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Subject: Vulnerability Assessment and Resilience Planning, Lobster Coop, Stonington, Maine
Penobscot Bay Working Waterfront Resiliency Analysis
State of Maine, Department of Marine Resources

Wood Environment & Infrastructure Solutions, Inc. (Wood) is pleased to provide the Maine Department of Marine Resources (DMR) this report on the baseline characterization, vulnerability assessment and resilience planning for the Lobster Coop, Stonington, Maine. This report provides findings for one of ten sites included in DMR's Penobscot Bay Working Waterfront Resiliency Analysis project. Reports on the other nine sites are provided under separate cover. Our work was performed in general accordance with the scope of work and the terms and conditions included in Wood's proposal dated 1 March 2019.

1.0 INTRODUCTION

As proposed for DMR's Penobscot Bay Working Waterfront Resilience project, Wood conducted an assessment of the Lobster Coop in Stonington, Maine which included:

- Facility baseline characterization including a review of available site documents, interviews with community representatives, survey of site topography and elevations of key site features, and review of the general condition of existing site structures by a Wood structural engineer;
- Facility vulnerability analyses based on the baseline survey data, condition of structures, and modelling of potential storm surge and wave affects under three sea-level rise (SLR) scenarios; and
- Development of resilience measures, including strategies for incremental adaptation under the modelled storm and SLR scenarios.

This report contains a summary of our document review, personnel interviews, structural observations, photographs documenting our observations (**Appendix A**), and the approximate location of potential structural deficiencies. Following our analysis of the site and as part of the vulnerability analysis, we were able to identify the risks for the affected site features (see **Table 4**) from inundation data. Inundation maps developed for the site by Wood's consulting partner, Woods Hole Group (WHG) are provided in **Appendix B**. The vulnerability analysis establishes the future risk framework for the site and its structural features. Wood has evaluated the degree of impact of these site-specific vulnerabilities, and we have provided recommendations for improved resilience (e.g., repair, reinforcement) in relation to the feature's immediate performance and/or expected performance per the vulnerability analysis.

As part of the subsequent discussion, the following terms are defined below:

Base Flood Elevation (BFE) -	Elevation of flooding, including wave height, having a 1% chance of being equaled or exceeded in any given year.
Checks	A separation of the wood occurring across or through the rings of annual growth and usually as a result of seasoning.
Coastal High hazard Area (CHHA) -	Area within a special flood hazard area extending from off-shore to the inland limit of a primary frontal dune along an open coast and any other area that is subject to high velocity wave action.
Design Flood Elevation (DFE)	Based on the design flood, the DFE is the higher of the base flood elevation (BFE) shown on FIRMs prepared by FEMA or the flood elevations shown on the map adopted by a community.
FIRM -	Flood Insurance Rate Map. Official map of a community on which FEMA has delineated both special flood hazard areas and the risk premium zones applicable to the community.
Highest Annual Tide (HAT) –	The elevation of the highest predicted astronomical tide expected to occur at a specific tide station over the National Tidal Datum Epoch.
Mean Higher High Water (MHHW) –	The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch. The highest high tide or water height is referred to as the Highest Astronomical Tide (HAT) and is defined as the highest level which can be predicted to occur under average meteorological conditions and any combination of astronomical conditions.
National Tidal Datum Epoch –	The specific 19-year period (Currently 1983 to 2001) adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (Mean Lower Low Water, etc.) for tidal datums.
Pre-FIRM	Construction or substantial improvement occurred on or before December 31, 1974.
Shakes	Lengthwise separations of the wood along the grain, usually occurring between or through the rings of annual growth.
Splits	A separation of the wood through the piece to the opposite surface or to an adjoining surface due to tearing apart of the wood cells.
Still Water Elevation –	Elevation that the surface of the water would assume in the absence of waves referenced to a specified vertical datum at the defined recurrence interval.
Wave Height –	Vertical distance between the crest and the trough of a wave.

2.0 DOCUMENT REVIEW AND PERSONNEL INTERVIEWS

Wood was escorted by Mr. Ron Trundy, Coop Manager, during a site visit on 27 June 2019. We discussed the site features and historical development of the site. Mr. Trundy mentioned that the primary use of the site is commercial fishing. He advised that lobster, scallops and crab are the primary commodity and that the fisherman are the owners of the coop, whereby he provides a service of maintaining the site. According to his recollection, the site was established in the late 1940's. The Main Office building (outside Wood's evaluation scope), recently relocated from the current flood zone, was originally built in the 1960's. A second building was demolished within a year of our site visit, with only a paved patch now remaining in the parking area. He mentioned that the current Fish House was built in the 1990's. Some major repair work, including pile driving, was performed at the adjacent pier (out of scope) within the last year.

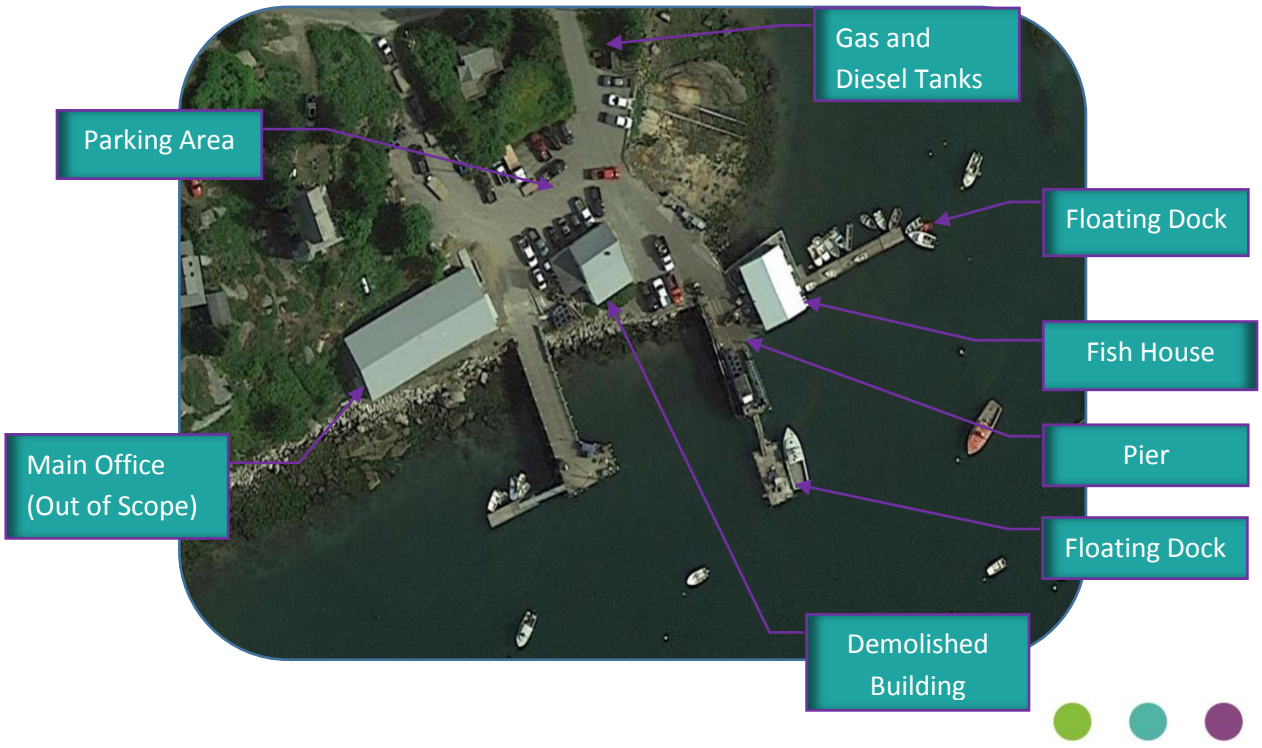
Mr. Trundy mentioned that although no single event, to his recollection, caused notable damage, there is flooding on at least three to four occasions a year in which the water level is nearly to the parking lot elevation. His current plans for the site include addition of a boat ramp at the shore near Floating Dock 2 (**See Photograph No. 1, Appendix A**). He also showed us concept drawings he procured for a sea wall which would run adjacent to the shoreline near the main office building.

The following is a summary of key site features identified during the site visit:

- The site consists of the piers, parking area, and shoreline protection (See **Figure 1** below).
- Within our assessment area, a Fish House and small Fisherman's Office.
- Gas and diesel tanks are located onsite and are owned and maintained by a fuel supply company.
- A waste oil disposal tank is located on site.
- Two (2) wooden floating docks are located along the north and east sides of the pier (see **Photograph No. 1, Appendix A**).
- There is no formal ongoing maintenance plan in place; maintenance is addressed, as needed, when a deficiency is identified.

