ResilientWoodsHole
Phase 3
Business Resilience Guide

Funded by a CZM Coastal Resilience Grant

June 2022

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Credit: Woods Hole Business Association

Disclaimer:

This document was prepared for ResilientWoodsHole as a guide for businesses in Woods Hole to be prepared for future coastal storms. The exposure assessments rely on the Massachusetts Coast Flood Risk Model and the most recent LiDAR elevation data. Since modeling climate-related hazards is inherently uncertain, this information should be accepted and used with the understanding that it was developed for future flooding analysis only, and no liability is assumed as to its accuracy, sufficiency or suitability for any other use. Additionally, bare earth LiDAR data may not accurately reflect building exposure due to elevated ground floors, fenestrations and other constructed features; site specific evaluations will provide the best understanding of local vulnerabilities.

This guide is not intended nor should be used to give any engineering, design or legal advice nor supersede any state building code requirements or state or federal statutory or regulatory language or interpretation of such language. Certain adaptation techniques will not be applicable in all situations and many require professional assistance to ensure structural integrity.

1.0 COASTAL FLOOD RISK

As a seaside community, Woods Hole is well aware of the risk of flooding from coastal storms. Throughout its history, the village has been impacted by hurricanes and Nor'easters. Recently, even high tides with a strong wind can expose built infrastructure to ocean-based floodwaters.

Water Street during Hurricane Carol, 1954 (Credit: GW Mead, courtesy Woods Hole Historical Museum)

Virtually all of Woods Hole's business district is currently mapped in the special flood hazard area, indicating at least a 1% annual chance of flooding – this equates to a one-in-four chance of flooding over the course of a 30-year mortgage. Base flood elevations for the 1% annual chance event are between 12 and 14 feet NAVD88 in this area. Properties with a federally-backed mortgage in these zones are required to purchase flood insurance. Additionally, improvements or repairs to buildings in these areas that exceed 50% of the appraised value may be required to meet the minimum National Flood Insurance Program requirements.

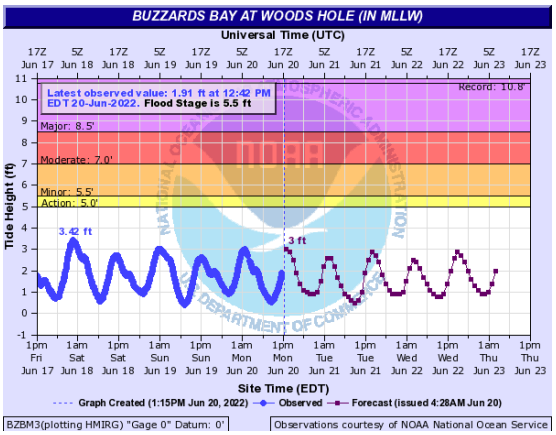
FEMA maps and resources are available online at:

https://msc.fema.gov/portal/home

FEMA Flood Insurance Rate Map for Woods Hole (25001C0718J, effective on 7/16/2014)

If a storm threatens to impact Woods Hole, a variety of tools are available to track position and projected water levels. One especially useful tool is the NOAA National Weather Service's Advance Hydrologic Prediction Service. This website provides forecast water levels that include tides and storm surge, and indicates what water levels constitute flooding in the area. This website can be monitored in real-time as a storm approaches to get a sense of the anticipated magnitude of flooding:

https://water.weather.gov/ahps2/hydrograph.php?wfo=box&gage=bzbm3



National Weather Service Advanced Hydrologic Prediction Service (Station BZBM3)

Additional resources are available for tropical storm (hurricane) forecasting and monitoring. NOAA's National Hurricane Center provides advisories/warnings as well as data and forecasts on storm track and wind speeds for these events:

https://www.nhc.noaa.gov/

To anticipate and plan for climate change, which is expected to bring more frequent and more intense coastal storms, Massachusetts businesses can refer to the Commonwealth's climate change planning resources. ResilientMA provides projections for heat, precipitation, sea level rise and coastal storm surge.

