GREAT CHEBEAGUE ISLAND

MAINE

NAVIGATION IMPROVEMENT PROJECT

APPENDIX B

ENGINEERING DESIGN

This Page Intentionally Left Blank

APPENDIX B
ENGINEERING DESIGN

Table of Contents

List of Tables and Figures

This Page Intentionally Left Blank

Great Chebeague Island Navigation Improvement Study
Chebeague Island, Maine
Design Analysis

I. Introduction

The municipally chartered Chebeague Transportation Company (CTC) provides year-round barge and ferry service for passengers and light cargo from nearby Portland. The principle Town landing is at the Stone Wharf on the northwest shore of the island. The shallow water at the Stone Pier on Great Chebeague Island limits access to higher stages of the tide and causes damage to craft using the pier. Deepening the Entrance Channel to the pier, with adequate maneuvering/turning areas adjacent to the pier and boat dock for vessels are necessary for safe navigation access.

The purpose of the Navigation Improvement Study is to ensure safe and efficient access to the landing at the Stone Pier for ferries and cargo carriers, and vital services for Great Chebeague Island.

II. Existing Conditions

a. Existing Bathymetry:

For the purposes of this study, the existing conditions of Great Chebeague is represented from the July 2012 USACE hydrographic survey (GREAT CHEBEAGUE JULY 2 &31 ALL EDIT DATA-F_volume.xyz).

b. Existing Structures and Utilities:

There are no known submarine utilities or structures located within the proposed project area and adjacent to the existing Stone Pier.

c. Existing Subsurface Conditions:

For the purposes of this study, the existing subsurface conditions are based on the subsurface probes conducted during the 1978 DPR Survey. No ledge or refusal was observed in any of the probes conducted within the study area. The depths of the probes ranged between 8 feet MLW and 13 feet MLW. No ledge is expected to be encountered in the area to be dredged. Dredged material is anticipated to be a mix of silts, clays and sand.

III. Channel Design

a. Reference Guidance:

i. Hydraulic Design of Deep-Draft Navigation Projects. EM 1110-2-1613, dated 31 May 2006
Manual provides design guidance for improving deep-draft navigation projects.

ii. Hydraulic Design of Small Boat Harbors. EM 1110-2-1615, dated 25 September 1984.
Manual provides guidance for planning, layout and design of small boat harbor projects. Small boats are classified as recreational craft, fishing boats, or other small commercial craft with lengths less than 100 feet.

iii. Layout and Design of Shallow-Draft Waterways. EM 1110-2-1611, dated 31 July 1997 *Manual provides guidance for planning, layout and design of shallow-draft waterways.*

The small boat harbor and shallow draft guidance listed above is primarily geared towards developing new harbors where breakwaters enclose an area for marina development. The deep draft guidance is for large scale improvement projects. The Great Chebeague Harbor Improvement Project does not fit either of these categories. The Great Chebeague Harbor Improvement Project instead is a commercial fishing harbor where the channels and anchorages operate year-round and slips are not appropriate.

Since neither of the guidance documents directly reflect the Great Chebeague Harbor Improvement Project conditions, an additional 'rule of thumb' was used a line of evidence in calculating the recommended channel and turning area width as well as pilot and harbor solicitation. The rule of thumb states that for two-way traffic, the channel width would be the sum of two bank clearances, two travel lanes and one separation lane.

b. Design Vessel:

The Entrance Channel is designed for two way traffic of the Larger-Draft Fishing Vessel and the Chebeague Transportation Company Ferry. The draft, length and beam of these vessels are drawn from 2012 fleet data provided by the Chebeague Island Harbormaster. Refer to the economics appendix for more information.

c. Alignment:

The Entrance Channel is designed to follow the course of the existing deeper channel and to facilitate two-way traffic with fishing boats passing a ferry or barge. The Navigation Improvement Project alignment consists of a straight north-west to south-east orientation. The straight alignment provides better pilot control.

It is assumed that two-way traffic extends from the Entrance Channel to the Turning Area. The two-way traffic must facilitate the largest ferry and fishing boat. The Turning Area must facilitate the two-way traffic as well as the turning of the largest ferry. It is assumed that only one-way traffic is required within the Stone Wharf Upper Turning Basin reach. This reach must facilitate launching and turning of fishing boats and the garbage barges. The ferry will not travel within the boat dock area.

