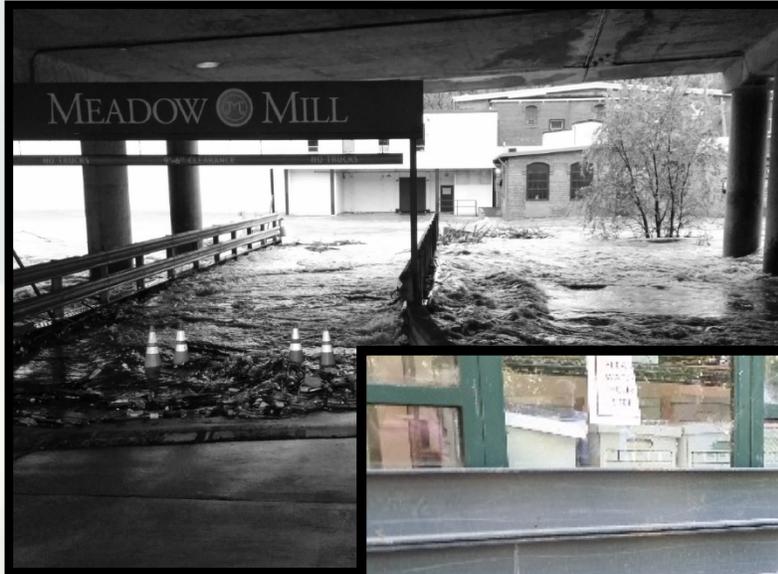




ASSESSMENT OF FLOOD RISK ADAPTIVE MEASURES BALTIMORE CITY, MARYLAND



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MARCH 2019

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1 INTRODUCTION

1.1 BACKGROUND

Baltimore City, Maryland is one of the oldest port cities on the east coast. Land use and floodplain regulations were not yet in place when the area was first settled by Europeans, so many buildings were built in areas with a high risk for flood damages. Today, Baltimore has about 80,000 historic buildings with approximately 8,000 of those in the regulated floodplain (mainly in the neighborhoods of Fells Point, Dickeyville, Mill Valley, Federal Hill, and Locust Point). Given the significant historical resources in the area and the high risk of flooding, Baltimore City, Maryland (Baltimore City or City) and members of the Maryland Silver Jackets team, an interagency flood risk management team, partnered to investigate potential flood risk adaptive measures (FRAMs) for use on properties in the study area for residential, commercial, and public buildings. The partnering agencies included: the U.S Army Corps of Engineers, Baltimore District (USACE), the Maryland Historical Trust (MHT), the Maryland Department (MDE) of the Environment, the National Weather Service, and Baltimore City.

FRAMs are physical and nonphysical flood risk management measures that reduce flood risk by modifying the characteristics of structures or modifying the behavior of people living in or near floodplains. These measures differ from more traditional structural measures, such as floodwalls and levees, which reduce the risk of flood waters making contact with buildings. This assessment focuses on physical FRAMs and is part of a larger effort by the City to identify specific solutions that will minimize flood damages to historic buildings in Baltimore City.

The goals of this assessment are to evaluate and recommend FRAMs for features on nine sample buildings with flood risk, including historic residential, commercial and public buildings, and to provide property owners with helpful information to implement these types of measures.

The City plans to incorporate the results of this assessment and the recommended solutions into a design guidance manual for flood proofing historic buildings, which will be made available to the public.

1.2 PURPOSE AND NEED

The purpose of this assessment is to identify FRAMs for nine sample buildings located in the floodplain and provide helpful information to building owners on how to implement these measures. To meet this purpose, the project team accomplished the following tasks:

- Conducted building elevation surveys for nine sample buildings in the floodplain.
- Performed inside and outside assessment for the sample buildings.