Due to elevation and constructed fill (bulkheads) in the developed waterfront areas of Woods Hole, sea level rise alone is not anticipated to directly impact Woods Hole businesses for some time. While there is some potential for long term (2070 or beyond) sea level rise to expose low lying waterfront businesses to tidal flooding, a nearer term more likely impact could be basement flooding as groundwater levels continue to rise.

Since relative sea level rise (expanding water volume, glacial ice melt, local land subsidence) is not anticipated to be a significant hazard for the commercial district in Woods Hole, this guide focuses on anticipating and preparing businesses for future storm surge water levels.

The Massachusetts Coast Flood Risk Model (MC-FRM) incorporates tidal cycles, sea level rise, storm surge, wave run-up and overtopping to statistically project the annual coastal flood exceedance probability (ACFEP), and potential water surface elevation (WSE) and maximum wave crest elevation (MWCE) across the landscape for a range of probability levels and projected climate scenarios.

Woods Hole Climate Vulnerability Assessment (2030) in commercial corridor

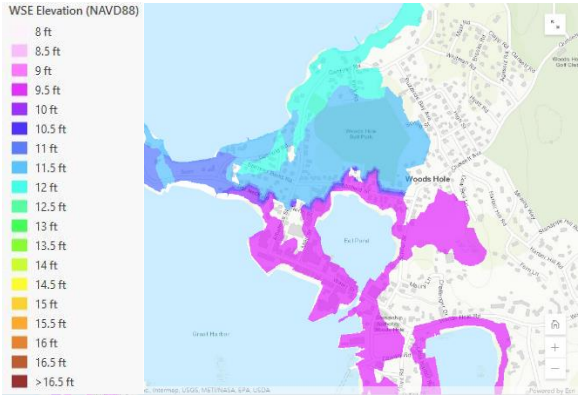
The "Woods Hole Climate Vulnerability Assessment" section of the StoryMap for ResilientWoodsHole Phase 3 provides data viewers for 2030, 2050 and 2070 annual coastal flood exceedance probability for each building in the study area. These projected annual chances of flooding are based on the minimum grade elevation of the LiDAR data within the building's footprint (note that in some cases elevation could be underestimated, and therefore flood probability overestimated, for buildings at or on the water on pilings or bulkheads). Cumulative risk, or annual risk compounded over the lifetime of an asset/project, is an important factor to consider for business planning and preparedness. For example:

the 1% ACFEP (commonly referred to as the "100-year storm") has a ~10% chance of occurring in a 10 year period, and a ~22% chance of occurring in a 25 year period

the 10% ACFEP (commonly referred to as the "10-year storm") has a ~65% chance of occurring in a 10 year period, and a ~93% chance of occurring in a 25 year period

The annual flooding probability can give business owners a screening-level understanding of flood risk at their location, but detailed vulnerability assessment requires a comparison of projected flood elevations to measured elevations of known vulnerable points on a building or exterior equipment.

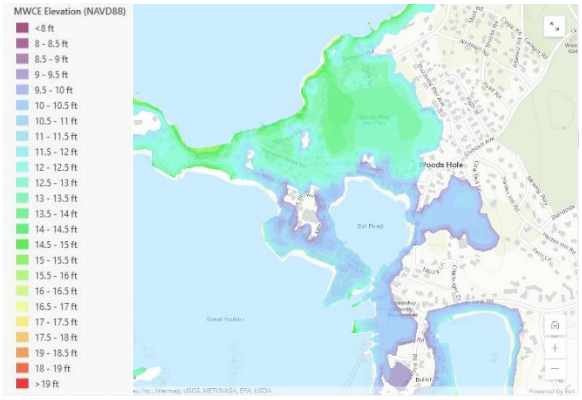
The "Storm Flood Elevations" section of the StoryMap for ResilientWoodsHole Phase 3 provides data viewers for 2030, 2050 and 2070 1% water surface elevation (WSE). The WSE data provide an assessment of how high stillwater flooding could get in future "100-year" storm events.



