Wood Environment & Infrastructure Solutions, Inc.
511 Congress Street, Suite 200
Portland, ME 04101, USA
T: +1 (207) 775-5401
**www.woodplc.com**

20 December 2019

Project Number: 3611191238

Kathleen Leyden
Director, Maine Coastal Program
32 Blossom Lane
Augusta, ME. 04333-0021

**Subject: Vulnerability Assessment and Resilience Planning, Public Landing and Harbor Park, Camden, 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 Public Landing and Harbor Park in Camden, 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 Public Landing in Camden, 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 5**) 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. |

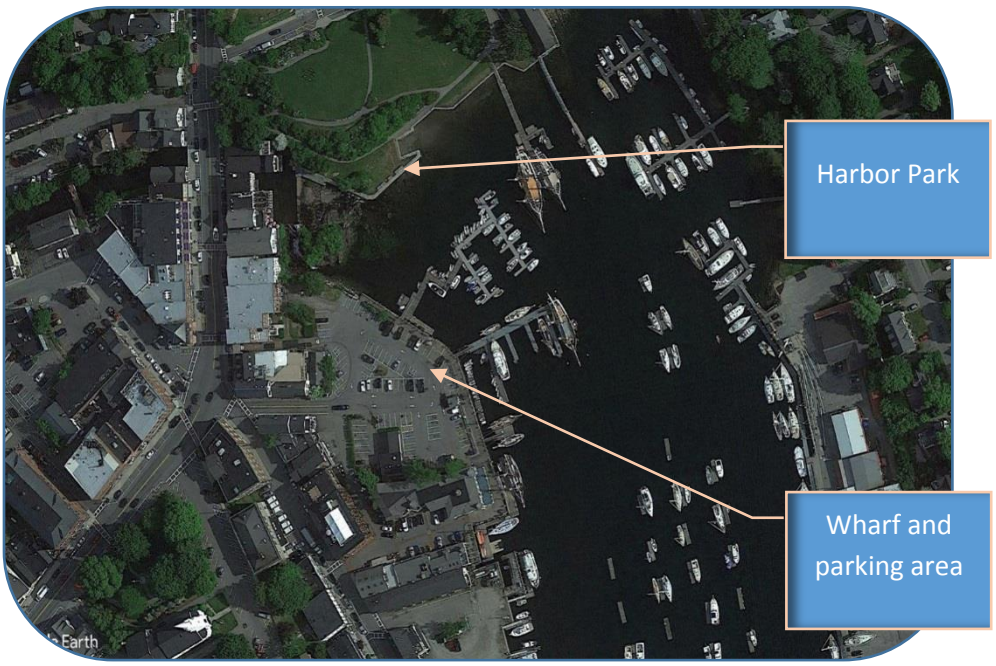
## 2.0 DOCUMENT REVIEW AND PERSONNEL INTERVIEWS

Wood was escorted by Mr. Jeremy Martin, Planning and Development Director, and Steve Pixley, the Harbor Master, during a site visit on 24 June 2019. We discussed the site features and historical development of the site. Harbor Master Pixley mentioned that the tide rises to just below the top of wharf elevation, at the waterfront, 2 to 3 times a year. Following such events, the Town of Camden (Town) must often replace certain electrical appurtenances due to system failures. Both gentlemen discussed previous plans to install a breakwater in the outer bay. This action would presumably allow for expanding the harbor within this protected area and allow space for additional moorings. Mr. Pixley also mentioned plans for dredging activities within the harbor. Their ultimate goal for these actions is to create more capacity for an already busy harbor. The following is a summary of key site features identified during the site visit:

- The site consists of the wharf, parking area, and a public park/greenspace (See **Figure 1** below).
- Structures located on site include an office (Harbor Master) and public restrooms.
- The wharf is constructed of quarried granite blocks, timber piles and timber framing.
- Four wooden floating dock systems are located on the east side of the wharf (see Photograph No. 16).
- There was some previous renovation work of the Harbor Park sea wall.
- 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.

**Figure 1: Site Overview**




## 3.0 OBSERVATIONS AND FINDINGS

Todd Coffin, Tirrell Day and Lane Gray of Wood performed a site assessment and gathered geospatial data for key site features during the 24 June 2019 visit. This assessment included documenting the general condition and recording elevations of key features and structures. At the request of the Town, two town-owned waterfront properties were evaluated and are referenced herein as Sites 1 and 2. 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 between -4.3 ft and 3.9 ft (predicted min. of -4.8 ft, max. of 4.2 ft).

### 3.1 Property Overview

Site 1

This site is a 1.4-acre property containing a waterfront wharf structure and a parking lot. The wharf is located at the east side of the site, bordering the harbor. The four floating docks are located on the east side of the wharf (**Photographs 16-32**). The floating dock gangways are typically attached to the wharf via the wooden header along the top edge (**Photograph 25**). The floats are secured by either isolated timber pile groups with mooring chains, or a timber pile and mooring chain assembly (**Photographs 21, 28, 31 & 32**). Wood observed the function of the gangway and floats during tidal action and the system appeared to function as intended.

The wharf appears to be constructed by a combination of stacked granite blocks, timber framing and backfill. Indications of a select backfill such as crushed stone bedding were noted at the underside of timber boardwalk (**Photograph 14**). The Subsurface conditions of the site were not probed or verified by testing as part of Wood's scope of work. Granite blocks are stacked to make up the exterior face of the wharf. The depth of the blocks could not be verified. Timber framing is applied at the surface which is seen at the boardwalk and timber header beam. Timber framing appears to be attached using a combination of through bolts, nails, or screws. Attachment of the timber to the granite was observed at some locations by means of a metal dowel. Decking is attached to framing via framing nails.

Shoreline protection exists to the north of the wharf and is provided by means of large riprap (**Photographs 6 & 35**). Site utilities include electrical and water, whereas only water is provided at the floating dock.

**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 | 7.445 | 8.07 | n/a | n/a |
| Floating Dock 1 | 6 | n/a | n/a | 8.69 |
| Floating Dock 2 | 6 | n/a | n/a | 8.38 |
| Floating Dock 3 | 6 | n/a | n/a | 7.77 |
| Floating Dock 4 | 6 | n/a | n/a | n/a |
| Shoreline Protection | n/a | 8 | n/a | 13 |
| Harbor Master Office | n/a | 7.71 | 8.21 | 11.21 |
| Public Restrooms | n/a | 9.68 | 10.18 | 13.18 |
| Parking Area | n/a | 7.71 | 11 | 15 |

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

Site structures include the Harbor Master's office and the public restrooms. The office appears to be a wood-framed structure on a thickened concrete slab with gable type roof (**Photograph 33**). The building has two (2) doors and windows of varying sizes and shapes. Exterior cover appears to be wood siding and asphalt shingle roofing. The top of grade elevation at the building is 7.7 feet with a finish floor elevation (FFE) approximately 6 inches above grade.

The public restrooms (**Photograph 34**) appears to be of similar construction as the harbor office and located further inland. The structure is built near the grade elevation at that location. The building has many openings of various sizes and shapes.

Site 2

At the request of the Town, the Harbor Park (Site 2) was added to the inundation/flood analysis conducted by WHG. The Harbor Park is a 1.9-acre site with a beach, walking paths and grass fields (**See Photographs 36 - 40, Appendix A)**. Site features observed by Wood include the sea walls and a floating dock (**Photograph 38**). The elevation of the site increases considerably from the shoreline to the adjacent road at the northern border of the property. Structural assessment or otherwise a vulnerability analysis of these site features is not a part of our scope for Site 2.

### 3.2 Noted Deficiencies

The wharf structure, particularly the stacked granite wall, exhibited no apparent signs of extreme translation or dislodgment for the members observed. Smaller stone material was noted between the surface and granite blocks, observable through the large openings between the blocks (**Photographs 6 – 9**). This material appears to be loosely placed and possibility for washout during an extreme event exists. Wooden members, which include bearing and fender piles, stringers, and decking exhibit signs of minor to moderate deterioration depending on their exposure and location in relation to the water. Some minor to moderate conditions of shakes, checks and splits were observed throughout. Some piles exhibited signs of infestations such as marine borers, weathering, or combination of both (**Photograph 10**).

