Petersburg Navigation Improvements

Appendix B: Hydraulics and Hydrology

Petersburg, Alaska

US Army Corps of Engineers
Alaska District

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1.0 INTRODUCTION

1.1 Appendix Purpose

This appendix describes the hydraulic design of navigation improvements for the South Harbor at Petersburg by deepening the harbor

- for the approach to the Crane Dock,
- between floats C and D,
- for small vessels along the main south harbor float, and
- removal of a mound of sediment that feeds sedimentation into the middle Harbor (Figure 4).

It provides the background for determining the Federal interest in deepening and operation and maintenance of the South Harbor in Petersburg Alaska.

1.2 Description of Project Area

Petersburg is located on the northwest end of Mitkof Island, where the Wrangell Narrows meet Frederick Sound. It lies midway between Juneau and Ketchikan, about 120 miles from either community (Figure 1- Figure 3).

Figure 1: State of Alaska location map with location of Petersburg.

Figure 2: Petersburg's location in relation to Juneau and Ketchikan

Figure 3: Petersburg's location

Figure 4: Location of South Harbor, Main Dock, Crane Dock, and C&D Floats

2.0 CLIMATOLOGY, METEOROLOGY, HYDROLOGY

2.1 Temperature and Precipitation

Petersburg falls within the southeast maritime climate zone, characterized by cool summers, mild winters and heavy rain throughout the year. Summer temperatures range from 57-63° F. Winter temperatures range from 36 to 49° F. Average annual precipitation is 109 inches, and average annual snowfall is 77 inches (Table 1).

Table 1: Monthly Climate Summary Petersburg, Alaska

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	36.2	38.3	42.4	49.5	56.5	61.9	64.0	63.2	57.0	48.9	40.4	36.3	49.6
Average Min. Temperature (F)	26.0	27.1	29.6	34.1	40.4	46.3	49.2	48.2	44.0	38.1	30.9	27.2	36.8
Average Total Precipitation (in.)	11.48	7.36	8.45	6.04	5.92	4.94	5.21	7.20	13.65	15.71	12.22	11.05	109.23
Average Total SnowFall (in.)	21.9	16.1	16.9	0.7	0.0	0.0	0.0	0.0	0.0	0.6	9.1	11.4	76.7

Period of Record : 1981-2010, provided by the National Climate Data Center

2.2 Ice Conditions

Petersburg is ice free year round.

2.3 Tides

Petersburg is in an area of semi-diurnal tides with two high waters and two low waters each lunar day. The tidal parameters in Table 2 were determined using National Oceanic and Atmospheric Administration published data for Turn Point (approximately 1 mile southwest of Petersburg) published June 2009 for the tidal epoch 1983-2001. There was no reported highest observed water level and no lowest observed water level.

Table 2: Tidal Parameters – Petersburg

Parameter	Elevation (ft)
Highest Predicted Tide	19.69
Mean Higher High Water (MHHW)	16.07
Mean Sea Level (MSL) *	8.34
Mean Tide Level (MTL) **	8.34
Mean Lower Low Water (MLLW)	0.00
Lowest Predicted Tide	-4.15

*MSL The arithmetic mean of hourly heights observed over the National Tidal Datum Epoch. Shorter series are specified in the name; e.g. monthly mean sea level and yearly mean sea level.
**MTL The arithmetic mean of mean high water and mean low water.

2.4 Water Level

The effect of an increase in water level needs to be evaluated when designing a navigation project. Water level increase is typically a result of wave set up, storm surge, inverted barometer effects, and tide. Relative sea level rise is a longer term change in water level and its effects on a project is an additional factor that needs to be considered in design of navigation improvements.

Wave Setup
Wave setup is the water level rise at the coast caused by breaking waves. The features of this project extend beyond the area of breaking waves so wave set up was not considered in the calculations for the Petersburg Navigation Improvement project.

Storm Surge
Storm surge is an increase in water elevation caused by a combination of relatively low atmospheric pressure and wind driven transport of seawater over relatively shallow and large unobstructed waters. Friction at the air-sea interface is increased when the air is colder than the water, which causes more wind-driven transport. Storm induced surge can produce short term increases in water level, which can rise to an elevation considerably above tidal levels. Petersburg experiences low pressure events that could contribute to storm surge, but the water is too deep to stack up and cause a significant surge. A rise in the water elevation due to surge has not been a problem reported at Petersburg, so no storm surge was used in the calculations for the project.

Inverted Barometer
The inverted barometer is the response of the sea surface to changes in atmospheric pressure. A high pressure system decreases sea level, and conversely, low atmospheric pressure results in sea level rise. Generally, a 1 millibar change in pressure results in a 1 cm change in the water surface. To compensate for a lowered water level due to a high pressure system the lowest astronomic tide was used when determining the dredge depth.

Tide
The mean higher high tide of 16.07 feet was used for the high water elevation.

Sea Level Rise
The Corps of Engineers requires that planning studies and engineering designs over the project life cycle (ER 1100-2-8162), for both existing and proposed projects consider alternatives that are formulated and evaluated for the entire range of possible future rates of sea-level change (SLC), represented by three scenarios of “low,” “intermediate,” and “high” sea-level change. The SLC “low” rate is the historic SLC. The “intermediate” and “high” rates are computed using the following:

- Estimate the “intermediate” rate of local mean sea-level change using the modified National Research Council’s (NRC) Curve I and the NRC equations. Add those to the local historic rate of vertical land movement.
- Estimate the “high” rate of local mean sea-level change using the modified NRC Curve III and NRC equations. Add those to the local rate of vertical land movement. This “high” rate exceeds the upper bounds of the Intergovernmental Panel on Climate Change

(IPCC) estimates from both 2001 and 2007 to accommodate potential rapid loss of ice from Antarctica and Greenland.

