Town of Boothbay Harbor

Flood Impact Preliminary Engineering Study

Project Overview, Findings, and Preliminary Recommendations

September 2017

Prepared for

TOWN OF BOOTHBAY HARBOR, ME
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Acronyms

BFE	-	Base Flood Elevation
FEMA	-	Federal Emergency Management Agency
FIRM	-	Flood Insurance Rate Maps
FIS	-	Flood Insurance Study
HAT	-	Highest Astronomical Tide
IPCC	-	Intergovernmental Panel on Climate Change
LCRPC	-	Lincoln County Planning Commission
MCP	-	Maine Coastal Program
MGS	-	Maine Geological Survey
MHHW	-	Mean Higher High Water
MSL	-	Mean Sea Level
NAVD88	-	North American Vertical Datum of 1988
NFIP	-	National Flood Insurance Program
NGVD29	-	National Geodetic Vertical Datum of 1929
NOAA	-	National Oceanic and Atmospheric Administration
SFHA	-	Special Flood Hazard Area
TNC	-	The Nature Conservancy

1 Introduction

1.1 Introduction

The Lincoln County Regional Planning Commission (LCRPC) and Maine Geological Survey (MGS) in 2012 undertook a study of 450 miles of Maine's mid-coast region, including the Town of Boothbay Harbor ("the Town" or "Boothbay Harbor"), to evaluate the effect of various sea level rise scenarios. Additionally, the Federal Emergency Management Agency (FEMA) published new Flood Insurance Rate Maps (FIRMs) for the region in 2015. The results of the LCRPC study and the new FEMA maps suggest that much of Boothbay Harbor's commercial waterfront is at risk from inundation under current and future conditions. Boothbay Harbor is defined by the restaurants, stores, hotels, lobster wharfs, fish piers and marinas along the water; significant damage to, or loss of, these properties could have devastating effects on the Town's economy and quality of life, as well as the local community's cultural identity and sense of place.

1.2 Project Goal

The goals of this study include:

1. Incorporate the revised FEMA maps published in 2015 and the LCRPC sea level rise scenarios developed in 2012 into Boothbay Harbor's resilience planning.
2. **Characterize the vulnerabilities and risks to coastal flooding** of participating properties.
3. **Identify opportunities** and **recommend improvements** for making waterfront properties more resilient in the face of existing flooding hazards and potential future hazards created by rising sea levels.
4. Provide building-specific technical information and ranges of adaptation strategies to property owners.
5. Comment on the applicability of flood insurance under the National Flood Insurance Program (NFIP) and potential for premium reductions.

As noted above, Boothbay Harbor is defined by its commercial waterfront character, especially its numerous businesses, restaurants, hotels, and stores constructed on piers over the water. An important aspect of this study, therefore, was to promote coastal resilience strategies that do not diminish that unique character. This approach falls under the category of *Community Resilience*, ensuring that not only is the community able to withstand and recover from a coastal storm, but it maintains its community character and culture through the process.

This report has been developed as a toolbox to guide efforts to protect buildings and build coastal resilience in the coming years. The planning process parallels **steps one and two** of the coastal resilience planning process established by The Nature Conservancy (TNC) (http://coastalresilience.org/approach/, see Figure 1).

The four steps of the process are:

1. **Assess Risk and Vulnerability**, including alternative storm and sea level rise scenarios
2. **Identify Solutions**, focusing on joint solutions across social, economic and ecological systems
3. **Take Action** at key sites to help communities identify and implement solutions
4. **Measure Effectiveness** to ensure efforts are successful

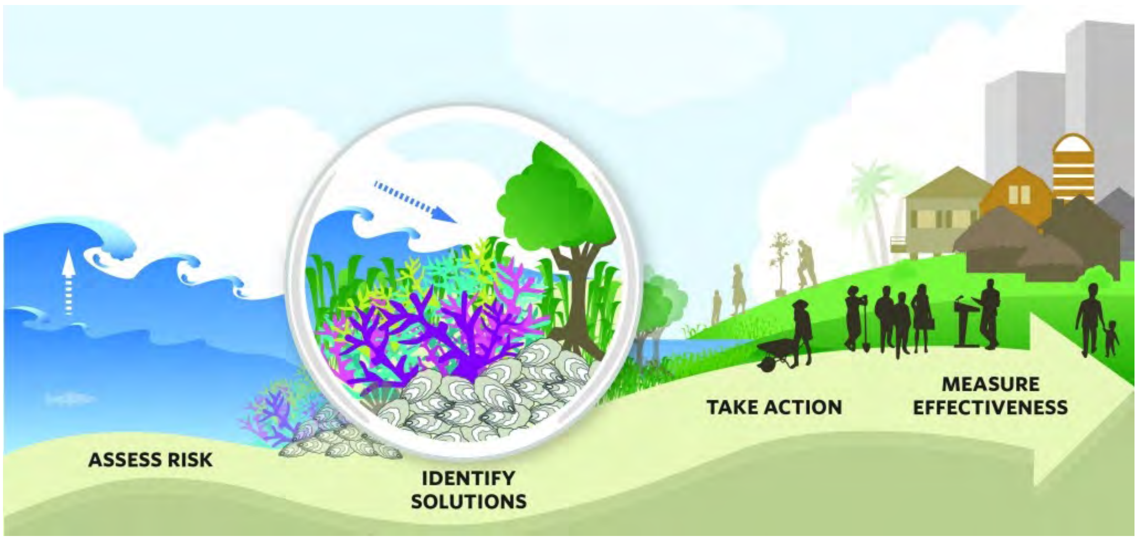


Figure 1: Steps to Coastal Resilience.

Image from www.reefresilience.org

1.3 Project Funding

This project was funded principally by the Maine Coastal Program (MCP), with additional financial and staff support provided by the Town of Boothbay Harbor and the LCRPC.

2 Vulnerability and Risk

2.1 Existing Conditions

2.1.1 Setting

Boothbay Harbor developed as a fishing port in the 1800s, and served as the commercial, industrial, residential and social center of the Boothbay peninsula. Over time, the traditional fishing sector was largely replaced by tourism and related commercial sectors. The Town now consists primarily of hotels, restaurants, recreational boating and sightseeing facilities, and retail properties. A small number of commercial fishing and shipbuilding facilities continue to operate in the harbor. Boothbay Harbor's population was estimated at 2,151 in 2011.

The 2015 Boothbay Harbor Comprehensive Plan states that "water is integral to most every aspect of life in Boothbay Harbor." Waterfront properties and harbor access are essential to the Town's history and sense of place, and will continue to be the community's focal point into the future. The community recognizes the risks associated with waterfront activities, including rising sea levels and storm surges, and is taking steps to protect susceptible areas and reduce adverse impacts.

2.1.2 Existing Challenges

Boothbay Harbor has many commercial properties directly adjacent to the harbor that are susceptible to inundation and wave damage during storm events. Additionally, many structures are built on piers seaward of the mean high tide line; that is, these structures are located over water at high tide. The elevations of buildings vary, with some constructed above current base-flood elevations (BFEs) and therefore outside of the flood hazard zone as mapped by FEMA, while many others were built to lower elevations due to their construction before the most recent FIRM was published in 2015.

The unique waterfront characteristics of Boothbay Harbor make it so that traditional coastal protective measures – such as construction of seawalls or levees, nourishment of beaches and dunes, or development of tide-control infrastructure – generally are not applicable. Likewise, increasingly popular green infrastructure approaches such as living shorelines will not benefit local waterfront properties. Flood mitigation and climate change adaptation will instead take the form of individual property retrofits. At the same time, preservation of the community character requires that care be taken when considering building-specific adaptation measures.

2.2 Sea Level Rise

2.2.1 Existing Conditions

Sea Level

A tide gauge is operated by the National Oceanic and Atmospheric Administration (NOAA) in Portland, Maine (Station ID: 8418150). This gauge has been operating since March 4, 1910. The figures below were calculated by NOAA based on data collected by the Portland, Maine gauge between 1983 and 2001. It is expected that those figures will be similar, but not identical, in Boothbay Harbor.

According to data collected by this gauge (available online at tidesandcurrents.noaa.gov), the mean sea level (MSL) in Portland is negative (-) 0.32 feet, or 0.32 feet below the North American Vertical Datum of 1988 (NAVD88). The average maximum elevation of high tide ("mean higher-high water, or MHHW") is 4.97 feet above the MSL, or 4.65 feet elevation, NAVD88. The average elevation of the highest tide in a given year (the "highest annual tide" or the "highest astronomical tide"; the "HAT") is 6.69 feet, NAVD88. This information is summarized in Table 1, below.

Table 1: Sea Level at the Portland, ME NOAA Gauge

Factor	Portland Elevation (NAVD88)
Mean Sea Level (MSL)	-0.32
Mean Higher High Water (MHHW)	4.65
Highest Astronomical Tide (HAT)	6.69

The LCRPC has determined planning-level sea level figures for Boothbay Harbor. According to the Commission, the current HAT in the harbor is 6.7 feet NAVD88.

Flood Conditions

A new FEMA Flood Insurance Study (FIS) and FIRM for Lincoln County, Maine, was published with an effective date of July 16, 2015; the previous FIS and FIRM that included Boothbay Harbor was dated May 17, 1988. The new study and maps classify flood risks for Boothbay Harbor, and include coastal flood elevations for the harbor's shoreline under different storm conditions. These are summarized in Table 2, below.