### 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.

[1] https://www.maine.gov/dacf/mgs/hazards/highest_tide_line/index.shtml

**Table 2: Site 1**

| *Scenario* | *MHHW* | *HAT* | *1% Still Water Level* | *1% Wave Crest Elevation (BFE)* |
|---|---|---|---|---|
| Present day | 4.8 | 7.1 | 9.1 | 10-11 |
| Short Term (+1 ft) | 5.8 | 8.1 | 10.1 | 11-12 |
| Mid Term (+2 ft) | 6.8 | 9.1 | 11.1 | 12-14 |
| Long Term (+4 ft) | 8.8 | 11.1 | 13.1 | 15-16 |

**Table 3: Site 2**

| *Scenario* | MHHW | *HAT* | *1% Still Water Level* | *1% Wave Crest Elevation (BFE)* |
|---|---|---|---|---|
| Present day | 4.8 | 7.1 | 9.1 | 10-11 |
| Short Term (+1 ft) | 5.8 | 8.1 | 10.1 | 11-12 |
| Mid Term (+2 ft) | 6.8 | 9.1 | 11.1 | 13-14 |
| Long Term (+4 ft) | 8.8 | 11.1 | 13.1 | 15-16 |

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 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 and Table 3** include 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 4**.

**Table 4: 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 5**, 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 5 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.

[2] https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

## Table 5: 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 | Lowest Horizontal | 7.445 ft | | | 1.655 | 3.56 | | 0.65 | 2.655 | 4.56 | | 1.66 | 3.655 | 6.56 | 1.355 | 3.66 | 5.655 | 7.56 |
| | Lowest Deck or Adjacent Grade | 8.07 ft | | | 1.03 | 2.93 | | 0.03 | 2.03 | 3.93 | | 1.03 | 3.03 | 5.93 | 0.73 | 3.03 | 5.03 | 6.93 |
| Floating Dock 1 | Buoy Chain max elevation | 6 ft | | 1.1 | 3.1 | 5 | | 2.1 | 4.1 | 6 | 0.8 | 3.1 | 5.1 | 8 | 2.8 | 5.1 | 7.1 | 9 |
| | Gangway support | 8.69 ft | | | 0.41 | 2.31 | | | 1.41 | 3.31 | | 0.41 | 2.41 | 5.31 | 0.11 | 2.41 | 4.41 | 6.31 |
| Floating Dock 2 | Buoy Chain max elevation | 6 ft | | 1.1 | 3.1 | 5 | | 2.1 | 4.1 | 6 | 0.8 | 3.1 | 5.1 | 8 | 2.8 | 5.1 | 7.1 | 9 |
| | Gangway support | 8.38 ft | | | 0.72 | 2.62 | | | 1.72 | 3.62 | | 0.72 | 2.72 | 5.62 | 0.42 | 2.72 | 4.72 | 6.62 |
| Floating Dock 3 | Buoy Chain max elevation | 6 ft | | 1.1 | 3.1 | 5 | | 2.1 | 4.1 | 6 | 0.8 | 3.1 | 5.1 | 8 | 2.8 | 5.1 | 7.1 | 9 |
| | Gangway support | 7.77 ft | | | 1.33 | 3.23 | | 0.33 | 2.33 | 4.23 | | 1.33 | 3.33 | 6.23 | 1.03 | 3.33 | 5.33 | 7.23 |
| Floating Dock 4 | Buoy Chain max elevation | 6 ft | | 1.1 | 5 | | | 2.1 | 4.1 | 6 | 0.8 | 3.1 | 5.1 | 8 | 2.8 | 5.1 | | |
| Shoreline Protection | Top of riprap | 8 ft | | | 1.1 | 3 | | 0.1 | 2.1 | 4 | | 1.1 | 3.1 | 6 | 0.8 | 3.1 | 5.1 | 7 |
| | Critial Elevation | 13 ft | | | | | | | | | | | | 1 | | | 0.1 | 2 |
| Harbor Master Office | Adjacent Grade | 7.71 ft | | | 1.39 | 2.29 | | 0.39 | 2.39 | 3.29 | | 1.39 | 3.39 | 6.29 | 1.09 | 3.39 | 5.39 | 7.29 |
| | First Finished Floor | 8.21 ft | | | 0.89 | 1.79 | | | 1.89 | 2.79 | | 0.89 | 2.89 | 5.79 | 0.59 | 2.89 | 4.89 | 6.79 |
| | Lowest Opening | 8.21 ft | | | 0.89 | 1.79 | | | 1.89 | 2.79 | | 0.89 | 2.89 | 5.79 | 0.59 | 2.89 | 4.89 | 6.79 |
| Public Restrooms | Adjacent Grade | 9.68 ft | | | | 0.32 | | | 0.42 | 1.32 | | | 1.42 | 3.32 | | 1.42 | 3.42 | 5.32 |
| | First Finished Floor | 10.18 ft | | | | | | | | 0.82 | | | 0.92 | 2.82 | | 0.92 | 2.92 | 4.82 |
| | Lowest Opening | 10.18 ft | | | | | | | | 0.82 | | | 0.92 | 2.82 | | 0.92 | 2.92 | 4.82 |
| Parking Area | Boardwalk | 7.71 ft | | | 1.39 | 2.29 | | 0.39 | 2.39 | 3.29 | | 1.39 | 3.39 | 5.29 | 1.09 | 3.39 | 5.39 | 7.29 |
| | Mid Mark | 11 ft | | | | | | | | 0 | | | 0.1 | 2 | | 0.1 | 2.1 | 4 |
| | Commercial St | 15 ft | | | | | | | | | | | | | | | | 0 |
| Harbor Park | Front/Wall | 0.23 ft | 4.57 | 6.87 | 8.87 | 9.77 | 5.57 | 7.87 | 9.87 | 10.8 | 6.57 | 8.87 | 10.87 | 12.8 | 8.57 | 10.9 | 12.87 | 14.8 |
| | Granite Seawall | 6.43 ft | | 0.67 | 2.67 | 3.57 | | 1.67 | 3.67 | 4.57 | 0.37 | 2.67 | 4.67 | 6.57 | 2.37 | 4.67 | 6.67 | 8.57 |
| | Walkway | 10 ft | | | | 0 | | | 0.1 | 1 | | | 1.1 | 3 | | 1.1 | 3.1 | 5 |

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

### 3.4.1 Pier and Wharf

Based on the present-day model for BFE of 10 to 11 feet, which includes a wave height of 1 to 2 feet, the wharf and boardwalk decking could be potentially impacted by nearly high velocity wave action. In the case that any elements such as the stringers, decking, etc., are not positively attached to associated load carrying members, dislodgement or delamination of material at the top of deck can be expected. Otherwise, we would not expect significant impact to the wharf. We were unable to view and assess locations behind the face of the wharf or subsurface conditions beyond observations noted beneath the boardwalk. The wharf can be expected to experience some loss of the smaller diameter crushed rock at the sub-base and gravels between the top of the granite blocks and bottom of the boardwalk from washout. Similar behaviour of the wharf can be expected for future flood scenarios and the possibility of impact is more likely as the return period for conditions representing the present day BFE decreases.

Site utilities which include water and electricity (**Photographs 12 & 13**) are exposed to wave action and inundation at the wharf and the floating dock. In addition, apparent electrical wiring is hanging at the underside of the framing at the adjacent property (**Photograph 15**). Although this is beyond the boundary of the site, the wiring appears to continue below grade on Town-owned property.

### 3.4.2 Floating Docks

The floating dock assembly consists of the gangway, float piles, and mooring mechanism when applicable. The critical elevation for typical use of the floating docks is the MHHW for these scenarios. As is indicated in **Table 5** for the Present Day Scenario, we can expect seasonal high water levels from the HAT resulting in possible strain on the timber header at the wharf. For the Mid Term scenario, the MHHW increases the frequency for which the dock exerts forces on the wharf which may ultimately lead to damage. However, the risk of damage due to the BFE during all events from starting with the Present Day scenario are of concern. Damage to the structures and their attachment can be expected if not properly designed and secured.

### 3.4.3 Site Structures

Site 1

The two structures observed at the site are the Harbor Master's office and the public restrooms. The estimated top of slab elevation at the office is elevation 8.21 feet. The BFE at this location as shown in **Table 2** for the Present Day scenario is 11 feet; Given the building's close proximity to the shore, we would expect some critical wave impact. For a 1% Stillwater elevation just slightly over the FFE for the building, flooding will be minimal. For the Short and Mid Term Scenario, flooding becomes a notable factor and is likely to impact the integrity of the structure based on the construction type as wood framed. The BFE for this period will be well over typical window height for this type of structure, with the expectation of considerable damage to the exterior and interior of the building, to include finishes and structural members.

The public restrooms are positioned more inland and flood modelling results reveal minimal impact until the Mid and Long Term scenarios. At this point, above-ground architectural and structural elements will likely be impacted, during which coatings, coverings and their fastenings may yield or fail from inundation during the design Stillwater.

