US Army Corps of Engineers
-Alaska District

Appendix A:
Hydraulic Design

Unalaska (Dutch Harbor) Channels

Unalaska, Alaska

February 1, 2019

Appendix A
Hydraulic Design

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1.0 INTRODUCTION

1.1 Appendix Purpose

This hydraulic design appendix describes the technical aspects of the Unalaska navigation improvements. It provides the background for determining the Federal interest in construction of a navigation improvement project to decrease transportation inefficiencies in the region and increase vessel access and safety in the region. To determine the feasibility of a project to improve shipping, studies were conducted of the wind, waves, and currents at the site. A ship simulation study was also performed to verify channel width and orientation for safe navigation.

1.2 Background

A shoal at the entrance of Ililiuk Bay (Figure 1), which henceforth will be referred to as the bar, restricts the movement of deep draft vessels. The bar ranges in elevation from -47’MMLW to its shallowest point at -42’MLLW. This is an outer bar separating the Pacific Ocean (Bering Sea) from a more protected embankment. Wave heights 1-2 miles outside this bar frequently reach 25 feet in height with 12 second periods. Current operations dictate that vessels light load from point of origin in order to maintain an average of 4 to 7 feet of underkeel clearance over the bar. This results in inefficient and potentially unsafe delivery of fuel, durable goods, and exports to and from Unalaska.

Unalaska has a history of involvement in WWII which resulted in the Munitions of Concern (MEC) identified in and around the project area. MEC includes discarded military munitions (DMM) and unexploded ordinance (UXO). Construction of naval and army facilities and barracks in Dutch Harbor began in 1940, and Japanese air forces attacked Dutch Harbor in 1942 (Sepez, Package, Malcolm, & Poole, 2007). MEC entered the water from coastal defense artillery and anti-aircraft gun batteries during training and testing, during transfer from ships to port, disposing after the conclusion of hostilities, and being dropped or fired by Japanese forces (NAVFAC, 2013). MEC relating to the project are further discussed in section 1.4.1 Geophysical Survey.

1.3 Description of Project Area

Unalaska is located west of Akutan Pass in the Aleutian Island chain approximately 840 miles southwest of Anchorage. Unalaska Bay and the contiguous marine waters are located at latitude 54°00’N and longitude 166°50’W (CH2M HILL, 1994). The bay opens to the Bering Sea towards the north. Amaknak Island and Hog Island are the two significant land features in the bay. The City of Unalaska occupies the eastern shore of Iliuliuk Bay and Captains Bay and extends across to the western shores of central Amaknak Island. The project site is a continuous bar running roughly North-South from the start of the spit to Mainland of Unalaska Island. The project area is bounded by the box shown at the bottom of Figure 1. Henceforth the project location will be referred to as Dutch Harbor.

Dutch Harbor is located 50 miles off the Great Circle shipping route, which is the shortest marine route between Asia and the United States / Canada. Dutch Harbor serves as the major transshipment point for the Western Aleutian Chain, as well as the operations center for commercial fishing in the Bering Sea.

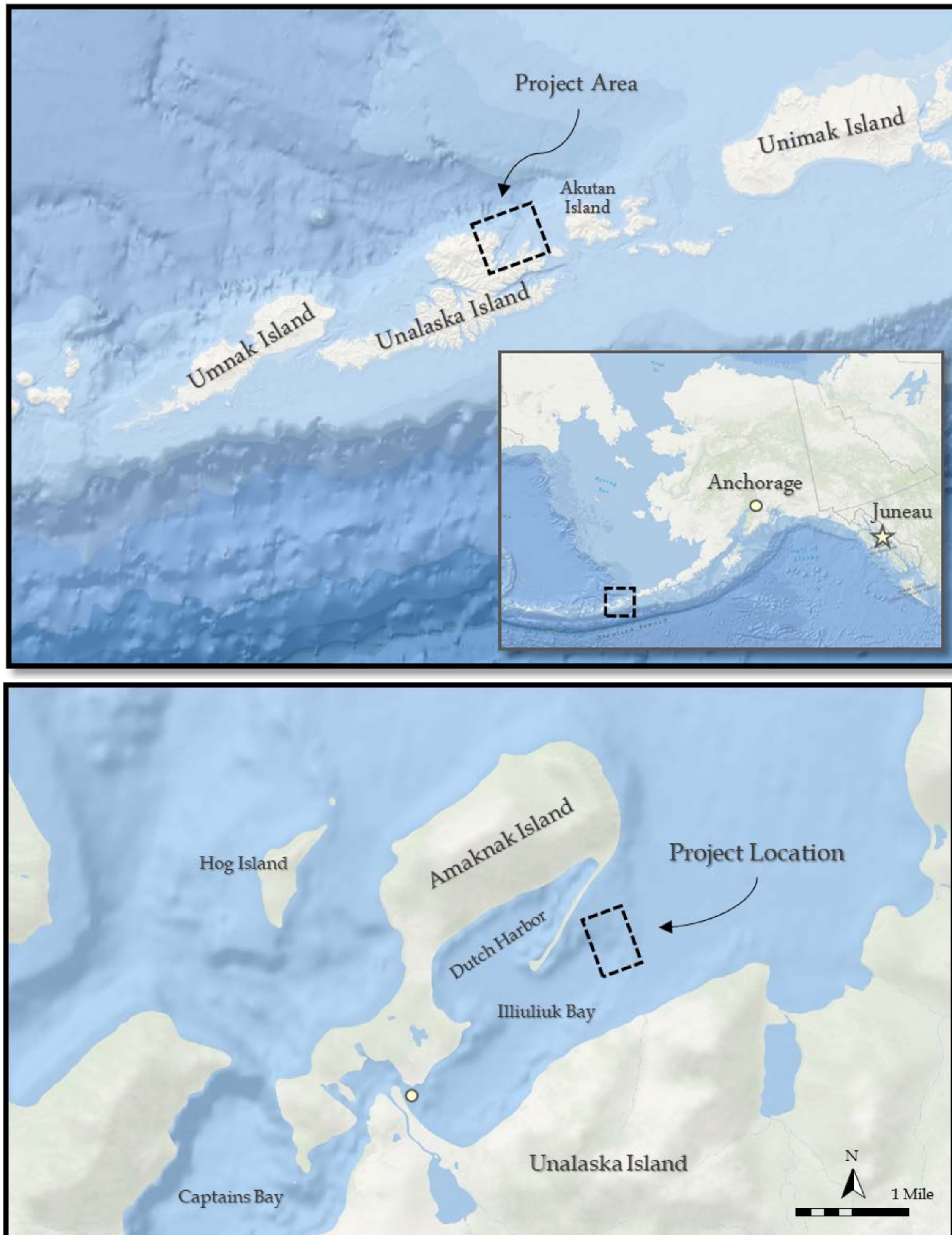


Figure 1: Location / Vicinity map of Dutch Harbor, Unalaska

1.4 Bathymetry

The shoreline along Unalaska Bay is formed mostly of steep cliffs with few narrow beaches (CH2M HILL, 1994). Traditionally, several semi-enclosed bays along the edges of Unalaska Bay have provided a safe haven for vessels during storms.

The deepest water in Unalaska Bay, approximately 400 feet deep, is found west of Hog Island. Shallower water, approximately 90 feet deep, is found east of Amaknak Island. The Aleutian Trench, approximately 25,000 feet deep, is located 100 miles south of the bay.

The bar has existed in its present form for at least 80 years according to historic nautical charts. It is believed to be a glacier moraine, or debris deposited by an advancing glacier from when the shoreline was covered with shelf ice approximately 8,000 years ago (Drewes, et al., 1961).

The earliest detailed survey is from NOAA from 1934, shown as a nautical chart from 1937 in Figure 2 (Survey, 2017). Two more NOAA surveys of Dutch Harbor were completed in 1991 and 2011. In 2017, a marine geophysical survey investigation of Dutch Harbor was performed by eTrac Inc. shown in Figure 3 (Consultants, 2017). A comparison of these four surveys is completed in Section 7.0 CHANNEL MAINTENANCE.

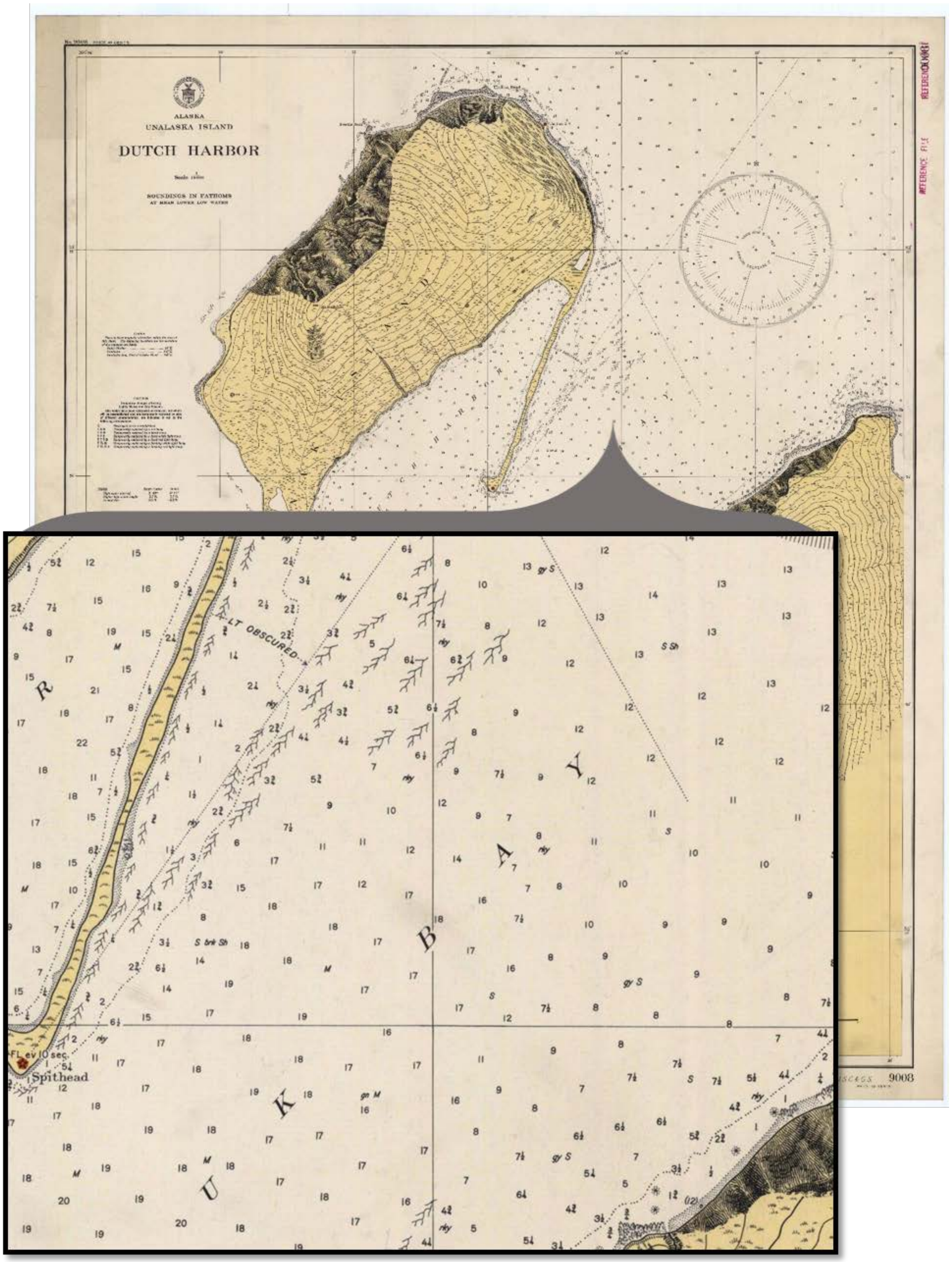


Figure 2: NOAA Survey of Dutch Harbor, 1937 Nautical Chart

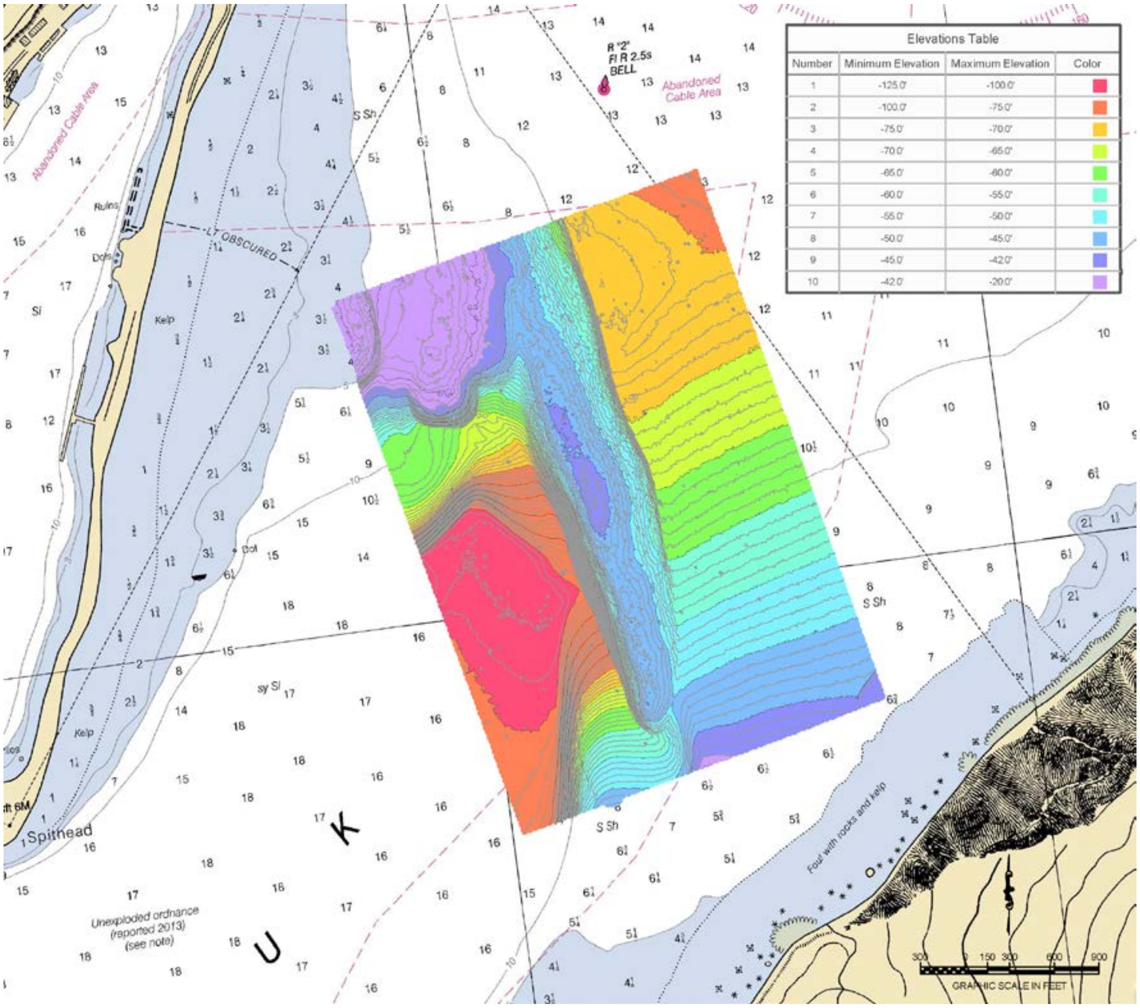


Figure 3: eTrac Inc Survey of Dutch Harbor, 2017

1.4.1 Geophysical Survey

The 2017 marine geophysical survey investigation was performed to identify the material makeup of the bar and identify MEC. The bar was interpreted to consist of a dense, consolidated, glacial drift deposit overlying bedrock. The material would not be expected to be rippable by a bulldozer in a terrestrial setting. It is anticipated that drill and blast method will be used to dredge the channel.

Several potential MEC were identified within the project limits during the 2017 survey. Further investigation is necessary to determine the objects' identity. See Geotechnical appendix for more information.

2.0 CLIMATOLOGY, METEOROLOGY, HYDROLOGY

2.1 Weather Conditions

Dutch Harbor lies within the southwest maritime climate zone (Affairs, 2017). The area is characterized by persistently overcast skies, high winds, and frequent cyclonic storms.

2.1.1 Temperature and Precipitation

Climate data for Dutch Harbor from 1951 to 2005 is provided in Table 1 below (DUTCH HARBOR, ALASKA (502587), 2017). The highest recorded temperature is 81°F, and the lowest recorded temperature is -8°F, but typically temperatures range from 36°F to 46°F year round.

Table 1: Average Temperature, Precipitation, and Snowfall

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Min Temp *(°F)*	28	27	29	31	37	42	46	48	43	37	32	30	36
Max Temp *(°F)*	37	37	39	41	46	52	57	59	54	47	43	39	46
Ave Precip *(in)*	8	7	6	4	4	3	2	3	5	7	7	8	63
Ave Snowfall *(in)*	23	22	15	6	0	0	0	0	0	1	6	16	89
Ave Snow Depth *(in)*	4	5	3	1	0	0	0	0	0	0	0	3	1

2.1.2 Wind

Violent williwaws are experienced with southerly gales and winds from the southeast, southwest, and northeast, which can reach hurricane velocity (Tryck Nyman Hayes, 1995). Local pilots indicate they frequently experience 35 knot wind from the north and northeast. Prevailing wind direction is from the southeast. In the fall, wind direction shifts to the northwest.

Localized wind conditions were taken from airport station PADU and spit station DUTA2, (Figure 4). Other wind stations are shown in the figure, but because of location or short length of record, they were excluded from further analysis.

Figure 4: Location of Wind Data in Dutch Harbor

The Air Force Combat Climatology Center performed an extreme value analysis and produced return interval wind speed tables for four direction sectors. The analysis was performed at airport station PADU (Table 2). The 50 year return period for one hour wind duration was determined to be 54.9 knots (Zautner, 2017). A similar analysis for station DUTA2 on the spit was not able to be performed with only 5 years of historical data. DUTA2 is the wind site that most represents the wind the vessels feel when egressing and ingressing. Note that historic station 70489099999 from 1946 to 2008 has a wind exposure differing from that of the project site.

Table 2: One Hour Sustained Winds Extreme Value Analysis at Airport (PADU)

Quantiles	0.1	0.2	0.5	0.8	0.9	0.95	0.98	0.99	0.999	0.9999
Return Period (Yrs)	1.1	1.25	2	5	10	20	50	100	1000	10000
Variate: All Directions 1 Hour Sustained Winds (Knots)	35.8	37.9	42.3	47.1	49.8	52.2	54.9	56.8	62.5	67.5
Variate: 30°- 60° 1 Hour Sustained Winds (Knots)	23.05	24.6	28.02	32.08	34.47	36.58	39.13	40.92	46.34	51.28
Variate: 130°- 160° 1 Hour Sustained Winds (Knots)	27.32	30.43	36.23	41.85	44.72	47.05	49.63	51.34	56.01	59.75
Variate: 210° - 240° 1 Hour Sustained Winds (Knots)	27.63	30.25	35.27	40.28	42.9	45.07	47.5	49.12	53.66	57.39
Variate: 280°- 310° 1 Hour Sustained Winds (Knots)	29.19	32.32	37.68	42.15	44.16	45.66	47.18	48.11	50.33	51.78

Table 3 compares the years available for both PADU and DUTA2 stations (2013 to 2017). In general, maximum wind speed and gust are 30% lower at the spit. This is due to a number of factors including site geography, gage height of 23.3 feet for PADU compared to 15 feet for DUTA2, and the amount of data recorded during the compared years. PADU has approximately six times the number of recording hours for windspeed and gust compared to DUTA2 between 2013 and 2017. The airport station PADU was chosen as the best representative site to perform long term statistics. However, it is not the same as the spit site, which is more indicative of what the vessels experience.

Table 3: Comparison of Windspeed and Gust at Airport (PADU) and Spit (DUTA2) Stations

Year	Location	Max Windspeed (Knots)	Max Gust (Knots)
2013	Airport	43	59
	Spit	-	63
2014	Airport	43	61
	Spit	36	56
2015	Airport	48	69
	Spit	32	38
2016	Airport	44	76
	Spit	25	40
2017	Airport	49	68
	Spit	24	41

Wind roses for the airport station are provided in Figure 6 through Figure 10, with one wind rose for the spit (Figure 5) provided for comparison. Notice that the location of the spit station is sheltered by Amaknak Island and is bidirectional (affected more by winds from the north and southwest). The airport station is more omnidirectional, but is sheltered by winds from the Northeast.

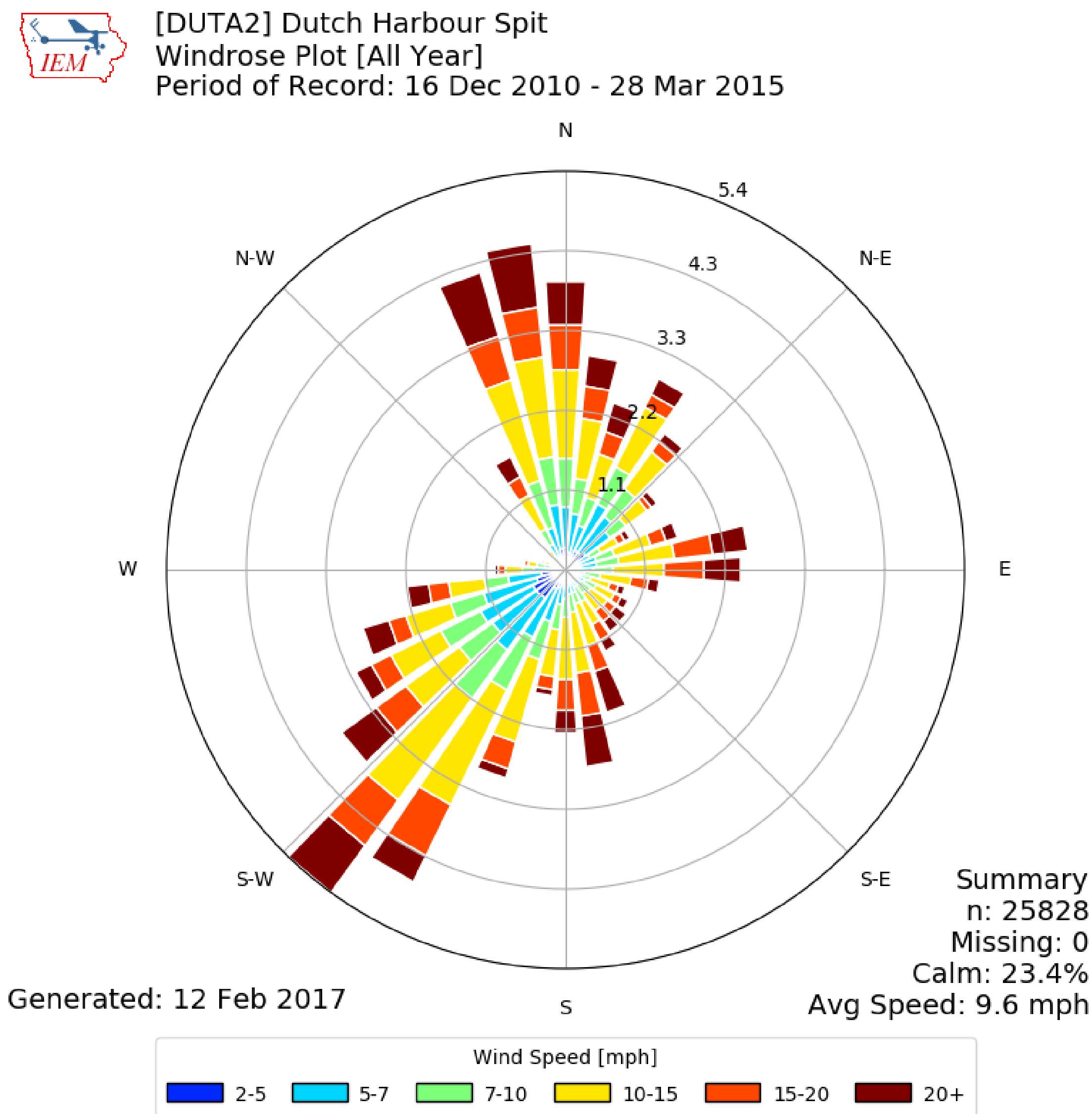


Figure 5: Wind Rose for Spit – All Months

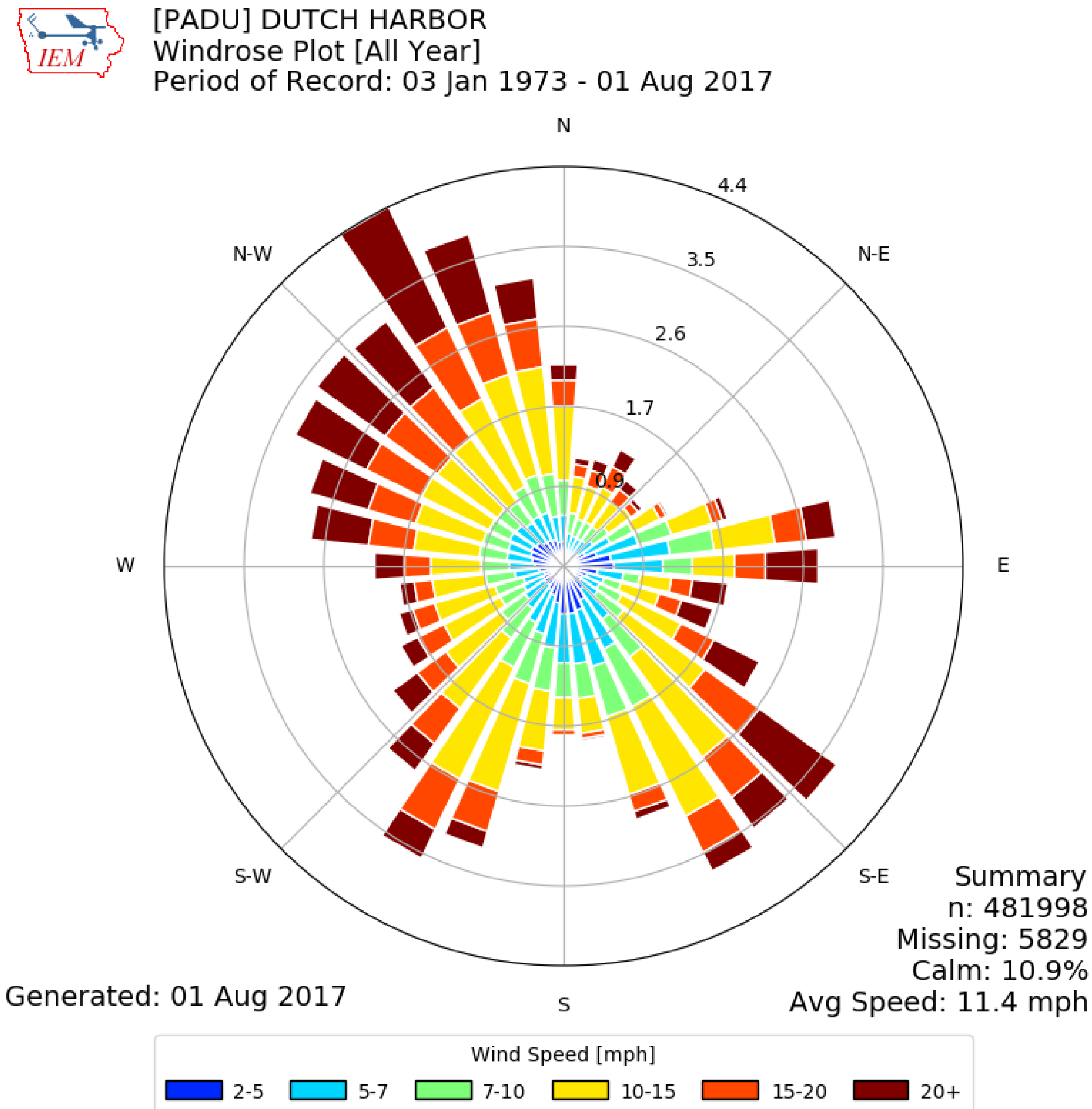


Figure 6: Wind Rose for Airport – All Months

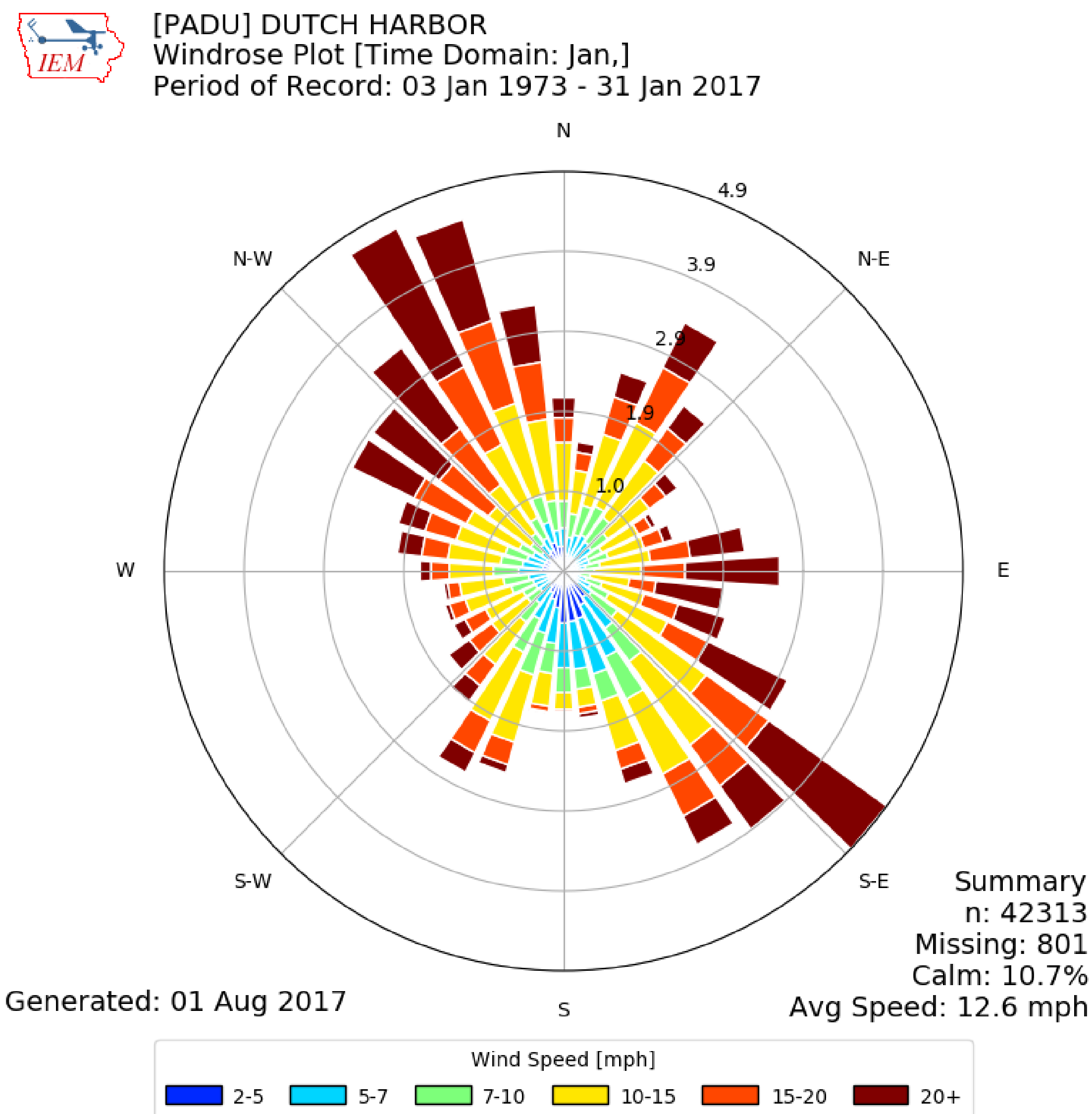


Figure 7: Wind Rose for Airport – Winter (January)