The eastern limits of the proposed channel and turning areas are off-set from the existing Stone Wharf Pier's birthing area. The off-set distance is assumed as 50 feet.

d. Channel Width:

Entrance Channel

The various Engineering Guidance documents, general rules of thumb and and pilot/Harbor Master solicitation were referenced in determining the recommended entrance channel.

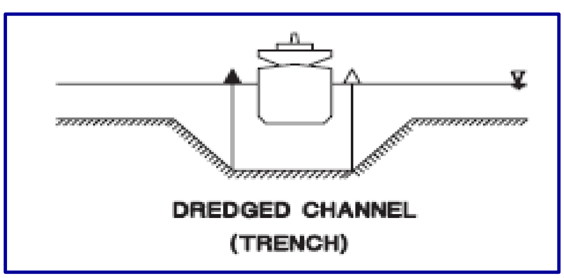
i. Hydraulic Design of Small Boat Harbors (EM 1110-2-1615) provides guidance in calculating a minimum Channel width for one-way traffic. The guidance recommends minimum percent of beam for Maneuvering Lane or Straight Channel of 200%. With a design vessel (CTC Ferry) beam of 18.3 feet, this would result in a minimum width of **36.6 feet**. The guidance states that these widths can be increased for adverse wind, wave and current conditions, or for high traffic volumes (congestion). Since this guidance does not account for two-way traffic, the channel width of 36.6 feet is considered too narrow to ensure safe navigational traffic.

ii. Layout and Design of Shallow-Draft Waterways (EM 1110-2-1611) provides general channel width requirements for two-way traffic. The guidance recommends that the minimum clearance required for reasonable safe navigation in straight reaches should be at least 20 feet between vessel and channel limits for two-way traffic and at least 50 feet between vessels when passing. When utilizing the ferry and fishing design vessels, this would result in a recommend channel width of **123 feet** (20+b1+50+b2+20) where b1 is the beam of the ferry of 18.3 feet and b2 is the beam of the fishing design vessel of 14.8 feet. Since this guidance includes conservative bank clearances and separation lane widths which are not based on the design vessel beam, the channel width of 123 feet is considered very conservative.

iii. Hydraulic Design of Deep-Draft Navigation Projects (EM 1110-2-1613) provides guidance for Deep-draft improvement projects. This project classification is not applicable to the Great Chebeague project, however, this guidance provides more detailed channel width calculation guidance. The outcome of the EM 1110-2-1613 analysis is found below. It will be utilized as part of the overall analysis from the previously discussed design guidance and pilot solicitation.

The proposed Great Chebeague channel is considered an Interior Channel, since it provides access to the turning area and is located within a relatively sheltered location within Casco Bay. Interior Channel without any turns should be designed based on the following factors in order of importance (EM 1110-2-1613):

1. Traffic Pattern (one-way or two-way)
   Channel width assumes two-way traffic with fishing boats passing a barge or ferry.
2. Design ship beam and length
   Chebeague Transportation Company Ferries: Beam Range (16-18.3 feet); Length Range (52-56 feet)
   Larger-Draft Fishing Vessels: Average Beam (14.8 feet); Average Length (43.9 feet)
3. Channel cross section shape
   Dredged Channel (Trench)



4. Current speed and direction
   Currents are limited to tidal flow less than 3.0 knots. The Design channel width for navigation project with maximum currents greater than 3.0 knots should be developed with the assistance of a ship simulator design study.
5. Quality and accuracy of aids to navigation
   There are currently no USCG navigation aids.
6. Variability of channel and currents
   Mean tide range of 9.11 feet (NOAA STA 8417881 Located at Indian Point- southern limit of island).