NRC Equations

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

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

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

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

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

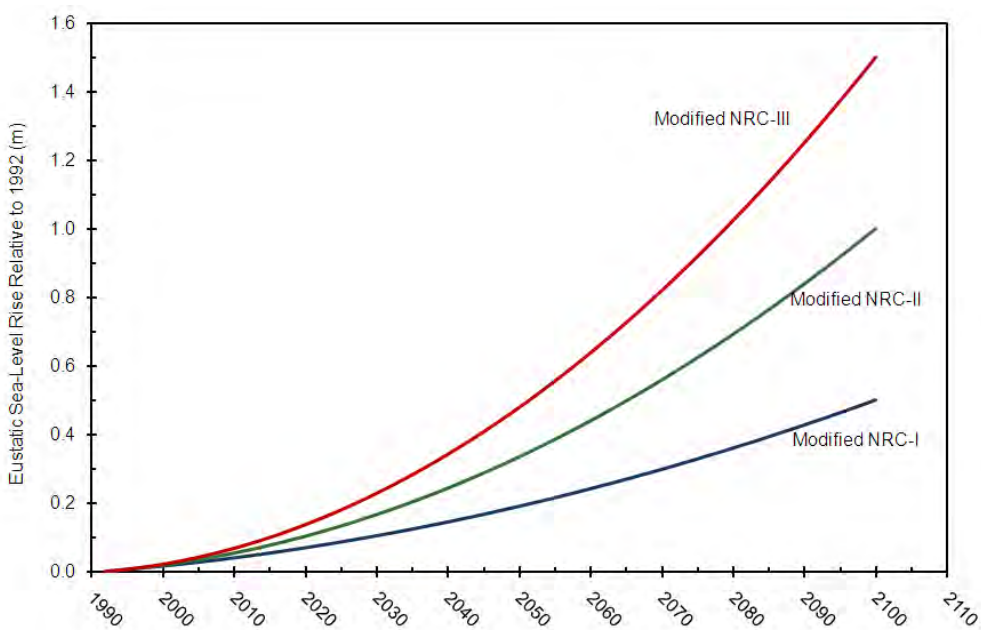


Figure 5: Scenarios for GMSL Rise (based on updates to NRC 1987 equation).

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

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

where t_1 is the time between the project's construction date and 1992 and t_2 is the time between a future date at which one wants an estimate for sea-level change and 1992 (or $t_2 = t_1$ + number of years after construction) .

The USACE SLC scenarios were developed using the guidance in ER 1100-2-8162 and ETL 1100-2-1. Assuming a eustatic SLC rate of 1.7 mm/year and start date of 1992 (mid-year of the NOAA National Tidal Datum Epoch (NTDE) of 1983-2001), the updated values for the variable b in the 1987 NRC report are equal to 2.71E-5 for the modified NRC Curve I (USACE Intermediate Scenario), and 1.13E-4 for modified NRC Curve III (USACE High Rate Scenario). The USACE Low Rate Scenario extrapolates the historic rate of sea level change.

There is no sea level trend data for Petersburg. NOAA has sea level trends published for Juneau, Sitka, and Ketchikan, Alaska, which are the closest stations to Petersburg (Figure 2). Each of the gages has record durations over 40 years. The sea level trend for Juneau is -0.52 inches/year (Figure 6), Sitka is -0.092 (Figure 7), and Ketchikan is -0.013 inches/year (Figure 8). These values were used with the equations in ER 1100-2-8162 to determine the possible sea level rise at the end of the project life.

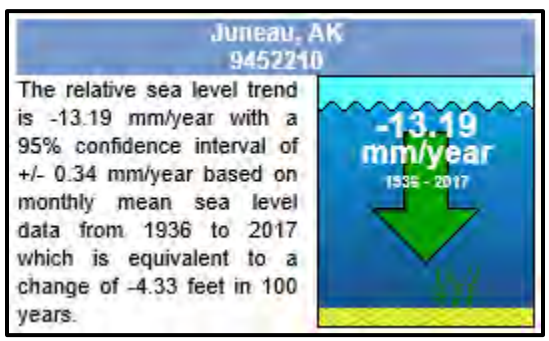


Figure 6: Relative sea level trend for Juneau

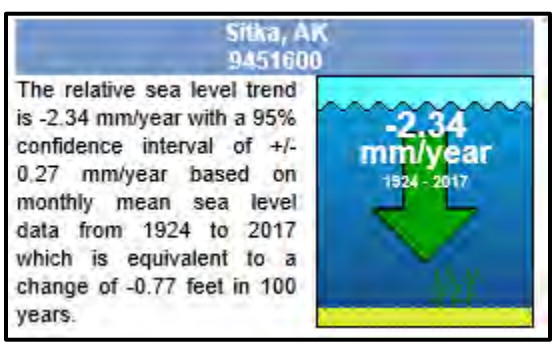


Figure 7: Sea level trend for Sitka

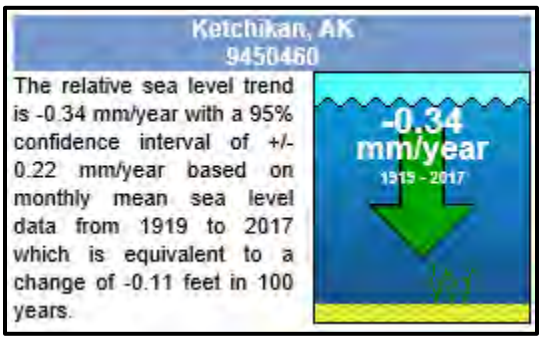


Figure 8: Sea level trend for Ketchikan

In addition to looking at the SLC based on Juneau, Sitka, and Ketchikan, the SLC was evaluated using the GMSL change (1.7 mm/year or 0.0669 inches/year) added to the vertical land movement (VLM) at Petersburg as measured by the Jet Propulsion Laboratory (JPL), California Institute of Technology under contract with the National Aeronautics and Space Administration (NASA) (Figure 9). The VLM reported by JPL is 0.614 inches/year (Figure 10). This was subtracted from the GMSL change and resulted in a SLC of -0.547 inches/year (falling sea level).

