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Subject: Vulnerability Assessment and Resilience Planning, Town Dock, Castine, 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 Town Dock, Castine, 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 Town Dock in Castine, 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. James Goodson, Town Manager, during a site visit on 26 June 2019. We discussed the site features and historical development of the site. Mr. Goodson mentioned that the primary use of the site is recreational boating. The site has approximately 120 moorings and given the increased activity in the summer, parking is often an issue. He also mentioned

that during a 2007 storm event some of the guide poles broke away from the pier. Rebuilding work was performed in 2015 for the cross bracing at the pier. During a more recent event in 2017, the water level inundated a portion of the parking lot up to the base of a light post (**Photograph 2**). Additionally, it is within the maintenance plan to replace the remaining older railing in later summer of 2019 to match other locations which incorporate stainless steel cable horizontals. During our site visit to Castine, Mr. Goodson was serving his final days as Town Manager. He advised that we should direct all future inquiries to Sean Blodgett, the new Town Manager.

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

- The site consists of the wharf, piers, parking area, and a boat ramp (See **Figure 1** below).
- A Harbor Master's Office is located at the north side of the pier.
- There were no other structures identified onsite specifically associated with the Harbor.
- One (1) wooden floating dock is located along the east side of the pier (see **Photograph 33, Appendix A**).
- There is no formal ongoing maintenance plan in place; maintenance is addressed, as needed, when a deficiency is identified.

No structural plans or as-built drawings were available for our review. A site survey drawing produced by Sage Collins Surveying, Inc., dated 26 August 2005, was provided by Mr. Goodson during our site visit. However, in general our assessment is based on details provided onsite by our contact and information gathered during our site visit.

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 26 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 wharf, pier, attached floating dock, parking, and a boat ramp. Photos of the site features 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 can be found in **Table 1** for reference. During our site visit the approximate tidal levels where observed between -4.1 ft and 4.5 ft (predicted min. of -4.5 ft, max. of 4.1 ft).

3.1 Property Overview

The site is a 0.31-acre property, identified as Acadia Wharf, consisting of a wharf, timber pier, floating dock, a parking area and boat ramp (**Photographs 1 – 4**). The wharf and pier are located at the east side of the property. The wharf is formed by sheet piling along the east and north perimeter (**Photographs 5 & 8 – 13**). Fill material for the wharf or subsurface conditions were not investigated during our site visit. The wharf also provides support for the pier framing at one end, whereby the remaining structure is supported by timber piles, pile caps and stringers (**Photographs 5 – 9 & 14 – 18**). Timber framing appears to be attached using a combination of galvanized steel through-bolts, nails, and/or screws. 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 dock is provided via a gangway and wooden ladder attached to the pier (**Photograph 15**). The pontoon is secured to the pier by means of mooring chains which are attached to the mooring piles at the exterior (east) face of the pier (**Photograph 35**). Wood observed the function of the gangway and floats during tidal action and the system appeared to function as intended. The boat ramp is adjacent to the wharf at the north side. Articulated concrete pavement (ACP) is used as the base for the ramp. The slope of the ramp appears to be within the ideal range for boat launching (**Photographs 36 – 39**).

Site utilities include power, water and a sewer pump-out system provided at select locations at the wharf and/or floating docks (**Photographs 6, 7, 25, 27, 29 & 32**). Electrical lines are, for the most part, encased in what appears to be polyvinyl chloride (PVC) piping; however, this encasement does not appear to be water tight. No electrical service was observed on the floating docks. Water is provided on the floating dock by means of a standard hose. The sewer pump-out service extends to the floating dock whereas the temporary storage is located at the pier deck elevation near the Harbor Master's Office (**Photograph 25**)

The Harbor Master's Office appears to be a wood framed structure with wood siding and asphalt shingle roof. Although this type of construction is typically supported by a shallow foundation, we were unable to confirm the subgrade support system. The structure appeared in decent condition based on our limited review and no notable deficiencies were observed at the time of our site visit.

An asphalt-paved parking lot encompasses most of the site and provides access to the wharf, pier and boat ramp. The parking area slopes down toward the harbor. The top coat (exposed surface) of pavement appeared to be in decent condition with normal cracking as typical for the age of the material. Slope of the parking area is variable depending on location with the greatest slope along the intersection with Main St.

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***
Facility	***[ft]***	***[ft]***	***[ft]***	***[ft]***
Wharf & Pier	6.56	8.24	n/a	n/a
Floating Dock (at max elevation)	n/a	9.52	n/a	8.95
Harbor Master's Office	n/a	8.93	9.43	9.43
Boat Ramp	n/a	-4	2	7
Parking	n/a	8.68	8.8	8.94

**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:

- Corrosion at the sheet pile which forms the wharf (**Photograph 8 & 9**).
- Electrical lines located at east face of pier, potentially exposed to wave action (**Photograph 15**).
- Some surface wear of wood decking at top of pier (**Photograph 23**).
- Some signs of subgrade settlement of the pavement (**Photograph 26**).
- Signs of corrosion at metal header attachment for floating dock gangway (**Photograph 31**).

The adjacent pier structure located at the wharf south of the site of interest exhibited conditions of concern. The following deficiencies were noted and considered out of scope, but nonetheless based on the proximity to the site and severity were included:

- Severe splitting and checks noted at timber pile cap for the adjacent pier structure (**Photograph 19 & 20**).

3.3 Risk Framework

As a basis for the vulnerability analysis, water surface elevation exposure profiles under various projected environmental conditions 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	4.9	7.2	9.6	10-12
Short Term (+1 ft)	5.9	8.2	10.6	11-13
Mid Term (+2 ft)	6.9	9.2	11.6	13-15
Long Term (+4 ft)	8.9	11.2	13.6	14-18

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.

[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

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 range of 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**.

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 provided in Table 4 where no inundation of the feature is anticipated (i.e., flood elevation is lower than that of the site feature).

