ResilientWoodsHole Phase 2 Report

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1.0 INTRODUCTION AND PURPOSE

With roots in whaling, shipping, and fishing, Woods Hole has been a hub for marine commerce and a significant working waterfront in the Commonwealth for centuries. Since 1871 with the establishment of the U.S. Commission of Fish and Fisheries, Woods Hole has transitioned to its current identity as a center for marine science, management, and education. Currently, three major ocean research organizations – Woods Hole Oceanographic Institution (WHOI), the Marine Biological Laboratory (MBL), and NOAA's Northeast Fisheries Science Center (NOAA) – base their marine operations (as well as other research, operational, and educational functions) out of Woods Hole. As global greenhouse gas emissions have risen since the industrial revolution (on a timescale similar to the existence of the scientific community in Woods Hole), sea level rise and climate change have now become significant drivers of scientific investigation for WHOI, MBL, and NOAA as well as existential threats to the organizations themselves, and to Woods Hole more generally.

Woods Hole Group is an environmental consulting firm with roots in the Woods Hole scientific community. An outgrowth of WHOI, Woods Hole Group was formed to apply scientific principles in oceanography and coastal processes to solve on-the-ground problems, and now consists of four major business units – Environment & Climate Consulting, Sustainable Fisheries, Energy & Mining, and Satellite Telemetry. Woods Hole Group's consulting group specializes in coastal planning, climate change vulnerability assessment and adaptation planning, and modeling the risks to coastal communities and infrastructure from sea level rise and storm surge.

WHOI, MBL and NOAA commissioned Woods Hole Group to continue and expand upon the climate change vulnerability assessment (CCVA) and adaptation plan developed in Phase I (Woods Hole Group, 2020b), using the Massachusetts Coast Flood Risk Model (MC-FRM) to assess future impacts from sea level rise and storm surge. ResilientWoodsHole Phase 2 was designed to prepare a foundation of assessment and outreach for ResilientWoodsHole Phase 3, the development of dynamic adaptation pathways for Woods Hole.

Specifically, ResilientWoodsHole Phase 2 analyses included:

- vulnerability assessment for Woods Hole lifeline infrastructure;
- vulnerability assessment for Woods Hole residential and business structures;
- vulnerability assessment for Woods Hole roadways;
- mapping of flood pathways to determine initial flood encroachment areas;
- recommendations for high priority asset adaptations;
- refinement of WHOI and MBL CCVA district adaptations; and
- development of additional district adaptations for WHOI (Redfield) and MBL (Swope/Ebert).

2.0 PHASE 2 VULNERABILITY ASSESSMENT METHODS

All vulnerability assessments performed in Phase 2 utilized the Massachusetts Coast Flood Risk Model and associated water surface elevation data. The Massachusetts Coastal Flood Risk Model (MC-FRM) developed by the Woods Hole Group is the most comprehensive and sophisticated model available for anticipating how climate change (specifically sea level rise and coastal storm events) will influence future coastal flood risks in Massachusetts coastal communities (MassDOT, 2019 in publication). MC-FRM was developed for the Massachusetts Department of Transportation (MassDOT) to assess potential flooding vulnerabilities to highways and other transportation infrastructure throughout the coastline of Massachusetts. The model is based on mathematical representations of the hydrodynamic processes that affect water levels along the coast, including tides, waves, winds, storm surge, sea level rise, wave set-up, wave run-up and overtopping, etc. These processes were modeled at a high enough resolution to identify site-specific locations in Woods Hole that are vulnerable and may require adaptation responses.

The model is based upon a numerical mesh that provides a digital representation of the geometry of the physical environment. The numerical mesh represents the bathymetry and topography (elevations) of the land, ocean, rivers, and bays at high resolution in order to predict the physical movement of water during coastal storm events (nor'easters, hurricanes, etc.). The model mesh creates discrete nodes at which the governing equations of water flow can be solved. While the model mesh encompasses the entire Atlantic Ocean, the resolution of the model gets finer – meaning the nodes get closer together – as the mesh gets closer to the shoreline. The mesh for the Woods Hole study area is shown in Figure 2-1, overlaid on an aerial image. The MC-FRM mesh has a resolution of 10 meters or less between nodal points, and sometimes as low as 2-3 meters to capture important changes in topography and physical processes related to storm dynamics. It includes areas of open water, estuaries, bays, rivers, and upland subject to present and future flooding.

The MC-FRM is comprised of a tight coupling of the Advanced CIRCulation (ADCIRC) model, which calculates the water levels and velocities, and the UNSWAN model (Unstructured Simulated Waves Nearshore), which calculates wave generation and transformation. These two models dynamically exchange information on physical processes every time step of the model simulation. This allows MC-FRM to provide an accurate representation of the resulting wave surface elevation, waves, winds, and flooding at each node, over each time step, in the model domain. The MC-FRM also includes the addition of wave run-up and overtopping at major coastal structures across the Commonwealth. This added module dynamically calculates the volume of seawater that advances landward over the coastal structure over time. The volume is calculated over each time step and allowed to flow over the landscape. MC-FRM was calibrated and validated to normal tidal conditions (at observation stations from the Caribbean Islands to Canada), as well as to historic storm events that impacted the coastline of Massachusetts (e.g., Hurricane Bob, Perfect Storm, Blizzard of 1978, etc.) Complete details on the development of the Massachusetts Coastal Flood Risk Model (MC-FRM) can be found in MassDOT (2019, in publication).

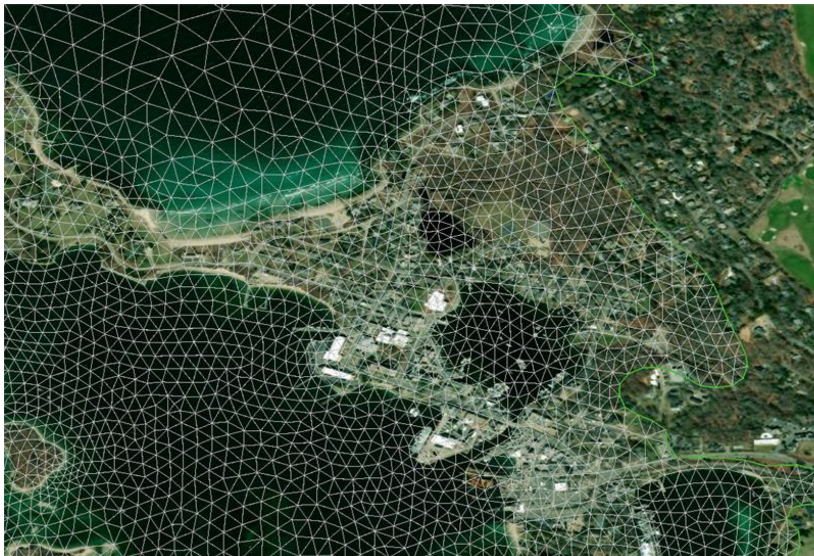


Figure 2-1 Massachusetts Coast Flood Risk Model resolution in Woods Hole

Details on the development of MC-FRM and its application to asset vulnerability assessments in Woods Hole is provided in the Woods Hole Village CCVA (Woods Hole Group, 2020b). Similar data and processes were utilized in this ResilientWoodsHole Phase 2 assessment; unique analyses are described below. The ResilientWoodsHole study area, defining Woods Hole for the purpose of this project, is shown in Figure 2-2.

Figure 2-2 ResilientWoodsHole study area

A variety of technical terms and procedures are used in this document. A brief primer is provided below.

There are two types of elevations used in the vulnerability assessment – water surface elevations and critical elevations. Water surface elevations are the levels of water on the landform resulting from normal tidal or storm surge events. Critical elevations are the levels that water would have to reach on the ground (e.g. a road surface) or on infrastructure (e.g. a first floor of a building) to cause flooding impacts to an asset. All elevations (water surface and critical elevations) reported in this document are in reference to the North American Vertical Datum of 1988 (NAVD88), which is the current standard reference system for elevation surveys in the United States. Using this system, elevations are consistently measured and compared to a fixed "zero" elevation reference point.

Tidal datums describe the elevations of different water levels tracked by a local tide gauge; they can be referenced to other tidal datums (e.g. Mean High Water in Woods Hole is 1.92 feet above Mean Lower Low Water), but since sea level can vary spatially the standard practice for engineering and surveying is to report in the standard reference datum NAVD88. For reference in this document, Figure 2-3 shows the tidal datums for Woods Hole referenced to NAVD88 (e.g. Mean High Water in Woods Hole is 0.56 feet above NAVD88).

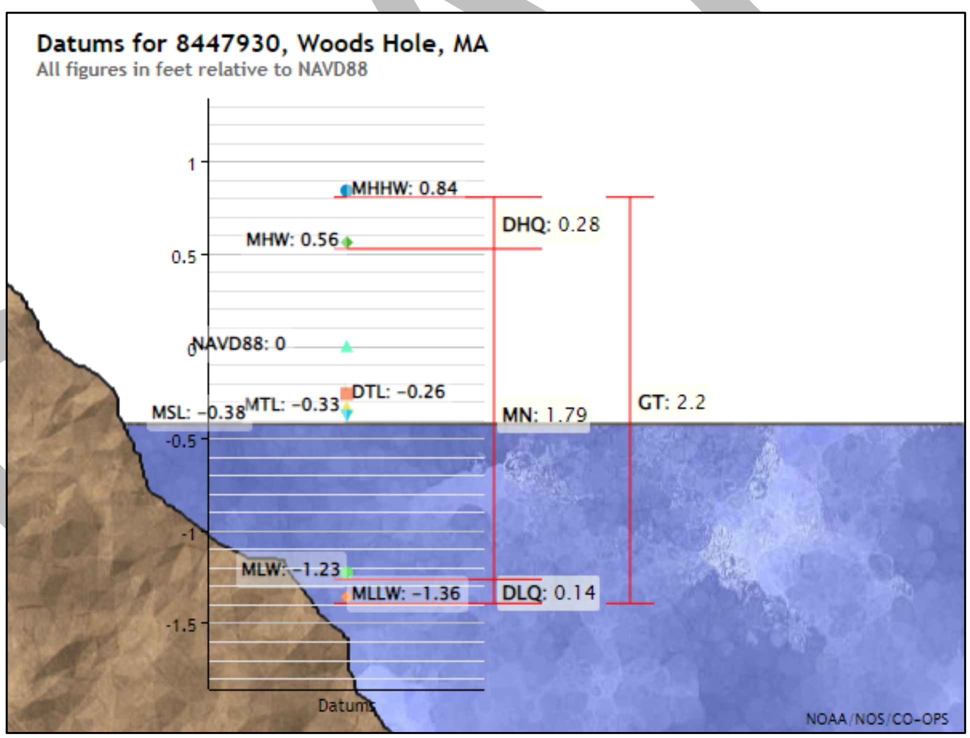


Figure 2-3 Woods Hole tide gauge datums in feet NAVD88

As detailed in the Falmouth CCVA (Woods Hole Group, 2020b) and Woods Hole Village CCVAs (Woods Hole Group, 2020b), MC-FRM uses sea level rise projections developed by the Commonwealth of Massachusetts (DeConto & Kopp, 2017) for climate change planning. These projections for future mean sea level elevation (in NAVD88) are based on a range of potential greenhouse gas emissions scenarios and potential contributions from ice sheet melt (from the state of the science), and use a probabilistic approach such that each projection is associated with a range of confidence intervals depending on greenhouse gas emissions and ice sheet contributions. The intent of these projections is not to state that mean sea level will be "at elevation X by year 20YY" but rather to indicate very high degrees of confidence that conditions will "not be worse than elevation X by year 20YY". This important distinction highlights the unique purpose of these projections (planning) and underscores the importance of applying them in a flexible framework given the expanding uncertainty associated with far future planning horizons. The Massachusetts probabilistic sea level rise projections for Woods Hole are presented in Figure 2-4.