"Annual Chance Storm" refers to the likelihood of a storm of a given magnitude occurring during any one year. A 1% annual-chance storm has a 1% chance of occurring each year; historically this has been referred to as a "one-hundred year storm." The "Annual Chance Storm" elevations in Table 2 represent "stillwater" conditions, or inundation without the effects of waves. Wave action can increase the effective flood elevation through three main processes:

- Wave Action: waves push water above (and below) the stillwater elevation
- Wave Setup: the piling up of water against the shoreline by wind and currents
- Wave Runup: breaking waves can extend inland and uphill due to the water's inertia

The column titled "1% with Wave Setup" reflects the effects of "Wave Setup."

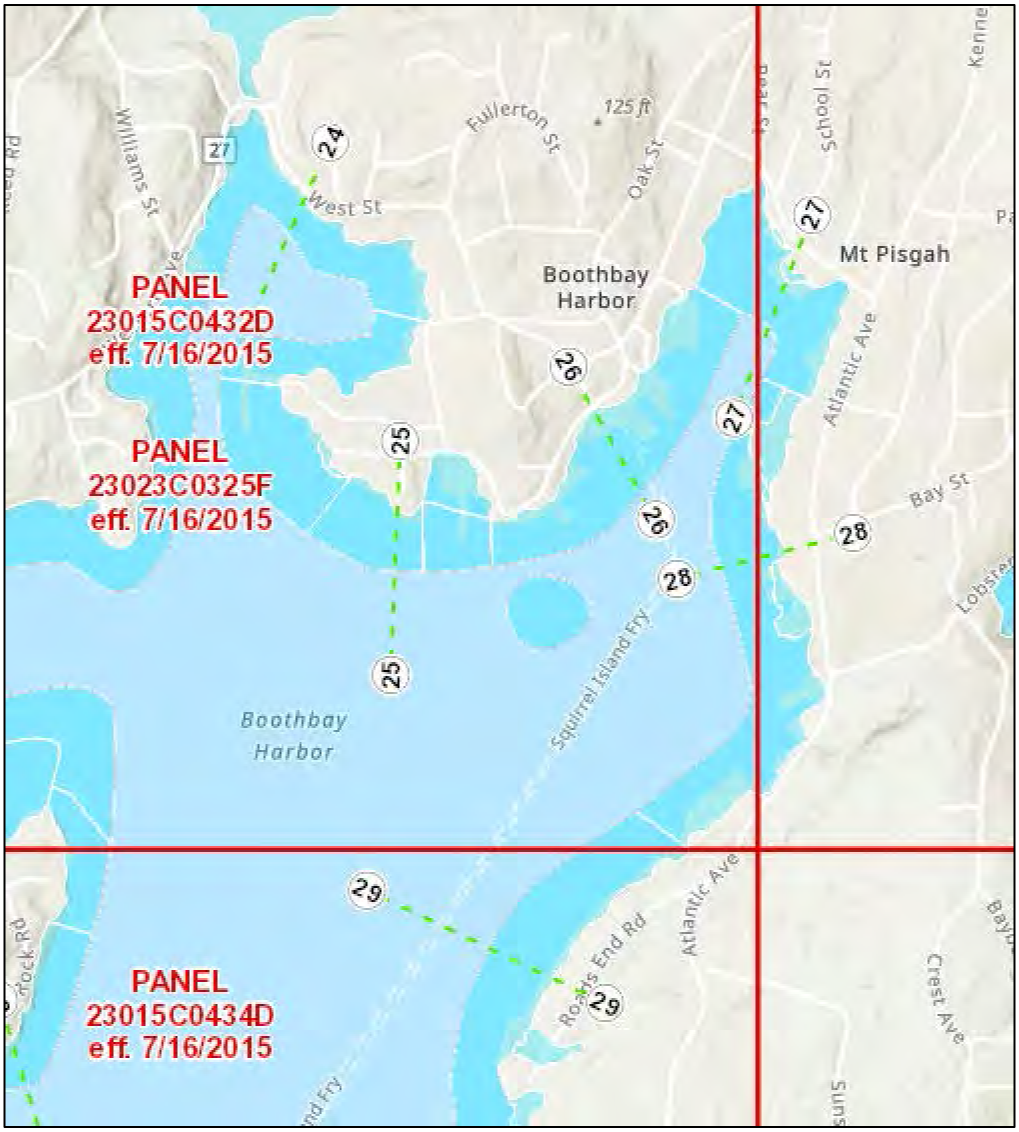


Figure 2 : Map of Boothbay Harbor Area Showing Coasal Transect Locations

Table 2 : Boothbay Harbor Coastal Transect Flood Elevations

	Annual Chance Storm						
Transect	**10%**	**2%**	**1%**	**0.2%**	**1% with Wave Setup**	**Zone**	**Base Flood Elevation**
24	8.2	9.2	9.7	11.1	10.1	VE	13
25	8.2	9.2	9.7	11.1	10.3	VE	16
26	8.2	9.2	9.7	11.1	9.9	AE	11
27	8.2	9.2	9.7	11.1	10.0	AE VE	12 12
28	8.2	9.2	9.7	11.1	9.9	VE	11
29	8.2	9.2	9.7	11.1	10.0	VE	12

Refer to Figure 2 for coastal transect locations.

The BFE is the regulatory elevation used by FEMA to protect against, and to insure for, the flood hazards posed by a 1% annual-chance storm. The BFE accounts for Wave Action, Wave Setup, and Wave Runup. The BFE for Boothbay Harbor ranges from 11 feet NAVD88 to 16 feet NAVD88; for the properties evaluated as part of this project BFEs are 11 to 13 feet NAVD88.

The FEMA-defined BFE must be used when determining flood levels and flood risk for all regulatory, legal, and insurance purposes.

2.2.2 Historic Trends

Examination of over one-hundred years of tidal data collected at the Portland gauge (from January 1912 through June 2017) finds that **MSL has been increasing at a rate of 0.073 inches (or 1.86 millimeters) per year**. See Figure 3, below. This is equivalent to a rise of 7.3 inches, or 0.6 feet, over one-hundred years.

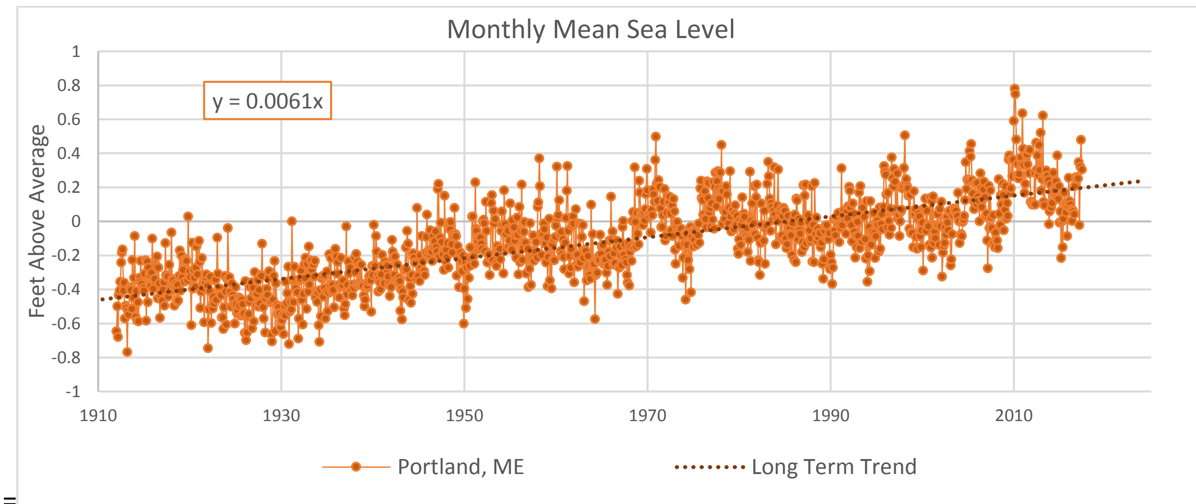
=

Figure 3: Observed Sea Level Data from the Portland, Maine Tide Gauge

Sea Levels on the central Maine coastline have been rising at a rate of around 7.3 inches per 100 years

2.2.3 Sea Level Projections

Thermal expansion of water as ocean temperatures increase, and the addition of water that is currently stored on land into the ocean as glaciers melt, will increase the average sea level across the globe.

Local variations in currents, the vertical movement of land, and other processes create different rates of relative sea level change at particular locations on land. Practically, this means that sea level change is not consistent across the Earth.

The following sections summarize findings with regards to sea level change globally and in Boothbay Harbor.

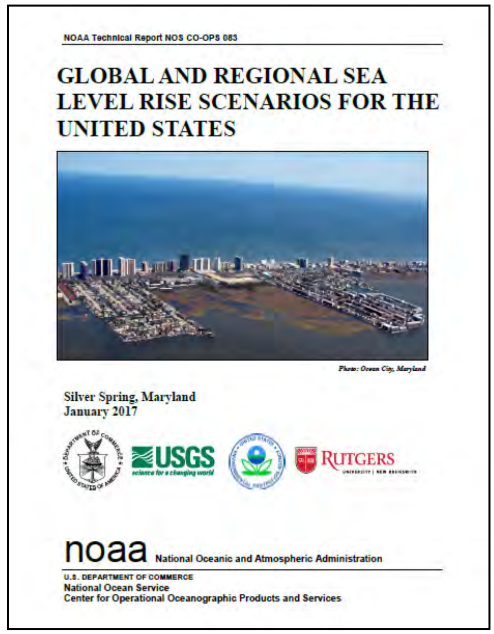
Global Mean Sea Level

In its landmark 2001 report, the Intergovernmental Panel on Climate Change (IPCC) projected that global sea level may rise nine to 88 centimeters (0.30 - 2.89 feet) during the 21st century. According to the most recent update, *Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2013*, these predictions have been revised to a rise of **28 to 98 centimeters (0.9 to 3.2 feet)** by 2100 relative to 1986-2005 levels.