Table 4: Site Elevations and Risks

Facility			*Inundation above Elevation of Facility*															
Description			*Present Day*				*Short Term Scenario*				*Mid Term Scenario*				*Long Term Scenario*			
			MHHW	*HAT*	*1% Stillwater*	*BFE*	*MHHW*	*HAT*	*1% Stillwater*	*BFE*	*MHHW*	*HAT*	*1% Stillwater*	*BFE*	*MHHW*	*HAT*	*1% Stillwater*	*BFE*
Elevation (ft) to NAVD88			*[ft]*	*[ft]*	*[ft]*	*[ft]*	*[ft]*	*[ft]*	*[ft]*	*[ft]*	*[ft]*	*[ft]*	*[ft]*	*[ft]*	*[ft]*	*[ft]*	*[ft]*	*[ft]*
Wharf & Pier	Lowest Horizontal	6.66 ft		0.54	2.94	5.3	0.24	1.54	3.94	6.34	0.24	2.54	4.94	7.34	2.24	4.54	6.94	9.34
	Top of Deck	8.24 ft			1.36	3.8			2.36	4.76		0.96	3.36	5.76	0.66	2.96	5.36	7.76
Floating Dock	Buoy Chain max elevation	9.52 ft			0.08	2.5			1.08	3.48			2.08	4.48		1.68	4.08	6.48
	Gangway support	8.95 ft			0.65	3.1			1.65	4.05		0.25	2.65	5.05		2.25	4.65	7.05
Harbor Master's Office	Adjacent Grade	8.93 ft			0.67	2.1			1.67	3.07		0.27	2.67	5.07		2.27	4.67	7.07
	First Floor Elevation	9.43 ft			0.17	1.6			1.17	2.57			2.17	4.57		1.77	4.17	6.57
	Lowest Opening	9.43 ft			0.17	1.6			1.17	2.57			2.17	4.57		1.77	4.17	6.57
Boat Ramp	Lower elevation	-4 ft	8.9	11.2	13.6	16	10.9	12.2	14.6	17	10.9	13.2	15.6	18	12.9	15.2	17.6	20
	Mid mark	2 ft	2.9	5.2	7.6	10	4.9	6.2	8.6	11	4.9	7.2	9.6	12	6.9	9.2	11.6	14
	Upper elevation	7 ft		0.2	2.6	5		1.2	3.6	6		2.2	4.6	7	1.9	4.2	6.6	9
Parking	Lower elevation	8.68 ft			0.92	2.3			1.92	4.32		0.52	2.92	5.32	0.22	2.52	4.92	7.32
	Mid mark	8.7 ft			0.9	2.3			1.9	3.3		0.5	2.9	5.3	0.2	2.5	4.9	7.3
	Upper elevation	8.94 ft			0.66	2.1			1.66	3.06		0.26	2.66	5.06		2.26	4.66	7.06

Note: Facility elevations presented in this Table are referenced to NAVD88.

Below are the site-specific vulnerabilities based on our review of the property.

3.4.1 Wharf and Pier

From our preliminary non-destructive investigation, most areas of the wharf appear to be of sound condition, securely fastened and restrained against movement. The behaviour of the wharf for the Present Day scenario, where the BFE and 1% Stillwater elevation are above the deck, is dependent on these elements being properly attached.

Site utilities at the wharf, which include water, sewer 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 wharf header from rising water level and functionality of the system for these levels. As is indicated in **Table 4** for the Present Day Scenario, minimal risk is foreseen for damage to the wharf from tidal action forces exerted from the gangway. However, the risk of damage from the BFE during events from Present Day to Mid Term scenarios are of concern. The potential for damage to this system for normal tidal action becomes more likely during the Long Term scenario during which the HAT is 2.25 feet above the current attachment elevation.

3.4.3 Harbor Master's Building

The Harbor Master's Building is located some yards beyond the face of the pier but based on the exposure we have assumed a conservative approach in reviewing the risks. For the Present Day scenario, this building is subject to an almost 2 ft wave height for the BFE and will experience surface level inundation of the office floor during the Present Day scenario for the 1% Stillwater. This condition increases to over 4 foot waves and 4 foot of inundation at the Long Term scenario.

Periodic flooding under the HAT is also forecasted as 1.77 feet during the Long Term scenario. Also, during the Long Term scenario, the structure is expected to lie within a Coastal High Hazard Area (CHHA, see definition above), having been designated in a Coastal A zone for all previous scenarios. Under this designation the structure is subject to high velocity wave action, or otherwise waves three (3) feet or more in height.

3.4.4 Boat Ramp

We expect the boat ramp to remain operational during the Present Day scenario. During the Short Term scenario, the MHHW levels increase to exceed elevations of the most preferred conditions of loading and unloading, going beyond 5 ft (NAVD88). Due to rising water levels the ramp may become too deep to access during times of higher tides. During these periods, the accessible areas are sloped below the minimum recommended values for boat ramps, creating undesirable conditions for loading and unloading. Conditions worsen for the Mid Term and Long Term scenarios, for the current construction.

3.4.5 Parking

Although our site contact reported recent events (2017) indicating a 1% Stillwater inundation of the parking lot, we anticipate normal use of this area will continue to be possible for the Present Day and Short Term scenarios. For the Mid Term and Long Term scenarios the frequency of inundation is expected to increase with the MHHW for the Long Term nearing the current 1% Stillwater elevation. As a reference, this is approximately at the base of the light post (**Photograph 2**) mentioned earlier.

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 Town Dock, 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 (See Photographs 19 & 20, Appendix A).** We do not anticipate the failure of this structure to directly affect the function of the subject property, however an in-depth analysis is required to estimate the extent and implications of this damage**.** The following are recommendations for the features identified at risk within the Town Dock, Castine.

4.2.1 Wharf and 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.

- 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 enclosures should be incorporated for electrical equipment and conduits.

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 rising water level such as re-enforcement and/or raising deck of pier and elevation of wharf at least above the MHHW elevation for the Long Term scenario.