During our site visit, permit drawings were reviewed for a building relocation project for the Main Office & lobster hatchery building to relocate the building footprint outside the flood zone. Although we noted this information, this asset is outside the scope of our assessment. Design drawings or specifications were not provided for any structure within the scope of our assessment.

Figure 1: Site Overview



3.0 OBSERVATIONS AND FINDINGS

Tirrell Day and Lane Gray of Wood performed a site assessment and gathered geospatial data for key site features during the 27 June 2019 visit. This assessment included documenting the general condition and recording elevations of key features and structures. At the request of the Town, the limits of our investigation included the pier, attached floating docks, adjacent parking area, and associated facilities. The facilities noted include the Fish House, where bait is prepared, and a Fisherman's Office. Photos of the sites and Wood's noteworthy observations are included in the Photolog (**Appendix A**). Elevations discussed in this report are with respect to North American Vertical Datum of 1988 (NAVD88). The site facilities and their associated elevations are included in **Table 1** for reference. During our site visit the approximate tidal levels where observed between -4.2 ft and 2 ft (predicted min. of -4.5 ft, max. of 4.4 ft).

3.1 Property Overview

This site is a 1.51-acre property, consisting of a timber pier, floating docks, and a parking area (**Photographs 1 – 4**). The pier is located at the southeast corner of the property. Support for the pier at one end is provided by stacked granite blocks (**Photographs 4 – 8, 13 – 19**). Fill material for this area or subsurface conditions were not investigated during our site visit.

The pier structure is, for the most part, supported by timber piles, pile caps and stringers (**Photographs 7 – 12**). Timber framing appears to be attached using a combination of through-bolts, nails. An exposed bolt was noted a one location at the underside of the deck for attachment of pile cap to a timber stringer (**Photograph 9 & 10**). Attachment methods for other members could not be viewed or assessed. Details on timber pile embedment were not available. Investigation of the subsurface conditions of the site is not a part of Wood's scope of work.

Access to the floating docks are provided via a gangway attached to the pier (**Photographs 20 & 28**). The pontoons appear to be secured to the pier by means of ropes and straps which are attached to the mooring piles at the exterior face of the pier (**Photographs 20 – 28**). Wood observed the function of the gangway and floats during tidal action and the system appeared to function as intended.

Site utilities include power, water and fuel provided at select locations at the pier and/or floating docks (**Photographs 19, 20, 29 & 30**). Power is provided via outdoor electrical cables at Floating Dock 1. Diesel and gasoline fuel supply is also provided at this floating dock (**Photograph 20**). Power is also provided to conveyor equipment located at the west side of the pier, near Floating Dock 1 (**Photographs 18, 19, 31**). Electrical receptacles viewed throughout appear to be of the moisture resistant type. No utilities were observed on Floating Dock 2.

Site facilities include the Fish House, for preparation of bait, and the fisherman's office. The Fish House appears to be a wood framed structure with metal siding and roof (**Photographs 32 – 37**). The structure appears to be seated directly on the pier and thus shares the same floor elevation. We did not observe any supplementary framing specifically to support the building. Power and water which is supplied to the pier is also provided at the building (**Photographs 33 & 36**). The Fisherman's Office was viewed onsite at the end of the pier near Floating Dock 1. The structure appears to be wood-framed and built directly on the pier. The exterior covering appears to be wood siding and asphalt shingle roof (**Photographs 38 & 39**). The means of attachment of both structures to the pier below was not readily apparent. Anchorage was not visible from the building interior or exterior faces.

Diesel and gasoline are stored onsite in two above ground metal tanks located at the north end of the site, adjacent to the site access road (**Photographs 40 – 43**). The tanks are seated in a concrete containment which encloses the tanks on all sides and the bottom. A catwalk is provided for access to the top of the tank, accessible from the main road. Fill piping for the tanks appears to be steel, whereas galvanized steel piping appears to be the supply line to the fuel pumps and travels partly in a grated concrete chase and partway along a concrete wall (**Photographs 41, 48 & 49**). The steel piping is encased in a polyvinyl chloride (PVC) sleeve for a portion of its length along the shore. An additional tank was observed onsite south of the fuel tanks

(**Photographs 44 – 46**). This tank serves as a collection for waste oil at the site. This tank is also located within a concrete containment which has a wood-framed canopy attached. The three tanks are maintained and serviced by their respective venders.

An asphalt-paved parking lot and access road encompasses most of the site (**Photograph 2, 50 & 51**). The parking area slopes down toward the harbor with most site drainage accomplished by means of gravity flow. A culvert was noted on site as apparent passthrough drainage from the neighboring property (**Photographs 47 & 48**). The culvert is plastic on the upstream end and is galvanized at the discharge end along the shore, indicating possible past repair or replacement. The top coat (exposed surface) of pavement exhibits signs of typical wear with cracking as some minor material delamination.

Shoreline protection for the site is granite block revetment ranging from 1.5 feet to 4 feet in length. The protection continues beyond either end of the site and was observed as extending from below the waterline at the time of our site visit to the top of grade with a slope ranging from roughly 2 foot vertical to 1 foot horizontal, and 3 foot vertical to 1 foot horizontal.

Table 1: Site Elevations

Location	***Lowest Horizontal Member***	***Lowest Deck or Adjacent Grade***	***First Finished Floor / Mid Mark***	***Lowest Opening/ Critical Elevation***
Source	***Estimate****	***Survey***	***Survey***	***Survey***
Facilities	***[ft]***	***[ft]***	***[ft]***	***[ft]***
Pier	8.76	10.05	n/a	n/a
Floating Docks	n/a	9.73	n/a	n/a
Facilities	n/a	10.32	10.32	10.32
Fuel Tank Enclosure	n/a	12	n/a	12.33
Parking Area	n/a	7.5	9.74	14
Shoreline Protection	n/a	7.34	n/a	12.34

**Estimates indicate measurements referenced or derived from the actual site survey data.*

3.2 Noted Deficiencies

Based on limited visual inspection of the site features, we have the following notable observations:

- Lack of stable gravity support at pier attachment to granite blocks (**Photographs 5, 6 & 15**) – bearing condition appears to be either deflected or not level. During closer inspection it appears that framing members are not attached such that they can provide lateral or uplift resistance.

- Lack of full lateral bracing (**Photographs 7-11 & 23**) – Lateral bracing was noted in only the north-south direction at one pier and no lateral bracing was noted for the other.

- Lack of blocking or bridging (**Photograph 12**) – Bridge or blocking between deck stringers were not present at locations observed.

- Moderate to major corrosion of fasteners (**Photographs 9, 10, 23**) – Exposed fastener reveals condition of progressive corrosion at exposed fastener in pier framing.

- Concrete cracking and/or delamination (**Photograph 43**) – Crack noted in concrete enclosure wall for fuel tanks. An attempt at a previous repair was noted which appears to be inadequate from visual inspection.

- Deteriorated wood members (**Photograph 5 – 12, 17, 18 & 23**) – Minor to moderate deterioration of wood members at various locations throughout the pier structure.

3.3 Risk Framework

As a basis for the vulnerability analysis, water surface elevation (WSE) exposure profiles were developed by WHG which summarize current and potential future tidal and storm surge inundation/wave impacts. The key flood elevation profiles provided include the Mean Higher High Water (MHHW), the Highest Astronomical Tide (HAT), the 1% Still Water Level, and the Base Flood Elevation (BFE). Values for these scenarios are site specific and take into consideration the topographic survey data obtained by Wood.

The MHHW and HAT tidal datums (present day) were sourced from the nearest long-term NOAA tide station and from spatial files developed by Maine Geological Survey[1]. The 1%-annual-chance still water level (present day) was obtained from the 2016 FEMA Flood Insurance Study for Knox County.

Table 2: Flood Modelling Data Summary

Scenario	*MHHW*	*HAT*	*1% Still Water Level*	*1% Wave Crest Elevation (BFE)*
Present day	5.1	6.9	9.3	12-14
Short Term (+1 ft)	6.1	7.9	10.3	13-15
Mid Term (+2 ft)	7.1	8.9	11.3	14-16
Long Term (+4 ft)	9.1	10.9	13.3	16-18

Site-specific wave modelling was conducted for existing and future sea levels to better quantify wave hazards and potential increases in wave heights at the site. Wave modelling was conducted using FEMA's overland wave modelling approach for consistency in providing an estimate of the 1% BFE for the future scenarios.

For potential future flood impacts, relative SLR scenarios were reviewed using the U.S. Army Corps of Engineers' Sea-Level Change Curve Calculator (Version 2017.55), specifying the Bar Harbor long-term tide gauge, a regionally-informed vertical land movement rate (from NOAA), and the NOAA et. al (2017)[2] SLR curves.

