windfarm size
- Windfarm distance
- Vessel requirements for specific repair and maintenance activities
- Number and type of vessels required for O&M

Objectives of this Appendix

- Outline O&M activities which may be required, and develop a conceptual example O&M strategy for use in developing what potential port infrastructure requirements could be.
- Identify potential risks and considerations for O&M activities in Humboldt Bay and offshore at Windfarm
- Develop conceptual assessment criteria and qualitatively assess locations and improvements needed for an O&M Base

Type of Activities

Operations and Maintenance

Preventive Maintenance & Minor Corrections

WTG

- Remote Resets.
- Programmed up tower and external inspections.
- Replacement of small parts (using internal hoist crane when needed).
- Inspection and small repair of the outside of the WTG

Electrical/Civil Balance of Plant (BoP)

- Remote Resets of offshore substation.
- Programmed inspections of the offshore substation.
- Small repairs and replacements of the offshore substation.
- Small repair of foundation/floating platform (requires specialized personnel for underwater repairs).

Major Corrective Repairs

WTG

- Replacement of large components.

BoP

- Network cable replacement
- Major floating platform repair

Activity Locations

Operations and Maintenance

Preventive Maintenance & Minor Corrections

WTG

- At wind farm

BoP

- At wind farm

Major Corrective Repairs

WTG

- Current technology limits WTG repairs to sheltered harbor area.

BoP

- Major floating platform repair → Floating WTG typically gets disconnected & tow the entire WTG back to port or protected harbor (in case of a jack-up vessel).
- Cable replacement → Typically requires a cable laying vessel.

Floating Offshore Wind O&M Vessels

Preventive Maintenance and Small Corrective Maintenance

Onshore Based Strategy

- Crew Transfer Vessels (CTV) Approach (up to ~12 NM)
  - Components are stored onshore.
  - Vessels consist of Crew Transfer Vessels.
  - CTV types include (Daughter Crafts, Catamarans and SWATH vessels).
- CTV + Heli-support (up to ~40 NM)
  - Includes the support from helicopters to quickly reach the affected WTG for small interventions.

Offshore Based Strategy

- Service Operation Vessel (SOV) Approach. (~40 NM+)
  - Components are stored in the SOV.
  - CTVs accompany the SOV.
  - Allows for larger maintenance crews to remain offshore longer.
  - SOV can include a helipad.

Floating Offshore Wind O&M Vessels

Major Corrective Maintenance

Towing Vessels

Towing vessels will tow the entire WTG platform to shore for major corrective maintenance.

Cable Laying Vessel

A cable laying vessel will be needed in case of a MV network cable repair

Jack-Up Vessel with Crane

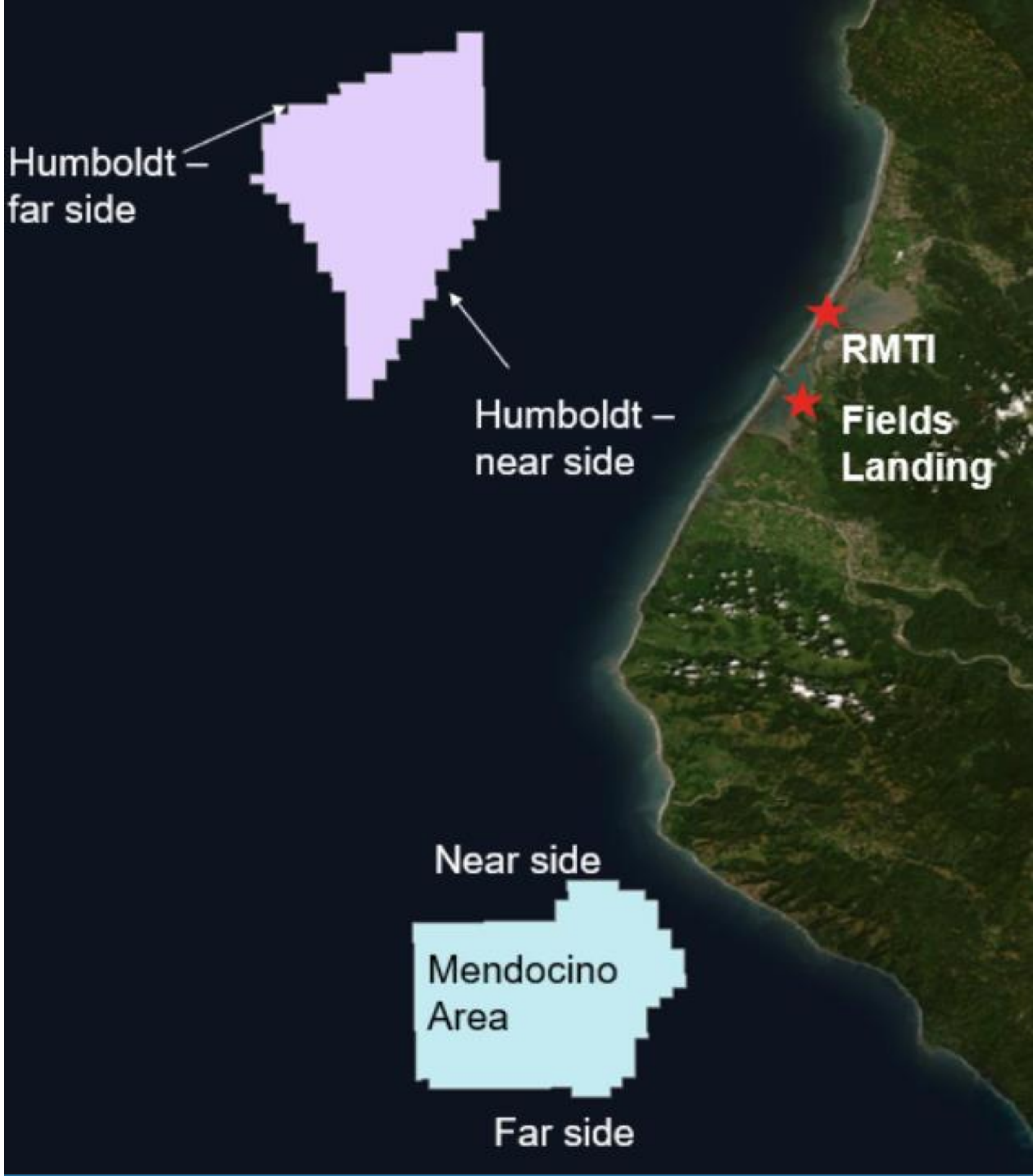
This type of crane should only be considered in case there is no possibility or infrastructure to tow the floating platform to port for repairs.