Site 2

No assessment of structures is included for this site however we have included some details regarding the impact of the various scenarios for comparison purposes (**Table 5**), identified as Harbor Park. It should be noted that for each modelled flood scenario, the seawall is overtopped by waves.

### 3.4.4 Shoreline Protection

Shoreline protection is provided by a revetment located north of the wharf with a top elevation of roughly 8 ft. Large diameter (roughly 1.5 to 4 ft) riprap is provided at this location of the site extending from below the low tide level to the top of grade (**Photographs 3, 6 & 35**). The estimated slope is a maximum of 2.5 to 1, horizontal to vertical, and gradation appears to be suitable based on condition of slope. No signs of material degradation or slope instability or piping were noted. Based on the modelled wave height and flood elevations, we expect minimal impact for material of this size.

## 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, piers, 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.
- Erosion control structures shall not be attached to the building or its foundation
- 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 Public Landing, Camden, there may be features of similar construction in close proximity and exposed to similar risks as described in this report but fall outside the property limits. **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 Public Landing, Camden.

#### 4.2.1 Wharf

The following recommendations are provided in reference to the **Present Day** scenario for flood values provided in **Table 2** above:

- Confirm positive attachment of all structural members to their substrate or load-bearing elements.
- Utilities 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 electrical fixtures should be incorporated.

- Measures should be taken for the smaller size gravel stone between the top of the granite blocks and bottom of the boardwalk (shown in **Photograph No. 14**) to prevent washout due to wave attack.

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

- Evaluate reconstruction of the wharf to accommodate SLR and increased risk of damage due to more frequent events. Incorporation of a breakwater, which provides protection for the coastline, is also a consideration. Modelling of the scenario which incorporates an elevated breakwater may be valuable in providing comparative values for a repair/replacement feasibility study. All designs should be performed in accordance with International Building Code with State of Maine amendments and ASCE 24.

### 4.2.2 Floating Dock

The following recommendation is provided in reference to the **Present Day and all future scenarios** with regard to construction of the floating dock assembly:

- Design and install separate mooring piles for the floats to avoid attachment to the pier. Piles and gangways should be installed to accommodate a BFE of at least the Mid Term condition with the addition of any required freeboard.

### 4.2.3 Site Structures

The basis of our recommendation for buildings or other structures is the inland location of the structure and behaviour of the event at that location. For structures located in close proximity to the shoreline, wave impact from the BFE is a concern and the possibility of immediate damage more likely. For inland structures where wave action has subsided, concerns of static flooding are more prevalent. For these cases, we are concerned about long-term inundation, such as for the MHHW/HAT at the first finish floor elevation, where the usefulness of the structure is compromised.

<u>Harbor Master's Office</u>

The following recommendations are provided in reference to the **Present Day and all future scenarios** with regard to the structure:

- Consider either **1)** relocation of the Harbor Master's office further inland near elevation 15 ft (e.g., near Commercial Street), **2)** raising the structure above the Mid Term 1% Stillwater and providing local wave protection in the form of a seawall, or **3)** construction of the building with a more robust material with sealed openings against moisture intrusion. A combination of these items is also an option based on the particular situation and cost benefits.
- Confirm that all building utilities are placed above the flood elevation and/or sealed from inflow of flood water.

<u>Public Restrooms</u>

The following recommendations are provided in reference to the **Mid Term and Long Term** scenarios with regard to the structure:

- We recommend either 1) raising the structure above the 1% Stillwater elevation of 11.1 ft (approx. 2 ft) or 2) incorporating moisture resistant material at the base of the structure (4 ft stem wall) to accommodate a 1% Still water elevation for the Long Term scenario. Alternatively, the structure can be relocated further inland near elevation 15 ft.
- Confirm that all building utilities are placed above the flood elevation and/or sealed from inflow of flood water.

In general, existing structures and their foundations should be assessed for the applicable design loading and for the various flood scenarios. All substantial improvements and new construction should be designed with consideration of provisions

provided within ASCE 24 and the FEMA Flood Design Manual. Repairs, retrofits, or improvements should be per the local Building Code and performed under recommendation and guidance of a Professional Engineer Registered in the State of Maine.

#### 4.2.4 Shoreline Protection

Based on our field observations and analysis of data for all scenarios provided in **Table 2** above, we are of the opinion that minimal damage should be expected or otherwise no catastrophic failure of the revetment is anticipated. Preliminary calculations, given certain assumptions, indicate the current riprap size can be expected to perform sufficiently for these events.

## 5.0 OPINION OF PROBABLE CONSTRUCTION COSTS

The costing information provided below corresponds with our recommendations for remedial action of the corresponding events as outlined in **Table 2 and 3** of this report. These estimated costs include the associated design and engineering services where applicable. In **Table 6** is a summary of the estimated cost for repair or replacement of the identified vulnerabilities. A cost savings may also be expected for combined efforts for 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 6: Repair / Replacement / Retrofitting Costs**

| ***Facility*** | ***Present Day*** | ***Short Term*** | ***Mid Term*** | ***Long Term*** |
|---|---|---|---|---|
| Pier / Wharf | $365,500 | $365,500 | $2,850,000 | $2,850,000 |
| Floating Docks | $1,800,000 | $1,800,000 | $1,800,000 | $1,800,000 |
| Harbor Master Office* | $500,000 | $500,000 | $500,000 | $500,000 |
| Public Restroom | | | $750,000 | $750,000 |
| **TOTAL:** | **$2,665,500** | **$2,665,500** | **$5,900,000** | **$5,900,000** |

### 5.1 Present Day Scenario

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

**Wharf:**

- Relocate/Secure utilities against impact and moisture infiltration. Replace current electrical cabinet with stainless steel watertight cabinet. Design and Construction **$350,000.**
- Confirm positive attachment of all structural members to their substrate or load-bearing elements. Secure bedding material for boardwalk to prevent washout. Design and Construction **$15,500.**

**Floating Docks:**

- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$1,800,000.**

**Site Structures:**

Harbor Master's Office (Storm Surge Mitigation)

- Either 1) relocation of the structure further inland, 2) raising the structure above the Mid Term 1% Stillwater and providing local wave protection in the form of a seawall, or 3) construction of the building with a more robust material with sealed openings against moisture intrusion. Design and Construction **$250,000 - $500,000**.

### 5.2 Short Term Scenario

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:**

- Relocate/Secure utilities against impact and moisture infiltration. Replace current electrical cabinet with stainless steel watertight cabinet. Design and Construction **$350,000.**
- Confirm positive attachment of all structural members to their substrate or load-bearing elements. Secure bedding material for boardwalk to prevent washout. Design and Construction **$15,500.**

**Floating Docks:**

- Moor all floats to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$1,800,000.**

**Site Structures:**

Harbor Master's Office (Storm Surge Mitigation)

- Either 1) relocation of the structure further inland, 2) raising the structure above the Mid Term 1% Stillwater and providing local wave protection in the form of a seawall, or 3) construction of the building with a more robust material with sealed openings against moisture intrusion. Design and Construction **$250,000 - $500,000**.

### 5.3 Mid Term Scenario

**Wharf:**

This section exhibits costs which are expected due to the need for substantial improvements in response to inundation during the HAT:

- Reconstruction of the wharf using construction as the existing to accommodate SLR and increased risk of damage due to more frequent events. Design and Construction **$2,500,000.**
- Relocate/Secure utilities against impact and moisture infiltration. Replace current electrical cabinet with stainless steel watertight cabinet. Design and Construction **$350,000.**

**Floating Dock:**

- Moore the float to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$1,800,000.**

**Site Structures:**

Harbor Master's Office (Storm Surge Mitigation)

- Either 1) relocation of the structure further inland, 2) raising the structure above the Mid Term 1% Stillwater and providing local wave protection in the form of a seawall, or 3) construction of the building with a more robust material with sealed openings against moisture intrusion. Design and Construction **$250,000 - $500,000**.

Public Restrooms

- Either 1) raise the structure above the 1% Stillwater elevation with applicable freeboard, 2) incorporating moisture resistant material at the base of the structure to accommodate a 1% Still water elevation, 3) relocate the structure further inland. Design and Construction **$250,000-$750,000.**

### 5.4 Long Term Scenario

This section includes costs which are expected due to the need for substantial improvements, however some of these actions are recommended as early as the Mid Term scenario. Items which are not addressed in earlier time periods are included here when not addressed during the course of other referenced improvements.

