EXHIBIT I

Blue Coast Engineering, Coastal Engineering Review Technical Memorandum

(May 18, 2020)

To: John Piccone, P.E. (Soundwest Engineering Associates)

From: Greg Curtiss, P.E., Kathy Ketteridge, Ph.D., P.E.

Date: May 18, 2020

Re: Port of Poulsbo Floating Breakwater, Coastal Engineering Review

The Port of Poulsbo marina is located at the north end of Liberty Bay in Puget Sound, Washington (WA). Soundwest Engineering Associates (Soundwest) is currently preparing design and permitting documents for the marina breakwater replacement. The existing soldier pile breakwater is proposed to be replaced with a floating breakwater. At the request of Soundwest, Blue Coast Engineering LLC (Blue Coast) has prepared this technical memorandum documenting a targeted coastal engineering review of the proposed floating breakwater design. As part of the permitting effort for the replacement, the Port of Poulsbo (Port) is required to demonstrate that the proposed design will meet the Poulsbo Municipal Code (PMC). Specifically, the following needs to be demonstrated (per PMC 16.08.430):

1. *Breakwaters may only use floating or open-pile designs unless such a design is demonstrated to not be practicable.*
2. *The structure is essential to the safe operation of marina facility*
3. *Engineer shall demonstrate based on accepted industry engineering standards or guidelines that the structure is the smallest feasible structure to meet the requirements and accomplish its purpose, and that…*
4. *the design will result in the minimum feasible adverse impacts upon the environment, nearby waterfront properties, and navigation. The location, size, design and accessory components shall not result in undesirable or adverse impacts to the shoreline and aquatic environment, navigation, or nearby waterfront properties.*

Each of the above requirements from the PMC are addressed in this technical memorandum in the following sections. The purpose of this review is to specifically address the coastal engineering aspects of PMC requirements. Furthermore, this review provides a wind-wave climate to inform the proposed project structural design and offers the Port an estimated range of anticipated breakwater performance.

1. Type of breakwater structure selected in design

Per the PMC 16.08.430, the proposed breakwater structure "may only use floating or open-pile designs unless such a design is demonstrated to not be practicable."

The proposed breakwater design is for a floating concrete pontoon with a wave skirt and therefore meets this requirement. The concrete floats proposed for use in the design are appropriate for use at the marina and are being provided to the Port at little or no cost from another marina.

2. Wave climate and safe operation of the marina facility

PMC 16.08.430 requires "the structure is essential to the safe operation of marina facility."

An acceptable wave climate within a marina is essential to the safe operation of the facility. To assess the need for a breakwater to provide an acceptable (safe) wave climate within the marina, several steps were taken:

- Define the wave climate in the absence of a breakwater
- Evaluate the wave climate against the recommended design criteria for wave climate in small craft harbors
- Estimate the effectiveness of the proposed floating breakwater at attenuating the wave height within the marina for comparison against the wave climate design criteria

Wind-Wave Climate:

A wind-wave hindcast was completed to estimate wave conditions at the Port of Poulsbo marina for the 1-year (annual) return interval wind speed and a 50-year return interval wind speed. The 1-year and 50-year return interval events were selected for direct comparison with those provided in the recommended design criteria. Extreme wind speeds were estimated based on the historical record of hourly wind speeds at West Point (Seattle) from 1975 to 2019. The West Point station is exposed to a southerly fetch and was therefore deemed representative of southerly wind events in Liberty Bay.

The wind-wave parameters at the marina were calculated using the Automated Coastal Engineering System (ACES) software (Leenknecht et al. 1992) developed by the United States Army Corps of Engineers (USACE) to estimate wind-wave growth in shallow water. The estimated wind-wave parameters are presented in Table 1. For reference, the wind-wave estimates (2-year and 50-year) from an earlier study of breakwater performance conducted by Mott MacDonald (2019a) are also included in Table 1. No methods for estimating wave conditions are provided in the documentation available from Mott MacDonald. We assume from the figures provided in the reference that the values are derived from two-dimensional wave modeling, but that has not been verified by the authors. Wave heights predicted using ACES as part of this evaluation are within 4 to 13% of values provided by Mott MacDonald.

Table 1 Wind-wave hindcast scenarios and results.