Possible Project Strategy

Onshore Base		Project Area	Distance near side (nautical mi)		Distance far side (nautical mi)	Possible O&M Strategy
RMTI	to	**Humboldt Call Area**	23	-	34	**Onshore Based + Heli-Support**
RMTI	to	**Mendocino Call Area**	46	-	60	**Offshore Based**
Fields Landing	to	**Humboldt Call Area**	20	-	31	**Onshore Based + Heli-Support**
Fields Landing	to	**Mendocino Call Area**	43	-	57	**Offshore Based**

Takeaways:

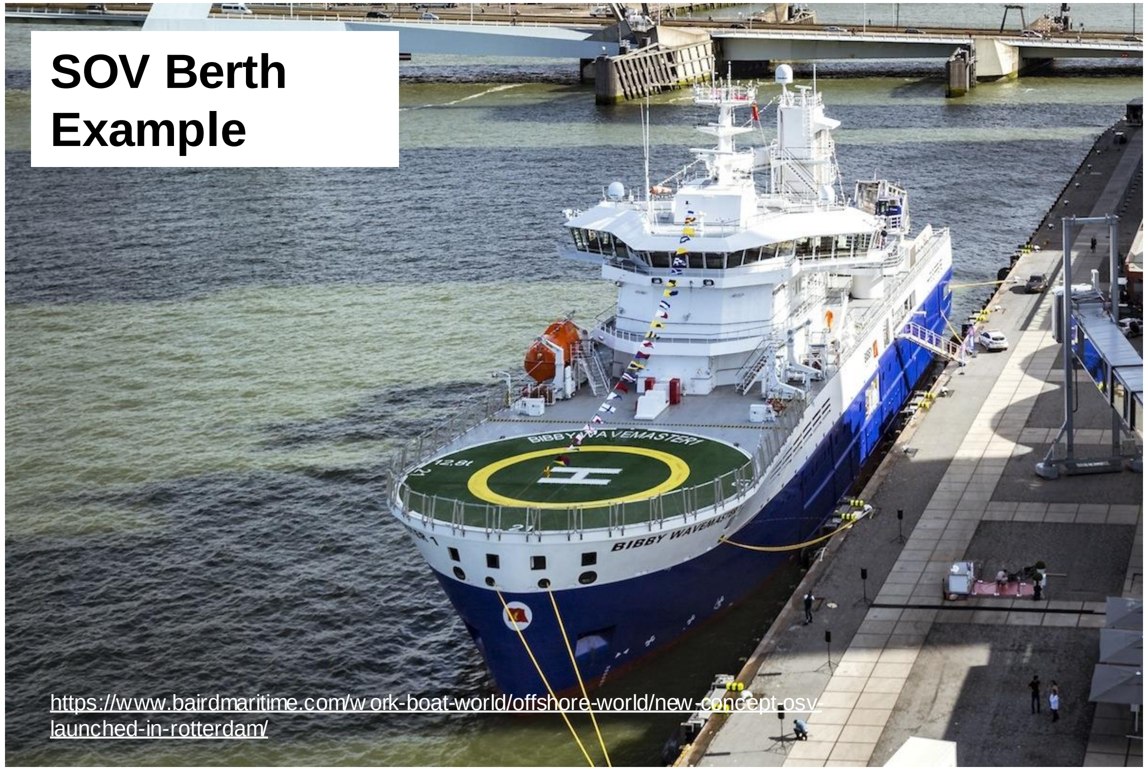
- O&M base near Field's Landing or Near RMT1 will likely have similar vessel requirements – based on distance from wind farm
- Due to distance from wind farm – Helicopter support may be needed in addition to CTVs if an onshore-based strategy is selected



Possible Crew Transport Units

	Pilot/Small-Commercial (4-12 turbines)		Large Commercial (150 turbines)	
Strategy	**Onshore**	**Offshore**	**Onshore**	**Offshore**
CTV	1-2	-	8-10	2-4
Helicopters	-	-	1-2	1-2
SOV	-	-	-	1-3

O&M Requirements



O&M Facility Assessment

Site	Yard Area	Live Load Condition	SOV Berth Length	CVT Pier/Floats	CTV Wave Exposure
Criteria	2-10 acres	500-1000 PSF	300-600+ft.	450-900 LF	Protected
RMT 1	(green)	(orange)	(green)	(green)	(yellow)
RMT 2	(green)	(orange)	(green)	(green)	(yellow)
Schneider Dock	(green)	(yellow)	(yellow)	(yellow)	(yellow)
Fields Landing	(green)	(yellow)	(orange)	(green)	(yellow)
Sierra Pacific	(green)	(orange)	(yellow)	(yellow)	(yellow)
Redwood	(green)	(orange)	(yellow)	(yellow)	(yellow)
Fairhaven	(red)	(yellow)	(yellow)	(yellow)	(yellow)
Forest Products	(green)	(yellow)	(yellow)	(yellow)	(yellow)
Woodley Island	(yellow)	(yellow)	(red)	(yellow)	(green)

Facility Likely Meets Criteria (green)

Facility May Meets Criteria or Minor Upgrades Needed (yellow)

Facility Upgrades Needed (orange)

Facility is Likely Unable to Meet Criteria (red)

Downtime Considerations

	Downtime Risk Assessment	
Activity	Summer (May-Sept)	Winter (Oct-April)
Crew Transfer		
Offshore Crew Vessel Center Transit		
Crew Transfer to Substructure		
Major Repairs		
Cross Bar – Outer Channel		
Open Ocean Transit Towing		
Hook-Up of Device		
Dynamic Cable Install		

Few Operational Restrictions

Some Operational Restrictions

Operational Restrictions Common

Operational Restrictions May Require Additional Planning

Takeaways:

- Minor repairs requiring crew transfer needs to be coordinated with weather window forecasts
- Major repairs likely to occur in summer season

Takeaways

Pilot/Small-Commercial Scale

- Likely consist of 1-2 CTVs. SOV likely not required.
- Fewer restrictions than assembly and fabrication sites – numerous options throughout the bay, but no existing facility appears to be able to provide combination of dock and exclusive upland facilities.
- CTV floating dock berths likely consist of a set of floats accessed via gangway – does not require deep draft access.
- Wave exposure needs to be assessed for siting of CTV harbor. More exposed sites may require a breakwater.
- Some limitations on access to the windfarm should be planned for due to offshore wave conditions.
- 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 may be limited to summer conditions

Large-Commercial Scale

- May either be a
  - Onshore support system option - likely consist of 8-10 CTVs and may require helicopter support
  - Offshore support system option - consisting of 1-3 SOVs, 2-4 CTVs, and 1-2 helicopters
- Requires more infrastructure than the small/pilot-scale due to increased support of at-sea operations. May required 10 CTV berths, or a 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, Field's Landing FNC geometry may limit SOV vessel specifications (e.g. draft)

Appendix H Vessel Database

This appendix evaluates the ranges of dimensions for various categories of vessels that support floating offshore wind based on prototype review and engagement with industry specialists. For each category of vessel, a range of design dimensions (length, beam, and draft) were developed for use in navigation and port infrastructure assessments.