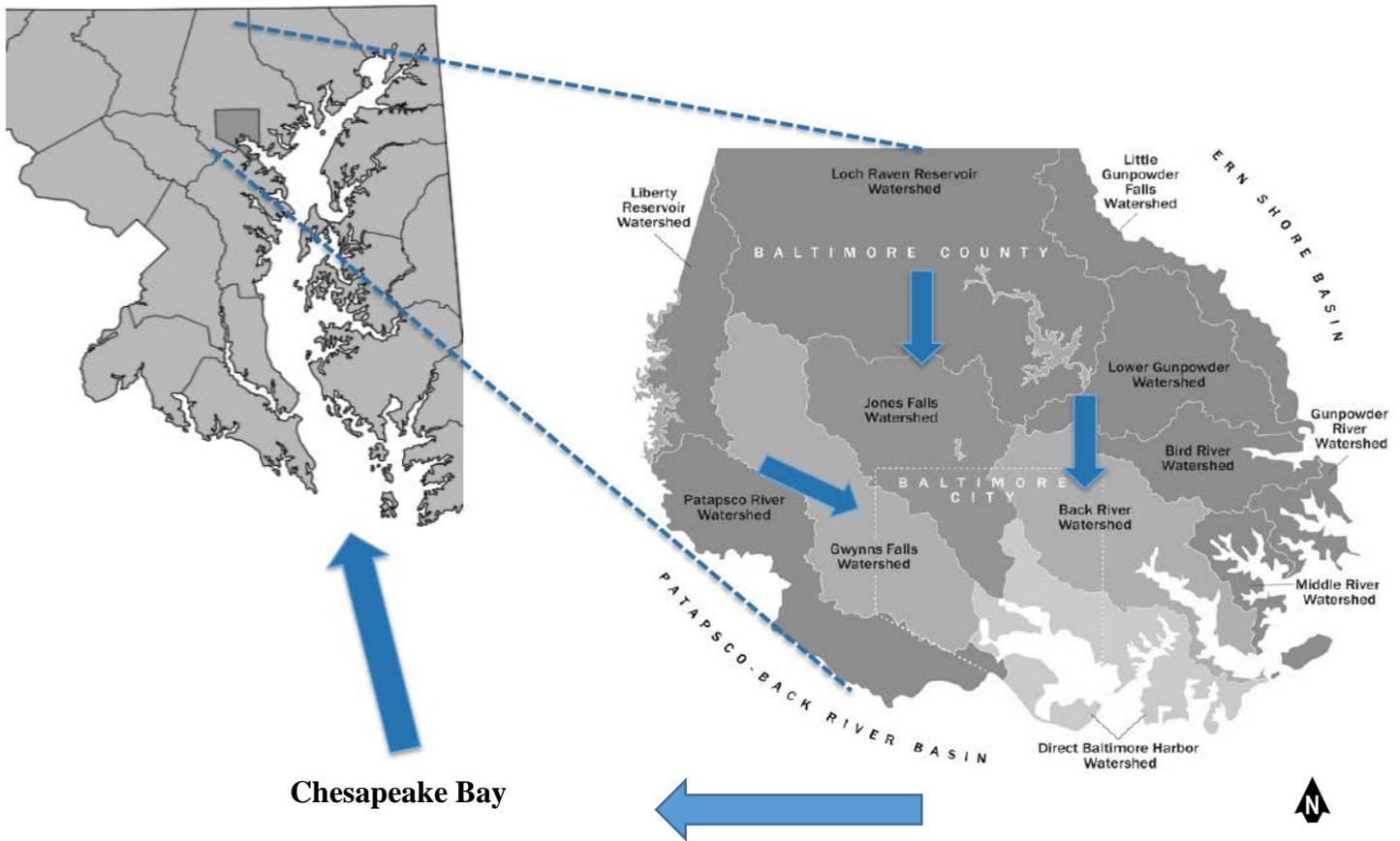
- Developed preliminary recommendations for FRAMs on specific historic features.
- Prepared specific concept sheets for the nine sample buildings and summarized into a final report

1.3 STUDY AREA

The nine sample buildings evaluated in this study are located either in the 1% annual chance (100-year) floodplain or the 0.2% annual chance (500-year) floodplain in Baltimore City, Maryland. The City, which has approximately 52 miles of shoreline, is located adjacent to the Baltimore Harbor and its tributaries feed into the Chesapeake Bay. The City lies within two major drainage basins—the Patapsco River Basin and Back River Basin. The Gwynns Falls drains the northwest and western portions of the City, and the Jones Falls drains the upper northwest and central portions of the City, both emptying into the Patapsco River. Herring Run drains the eastern part of the City, emptying into Back River in Baltimore County. During periods of heavy rainfall, these tributaries can be subject to dangerous riverine flooding. Figure 1-1 shows the location of Baltimore City area relative to the Chesapeake Bay.

