Appendix A
Hydraulic Design

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1.0 INTRODUCTION

1.1 Project Purpose

The following objectives were identified for the navigation improvements:

1. Improve access to Unalaska-Dutch Harbor to decrease transportation inefficiencies in the region.
2. Improve access to Unalaska-Dutch Harbor to increase vessel access and safety in the region.

1.2 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 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, orientation, and wind speeds allowable for safe navigation.

1.3 Background

Current operations dictate that vessels light load from point of origin in order to have an average of 4 to 7 feet (1.2 to 2.1 meters) of clearance over the shoal at the entrance of Dutch Harbor, which henceforth will be referred to as the bar. This results in inefficient and potentially unsafe delivery of fuel, durable goods, and exports to and from Dutch Harbor. According to local knowledge, large container vessels must wait to enter or exit Dutch Harbor about twice a month due to waves being 6 feet (1.8 meters) or larger at the bar.

1.4 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 Harbor and Captains Bay and extends across to the western shores of central Amaknak Island.

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

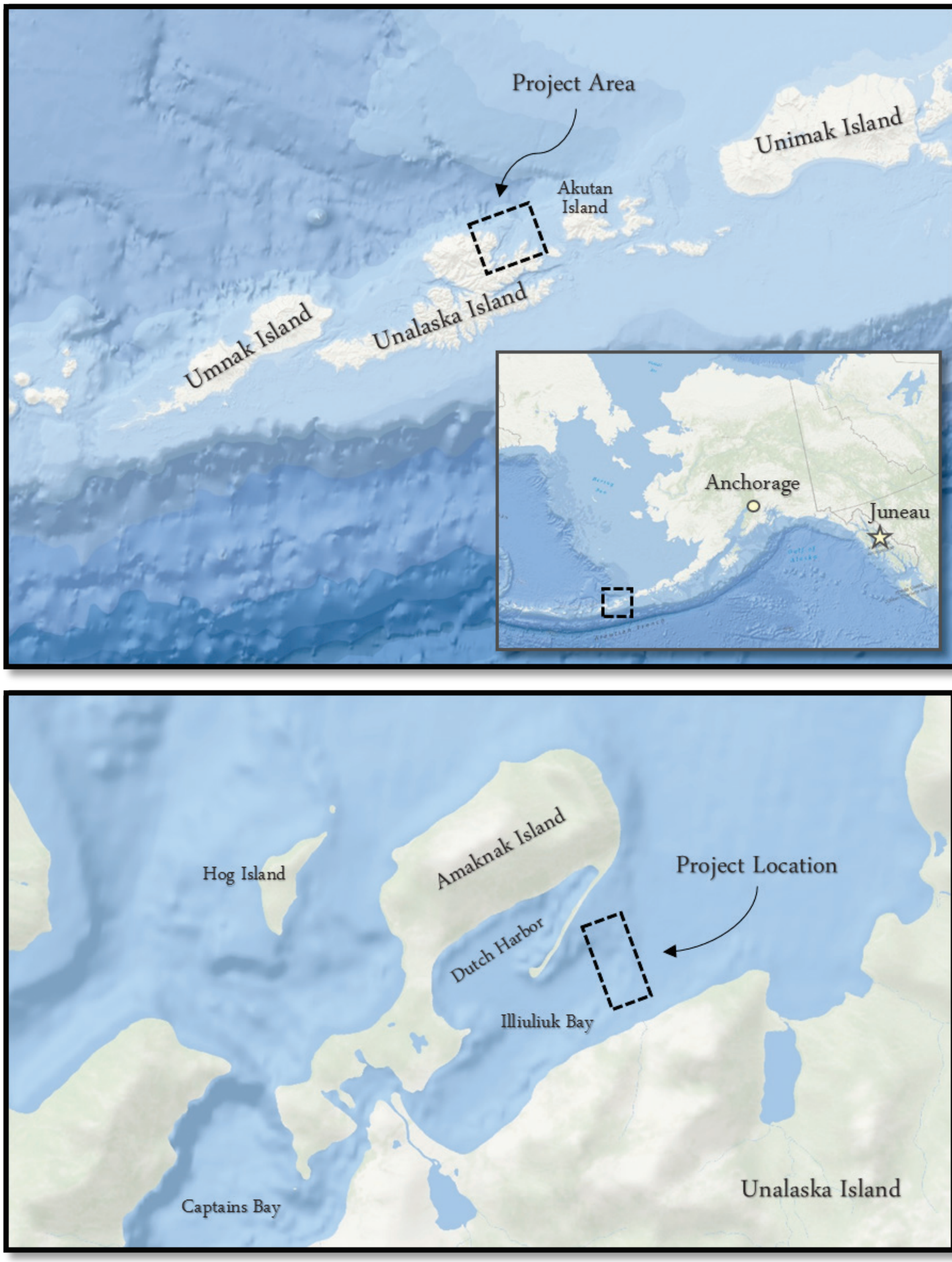

Figure 1: Vicinity map of Dutch Harbor, Unalaska

2.0 CLIMATOLOGY, METEOROLOGY, HYDROLOGY

2.1 Weather Conditions

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

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

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 2 below (West Comp Fog, 2017). Heavy fog constitutes visibility of a ¼ mile or less observed sometime during the day.

Table 2: 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%

Dutch Harbor remains ice-free year round.

2.2 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.

Several sills dominate the bathymetry of the bay, the largest being the Chelan Bank at the mouth of the bay. Another sill connects Eider Point with Amaknak Island, passing the Northern tip of Hog Island. The Dutch Harbor Navigations Improvement project is investigating the sill north of Iliuliuk Bay, referred to as the bar.

Historic nautical chart records show that the bar has existed for at least 80 years. Depths read 7 to 8 fathoms (42 to 48 feet) along the bar in a chart dating from 1937 from a NOAA survey performed in 1934 (Figure 2). This is the earliest survey with enough detail to show the bar. Immediately adjacent to the bar, depths read 11 fathoms and greater (66 feet). This is consistent with the dimensions of the bar today (Figure 3)

In 2017, a marine geophysical survey investigation of Dutch Harbor was performed by eTrac Inc. (Consultants, 2017). The plan view of the design channel is overlaid on this survey later in the report at Figure 16.

A comparison is currently being made between the three historical NOAA surveys conducted in 1934, 1991, and 2011, and the eTrac Inc. survey conducted in 2017. Preliminary findings indicate that the area has changed little in nearly 100 years. The results generated will be used for estimating operation and maintenance quanitities and reoccurance intervals.

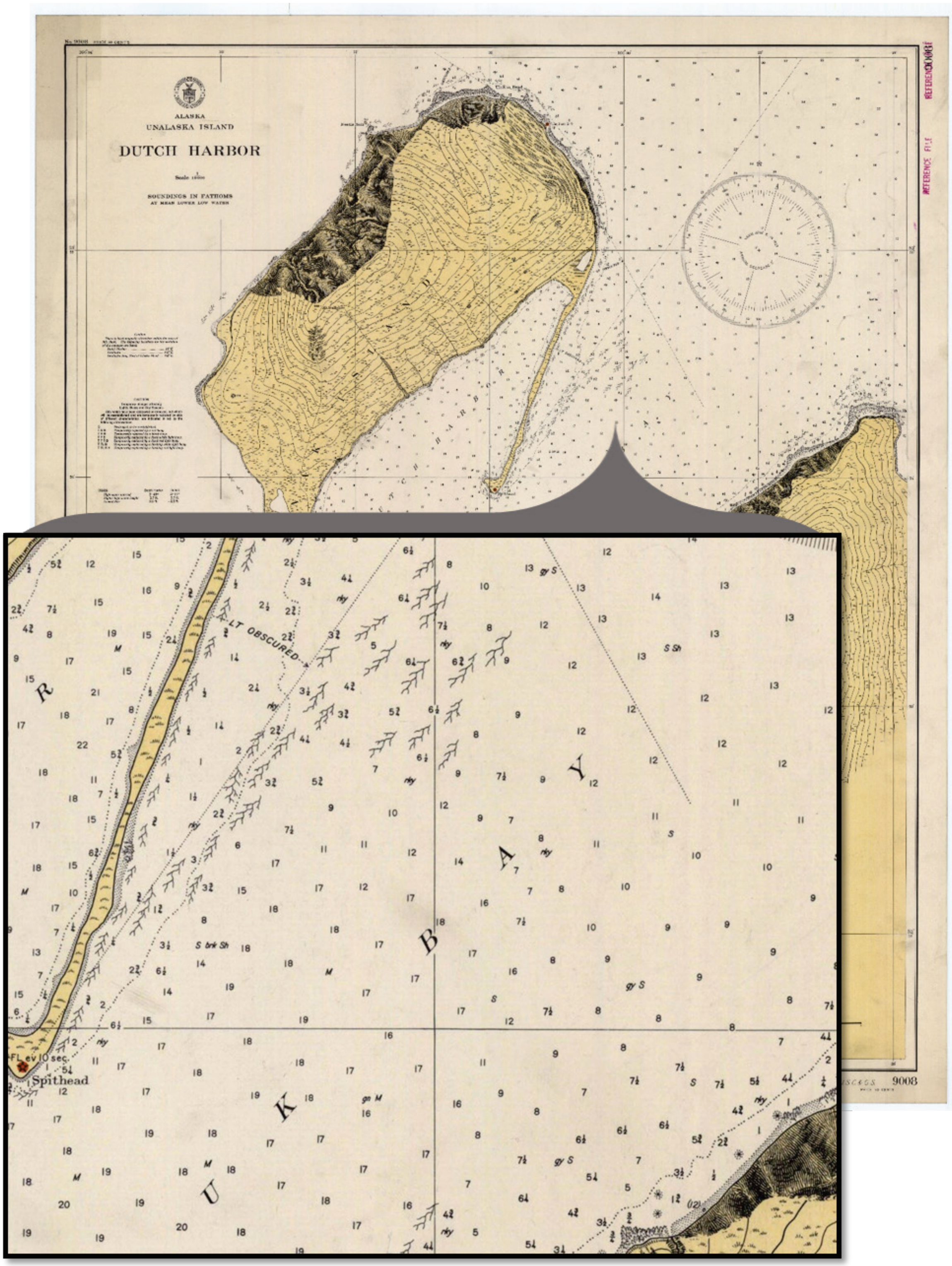

Figure 2: Historical Bathymetry of Dutch Harbor, 1937 (Survey, 2017)