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Schatz Energy Research Center

Appendix H - Vessel Database

Humboldt Offshore Wind Study

Prototype Vessel Appendix

- Ranges of dimensions for various categories of vessels that support floating offshore wind based on prototype review and engagement with industry specialists.
- For each category of vessel, a range of design dimensions (length, beam, and draft) were developed for use in navigation and port infrastructure assessments.

Component Delivery Vessels

Dimension	Range of Observed Dimensions
Length	400ft - 650ft
Beam	80ft - 140ft
Draft	18ft - 35ft

- Component delivery vessels consist of breakbulk carriers, cargo ships, and barges that transport wind turbine generator (WTG) components.

Examples

Vestvind

Combi Dock I

Heavy Lift Vessels

Dimension	Range of Observed Dimensions
Length	500ft - 800ft
Beam	140ft - 170ft
Draft	28ft - 35ft

- Heavy lift vessels are specially designed to transport very large loads. Heavy lift vessels may be used to deliver WTG components or substructures that are fabricated elsewhere.

Examples

Bokalift 1

Zhi Zian Zhi Xing

Semi-Submersible Heavy Lift Vessels

Dimension	Range of Observed Dimensions
Length	523ft - 900ft
Beam	150ft - 230ft
Submerged Draft	63ft - 100ft

- Semi-submersible heavy lift vessels are specially designed to transport very large floating loads with semi-submersible capabilities for loading/offloading.
- Semi-submersible heavy lift vessels may be used to deliver floating offshore wind substructures that are fabricated elsewhere.

Examples

Semi-Submersible Heavy Lift Barge

Dimension	Range of Observed Dimensions
Length	500ft.
Beam	100ft.
Submerged Draft	~20-26ft.

- Semi-submersible Heavy Lift Barges are specially designed to transport very large floating loads with semi-submersible capabilities for loading/offloading.
- Semi-submersible heavy lift vessels may be used to deliver floating offshore wind substructures that are fabricated elsewhere.

Example

Semi-Submersible Dockside Barge

Dimension	Range of Observed Dimensions
Length	250ft - 405ft
Beam	75ft - 105ft
Draft	10ft - 18ft below device draft

- Semi-submersible dockside barges are used to lower devices into the water.
- Floating OSW substructures that are fabricated upland could be floated-off via semi-submersible dockside barges.

Examples

Crane Vessel

Dimension	Range of Observed Dimensions
Length	280ft - 350ft
Beam	140ft - 175ft
Draft	10ft – 20ft

- Crane Vessels may be used for heavy lifts (e.g. dockside float off).

Examples

Anchor Handling Vessel (AHV)/Tug

Dimension	Range of Observed Dimensions
Length	~145ft
Beam	~50ft
Draft	~18ft

- Anchor handling vessels/tugs may be used for tow-in and tow-out of assembled floating WTG substructures.

Example(s)

Service Offshore Vessel (SOV)

Dimension	Range of Observed Dimensions
Length	150ft – 400ft
Beam	50ft- 80ft
Draft	16ft-30ft.

- SOVs are oceangoing ships that support multi-day offshore operation and maintenance trips.

Examples

Crew Transfer Vessel (CTV)

Dimension	Range of Observed Dimensions
Length	65ft-100ft
Beam	22ft-30ft
Draft (Depth)	5-10ft

- CTVs support transfer of crew members and light supplies for daily trips to the offshore wind farm for operation, inspection, and maintenance activities.

Example(s)

Appendix I Sea-Level Rise, Climate Change, and Tsunami Vulnerability

This appendix presents a conceptual-level assessment that was conducted to evaluate potential effects 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 build-out of OSW infrastructure and providing a framework for quantitative risk assessments and adaptive planning studies. The best available science was reviewed to document the hazards and climate change parameters the infrastructure may be exposed to. Infrastructure and system vulnerability have been assessed as a combination of exposure to the hazards/processes, sensitivity to the hazard/process, and ability to adapt to the hazard/process.

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Appendix I
Climate Change & Tsunami Vulnerability Assessment

Project:	Humboldt Offshore Wind		
Our reference:	507100657	**Subject:**	Climate Change, Sea Level Rise, & Tsunami Vulnerability Assessment
Prepared by:	Aaron Porter, PE	**Date:**	6/30/2020
Approved by:	Shane Phillips, PE	**Checked by:**	Abigail Mitchell, PE

Executive 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 build-out of OSW infrastructure and providing a framework for quantitative risk assessments and adaptive planning studies. The best available science 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[1]. 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).
- Port facilities (wharf and yard), and

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 summarized in Figure 1. 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.