The City is vulnerable to a variety of types of flooding – storm surges, tidal flooding, sea level rise, riverine flooding, and stormwater flooding. A common type of flooding seen in this region is flash flooding. Flash floods are local floods of short duration generally resulting from heavy rainfall in the immediate vicinity. They are extremely dangerous, being the number one cause of weather-related deaths in the United States. Flash floods catch people off guard, occurring within six hours of the rain event; as opposed to non-flash flooding, which is a longer term event. This assessment focused on nine buildings in some of the highest risk areas prone to flooding in Baltimore including Fells Point, Jones Falls, and the Baltimore Harbor.

Figure 1-1: Map of Baltimore City Relative to the Chesapeake Bay



Chesapeake Bay

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2 BUILDING SELECTION AND DATA COLLECTION

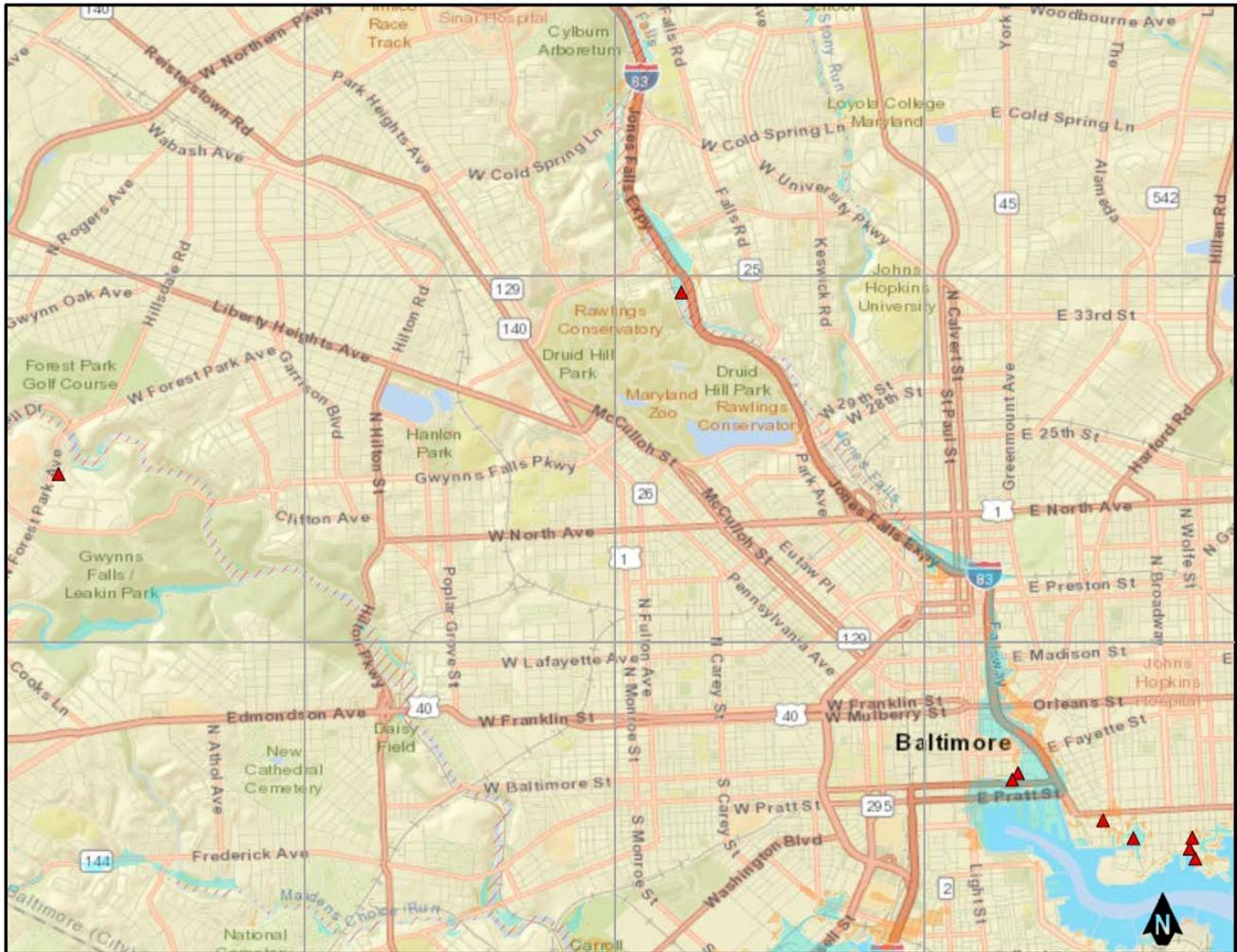
2.1 BUILDING SELECTION

The City identified nine buildings to use as samples for the assessment based on two major criteria: (1) location in the floodplain with features that routinely facilitate flooding, and (2) whether the building was listed as historic. For the nine buildings, three were considered commercial buildings; four were residential; and two were public buildings. Figure 2-1 shows the location of the sample buildings. Through research and coordination with the study partners and the property owners, the team was able to better understand the extent of the flood risk in the study area, as well as the historic preservation requirements.

2.2 HISTORICAL CONSIDERATIONS

Section 106 of the National Historic Preservation Act (NHPA) requires state and federal government agencies to consider the effects of their projects on historic and archeological resources through a consultation process. Protecting cultural resources benefits the public by revitalizing communities, promoting heritage tourism, and preserving tangible links with our past. Many of the buildings in Baltimore City are listed on the National Register of Historic Places, therefore, modification to the buildings are subject to approval from various historic preservation organizations, such as the Baltimore