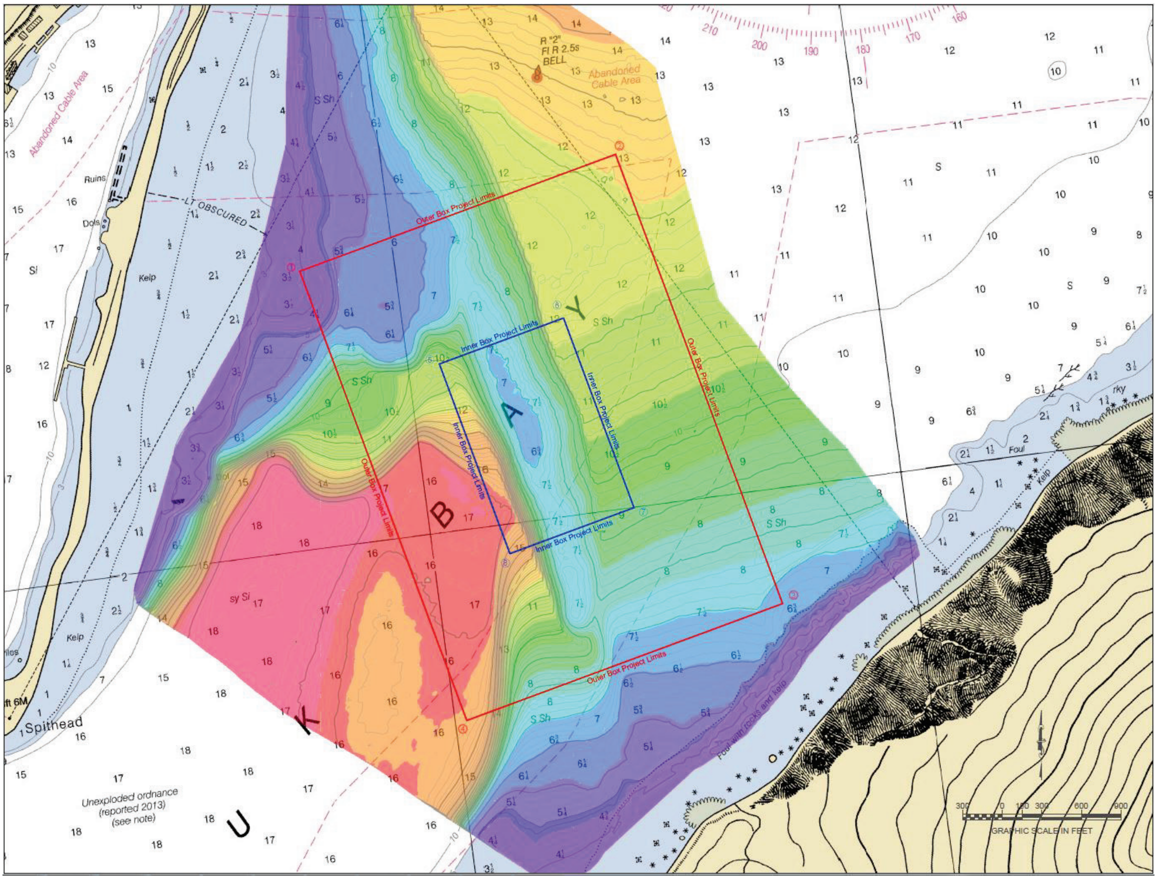

Figure 3: Most Recent NOAA Survey of Dutch Harbor, 2011

The 2017 marine geophysical survey investigation was performed to identify the material makeup of the shoal and identify possible munitions of concern (MEC). The shoal was interpreted to consist of a dense, consolidated, glacial drift deposit overlying bedrock The material is not 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. Thirty-eight potential MECs were identified within the inner box. Further investigation is necessary to determine the objects' identity. See Geotechnical appendix for more information.

2.3 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 3 were determined by NOAA using data from the period May 7, 1955 to present (NOAA, 2017).

Table 3: Tidal Parameters – Unalaska

	Elevation (feet MLLW)	Elevation (meters MLLW)
Highest Observed Water Level (01/27/1960)	6.70	2.04
Mean Higher High Water (MHHW)	3.60	1.10
Mean High Water (MHW)	3.31	1.01
Mean Sea Level (MSL)	2.08	0.63
Mean Low Water (MLW)	0.93	0.28
Mean Lower Low Water (MLLW)	0.00	0.00
Lowest Observed Water Level (12/13/2008)	-2.78	-0.85

A tide curve (Figure 4) was created from Station 9462620 data recorded between 1982 and 2017. During this period, the tide was above 0 feet MLLW 92.2 percent of the time, above -0.5 feet MLLW 96.5 percent of the time, and above -1foot MLLW 98.8 percent of the time. Economics will determine if the bar should be deepened to allow for greater than 92.2 percent tidal access.

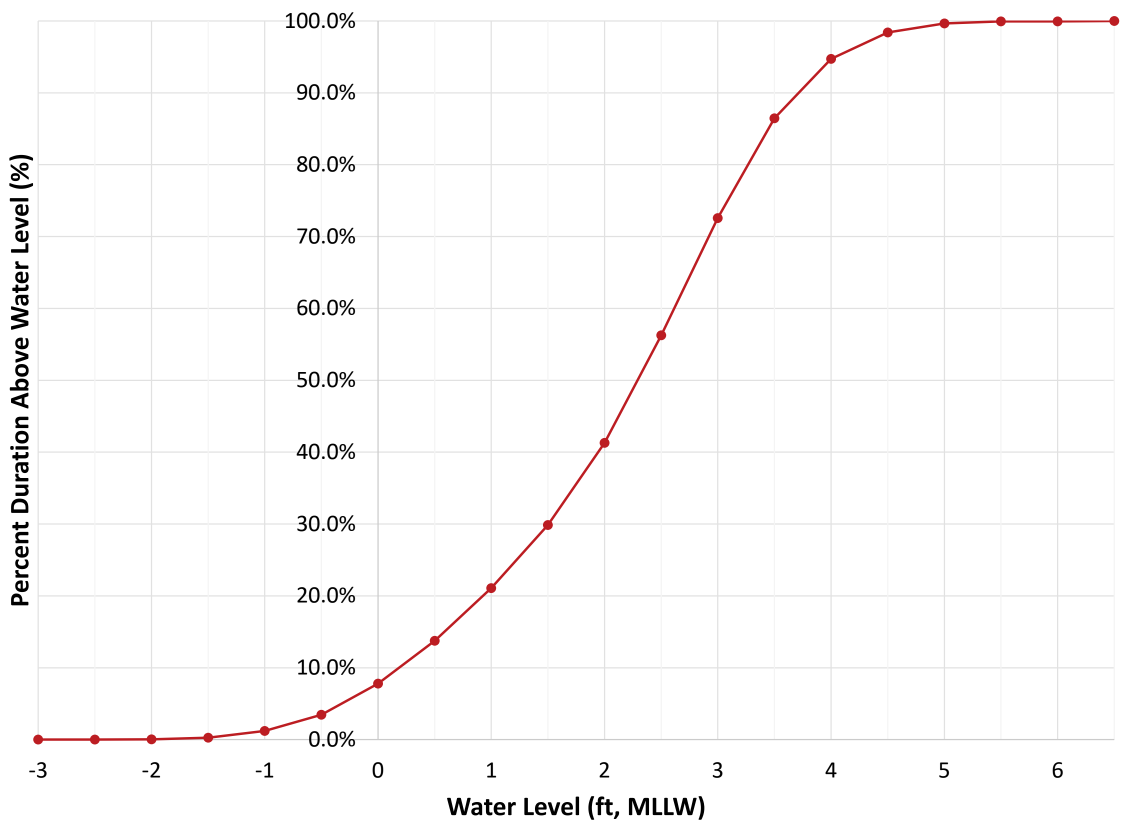

Figure 4: Tide Curve for Percent Duration Above 0' MLLW

3.0 WAVE CLIMATE

The Coastal and Hydraulics Laboratory (CHL) of the Engineer Research and Development Center (ERDC) is currently developing a hindcast of the wave climate at Dutch Harbor using wind data generated from the wind hindcast. The wave hindcast will be verified using National Data Buoy Center (NDBC) buoy data. An NDBC buoy (9462620) has been at the site since July 27, 2010. The data from this buoy and a buoy in the Bering Sea (46073) will be used to validate the hindcast results.

4.0 CURRENTS AND WATER LEVELS

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.

Sea level rise estimates using EC 1165-2-212 and NOAA historic rates can be seen in Figure 5 below. Low sea level change estimates predict that the sea level will drop by 0.80 feet (0.24 meters) between 2020 and 2070 if isostatic rebound is greater than sea level rise. Though there is a great deal of uncertainty in this estimate, there a potential impact on the proposed project or the ability of Dutch Harbor to serve as a maritime hub over the next 50 years. The situation of sea level decrease of 0.80 feet would be problematic since it would decrease the water level over the bar and pose a larger navigation hazard with increased economic impacts on shipping. The bar would need to be dredged an additional 0.8 feet to mitigate the effects of this scenario. A sea level increase would reduce the impact of the bar in a future without project scenario by providing more water depth. High sea level change estimates predict that the sea level will rise by 1.17 feet (0.36 meters) between year 2020 and 2070 if isostatic rebound is less than sea level rise. At this time, no additional depth of the channel is being considered due to sea level rise.