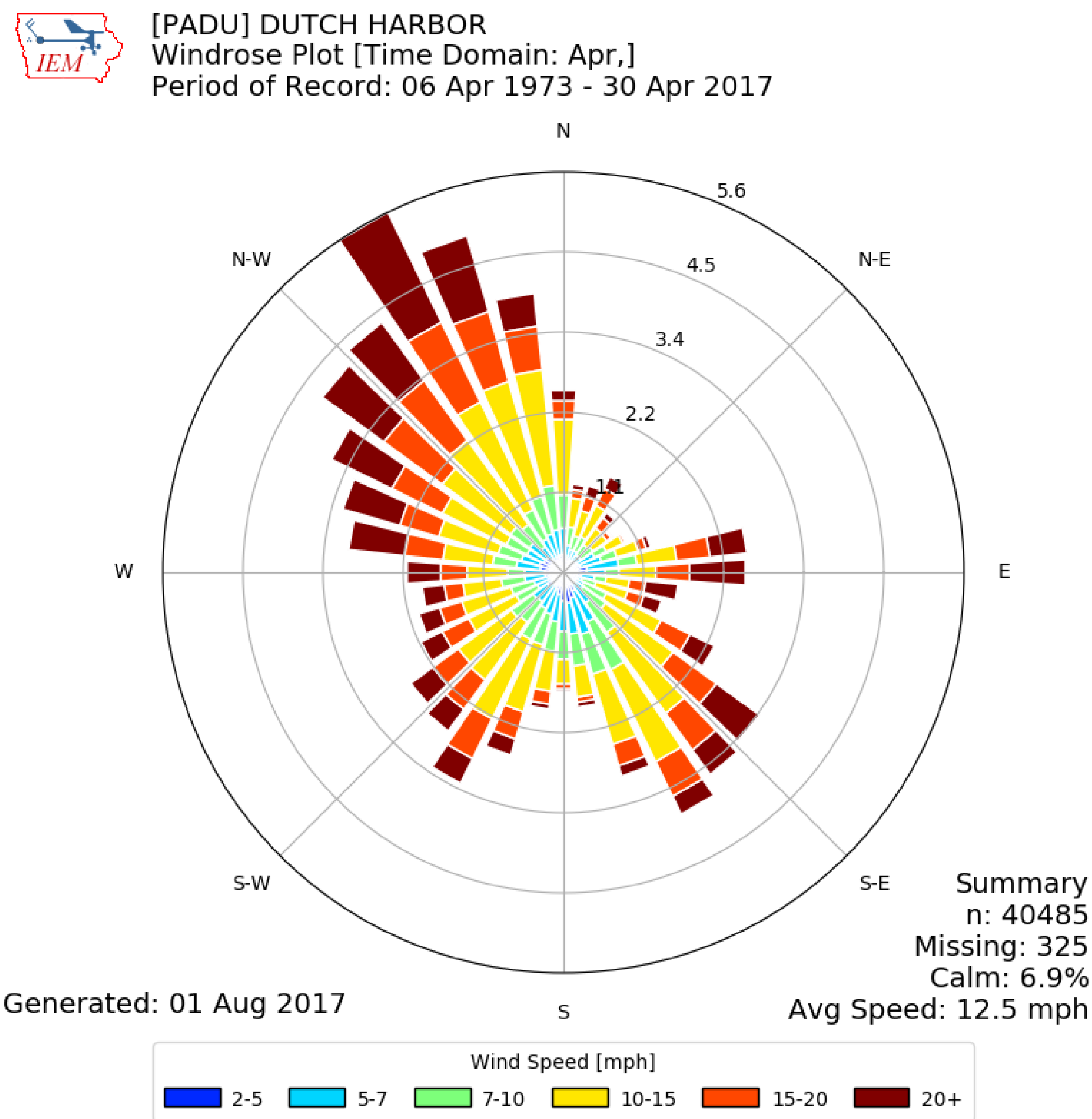


Figure 8: Wind Rose for Airport – Spring (April)

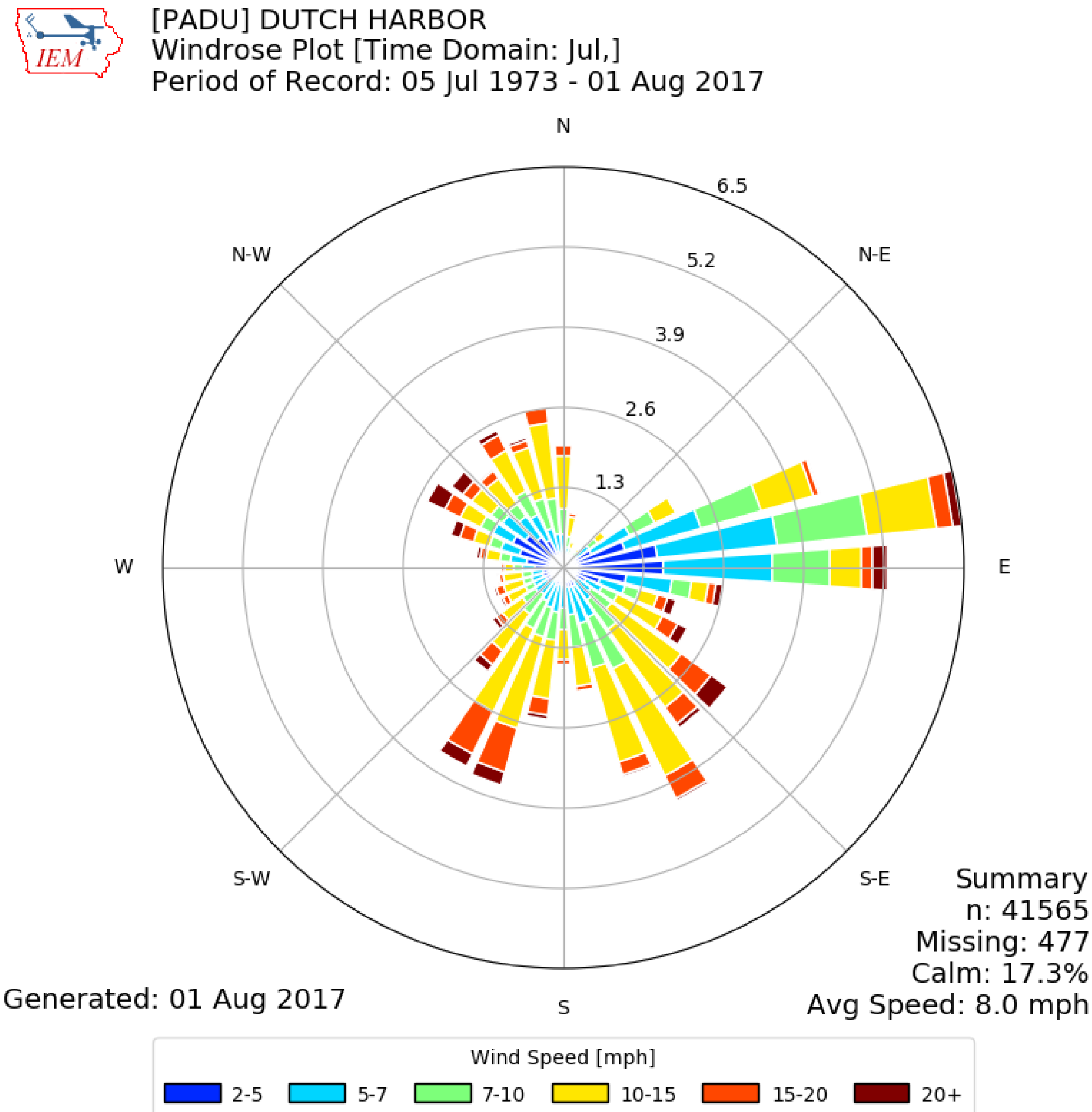


Figure 9: Wind Rose for Airport – Summer (July)

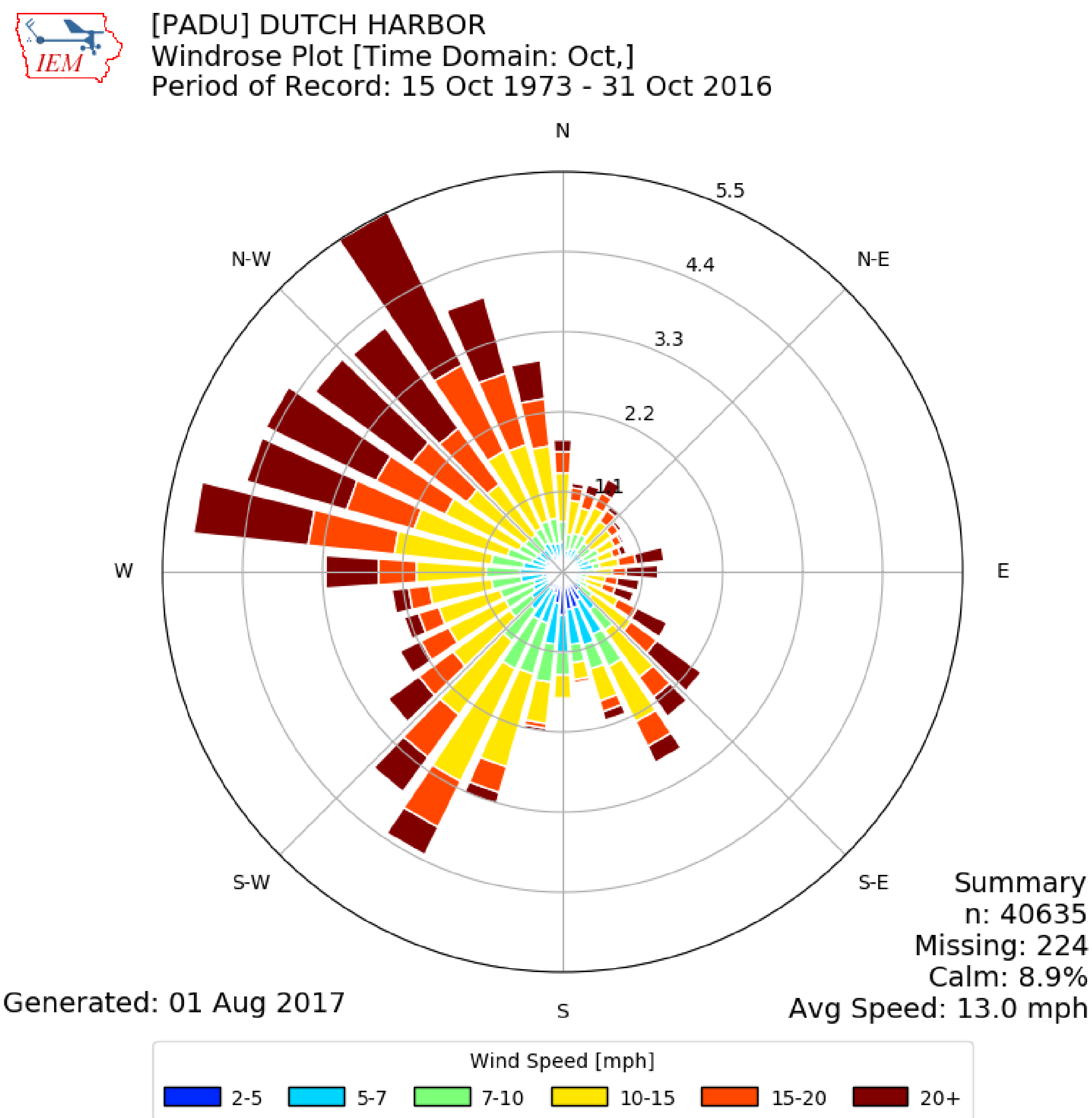


Figure 10: Wind Rose for Airport – Fall (October)

2.1.3 Wind Conditions with Project

Wind percent occurrence for the airport for 7/1/1951 through 6/30/2018 is presented in Table 4. The data is binned by direction (+-15° bands) and windspeed (2 minute average).

Table 4: Airport (PADU) - Wind Percent Occurrence

Wind Direction	Frequency of Wind Speed						Total Frequency of Wind Speed
	< 5.8 (mi/hr)	*5.8 - 11.4 (mi/hr)*	*11.5 - 17.1 (mi/hr)*	*7.2 - 28.7 (mi/hr)*	*28.8 - 40.2 (mi/hr)*	*40.3 > (mi/hr)*	
	< 5.0 (knots)	*5.0 - 9.9 (knots)*	*10.0 - 14.9 (knots)*	*15.0 - 24.9 (knots)*	*25.0 - 34.9 (knots)*	*35.0 > (knots)*	
	< 2.6 (m/s)	*2.6 - 5.1 (m/s)*	*5.2 - 7.7 (m/s)*	*7.8 - 12.8 (m/s)*	*23.9 - 18.0 (m/s)*	*18.1 > (m/s)*	
0°	11.6%	2.3%	2.1%	1.2%	0.1%	0.0%	17.3%
30°	0.5%	1.4%	1.1%	0.8%	0.1%	0.0%	3.9%
60°	0.8%	2.1%	0.9%	0.3%	0.0%	0.0%	4.1%
90°	1.4%	2.8%	1.4%	1.6%	0.3%	0.0%	7.5%
120°	0.7%	1.8%	2.1%	2.2%	0.6%	0.1%	7.5%
150°	1.3%	4.2%	3.2%	1.5%	0.1%	0.0%	10.3%
180°	1.5%	3.2%	1.1%	0.3%	0.0%	0.0%	6.1%
210°	1.0%	3.6%	3.3%	1.8%	0.1%	0.0%	9.8%
240°	0.7%	2.1%	1.9%	1.2%	0.1%	0.0%	6.0%
270°	0.9%	2.1%	1.7%	1.5%	0.3%	0.0%	6.6%
300°	1.1%	1.9%	2.4%	3.1%	0.6%	0.0%	9.2%
330°	1.0%	2.5%	3.1%	4.1%	0.8%	0.0%	11.5%
Total	22.5%	30.1%	24.3%	19.7%	3.2%	0.2%	100.0%

2.1.4 Fog

The percentage of days each month that are cloudy or experience heavy fog are given for Cold Bay, 175 miles to the east, in Table 5 below (West Comp Fog, 2017). Heavy fog constitutes visibility of a ¼ mile or less observed sometime during the day. Local pilots report that seas are calm approximately half of the time; when seas are calm it is typically foggy in Dutch Harbor.

Table 5: Percent of Cloudy and Foggy Days

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cloudy	75%	78%	75%	85%	89%	90%	92%	93%	88%	81%	78%	78%	84%
Heavy Fog	6%	5%	6%	4%	5%	7%	13%	11%	3%	1%	2%	5%	6%

2.1.5 Ice

Dutch Harbor remains ice-free year round. A recent study analyzed the sea ice extents in the Bering Sea from 1979 to 2012; Unalaska Island was at least 100 miles from the maximum ice extent on March 31, 2008 and at least 300 miles from the maximum ice extent on April 10, 2005 (Wendler, 2014).

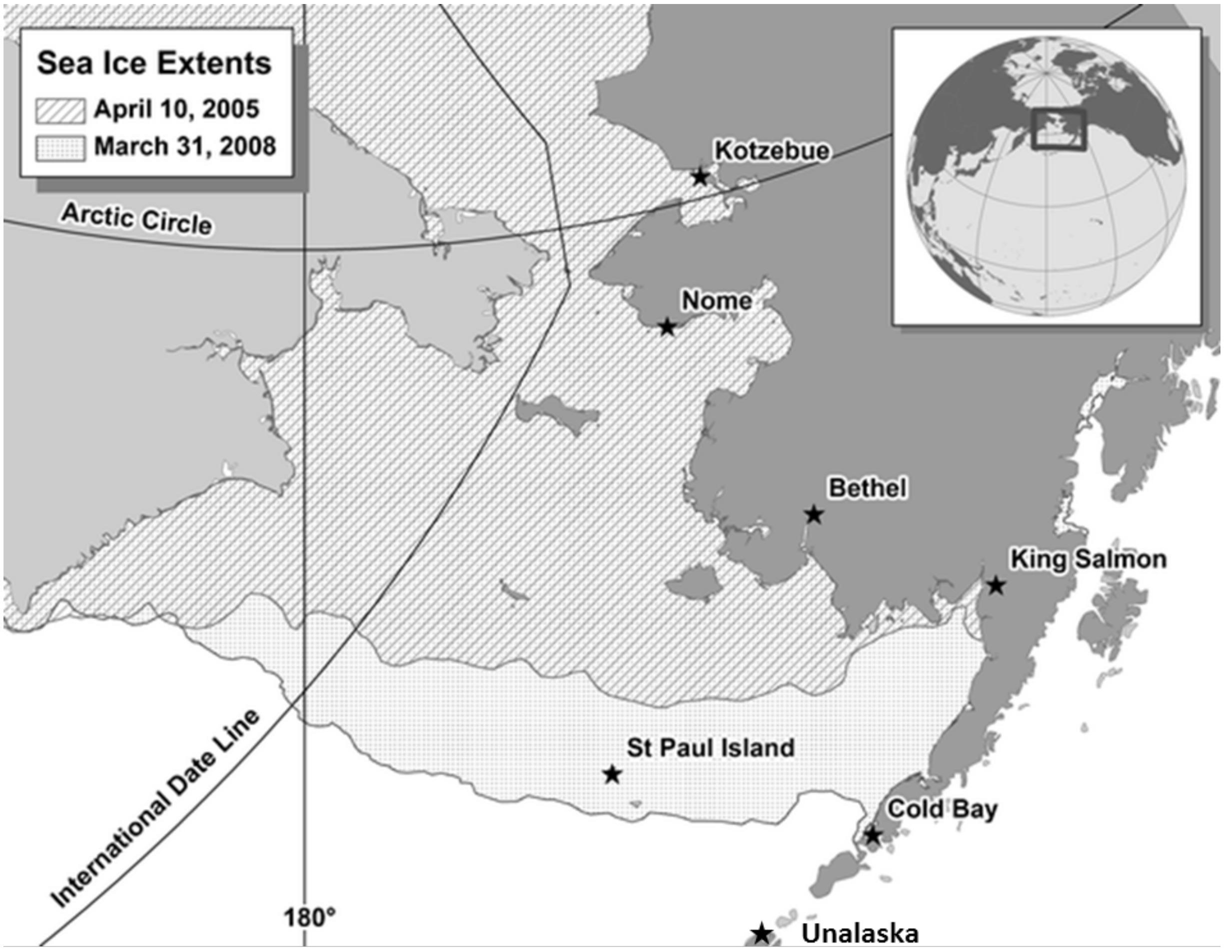


Figure 11: Bering Sea Ice Extents

2.2 Vessel Operation

According to local pilots, wind speeds that generally prevent operations for bringing large containerships inbound over the bar are as follows in Table 6. Outbound vessels are less affected by wind due to the straight-line exit path over the bar. Inbound vessels must immediately turn to the west after transiting over the bar to approach docking areas (Figure 12). According to pilots, approximately half of the vessels transiting the bar in the winter when winds are strongest do not have bow thrusters. These vessels are easily turned by wind catching the bow.

Table 6: Wind Parameters for Cease Operations

Wind Parameters		
Direction	*Middle Azimuth*	*Knots*
NE	45.00°	20
SE-S	146.25°	20
SW	225.00°	25
W-NW	292.50°	25

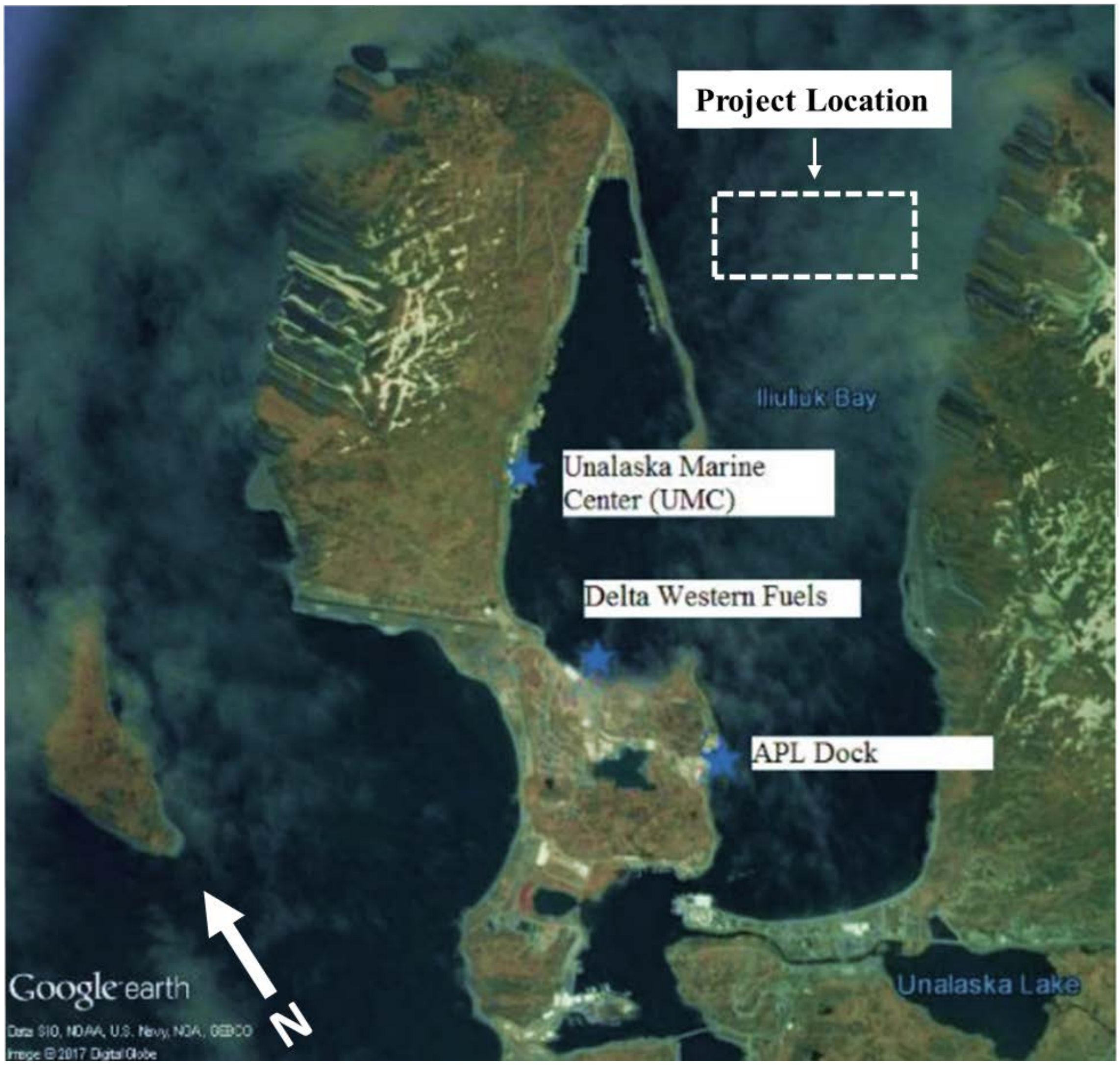


Figure 12: Location of Docks in Relation to the Project Location

3.0 CURRENTS AND WATER LEVELS

3.1 Currents

Tidal currents contribute less to the overall circulation patterns in the project area. A maximum flood current velocity of 1.6 knots and a maximum ebb current velocity of 2.0 knots are predicted in the NOAA Tides & Currents program for Priest Rock approximately 7 nautical miles from the project site (NOAA, 2017). The flood and ebb currents closer to the project site at Ulakta Head are reported as weak and variable.

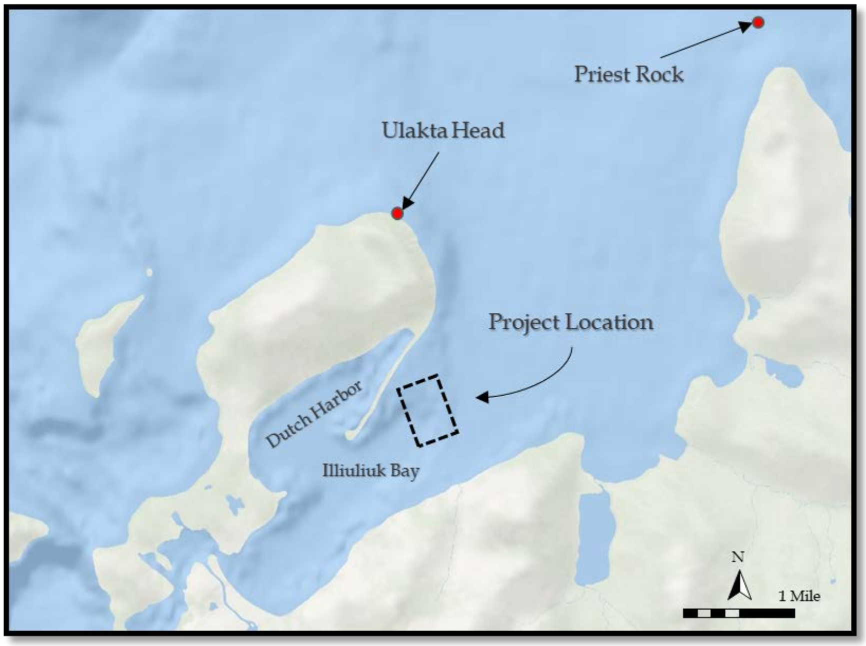


Figure 13: Location of Reported Tidal Currents

According to pilots' accounts during Ship Simulation, tidal currents are not a significant factor when transiting over the bar and were not included in the simulation runs. Tidal currents are considered to be non-relevant to this project.

3.2 Tides

Iliuliuk Bay is in an area of semi-diurnal tides with two high waters and two low waters each lunar day. Tidal parameters at Iliuliuk Bay are closest to those determined by NOAA for Station 9462620 – Unalaska (53º52.8'N, 166º32.2'W). The tidal parameters in Table 7 were provided by NOAA with the station established on May 7, 1955 (NOAA, 2017). Elevations are given with respect to 0' MLLW.

Table 7: Tidal Parameters – Unalaska

Parameter	Elevation (feet MLLW)
Highest Observed Water Level (01/27/1960)	6.70
Mean Higher High Water (MHHW)	3.60
Mean High Water (MHW)	3.31
Mean Sea Level (MSL)	2.08
Mean Low Water (MLW)	0.93
Mean Lower Low Water (MLLW)	0.00
Lowest Observed Water Level (12/13/2008)	-2.78

A tide curve (Figure 14) was created from Station 9462620 data recorded between 1982 and 2017. During this period, the tide was above 0’MLLW 92.2% of the time, above -0.5’MLLW 96.5% of the time, and above -1’MLLW 98.8% of the time. Economics will determine if the bar should be deepened to allow for greater than 92.2% tidal access. According to local pilots, current practice is for deep draft vessels to time their arrivals and departures at Dutch Harbor to coincide with high tide.