In discussion with the project team, the preferred SLR scenarios defined for evaluating short-term, mid-term, and long-term impacts were selected as 1 ft, 2 ft, and 4 ft, respectively. These projected increases in sea level roughly correspond with NOAA's Intermediate scenario for the years 2030, 2050, and 2085 with a rather low exceedance probability (17%) and are within the SLR scenarios recommended by Maine DOT for design of transportation infrastructure.

3.4 Site Vulnerabilities

The flood modelling data provided above in **Table 2** includes scenarios for the Short Term, Mid Term, and Long Term SLR scenarios. NOAA's Intermediate scenario mentioned above compared with these timeframes should be taken into consideration for the identified return periods as illustrated in **Table 3**.

[1] https://www.maine.gov/dacf/mgs/hazards/highest_tide_line/index.shtml
[2] https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

Table 3: Flood Return Period

Event Return Period	Percent Chance of Occurrence per Period			
	5 Years	10 Years	25 Years	50 Years
100 Year Flood (1%)	4.9%	9.6%	22.2%	39.5%
500 Year Flood (0.2%)	1%	2%	4.9%	9.5%

The various site features have been summarized in **Table 4**, for each facility, indicating the associated risk and flood scenario which result in inundation. Those elevations noted as 0 ft indicate an elevation equal to the identified feature of the facility. No elevations are noted in **Table 4** where no inundation of the feature was identified (i.e., flood elevation is lower than that of the site feature). Below are the site-specific vulnerabilities based on our review of the property.

Table 4: Site Elevations and Risks

Facility			*Inundation above Elevation of Facility*															
*Facility / Elevations**			*Present Day*				*Short Term Scenario*				*Mid Term Scenario*				*Long Term Scenario*			
			MHHW [ft]	*HAT [ft]*	*1% Stillwater [ft]*	*BFE [ft]*	*MHHW [ft]*	*HAT [ft]*	*1% Stillwater [ft]*	*BFE [ft]*	*MHHW [ft]*	*HAT [ft]*	*1% Stillwater [ft]*	*BFE [ft]*	*MHHW [ft]*	*HAT [ft]*	*1% Stillwater [ft]*	*BFE [ft]*
Pier	Bottom Lowest Horizontal	8.76 ft			0.54	5.2			1.54	6.24		0.14	2.54	7.24	0.34	2.14	4.54	9.24
	Deck / Adjacent Grade	10.05 ft				4			0.25	4.95			1.25	5.95		0.85	3.25	7.95
Floating Dock 1	Buoy Chain max elevation																	
	Gangway support	9.73 ft				4.3			0.57	5.27			1.57	6.27		1.17	3.57	8.27
Floating Dock 2	Buoy Chain max elevation																	
	Gangway support	9.79 ft				4.2			0.51	5.21			1.51	6.21		1.11	3.51	8.21
Facilities - Fish House / Office	Adjacent Grade	10.32 ft				3.7				4.68			0.98	5.68		0.58	2.98	7.68
	First Floor Elevation	10.32 ft				3.7				4.68			0.98	5.68		0.58	2.98	7.68
	Lowest Opening	10.32 ft				3.7				4.68			0.98	5.68		0.58	2.98	7.68
Fuel Tank Enclosure	Adjacent Grade	12 ft				2				3				4			1.3	6
	Top of barrier wall	12.33 ft				1.7				2.67				3.67			0.97	5.67
Oil Tank Enclosure	Adjacent Grade	14 ft				0				1				2				4
	Top of barrier wall	15.5 ft												0.5				2.5
Parking Area / Access	Lower elevation	7.5 ft			1.8	6.5		0.4	2.8	7.5		1.4	3.8	8.5	1.6	3.4	5.8	10.5
	Mid mark	9.74 ft				4.3			0.56	5.26			1.56	6.26		1.16	3.56	8.26
	Upper elevation	14 ft				0				1				2				4
Shoreline Protection	Top Elevation	7.34 ft			1.96	6.7		0.56	2.96	7.66		1.56	3.96	8.66	1.76	3.56	5.96	10.7
	Critical Elevation	12.34 ft				1.7				2.66				3.66			0.96	5.66

**** Facility elevations presented in this Table are referenced to NAVD88.***

3.4.1 Pier

From our preliminary non-destructive investigation, the pier appears to exhibit signs of minor to moderate weathering of timber members. The condition and presence of fasteners could not be thoroughly examined; however, fasteners at those locations observed appear to show signs of extensive corrosion. The behaviour of the pier for the Present Day scenario, where the BFE and

1% Stillwater elevation are above the deck, is dependent on structural elements being properly attached. In addition, we noted a lack of lateral bracing at the piles in the east-west direction for the entire pier and in both directions for one section of pile framing. Based on the type of construction and the total unbraced length of the piles above their embedment in the sea floor, we would expect bracing at regular intervals.

Beginning with the Short Term condition, wave heights become greater than 3 feet and high velocity wave impact to the pier and deck elements can be expected during the BFE. Inundation of the deck is not of concern for routine use, until the Long Term scenario, during which the HAT is several inches above top of deck. Site utilities at the pier, which include fuel and power, are exposed to wave action and inundation under the Present Day BFE. The risks increase for all noted elements above for future scenarios.

3.4.2 Floating Docks

The floating dock assembly consists of the gangway and pontoons. The critical elevation for proper function during normal use of the floating docks is the MHHW. This is based on the relatively frequent occurrence and the forces the gangway will exert on the attached pier header from rising water level and functionality of the system for these levels. As is indicated in **Table 4** for the Present Day, Short Term and Mid Term Scenarios, minimal risk is foreseen for damage to the pier from tidal action forces exerted from the gangway. However, the risk of damage from the BFE during all scenarios is of concern. Due to the attachment of the docks to the pier by means of ropes and straps, it appears that these structures are intended to be for temporary use. If the floats are not removed prior to commencement of an event, they could exert additional eccentric loading on the pier-gangway attachment from excessive deflections.

3.4.3 Facilities – Fish House & Fisherman's Office

The Fish House Building is located 3 to 4 feet from the face of the pier on all sides and can expect no shielding from an adjacent structure during a storm event. For **all scenarios**, waves are over 3 to 4 feet in height, with **high velocity wave action impacting the structure,** indicative of the CHHA to which it belongs. Additionally, the means by which structure is secured to the deck or substructure is critical for its vulnerability during a storm event. Given that the structure is built directly on the pier deck as an unsealed space, the many openings in the deck floor will easily allow water to enter and exit during inundation. Beginning with the 1% Stillwater inundation depth of 0.98 feet for the Mid Term scenario, the increasing flood risk will threaten lower framing members and finishes with conditions of saturation which could lead to deterioration. All power and other utilities which are not raised, sealed and/or secured against moisture intrusion, wind and wave loading would also be impacted. Similar risks exist for the Fisherman's Office, which is also positioned close to the edge of the pier. While the location of both structures is convenient for their intended use, they are highly vulnerable and their risk of damage is high for all scenarios.

3.4.4 Above Ground Storage Tanks (ASTs)

As previously mentioned, the two fuel ASTs and one waste oil AST are placed within concrete enclosures. Given the inland location and elevation of both enclosures, effects of wave action at the enclosure walls and ASTs as result of the BFE is expected to be negligible for the Present Day, Short, and Mid Term scenarios. For the fuel ASTs, data also indicates minimal risk to the tanks and enclosure from inundation during the Present Day, Short and Mid Term scenarios. During the Long Term scenario, overflow of the enclosure wall and increased risk of wave action is expected. It should also be noted that the cracking and delamination of the fuel AST enclosure wall may worsen during ongoing freeze/thaw events and in the presence of moisture and any loading from hydrostatic pressure during a flood event. For the oil AST enclosure, minimal risk was identified for all scenarios within our analysis period, however the structure may exhibit defects underneath the tank which were not visible during our inspection. In addition, a similar analysis should be anticipated for suitability for the defined loading conditions as previously mentioned.

3.4.5 Parking

For the Present Day, Short and Mid Term scenarios, we expect minimal impact with regard to flooding of the parking area in the absence of a storm event. For the Mid Term event, inundation for the 1% Stillwater is expected to cover more than half of the

parking area, signalling the need to address all equipment or other assets in this area. The frequency of such levels of flooding can be expected to increase for the Long Term scenario with a HAT of more than 1 foot over half of the parking lot. It should also be noted that the 1% Stillwater is only several inches from inundating the entire parking area (not including the access road) for the Long Term scenario.