While raising the wharf and associated docks may reduce the impact of rising sea levels and storm events, such construction is expensive, particularly considering the need to accommodate impacts to adjacent parking lots, roads and utilities, and a detailed costing analysis should be executed which considers these interrelated aspects. With regard to resisting anticipated design forces, it is likely more feasible to invest in proactive wharf maintenance, such as weatherizing vulnerable assets and properly securing structures (e.g., chains, anchors, tie-backs, etc.). With regard to rising water levels, the Town may find a detailed cost-benefit analysis to be a valuable tool for weighing the impact to local communities, businesses and industry against the costs for retrofit, adaptation or relocation of each impacted asset.

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:

- Given the wharf elevation is not scheduled to be raised, consider raising the gangway and gangway platform to accommodate the rising water level. This alternative will provide an elevated gangway platform above the deck elevation, and greater resilience during future extreme high tide and storm events. Although raising the wharf should be considered for subsequent scenarios, this option may be an economically-viable alternative.
- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed.

4.2.3 Harbor Master's Office

The following recommendation is provided in reference to the **Present Day and Short Term scenarios** with regard to the current building:

- Consider either flood proof construction at lower portion of building such as a minimum 5-foot stem wall, sealed openings, or relocation at or above Mid Term DFE. Confirm waterproof conduits and fixture/receptacles for electrical, water and sewer or other utilities/equipment to prevent intrusion and/or backflow.

The following recommendation is provided in reference to the **Mid and Long Term scenarios** with regard to the current building:

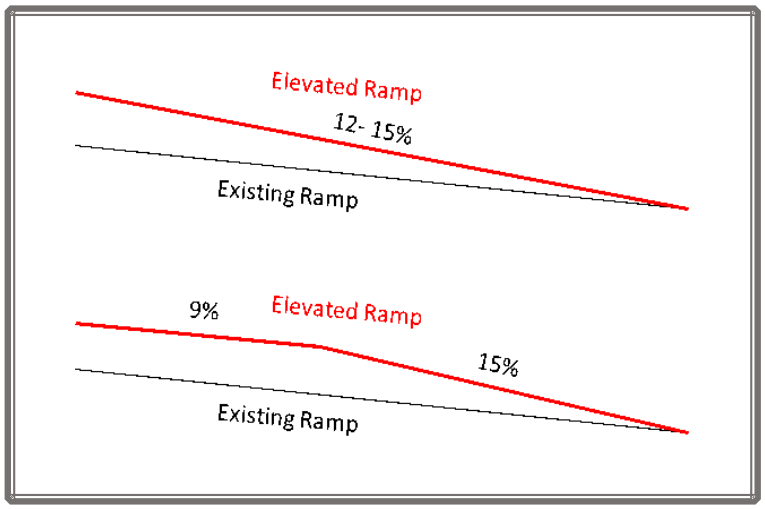
- Recommend raising or relocating the structure to accommodate the rising water level and wave heights.

4.2.4 Boat Ramp

The following recommendation is provided in reference to the **Short and Mid Term scenarios** with regard to existing boat ramp:

- Recommend raising the ramp commensurate with the rising tide and providing the recommended slope between 12% and 15%. Depending on available space, options which incorporate varying slopes may be necessary to transition from the parking lot to the shore (See **Figure 2** below).

Figure 2: Ramp Remediation Options



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

- In addition to the previously recommended re-grading effort, a more extensive cut and fill operation may be required to achieve optimum conditions and coincide with the adjacent slopes of the parking area, assuming this area has not already been raised.

4.2.5 Parking Area

Given that the parking lot and wharf structure are interconnected, an effort to remediate the parking area against sea level rise would be best coordinated with any greater wharf resiliency effort. Recommendations provided for the wharf 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 site upper elevation of 9 ft (NAVD88)

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 / Wharf	$175,000	$175,000	$175,000	$1,500,000
Floating Docks	$270,000	$270,000	$270,000	$375,000
Harbor Master's Office	$250,000	$250,000	$350,000	$350,000
Boat Ramp			$150,000	$365,000
TOTAL:	**$915,000**	**$915,000**	**$1,165,000**	**$2,665,000**

5.1 Present Day Scenario

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

Wharf and Pier:

- 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. Design and Construction **$150,000.**
- 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 enclosures should be incorporated for electrical equipment and conduits. **$10,000 - $25,000.**

Floating Docks:

- Moor float to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$100,000.**
- 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.**
- Confirm the gangway attachments ability to resist the design loading and repair or replace as needed. Design and Construction **$105,000.**

Harbor Master's Office:

- Incorporation of flood proof construction at lower portion of building or relocation. Design and Construction **$250,000.**

5.2 Short and Mid Term Scenarios

Items addressed for this section include any unaddressed items of the previous scenario (Present Day) and new risks related to the Short Term scenario. The following costs should be expected to accommodate events associated with the Short Term scenario:

Wharf and Pier:

- 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. Design and Construction **$150,000.**
- 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 enclosures should be incorporated for electrical equipment and conduits. **$10,000 - $25,000.**

Floating Docks:

- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$100,000.**
- 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.**
- Confirm the gangway attachments ability to resist the design loading and repair or replace as needed. Design and Construction **$105,000.**

Harbor Master's Office:

- Incorporation of flood proof construction at lower portion of building or relocation. Design and Construction **$250,000**

Boat Ramp:

- Local re-grading for optimum slope. Design and Construction **$150,000.**

5.3 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. Items which are not addressed in earlier time periods are included here when not addressed during the course of other referenced improvements.

Wharf and Pier:

- Raise wharf and pier to accommodate at least the Long Term scenario. Construction should include sustainable design based on 50 year plus design life. Design and Construction **$1,500,000.**

Floating Docks:

- Raise the gangway and gangway platform to accommodate the rising water level. Design and Construction **$275,000.**
- Moor all floats to independent mooring piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$100,000.**

Harbor Master's Office:

- Raise or relocate structure to at or above Long Term DFE. Design and Construction **$275,000 - $350,000.**

Boat Ramp:

- More extensive re-grading effort for optimum conditions. Design and Construction **$365,000.**

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.