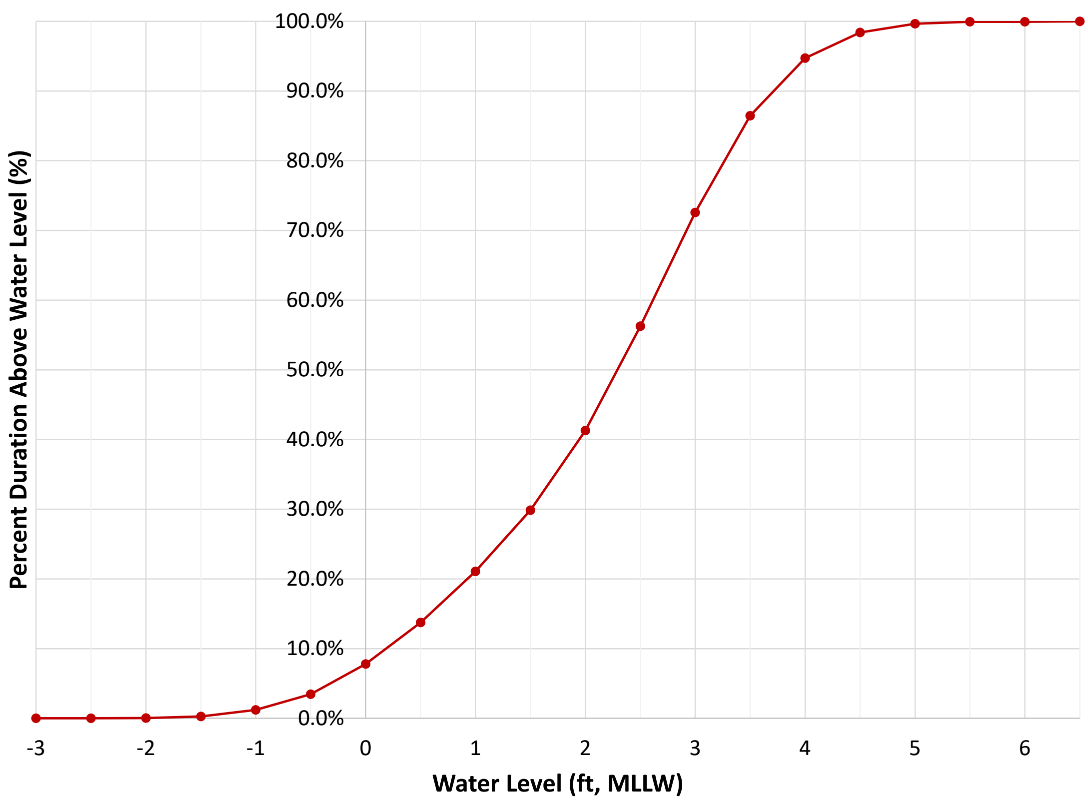


Figure 14: Tide Curve for Percent Duration Above 0’ MLLW

3.3 Sea Level Change

The Corps of Engineers requires that planning studies and engineering designs consider alternatives that are formulated and evaluated for the entire range of possible future rates of sea level change (SLC). Guidance for addressing SLC is in Engineer Regulation ER 1100-2-8162 and detailed below. Three scenarios of “low,” “intermediate,” and “high” SLC are evaluated over the project life cycle. According to the EC, the SLC “low” rate is the historic SLC. The “intermediate” and “high” rates are computed using the following:

> Estimate the “intermediate” rate of local mean sea-level change using the modified NRC Curve I and the NRC equations. Add those to the local historic rate of vertical land movement.
>
> Estimate the “high” rate of local mean SLC using the modified NRC Curve III and NRC equations. Add those to the local rate of vertical land movement. This “high” rate exceeds the upper bounds of Intergovernmental Panel on Climate Change (IPCC) estimates from both 2001 and 2007 to accommodate potential rapid loss of ice from Antarctica and Greenland.

3.3.1 NRC Equations

The 1987 NRC described these three scenarios using the following equation:

$$E(t) = 0.0012t + bt^2$$

in which t represents years, starting in 1986, b is a constant, and $E(t)$ is the eustatic sea level change, in meters, as a function of t. The NRC committee recommended "projections be updated approximately every decade to incorporate additional data." At the time the NRC report was prepared, the estimate of global mean sea level change was approximately 1.2 mm/year. Using the current estimate of 1.7 mm/year for GMSL change, as presented by the IPCC (IPCC 2007), results in this equation being modified to be:

$$E(t) = 0.0017t + bt^2$$

The three scenarios proposed by the NRC result in global eustatic sea level rise values, by the year 2100, of 0.5 meter, 1.0 meter, and 1.5 meters. Adjusting the equation to include the historic GMSL change rate of 1.7 mm/year and the start date of 1992 (which corresponds to the midpoint of the current National Tidal Datum Epoch of 1983-2001), results in updated values for the variable b being equal to 2.71E-5 for modified NRC Curve I, 7.00E-5 for modified NRC Curve II, and 1.13E-4 for modified NRC Curve III. The three GMSL rise scenarios are shown in Figure 15 (Figure 5 from EC 1165-2-212).

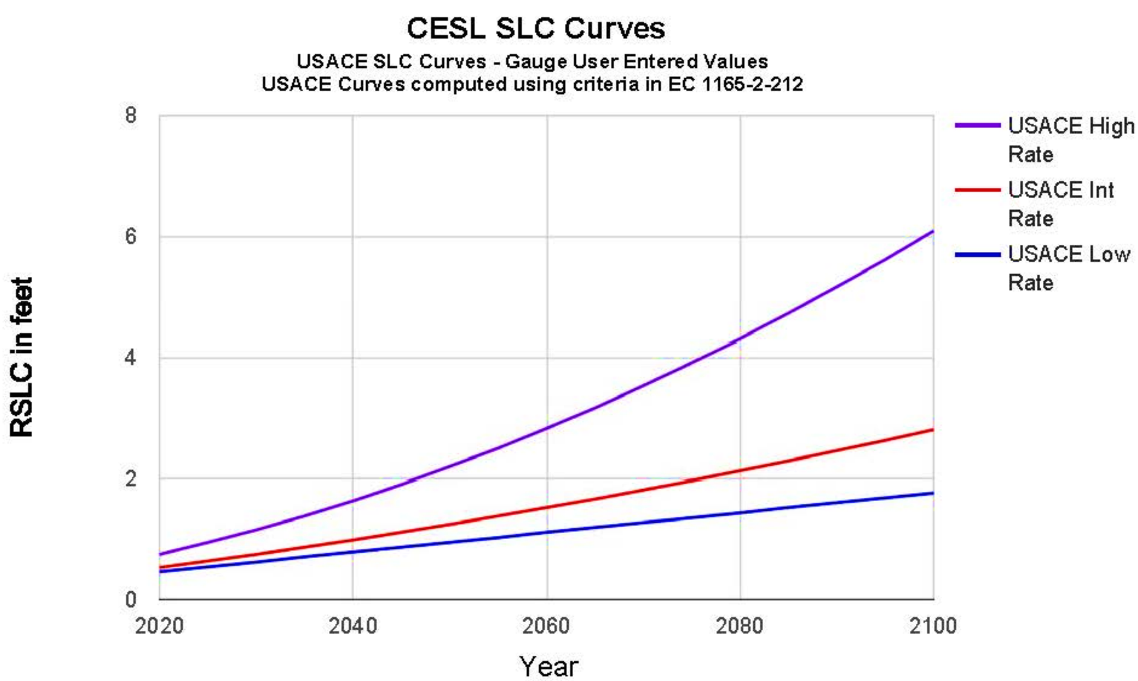


Figure 15: Scenarios for GMSL Rise (based on updates to NRC 1987 equation)

Manipulating the equation to account for the fact that it was developed for eustatic sea level rise starting in 1992, while projects will actually be constructed at some date after 1992, results in the following equation:

$$E(t_2) - E(t_1) = 0.0017(t_2 - t_1) + b(t_2^2 - t_1^2)$$

where t_1 is the time between the project's construction date and 1992 and t_2 is the time between a future date at which one wants an estimate for sea level change and 1992 (or $t_2 = t_1$ + number of years after construction) . For the three scenarios proposed by the NRC, b is equal to 2.71E-5 for Curve 1, 7.00E-5 for Curve 2, and 1.13E-4 for Curve 3.

This sea level change should then be added to a measured sea level trend for Dutch Harbor. The nearest tide station is the Unalaska, AK station (Gage ID: 9462620), located approximately 2.5 miles southwest of the project site.

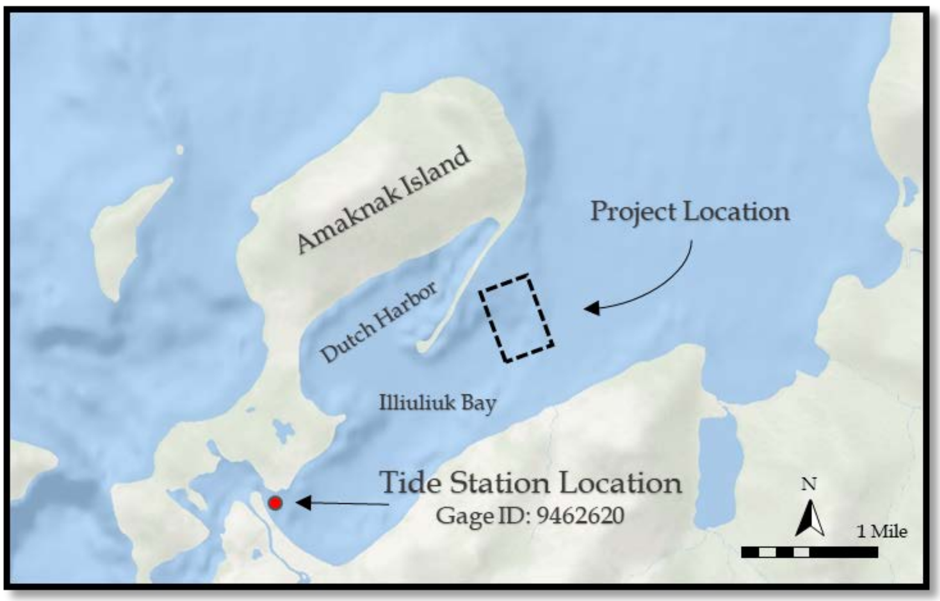


Figure 16: Unalaska, AK Tide Station Location

Sea level change estimates using EC 1165-2-212 and NOAA historic rates can be seen in Figure 17 and Table 8 below. Low and intermediate sea level change estimates predict that the isostatic rebound rate will be greater than the sea level rise rate, resulting in an overall sea level drop between 2020 and 2070. High sea level change estimates predict that the isostatic rebound rate will be less than the sea level rise rate.

It is recommended that the intermediate sea level change scenario of -0.46 feet over 50 years be considered for this project. There is an anticipated need for maintenance dredging at year 25 of the project. An evaluation should be performed at this time to determine how the MSL has changed since construction and what the latest projection for change during the next 25 years. If it is found that the MSL has decreased as anticipated by the intermediate scenario, the maintenance dredging should incorporate the depth needed to bring the project to construction levels, with an allowance for the anticipated sea level change at year 50.

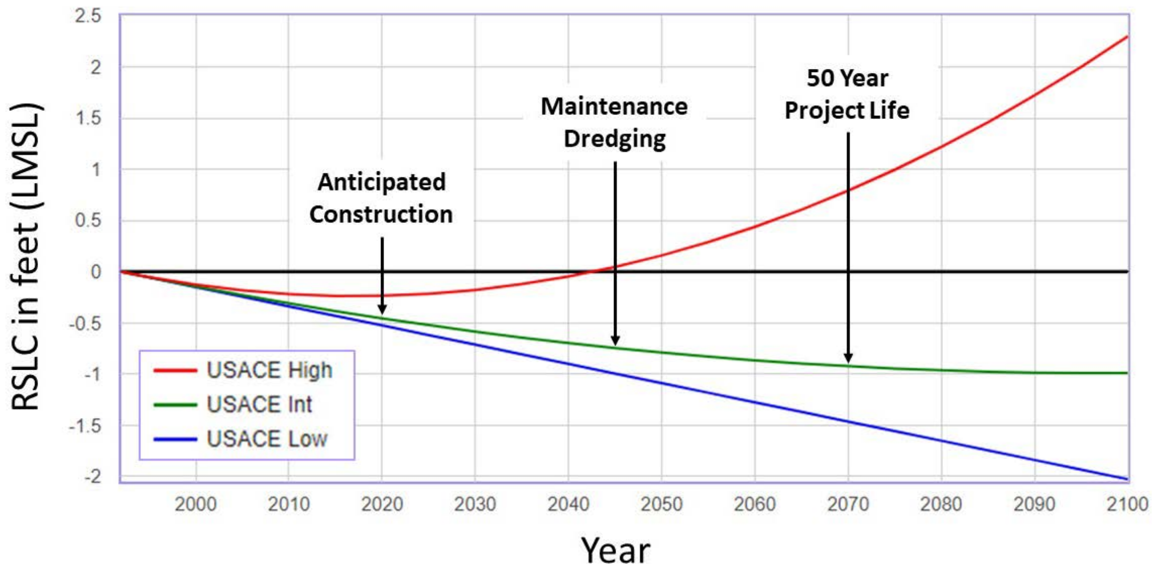


Figure 17: Sea Level Change Predictions from 1992 to 2100 for Unalaska, AK

Table 8: Sea Level Change Prediction for a 50-Year Project Life in 2070

Year	Description	USACE Low	USACE Intermediate	USACE High
2070 - 2020	RSLC During Project Life	-0.93 ft	-0.46 ft	+1.03 ft
1992	USACE RSLC Projection Begins	0.0 ft	0.0 ft	0.0 ft
2020	Anticipated Construction	-0.53 ft	-0.46 ft	-0.24 ft
2045	Maintenance Dredging	-1.00 ft	-0.75 ft	+0.05 ft
2070	50 Year Project Life	-1.46 ft	-0.92 ft	+0.79ft
2100	Recommended RSLC End	-2.03 ft	-0.99 ft	+2.30 ft

4.0 WAVE CLIMATE

4.1 Wave Hindcast

The Wave Information Studies (WIS) is a US Army Corps of Engineers (USACE) sponsored project that generates consistent, hourly, and long-term wave climatologies (Hesser, 2018). WIS point 82326 was chosen to be representative of offshore deep-water wave conditions that would affect Dutch Harbor. Its position is preferred over adjacent stations by Engineer Research and Development Center (ERDC) Research Oceanographer Bob Jensen. Station 82327 to the east is too sheltered while station 82325 to the west is less influenced by land points, making station 82326 the best choice. The WIS point is located approximately 40 miles from the project site. Wave roses for 82326 are given in Figure 19 through Figure 23.

Figure 18: WIS Station 82326 - Location

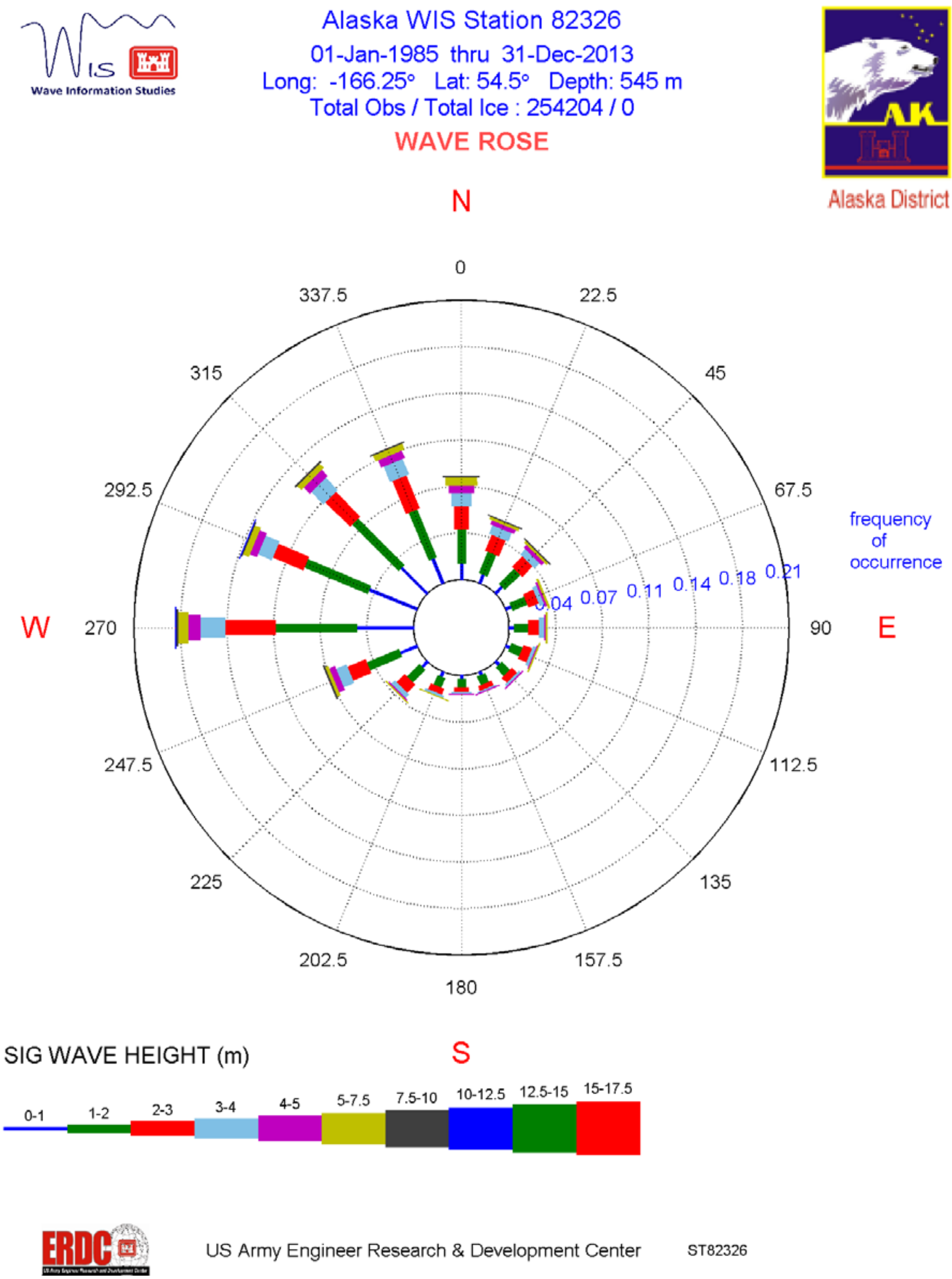


Figure 19: Wave Rose for Station 82326 – All Year

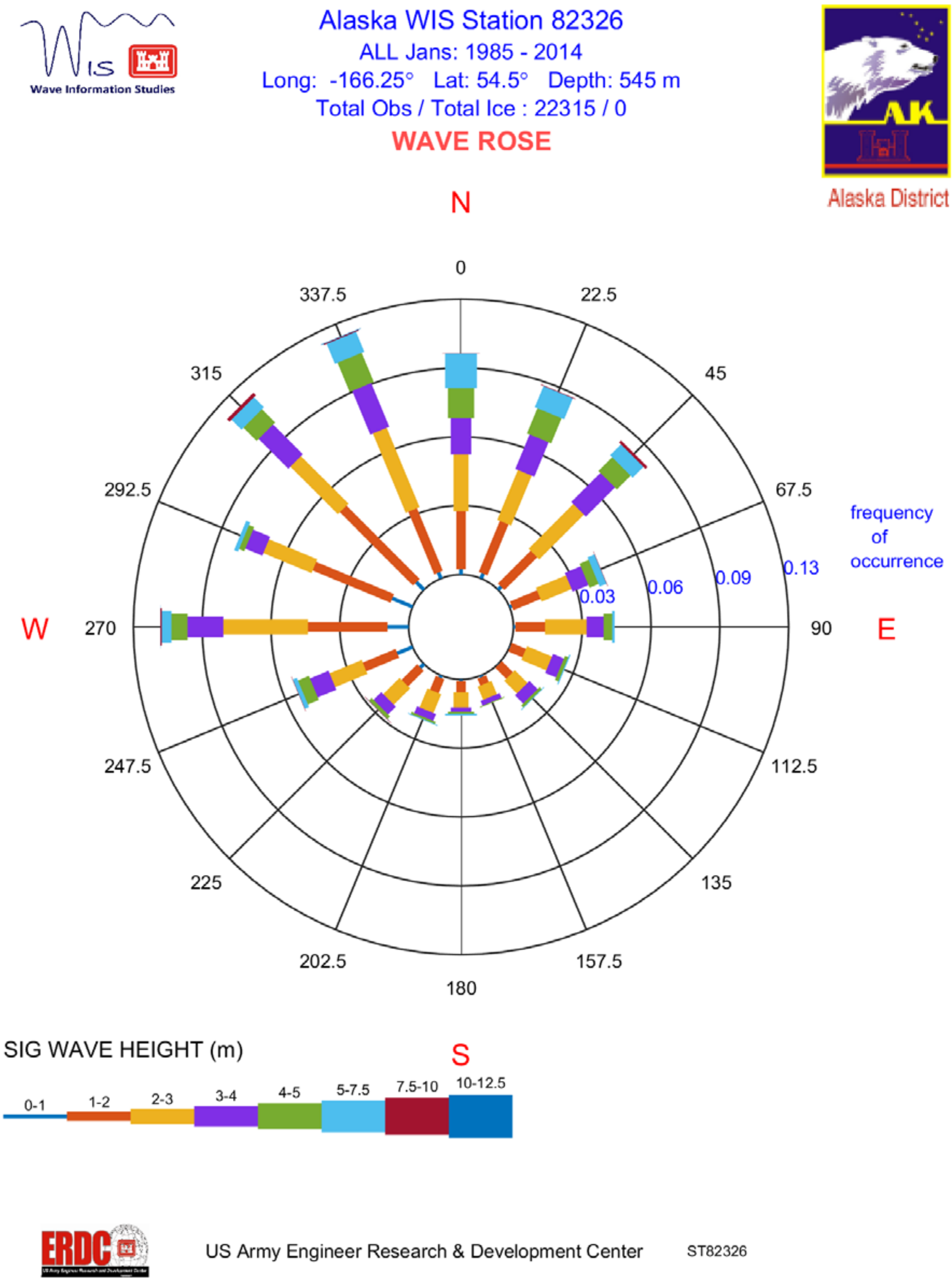


Figure 20: Wave Rose for Station 82326 – Winter (January)

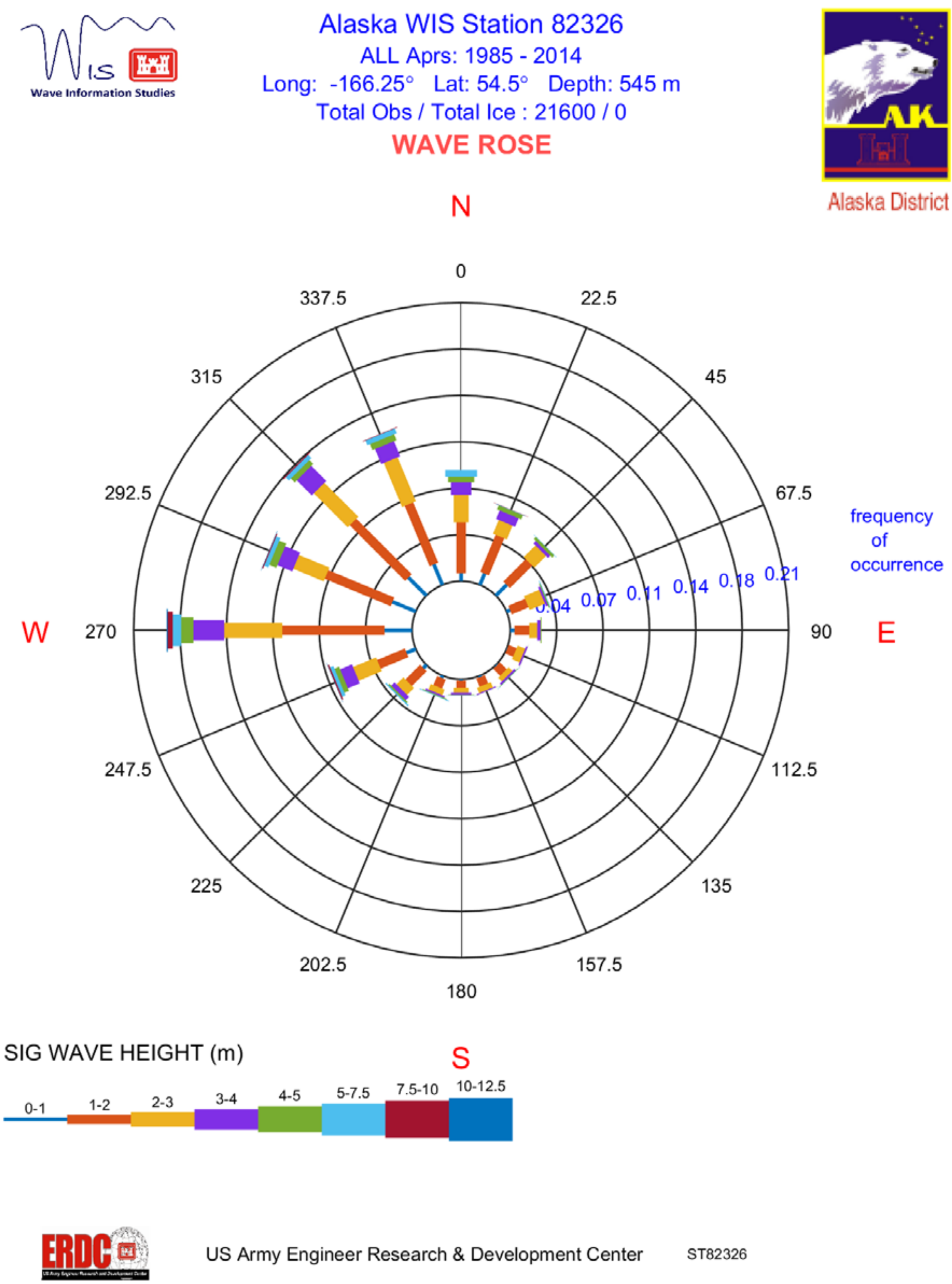


Figure 21: Wave Rose for Station 82326 – Spring (April)

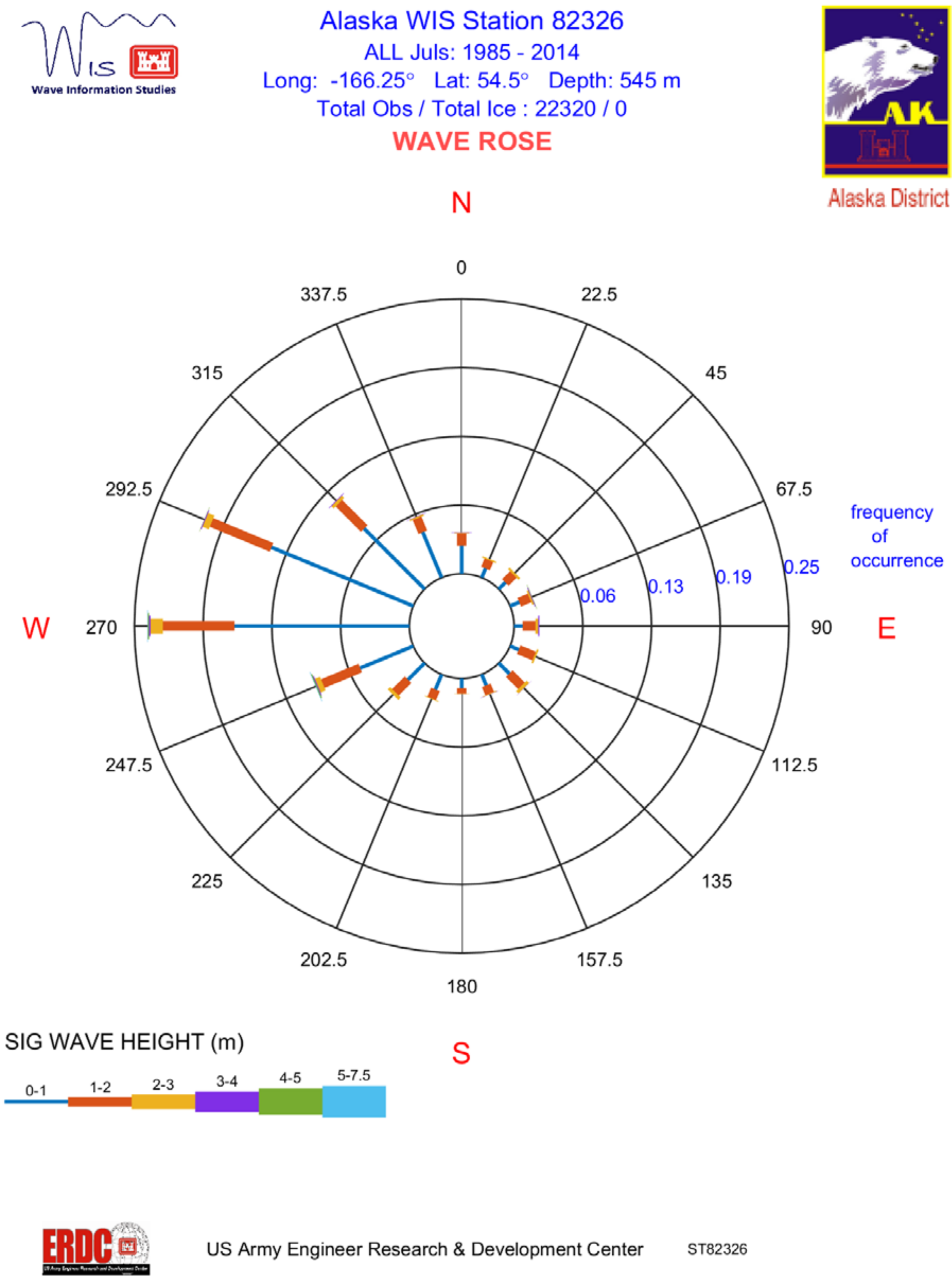


Figure 22: Wave Rose for Station 82326 – Summer (July)

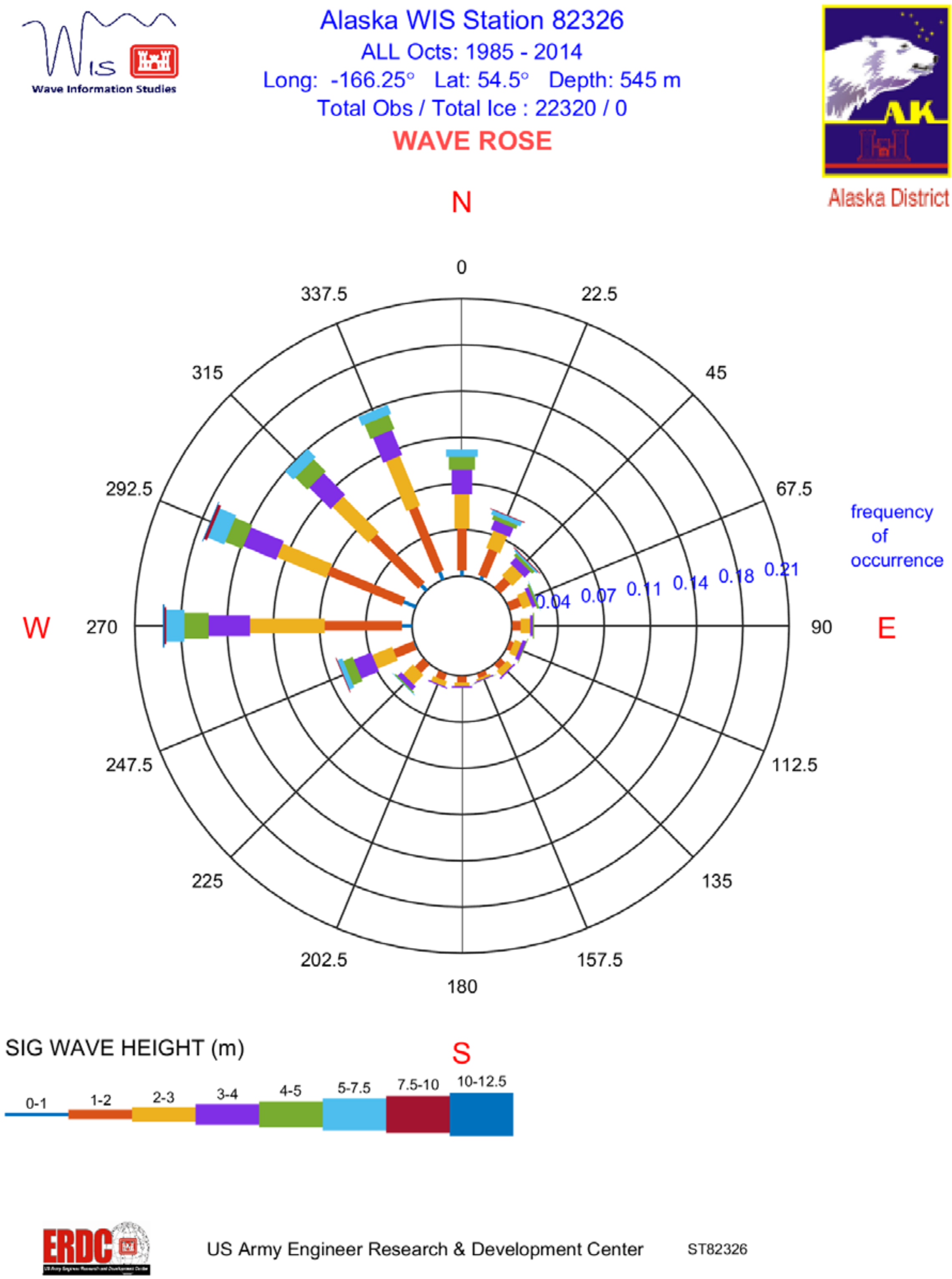


Figure 23: Wave Rose for Station 82326 – Fall (October)

Storm hindcast data is available for station 82326 from 1954 to 2014 (61 years), and wave hindcast data is available from 1985 to 2014 (30 years). The wave of record for the 61 year hindcast is the same wave of record for the 30 year hindcast, meaning the 30 year wave is considered conservative. For the purpose of this analysis, the 61 year storm hindcast data was not used because it was not a continuous time series, but rather it captured individual storms that met a certain undescribed threshold.