The January 2017 NOAA Technical Report titled *Global and Regional Sea Level Rise Scenarios for the United States* builds on and updates their December 2012 Report, and is the current reference for sea level rise planning in the United States. The report's updated global mean sea level range for the year 2100 is between **0.3 and 2.5 meters (1.0 to 8.2 feet)** above current levels.

Local Relative Sea Level

Relative sea level refers to sea level relative to a particular location on land. Changes in relative sea level can occur due to global sea level changes, localized sea level changes, and the vertical movement of land.



The 2017 NOAA report lists the following key processes that contribute to the rate of relative sea level change at a given location:

- Melting glaciers and ice-sheets
- Changes in ocean circulation
- Glacial rebound (vertical land movement as the Earth adjusts to the end of the last ice age)
- Tectonics and sediment compaction

The 2017 NOAA report finds that sea level along the Northeast Atlantic Coast is projected to be greater than the global average for almost all future scenarios.

Projections and Uncertainty

Relative Sea Level on the Maine Coast is Projected to Rise <u>1.1-10.8 feet</u> Above 2000 Levels by 2100.

Uncertainties exist regarding each of the processes that contribute to sea level change, as listed above. Human development and greenhouse-gas emission patterns in the future are also uncertain, and important for predicting future climate change and sea level rise. For this reason, multiple projections are available.

The USACE hosts a sea level rise web tool ("Sea-Level Change Curve Calculator") that provides sea level projections using both USACE and NOAA projections at existing tidal gauges. The most recent version (2017.55) provides projections developed as part of the 2017 NOAA technical report.

Projected sea level rise using this tool is depicted in the following table and graph. In each case, the base year is 2000.

Table 3: Sea Level Rise in Portland, ME

Gauge 8418150, Portland, ME NOAA 2017 Vertical Land Movement: 0.00 feet per year Values expressed in feet relative to the 2000 Local Mean Sea Level (LMSL)						
Year	**NOAA2017 Low**	**NOAA2017 Int-Low**	**NOAA2017 Intermediate**	**NOAA2017 Int-High**	**NOAA2017 High**	**NOAA2017 Extreme**
2000	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.13	0.16	0.23	0.33	0.43	0.46
2020	0.26	0.33	0.49	0.69	0.82	0.89
2030	0.39	0.49	0.79	1.12	1.38	1.51
2040	0.49	0.66	1.12	1.61	2.13	2.36
2050	0.62	0.82	1.48	2.17	2.95	3.38
2060	0.79	1.02	1.90	2.79	3.90	4.59
2070	0.89	1.18	2.33	3.48	4.92	5.91
2080	0.98	1.31	2.82	4.27	5.97	7.32
2090	1.05	1.44	3.35	5.12	7.28	9.02
2100	1.12	1.54	3.84	6.00	8.73	10.79

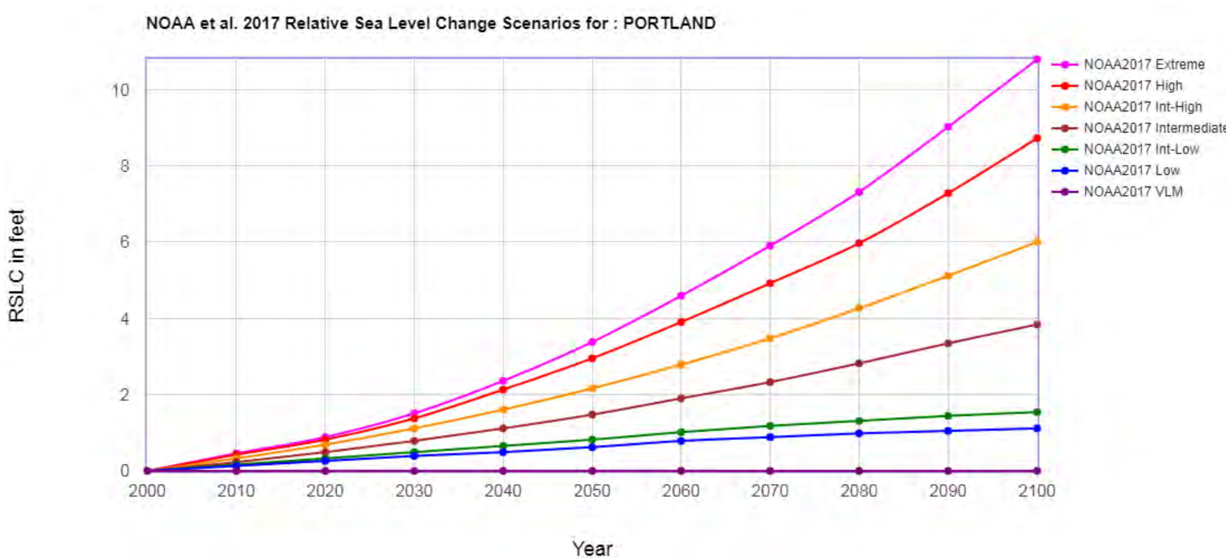


Figure 4: Relative Sea Level Change Projections; Gauge 8418150, Portland, ME

The ranges calculated in Figure 4 and Table 3 are quite wide, but even the low projections show that sea level rise will continue throughout the current century. It is important to note that the slopes of the various projections are based on equations that correspond to the different modeling outcomes[1]. Actual sea level rise will not follow the smooth slopes depicted in the curves on the graph.

2.2.4 Lincoln County Planning Scenarios

The Lincoln County Sea Level Rise – Coastal Hazard Study was conducted in 2013 by the LCRPC and the MGS with support from the MCP. The purpose of the study was to determine the impact that increasing sea level will have on the county's 450 miles of tidal shoreline.

The study examined the impact of 0.3 meter (1-foot), 0.6 meter (2-foot), 1.0 meter (3.3-foot) and 1.8 meter (6-foot) increases in sea level on the HAT as well as the "storm of record" for Lincoln County, which was the February 1978 storm that combined an approximate 3.5 feet of storm surge with astronomically high tides.

The impact of such increases on the water elevation in Boothbay Harbor, as determined by this study, are listed in the table below:

Table 4: LCRPC Sea Level Rise Scenarios

Scenario:	**Highest Astronomical Tide**	**1% Annual Chance Storm**
Current/Historical	**6.5** feet NAVD88	**9.5** feet NAVD88
+ 0.3 meter	**7.5** feet NAVD88	**10.5** feet NAVD88
+ 0.6 meter	**8.5** feet NAVD88	**11.5** feet NAVD88
+ 1.0 meter	**9.8** feet NAVD88	**12.8** feet NAVD88
+ 1.8 meter	**12.5** feet NAVD88	**15.5** feet NAVD88

Note that the increases in sea level (by one foot, two feet, 3.3 feet, or six feet) can be compared to the projections in Table 3 to estimate when such a rise can be expected according to different NOAA sea level rise scenarios.

The LCRPC scenarios presented above are referenced in this document for planning purposes only, in order to remain consistent with regional planning efforts. Note that, as mentioned is section 2.2.1, the FEMA-defined BFE must be used when determining flood levels and flood risk for all regulatory, legal, and insurance purposes.

[1] Personal correspondence June 20, 2017 with Kevin Knuuti, P.E., D.C.E., Former Technical Director, Cold Regions Research and Engineering Laboratory, U.S. Army Corps of Engineers.

2.3 Risk and Resilience Concepts

In the context of hazards, **risk** is the product of **vulnerability** and **frequency**. Here, vulnerability refers to the number of people, structures, and infrastructure vulnerable to a hazard event, as well as the degree to which those assets are incapable of withstanding the effects of that event.

The frequency with which a particular event occurs, combined with level of vulnerability to that event, determines the risk posed by that event.

Risk = Vulnerability X Frequency

This combination can be simplified into the following possibilities:

- **Low** Vulnerability and **Low** Frequency = **Low** Risk
- **Low** Vulnerability and **High** Frequency = **Moderate** Risk
- **High** Vulnerability and **Low** Frequency = **Moderate** Risk
- **High** Vulnerability and **High** Frequency = **High** Risk

		Vulnerability		
		Low	Med	High
Frequency	Low	Minimal Risk	Low Risk	Moderate Risk
	Med	Low Risk	Moderate Risk	High Risk
	High	Moderate Risk	High Risk	Extreme Risk

Figure 5: Risk Matrix Depicting Combination of Levels of Vulnerability & Frequency

In the context of coastal hazards, risk depends on:

- The **vulnerability** of coastal communities and infrastructure
- The **frequency** of flooding and storm events

Coastal storms are believed to be increasing in frequency, and flooding will increase in frequency as sea level continues to rise. **Thus, even if coastal vulnerabilities remain static, risks will increase.**

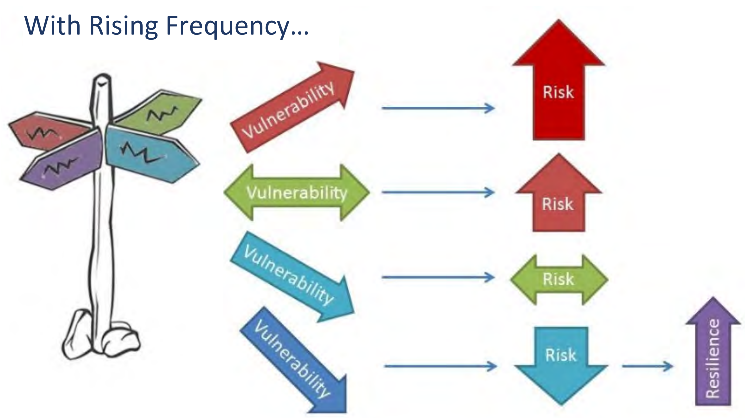


Figure 6: Conceptual model of impact of changing hazard frequency on future risk.

