Town of Boothbay Harbor

Flood Impact Preliminary Engineering Study

Individual Property Report

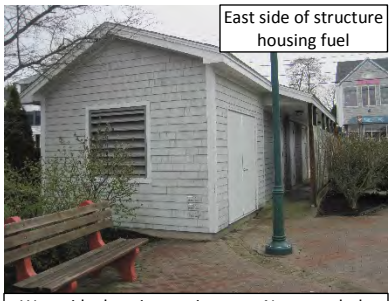
36 Commercial Street

Whale Park & Pumping Station

Property Overview

36 Commercial Street is a public park with a one-story wood-frame structure built on a slab-on-grade foundation. The structure currently houses a public restroom and a municipal sewer pumping station.

Fuel to power the pumping station is located on the east side of the structure. Pumping station equipment is located on the west side of the structure, as well as underground below the sidewalk to the west of the structure. The restroom is in the center portion of the structure



East side of structure housing fuel

West side, housing equipment. Note manhole over additional equipment to right.

Table 1: Property Summary

Foundation	Slab
Structure	Wood Frame
Stories	One
Use	Pumping Station / Restroom
Site	Over Land

Risk Framework

Table 2 lists the elevations, determined by the Lincoln County Sea Level Rise - Coastal Hazard Study conducted by the Lincoln County Regional Planning Commission (LCRPC) and Maine Geological Survey (MGS) in 2013. These elevations represent "stillwater" flood elevations from the effective FEMA Flood Insurance Study. Stillwater elevations are the basis for special flood hazard area (SFHA) elevation mapping, and do not include the effects of wave action or local variations. In order to be consistent with the LCRPC study, these elevations are used for the 1% annual chance storm flood planning in this report.

Table 2: 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

This property is located completely within a FEMA AE Special Flood Hazard Area (SFHA) with a base flood (1% annual chance storm) elevation (BFE) of 11 feet NAVD88.

Please note that the FEMA BFE addresses local variations and includes the effects of waves, wave setup, and wave runup; therefore this figure may be different than the "Current/Historical" scenario 1% chance storm elevation in Table 2, which is a stillwater elevation only. The FEMA BFE is derived from the 2015 Flood Insurance Rate Map update and is the regulatory elevation for purposes of new construction and flood insurance.

For the purposes of this report, findings and recommendations are based on the highest astronomical tide and 1% storm elevations presented in Table 2.

Elevations of key features of the main building at 36 Commercial Street were surveyed or measured. The elevations of those features, and whether they were surveyed or estimated relative to a surveyed point, are presented in Table 3, below.

Feature elevations were compared to the LCRPC Sea Level Rise scenario figures in Table 2. If the elevation of a given feature is equal to or below a given LCRPC flood elevation, that feature is vulnerable to that LCRPC scenario. For example, if the first floor is 9.0 feet NAVD88, it is vulnerable to a 1% annual-chance storm under current conditions (9.5 feet NAVD88), and HAT under 3.3 feet of sea level rise (9.8 feet NAVD88). In Table 3, the HAT and 1% annual-chance flood vulnerability of each building feature is presented.

Table 3: Property Elevations (NAVD88)

Feature:	Elevation	Source	Vulnerability
Lowest Adjacent Grade	9.48	Surveyed	HAT + 1.0 m; 1% Storm
First Floor Elevation	10.39	Surveyed	1% Storm + 0.3 m
Lowest Opening	10.4	Estimated	1% Storm + 0.3 m

Attachment 1 displays the property, the location of key features, and the surveyed elevations.

Building Vulnerabilities

Foundation Degradation

The building's slab-on-grade foundation is not at a relatively minimal risk of damage from coastal hazards.

Structural Damage

The 36 Commercial Street structure is located on land in a FEMA AE zone, with the adjacent grade at approximately the elevation of current stillwater flood elevations. The first floor may experience shallow inundation of less than a foot during a current 1% annual-chance storm according to the FEMA base flood elevation. As sea levels rise, flood depths will increase. Nevertheless, given the structure's elevation and location, it is not expected that coastal flooding will cause significant damage to this building's structure.