Figure 9: Location of JPL's vertical land movement data site at Petersburg

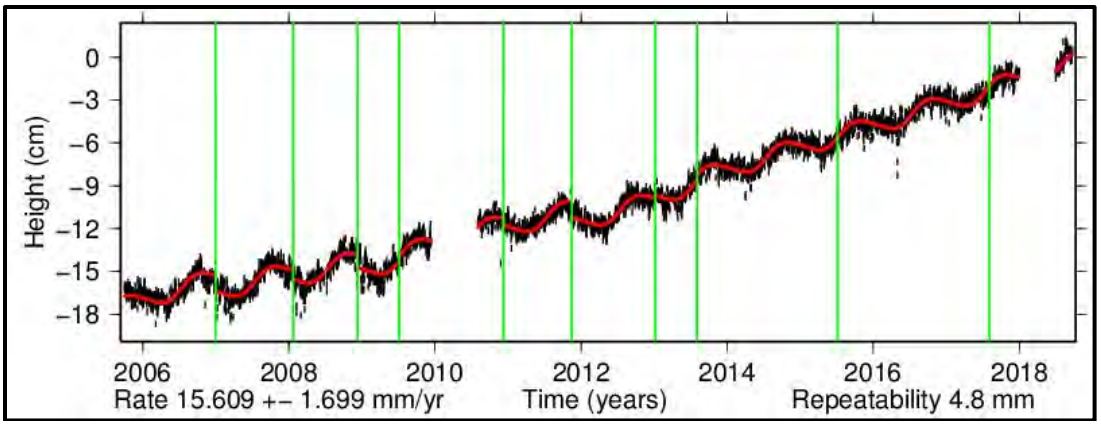


Figure 10: Vertical land movement data for Petersburg

For a fifty year project life, a project at Petersburg could see sea level fall by as much as 2.28 feet (-2.28 feet sea level rise) or rise much as 1.91 feet (Table 3-Table 6). Any fall in sea level will be managed with maintenance dredging to ensure design depth.

Table 3: Sea Level Rise Prediction for Juneau for a 50 Year Project Life.

Sea Level Change	Low	Intermediate	High
	-2.16 feet	-1.69 feet	-0.20 feet

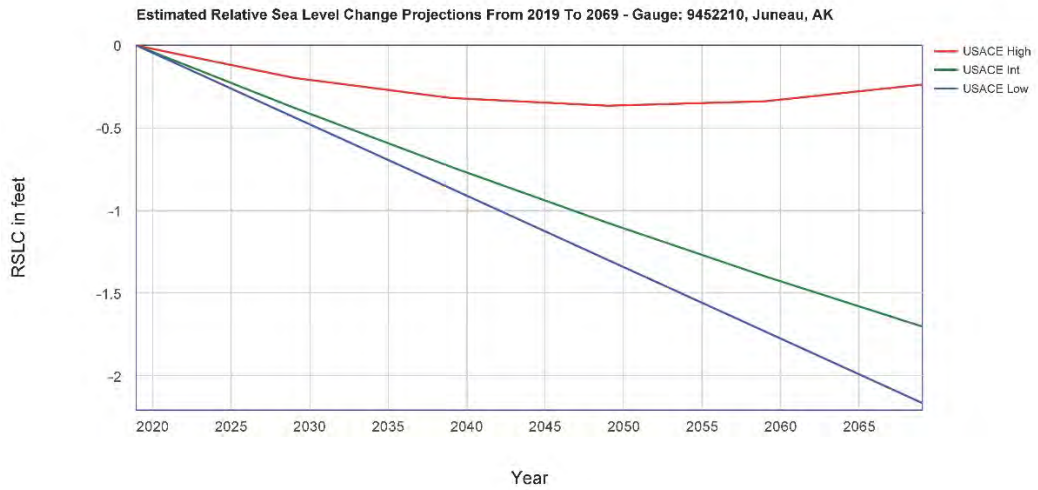


Table 4: Sea Level Rise Prediction for Sitka for a 50 Year Project Life.

Sea Level Change	Low	Intermediate	High
	-0.38 feet	0.09 feet	1.58 feet

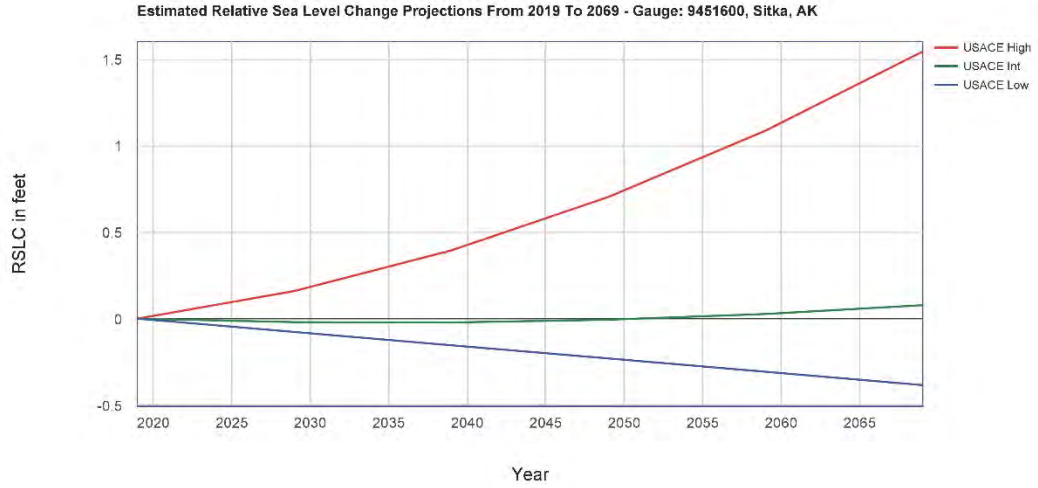


Table 5: Sea Level Rise Prediction for Ketchikan for a 50 Year Project Life.