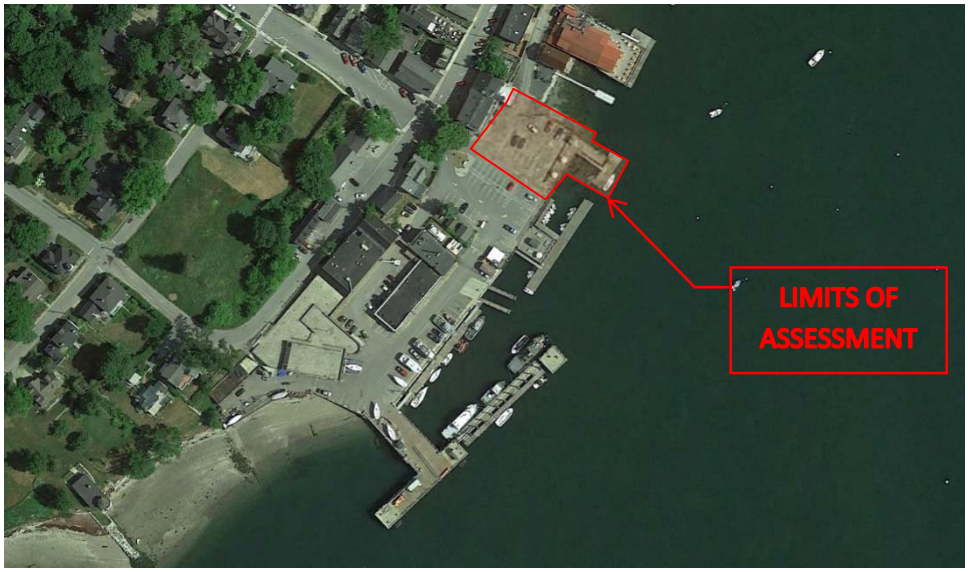
Tirrell Day, PE
Senior Structural Engineer

D. Todd Coffin
Associate Project Manager

Attachments: Appendix A - Photolog
Appendix B – Inundation Maps

Appendix A - Photolog for Town Dock
Castine, ME

By: T. Day *Date:* 07NOV2019 *Reviewed:* K. Sun *Date:* 08NOV2019

Photograph No. 1:  	**Comment:** **Overview of Site**
Photograph No. 2:  	**Comment:** **Overview of site from west side looking east.** **View of site parking, Harbor Master's office and wharf/pier.** **1. Light Post to which flooding was noted.**

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 3:

Comment:

View of site from east, looking west.

1. **View at limits of site and adjacent property (out of scope)**
2. **View of area drainage below wharf and pier. 1 of 2 drainage pipes at this location.**

Photograph No. 4:

Comment:

View of pier from south side looking north.

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 5:

Comments:

View of wharf and underside of pier from face of wharf, looking south.

1. **Draining pipes beyond.**

Photograph No. 6:

Comment:

View of underside of pier and condition of timber framing.

1. **Pump out (Sewer) piping**
2. **Power conduit.**

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

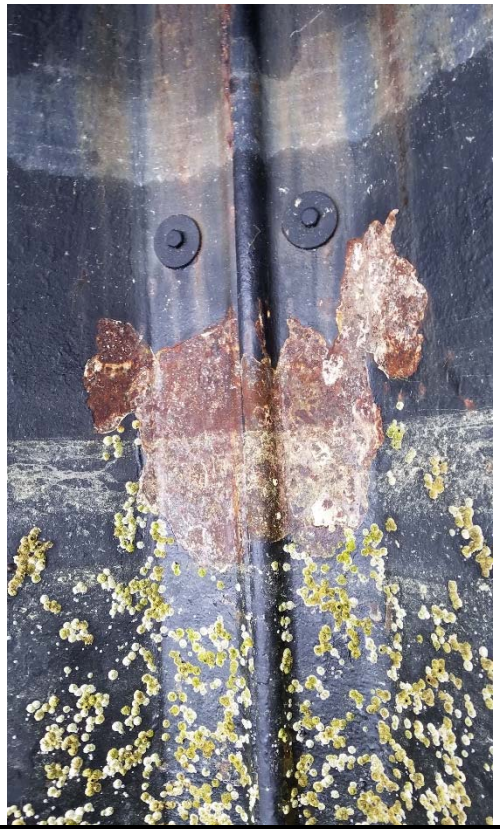
Photograph No. 7:

Comment:

Additional view of framing and sub-framing of pier beneath Harbor Master's office.

1. **Pump out (Sewer) piping**

Photograph No. 8:



Comment:

Typical view exhibiting condition of sheet pile wall at face of wharf.

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 9:

Comment:

Close-up at top of sheet pile wall showing header angle or channel.

Signs of apparent surface corrosion. Extent of corrosion must be determined by intrusion means.

Photograph No. 10:

Comment:

View of steel header for sheet pile wall at adjacent wharf as indicated in Photograph 18.

Example of probable extent of corrosion at top and side face of header as viewed on previous photograph.

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 11: 	**Comments:** **View of cathodic protection on sheet pile wall.**
Photograph No. 12: 	**Comment:** **View of Sheet piling joint between site adjacent property.** **View of area drainage.**

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

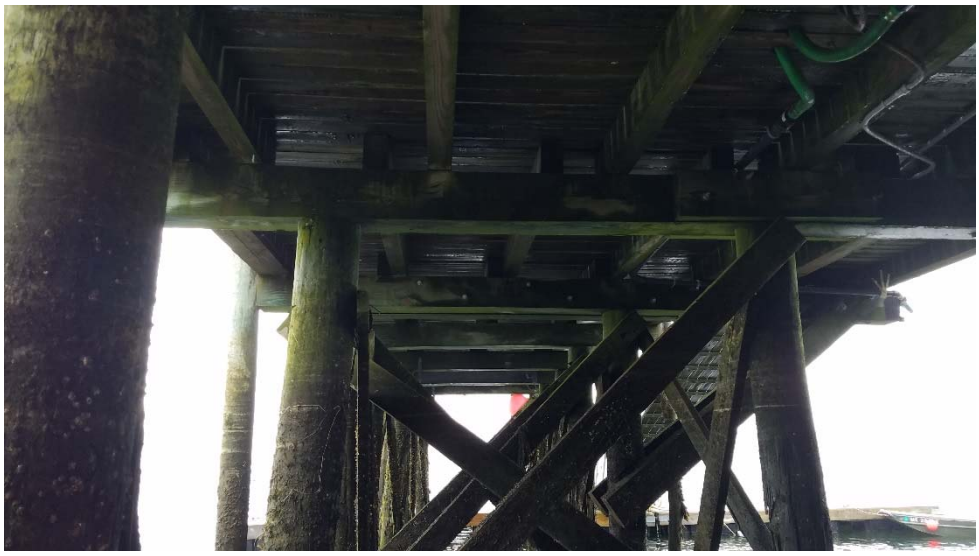
Photograph No. 13:

Comment:

View of both drainage pipes located under pier at sheet pile wall.

View of galvanic protection below larger pipe.

Photograph No. 14:



Comment:

View facing east at underside of pier. Stringers, cross beams, piles and cross bracing visible.

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 15:

Comment:

View facing west at pier.

1. **Electrical utilities noted at exterior of pier.**

Photograph No. 16:

Comment:

Closer view at underside of pier. Supplementary framing/retrofitting, presumably for hoist above, noted as galvanized steel.

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 17:

Comment:

Closer view of timber framing at underside of pier deck.

Photograph No. 18:

Comment:

East elevation of pier.

1. **Adjacent pier structure (out of scope).**
2. **Adjacent wharf (out of scope).**

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 19: 	**Comment:** **Severe splits and/or checks in the timber cross section.** **Condition noted in photo is located at adjacent pier structure south of site of interest (See previous photograph) and considered out of scope. However, due to the serious extent of deterioration we have noted here with regard to the potential for substantial damage during wave action of the Present Day scenario for the Base Flood Elevation. See data in Tables 2 & 3 and Appendix C of the report.**
Photograph No. 20: 	**Comment:** **Additional location of severe splits and/or checks in the timber cross section (adjacent site).** **We do not anticipate the failure of this structure to directly affect the function of the subject property, however an in-depth analysis is required to estimate the extent and implications of this damage.**

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 21:

Comment:

View at south end of site looking north.

View of deck at location of timber damage at adjacent pier identified in previous photograph.

Photograph No. 22:

Comment:

View looking east at location of timber damage identified in previous photograph.

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 23:

Comment:

Close-up of condition of deck timber.

Moderate deterioration with signs of weathering and minor delamination.

Photograph No. 24:

Comment:

View of south side of Harbor Master's Office.

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 25:

Comment:

View of east side of Harbor Master's Office.

1. **View of sewer Pump out at front of office.**

Photograph No. 26:

Comment:

View of parking area and entrance to boat ramp near office.

1. **Signs of subgrade settlement.**

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 27:

Comment:

Electrical equipment near office. Some equipment appears to be waterproof, however the cabinet construction should be verified.

Photograph No. 28:

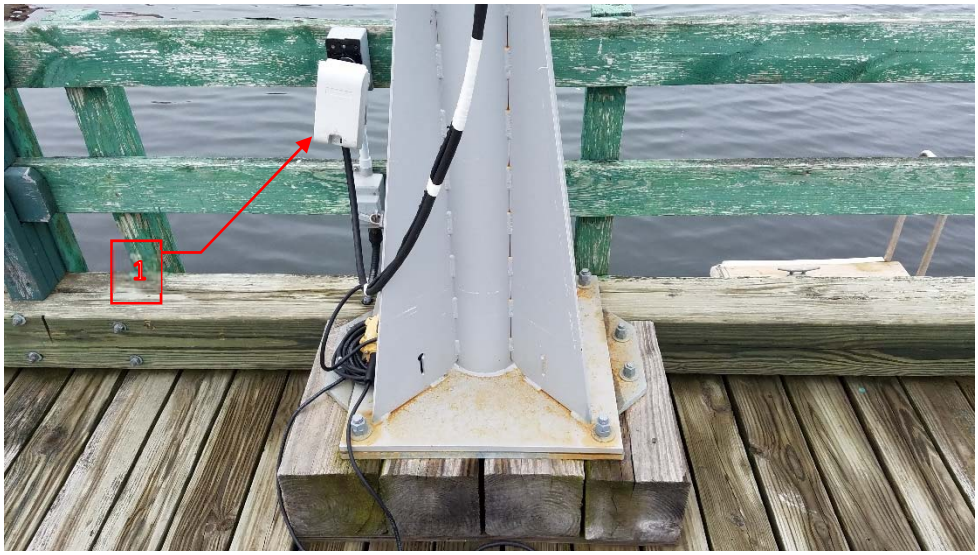
Comment:

View looking east of extended pier.

View of dock hoist.

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 29:



Comment:

Close-up of deck hoist attachment to deck.

1. **View of electrical fixture.**

Outlets should be raised above DFE and/or weatherized to prevent damage to system.

Photograph No. 30:

Comment:

View of floating dock gangway.

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

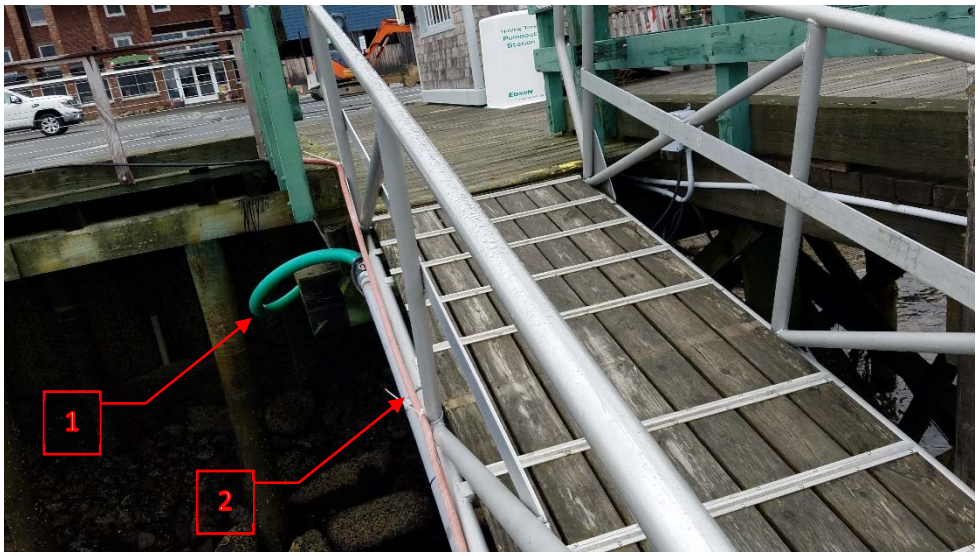
Photograph No. 31:

Comment:

View of gangway attachment to wharf via metal header.

Signs of corrosion noted at header and rod/pin steel.

Photograph No. 32:



Comment:

View of gangway attachment to wharf.

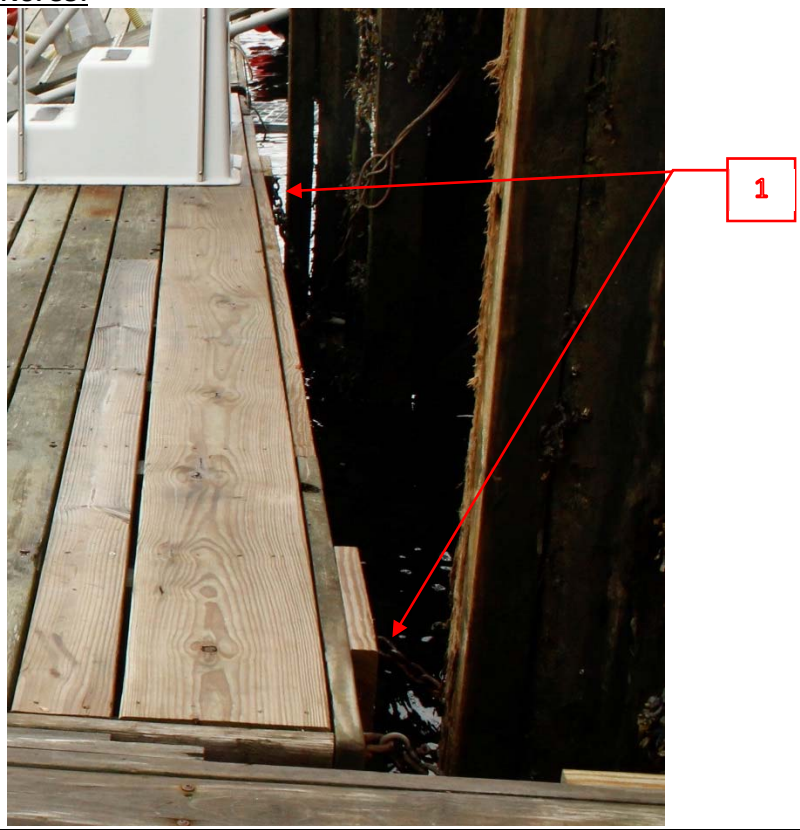
1. **View of sewer pump out and piping on gangway.**
2. **Water supply line for use on floating dock.**

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 33: 	**Comment:** **Overview of floating dock.**
Photograph No. 34: 	**Comment:** **Closer view of floating dock. Condition noted as decent. Pontoons appear to function as intended.**

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 35:



Comment:

View of floating dock near pier.

1. **Connection of floating dock to piles with mooring chains.**

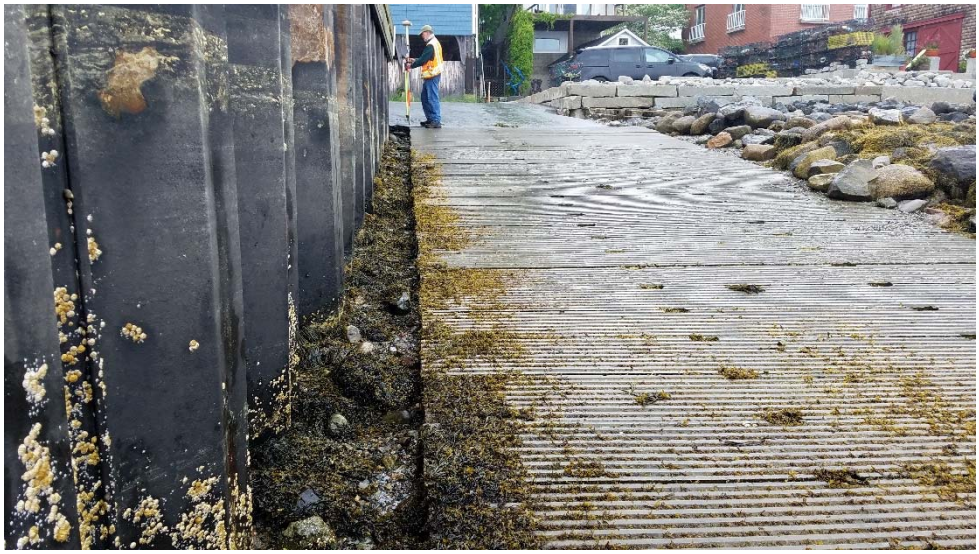
Photograph No. 36:

Comment:

Overview of Boat Ramp.

View of paved portion of ramp.