[1] 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

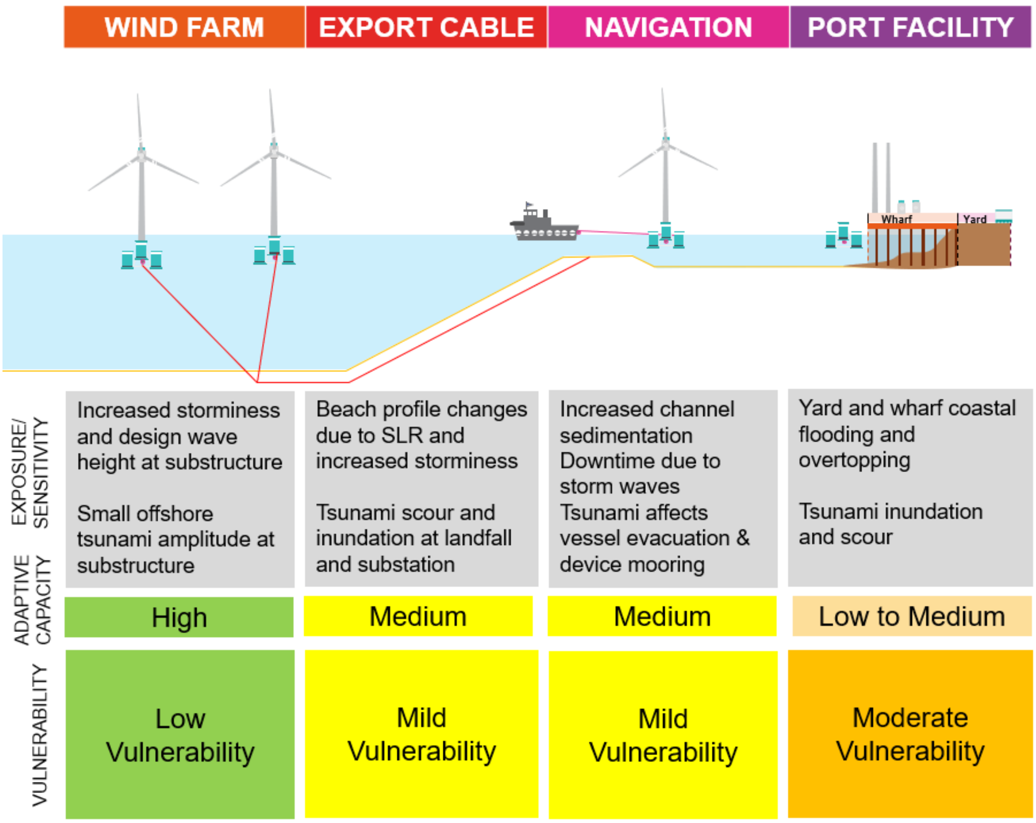

Figure 1 – Vulnerability Assessment Summary

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.

Navigation. Navigation infrastructure appears to be mildly vulnerable. The channel could be sensitive to increased or change in location of sedimentation due to climate change/SLR. Navigational downtime planning could be sensitive to increased storminess. Tow-out of device may reduce ability for other vessels to exit the harbor in response to tsunami, and moored devices could potentially become loose if not designed for tsunami loads. Risks should be quantified and an adaptive planning study should be conducted.

Port Facilities. The port facility area is vulnerable to tsunami hazards and mildly vulnerable to climate change. A portion of the port facility area is currently within the 100-year flood zone and with SLR the flood zone area, and the size of the flood zone is sensitive to SLR. Port design should include adaptive planning study for SLR to determine wharf elevations. The port may not be able to fully adapt to tsunami inundation sensitive to tsunami inundation, and an adaptive capacity study should be conducted to determine what level of risk the port development is willing to accept and what mitigation elements can be incorporated into design of the wharf and yard facilities.

1 Introduction

This memorandum is a qualitative vulnerability assessment regarding climate change parameters and tsunamis on proposed floating OSW and port infrastructure in the Humboldt Bay region. This assessment was conducted at a concept-level only and is intended to support the Humboldt Offshore Wind Project by identifying features to be addressed in the design and long-term planning of the project. This assessment identifies potential effects of climate change on the OSW infrastructure and areas of vulnerability and risk that should be addressed. This assessment was conducted using available literature, and information included in Port Infrastructure Memorandum and North Coast Offshore Wind Study: Offshore Wind Scenario Description provided by Schatz Energy Research Center.

This memorandum contains a basis of assessment (Section 2) summary of best available science on climate change parameters and tsunami hazards in the Humboldt region (Section 3), a vulnerability assessment of the assessed infrastructure (Section 4) and next steps (Section 5). For the purposes of this assessment the OSW infrastructure has been divided into 4 categories, and is shown in Figure 2 - Project Infrastructure Elements Assessed :

- Offshore wind farm
  - Consisting of the turbine, the floating substructure, anchoring and mooring lines, inter-array cables), export cable.
- Transmission lines to/from Humboldt Bay
  - Consisting of the export cable, the HVDC transmission cable, shoreline landfalls of the export and HVDC cables, and any offshore transmission infrastructure, onshore electrical facilities associated with the submarine export cables.
- Port facilities
  - Consisting of the wharf area, the storage yard, and other marine support facilities.
- Navigation (both offshore and onshore).
  - Federal Navigation Channel, anchorage areas, berth dredging, access to platforms for operations and maintenance.

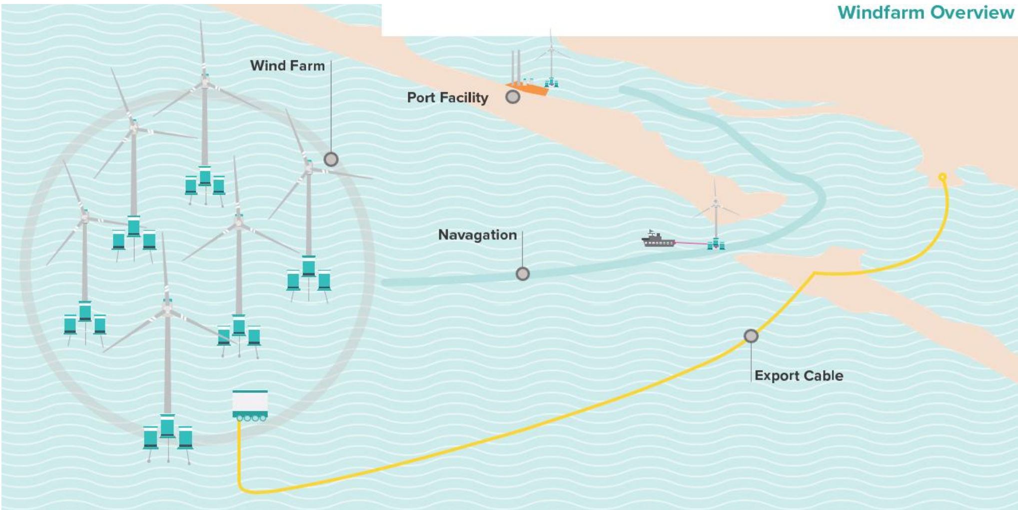

Figure 2 - Project Infrastructure Elements Assessed

2 Basis of Assessment

2.1 Best Available Science

2.1.1 Tsunami Hazard

Tsunami effects including inundation have been assessed for the different tsunami inundation modeling data available. The two primary tsunami inundation maps include maps produced for Humboldt County (Eureka and Fields Landing Quadrangles, 2009) and the American Society of Civil Engineering (ASCE, 2016) Tsunami Inundation Geodatabase. Tsunami hazards have also been coordinated with the Schatz project team (HSU, 2020)

2.1.2 Climate Change Parameters

For the purposes of this assessment, the climate-related processes have been divided into 7 categories. These categories were selected based on their potential effects on OSW infrastructure, they include wind, current, storminess, fire, precipitation/streamflow, sea level rise, and fog.