Sea Level Change	Low	Intermediate	High
	-0.06 feet	0.42 feet	1.91 feet

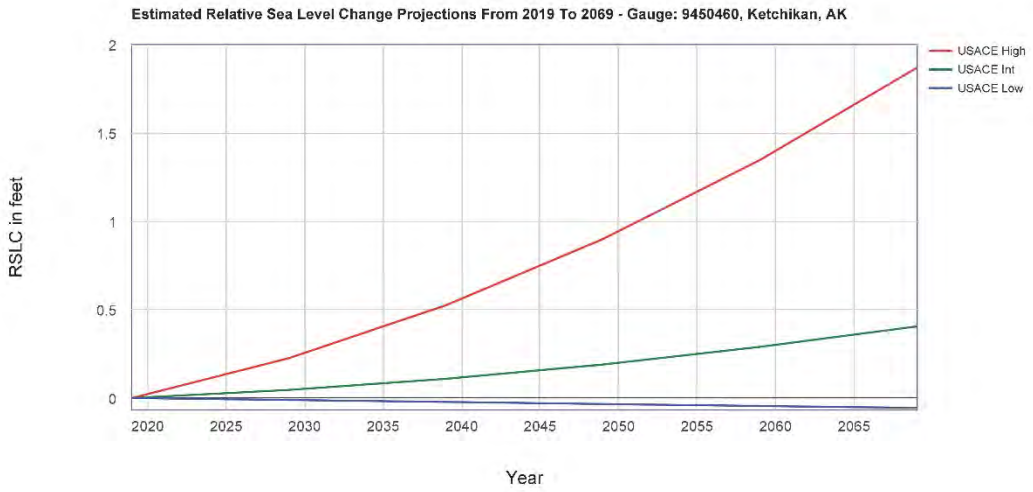
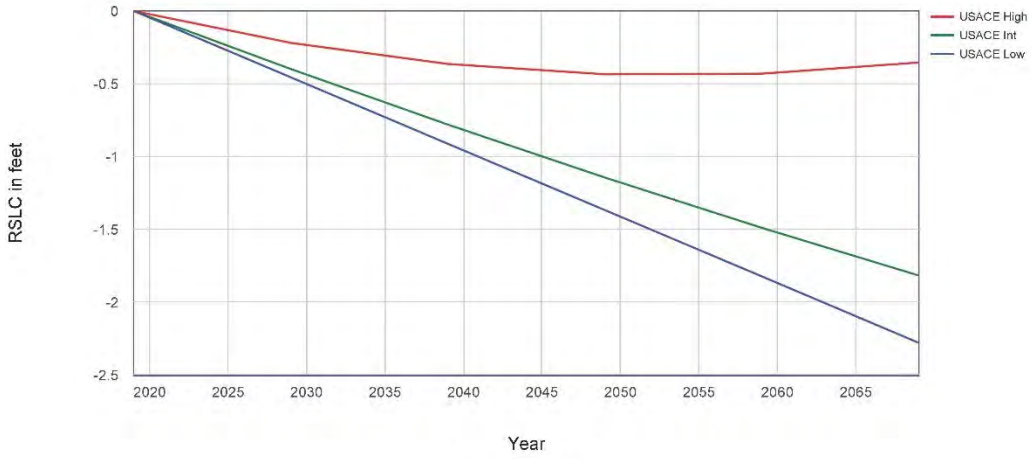


Table 6: Sea Level Rise Prediction using GMSL and VLM for a 50 Year Project Life.

Sea Level Change	Low	Intermediate	High
	-2.28 feet	-1.81 feet	-0.20 feet



2.5 Wind

The wind speeds presented in Table 6 and Table 7 were developed by Air Force Combat Climatology Center using historical wind speeds from the Five Finger Coastal-Marine Automated Network (C-MAN) at the Five Finger lighthouse (Figure 6). The Five Fingers data represents unobstructed wind speeds.

Figure 11 Location of C-MAN station used for wind data

Table 7: North Wind Speed Extremal Analysis

One-Hour Sustained Wind (Knots) EXTREME VALUE ANALYSIS
Five Finger AK Buoy - NORTH WIND
55.27 N 133.63 W Elevation = 7 meters PERIOD OF RECORD: 1985-2013

QUANTILES	0.1	0.2	0.5	0.8	0.9	0.95	0.98	0.99	0.999	0.9999
RETURN PERIOD (YRS)	1.1	1.25	2	5	10	20	50	100	1000	10000
VARIATE 1 Hour Sustained Winds (Knots)	37.0	37.6	41.2	50.3	58.0	66.0	77.0	85.4	114.0	143.1

NOTE: The return period is the average elapsed time between occurrences of an event with a certain magnitude or greater.

Table 8: South Wind Speed Extremal Analysis

One-Hour Sustained Wind (Knots) EXTREME VALUE ANALYSIS Five Finger AK Buoy - SOUTH WIND 55.27 N 133.63 W Elevation = 7 meters PERIOD OF RECORD: 1985-2013										
QUANTILES	0.1	0.2	0.5	0.8	0.9	0.95	0.98	0.99	0.999	0.9999
RETURN PERIOD (YRS)	1.1	1.25	2	5	10	20	50	100	1000	10000
VARIATE 1 Hour Sustained Winds (Knots)	39.8	40.1	42.9	50.8	57.7	65.1	75.2	83.1	110.0	137.5

NOTE: The return period is the average elapsed time between occurrences of an event with a certain magnitude or greater.

2.6 Rivers and Creeks in the Project Vicinity

Hammer Slough feeds into the area to be deepened. This slough appears to be the main supply of sediment that settles in the harbors. The frequency of infilling for this project is assumed to be similar to the USACE dredging in the north harbor (Figure 7) which was dredged in 1971, and 42 years later in 2013 maintenance dredging removed approximately 27,000 cubic yards of material.