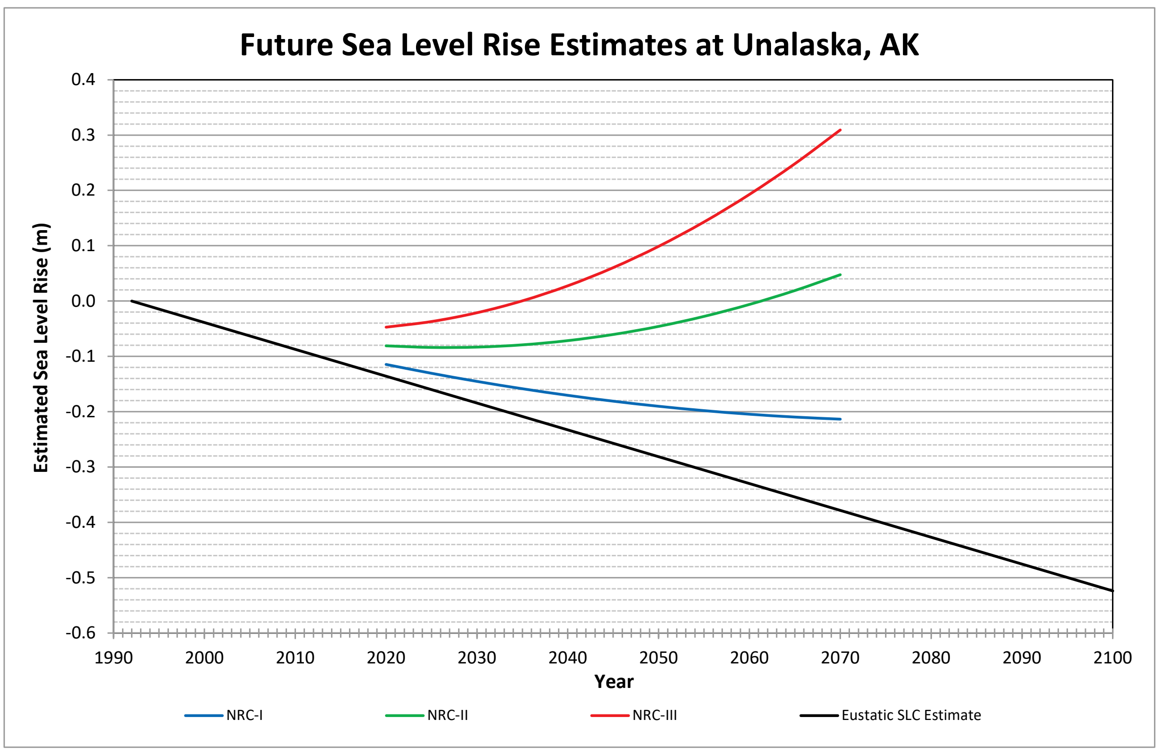

Figure 5: Sea Level Rise Estimates

5.0 SEDIMENT MOVEMENT

Historic NOAA bathymetry for Dutch Harbor is available for the past 84 years. A comparison will be made of the NOAA surveys conducted in 1934, 1991, and 2011 to the 2017 eTrac Inc. survey to confirm whether any sediment has moved. If there is evidence of movement, wave analysis will be performed to verify whether sand can be moved at this depth. Estimates of dredging maintenance quantities will be determined from this model.

6.0 CHANNEL DESIGN

The purpose of dredging the channel is 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. It is necessary to study constructible channel depths, which accommodate desired vessel drafts.

6.1 Wind

According to local pilots, the existing parameters that cease operations of bringing large containerships over the bar are as follows in Table 4. The wind speed must be sustained approximately 15 minutes or longer.

Table 4: 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

A wind hindcast is being performed by the Engineer Research and Development Center (ERDC) to accurately reflect the forcing mechanism for the wave and current modeling, which will in turn be provided as input to the modeling of sediment movement at Front Beach. The wind data will also be directly used in the ship simulation study.

An extreme value analysis was performed for Station PADU (Table 5), with the location shown in Figure 6. The analysis revealed the 50-year return period wind as 54.9 knots (28.2 m/s) (Zautner, 2017). A similar analysis for Station DUTA2 on the spit was not able to be performed with only 5 years of historical data.

Table 6 compares the years available for both stations from 2013 to 2017. In general, maximum wind speed and gust are 30 percent lower at the spit. This is due to a number of factors including site geography, gage height of 23.3 feet (7.1 meters) for PADU compared to 15 feet (4.6 meters) 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. Therefore, using airport data for wind analysis should be sufficiently conservative.

Figure 6: Location of Wind Data in Dutch Harbor

Table 5: 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 6: 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

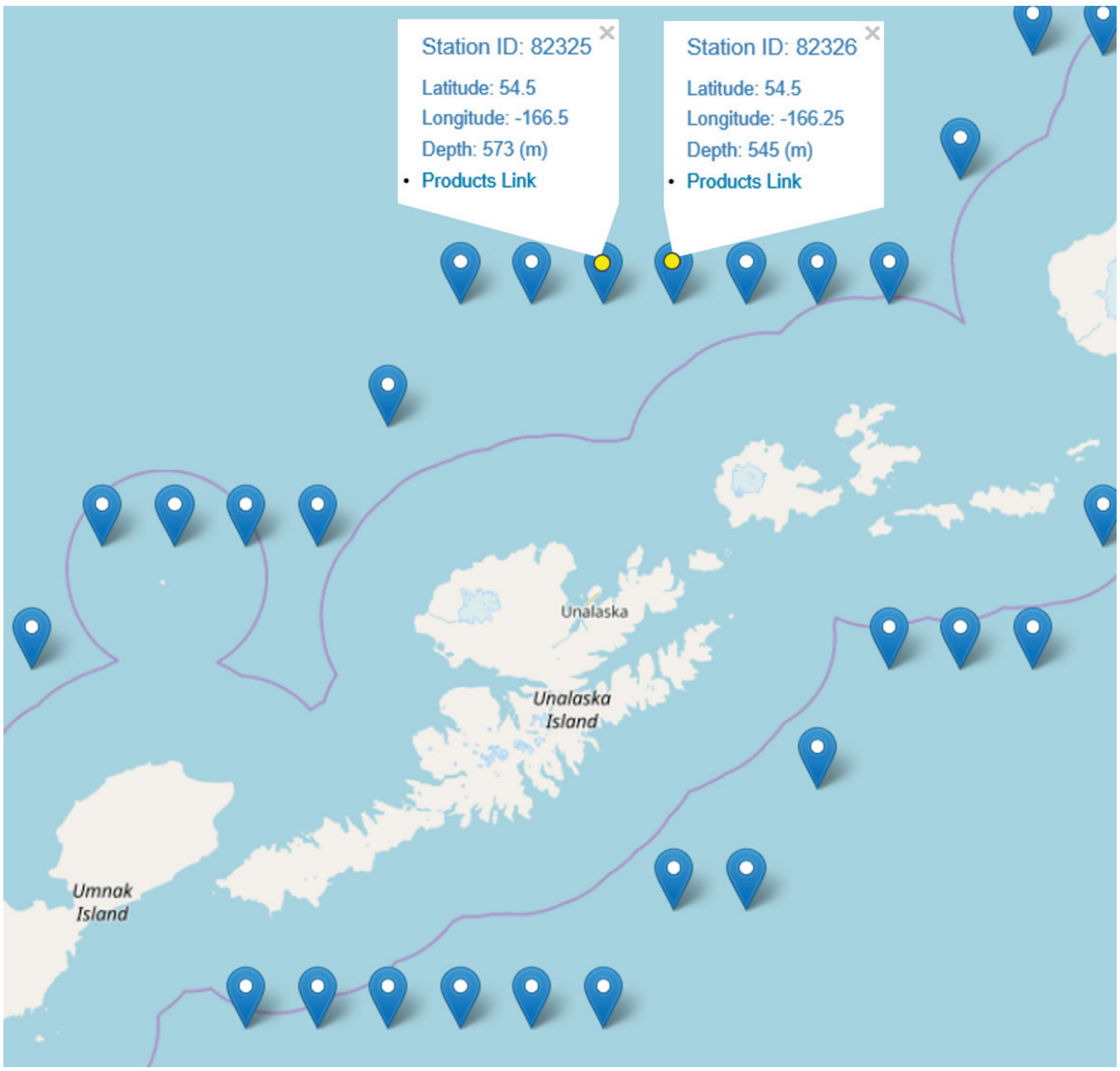

Figure 7: WIS Point Locations Chosen for Study

Wave information studies (WIS) stations 82325 and 82326 were chosen for this study because their locations are such that waves generated at these sites have a clear path to Iliuliuk Bay. Only wind and waves from 0° to 67.5° were considered, as all other directions would be protected by geography of the island. As seen from Figure 8 to Figure 12, wind and waves occur with a lower magnitude at a lower frequency in this direction.

The difference in data from stations 82325 and 82326 is less than 1 percent; the data for the stations are averaged together in Table 7 and Table 8. Table 7 gives a summary of information presented in the wave roses. Table 8 gives a summary of information presented in the wind roses. Wind blows between directions 0° and 67.5° approximately 21.4 percent of the time, and 8.5 percent of the time in that direction the wind is stronger than 19.3 knots (10 m/s).