2.2 Literature Reviewed

Literature was compiled from a selection of public sources. The publications reviewed for this study include, but are not limited to, climate change assessments at the state, regional, and local level; the latest research papers on climate change applicable to this assessment; local SLR and tsunami studies, OSW and offshore industry standards and design guidelines, and international guidelines on climate change adaptation planning for ports and inland waterways.

2.3 Limitations of the Assessment

The focus of this assessment is to evaluate the high-level potential effects of changes in climate-related parameters and processes on OSW infrastructure. This review is based only on publicly available information, no new data has been collected. The assessment is an application of the best available science to the OSW infrastructure and operations. This qualitative assessment is not intended to be all inclusive for climate-related parameters and processes but is focused on impacts and potential effects on OSW infrastructure for the Humboldt Offshore Wind Project in the Humboldt Bay region. Offshore hazards such as presence of gas hydrates, submarine landslides, and seismic shaking are not part of this document.

2.4 Service Life

The service life of the infrastructure elements has been documented for the purpose of qualitatively assessing the vulnerability of the asset.

- The service life for the offshore wind farm (turbines, anchors, mooring lines, floating substructure, inter-array cables, maintenance operations) was assumed to be 20 years based on the North Coast Offshore Wind Study: Offshore Wind Scenario Description provided by Schatz Energy Research Center.
- The service life for the export cable infrastructure is assumed to be 20 years (HSU, 2020).
- The service life for the port facilities (e.g., wharf) is typically approximately 50 years (UFC, 2017).

3 Best Available Science

3.1 Tsunami Hazard

Historical and prehistorical evidence indicate that significant tsunami inundation has previously occurred in the area (HSU, 2020). Tsunami inundation maps were produced for Humboldt County to encourage awareness and help with emergency planning efforts (Patton and Dengler 2006). Figure 3 below includes excerpts from the tsunami inundation maps (Eureka and Fields Landing Quadrangles, 2009) for the area of interest for this project. These maps indicate the majority of the North and Samoa Peninsula are within tsunami evacuation zones for "worst case" tsunami event, as well as portions of the mainland.

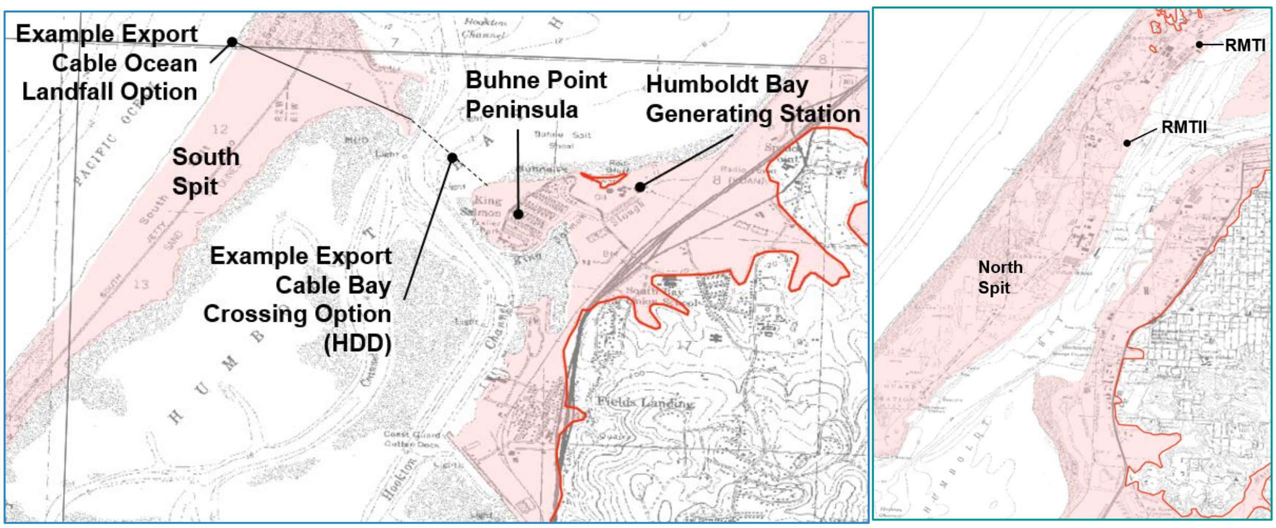

Figure 3 - Excerpt from 2009 Tsunami Inundation Map for Emergency Planning – Field's Landing and Eureka Quadrangles

Based on the ASCE Tsunami Design Geodatabase (ASCE, 2016), the north spit may be inundated between approximately 16 to 45 ft during the design tsunami event (annual likelihood of tsunami in this study is 1/2500 years).

3.2 Climate Change

This section is a summary of the current knowledge of projected change in conditions due to climate change which may affect project related infrastructure. Although the projected climate change elements have been divided into categories, it is important to note that many of the parameters and processes are interconnected and affect each other. For example, a potential increase in winds could lead to an increase in waves, or a decrease in precipitation could lead to an increase risk of fire. The main connections that have been evaluated to effect OSW infrastructure have been highlighted but this assessment is not all encompassing and does not discuss all potential connections between climate change parameters, tsunami hazards, and processes.

3.2.1 Winds

Land temperatures are increasing faster than ocean temperatures, creating a thermal gradient between the land and ocean. This could be driving an increase in winds off the west coast of California (Snyder et al. 2003). Based on Snyder et al. 2003, wind speeds could increase up to 1-2 m/s and 0-1 m/s along the northern coast of California by 2070 in April and September, respectively. Although some studies report potential increases in winds along the California Coast, there is still some uncertainty in this conclusion. Sydeman et al. 2020 synthesized results from 22 studies with qualitative information on wind trends. For the Humboldt system, there was good agreement on warm season (May to August) wind intensification trends but no significant trend when looking at annual winds.