**Wharf:**

This section exhibits costs which are expected due to the need for substantial improvements in response to inundation during the HAT:

- Reconstruction of the wharf using construction as the existing to accommodate SLR and increased risk of damage due to more frequent events. Design and Construction **$2,500,000**

- Relocate/Secure utilities against impact and moisture infiltration. Replace current electrical cabinet with stainless steel watertight cabinet. Design and Construction **$350,000.**

**Floating Dock:**

- Moore the float to independent float piles or using mooring chains/ropes anchored to the seabed. Design and Construction **$1,800,000.**

**Site Structures:**

Harbor Master's Office (Storm Surge Mitigation)

- Either 1) relocation of the structure further inland, 2) raising the structure above the Mid Term 1% Stillwater and providing local wave protection in the form of a seawall, or 3) reconstruction of the building at its current location with a more robust material with sealed openings against moisture intrusion. Design and Construction **$250,000 - $500,000**.

Public Restrooms

- Either 1) raise the structure above the 1% Stillwater elevation with applicable freeboard, 2) incorporating moisture resistant material at the base of the structure to accommodate a 1% Still water elevation, 3) relocate the structure further inland. Design and Construction **$250,000-$750,000.**

## 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 all aspects of the work and site conditions, based on information made available to us at this stage of the project. Costs

will be modified during subsequent stages of project execution, as the level of project definition increases. 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 Public Landing
# Camden, ME

*By:* T. Day *Date:* 04OCT2019 *Reviewed:* K. Sun *Date:* 07OCT2019

| | |
|---|---|
| **Photograph No. 1:**<br>  <br> | **Comment:**<br><br>**Overview of Sites** |
| **Photograph No. 2:**<br>  | **Comment:**<br><br>**View of Public Landing, Camden looking west.** |

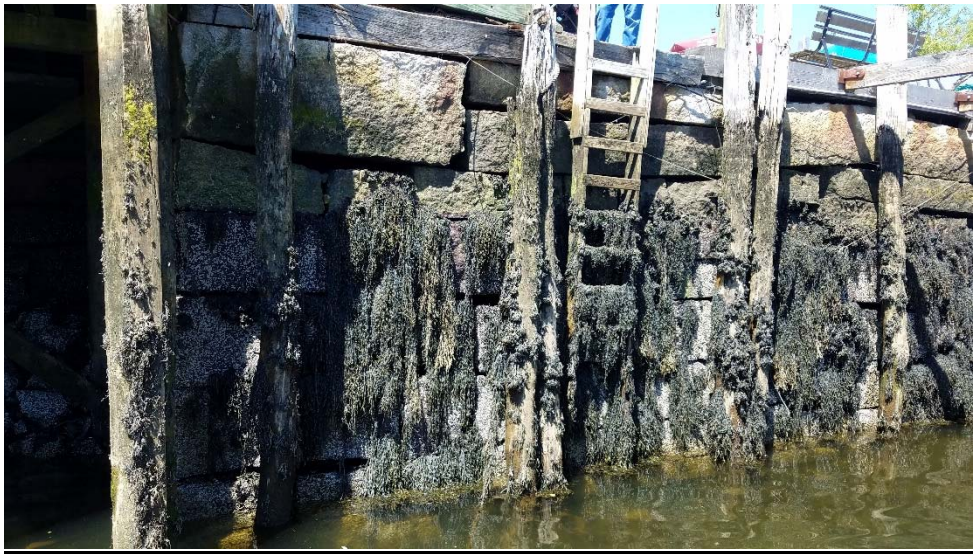
*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

| | |
|---|---|
| **Photograph No. 3:**<br>  | **Comment:**<br><br>**View of Megunticook River outfall and shoreline north of site.** |
| **Photograph No. 4:**<br>  | **Comment:**<br><br>**View of Camden Harbor Park looking north.** |

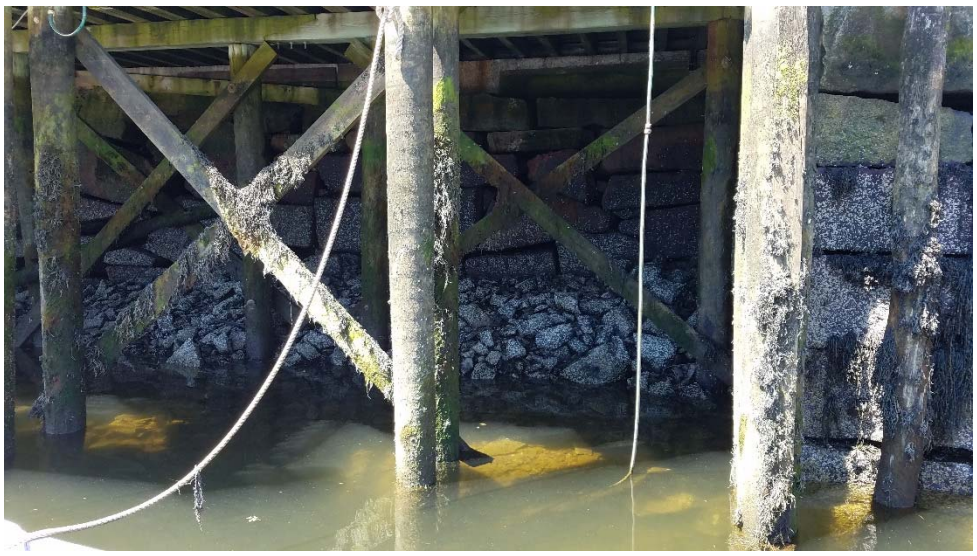
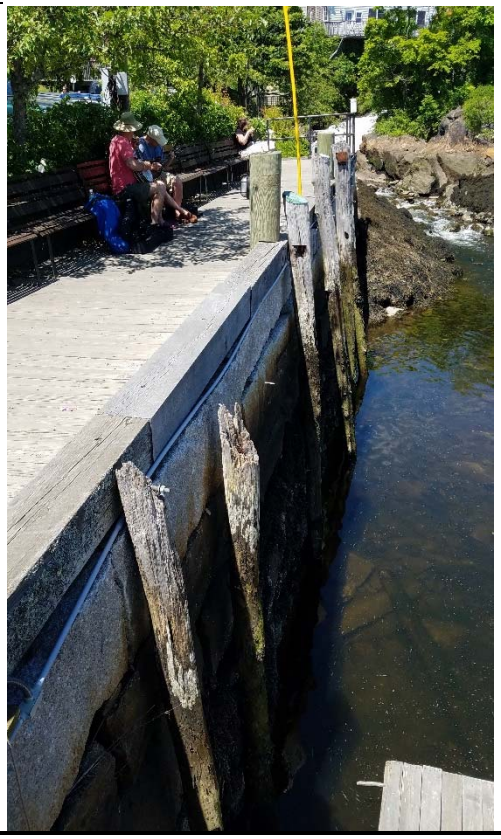
*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

| | |
|---|---|
| **Photograph No. 5:**<br>  | **Comment:**<br><br>**View of typical construction of wharf (Looking south).**<br><br>**Stacked granite at exterior face of wharf for the Public Landing.** |
| **Photograph No. 6:**<br>  | **Comment:**<br><br>**View looking north of the wharf and transition to the river outfall.** |

*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

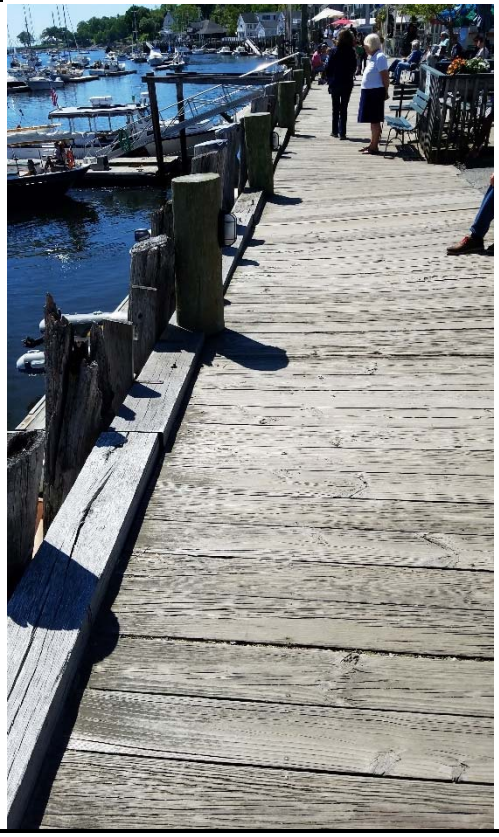
| | |
|---|---|
| **Photograph No. 7:**<br>  | **Comment:**<br><br>**Closer view at face of stacked granite.**<br><br>**Stacked blocks appear to be mostly intact. Minor signs of delamination or deflection.**<br><br>**No signs of failure noted at location of harbor.** |
| **Photograph No. 8:**<br>  | **Comment:**<br><br>**Closer view at face of stacked granite, similar to Photograph No. 7. No obvious signs of delamination or deflection noted.**<br><br>**Cables noted at face of wall.** |

