Draft Integrated Feasibility Report
and Environmental Assessment and Draft Finding of No Significant Impact

APPENDIX A: HYDROLOGY AND HYDRAULICS

Whittier, Alaska

June 2018

US Army Corps
of Engineers
Alaska District

APPENDIX A
HYDRAULIC DESIGN

TABLE OF CONTENTS

TABLES

FIGURES

ATTACHMENTS

1.0 INTRODUCTION

1.1 Draft Appendix Purpose

This draft appendix describes the hydraulic design of select alternatives for navigation improvements at Whittier, Alaska. It provides the hydraulic background for determining the engineering feasibility in the major construction features including water levels, wind and wave analyses, engineering design criteria and structure design.

1.2 Project Purpose

The City of Whittier requested the Corps of Engineers conduct a feasibility study of navigation improvements in Whittier, Alaska. Additional launch ramps and moorage space for commercial fishing boats has been identified as necessary to reduce vehicle traffic congestion, vessel delays, vessel damage associated with rafting, and to increase the overall efficiency of the fishing industry in Whittier.

2.0 PHYSICAL SETTING

2.1 Geography

The City of Whittier and Passage Canal are located in the northwestern part of Prince William Sound in South Central Alaska (Figure A-3). Whittier is located 59 miles southeast of Anchorage by road. Travel to Whittier is accomplished by vehicle, rail, ferry, and infrequently by small plane. The most common modes of transportation, vehicle and rail, must utilize the Anton Anderson Tunnel, a state owned 2.5 mile long one-way combination rail and vehicle tunnel.

The town of Whittier is located on the fan-shaped delta of Whittier Creek at the southwestern end of Passage Canal. The project site is located roughly 1 mile west of town at the head of Passage Canal, just north of the local gravel airstrip.

The project site is located on glacial till that was deposited during advances of Learnard Glacier. The material is moderately to highly permeable allowing rapid infiltration of surface water and precipitation. Cobbles and boulders are common on the upland area and boulders large than 10 feet across have been seen. The beach material is generally coarser than that of the upland area. Beach surface materials consist of large portions of gravel with sand, cobbles and boulders. The coarser beach material is likely a product of wave erosion during storms.

2.2 Climatology

2.2.1. Temperatures. Whittier has a maritime climate characterized by cool summers and mild winters. Whittier's annual mean temperature is 41°F; average July temperatures range between 51° F and 63° F, while in the average January temperature ranges between 23° F and 31°F.

2.2.2. Precipitation. The average annual precipitation in Whittier is just over 185 inches, with nearly 70 inches of that total falling as snow from November through March. Whittier has an average annual snowfall is 257 inches. Fog is common year-round, due to the cold air generated by glaciers in the mountains interacting with the warmer air over the waters of Passage Canal.

2.2.3. Winds. Strong winds are driven through Portage Pass by air mass exchanges between Cook Inlet and Prince William Sound and by temperature differentials induced by glaciers above Whittier. Winds are generally from the east and northeast sectors. These directions are aligned with Portage Pass to the southwest and Passage Canal to the northeast.

2.3 Oceanography

Passage Canal is located in the northwest corner of Prince William Sound. Passage Canal is a deep fjord, approximately 12 miles in length. Passage Canal is fairly straight except for a large bend that occurs near it connection with Prince William Sound. The bend in Passage Canal effectively filters out much of the wave energy generated in the sound, limiting the wave climate in western Passage Canal. From the bend, Passage Canal extends approximately 6 miles southwest toward to the fjord's terminal end and Whittier. The fjord is roughly 1-1/4 miles wide and has a mean depth of about 100 fathoms with an extreme depth of 190 fathoms. The depth shallows slowly, roughly 60 feet per mile, from the entrance to approximately quarter mile from the head of the fjord and then slopes upwards much faster, from roughly 50 fathoms to shore in the last 1/4 mile of the fjord.

2.4 Water Levels

2.4.1. Tides. Tide datums at Whittier, referenced to mean lower low water (MLLW), are provided in Table A.1. The tidal datums shown below are based on the 1983-2001 tidal epoch.

Table A-1. Tidal Datums, Whittier, Alaska

Tide	Elevation (feet MLLW)
Highest Astronomical Tide	15.83
Mean Higher High Water	12.19
Mean High Water	11.27
Mean Sea Level	6.52
Mean Low Water	1.49
Mean Lower Low Water (datum)	0.00
Lowest Astronomical Tide	-3.92

2.4.2. Sea Level Change. Engineer Regulation (ER) 1100-2-8162 states that potential sea level rise must be considered in every USACE coastal activity. Studies and designs must consider multiple sea level rise scenarios to deal with uncertainties within the estimates. The sea level rise scenarios include a “low” estimate which corresponds to the historic rate of sea level rise, an “intermediate” estimate which corresponds to the modified NRC Curve I, and a “high” estimate which corresponds to the modified NRC Curve III. The intermediate sea level rise estimate was incorporated into all alternative designs (Figure A-1).

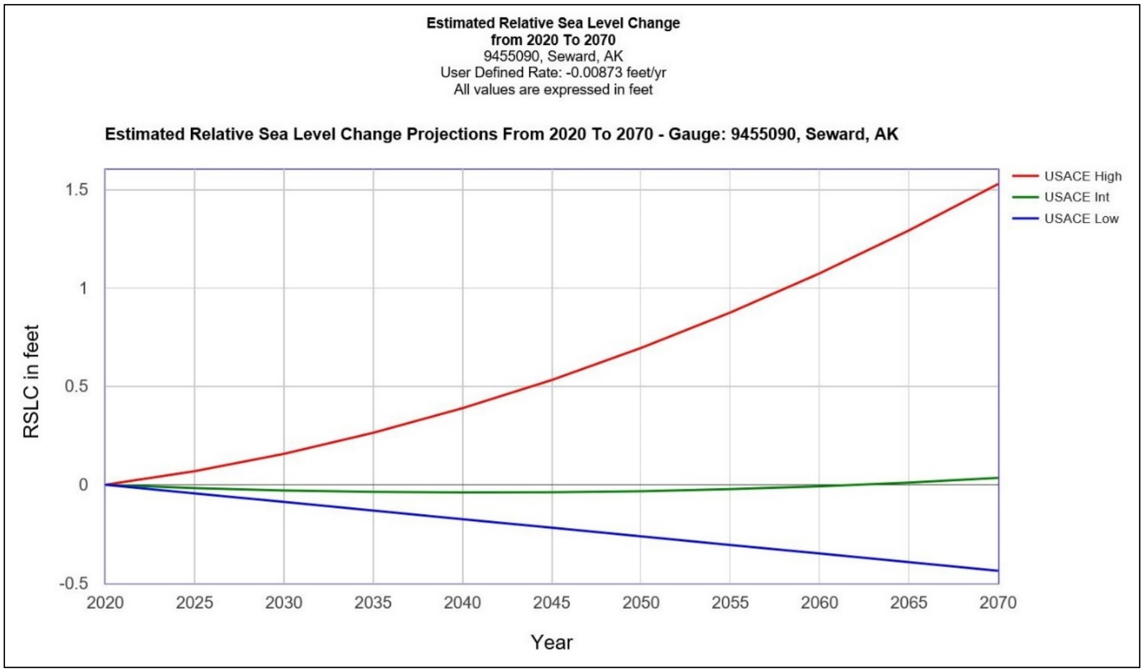


Figure A-1. Estimated Sea Level Rise

Whittier does not have a continuously operating tide station. The closest tide station with a sufficient period of record is station 9455090 Seward, Alaska. The NOAA analysis of historic sea level data for station Seward shows a decrease in sea level during the analysis period of 1964 through 2017 (Figure A-2). The mean sea level trend is -2.53 mm/yr with a 95% confidence interval variance of 0.68 mm/yr.

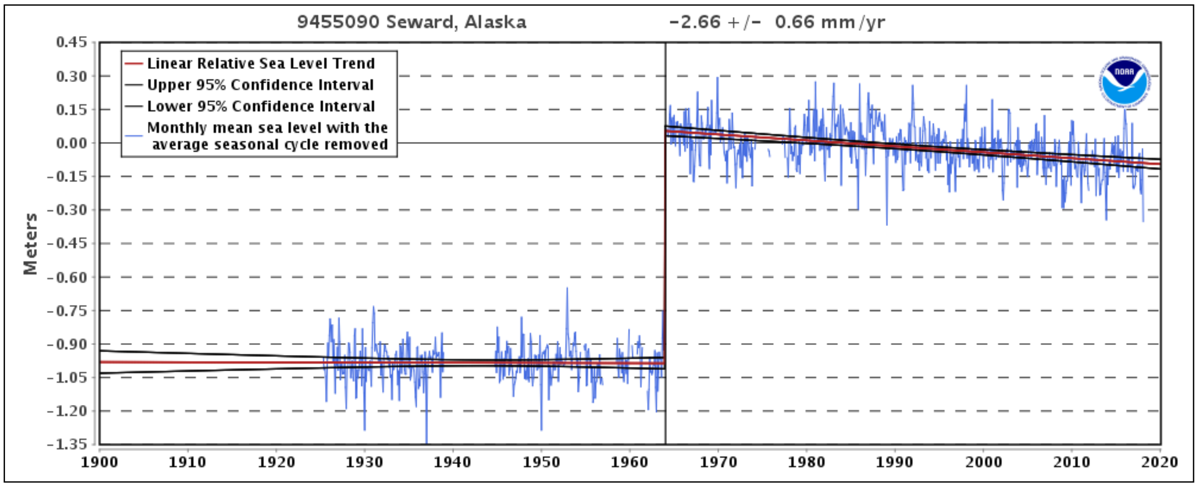


Figure A-2. NOAA Analysis of Sea Level Trend for Station 9455090 Seward, AK

For the standard project design life of 50 years the "low" estimated sea level rise is -0.44 feet, the "intermediate" estimated sea level rise is +0.04 feet, and the "high" estimated sea level rise is +1.53 feet. The historical sea level trend and the CNR low curve indicate a decreasing sea level, while the NRC intermediate and high curves indicate increases in sea level.

Impacts of the "low" estimated sea level rise would include minor reduction in water levels. The low (historic) sea level rise estimate would result in minor reductions in project water depths at the end of project life. Potential project alternatives would experience minor reductions in channel and mooring depths.

Impacts of the "intermediate" estimated sea level rise would include negligible decreases and increases in water levels. The negative and positive changes in water depth would not be noticed during the project life. Potential project alternatives would experience minor increases in channel and mooring depths and little to no over topping of wave protection structures during a design event occurring near the end of project life.

Impacts of the "high" estimated sea level rise would include a significant increase in water level. Potential project alternatives would experience increases in channel and mooring depths and over topping of wave protection structures during a design event occurring especially during the latter half of project life. The potential for damages to wave protection structures during the design event and smaller events would be increased.

2.4.3. Storm Surges. Storm surge is the change in sea level due to meteorological effects including wind stress and atmospheric pressure differentials.

Since Passage Canal is a deep fjord, it does not experience significant storm surges due to wind stresses. Storm surge can be shown to be inversely dependent on water depth. That is, for a given wind speed, storm surge is less in deep water than in shallow water. To reinforce this assertion, to the study team's knowledge, no one has indicated that storm surge has been, or should be, of concern in Whittier. No historical record of storm surge activity is known to exist. There may be a surge elevation of up to a foot on occasion due to atmospheric pressure differentials. We have included a value of about 1.0 foot to account for this possibility; however, there is no direct correlation that these pressure-induced surges would occur at the same time as large-wave generating winds.

2.5. Currents

Current flows in Passage Canal are normally tidally generated. Tidal velocities are generally less than one knot.

2.6. Ice Conditions

Passage Canal is an ice-free water body. Existing harbors in Whittier remain ice-free the entire year.

2.7. Wind Data

Twenty-one years (1988-2009) of meteorological records were acquired from NOAA's National Weather Service (NWS). The wind recorder was located next to the Harbor masters office. The site is no more than 25 yards from the water with little or no obstruction. The anemometer was located on a tower which was attached to a pavilion adjacent to the harbormasters office. Due to its proximity to the water, no "over water" correction was used. According to the NWS, the anemometer was located 25 feet above sea level. The Air Force Combat Climatology Center performed an extreme value analysis and produced return interval wind speed tables for each of the eight direction sectors.

Since the compass was divided into eight directional sectors, each sector consisted of 45 degree increments. For example, north, in fact, consists of the averages for the wind speeds between 337.5° and 22.5°, northeast is the average for the speeds between 22.5° and 67.5°, and so on for the other six sectors.

Four wind directions were originally analyzed in detail (north, northeast, east, and southeast). The other four directions came directly off the land and would not generate waves of any significance for these proposed project sites.
The wind data values were adjusted to the 10 meter elevations standard. The adjustment for elevation was conducted according to:

$$U_{10} = U_z \left(\frac{z}{10} \right)^{1/7}$$

where z represents the height of the anemometer above ground in meters and U_{10} and U_z are the wind speeds at a height of 10 and z meters, respectively.

The data consisted of hourly winds speed and direction entries that, according to NWS should represent 2-minute means for the period when the observation was made. Because these wind averages are for a duration of less than one hour, they are converted to their 1-hour average equivalent. The conversion used was that shown in the Coastal Engineering Manual for Ratio of wind speed of any duration. The 2-minute to 1-hour wind speed conversion was $U_{3600}/U_2 = 1.17$. The conversions resulted in the standardized wind speed table (Table A-2) for various return periods.

Table A-2. Maximum Wind Speed (Knots) for Selected Return Periods (Yrs)

Return Period	Wind Direction Sector			
	North (340º -20º)	Northeast (25º -65º)	East (70º -110º)	Southeast (115º -155º)
2	26.3	42.3	40.2	39.4
5	38.6	51.9	53.2	49.2
10	45.8	58.2	63.0	57.7
20	52.0	64.1	72.9	65.6
50	59.4	71.5	85.9	75.2
100	64.6	76.9	95.7	82.1

2.8. Littoral Drift

There are no indications that littoral transport is significant at the proposed project site. The shorelines in the vicinity of the proposed harbors consist of gravel and cobbles. It is not easily transported as littoral material. Two glacial creeks, Learnard Glacier Creek on to the north and Shakespeare Creek on the south of the project area, transport the sediments to Passage Canal. Both creeks have limited areas of sedimentation that are be avoided by most of the alternatives. Sediment transport and shoaling caused by these streams is expected to be minimal and impacted alternatives include sediment control measures.

3.0 WAVE STUDIES

3.1 Normal Wave Conditions

Since the proposed harbor will be located along the west shore of Passage Canal, only winds from four sectors (north, northeast, east, and southeast) were considered for this analysis. Winds from overland directions were considered to have no impact on the project site.

Wave heights were calculated using the STWave program. 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 Passage Canal and 50-year return interval wind speeds were input to model locally generated waves in STWave. Separate model grids were generated for the four compass sectors applicable to the head of the bay site. Model runs were evaluated at a design still water level including Mean Higher High Water (MHHW) level and applicable storm surge. The calculated wave height represents the significant wave height, Hs, which is the average of the highest one-third of all waves.

Table A-3 shows the fetches and their associated angles (relative to true north) that were used for each compass sector. The point in Passage Canal where these waves apply is the general area of the head of the bay site, applicable to all of the alternatives located therein.

Table A-3. Fetch Lengths (miles) and Directions Used to Model Wave Conditions.

Fetch No.	Compass Sectors							
	North		Northeast		East		Southeast	
	Dir	Len	Dir	Len	Dir	Len	Dir	Len
1	340	0.38	25	0.69	70	10.32	115	0.56
2	345	0.40	30	0.76	75	3.95	120	0.55
3	350	0.42	35	0.81	80	3.11	125	0.52
4	355	0.44	40	0.94	85	2.44	130	0.46
5	0	0.45	45	1.25	90	2.15	135	0.43
6	5	0.47	50	2.01	95	1.85	140	0.41
7	10	0.48	55	3.53	100	0.36	145	0.41
8	15	0.55	60	6.81	105	0.81	150	0.40
9	20	0.61	65	6.81	110	0.60	155	0.39

Table A-4 presents the results of the STWAVE modeling. Significant wave heights and periods for the given directions and wind speed classes.

Table A-4. STWave Modeled Wave Heights and Periods

	Wind Direction Sector			
	North (020º)	**Northeast (065º)**	**East (070º)**	**Southeast (125º)**
Wave Height (ft)	1.1	5.4	6.3	1.8
Period (sec)	2.2	4.5	5.8	2.4

3.2 Wave Exposure for the Harbor Alternatives

Each harbor alternative has somewhat different wave exposures or fetches. Since only those wave-generating conditions that will produce the largest design waves either on the structure and/or in the harbor entrance need be considered, not all directions have been used in the analysis. The important directions have been determined to be from the north, northeast, east, and the southeast. The other directions either have winds that are too low, fetches that are too short, or else they are oriented so that large waves could not arrive at the entrance; some directions meet more than one of these limitations.

The STWave results presented above represents the wave conditions of the 50-year recurrence interval storm and does not account for the rare extreme wave event. The design wave conditions have been determined from the 50-year recurrence interval winds presented in Section 2.6 using the fetches that correspond to a particular harbor alternative and principal wind direction. For the harbor design, the important wave parameters are the design wave heights and periods that can develop at the harbor entrance and on the breakwaters. Waves at an entrance can affect navigation into and out of the harbor and are used to determine inter-harbor wave conditions. Wave conditions on the breakwaters dictate rock sizes, layout configurations and breakwater design heights.

The 50-year extreme winds, based on elevation-corrected winds, were presented in Table A-2. Those winds, along with the appropriate fetches, were used by the numerical model to determine the 50-year extreme wave heights and periods shown in table above. These values represent the significant wave height near the breakwater location transformed by refraction and shoaling processes.

3.3 Boat Wakes

Since the project site is located beyond most of Whittier's waterfront, the likelihood of large boats traversing the harbor entrance with enough speed to generate any significant boat wake is small. Boat wakes are complex and not fully understood. Tobiasson and Kollemeyer (1991) suggest that non-planing boats traveling at speeds of 8 knots or less, which includes most of the boats affecting the harbor, would produce wakes with periods of less than 2.2 seconds. According to Tobiasson *et. al.*, such wakes should be below 1 foot high within about 400 feet of the source vessel. While it is possible that non-planing vessels may pass the harbor entrance at rates less than 8 knots or closer than 400 feet, or that small, powerful planing boats at high speeds could possibly generate waves higher than 1 foot in the entrance, it is very unlikely that these short period waves could enter the harbor basin without a significant reduction in height.