Wind Scenario	Comments	Wind Direction	Wind Speed (mph)	Fetch (miles)	Significant Wave Height, Hs (feet)	Peak Wave period, Tp (seconds)
1-year return interval		165	43	1.6	1.6	2.2
50-year return interval		165	56	1.6	2.2	2.5
2-year return interval	Mott MacDonald (2019a)	N/A	N/A	N/A	1.4	2.4
50-year return interval	Mott MacDonald (2019a)	N/A	N/A	N/A	2.3	3.1

Evaluate wave climate against design criteria:

The predicted wave climate within the marina in the absence of a breakwater was evaluated against the recommended design criteria for wave climate in small craft harbors as provided by Northwest Hydraulic Consultants (1980) and adopted by the Permanent International Association of Navigation Congresses (PIANC) design guide for floating breakwaters (PIANC 1994). The design criteria provide target significant wave heights (H_s) for three wave climate classifications ("Moderate", "Good" and "Excellent") dependent on peak wave period (T_p) and the wave direction relative to the vessel (head and beam). The wave climate classifications are defined based on the allowable motion (e.g. heave, pitch, sway, surge) for moored vessels and floating walkways based on a series of field measurements, model tests, and interviews with marina stakeholders. The relevant design criteria are reproduced in Figure 1 along with comparisons to the predicted design wave heights for the 1-year and 50-year return interval event for the project site (Table 1). The estimates from Mott MacDonald (2019a) are included in Figure 1 for reference as well.

The predicted significant wave height (H_s) and peak wave period (T_p) at the marina exceeds the design criteria for all cases except the "moderate" classification for a 50-year return interval with head seas (waves taken on the bow or stern). The berths within the marina are orientated oblique to the wave directions from the south or southwest and moored vessels will most commonly experience beam seas (waves taken on the side). Therefore, the wave climate within the marina does not meet the design criteria and is unsafe based on the PIANC guidance without a properly designed breakwater.

Estimate the effectiveness of the proposed floating breakwater:

Floating breakwaters are commonly used for the protection of small boat harbors in low wave energy environments. In general, a floating breakwater's usefulness is limited to short period wave environments and are not recommended for sites where wave periods are larger than 4 to 5 seconds (PIANC 1994). Wave attenuation of a solid breakwater structure, such as the existing solider pile breakwater, will almost always be better (less wave energy getting through the breakwater) than a floating breakwater.

An assessment was completed to estimate the effectiveness of the proposed concrete pontoon floating breakwater at attenuating the wave height within the marina for comparison against the wave climate design criteria described earlier. The assessment should be considered a reasonable approximation of the functional performance of a floating body wave attenuator; further project-specific numerical or experimental study may refine the assessment.

The effectiveness of a floating breakwater in attenuating waves can be evaluated based on the dissipation of wave energy through the structure, defined by the wave height transmission coefficient, C_t, (the ratio of the wave height on the lee side of the breakwater to the wave height on the exposed side). The effectiveness is primarily a function of the wavelength associated with the period of the incident waves and the breakwater characteristics (beam width, draft, mass, and rigidity).

The wave height transmission coefficient for concrete pontoon breakwaters was calculated using methods from existing literature and design guidance documents based on the beam width, draft, and incident wave periods and assuming the wave direction is orthogonal to the breakwater (PIANC 1994; Issacson and Byres 1988; Carver 1979; Adee et al 1976; and Adee 1977). Attenuation generally increases as wave period becomes shorter and as the width and draft of the breakwater becomes larger. However, wave attenuation achieved by a specific floating breakwater system can vary widely depending on the incident wave conditions (wave height and period) and the water depth at the breakwater (which is variable over the tide). Thus, wave attenuation and/or the wave transmission coefficient for a proposed floating breakwater is provided as a range of values.

The approximate dimensions of potential concrete floats solutions used in the assessment were as follows:

- Depth: 4 feet (freeboard of 1.7 feet and draft of 2.3 feet)
- Waveward and leeward wave skirt draft: 6 feet
- Beam width: 12 feet

An overall draft of 4 feet was assumed to account for the presence of the wave skirt, which is not expected to provide the same level of wave attenuation as a concrete pontoon with a similar draft. Additional attenuation of the waves should be expected as the waves propagate past the interior marina floats towards shore, however, this attenuation was not specifically quantified as part of this assessment.

Results:

The results found the C_t ranges from 20% to 45% with an average of 35% for the 1-year wave event and 25% to 50% with an average of 40% for the 50-year wave event. For reference, the two-dimensional numerical wave modeling completed earlier by Mott MacDonald (2019b) found the C_t to range from 30% to 50% for the 50-year event. The resulting estimated transmitted wave heights inside the marina are compared against the small harbor design criteria in Figure 2. The proposed floating breakwater meets “moderate” conditions for the 1-year and 50-year events for beam seas and all wave conditions for head seas. The transmission coefficients result in the following:

- For the 50-year event, the predicted H_s of 2.1 feet at the exterior of the breakwater is reduced to 0.9 feet (with a range of 0.6 to 1.1 feet) on the lee side of the breakwater.
- For the 1-year event, the predicted H_s of 1.6 feet at the exterior of the breakwater is reduced to 0.6 feet (with a range of 0.3 to 0.7 feet).