*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

| | |
|---|---|
| **Photograph No. 9:**<br>  | **Comment:**<br><br>**Transition of stacked granite, typical of Public Landing, and adjacent property.**<br><br>**View of pier framing and continuation of stacked granite beyond.** |
| **Photograph No. 10:**<br>  | **Comment:**<br><br>**View of northern section of public landing.**<br><br>**Timber boardwalk at wharf and typical timber framing at interface to granite.**<br><br>**Timber piles exhibit signs of deterioration which may stem from weathering or microbial attack.** |

*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

**Photograph No. 11:**



**Comment:**

**View of southern end of public landing wharf and timber boardwalk.**

**Photograph No. 12:**

**Comment:**

**View facing north at Harbor Master's office.**

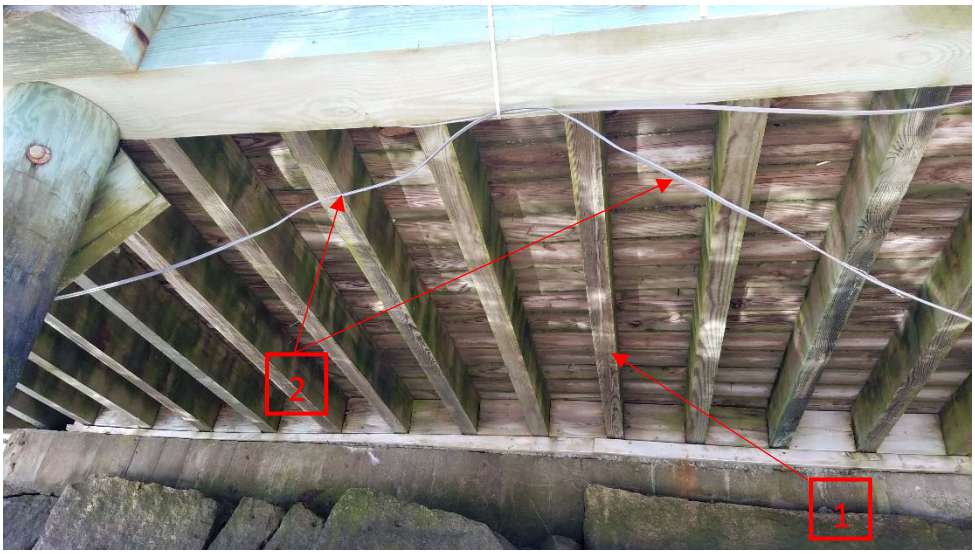
**Harbor hoist and site utilities noted.**

*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

| | |
|---|---|
| **Photograph No. 13:**<br>  | **Comments:**<br><br>**Boardwalk framing on granite block.**<br><br>**View of utilities at face timber framing and granite at wharf.** |
| **Photograph No. 14:**<br>  | **Comments:**<br><br>**Close-up of timber framing at boardwalk on granite block and gravel bedding.** |

*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

**Photograph No. 15:**




**Comment:**

1. **View of underside of deck at adjacent property.**

2. **Hanging wires which appear to be electrical are attached at underside of framing.**

**Electrical service conduits and cables below the Design Flood Elevation (DFE) shall be waterproofed or conform to the provisions of NFPA 70 National Electrical Code (NFPA 2011 ) for wet locations.**

**Photograph No. 16:**

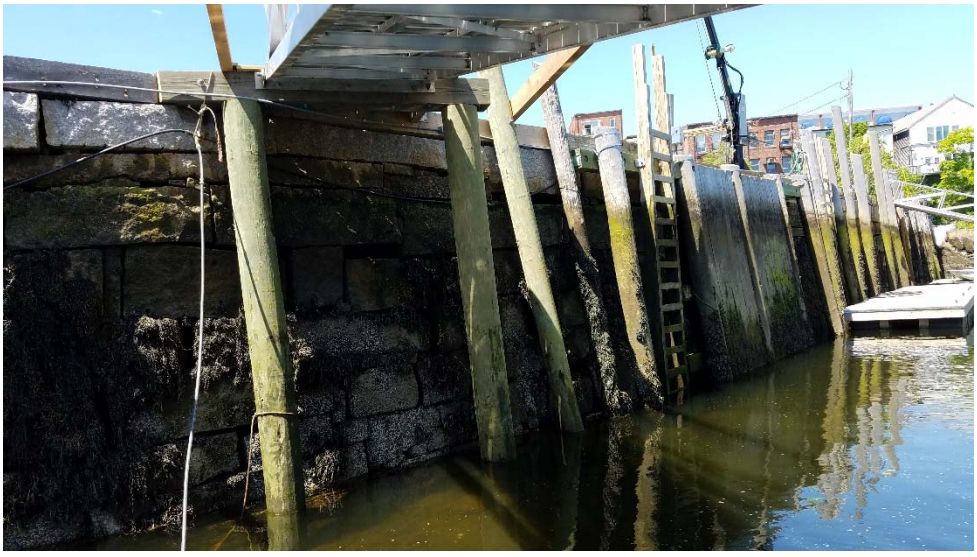

**Comment:**

**Floating Dock Key**

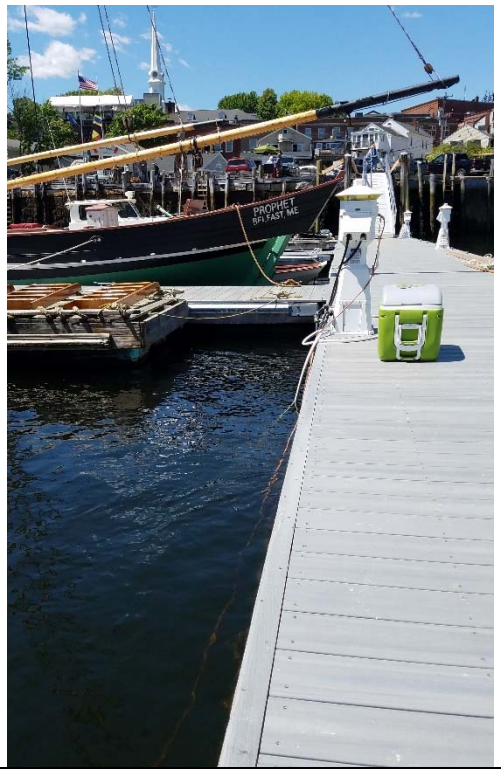
*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

| | |
|---|---|
| **Photograph No. 17:**<br>  | **Comment:**<br><br>**View of floating dock 1** |
| **Photograph No. 18:**<br>  | **Comment:**<br><br>**View of gangway attachment to wharf/boardwalk.** |