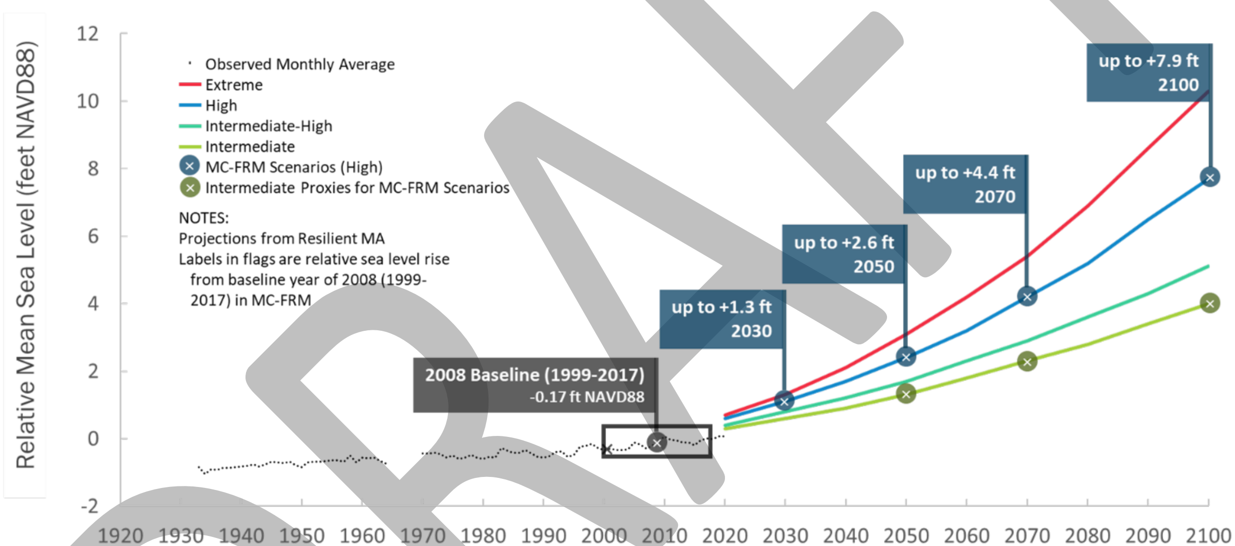


Figure 2-4 Massachusetts sea level rise projections (DeConto & Kopp, 2017)

In this report and in the Woods Hole Village CCVA (Woods Hole Group, 2020b), asset-specific vulnerability assessments were performed by comparing the projected water surface elevation (WSE) to the critical elevation (CE) for the asset. Since both elevations were reported in NAVD88, they could be readily compared to determine if an asset could be flooded under different circumstances and subtracted to determine the depth of flooding above the critical elevation. Figure 2-5 provides a visualization of projected water surface elevations compared to the Woods Hole Drawbridge infrastructure.

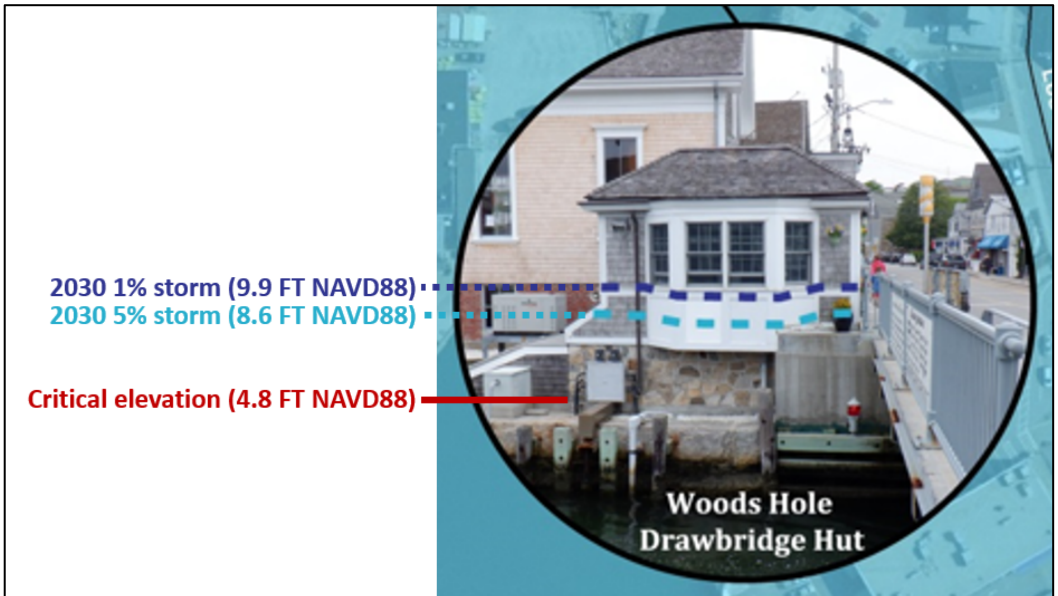


Figure 2-5 Example of vulnerability assessment (WSEs vs. CE)

In this assessment, each projected water surface elevation (WSE) is associated with a certain probability level (chance of flooding during a calendar year). These series of probabilities and WSEs are referred to as coastal flood exceedance probabilities (CFEPs) and presented as 0.1%-100% flood probabilities in the vulnerability assessment tables or "probability of flood exposure" in the vulnerability assessment maps.

2.1 Lifeline Infrastructure

Woods Hole Group evaluated the vulnerability of lifeline infrastructure in the study area to storm surge inundation by comparing MC-FRM projected water surface elevations to asset critical elevations to determine the probability of flooding. Lifeline infrastructure included: the Woods Hole Drawbridge, the Town-owned sewer pump stations, U.S. Coast Guard Station Woods Hole buildings, and the Steamship Authority's proposed buildings and ramps. The Drawbridge and sewer infrastructure were included in the Town of Falmouth CCVA (Woods Hole Group, 2020a), so surveyed critical elevations were compared to projected water surface elevations directly. Critical elevations for the U.S. Coast Guard Station Woods Hole were derived by adding field-measured heights to bare earth elevations extracted from the latest LiDAR data. Critical elevations for the proposed Steamship Authority renovated facilities (buildings and ramps) were derived from reviewing the Woods Hole Ferry Terminal Reconstruction design drawings (dated June 11, 2021).

Probabilities of flooding were determined by comparing these critical elevations to the projected MC-FRM Coastal Flood Exceedance Probability (CFEP) distributions from MC-FRM model nodes used in the Woods Hole Village CCVA (Woods Hole Group, 2020b).

2.2 Residential and Business Structures

Woods Hole Group evaluated the vulnerability of buildings in Woods Hole to storm surge inundation by extracting the maximum probability of flooding within each building footprint (July 2021 MassGIS Building Structures 2-D) in the study area from MC-FRM probability maps. Residential and business (and other) building use was determined with the Land Use Codes listed in the MassGIS Property Tax Parcels dataset, which also differentiates non-profit uses). This building level analysis was supplemented by the Woods Hole Village CCVA (Woods Hole Group, 2020b) results for WHOI/MBL/NOAA buildings (including the CWATER project replacing the existing Iselin facility), the Falmouth CCVA (Woods Hole Group, 2020a) for Town-owned buildings, and the lifelines assessment (Section 2.1) for Steamship Authority and Coast Guard buildings using the critical elevation and CFEP distribution water surface elevation comparison.

2.3 Roadways

Woods Hole Group evaluated the vulnerability of roadways in the study area to storm surge inundation by comparing MC-FRM projected water surface elevations to roadway critical elevations to determine the probability of flooding. Roadway critical elevations were determined by extracting bare earth elevation from the recent LiDAR dataset (2016 USGS CoNED Topobathymetric Model) on a 20-foot interval along road segment centerlines. The road segments used for this assessment were derived from the same source as the Falmouth CCVA (Woods Hole Group, 2020a).

2.4 Flood Pathways

Woods Hole Group evaluated the initial pathways for flooding in the Woods Hole village core. Flood pathways indicate low-lying entry points and conduits for coastal storm surge within the developed and natural landscape. Within the boundaries of the MC-FRM Present Day 1% flood extent, Woods Hole Group used high resolution elevation data to investigate these potential first entry points for flooding to identify strategic points of intervention for low-level storms.

3.0 PHASE 2 VULNERABILITY ASSESSMENT RESULTS

The following sections present the results of the extended Woods Hole vulnerability assessments for lifelines, residential and business structures, roadways, and flood pathways conducted for ResilientWoodsHole Phase 2 in support of future planning and design in Phase 3 (dynamic adaptation pathways).

3.1 Lifeline Infrastructure

Lifeline infrastructure for Woods Hole included Town assets (Woods Hole Drawbridge Hut, Woods Hole Sewer Lift Station, Park Road Sewer Lift Station), U.S. Coast Guard buildings (Small Boat Barn, Hazmat Storage, Large Boat Barn, ANT/ENG, Gatehouse, WPB/Station Woods Hole, Administration, Station Boat House), and Steamship Authority infrastructure (Proposed Terminal Building, Proposed Utility Building, Proposed Ferry Vehicle Ramps). Vulnerability results for lifeline infrastructure are presented in Tables 3-1 through 3-14.

Table 3-1 Woods Hole Drawbridge Hut flooding projections

CE = 4.8 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	11.5	6.8	12.2	7.4	15.0	10.2	17.1	12.3
0.2%	10.7	5.9	11.4	6.6	14.1	9.3	16.2	11.4
0.5%	10.0	5.3	10.8	6.0	13.4	8.6	15.4	10.6
1%	9.1	4.3	9.9	5.1	12.3	7.5	14.3	9.6
2%	8.4	3.6	9.2	4.5	11.5	6.7	13.5	8.7
5%	7.7	2.9	8.6	3.8	10.7	5.9	12.7	7.9
10%	6.7	1.9	7.6	2.9	9.7	4.9	11.6	6.8
20%	5.8	1.1	6.9	2.1	8.8	4.0	10.7	5.9
25%	5.0	0.2	6.1	1.3	7.9	3.1	9.7	5.0
30%	4.7	dry	5.8	1.0	7.6	2.8	9.4	4.6
50%	4.5	dry	5.6	0.8	7.3	2.5	9.1	4.3
100%	3.6	dry	4.8	dry	dry	dry	8.1	3.3

Table 3-2 Woods Hole Sewer Lift Station flooding projections

CE = 8.3 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	11.5	3.1	11.9	3.6	14.8	6.5	17	8.7
0.2%	10.7	2.3	11.2	2.9	13.9	5.6	16.1	7.7
0.5%	10	1.6	10.6	2.3	13.2	4.9	15.3	7.0
1%	9.0	0.7	9.7	1.4	12.2	3.9	14.3	5.9
2%	8.3	dry	9.1	0.8	11.4	3.1	13.4	5.1
5%	7.6	dry	8.4	0.1	10.6	2.3	12.6	4.3
10%	6.6	dry	7.5	dry	9.5	1.2	11.5	3.2
20%	5.8	dry	6.8	dry	8.7	0.4	10.6	2.3
25%	5.0	dry	6.1	dry	7.8	dry	9.7	1.4
30%	4.7	dry	5.8	dry	7.5	dry	9.4	1.0
50%	4.5	dry	5.6	dry	7.2	dry	9.1	0.7
100%	3.6	dry	4.8	dry	6.2	dry	8.1	dry

Table 3-3 Park Road Sewer Lift Station flooding projections

CE = 4.6 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	14.1	9.5	15.4	10.7	17.8	13.2	20.4	15.8
0.2%	13.1	8.5	14.4	9.8	16.7	12.1	19.2	14.6
0.5%	12.4	7.7	13.6	9.0	15.8	11.2	18.3	13.7
1%	11.3	6.7	12.5	7.9	14.5	9.9	16.9	12.3
2%	10.5	5.8	11.7	7.0	13.6	9.0	15.9	11.3
5%	9.6	5.0	10.8	6.2	12.6	8.0	14.9	10.2
10%	8.5	3.9	9.7	5.0	11.3	6.7	13.5	8.8
20%	7.6	3.0	8.8	4.1	10.2	5.6	12.4	7.7
25%	6.6	2.0	7.8	3.2	9.1	4.5	11.2	6.5
30%	6.3	1.7	7.4	2.8	8.7	4.1	10.7	6.1
50%	6	1.4	7.1	2.5	8.4	3.8	10.4	5.7
100%	4.9	0.3	6.1	1.4	7.2	2.6	9.1	4.5