If vulnerabilities increase as well, due to new development in hazard areas (increasing the number of vulnerable assets) or failure to maintain existing protective structures (increasing the level of vulnerability of assets), risks will increase more dramatically. Alternatively, if vulnerabilities are **reduced** through adaptation, risk levels can be held steady into the future. If vulnerabilities can be reduced even further, then risks can be lowered in the face of rising sea level and increased coastal storms, leading to **increased resilience**.

2.4 Specific Vulnerabilities and Risks

2.4.1 Boothbay Harbor Hazards

Generally, coastal **hazards** that place buildings at risk can include:

- **Inundation** – high water without the effects of waves or currents
- **Waves and Currents** – horizontal movement of water
- **Erosion** – removal of earth by waves

Among the greatest threats to Boothbay Harbor Properties are:

- Damage to utility equipment and lines
- Structural damage to floors
- Loss of access to buildings due to inundation of surrounding land and walkways
- Inundation of building contents

Vulnerabilities can fall under a variety of categories, as follows:

- **Structural** – building foundations and frames
- **Economic** – inventory, equipment, operational capacity (employee and customer access)
- **Utilities** – sewer pumping stations, fuel tanks, utility lines and connections
- **Access** – even if a building is above the flood elevation, ingress and egress can be lost due to flood conditions

Risks and vulnerabilities of properties in Boothbay Harbor were determined through on-site inspections and property-owner interviews. Key Building Risks in Boothbay Harbor:

- Damage to building **structure and foundation**
  - Shifting or toppling of foundations by waves and currents
  - Degradation of foundation by saltwater and sea life
  - Uplift of building off its foundation by hydrostatic forces
  - Erosion or undermining of building foundation
  - Damage to building structure or frame by waves, currents, and debris
- Damage to building **interior**
  - Window damage from waves and debris
  - Mold caused by inundation
  - Damage to business inventory and equipment
- Damage to building **utilities**
  - Inundation and shorting of electrical system
  - Inundation of sewer pumping stations
  - Breakage of utility lines by wave action
- Damage to building **operations**
  - Loss of access due to high water
  - Loss of business or operations due to structure, inventory, or equipment damage

Vulnerabilities can also be viewed in the context of primary and secondary impacts. **Primary impacts** describe direct damages to building and infrastructure, while **secondary impacts** include disruptions to commerce, isolation of areas from emergency services, and the like.

Risks are anticipated to increase over time due to sea level rise and climate change, and may be compounded by increased development and population growth. High winds during storm events, which are also predicted to increase with climate change, may put further pressure on vulnerable areas.

2.4.2 Site Inventories

As noted above, individual structures were surveyed for this project in order to identify specific risks and vulnerabilities. Thirty structures on nineteen parcels were assessed.

For each structure, the elevations of the following features were surveyed directly or measured relative to a surveyed feature:

- **Lowest Horizontal Structural Member or Lowest Adjacent Grade**: determine the elevation at which water will begin to come into contact with the structure.
- **First Floor or Top of Deck**: determine the elevation at which water may inundate the building's interior and contents
- **Lowest Opening** (window or door thresholds, vents, etc.): determine the elevation at which water will be able to access the building interior.
- **Critical Systems and Utilities** (including fuel tanks and lines; electrical generators, outlets, and wiring; water and wastewater pipes and pumps, etc.)
- **Other Features** of Note (such as unique equipment and modes of access and egress).

When applicable, the structural integrity of a building's pier-foundations was evaluated through direct observations. Geotechnical methods such as soil load testing were **not** employed.

Three general findings resulted from the surveys, assessments and property owner interviews:

1. **Some buildings may have been elevated or floodproofed in accordance with the previous FEMA FIS and FIRM published in 1988.** The BFE for the entire Town's coastline according to that study had been 10 feet above the National Geodetic Vertical Datum of 1929 (NGVD29). This translates to 9.285 feet NAVD88. Current BFEs for Boothbay Harbor are 11 feet or 12 feet NAVD88.
2. **Some buildings may have been elevated or floodproofed in accordance with the current BFE of 11 NAVD.**
3. **Many or most buildings have not been elevated or floodproofed.**

Buildings were constructed, elevated, or floodproofed to elevations as follows:

- **10-15 in accordance with 1988 BFE**
- **5 in accordance with the current BFE**
- **10-15 not in accordance with any BFE**

Review of current sea level and projected trends, along with evaluation of property-specific risks and vulnerabilities, led to the conclusion that the current and future HAT is the largest driving factor for risk in Boothbay Harbor.

Based on survey results and the **LCRPC sea level figures**, of the properties assessed:

Table 5: Boothbay Harbor Building Vulnerabilities (of 31 Buildings surveyed)

Scenario:	**Highest Astronomical Tide**		**1% Annual Chance Storm**	
	Contact with Building Frame	Inundation	Contact with Building Frame	Inundation
Current	1	0	28	18
+ 0.3 meter	9	0	29	25
+ 0.6 meter	18	9	30	27
+ 1.0 meter	28	20	30	28
+ 1.8 meter	30	27	31	30

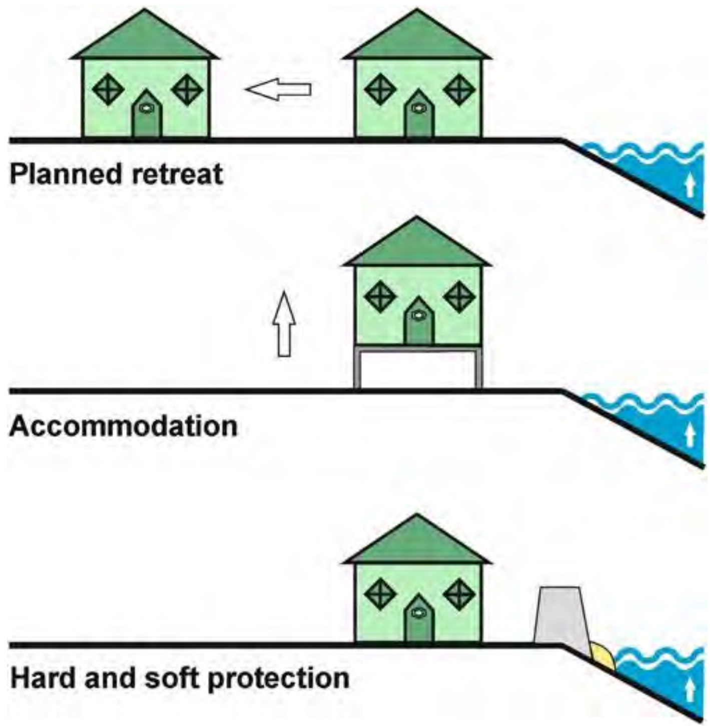
3 Coastal Adaptation Strategies

3.1 Approaches to Adaptation

Adaptation Categories

The IPCC published the landmark paper "Strategies for Adaptation to Sea Level Rise" in 1990. Three basic types of adaptation were presented in the report:

- *Retreat*: abandonment of the coastal zone with no effort to protect the land from the sea.
- *Accommodation*: use of at-risk land continues, but prevention of flooding is not pursued.
- *Protection*: at-risk land is protected from coastal hazards so existing uses can continue.



https://sites.google.com/site/ccbangladesh/

In 2010, the NOAA Office of Ocean and Coastal Resource Management published the manual *Adapting to Climate Change: A Planning Guide for State Coastal Managers*. According to the manual, NOAA's seven categories of "Climate Change Adaptation Measures" are:

- Impact Identification and Assessment
- Awareness and Assistance
- Growth and Development Management
- Loss Reduction
- Shoreline Management
- Coastal Ecosystem Management
- Water Resource Management and Protection

Elements of *protection, retreat*, and *accommodation* are found in several of these categories and subcategories of adaptation. NOAA notes that these adaptation measures are organized into categories that describe their primary purpose but, in many cases, they serve multiple purposes and could fit into multiple categories.

Given Boothbay Harbor's waterfront and overwater character, the most applicable adaptation approaches will fall under the IPCC's accommodation category and will focus on the NOAA categories of

Impact Identification and Assessment, Awareness and Assistance, and Loss Reduction. Other approaches may be relevant in other areas, contributing to advancement of town-wide resilience.

Physical Measures and Planning Tools

Coastal adaptation strategies include both planning (non-physical) and physical modifications.

Planning measures include:

- Emergency preparation and response
- Redirection or retreat of development
- Procedural, regulatory, and financial modifications

Physical measures include:

- Construction of dikes, seawalls, groins, and jetties
- Installation of temporary flood barriers
- Floodproofing of buildings
- Elevation of buildings

Ideally, any measures taken should be sufficiently robust to provide adequate protection, and flexible enough to allow for adjustment under changing conditions. Such robustness and flexibility typically requires a combination of methods rather than a single solution.

Floodproofing measures permitted for residential structures are more limited than those available to commercial buildings. The following section summarizes approaches to floodproofing that may be used individually or in combination for most commercial buildings.

Scale

Adaptation measures can address risk at specific sites, can be designed to protect many square miles of land, or focus on a neighborhood-sized geographic area.