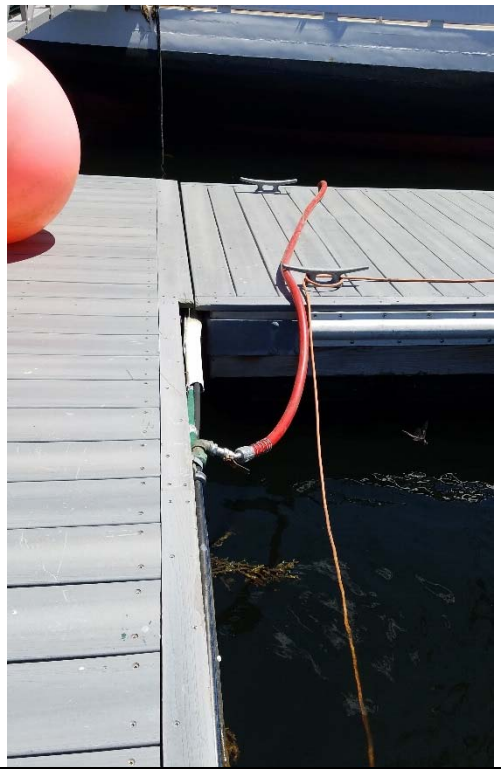
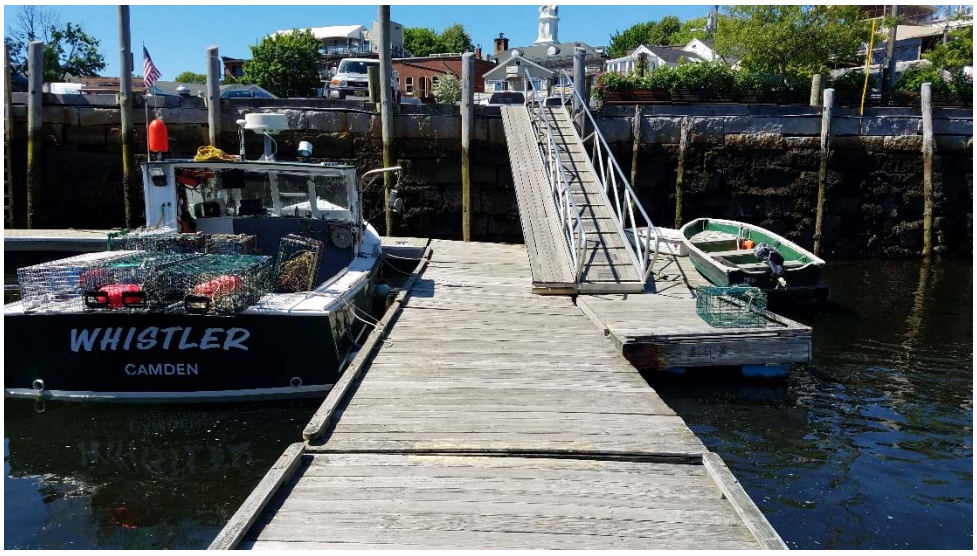
*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

| | |
|---|---|
| **Photograph No. 19:**<br>  | **Comment:**<br><br>**Close-up of gangway attachment to wharf.** |
| **Photograph No. 20:**<br>  | **Comment:**<br><br>**View from below of support structure for gangway of floating dock 1.** |

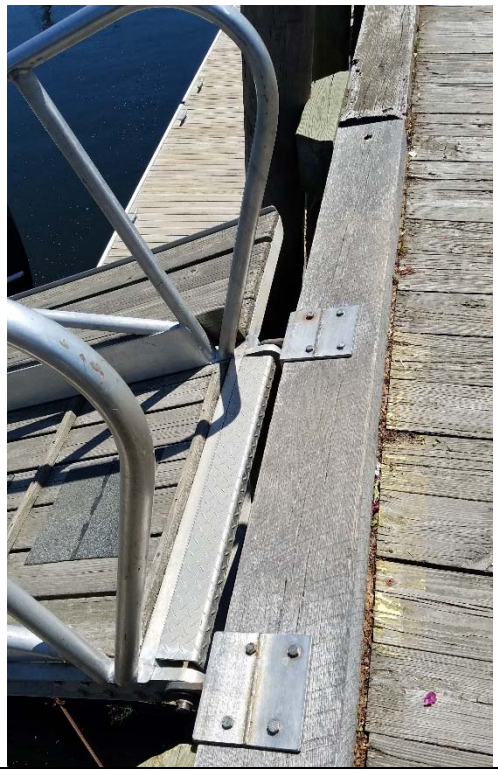
*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

| | |
|---|---|
| **Photograph No. 21:**<br>  | **Comments:**<br><br>**Typical battered pile support of dock and slips.** |
| **Photograph No. 22:**<br>  | **Comment:**<br><br>**View of floating dock.**<br><br>**View of water supply station provided on dock.** |

***By:*** *T. Day* ***Date:*** *04OCT2019* ***Reviewed:*** *K. Sun* ***Date:*** *07OCT2019*

| | |
|---|---|
| **Photograph No. 23:**<br>  | **Comment:**<br>**View of floating dock.**<br><br>**View of dock supply water hoses and fittings.** |
| **Photograph No. 24:**<br>  | **Comment:**<br>**Overview of Floating dock 2** |

*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

| | |
|---|---|
| **Photograph No. 25:**<br>  | **Comment:**<br><br>**Close-up of gangway attachment to wharf.**<br><br>**Hinge hardware appear in decent condition.**<br><br>**Embedment of fasteners not apparent.** |
| **Photograph No. 26:**<br>  | **Comment:**<br><br>**View of typical condition of a float at Floating Dock 2.**<br><br>1. **Deck wood exhibits signs of weathering.**<br>2. **The pontoons appear to function as intended.** |