Risk of damage to the building structure is considered to be relatively minimal.

Erosion

The land on which this building sits may potentially be at risk from erosive forces, though the structure is located more than 50 feet from the shoreline. No significant erosion was observed at this site. Geotechnical methods such as soil load testing were **not** employed during field observations.

Risk of damage from erosion is relatively minimal.

Hydrostatic Forcing

This structure is built on a slab-on-grade foundation and even during extreme events flood depths are not projected to be enough to cause damage through hydrostatic pressure.

Risk of damage from hydrostatic forces is considered to be relatively minimal.

Interior Inundation

The lowest opening of this structure is elevated above current stillwater flood elevations. With rising seas the risk of breach at that opening will increase relatively rapidly. The structure interior houses an essential municipal facility; therefore inundation represents a significant risk.

Risk of damage due to interior inundation is relatively moderate.

Utility Damage

As noted above, this structure houses an essential municipal facility, along with support utilities (fuel and a generator). The elevation of these utilities is assumed to be the same as the first floor elevation, or around 10.4 feet NAVD88.

Risk of damage to these utilities is considered to be relatively moderate.

Operation

Damage to the pumping station would result in significant disruption to the Town's utility operations.

Damage to the restrooms would have a relatively minor impact.

The risk of disruption of this property's operations is relatively moderate.

Summary

36 Commercial Street risks are summarized in the table below.

Table 4: Risk Summary

Risk	**Vulnerability**	**Scenario of Concern**		**Notes**
		HAT	***1% Storm***	
Foundation Degradation	Minimal	None	None	None
Structural Damage	Minimal	None	+ 1.8 m	None
Erosion	Minimal	None	None	None
Hydrostatic Forcing	Minimal	None	+ 1.8 m	None
Interior Inundation	Moderate	+1.8 m	+ 0.3 m	Vulnerable municipal utility
Utility Damage	Moderate	+1.8 m	+ 0.3 m	Vulnerable municipal utility
Business Operation	Moderate	+1.8 m	+ 0.3 m	Vulnerable municipal utility

Adaptation Alternatives

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

A "Flood Damage Reduction Matrix" developed by the US Army Corps of Engineers is available as Attachment 2; this worksheet can be used to help guide decision-making with regards to appropriate adaptation alternatives for a site.

Cost Estimates

Flood mitigation project costs vary depending on

- Building size (square footage of footprint, number of stories)
- Building construction material (wood-frame, masonry, brick, etc.)
- Foundation type (basement, crawlspace, slab-on-grade, pilings)
- Flood depth at the site (the higher the floodwaters, the more expensive the project)
- The local availability of resources and professionals (this will affect the cost of labor and materials)
- Other variables (including the costs of surveys, design work, permits, and maintenance_

These factors makes providing meaningful cost estimates difficult. Nevertheless, rough concept-level cost estimates for different alternative were developed for this project based on:

- A variety of FEMA publications, including P-259, P-551, and P-1037
- "Selecting Floodproofing Techniques - Financial Considerations" prepared by the Southern Tier Central Regional Planning and Development Board (STCRPDB)
- ClimateTechWiki (www.climatetechwiki.org, accessed 9/26/2017; authored by Matthew M. Linham and Robert J. Nicholls, School of Civil Engineering and the Environment, University of Southampton, UK.)
- Information gleaned from previous Milone & MacBroom, Inc. experience

These cost estimates are summarized in Table 5, below:

Table 5: Adaptation Alternatives Cost Estimates

Measure	Description	Cost ($)	Unit	Additional Costs	Source
Elevation	Raise structure so first floor is above the water surface elevation during a flood event.	**$29.00 to $96.00**	Per Square Foot		ClimateTechWiki STCRPDB
Wet Floodproof	Building is retrofitted to allow flooding without being damaged.	**$2.20 to $17.00**	Per Square Foot		ClimateTechWiki STCRPDB
Dry Floodproof	Building is retrofitted to withstand flooding.	**$5.50 to $16.80**	Per Linear Foot of Wall	$3,000 for drainage and check valves $400-1230 per door	ClimateTechWiki STCRPDB
Floodwalls	Walls built to protect against flooding. Control gates are open to allow access under normal conditions, and are closed during storms.	**$100.00 to $5,000.00**	Per Linear Foot	$5,000 interior drainage $2,000-$5,000 per opening	STCRPDB NOAA
Rearrange Property	Relocate building or sections within parcel	**$29.00 to $77.00**	Per Square Foot	Demolition & new construction.	STCRPDB

More Information on cost estimates is available through Attachment 3, "Selecting Floodproofing Techniques - Financial Considerations" prepared by the Southern Tier Central Regional Planning and Development Board.

It is important to note that any project that triggers "Substantial Improvement" will require that the building be made compliant with the local flood damage prevention ordinance. "Substantial Improvement" is defined in the Boothbay Harbor ordinances as improvements that cost more than 50% of the value of the property before the improvements were made. Review the Boothbay Harbor ordinances (§ 170-95.5: Definitions) or contact the Town of Boothbay Harbor for more information.

Recommended Alternatives:

Short Term

- **Monitor Sea Level Rise** and determine whether steps need to be taken.

Long Term

- **Dry Floodproof** the pumping station and its support utilities (fuel and generator). The restroom does not need to be dry floodproofed.
- **Wet Floodproof** or **Elevate Interior Floor** of the restroom to minimize damage during storms.

Lower Insurance

- No actions are recommended to reduce flood insurance premiums.

Cost Estimate

Table 6: Cost Estimate for Recommended Alternatives

Alternative	Details	Cost	Frequency
Monitor Sea Level Rise	Professional survey every 5 years	$1000	Every Five Years
Dry Floodproof	~ 100 feet of wall pumping station & utilities	$10 per foot of wall Total $10,000	Once
Elevate Interior Floor Or Dry Floodproof	~400 square feet restroom area	$10 per ft^2 $5,000 for facility realignment Total $9,000	Once
	Total Cost	**$25,000**	**Over 30 years**

Summary

This building is currently at risk of damage to its utilities from inundation during a 1% annual-chance storm according to FEMA. According to the LCRPC, it will be at risk from stillwater inundation during a 1% annual-chance storm with one-foot (0.3 meters) of sea level rise.

The most immediate threat to this property is damage to its utilities from inundation.

It is recommended that sea level rise be monitored, and the pumping station and utilities at this building be dry-floodproofed. It is recommended that the restroom be wet-floodproofed or its interior floor be elevated.