4.0 EXISTING HARBORS

Whittier Harbor was built by the State of Alaska in 1971. The harbor is located east of Whittier Creek in front of the town. The original harbor capacity was 100 berths. A 225-foot sheet-pile breakwater extension was added in 1972 and a 130-foot floating breakwater was added in 1978. The basin was expanded in 1981 to accommodate 332 vessels. In 1990 the State of Alaska replaced the sheet-pile and floating breakwaters because of pile corrosion and concrete damage. The harbor currently has three boat launch lanes on the east side of the harbor. Other harbor services include a harbor masters office, 30-ton boatlift, water and power at the berths, and a fuel float adjacent to the entrance channel.

Cliffside Marina is a private harbor accommodating 99 berths and limited transient moorage. The harbor is located west of Whittier Creek. The harbor is protected by a sheet-pile wave barrier and a floating breakwater. Harbor depths vary from 25 to over 100 feet. Slips are privately owned or leased from the marina. No boat launching facilities are located at the harbor.

5.0 HARBOR DESIGN CRITERIA

5.1 Design Vessels

The Alaska District Economics Section determined the design fleet for this study based on a harbor users survey and the locally-maintained harbor moorage waitlist. The number and length class of vessels in the design fleets are shown in the tables below. Lengths, beams and drafts for the fleet were developed using published vessel dimensions and harbor user data.

The design vessel for alternatives containing moorage was determined from a list of tenders. Tenders are the largest vessels that are anticipated to regularly use the harbor. A list of tenders that have used the harbor was used to determine the design vessel dimensions. Using the dimensions of these vessels, a “generic” design vessel was determined that would include all but one of the tender vessels. The design vessel for alternatives containing vessel moorage is 80 feet long with a beam of 21 feet and a draft of 12 feet.

The design vessel for alternatives which only include vessel launching was determined from a list of vessels that regularly launch from a trailer at the existing harbor. This vessel represents the largest vessels that regularly launch at the existing harbor. The design vessel for alternatives which only include vessel launching is 37 feet long with a beam of 11.5 feet and a draft of 4.5 feet.

5.2 Alternative Fleets

The three alternatives that include moorage present an array of vessel numbers that represent fulfilling the needs of the harbor waitlist, portions of the list, and the maximum number of vessels that can be accommodated in a physically and environmentally bounded harbor sites. The 150-vessel fleet represents half the range of the harbor waitlist. The 300-vessel fleet represents the full range of the harbor waitlist. The 105-vessel fleet represents a harbor physically bounded by and anadromous fish stream. The following fleets (Tables A-5, A-6, A-7) were used to develop concept basin layouts to accommodate the various fleets.

Table A-5. 150 Vessel Design Fleet

Length Class (ft)	Number
28	36
34	42
37	20
45	26
54	11
60	4
80	11

Table A-6. 300 Vessel Design Fleet

Length Class (ft)	Number
28	72
34	84
37	40
45	51
54	23
60	8
80	22

Table A-7. 105 Vessel Design Fleet

Length Class (ft)	Number
28	29
34	28
37	13
45	17
54	8
60	3
80	7

5.3 Allowable Wave Heights

Two allowable wave height criteria were used for this study. In Alternatives 2, 3, 4, and 5, moorage and launch areas would be protected from wave heights greater than one foot during a 50-year storm event. This criterion is outlined in Engineering Manual (EM) 1110-2-1615, *Hydraulic Design of Small Boat Harbors,* and the ASCE Planning and Design Guidelines for Small Craft Harbors. In Alternatives 6, 7, 8, and 9 that do not include moorage, the vessel launch areas would be protected from wave heights greater than 2 feet during a 50-year storm event. It is likely that the vessel launch facility would not be used during the design event since vessels would rarely if ever travel during a 50-year storm.

Breakwaters for the proposed alternatives were positioned so that the waves at the moorage area or launch area would not exceed the specific wave condition for the particular vessel facility. Diffraction analyses diagrams from the Coastal Engineering Manual were used to determine the wave heights expected for each harbor alternative considered in this study.

5.4 Entrance Channel and Maneuvering Channel Widths

The entrance channel width was determined using criteria in EM 1110-2-1615. This reference recommends channel width based on vessel size, type of traffic, vessel controllability, and channel shape. It is also recommended to increase channel width for other factors such as traffic congestion and wind, waves and current conditions.

Entrance channel width for all alternatives is 112 feet. This channel width is based on two-way traffic for the design vessel for boat launch only alternatives. The defined channel width would also provide sufficient width for the larger design vessel, from alternatives that include moorage, to enter or leave the harbor in a one-way traffic mode.

Maneuvering channel and fairway widths were designed so there would be enough room for vessels to turn and dock. Width of fairways was determined using a factor of 1.5 times the length of the longest finger piers in that area of the basin. The 1.5 times the longest finger pier length factor is the minimum acceptable fairway width. Vessels extending beyond the finger pier length must be prohibited when specifying the minimum width fairway.

5.5 Moorage Basin Depth

The basin depth was determined from the design tide level, vessel draft, vessel movement due to the allowable wave height, vessel squat, and a safety clearance. The lowest astronomical tide was selected as the design tide level for moorage areas. The minimum depth is defined as follows.

Design Tide Level (Lowest astronomical tide)	-3.92 ft MLLW
Vessel Draft	12.0 ft
Wave Allowance (1/2 allowable wave height)	0.5 ft
Squat	0.5 ft
Safety Clearance (sand & gravel bottom)	2.0 ft
Mooring Basin Depth	**-18.9 ft MLLW**

The design vessel will have at least 2 feet clearance at the lowest predicted tide to prevent grounding of keel coolers, instruments and other outside hull features from damage. The basin layouts was stepped up from the –11.5 feet depth to –14.0 and –19.0 depth to account for the shallower draft vessels that would be using the inner harbor basin.

5.6 Entrance and Maneuvering Channel Depths

The entrance channel was established based on the channel depth criteria found in EM 1110-2-1615.

Channel Depth for Alternatives Including Vessel Moorage

Design Tide Level	0.0 ft MLLW
Vessel Draft	12.0 ft
Wave Allowance (1/2 entrance wave height)	3.2 ft
Squat	0.5 ft
Safety Clearance (sand & gravel bottom)	2.0 ft
Entrance Channel Depth	**-18.2 feet MLLW**

The entrance channel depth is increased to match maximum basin depth of –19.0 feet. Creating a sill by reducing the entrance channel depth to less than the basin depth is inappropriate for small harbors, because of the negative effects on the water exchange, circulation, water quality and potential sedimentation. The entrance channel depth will not allow access during all tide levels. Water levels periodically fall below the design tide level for short periods of time, normally due to spring tides and low atmospheric pressure. An entrance channel with a depth of -19 feet MLLW will allow the design vessel to access the harbor 99.4% of the time based on NOAA predicted tides for Whittier.

Channel Depth for Alternatives Only Including Vessel Launching

Design Tide Level	0.0 ft MLLW
Vessel Draft	4.5 ft
Wave Allowance (1/2 entrance wave height)	3.2 ft
Squat	0.5 ft
Safety Clearance (sand & gravel bottom)	2.0 ft
Entrance Channel Depth	**-10.2 feet MLLW**

The entrance channel depth is rounded to –10.5 feet. The entrance channel depth will not allow access during all tide levels. Water levels periodically fall below the design tide level for short periods of time, normally due to spring tides and low atmospheric pressure. An entrance channel with a depth of -10.5 feet MLLW will allow the design vessel to access the harbor 99.2% of the time based on NOAA predicted tides for Whittier.

5.7 Breakwater Design

Evaluation of the sites and various breakwater configurations resulted in the rubble mound breakwater being selected as the most appropriate for the shallow shore areas at the west end of Passage Canal. Several alternative breakwater types were considered; rubble mound, floating, composite berm with vertical wall and partial depth vertical wave barrier.

Rubble mound breakwaters are the most common type of breakwater and are often used in shallow water, usually less than 30 feet and are most effective against short and long period waves. They can withstand minor settlement and damage without catastrophic failure, require a minimum of long term maintenance and are often the most cost effective from a life cycle perspective than other types of breakwaters in similar water depths. Historically in Alaska, rubble mound breakwaters have performed very well.

A floating breakwater was also considered. In general practice, floating breakwaters are not used in wave climates exceeding a 4 feet wave height and 4 second periods. They work principally by both reflection of wave energy and must be relatively wide to be effective. The waves from the east and northeast sectors at the west end of Passage Canal exceed the upper limits of wave height and period for this breakwater type. Floating breakwaters are generally most cost effective in water depths of 30 to 100 feet. Floating breakwaters were found to be unsuitable for alternatives located at the west end of Passage Canal. Floating breakwaters would likely be suitable for alternatives located within Shotgun Cove.

A composite low rubble berm with vertical sheet pile wall, similar to those found in the Aurora and Harris Harbors in Juneau, was considered, but was found to have no significant advantage over the rubble mound alternative. The lower weight of the breakwater structure was the only advantage, but the cost of supplying and constructing both rock and sheet pile was determined to be more expensive than rock only for the initial construction. Maintenance of the sheet pile and reflected wave effects were the major disadvantages.

After an examination of the harbor sites the rubble mound breakwater type was chosen for the Head of the Bay site. The breakwater design (rock sizes and layer thickness) is based on significant wave height and accepted rock sizing criteria.

Wave Heights. All the sites located at the west end of Passage Canal have similar wave exposures with the most significant exposure being to the north east. This wind and wave exposure was used as the basis for design for all the breakwaters alternatives included for both the Head of the Bay and Shakespeare Creek sites. The design wave height of 6.3 feet with a period of 5.8 seconds was generated from the longest fetch and comes from the eastern sector.

Armor Stone. Using Hudson's equation for a wave of 6.3 feet from the north northeast and a K_d of 1.9 results in an average armor stone size of 4,000 pounds for armor stone with a specific gravity of 2.65 and structure slope of 1V:1.5H. The resulting equivalent cubic volume of the average armor is 2.9 feet

Crest Height. The crest height of the breakwater was determined by combining the maximum water level and maximum wave runup to prevent wave overtopping. Runup was calculated using equation VI-5-13 in the Coastal Engineering Manual. The calculated value for wave runup was 8.5 feet. The MHHW level of 12.2 feet was used as the still water level. A storm surge value of 1.0 foot was included in the calculations to account for atmospheric variations. The combine water level and wave runup resulted in a breakwater crest height of 21.7 feet MLLW. The crest width was set at 9 feet based on the width of three armor stones.

Section Type. All the alternatives were designed using three layer rubble-mound breakwater sections with sacrificial toes. Alternatives 2 through 5 were designed using an overtopping breakwater section with a primary armor rock layer on both sides of the breakwater section. Alternatives 6 through 9 were given different breakwater section during the optimization process. The new section is a non-overtopping section that only has a primary armor rock layer on the seaward side. The new section provides some cost savings by utilizing less of the more expensive primary armor rock which results in a higher risk of damages from storms exceeding the design level event.

Life Cycle. Alaska harbors have typically been designed for a 50-year economic life. The use of rubble mound breakwaters, which can withstand some settlement or minor damage, is the best and most common type of breakwater for shallow water depths and larger wave heights and periods. This breakwater type normally has a significant initial cost but a low maintenance cost due to the use of very durable construction materials. A rubble mound breakwater is the recommended breakwater type for the Head of the Bay site. The breakwater design (rock sizes and layer thicknesses) is based on significant wave height (H_S) and rock sizing criteria.

A brief review of breakwater maintenance projects with the Alaska District Construction Operations Division also indicates there has been very little maintenance on the District's breakwaters. Many of the breakwaters have required no maintenance since there construction.

6.0 ALTERNATIVES CONSIDERED

6.1 General

Five sites were considered for the development of additional harbor facilities in the Whittier area. Most of the sites listed below have been under discussion for many years and included in several prior reports. Most of these sites were initially evaluated and removed from further consideration due to undesirable various problems with the site. These are discussed briefly below. Two sites received detailed consideration in this feasibility study: Head of the Bay and Shakespeare Creek. These site displayed favorable site conditions and likely economic feasibility and more detailed studies were then made of the two sites.

Hydrographic surveys and geophysical studies were completed and the economics were reviewed in more detail. With this information, more detailed design analyses were made to locate the various project features within very restrictive physical and environmental constraints. Details of each site are described in the following sections.

6.2 Alternative Sites

The following sites were considered in this report or in earlier reports.

6.2.1. Shotgun Cove. The site is located in a protected cove roughly 4 miles northeast from Whittier. The site is only exposed to waves from the north and northeast, limiting the fetch for wave growth. Depths at the south end of the cove range from 1 to 30 fathoms. The site wave environment would make it a likely candidate for the use of floating breakwaters. There are roughly 50 acres of undeveloped land at the southwest end of the cove that could be used for upland development. It is unlikely that the site has existing utilities and no upland facilities exist.

Currently road access extends 1.9 miles out of Whittier and roughly 4 additional miles of road would have to be constructed to provide vehicle access to the south end of Shotgun Cove. Extension of the road to Shotgun cove would be difficult and expensive due it its location on a steep mountainside.

This site was eliminated from further analysis due to the lack of existing vehicle access to the site.

6.2.2. Neptune Point. This site is also located within Shotgun Cove. It is located on the northeast shore of Shotgun Cove. It is naturally protected from most waves due to its location within the cove and behind Neptune Point. Depths in the area range from 1 to 18 fathoms. The site wave environment would make it a likely candidate for the use of floating breakwaters. There are limited upland that would be suitable for upland development. It is unlikely that the site has existing utilities and no upland facilities exist.

This site was eliminated from further analysis due to the lack of existing vehicle access to the site.

6.2.3. Learnard Creek. The site is located at the west end of Passage Canal north of Learnard Creek. This site has the worst wind and wave exposure of the three sites located at the west end of Passage Canal. The depths in the nearshore area drop off quickly limiting the limiting the area available for breakwater placement and harbor facilities. The site has roughly 10 acres of developable upland for use in harbor development. Due to the limited nearshore area at this site, alternatives would likely need to excavate uplands to accommodate harbor facilities.

Currently the site has no vehicle access. Less than a half mile of road and a bridge crossing Learnard Creek would have to be built to connect this site with the existing road system.

This site was eliminated from further analysis due to the lack of existing vehicle access and limited nearshore area for harbor facilities.

6.2.4. Head of the Bay. This site is located at the west end of Passage Canal between Learnard Creek to the north and the airstrip to the south. This site has northeast wind and wave exposure similar to all sites located at the west end of Passage Canal. The depths in the intertidal and nearshore zones have a mild slope down to -10 feet MLLW and the bathymetry drops off steeply into Passage Canal below -10 feet MLLW. The site has extensive upland area for development of harbor features and future expansion. Due to the limited nearshore area at this site, harbor alternatives would likely need to excavate uplands to accommodate harbor facilities.

The site has existing vehicle access via a gravel road linking the site to the paved West Camp Road on the west side of the airstrip. The site has an existing parking area which can accommodate roughly 50 trucks and trailers. No existing utilities are present.

This site was selected for development of harbor alternatives.

6.2.5. Shakespeare Creek. The site is located at the west end of Passage Canal south of the airstrip. This site has the best wind and wave exposure of the three sites located at the west end of Passage Canal. There is a significant nearshore bench with water depths ranging from 0 to 20 feet. The site has limited developable uplands for use in harbor development and available uplands are further restricted by the presence of Shakespeare Creek, an anadromous stream, which may have to be rerouted to accommodate harbor facilities. The site has limited area for future harbor expansion. There are not existing facilities at this site. Site access would be made using the paved West Camp Road.

This site was selected for development of harbor alternatives.

6.3. Alternatives Considered in Detail

6.3.1 Alternative 1 - No Action. The No Action plan would leave the community with no additional harbor moorage space and no additional boat launch ramps. Increased rafting, crowding and damage would continue and become worse. Delays to commercial, subsistence and recreational users would continue and likely increase as the number of visitors to Whittier increases.

6.3.2 Alternative 2 - 4-Lane Boat Launch with Breakwater. This alternative is located at the Head of the Bay site. The Alternative includes a 4-lane launch ramp, dredge entrance and maneuvering channel and a rubble mound breakwater. No vessel moorage is included in this alternative. A detailed quantity listing for this alternative can be found in Attachment A-A of this appendix.

Launch Ramp. This alternative would add four launch ramp lanes to the three in the existing harbor. The additional launch lanes will significantly reduce the delay time to launch and recover vessels but launching and recovery delays will not be completely eliminated. The additional launch ramps will also reduce one of the city's primary safety concerns, the amount of vehicle congestion at the existing harbor. The launch ramps are designed similar to those installed at the existing harbor in Whittier. The ramps will have an asphalt turn-around area at the top of the ramp, a parabolic concrete apron, concrete ramp planks, and a pipe-pile supported, articulated boarding float made up of individual modules.

The asphalt turn-around area is the full width of the four ramps or 80 feet wide, providing a turning radius 40 feet. The turn-around is 100 feet in length or 1.5 times the estimated vehicle and trailer length (66 feet). The turn-around will be constructed of a 6-inch layer of roller compacted asphalt on top of a 12-inch layer compacted crushed gravel base course.

The concrete ramp apron will have a parabolic shape to transition from the turnaround to the ramp slope without trailer high centering. The concrete apron will also include wedge shaped abutments for the connection of the boarding floats. The ramp apron will be constructed of a 9-inch layer of poured concrete on top of a 12-inch layer compacted crushed gravel base course.

The boat launch ramp, including the concrete apron, extends from the existing grade of +18 feet MLLW down to a depth of -6.6 feet MLLW ensuring that the ramp will be usable during all tide levels. The ramp section will have a 13% slope and a length of 156 feet. The ramp section will be constructed of many individual concrete planks that are bolted to a heavy timber sleeper frame. The timber frame is filled with compacted crushed gravel base course. The 20-foot width of the ramp planks will provide a 16-foot wide launch lane and half of the width, 4 feet, for the boarding float. A layer of slope protection rock will extend down from the end of the ramp slope for an additional 10 feet and then continue down to the dredge depth at the standard 1V:2H slope.