Woods Hole 1% Water Surface Elevation (2030)

If a business has doorways, windows, basement bulkheads, loading docks, vents or other fenestrations below these projected storm surge elevations, floodwater could get into the facility and impact business operations unless floodproofing measures are implemented. Once flooding enters a building, any equipment, building infrastructure, electrical systems, finished surfaces, furnishings or inventory at or below the projected flood elevation could be damaged or lost.

The "Storm Flood Elevations" section of the StoryMap for ResilientWoodsHole Phase 3 also provides data viewers for 2030, 2050 and 2070 1% maximum wave crest elevation (MWCE). The MWCE data provide an assessment of how high waves could get in future "100-year" storm events.



Woods Hole 1% Maximum Wave Crest Elevation (2030)

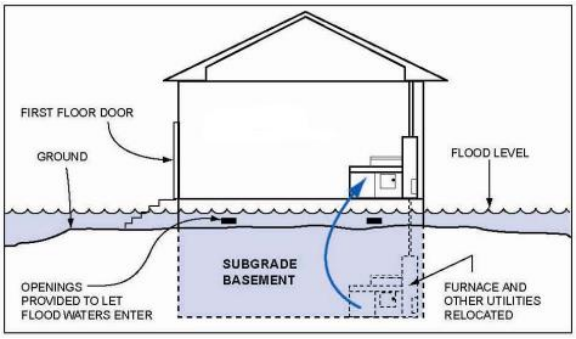
If a business has structural building elements or other infrastructure vulnerable to wave forces at or below these projected wave crest elevations, these components could be damaged or relocated by storm waves unless they are elevated or secured. It is possible to obtain information on velocities and forces associated with these waves, but this requires additional analysis.

A critical concept to consider for businesses near the water is that their vulnerability is a function of their exposure to flooding, sensitivity (how could flooding impact the business) and adaptive capacity (what can the business do to decrease the impacts of the flooding). Businesses have the ability to change all three factors influencing vulnerability to coastal flooding with strategic planning and investments.

2.0 BUILDING SCALE ADAPTATION

Aside from moving away from a flood hazard area, which is not viable near-term option for established businesses in developed areas such as Woods Hole, there are two general approaches at the building scale that business owners can implement – accommodation or protection.

Accommodation of floodwaters – also referred to as wet floodproofing – generally means letting storm surge encroach into the existing building and ensuring that hydrostatic pressure does not compromise the structure and that operations can resume quickly when flooding recedes.



Wet floodproofing diagram (FEMA)

Structural issues are addressed by anchoring the structure and installing flood vents or breakaway walls so that flooding can pass through the enclosure without exerting excessive pressure on structural elements. Potentially exposed exterior or interior mechanical and utility equipment (electrical systems, HVAC equipment and ductwork, hot water heaters, large appliances) should be elevated or protected with an interior floodwall or other flood protection system. Below the projected flood elevation, the facility should replace vulnerable finish materials (drywall, blown-in or fiberglass batt insulation, carpeting, non pressure-treated wood or plywood) with flood resistant materials (concrete, stone, masonry block, ceramic or clay tile, pressure-treated or naturally decay-resistant lumber, epoxy paints, metal).


Utility flood covers are anchored to the floor and can be pulled up and secured around equipment in the event of a flood, assuming the equipment cannot be elevated and flooding is not excluded from the equipment room (floodproofing.com)

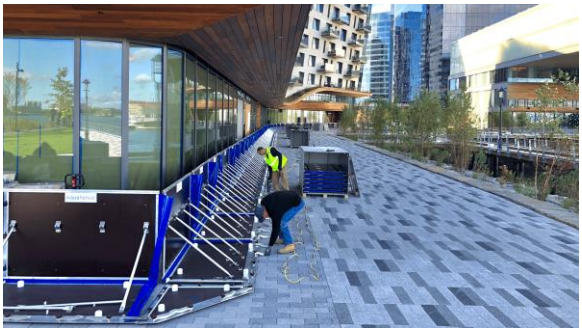
Protection from flooding – also referred to as dry floodproofing – generally refers to measures installed to exclude floodwaters from entering a building (or a critical part of a building). This is achieved typically by some combination of floodproofing membranes installed on foundations and concrete masonry unit blocks (plus veneers) and deploying flood shields or barriers on any openings/fenestrations. Alternatively, non-essential openings in the building below the flood elevation can be completely or partially filled in. In some cases, custom solutions are available for dry floodproofing specific mechanical equipment. It should be noted that code requires a dry floodproofed building must have at least one unblocked egress above the flood elevation, so dry

floodproofing may not be possible in all structures.