City Historic Preservation Office and MHT. During the assessment process, through coordination with representatives from MHT and Baltimore City Historic Preservation Office, every effort was made to ensure that the recommendations set forth in the assessment are consistent with the historic preservation guidelines as currently written and understood. However, specific approval from the pertinent historic preservation entities must be obtained prior to implementation of any FRAM, whether recommended in this assessment or otherwise.

Figure 2-1: Locations of the Nine Sample Buildings Assessed



2.3 DATA COLLECTION

2.3.1 BUILDING ELEVATION SURVEYS

In the fall of 2016, USACE performed building elevation surveys on the nine historic buildings to determine first floor elevation, low opening/first point of entry elevation, and lowest adjacent grade (LAG). Figure 2-2 shows the location points for each building. Real Time Kinematic (RTK) Global Positioning System (GPS) technology was used to collect the data. If the data could not be collected using the RTK system due to obstructed signals, existing topography was used to estimate the elevations as an alternative method. All elevations included in this report are referenced to the North American Vertical Datum 1988 (NAVD88). The building elevation data was necessary to show the relationship between the low opening and first floor elevations with the various flood elevations. The elevation data collected for each building can be found in Appendix A – Concept Plans. Note: elevations are based on a specific datum and are not heights above the ground.

Figure 2-2: Building Elevation Survey Data Collected



2.3.2 FLOOD ELEVATION DATA

The flood elevation data utilized in the development of the concept alternatives was sourced from the April 2, 2014 FEMA Flood Insurance Study (FIS) for Baltimore City. Table 2-1 shows the nine historic buildings and the flood elevation for various flood events, from the 50% annual chance (2-year) flood up to the 0.2% annual chance (500-year) flood. This information is necessary when conducting the assessment and developing flood risk adaptive measures for each building. The table also shows the flooding source (tidal or riverine) and the building type.