3.4.6 Shoreline Protection

Shoreline protection is provided in the form of a riprap revetment. No signs of material degradation or slope instability or piping were noted. For the Present Day, Short and Mid Term scenarios, there is minimal risk foreseen based on the data in **Table 4**. Some overtopping is noted for these scenarios, ranging from 2 to 4 feet, but we do not expect it will undermine the revetment. For the Long Term scenario, a future risk is identified due to higher water levels and waves. Under wave attack, randomly placed riprap will experience some settlement and readjustment; however, the risk of wide-scale riprap slope failure appears low.

4.0 RECOMMENDATIONS

4.1 General Recommendations

In accordance with American Society of Civil Engineers / Structural Engineering Institute Standard 24 – Flood Resistant Design and Construction (ASCE 24), existing structures that sustain substantial damage, or that are substantially improved, are treated as new construction. This standard considers damage beyond routine maintenance or otherwise minimal damage following an event, which nonetheless requires major improvements and even applies to structures classified as pre-FIRM. For new construction we recommend, in light of the forecasted increase in water levels and the schedule for these events in relationship to the life of the structure, design should be based on the either BFE plus 2 feet of freeboard, the DFE, or 500-year event, whichever is higher. It is understood that local requirements coupled with available resources will dictate the ability for the communities to incorporate proactive designs. The following recommendations are provided with regard to areas of the site which fall within a special flood hazard area:

- All new construction, substantially improved, and substantially damaged buildings must be elevated on pilings, posts, wharfs, or columns so that the bottom of the lowest horizontal structural member of the lowest floor is at or above the BFE with any applicable freeboard (or DFE), per ASCE 24.
- The foundation system must be anchored to resist flotation, collapse, lateral movement due to wind and water loads acting simultaneously on all components of the building.
- Use of flood damage-resistant materials above the BFE per ASCE 24 and the local Building Code.
- Slab on grade construction in this zone is not permitted and should be avoided.
- Electrical, heating, ventilation, Plumbing and Air Conditioning Equipment should be located on the **landward side of any building and/or behind structural elements. They must be elevated and designed to prevent flood waters from entering and accumulating in components during flooding**.
- Install shutoff and isolation valves on water and sewer lines that extend into the flood-prone areas.

This list is not comprehensive but rather applies to site features observed during our site visit. There may exist other relevant items addressed in any of the above-mentioned design standards which are applicable for the site at a future date. We recommend a detailed site assessment be performed during the design stage to ensure implementation of all applicable items.

4.2 Site Specific Recommendations

Although the risks, vulnerabilities, and associated recommendations addressed herein are in reference to features located within the property limits of the Lobster Coop, there may be features of similar construction in close proximity and exposed to

similar risks as described in this report but fall outside the limits of assessment. **We recommend that these sites and features undergo a similar assessment with the assumption that similar or greater risks may apply.** The following are recommendations for the features identified at risk within the Lobster Coop, Stonington.

4.2.1 Pier

The following recommendations are provided in reference to the **Present Day, Short and Mid Term scenarios** for flood values provided in **Table 2** above:

- Confirm positive attachment of all structural members to their substrate or load-bearing elements. Incorporate redundancies in design as needed based on a detailed structural analysis. Provide additional lateral bracing throughout as battered piles and/or cross bracing in both directions. Verify adequate support for the above structures (Fish House, Fisherman's Office) is provided for lateral and gravity loading. Recommend an investigation to confirm the presence of decay, shipworms or marine borers and determine the need for corrective action for all above cases per a Structural Engineer licensed in the State of Maine.
- Utilities and equipment should be properly secured to resist design wind and water loading or relocated above the flood elevation as specified in ASCE 24. Watertight and stainless-steel enclosures should be incorporated for electrical equipment and conduits. Fuel lines should be located above flood elevation and/or properly secured to resist design wind and wave loading.

The following recommendations are provided in reference to the **Long Term scenario** for inundation values provided in **Table 2** above:

- Recommend structural improvements to accommodate the risks associated with rising water levels and increased wave height such as weatherizing vulnerable assets and properly securing structures (e.g., chains, anchors, tie-backs, supplementary lateral bracing, etc.). Our assessment approach and recommendations take into consideration the use of the site and practical positioning of certain assets to accommodate the daily functions. We therefore recommend the town continue to allow for updated SLR analysis on a 5 to 10 year interval to capture changes in data and regulatory requirements. This will aid in developing an incremental design approach for the site-specific risks and needs. Opportunity should be taken to incorporate a sustainable design for any future substantial improvements as budget allows.

4.2.2 Floating Docks

The following recommendation is provided in reference to the **Present Day, Short and Mid Term scenarios** with regard to construction of the floating dock assemblies:

- Clean and coat all corroded steel framing members and replace corroded hardware. Confirm that all members are positively connected and the substrate is in decent condition to resist the intended design loading.
- Confirm the gangway attachments are sufficient to resist the design loading and repair or replace as needed.
- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed.

The following recommendation is provided in reference to the **Long Term scenario** with regard to construction of the floating dock assembly:

- In the event the pier elevation is not raised, consider raising the gangway and gangway platform to accommodate rising water levels. This alternative will provide an elevated gangway platform above the deck elevation, and greater resilience during future extreme high tide and storm events.
- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed.

4.2.3 Facilities – Fish House & Fisherman's Office

The following recommendations are provided for **All scenarios** with regard to the current buildings:

Fish House

- It is understood that the location of this structure is practical for its intended use. Therefore, we recommend a detailed analysis to confirm the structure is designed to support the loading from wind and wave, and can successfully transfer these forces to the substructure. Also, this analysis should include verifying that the support system is adequate for all code defined design loading and other applicable loading conditions. Retrofitting and/or repair of the structure and all supporting elements should be performed based on the results of the analysis, performed by a Structural Engineer registered in the State of Maine (See recommendation for Pier above).

Fisherman's Office

- Based on high velocity wave action for all scenarios, we recommend relocation of the structure at least 50 feet inland from its current location and at an elevation above the 1% Stillwater elevation for the Mid Term scenario or at a site location of equivalent grade.

4.2.4 Above Ground Storage Tanks (ASTs)

The following recommendation is provided in reference to the **Present Day and Short Term scenarios** with regard to the concrete enclosures (containment) for securing of the three ASTs:

- Assess the integrity of concrete sump walls for fuel containment and seal or repair as needed. Perform structural inspection of enclosure to confirm presence of defects and repair as needed.

The following recommendation is provided in reference to the **Mid and Long Term scenario** with regard to the concrete enclosures for securing of the ASTs:

- Perform a detailed assessment and analysis to estimate the ability of the structure to withstand hydrostatic loading and repair or replace damaged or insufficient elements under direction of a qualified design professional registered in the State of Maine. In the event replacement of the containment is required, the structure should be built to accommodate the most stringent of the current DFE or 1% Stillwater elevation for the Long Term scenario plus 1 foot of freeboard.

4.2.5 Parking Area

Given that the parking lot and pier structure is interconnected, an effort to remediate the parking area against sea level rising would be best coordinated with any greater harbor resiliency effort. Recommendations provided for the harbor shall apply here and vice versa to provide the best design solution with regard to functionality of the site.

The following recommendation is provided in reference to the **Long Term scenario** with regard to existing parking area:

- Recommend regrading to increase height to accommodate rising water levels to match upper elevations of the site between 12 and 14 ft (NAVD88)

4.2.6 Shoreline Protection

The following recommendation is provided in reference to the **Long Term scenario** with regard to the current revetment:

- Consider localized re-grading and raising area to accommodate rising water levels and increased wave height above the top of riprap. Design and apply correctly sized stone at the shoreline based on detailed analysis.

5.0 OPINION OF PROBABLE CONSTRUCTION COSTS

The costing information below is based on our recommendations for remedial action considering the flood modelling and observation of structures addressed herein. These estimated costs include the associated design and engineering services where applicable. **Table 5** provides a summary of the estimated cost for repair or replacement of the identified vulnerabilities. A cost savings may also be expected for combined efforts of items similar in nature, for example, replacing an electrical cabinet while updating and/or securing electrical conduits. We have not considered this variable in our values. Where a complete replacement option is provided, this option and associated costs may be implemented sooner depending on the priorities and funding available to the Town. Costing for the referenced scenario represents summation of all non-complementary improvements. That is, where other repairs or intermediate retrofitting are performed during preceding scenarios the associated costs become additive. All costs are based on present value without inflation. Provided below is a more detailed description of the items included for the associated risk scenario.