Earlier modeling completed by Mott MacDonald (2019a) of the existing conditions showed the soldier pile breakwater results in “good” wave conditions for beam seas (Figure 2). This means, for the 50-year event, an H_s of 0.8 feet, and for the 1-year event, an H_s of 0.5 feet. Comparing these estimates to those for the proposed floating breakwater (above) the wave energy within the marina will increase by approximately 10 to 20% after the existing solider pile breakwater is replaced with a floating breakwater.

Summary:

The results of the assessment suggest that a breakwater design is essential to the safe operation of the marina facility because an adequate wave climate is not met without a breakwater. The proposed floating breakwater provides “moderate” conditions in the marina (on average). The assessment of the breakwater wave transmission should be considered a reasonable approximation of the performance using industry standard methods. Physical scale model testing of the breakwater would be required to assess the wave attenuation capabilities more accurately.

3. Size of the proposed floating breakwater to meet design requirements

PMC requires that the “*Engineer shall demonstrate based on accepted industry engineering standards or guidelines that the structure is the smallest feasible structure to meet the requirements and accomplish its purpose.”*

The proposed breakwater as designed appears to be the smallest feasible structure to meet the design criteria for small craft harbors as it results in only a “moderate” wave climate, whereas a larger floating structure would result in a “good” or better wave climate.

4. Evaluation of potential impacts to environment, navigation, and nearby waterfront properties

PMC 16.08.430 requires that *“the design will result in the minimum feasible adverse impacts upon the environment, nearby waterfront properties, and navigation” and that “the location, size, design and accessory components shall not result in undesirable or adverse impacts to the shoreline and aquatic environment, navigation, or nearby waterfront properties.”*

Anticipated impacts to the environment, navigation, adjacent shorelines and properties due to replacement of the existing solider pile breakwater with the proposed floating breakwater are discussed in this section.

Marina setting:

The Port of Poulsbo marina is located on the eastern shoreline near the head of Liberty Bay in central Puget Sound. The marina is located between approximately –12 feet Mean Lower Low Water (MLLW) at the breakwater and 0 feet MLLW at the connection of the interior floats to the uplands (Soundwest 2020). Water level fluctuations at the marina primarily result from astronomical tidal influences (mixed semi-diurnal tide resulting in two highs and two lows per day). The National Oceanic and Atmospheric Administration (NOAA) National Ocean Service (NOS) subordinate water level station #9445719, located in Poulsbo reports a mean tide range of 8 feet and a Mean Higher High Water (MHHW) elevation of 11.7 feet (NOAA-NOS 2020).

NOAA-NOS also provide tidal current predictions for the entrance to Liberty Bay that range up to approximately 1.3 knots. The marina is located closer to the head of the bay and subject to a significantly smaller tidal prism, therefore currents near the marina would be expected to be substantially less than at the entrance, likely on the order of 0.5 knots or less.

The United States Coast & Geodetic Survey topographic sheet (T-sheet) from 1881 indicates the marina is located within former tidelands and the adjacent marina uplands are filled land (Figure 3) (PSRHP 2003). Shoreline mapping from the 2017 Beach Strategies Phase 1 project (CGS 2017) delineate shoreline armoring along most of the shoreline except for a few hundred feet of shoreline immediately to the east of the marina (Figure 4).

Shoreline armoring within the marina consists of sloped riprap (angular rock) revetments (Ecology 2020). Along the shoreline east of the marina, armoring consists of a series of concrete bulkhead walls. The unarmored shoreline is mapped as marsh and feeder bluff (CGS 2017 and WA Ecology 2020).

The marsh shoreline (PSRHP 2003; WA Ecology 2020) is located immediate adjacent to the marina within the shadow of the breakwater and log boom. The marsh shoreline appears to be low energy and consist of mostly fine sediments and with a few small unmapped drainage outfalls. To the south of the marsh area, the shoreline geometry changes from a north to south alignment to a south-easterly alignment that is more closely aligned with the main axis of Liberty Bay. The immediate shoreline south of the headland is mapped as approximately 500 feet of unarmored feeder bluff with net shore drift from the south to the north.

A small cuspate-shaped headland feature (Figure 6) is located where the shoreline changes geometry and appears to be formed in part by a recent slide mapped by CGS (2017). The headland feature also lines up with the marina log boom which accumulates sediment within its piles. The four deepest piles (between -12 feet and -4 feet MLLW) from the log boom are planned to be removed to make room for inner harbor access by small vessels (Soundwest 2020). The accumulated sediment around the log boom piles is likely transported from the adjacent drift cell to the south and is visible in the site bathymetry (Figure 5).

Changes resulting from breakwater replacement:

The following changes have been identified which will result from the replacement of the existing solider pile breakwater with a floating breakwater.