Recurrence intervals for waves were calculated by first filtering the waves by direction. It was determined that in order to capture all the waves that could enter Dutch Harbor, waves entering from 270° to 90° would be analyzed. This area of interest was broken into two directional bands, 270° to 0° and 0° to 90°. Waves were then filtered in the two bands from largest to smallest. It was assumed that storm durations were 12 hours or less for this application. The first or highest event is the 30 year wave, or the wave that has a 1 in 30 chance of occurring in any given year, and the 30^{th} event is the 1 year wave.

Wave directions are given in degrees and are the direction that waves are arriving from. The 30, 25, 10, 5, and 1 year waves can be found in Table 9. The 30 year wave was chosen to determine if there was a distinguishable difference in wave height over the bar and at Front Beach with and without the channel cut. Based on engineering judgement, the 1 year wave was chosen to be used in ship pitch, roll, and heave calculations.

Table 9: Recurrence Intervals for Waves (Station 82326)

	Recurrence Interval			
	270° - 0°		0° - 90°	
	Feet	*Period (s)*	*Feet*	*Period (s)*
30 Year	51.8	16	37.5	14
25 Year	36.3	18	29.2	11
10 Year	33.6	16	26.3	11
5 Year	32.4	12	25.0	11
1 Year	31.8	15	24.6	12

4.2 Wave Modeling

Wave modeling for determining the wave height over the bar as well as the effects of the channel cut on Front Beach were performed using the Steady-State Spectral Wave (STWAVE) model. STWAVE is a spectral wave energy propagation model that includes refraction, diffraction, and shoaling, but does not include reflection.

Shoreline and bathymetric conditions were defined by inputting water depths and locations of the land into the STWAVE model at a specific grid spacing. Model depths obtained from NOAA charts showing the bathymetry of Dutch Harbor. Two directional bands were analyzed for producing waves for inputting into the STWAVE Model. Two grids were produced, shown in Figure 24. One grid transmits the wave from the 0° to 90° bin to Dutch Harbor from the 45° direction, while the other transmits the wave from the 270° to 0° bin from the 315° direction. Both grids are made up of 100 meter by 100 meter (328 foot by 328 foot) grid cells.

At the entrance to Dutch Harbor, shown as the yellow Entrance point in Figure 24, each wave height, period, and direction was recorded and then run through a finer grid of 32.8 foot by 32.8 foot cells. Runs were made with the channel cut and without the channel cut (without project condition). Wave heights were recorded for the entrance, bar, and front beach locations in Table 10 and Table 11. Wave heights at the bar were slightly greater with the channel cut, but were indistinguishable from without project condition at Front Beach.

Graphical results of the STWAVE modeling are presented in Figure 25 through Figure 37 below. Distances (x-axis) and wave heights (y-axis) are given in meters. Runs were first made with the 30 year wave with and without the channel cut to determine if there was a perceivable difference in wave height across the bar and at Front Beach. It was determined that waves across the bar marginally increased by less than 0.3 feet when the cut was installed, and no measurable difference (less than 0.1 foot) was observed at front beach. It was determined unnecessary to run the with channel condition for the 1 year wave since its results would be unperceivably different than the without channel condition. Runs were then made with the 1 year wave without the channel cut to determine the wave height at the bar to be used in pitch, roll, and heave calculations.

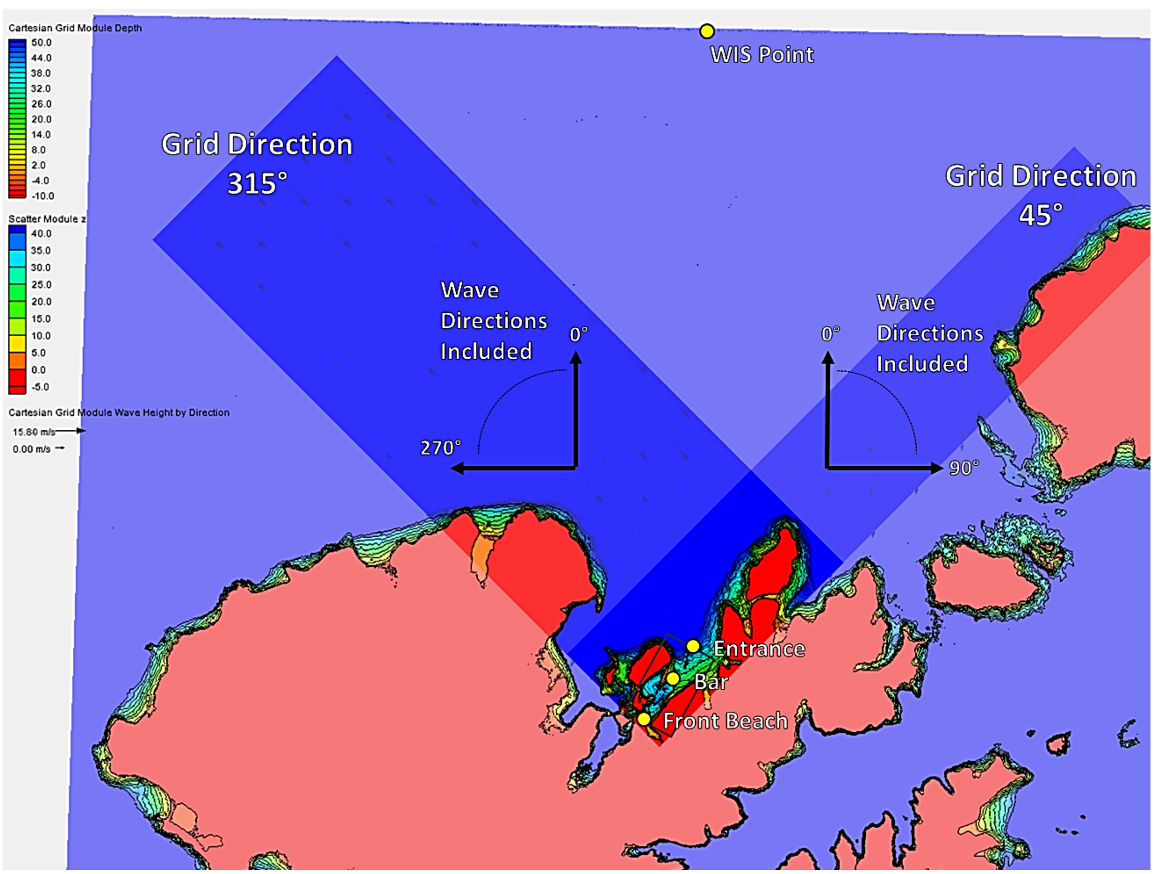


Figure 24: STWAVE Grid Diagram

Table 10: STWAVE Modeling Results for 30 Year Wave – With and Without Channel

	30 Year Wave - No Channel			
	270° - 0°		0° - 90°	
	Feet	*Period (s)*	*Feet*	*Period (s)*
Wave at WIS Point	51.8	16	37.5	14
Wave at Entrance	22.0	13	13.1	14
Wave at Bar	6.8	13	9.2	13
Wave at Front Beach	1.3	12	2.0	12

	30 Year Wave - Channel			
	270° - 0°		0° - 90°	
	Feet	*Period (s)*	*Feet*	*Period (s)*
Wave at WIS Point	51.8	16	37.5	14
Wave at Entrance	22.0	13	13.1	14
Wave at Bar	7.0	13	9.5	13
Wave at Front Beach	1.3	12	2.0	12

Table 11: STWAVE Modeling Results for 1 Year Wave – Without Channel

	1 Year Wave - No Channel			
	270° - 0°		0° - 90°	
	Feet	*Period (s)*	*Feet*	*Period (s)*
Wave at WIS Point	31.9	15	24.9	12
Wave at Entrance	15.1	12	8.5	11
Wave at Bar	4.6	11	5.6	10
Wave at Front Beach	1.0	11	1.4	9