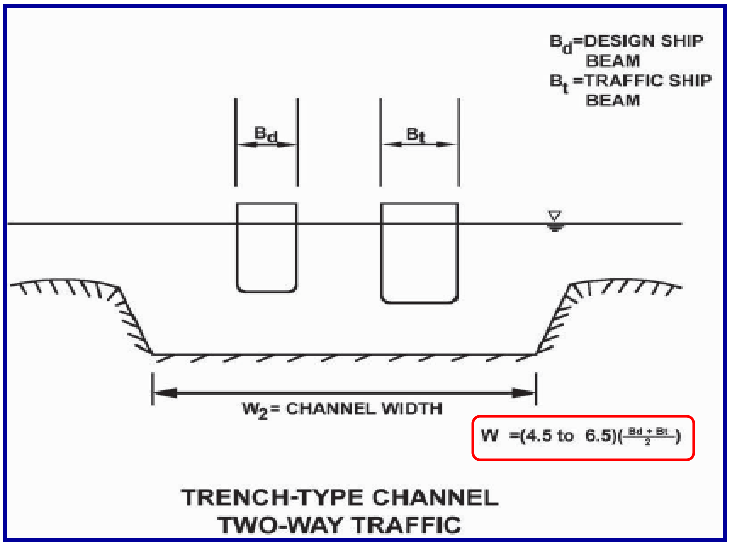


Table 8-3
Two-Way Ship Traffic Channel Width Design Criteria

Uniform Channel Cross Section	Design Ship Beam Multipliers for Maximum Current, Knots (ft/sec) 0.0 to 0.5 (0.0 to 0.8)	0.5 to 1.5 (0.8 to 2.5)	1.5 to 3.0 (2.5 to 5.0)
Best Aids to Navigation			
Shallow	5.0	6.0	8.0
Canal	4.0	4.5	5.5
Trench	4.5	5.5	6.5

Assuming Trench Channel, good navigation aids and a max current of 1.5-3.0 knots, the width multiplier is assumed as 6.5. Utilizing the equation above and incorporating the ferry and fishing design vessels, the recommend width is **107.5 feet** (W = 6.5 [(18.3+14.8)/2]).

The analysis above provides various lines of evidence in selecting the recommended Entrance Channel Width. Based upon this analysis, a reasonable channel width will range between 36.6 feet to 123 feet. This channel width range was compared to the engineering 'rule of thumb' which adds two bank clearances, two travel lanes and one separation lane. One travel lane and bank clearance will be represented by the ferry beam, and the second travel land and bank clearance will be represented by the fishing vessel beam. Therefore, the 'rule of thumb' channel width recommends **84.5 feet** (W = 18.3+18.3+18.3+14.8+14.8).

Based on the above design analysis, the team recommends an entrance channel width of **100 feet** for two-way traffic at Great Chebeague Island.

e. <u>Maneuvering Area</u>

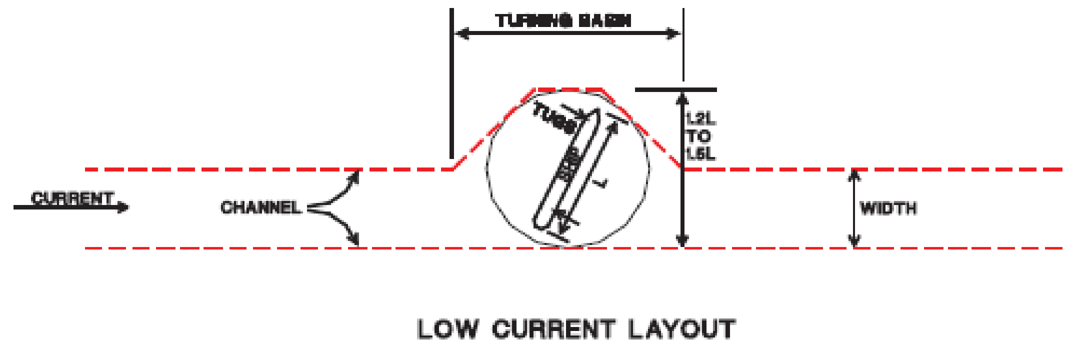
The Maneuvering Area is located alongside the Stone Pier and terminates before the boat dock and ramp area. The Maneuvering Area must facilitate the two-way traffic as well as the turning of the largest ferries. The CTC ferry is used as the design vessel instead of the larger-draft fishing vessel, because it is the larger vessel.