AQUATIC ENVIRONMENT

The proposed design will replace the rigid pile wall structure with a floating pontoon with a wave skirt, increasing the flow of tidal currents past the breakwater. The resulting change in flow will likely have a very localized effect on hydrodynamics in the area of the marina. This may result in a positive change in water quality and no change to the adjacent shorelines. The project Biological Assessment provides more discussion on impacts to the aquatic environment.

Navigation

The proposed design moves the southern breakwater segment approximately 40 feet waterward and the western breakwater segment approximately 60 feet waterward to improve the maneuverable area between the breakwater and interior docks. The changes to wave energy are not expected to have any impact on navigation.

Shoreline and nearby waterfront properties

The proposed design will remain in nearly the same location and orientation as the existing breakwater, such that the area of attenuated waves inside the breakwater will not change substantially. However, the transmission of wave energy within the marina will increase as a result of replacing the fixed pile structure with a floating breakwater, particularly during the largest storm events. Floating breakwaters attenuate less wave energy at all wave periods than a fixed structure and are less effective at attenuating energy as wave periods increase.

The increase in wave energy in the marina from storm events due to replacement of the solider pile breakwater with the proposed floating breakwater is 10 to 20% (Figure 2, Mott MacDonald 2019b). Additional wave attenuation will occur as the waves propagate through the interior marina floats to the shoreline. The difference in the amount of attenuation at the shoreline due to wave attenuation by the marina floats is difficult to quantify without a detailed two-dimensional wave model which is beyond the current scope of this investigation. For the purposes of this evaluation, we have assumed that the floats do not provide any additional wave attenuation which is conservative.

No change to the armored shorelines within and adjacent to the marina shoreline are expected because the increase in wave energy (maximum) is not expected to require larger rock or other modifications to the existing armored shorelines to maintain their stability.

Removal of the four piles from the log boom will result in a local re-working of sediments and may result in a small increase in longshore transport along this section of the shoreline. The log boom pile is located at the end of the drift cell where it transitions to an accretion shoreform, which indicates wave energy at this location is currently not very significant in terms of sediment mobilization and transport. However, this local small increase in longshore transport may result some visible changes to the shape of the shoreline as the shoreline "straightens out" after the piles are removed. The unarmored length of marsh shoreline appears to be naturally sheltered and will also remain within the shadow of the floating breakwater for any southwesterly or westerly wave events. No significant long-term increase to shoreline erosion is expected along these unarmored shorelines.

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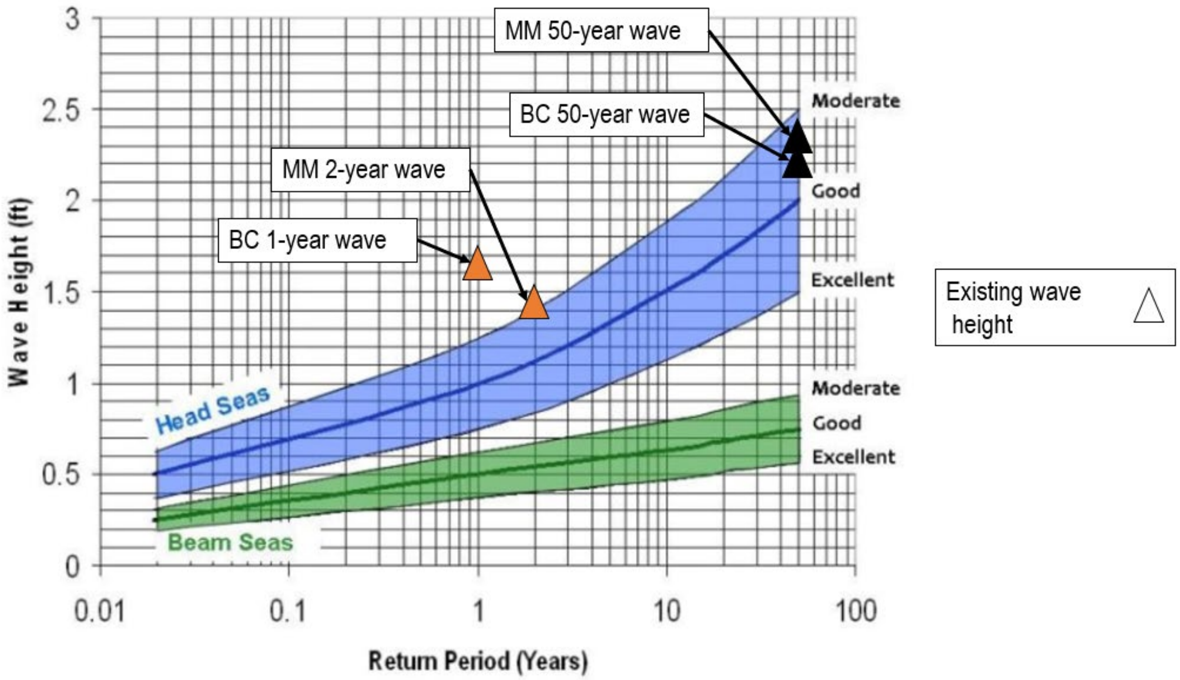