- Site-specific measures pertain to floodproofing specific structures on a case-by-case basis (often referred to in federal literature as "nonstructural flood protection")
- Neighborhood-scale measures apply to a specific group of buildings that are adjacent to each other
- Large-scale measures might include large dike and levee systems or tide gates that can prevent tidal surge from moving upstream (often referred to in federal literature as "structural flood mitigation")

Community Resilience

Beyond the physical and economical risks posed by flooding and storms, Boothbay Harbor's over-water buildings are subject to regulatory requirements that would come into effect following a damaging storm event. Two of those requirements are as follows:

- The building must be elevated, dry floodproofed, or wet-floodproofed to or above the base flood elevation (depending on the FEMA Special Flood Hazard Area (SFHA) zone designation and the local ordinances; in "velocity zones" (VE zones), only elevation is allowable)
- The building must be located entirely inland of mean high water (the high tide line)

While these requirements are intended to protect life and property, and compliance is encouraged, such compliance may result in loss of local character and culture. Perhaps more importantly, these requirements may be at odds with the continuance of true water-dependent uses[2]. The goals of this project were not only to determine methods of protecting properties in Boothbay Harbor from flooding and rising sea levels, but to determine ways that properties in Boothbay harbor can be protected from flooding while still maintaining the Town's harbor-front, fishing-village feel. For that reason, adaptation options presented in this report address the impacts of such adaptations on flood insurance rates, short and long term adaptation options, and adaptation options that limit the impact that changes will have on the Town's culture.

3.2 Adaptation Measures

Table 6, at the end of this section, provides a summary of adaptation and resilience methods considered for Boothbay Harbor. Each of these is described in detail in the following sections. The methods considered include mostly site-specific physical adaptation measures, but also include larger-scale structural approaches and planning approaches.

3.2.1 Protective Infrastructure

This section introduces adaptation measures that are intended to protect large areas of land from the impacts of flooding. They are described here for reference only. **These alternatives are not appropriate for large-scale application in Boothbay Harbor given the local geology, coastal hazard profile, and social and economic context.**

Hard Sediment Management Structures

Hard structures may be placed within the near-shore marine environment in order to reduce the energy of wave and currents; this often is done for the purpose of managing sediment.

- Jetties & Groins are built perpendicular to the beach to interrupt the flow of sand along the shoreline. Over time, sand builds up on one side (the "updrift" side) and is eroded from the other (the "downdrift" side).
- Breakwaters are built parallel to the beach in the water offshore. They are designed to block waves, reducing wave energy at the shoreline. Over time, sand will accumulate towards the breakwater, eventually causing a similar effect as a groin.

Boothbay Harbor's rocky shoreline and lack of beaches makes it so that sediment management is not a significant goal. These structures can serve to reduce wave energy, but do not prevent inundation. Additionally, construction of rocky structures within Boothbay Harbor may interfere with commercial and recreational boating.

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[2] The Coastal Zone Management Act (CZMA) of 1972 provides the basis for protecting, restoring, and responsibly developing the nation's coastal communities and resources. Prioritizing water-dependent uses is a key element.

Soft Infrastructure

Soft infrastructure, also known as "**Living Shorelines**," defends against inundation and wave power by dissipating and absorbing energy, rather than deflecting or reflecting it. Often, these techniques are also designed to enhance habitat and water quality, and to preserve the natural processes and connections between riparian, intertidal, and subaqueous areas.

Some specific living shoreline approaches include the following:

- Beach Replenishment involves importing sand to an eroding or eroded beach from sediment-rich areas, such as a harbor undergoing dredging. Beaches can reduce flood risks and erosion hazards while creating public recreation opportunities, aesthetic value, and in the right conditions support unique habitats (climatetechwiki.org).

- Dune Management involves constructing and stabilizing dunes. FEMA describes dunes as "important first lines of defense against coastal storms" that can "reduce losses to inland coastal development." The Lake Huron Centre for Coastal Conservation lists the benefits of dunes as including shore protection, water purification, biological diversity, erosion control, and acting as a source of sediment for natural beach replenishment.

- Artificial Reefs are created by installing specifically-designed hard structures in the intertidal zone to support the colonization of reef-building organisms. Successful artificial reefs act like breakwaters and reduce wave energy while also trapping sediment and potentially supporting the growth of new tidal wetland.

- Tidal Wetland Management creates or supports the natural flood mitigation capabilities of this rare ecosystem. Tidal Wetlands have been found to reduce wave energy and decrease water surface elevations at their inland edges during storm surges. Preservation of tidal wetlands also prevent development in hazardous areas and support important habitat.

Given Boothbay Harbor's waterfront and over-water properties, the importance of an active harbor to the community's culture, and the importance of a navigable harbor to the community's economy, none of the soft infrastructure measures listed here are recommended for application locally.

In general, incorporating green infrastructure concepts into adaptation measures (including use of vegetation and porous materials and creation or support of habitat) is encouraged.

3.2.2 Property-Specific Approaches

Elevation

Elevating a structure requires raising the lowest floor so that it is above the target design level. Almost any structurally-sound building can be elevated. Design standards vary between FEMA VE-zones and AE-zones. It is possible that elevation of commercial buildings to more than a few feet above street level can create unattractive and hard to manage areas below a building, and can make retail space less inviting and harder to access; however, due to Boothbay Harbor's steep topography and existing architectural style of elevated buildings on piers, neither of these issues is likely to be a major barrier. The impact that elevating a property will have on views from inland buildings must be considered.

Wet Floodproofing

Modifying the operations and use of existing structures to allow flooding to occur while minimizing property damage is considered "wet floodproofing." Under this scenario, most of the contents (including utilities) are removed from below the flood elevation, and openings in the building wall are either maintained or increased in size to allow water to readily enter the lower floors. The openings allow the hydrostatic pressure inside and outside the building to equalize, reducing the potential for structural failure. All construction materials that may be inundated may be flood-resistant to avoid deterioration and mold.

Many of the commercial waterfront properties in Boothbay Harbor (the fish piers and lobster wharfs) are already partly or fully wet-floodproofed, or at least can be returned to service quickly after flooding due to the nature of the contents of the buildings

Dry Floodproofing

Dry Floodproofing entails making a structure watertight by sealing **walls** and **floors**. Openings such as doors, windows, and vents, need to be fitted with removable barriers that can be installed manually or deployed automatically during flood events. The structure being made watertight must be able to withstand the significant hydrostatic pressure that will be exerted on it during a flood event. Dry floodproofing requires implementation planning to ensure removable barriers are appropriately deployed before floods.

Unlike wet floodproofing, dry floodproofing a structure aims to withstand hydrostatic forces, rather than equalize them. This leads to a number of important considerations:

- Dry floodproofing to an elevation greater than three feet above the base of a structure's wall is generally prohibited, as the hydrostatic pressure exerted by three feet of water will overwhelm most structures.
- Some structural materials are more conducive to sealing and dry-floodproofing than others; wood frame buildings can be particularly porous and difficult to dry-floodproof.
- It is **not recommended** to dry-floodproof buildings on pilings over water. During a flood the upward forces caused by the water on a dry-floodproofed building would cause it to act like a boat; the entire building may float and be lifted off of its foundations (uplift), leading to serious secondary hazards of collision with other structures and people.

Floodwalls, Levees, and Temporary Flood Barriers

Floodwalls and levees are located away from the structure to be protected and are designed to prevent the encroachment of floodwaters. It is possible to install barriers on a neighborhood scale to protect multiple buildings. A well-designed and constructed barrier prevents floodwater from exerting hydrostatic or hydrodynamic forces on buildings, as well as from wetting structures. This avoids the need for retrofits or cleanup. Floodwalls and levees may have openings for access. These can be sealed using automatically closing barriers or manually installed barriers that depend on human intervention when flooding is predicted.

Levees are earthen embankments of compacted soils. They require large amounts of land area, since, for structural purposes, they are typically constructed to be 5 to 6 times wider than they are tall.

Floodwalls are constructed of a variety of materials, and do not require large amounts of space for construction. They typically are not viable in areas of very deep flooding.

Temporary flood barriers are erected manually only when flooding is imminent. These systems have a lower capital cost than a floodwall or the self-closing barriers described above, but they require human intervention prior to flooding, generating a risk that the installation is not completed and the structures are not protected.

Floodwalls, levees, and barriers are potentially effective only for the few properties in Boothbay Harbor that are located on land, as they require dry land footings and foundations.

Relocation

Relocating a structure is the most dependable method of reducing flood risks. The method involves moving the structure out of the floodplain away from potential flood hazards. Costs and new sites are usually major concerns associated with building relocation.

Due to Boothbay Harbor's essential culture of waterfront retail and dining, and water-based commerce and tourism, relocation is not recommended at this point for most of the properties assessed. There are, however, opportunities for relocation of structures and features within certain properties such that they retain their waterfront characteristics but are moved to a somewhat protected location.

Acquisition & Demolition

Owners of highly vulnerable properties may wish to sell their properties, thereby avoiding the costs of continued protection and maintenance. In Boothbay Harbor, an acquired property could be converted to waterfront open space and public access in order to ensure that a public benefit results from the loss of the land use.

Community Utilities

Every building that has its own electric, heat, or cooling system or equipment (including fuel tanks) creates an additional important vulnerability. Replacing dispersed utility systems with centralized community- or neighborhood-scale facilities can decrease overall vulnerabilities. Such facilities may be located farther from the hazard zones than the buildings that they serve, and the cost-effectiveness of hazard mitigation retrofits will be greater.