i. Hydraulic Design of Small Boat Harbors (EM 1110-2-1615) provides minimal guidance in calculating turning basin size. The guidance states that the turning area "be large enough to allow turning of small recreational craft without backing (vessel turning radius)." The guidance further states that, "Larger commercial vessels may be required to maneuver forward and reverse several times to turn if such traffic is infrequent." In this case, larger commercial vessels (i.e. CTC ferry) operate frequently. The turning basin should be designed to facilitate CTC ferry turning with minimal forward and reverse maneuverability.

ii. Layout and Design of Shallow-Draft Waterways (EM 1110-2-1611) does not provide any additional guidance on calculating turning area width.

iii. For additional guidance, Hydraulic Design of Deep-Draft Navigation Projects (EM 1110-2-1613) was referenced to calculate the recommended turning basin width. In normal operations, turning basins are used by the pilots in conjunction with two or more tugs to bring the ship about. The CTC ferry (design vessel) entering Stone Pier, however, does not utilize tugs for turning. However, based on its frequent use, the turning basin width should be based on minimal maneuverability effort.

Based on the recommendations of the pilots and the Engineering Manual Analysis, the recommended Turning Area diameter is **150 feet**.



CURRENT SPEED KNOTS	TURNING BASIN SIZE MULTIPLIER (*L)
0 < 1/2	1.2
1/2 < 1 1/2	1.5
> 1 1/2	SIMULATOR DESIGN

Assuming a current of 1.5 knots, the turning basin multiplier is 1.5. With the Ferry vessel length of 56 feet, the turning basin diameter is estimated to be **84 feet**. This diameter is for one-way traffic, so an additional lane width and bank clearance for the fishing vessels are added to calculate a total turning area width of **113.2 feet** (84+14.4+14.8).

f. Upper Turning Basin

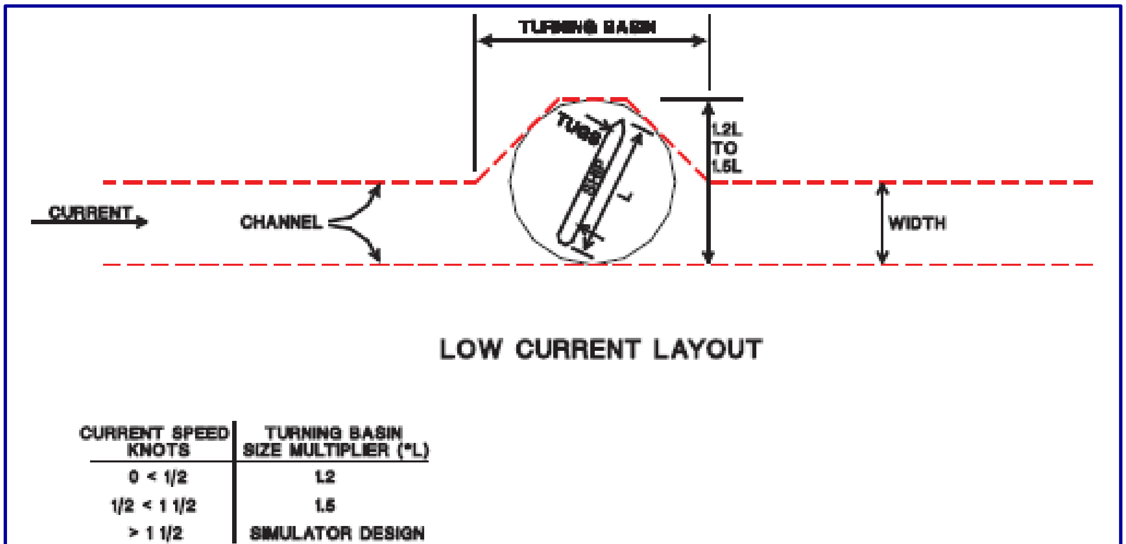
The Upper Turning Basin at the Stone Wharf Barge Ramp is located along the inshore end of Stone Pier at the boat dock and ramp. The Turning Basin must facilitate the two-way traffic for the fishing vessels as well as the turning and launching of the fishing vessels and the trash and freight barges. The CTC ferry does not navigate this reach.