Table 5: Repair / Replacement / Retrofitting Costs

Facility	Present Day	Short Term	Mid Term	Long Term
Pier	$535,000	$535,000	$535,000	$2,100,000
Floating Docks	$165,000	$165,000	$165,000	$205,000
Facilities	$550,000	$550,000	$550,000	$550,000
ASTs/Enclosures	$30,000	$30,000	$185,000	$185,000
Parking Area				$350,000
Shoreline Protection				$295,000
TOTAL:	**$1,280,000**	**$1,280,000**	**$1,435,000**	**$3,685,000**

5.1 Present Day Scenario

The following costs should be expected to accommodate events associated with the Present Day scenario.

Pier:

- Confirm positive attachment of all structural members to their substrate or load-bearing elements. Design and Construction **$350,000.**
- Securing of existing utilities for all design loading. Design and Construction **$185,000.**

Floating Docks:

- Clean and coat all corroded steel framing members and replace corroded hardware. Confirm that all members are positively connected and the substrate is in decent condition to resist the intended design loading. Design and Construction **$65,000.**
- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$100,000.**

Facilities – Fish House & Fisherman's Office:

Fish House

- Repair and/or retrofit building to accommodate design loading. Design and Construction **$450,000.**

Fisherman's Office

- Relocate structure based on exposure to wave action. Design and Construction **$50,000 - $100,000.**

ASTs/Enclosures:

- Assess integrity of concrete enclosures for all ASTs and seal or repair as needed. Design and Construction **$30,000.**

5.2 Short Term Scenario

The following costs should be expected to accommodate events associated with the Short Term scenario:

Pier:

- Confirm positive attachment of all structural members to their substrate or load-bearing elements. Design and Construction **$350,000.**
- Securing of existing utilities for all design loading. Design and Construction **$185,000.**

Floating Docks:

- Clean and coat all corroded steel framing members and replace corroded hardware. Confirm that all members are positively connected and the substrate is in decent condition to resist the intended design loading. Design and Construction **$65,000.**
- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$100,000.**

Facilities – Fish House & Fisherman's Office:

Fish House

- Repair and/or retrofit building to accommodate design loading. Design and Construction **$450,000.**

Fisherman's Office

- Relocate structure based on exposure to wave action. Design and Construction **$50,000 - $100,000.**

Tank Enclosures:

- Assess integrity of concrete enclosures for all tanks and seal or repair as needed. Design and Construction **$30,000.**

5.3 Mid Term Scenario

Pier:

- Confirm positive attachment of all structural members to their substrate or load-bearing elements. Design and Construction **$350,000.**
- Securing of existing utilities for all design loading. Design and Construction **$185,000.**

Floating Docks:

- Clean and coat all corroded steel framing members and replace corroded hardware. Confirm that all members are positively connected and the substrate is in decent condition to resist the intended design loading. Design and Construction **$65,000.**
- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$100,000.**

Facilities – Fish House & Fisherman's Office:

Fish House

- Repair and/or retrofit building to accommodate design loading. Design and Construction **$450,000.**

Fisherman's Office

- Relocate structure based on exposure to wave action. Design and Construction **$50,000 - $100,000.**

Tank Enclosures:

- Perform a detailed assessment and analysis and repair/replacement structures. Design and Construction **$185,000.**

5.4 Long Term Scenario

This section includes costs which are expected due to the need for substantial site improvements, however some of these actions are recommended as early as the Present Day scenario, such as independent mooring piles for the floating docks and improvements to the facilities. Items which are not addressed in earlier time periods are included here when not addressed during the course of other referenced improvements.

Pier:

- Structural improvements or relocation of certain elements of structure. Design and Construction **$2,100,000.**

Floating Docks:

- Raise and/or relocate elements of the pier and pier as feasible and practical for current use. Design and Construction **$105,000.**
- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$100,000.**

Facilities – Fish House & Fisherman's Office:

Fish House

- Repair and/or retrofit building to accommodate design loading. Design and Construction **$450,000.**

Fisherman's Office

- Relocate structure based on exposure to wave action. Design and Construction **$50,000 - $100,000.**

Tank Enclosures:

- Perform a detailed assessment and analysis and repair/replacement structures. Design and Construction **$185,000.**

Parking Area:

- Regrading to increase height to accommodate rising water levels. Design and Construction **$350,000.**

Shoreline Protection:

- Localized re-grading and raising area to accommodate rising water levels and increased wave height. Design and Construction **$295,000.**

6.0 QUALIFICATIONS OF THE REPORT

The DMR should understand that our observations may be inconclusive, or it may not be possible to identify a definitive cause of distress based on a structural inspection and visual observations alone/without further testing. The recommendations are made based on these limitations.

The "Opinion of Probable Construction Costs" is made on the basis of Wood PLC's judgment, as experienced and qualified professionals generally familiar with the construction industry. However, since Wood, PLC has no control over the cost of labor, materials, equipment, or services furnished by others, or over the construction contractor's methods of determining prices, or over competitive bidding or market conditions, Wood cannot, and does not, guarantee that proposals, bids, or actual construction cost will not vary from the Opinion of Probable Construction Costs prepared by Wood PLC. We have attempted to consider the general nature of the work and site conditions, based on information made available to us at this stage of the project. All costs are based on actual costs as provided by RS Means Costworks 2018, additional or other specified suppliers vendors and contractors.

7.0 CLOSING

Wood appreciate the opportunity to provide these services to DMR on this project. Please contact us with any questions or comments.

Sincerely,
Wood Environment & Infrastructure Solutions, Inc.

Tirrell Day, PE
Senior Structural Engineer

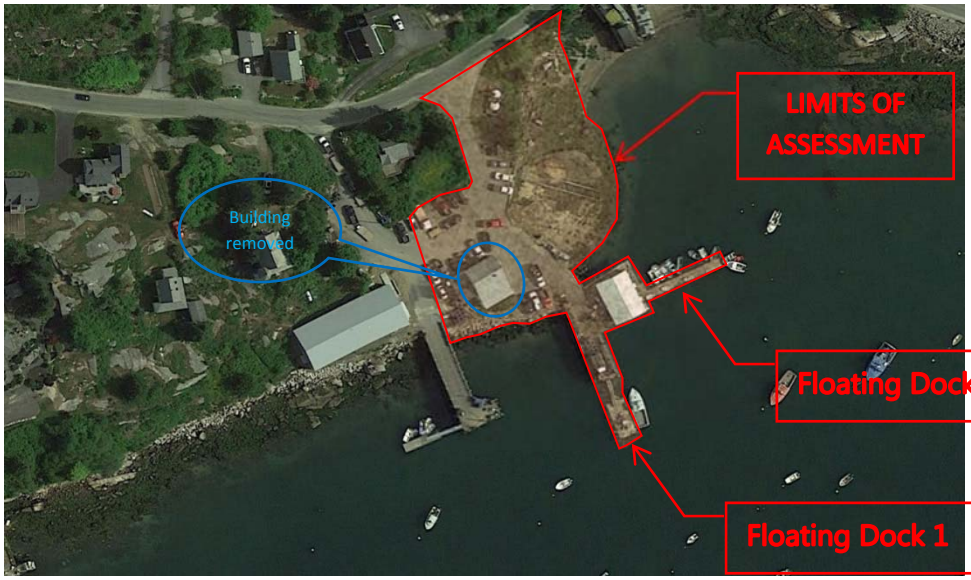
D. Todd Coffin
Associate Project Manager

Attachments: Appendix A - Photolog
Appendix B – Inundation Maps

Appendix A - Photolog for Lobster Coop Stonington, ME

By: T. Day *Date:* 22OCT2019 *Reviewed:* K. Sun *Date:* 25OCT2019

Photograph No. 1:



Comment:

Overview of Site

Note: Previous building removed prior to site visit.

Photograph No. 2:

Comment:

Overview of site from north at entrance looking south.

View of site parking, Fish House and wharf/pier.

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 3:

Comment:

View of pier from west, looking east.

1. **Fish House**
2. **Fisherman's Office**
3. **Floating Dock 1**

Photograph No. 4:

Comment:

View of pier from north of Fish House looking south.

1. **Fish House**
2. **Floating Dock 2**

By: T. Day *Date:* 22OCT2019 *Reviewed:* K. Sun *Date:* 25OCT2019

Photograph No. 5:

Comments:

View of pier from north facing south.

1. **Support of pier at granite blocks and piles.**

Photograph No. 6:

Comment:

Close-up of condition in previous photograph.