Examples of a range of dry floodproofing solutions for buildings are provided below. This is not an exhaustive list, but rather a demonstration of the types of strategies typically deployed. Feasibility of installation, including an evaluation of whether strategies should go directly on the building façade or independently surround the building, should be evaluated on an individual engineering basis. Any solution considered by a business should include an evaluation of ease of deployment since effective solutions depend on correct and timely installation.

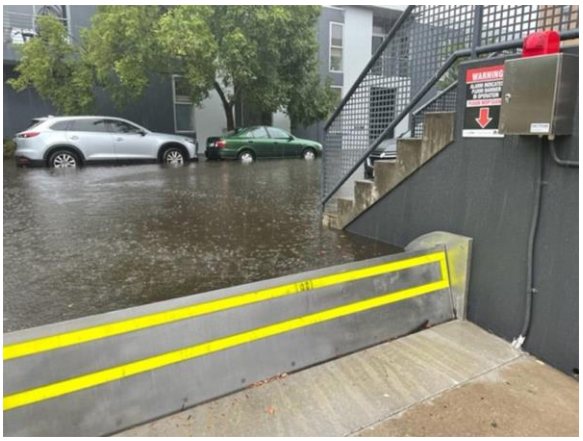
Barrier panels can be installed on door and windows, and typically have a gasket to make the seal to wall and ground. Some products can be linked together with posts to form a fence-like barrier linked to, or independent of, the building (floodriskamerica.com)

Flood planks are individual modular units that can be stacked between channeled columns on door and windows, and typically have a gasket to make the seal to wall and ground. The columns can also be strung across a span and linked together to form a fence (psfloodbarriers.com)

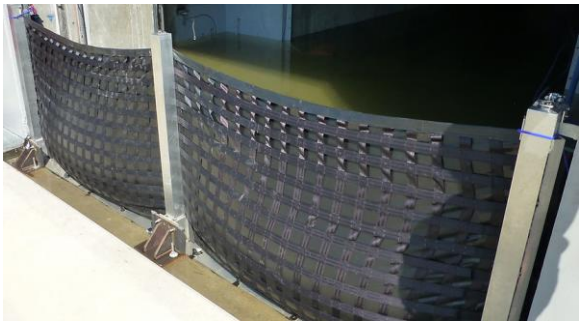


Perimeter fence barriers link with baffles and are anchored to the ground; they can completely surround a building or link into the façade; some are made of flexible fabric or molded plastic (aquafence.com)

Glass flood walls using structural glass preserve views and can be installed atop existing walls or on their own; floodproof windows are also available (https://floodcontrolinternational.com)



Integrated vertical and horizontal flood barriers are installed permanently in the sidewalk or streetscape and are activated either passively (floodwaters fill chamber and use buoyancy to raise) or actively (powered systems); these systems have end gaskets to span gaps between vertical structures (https://www.floodfree.com.au/)



Point-of-use flexible fabric barrier are stored in place and can be pulled down/up/across for rapid deployment; also available for stairwells (floodproofing.com)

Additional floodproofing strategies include installing valves on sewer lines to prevent back-flow and installing sump pumps to discharge water that may seep in.

Many commercial buildings in Woods Hole are wood-frame construction, which is not as easily floodproofed as masonry construction. If the building façade itself is not floodproofed, many of the solutions shown above may not be feasible.