3.2.3 Variances

All of the actions above are intended to protect properties from coastal flood hazards. As discussed previously, the commercial properties located along the harbor, or even over the harbor, are essential to Boothbay Harbor's culture, community character, and tourism economy. In some cases, certain flood mitigation actions may cause the loss of this character; furthermore, floodplain ordinances may require that those actions be taken if "substantial damage" or "substantial improvement" thresholds are met during a storm or during renovations, respectively.

Within this regulatory framework, a resilient Boothbay Harbor must also be able to retain and rebuild its harbor-front properties despite floodplain management regulations. This can be accomplished through the granting of *variances* for qualifying structures. There are two types of structures that qualify for floodplain management ordinance variances:

- Functionally Dependent Uses
- Designated Historic Resources

Functionally Dependent Use

Boothbay Harbor's floodplain management ordinance includes the following in Section 170-95.1.D:

> *Variances may be issued for new construction, substantial improvements, or other development for the conduct of a functionally dependent use, provided that:*
>
> > *(1) Other criteria of §§ 170-95.1 and 170-92K are met; and*
> > *(2) The structure or other development is protected by methods that minimize flood damages during the base flood and create no additional threats to public safety.*

Functionally dependent uses are those that require access to water for their operations; that is, a business that would not be able to operate if it were relocated away from the waterfront. In Boothbay Harbor, marinas, fish piers, and lobster wharfs may qualify as functionally dependent uses.

Historic Resources

Boothbay Harbor's floodplain management ordinance includes the following in Section 170-95.1.E:

> *Variances may be issued for the repair, reconstruction, rehabilitation, or restoration of historic structures upon the determination that:*
>
> > *(1) The development meets the criteria of § 170-95.1A through D, above; and*
> > *(2) The proposed repair, reconstruction, rehabilitation, or restoration will not preclude the structure's continued designation as an historic structure, and the variance is the minimum necessary to preserve the historic character and design of the structure.*

Historic Resources must be listed on an official register; this includes the national register of historic places, the state register of historic places, and a local register, were one to exist in Boothbay Harbor.

3.2.4 Review of Measures

Table 6: Summary of Adaptation Measures

Measure	Summary	Benefits	Barriers to Implementation
Flood Protection			
Elevation	Raise structure so first floor is above the water surface elevation during a flood event.	Reduce insurance premium Open to residences Permitted in VE zones	Harder to access "Dead space" under structure Difficult for some buildings
Wet Floodproofing	Retrofit building to allow flooding	Relatively inexpensive	Extensive post-flood cleanup Inappropriate for most residential
Dry Floodproofing	Waterproof structure Barriers at openings	Relatively inexpensive Doesn't require extra space	Manual barrier installation Subject to storm predictions Vulnerable to flow & waves Inappropriate for most residential
Floodwalls & Levees	Install concrete or earthen barriers	Prevent water contact with structure & need for retrofits	May require large area Obstructs views
Temporary Flood Barriers	Deployable & removable barriers	Prevent water contact with structure & need for retrofits Relatively inexpensive	Manual installation Subject to storm predictions Short-term only
Relocation	Move structure to safer location	All vulnerability removed Open to residences	Cost, decreased value of new site Loss of Neighborhood Cohesion
Acquisition & Demolition	Willing landowners sell property to town, followed by demolition and conversion to public open space.	Landowner compensated All vulnerability removed Public & habitat benefit	Municipal Cost Loss of Neighborhood Cohesion Requires landowner interest
Community Utilities	Construct community-level infrastructure for utilities, such as gas or heat distribution.	Replace numerous vulnerable utility features (such as propane tanks) with a more robust system located outside of hazard areas.	Very High Municipal Cost
Regulatory Tools			
Functionally Dependent Use	Designate qualifying businesses as functionally dependent; grant variances to prevent relocation; floodproof	Maintain water-based businesses and community character	Maintains structures in hazard zones
Historic Designation	Designate qualifying businesses as historic; grant variances to prevent relocation; floodproof	Maintain distinctive waterfront and over-water businesses and community character	Maintains structures in hazard zones

4 Adaptation Options

4.1 Boothbay Harbor Options Summary

Suites of adaptation options have been prepared for each of the individual properties and buildings that participated in this project. In order to protect the privacy of those property owners, and to facilitate the application of the results of this report to other properties, recommendations are presented in this section based on the types of vulnerabilities of a given building.

Suites of adaptation options, or adaptation "alternatives," are presented here based on the types of vulnerabilities they address. The categories are as follows:

- **Elevated Structure over Water**: addresses the vulnerabilities of buildings constructed on pile foundation and over water at high tide, with first floors elevated above flood levels
- **Low Deck over Water**: addresses the vulnerabilities of buildings constructed on pile foundations and located over water at high tide, with first floors lower than flood elevations
- **Low First Floor over Land**: addresses the vulnerabilities of buildings constructed over land that have low-elevation first-floor spaces used for storage or operations
- **Elevated Structure over Land:** addresses the vulnerabilities of buildings constructed over land with elevated first floors
- **Low Utilities**: addresses vulnerabilities created by low-elevation utility infrastructure.

Adaption alternatives are intended to build resilience; that is, to increase the capability of a building to adapt to, resist, absorb, and recover from coastal hazards. To that end, the following factors were considered when developing alternatives:

- **Adapt** – alter structure to avoid hazard
- **Resist** – strengthen structure to withstand floods
- **Absorb** – design structure, contents, and operations to minimize damage from floods
- **Recover** – design structure, contents, and operations to allow for fast recovery from floods

Additionally, different alternatives have different goals, as follows:

- **Short Term**: can be applied relatively quickly to protect against immediate threats, but is intended to be replaced by a longer-term approach over time.
- **Long Term**: may not be achievable immediately, but will eventually be necessary as sea level rise and climate change exacerbate hazardous conditions
- **Insurance Reduction**: solely intended to lower insurance premiums, based on National Flood Insurance Program Requirements

4.1.1 Elevated Structure Over Water

Many structures in Boothbay Harbor are constructed seaward of the high-tide line on steel or wood pilings. Some of those structures are elevated so that the lowest horizontal member is above the hazard elevation; only in extreme flooding conditions is it expected that the elevated structure would come into contact with high water.

Based on the LCRPC sea level rise planning scenarios, and for planning purposes only, a structure can be considered to be elevated above the hazard zone if its lowest horizontal member is at an elevation above 10.5 feet NAVD88. A structure at this elevation is above short-term LCRPC sea-level-rise planning flood scenarios (10.5 feet NAVD88 during a 1% annual-chance storm after 0.3 meters of sea level rise).

These figures are from the LCRPC planning scenarios and are intended for planning purposes. Actual flood levels will vary depending on the precise location of a building. FEMA BFEs (11 feet NAVD88 or higher, depending on the precise location in Boothbay Harbor) must be used for legal, regulatory, and insurance purposes.

Vulnerabilities

While an elevated over water structure itself may be out of the flood zone, it may have the following vulnerabilities:

Foundation

While the structure described in this section is elevated above the base flood elevation, the piling foundation is submerged regularly. Constant exposure to salt water and sea life will make the foundations be at risk of corrosion, decay, and degradation. Waves, currents, and debris may cause structural damage to the foundations. If the piles are improperly secured to the ground (if they are not buried sufficiently deep or if they are improperly attached to one another) there is a risk that waves and currents may shift the entire foundation.

Utilities

If the utility infrastructure (electrical wires, water and wastewater pipes, pumping stations, etc.) associated with the structure are not *also* sufficiently elevated, they will be at risk of being damaged by floods. This is discussed later in this section.

Access

Finally, a building elevated over water risks isolation if the land around it, and thus its access points, are flooded or damaged. Roadways, stairways, and walkways that are not as high up as the building may be inundated or washed away during high water events.

Alternatives

Measures to build resilience into structures located over water but sufficiently elevated can be divided into the following categories:

Adapt

- **Elevate utility** infrastructure so that it is above flood elevations
- **Protect access and egress** by creating routes that are elevated above the flood zone and connect to land at elevations above the flood zone
- **Rearrange the property** so that the portion of any buildings located completely seaward of the high tide line are used only for temporary activities or functionally dependent activities. For example, the seating area of a restaurant may be located seaward of the high tide line while the kitchen, bathrooms, storage, and utilities are located over land. Placing these essential items and uses

farther from the water means moving them farther from the source of risk and decreasing their vulnerability, if only by a minor amount. Items and uses that remain on the seaward side of the building (such as chairs and tables used in the seating area) may be relocated prior to a storm more easily than large, permanent equipment.

Resist

- **Strengthen the building's foundation** by driving pilings more deeply into the ground or bedrock.
- **Fortify the foundation** pilings by adding protective coatings or reinforcing materials.

Absorb

- Develop **emergency plans** to prepare for and withstand isolation during flood events. Such plans may include evacuation of inventory, equipment, and personnel, turning off power and fuel intakes to limit fire risk, and communicating with emergency responders to inform them that the building is empty.

Recover

As the building described here is elevated outside of the flood zone, it is not expected that recovery will be a major concern, and no specific recommendations are provided here.

4.1.2 Low Structure Over Water

Many of the buildings in Boothbay Harbor constructed seaward of the high-tide line on piers are insufficiently elevated, such that the lowest horizontal member is **within** the hazard zone's elevation.

Based on LCRPC current and projected future flood elevations, a property owner should plan for a structure to come into contact with high water at least once a year currently if it is elevated to or below 6.5 feet NADV88, and in the near future if it is elevated to or below 7.5 feet NADV88. A property owner should plan for a structure to come into contact with high water during a storm with a 1% annual-chance of occurring or greater if its lowest horizontal member is at an elevation of 10.5 feet NAVD88 or lower. These figures are from the LCRPC planning scenarios and are intended for planning purposes. Actual flood levels will vary depending on the precise location of a building. FEMA BFEs must be used for legal, regulatory, and insurance purposes.