1. **Granite block support for pier framing. Block is not level**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

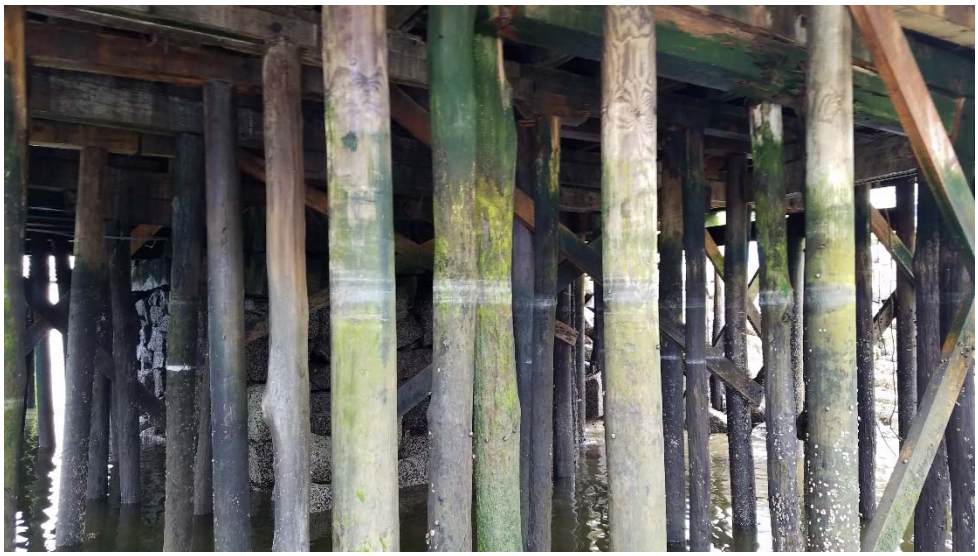
Photograph No. 7:

Comment:

View of north side of pier facing south.

1. **Typical pile layout. No lateral bracing in the east-west direction visible.**

Photograph No. 8:



Comment:

Closer view of timber piles and framing at underside of deck.

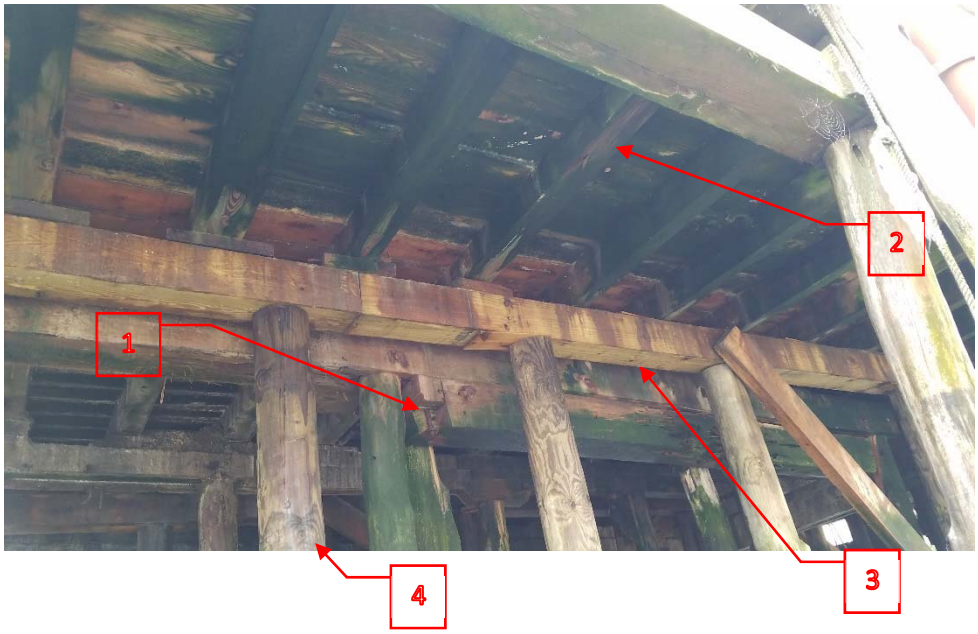
Minor to moderate weathering noted throughout the tidal zone.

Attachment of members could not be confirmed.

Cross bracing as lateral support noted in the north-south direction.

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 9:



Comment:

View at underside of deck. Pile caps and stringers visible. Signs of green algae and what appears to be white mold at underside of deck.

1. **View of exposed fastener.**
2. **Typical Stringer**
3. **Pile Cap**
4. **Pile**

Photograph No. 10:

Comment:

Close-up of condition noted in previous photograph.

View of exposed fastener at pile cap on underside of deck. Bolt exhibits signs of major corrosion.

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 11:

Comments:

View of framing at underside of pier facing west.

View of cross bracing in the north-south direction.

Pile cap to pile attachment method could not be confirmed.

No strap or other steel framing element noted.

Photograph No. 12:

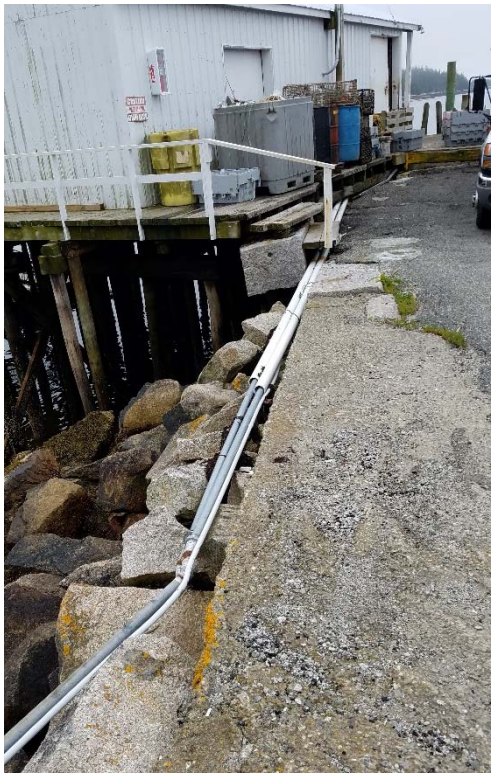
Comment:

Typical view between stringers.

No bridging or blocking noted.

By: T. Day *Date:* 22OCT2019 *Reviewed:* K. Sun *Date:* 25OCT2019

Photograph No. 13:



Comment:

View facing south at top of pier.

View of pier support at west side.

View of utility and fuel conduits.

Photograph No. 14:

Comment:

Close-up of condition noted in previous photograph.

1. **View of support condition for west side of pier. Granite support does not appear to be level and stable.**
2. **View of fuel piping adjacent to pier.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 15:

Comment:

Closer view of pier support on granite block at wharf/grade.

1. **Timber stringer bearing.**

Photograph No. 16:

Comment:

View of pier support on granite at wharf/grade.

1. **Stringer bearing sill plate.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 17:  	**Comment:** **View of deck from above. Deteriorated members noted from wear. Pitting and surface delamination noted.** **A battered pile noted at corner of deck.**
Photograph No. 18: 	**Comment:** **View of west side of wharf looking southeast. Stacked granite and wood framing observed.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 19: 	**Comment:** **View looking south for location identified in previous photograph.** **View of pier beyond and Floating Dock 1.**
Photograph No. 20: 	**Comment:** **View of Floating Dock 1 and gangway.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 21: 	**Comment:** **Close-up of gangway connection to pier.** **Condition of steel header noted with mild corrosion.** **Note misalignment of the gangway attachment. Need to monitor.**
Photograph No. 22: 	**Comment:** **View of Floating Dock 1.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

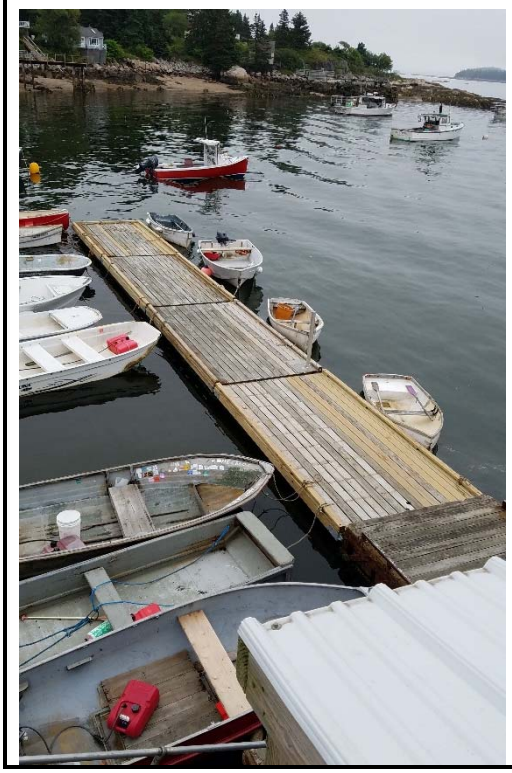
Photograph No. 23:

Comment:

View of pier facing north.