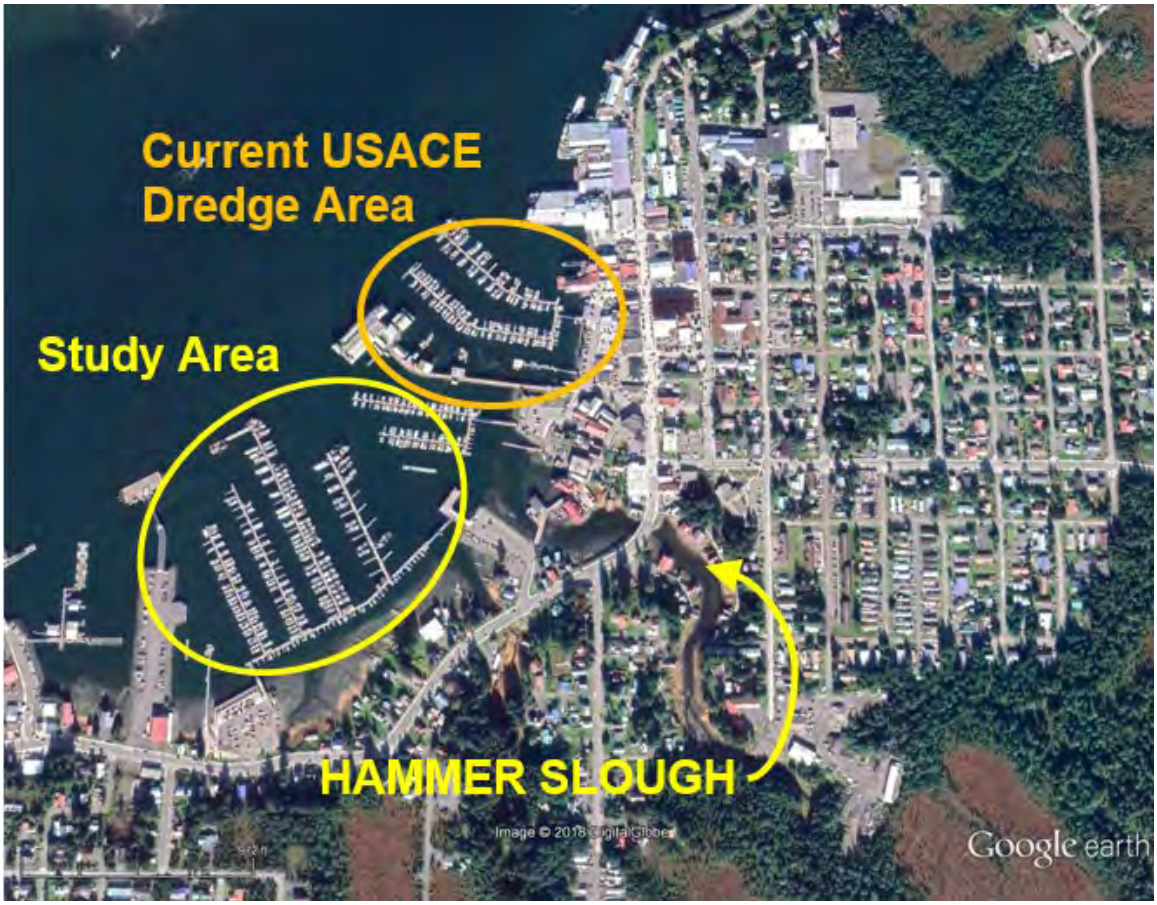


Figure 12: Location of Hammer Slough, current USACE dredge area, and study area

3.0 DESIGN CRITERIA

3.1 Design Vessel

The economic analysis generated the design vessel for this study. The design vessel is a hybrid of the National Geographic *Sea Lion* (length and beam) and a Seiner with a 12 foot draft. The characteristics of the design vessel is shown in Table 8.

Table 9: Design Ship Characteristics

Vessel Length [ft]	Design Beam [ft]	Design Draft [ft]
164	33	12

3.2 Dredge Depth

Moving vessels must maintain clearance between their hulls and channel bottom; accordingly, various navigational design parameters are analyzed. Design parameters such as squat, safety clearance, vertical motion due to waves, and water density effects are added to determine the minimum required under-keel clearance (Figure 8).

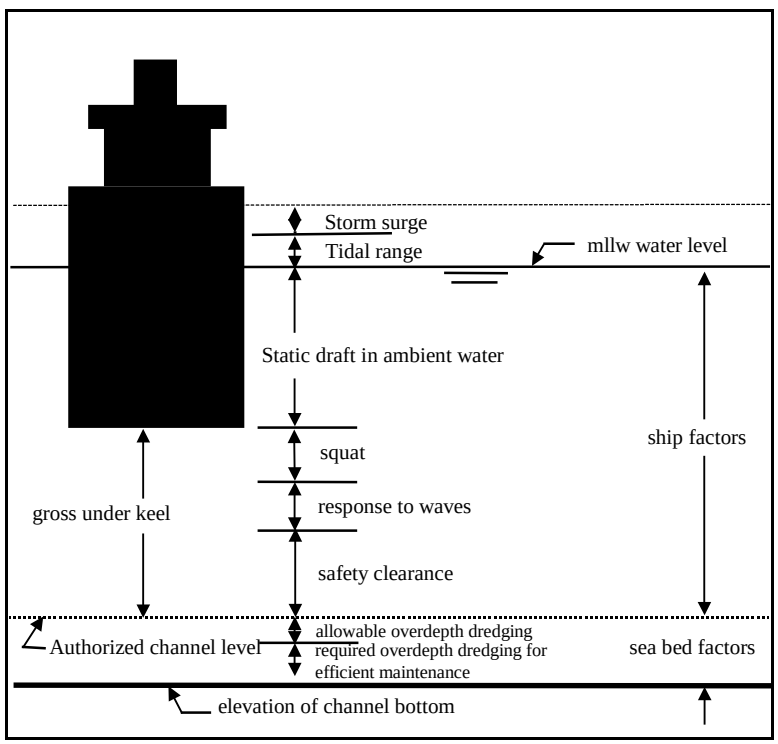


Figure 13: Under-keel clearance parameters

The maneuvering channel depth to the crane dock was determined using the criteria listed in Table 9. Fresh water effects from Hammer Slough discharge were considered to be negligible and not

included in the calculation. The lowest astronomical tide is -4.15 feet MLLW which results in a depth of -19.25 feet MLLW which is usable 100% of the time.