Each of the two boarding floats will be 280-feet long and 8-feet in width. Each float will service two launch lanes. The boarding floats will be made up of fourteen 20-foot long floating modules and every other module will have a pipe pile installed through the module to support the boarding float from lateral forces such as wind, waves, vessel impacts, etc.

Rubble-mound Breakwater. The breakwater is a three layer structure made up of primary armor layer, two armor stones thick, a secondary armor layer made of B rock, and a permeable core made up of core rock. The breakwater has an overtopping cross-section. The armor rock extends the full length of the seaward harbor-side slopes. The overtopping sections provides for some additional damage protecting during storms exceeding the design event.

The layout of the breakwater is designed such that the significant wave height from the 50-year storm is reduced to the maximum allowable wave height at the boat launch. The maximum allowable wave height for this alternative is 1 foot. The breakwater begins in a water depth of +8 feet MLLW and extends a total length of 880 feet to the north end of the breakwater at a depth of -1 feet MLLW.

The breakwater layout defines a north facing entrance channel and maneuvering channel. This breakwater alignment was defined to be the initial phase of an expandable harbor. The breakwater with its identical alignment could be lengthened with minimal breakwater removal effort to add the moorage area of Alternatives 3 or 4.

Entrance Channel. This alternative has an entrance and maneuvering channel 764 feet in length. Vessels would enter the entrance channel from the northeast and turn roughly 70 degrees to the south to access the boat launch. The design of the entrance channel for this alternative is based on the 80-foot design vessel. The channel depth is -19 feet MLLW. The channel width is defined to accommodate two-way traffic of the 37-foot design vessel and one-way traffic for the 80-foot design vessel based on percent beam widths as described in EM 1110-2-1615. The channel width is 112 feet.

Dredge material within the entrance channel should mainly consist of sand and gravels with some silt based on the previous geotechnical borings from the area. Encountering significant numbers of cobbles and boulders should also be expected. The geotechnical borings did not indicate the presence of bedrock but the borings limited depth did not define the bedrock surface. All dredging for this alternative is expected to be deposited upland due to the potential need for sediment treatment off-site. The dredged materials will have to be temporarily stocked piled upland and tested for contaminates prior to permanent upland disposal. Material found to be contaminated by laboratory tests will be separated and shipped off-site for treatment prior to disposal in a landfill. It is currently assumed that the contaminated dredged material amount will be roughly 5 percent of the total dredged quantity. Additional geotechnical and chemical testing will have to be conducted during the PED phase to verify the assumed percentage of contaminated dredging.

Annual maintenance dredging is not anticipated to be required for this alternative. Shoaling is not expected to be a significant issue with the location of the entrance channel. The lack of changes in the sites bathymetry indicate minimal sediment movement from littoral drift. Fine grained suspended sedimentation does not appear to be significant. The effects of sediment transported into Passage Canal from Learnard Creek appear to be limited to the immediate area of the alluvial fan at the mouth of the creek.

Circulation and Water Quality. As recommended by ASCE the harbor design parameters that most effect circulation and water quality are the tidal prism ratio (TPR), basin aspect ratio, and the entrance channel area ratio. The basin area for this alternative is basically the small basin at the end of the launch ramps with a shallow entrance channel. The MHHW tide range exceeds half the high tide water depth. The prism ratio is 0.65, which greatly exceeds the 0.35 ratio for good circulation. The shape of the harbor basin, in this case a channel, results in poor values for the aspect ratio at 3.3 and entrance area ratio at 63. Several of these parameters applied to this non-standard harbor basin tend to indicate that the Alternative may have circulation problems but the tidal flushing provided with a TPR of 0.65 this alternative would have good circulation and water quality.

After the local sponsor eliminated all the alternatives including moorage this alternative was optimized to produce the final array of alternatives 7-10.

6.3.3 Alternative 3 - 150 Vessel Harbor with 4-Lane Boat Launch. This alternative is located at the Head of the Bay site. The Alternative includes a 4-lane launch ramp, dredge entrance and maneuvering channel, mooring basin and a rubble mound breakwater. A detailed quantity listing for this alternative can be found in Attachment A-B of this appendix.

Launch Ramp. This alternative would add four launch ramp lanes to the three in the existing harbor. The additional launch lanes will significantly reduce the delay time to launch and recover vessels but launching and recovery delays will not be completely eliminated. The additional launch ramps will also reduce one of the city's primary safety concerns, the amount of vehicle congestion at the existing harbor. The launch ramps are designed similar to those installed at the existing harbor in Whittier. The ramps will have an asphalt turn-around area at the top of the ramp, a parabolic concrete apron, concrete ramp planks, and a pipe-pile supported, articulated boarding float made up of individual modules.

The asphalt turn-around area is the full width of the four ramps or 80 feet wide, providing a turning radius 40 feet. The turn-around is 100 feet in length or 1.5 times the estimated vehicle and trailer length (66 feet). The turn-around will be constructed of a 6-inch layer of roller compacted asphalt on top of a 12-inch layer compacted crushed gravel base course.

The concrete ramp apron will have a parabolic shape to transition from the turnaround to the ramp slope without trailer high centering. The concrete apron will also include wedge shaped abutments for the connection of the boarding floats. The ramp apron will be constructed of a 9-inch layer of poured concrete on top of a 12-inch layer compacted crushed gravel base course.

The boat launch ramp, including the concrete apron, extends from the existing grade of +18 feet MLLW down to a depth of -6.6 feet MLLW ensuring that the ramp will be usable during all tide levels. The ramp section will have a 13% slope and a length of 156 feet. The ramp section will be constructed of many individual concrete planks that are bolted to a heavy timber sleeper frame. The timber frame is filled with compacted crushed gravel base course. The 20-foot width of the ramp planks will provide a 16-foot wide launch lane and half of the width, 4 feet, for the boarding float. A layer of slope protection rock will extend down from the end of the ramp slope for an additional 10 feet and then continue down to the dredge depth at the standard 1V:2H slope.

Each of the two boarding floats will be 280-feet long and 8-feet in width. Each float will service two launch lanes. The boarding floats will be made up of fourteen 20-foot long floating modules and every other module will have a pipe pile installed through the module to support the boarding float from lateral forces such as wind, waves, vessel impacts, etc.

Mooring Basin. The mooring basin is sized to accommodate the 150 vessel fleet described previously. The fleet vessels range in size from 28 to 80 feet in length. The mooring basin depths are stepped to provide optimized depth for the largest vessels that would moor within that portion of the basin. The basin steps have depths of -11.5, -14, -17, and -19 feet MLLW. Overall mooring basin area is 7.0 acres.

Rubble-mound Breakwater. The breakwater is a three layer structure made up of primary armor layer, two armor stones thick, a secondary armor layer made of B rock, and a permeable core made up of core rock. The breakwater has an overtopping cross-section. The armor rock extends the full length of the seaward harbor-side slopes. The overtopping sections provides for some additional damage protecting during storms exceeding the design event.

The layout of the breakwater is designed such that the significant wave height from the 50-year storm is reduced to the maximum allowable wave height within the mooring basin. The maximum allowable wave height for this alternative is 1 foot. The breakwater begins in a water depth of +8 feet MLLW and extends a total length of 1366 feet to the north end of the breakwater at a depth of -1 feet MLLW.

The breakwater layout defines a north facing entrance channel and maneuvering channel. This breakwater alignment was defined to be the first expansion phase of an expandable harbor. The breakwater with its identical alignment could be lengthened with minimal breakwater removal effort to add additional moorage area as described in Alternative 4.

Entrance Channel. This alternative has an entrance and maneuvering channel 1360 feet in length. Vessels would enter the entrance channel from the northeast and turn roughly 70 degrees to the south to access the boat launch. The design of the entrance channel for this alternative is based on the 80-foot design vessel. The channel depth is -19 feet MLLW. The channel width is defined to accommodate two-way traffic of the 37-foot design vessel and one-way traffic for the 80-foot design vessel based on percent beam widths as described in EM 1110-2-1615. The channel width is 112 feet.

Dredge material within the entrance channel should mainly consist of sand and gravels with some silt based on the previous geotechnical borings from the area. Encountering significant numbers of cobbles and boulders should also be expected. The geotechnical borings did not indicate the presence of bedrock but the borings limited depth did not define the bedrock surface. All dredging for this alternative is expected to be deposited upland due to the potential need for sediment treatment off-site. The dredged materials will have to be temporarily stocked piled upland and tested for contaminates prior to permanent upland disposal. Material found to be contaminated by laboratory tests will be separated and shipped off-site for treatment prior to disposal in a landfill. It is currently assumed that the contaminated dredged material amount will be roughly 5 percent of the total dredged quantity. Additional geotechnical and chemical testing will have to be conducted during the PED phase to verify the assumed percentage of contaminated dredging.

Annual maintenance dredging is not anticipated to be required for this alternative. Shoaling is not expected to be a significant issue with the location of the entrance channel. The lack of changes in the sites bathymetry indicate minimal sediment movement from littoral drift. Fine grained suspended sedimentation does not appear to be significant. The effects of sediment transported into Passage Canal from Learnard Creek appear to be limited to the immediate area of the alluvial fan at the mouth of the creek.

Circulation and Water Quality. As recommended by ASCE the harbor design parameters that most effect circulation and water quality are the TPR, basin aspect ratio, and the entrance channel area ratio. The harbor basin has a roughly square shape with a basin aspect ratio (AR) of roughly 1.1 to 1 which is nearly ideal.

The TPR is also quite favorable with a value of 0.48, significantly exceeding the 0.35 good circulation value. The entrance area ratio is estimate at 141 which indicates poor circulation. These parameters indicate that this alternative would have adequate circulation and water quality.

This alternative was eliminated from further consideration due to sponsor funding limitations.

6.3.4 Alternative 4 - 300 Vessel Harbor with 4-Lane Boat Launch. This alternative is located at the Head of the Bay site. The Alternative includes a 4-lane launch ramp, dredge entrance and maneuvering channel, mooring basin and a rubble mound breakwater. A detailed quantity listing for this alternative can be found in Attachment A-B of this appendix.

Launch Ramp. This alternative would add four launch ramp lanes to the three in the existing harbor. The additional launch lanes will significantly reduce the delay time to launch and recover vessels but launching and recovery delays will not be completely eliminated. The additional launch ramps will also reduce one of the city's primary safety concerns, the amount of vehicle congestion at the existing harbor. The launch ramps are designed similar to those installed at the existing harbor in Whittier. The ramps will have an asphalt turn-around area at the top of the ramp, a parabolic concrete apron, concrete ramp planks, and a pipe-pile supported, articulated boarding float made up of individual modules.

The asphalt turn-around area is the full width of the four ramps or 80 feet wide, providing a turning radius 40 feet. The turn-around is 100 feet in length or 1.5 times the estimated vehicle and trailer length (66 feet). The turn-around will be constructed of a 6-inch layer of roller compacted asphalt on top of a 12-inch layer compacted crushed gravel base course.

The concrete ramp apron will have a parabolic shape to transition from the turnaround to the ramp slope without trailer high centering. The concrete apron will also include wedge shaped abutments for the connection of the boarding floats. The ramp apron will be constructed of a 9-inch layer of poured concrete on top of a 12-inch layer compacted crushed gravel base course.

The boat launch ramp, including the concrete apron, extends from the existing grade of +18 feet MLLW down to a depth of -6.6 feet MLLW ensuring that the ramp will be usable during all tide levels. The ramp section will have a 13% slope and a length of 156 feet. The ramp section will be constructed of many individual concrete planks that are bolted to a heavy timber sleeper frame. The timber frame is filled with compacted crushed gravel base course. The 20-foot width of the ramp planks will provide a 16-foot wide launch lane and half of the width, 4 feet, for the boarding float. A layer of slope protection rock will extend down from the end of the ramp slope for an additional 10 feet and then continue down to the dredge depth at the standard 1V:2H slope.

Each of the two boarding floats will be 280-feet long and 8-feet in width. Each float will service two launch lanes. The boarding floats will be made up of fourteen 20-foot long floating modules and every other module will have a pipe pile installed through the module to support the boarding float from lateral forces such as wind, waves, vessel impacts, etc.

Mooring Basin. The mooring basin is sized to accommodate the 150 vessel fleet described previously. The fleet vessels range in size from 28 to 80 feet in length. The mooring basin depths are stepped to provide optimized depth for the largest vessels that would moor within that portion of the basin. The basin steps have depths of -11.5, -14, and -19 feet MLLW. Overall mooring basin area is 12.3 acres.

Rubble-mound Breakwater. The breakwater is a three layer structure made up of primary armor layer, two armor stones thick, a secondary armor layer made of B rock, and a permeable core made up of core rock. The breakwater has an overtopping cross-section. The armor rock extends the full length of the seaward harbor-side slopes. The overtopping sections provides for some additional damage protecting during storms exceeding the design event.

The layout of the breakwater is designed such that the significant wave height from the 50-year storm is reduced to the maximum allowable wave height within the mooring basin. The maximum allowable wave height for this alternative is 1 foot. The breakwater begins in a water depth of +8 feet MLLW and extends a total length of 1,525 feet to the north end of the breakwater at a depth of -1 feet MLLW.

The breakwater layout defines a north facing entrance channel and maneuvering channel. This breakwater alignment was defined to be the final phase of an expandable harbor and represents the maximum practical extension of the breakwater to the north.

Entrance Channel. This alternative has an entrance and maneuvering channel 1600 feet in length. Vessels would enter the entrance channel from the northeast and turn roughly 70 degrees to the south to access the boat launch. The design of the entrance channel for this alternative is based on the 80-foot design vessel. The channel depth is -19 feet MLLW. The channel width is defined to accommodate two-way traffic of the 37-foot design vessel and one-way traffic for the 80-foot design vessel based on percent beam widths as described in EM 1110-2-1615. The channel width is 112 feet.

Dredge material within the entrance channel should mainly consist of sand and gravels with some silt based on the previous geotechnical borings from the area. Encountering significant numbers of cobbles and boulders should also be expected. The geotechnical borings did not indicate the presence of bedrock but the borings limited depth did not define the bedrock surface. All dredging for this alternative is expected to be deposited upland due to the potential need for sediment treatment off-site. The dredged materials will have to be temporarily stocked piled upland and tested for contaminates prior to permanent upland disposal. Material found to be contaminated by laboratory tests will be separated and shipped off-site for treatment prior to disposal in a landfill. It is currently assumed that the contaminated dredged material amount will be roughly 5 percent of the total dredged quantity. Additional geotechnical and chemical testing will have to be conducted during the PED phase to verify the assumed percentage of contaminated dredging.

Annual maintenance dredging is not anticipated to be required for this alternative. Shoaling is not expected to be a significant issue with the location of the entrance channel. The lack of changes in the sites bathymetry indicate minimal sediment movement from littoral drift. Fine grained suspended sedimentation does not appear to be significant. The effects of sediment transported into Passage Canal from Learnard Creek appear to be limited to the immediate area of the alluvial fan at the mouth of the creek.

Circulation and Water Quality. As recommended by ASCE the harbor design parameters that most effect circulation and water quality are the TPR, basin aspect ratio, and the entrance channel area ratio. The harbor basin has a rectangular shape with a basin AR of roughly 1.5 to 1 which is well within the good range. The TPR is also quite favorable with a value of 0.48, significantly exceeding the 0.35 good circulation value. The entrance area ratio is estimate at 222 which indicates marginal circulation. These parameters indicate that this alternative would have adequate circulation and water quality.

This alternative was eliminated from further consideration due to sponsor funding limitations.

6.3.5 Alternative 5 - 105 Vessel Harbor at Shakespeare Creek. This alternative is located at the Head of the Bay site. The Alternative includes a dredged entrance and maneuvering channel, mooring basin and a rubble mound breakwater. A detailed quantity listing for this alternative can be found in Attachment A-B of this appendix.

Launch Ramp. This alternative does not include any launch ramps.

Mooring Basin. The mooring basin is sized to accommodate the 105 vessel fleet described previously. The fleet vessels range in size from 28 to 80 feet in length. The mooring basin depths are stepped to provide optimized depth for the largest vessels that would moor within that portion of the basin. The basin steps have depths of -11.5, -14, and -19 feet MLLW. Overall mooring basin area is 4.0 acres.

Rubble-mound Breakwater. The breakwater is a three layer structure made up of primary armor layer, two armor stones thick, a secondary armor layer made of B rock, and a permeable core made up of core rock. The breakwater has an overtopping cross-section. The armor rock extends the full length of the seaward harbor-side slopes. The overtopping sections provides for some additional damage protecting during storms exceeding the design event.

The layout of the breakwater is designed such that the significant wave height from the 50-year storm is reduced to the maximum allowable wave height within the mooring basin. The maximum allowable wave height for this alternative is 1 foot. The breakwater begins in a water depth of +10 feet MLLW and extends a total length of 2144 feet to the east end of the breakwater at a depth of -8 feet MLLW.

The breakwater layout defines a south facing entrance channel and maneuvering channel. This breakwater alignment was defined to fully utilize the available area between the airstrip and the highway without requiring realignment of Shakespeare Creek. Little to no opportunities exist for harbor expansion due to the existing facilities to the north and south, Shakespeare Creek to the west and steep bathymetry to the east.

Entrance Channel. This alternative has an entrance and maneuvering channel 1790 feet in length. Vessels would enter the entrance channel from the northeast and turn roughly 130 degrees to the south to access the mooring area. The design of the entrance channel for this alternative is based on the 80-foot design vessel. The channel depth is -19 feet MLLW. The channel width is defined to accommodate two-way traffic of the 37-foot design vessel and one-way traffic for the 80-foot design vessel based on percent beam widths as described in EM 1110-2-1615. The channel width is 112 feet.

Dredge material within the entrance channel should mainly consist of sand and gravels with some silt based on the previous geotechnical borings from the area. Encountering significant numbers of cobbles and boulders should also be expected. The geotechnical borings did not indicate the presence of bedrock but the borings limited depth did not define the bedrock surface. All dredging for this alternative is expected to be deposited upland due to the potential need for sediment treatment off-site. The dredged materials will have to be temporarily stocked piled upland and tested for contaminates prior to permanent upland disposal. Material found to be contaminated by laboratory tests will be separated and shipped off-site for treatment prior to disposal in a landfill. It is currently assumed that the contaminated dredged material amount will be roughly 5 percent of the total dredged quantity. Additional geotechnical and chemical testing will have to be conducted during the PED phase to verify the assumed percentage of contaminated dredging.