i. Hydraulic Design of Small Boat Harbors (EM 1110-2-1615) provides minimal guidance in calculating turning basin size. The guidance states that the turning basin "be large enough to allow turning of small recreational craft without backing (vessel turning radius)." The guidance further states that, "Larger commercial vessels may be required to maneuver forward and reverse several times to turn if such traffic is infrequent." In this case, larger commercial vessels (i.e. larger-draft fishing vessels) operate frequently. The turning basin should be designed to facilitate fishing vessel turning with minimal forward and reverse maneuverability.

ii. Layout and Design of Shallow-Draft Waterways (EM 1110-2-1611) does not provide any additional guidance on calculating turning basin width.

iii. For additional guidance, Hydraulic Design of Deep-Draft Navigation Projects (EM 1110-2-1613) was referenced to calculate the recommended turning basin width. In normal operations, turning basins are used by the pilots in conjunction with two or more tugs to bring the ship about. The fishing vessels (design vessel) entering the boat dock area, however do not utilized tugs for turning. However, based on its frequent use, the turning basin width should be based on minimal maneuverability effort.

The barges that land at the Stone Wharf ramp have lengths of between 36 feet (fuel barge) and 50 to 80 feet (freight barges). The largest half of the fishing vessels in the fleet have an average length of about 44 feet and average beam of about 15 feet. Using the 1.5 turning basin multiplier the basin width would be at least 66 feet. Using the same 1,5 multiplier the freight barges would need a turning basin width of between 75 to 120 feet.



Assuming a current of 1.5 knots, the turning basin multiplier is 1.5. With the fishing vessel length of 43.9 feet, the turning basin diameter is estimated to be **66 feet**. For the freight barges with their beams of 50 to 80 feet a basin diameter (width) of 75 to 120 feet would be required.

The inshore end of the wharf is also used for servicing and provisioning of the fishing fleet and must accommodate two-way traffic for these vessels in the same manner as the channel. Using the fishing vessels dimension and analysis from section III.d. above the average fishing vessel beam of 14.8 feet and width multiplier of 6.5 gives a width of more than 96 feet.

Based on the recommendations of the pilots and the Engineering Manual Analysis for both two-way fisging boat traffic and the access and turning for the freight barges, the recommended Upper Turning Basin diameter is **100 feet**.

g. Channel Depth:

Channel depth "should be adequate to safely accommodate ships with the deepest drafts expected to use the waterway" according to EM 1110-2-1613. This statement not only addressed the physical characteristics of the design vessels but the economic projects of usage. See the economics appendix for discussion of the current and future vessels. The physical concerns are the draft of the vessel and how it operations when underway. Vessels will ride deeper in the water when underway than when at berth. The term for this is "squat" and conditions affecting the amount of squat can be water depths or channel cross-section. Ships also are impacted by the wave conditions and tend to roll, pitch, or heave. For instance, a long vessel can pitch forward or back and increase the depth required at the bow or stern by a foot or more in addition to the swell or squat additives. The EM provides technical guidance related to the design depth and this is considered by including about under-keel clearance* in the economics calculations. The alternatives analysis uses an economic approach of examining the costs of various channel depths compared to the economic benefits. Chanel design depths examined began at 6' and went to 12' with 1' of overdepth taken into consideration.

*Under-keel clearance for the Ferry is 3 feet

IV. Quantities

Using the hydrographic survey taken in 2012 and the proposed channel alignment with widths identified above, quantities of material to be removed were developed with the aid of Microstation's InRoads. An existing bottom surface was compared to the proposed channel bottom and the difference, material to be removed, is shown in the following table.