Resources

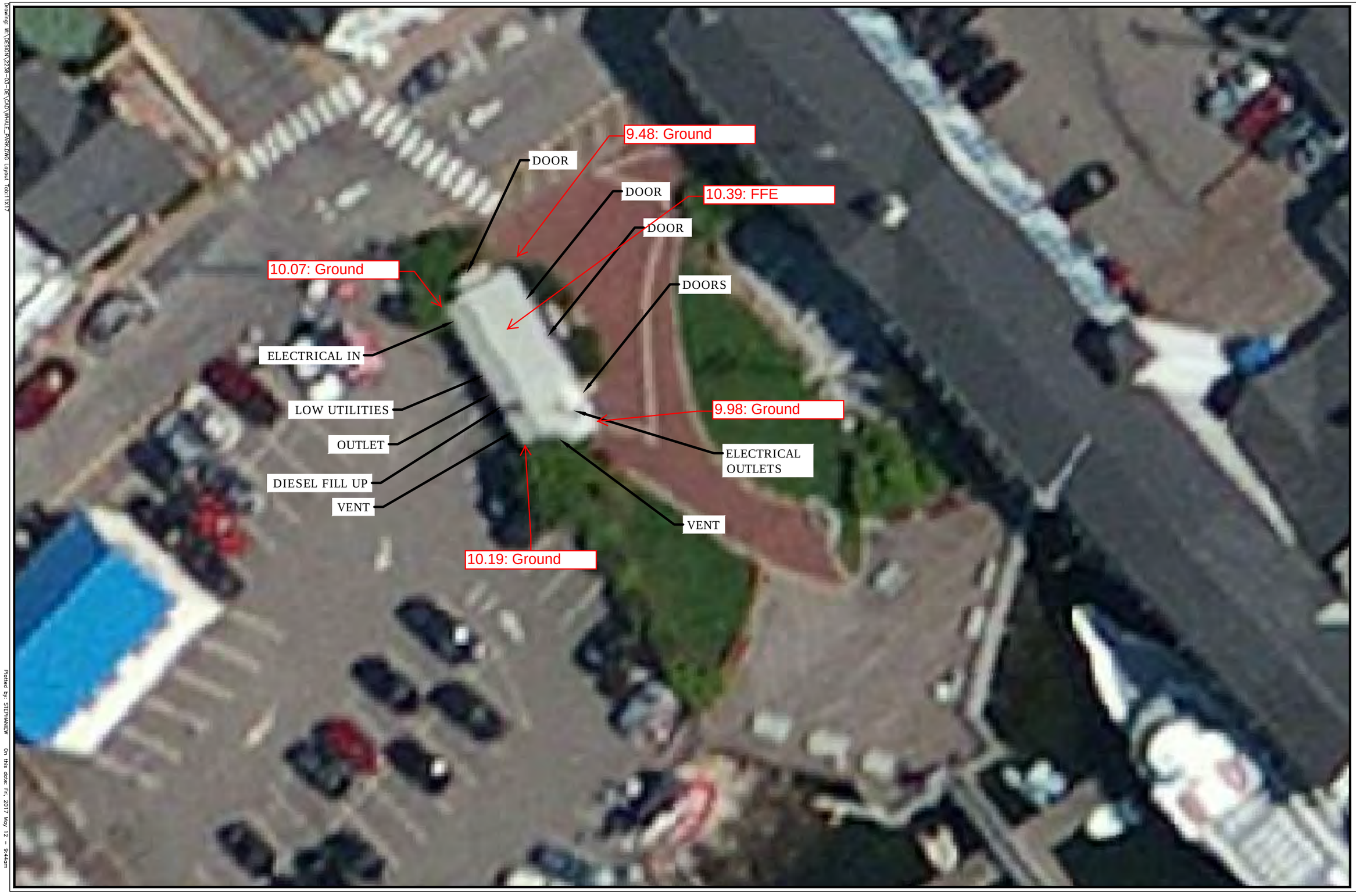
Low, DK., Mills, D., Quinn, R., Reeder, A., and J. Squerciati, 2017. "**Protecting building Utility Systems from Flood Damage; Principles and Practices for the Design and Construction of Flood Resistant Building Utility Systems.**" FEMA P-348, Edition 2 / February 2017.

Conrad, D., Kapur, O., Mahadevia, A., Maldonado, D., Moline, J., Overcash, G., Passman, S., Perotin, M., Reeder, A., Seitz, L., Sheldon, A., and J Squerciati, 2012. "**Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures.**" FEMA P-259 3rd Edition / January 2012

Frost-Tift, S., Mahadevia, A., Mills, D., Reeder, A., Sheldon, A., and J. Squerciati, 2014. "**Homeowner's Guide to Retrofitting: Six Ways to Protect Your Home From Flooding.**" FEMA P-312, 3rd Edition / June 2014.

US Army Corps of Engineers National Nonstructural Flood Proofing Committee, March 2016. "**Flood Damage Reduction Matrix."** <http://www.usace.army.mil/Missions/Civil-Works/Project-Planning/nfpc/>

Attachment 1: Key Features and Elevations



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REVISIONS

WHALE PARK

PROJECT NAME 1

36 COMMERCIAL STREET
BOOTHBAY HARBOR, MAINE

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DESIGNED	DRAWN	CHECKED

1"=20'
SCALE

MAY 10, 2017
DATE

2238-03
PROJECT NO.