Table 7: Frequency of Wave Heights and Periods Recorded at Stations 82325 & 82326

Wave Height (m)	Wave Height (ft)	Wave Period (seconds) < 5.0	5.0 - 11.9	12.0 <	Total
0.1 - 0.5	0.3 - 1.6	1.1%	0.9%	0%	2.0%
0.5 - 1.0	1.6 - 3.2	3.5%	8.8%	0.4%	12.8%
1.0 - 1.5	3.3 - 4.9	2.0%	14.7%	0.8%	17.5%
1.5 - 2.0	4.9 - 6.5	0.4%	16.3%	0.7%	17.3%
2.0 - 2.5	6.6 - 8.2	0.1%	13.9%	0.3%	14.2%
2.5 - 3.0	8.2 - 9.8	0%	10.3%	0.1%	10.4%
3.0 - 0.5	9.8 - 1.6	0%	7.1%	0.1%	7.2%
3.5 - 4.0	11.5 - 13.1	0%	5.4%	0.1%	5.4%
4.0 - 4.5	13.1 - 14.7	0%	3.8%	0.1%	3.9%
4.5 - 5.0	14.8 - 16.4	0%	2.7%	0.1%	2.7%
5.0 - 6.0	16.4 - 19.7	0%	3.5%	0.1%	3.7%
6.0 - 7.0	19.7 - 22.9	0%	1.3%	0.3%	1.7%
7.0 - 8.0	23.0 - 26.2	0%	0.3%	0.4%	0.7%
8.0 - 9.0	26.2 - 29.5	0%	0.1%	0.2%	0.3%
9.0+	29.5+	0%	0%	0.1%	0.1%
Total		7.1%	89.2%	3.7%	100.0%

Table 8: Frequency of Wind Speed and Direction Recorded at Stations 82325 & 82326

Wind Direction	Frequency of Wind Speed < 11.1 (mi/hr) < 9.6 (knots) < 4.9 (m/s)	11.2 - 22.3 (mi/hr) 9.7 - 19.3 (knots) 5.0 - 9.9 (m/s)	22.4 - 27.9 (mi/hr) 19.4 - 24.2 (knots) 10 - 12.4 (m/s)	28.0 - 33.4 (mi/hr) 24.3 - 29.0 (knots) 12.5 - 14.9 (m/s)	33.5 < (mi/hr) 29.1 < (knots) 15.0 < (m/s)	Total Frequency of Wind Speed
0°	1.1%	2.7%	1.1%	0.9%	0.8%	6.7%
22.5°	0.9%	2.3%	0.8%	0.5%	0.5%	5.1%
45°	1.0%	2.1%	0.8%	0.6%	0.4%	4.9%
67.5°	0.8%	2.0%	0.9%	0.5%	0.5%	4.7%
Total	3.8%	9.1%	3.6%	2.6%	2.3%	21.4%