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

Photograph No. 37: 	**Comment:** **View of articulated concrete pavement (ACP) which supports the boat ramp. View looking west.**
Photograph No. 38: 	**Comment:** **View of ACP at current water elevation.**

By: T. Day Date: 07NOV2019 Reviewed: K. Sun Date: 08NOV2019

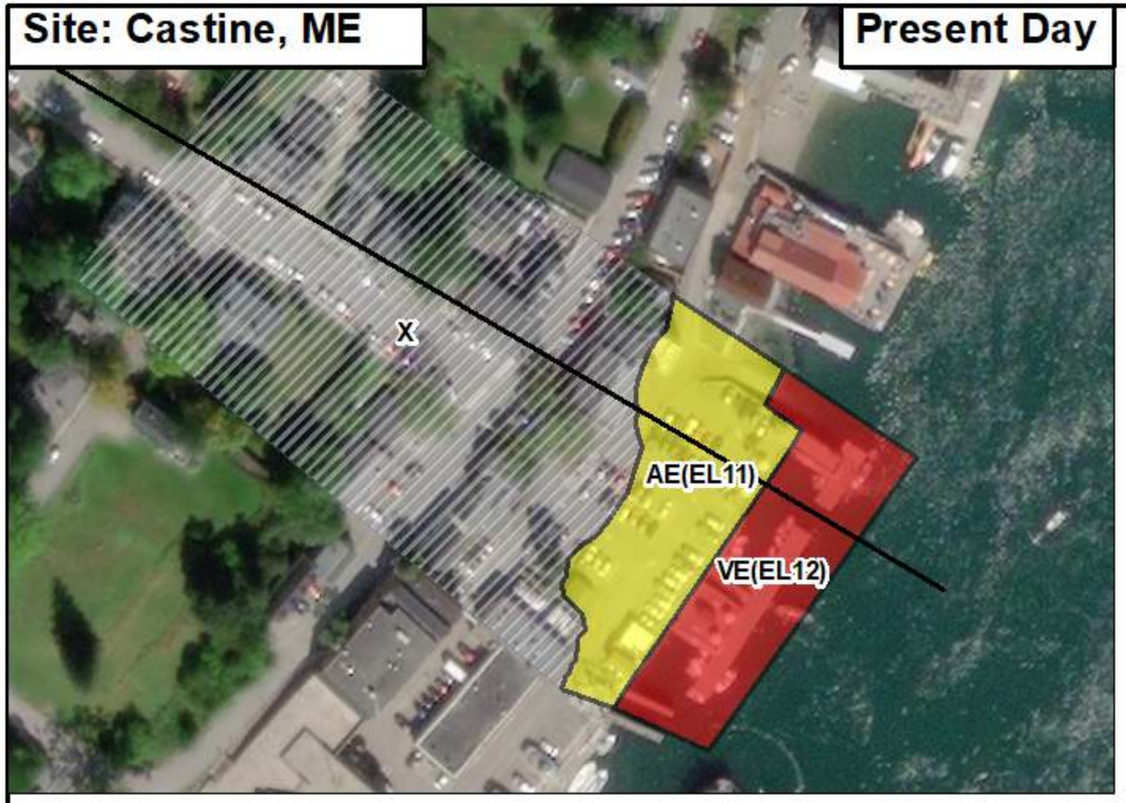
Photograph No. 39:

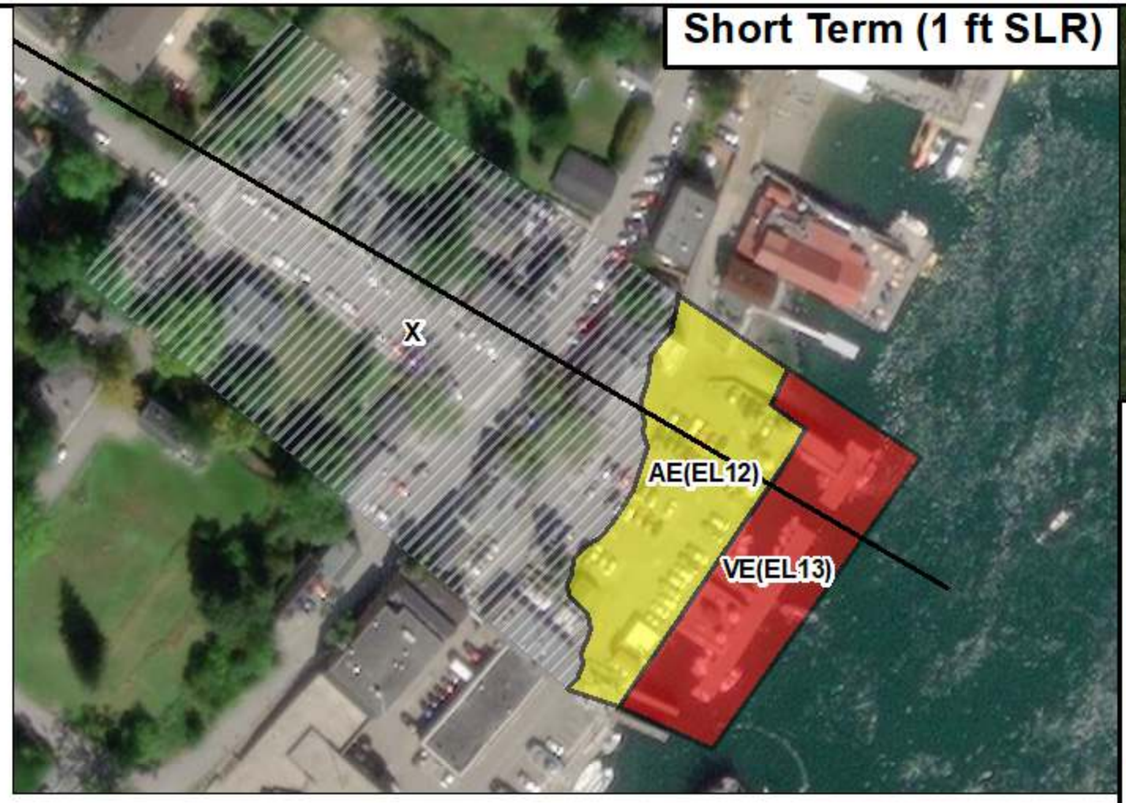
Comment:

Close-up of panel connection at boat ramp. Embedded steel with minor corrosion.