PROP-7
SHEET NO.

Drawing: W:\DESIGN\2238-03-DE\CAD\WHALE_PARK.DWG Layout: Tab:11X17
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Attachment 2: Flood Damage Reduction Matrix

US Army Corps of Engineers ®

Flood Damage Reduction

National Nonstructural/ Flood Proofing Committee

March 2016

	FLOOD DAMAGE REDUCTION MEASURES												
	NONSTRUCTURAL MITIGATION MEASURES												
											NFIP		
FLOOD DAMAGE REDUCTION MATRIX	Elevation on Foundation Walls	Elevation on Piers	Elevation on Posts or Columns	Elevation on Piles	Elevation on Fill	Relocation	Buyout/ Acquisition	Dry Flood Proofing	Wet Flood Proofing	Flood Warning Preparedness	Flood Plain Regulation	Flood Insurance	Flood Mitigation 1
Flooding Characteristics													
Flood Depth													
Shallow (<3 ft)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Moderate (3 to 6 ft)	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
Deep (greater than 6 ft)	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
Flood Velocity													
Slow (less than 3 fps)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Moderate (3 to 5 fps)	N	N	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y
Fast (greater than 5 fps)	N	N	N	Y	N	Y	Y	N	N	Y	Y	Y	Y
Flash Flooding													
Yes (less than 1 hour)	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y
No	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ice and Debris Flow													
Yes	N	N	N	Y	Y	Y	Y	N	N	Y	Y	Y	Y
No	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Site Characteristics													
Site Location													
Coastal Flood Plain													
Beach Front	N	N	N	Y	N	Y	Y	N	N	Y	Y	Y	Y
Interior (Low Velocity)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Riverine Flood Plain	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Soil Type													
Permeable	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
Impermeable	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Building Characteristics													
Structure Foundation													
Slab on Grade	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Crawl Space	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
Basement	Y	N	N	N	N	Y	Y	N	Y	Y	y	Y	Y
Structure Construction													
Concrete or Masonry	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Metal	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Wood	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Structure Condition													
Excellent to Good	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fair to Poor	N	N	N	N	N	N	Y	N	N	Y	Y	Y	2
NED/NER/Recreation/Social Characteristics													
Economic													
Structure Protected	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	4	N	Y
Cost to Implement	M	M	M	M	M	H	H	L	L	L	L	L	H/M
Potential Flood Insurance Cost Reduction (Residential)	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	-	Y
Potential Flood Insurance Cost Reduction (Commercial)	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	-	Y
Potential Adverse Flooding Impact on Other Property	N	N	N	N	Y	N	N	N	N	N	Y	N	N
Reduction in Admin Costs of NFIP	N	N	N	N	Y	Y	Y	N	N	N	5	-	2
Reduction in Costs of Disaster Relief	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Reduction in Emergency Costs	N	N	N	N	N	Y	Y	N	N	N	N	N	2
Reduction in Damage to Public Infrastructure	N	N	N	N	N	Y	Y	N	N	N	N	N	2
Potential for Catastrophic Damages if Design Elevation Exceeded	N	N	N	N	N	N	N	Y	N	N	N	N	N
Promotes Flood Plain Development	N	N	N	N	N	N	N	N	N	N	N	6	N
Environmental													
Ecosystem Restoration Possible	N	N	N	N	N	Y	Y	N	N	N	N	N	N
Potential Adverse Environmental Impact	N	N	N	N	N	N	N	N	N	N	N	N	N
Recreation													
Recreation Potential	N	N	N	N	N	Y	Y	N	N	N	N	N	2
Social													
Community Remains Intact	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	3
Population Protected	N	N	N	N	N	Y	Y	N	N	Y	N	N	2
Potential Structure Marketability Increase	Y	Y	Y	Y	Y	Y	N	Y	Y	N	4	N	Y

1 NFIP Flood Mitigation may vary by structure
2 Buyout/acquisition only
3 Elevation only
4 Post FIRM construction only
5 Post FIRM structures elevation on fill
6 Yes, if in floodplains less frequent than the 100-year

Y-Yes L-Low
N-No M-Med
H-High

The US Army Corps of Engineers National Nonstructural/Flood Proofing Committee [NFPC] is available to assist in any aspect of formulating and implementing nonstructural flood damage reduction measures and realizing the opportunities that exist with nonstructural.