Vulnerabilities

When waters rise above the base of a building, hydrostatic pressure is exerted on the structure. This pressure will push upward on a structure even if only a small portion is submerged. This upward pressure can warp or dislodge decking and floor. If the building is not properly anchored the entire structure can be lifted off of its foundations (uplift).

Regular contact with saltwater may accelerate degradation and decay of structural materials. The lower a structure on piers is, the more often it will be wetted, increasing its decay issues.

Finally, exposed utilities on the underside of a building may be damaged by high water, waves, and floating debris. Loss of utilities will affect the ability of a business to operate and recover from a storm.

Additionally, utility loss can lead to secondary risks; for example fire-suppressing sprinklers located under a wooden building may be damaged or clogged by debris carried by high water.

Alternatives

Measures to build resilience into structures located over water at low elevations can be divided into the following categories:

Adapt

- **Elevate the building** so that the lowest horizontal beam is well above the current and future flood levels.
- **Elevate utilities** as well.
- **Rearrange the property** as described in section 4.1.1 if for some reason the building, or a part of the building, cannot be elevated. The building, or its essential uses, can be relocated over land and farther from the hazard zone, while areas seaward of the high tide line are used only for temporary or functionally dependent activities.

It must be noted here that any large-scale project performed on a property may trigger substantial improvement requirements, forcing the building to be brought up to code. This would require the building to be located inland of the high tide line and elevated above the base flood elevation. A variance may be issued if the property is considered functionally dependent or a historic property. A designated historic property that is elevated, however, may be considered to have undergone sufficient alteration such that it no longer qualifies as historic, and therefore no longer qualifies for a variance. Functionally dependent facilities, too, may not be able to elevate without affecting the functionally dependent use. These factors should be considered prior to choosing an adaptation alternative.

Resist

If the adaptation measures listed above are not possible or are insufficient, additional measures under the “resist” category may be pursued.

- **Wet floodproofing** to allow water to enter a building through its walls and floor is the only physical flood-protection measure recommended for a low building over water. Dry-floodproofing such a building could exacerbate the problem posed by hydrostatic forces, risking turning a building into a large, floating piece of debris.
- **Secure the foundation** as described in section 4.1.1, regardless of whether a building over water is elevated, rearranged, wet floodproofed, or even dry floodproofed. Pilings should be properly buried and **secured**, and **reinforced** to prevent damage and decay.

Absorb

Measures to absorb flood impacts are the same as those listed in section 4.1.1

Recover

- **Relocate contents** such as inventory and equipment to a more protected area. This will limit losses during a storm and enable more rapid recovery.

Other actions associated with adapting to and absorbing flood impacts, such as rearranging uses within a structure and developing emergency plans, should also aid with recovery efforts.

Recommendations

Short Term

- **Historic Designation**: Determine whether structure has historic value, and pursue having it listed on the state or national register of historic places
- **Functionally Dependent**: Determine whether the property is considered functionally-dependent and work with municipal staff to determine options available
- **Infrastructure**: Raise infrastructure where possible. Place fuel tanks on elevated platforms; elevate wiring and outlets so that they are higher on the wall; reroute wires and pipes so that they are not underneath the building and susceptible to waves and high water if possible.
- **Rearrange**: Move permanent equipment and materials to the inland sections of the building.

Long Term

- **Foundation**: harden the building's foundation by deepening, securing, and reinforcing pilings
- **Elevate**: Raise the building so that its lowest horizontal member is higher than LCRPC sea-level-rise flood scenarios.
- **Relocate**: Move the building inland if possible.

Insurance

- **Relocate and elevate:** The only way to lower insurance premiums on these buildings is to relocate them so that they are inland of the high tide line, and to elevate them so that they are above the FEMA BFE.

4.1.3 Low First Floor Over Land

A few of the Boothbay Harbor properties that participated in this study are located completely on land, resting on slab or basement foundations, and are below LCRPC sea-level-rise planning scenario flood elevations.

Vulnerabilities

Though inland of the high tide line, these properties may still be at risk of flooding. The main vulnerabilities are:

Contents

Inundation can damage building contents through the physical force of the water, contaminants carried by the water, or mold that grows after the water recedes.

Interior

The internal walls and surfaces of a structure can be warped by the water, or damaged by contaminants carried by the water or mold that grows after the water recedes.

Utilities

Inundation can short electric utilities and damage other low-lying utility infrastructure.

Alternatives

Adapt

- **Elevate the building** above the flood elevation. In Boothbay Harbor this option has the added benefit of remaining consistent with the town's character, as many of its buildings are already elevated on piers.
- Create a **"Floodable First Floor"** by removing all contents, wet-floodproofing, and using that space only for temporary storage and access. It is important to note that for NFIP purposes this often is *not* considered equivalent to elevating a structure.
- **Raise the interior floor** without elevating the entire structure. In this approach, a higher floor is installed inside the building, and the building contents are placed atop that new, elevated floor. The space between the elevated floor and the original floor is either wet- or dry-floodproofed. This measure can only be implemented if there is sufficient clearance between the initial floor and the ceiling.

Resist

- **Dry-floodproofing** may be possible depending on the building material and foundation, as well as the flood depths.
- **Install flood barriers**, either permanent or temporary, and either as part of dry-floodproofing measures or as a separate structure. Flood barriers that include deployable and removable features (such as doorways) require plans and personnel for deployment prior to a flood.

Absorb

If the options above are not possible or are not sufficient, the following actions may help the property absorb the effects of flooding:

- **Relocate / reroute utilities** such as fuel tanks, outlets, and wiring or piping, so that they are outside of the hazard zone
- **Permanently relocate contents** such as inventory or equipment so that they are outside of the hazard zone. This differs from temporary relocation of contents in that it is performed once, rather than every time a storm is predicted.

Recover

- **Temporarily relocate contents** so they are not damaged during a storm.
- **Waterproof equipment** so that business can resume quickly following a storm
- **Have a recovery plan and procedure** to guide preparation and recovery. Maintaining backup equipment essential to business operations can be part of this action.

Recommendations

Short Term

- **Floodable First Floor**: move all operations, utilities, equipment, and contents out of the first floor area. This action will not lower insurance premiums.
- **Wet Floodproof**: ensure that the first floor can be safely flooded by implementing wet-floodproofing measures.

Long Term

Three different adaptation measures are suggested for long-term adaptation:

- **Elevate**: raise building on stilts so that it is above LCRPC sea-level-rise scenario flood elevations
- **Elevate Interior Floor**: if structural elevation is not feasible or is not necessary given flood depths, elevation of just the interior floor of the structure may be pursued.
- **Construct a Flood Barrier**: install a floodwall or level on the property surrounding the building, protecting it from coming into contact with high water. Install deployable floodgates at pass-through locations as necessary. It is important to note that installation of flood barriers is unlikely to lower flood insurance premiums.

  Note: because of residual risk of flooding behind flood barriers, it is recommended that installation of flood barriers be performed in unison with other, building-focused adaptation measures.

Insurance

Lowered insurance premiums can be secured through pursuing the following three adaptation measures, assuming they are performed to the appropriate elevation:

- **Elevate Structure above the FEMA BFE**
- **Wet- or Dry-Floodproof Structure to the FEMA BFE**

4.1.4 Elevated Structure Over Land

Only two of the buildings in Boothbay Harbor currently fall under this category. Those two properties are sufficiently elevated to be protected from floodwaters based on FEMA BFE, but are still located within or on the edge of flood hazard areas; therefore their lower structural features may be affected by the forces of waves, currents, and seawater.

Vulnerabilities

Structures built on land, with elevated first-floors, may still be vulnerable to the forces of the sea. The main risks these buildings face are:

- Erosion of the land upon which the structure is built
- Damage to the building foundations from waves and currents
- Degradation of the building foundations from long-term exposure to saltwater

Alternatives

Adapt

- **Eliminate first floor**: remove all contents, walls, and any other non-structural features, opening up the first floor so that the foundation is effectively converted to a pier or stilt foundation. This can also be thought of as bringing the building up to FEMA VE zone standards. This may require actually installing foundational stilts.

Resist

- **Structural reinforcement**: harden the foundations by installing reinforcing structural material, as well as decay-resistant coatings to protect against saltwater and marine life.

Absorb

- **Monitor and repair**: without making any long-term upgrades or investments, property owners may simply implement a regular monitoring procedure, ensuring structural issues are repaired before significant damage is incurred.

Recover

If significant damage is done to a building's foundation or structure, it will likely be very expensive to recover. No recovery-based options are presented here, other than implementing those measures listed under "adapt," "resist," and "absorb."

Recommendations

Short Term:

- **Reinforce Foundation**: harden and protect structure
- **Monitor and Repair**: as needed

Long Term:

- **Eliminate First Floor**: remove walls and contents

Insurance:

- **VE Zone Standards**: remove walls and contents from first floor, and install foundational stilts to bring building into VE zone standards. Simply removing the walls and contents as suggested above may not be sufficient.

4.1.5 Low Utilities

Finally, for a number of buildings the only real vulnerability is to the building's utilities.

Vulnerabilities

Utilities can be carried away by floodwaters, damaged by waves, damaged by water entering electrical systems, corroded by saltwater, or impacted by floating debris. Loss of utility functions will lead to interruption of the building's business and operations. Utility damage can cause secondary damages to building (for example, leaking fuel or clogged fire sprinkler systems), or secondary damage to the surroundings (for example, leaking fuel or floating utilities acting as debris).