Table 2-1: Flood Elevation Data for Nine Sample Buildings

Flood Elevation Data										
#	Flood Source	Building Type	50% Annual Chance (2-year)	20% Annual Chance (5-year)	10% Annual Chance (10-year)	4% Annual Chance (25-year)	2% Annual Chance (50-year)	1% Annual Chance (100-year)	0.5% Annual Chance (200-year)	0.2% Annual Chance (500-year)
1	Tidal Floodplain (Baltimore Harbor)	Single Family Dwelling (Residential)	4.0 feet	4.1 feet	4.2 feet	4.4 feet	4.8 feet	5.3 feet	5.9 feet	7.5 feet
2	Tidal Floodplain (Baltimore Harbor)	Single Family Dwelling (Residential)	4.0 feet	4.1 feet	4.2 feet	4.4 feet	4.8 feet	5.3 feet	5.9 feet	7.5 feet
3	Tidal Floodplain (Baltimore Harbor)	Preserved Historic Home (Museum)	4.0 feet	4.1 feet	4.2 feet	4.4 feet	4.8 feet	5.3 feet	5.9 feet	7.5 feet
4	Tidal Floodplain (Baltimore Harbor)	Office Building (Commercial)	4.0 feet	4.1 feet	4.2 feet	4.4 feet	4.8 feet	5.3 feet	5.9 feet	7.5 feet
5	Tidal Floodplain (Baltimore Harbor)	Office Building (Commercial)	4.0 feet	4.1 feet	4.2 feet	4.4 feet	4.8 feet	5.3 feet	5.9 feet	7.5 feet
6	Riverine Floodplain (Jones Falls)	Office Building (Government)	10.2 feet	10.6 feet	10.9 feet	11.3 feet	12.0 feet	12.6 feet	12.9 feet	13.9 feet
7	Riverine Floodplain (Jones Falls)	Office Building (Commercial)	10.5 feet	10.9 feet	11.1 feet	11.5 feet	12.2 feet	12.8 feet	13.2 feet	14.2 feet
8	Riverine (Jones Falls)	Mixed Use (Commercial)	139.3 feet	139.6 feet	140.2 feet	141.8 feet	143.3 feet	145.9 feet	148.1 feet	154.6 feet
9	Riverine (Gwynns Falls)	Single Family Dwelling (Residential)	237.0 feet	237.7 feet	238.4 feet	239.7 feet	241.8 feet	247.0 feet	248.3 feet	252.3 feet

Key	
Number Value Color	Origin of Numerical Value
	From FEMA Flood Insurance Study (FIS) April 2, 2014
	From linear interpolation of values derived from FIS
	From plotting blue and black values on a graph and extrapolating

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3 TYPES OF FLOOD RISK ADAPTIVE MEASURES

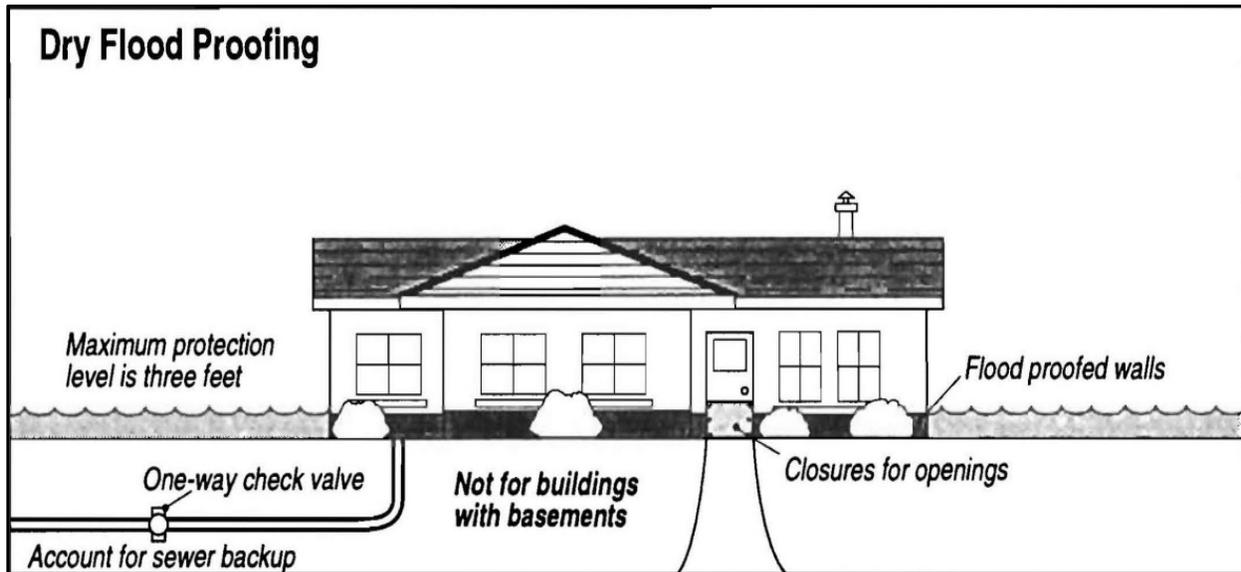
Flood risk adaptive measures (FRAMs) reduce flood risk by modifying the characteristics of buildings that are subject to flooding or modifying the behavior of people living in or near floodplains. In general, FRAMs do not modify the characteristics of floods (depth, velocity) nor do they induce development in a floodplain that is inconsistent with reducing flood risk. FRAM options consist both of measures that are physical: dry flood proofing, wet flood proofing, elevation of buildings, acquisition of buildings, relocation of buildings; and nonphysical: flood preparedness plans, flood insurance, evacuation plans, public warning systems, zoning, building codes, and land use changes. This assessment focuses on physical types of FRAMs.