For more information, please contact the NFPC Chairman and committee members at: dll-cenwo-nfpc@usace.army.mil
or visit the NFPC website at: http://www.usace.army.mil/Missions/CivilWorks/ProjectPlanning/nfpc.aspx

US Army Corps of Engineers
Nonstructural - Flood Proofing
National Nonstructural / Flood Proofing Committee

Structure Inventory Data Requirements
(Note: bold/shaded cells represent most pertinent data requirements)

Structure Data	Data Definition
Building Identification Number	**Specific to Structure (geo referenced, coordinates, etc.)**
Structure Address	**Specific Postal Location of Structure**
Critical Facility	**Yes / No**
Lowest Adjacent Ground Elevation	**Elevation of Lowest Ground at Structure**
First Floor Elevation	**Elevation of Finished First Floor**
Structure Category	**Residential, Commercial, Industrial, Public**
Structure Use	What is the Specific Use of Structure
Total Stories	Total Number of Floors Above Grade
Structure Footprint	**Total Square Foot Area of At-Grade Floor**
Number of Structural Corners	**Total Number of Corners in Perimeter**
Structure Foundation Type	**Slab, Reinforced Slab, CMU, Piers, Columns, Posts, Stone**
Structure Perimeter Distance	**Total Length of All Exterior Sides of Structure**
Exterior Wall Construction	**Wood, Masonry, Brick, Metal, Stone, Concrete, Other**
Structure Visual Condition	**Good / Fair / Poor**
Garage	**Attached, Detached, None**
Doorways	**Number of Pedestrian Doorways**
Basement	**Full Basement, Half, Crawl Space, None**
Structure Photos	**Photograph of Four Sides of Structure**
Utilities Location	**Electrical, Gas, Water, Sewer, Oil, Propane, Coal, Other**
Structure Value	**Assessed Value of Structure**
Fireplace	Yes / No
Structure Owner	Who Owns the Structure
Year Structure Built	Year Structure was Constructed (Any Historic Significance)
Water Surface Elevation	Elevation or Depth of Water at Structure (H&H activity)
Water Velocity	Erosive Potential of Flood Waters (H&H activity)

Attachment 3: Selecting Floodproofing Techniques- Financial Considerations

Selecting Floodproofing Techniques – Financial Considerations

Floodproofing costs money. Generally, a higher level of flood protection costs more. Prior to selecting a floodproofing method, it is necessary to evaluate the benefits of a proposed project and the anticipated cost of achieving those benefits. The following information can be used as general guidance for evaluating floodproofing options.[1]

Benefits

Floodproofing is principally a means for **reducing damages from future floods**. This includes the cost of repairing the building and its utility systems, repair or replacement of damaged contents, the time and expense for cleanup, the cost of housing during periods when the structure cannot be occupied, and loss of income if flood cleanup and repairs require time off from work. The tables on the following page can be used to estimate potential damages to buildings and contents based on the depth of flooding. The history of previous damages can also help with this assessment. Keep in mind that the damages from frequent events may be prevented numerous times over the life of the building. Because no floodproofing project can prevent all potential flood damages, the expected project benefit is the difference between the expected damages without the project and the expected damages if the project is implemented.