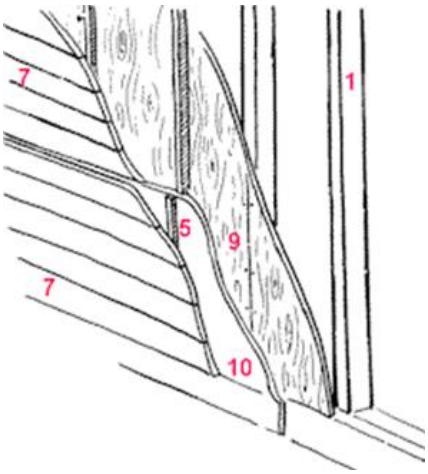
In these cases, the options generally include elevation of the building or interior first floor (both could have significant impacts on the streetscape), wet floodproofing (specific recommendations are provided for different business use cases in the following sections) or linking a series of panels/logs/ fences to surround the building.

The first floor of Quick's Hole Tavern is elevated about one-half story above street level (Quick's Hole / Facebook)

The Landfall Restaurant has integrated a range of wet floodproofing measures over the years, including removable glass doors, a floodable dining area with pop out floor hatches to relieve wave pressure under the section on piers, and a breakaway rear wall

Although dry floodproofing is not generally recommended practice for wood-frame construction, there are some examples of retrofitting this type of construction (provided the structure can withstand a modest amount of hydrostatic pressure…most dry floodproofing on wood-frame buildings is not recommended to be higher than 3 feet). Dry floodproofing can be

achieved (ask your local building inspector if such practice is permittable for commercial structures) by applying an impermeable membrane on the building sheathing, and then installing siding/cladding on furring strips to promote drainage and ventilation.

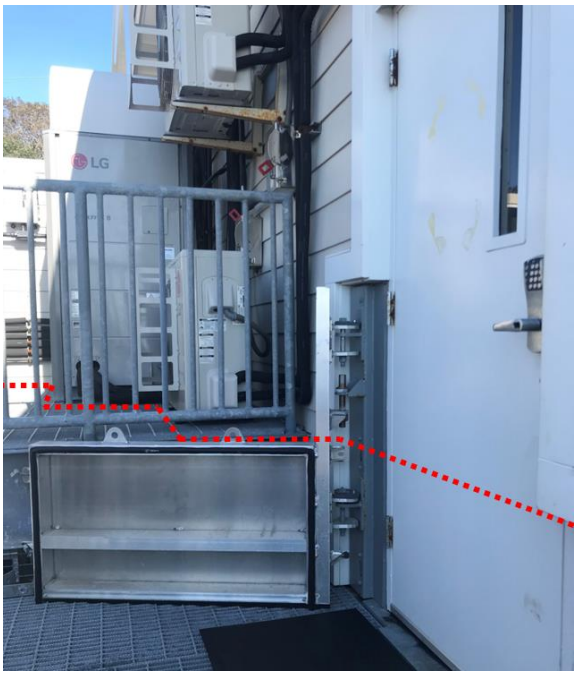


Waterproof membrane (10) installed between sheathing (9) and siding (7) with furring strips (5) (lsuagcenter.com)

Interior floodproofing system for historic wood-frame buildings (https://www.jlconline.com/how-to/framing/flood-hardy-wall-construction_o)

Additionally, where historical preservation of exterior cladding is a concern, some approaches have been developed by building scientists to floodproof wood-construction from the inside using a system of drain fabric, rigid polystyrene insulation board, and closed-cell high density spray foam insulation.

It should be noted that not all businesses own the building they occupy. Floodproofing measures, especially dry floodproofing, can only be implemented by a building owner. Businesses that lease space can apply wet floodproofing strategies to their interior finishes and systems, and can coordinate with building owners on other floodproofing measures.