Table 3-4 USCG Small Boat Barn flooding projections

CE = 6.9 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	10.3	3.4	11.5	4.6	14.7	7.8	16.7	9.8
0.2%	9.6	2.7	10.8	3.9	13.9	7.0	15.9	9.0
0.5%	8.7	1.8	9.9	3.0	12.8	5.9	14.7	7.8
1%	8.0	1.1	9.3	2.4	11.9	5.0	13.9	7.0
2%	7.4	0.5	8.6	1.7	11.1	4.2	13.0	6.1
5%	6.5	dry	7.7	0.8	9.9	3.0	11.9	5.0
10%	5.8	dry	7.0	0.1	9.1	2.2	10.9	4.0
20%	5.0	dry	6.2	dry	8.1	1.2	10.0	3.1
25%	4.7	dry	5.9	dry	7.8	0.9	9.6	2.7
30%	4.5	dry	5.7	dry	7.5	0.6	9.3	2.4
50%	3.7	dry	4.9	dry	6.5	dry	8.3	1.4
100%	1.9	dry	3.1	dry	4.2	dry	6.0	dry

Table 3-5 USCG Hazmat Storage flooding projections

CE = 5.1 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	10.3	5.2	11.5	6.4	14.7	9.6	16.7	11.6
0.2%	9.6	4.5	10.8	5.7	13.9	8.8	15.9	10.8
0.5%	8.7	3.6	9.9	4.8	12.8	7.7	14.7	9.6
1%	8.0	2.9	9.3	4.2	11.9	6.8	13.9	8.8
2%	7.4	2.3	8.6	3.5	11.1	6.0	13.0	7.9
5%	6.5	1.4	7.7	2.6	9.9	4.8	11.9	6.8
10%	5.8	0.7	7.0	1.9	9.1	4.0	10.9	5.8
20%	5.0	dry	6.2	1.1	8.1	3.0	10.0	4.9
25%	4.7	dry	5.9	0.8	7.8	2.7	9.6	4.5
30%	4.5	dry	5.7	0.6	7.5	2.4	9.3	4.2
50%	3.7	dry	4.9	dry	6.5	1.4	8.3	3.2
100%	1.9	dry	3.1	dry	4.2	dry	6.0	0.9

Table 3-6 USCG Large Boat Barn flooding projections

CE = 7.8 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	10.3	2.5	11.5	3.7	14.7	6.9	16.7	8.9
0.2%	9.6	1.8	10.8	3.0	13.9	6.1	15.9	8.1
0.5%	8.7	0.9	9.9	2.1	12.8	5.0	14.7	6.9
1%	8.0	0.2	9.3	1.5	11.9	4.1	13.9	6.1
2%	7.4	dry	8.6	0.8	11.1	3.3	13.0	5.2
5%	6.5	dry	7.7	dry	9.9	2.1	11.9	4.1
10%	5.8	dry	7.0	dry	9.1	1.3	10.9	3.1
20%	5.0	dry	6.2	dry	8.1	0.3	10.0	2.2
25%	4.7	dry	5.9	dry	7.8	0.0	9.6	1.8
30%	4.5	dry	5.7	dry	7.5	dry	9.3	1.5
50%	3.7	dry	4.9	dry	6.5	dry	8.3	0.5
100%	1.9	dry	3.1	dry	4.2	dry	6.0	dry

Table 3-7 USCG ANT/ENG flooding projections

CE = 15.2 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	10.3	dry	11.5	dry	14.7	dry	16.7	1.53
0.2%	9.6	dry	10.8	dry	13.9	dry	15.9	0.73
0.5%	8.7	dry	9.9	dry	12.8	dry	14.7	dry
1%	8	dry	9.3	dry	11.9	dry	13.9	dry
2%	7.4	dry	8.6	dry	11.1	dry	13	dry
5%	6.5	dry	7.7	dry	9.9	dry	11.9	dry
10%	5.8	dry	7	dry	9.1	dry	10.9	dry
20%	5	dry	6.2	dry	8.1	dry	10	dry
25%	4.7	dry	5.9	dry	7.8	dry	9.6	dry
30%	4.5	dry	5.7	dry	7.5	dry	9.3	dry
50%	3.7	dry	4.9	dry	6.5	dry	8.3	dry
100%	1.9	dry	3.1	dry	4.2	dry	6	dry

Table 3-8 USCG Gatehouse flooding projections

CE = 8.0 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	10.3	2.3	11.5	3.5	14.7	6.7	16.7	8.7
0.2%	9.6	1.6	10.8	2.8	13.9	5.9	15.9	7.9
0.5%	8.7	0.7	9.9	1.9	12.8	4.8	14.7	6.7
1%	8.0	dry	9.3	1.3	11.9	3.9	13.9	5.9
2%	7.4	dry	8.6	0.6	11.1	3.1	13.0	5.0
5%	6.5	dry	7.7	dry	9.9	1.9	11.9	3.9
10%	5.8	dry	7.0	dry	9.1	1.1	10.9	2.9
20%	5.0	dry	6.2	dry	8.1	0.1	10.0	2.0
25%	4.7	dry	5.9	dry	7.8	dry	9.6	1.6
30%	4.5	dry	5.7	dry	7.5	dry	9.3	1.3
50%	3.7	dry	4.9	dry	6.5	dry	8.3	0.3
100%	1.9	dry	3.1	dry	4.2	dry	6.0	dry

Table 3-9 USCG WPB/Station Woods Hole flooding projections

CE = 14.1 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	10.3	dry	11.5	dry	14.7	0.6	16.7	2.6
0.2%	9.6	dry	10.8	dry	13.9	dry	15.9	1.8
0.5%	8.7	dry	9.9	dry	12.8	dry	14.7	0.6
1%	8.0	dry	9.3	dry	11.9	dry	13.9	dry
2%	7.4	dry	8.6	dry	11.1	dry	13.0	dry
5%	6.5	dry	7.7	dry	9.9	dry	11.9	dry
10%	5.8	dry	7.0	dry	9.1	dry	10.9	dry
20%	5.0	dry	6.2	dry	8.1	dry	10.0	dry
25%	4.7	dry	5.9	dry	7.8	dry	9.6	dry
30%	4.5	dry	5.7	dry	7.5	dry	9.3	dry
50%	3.7	dry	4.9	dry	6.5	dry	8.3	dry
100%	1.9	dry	3.1	dry	4.2	dry	6.0	dry

Table 3-10 USCG Administration flooding projections

CE = 7.7 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	10.3	2.6	11.5	3.8	14.7	7.0	16.7	9.0
0.2%	9.6	1.9	10.8	3.1	13.9	6.2	15.9	8.2
0.5%	8.7	1.0	9.9	2.2	12.8	5.1	14.7	7.0
1%	8.0	0.3	9.3	1.6	11.9	4.2	13.9	6.2
2%	7.4	dry	8.6	0.9	11.1	3.4	13.0	5.3
5%	6.5	dry	7.7	0.0	9.9	2.2	11.9	4.2
10%	5.8	dry	7.0	dry	9.1	1.4	10.9	3.2
20%	5.0	dry	6.2	dry	8.1	0.4	10.0	2.3
25%	4.7	dry	5.9	dry	7.8	0.1	9.6	1.9
30%	4.5	dry	5.7	dry	7.5	dry	9.3	1.6
50%	3.7	dry	4.9	dry	6.5	dry	8.3	0.6
100%	1.9	dry	3.1	dry	4.2	dry	6.0	dry

Table 3-11 USCG Station Boat House flooding projections

CE = 3.5 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	10.3	6.8	11.5	8.0	14.7	11.2	16.7	13.2
0.2%	9.6	6.1	10.8	7.3	13.9	10.4	15.9	12.4
0.5%	8.7	5.2	9.9	6.4	12.8	9.3	14.7	11.2
1%	8.0	4.5	9.3	5.8	11.9	8.4	13.9	10.4
2%	7.4	3.9	8.6	5.1	11.1	7.6	13.0	9.5
5%	6.5	3.0	7.7	4.2	9.9	6.4	11.9	8.4
10%	5.8	2.3	7.0	3.5	9.1	5.6	10.9	7.4
20%	5.0	1.5	6.2	2.7	8.1	4.6	10.0	6.5
25%	4.7	1.2	5.9	2.4	7.8	4.3	9.6	6.1
30%	4.5	1.0	5.7	2.2	7.5	4.0	9.3	5.8
50%	3.7	0.2	4.9	1.4	6.5	3.0	8.3	4.8
100%	1.9	dry	3.1	dry	4.2	0.7	6.0	2.5

Table 3-12 Steamship Authority Proposed Terminal Building flooding projections

CE = 13.0 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	10.7	dry	11.8	dry	14.5	1.5	16.6	3.6
0.2%	10	dry	11.1	dry	13.7	0.7	15.7	2.7
0.5%	8.8	dry	10	dry	12.6	dry	14.6	1.6
1%	8.1	dry	9.3	dry	11.8	dry	13.8	0.8
2%	7.4	dry	8.6	dry	10.9	dry	12.9	dry
5%	6.5	dry	7.7	dry	9.8	dry	11.8	dry
10%	5.8	dry	7	dry	9	dry	10.9	dry
20%	5	dry	6.2	dry	8	dry	9.9	dry
25%	4.7	dry	5.9	dry	7.7	dry	9.6	dry
30%	4.5	dry	5.7	dry	7.4	dry	9.3	dry
50%	3.7	dry	4.8	dry	6.4	dry	8.3	dry
100%	2.1	dry	3.3	dry	4.6	dry	6.4	dry

Table 3-13 Steamship Authority Proposed Utility Building flooding projections

CE = 10.5 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	10.7	0.2	11.8	1.3	14.5	4	16.6	6.1
0.2%	10	dry	11.1	0.6	13.7	3.2	15.7	5.2
0.5%	8.8	dry	10	dry	12.6	2.1	14.6	4.1
1%	8.1	dry	9.3	dry	11.8	1.3	13.8	3.3
2%	7.4	dry	8.6	dry	10.9	0.4	12.9	2.4
5%	6.5	dry	7.7	dry	9.8	dry	11.8	1.3
10%	5.8	dry	7	dry	9	dry	10.9	0.4
20%	5	dry	6.2	dry	8	dry	9.9	dry
25%	4.7	dry	5.9	dry	7.7	dry	9.6	dry
30%	4.5	dry	5.7	dry	7.4	dry	9.3	dry
50%	3.7	dry	4.8	dry	6.4	dry	8.3	dry
100%	2.1	dry	3.3	dry	4.6	dry	6.4	dry

Table 3-14 Steamship Authority Proposed Ferry Vehicle Ramps flooding projections

CE = 9.0 ft NAVD88	Present		2030		2050		2070	
	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)	Flood Elevation NAVD88 (ft)	Depth Above Critical Elev. (ft)
0.1%	10.7	1.7	11.8	2.8	14.5	5.5	16.6	7.6
0.2%	10	1	11.1	2.1	13.7	4.7	15.7	6.7
0.5%	8.8	dry	10	1	12.6	3.6	14.6	5.6
1%	8.1	dry	9.3	0.3	11.8	2.8	13.8	4.8
2%	7.4	dry	8.6	dry	10.9	1.9	12.9	3.9
5%	6.5	dry	7.7	dry	9.8	0.8	11.8	2.8
10%	5.8	dry	7	dry	9	0	10.9	1.9
20%	5	dry	6.2	dry	8	dry	9.9	0.9
25%	4.7	dry	5.9	dry	7.7	dry	9.6	0.6
30%	4.5	dry	5.7	dry	7.4	dry	9.3	0.3
50%	3.7	dry	4.8	dry	6.4	dry	8.3	dry
100%	2.1	dry	3.3	dry	4.6	dry	6.4	dry

3.2 Residential and Business Structures

Within the Woods Hole study area (Figure 2-2) there are 1,089 structures documented in the MassGIS database. Of these 1,089 structures, land use codes indicate that 879 are residential, 28 are business (including 4 Steamship Authority buildings classified as lifeline infrastructure), 10 are federal government (USGC buildings classified as lifeline infrastructure), and 19 are non-profit (other than those owned by WHOI, MBL, or NOAA). A total of 153 buildings are owned by the ResilientWoodsHole project partners (WHOI, MBL, and NOAA).