Within the fairway area between floats C and D the squat and pitch, roll, and heave requirement is not necessary so required harbor depth reduces to -18 feet

Table 10: Maneuvering Channel Criteria

Vessel Draft [ft]	12.0
Pitch, Roll, Heave [ft]	0.6
Squat [ft]	0.5
Tide Allowance [ft]	4.15
Safety Clearance	2.0
Total depth required [ft]	19.25

The dredge depth landward of the main float would reduce to -10 feet MLLW due to the reduced vessel draft of the smaller boats (approximately 3.5 feet). The local sponsor requested that a fourth dredge area be dredged to -9 feet MLLW at the back of the Middle Harbor in order to trap the sediment accumulated from the Hammer Slough discharge (Figure 9). The estimated dredge volume for each area is presented in Table 10.

Figure 14: Dredge Areas

Table 11: Dredge Volumes and Areas

Dredge Area	Dredge Depth [ft]	Dredge Volume [cy]	Dredge Area [sf]	One Foot Overdepth Allowance [cy]	Total Dredge Volume [cy]
Maneuvering Channel	-19.25	34,814	299,249	11,110	45,924
Between C and D Floats	-18	5,820	237,369	8,800	14,620
Landward of Main Float	-10	17,370	62,390	2,320	19,690
Behind Floats 1 and 2	-9	2,370	10,191	380	2,750
Total		59,310		23,410	82,740

(Note: Volumes listed in table were computed using AutoCAD TIN surface comparison using 2017 survey data)

4.0 DREDGE DISPOSAL OPTIONS

Dredge disposal options evaluated include:

- Open water disposal or,
- Contained disposal at Scow Bay

4.1 Open Water Disposal

A determination on open water disposal will be made upon completion of the Section 404 (b) (1) evaluation in accordance with the Guidelines of the Clean Water Act to evaluate discharge of dredged material into waters of the United States. The Guidelines outline measures to avoid, minimize, and compensate for impacts. The areas being evaluated are Fredrick Sound approximately 2 miles from Petersburg and Thomas Bay located approximately 20 miles from Petersburg (Figure 10). It is assumed for this study that one of these sites will be allowed for disposal.

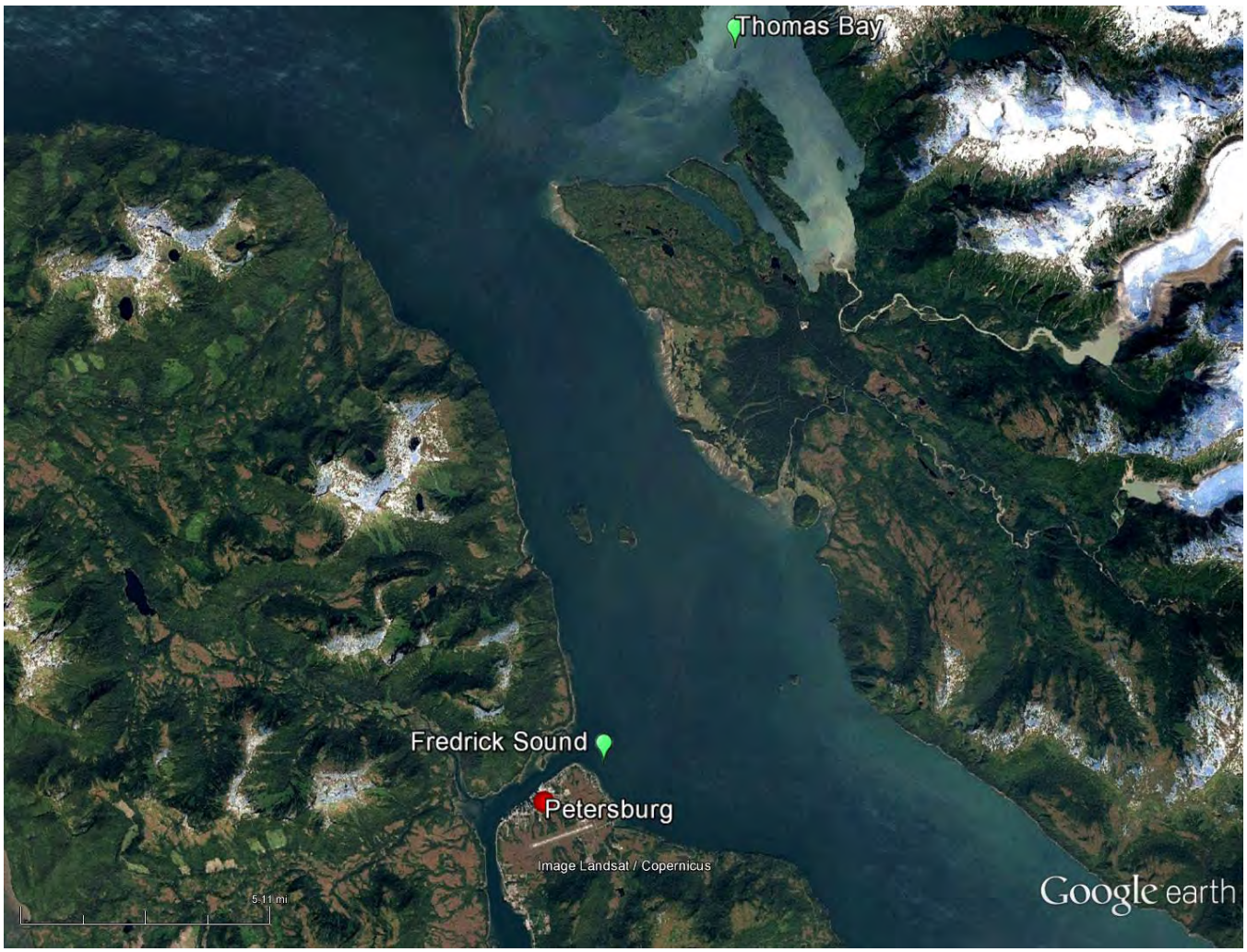


Figure 15: Location of Petersburg, Fredrick Sound, and Thomas Bay potential disposal sites

4.2 Contained Disposal

The contained disposal at Scow Bay would be combined with construction of a deeper water boat launch ramp. The launch ramp would need protection from waves from the south. Options considered for vessel protection during launching and landing included a floating breakwater or a rubble mound breakwater.