Elevated first floor, elevated systems, and door flood barrier up to design flood elevation at USCG Woods Hole

Apart from the building- and system-level floodproofing strategies described above, businesses can engage in proactive measures to make their business operations more resilient. Some strategies are provided for different types of businesses in Woods Hole in the following sections:

- Retail
- Food Service
- Office

3.0 PROFILE – RETAIL

The following table provides approximate ground floor elevations of commercial buildings with retail use on the ground floor in Woods Hole. These elevations were derived from recent LiDAR data but may not accurately reflect on-the-ground conditions with respect to critical building elevations (e.g., finished first floors, openings such as doors/windows/vents, mechanical systems, etc.) that could impact the business if exceeded by floodwaters. These approximate ground floor elevations can be compared to the 1% water surface elevations (WSE) also presented in the table to get a sense of how deep flooding could get at each location in a future (2030, 2050 or 2070) 1% annual chance event (the "100-year storm"). Lower-level storms will be associated with less flooding, but most emergency and adaptation planning focuses on the 1% annual chance storm. More detailed on-site survey would provide an enhanced understanding of potential building and business-specific vulnerabilities and inform specific adaptation strategies.

Address	Approximate Ground Floor Elevation (ft. NAVD88)	1% WSE (ft. NAVD88)		
		2030	2050	2070
28 Water Street	9.6	9.4	11.5	13.5
33 Railroad Avenue	13.0	9.3	11.5	13.5
87 Water Street	6.4	9.4	11.6	13.5
89 Water Street Front	6.5	9.4	11.6	13.5
9 Luscombe Avenue	8.0	9.4	11.5	13.5
20/22 Luscombe Avenue	6.5	9.4	11.5	13.5
19 Railroad Avenue	8.8	9.3	11.5	13.5
22 Water Street	17.6	-	11.5	13.5
16 Water Street	18.1	-	11.5	13.5
68 Water Street	5.4	9.4	11.6	13.5

Considerations for Retail flood resiliency if dry floodproofing is not undertaken:

- Identify your building's flood entry points and know their elevations in ft. NAVD88 and ft. MLLW (MLLW is 1.36 feet below NAVD88), which can be compared to forecast storm tide elevations from the National Weather Service: (https://water.weather.gov/ahps2/hydrograph.php?wfo=box&gage=bzbm3).

- Elevate building electrical and mechanical systems above the 1% WSE at appropriate time frame; consider utility flood covers for systems that are difficult to elevate.

- Investigate deployable barriers for doors, windows and any low vents or other building perforations. If the building is not completely watertight, these devices may prevent large volumes of water from getting into the building over the course of a storm (seepage may still occur in other areas, but should be slower and more manageable).

- Install a backflow preventer valve on the sewer line, and a sump pump in the basement (if applicable).

- Based on your understanding of site-specific critical elevations and projected water surface elevations, be prepared to elevate vulnerable equipment (computers, printers, cash registers, etc.) and inventory above potential flooding (second floor of building or on secured shelving on first floor) or temporarily relocate it to a dry upland location ahead of storms. Also consider securing or removing display tables and cabinets so that floodwaters can't mobilize these elements and damage other parts of the business.

- When remodeling, use flood resistant materials below the 1% WSE at appropriate time frame.

4.0 PROFILE – FOOD SERVICE

The following table provides approximate ground floor elevations of commercial buildings with food service use on the ground floor in Woods Hole. These elevations were derived from recent LiDAR data but may not accurately reflect on-the-ground conditions with respect to critical building elevations (e.g., finished first floors, openings such as doors/windows/vents, mechanical systems, etc.) that could impact the business if exceeded by floodwaters. These approximate ground floor elevations can be compared to the 1% water surface elevations (WSE) also presented in the table to get a sense of how deep flooding could get at each location in a future (2030, 2050 or 2070) 1% annual chance event (the "100-year storm"). Lower-level storms will be associated with less flooding, but most emergency and adaptation planning focuses on the 1% annual chance storm. More detailed on-site survey would provide an enhanced understanding of potential building and business-specific vulnerabilities and inform specific adaptation strategies.