Results of the structures vulnerability assessment are summarized in Figures 3-1 through 3-4 and Table 3-15.

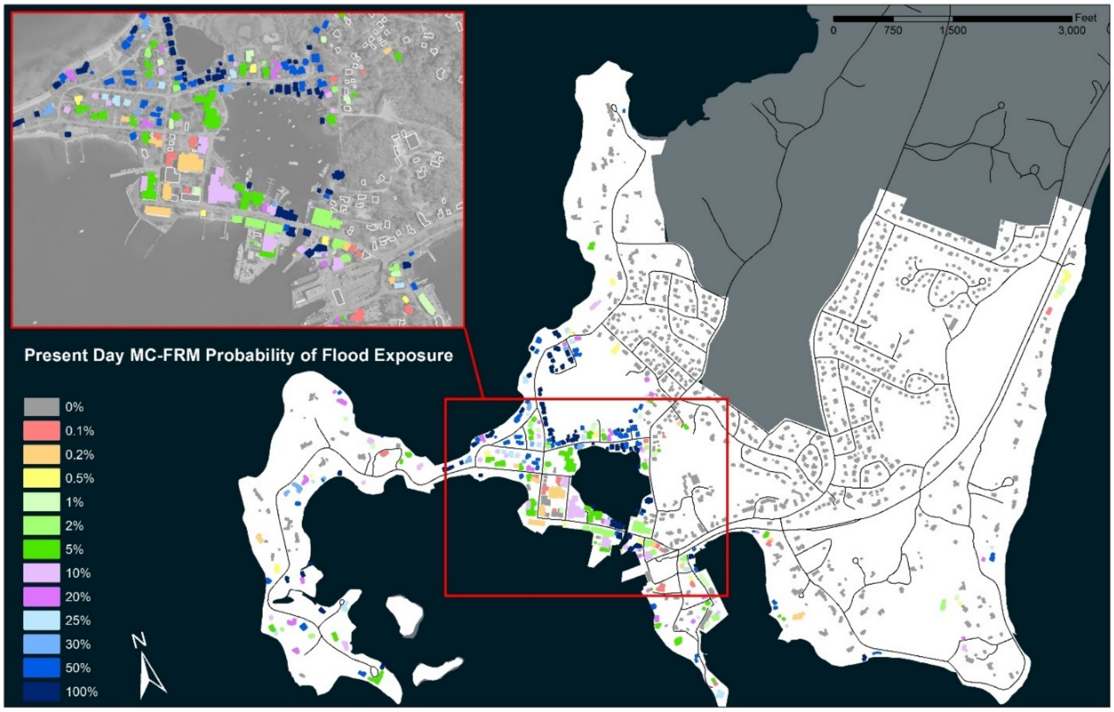


Figure 3-1 Building flooding projections – Present Day

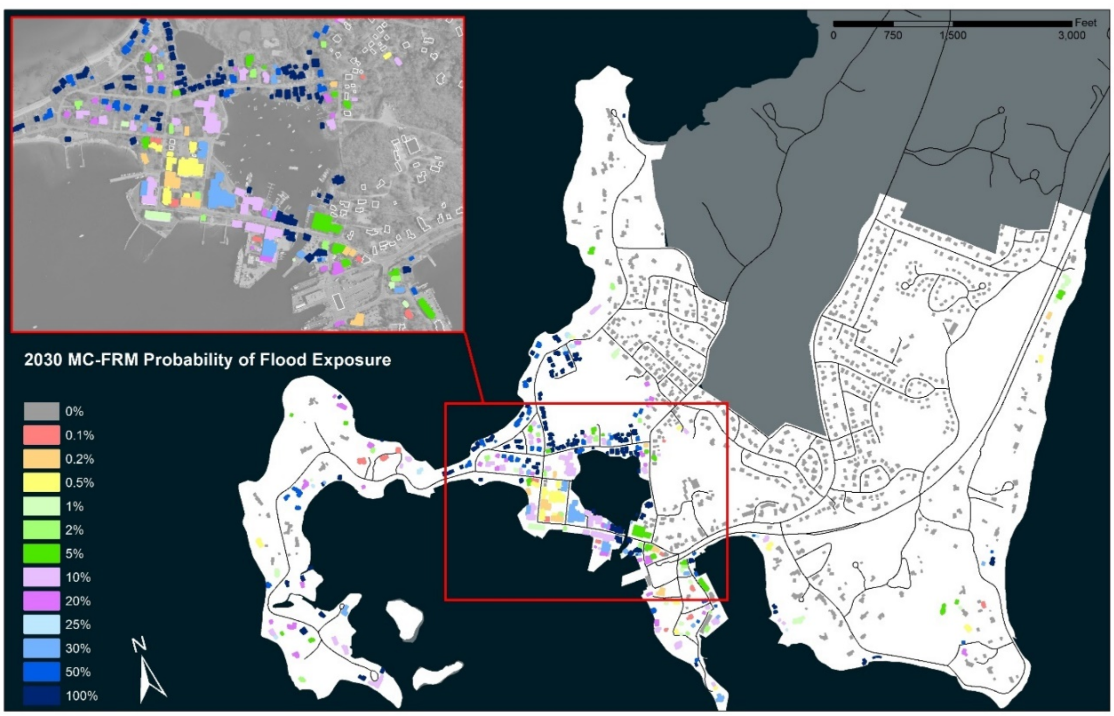


Figure 3-2 Building flooding projections – 2030

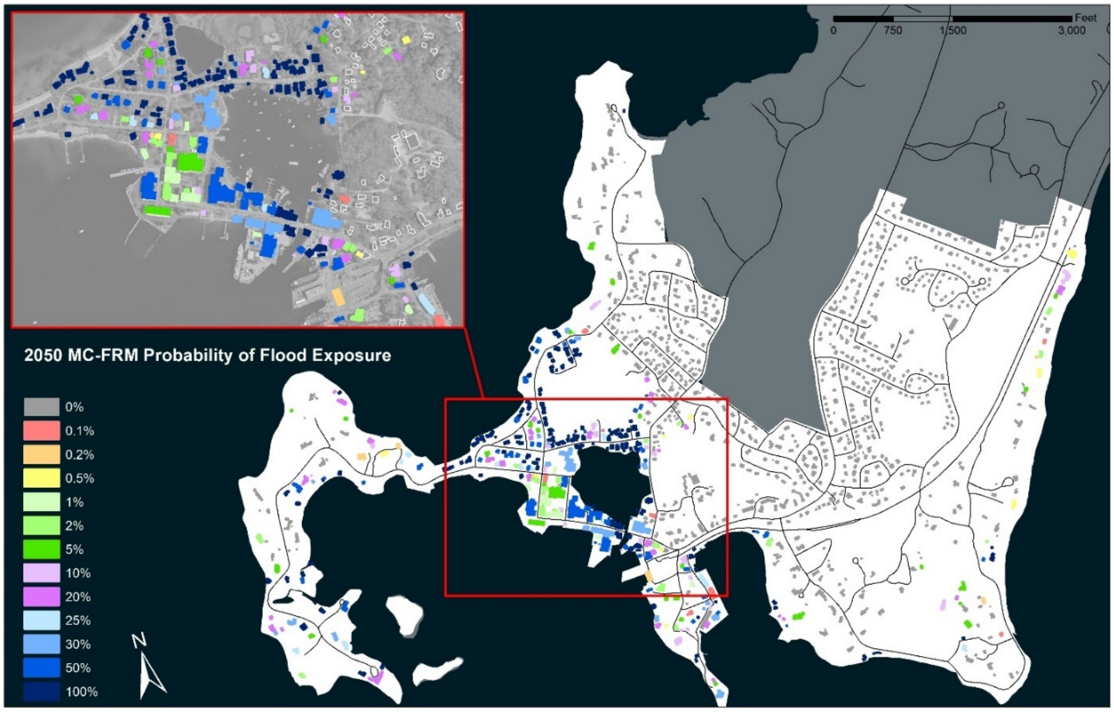


Figure 3-3 Building flooding projections – 2050

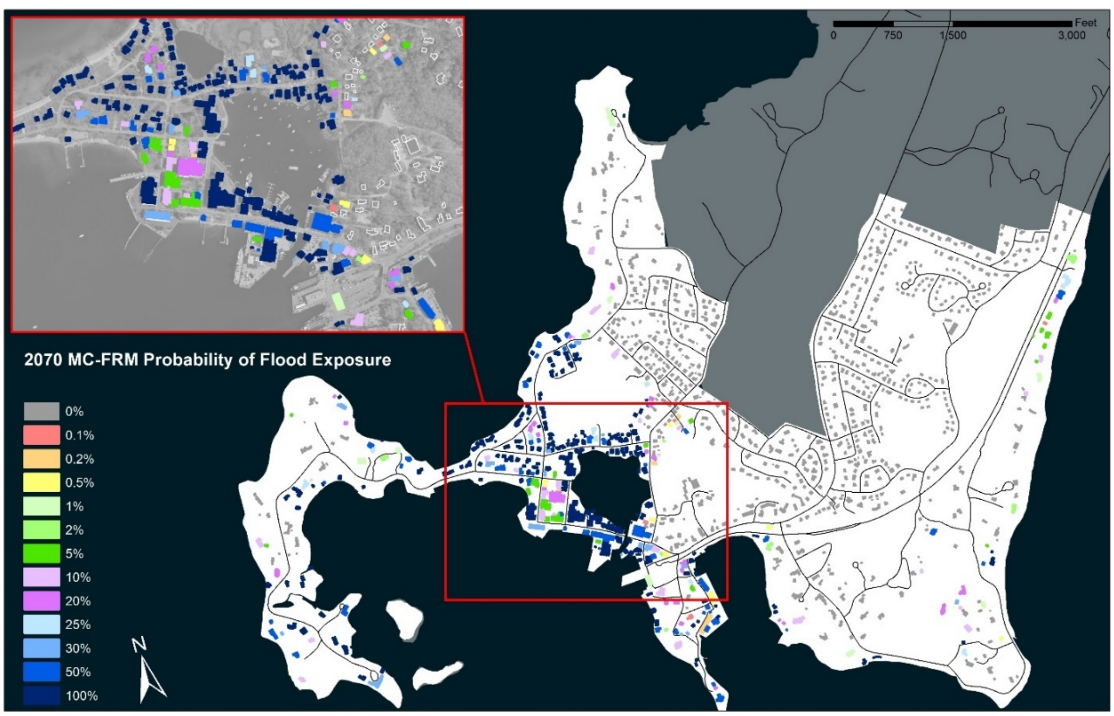


Figure 3-4 Building flooding projections – 2070

Under Present conditions, a 1% chance event would expose:

- 27/153 WHOI/MBL/NOAA buildings,
- 10/14 lifeline buildings,
- 14/24 business buildings,
- 220/879 residential buildings, and
- 6/19 non-profit buildings.

Under 2030 conditions, a 1% chance event would expose:

- 31/153 WHOI/MBL/NOAA buildings,
- 10/14 lifeline buildings,
- 15/24 business buildings,
- 238/879 residential buildings, and
- 7/19 non-profit buildings.

Under 2050 conditions, a 1% chance event would expose:

- 44/153 WHOI/MBL/NOAA buildings,
- 11/14 lifeline buildings,
- 17/24 business buildings,
- 257/879 residential buildings, and
- 7/19 non-profit buildings.

Under 2070 conditions, a 1% chance event would expose:

- 44/153 WHOI/MBL/NOAA buildings,
- 12/14 lifeline buildings,
- 18/24 business buildings,
- 281/879 residential buildings, and
- 7/19 non-profit buildings.