3.2.2 Ocean Currents

From southern British Columbia to Baja California, the offshore current, is driven by the alongshore winds and transports cold water south along the shoreline. Therefore, the changes in the offshore current are linked to changes in offshore wind. As discussed in Section 2.2, some studies report an increase in winds due to climate change, but other studies are inconclusive. Consequently, the changes is offshore currents follow a similar path, some studies estimate an increase in currents, while others are inconclusive. Brady et al. 2017, ran a climate model ensemble over the period of 1920 to 2100 estimating the effect of climate change. They found an intensifying of currents in the northern region (southern British Columbia) in the spring and weakening of the current in the center and northern regions in the summer. They also estimate these changes would not become evident until the second half of the century.

3.2.3 Storminess and Ocean Waves

There is potential for increased storminess (increased storm frequency, magnitude, and direction) but there is no consensus on this at this time for the Pacific coast of the U.S. Several studies (NRC 2012) have reported that the largest waves are getting higher and winds have been getting stronger in the NE Pacific over the past few decades, but these trends are still controversial due to the limited record length (35 years).

Global climate models have been used to determine future wave climate. These studies have projected poleward migration of storm track and a light decrease in wave heights for California (Erikson et al. 2015, Graham et al. 2013). Looking at trends in El Nino/La Nina events, Cai et al. 2014 found there could be a doubling in the occurrences of El Nino events due to climate change. El Nino events disrupt normal weather patterns and could bring intense storms or drought depending on location.

3.2.4 Fire

Increased temperatures and a drier climate are expected to result in increased frequency, extent, and strength of wildfires. The increase in population is anticipated to increase the probability of human-ignited wildfires, especially in the populated areas, such as Eureka. Westerling et al. (2011) predicted there could be a 100% increase in burned forests in northern California in both the lower and higher emissions scenarios.

3.2.5 Precipitation and Streamflow

According to California's 4th Climate Change Assessment North Coast Region Report (Grantham 2018), the annual precipitation is not expected to change significantly, but the wet and dry seasons are expected to become more extreme. More intense storms are anticipated to be delivered during shorter wet seasons followed by prolonged dry seasons. Snowfall is expected to decrease resulting in changes to timing of streamflow. Streamflow is projected to increase in the wet season and decreased in the dry season. There is a predicted rise in frequency and intensity of drought and extreme precipitation events, likely intensifying flooding in the north coast region of California. These changes are likely to increase the likelihood of landslides and debris flows.

3.2.6 Sea Level Rise

Humboldt Bay has the highest local sea-level rise rate (0.20 in/yr.) in California due to land subsidence (Patton et al. 2017) due to land subsidence in and around the bay in additional to local sea level rise. This means the

Humboldt Bay area may be impacted faster than other parts of the west coast (Anderson 2018). Table 1 below summarizes the projected median (50% probability) SLR for the north spit of Humboldt Bay, relative to 1991-2009 mean sea level, in feet (Anderson 2018).

Table 1 - Projected Median SLR for the North Spit of Humboldt Bay (Source: Anderson 2018).

Year	Projected median SLR (feet)
2030	0.6
2050	1.3
2100 (RCP[2] 4.5)	2.8
2100 (RCP 8.5)	3.3
2150 (RCP 4.50	4.3
2150 (RCP 8.5)	5.3

Anderson (2018) provides a table of tidal levels and annual extreme high-water level probability estimates near the Arcata Marsh & Wildlife Sanctuary for existing water levels and with different SLR scenarios. This table would be useful for predicting and designing for potential water level changes in the future. SLR inundation maps were produced using a hydrodynamic model which predicted water levels within the existing shoreline of Humboldt Bay for different SLR scenarios. These maps show inundation vulnerability throughout the bay based on different potential SLR scenarios (Anderson 2015).

Areas such as Fields Landing and King Salmon where the export cable landfall is proposed appear to be more vulnerable to SLR than the proposed port facilities locations (Redwood Marine Terminal 1 and 2 (RMT 1 and RMT 2)). The area of King Salmon could be significantly impacted by SLR by 2065 (OPC 2018) due to shoreline erosion, tidal inundation, rising groundwater, and saltwater intrusion (Laird 2019). Some of the existing jetties, rock revetment, and seawall protecting the shoreline could be overtopped by waves and SLR by 2076 based on the Ocean Protection Council's 2018 SLR guidance. By 2040, with 1.6 feet of SLR, most of King Salmon could be tidally inundation several times a year with the frequency of tidal inundation increasing over time (Laird 2019). The 2019 Humboldt County: Humboldt Bay Area Plan (Laird 2019) should be referred to for additional information on potential SLR impacts and recommended adaptation strategies and solutions.

3.2.7 Fog

Future trends in summertime fog are difficult to predict because fog is affected by several ocean-atmospheric processes. Grantham (2018), cited multiple studies (O'Brien et al. 2012, Johnstone and Dawson 2010, and others) on the predictions for the frequency of fog in the next century. O'Brien et al. (2012) suggested there could be a long-term 12-20% reduction in coastal fog in California between 1900-2070. Johnstone and Dawson (2010) found that the frequency of fog had decreased 33% since the beginning of the 20th century. Other studies have looked at fog records from the Arcata and Monterey airports and did not detect a significant change in fog occurrence over the last 60 years. Overall, coastal fog trends on the north coast of California are not conclusive but there is potential for a decrease in coastal fog in the future.

[2] Potential future carbon emission scenarios are parameterized as Representative Concentration Pathways (RCP): RCP 4.5 and RCP 8.5 represent the lower and upper bounds.

4 Vulnerability Assessment - Potential Effects on Offshore Wind Infrastructure

This section describes the vulnerability[3] of the different OSW infrastructure categories shown in Figure 4 relative to climate change and tsunami hazards. The potential effects (exposure and sensitivity to those exposures) of the different hazards and change in conditions on each OSW infrastructure category[4] were assessed based on coastal processes and engineering knowledge, industry standards and knowledge, previous project experience. A brief narrative of the potential capacity of the different project infrastructure elements to adapt to the exposed climate change and coastal hazards is included for each subsection. Vulnerability of each infrastructure category was assessed qualitatively based on the exposure, sensitivity, and adaptive capacity.