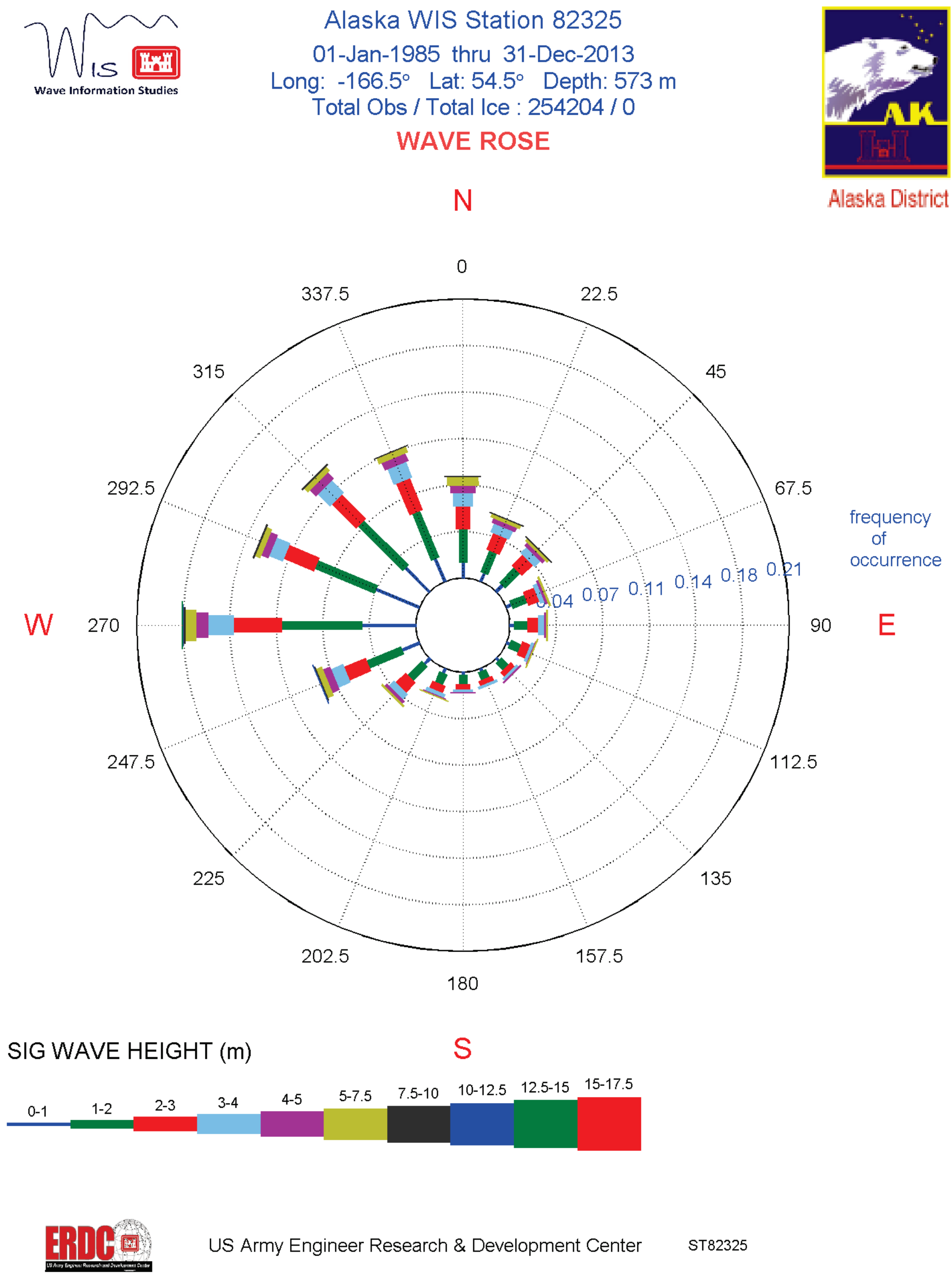

Figure 8: Wave Rose for Station 82325

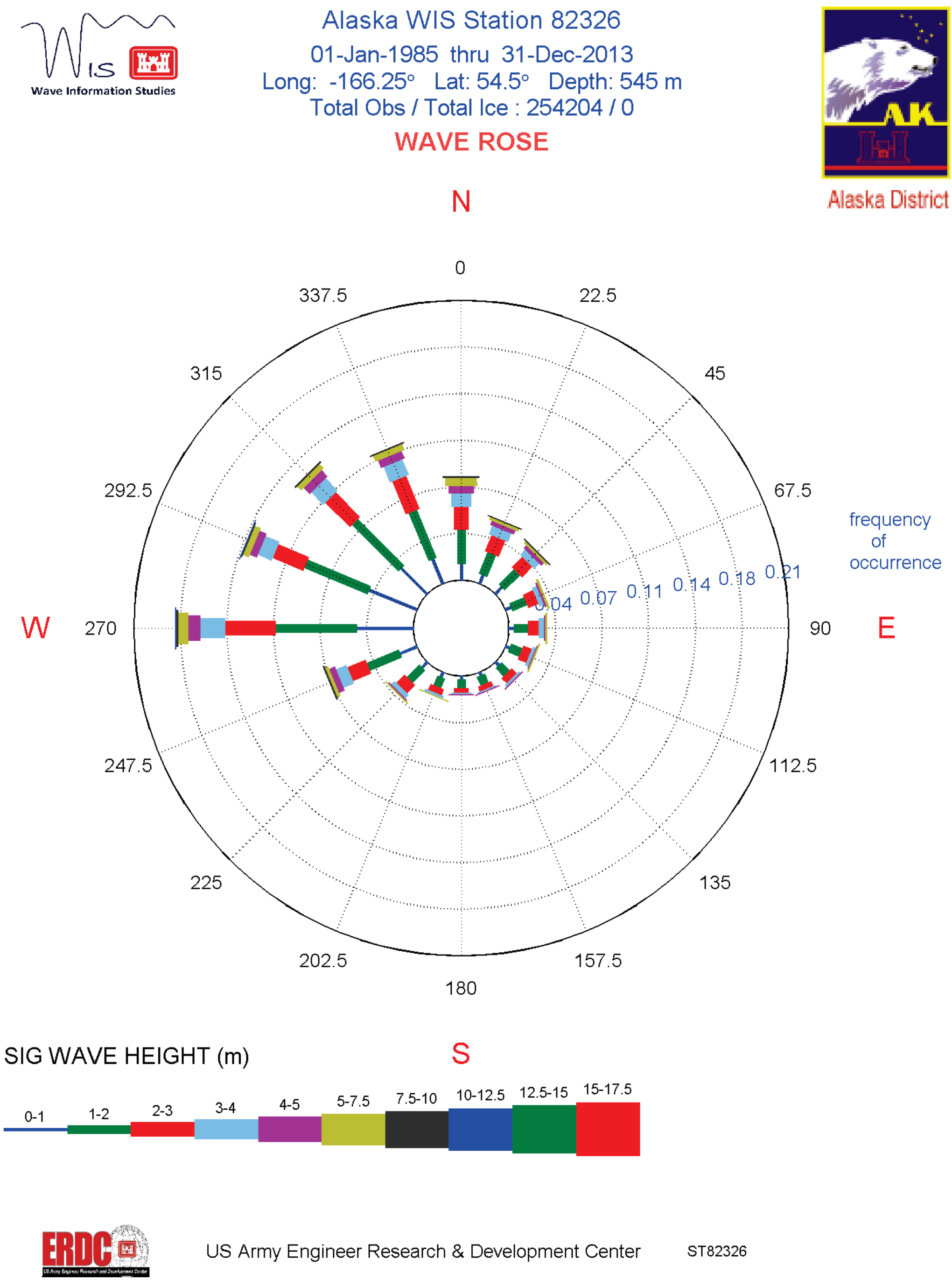

Figure 9: Wave Rose for Station 82326

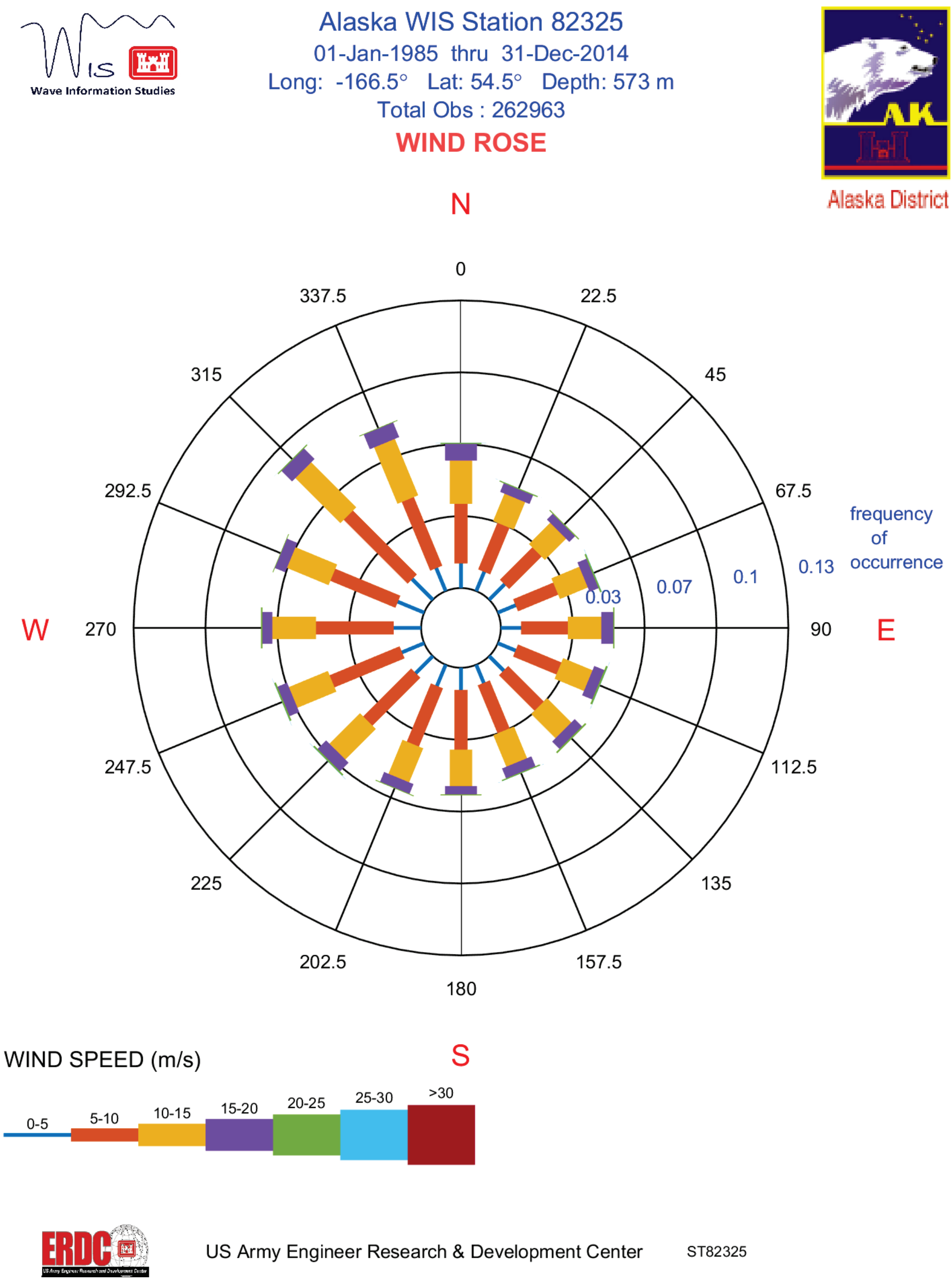

Figure 10: Wind Rose for Station 82325

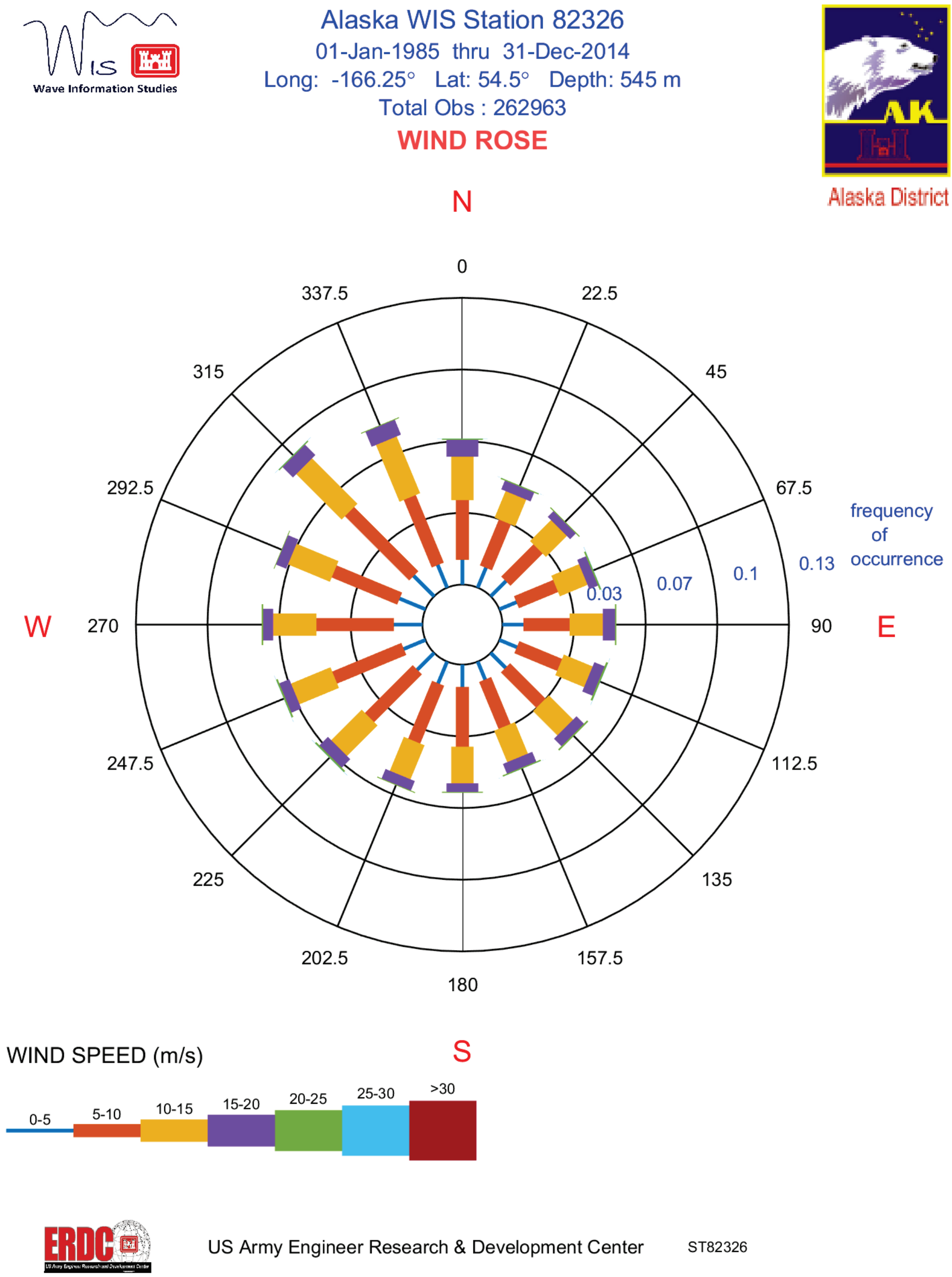

Figure 11: Wind Rose for Station 82326

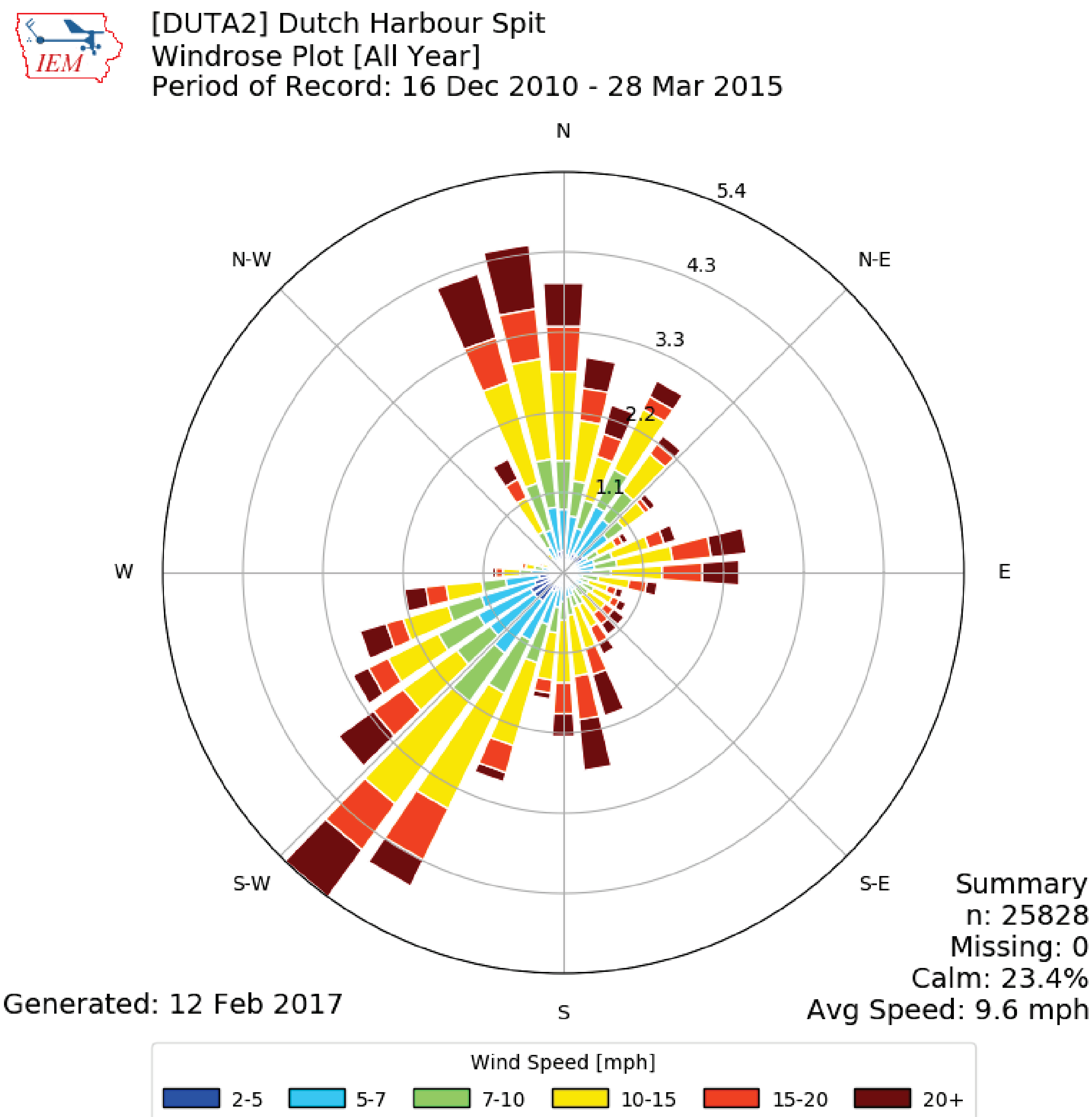

Figure 12: Wind Rose for Station DUTA2

6.2 Design Vessel Criteria

Design vessels are determined by examining the size of ships currently calling at 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.

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 are given in Table 9. Vessels of this type currently light load from point of origin in order to clear the bar and enter Dutch Harbor.

Table 9: Design Vessel for Deepening and Widening

	Design Vessel - APL Holland	
	Feet	*Meters*
Length Overall	909.6	277.3
Beam	131.4	40.0
Design Draft	45.9	14.0
Vessel Draft	44.0	13.4

Current practice is for vessels to light load from point of origin to a minimum draft of 40 feet to clear the bar. Local knowledge states that vessels require a minimum clearance of 4 to 7 feet (1.2 to 2.1 meters) 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 10 below were tracked for 1 year (1/1/2016 – 1/1/2017) as they called at Dutch Harbor. The Automatic Identification System Analysis Portal (AISAP) uses automatic identification system (AIS) data to display ship tracks queued over an area of interest for a given amount of time. The ship tracks over the bar are displayed in Figure 13, with the location of the channel to be dredged appearing in red. The width between the two outer bound ship tracks over the bar is approximately 1,200 feet.

Table 10: Lightly Loaded Vessels Calling on Dutch Harbor

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

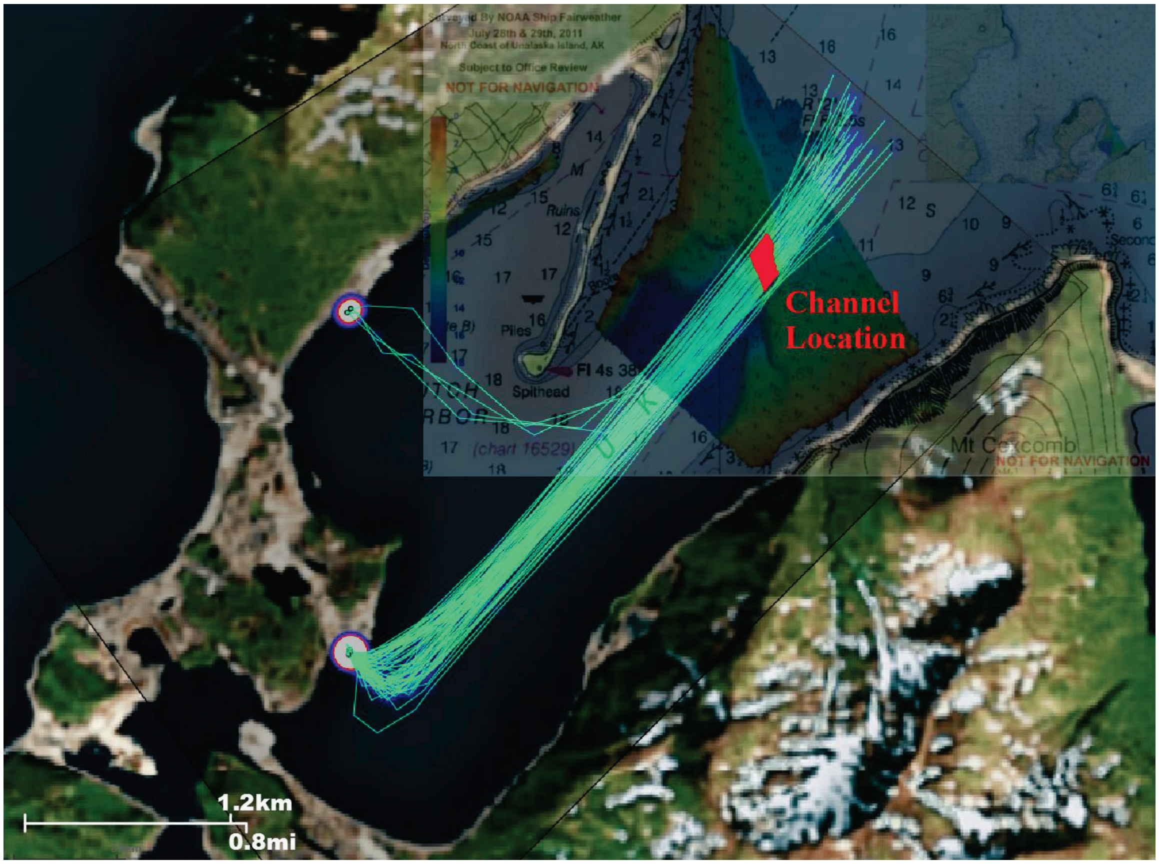

Figure 13: Channel to be Dredged overlaid on AIS Ship Tracks

6.3 Configuration and Use

The channel design is a straight channel 600 feet wide and approximately 400 feet long. The channel follows the alignment of the current route traveled over the bar by light loaded vessels. Vessels do not require tug assistance traveling over the bar. Ship simulation is being performed and will determine if the channel configuration is adequate and appropriate.

6.3.1 Channel Width