Annual maintenance dredging is not anticipated to be required for this alternative. Shoaling is not expected to be a significant issue with the location of the entrance channel. The lack of changes in the sites bathymetry indicate minimal sediment movement from littoral drift. Fine grained suspended sedimentation does not appear to be significant. The effects of sediment transported into Passage Canal from Shakespeare Creek appear to be limited to the mouth of the creek. The breakwater layout should prevent transport of sediment into the harbor.

Circulation and Water Quality. As recommended by ASCE the harbor design parameters that most effect circulation and water quality are the TPR, basin aspect ratio, and the entrance channel area ratio. The harbor basin has a roughly triangular shape with an average basin AR of roughly 1.1 to 1 which is nearly ideal. The TPR is also quite favorable with a value of 0.49, significantly exceeding the 0.35 good circulation value. The entrance area ratio is estimate at 121 which indicates poor circulation. These parameters indicate that this alternative would have adequate circulation and water quality.

This alternative was eliminated from further consideration due to sponsor funding limitations.

6.3.6 Alternative 6 - 4-Lane Boat Launch with North Entrance Channel.

This alternative is located at the Head of the Bay site. The alternative includes a 4-lane launch ramp, dredge entrance and maneuvering channel and a rubble mound breakwater. No vessel moorage is included in this alternative. A detailed quantity listing for this alternative can be found in Attachment A-B of this appendix.

Launch Ramp. This alternative would add four launch ramp lanes to the three in the existing harbor. The additional launch lanes will significantly reduce the delay time to launch and recover vessels but launching and recovery delays will not be completely eliminated. The additional launch ramps will also reduce one of the city's primary safety concerns, the amount of vehicle congestion at the existing harbor. The launch ramps are designed similar to those installed at the existing harbor in Whittier. The ramps will have an asphalt turn-around area at the top of the ramp, a parabolic concrete apron, concrete ramp planks, and a pipe-pile supported, articulated boarding float made up of individual modules.

The asphalt turn-around area is the full width of the four ramps or 80 feet wide, providing a turning radius 40 feet. The turn-around is 100 feet in length or 1.5 times the estimated vehicle and trailer length (66 feet). The turn-around will be constructed of a 6-inch layer of roller compacted asphalt on top of a 12-inch layer compacted crushed gravel base course.

The concrete ramp apron will have a parabolic shape to transition from the turnaround to the ramp slope without trailer high centering. The concrete apron will also include wedge shaped abutments for the connection of the boarding floats. The ramp apron will be constructed of a 9-inch layer of poured concrete on top of a 12-inch layer compacted crushed gravel base course.

The boat launch ramp, including the concrete apron, extends from the existing grade of +18 feet MLLW down to a depth of -6.6 feet MLLW ensuring that the ramp will be usable during all tide levels. The ramp section will have a 13% slope and a length of 156 feet. The ramp section will be constructed of many individual concrete planks that are bolted to a heavy timber sleeper frame. The timber frame is filled with compacted crushed gravel base course. The 20-foot width of the ramp planks will provide a 16-foot wide launch lane and half of the width, 4 feet, for the boarding float. A layer of slope protection rock will extend down from the end of the ramp slope for an additional 10 feet and then continue down to the dredge depth at the standard 1V:2H slope.

Each of the two boarding floats will be 280-feet long and 8-feet in width. Each float will service two launch lanes. The boarding floats will be made up of fourteen 20-foot long floating modules and every other module will have a pipe pile installed through the module to support the boarding float from lateral forces such as wind, waves, vessel impacts, etc.

Rubble-mound Breakwater. The breakwater is a three layer structure made up of primary armor layer, two armor stones thick, a secondary armor layer made of B rock, and a permeable core made up of core rock. The breakwater section is typical of a non-overtopping section. The armor rock extends the full length of the seaward side and the width of the crest and B rock extends down from the crest the length of the harbor-side slope.

The layout of the breakwater is designed such that the significant wave height from the 50-year storm is reduced to the maximum allowable wave height at the boat launch. The maximum allowable wave height for the boat launch only alternatives is 2 feet. The breakwater begins in a water depth of +8 feet MLLW and extends a total length of 602 feet to the north end of the breakwater at a depth of -1 feet MLLW.

The breakwater layout defines a north facing entrance channel and maneuvering channel. This breakwater alignment is longer and more costly than that of a south facing entrance channel due to the significant wave's southwest angle of incidence. The north breakwater alignment does have the advantage of a lower cost for future mooring basin expansion to the north since less breakwater would have to be demolished for a northward breakwater extension.

Entrance Channel. This alternative has an entrance and maneuvering channel 670 feet in length. Vessels would enter the entrance channel from the northeast and turn roughly 70 degrees to the south to access the boat launch. Due to the channel's northern orientation the channel's length will be longer and dredge quantity will be higher than alternatives with a southern orientation. The design of the entrance channel for this alternative is based on the 37-foot design vessel. The channel depth is -10.5 feet MLLW. The channel width is defined to accommodate two-way traffic of the design vessel based on percent beam widths as described in EM 1110-2-1615. The channel width is 112 feet.

Dredge material within the entrance channel should mainly consist of sand and gravels with some silt based on the previous geotechnical borings from the area. Encountering significant numbers of cobbles and boulders should also be expected. The geotechnical borings did not indicate the presence of bedrock but the borings limited depth did not define the bedrock surface. All dredging for this alternative is expected to be deposited upland due to the potential for fuel contamination from the former Army tank farm to the west. The dredged materials will have to be temporarily stocked piled upland and tested for contaminates prior to permanent upland disposal. Material found to be contaminated by laboratory tests will be separated and shipped off-site for treatment prior to disposal in a landfill. It is currently assumed that the contaminated dredged material amount will be roughly 5 percent of the total dredged quantity. Additional geotechnical and chemical testing will have to be conducted during the PED phase to verify the assumed percentage of contaminated dredging.

Annual maintenance dredging is not anticipated to be required for this alternative. Shoaling is not expected to be a significant issue with the location of the entrance channel. The lack of changes in the sites bathymetry indicate minimal sediment movement from littoral drift. Fine grained suspended sedimentation does not appear to be significant. The effects of sediment transported into Passage Canal from Learnard Creek appear to be limited to the immediate area of the alluvial fan at the mouth of the creek.

Circulation and Water Quality. As recommended by ASCE the harbor design parameters that most effect circulation and water quality are the TPR, basin aspect ratio, and the entrance channel area ratio. The basin area for this alternative is basically the small basin at the end of the launch ramps with a shallow entrance channel. The MHHW tide range exceeds half the high tide water depth. The tidal prism ratio is 0.66, which greatly exceeds the 0.35 ratio for good circulation. The aspect ratio for this alternative is 2.1, an acceptable value. The shape of the harbor basin, in this case a channel, results in a poor value for the entrance area ratio at 39. The entrance area ratio applied to this non-standard harbor basin tends to indicate that the alternative may have circulation problems but the tidal flushing provided with a TPR of 0.66 and aspect ratio indicted this alternative would have good circulation and water quality.

6.3.7 Alternative 7 - 6-Lane Boat Launch with North Entrance Channel. This alternative is located at the Head of the Bay site. The alternative includes a 6-lane launch ramp, dredge entrance and maneuvering channel and a rubble mound breakwater. No vessel moorage is included in this alternative. A detailed quantity listing for this alternative can be found in Attachment A-A of this appendix.

Launch Ramp. This alternative would add six launch ramp lanes to the three in the existing harbor. The additional launch lanes will reduce nearly all the delay time to launch and recover vessels with the exceptions of busy weekend and holiday use. The additional launch ramps will also reduce one of the city's primary safety concerns, the amount of vehicle congestion at the existing harbor. The launch ramps are designed similar to those installed at the existing harbor in Whittier. The ramps will have an asphalt turn-around area at the top of the ramp, a parabolic concrete apron, concrete ramp planks, and a pipe-pile supported, articulated boarding float made up of individual modules.

The asphalt turn-around area is the full width of the six ramps or 120 feet wide, providing a turning radius of 60 feet. The turn-around is 100 feet in length or 1.5 times the estimated combine vehicle and trailer length (66 feet). The turn-around will be constructed of 6-inch layer of roller compacted asphalt on top of a 12-inch layer compacted crushed gravel base course.

The concrete ramp apron will have a parabolic shape to transition from the turnaround to the ramp slope without trailer high centering. The concrete apron will also include wedge shaped abutments for the connection of the boarding floats. The ramp apron will be constructed of a 9-inch layer of poured concrete on top of a 12-inch layer compacted crushed gravel base course.

The boat launch ramp, including the concrete apron, extends from the existing grade of +18 feet MLLW down to a depth of -6.6 feet MLLW ensuring that the ramp will be usable during all tide levels. The ramp section will have a 13% slope and a length of 156 feet. The ramp section will be constructed of many individual concrete planks that are bolted to a heavy timber sleeper frame. The timber frame is filled with compacted crushed gravel base course. The 20-foot width of the ramp planks will provide a 16-foot wide launch lane and half of the width, 4 feet, for the boarding float. A layer of slope protection rock will extend down from the end of the ramp slope for an additional 10 feet and then continue down to the dredge depth at the standard 1V:2H slope.

Each of the three boarding floats will be 280-feet long and 8-feet in width. Each float will service two launch lanes. The boarding floats will be made up of fourteen 20-foot long floating modules and every other module will have a pipe pile installed through the module to support the boarding float from lateral forces such as wind, waves, vessel impacts, etc.

Rubble-mound Breakwater. The breakwater is a three layer structure made up of primary armor layer, two armor stones thick, a secondary armor layer made of B rock, and a permeable core made up of core rock. The breakwater section is typical of a non-overtopping section. The armor rock extends the full length of the seaward side and the width of the crest and B rock extends down from the crest the length of the harbor-side slope.

The layout of the breakwater is designed such that the significant wave height from the 50-year storm is reduced to the maximum allowable wave height at the boat launch. The maximum allowable wave height for the boat launch only alternatives is 2 feet. The breakwater begins in a water depth of +8 feet MLLW and extends a total length of 602 feet to the north end of the breakwater at a depth of -1 feet MLLW.

The breakwater layout defines a north facing entrance channel and maneuvering channel. This breakwater alignment is longer and more costly than that of a south facing entrance channel due to the significant wave's southwest angle of incidence. The north breakwater alignment does have the advantage of a lower cost for future mooring basin expansion to the north since less breakwater would have to be demolished for a northward breakwater extension.

Entrance Channel. This alternative has an entrance and maneuvering channel 670 feet in length. Vessels would enter the entrance channel from the northeast and turn roughly 70 degrees to the south to access the boat launch. Due to the channel's northern orientation the channel's length will be longer and the dredge quantity will be higher than the alternatives with a southern orientation. The design of the entrance channel for this alternative is based on the 37-foot design vessel. The channel depth is -10.5 feet MLLW. The channel width is defined to accommodate two-way traffic of the design vessel based on percent beam widths as described in EM 1110-2-1615. The channel width is 112 feet.

Dredge material within the entrance channel should mainly consist of sand and gravels with some silt based on the previous geotechnical borings from the area. Encountering significant numbers of cobbles and boulders should also be expected. The geotechnical borings did not indicate the presence of bedrock but the borings limited depth did not define the bedrock surface. All dredging for this alternative is expected to be deposited upland due to the potential for fuel contamination from the former Army tank farm to the west. The dredged materials will have to be temporarily stocked piled upland and tested for contaminates prior to permanent upland disposal. Material found to be contaminated by laboratory tests will be separated and shipped off-site for treatment prior to disposal in a landfill. It is currently assumed that the contaminated dredged material amount will be roughly 5 percent of the total dredged quantity. Additional geotechnical and chemical testing will have to be conducted during the PED phase to verify the assumed percentage of contaminated dredging.

Annual maintenance dredging is not anticipated to be required for this alternative. Shoaling is not expected to be a significant issue with the location of the entrance channel. The lack of changes in the sites bathymetry indicate minimal sediment movement from littoral drift. Fine grained suspended sedimentation does not appear to be significant. The effects of sediment transported into from passage canal from Learnard Creek appear to be limited to the immediate area of the alluvial fan at the mouth of the creek.

Circulation and Water Quality. As recommended by ASCE the harbor design parameters that most effect circulation and water quality are the TPR, basin aspect ratio, and the entrance channel area ratio. The basin area for this alternative is basically the small basin at the end of the launch ramps with a shallow entrance channel. The MHHW tide range exceeds half the high tide water depth. The tidal prism ratio is 0.66, which greatly exceeds the 0.35 ratio for good circulation. The aspect ratio for this alternative is 2.2, an acceptable value. The shape of the harbor basin, in this case a channel, results in a poor value for the entrance area ratio at 45. The entrance area ratio applied to this non-standard harbor basin tends to indicate that the alternative may have circulation problems but the tidal flushing provided with a TPR of 0.66 and aspect ratio indicted this alternative would have good circulation and water quality.

6.3.8 Alternative 8 - 4-Lane Boat Launch with South Entrance Channel. This alternative is located at the Head of the Bay site. The alternative includes a 4-lane launch ramp, dredge entrance and maneuvering channel and a rubble mound breakwater. No vessel moorage is included in this alternative. A detailed quantity listing for this alternative can be found in Attachment A-A of this appendix.

Launch Ramp. This alternative would add four launch ramp lanes to the three in the existing harbor. The additional launch lanes will significantly reduce the delay time to launch and recover vessels but launching and recovery delays will not be completely eliminated. The additional launch ramps will also reduce one of the city's primary safety concerns, the amount of vehicle congestion at the existing harbor. The launch ramps are designed similar to those installed at the existing harbor in Whittier. The ramps will have an asphalt turn-around area at the top of the ramp, a parabolic concrete apron, concrete ramp planks, and a pipe-pile supported, articulated boarding float made up of individual modules.

The asphalt turn-around area is the full width of the four ramps or 80 feet wide, providing a turning radius of 40 feet. The turn-around is 100 feet in length or 1.5 times the estimated vehicle and trailer length (66 feet). The turn-around will be constructed of a 6-inch layer of roller compacted asphalt on top of a 12-inch layer compacted crushed gravel base course.

The concrete ramp apron will have a parabolic shape to transition from the turnaround to the ramp slope without trailer high centering. The concrete apron will also include wedge shaped abutments for the connection of the boarding floats. The ramp apron will be constructed of a 9-inch layer of poured concrete on top of a 12-inch layer compacted crushed gravel base course.

The boat launch ramp, including the concrete apron, extends from the existing grade of +18 feet MLLW down to a depth of -6.6 feet MLLW ensuring that the ramp will be usable during all tide levels. The ramp section will have a 13% slope and a length of 156 feet. The ramp section will be constructed of many individual concrete planks that are bolted to a heavy timber sleeper frame. The timber frame is filled with compacted crushed gravel base course. The 20-foot width of the ramp planks will provide a 16-foot wide launch lane and half of the width, 4 feet, for the boarding float. A layer of slope protection rock will extend down from the end of the ramp slope for an additional 10 feet and then continue down to the dredge depth at the standard 1V:2H slope.

Each of the two boarding floats will be 280-feet long and 8-feet in width. Each float will service two launch lanes. The boarding floats will be made up of fourteen 20-foot long floating modules and every other module will have a pipe pile installed through the module to support the boarding float from lateral forces such as wind, waves, vessel impacts, etc.

***Rubble-mound Breakwater*.** The breakwater is a three layer structure made up of primary armor layer, two armor stones thick, a secondary armor layer made of B rock, and a permeable core made up of core rock. The breakwater section is typical of a non-overtopping section. The armor rock extends the full length of the seaward side and the width of the crest and B rock extends down from the crest the length of the harbor-side slope.

The layout of the breakwater is designed such that the significant wave height from the 50-year storm is reduced to the maximum allowable wave height at the boat launch. The maximum allowable wave height for the boat launch only alternatives is 2 feet. The breakwater begins in a water depth of +5 feet MLLW and extends a total length of 443 feet to the north end of the breakwater at a depth of -12 feet MLLW.

The breakwater layout defines a south facing entrance channel and maneuvering channel. This breakwater alignment is the shortest and is the least costly of all of all the alternatives. The south breakwater alignment does have the disadvantage of a higher cost for future mooring basin expansion to the north since more breakwater would have to be demolished for a northward breakwater extension.

Entrance Channel. This alternative has an entrance and maneuvering channel 450 feet in length. Vessels would enter the entrance channel from the northeast and turn roughly 110 degrees to the north to access the boat launch. Due to the channel's southern orientation the channel's length is shorter and dredge quantity will be lower than the alternatives with a northern orientation. The design of the entrance channel for this alternative is based on the 37-foot design vessel. The channel depth is -10.5 feet MLLW. The channel width is defined to accommodate two-way traffic of the design vessel based on percent beam widths as described in EM 1110-2-1615. The channel width is 112 feet.

Dredge material within the entrance channel should mainly consist of sand and gravels with some silt based on the previous geotechnical borings from the area. Encountering significant numbers of cobbles and boulders should also be expected. The geotechnical borings did not indicate the presence of bedrock but the borings limited depth did not define the bedrock surface. All dredging for this alternative is expected to be deposited upland due to the potential for fuel contamination from the former Army tank farm to the west. The dredged materials will have to be temporarily stocked piled upland and tested for contaminates prior to permanent upland disposal. Material found to be contaminated by laboratory tests will be separated and shipped off-site for treatment prior to disposal in a landfill. It is currently assumed that the contaminated dredged material amount will be roughly 15 percent of the total dredged quantity. Additional geotechnical and chemical testing will have to be conducted during the PED phase to verify the assumed percentage of contaminated dredging.

Annual maintenance dredging is not anticipated to be required for this alternative. Shoaling is not expected to be a significant issue with the location of the entrance channel. The lack of changes in the sites bathymetry indicate minimal sediment movement from littoral drift. Fine grained suspended sedimentation does not appear to be significant.