Initial screening of potential FRAMs identified dry flood proofing, wet flood proofing, and structural elevation as the primary physical measures applicable to the nine sample buildings in Baltimore City. FRAMs, similar to those recommended in this study, have been employed in similar situations across the country and have been proven to successfully reduce flood damage. They are effective for reducing both short- and long-term flood risk and flood damage and can be cost effective when compared to larger structural measures.

3.1 DRY FLOOD PROOFING

Dry flood proofing consists of waterproofing the exterior of a structure up to a determined height in order to reduce the probability of flooding to the building interior. Dry flood proofing of a structure can generally provide effective flood risk management up to a height of 3-4 feet on the exterior walls, after which point the hydrostatic load on the walls may be high enough to significantly increase the risk of structural damage. Buildings may be dry flood proofed above this 3-4 foot height if a full structural analysis is performed and the walls are found to have sufficient flexural capacity. Full structural analysis should also be performed if erosive flood velocities are greater than 3 ft. /sec due to lateral/shear forces. In some cases, where necessary, sealant may be applied to exterior walls in order to make them sufficiently impermeable to resist water penetration up to the targeted elevation (Design Flood Elevation (DFE)). Otherwise, provisions can be made for the installation of a temporary impermeable membrane around the building exterior just before a flood event begins, if there is adequate warning time. If a building contains a basement area, it typically must be removed by filling prior to implementation of dry flood proofing measures to the first floor and above. Provisions must also be made for the closure of building openings, specifically doors and windows with a sill below the DFE. Such openings may have permanent framing installed which allows for the placement of a temporary flood shield to seal the opening in the case of a flood event; or existing doors, windows and frames may be completely replaced with structural flood proof products. Interior drainage collection systems and pumps are required to control the interior water level and collect seepage. Figure 3-1 shows a diagram of a typical dry flood proofed structure.

Figure 3-1: Dry Flood Proofing



Source: Federal Emergency Management Agency

Suitability for Baltimore City

Dry flood proofing is an effective FRAM option in Baltimore City in certain applications, particularly for masonry buildings where the final DFE is no greater than 3-4 feet above the finished floor elevation. Due to the short duration of flooding in Baltimore City, combined with the masonry wall construction, flood waters cannot easily penetrate through the walls, therefore an impermeable membrane is not needed.