Figure 1. Extrapolated results of the target wave height tolerance of docks and berthed vessels facing head seas and beam seas with superimposed results for the Port of Poulsbo marina in the absence of a breakwater (figure modified from Cox 2018). "BC" refers to wave conditions determined by Blue Coast Engineering as part of this evaluation and "MM" refers to wave conditions previously estimated by Mott Macdonald (2019a).

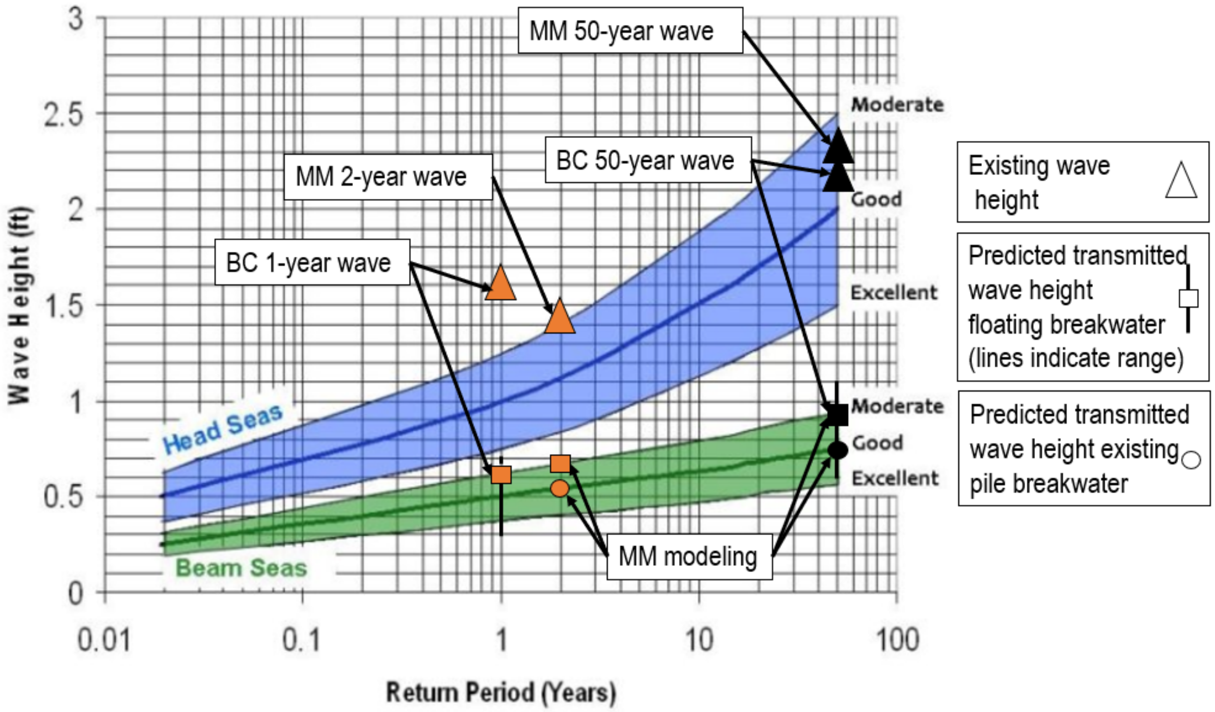

Figure 2. Extrapolated results of the target wave height tolerance of docks and berthed vessels facing head seas and beam seas with superimposed results for the Port of Poulsbo marina with existing pile and proposed floating breakwater (figure modified from Cox 2018). "BC" refers to wave conditions determined by Blue Coast Engineering as part of this evaluation and "MM" refers to wave conditions previously estimated by Mott Macdonald (2019a).