Circulation and Water Quality. As recommended by ASCE the harbor design parameters that most effect circulation and water quality are the TPR, basin aspect ratio, and the entrance channel area ratio. The basin area for this alternative is basically the small basin at the end of the launch ramps with a shallow entrance channel. The MHHW tide range exceeds half the high tide water depth. The tidal prism ratio is 0.68, which greatly exceeds the 0.35 ratio for good circulation. The aspect ratio for this alternative is 1.5, a good value. The shape of the harbor basin, in this case a channel, results in a poor value for the entrance area ratio at 37. The entrance area ratio applied to this non-standard harbor basin tends to indicate that the alternative may have circulation problems but the tidal flushing provided with a TPR of 0.68 and aspect ratio indicted this alternative would have good circulation and water quality.

6.3.9. Alternative 9 - 6-Lane Boat Launch with South Entrance Channel. This alternative is located at the Head of the Bay site. The alternative includes a 6-lane launch ramp, dredge entrance and maneuvering channel and a rubble mound breakwater. No vessel moorage is included in this alternative. A detailed quantity listing for this alternative can be found in Attachment A-B of this appendix.

Launch Ramp. This alternative would add six launch ramp lanes to the three in the existing harbor. The additional launch lanes will reduce nearly all the delay time to launch and recover vessels with the exceptions of busy weekend and holiday use. The additional launch ramps will also reduce one of the city's primary safety concerns, the amount of vehicle congestion at the existing harbor. The launch ramps are designed similar to those installed at the existing harbor in Whittier. The ramps will have an asphalt turn-around area at the top of the ramp, a parabolic concrete apron, concrete ramp planks, and a pipe-pile supported, articulated boarding float made up of individual modules.

The asphalt turn-around area is the full width of the six ramps or 120 feet wide, providing a turning radius of 60 feet. The turn-around is 100 feet in length or 1.5 times the estimated combine vehicle and trailer length (66 feet). The turn-around will be constructed of 6-inch layer of roller compacted asphalt on top of a 12-inch layer compacted crushed gravel base course.

The concrete ramp apron will have a parabolic shape to transition from the turnaround to the ramp slope without trailer high centering. The concrete apron will also include wedge shaped abutments for the connection of the boarding floats. The ramp apron will be constructed of a 9-inch layer of poured concrete on top of a 12-inch layer compacted crushed gravel base course.

The boat launch ramp, including the concrete apron, extends from the existing grade of +18 feet MLLW down to a depth of -6.6 feet MLLW ensuring that the ramp will be usable during all tide levels. The ramp section will have a 13% slope and a length of 156 feet. The ramp section will be constructed of many individual concrete planks that are bolted to a heavy timber sleeper frame. The timber frame is filled with compacted crushed gravel base course. The 20-foot width of the ramp planks will provide a 16-foot wide launch lane and half of the width, 4 feet, for the boarding float. A layer of slope protection rock will extend down from the end of the ramp slope for an additional 10 feet and then continue down to the dredge depth at the standard 1V:2H slope.

Each of the three boarding floats will be 280-feet long and 8-feet in width. Each float will service two launch lanes. The boarding floats will be made up of fourteen 20-foot long floating modules and every other module will have a pipe pile installed through the module to support the boarding float from lateral forces such as wind, waves, vessel impacts, etc.

Rubble-mound Breakwater. The breakwater is a three layer structure made up of primary armor layer, two armor stones thick, a secondary armor layer made of B rock, and a permeable core made up of core rock. The breakwater section is typical of a non-overtopping section. The armor rock extends the full length of the seaward side and the width of the crest and B rock extends down from the crest the length of the harbor-side slope.

The layout of the breakwater is designed such that the significant wave height from the 50-year storm is reduced to the maximum allowable wave height at the boat launch. The maximum allowable wave height for the boat launch only alternatives is 2 feet. The breakwater begins in a water depth of +5 feet MLLW and extends a total length of 482 feet to the north end of the breakwater at a depth of -12 feet MLLW.

The breakwater layout defines a south facing entrance channel and maneuvering channel. This breakwater alignment is shorter and is the less costly than the north oriented breakwater alternatives. The south breakwater alignment does have the disadvantage of a higher cost for future mooring basin expansion to the north since more breakwater would have to be demolished for a northward breakwater extension.

Entrance Channel. This alternative has an entrance and maneuvering channel 470 feet in length. Vessels would enter the entrance channel from the southeast and turn roughly 110 degrees to the north to access the boat launch. Due to the channel's southern orientation the channel's length will be shorter and the dredge quantity will be lower than the alternatives with a northern orientation. The design of the entrance channel for this alternative is based on the 37-foot design vessel. The channel depth is -10.5 feet MLLW. The channel width is defined to accommodate two-way traffic of the design vessel based on percent beam widths as described in EM 1110-2-1615. The channel width is 112 feet.

Dredge material within the entrance channel should mainly consist of sand and gravels with some silt based on the previous geotechnical borings from the area. Encountering significant numbers of cobbles and boulders should also be expected. The geotechnical borings did not indicate the presence of bedrock but the borings limited depth did not define the bedrock surface. All dredging for this alternative is expected to be deposited upland due to the potential for fuel contamination from the former Army tank farm to the west. The dredged materials will have to be temporarily stocked piled upland and tested for contaminates prior to permanent upland disposal. Material found to be contaminated by laboratory tests will be separated and shipped off-site for treatment prior to disposal in a landfill. It is currently assumed that the contaminated dredged material amount will be roughly 15 percent of the total dredged quantity. Additional geotechnical and chemical testing will have to be conducted during the PED phase to verify the assumed percentage of contaminated dredging.

Annual maintenance dredging is not anticipated to be required for this alternative. Shoaling is not expected to be a significant issue with the location of the entrance channel. The lack of changes in the sites bathymetry indicate minimal sediment movement from littoral drift. Fine grained suspended sedimentation does not appear to be significant.

Circulation and Water Quality. As recommended by ASCE the harbor design parameters that most effect circulation and water quality are the TPR, basin aspect ratio, and the entrance channel area ratio. The basin area for this alternative is basically the small basin at the end of the launch ramps with a shallow entrance channel. The MHHW tide range exceeds half the high tide water depth. The tidal prism ratio is 0.67, which greatly exceeds the 0.35 ratio for good circulation. The aspect ratio for this alternative is 1.8, a good value. The shape of the harbor basin, in this case a channel, results in a poor value for the entrance area ratio at 42. The entrance area ratio applied to this non-standard harbor basin tends to indicate that the alternative may have circulation problems but the tidal flushing provided with a TPR of 0.67 and aspect ratio indicted this alternative would have good circulation and water quality.

7.0 PLAN IMPLEMENTATION

7.1 Aids to Navigation

Navigation marker bases will be constructed at the entrance channel ends of the breakwaters as part of the initial project. Navigation aids are typically installed and maintained by the U.S. Coast Guard upon completion of a project.

7.2 Operations and Maintenance

Operation and maintenance of the local service facilities would be accomplished by the City of Whittier. These include the mooring basin, launch ramps, float system and associated maintenance dredging for the previous items. The Federal Government would be responsible for the breakwaters, entrance channel and maneuvering channel for the project. The Alaska District would make periodic site visits to inspect the breakwaters and accomplish hydrographic surveys of the harbor at approximately 5 year intervals. The inspections and surveys provide the information necessary to determine if maintenance of the breakwater or dredging of the basin, maneuvering channel or entrance channel is needed. Federal and local maintenance dredging would likely be combined to minimize costs by reducing the mobilization and demobilization cost, and maximizing the dredging quantity. The existing harbor and entrance channel have not required dredging since its completion over 50 years ago. Based on past experience with the existing harbor it is assumed that the harbor alternatives will only require maintenance dredging after near design event storms.

The breakwater was designed to be stable in storm conditions that could be expected during the 50-year return interval storm event. Little, if any, loss of armor rock or other maintenance of the breakwater would be expected over the life of the project. Historically, breakwaters designed similar criteria have experienced little or no deterioration requiring maintenance during 50-year design life. However, a value of 10% of the armor stone has been assumed for evaluation of the alternatives to need replacement after 25 years.

Shoaling has not been a problem at the existing harbor entrance or within the existing harbor. Any littoral drift material will tend to move into deeper waters off the breakwaters. Suspended sediments most likely from Whittier Creek, also have not been a problem in the existing harbor and, and it is expected that suspended sediment from Learnard and Shakespeare Creeks will not be a problem for any of the remaining alternatives at the head of the bay.

7.3 Detailed Quantity Estimates

Quantity estimates for each alternative are provided in the tables in Attachment A-A. Quantities were estimated from detail drawings using AutoCAD software and were checked by hand calculations.

7.4 Construction Schedule

The major harbor construction items from the alternatives previously described include the rubble-mound breakwaters, dredging, disposal areas, and boat launches. The sequence of construction will depend on the components that make up the final plan but several construction sequencing requirements will dictate the construction schedule. Breakwater construction and dredging can occur simultaneously. Slope protection for the dredged slopes will take place after those slopes have been cut to grade. Similarly the constructions of the ramps will have to take place after those areas are dredged/excavated to grade.

No environmental windows or administrative restrictions on construction activities have been identified to date that would limit construction operations. Subsequent environmental windows and/or construction restrictions would be detailed in the development of plans and specifications. Each of the four optimized alternatives that were carried forward for detailed analysis are very similar in scope and construction quantities therefore the construction schedule will be similar for each of the remaining alternatives. The construction duration for the remaining alternatives is estimated to be 12-24 months depending on the alternative selected for construction, timeframe of contract award, and the quantity of contaminated dredging encountered.

8.0. REFERENCES

Tobiasson, Bruce O., and Ronald C. Kollmeyer, 1991, *Marinas and Small Craft Harbors*, Van Nostrand Reinhold, 584 pp.

EM 1110-2-1100, Coastal Engineering Manual, U.S. Army Corps of Engineers, Aug 2008.

EM 1110-2-1615, Hydraulic Design of Small Boat Harbors, U.S. Army Corps of Engineers, September 1984.

EM 1110-2-1260, Environmental Engineering for Small Boat Basins, U.S. Army Corps of Engineers, October 1993.

Shore Protection Manual, Fourth Edition, U.S. Army Corps of Engineers, 1984.

Planning and Design Guidelines for Small Craft Harbors, Revised Edition, American Society of Civil Engineers, prepared by the Task Committee on Marinas, 2012.

Nece, Ronald E, Richey, Eugene P, Rhee, Joonpyo, and Smith, H. Norman, *Effects of Planform Geometry on Tidal Flushing and Mixing in Marinas*, Technical Report No. 62, Charles W. Harris Hydraulics Laboratory, Department of Civil Engineering, University of Washington, Seattle, Washington, December 1979.

U.S. Army Corps of Engineers, Alaska District. *Feasibility Scoping Meeting Report, Navigation Improvements, Whittier, Alaska*, July 2009

HDR, Inc. *Whittier Boat Ramp Preliminary Design Technical Memorandum*, Sep 1999

U.S. Army Corps of Engineers, Alaska District. *Harbor Improvement Technical Report, Whittier, Alaska*, Feb 1997

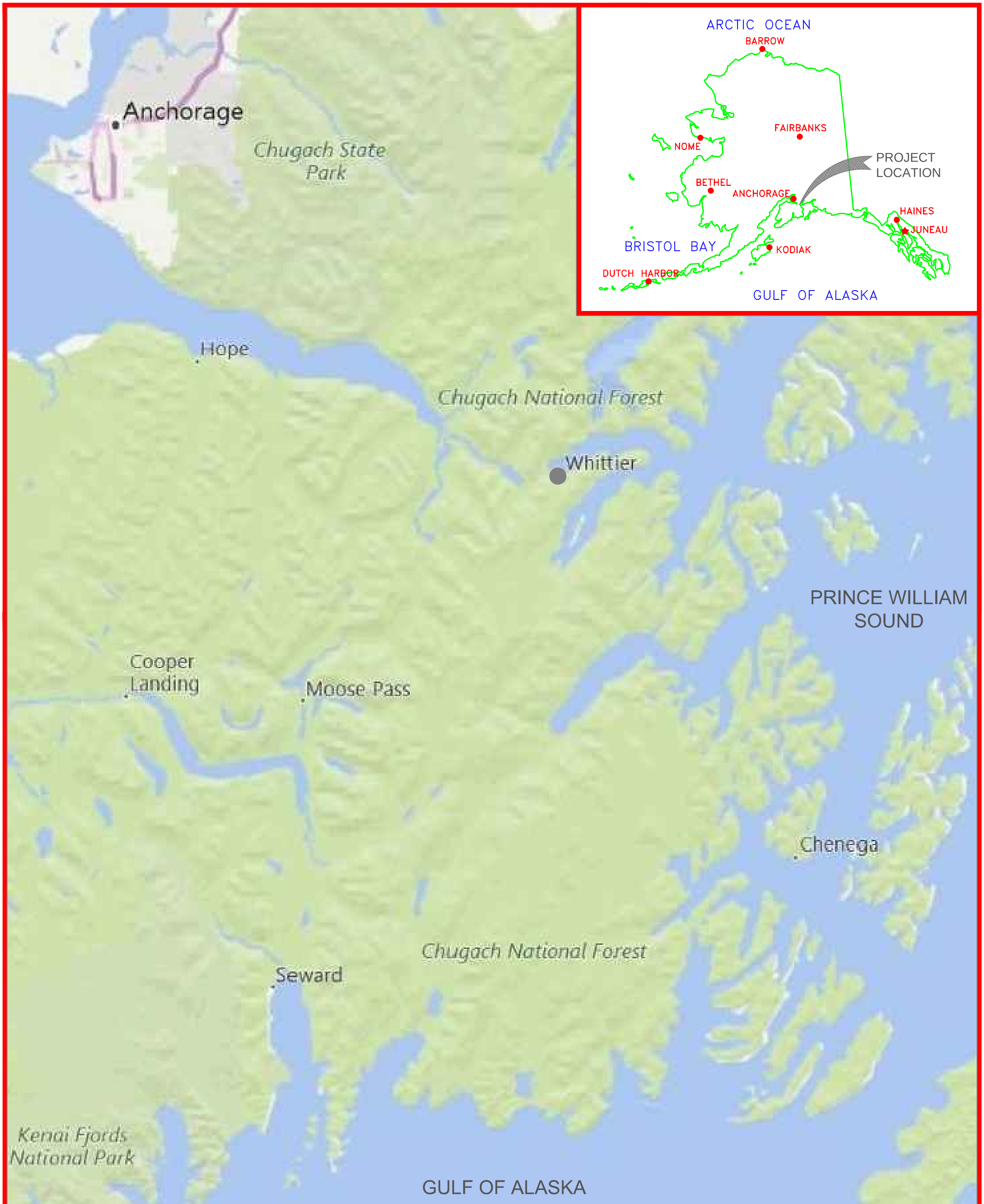
Tryck Nyman Hayes, Inc. *Design of Boat Harbor Improvements Whittier, Alaska*, Jan1997

Tryck Nyman Hayes, Inc. *Whittier Harbor Feasibility Study*, Jan1996

U.S. Army Corps of Engineers, Alaska District. *Reconnaissance Report for Boat Harbor Improvements, Whittier, Alaska*, Apr 1994

U.S. Army Corps of Engineers, Alaska District. *Detailed Project Report and Environmental Considerations, Small Craft Navigation Study, Whittier, Alaska*, July 2009