Table 3-15 Summary (counts) of flooding by building type and probability

	Present					2030					2050					2070				
	WHOI-MBL-NOAA	Lifelines	Business	Residential	Non-Profit	WHOI-MBL-NOAA	Lifelines	Business	Residential	Non-Profit	WHOI-MBL-NOAA	Lifelines	Business	Residential	Non-Profit	WHOI-MBL-NOAA	Lifelines	Business	Residential	Non-Profit
0%	117	3	6	634	12	110	3	6	616	12	107	1	6	604	12	104	0	5	590	12
0.1%	36	11	18	245	7	43	11	18	263	7	46	13	18	275	7	49	14	19	289	7
0.2%	33	10	16	237	7	41	11	17	253	7	44	12	18	270	7	48	14	19	286	7
0.5%	28	10	15	230	7	36	10	15	251	7	44	11	18	265	7	46	13	19	285	7
1%	27	10	14	220	6	31	10	15	238	7	44	11	17	257	7	44	12	18	281	7
2%	25	7	14	211	6	28	10	15	225	7	37	11	17	256	7	44	11	18	273	7
5%	19	6	12	205	5	25	8	14	217	6	32	10	15	243	7	44	11	17	265	7
10%	8	5	12	178	4	23	7	12	203	5	29	10	15	219	7	37	11	17	250	7
20%	1	4	10	162	4	10	6	12	178	4	24	9	14	206	5	32	10	15	232	7
25%	1	2	8	137	4	8	4	9	151	4	24	8	12	180	4	30	10	15	210	6
30%	1	1	7	120	4	8	4	9	143	4	24	7	11	170	4	30	10	15	200	5
50%	1	1	6	110	4	1	3	7	132	4	15	6	11	158	4	26	10	13	190	5
100%	1	0	6	55	3	1	0	6	94	4	1	3	8	122	4	19	6	12	153	4

3.3 Roadways

Within the Woods Hole study area (Figure 2-2) there are 20.6 miles of roadway and bikepath. Results of the roadways vulnerability assessment are summarized in Figures 3-5 through 3-8 and Table 3-16.

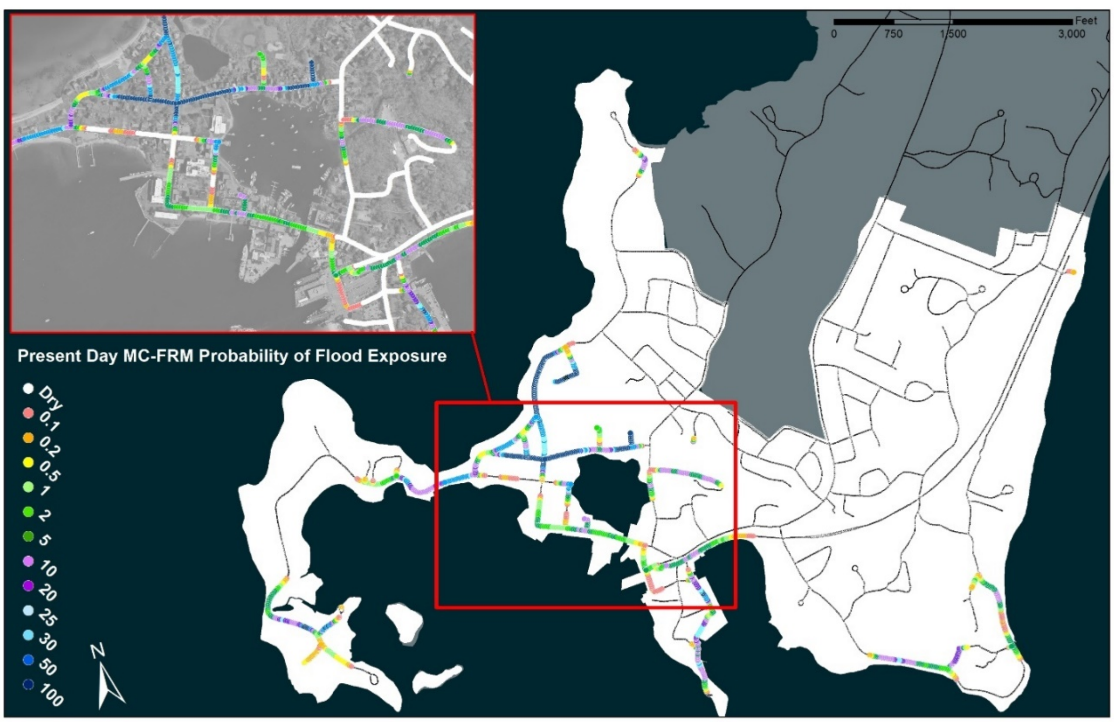


Figure 3-5 Roadway flooding projections – Present Day

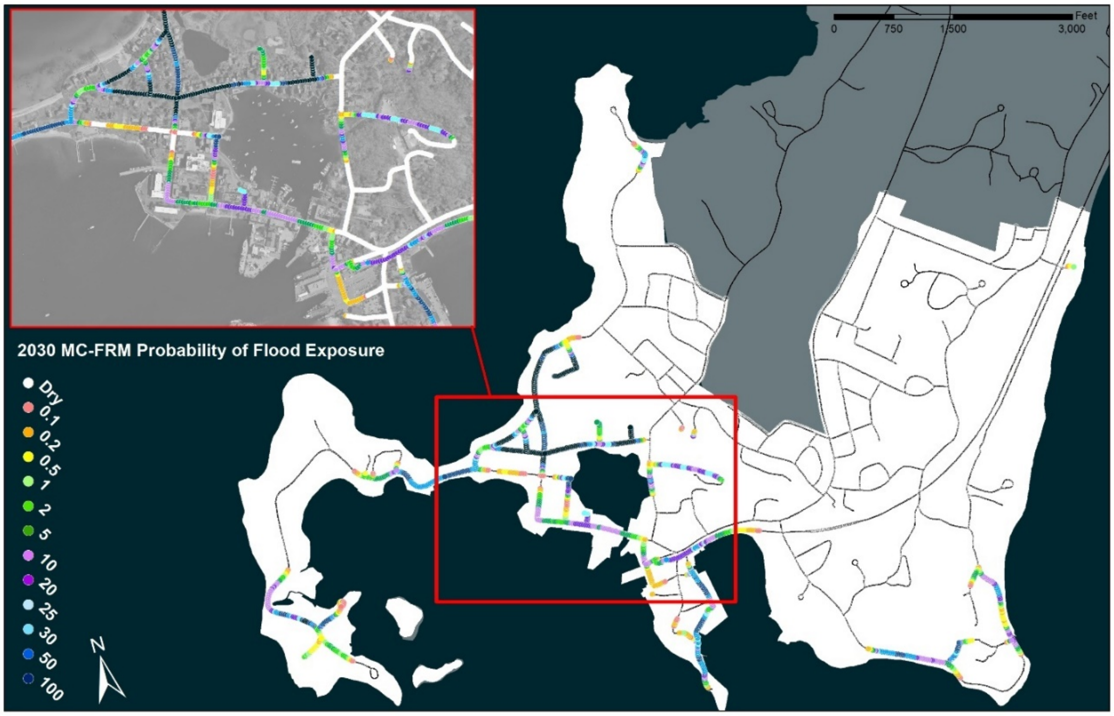


Figure 3-6 Roadway flooding projections – 2030

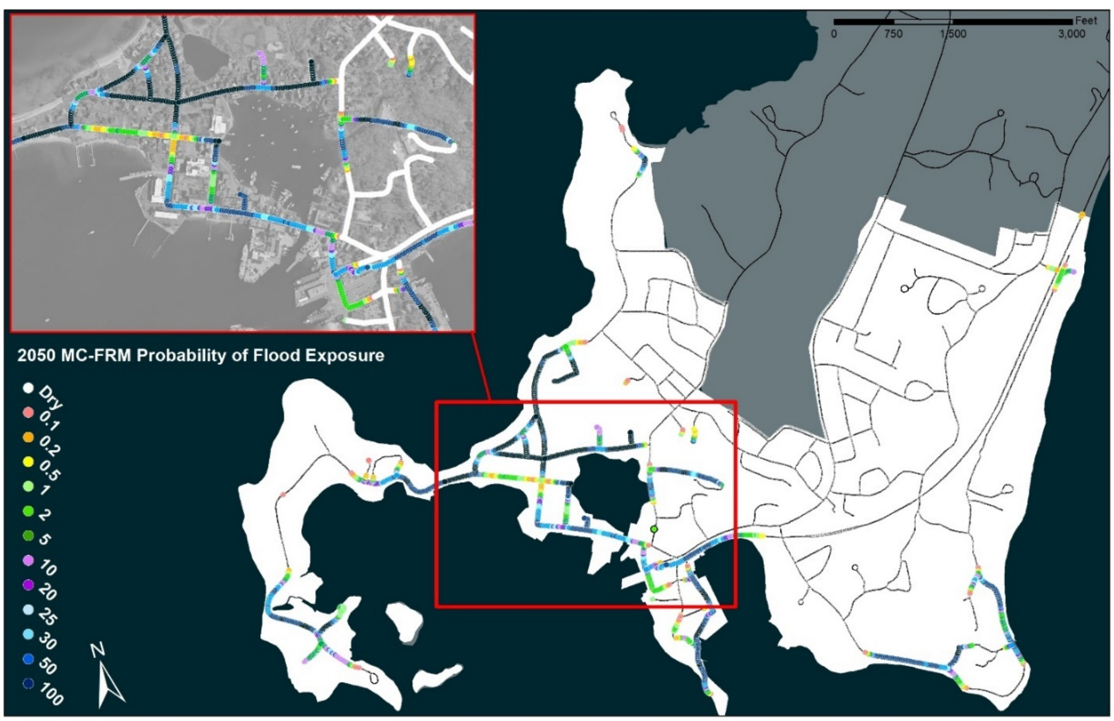


Figure 3-7 Roadway flooding projections – 2050

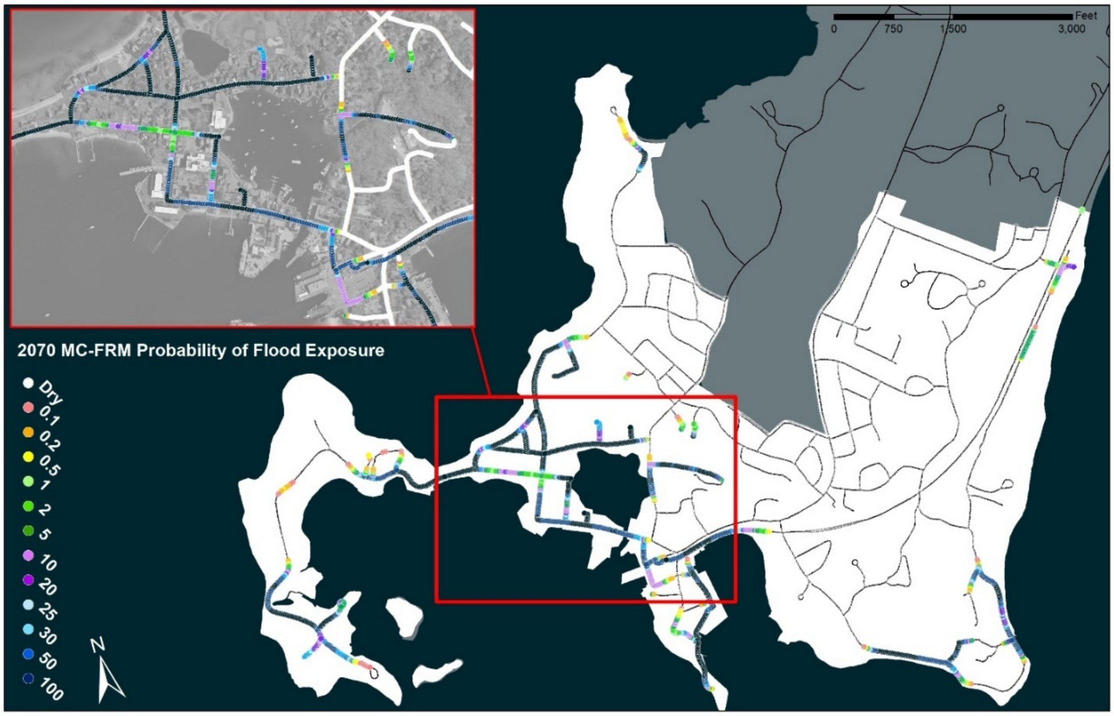


Figure 3-8 Roadway flooding projections – 2070

Most of the vulnerable roadways are in the low-lying portion of the village core surrounding Eel Pond, with notable existing high probabilities of inundation along Gardiner Road, Spencer Baird Road, Gardiner Road, Gosnold Road, Park Road, and Bar Neck Road. As climate conditions evolve, other future high vulnerability roadways include Water Street, MBL Street, and Albatross Street in the village core, and low points at Gardiner Point and Penzance Point, low-lying segments of Church Street and Nobska Road surrounding Nobska Point, Little Harbor Road, and Hickley Road outside the village core. MC-FRM storm surge projections indicate that:

- a Present Day 1% chance event would expose 3.5 miles of roadway,
- a 2030 1% chance event would expose 4.0 miles of roadway,
- a 2050 1% chance event would expose 4.9 miles of roadway, and
- a 2070 1% chance event would expose 5.4 miles of roadway.