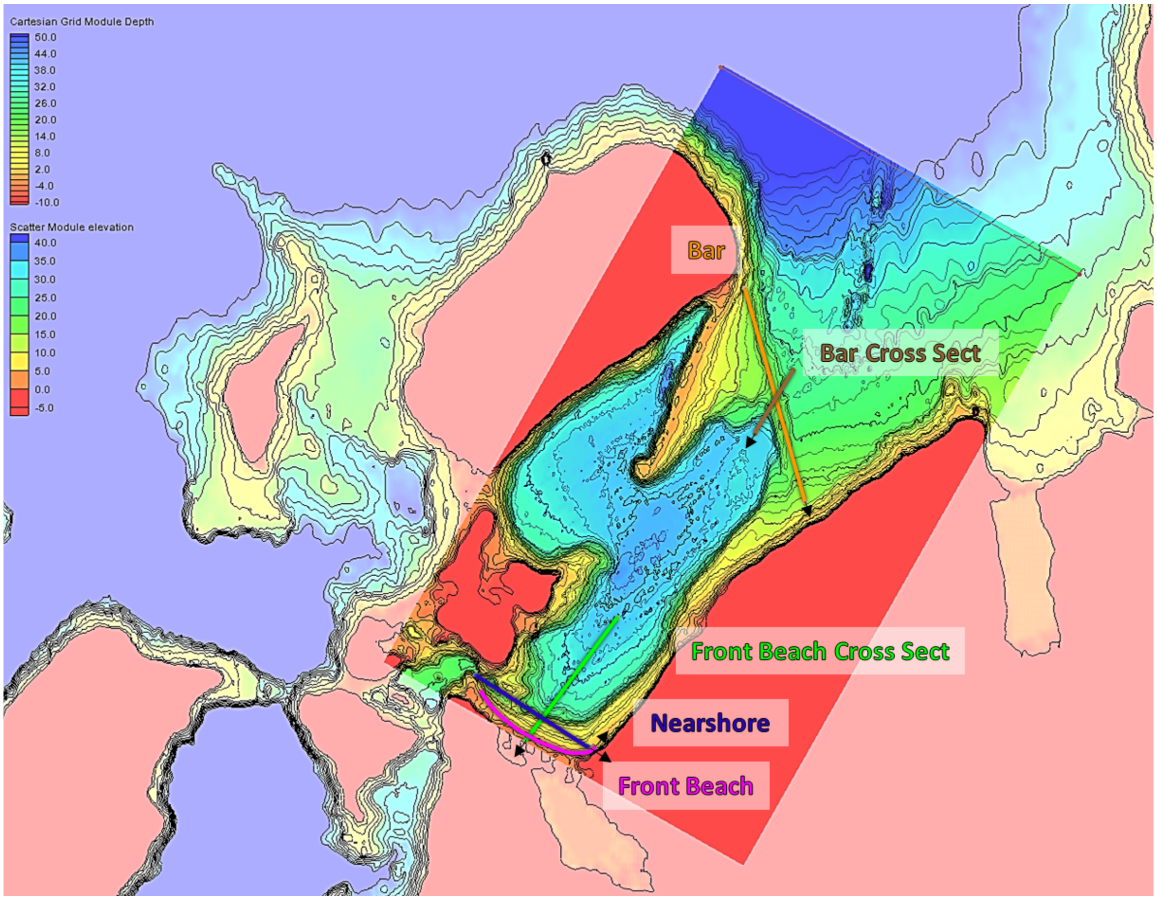


Figure 25: Location and Directions of STWAVE Profile Observations

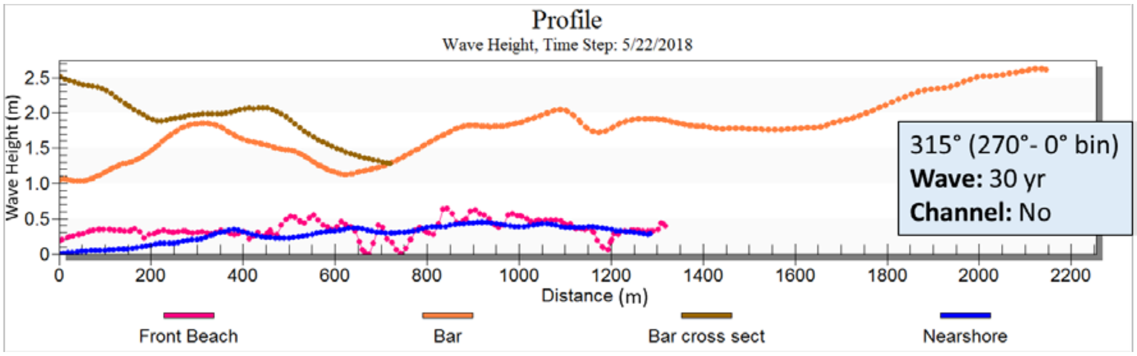


Figure 26: Southeast 30 Year Wave Without Project Condition - Overview

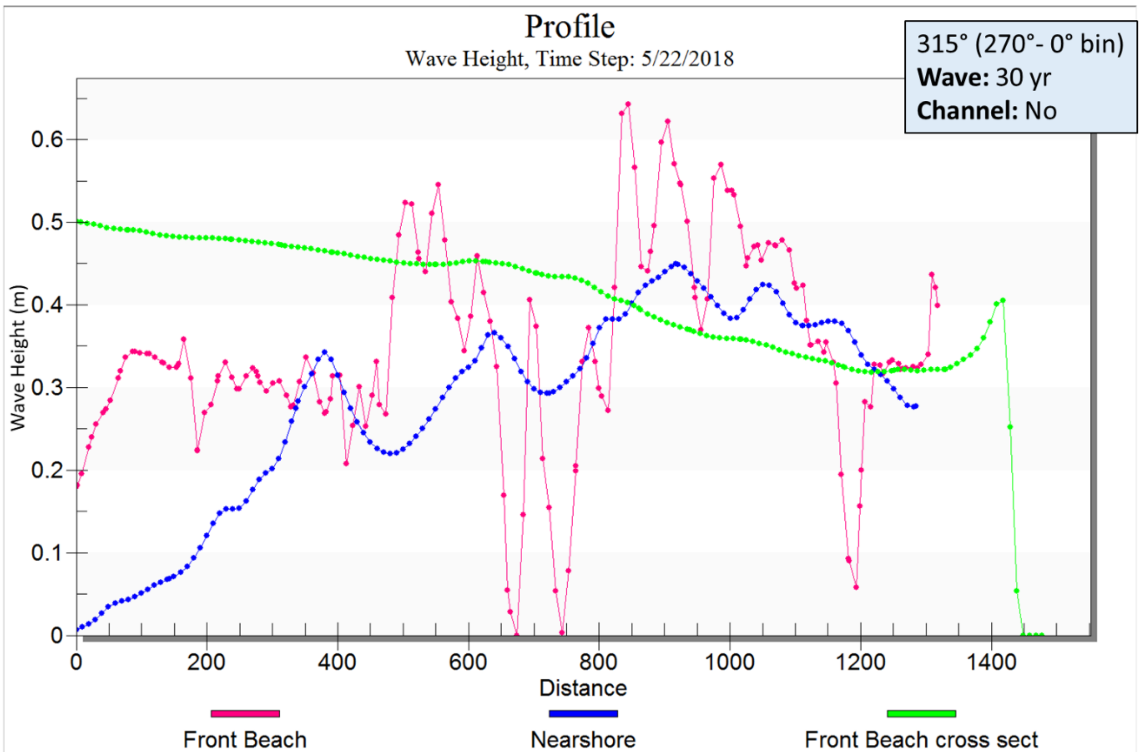


Figure 27: Southeast 30 Year Wave Without Project Condition - Front Beach

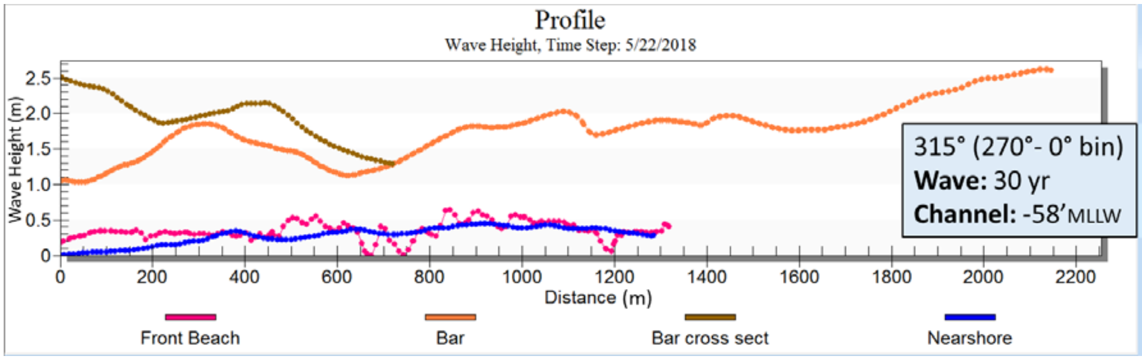


Figure 28: Southeast 30 Year Wave -58'MLLW Channel - Overview

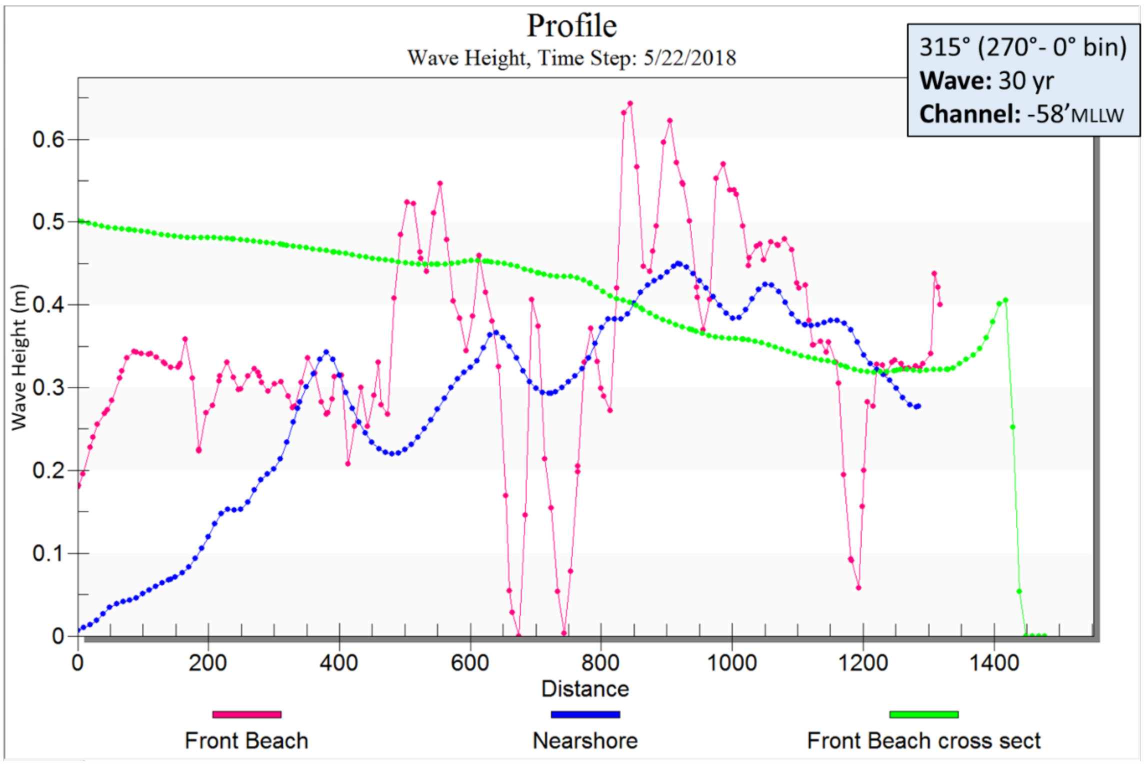


Figure 29: Southeast 30 Year Wave -58'MLLW Channel - Front Beach

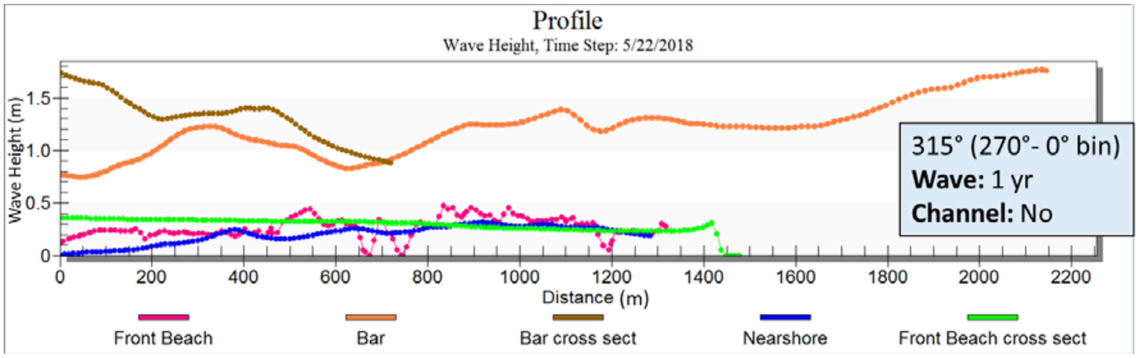


Figure 30: Southeast 1 Year Wave Without Project Condition - Overview

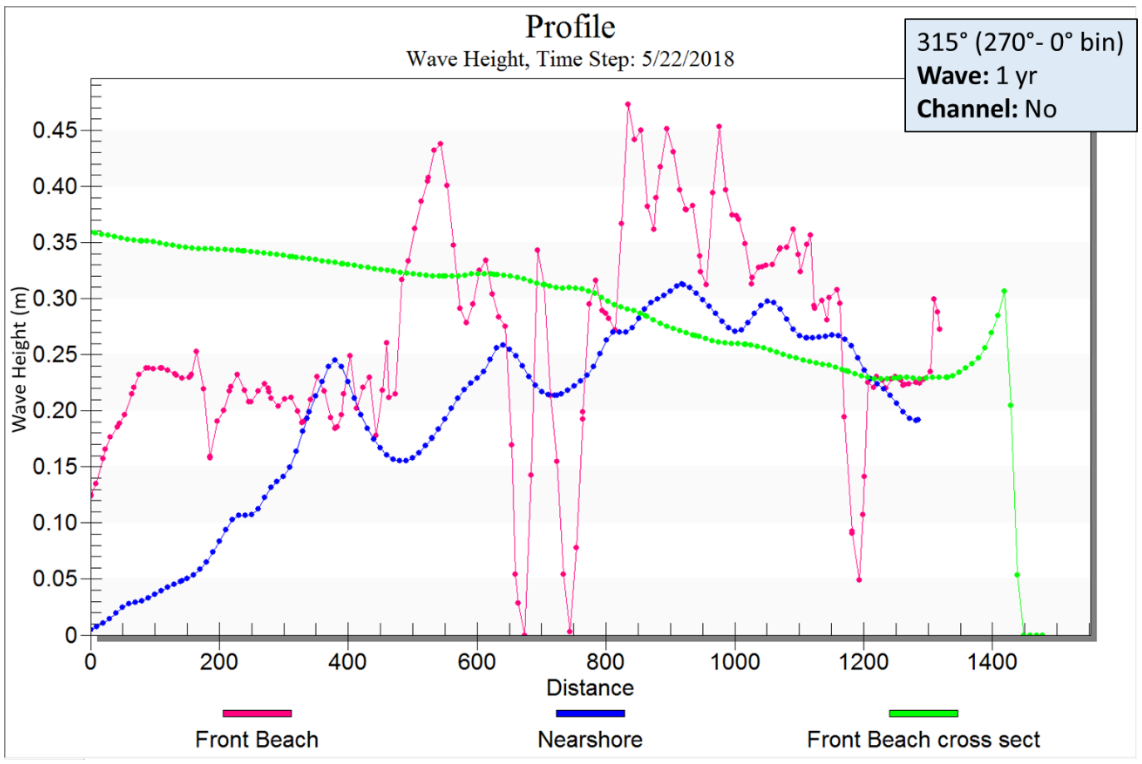


Figure 31: Southeast 1 Year Wave Without Project Condition - Front Beach

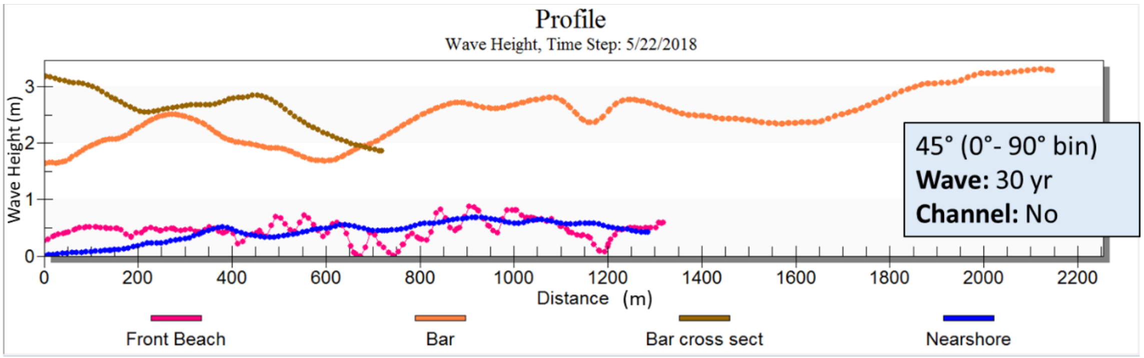


Figure 32: Southwest 30 Year Wave Without Project Condition - Overview

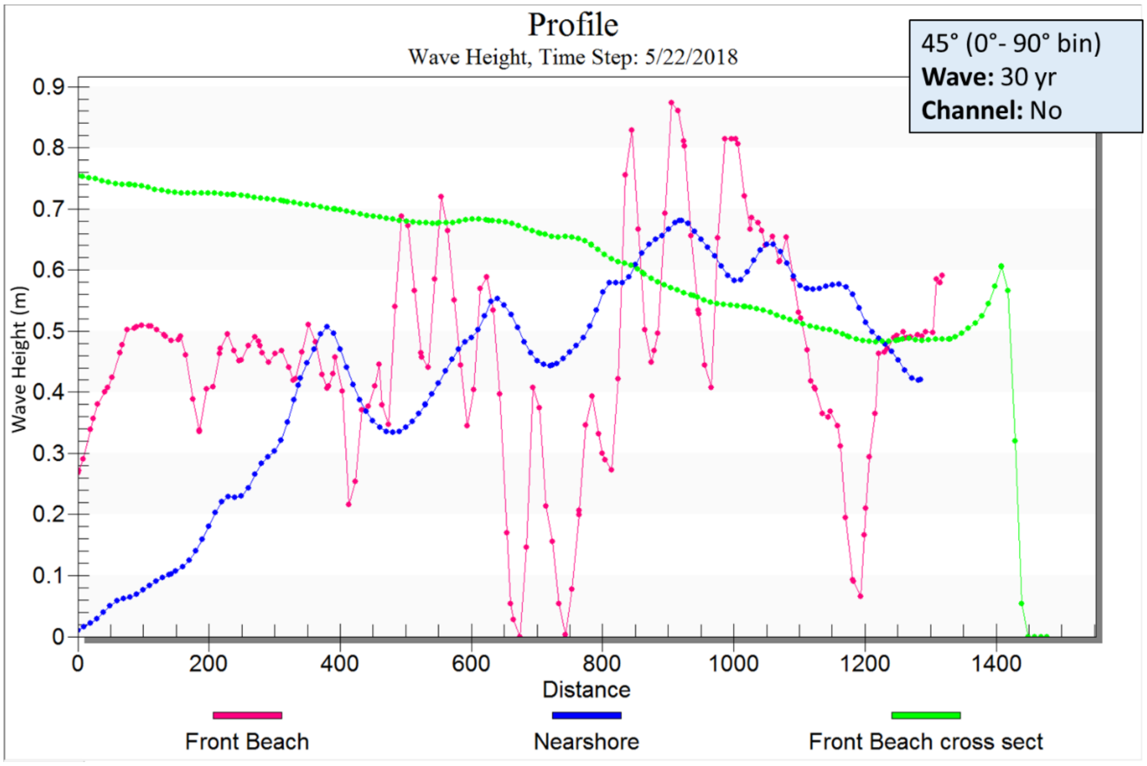


Figure 33: Southwest 30 Year Wave Without Project Conditon - Front Beach

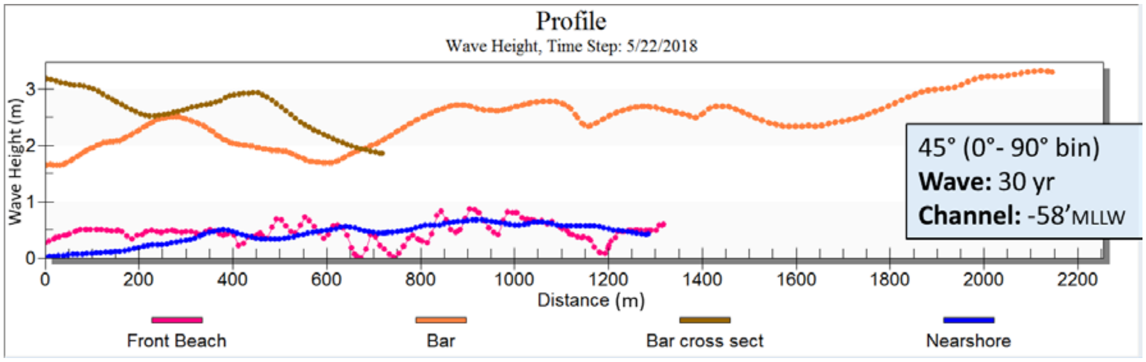


Figure 34: Southwest 30 Year Wave -58'MLLW Channel - Overview

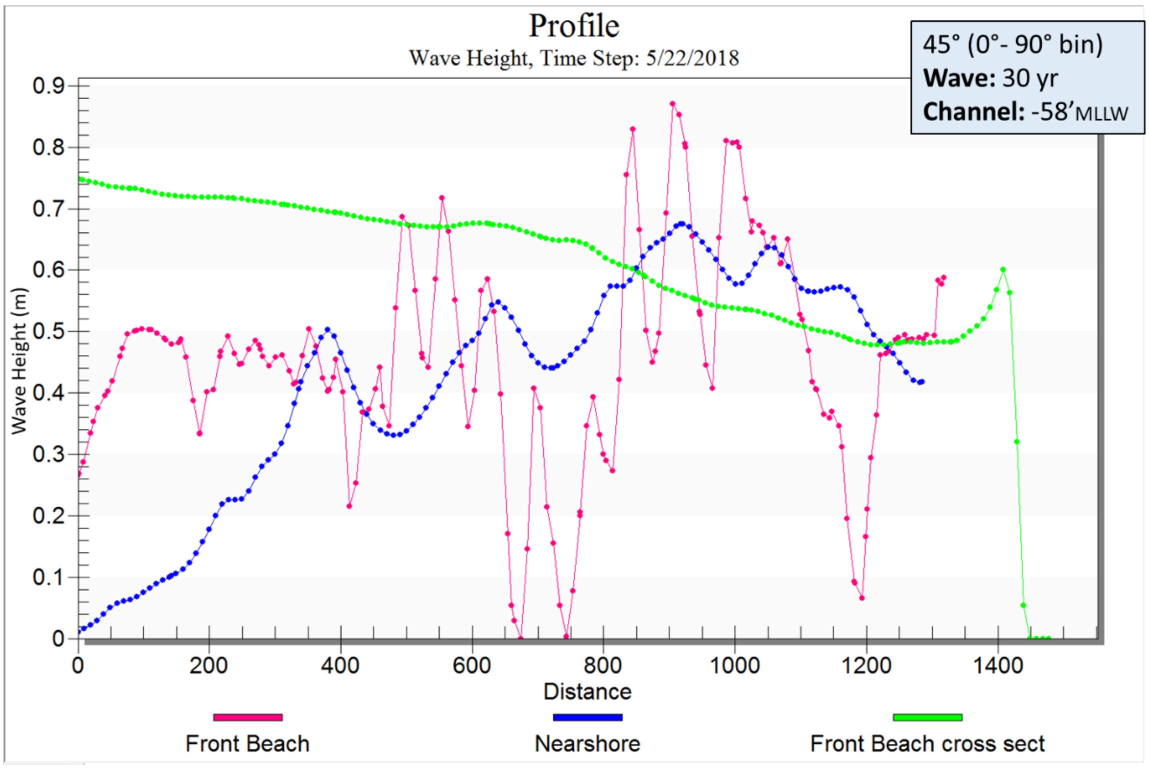


Figure 35: Southwest 30 Year Wave -58'MLLW Channel - Front Beach

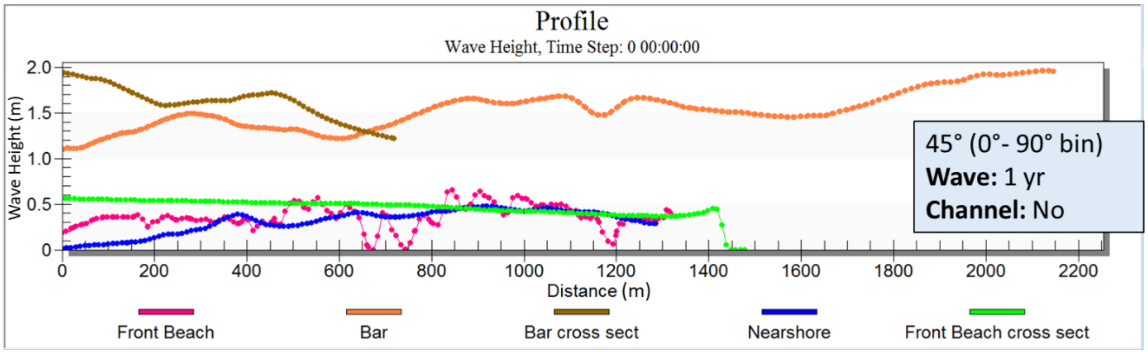


Figure 36: Southwest 1 Year Wave Without Project Condition - Overview

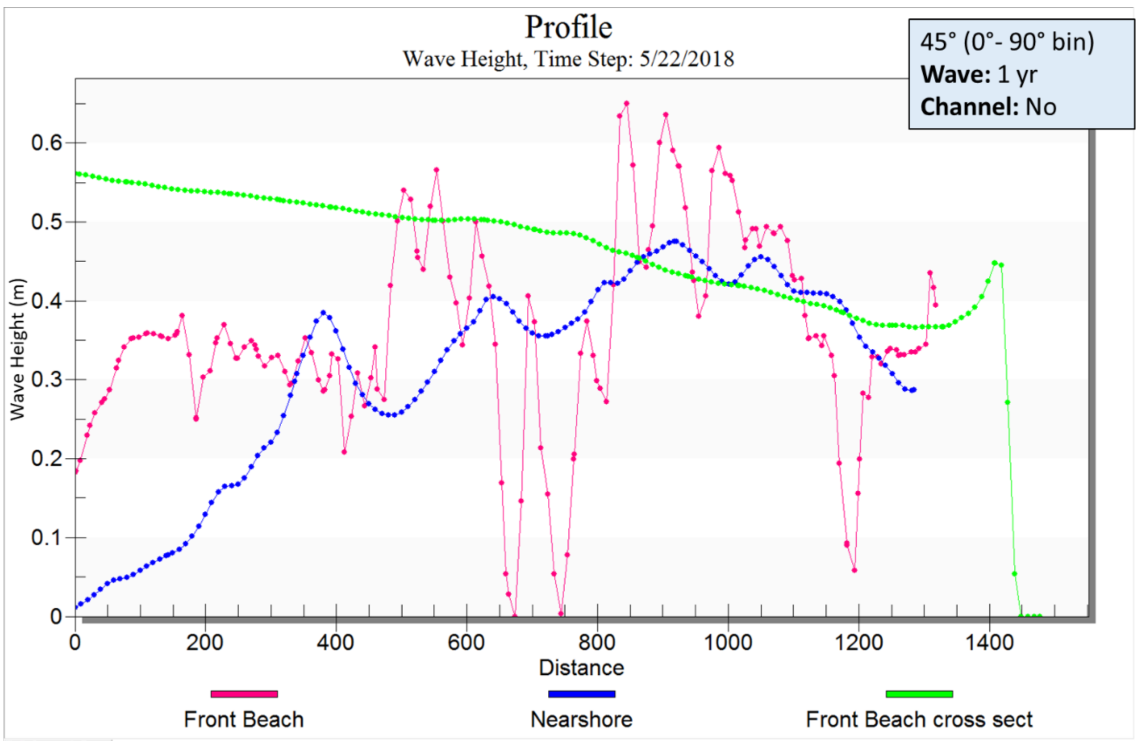


Figure 37: Southwest 1 Year Wave Without Project Condition - Front Beach

4.3 Projected Wave Climate

Wave percent occurrences for WIS station 82326 are given in Table 12. In reference to Table 10, a 24.9 foot wave at 82326 produced a 5.6 foot wave at the bar for directional bin 0° to 90°. The channel was designed to accommodation vessel motion for up to a 5.6 foot wave. According to pilot knowledge, a 6 foot wave at the bar generally shuts down operations. Waves at 82326 that would produce a 6 foot wave occur approximately 0.4% of the time. The wave height that shuts down operations with and without project condition is expected to be 6 feet at the bar.

Project does not affect offshore wave climate. STWAVE results show slightly higher waves at the bar with the channel. While there is no change in wave threshold conditions at the bar, the channel allows for greater loaded draft for vessels transiting the bar.

Table 12: WIS Station 82326 - Wave Percent Occurrence

Wave Height (ft)	Wave Period (seconds)			
	< 5.0	*5.0 - 11.9*	*12.0 <*	*Total*
0.3 - 1.6	1.1%	0.9%	0.0%	2.1%
1.7 - 3.2	3.6%	9.1%	0.5%	13.2%
3.3 - 4.9	2.1%	14.9%	0.8%	17.8%
5.0 - 6.5	0.4%	16.3%	0.7%	17.4%
6.6 - 8.2	0.1%	13.8%	0.2%	14.1%
8.3 - 9.8	0.0%	10.1%	0.1%	10.2%
9.9 - 11.5	0.0%	7.1%	0.1%	7.1%
11.6 - 13.1	0.0%	5.3%	0.0%	5.4%
13.2 - 14.7	0.0%	3.7%	0.1%	3.8%
14.8 - 16.4	0.0%	2.6%	0.0%	2.7%
16.5 - 19.7	0.0%	3.5%	0.1%	3.6%
19.8 - 22.9	0.0%	1.3%	0.3%	1.6%
23.0 - 26.2	0.0%	0.3%	0.4%	0.7%
26.3 - 29.5	0.0%	0.1%	0.2%	0.3%
29.5+	0.0%	0.0%	0.1%	0.1%
	7.3%	89.0%	3.7%	100.0%

5.0 VESSEL OPERATIONS

5.1 Current Operations

In general, winds of 25 knots or greater which occur approximately 3.4% of the time currently shut down operations. Pilots anticipate that the new channel will need new wind parameters to cease operations. After ship simulation, it was estimated that a 35 knot or greater wind which occur 0.2% of the time will be difficult to handle transiting the bar and would require more than three tug boats to safely dock. Pilots will have to evaluate the handleability of the deeper draft vessels, wind, and wave conditions to develop cease operation conditions for the new channel. The windspeed that shuts down operations with project condition is expected to increase by 10 knots or 3% of the time as compared to without project condition.

According to local pilot knowledge, large container vessels must wait to enter or exit Dutch Harbor about twice a month due to waves being approximately 6 feet or larger at the bar. The 6 foot wave condition was not used to evaluate the underkeel clearance requirement for ship motion due to waves, but is included for comparison. Instead, a wave hindcast was performed to determine the 1-year wave offshore Dutch Harbor (see section 4.1 Wave Hindcast), and modeling was performed (see section 4.2 Wave) to determine what this wave height would be at the bar. This value of 5.6 feet was similar to the 6 feet quoted by pilots.

In order to have some quantification on vessels delays, two years of data (7/1/2016 – 7/1/2018) for 32 containerships were plotted using the Automatic Identification System Analysis Portal (AISAP). The AISAP uses automatic identification system (AIS) Coast Guard data to display ship tracks queued over an area of interest for a given amount of time, with a maximum record of 2 years piror. Several ships can be seen circling in Figure 38, most notably the Nicolai Maersk and Maersk Danag. These vessel tracks have been plotted separately in Figure 39. On average, the vessels spent five to ten hours each way traveling inbound and outbound in the area covered by Figure 38 and Figure 39. During the two years of coverage, it appears there were four circling vessels that spent an additional several hours to three days in the area.

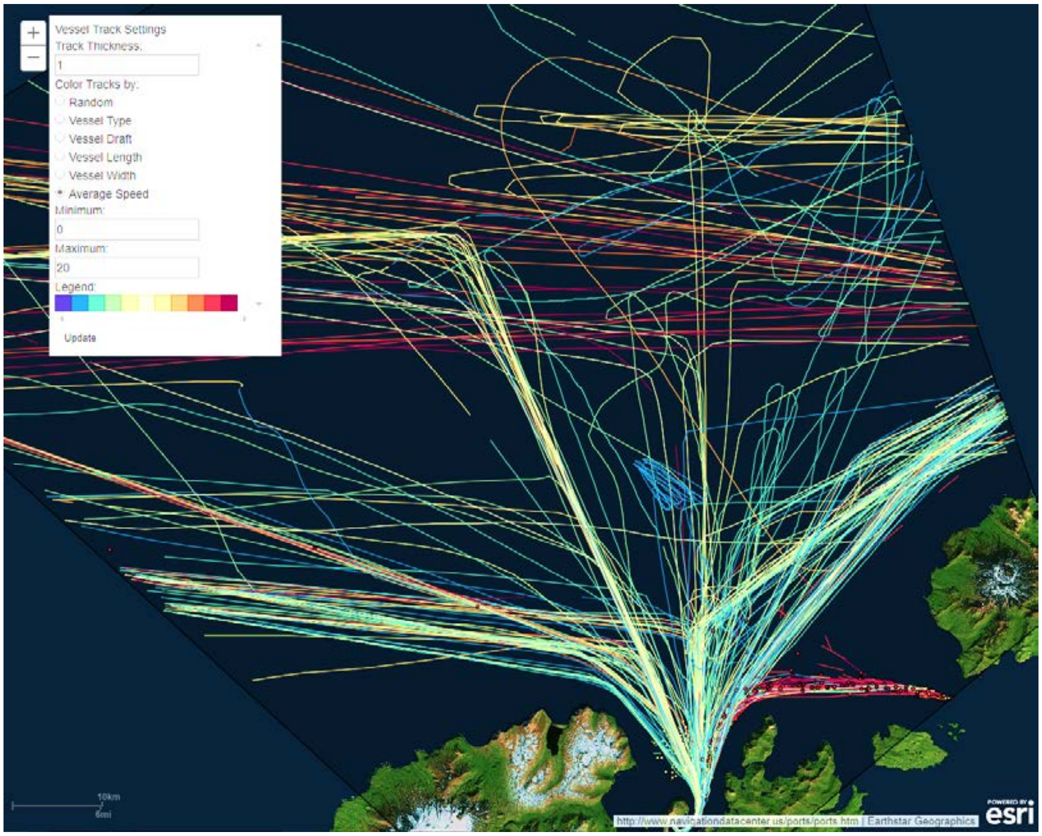


Figure 38: Ship Tracks (7/16 – 7/18) Including Vessels Circling

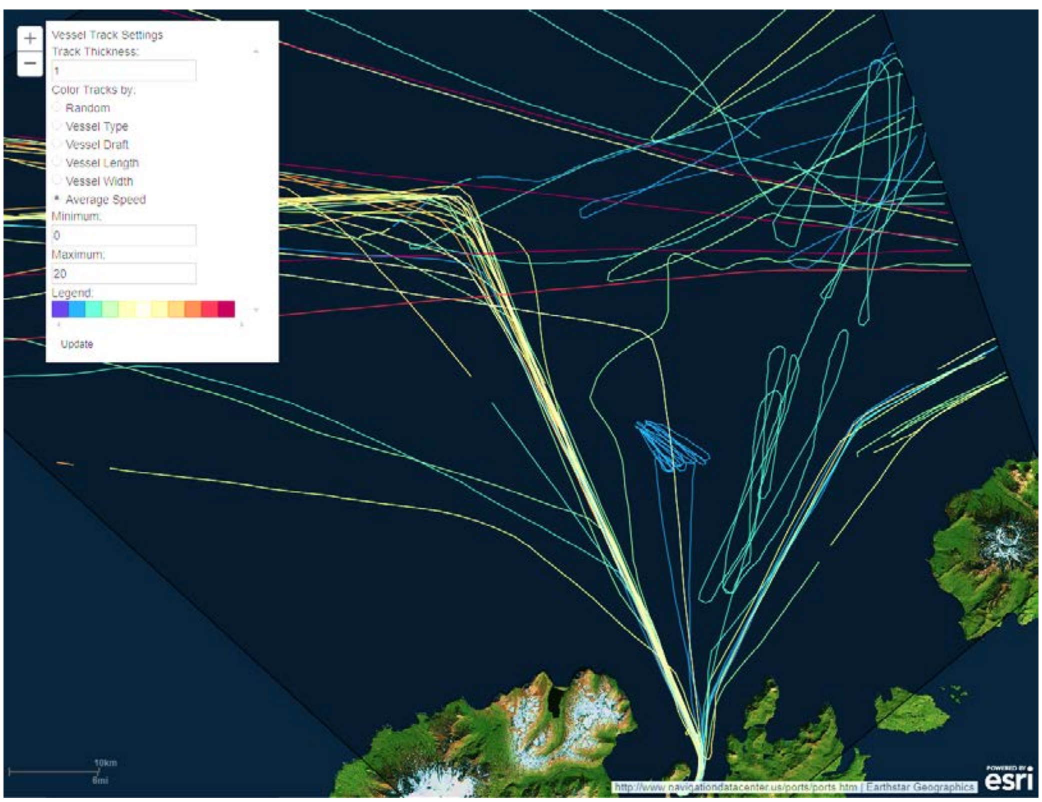


Figure 39: Ship Tracks (7/16 – 7/18) Nicolai Maersk & Maersk Danang Only

Pilots are currently operating at the limits of their capabilities; margins of safety are minimal if incorrect draft information is provided to the pilots or if weather is nearing cease operation conditions. Consequences of touching the bottom or sides of the channel are high. Vessels will circle north of Dutch Harbor until conditions improve or the tide is high, but no records are available from ship captains regarding how often and for how long these delays occur.

5.1.1 Channel Location

The alignment of the design channel was placed to follow the current routes of the light loaded vessel tracks (Figure 40). This location was confirmed during ship simulation as Pilots would not have to alter their current practice. Important landmarks, distances, and bearings that the pilots rely on to bring ships in safely will remain the same.

Altering the channel location to minimize dredging quantities or avoid munitions and explosives of concern (MEC) was considered but not recommended. Dredging quantities are relatively small (less than 200,000 cubic yards), and potential MEC in the area have been identified but their identities remain unknown. Further investigation is necessary to determine if any MEC would need to be removed prior to dredging. Conditions at Dutch Harbor, including visibility, can change quickly and navigation instruments and handling vary from vessel to vessel. From a safety perspective, it is not recommended to alter the approach across the bar.

6.0 CHANNEL DESIGN

The channel is designed to allow currently calling light loaded Post-Panamax vessels to travel over the bar with drafts loaded up to 44 feet based on the economic appendix (see economic appendix). The ultimate selection of a channel alternative requires the comparison of channel construction and maintenance costs to the transportation benefits for each different draft loading case. Applicable design threshold considerations include wind and waves; current does not have a considerable effect according to local pilots. Design water level, maintenance quantities, squat, wave allowance, survey and dredging tolerance, and resilience are all factors that have previously been discussed. Wind and wave thresholds are anticipated to be slightly higher with the dredged channel.

6.1 Design Vessel Criteria

Design vessels are determined by examining the size of ships currently calling at the Dutch Harbor and those that can be reasonably expected to use the terminal in the future. The design vessel used is a joint decision made by engineering and economics. Constraining depths of the bar vary from a maximum depth of -47'MLLW to a minimum depth of -42'MLLW. The channel location includes the high spot of the bar; after dredging the surrounding constraining depths of bar outside the proposed channel limits will vary from -47' to -44'MLLW.

The design vessel used for design considerations in engineering the channel is a 68,000 Dead Weight Ton (DWT) Post-Panamax bulk carrier. APL Holland is an example of such a design vessel that calls on Dutch Harbor, dimensions given in Table 13. Vessels of this type currently light load from point of origin in order to clear the bar and enter Dutch Harbor.

Table 13: Design Vessel for Deepening and Widening

Design Vessel	
Parameter	*Feet*
Length Overall	909.6
Beam	131.4
Design Draft	45.9
Vessel Draft	44.0

Current practice is for vessels to light load from point of origin to a maximum draft of 38 feet to clear the bar. Pilots board the vessel approximately two miles northeast of the bar, maneuver the vessel over the bar, and bring the vessel to berth. Local knowledge states that vessels require a minimum underkeel clearance of four to seven feet over the bar, depending on wave conditions. The APL Holland design vessel draft of 44 feet is used for channel design.

Seven light loaded vessels listed in Table 14 below were tracked using AIS Coast Guard Data at 5 minute intervals for 1 year (1/1/2016 – 1/1/2017) as they called at Dutch Harbor. The ship tracks over the bar are displayed in Figure 40, with the location of the channel north and south extents shown in red. The directional bearings for the channel extents are provided in the figure.

Table 14: Light Loaded Vessel Dimensions

Lightly Loaded Vessels					
Name	*MMSI*	*Design Draft (ft)*	*Loaded Draft (ft)*	*Length Overall (ft)*	*Beam (ft)*
APL Belgium	367578740	45.9	38.1	909.6	131.4
APL China	369247000	45.9	39.7	906.5	131.2
APL Korea	368685000	45.9	38.7	906.5	131.2
APL Philippines	368684000	45.9	37.4	906.5	131.2
APL Singapore	368680000	45.9	37.4	906.5	131.2
APL Thailand	368686000	45.9	37.4	906.5	131.2
Maersk DaNang	636091595	44.3	38.1	964.7	105.9

Figure 40: AIS Ship Tracks and Channel Extents

6.2 Configuration and Use

Channel design prior to ship simulation was a straight channel with a width of 600 feet following the alignment of the current route traveled over the bar by light loaded vessels. During ship simulation, it was found that instead of the approximately 1200 feet of width available over the bar, the channel restricted the pilots to a width of 600 feet. Current practice is for pilots to take vessels out of gear over the bar to slow to speeds of 4.5 to 6.5 knots. It was found that in order to maintain control over the vessel through the channel, speeds of 8 to 12 knots were necessary on inbound transits with the new channel. This resulted in an increase in ship squat from 1 foot at 4.5 knots to 3.5 feet at 8 knots. It is anticipated that tug assist will be required to slow down vessels and allow them to berth safely.

6.2.1 Channel Width

USACE guidance (EM 1110-2-1613) sets the channel at a width of 560 feet based on one way traffic, variable cross section, average aids to navigation, and currents between 0.5 and 1.5 knots. The channel cross section is considered a trench due to Iliuliuk Bay being a wide, unrestricted waterway without channel banks. These design criteria produce beam multiplier of 4.5 (see Table 15). A beam of 131 feet and a multiplier of 4.5 produces a channel width of 560 feet.

Table 15: USACE One-Way Ship Traffic Channel Width Design Criteria

Design Ship Beam Multipliers for Maximum Current			
Channel Cross Section	*0.0 to 0.5 knots*	*0.5 to 1.5 knots*	*1.5 to 3.0 knots*
	Constant Cross Section, Best Aids to Navigation		
Shallow	3.0	4.0	5.0
Trench	2.75	3.75	4.0
	Variable Cross Section, Average Aids to Navigation		
Shallow	3.5	4.5	5.5
Trench	3.5	4.0	5.0

The channel width was checked using Permanent International Association of Navigation Congresses (PIANC) guidance (PIANC, 2014). The PIANC width detailed in Table 16 shows the need for an approximate width of 660 feet. The final channel width was set at 600 feet.

Table 16: PIANC Width Factors

Condition	Site Description	Width Factor
Vessel Speed (knots)	Moderate (8-12)	0B
Prevailing Cross Wind (knots)	Strong (33-48)	1.1B
Prevailing Cross Current (knots)	Negligible (<0.2)	0B
Prevailing Longitudinal Current (knots)	Low (<1.5)	0B
Beam and Stern Quartering Wave Height (m)	$1 < H_s < 3$	0.5B
Aids to Navigation	Good	0.2B
Bottom Surface	Rough and hard	0.2B
Depth of Waterway	$< 1.25T$	0.2B
Basic Ship Maneuverine Lane	Poor	1.8B
Additional Width for Bank Clearance (x2)	Steep and hard embankments	0.5B x 2
Total Width Factor	5.0B	

The channel was initially set at 600 foot width with a bearing of 220° based on USACE design guidance and following light loaded AISAP ship tracks. Ship simulation and pilot input modified channel width and alignment as described in 6.5.1 Ship Simulation.

6.2.2 Channel Depth

Vessels moving in navigation channels must maintain clearance between their hulls and channel bottom. Navigational design parameters were analyzed including squat, safety clearance, vessel motion due to waves, and water density effects. Storm surge was not included as it is not commonly encountered at Dutch Harbor and results in a small incremental increase in depth that would benefit travel over the bar. Minimum gross underkeel clearance was calculated from the sum of the depth requirement from each design parameter.

The final channel depth was determined by comparing economic benefits to costs for depths of 48'MLLW to 66'MLLW at two foot increments. All vessels currently calling on Dutch Harbor were represented. Vessels had a maximum design draft of 45.9 feet; however, loading was limited to 44.0 feet by dock depths of 45 feet at both the APL and UMC City Dock, given a 1 foot clearance required at the dock. Delays related to channel access were also considered, and benefits were maximized when a vessel is loaded to 44.0 feet. See the economics appendix for more information.

Considerations for channel design follow the standards of Engineering Manual (EM) 1110-2-1613, "Hydraulic Design of Deep-Draft Navigation Projects," and were checked against globally used PIANC guidance (USACE, 2006). The first consideration is to define the fleet of vessels likely to use the prospective channel. Vessels now serving Dutch Harbor include Panamax and Post-Panamax classes. Dimensions of vessels representative of the fleet to call are presented in Table 14. The dimensions chosen for the design vessel (Table 13) are a length over all (LOA) of 909.6 feet, a beam (width) of 131.4 feet, and a static design draft of 44.0 feet.

Figure 41 illustrates the increments of channel depth design. The optimum elevation of an excavated channel bottom is determined by economic criteria.