Challenges

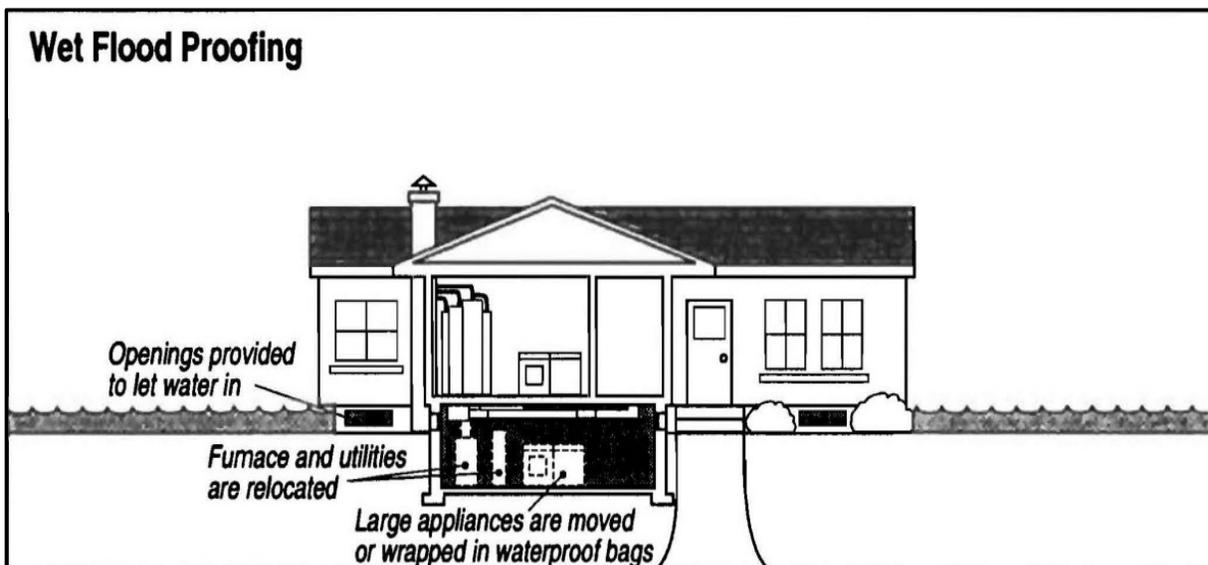
The challenges for dry flood proofing buildings in Baltimore City are the limited warning time to implement closure barriers, maintaining historic aesthetics of buildings, and, in some cases, the limited level of flood risk management. The number of pre-flood actions can be reduced by purchasing flood proof doors and windows that are watertight and able to resist hydrostatic force during a flood event. However, these doors are relatively expensive and may be difficult to implement in a way that meets the pertinent historic preservation guidelines.

3.2 WET FLOOD PROOFING

Wet flood proofing is the process of modifying a building to allow flood waters to enter and inundate a portion of the building in order to minimize the risk of structural damage. The designed inundation area may be the sub-grade basement or crawlspace of a building, or the ground floor up to the DFE. Raising utilities, important building contents, moving equipment to higher floors above the DFE, using flood-damage-resistant materials in the building interior, and installing flood louvers, or flood openings, in exterior walls to equalize the hydrostatic pressure are examples of

some of the most common wet flood proofing measures. Additional provisions may be required to ensure minimal damage to the building's mechanical and electrical systems in the event of a flood. Figure 3-2 shows a diagrammatic detail/section of a typical wet flood proofed structure.

Figure 3-2: Wet Flood Proofing



Suitability for Baltimore City

Wet flood proofing is an effective FRAM option in Baltimore City for a relatively small number of cases where structure type and first floor occupancy allow for it. The measure is low cost, requires minimal pre-flood actions, and is generally agreeable with historic preservation guidelines.

Challenges

Implementation would require significant changes to interior building layout and functionality, which may not be desirable in many cases. Allowing flood waters into the structure would require all valuables and utilities to be elevated above the DFE, which may be costly depending on the original building layout. This would also require pumping the water out and cleaning of the sub grade. Typically these options are also not practical for row homes considering many of these buildings have multiple owners.