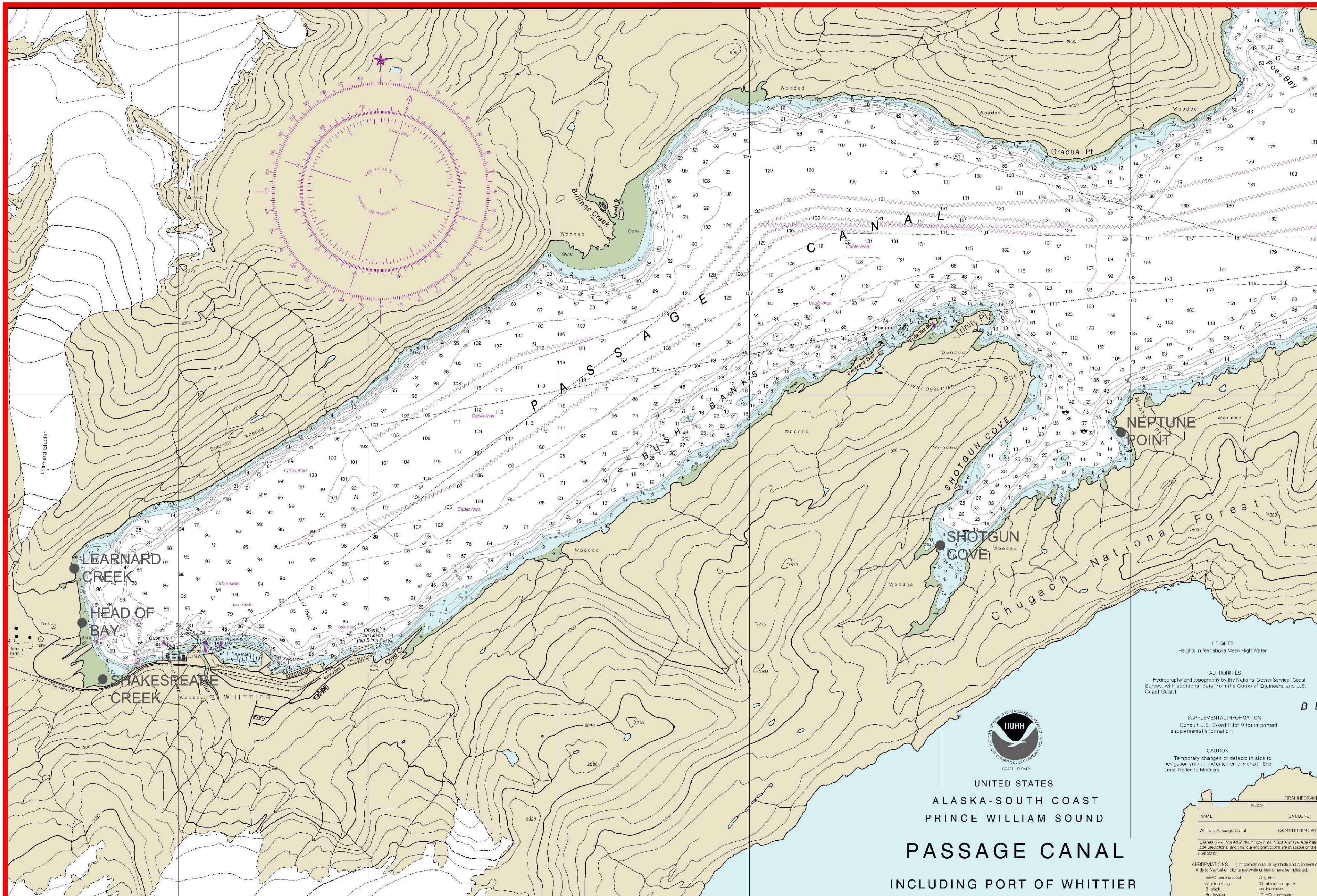
ATTACHMENT A-A
APPENDIX FIGURES



ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH

LOCATION AND VICINITY MAP
WHITTIER HARBOR

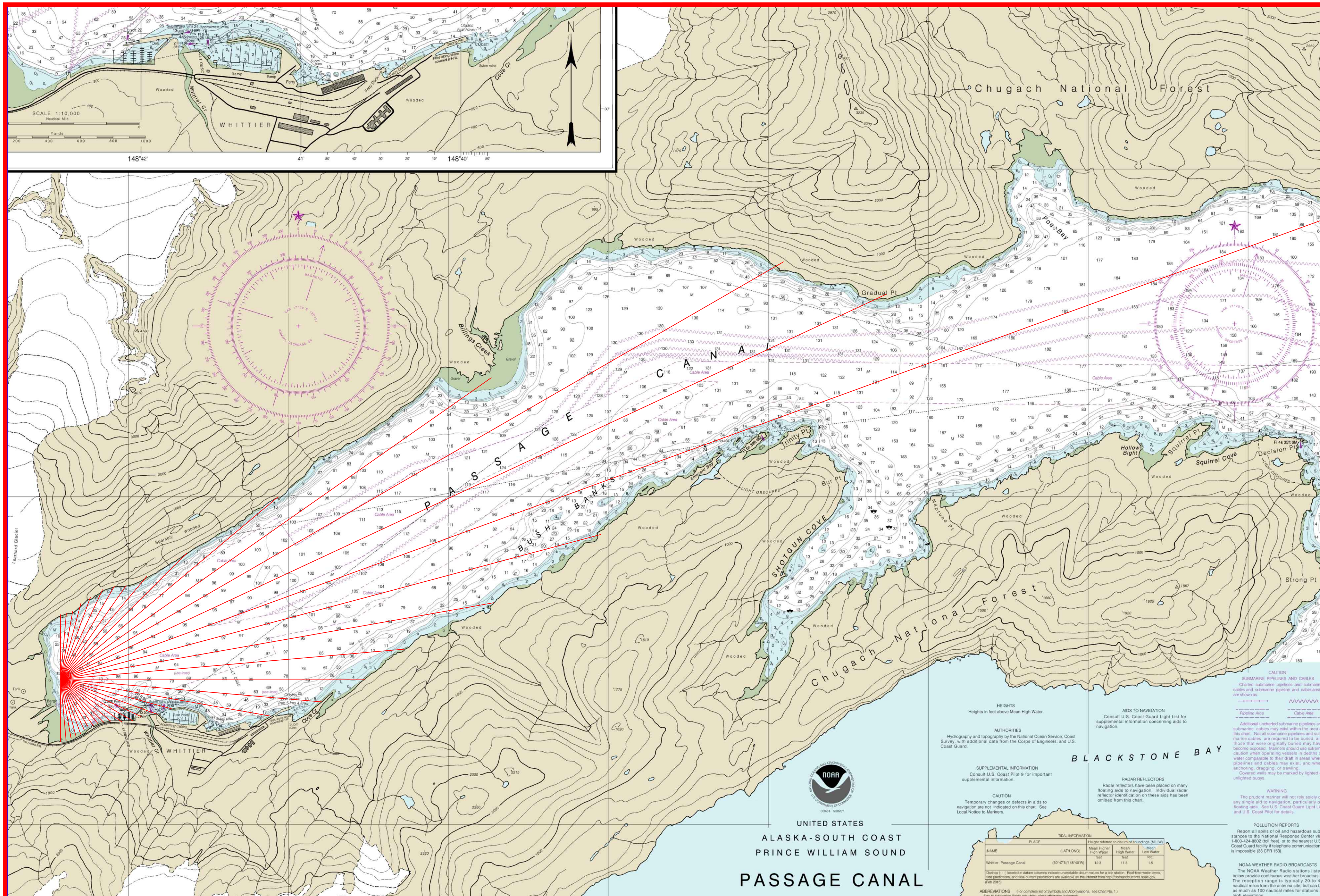
A-3



ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH

SITES MAP
WHITTIER HARBOR

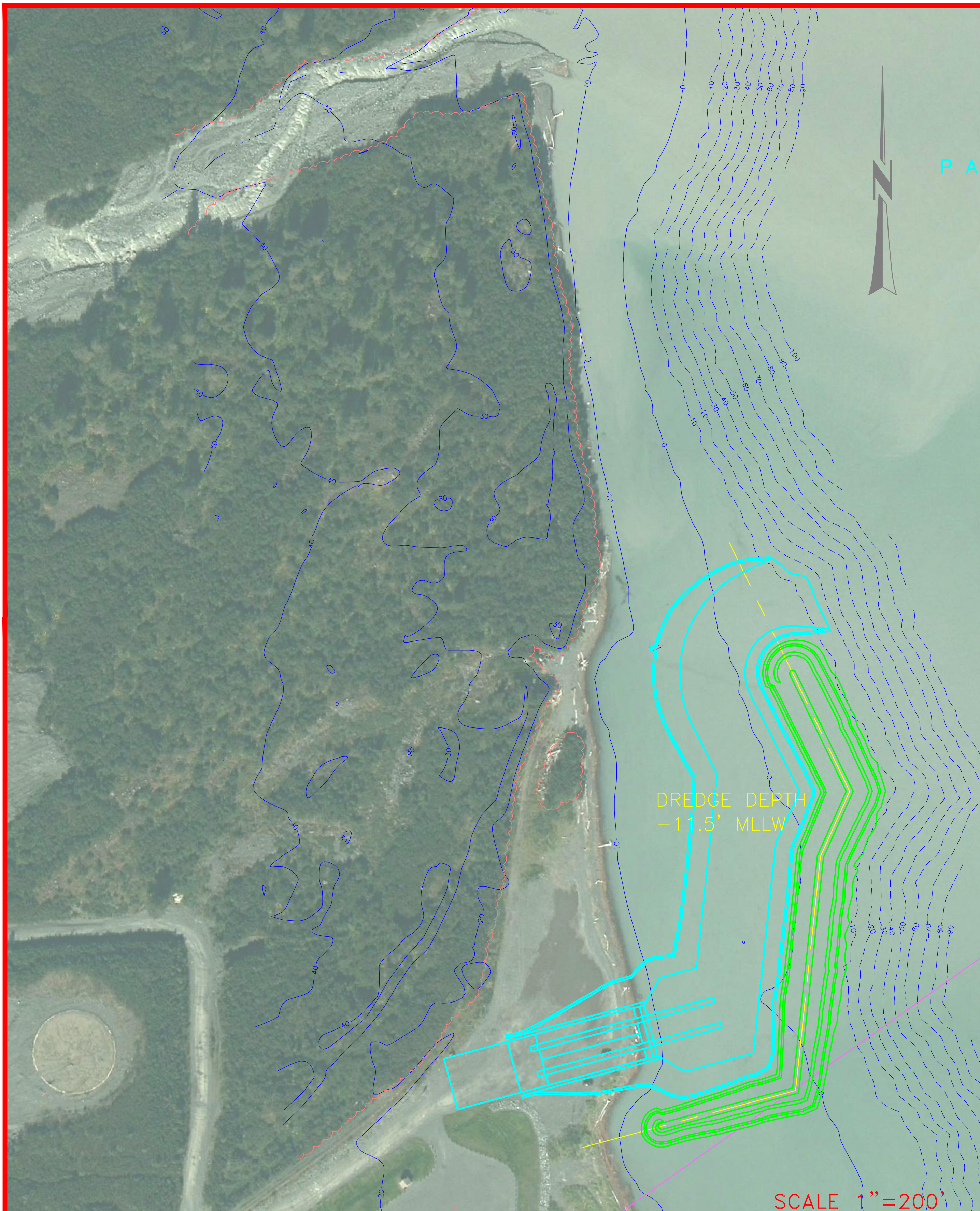
A-4



ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH

ALTERNATIVE FETCHES – HEAD OF BAY SITE
WHITTIER HARBOR

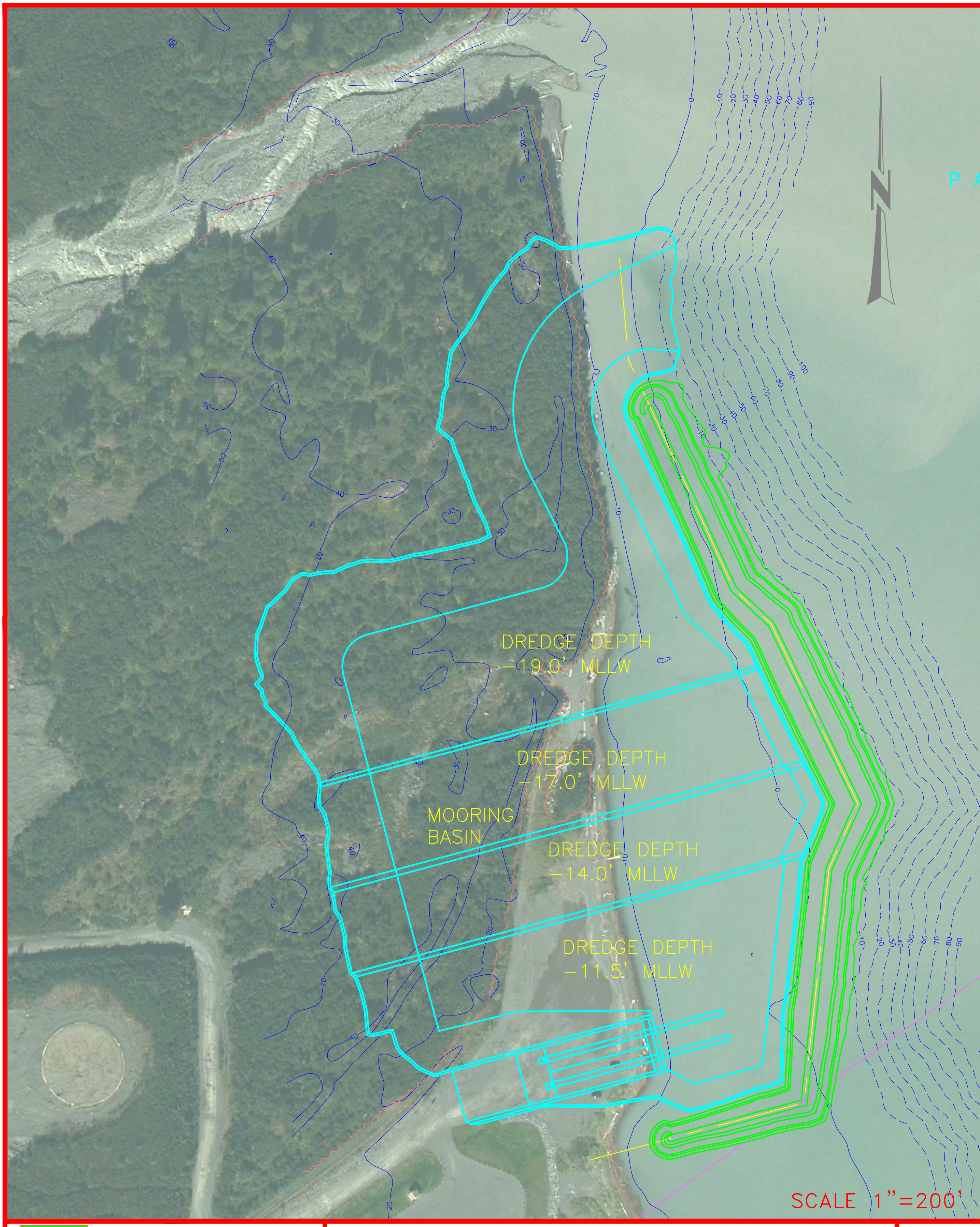
A–5



ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH

ALT 2 – 4 LANE LAUNCH RAMP
WHITTIER HARBOR

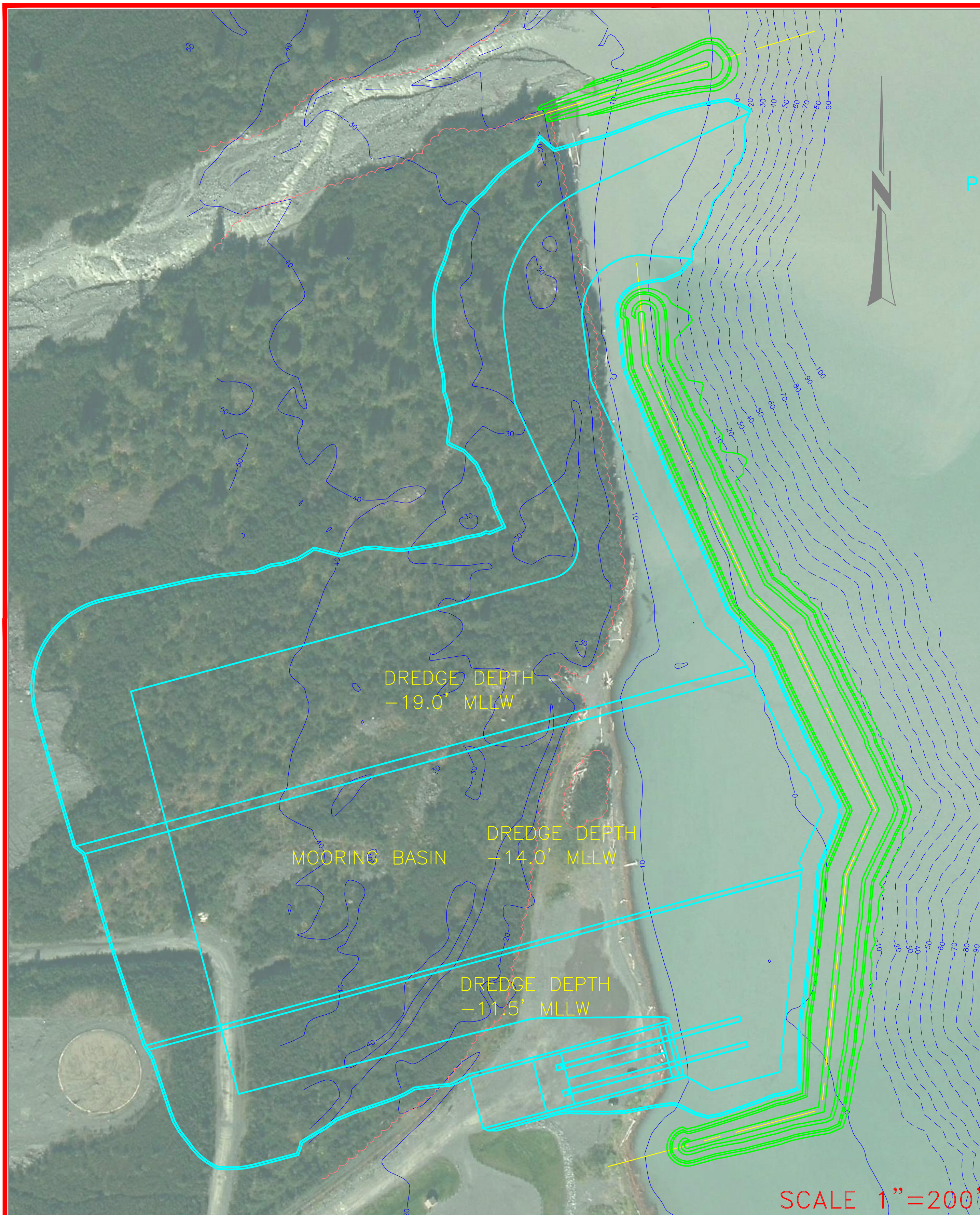
A–6



ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH

ALT 3 – 150 VESSEL HARBOR
WHITTIER HARBOR

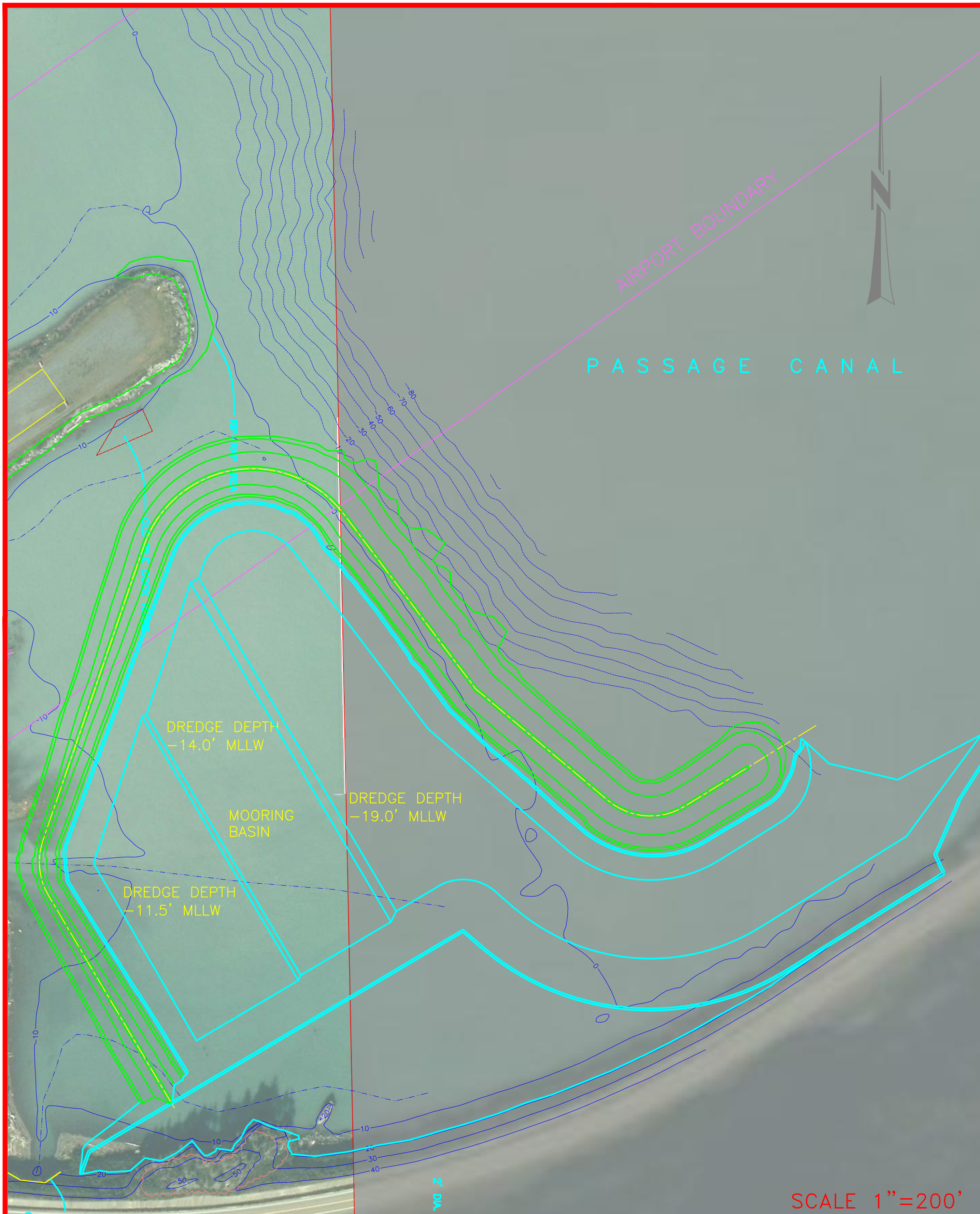
A-7



ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH

ALT 4 – 300 VESSEL HARBOR
WHITTIER HARBOR

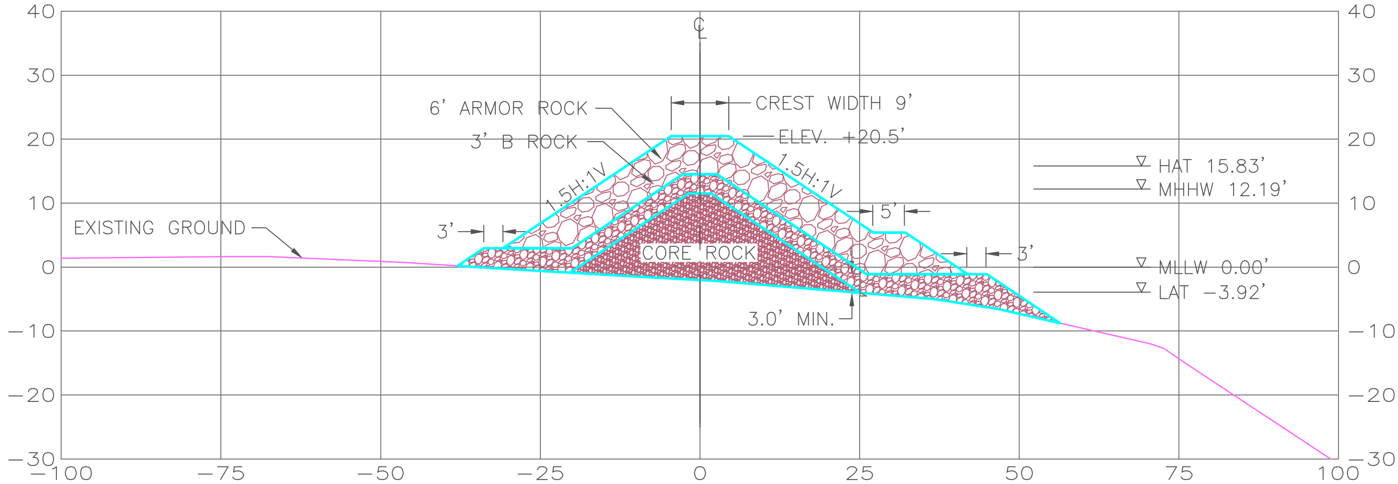
A-8



ALASKA DISTRICT
U.S. ARMY
CORPS OF ENGINEERS

ALT 5 – SHAKESPEARE CREEK HARBOR
WHITTIER HARBOR

A–9



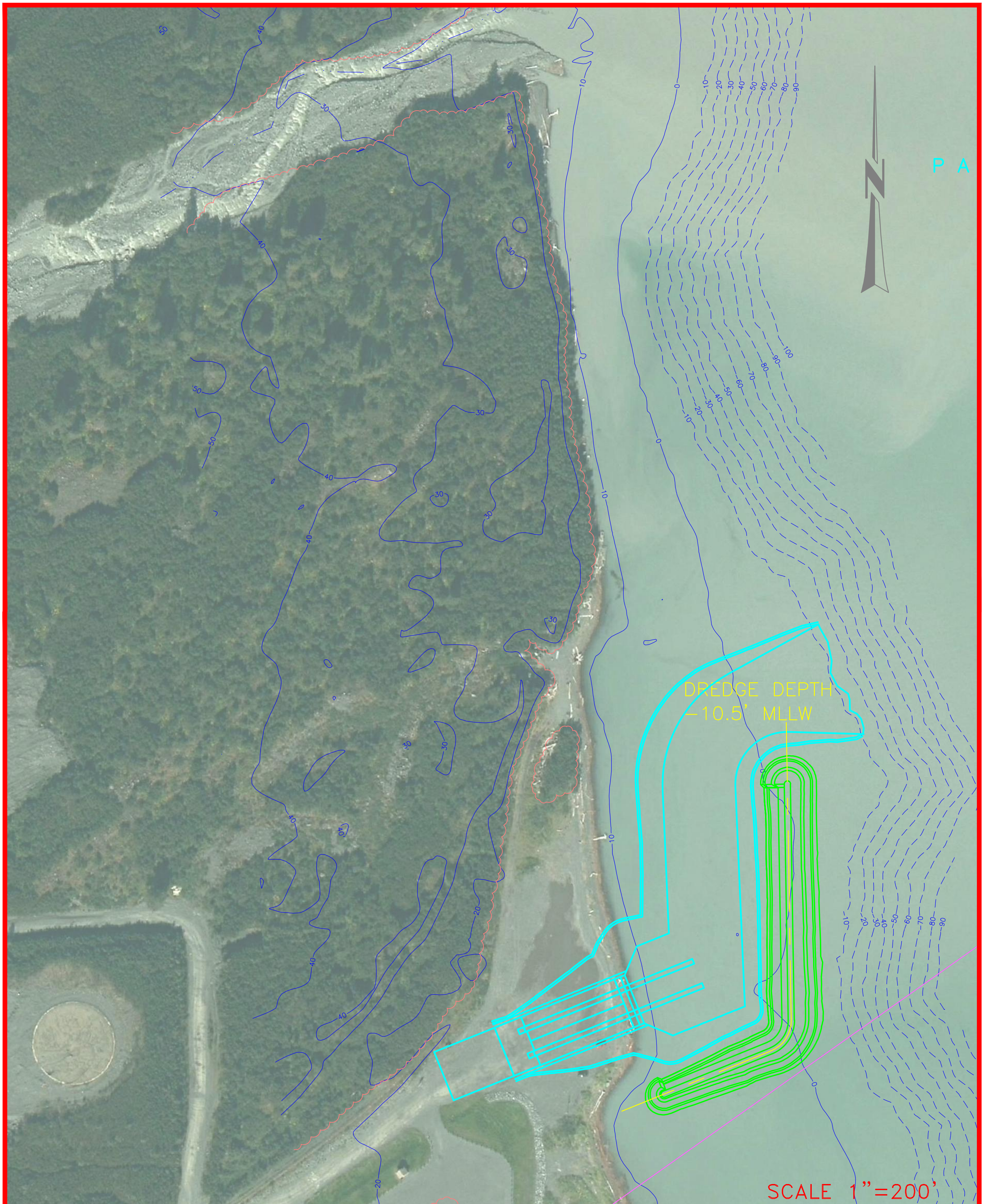
OVERTOPPING BREAKWATER SECTION

1. SECTION VERTICAL UNITS ARE FEET MEAN LOWER LOW WATER (MLLW).
2. SECTION HORIZONTAL UNITS ARE REFERENCE PERPENDICULAR TO THE BREAKWATER ALIGNMENT.
3. BREAKWATER ARMOR ROCK, B ROCK AND CORE ROCK SLOPES ARE 1.5H:1V UNLESS NOTED OTHERWISE.

ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH

OVERTOPPING BREAKWATER SECTION
WHITTIER HARBOR

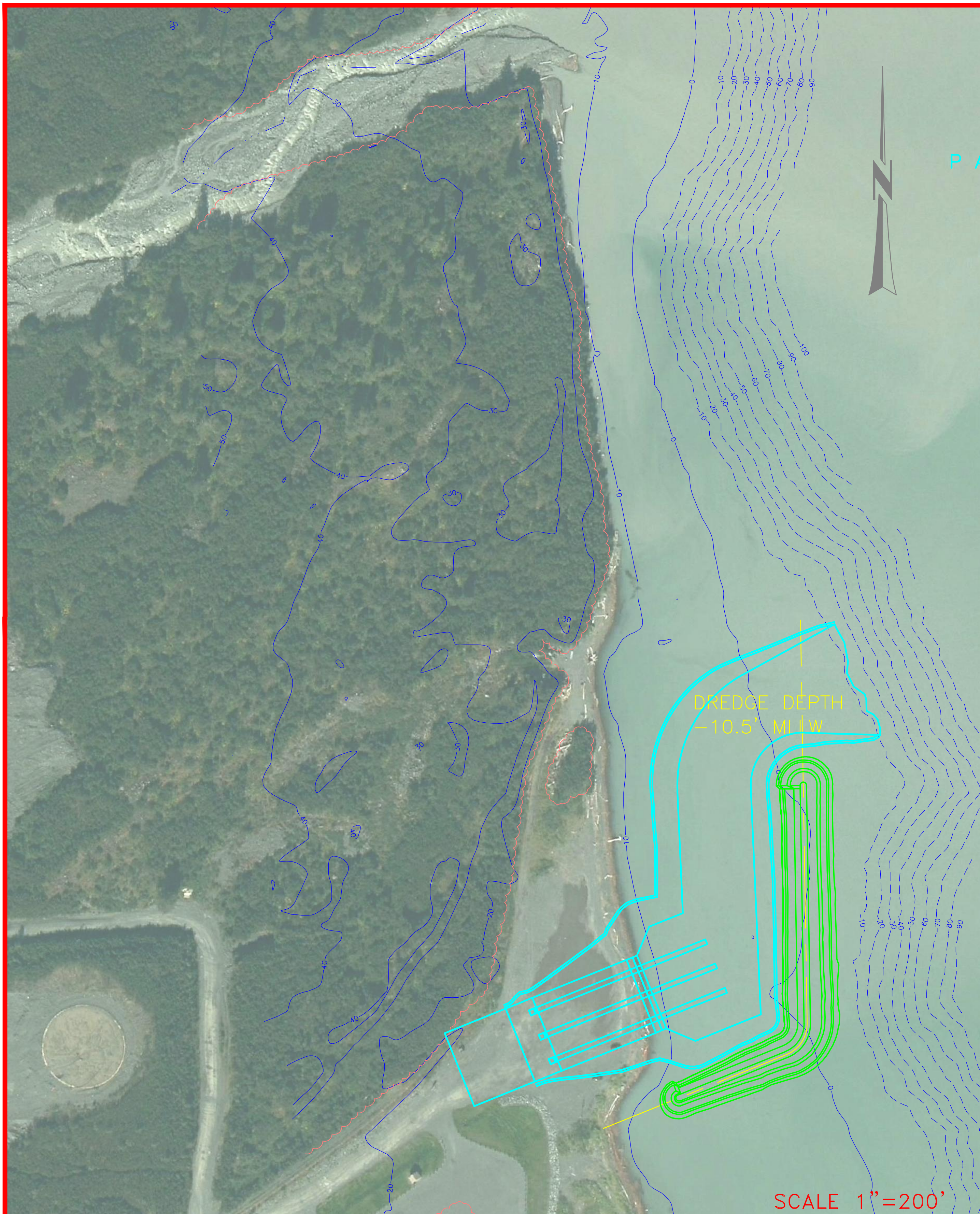
A-10



ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH

ALT 6 – 4 LANE LAUNCH RAMP
WITH NORTH ENTRANCE
WHITTIER HARBOR

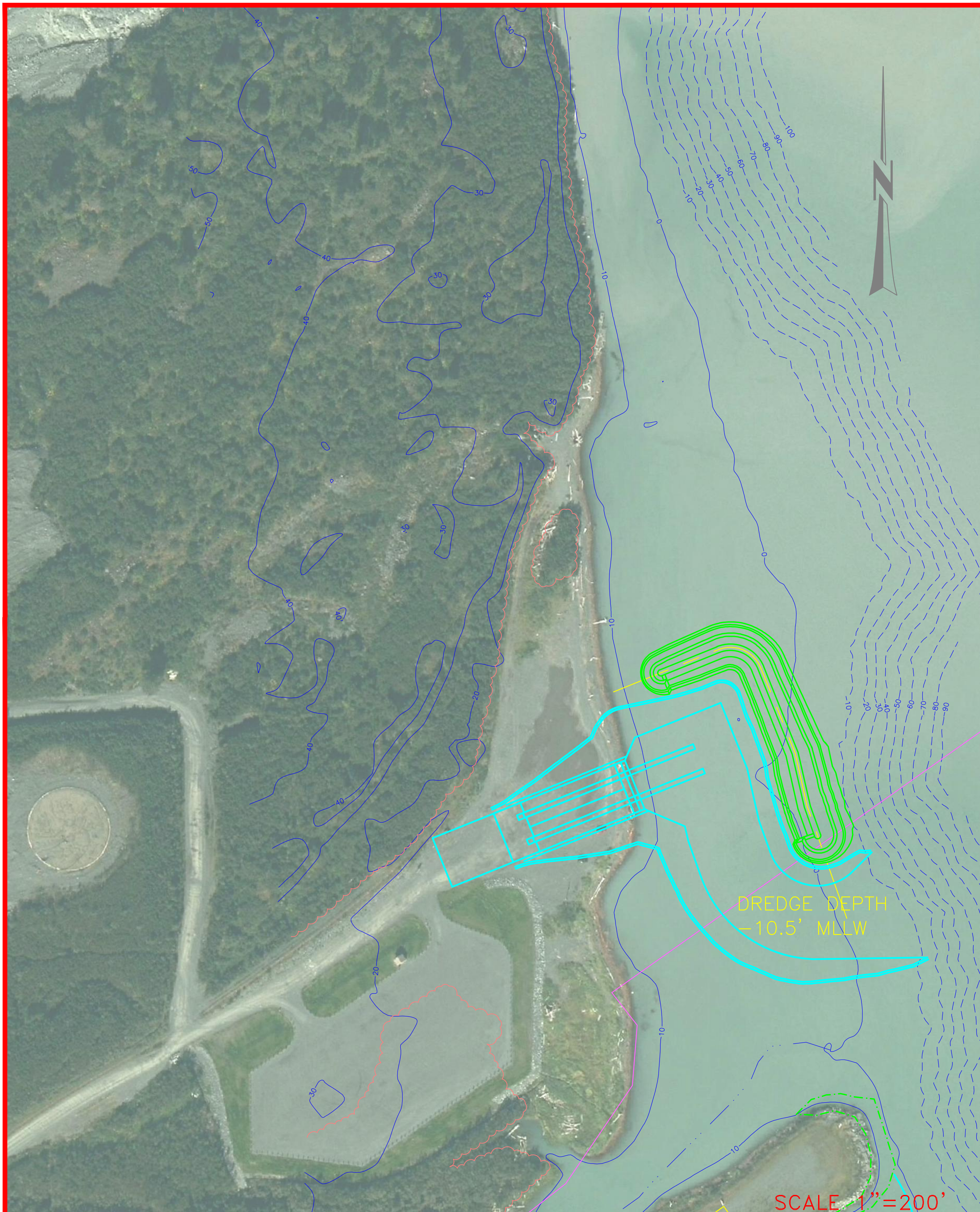
A-11



ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH

ALT 7 – 6 LANE LAUNCH RAMP
WITH NORTH ENTRANCE
WHITTIER HARBOR

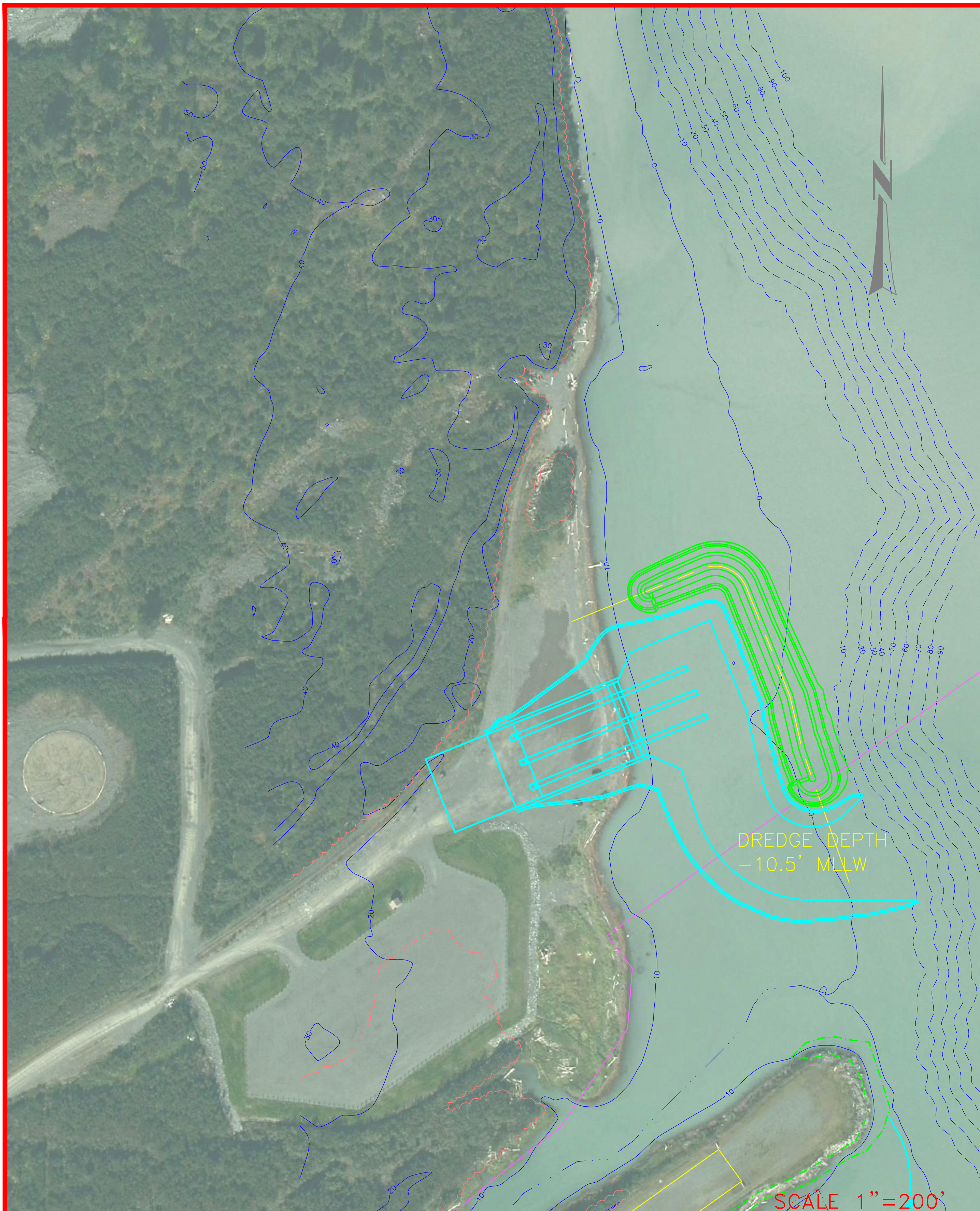
A–12



ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH

ALT 8 – 4 LANE LAUNCH RAMP
WITH SOUTH ENTRANCE
WHITTIER HARBOR

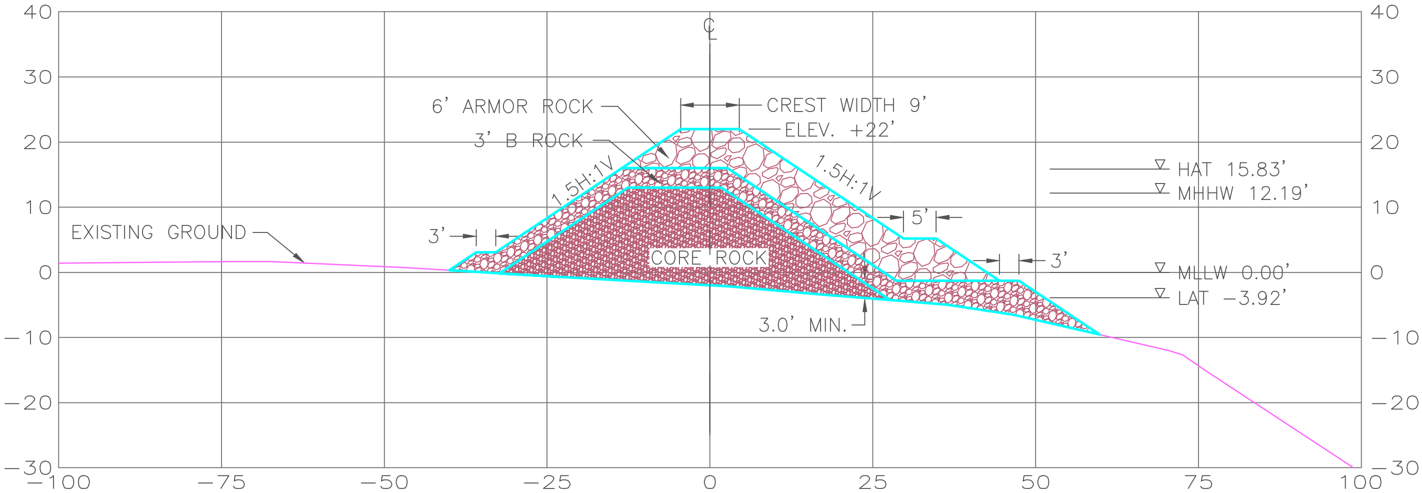
A-13



ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH

ALT 9 – 6 LANE LAUNCH RAMP
WITH SOUTH ENTRANCE
WHITTIER HARBOR

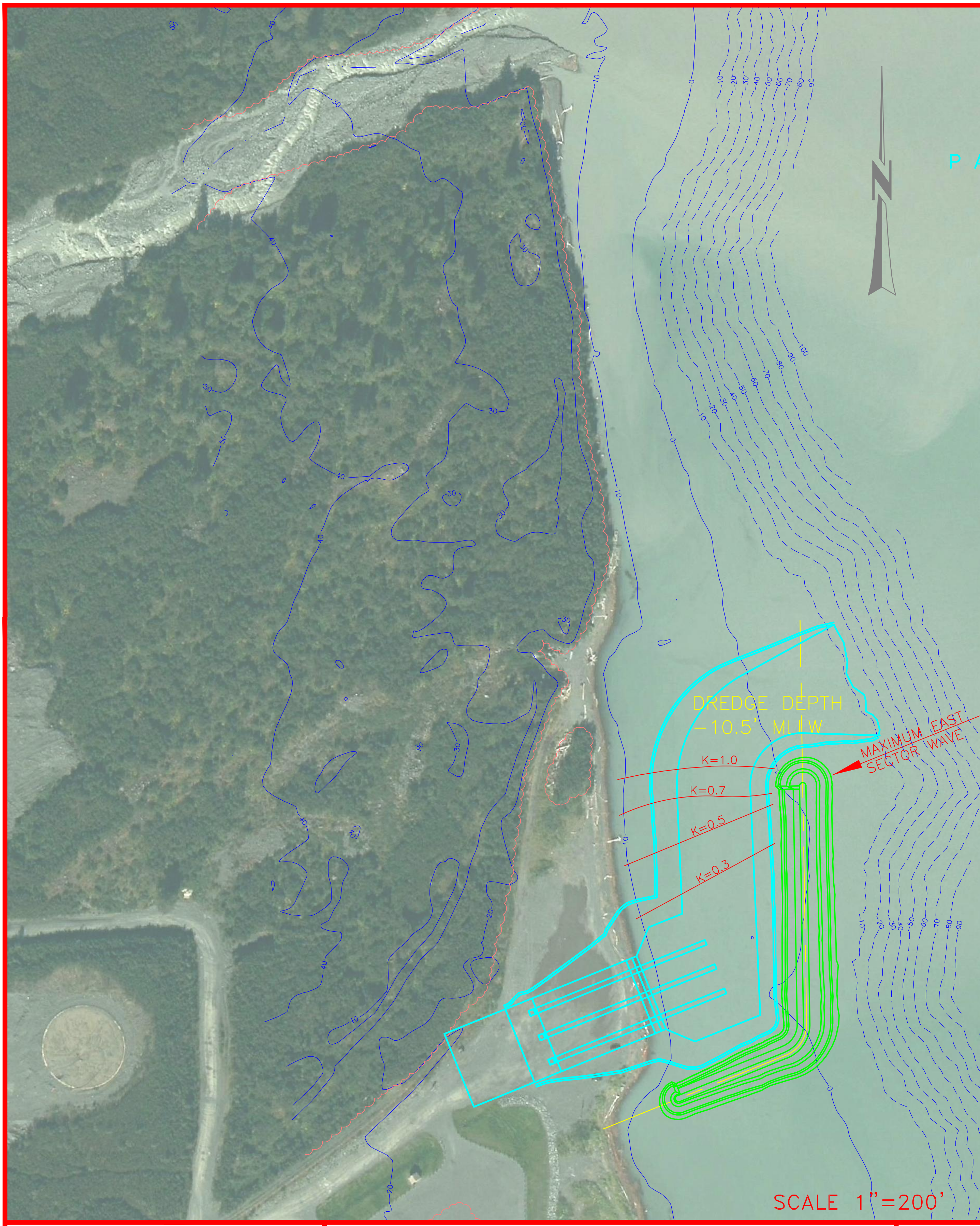
A–14



NONOVERTOPPING BREAKWATER SECTION

1. SECTION VERTICAL UNITS ARE FEET MEAN LOWER LOW WATER (MLLW).
2. SECTION HORIZONTAL UNITS ARE REFERENCE PERPENDICULAR TO THE BREAKWATER ALIGNMENT.
3. BREAKWATER ARMOR ROCK, B ROCK AND CORE ROCK SLOPES ARE 1.5H:1V UNLESS NOTED OTHERWISE.

ALASKA DISTRICT CORPS OF ENGINEERS CIVIL WORKS BRANCH	NONOVERTOPPING BREAKWATER SECTION WHITTIER HARBOR	A−15



ALASKA DISTRICT
CORPS OF ENGINEERS
CIVIL WORKS BRANCH

ALT 7 – 6 LANE LAUNCH RAMP WITH NORTH ENTRANCE – EAST SECTOR WAVE DIFFRACTION
WHITTIER HARBOR

A-16

ATTACHMENT A-B
QUANTITY ESTIMATES

Alternative 2
4-Lane Boat Launch with North Entrance Channel
Detailed Quantity Estimate

Item	Quantity	Unit
Breakwater		
Breakwater Rock Placement		
Armor rock placement	14,950	CY
Secondary rock placement	10,890	CY
Core rock placement	11,890	CY
Navigation aid foundation	1	EA
Entrance & Maneuvering Channel Dredging		
Entrance channel Excavation	46,100	CY
Slope protection	2,470	CY
Ramp Excavation		
Excavation	25,500	CY
Slope protection	1,330	CY
Hydrographic/Topographic Surveys	3	EA
Local Harbor Facilities		
Boat Ramps		
Asphalt Turnaround Area	148	CY
Concrete Ramp Apron	118	CY
Concrete Ramp Planks	316	EA
Gravel Fill	1,140	CY
Timber Sleepers	240	EA
Boarding Float Modules 8'x20'	28	EA
Boarding Float Piling 12"dia.x66'	12	EA
Upland Parking Area	1	JOB
Design/construct floats & Utilities	1	JOB
Dredge Material Disposal		
Onshore disposal	71,600	CY
Contaminated material disposal	3,580	CY

Alternative 3
150 Boat Harbor with 4-Lane Boat Launch
Detailed Quantity Estimate

Item	Quantity	Unit
Breakwater		
Breakwater Rock Placement		
Armor rock placement	22,920	CY
Secondary rock placement	16,870	CY
Core rock placement	18,890	CY
Navigation aid foundation	1	EA
Entrance & Maneuvering Channel Dredging		
Entrance channel Excavation	194,300	CY
Slope protection	6,290	CY
Mooring Basin and Ramp Excavation		
Excavation	535,300	CY
Slope protection	8,200	CY
Hydrographic/Topographic Surveys	3	EA
Local Harbor Facilities		
Boat Ramps		
Asphalt Turnaround Area	148	CY
Concrete Ramp Apron	118	CY
Concrete Ramp Planks	316	EA
Gravel Fill	1,140	CY
Timber Sleepers	240	EA
Boarding Float Modules 8'x20'	28	EA
Boarding Float Piling 12"dia.x66'	12	EA
Upland Parking Area	1	JOB
Design/construct floats & Utilities	1	JOB
Dredge Material Disposal		
Onshore disposal	729,600	CY
Contaminated material disposal	36,480	CY

Alternative 4
300 Boat Harbor with 4-Lane Boat Launch
Detailed Quantity Estimate

Item	Quantity	Unit
Breakwater		
Breakwater Rock Placement		
Armor rock placement	27,290	CY
Secondary rock placement	20,230	CY
Core rock placement	20,230	CY
Navigation aid foundation	2	EA
Entrance & Maneuvering Channel Dredging		
Entrance channel Excavation	46,100	CY
Slope protection	8,150	CY
Mooring Basin and Ramp Excavation		
Excavation	1,401,600	CY
Slope protection	16,650	CY
Hydrographic/Topographic Surveys	3	EA
Local Harbor Facilities		
Boat Ramps		
Asphalt Turnaround Area	148	CY
Concrete Ramp Apron	118	CY
Concrete Ramp Planks	316	EA
Gravel Fill	1,140	CY
Timber Sleepers	240	EA
Boarding Float Modules 8'x20'	28	EA
Boarding Float Piling 12"dia.x66'	12	EA
Upland Parking Area	1	JOB
Design/construct floats & Utilities	1	JOB
Dredge Material Disposal		
Onshore disposal	1,331,520	CY
Contaminated material disposal	70,080	CY

Alternative 5
105 Boat Harbor at Shakespeare Creek
Detailed Quantity Estimate

Item	Quantity	Unit
Breakwater		
Breakwater Rock Placement		
Armor rock placement	31,600	CY
Secondary rock placement	20,790	CY
Core rock placement	32,110	CY
Navigation aid foundation	1	EA
Entrance & Maneuvering Channel Dredging		
Entrance channel Excavation	123,800	CY
Slope protection	9,970	CY
Mooring Basin and Ramp Excavation		
Excavation	225,500	CY
Slope protection	3,540	CY
Hydrographic/Topographic Surveys	3	EA
Local Harbor Facilities		
Upland Parking Area	1	JOB
Design/construct floats & Utilities	1	JOB
Dredge Material Disposal		
Onshore disposal	331,800	CY
Contaminated material disposal	17,470	CY

Alternative 6
4-Lane Boat Launch with North Entrance Channel
Detailed Quantity Estimate

Item	Quantity	Unit
Breakwater		
Breakwater Rock Placement		
Armor rock placement	6,670	CY
Secondary rock placement	6,580	CY
Core rock placement	7,440	CY
Navigation aid foundation	1	EA
Entrance & Maneuvering Channel Dredging		
Entrance channel Excavation	41,180	CY
Slope protection	1,835	CY
Ramp Excavation		
Excavation	21,690	CY
Slope protection	1,315	CY
Hydrographic/Topographic Surveys	3	EA
Local Harbor Facilities		
Boat Ramps		
Asphalt Turnaround Area	148	CY
Concrete Ramp Apron	118	CY
Concrete Ramp Planks	316	EA
Gravel Fill	1,140	CY
Timber Sleepers	240	EA
Boarding Float Modules 8'x20'	28	EA
Boarding Float Piling 12"dia.x66'	12	EA
Upland Parking Area	1	JOB
Design/construct floats & Utilities	1	JOB
Dredge Material Disposal		
Onshore disposal	59,730	CY
Contaminated material disposal	3,144	CY

Alternative 7
6-Lane Boat Launch with North Entrance Channel
Detailed Quantity Estimate

Item	Quantity	Unit
Breakwater		
Breakwater Rock Placement		
Armor rock placement	6,670	CY
Secondary rock placement	6,580	CY
Core rock placement	7,440	CY
Navigation aid foundation	1	EA
Entrance & Maneuvering Channel Dredging		
Entrance channel Excavation	35,760	CY
Slope protection	1,750	CY
Ramp Excavation		
Excavation	32,520	CY
Slope protection	1,780	CY
Hydrographic/Topographic Surveys	3	EA
Local Harbor Facilities		
Boat Ramps		
Asphalt Turnaround Area	222	CY
Concrete Ramp Apron	177	CY
Concrete Ramp Planks	474	EA
Gravel Fill	1,706	CY
Timber Sleepers	360	EA
Boarding Float Modules 8'x20'	42	EA
Boarding Float Piling 12"dia.x66'	18	EA
Upland Parking Area	1	JOB
Design/construct floats & Utilities	1	JOB
Dredge Material Disposal		
Onshore disposal	64,870	CY
Contaminated material disposal	3,414	CY

Alternative 8
4-Lane Boat Launch with South Entrance Channel
Detailed Quantity Estimate

Item	Quantity	Unit
Breakwater		
Breakwater Rock Placement		
Armor rock placement	5,440	CY
Secondary rock placement	5,240	CY
Core rock placement	6,390	CY
Navigation aid foundation	1	EA
Entrance & Maneuvering Channel Dredging		
Entrance channel Excavation	31,500	CY
Slope protection	1,490	CY
Ramp Excavation		
Excavation	25,760	CY
Slope protection	1,285	CY
Hydrographic/Topographic Surveys	3	EA
Local Harbor Facilities		
Boat Ramps		
Asphalt Turnaround Area	148	CY
Concrete Ramp Apron	118	CY
Concrete Ramp Planks	316	EA
Gravel Fill	1,140	CY
Timber Sleepers	240	EA
Boarding Float Modules 8'x20'	28	EA
Boarding Float Piling 12"dia.x66'	12	EA
Upland Parking Area	1	JOB
Design/construct floats & Utilities	1	JOB
Dredge Material Disposal		
Onshore disposal	54,400	CY
Contaminated material disposal	2,863	CY

Alternative 9
6-Lane Boat Launch with South Entrance Channel
Detailed Quantity Estimate

Item	Quantity	Unit
Breakwater		
Breakwater Rock Placement		
Armor rock placement	7,000	CY
Secondary rock placement	5,560	CY
Core rock placement	6,760	CY
Navigation aid foundation	1	EA
Entrance & Maneuvering Channel Dredging		
Entrance channel Excavation	32,110	CY
Slope protection	1,530	CY
Ramp Excavation		
Excavation	31,760	CY
Slope protection	1,720	CY
Hydrographic/Topographic Surveys	3	EA
Local Harbor Facilities		
Boat Ramps		
Asphalt Turnaround Area	222	CY
Concrete Ramp Apron	177	CY
Concrete Ramp Planks	474	EA
Gravel Fill	1,706	CY
Timber Sleepers	360	EA
Boarding Float Modules 8'x20'	42	EA
Boarding Float Piling 12"dia.x66'	18	EA
Upland Parking Area	1	JOB
Design/construct floats & Utilities	1	JOB
Dredge Material Disposal		
Onshore disposal	60,680	CY
Contaminated material disposal	3,194	CY