TABLE B-1 – Dredging Volume and Area Estimates				
Design Depth (MLLW)	Required Dredging CY	Allowable Overdepth CY	Total Cubic Yards Dredged	Area Dredged (SF)
Channel with Turning Area along Wharf				
8 Feet	8,700	3,600	12,300	91,100
9 Feet	12,300	4,300	16,600	110,560
10 Feet	16,600	5,000	21,600	122,690
11 Feet	21,600	6,000	27,600	130,300
Upper Turning Basin				
6 Feet	7,500	1,400	8,900	39,700
7 Feet	8,900	1,500	10,400	41,670
8 Feet	10,400	1,600	12,000	43,710
9 Feet	12,000	1,700	13,700	45,800
10 Feet	13,700	1,700	15,400	47,940
Northeast Anchorage – 13 Acres				
6 Feet	2,300	4,100	6,400	153,310
7 Feet	6,400	6,900	13,300	241,570
8 Feet	13,300	10,500	23,800	331,000
9 Feet	23,800	13,700	37,500	402,190
Southwest Anchorage – 13 Acres				
6 Feet	34,700	18,400	53,100	572,800
7 Feet	53,100	23,500	76,600	706,120
8 Feet	76,600	28,500	105,100	823,020
9 Feet	105,100	32,100	137,200	896,270
Note: All estimates inlcude a 1:3 side slope. Allowable overdepth is 1 foot.				

These volume estimates were further combined into estimates for the various alternative plans and project depth increments for the channel and turning basin. Plans including anchorage area dredging were eliminated from more detailed analysis at the sponsor's request due to excessive impacts on eelgrass beds in the dredging footprint for those features.

Upper Turning Basin depths greater than 9 feet were eliminated from consideration because the ferry and most other vessels can maneuver successfully in the 150-foot dredged channel along the wharf, and the barge services and other boats using the ramp only require 8 to 9 feet of depth to maneuver safely in that location. The barges generally have drafts two feet less than those of the ferries. The fishing fleet uses both the pier and the boat ramp for access and service. Therefore, the range of depth optimization measures involved four separate increments as follows, and will be measured according to their ability to reduce tidal delays and the potential for vessel groundings:

- Plan A-1 - 8-foot channel & turning area with 6-foot upper turning basin
- Plan A-2 - 9-foot channel & turning area with 7-foot upper turning basin
- Plan A-3 - 10-foot channel & turning area with 8-foot upper turning basin
- Plan A-4 - 11-foot channel & turning area with 9-foot upper turning basin

The Channel & Turning area and Upper Turning Basin layout are shown in the figure below. Table B-2 below shows the quantity estimates for the four combined depth increments.