Table 3-16 Summary (miles) of roadway flooding by probability

	Present	2030	2050	2070
0.1%	4.5	4.8	5.4	5.8
0.2%	4.2	4.6	5.2	5.7
0.5%	3.8	4.3	5.1	5.5
1%	3.5	4.0	4.9	5.4
2%	3.2	3.7	4.6	5.2
5%	2.7	3.3	4.2	5.0
10%	2.0	2.9	3.8	4.6
20%	1.3	2.3	3.4	4.2
25%	1.1	1.9	3.2	4.0
30%	0.9	1.7	3.0	3.8
50%	0.6	1.1	2.4	3.5
100%	0.0	0.7	1.1	2.3

3.4 Flood Pathways

The flood pathways analysis (Figure 3-9) indicates multiple points of entry for flooding in the low-lying village core. Initial incursion at ~3.0 ft NAVD88 occurs over Gardiner Road into Mill Pond and the Woods Hole Park area wetlands, affecting homes along Gardiner Road. Secondary incursion of flooding occurs along Millfield Road, both from the north via the Woods Hole Park wetlands and Mill Pond, as well as from the south via Eel Pond. At ~4.0 ft NAVD88, flooding encroaches on the eastern portion of Millfield Road. At ~4.5 ft NAVD88, flooding overtops Mill Pond from the north and Eel Pond from the south near the Bell Tower and Swope, affecting western portions of Millfield Road and flowing west along Spencer Baird Road. Similar flood levels can also inundate Bar Neck Road, restricting access to Penzance Point. Tertiary incursion of flooding at ~5.6 and ~6.0 ft NAVD88 affect the commercial and institutional corridor. At these levels, storm surge can flow under Crane Street via the Bike Path affecting the Steamship Authority lot, up around Dyers Dock, throughout the parking lot behind Lillie Laboratory, and eventually along Water Street from Lillie and the NOAA campus.

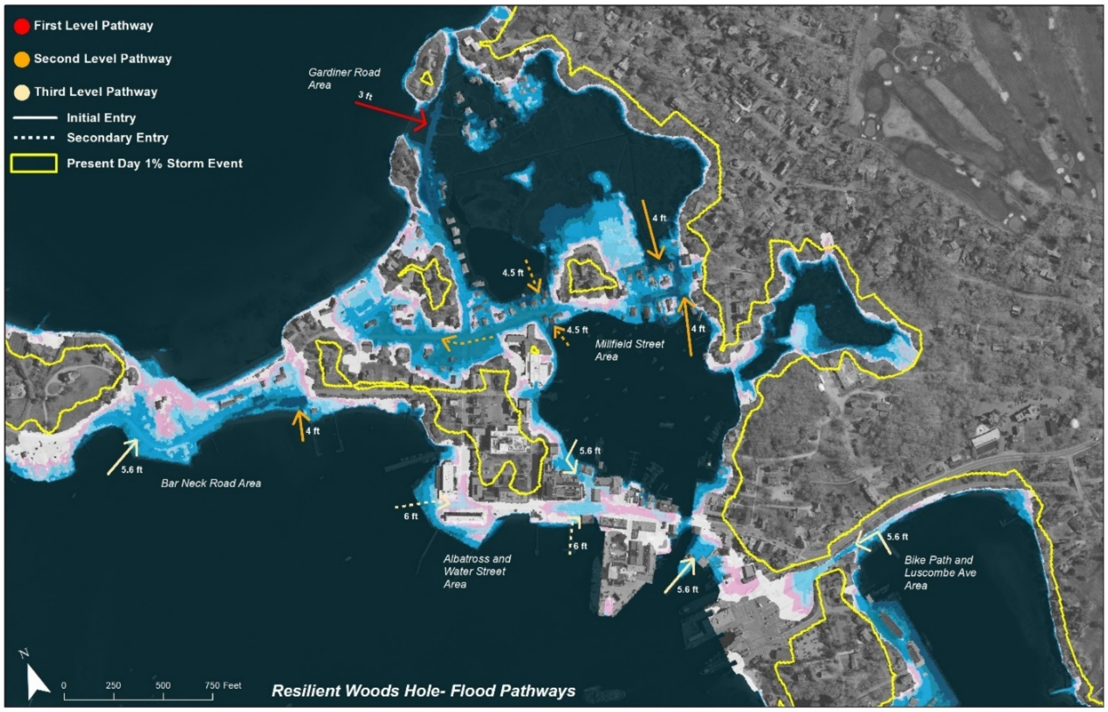


Figure 3-9 Flood pathways analysis

4.0 PHASE 2 ADAPTATION PLANS

Adaptation plans were advanced in ResilientWoodsHole Phase 2 in order to inform short term and long term institutional planning. High Priority Asset adaptations were explored to assist WHOI, MBL and NOAA in identifying immediately implementable actions to reduce asset inundation exposure. Phase 1 district-level adaptation concepts for WHOI (Smith and Bigelow) and MBL (Eel Pond Triangle) were refined to advance longer term incremental and modular approaches. Finally, new district-level adaptation concepts were drafted to explore potential additional solutions for WHOI (Redfield) and MBL (Swope and Ebert Hall).

All High Priority Asset adaptations and district-level adaptation concepts developed/refined in Phases 1 and 2 were preliminary concepts to initiate internal discussions and planning at WHOI, MBL and NOAA regarding climate change planning. These concepts do not represent any institution's final plan to address flooding concerns in Woods Hole, but rather a first step towards addressing their own assets. In ResilientWoodsHole Phase 3, adaptation planning will be outward-facing and collaborative by necessity, integrating planning across the institutions and the community, since flooding concerns will increasingly impact a wide array of institutional, municipal, commercial and private infrastructure that must all align in terms of adaptation strategies to maintain function in Woods Hole over time.

4.1 High Priority Asset Adaptations

Several potential solutions were explored for adapting WHOI, MBL, and NOAA facilities and assets in the near term using strategic and focused strategies to reduce or eliminate exposure to storm surge for high priority assets. The intent was to identify 'low-hanging fruit' such that each institution could reduce critical vulnerabilities with minimal investment. In some cases, due to the complex nature of flood exposure and facility design, such simple and targeted solutions were not immediately identified. Further investigation and discussion may ultimately provide additional targeted solutions.

Asset adaptations explored for WHOI, MBL and NOAA are summarized in Appendix A. Facilities managers from each institution prioritized three adaptations for presentation below.

4.1.1 WHOI High Priority Asset Adaptations

A solution to protect Smith Room 108, which contains chiller and boiler infrastructure is diagrammed in Figure 4-1. This approach uses building floodproofing techniques and two deployable door barriers to seal off exterior and interior flooding from this critical infrastructure area.

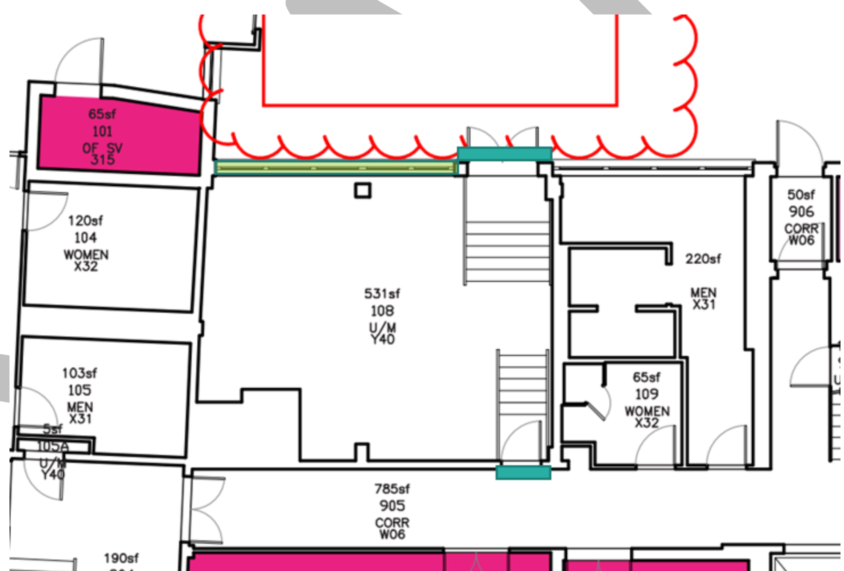


Figure 4-1 Smith 108 Adaptation Diagram

A solution to protect Smith Rooms 113/113A/113B, which contain generator and switchgear infrastructure is diagrammed in Figure 4-2. This approach uses building floodproofing techniques and two deployable door barriers to seal off exterior and interior flooding from this critical infrastructure area.

Figure 4-2 Smith 113/113A/113B Adaptation Diagram

A solution to protect Bigelow Room G-1, which contains chiller and boiler infrastructure is diagrammed in Figure 4-3. This approach uses deployable flood barriers (e.g. Aquafence) and one deployable door barrier to seal off exterior and interior flooding from this critical infrastructure area. Additionally, this solution requires a duckbill or valve to be installed on a drain pipe on the Iselin bulkhead to prevent backups into the facility.

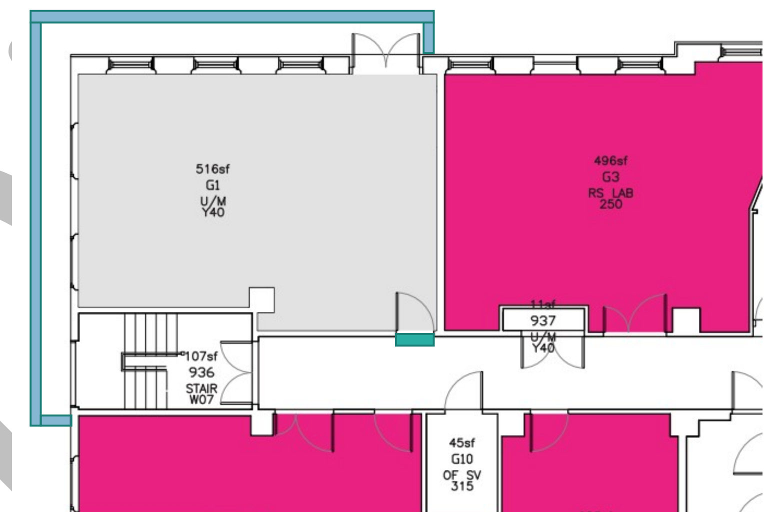


Figure 4-3 Bigelow G1 Adaptation Diagram

4.1.2 MBL High Priority Asset Adaptations

A solution to protect the Seawater Pump House, which contains pump infrastructure supplying seawater to MBL labs, is diagrammed in Figure 4-4. This approach uses building floodproofing techniques and one deployable door barrier to seal off exterior flooding from this critical infrastructure.

Figure 4-4 Seawater Pump House Adaptation Diagram

A solution to protect Lillie Laboratory is diagrammed in Figure 4-5. This approach uses building floodproofing techniques (including door and window barriers) and deployable flood barriers (e.g. Aquafence) to seal off exterior flooding from this facility. If district-level solutions are implemented that include Lillie, flood barrier components of this solution could be repurposed in other areas of the campus.