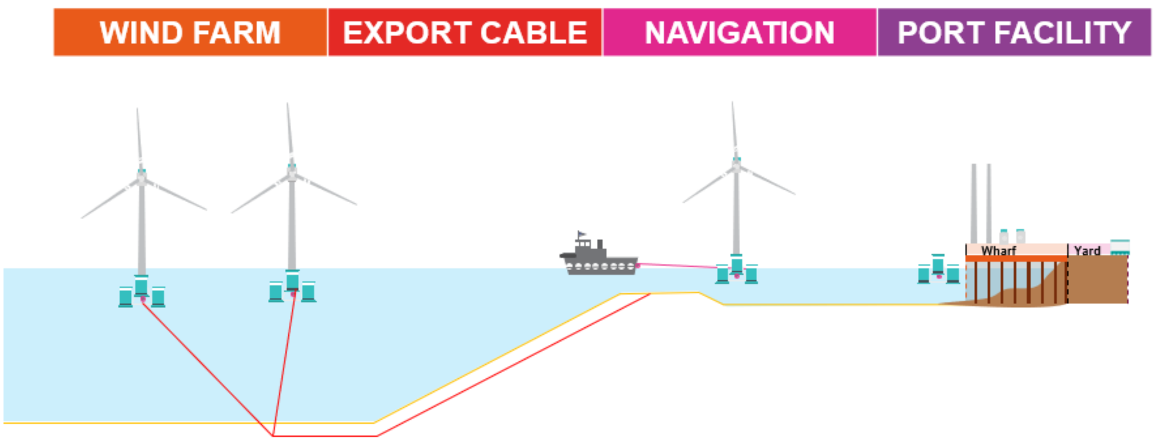

Figure 4 - Offshore Wind Farm Project Infrastructure Schematic

4.1 Offshore Wind Farm

Exposure and Sensitivity

- Wind and storminess
  - Changes in wind patterns, waves, currents, tidal inundation, swell, and storm surge could affect the installation in the near-term, and operations and maintenance in the longer term. The result of this could be increased operational downtime relative to existing conditions, or a change in marine equipment to accommodate changes in climate.
  - Floating wind substructures and mooring systems/anchors are typically designed to a survivability standard considering wave conditions (DNV-GL ST-0119). Increase in extreme wave heights may increase vulnerability of system unless accounted for in design.
- Tsunami
  - Tsunami amplitude in deep water is less than a typical storm wave amplitude and will likely have no to minimal impact on the wind farm within the lease areas.

Adaptive capacity

[3] Combination of likelihood of occurrence, site sensitivity, severity of the impact, adaptability

[4] Only the processes that were estimated to have an impact on each OSW component are summarized in this section.

- Designs may be able to be adapted to include a change in conditions throughout the service life of the element.

Qualitative Vulnerability Assessment: Low

4.2 Export Cable to Humboldt Bay

Exposure and Sensitivity

- Wind and storminess
  - If a trenched burial is selected as the preferred landfall concept, the export cable could be at a higher risk than with a trenchless option for reduced burial depth or exposure in the nearshore due to adjustments in beach profile elevations in response to changes in wave climate and current patterns. This risk should be studied in more detail as part of a coastal engineering assessment during concept design of the landfall and export cable route.
  - If a trenchless option is selected for landfall, changes in waves and currents could result in a change in beach closure depth, which could affect the stability of the trenchless conduit exit.
  - If the export cable is buried within a trench on the South or North Spit, the depth and location of these trenches could be at risk for damage if the spit retreats in response to changes in storminess.
  - Fire and precipitation/streamflow
  - If increased sedimentation resulted from increased fires and/or streamflow, the export cable may be buried deeper in some locations. In the case of a trenched landfall additional depth could increase the complexity and cost for cable retrieval in the case cable repairs are required.
- SLR
  - If a trenched burial is selected as the preferred landfall concept, the export cable could be at higher risk for reduced burial depth or exposure in the nearshore due to adjustments in beach profile elevations in response to changes in water level. This risk should be studied in more detail as part of a coastal engineering assessment during concept design of the landfall and export cable route.
  - If a trenchless option is selected for landfall, changes in waves and currents could result in a change in beach closure depth, which could affect the stability of the trenchless conduit exit.
  - Cables could be buried deeper than designed due to increased sedimentation if the beach profile were to accrete over time.
- Tsunami
  - A tsunami could affect the beach profile of the spits and inundate the majority of the spits of Humboldt Bay and areas of the mainland where the export cable conduit exit, and electrical substations are located.
  - If a trenched burial is selected as the preferred landfall concept, a change in the beach profile of the spit could result in reduced burial depth or exposure in the nearshore. This risk should be studied in more detail as part of a coastal engineering assessment during concept design of the landfall and export cable route.
  - If a trenchless option is selected for landfall, a change in the beach profile could affect the stability of the trenchless conduit exit.
  - A tsunami could alter the bathymetry of the bay and result in increased burial or exposure of the export cable crossing the bay. In the case of a trenched landfall additional depth could increase the complexity and cost for cable retrieval in the case cable repairs are required. This risk should be studied in more

detail as part of a coastal engineering assessment during concept design of the landfall and export cable route.

Adaptive Capacity

- The cable landfall design may be able to be developed to account for change in beach profiles or tsunami scour risk, pending additional studies
- Depending on inundation level and location of onshore substations or converter stations, the structures may be able to incorporate climate change parameters and tsunami hazard risk into the design basis.

Qualitative Vulnerability Assessment: Mild

4.3 Navigation

Exposure and Sensitivity

- Wind, waves, currents, and storminess
  - Changes in wind patterns, waves, currents, tidal inundation, swell, and storm surge could result in additional vessel navigation downtime at the entrance to the bay and within the bay.
  - The downtime due to wind, waves, currents, and storminess should be assessed as part of a coastal engineering assessment during conceptual design of the OSW facility. The study should include an assessment of the installation sequencing accounting for the ability of the vessels towing the wind turbines to exit the bay. Navigation limits within the bay and potential downtime should also be considered for planning staging areas within the bay and operation and maintenance once the OSW farm is operational.
- Fire
  - Fire may result in increased run-off within the Eel River watershed (sediment source for channel sedimentation) Increased sedimentation in the navigation channels could result in increased frequency and volume of dredging operations. An assessment should be conducted to understand the potential increased in sedimentation due to increased fires and changes in precipitation and streamflow. The assessment should include the long-term effects on navigation in Humboldt Bay.
- SLR
  - The secondary effects of SLR may have an impact on navigation into and within the bay. There is a risk that the entrance jetties and other shoreline infrastructure are overtopped more frequently due to SLR. Navigation and mooring within the bay may also become more challenging due to secondary effects from SLR such as changes in currents, waves, and sedimentation patterns. The impacts of SLR on navigation into and within the bay should be included in a coastal engineering assessment during the conceptual design phase of the OSW project.
- Fog
  - Studies are not yet conclusive, and an increase or decrease in fog or change in the coastal fog patterns is possible and may affect vessel navigation in and out of the bay.
- Tsunami
  - The Humboldt Harbor Safety Committee rules on tsunamis countermeasures for ships and barges at port should be evaluated to determine the applicability to OSW related vessels and adjustments should be made to the countermeasures if necessary.
  - Guidelines should be developed to account for potential scenarios if an OSW device is being towed out of the harbor when a tsunami warning occurs or what protocol should be for devices that are temporarily moored in the bay or at the port facilities.