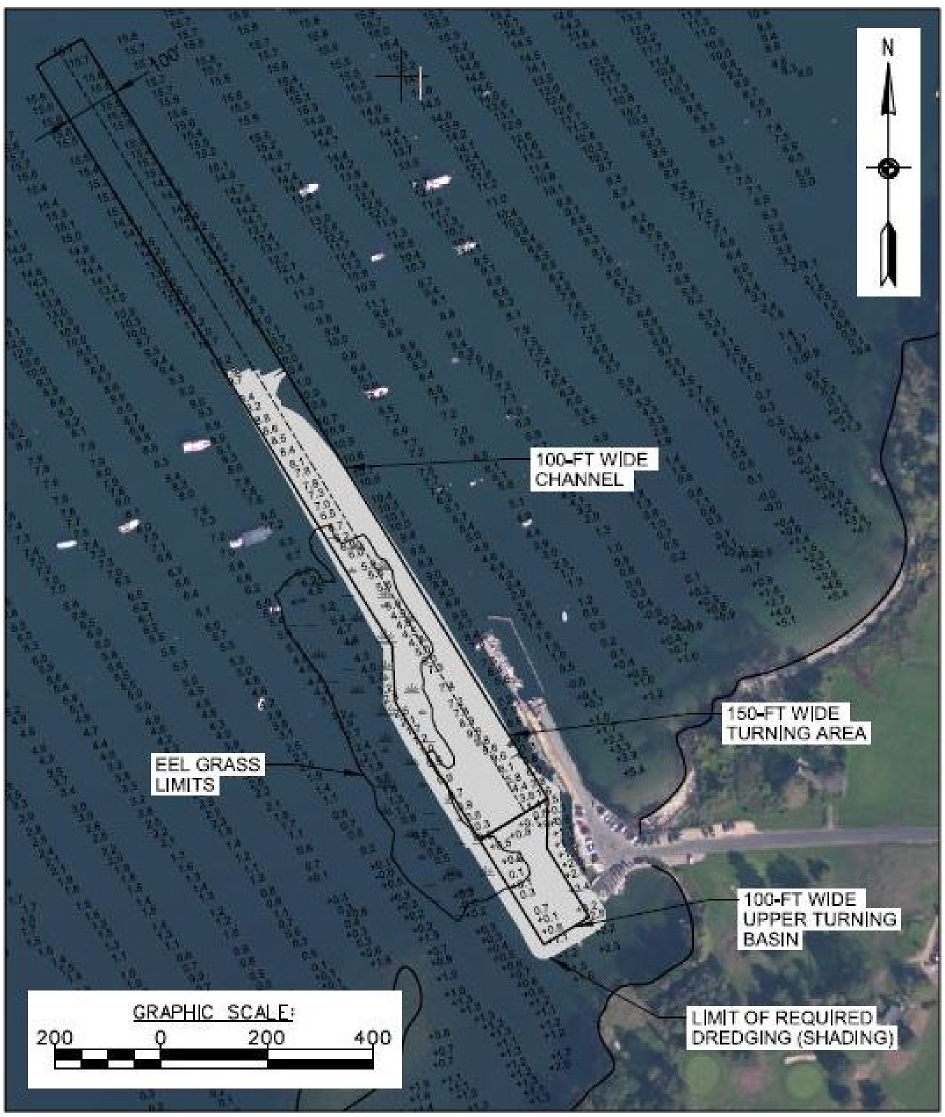


Figure B-1 – Channel & Turning Area and Upper Turning Basin Plans

Table B-2 Great Chebeague Island, Maine – Plan Depth Increment Details			
Depth Increment	Required Dredging (CY)	Allowable Overdepth (CY)	Total Dredge Volume
8-Foot Channel with 6-Foot Turning Basin	16,200	5,000	21,200
9-Foot Channel with 7-Foot Turning Basin	21,200	5,800	27,000
10-Foot Channel with 8-Foot Turning Basin	27,000	6,600	33,600
11-Foot Channel with 9-Foot Turning Basin	33,600	7,700	41,300

V. Climate Change and Sea Level Rise

Based on ER 1100-2-8162[1] and EP 1100-2-1, USACE studies must consider future rates of sea level change to account for the potential impacts of climate change. Due to the uncertainty associated with future sea level change, USACE policy is to look at three scenarios of sea level change and investigate impacts to project feasibility. The three sea level change scenarios are illustrated by curves representing the low (historic) rate of Sea Level Change (SLC) at the project site, an intermediate rate (modified National Research Council (NRC) Curve I), and a high rate of SLC (modified NRC Curve III). All three local SLC curves include the global (eustatic) sea level rise rate (approximately 1.7 mm/year) as well as vertical land movement. These rates were calculated using the USACE Sea Level Change Calculator (Version 2019.21) (http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html). The tool uses the closest NOAA tide station with an adequately long water level record to determine the historical trend. The historical trend is then used with a formulation provided in the ETL to determine the intermediate and high rates of change.

The Portland, ME station (NOAA 8418150), also located in Casco Bay, was used to approximate changes in sea level rise for Great Chebeague Island from 2022 to 2122. This time range includes both anticipated project economic life and the planning horizon. The historic rate of sea level rise at Portland is 0.00617 feet/year (1912 to 2018). Sea level is expected to rise between 0.49 feet and 2.87 feet by 2072 and between 0.80 feet and 7.07 feet by 2122 from the 1992 midpoint of the present National Tidal Datum Epoch (1983-2001). Sea level change for each of the three scenarios is presented in Figure B-2 and Table B-3.

---

[1] *Engineer Regulation No. 1100-2-8162, Incorporating Sea Level Change in Civil Works Programs, 15 JUN 2019.*