USACE guidance (EM 1110-2-1613) sets the channel at a width of 560 feet (180 meters) based on one way traffic, constant shallow channel cross section, average aids to navigation, and currents between 0.5 and 1.5 knots. The channel cross section is considered shallow water due to Iliuliuk Bay being a wide, unrestricted waterway without channel banks. Anecdotal information indicates that currents in the bay are minimal. These design criteria produce beam multiplier of 4.5 (see Table 11). A beam of 131 feet (40 meters) and a multiplier of 4.5 produces a channel width of 560 feet (180 meters).

Table 11: 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. The PIANC width detailed in Table 12 shows the need for an approximate width of 660 feet (200 meters). The final channel width was set at 600 feet.

Table 12: PIANC Width Factors

Condition	Site Description	Width Factor
Vessel Speed (knots)	Slow (5-8)	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

Ship simulation will be performed at the Coastal Hydraulics Laboratory to determine whether the design channel width and location is sufficient.

6.3.2 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, vertical motion due to waves, and water density effects. Minimum under-keel clearance was calculated from the sum of the depth requirement from each design parameter.

The final channel depth is determined by comparing economic benefits to costs for depths of 46, 48, 50, 52, 56, and 58 feet. All vessels currently calling on Dutch Harbor were represented. Vessels had a maximum design draft of 45.9 feet (14.0 meters);

however, loading was limited to 44.0 feet (13.4 meters) 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 loaded to 44.0 feet could enter or depart Dutch Harbor at any stage of tide without delay. 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 PIANC guidance. 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. Dimensions of vessels representative of the fleet to call are presented in Table 10. The dimensions chosen for the design vessel (Table 9) are a length over all (LOA) of 909.6 feet (227.3 meters), a beam (width) of 131.4 feet (40.0 meters), and a static design draft of 44.0 feet (13.4 meters).

Figure 14 illustrates the increments of channel depth design. The optimum elevation of an excavated channel bottom is determined by economic criteria.