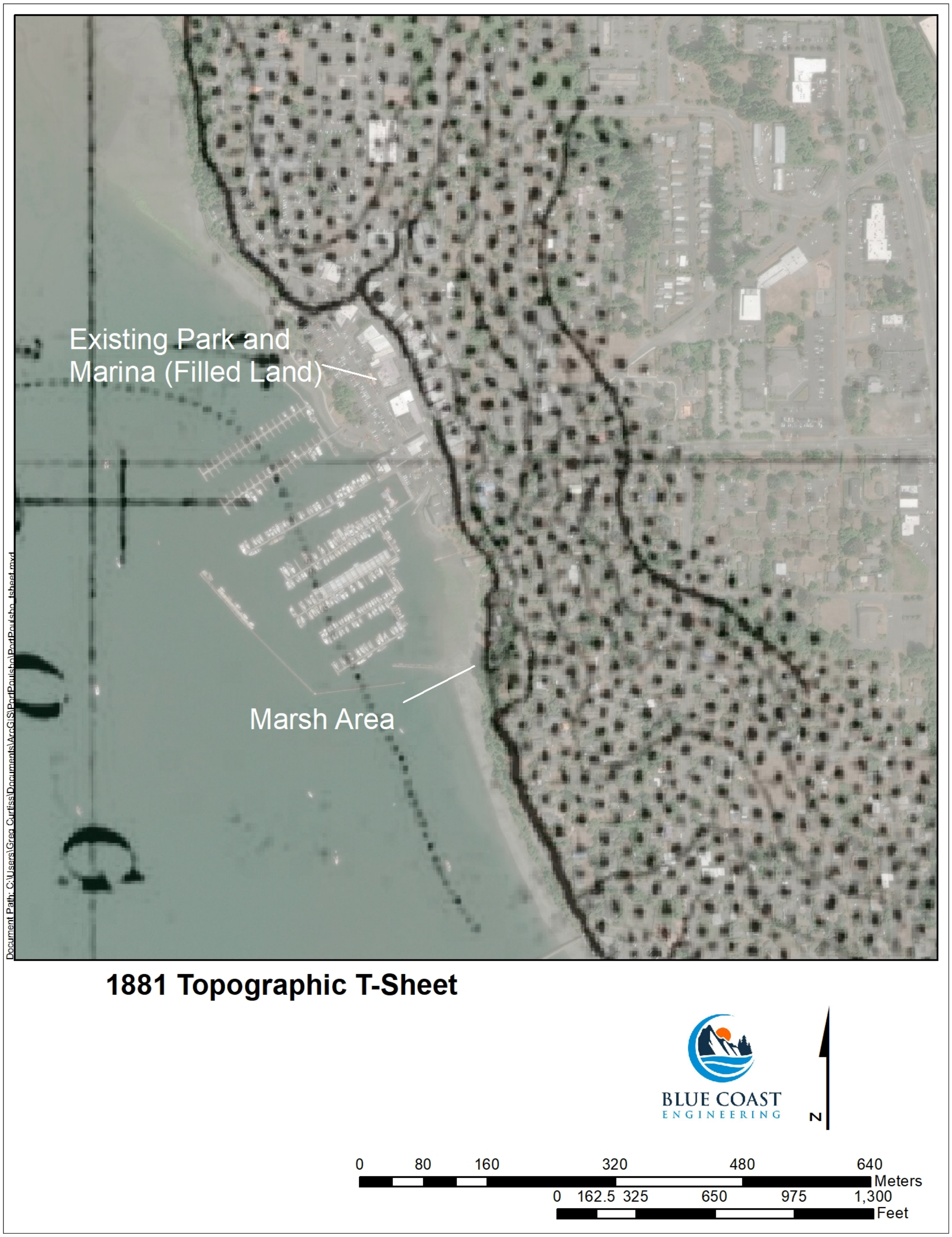

Figure 3. 1881 topographic sheet of marina and adjacent shoreline.