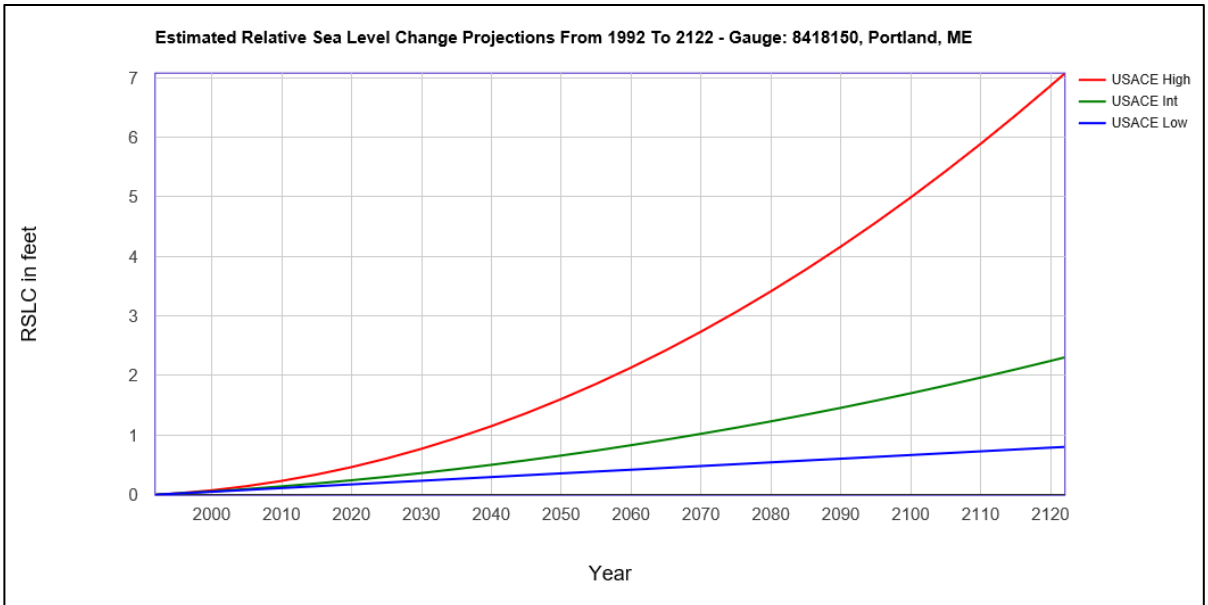


Figure B-2 – Sea Level Change Projections at Portland, Maine

Table -B-3 – USACE Sea Level Change Rates – Future Scenarios			
Year	**Low RSLC (Feet)**	**Intermediate RSLC (Feet)**	**High RSLC (Feet)**
2072	0.49	1.06	2.87
2122	0.80	2.30	7.07
Note: Sea level change values are relative to the base year of 1992 which corresponds to the midpoint of the current National Tidal Datum Epoch of 1983-2001			

Increases in sea level will deepen the existing channel and proposed improvements, resulting in safer vessel transits with greater under-keel clearance. However, sea level change is expected to impact landside infrastructure on or access to the pier over time. To assess the pier's vulnerability to sea level change, projected changes in sea level were added to existing water levels to evaluate if sea level rise will impact landslide infrastructure on or access to the pier over the project's 50-year economic life and the 100-year planning horizon. Future Mean Higher High Water (MHHW) and Highest Annual Tide (HAT) water levels for the years 2072 and 2172 are provided in Table B-4 for each scenario.

Table B-4 – Projected Water Surface Elevations – Future Scenarios			
Year	**Scenario**	**MHHW (Feet, MLLW)**	**HAT (Feet, MLLW)**
2072 (50 Years)	Low	10.40	12.29
	Intermediate	11.97	12.86
	High	12.78	14.67
2122 (100 Years)	Low	10.71	12.60
	Intermediate	12.21	14.10
	High	16.98	18.87

The Town of Chebeague Island Sea Level Rise Vulnerability Assessment, prepared by the Greater Portland Council of Governments in April 2016, noted the pier elevation is approximately 13 feet above Mean Lower Low Water (MLLW) for the majority of its length, putting it 1 to 2 feet above present-day HAT. However, high water currently tops the pier about once a year, typically when abnormally high tides coincide with strong winds and extreme weather.

A comparison of the wharf elevation to the projected tide levels in Table B-4 shows that the pier is not projected to be impacted by MHHW alone under the three sea level change scenarios nor HAT alone under the low and intermediate sea level change scenarios through 2072. Looking out to 2122, the pier will not be exceeded by MHHW alone under the low and intermediate sea level change scenarios nor HAT alone under the low sea level change scenario. This level of risk was not assumed to impact project feasibility.