Alternatives

Adapt

- **Elevate utilities** so they are above the reach of floodwaters and waves
- **Relocate utilities** to parts of the property farther from the shoreline
- **Develop community infrastructure**: replace individual building utility systems with community-wide systems located in protected areas. Community wastewater systems or microgrids are examples of community infrastructure.

Resist

- **Tie-Down / Secure Utilities** so that they are not dislodged during a flood

Absorb

- **Install backup systems** such as emergency power generators so the building can continue to operate during or after utility loss.
- **Implement emergency procedural measures** to minimize the effects of utility loss, for example:
  - Community Shelters / Warming Huts can provide shelter during power/heat loss
  - Emergency Refrigeration Systems can store perishables during power loss
  - Battery Distribution can provide property owners with backup batteries

Recover

Recovery from utility loss consists of having plans and procedures in place to repair utilities quickly, and replace them with temporary systems while repairs are performed.

Recommendations

Short Term

- **Elevate Utilities**

Long Term

- **Elevate Utilities** above LCRPC sea-level-rise planning scenario flood elevations
- **Develop Community Infrastructure** where possible

Insurance:

- **Elevate Structure & Utilities** together to an elevation above the FEMA BFE

5 Implementation

Individual property owners are encouraged to explore the adaptation alternatives most appropriate for their properties. Important considerations will be cost, short-term and long-term solutions, and a changing coastal risk regime. Not all adaptation measures need to be implemented at once; a property owner may take small steps such as elevating utilities and equipment immediately, while pursuing a more significant project such as elevation of the entire structure over a number of years.

The Planning and Development Department is the appropriate entity to work with property owners to encourage, prioritize, and track actions. This department is also the appropriate entity to prioritize and track municipal actions; the department's involvement will ensure that objectives from the Flood Impact Preliminary Engineering Study are addressed in a coordinated manner with other planning documents.

5.1 Implementation Steps

Having decided to take steps to protect their property, a property owner must determine a path toward implementation:

- **Choose Alternative**
    - Assess specific risks and vulnerabilities
    - Determine appropriate measures
    - Prioritize actions
- **Monitor Conditions**
    - Sea level rise
    - Future FIS and FIRM updates
    - Changes to the property
- **Consider Regulatory Framework**
    - If property experiences "Significant Damage" or undergoes "Significant Improvement" it will need to be brought into compliance with the most up-to-date floodplain management code.
    - Floodplain management regulation exceptions may be made for functionally-dependent use buildings
    - Floodplain management regulation exceptions may be made for buildings on the historic register

5.2 Funding Sources

Many of the programs that fund flood mitigation and sea level rise are opportunistic, meaning they are developed following specific storms and will require the town to pay attention to funding availability. The following is a summary of potential programs that can be investigated.

New and Emerging Sources of Funding

Northeast Regional Ocean Council (NROC)
NROC is a state/federal partnership that facilitates the New England states, federal agencies, regional organizations, and other interested regional groups in their efforts to address ocean and coastal issues from a regional perspective. NROC builds capacity of New England communities through training and a small grants program to improve the region's resilience and response to impacts of coastal hazards and

climate change. The town should access NROC grants as applicable projects are advanced from this plan.

National Oceanic and Atmospheric Administration (NOAA) Regional Coastal Resilience Grants
NOAA is committed to helping coastal communities address increasing risks from extreme weather events, climate hazards, and changing ocean conditions. To that end, NOAA's National Ocean Service is providing funding through competitive grant awards through the Regional Coastal Resilience Grants program. Awards are made for project proposals that advance resilience strategies, often through land and ocean use planning; disaster preparedness projects; environmental restoration; hazard mitigation planning; or other regional, state, or community planning efforts. Successful proposals demonstrate regional coordination among project stakeholders, leverage resources (such as funds, programs, partnerships, and others), and create economic and environmental benefits for coastal communities. Project results are evaluated using clear measures of success, with the end goal being improved preparation, response, and recovery.

Eligible applicants include nonprofit organizations; institutions of higher education; regional organizations; private (for profit) entities; and local, state, and tribal governments. Award amounts typically range from $500,000 to $1 million for projects lasting up to 36 months. Cost sharing through cash or in-kind matches is expected. Applicants must conduct projects benefiting coastal communities in one or more of the 35 U.S. coastal states or territories.

Because the Regional Coastal Resilience Grants program favors regional approaches to resilience problems, the town should pursue future funds with a group of municipalities (such as through the LCRPC) or with the State of Maine.

Regional and National Design Competitions
Although the Rebuild By Design (RBD) competition and National Disaster Resilience Competition (NDRC) awards were announced in the last 3 years and the competitions are complete, they have provided a new model for screening and selecting resilience grant awardees in the United States. The town should keep abreast on future design competitions and consider pursuing these competitions as an individual applicant (if eligible), with a group of municipalities, or directly as an active participant with the State of Maine.

Traditional Sources of Funding

U.S. Department of Housing and Urban Development (HUD)

Community Development Block Grant (CDBG)
The Maine Department of Economic and Community Development administers the CDBG program in Maine through its Office of Community Development. The CDBG program provides financial assistance to eligible municipalities in order to develop viable communities by providing affordable housing and suitable living environments, as well as expanding economic opportunities, principally for persons of low and moderate income. It is possible that the CDBG funding program could be applicable for floodproofing and elevating residential and nonresidential buildings, depending on eligibility of those buildings relative to the program requirements.

CDBG Disaster Recovery (CDBG-DR)

After disaster declarations, and when funds are appropriated to HUD and The Maine Department of Economic and Community Development, the Town of Boothbay Harbor should apply for CDBG-DR grants.

Federal Emergency Management Agency (FEMA)

Pre-Disaster Mitigation (PDM) Program

The Pre-Disaster Mitigation Program was authorized by Part 203 of the Robert T. Stafford Disaster Assistance and Emergency Relief Act (Stafford Act), 42 U.S.C. 5133. The PDM program provides funds to states, territories, tribal governments, communities, and universities for hazard mitigation planning and implementation of mitigation projects prior to disasters, providing an opportunity to reduce the nation's disaster losses through predisaster mitigation planning and the implementation of feasible, effective, and cost-efficient mitigation measures. Funding of predisaster plans and projects is meant to reduce overall risks to populations and facilities.

Hazard Mitigation Grant Program (HMGP)

The HMGP is authorized under Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act. The HMGP provides grants to states and local governments to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the HMGP is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster. A key purpose of the HMGP is to ensure that any opportunities to take critical mitigation measures to protect life and property from future disasters are not "lost" during the recovery and reconstruction process following a disaster.

HMGP is available only in the months subsequent to a federal disaster declaration. Because the state administers HMGP directly, application cycles will need to be closely monitored after disasters are declared.

Flood Mitigation Assistance (FMA) Program

The FMA program was created as part of the National Flood Insurance Reform Act (NFIRA) of 1994 (42 U.S.C. 4101) with the goal of reducing or eliminating claims under the National Flood Insurance Program (NFIP). FEMA provides FMA funds to assist states and communities with implementing measures that reduce or eliminate the long-term risk of flood damage to buildings, homes, and other structures insurable under the NFIP. The long-term goal of FMA is to reduce or eliminate claims under the NFIP through mitigation activities.

One limitation of the FMA program is that it is generally used to provide mitigation for structures that are insured or located in Special Flood Hazard Areas (SFHAs).

U.S. Army Corps of Engineers (USACE)

The U.S. Army Corps of Engineers provides 100% funding for floodplain management planning and technical assistance to states and local governments under several flood control acts and the Floodplain Management Services (FPMS) Program. Specific programs used by USACE for mitigation are listed below.

Section 205 – Small Flood Damage Reduction Projects
This section of the 1948 Flood Control Act authorizes USACE to study, design, and construct small flood control projects in partnership with nonfederal government agencies. Feasibility studies are 100% federally funded up to $100,000 with additional costs shared equally. Costs for preparation of plans and construction are funded 55% with a 35% nonfederal match. In certain cases, the nonfederal share for construction could be as high as 50%. The maximum federal expenditure for any project is $7 million.

Section 14 – Emergency Streambank and Shoreline Protection
This section of the 1945 Flood Control Act authorizes USACE to construct emergency shoreline and stream bank protection works to protect public facilities such as bridges, roads, public buildings, sewage treatment plants, water wells, and nonprofit public facilities such as churches, hospitals, and schools. Cost sharing is similar to Section 205 projects above. The maximum federal expenditure for any project is $1.5 million.

Section 205 – Floodplain Management Services
This section of the 1950 Flood Control Act, as amended, authorizes USACE to provide a full range of technical services and planning guidance necessary to support effective floodplain management. General technical assistance efforts include determining the following: site-specific data on obstructions to flood flows, flood formation, and timing; flood depths, stages, or floodwater velocities; the extent, duration, and frequency of flooding; information on natural and cultural floodplain resources; and flood loss potentials before and after the use of floodplain management measures. Types of studies conducted under FPMS include floodplain delineation, dam failure, hurricane evacuation, flood warning, floodway, flood damage reduction, stormwater management, floodproofing, and inventories of floodprone structures. When funding is available, this work is 100% federally funded.

In addition, USACE also provides emergency flood assistance (under Public Law 84-99) after local and state funding has been used. This assistance can be used for both flood response and postflood response. Corps assistance is limited to the preservation of life and improved property; direct assistance to individual homeowners or businesses is not permitted. In addition, USACE can loan or issue supplies and equipment once local sources are exhausted during emergencies.

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