Address	Approximate Ground Floor Elevation (ft. NAVD88)	1% WSE (ft. NAVD88)		
		2030	2050	2070
28 Water Street	9.6	9.4	11.5	13.5
87 Water Street	6.4	9.4	11.6	13.5
89 Water Street Rear	6.5	9.4	11.6	13.5
38 Water Street	7.3	9.4	11.6	13.5
9 Luscombe Avenue	4.8	9.4	11.5	13.5
71 Water Street	6.6	9.4	11.6	13.5
56 Water Street	7.6	9.4	11.6	13.5
10 Water Street	18.0	-	-	13.5
77 Water Street	6.4	9.4	11.6	13.5
20/22 Luscombe Avenue	6.5	9.4	11.5	13.5
29 Railroad Avenue	6.5	9.4	11.5	13.5

Considerations for Food Service flood resiliency if dry floodproofing is not undertaken:

- Identify your building's flood entry points and know their elevations in ft. NAVD88 and ft. MLLW (MLLW is 1.36 feet below NAVD88), which can be compared to forecast storm tide elevations from the National Weather Service: (https://water.weather.gov/ahps2/hydrograph.php?wfo=box&gage=bzbm3).

- Elevate building electrical and mechanical systems above the 1% WSE at appropriate time frame; consider utility flood covers for systems that are difficult to elevate.

- Investigate deployable barriers for doors, windows and any low vents or other building perforations. If the building is not completely water tight, these devices may prevent

large volumes of water from getting into the building over the course of a storm (seepage may still occur in other areas, but should be slower and more manageable).

- Install a backflow preventer valve on the sewer line, and a sump pump in the basement (if applicable).

- Based on your understanding of site-specific critical elevations and projected water surface elevations, be prepared to elevate vulnerable equipment (computers, printers, cash registers, etc.) and supplies (cookware, dinnerware, glasses, utensils, linens, paper goods, etc.) above potential flooding (second floor of building or on secured shelving on first floor) or temporarily relocate it to a dry upland location ahead of storms. Also consider securing or removing tables and chairs so that floodwaters can't mobilize these elements and damage other parts of the business.

- Food storage presents a unique challenge when considering flooding. Dry, canned and other non-perishable items may be elevated or relocated similar to other non-food inventory (as discussed above). For cold storage (refrigerated or frozen) items, it may be possible to elevate or relocate small refrigerators and freezers, but walk-in units and cold cases (and the food inventory they store) are vulnerable. Explore options for sealing doors or using deployable barriers if walk-in units and/or their electrical connections are potentially exposed to floodwaters. Also, power loss is common during storms, so options for backup generators should be explored to keep these critical systems running to preserve food items during extended power outages.

- Food service equipment, such as ovens, ranges, fryers, microwaves, coffee machines, fountain beverage/carbonation systems, water filtration systems, mixers, dishwashers, etc., can be damaged by flooding but have variable mobility. For smaller units, options for temporarily elevating or moving to a dry location should be examined. For the larger units that are fixed in place, it may be possible to use custom flood covers or deployable barriers to exclude floodwaters. Alternatively, it may be possible to elevate electrical components on some units. If non-movable kitchen equipment cannot be adapted or protected, food service businesses may sustain some equipment losses, depending on the magnitude of flooding (in these cases, pre-storm inventory and post-storm documentation will be important for insurance purposes.

- When remodeling, use flood resistant materials below the 1% WSE at appropriate time frame. If remodeling a kitchen, explore opportunities to consolidate expensive and non-movable equipment into protectable areas.

5.0 PROFILE – OFFICE

The following table provides approximate ground floor elevations of commercial buildings with office use on the ground floor in Woods Hole. These elevations were derived from recent LiDAR data but may not accurately reflect on-the-ground conditions with respect to critical building elevations (e.g., finished first floors, openings such as doors/windows/vents, mechanical systems, etc.) that could impact the business if exceeded by floodwaters. These approximate ground floor elevations can be compared to the 1% water surface elevations (WSE) also presented in the table to get a sense of how deep flooding could get at each location in a future (2030, 2050 or 2070) 1% annual chance event (the "100-year storm"). Lower-level storms will be associated with less flooding, but most emergency and adaptation planning focuses on the 1% annual chance storm. More detailed on-site survey would provide an enhanced understanding of potential building and business-specific vulnerabilities and inform specific adaptation strategies.