Appendix B – Inundation Maps

Site: Castine, ME



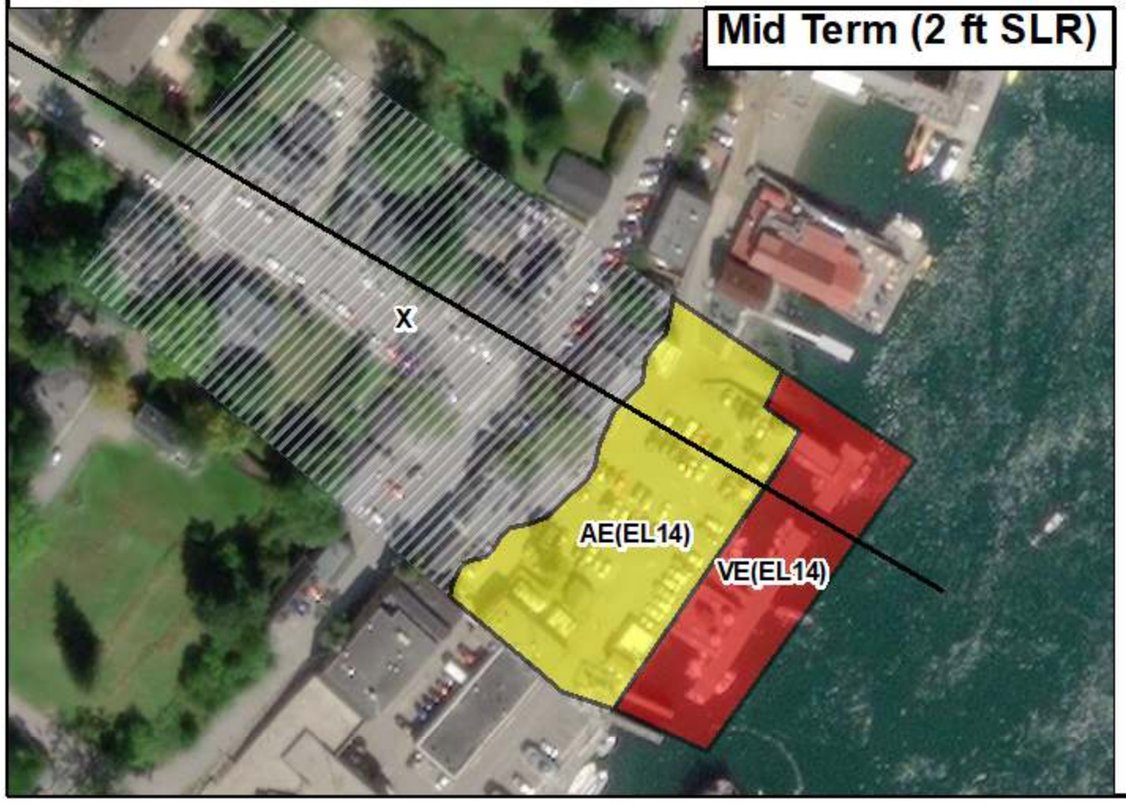


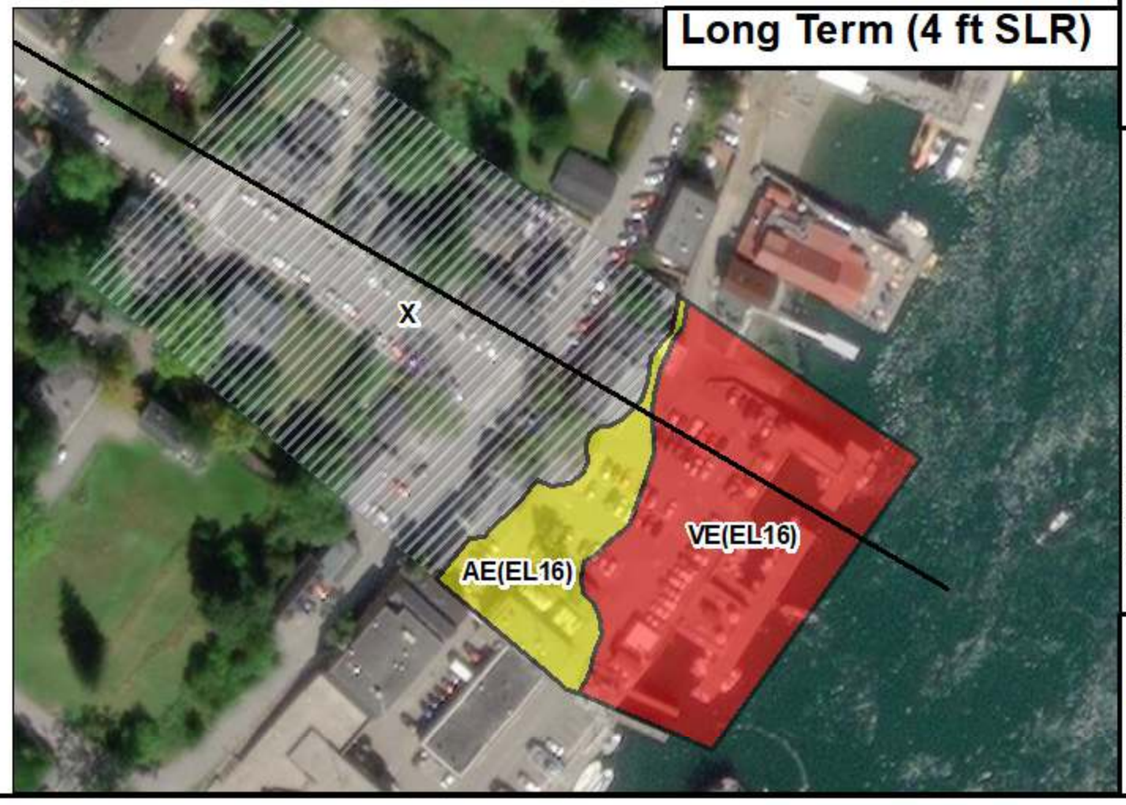
1. Maps indicate the 1%-annual-chance flood zones and base flood elevations.

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





Castine 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 75 150 Feet

WOODS HOLE GROUP
A CLS COMPANY