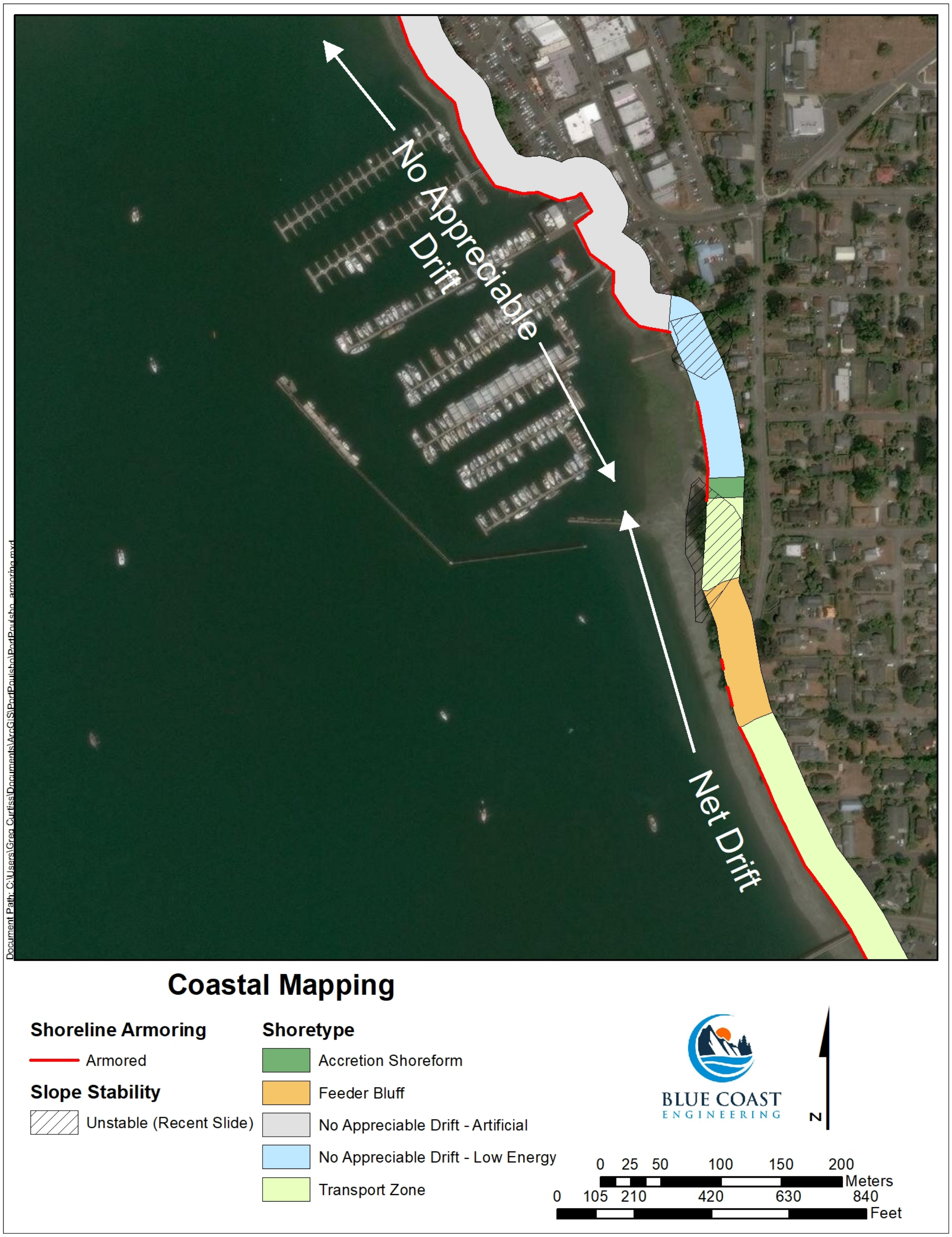

Figure 4. Coastal landform and mapping of shoreline within and adjacent to the marina.