Figure 4-5 Lillie Laboratory Adaptation Diagram

A solution to protect Loeb Laboratory is diagrammed in Figure 4-6. This approach uses a landscape wall and a deployable walkway barriers to seal off exterior flooding from this facility.

Figure 4-6 Loeb Laboratory Adaptation Diagram

4.1.3 NOAA High Priority Asset Adaptations

A solution to protect the Gear Shed / Aquarium Basement Vent is diagrammed in Figure 4-7. This approach uses a masonry wall to seal off Gear Shed flooding from getting into the Aquarium Basement, where pumps and water treatment systems are located.

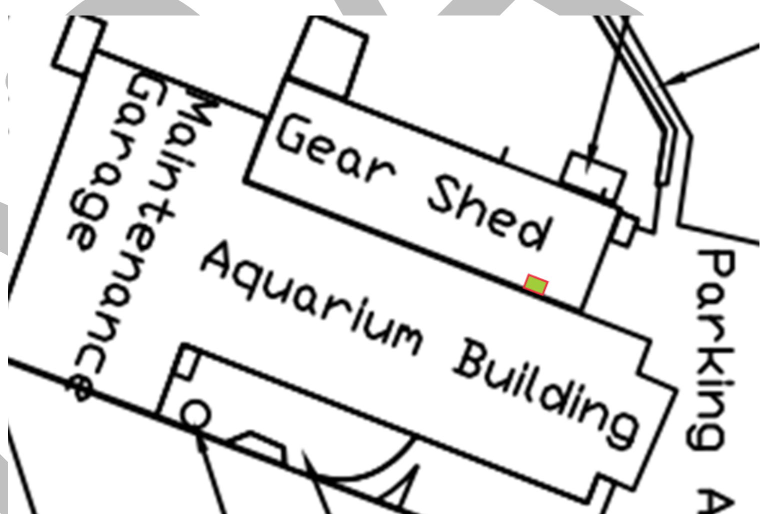


Figure 4-7 Gear Shed / Aquarium Basement Vent Adaptation Diagram

A solution to protect the Seawater Pump/Tank and Hazmat Storage Sheds is diagrammed in Figure 4-8. This approach uses deployable flood barriers (e.g. Aquafence) tied into the Main Office to seal off exterior flooding from these assets. If district-level solutions are implemented that protect these assets, flood barrier components of this solution could be repurposed in other areas of the campus.

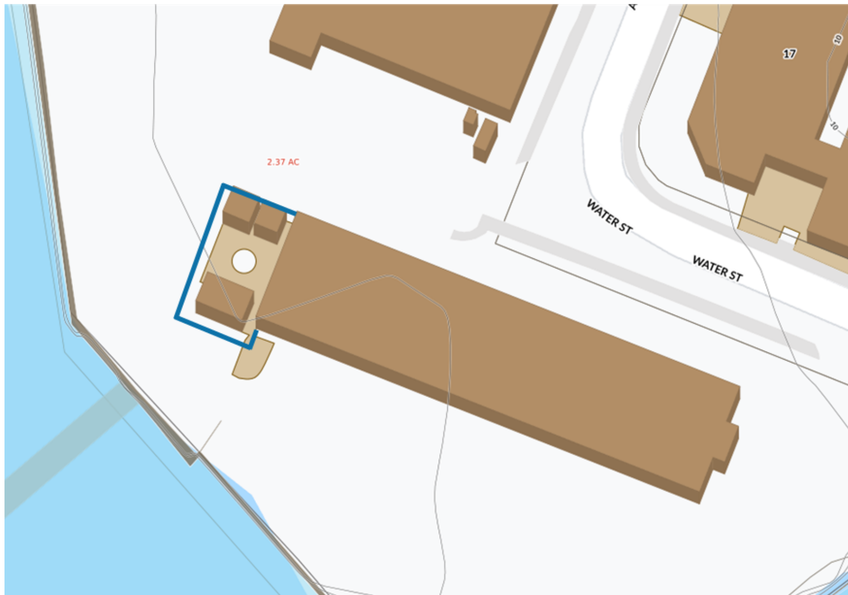


Figure 4-8 Seawater Pump/Tank and Hazmat Storage Sheds Adaptation Diagram

A solution to protect the Aquarium Salt Water Drain is diagrammed in Figure 4-9. This approach uses a duckbill or valve installed on a drain pipe on the Small Vessel bulkhead and manhole sealing measures to prevent backups into the facility.

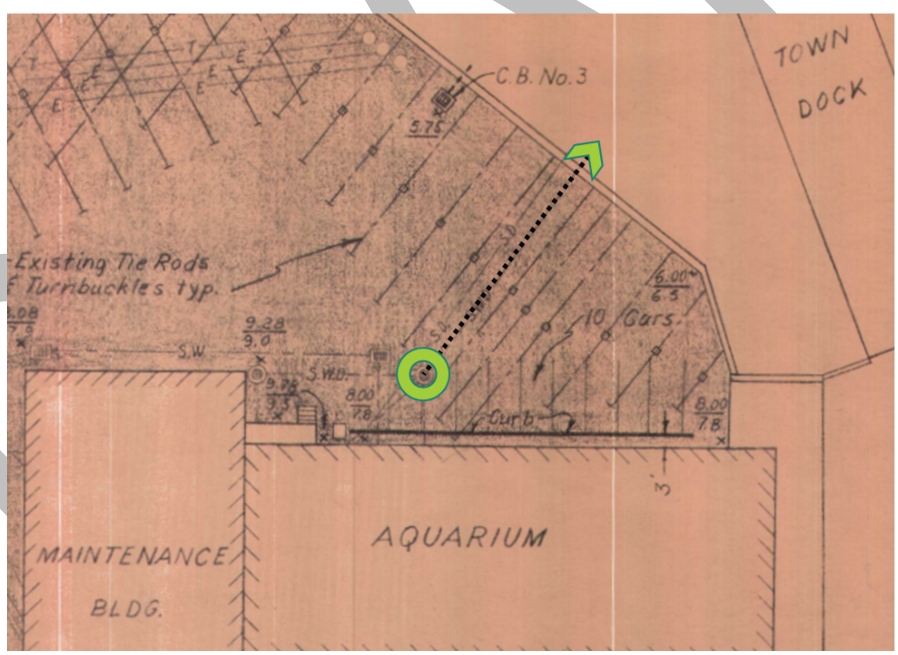


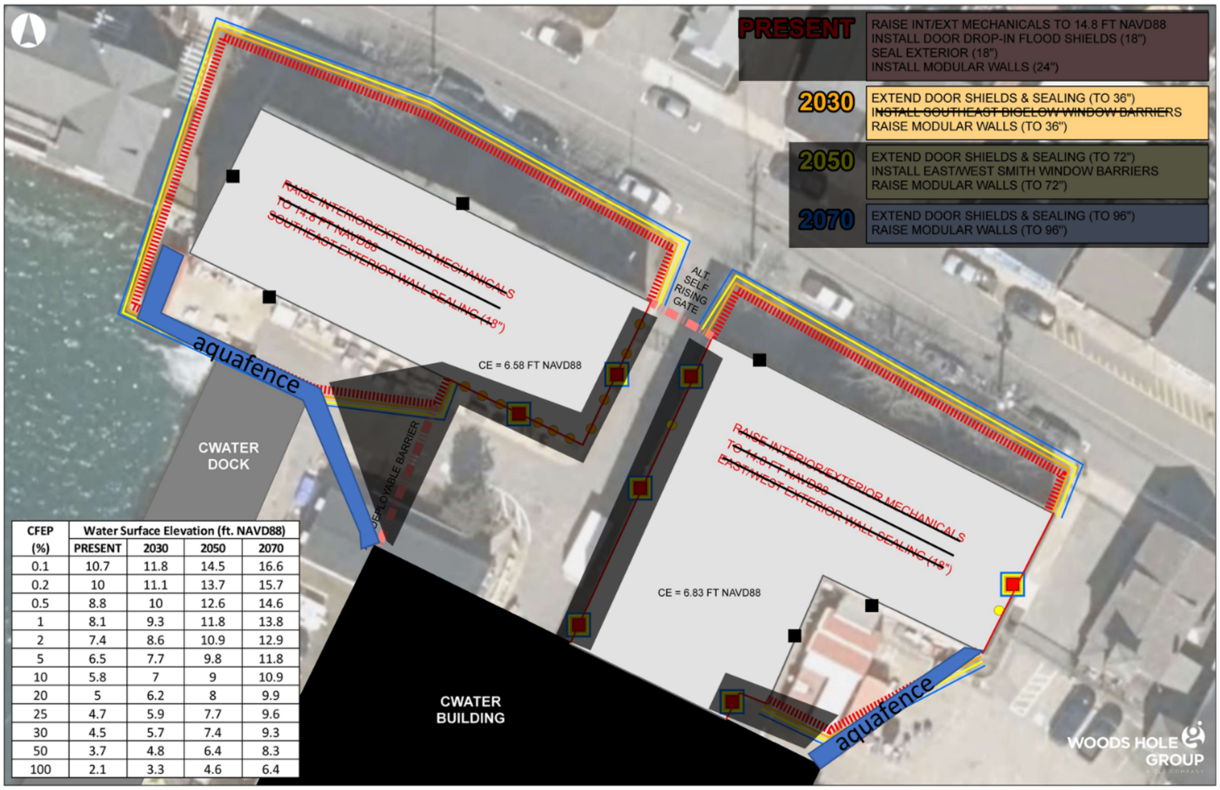
Figure 4-9 Aquarium Salt Water Drain Adaptation Diagram

4.2 Refinement of Phase 1 WHOI and MBL District-Level Adaptations

Woods Hole Group developed conceptual district-level adaptation plans for WHOI, MBL, and NOAA in the Phase 1 Woods Hole Village CCVA (Woods Hole Group, 2020b) project. For Phase

2, WHOI and MBL elected to explore these solutions further and explore preliminary implementation. Woods Hole Group revisited each district level solution (Bigelow and Smith for WHOI, Eel Pond Triangle for MBL), and suggested refinements based on further assessment and strategy.

All Phase I preliminary implementations incorporated 2030 design recommendations. The diagrams presented in this section show revisions in blue and exclusions in black.



CFEP (%)	Water Surface Elevation (ft. NAVD88)			
	PRESENT	2030	2050	2070
0.1	10.7	11.8	14.5	16.6
0.2	10	11.1	13.7	15.7
0.5	8.8	10	12.6	14.6
1	8.1	9.3	11.8	13.8
2	7.4	8.6	10.9	12.9
5	6.5	7.7	9.8	11.8
10	5.8	7	9	10.9
20	5	6.2	8	9.9
25	4.7	5.9	7.7	9.6
30	4.5	5.7	7.4	9.3
50	3.7	4.8	6.4	8.3
100	2.1	3.3	4.6	6.4

Figure 4-10 WHOI Bigelow and Smith District Phase 1 Adaptation Diagram

The Bigelow and Smith revised adaptation is diagrammed in Figure 4-10. The approach integrates a set of modular flood walls along the streetscapes of each facility, with integrated deployable flood barriers at the walkway cuts. Building-level floodproofing (including door barrier) on the east façade of Smith, deployable Aquafence barriers tied into the proposed CWATER building, and deployable barrier between the two buildings enable flood protection to be deployed ahead of storms while keeping operable areas free of encumbrances during normal operating conditions.