Additional benefits of floodproofing include:

- **Increased safety:** Floodproofing reduces health and safety impacts associated with reentry into a flooded structure. Relocation away from the flood hazard area precludes the need to evacuate and is thus even safer.
- **Reduced flood insurance premiums:** The cost of flood insurance for buildings that do not comply with floodplain development standards (at the time of construction) is generally quite high. Actuarial rates are based on the height of the first floor (or dry floodproofing of non-residential buildings) relative to the height of the 100-year flood. A project that brings a building into compliance and/or increases the level of protection can significantly reduce the annual cost of flood insurance.
- **Increased resale value**.
- **Intangible benefits** result from reducing the annoyance, inconvenience, and stress associated with preparation for and recovery from flood events.

Project Costs

General information about construction costs for retrofitting projects is provided on the following pages. These values are only appropriate for preliminary planning purposes. Once a floodproofing method has been selected and the project is designed, a more accurate cost estimate can be developed. Make sure that the detailed cost estimate includes all of the project elements, such as temporary housing during construction, landscaping, and annual maintenance expenses.

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[1] Additional information for assessing the financial benefits of a floodproofing project is provided in *Chapter V: Benefit / Cost Analysis and Alternative Selection*, in FEMA 259, *Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures (2001) at* http://www.fema.gov/library/viewRecord.do?id=1645.

Depth-Damage Tables

The following tables can be used to estimate the damage that may be sustained each time a building is flooded, based on the depth of flooding relative to the top of the first floor (excluding the basement, which is defined as any portion of the building with its floor below grade on all sides).

Flood Depth	**Building Damage Percent by Building Type** (based on Building Replacement Value)						
	1 Story without Basement	2 or More Stories without Basement	Split Level without Basement	1 Story with Basement	2 or More Stories with Basement	Split Level with Basement	Mobile Home*
-2	0.0	0.0	0.0	13.8	10.2	10.4	0.0
-1	2.5	3.0	6.4	19.4	13.9	14.2	0.0
0	13.4	9.3	7.2	25.5	17.9	18.5	8.0
1	23.3	15.2	9.4	32.0	22.3	23.2	44.0
2	32.1	20.9	12.9	38.7	27.0	28.2	63.0
3	40.1	26.3	17.4	45.5	31.9	33.4	73.0
4	47.1	31.4	22.8	52.2	36.9	38.6	78.0
5	53.2	36.2	28.9	58.6	41.9	43.8	80.0
6	58.6	40.7	35.5	64.5	46.9	48.8	81.0
7	63.2	44.9	42.3	69.8	51.8	53.5	82.0
8	67.2	48.8	49.2	74.2	56.4	57.8	82.0
9	70.5	52.4	56.1	77.7	60.8	61.6	82.0
10	73.2	55.7	62.6	80.1	64.8	64.8	82.0
11	75.4	58.7	68.6	81.1	68.4	67.2	82.0
12	77.2	61.4	73.9	81.1	71.4	68.8	82.0
13	78.5	63.8	78.4	81.1	73.7	69.3	82.0
14	79.5	65.9	81.7	81.1	75.4	69.3	82.0
15	80.2	67.7	83.8	81.1	76.4	69.3	82.0

Source: "Default Building Depth-Damage Functions: Residential Buildings" from FEMA Retrofitting Flood-Prone Residential Buildings Training (January 2009).

Flood Depth	**Contents Damage Percent by Building Type** (based on total value of contents)					
	1 Story without Basement	2 Story without Basement	Split Level without Basement	1 or 2 Story with Basement	Split Level with Basement	Mobile Home
-2	0	0	0	6	5	0
-1	0	0	0	12	8	0
0	14	8	5	17	9	12
1	21	14	14	23	24	66
2	33	20	20	30	29	90
3	41	27	38	35	33	90
4	44	30	41	42	41	90
5	45	33	42	50	48	90
6	60	36	50	57	53	90
7	65	39	51	66	54	90
8	66	44	62	74	66	90
>8	68	50	65	77	72	90

Source: FEMA 259, *Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures (2001).*

Floodproofing Cost Estimates

The following cost estimates are for preliminary planning purposes only. They are based on nationwide averages and published in 2001.[2]

Elevation:

2-foot raise: Wood frame building with basement or crawlspace – $18 per square foot
Wood frame building with slab-on-grade foundation – $50 per square foot
Masonry building with basement or crawlspace – $37 per square foot
Masonry building with slab-on-grade foundation – $50 per square foot

3- to 8-foot raise – add $0.80 per square foot for each additional foot of elevation
Above 8 feet – add $1.05 per square foot
Wood frame with brick veneer on walls – add 10 percent

These costs include foundation, existing utilities, and miscellaneous items. Large buildings (3 or more stories and those with footprints more than 2,500 square feet) and those with complex shapes are technically more difficult to elevate and may thus be more costly.

Displacement costs – Additional expenses will be incurred to remove and store contents and for temporary living quarters during construction, which may last 2 to 3 weeks.

Relocation:

Relocation costs: Wood frame building with basement – $34 per square foot
Wood frame building with crawlspace – $29 per square foot
Wood frame building with slab-on-grade foundation – $54 per square foot
Masonry building with basement – $52 per square foot
Masonry building with crawlspace – $34 per square foot
Masonry building with slab-on-grade foundation – $65 per square foot

Wood frame with brick veneer on walls – add 10 percent
Restoration of old site: $12 per square foot of building footprint

These costs include off-site relocation (less than 5 miles) and new site development for a 1,000 square foot building. Extrapolation of this unit cost to larger buildings may result in artificially high estimates because the costs of relocation do not increase proportionally with building size. However, if the building has 3 or more stories, a footprint greater than 2,500 square feet, or a complex shape, technical challenges may result in increased costs.

Displacement costs – Additional expenses will be incurred to remove and store contents and for temporary living quarters during construction, which may last 3 to 4 weeks.

[2] Source: FEMA 259, *Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures (2001).*

Dry Floodproofing
Sprayed-on cement (above grade) – $3.50 per square foot
Waterproof membrane (above grade) – $1.17 per square foot
Asphalt (2 coats below grade; not including cost of excavation) – $1.17 per square foot
Perimeter drainage – $33 per linear foot
Plumbing check valve – $660 lump sum
Sump pump (with backup battery) – $1,060 lump sum
Metal flood shield – $77 per square foot
Wood flood shield – $24 per square foot
Sprayed-on cement (above grade) – $3.50 per square foot

Wet Floodproofing
Unfinished basement: 2 feet height (above basement floor) – $1.80 per square foot of house footprint
4 feet height (above basement floor) – $3.70 per square foot of house footprint
8 feet height (above basement floor) – $10.60 per square foot of house footprint
Crawlspace: 2 feet height (above lowest adjacent grade) – $1.40 per square foot of house footprint
4 feet height (above lowest adjacent grade) – $3.45 per square foot of house footprint

Floodwalls and Levees
Floodwalls: 2 feet above ground level – $90 per linear foot
4 feet above ground level – $132 per linear foot
Levees: 2 feet above ground level – $39 per linear foot
4 feet above ground level – $73 per linear foot
6 feet above ground level – $122 per linear foot
Interior drainage – $4,500 lump sum
Closures – $77 per square foot
Riprap – $33 per cubic yard
Seeding of disturbed areas – $0.05 per square foot

Floodwall costs are based upon typical foundation depth of 30 inches. Levee costs are based upon typical foundation depth of one foot, 5-foot top width, and 1:3 side slopes. Levee costs include seeding and stabilization.

Additional Costs
- Compliance with building codes – These estimates do not include additional expenditures that may be required to bring the building into compliance with building codes.
- Professional or architectural design – 10% of estimated costs
- Contractors' profit – 10% of estimated costs
- Contingency to account for unknown or unusual conditions
- Annual maintenance expenses – Levees, floodwalls, dry floodproofing, and wet floodproofing projects all require ongoing maintenance.

Additional Information
- **FEMA's Benefit-Cost Analysis** methodology and tools can be used to evaluate the cost effectiveness of proposed retrofitting projects (http://www.fema.gov/government/grant/bca.shtm).