1. **Rope attachment to pier for floating dock.**
2. **No signs of lateral bracing noted.**

Photograph No. 24:



Comment:

Overview of Floating Dock 2.

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 25:

Comment:

View of gangway attachment to pier for Floating Dock 2.

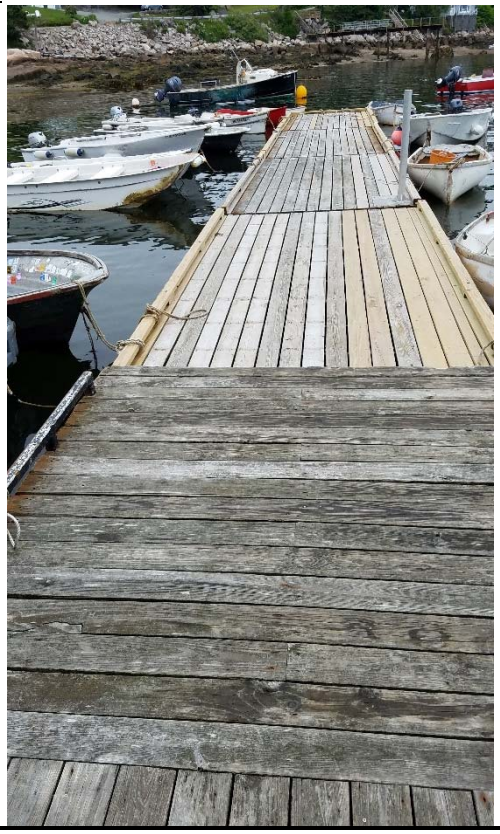
Photograph No. 26:

Comment:

Close-up of connection of gangway to pier.

Fastener attached with exposed threads into deteriorated base material.

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 27: 	**Comment:** **View looking east of deck at Floating Dock 2.**
Photograph No. 28: 	**Comment:** **View lookng west of Floating Dock 2 and gangway.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 29:

Comment:

View of fuel pump located at east end of site just north of the Fish House.

Photograph No. 30:

Comment:

View of south end of pier.

1. **Fuel Pump at Floating Dock**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 31: 	**Comment:** **View of rear (north side) of pier.** **Conveyor and support equipment visible.**
Photograph No. 32: 	**Comment:** **View at pier facing east.** **View of west side of Fish House.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 33: 	**Comment:** **Additional view at west side of Fish House and siding.** **View of electrical service to building.**
Photograph No. 34: 	**Comment:** **View at north side of Fish House and siding. Building penetration for water supply.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 35:

Comment:

View at east side of Fish House and siding.

Photograph No. 36:

Comment:

Close-up of electrical receptacles at interior of building.

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 37:

Comments:

View of interior wall of Fish House building.

Wall breach indicates type of construction.

Photograph No. 38:

Comment:

View of Fisherman's Office at end of pier near Floating Dock 1.

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 39: 	**Comment:** **View of roof at Fisherman's Office.** **Asphalt shingle roof observed.**
Photograph No. 40: 	**Comment:** **View at north end of property at site access.** **View of onsite tanks.** **1. Fuel Tanks** **2. Waste oil storage tank**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 41: 	**Comment:** **View facing northwest of fuel storage tanks and concrete enclosure.**
Photograph No. 42: 	**Comment:** **Close up of fuel tanks.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 43: 	**Comment:** **Close up of concrete vault, tank and fuel supply lines.** **View of existing crack and previous repair in concrete enclosure wall.**
Photograph No. 44: 	**Comment:** **View of housing for waste oil tank.** **Concrete enclosure with canopy roof visible.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 45: 	**Comment:** **View of waste oil tank**
Photograph No. 46: 	**Comment:** **Closer view of oil tank and interior of concrete enclosure.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 47:  	**Comment:** **View of culvert under access road at north end of property.**
Photograph No. 48: 	**Comment:** **View of apparent opposite and discharge end of culvert noted in previous photograph.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 49: 	**Comment:** **View of fuel lines leading from tanks to pumps.**
Photograph No. 50: 	**Comment:** **View of parking area.** **View of main office from east side (entrance).** **1. View of asphalt patch at location of previous office building.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 51: 	**Comment:** **View of site at south end (Pier) facing north.** **Some surface deterioration noted in top coat.**
Photograph No. 52: 	**Comment:** **View of revetment composed of stone blocks.**

By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

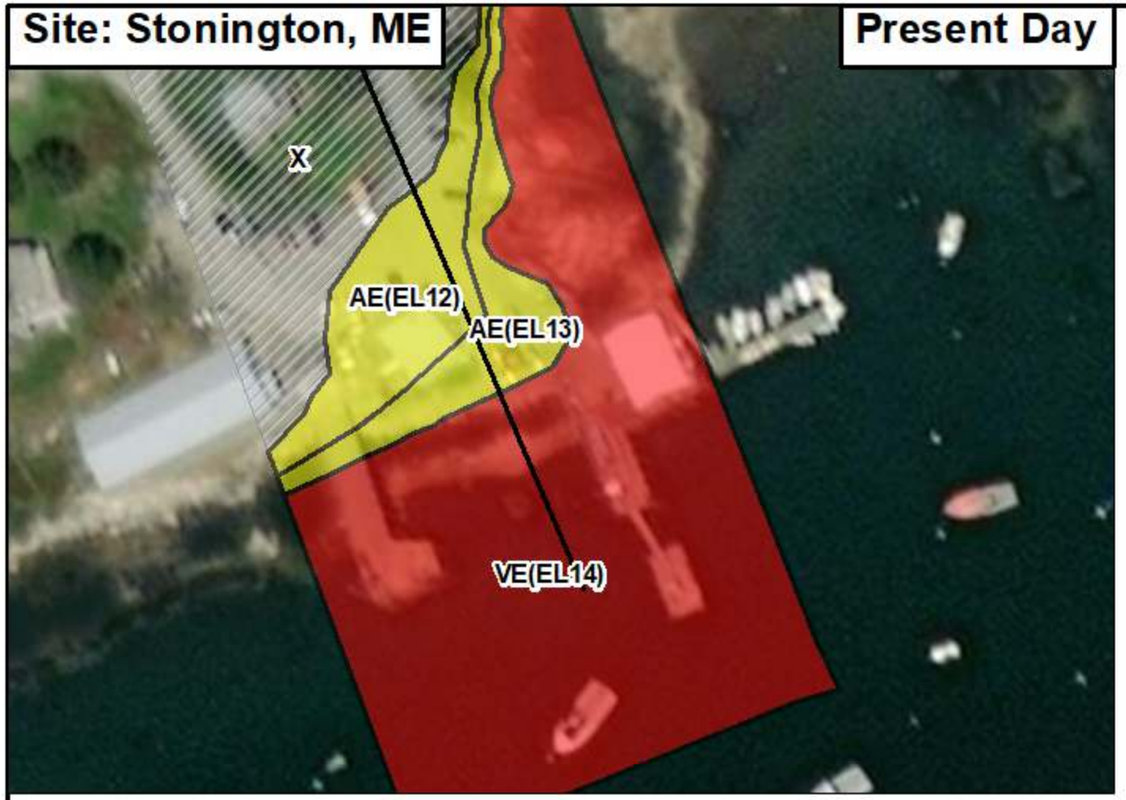
Photograph No. 53: 	**Comment:** **View of revetment at east side of property.** **View of fuel lines.**
Photograph No. 54: 	**Comment:** **View at east side of property facing west.** **View of stacked stone sea wall.** **View of rock outcroppings.**