*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

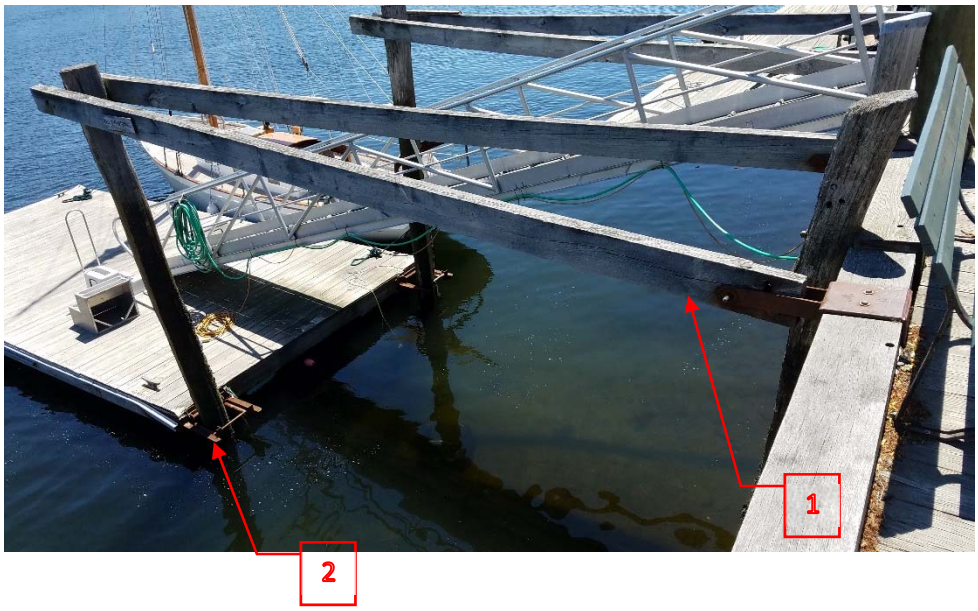
**Photograph No. 27:**

**Comment:**

**Close-up of the adjacent float connection.**

**Bolt and hinge appear moderately corroded. Bolt appears to be galvanized steel.**

**Photograph No. 28:**



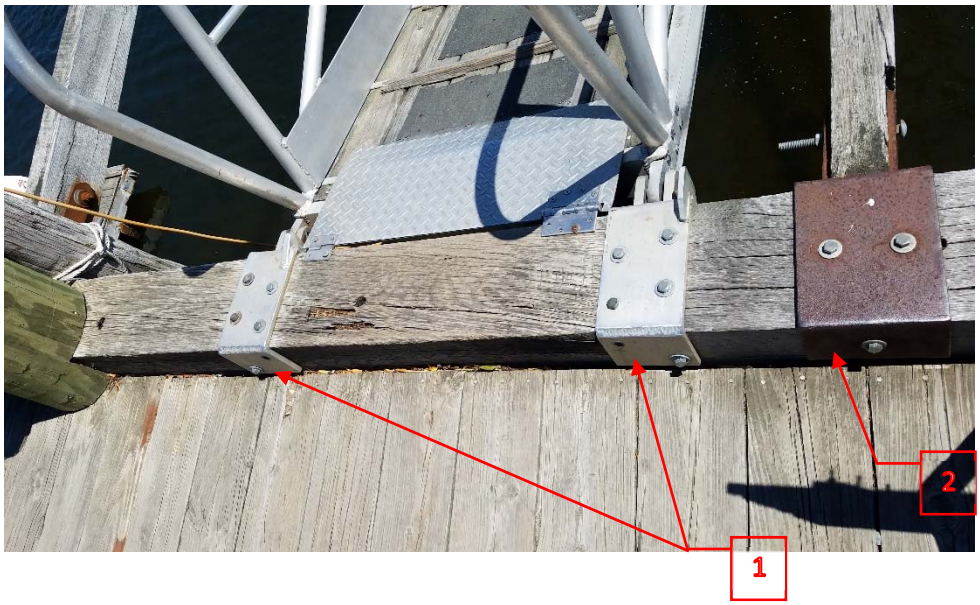

**Comments:**

**Overview of floating dock 3.**

1. **View of bracing for support piles.**
2. **View of mooring hardware.**

*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

**Photograph No. 29:**

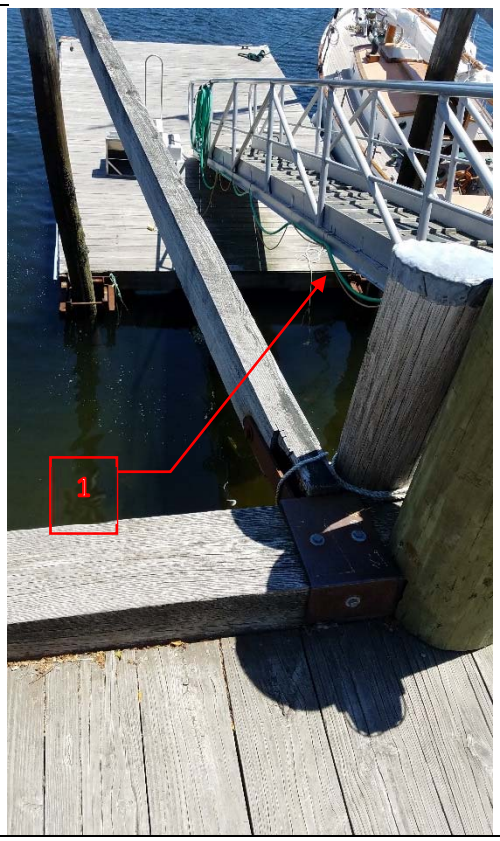



**Comments:**

**Close-up of gangway attachment to wharf.**

1. **Hardware for attachment of gangway to wharf appears in decent condition.**
2. **Hardware for attachment of pile bracing to wharf appears mildly corroded. Bracing appears to be moderately weathered.**

**Photograph No. 30:**




**Comments:**

**Additional view of gangway.**

1. **Water hoses observed along gangway for supply to dock.**

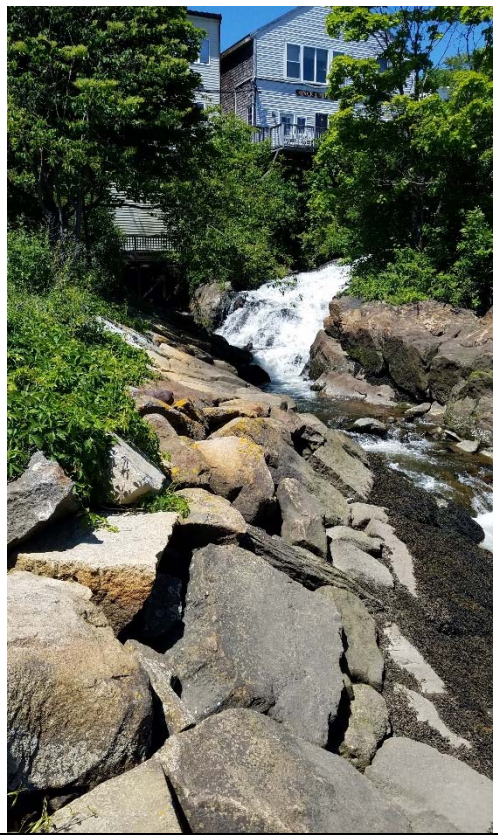
*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

| | |
|---|---|
| **Photograph No. 31:**<br>  <br> | **Comment:**<br><br>**View of floating dock 4.**<br><br>**1. Support piles attachment to wharf**<br><br>**2. Water hoses for supply to dock.** |
| **Photograph No. 32:**<br>  <br> | **Comment:**<br><br>**Close up of dock attachment to support piles by means of mooring chains.** |

*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

| | |
|---|---|
| **Photograph No. 33:**<br>  | **Comments:**<br><br>**View of Harbor Master's Office.** |
| **Photograph No. 34:**<br>  | **Comments:**<br><br>**View of public restrooms and other building on site.** |

*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

| | |
|---|---|
| **Photograph No. 35:**<br>  | **Comments:**<br><br>**Shoreline/outfall protection adjacent to the public landing and waterfall.** |
| **Photograph No. 36:**<br>  | **Comment:**<br><br>**Overview of Harbor Park looking south from the field.** |

*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

| | |
|---|---|
| **Photograph No. 37:**<br>  | **Comment:**<br><br>**View of harbor and outlet of Megunticook River.**<br><br>**Large rocks and vegetation noted.** |
| **Photograph No. 38:**<br>  | **Comment:**<br><br>**View of park and shoreline.**<br><br>**Floating dock noted as within property limits.**<br><br>**Structures noted such as earth retaining and/or seawalls.** |

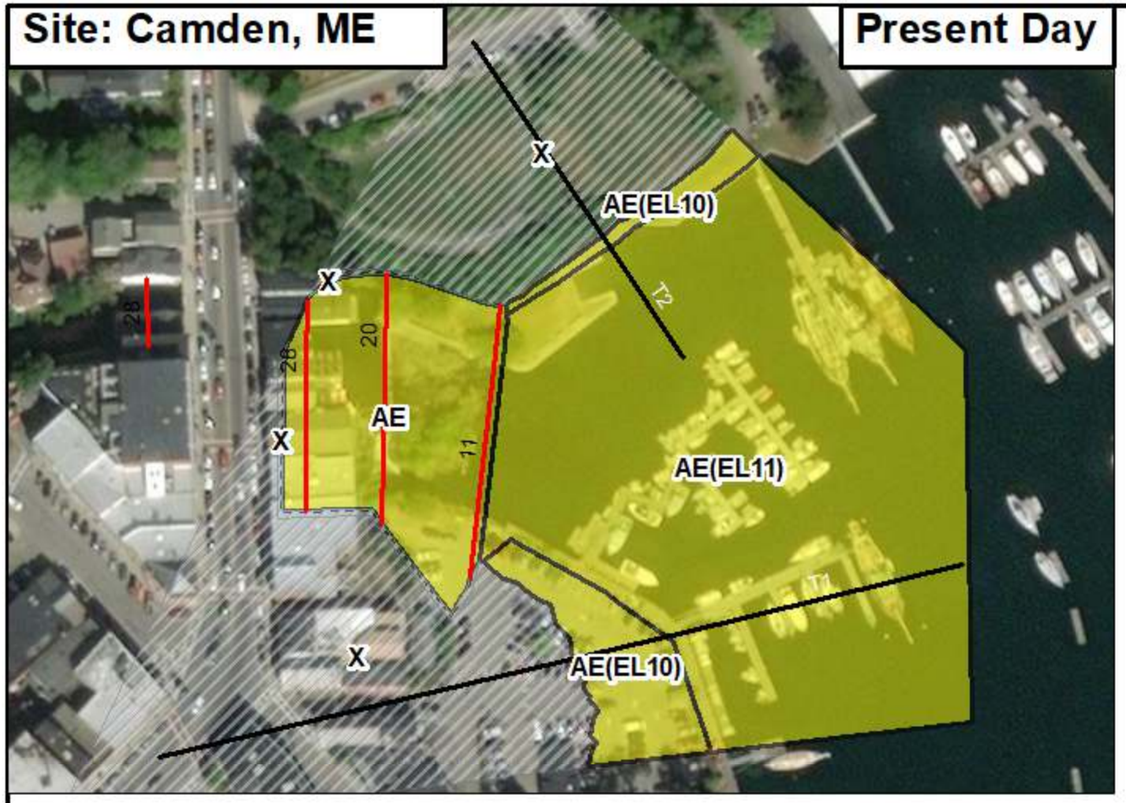
*By: T. Day Date: 04OCT2019 Reviewed: K. Sun Date: 07OCT2019*

| | |
|---|---|
| **Photograph No. 39:**<br>  | **Comments:**<br><br>**Close-up of beach looking west.**<br><br>**View of stacked granite wall at upper right side of photo.** |
| **Photograph No. 40:**<br>  | **Comments:**<br><br>**View of stacked granite walls and various other large rocks.** |