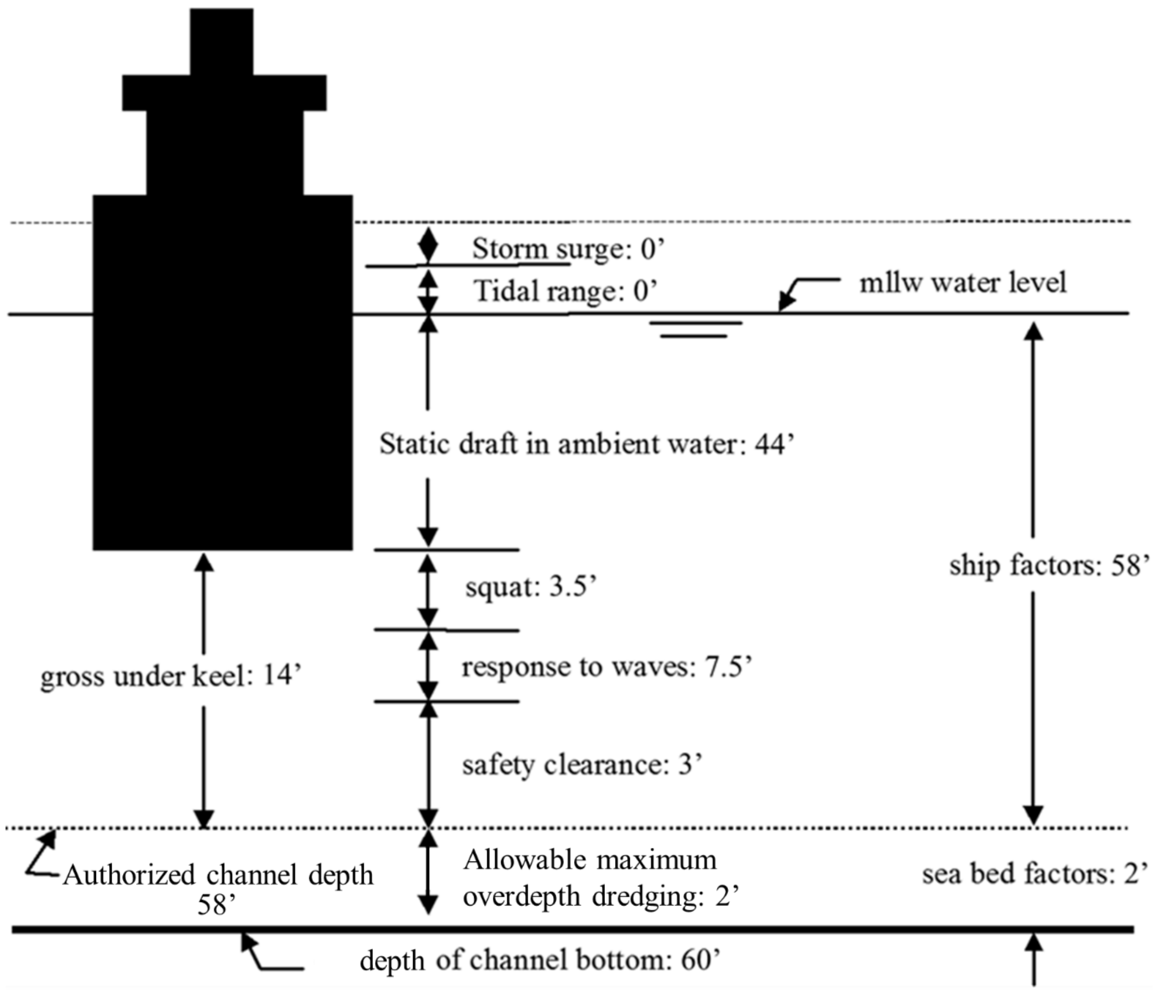


Figure 41: Channel Design Parameters

6.2.3 Ships Factors

Draft.
APL and UMC City Dock require 1 foot of clearance at a depth of 45 feet. Therefore, a maximum draft of 44 feet is used for the design vessel. For more information, see the economic appendix.

Squat. Vessel draft increases when vessel sailing depth adjusts to the energy balance between hydrostatic and kinetic energy due to the fluid velocity around and under the vessel hull. It is pulled down into the water column by the hydrodynamic pressure gradient. This phenomenon and related vertical hydrodynamic effects are defined here as "squat," which varies with vessel speed, water depth beneath the keel, and the ratio of the vessel cross-section area to the cross-section area of the channel.

Iliuliuk Bay is a wide, unrestricted waterway without channel banks. Vessels should not notice bank forces or reaction to the proximity of the channel edge due the surrounding high points of the bar being at depths of -44' to -47' MLLW after dredging, and vessel design draft is 44 feet. Therefore, the unrestricted Norrbin equation is used to determine squat.

Pilots report that large vessels typically travel over the bar at 4.5 to 6.5 knots. Pilots will take vessels out of gear over the bar to slow down since steering is not an issue. During ship simulation, it was found that in order to maintain control over the vessel through the channel, speeds of 8 to 12 knots were needed. See Table 17 for vessel speed verses squat comparisons.

Computations for prediction of squat assume a typical container vessel block coefficient of 0.7, vessel beam of 131.4 feet, vessel draft of 44 feet, vessel length of 909.6 feet, water depth of 58 feet, and vessel speed of 8 knots.

USACE guidance (EM 1110-2-1613) using the Norrbin equation

$$z_{max} = \frac{C_B B T V^2}{4.573 L h}$$

predicts a total vertical ship motion resulting from sinkage and running trim of 3.5 feet (1.1m), where z_{max} is ship squat, C_B is block coefficient, B is max beam, T is fully loaded draft, V is ship velocity, L is length of vessel, and h is channel depth. Various vessel speeds were tested in the Norrbin equation with their results in Table 17 below.

Table 17: Vessel Squat for Speeds of 4 – 12 knots

Vessel Speed Knots	Vessel Squat Feet
4.5	1.1
5	1.4
6	2.0
7	2.7
8	3.5
9	4.4
10	5.5
11	6.6
12	7.9

The USACE guidance value was checked against PIANC guidance Barrass (B3) equation

$$S_{Max,B3} = \frac{C_B V_k^2}{100/K}$$

where $S_{Max,B3}$ is ship squat, C_B is the block coefficient, V_k is ship speed, and $K = 5.74 S^{0.76}$, predicting a squat value of 3.0 foot (0.9m). A squat allowance of 3.5 feet for the channel is estimated for the design ship.

Response to Waves. USACE guidance (EM 1110-2-1613) estimates the effect of pitch, roll, and heave using the Noble equation

$$P_{avg} = 0.57 + 0.99 \left(\frac{H_S T_\emptyset}{T_e} \right)$$

where P_{avg} is average ship motion in waves, H_S is significant wave height, $T_\emptyset$ is natural ship pitch period, and T_e is encounter period. Using a 5.6 foot design wave, the effects of pitch, roll, and heave are calculated at 7.3 feet.

A second method of evaluating wave-induced motions is the trigonometric method in PIANC guidance. It is a simplistic and conservative method that assumes that all wave components would occur in phase for a value twice the significant wave height. Using a 5.6 foot design wave, the effects of pitch, roll, and heave are 11.2 feet. For the purpose of this study, the PIANC guidance was deemed too conservative. A ship response to waves of 7.5 feet corresponding to USACE guidance was chosen. Table 18 shows ship response to the one-year wave as one of the parameters used for the gross underkeel clearance calculation.

Safety Clearance. USACE guidance (EM 1110-2-1613) suggests a minimum net underkeel clearance of 2 feet; however, for hard bottom conditions such as rock, consolidated sand or clay, 3 feet of net underkeel clearance is recommended. The channel bottom has been described in the geophysical survey report as dense, consolidated, glacial moraine deposit overlying bedrock (Consultants, 2017). PIANC guidance suggests a net underkeel clearance of 3.3 feet. Based on the description of the material and the geotechnical sampling data, a safety factor of 3 feet was used for this analysis.

Gross Underkeel Clearance. The subtotal of squat, response to waves, and safety clearance for the channel provides a gross underkeel clearance of 14.0 feet. This is for a 0.0’ MLLW datum channel that is accessible 92.2% of the time. The bar would be deepened by 16 feet to a depth of -58’ MLLW.

Table 18: Design Parameters for Gross Underkeel Clearance Calculation

Design Parameter	Depth Allowance Feet MLLW
Storm Surge	0
Tidal Range	0
Vessel Draft	44
Squat	3.5
Response to Waves	7.5
Safety Clearance	3
Design Channel Depth	**58**
Allowable Overdepth Dredging	2
Elevation of Channel Bottom	**60**

Dredging equipment and procedures cannot provide a smoothly excavated bottom at a precisely defined elevation. One foot of required overdepth and one foot of allowable overdepth dredging was added to the design depth of excavation to guarantee mariners a least-depth equivalent to the sum of ship factors. Profiles showing a cross section of the channel centerline, north and south extents (300’ offsets from the channel centerline), and along the axis of the bar are shown in Figure 42 and Figure 43.

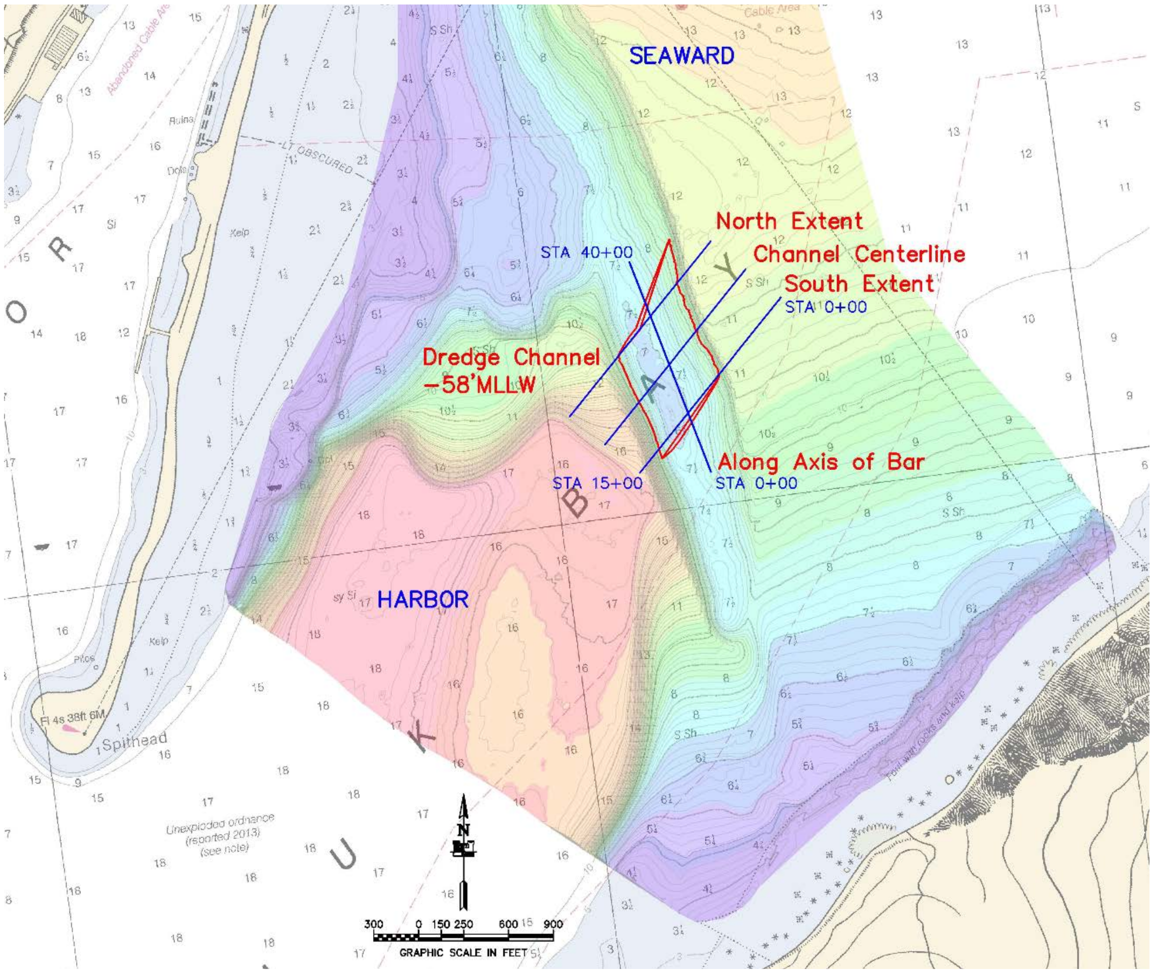
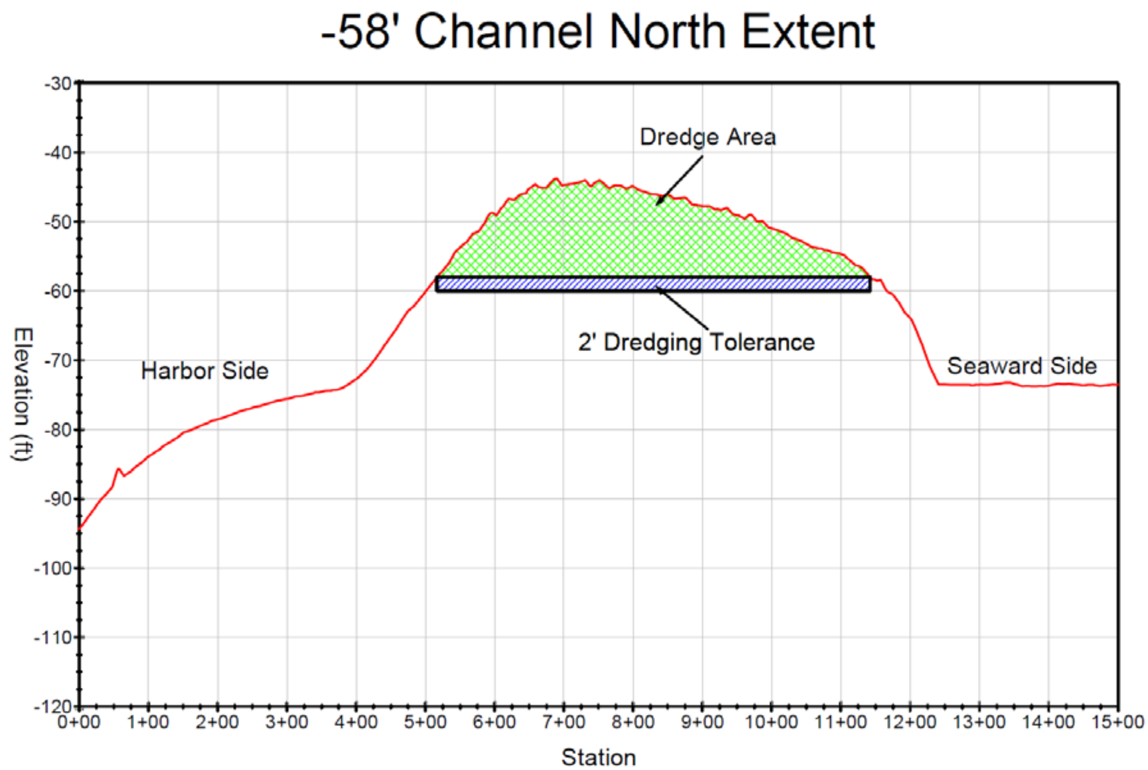
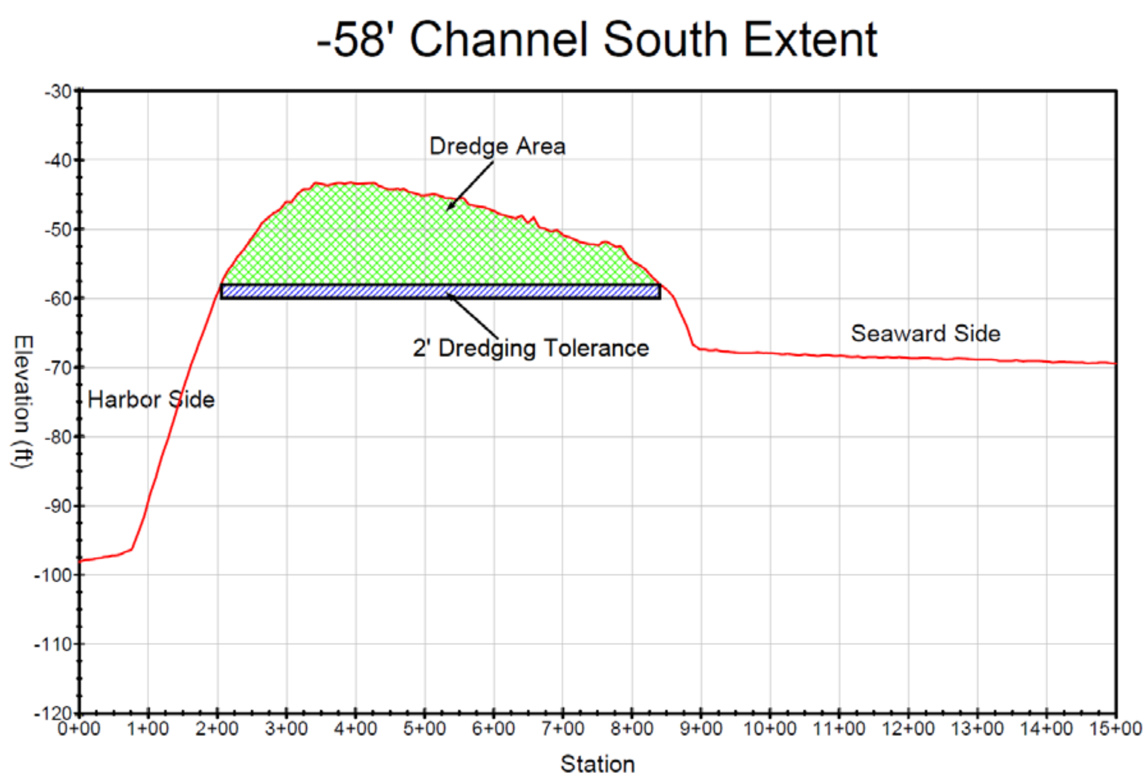


Figure 42: Plan View of Dredge Channel Profiles


-58' Channel North Extent
Dredge Area
2' Dredging Tolerance
Harbor Side
Seaward Side
Elevation (ft)
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
9+00
10+00
11+00
12+00
13+00
14+00
15+00
Station


-58' Channel South Extent
Dredge Area
2' Dredging Tolerance
Harbor Side
Seaward Side
Elevation (ft)
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
0+00
1+00
2+00
3+00
4+00
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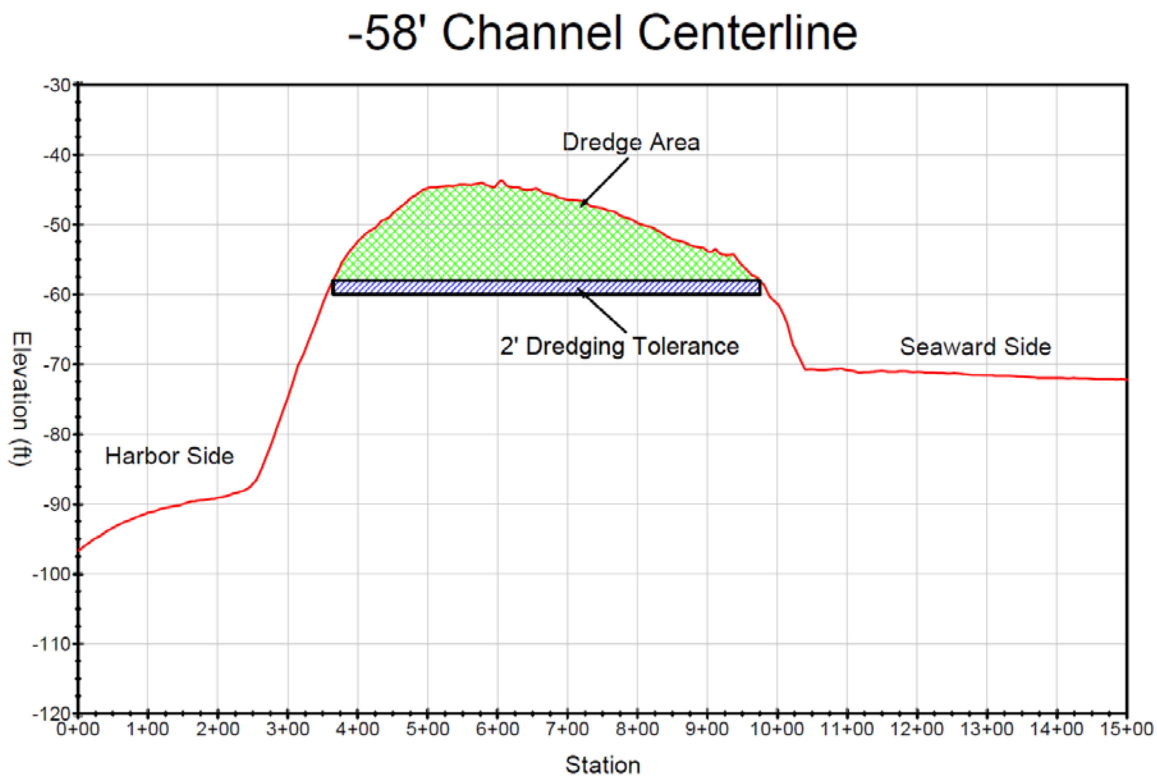


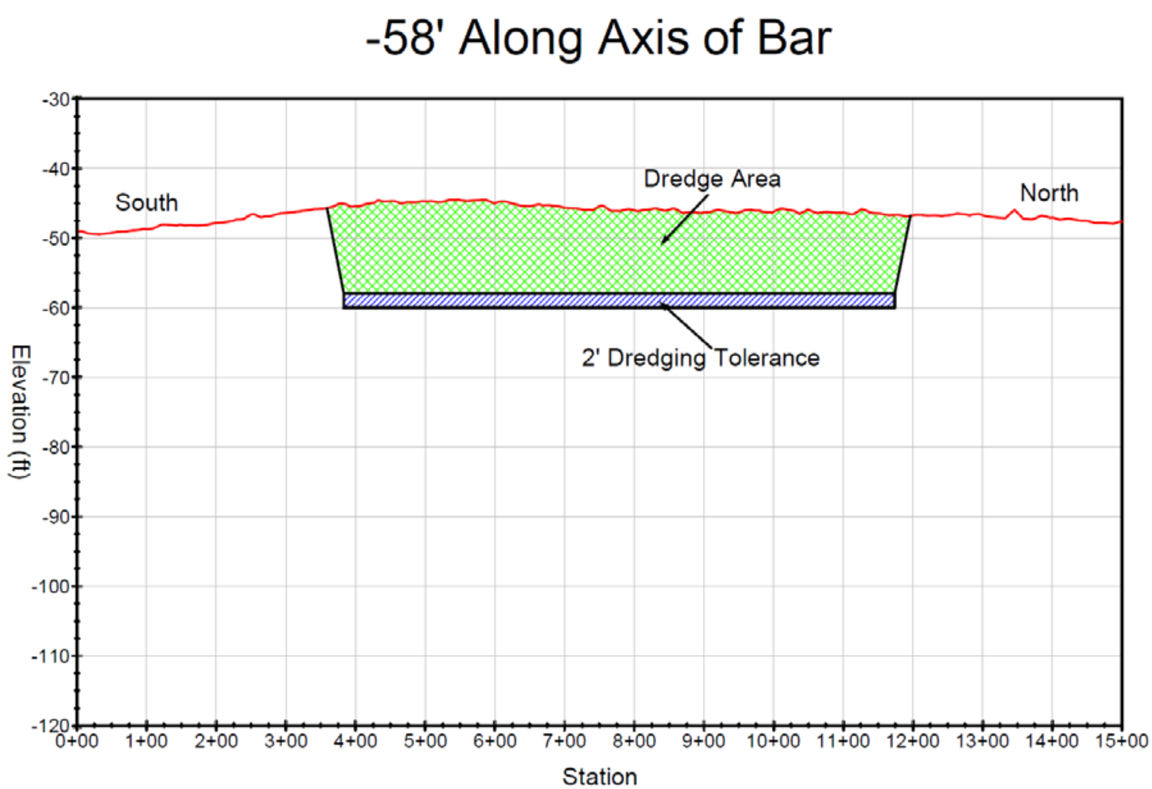


Figure 43: Profile Views of Dredge Channel

6.3 Sideslopes and Bank Stability

The channel would be dredged with a side slope of 1 vertical to 2 horizontal. The material to be dredged has been characterized as a dense, consolidated, glacial drift deposit overlying bedrock. It is anticipated that this material will have a high in-situ strength, requiring blasting prior to removal. It is anticipated that some of the side slope material at the north and south cuts will slough into the channel. In order to reduce risk and limit loss of function of the project, one foot depth, or 16,000 cubic yards of maintenance dredging will be performed at year 25.

6.3.1 Resiliency

ECB-2018-2 describes resilience principles to be implanted in the engineering and construction community of practice (USACE, Implementation of Resilience Principles in the Engineering & Construction Community of Practice, 2018). Wind, wave, and currents in and around Dutch Harbor are not anticipated to change in the 50 year project life. The anticipated changing condition at the site is sea level drop due to isostatic rebound in the area.

6.4 Initial Dredging Quantity

Initial dredging quantities will vary with channel depth. Table 19 displays dredge quantities associated with each scenario. The quantities presented include grading a 2:1 sideslope as well as a two-foot dredging tolerance due to the inaccuracies of the anticipated method of dredging by blasting. For the design depth of -58’ MLLW, a total of 182,000 cubic yards of material would be dredged. A comparison of the surface areas of all dredge depth scenarios is shown in Figure 44.

Table 19: Initial Dredging Quantities

Dredge Depth *Feet*	Dredge Surface Area *Square Feet*	Dredge Quantity *Cubic Yards*
-48	211,000	36,000
-50	267,000	61,000
-52	311,000	88,000
-54	363,000	119,000
-56	408,000	154,000
-58	437,000	182,000
-60	457,000	227,000
-62	474,000	266,000
-64	488,000	306,000
-66	501,000	339,000

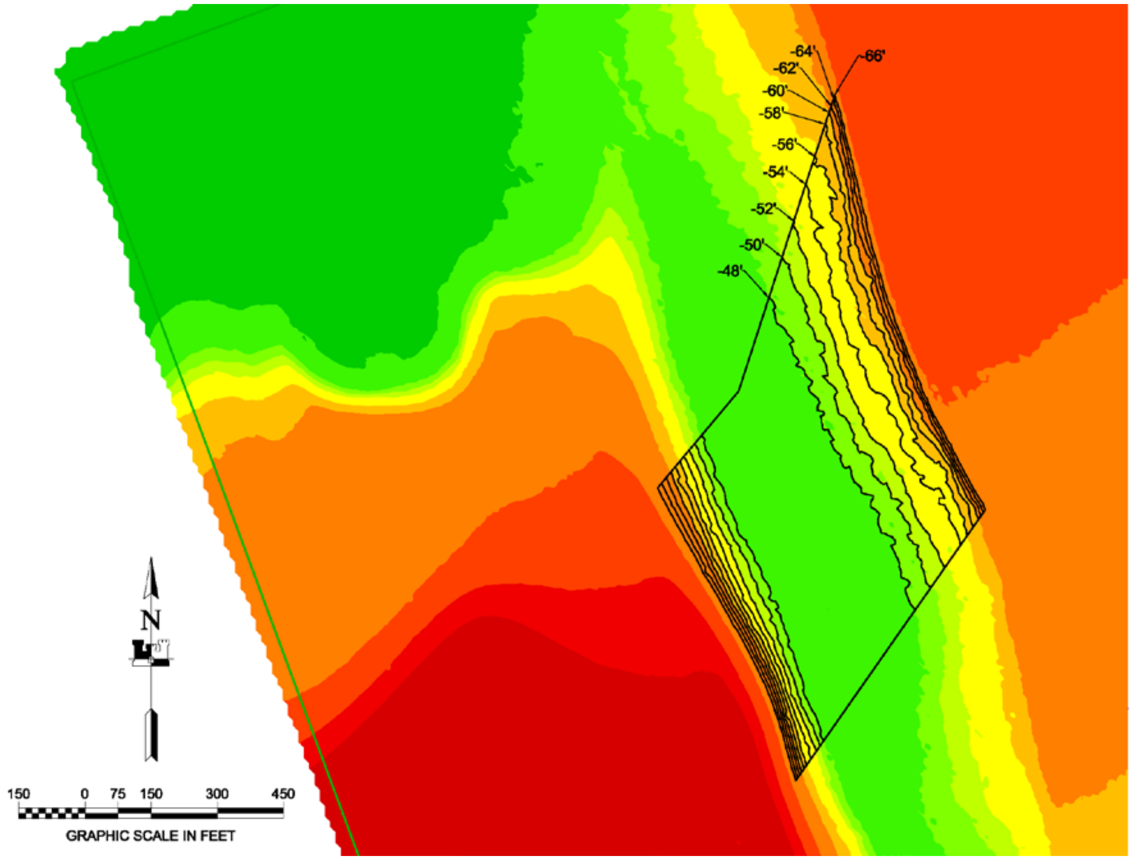


Figure 44: Comparison of Dredging Areas for Depth Scenarios

6.5 CHANNEL NAVIGATION

6.5.1 Ship Simulation

Ship Simulation is required to be performed for all deep draft hydraulic design studies per ER 1110-2-1403 guidance unless omission is approved by HQUSACE. A real time ship simulator, where events on the simulator require the same amount of time as they do in real life, was used to evaluate the channel. A reconnaissance trip was performed October 12 and 13, 2017 to Dutch Harbor to sail across the bar and collect imagery to be used in the simulator. Ship simulation was performed at ERDC from February 26 to March 2, 2018.

The Kongsberg simulator uses a three screen visual display that provides 140 degree field of view. The viewing angle is mariner controlled and can be rotated 360 degrees. Changing the view angle accomplishes the same effect as turning one's head in real life. The Ship/Tow simulator has two radar displays. One display has three variable scales, which are usually set to 1 ½, ¾, and ½ mile. The other radar display is ¼ mile scale and is used to display tugs and thrusters as vectors either pushing or pulling the ship. The hydrodynamic model used in the marine simulator calculates the ship response to the variety of forces being exerted on the vessel. The model uses an iterative process that modifies flows in response to the changed topography caused by the channel incision and passage of a vessel. Wind effects are incorporated by applying either a steady state wind field or wind with gusts. Wind gusts can exceed the steady state condition during short bursts, which applies erratic forces on vessels that may not be accounted for in the model under steady wind forcing. Forces causing ship motion are both environmental and mariner controlled. Environmental forces include: current, bank effects, wind, and waves. Mariner controlled forces include: rudder angle, propeller revolution, tugs, and bow and stern thrusters.