4.2.1 Floating Breakwater

A floating breakwater consists of a floating structure that can provide wave protection for short period waves with heights up to 4 feet. A floating breakwater is anchored with chain or piles. Because the design wave at Scow Bay is greater than 4 feet, a floating breakwater was dropped from further consideration.

4.2.2 Rubble Mound Breakwater

A rubble mound breakwater is already present at Scow Bay to protect a boat launch ramp. This rubble mound would be extended to protect the contained disposal area and a new boat launch ramp that would be constructed (Figure 11). The use of a rubble mound breakwater to provide wave protection is a proven concept. Rubble mound breakwaters have been successfully used in southeast Alaska.

Figure 16: Plan view of dredge disposal area and protective breakwater

5.0 BREAKWATER DESIGN PARAMETERS

5.1 Wave Analysis

5.1.1 Wave Climate

The wave climate at a proposed dredge disposal area at Scow Bay was evaluated to determine the effort required to develop this area for disposal. The area is subject to short period wind generated waves from the south. Due to lack of measured information on wave height, basic methods presented in the Coastal Engineering Manual were used to develop a design wave. Currently there is a single breakwater at Scow Bay that protects a small launch ramp from south waves. There is no protection for waves from the north or west.

5.1.2 Fetch

The coastline at Scow Bay is oriented generally north to south. Since the north has a limited fetch distance, only wind from the south was used for wave growth. The fetch was calculated using the average length of nine radial lines at 3 degree spacing, extending from Scow Bay area to the shoreline (Figure 12). The average fetch was determined to be 3.1 miles.

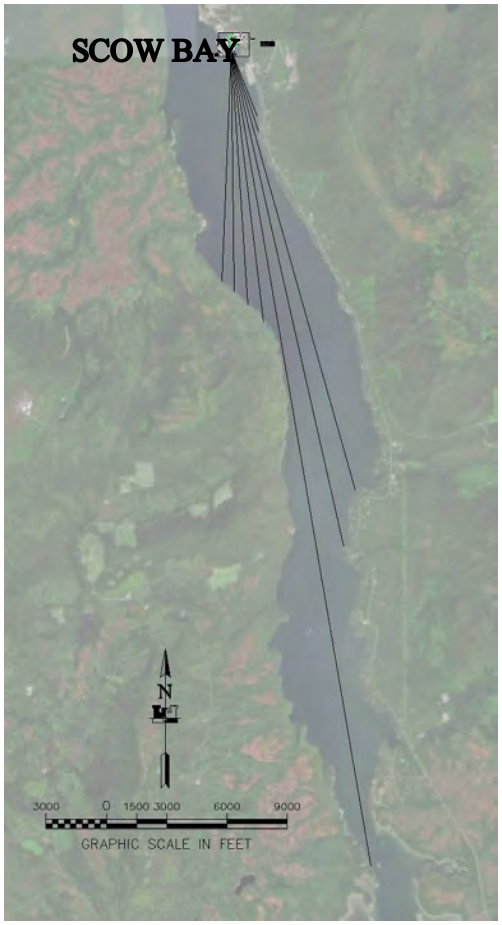


Figure 17: Fetches used in design

5.1.3 Wave Prediction

The 72.6 year return interval wind from the south (derived from Table 7) was used to determine the design storm wave corresponding to a 50 year design life with a 50% probability of being equaled or exceeded (Figure 13). This is more conservative than using a 50 year return interval which would has a 64% chance of being equaled or exceeded. Methods described in the Coastal Engineering Manual (CEM) were used to predict wave height based on a fetch distance of 3.1 miles and a wind speed of 78.8 knots.

The significant wave from the south is 6.2 feet and the average height of the highest 1/10 of waves (H_{10}) is 7.9 feet. The design wave from the north was not calculated due to the short fetch distance.