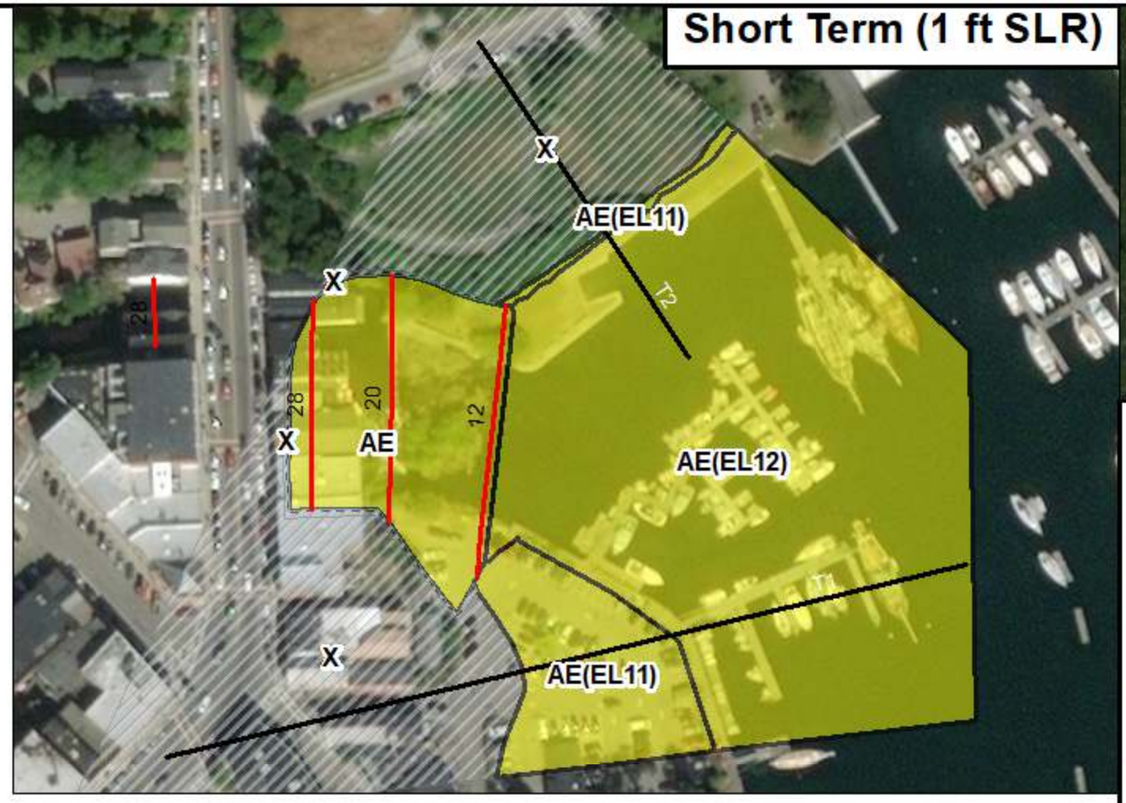
# Appendix B – Inundation Maps

Site: Camden, ME

Present Day




Short Term (1 ft SLR)




Penobscot Bay

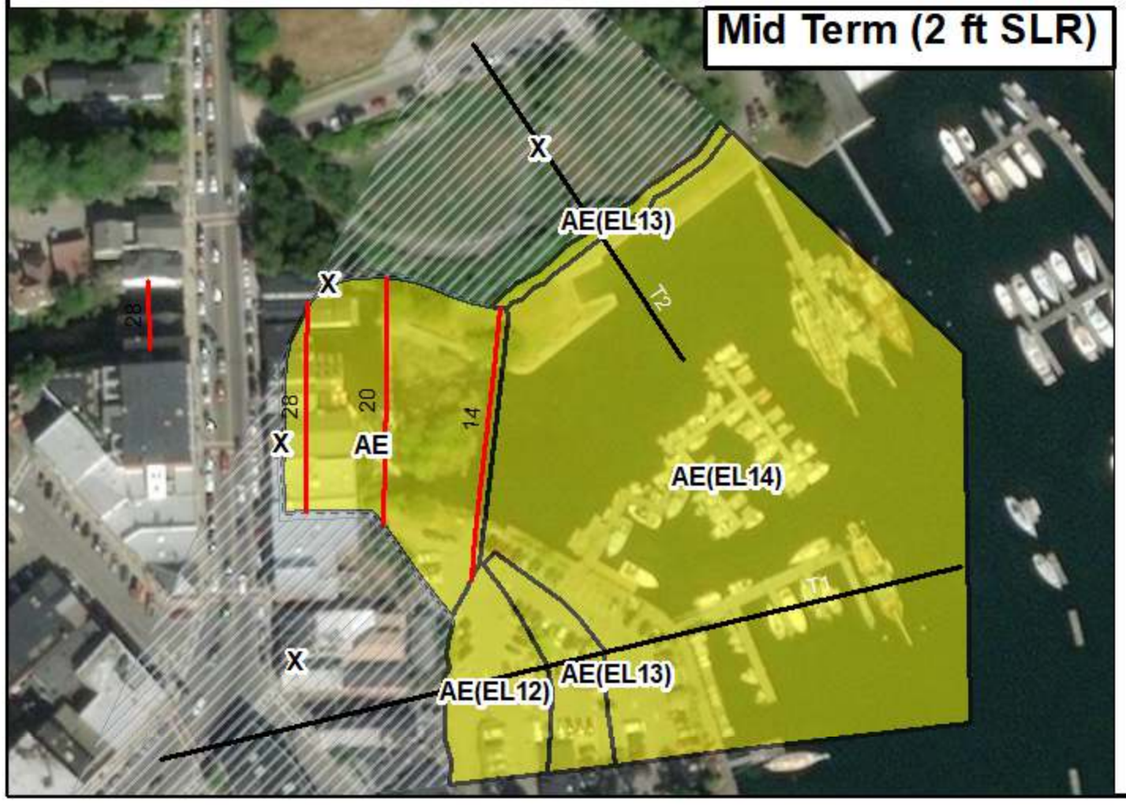
1. Maps indicate the 1%-annual-chance flood zones and base flood elevations.

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.

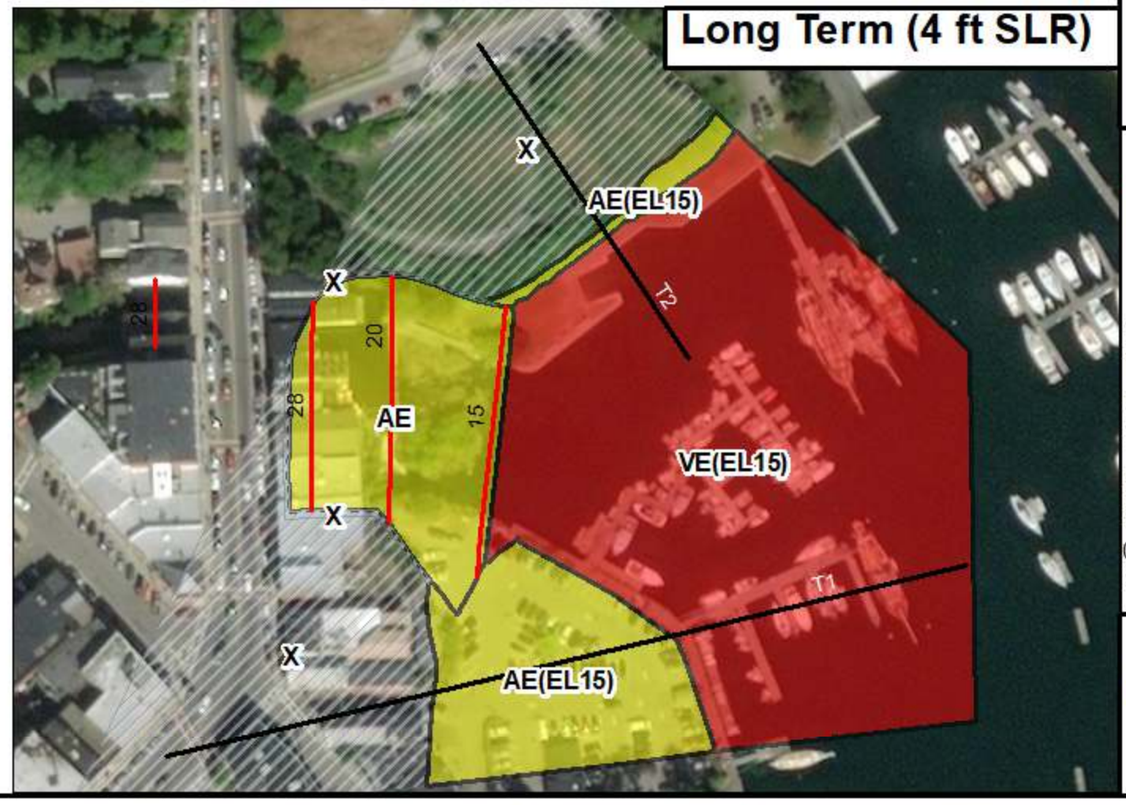
3. Flood mapping was developed for planning purposes only. No other use of this map should be made.

4. Elevations in reference to vertical datum NAVD88

Mid Term (2 ft SLR)




Long Term (4 ft SLR)




Camden Transects
BFE
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