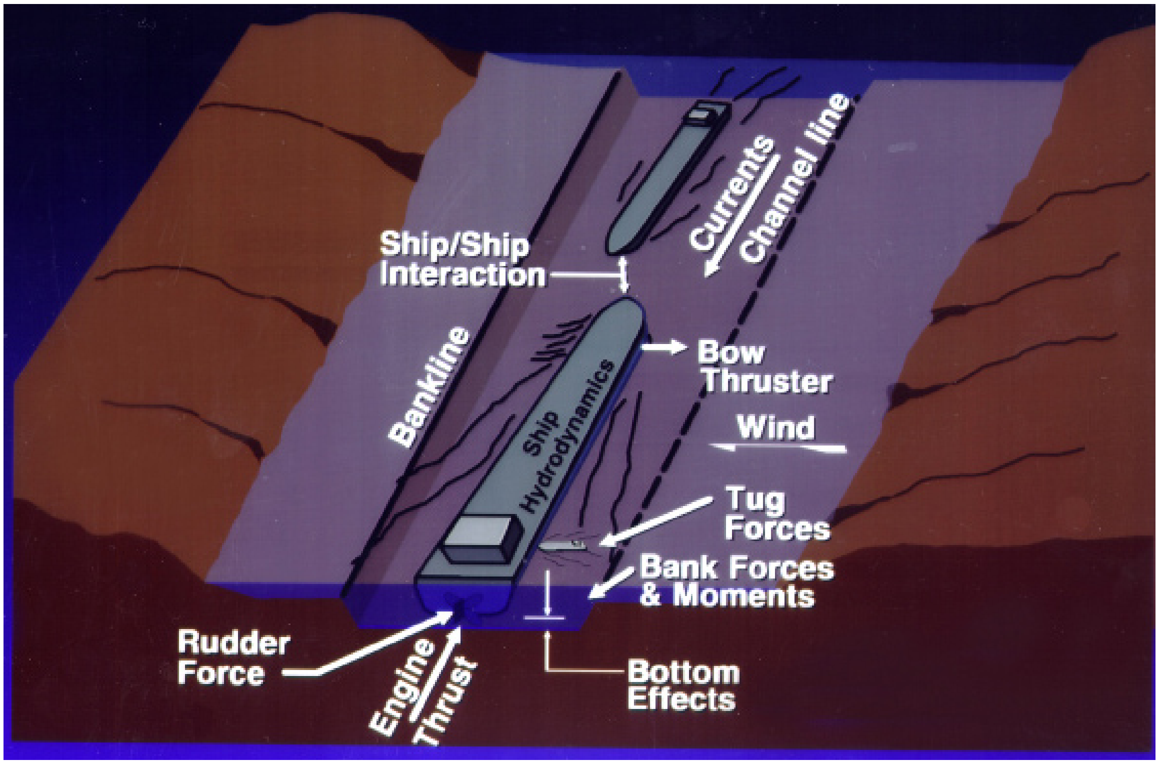


Figure 45: Forces Modeled in Ship Simulator

Two pilots from the Alaska Marine Pilots Association, Capt. Bill Gillespie and Capt. Rick Entenmann traveled to ERDC to participate in the simulation. All exercises were one-way transits either inbound or outbound. The model consisted of without project conditions bathymetry with an added 10 foot tide to prevent the simulated vessels from running aground. Channel extents were shown on the pilots' GPS in the simulator. The ship tracks were printed out after each run and given to each pilot to add notes. Comments included changes to be made on the next simulation, ship handleability, characteristics of the transit, and whether the ship ran aground / hit the channel extents.

Figure 46: View from Bridge, Inbound Ship Entering Dutch Harbor

Channel design at the time of ship simulation was straight with a width of 600 feet. Instead of approximately 1200 feet of width available over the bar, the pilots were restricted to navigating extents half that size. Current practice is for pilots to take vessels out of gear over the bar to slow to speeds of 4.5 to 6.5 knots. It was found that in order to maintain control over the vessel, speeds of 8 to 12 knots were necessary on inbound transits with the new channel. This resulted in an increase in ship squat from 1 foot at 4.5 knots to 3.5 feet at 8 knots.

During ship simulation, the channel was given an extra cut on the northern extent to allow for the pilots to make the inbound turn corner as well as a 4° rotation on the southern extent to allow more room for vessel drifting after the turn. A comparison of these changes to the channel alignment is shown in Figure 47.

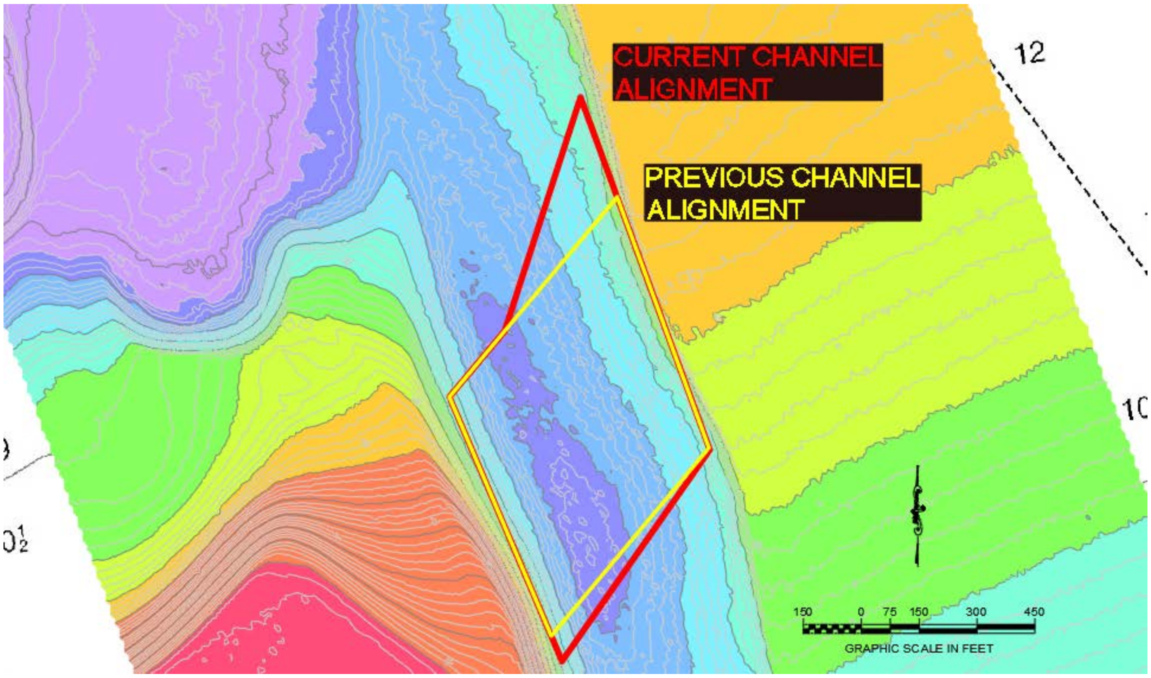


Figure 47: Comparison of Changes to the Channel Alignment

Dimensions of the four vessels, three containerships and one tanker, used during ship simulation are given in Table 20. The four vessels covered a variety of conditions, including vessels that are difficult to handle (KMSS Dainty and Ultra), as well as a closer depiction to what is normally encountered (MT Britannia and Konway I). Containerships are more difficult to transit over the bar than tankers and were tested most frequently during the week. Compiled ship tracks of different variables are shown in Figure 48 through Figure 55. Each ship outline marks 30 seconds, so farther spaced out ship tracks indicate a faster speed. In all, 70 ship simulation runs were performed during the week.

Table 20: Simulated Vessels Used During Ship Simulation

Simulated Vessels					
Model	*Name*	*Description*	*Draft (ft)*	*Length Overall (ft)*	*Beam (ft)*
VLCC15L	MT Britannia	Tanker	860	138	49.2
CNTNR20L	KMSS Dainty	Container	965	106	41.3
CNTNR21L	KMSS Ultra	Container	935	131.2	41.7
CNTNR41	Konway I	Container	1102	141	45.9