Adaptive Capacity

- Changes in parameters that affect navigability (e.g. storminess, fog, sedimentation) – may be able to be managed with a change in policies and practices.
- Changes to the Harbor Safety Committee rules may be approved by the committee

Qualitative Vulnerability Assessment: Mild

4.4 Port Facilities

Exposure and Sensitivity

- Winds and storminess
  - Changes in wind patterns, waves, currents, tidal inundation, swell, and storm surge could affect the vessel berthing and portside assembly. Changes in storminess could result in more downtime at the port facilities and reduced throughput rates.
  - Increased risk of tidal inundation and inundation due to storm surge should be accounted for in the design of the port facilities. This risk should be studied in more detail as part of a coastal engineering assessment during preliminary design of the port facilities.
- Precipitation/Streamflow
  - There is a risk the change in precipitation/streamflow patterns may lead to increased wet and dry seasons. State sponsored publications on the impacts of climate change have highlighted that water, electricity, and transportation infrastructure designed for a milder climate may be at risk. Port and emergency response infrastructure design should account for increased wet and dry seasons.
- Fog
  - Studies are not yet conclusive, and an increase or decrease in fog or change in the coastal fog patterns is possible and may affect vessel navigation around the port facility.
- SLR
  - SLR could lead to an increased risk of tidal inundation, flooding, and rising groundwater which could result in inundation of the port facility and impacts to the underground utilities. Port infrastructure should account for SLR over the design life of the infrastructure.
  - Anderson 2014 produced publicly available inundation maps for different SLR scenarios at different water levels. As an example, the inundation map for 1 meter of SLR at the mean annual maximum water (MAMW) water level is shown in Figure 5 for Humboldt Bay. This scenario is representative of the projected SLR for 2100 (RCP 8.5, higher emission scenario). The same figure shows the area around the proposed port facilities (RMTI and RMTII). RMTI appears to be inundated for this SLR scenario and in general appears to be more vulnerable to SLR due to being at a lower elevation than RMTII. The specific design water level for the port facilities may differ from this example and should incorporate service life of the facility and balance the sensitivity and adaptive capacity of the port facility.

Figure 5 - Left Panel - SLR Inundation Map for MAMW with 1m of SLR for Humboldt Bay (existing conditions based on 2000 water levels) (Anderson 2014). Right Panel - SLR Inundation Map for MAMW with 1m of SLR for the area around RMTI and RMTII (existing conditions based on 2000 water levels) (Anderson 2014)

- Tsunami
  - ASCE tsunami geodatabase indicates the area around the proposed port facilities the average inundation depth is 35 ft.
  - In additional to the potential for inundation due to a tsunami, port infrastructure may be exposed to a risk of scour of the ground surface due to tidal flows
  - The risk of inundation due to a tsunami should be studied in more detail as part of a coastal engineering assessment during concept design of the port facilities.

Adaptive Capacity

- The port facility yard and wharf deck elevations may be able to be designed to accommodate SLR.
- The inundation depth of the tsunami may be too large to adapt to or mitigate for, depending on the event.

Qualitative Vulnerability Assessment: Moderate

5 Summary and Next Steps

A conceptual-level assessment was conducted to evaluate potential exposure, sensitivity, and adaptive capacity of potential offshore wind (OSW) infrastructure in the Humboldt Bay region relative to climate change and tsunamis hazards, to assess the associated vulnerability of. The best available science for a tsunami hazard and climate change parameters was compiled based on public data. The science behind 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. The four different wind farm project infrastructure elements included the offshore wind farm, the export cable, navigation activities, and the port facility. A summary of the results of this assessment are included in Table 2.

Overall the vulnerability appears to range between low for the offshore wind farm itself, and moderate for the port facilities. The port area is primarily classified as moderate, primarily because the entire Samoa Peninsula may be inundated with more than 10 feet of water during a tsunami event, and RMT II may be sensitive to SLR without regrading the yard elevations.

Table 2 - Vulnerability and Risk Assessment Summary

Element	Exposure	Sensitivity to Coastal Hazards	Sensitivity to Climate Variables	Adaptive Capacity	Qualitative Vulnerability Assessment
Wind Farm	Complete exposure to ocean conditions	Minimal impact of tsunamis on windfarm	Increased storminess and design wave height	High	Low Vulnerability
Export Cable	Cable landfall burial is dependent on beach stability.	Scour due to tsunami, inundation of substation.	Beach profile changes due to SLR and increased storminess.	Medium	Mild Vulnerability
Navigation	Shoaling due to sedimentation. Only one entrance in and out of harbor.	Tow-out of device may reduce ability for other vessels to exit the harbor in response to tsunami. Device moorage loading.	Increased runoff and subsequent channel shoaling.	Medium	Mild Vulnerability
Port Facilities	Port are low-lying– adjacent to water. Samoa peninsula is exposed to tsunami attack	Port areas are within tsunami inundation zone. Select areas within 100-yr flood zone	Increased coastal flooding due to SLR.	Low to Medium	Moderate Vulnerability

Additional work should be conducted to quantify the risk into quantities such as consequences, likelihood, redundancy etc. and to determine adaptation or mitigation options to improve resiliency. Next steps could include the following:

- Assessment on impacts from a tsunami on export cable landfall, spit profile adjustment, inundation of port infrastructure. Safe harbor guidelines for OSW vessels.
- A beach morphology study should be conducted to evaluate potential changes in the beach profile due to SLR and define design conditions for a cable landfall.
- The electrical infrastructure associated with the export cable landfall should be located outside areas of predicted tidal inundation during the design life of the infrastructure, and a siting analysis should be conducted. Export cable design should account for changes in groundwater.
- Quantification of appropriate deck elevation risk based on SLR, adaptability, acceptable costs, severity of inundation, and recurrence interval of coastal flooding events.
- Detailed assessment of tsunami impacts, and associated loads may need to be developed in order to design the structure for tsunami inundation (if required).

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