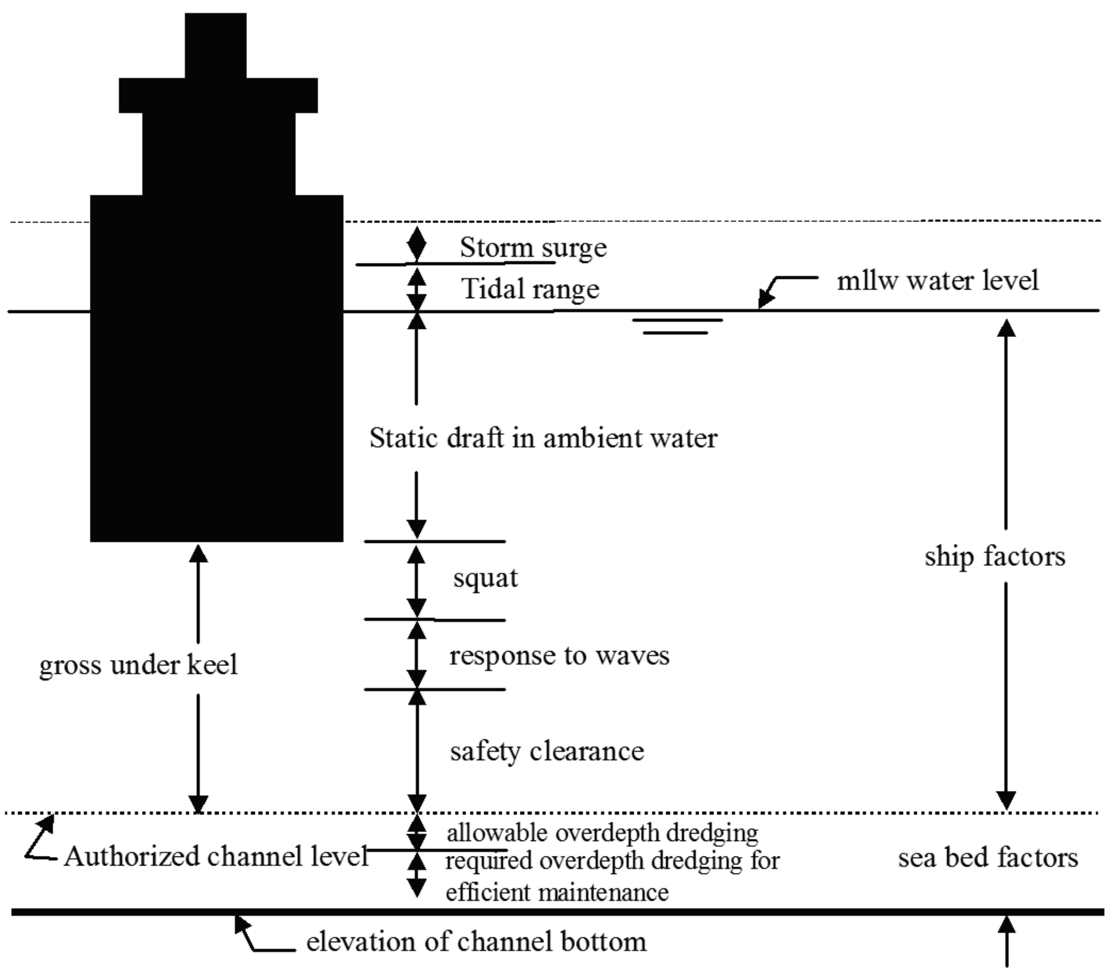

Figure 14: Channel Design Parameters

6.3.3 Ships Factors

Draft.
APL and UMC City Dock require 1 foot (0.3 meters) of clearance at a depth of 45 feet (13.7 meters). Therefore, a maximum draft of 44 feet (13.4 meters) 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. Computations for prediction of squat assume a typical container vessel block coefficient of 0.7, channel width of 600 feet (182.9 meters), water depth of 52 feet (15.8 meters), vessel length of 909.6 feet (277.3 meters), vessel beam of 131.4 feet (40 meters), vessel draft of 44 feet (13.4 meters), and vessel speed of 5.5 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 0.5 feet (0.16m), 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. This 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, $K = 5.74S^{0.76}$, and S is the blockage factor coefficient, predicting a squat value of 1.4 foot (0.42m). A squat allowance of 1.0 feet (0.3 meters) for the channel is estimated for the design ship.

Response to Waves. USACE guidance 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 4-foot (1.2 meter) design wave, the effects of pitch, roll, and heave are calculated at 5.8 feet (1.8 meters).

A second method of evaluating wave-induced motions is the trigonometric method in PIANC. 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 4-foot (1.2 meter) design wave, the effects of pitch, roll, and heave are 8 feet (2.4 meters). A ship response to wave value of 6 feet (1.8 meters) was determined to be reasonable. A wind and wave hindcast study are underway and will be used to further evaluate wave heights over the bar, and in turn clarify ship response to waves.

Safety Clearance. USACE guidance suggests a minimum net under-keel clearance of 2 feet (0.61 meter); however, for hard bottom conditions such as rock, consolidated sand or clay, 3 feet (0.91 meter) of net under-keel 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 under-keel clearance of 3.3 feet (1.0 meter). Based on the description of the material and the geotechnical sampling data, a safety factor of 3 feet (0.91 meter) was used for this analysis.

Total Clearance. The subtotal of squat, response to waves, and safety clearance for the channel provides a design depth of 10.0 feet (3.0 meters). This would deepen the bar to -52 feet MLLW. At this time, response to waves is not included in the channel depth analysis, and a depth of -48 feet MLLW is recommended.

The depth of 48 feet (14 meters) recommended in the Economic appendix takes into account 4 feet (1.2 meters) of clearance over the bar per guidance given by the Alaska Marine Pilot’s Association. Recent inquiries reveal that this number may be out of date, and a recent polling of vessels traversing the bar have required between 4 and 7 feet (1.2 to 2.1 meters) of clearance. Further investigation is necessary to align the economic and engineering differences in depths.

Dredging equipment and procedures cannot provide a smoothly excavated bottom at a precisely defined elevation. Two feet (0.3 meters) of allowable over depth dredging was added to the target depth of excavation to guarantee mariners a least-depth equivalent to the sum of ship factors. This allows for a deepening of the bar to a maximum of -54 feet MLLW. Cross sections of the channel showing the dredged area and dredging tolerance for the economics depth of -48 feet MMLW are shown in Figure 15, with locations of where the cross sections are taken in Figure 16.