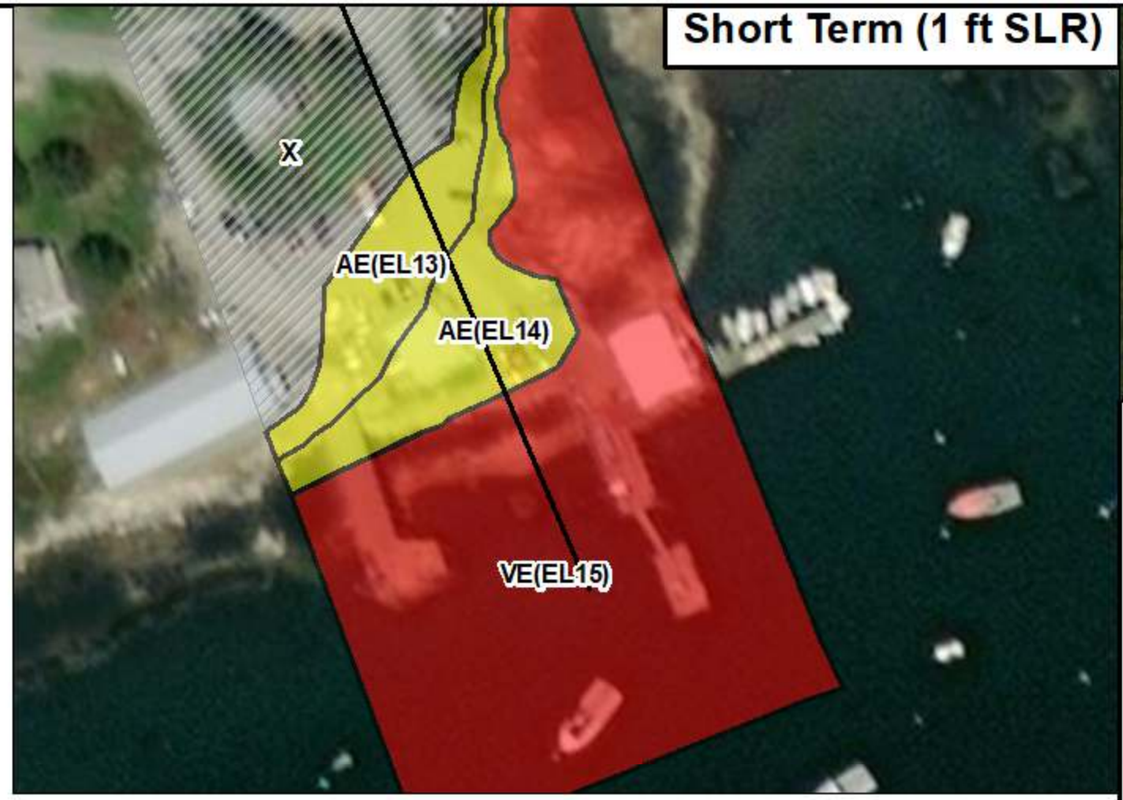
By: T. Day Date: 22OCT2019 Reviewed: K. Sun Date: 25OCT2019

Photograph No. 55:	**Comment:**
	**East side of property, facing northwest.**

Appendix B – Inundation Maps

Site: Stonington, ME



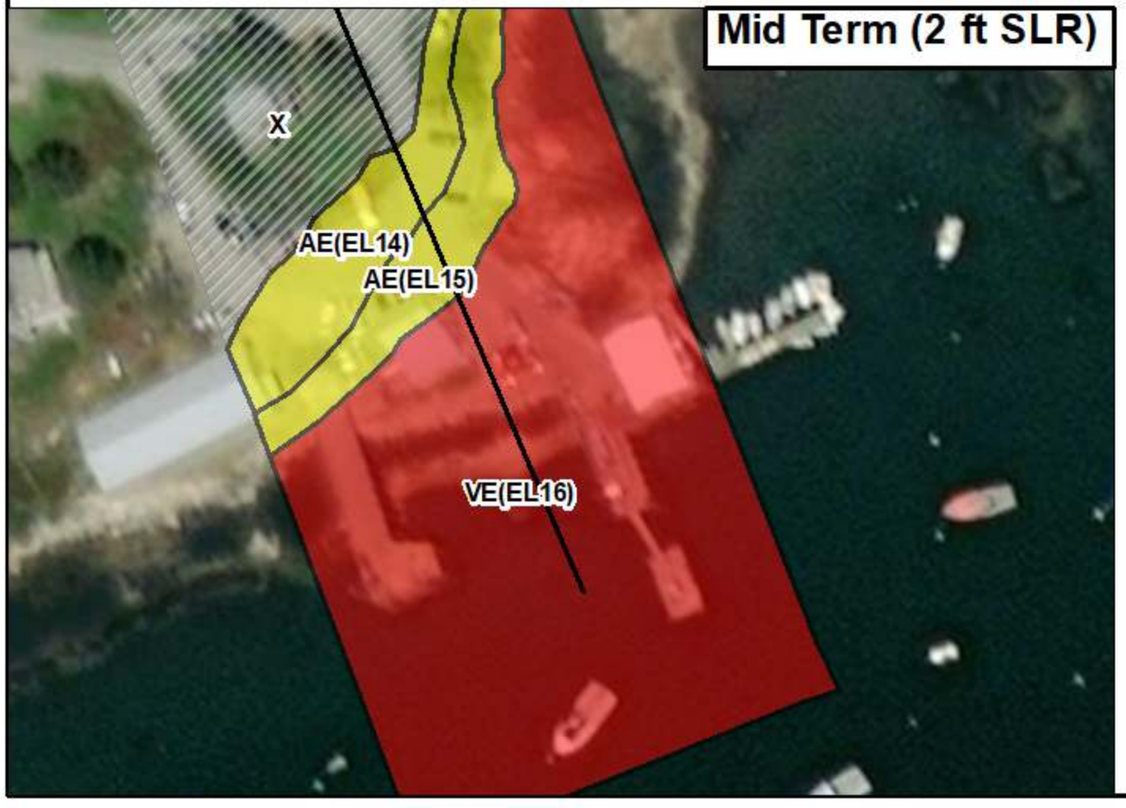


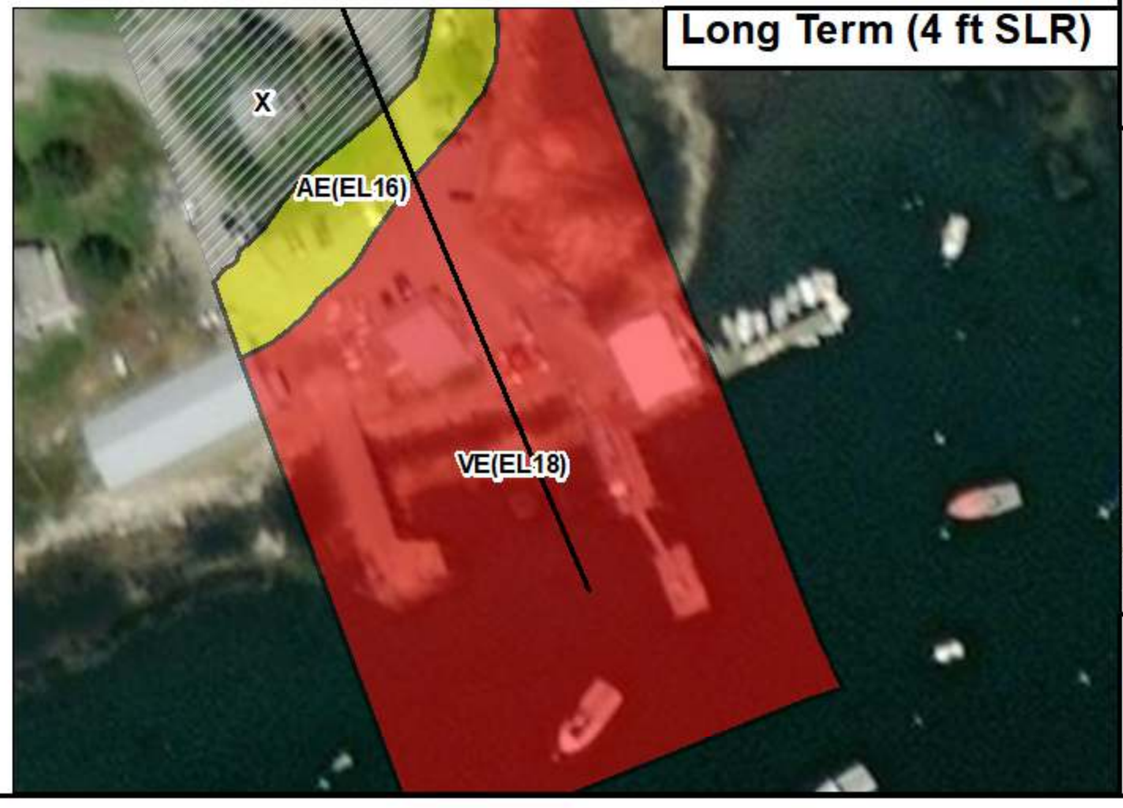
1. Maps indicate the 1%-annual-chance flood zones and base flood elevations.

2. This does not constitute a revision to the FEMA FIRM map which is done through FEMA's Letter of Map Revision process for which additional analysis and/or modeling may be required.

3. Flood mapping was developed for planning purposes only. No other use of this map should be made.

4. Elevations in reference to vertical datum NAVD88





Stonington Transects

AE

VE

X

N

Zone AE : Coastal flood zone. Base Flood Elevations determined.

Zone VE : Coastal flood zone with velocity hazard (wave action). Base Flood Elevations determined.

Zone X : Areas determined to be outside the 1% annual chance floodplain.

0 50 100 Feet

WOODS HOLE GROUP
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