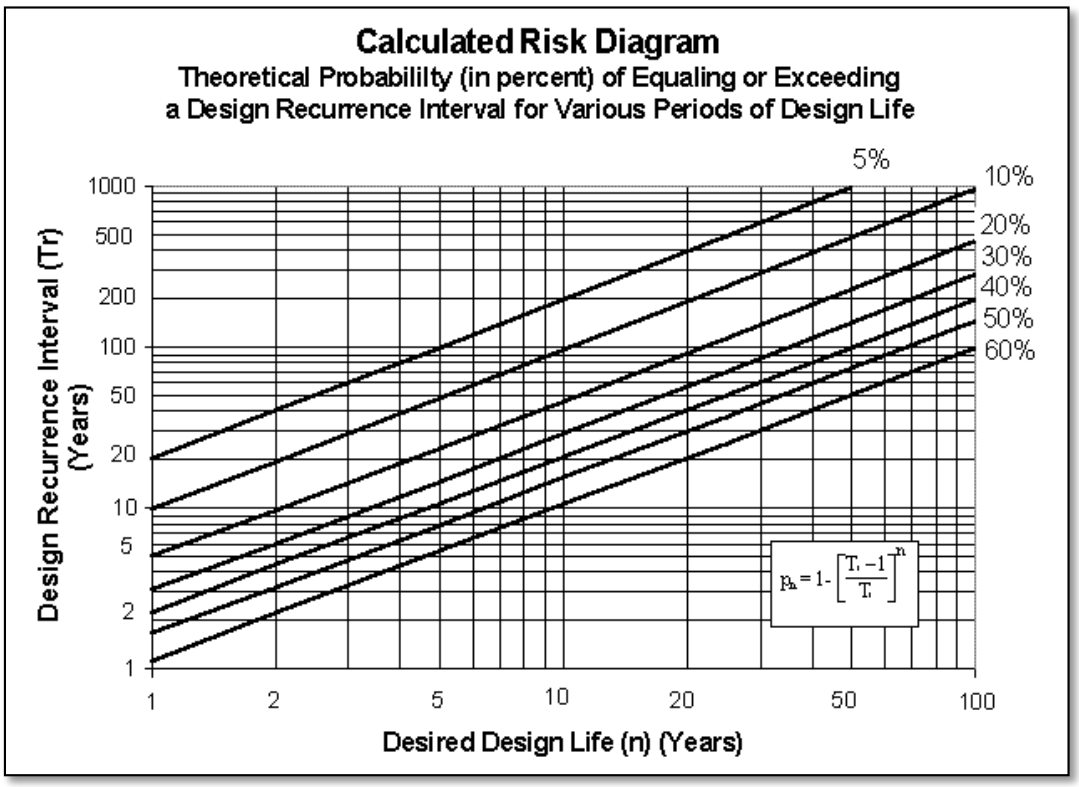


Figure 18: Calculated Risk Diagram

5.2 Rubble Mound Design

5.2.1 Armor Stone

Using Hudson's equation for a wave of 7.9 feet from the south and a K_d of 3.2 results in an average armor stone size of 4270 pounds and a two layer thickness of 6.5 feet.

5.2.2 Crest Height

The crest height was set at 25 feet using equation VI-5-13 in the Coastal Engineering Manual and an exceedance level of 10% to determine run-up. The 10% exceedance level was deemed to be acceptable since no boats would be moored behind the breakwater. The mean higher high water level of 16 feet was used as the still water level. Storm surge was not included in the calculations since storm surge in not typically an issue at Petersburg. The crest width was set at 9.5 feet based on armor stone size. A typical breakwater cross section is shown in Figure 14.

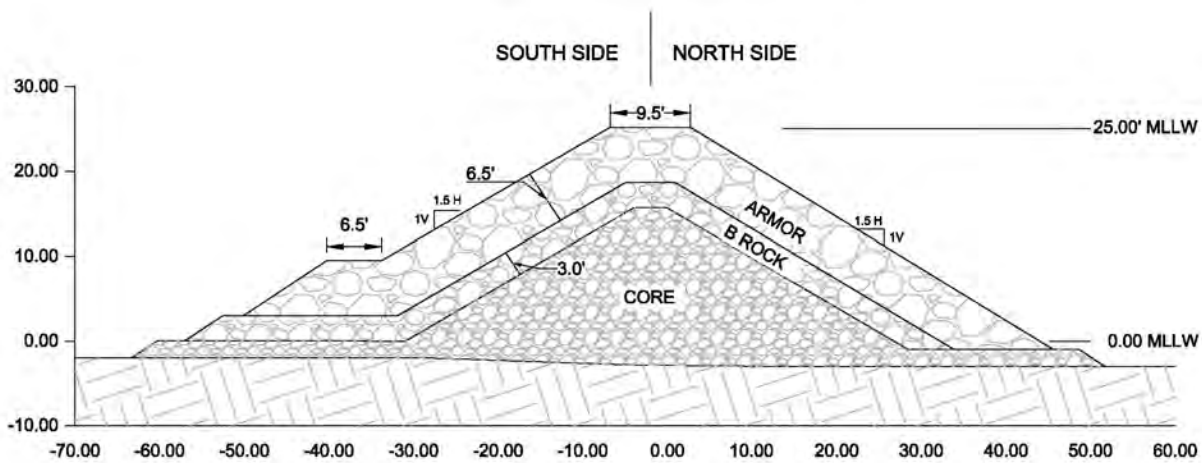


Figure 19: Typical cross section

6.0 MAINTENANCE

The main source of sediment in the North, Middle, and South harbors appears to be sediment from Hammer Slough. Bathymetric survey of the area indicates that the Slough flow is channelized and directed towards Middle and North Harbor. The frequency of infilling and need to dredge for this project is assumed to be similar or less than the infilling in the North Harbor. USACE dredged the North Harbor in 1971 and, 42 years later, in 2013 maintenance dredging removed approximately 27,000 cubic yards of material.

The assumption that the maintenance dredging requirement would be similar to the North Harbor was checked by comparing the current bathymetric survey to a 1983 project layout sheet from the State of Alaska Department of Transportation that shows the bathymetry in South Harbor. The comparison indicates that South Harbor has had 20,000 cubic yards of sedimentation in 34 years. This compares well with the North Harbor dredging requirement.

7.0 CONSTRUCTION CONSIDERATIONS

Prior to preparing plans and specifications, a survey of the dredge areas and Scow Bay should be performed to verify project quantities. In addition to survey work, soil borings should be obtained to confirm that the material is suitable for its selected disposal method. The nature of the obstructions identified during the 2017 survey of the South Harbor should be identified to aid in planning for proper disposal of the obstructions.

The dredging is anticipated to take one year to complete. Dredging activities will need to be closely coordinated with the Petersburg harbormaster in order to efficiently dredge in an active harbor. It is assumed that the dredge window will be similar to the window for the North Harbor dredging which stipulated that no in-water work will be performed between 15 March and 15 June in order to avoid the peak herring spawn and juvenile salmon out-migration and rearing activities, and when Steller sea lion and humpback whale feeding and abundance is expected to be greatest in the project area.

In order to attract a number of bidders, it is recommended that the project be advertised early in the year to maximize the number of contractors to bid on this project.

8.0 REFERENCES

American Society of Civil Engineers Task Committee on Maninas. 2012. *Planning and Design Guidelines for Small Craft Harbors, Revised Edition*. New York: American Society of Civil Engineers.

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