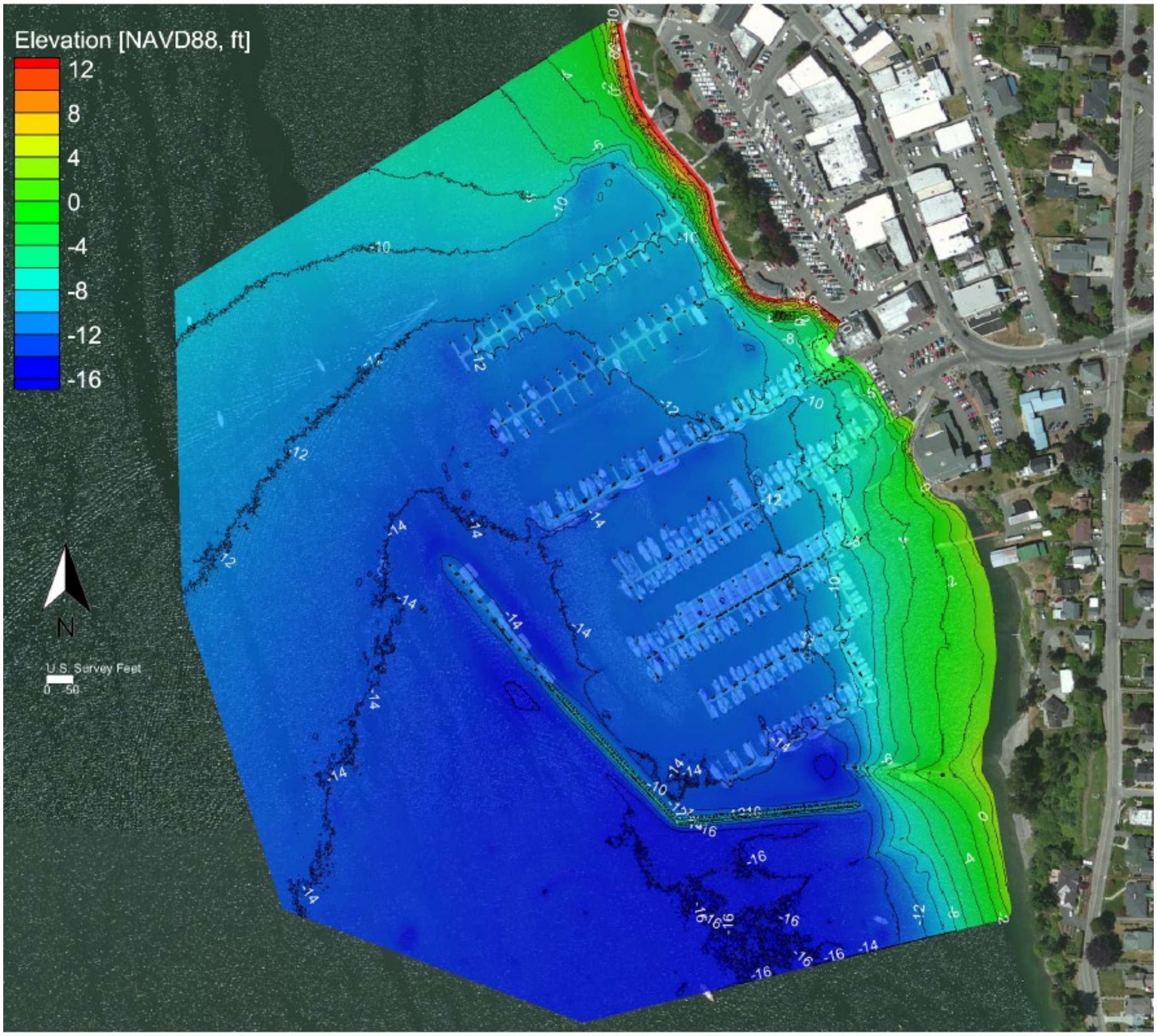

Figure 5. 2019 bathymetry map.

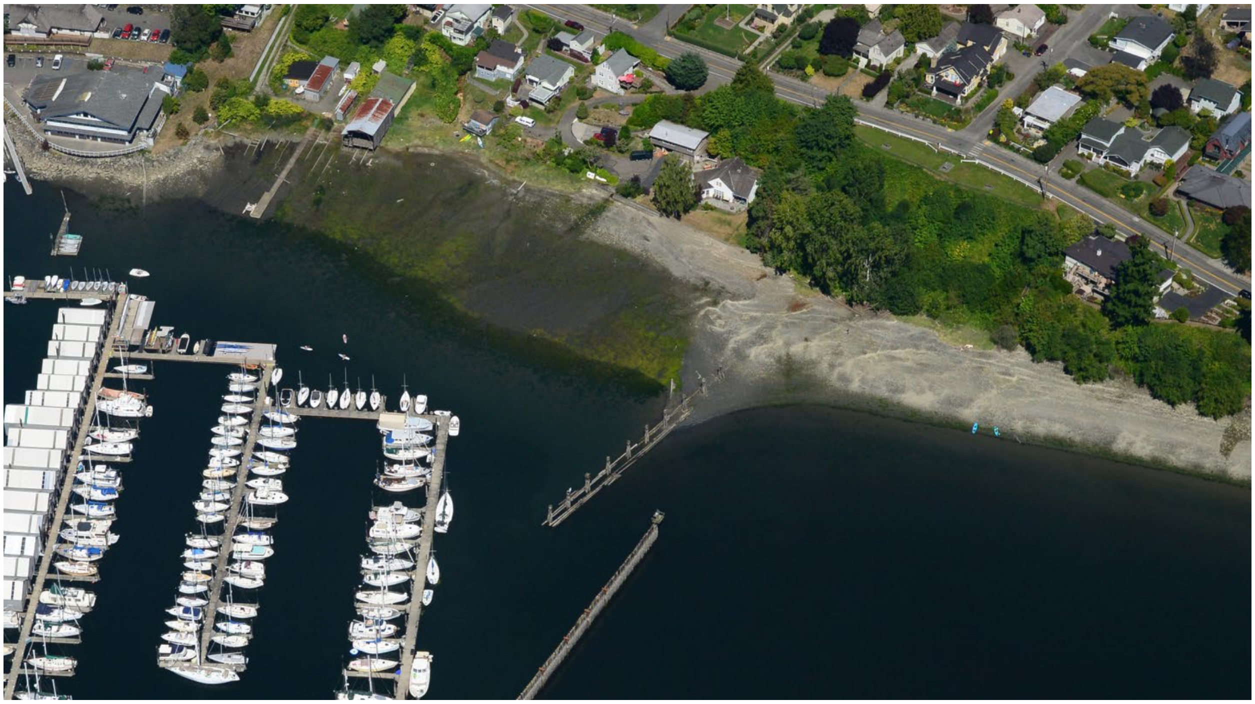

Figure 6. 2016 oblique aerial photograph of the shoreline adjacent to the marina (Ecology 2020).