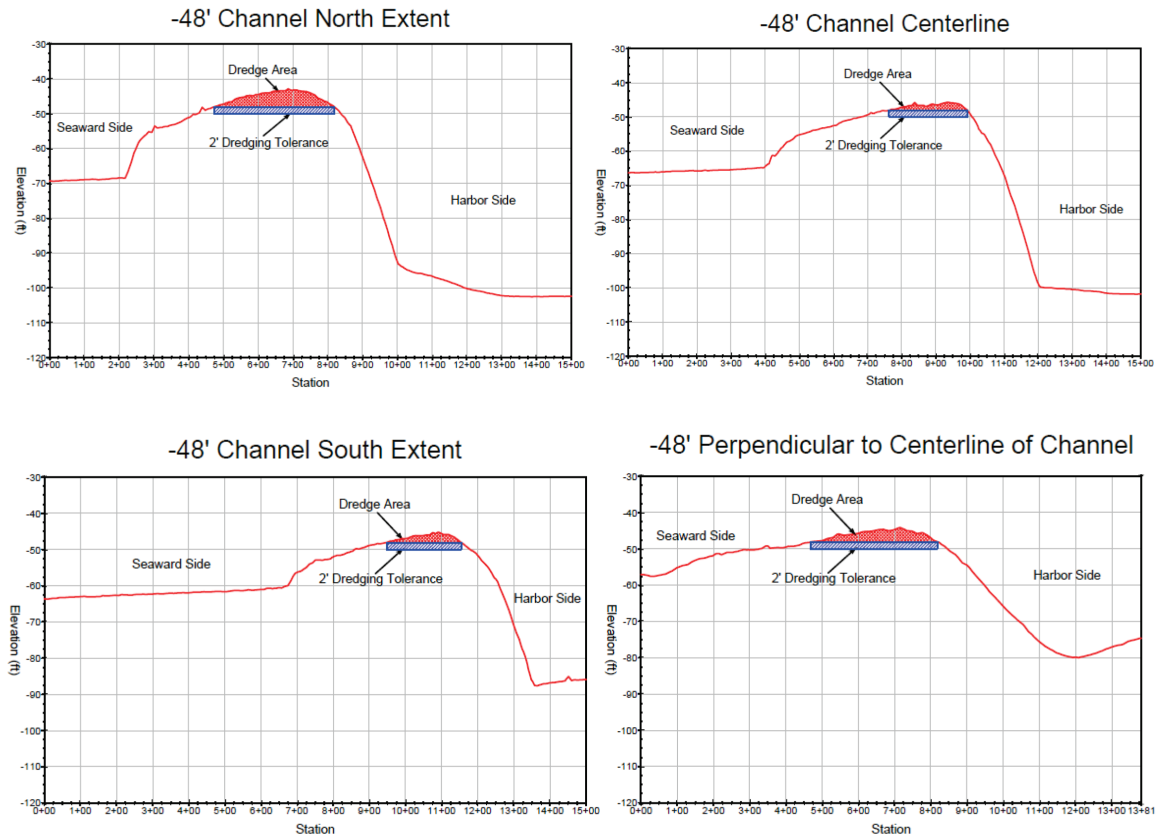

Figure 15: Profile View of Dredge Channel -48'MLLW Depth

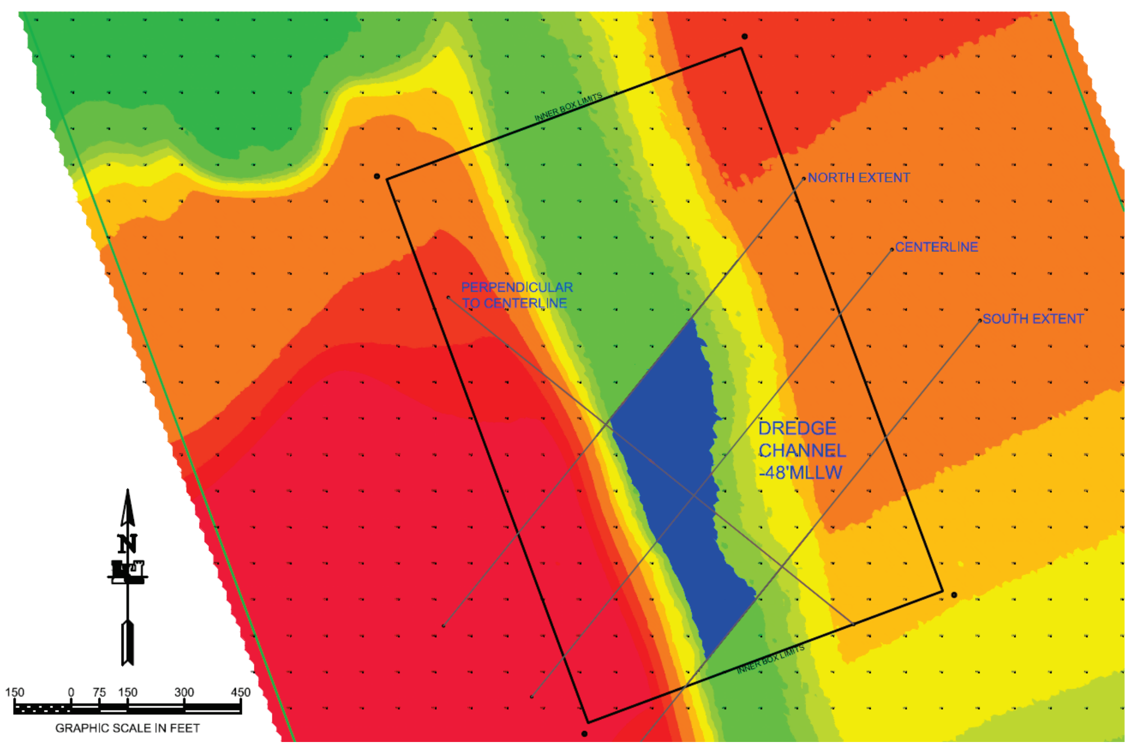

Figure 16: Plan View of Dredge Channel at -48'MLLW Depth

6.3.4 Channel Location

The channel for access to Dutch Harbor is nearly perpendicular to the bar. The centerline of the design channel was placed to follow the centerline of the light loaded vessel tracks (Figure 13).

Future SBEACH modeling will investigate how waves entering Dutch Harbor will change with a maximum 12-foot (3.7 meter) deepening at the bar. If it is determined that erosion could occur at Front Beach, erosion control methods will be addressed.

6.3.5 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. See geotechnical appendix for more information.

6.4 Initial Dredging Quantity

The initial dredging quantity would vary with channel depth and location. Table 13 shows the channel quantities associated with each scenario. The quantities presented include a 2-foot dredging tolerance due to the inaccuracies of blasting. For the chosen depth of -48 feet MLLW, 27,500 cubic yards (21,025 cubic meters) of material would need to be dredged. Due to the relatively small area being dredged, an increase in depth results in a nominal increase in dredging quantity.

Table 13: Initial Dredging Quantities

Dredge Depth		Dredge Surface Area		Dredge Quantity	
Feet	*Meters*	*Square Yards*	*Square Meters*	*Cubic Yards*	*Cubic Meters*
-46	-14.0	6,400	5,400	12,000	9,200
-48	-14.6	16,600	13,900	27,500	21,000
-50	-15.2	24,200	20,200	47,200	36,100
-52	-15.8	28,300	23,700	61,600	47,100
-54	-16.5	34,900	29,200	95,200	72,800
-56	-17.1	38,600	32,300	122,000	93,300
-58	-17.7	40,700	34,000	153,600	117,400
-66	-20.1	87,200	72,900	333,200	254,800

6.5 CHANNEL NAVIGATION

6.5.1 Analysis of Currents With Respect to Navigation

Ship simulation is being performed with currents at increments 0 knots, 0.5 knots (0.25 m/s), 1.0 knots (0.5 m/s), and 1.5 knots (0.75 m/s), with both ebb and flow tides. Results are to follow once the simulation is completed.

6.5.2 Joint Probability of Currents and Wind

Ship simulation is being performed with incremental currents described above in conjunction with the four worst case wind magnitude and directions described in Table 4.

6.5.3 Ship Simulation

Ship simulation using a real time ship simulator, where events on the simulator require the same amount of time as they do in real life, will be used to evaluate the channel. The ship simulation was scheduled to be performed January 22-28, 2018, but was rescheduled to February 26-March 2 due to the Federal Government shutdown.

The simulations began with a design session used to test the model for reasonableness. Two pilots from the Alaska Marine Pilots Association who work at Dutch Harbor participated in the design session.

The 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 forces. 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.

The model will consist of the channel with a width of 600 feet. Two ships will be used in the evaluation for the bulk concentrate ships: a 41.7-foot (12.7-meter) draft ship and a 49.2-foot (15.0-meter) draft ship. The 41.7-foot (12.7 meter) draft ship had similar ship dimensions to the design ship for the site; however, the draft was shallower than the 44-foot (13.4-meter) draft design vessel. The 49.2-foot (15.0-meter) draft ship had a similar design draft, but its length and beam were larger than the design ship. To resolve the problem, both ships were used. A fully loaded fuel tanker was also simulated. Dimensions of the ships used in the simulator are listed in Table 14.

Table 14: Ship Simulation Vessel Dimensions

	Vessel CNTNR21L		Vessel VLCC15L	
	Feet	*Meters*	*Feet*	*Meters*
Length Overall	935.0	285.0	859.6	262.0
Beam	131.0	39.9	137.8	42.0
Design Draft	41.7	12.7	49.2	15.0

6.5.4 Vessel Motion in the Dredged Channel

To be described following ship simulation results.

6.5.5 Navigation Aids

To be described following ship simulation results and coordination with the Coast Guard.

6.6 Disposal of Dredge Material

Figure 17 shows the proposed dredged material disposal areas. The sites in question range in depth from 102 to 204 feet (31 to 62 meters), approximately 6,000 to 14,000 feet (1,829 to 4,267 meters) 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.

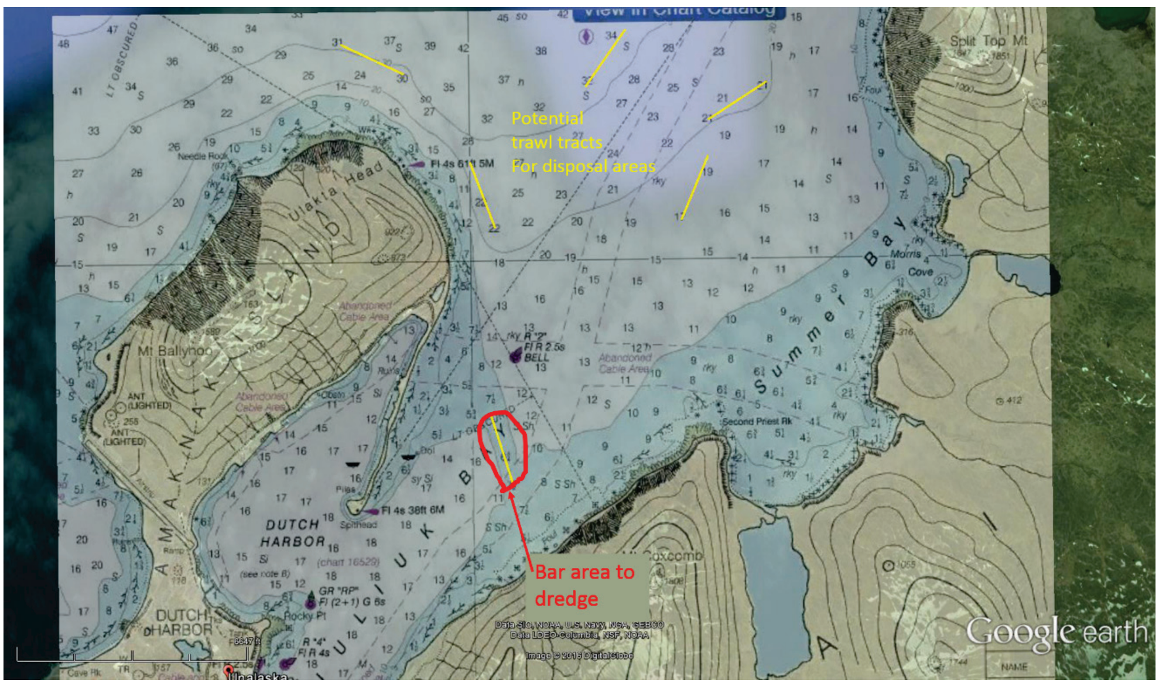

Figure 17: Potential Dredging Disposal Sites

7.0 GEOTECHNICAL CONSIDERATIONS

7.1 Site Geology and Soils

To be described.

8.0 CHANNEL MAINTENANCE

Historic NOAA bathymetry for Dutch Harbor is available for the past 100 years. A comparison will be made of the bathymetry to confirm whether any sediment has migrated from the seaward side of the bar to the harbor side. If there is evidence of movement, wave analysis will be performed to verify whether sand can be moved at this depth. Estimates of dredging maintenance quantities will be determined from this model.

Initial comparisons of NOAA bathymetry dating back from 1934 indicate that an average of 68,000 cubic yards (51,990 cubic meters) of material will infill the dredged area in 20 years.

8.1 Channel Sedimentation

8.1.1 Side Slope Sloughing

Side slopes of the channel are not expected to deteriorate from the 1 on 2 constructed slopes due to the consolidated nature of the material.

8.1.2 Overdepth Dredging Options

To be described following sediment movement analysis results.

8.1.3 Overdepth Dredging For Efficient Maintenance

To be described following sediment movement analysis results.

9.0 CONSTRUCTION CONSIDERATIONS

To be described.

9.1 Construction Considerations

To be described.

10.0 RISK AND UNCERTAINTY

To be described.

11.0 CONCLUSIONS AND RECOMMENDATIONS

To be described.

11.1 Conclusions

To be described.

11.2 Recommendations

To be described.

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