Address	Approximate Ground Floor Elevation (ft. NAVD88)	1% WSE (ft. NAVD88)		
		2030	2050	2070
97 Water Street	7.1	9.3	11.6	13.6
2 Water Street	17.9	-	-	-
21 Luscombe Avenue	5.7	9.3	11.5	13.5

Considerations for Office flood resiliency if dry floodproofing is not undertaken:

- Identify your building's flood entry points and know their elevations in ft. NAVD88 and ft. MLLW (MLLW is 1.36 feet below NAVD88), which can be compared to forecast storm tide elevations from the National Weather Service: (https://water.weather.gov/ahps2/hydrograph.php?wfo=box&gage=bzbm3).

- Elevate building electrical and mechanical systems above the 1% WSE at appropriate time frame; consider utility flood covers for systems that are difficult to elevate.

- Investigate deployable barriers for doors, windows and any low vents or other building perforations. If the building is not completely watertight, these devices may prevent large volumes of water from getting into the building over the course of a storm (seepage may still occur in other areas, but should be slower and more manageable).

- Install a backflow preventer valve on the sewer line, and a sump pump in the basement (if applicable).

- Based on your understanding of site-specific critical elevations and projected water surface elevations, be prepared to elevate vulnerable equipment (computers, printers, paper files, etc.) and office supplies above potential flooding (second floor of building or

on secured shelving on first floor) or temporarily relocate it to a dry upland location ahead of storms. Also consider securing or removing desks, tables and chairs so that floodwaters can't mobilize these elements and damage other parts of the business.

- When remodeling, use flood resistant materials below the 1% WSE at appropriate time frame.

6.0 PREPAREDNESS AND RECOVERY

Planning helps your business grow. Similarly, planning for coastal storm impacts will help your business recover faster from these hazards.

The U.S. Small Business Administration provides resources to plan for disasters as well as post-disaster recovery loans for physical damage and economic injury:

https://www.sba.gov/funding-programs/disaster-assistance

The SBA also provides helpful general checklists for business preparedness, including for flooding and hurricanes:

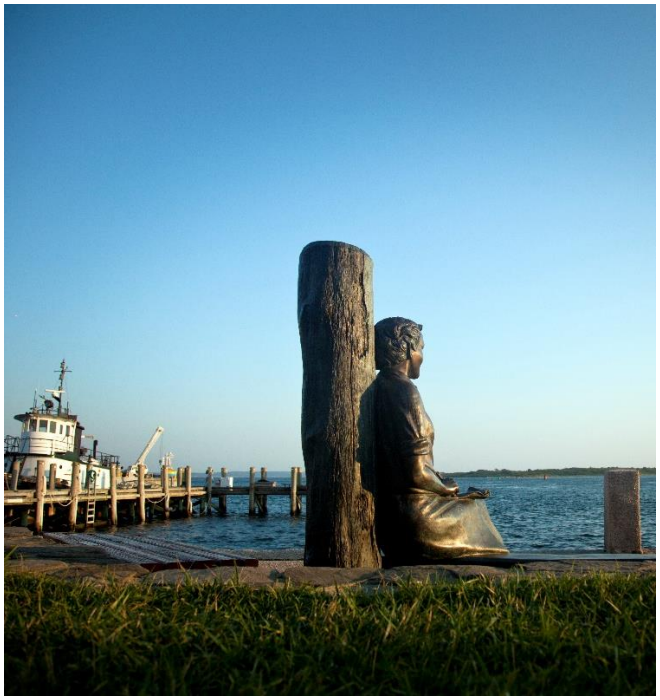
https://www.sba.gov/sites/default/files/2020-09/FloodPreparednessSBA.pdf

https://www.sba.gov/sites/default/files/2020-09/HurricanePreparednessSBA.pdf

In addition to the recommendations in these checklists, businesses should:

- Maintain a current contact list of suppliers and contractors in case you need to order/stop supplies or have repairs made

- Develop a storm preparation checklist and operational plan that includes deployment of any floodproofing equipment (this requires that you also know your vulnerable elevations, monitor each storm's projected water levels, and have pre-determined action thresholds for contacting and coordinating employees, relocating inventory and equipment, deploying flood protection systems, etc.)



Credit: Daniel Cojanu