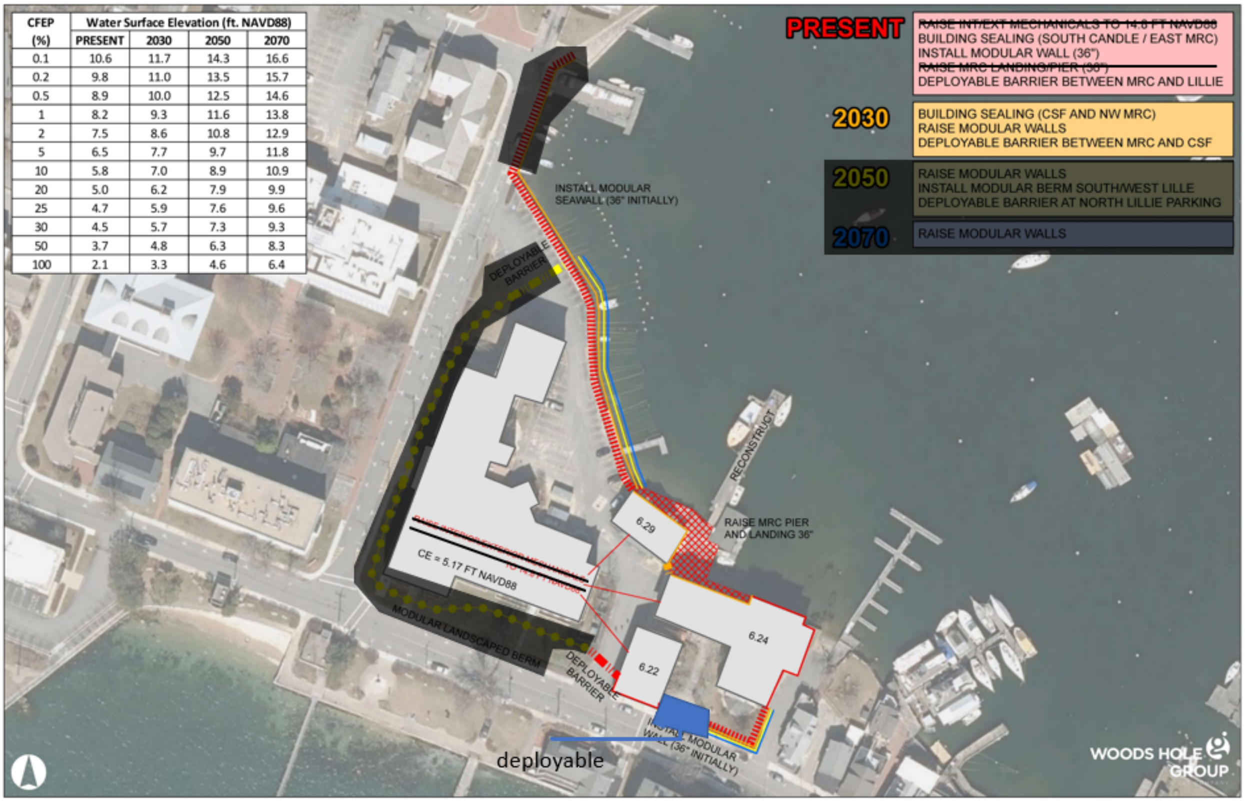


Figure 4-11 MBL Eel Pond Triangle District Phase 1 Adaptation Diagram

The Eel Pond Triangle revised adaptation is diagrammed in Figure 4-11. The approach integrates a set of modular flood walls along Eel Pond (excluding a portion by Swope included in that facility's adaptation (Section 4.3) and a portion of Water Street, with integrated deployable flood barriers on either side of Candle House and between Collection Support Facility (CSF) and Marine Resources Center (MRC). Building-level floodproofing (including door barrier) would be required for CSF and MRC for the facades facing Eel Pond.

4.3 Development of Phase 2 WHOI and MBL District-Level Adaptations

Woods Hole Group developed conceptual district-level adaptation plans for WHOI and MBL for this ResilientWoodsHole Phase 2 project. These adaptation solutions focused on Redfield and the Swope/Ebert complex, explored two alternative approaches for each district – a more targeted solution (A) and a more expansive solution that integrates resilient open space into the design (B).

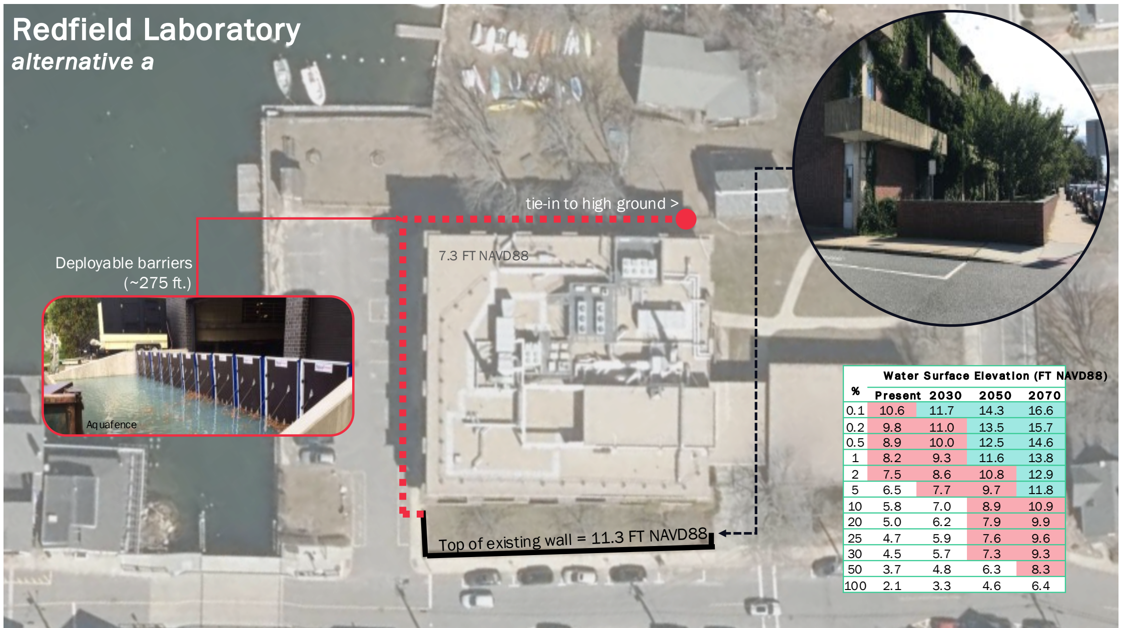


Figure 4-12 WHOI Redfield District Adaptation (Alternative A) Diagram

The Redfield District Adaptation (Alternative A) is diagrammed in Figure 4-12. This solution leverages the existing wall along Water Street, and integrates a deployable Aquafence system to wrap around the west and north faces of the building until. This approach ties into the high ground at the eastern end of the facility and greatly reduces the probability of even large future storms from impacting the building. If other projects elimintate the need for the deployable barriers, they may be repurposed for other facilities.

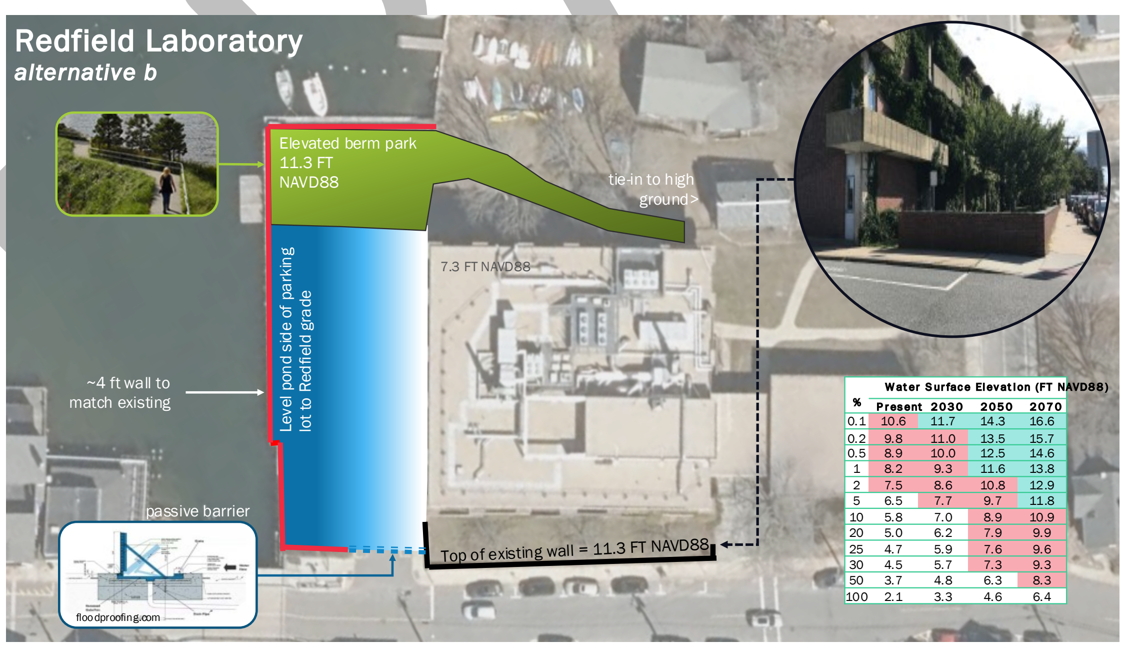


Figure 4-13 WHOI Redfield District Adaptation (Alternative B) Diagram

The Redfield District Adaptation (Alternative B) is diagrammed in Figure 4-13. This solution leverages the existing wall along Water Street, brings the western portion of the parking lot up to level with the rest of the area to reduce nuisance flooding over time, and adds a sea wall and elevated landscaped open space to provide protection from storm surge and a public amenity. A self-rising gate would be installed across the driveway such that as flooding encroaches on the site, the passive barrier would be raised to close the protection system. This approach ties into the high ground at the eastern end of the facility and greatly reduces the probability of even large future storms from impacting the building.

Figure 4-14 MBL Swope/Ebert District Adaptation (Alternative A) Diagram

The Swope/Ebert District Adaptation (Alternative A) is diagrammed in Figure 4-14. This solution builds upon the existing retaining wall behind the harborwalk along Eel Pond, and incorporates elevated landscape elements along Millfield Street and Swope parking to provide protection from storm surge. A self-rising gate would be installed across the Lillie parking lot entrance such that as flooding encroaches on the site, the passive barrier would be raised to close the protection system. This approach ties into the high ground west of Swope along North Street and greatly reduces the probability of even large future storms from impacting the building.

Figure 4-15 MBL Swope/Ebert District Adaptation (Alternative B) Diagram

The Swope/Ebert District Adaptation (Alternative B) is diagrammed in Figure 4-15. This solution builds a terraced harborwalk along the existing retaining wall and harborwalk along Eel Pond, and incorporates elevated landscape elements along Millfield Street and Swope parking to provide protection from storm surge. A self-rising gate would be installed across the Lillie parking lot entrance such that as flooding encroaches on the site, the passive barrier would be raised to close the protection system. This approach ties into the high ground west of Swope along North Street and greatly reduces the probability of even large future storms from impacting the building, with the additional benefit of providing a large resilient open space public amenity. Under current regulatory regimes, this alternative would be difficult to advance since it would place fill in parts of Eel Pond.

5.0 CONCLUSIONS AND NEXT STEPS

ResilientWoodsHole Phase 2 advanced CCVA work and adaptation planning in preparation for future planning and design. The extended vulnerability assessment for lifelines, structures, roadways, and flood pathways will supplement work done in the Woods Hole Village and Falmouth CCVAs to inform community discussions around sea level rise and storm surge vulnerability throughout the Woods Hole study area. These discussions will occur in Phase 3 workshops, and community feedback received from their review will inform additional adaptation planning and the development of dynamic adaptation pathways.

The additional adaptation planning (both asset-specific and district-level) will be used by WHOI, MBL and NOAA to inform future planning for coastal hazards. These adaptation solutions may also provide a basis for considering different adaptation themes for the ResilientWoodsHole Phase 3 dynamic adaptation pathways project.

The ResilientWoodsHole project aims to develop a comprehensive phased strategy for Woods Hole that considers how stakeholders can work together to ensure the future of our vibrant and productive seaside community. Through this process, ResilientWoodsHole will:

- Develop community-wide understanding of local climate impacts,
- Build effective partnerships for planning and visioning,
- Develop short-, mid-, and long-term climate adaptation actions across strategic themes,
- Identify key thresholds and transition points, based on adaptive management, and
- Chart dynamic adaptation pathways that optimize community outcomes over time, based on community preferences and scientific projections.

References

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