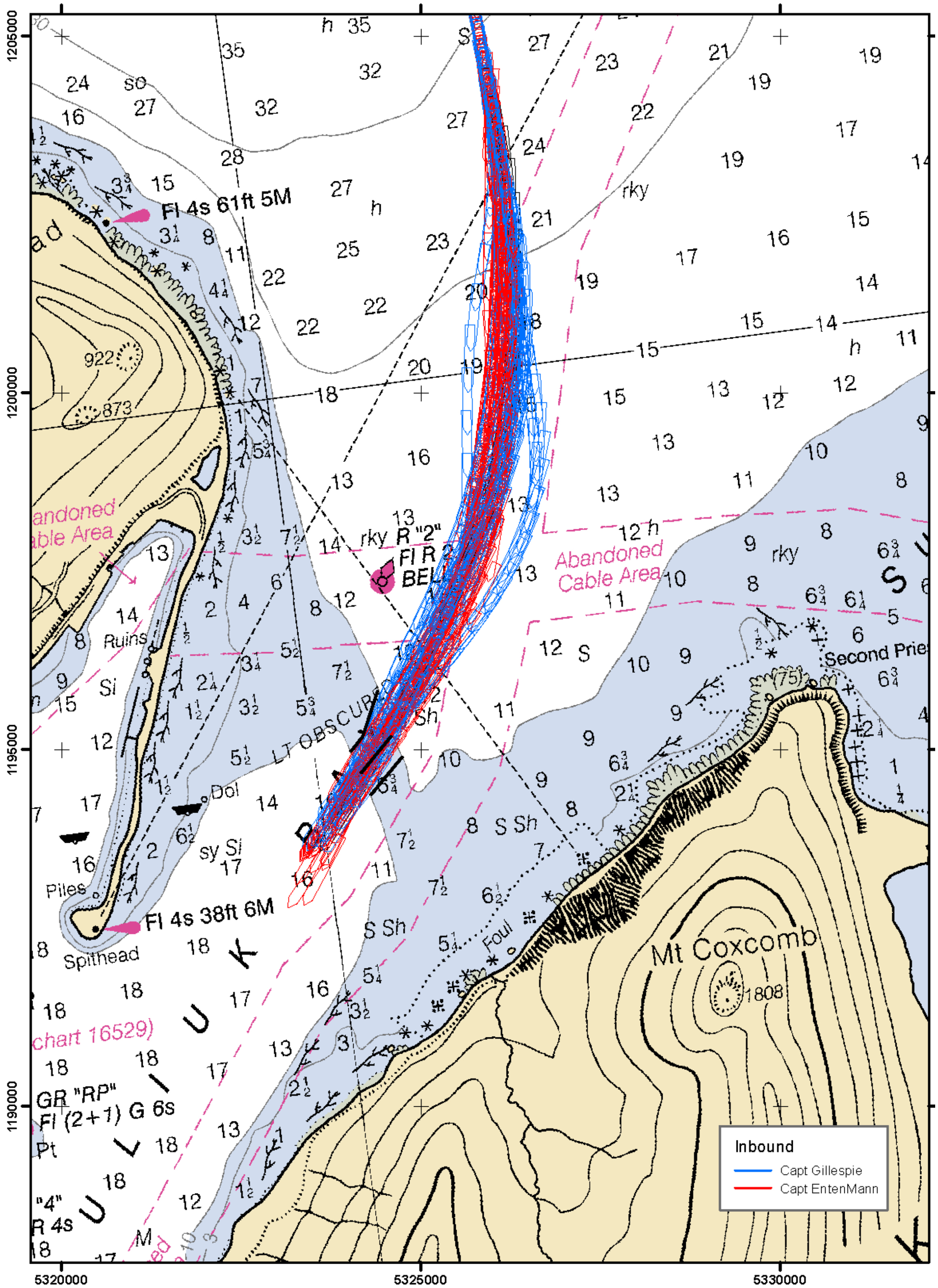


Figure 48: Ship Tracks – Inbound

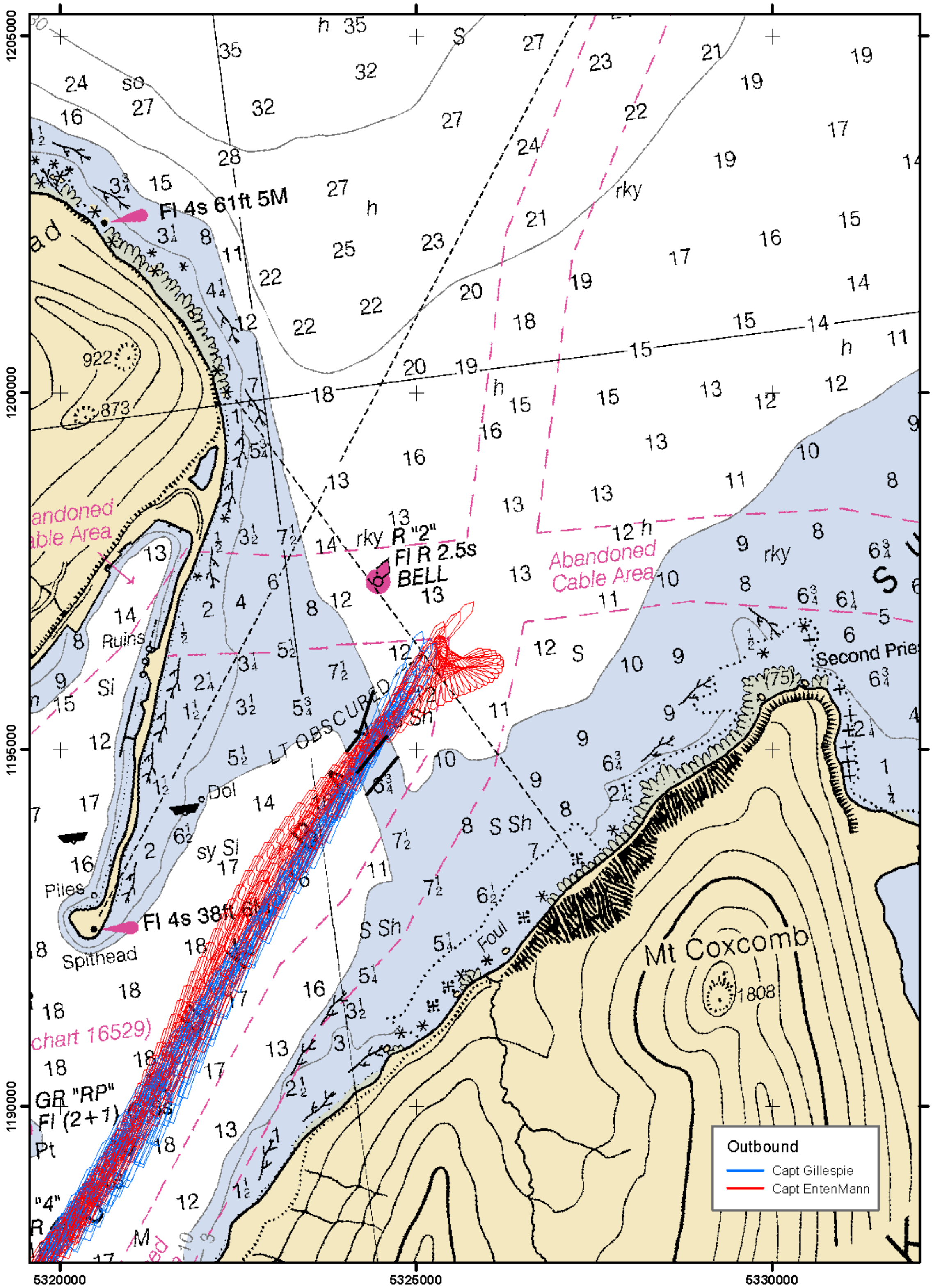


Figure 49: Ship Tracks – Outbound

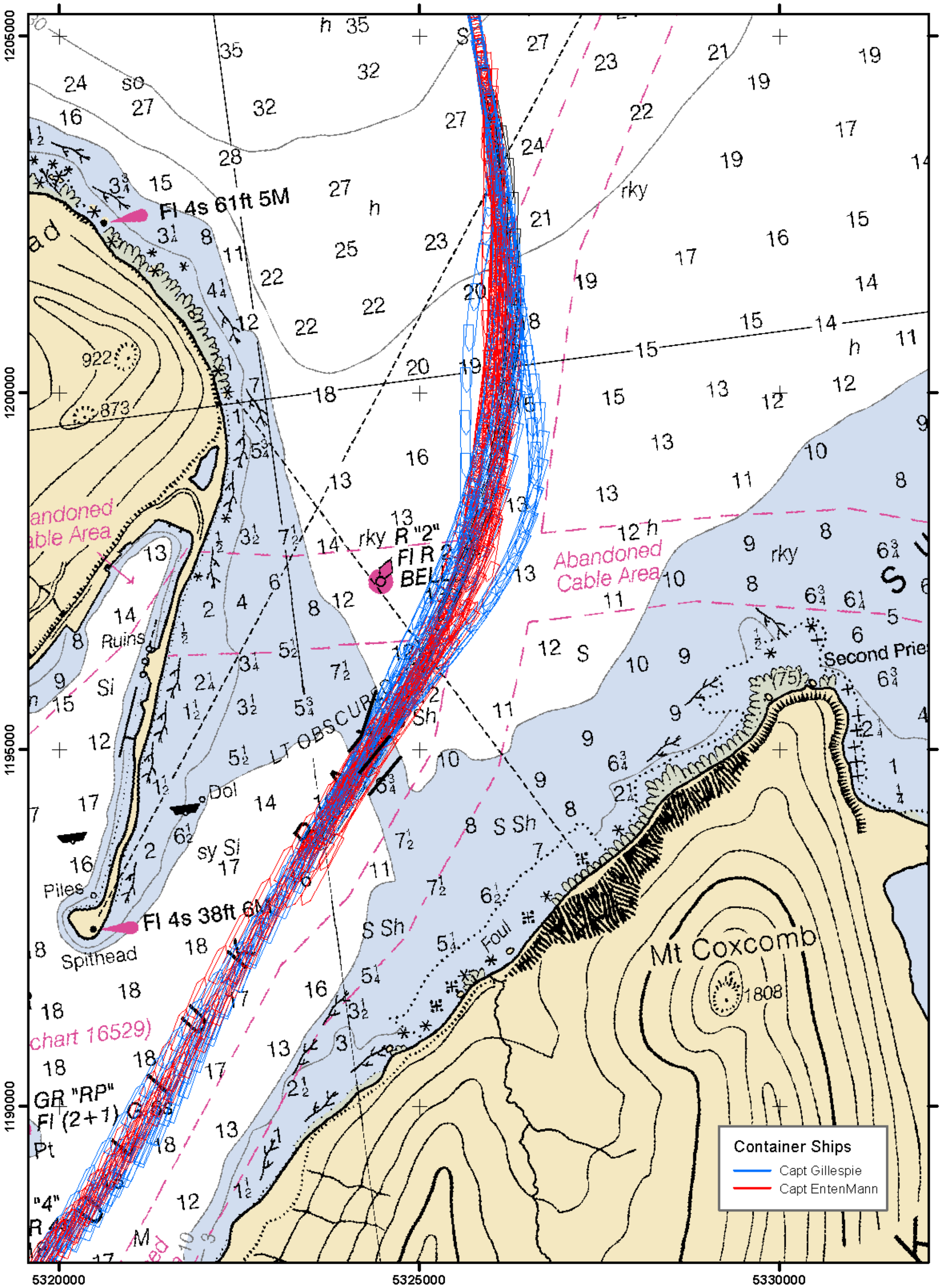


Figure 50: Ship Tracks – Container Ships

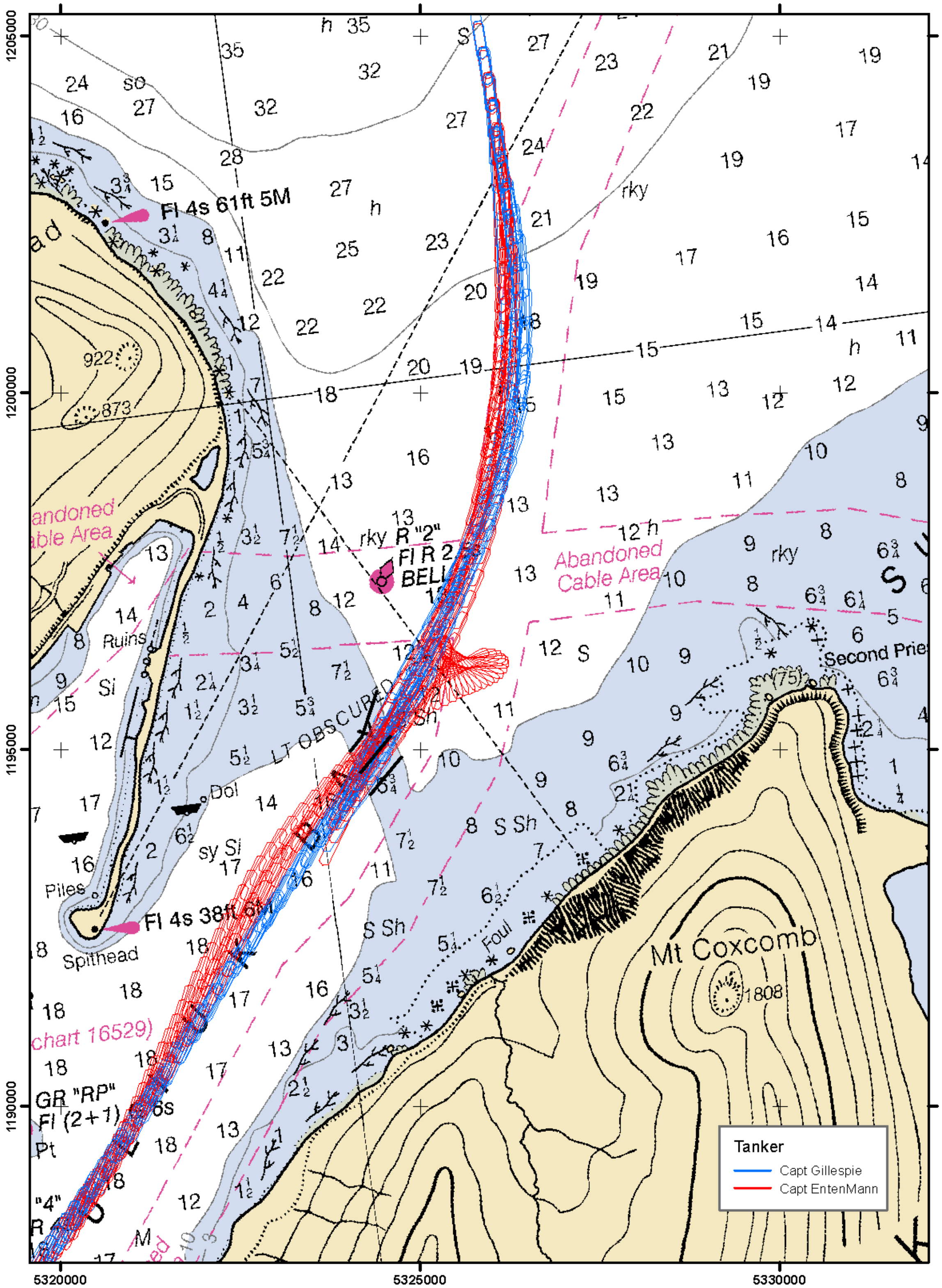


Figure 51: Ship Tracks - Tankers

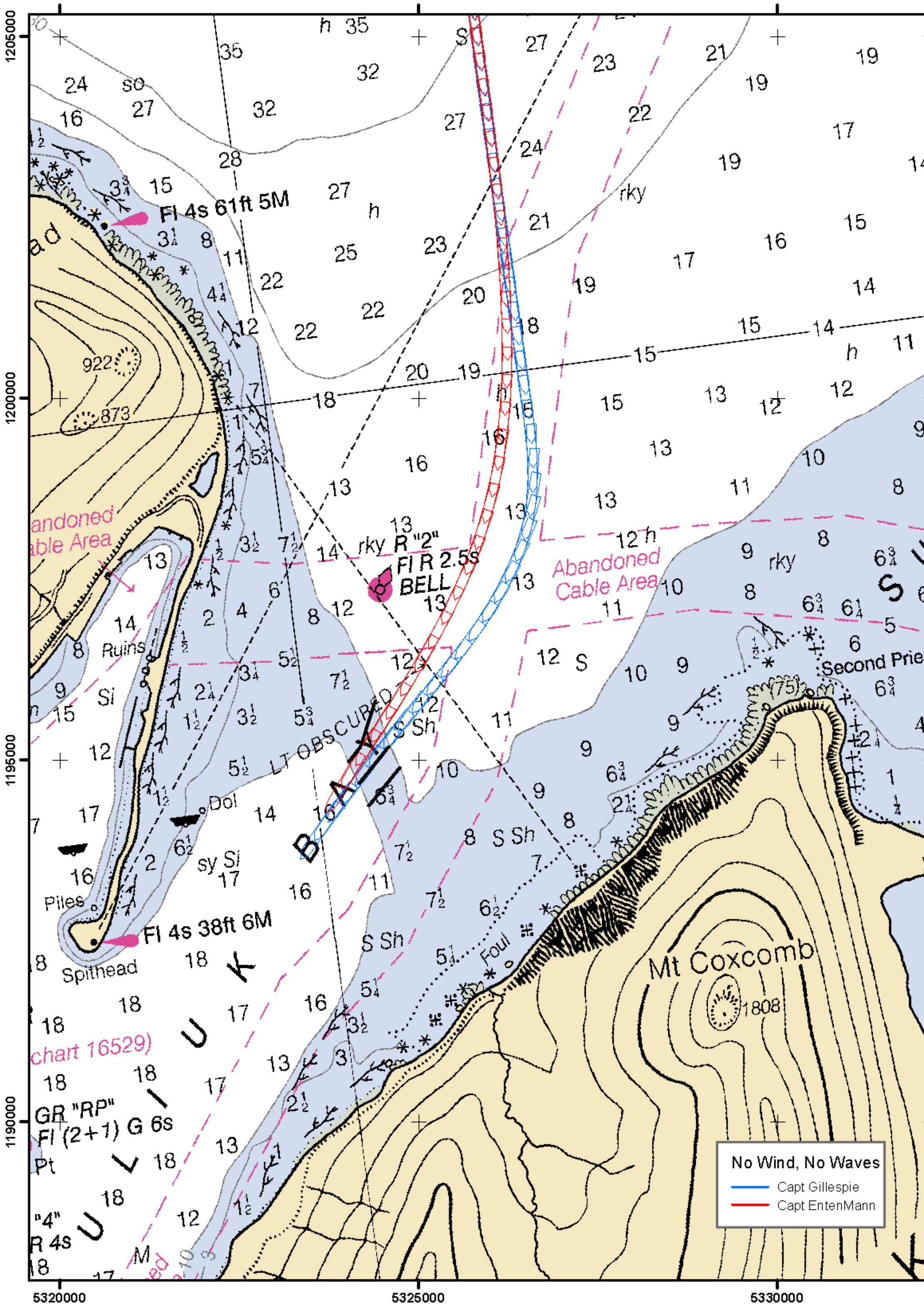


Figure 52: Ship Tracks – No Wind and No Wave Condition

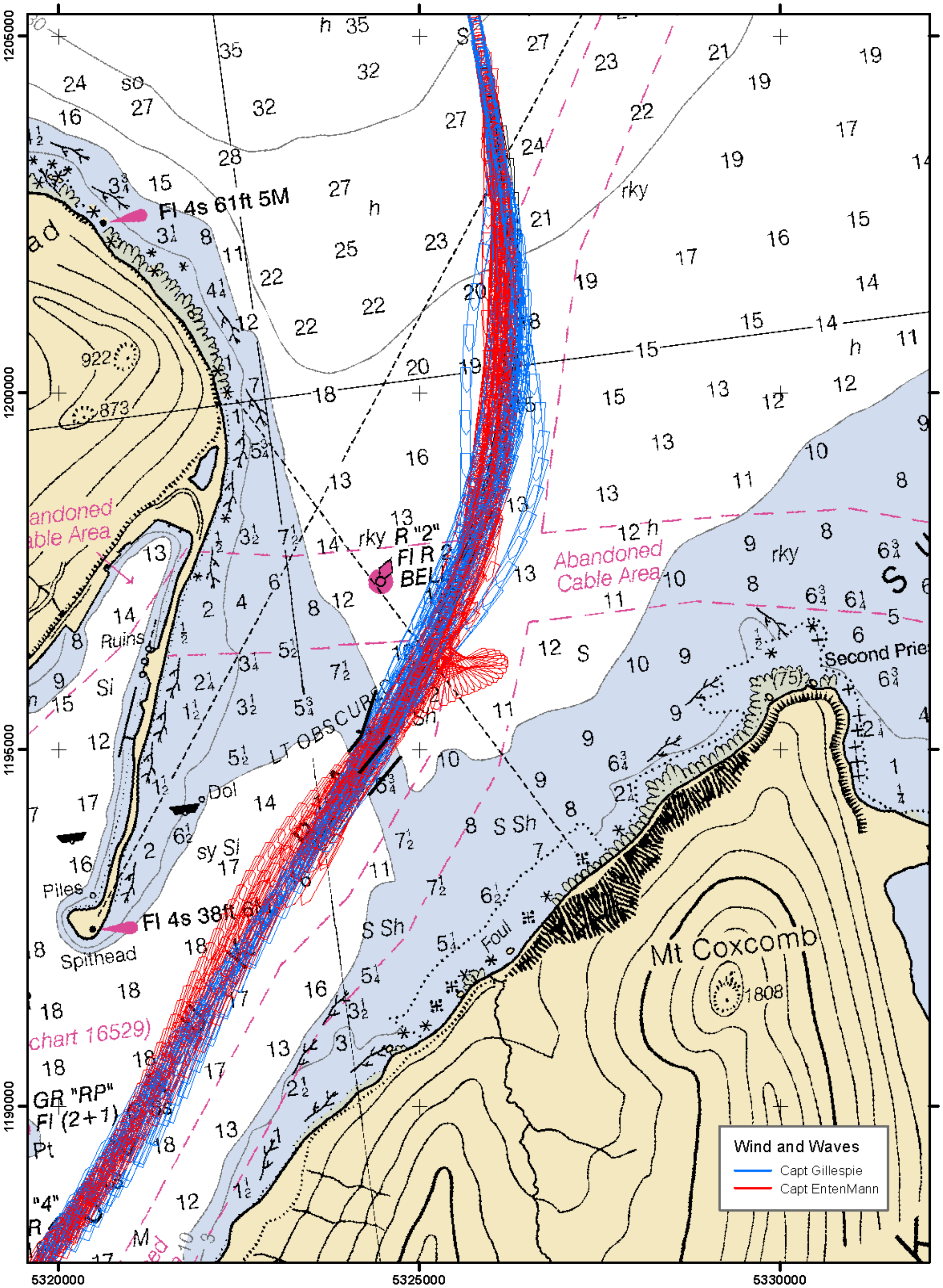


Figure 53: Ship Tracks – Wind and Wave Conditions Greater than 0 knots

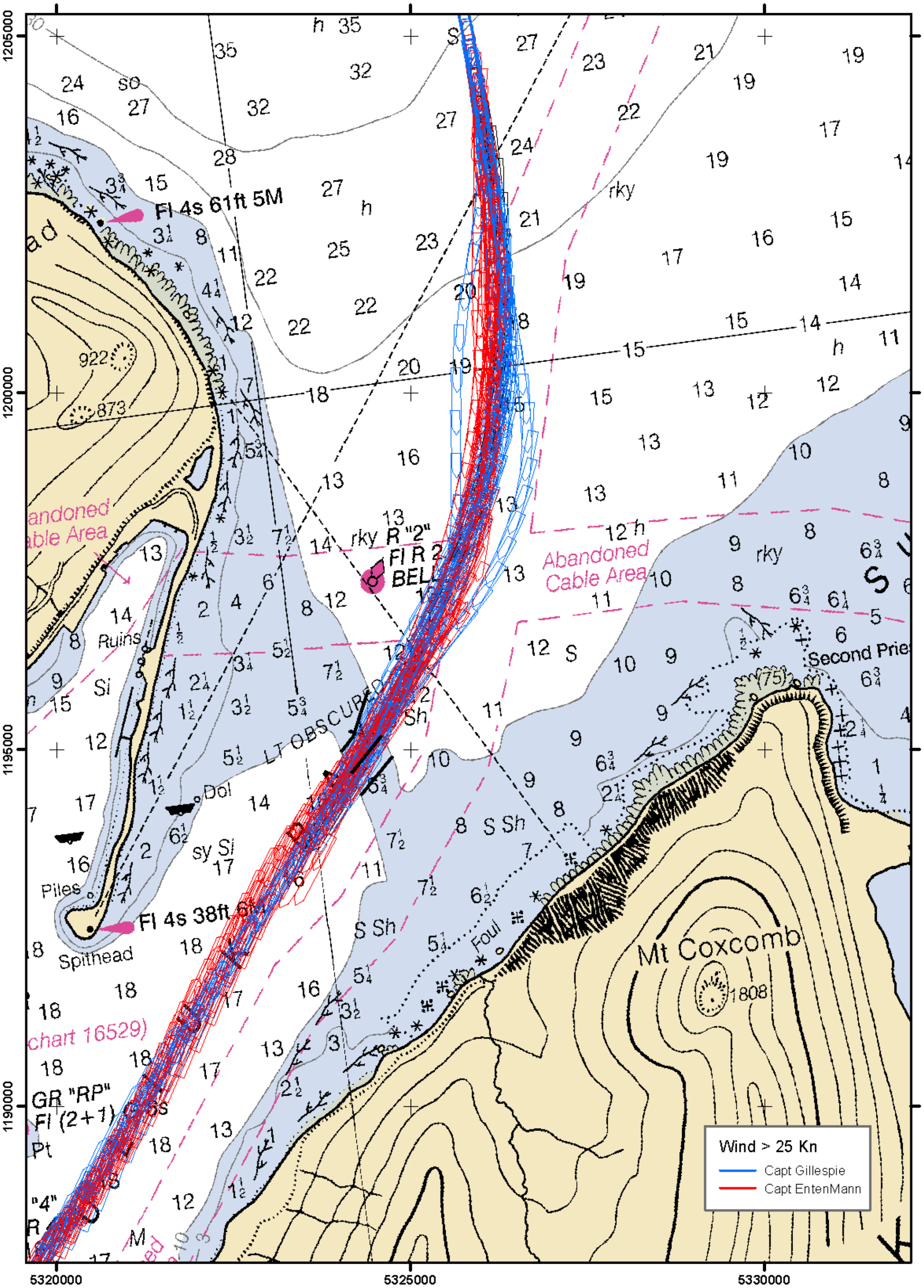


Figure 54: Ship Tracks – Winds Greater than 25 knots

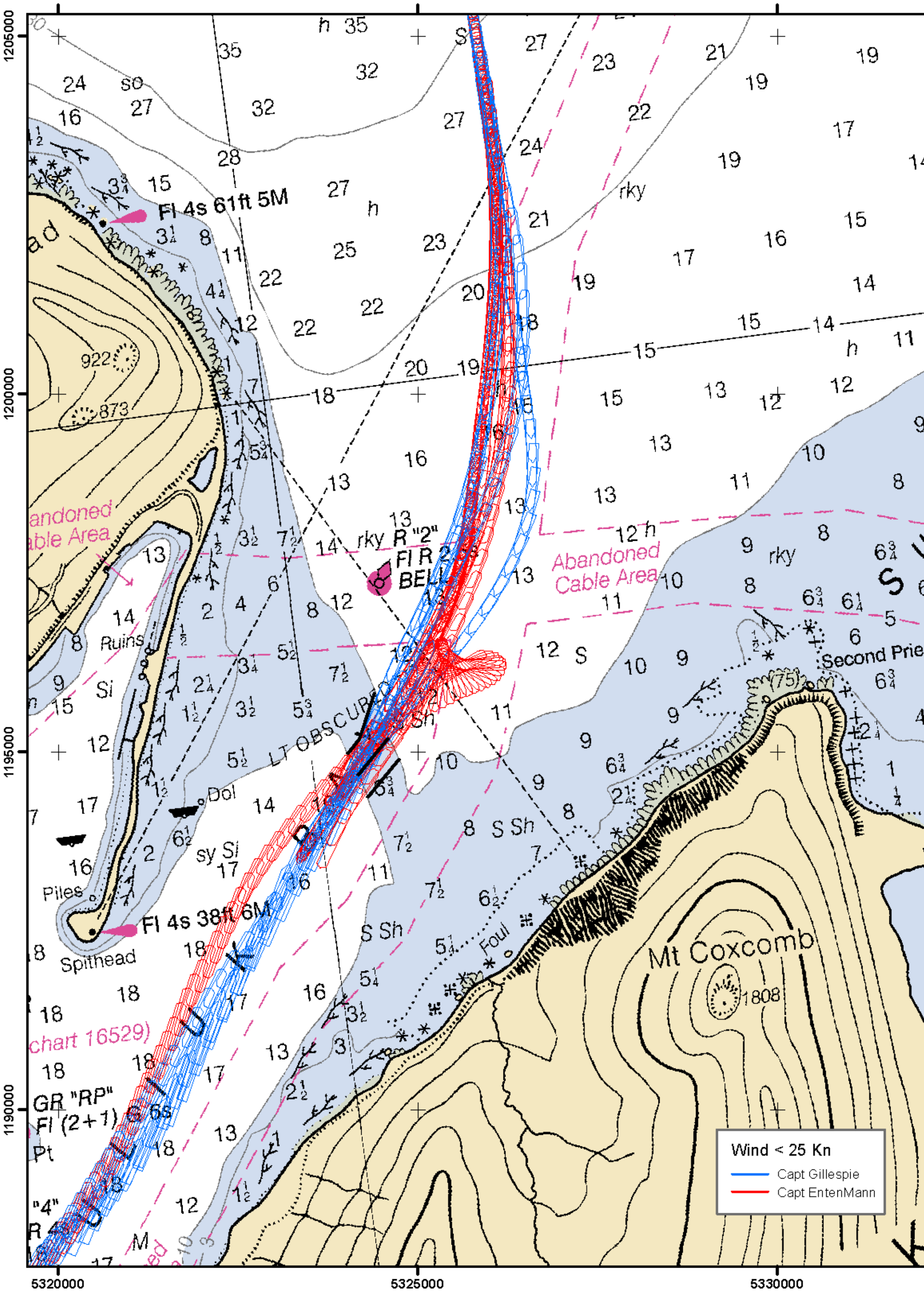


Figure 55: Ship Tracks – Winds Less than 25 knots

6.5.2 Navigation Aids

Navigational aids are the responsibility of the Coast Guard. During ship simulation it was discussed whether range lights would be beneficial for pilots. Disadvantages of range lights encouraging smaller ships to transit inside the channel may outweigh their advantages.

6.6 Construction Considerations

The channel construction is anticipated to take two years to complete. The construction contract will be an open invitation for bid. The type of dredge equipment used to perform the work will not be specified in the contract. It is anticipated that the bidders on the project will have experience blasting since it will likely be used in this project. To attract a number of bidders, it is recommended that the project be advertised early to interest dredging contractors in bidding on this project. In-water work will likely occur during the winter to avoid conflicts with marine mammals, which numbers peak during summer. Vessels are active in the area all year round, with crabbing season taking place in the winter. The work season length, remote site location, and wave climate are just some of the conditions that a contractor would need to consider when proposing on this contract.

6.7 Disposal of Dredge Material

Figure 56 shows the proposed dredged material disposal areas. The sites in question range in depth from 102 to 204 feet, approximately 6,000 to 14,000 feet from the bar. The sites in question are deep enough for disposal of the quantities to be excavated without significant impact on navigation or the coastal hydraulics of the area. A preferred disposal area will be identified by the Environmental team based on biological productivity levels identified at each site.

Figure 56: Areas of Investigation for Potential Dredging Disposal Sites

7.0 CHANNEL MAINTENANCE

Historic NOAA bathymetric surveys for Dutch Harbor were completed in 1934, 1991, and 2011. The most recent bathymetric survey was performed by eTrac Inc. in 2017. Sediment movement around the dredge channel extents can be performed by analyzing the four surveys. Figure 57 gives an overview of the four bathymetric survey profile locations used in the analysis. Figure 61 displays each of the four surveys with the dredge channel location shown in green with the two foot dredging tolerance. The profiles indicate that there has been little to no movement of material at the bar.

The sand migration around the southern tip of the bar is not expected to enter the channel due to the minimum seven foot difference in height of the sand (-65'MLLW) to the bottom of the channel (-58'MLLW), see Figure 62 and
Figure 63. The material at the north and south channel cuts is anticipated to have a high in-situ strength, but some material from the side slopes is expected to migrate into the channel.

Sea level change could also affect the navigability of the channel. Isostatic rebound is anticipated to outweigh the effects of sea level rise in the area, resulting in a sea level drop of 0.46 feet over 50 years (Figure 17).

It is recommended that one foot of depth, or 16,000 cubic yards of maintenance dredging be performed at year 25 to address the sloughing and the isostatic rebound of the area and ensure the bar is navigable at year 50.

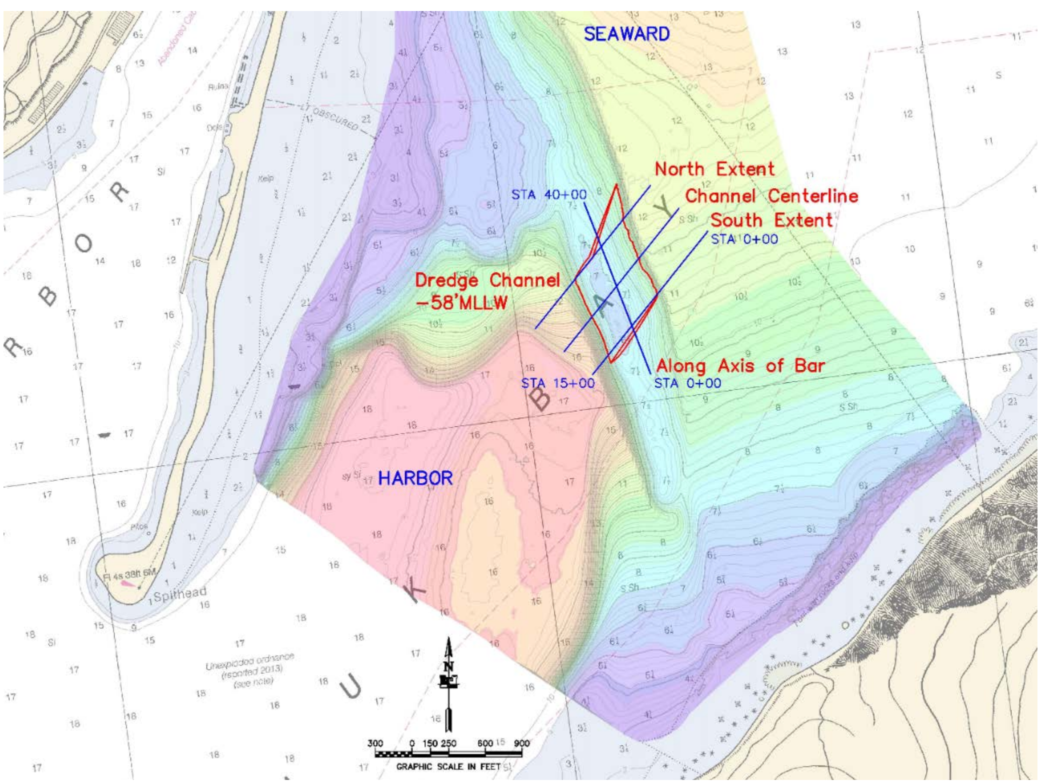


Figure 57: Bathymetric Survey Profile Locations (in Blue)

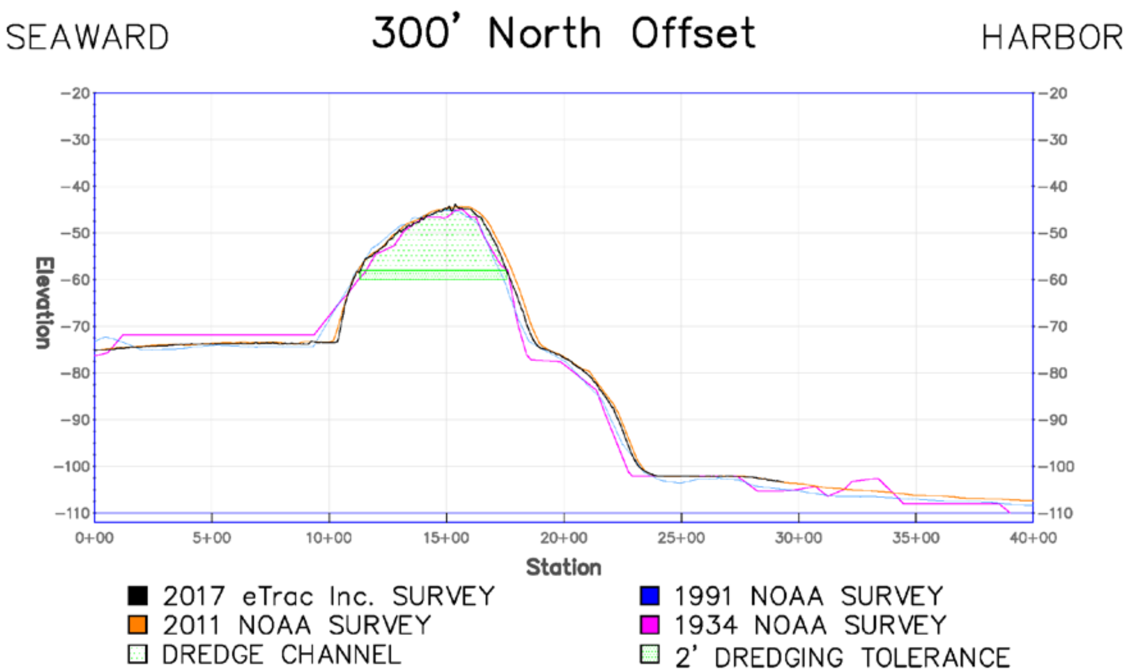


Figure 58: Profiles of Comparing Historic Bathymetry – 300' North Offset

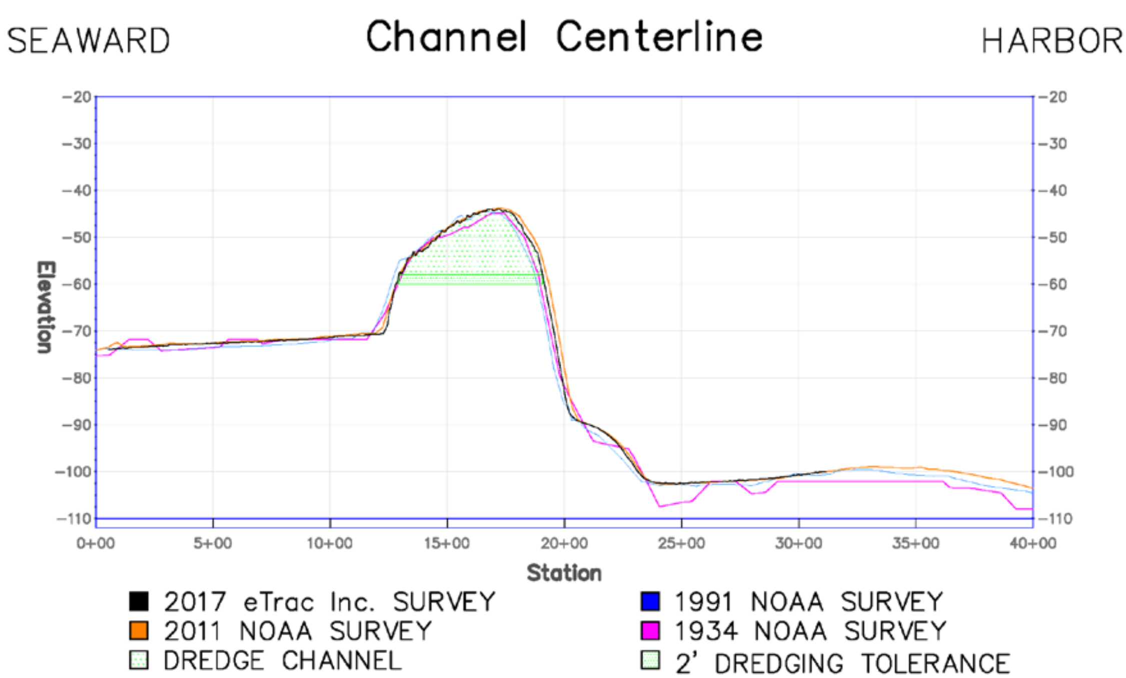


Figure 59: Profiles of Comparing Historic Bathymetry – Channel Centerline

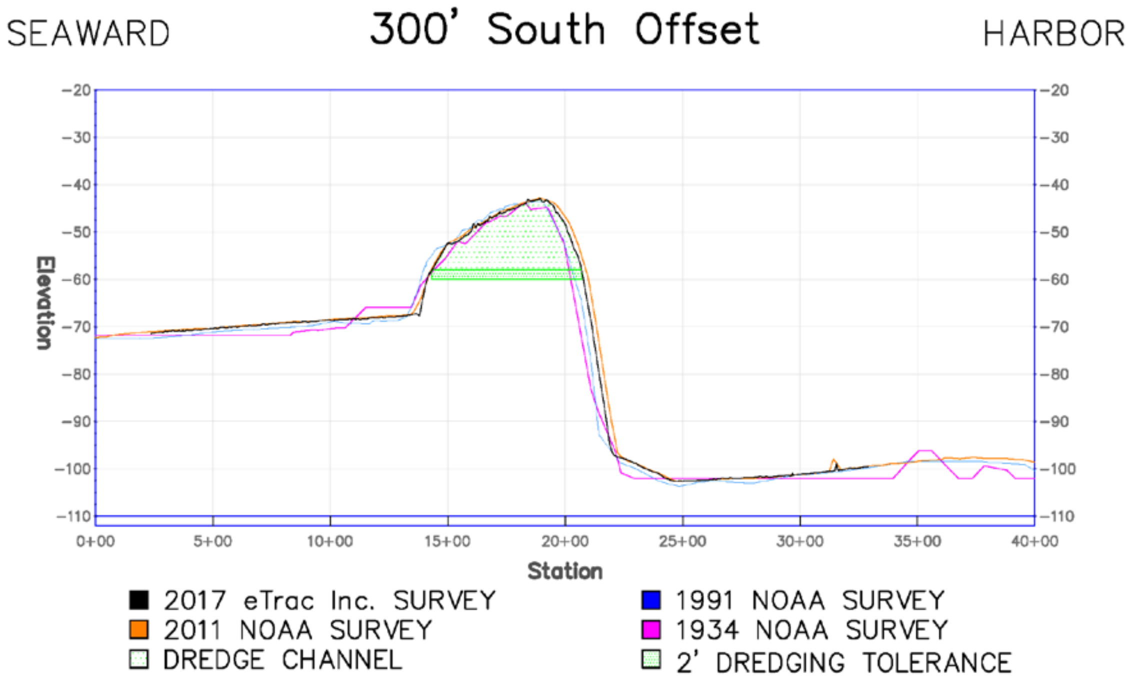


Figure 60: Profiles of Comparing Historic Bathymetry – 300' South Offset

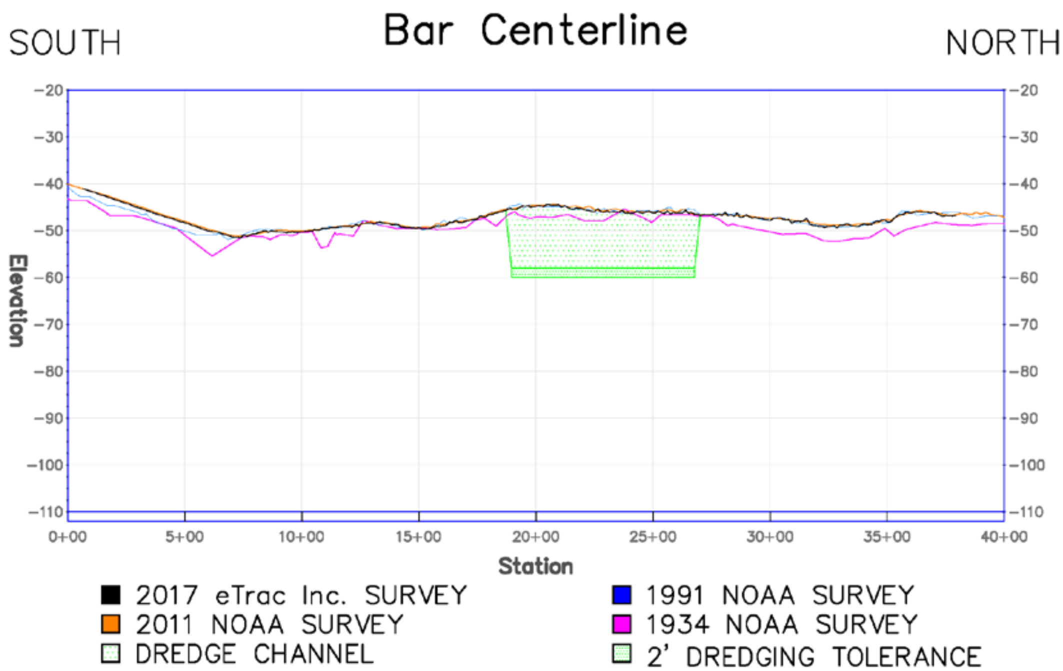


Figure 61: Profiles of Comparing Historic Bathymetry – Bar Centerline

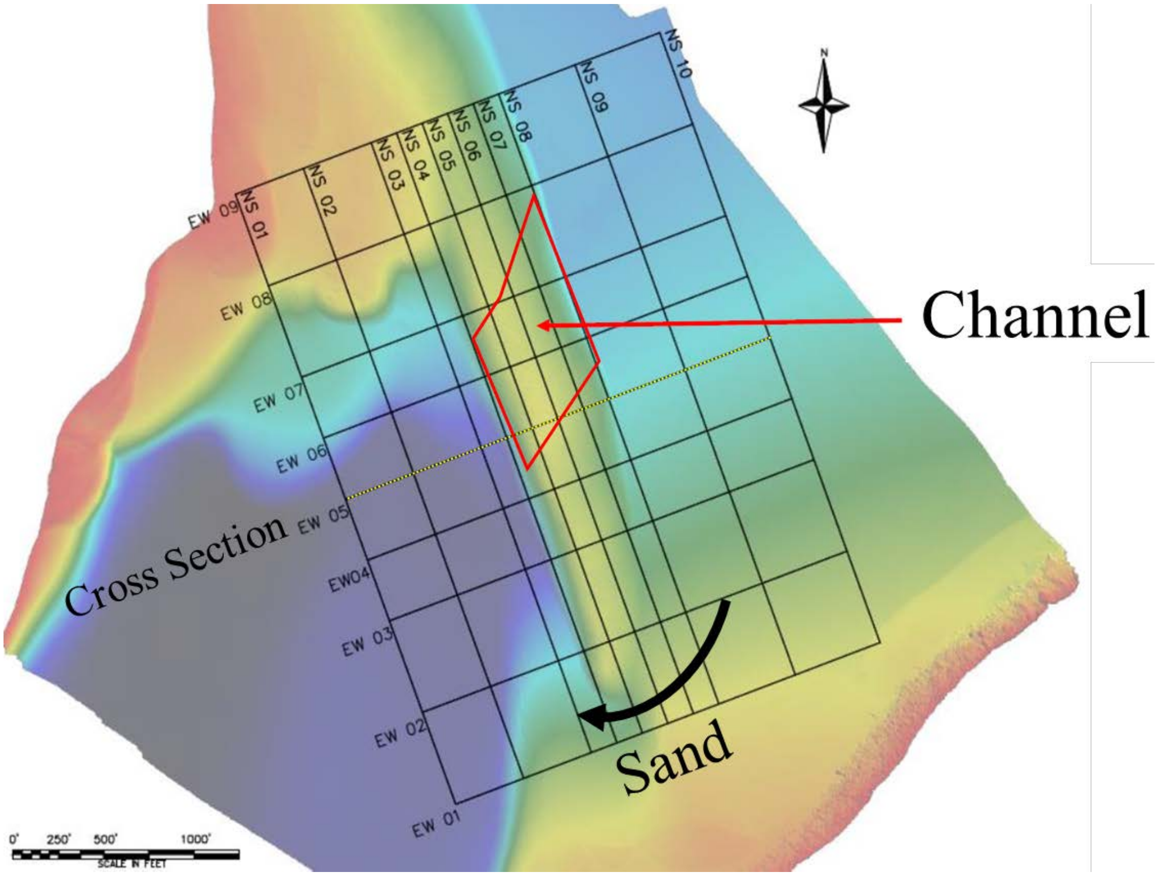
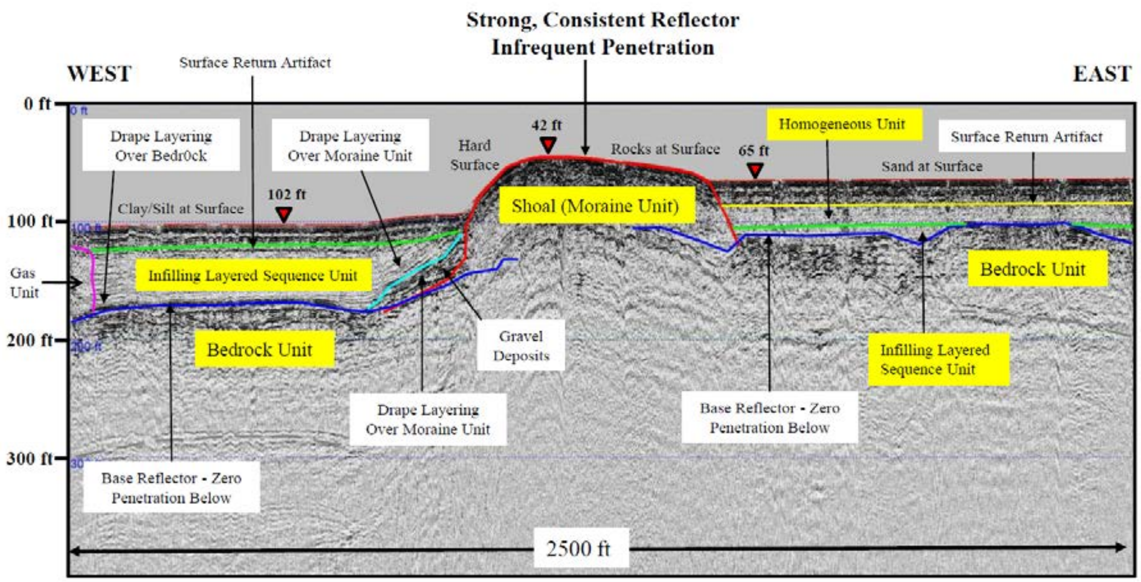


Figure 62: Stratigraphic Cross Section Locations



Notes:

1. Plot derived from bubble gun seismic profiler data.
2. Depths shown below MLLW.
3. Depth point. ▼

Figure 63:Stratigraphic Cross Section at EW05

8.0 RISK AND UNCERTAINTY

Uncertainty is associated with the need for blasting as well as if MEC are within the area. The 2017 marine geophysical survey investigation determined that the bar consisted of a dense, consolidated, glacial drift deposit overlying bedrock. It is anticipated that the material is unrippable and will need to be broken apart by the drill and blast method. Further geophysical testing of the bar will be performed during PED.

Thirty-eight MEC were identified in the inner project area by the 2017 geophysical survey. Divers or a remote operated vehicle should be used to identify the objects. It is likely that some of the ojects are unexploded ordinance that will need to be removed prior to dredging.

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