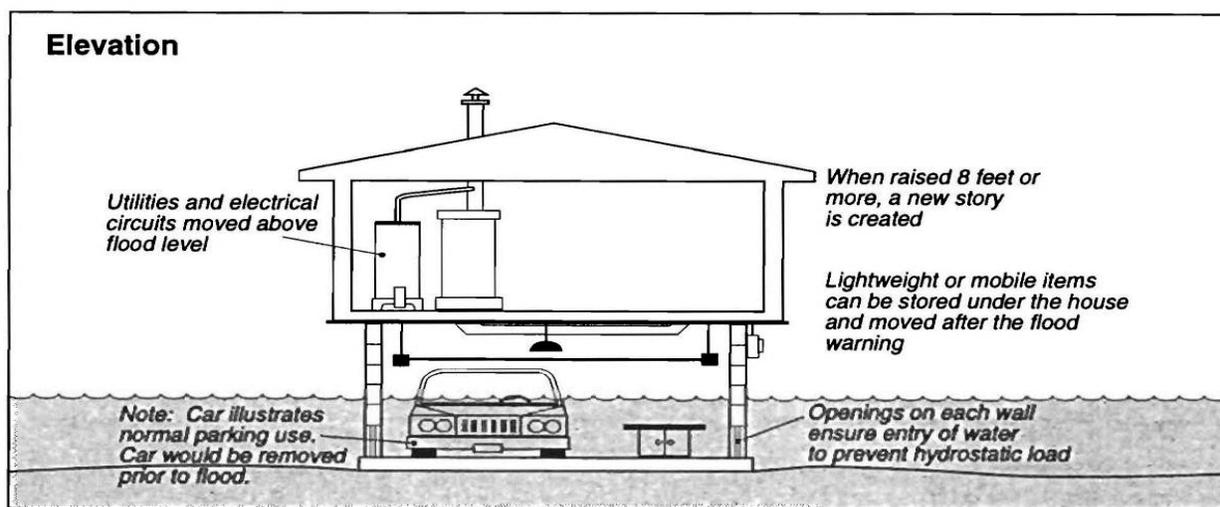
3.3 ELEVATION OF BUILDINGS

Elevation involves raising flood prone buildings in place so that the lowest floor is above the DFE. The building is raised on temporary framing and set on extended foundation walls or structural fill above the DFE. For buildings that include basements or crawl spaces, the basement or crawl space can be filled in, the building raised above the DFE, and additional living space can be added to

compensate for the lost basement space. Another option for basements and crawl spaces is wet flood proofing, which would allow water to pass through without damaging the structural integrity of the building.

The primary advantage of this measure is that the risk of flooding in all flood events up to the new low opening elevation is completely eliminated, without the need for any pre- or post-flood mitigation actions. Additionally, raising the low floor elevation typically makes the property eligible for a reduction in flood insurance premiums. The disadvantages are that residents/tenants would need to be relocated for a period of time during construction, the relatively high cost for construction, and possible impacts to the historic integrity of the building exterior. Prior to implementing this measure, a detailed assessment of the building is required. Factors such as foundation type, soil type and bearing capacity, weight of the building, lateral forces on the building, structural condition, and height of the desired elevation above grade, determine the feasibility of elevating the structure. Figure 3-3 shows a diagrammatic detail/section of a typical elevated structure.

Figure 3-3: Elevation of Buildings



Suitability for Baltimore City

Elevation is an option for many detached buildings, particularly those that are wood framed. However, it is not applicable in many circumstances in Baltimore City, since many buildings have shared structural walls with one or more adjacent buildings.

Challenges

Although simultaneous elevation of multiple adjacent buildings is technically feasible, the complication of coordination among multiple building owners does not make this a viable option. The primary concern with elevation in Baltimore City is historic preservation. Based on input from historic preservation representatives during the site visit process, the issues include consistency of new materials with the existing historic materials, and aesthetic consistency with surrounding

buildings after the elevation is complete. Close coordination with historic preservation organizations would be required to successfully elevate these buildings.

3.4 PASSIVE AND ACTIVE MEASURES

FRAMs can be either passive or active. A *passive* measure is one that requires minimal pre-flood actions and includes flood doors and windows (dry flood proofing), wet flood proofing, and structural elevation. An *active* measure requires property owners to perform pre-flood actions in order to deploy an adaptive measure, including temporary flood barriers. Property owners must consider the type of flooding they are vulnerable to and the amount of warning time they will have to implement measures prior to the flood. If there is minimal warning time, passive measures must be utilized.

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4 ASSESSMENT AND DESIGN CONSIDERATIONS

4.1 ASSESSMENT PROCESS

The team for the assessment consisted of members from USACE Baltimore District and two members of the USACE National Nonstructural Committee (NNC). Various representatives from Baltimore City Government and the MHT were present throughout the site visits, providing additional information and input for the preliminary development of concept alternatives.

The team conducted assessments for each building with the purpose of observing each structure from the exterior, interior first floor, and basement; take measurements; and visit with property owners. The building must be individually inspected in order to determine which type of measure is most appropriate for that particular structure given the building usage, condition, construction type, location within the floodplain, the specific flood characteristics (velocities and depths), and other site conditions. The local floodplain ordinance that requires buildings to meet certain elevation requirements must also be considered when evaluating adaptive measures.

The Baltimore City ordinance regulates commercial buildings in riverine and tidal floodplains; however, it does not regulate residential buildings. For the nine sample buildings, the team used the City ordinance to determine a target Design Flood Elevation (DFE), or level of flood risk management desired at each building.

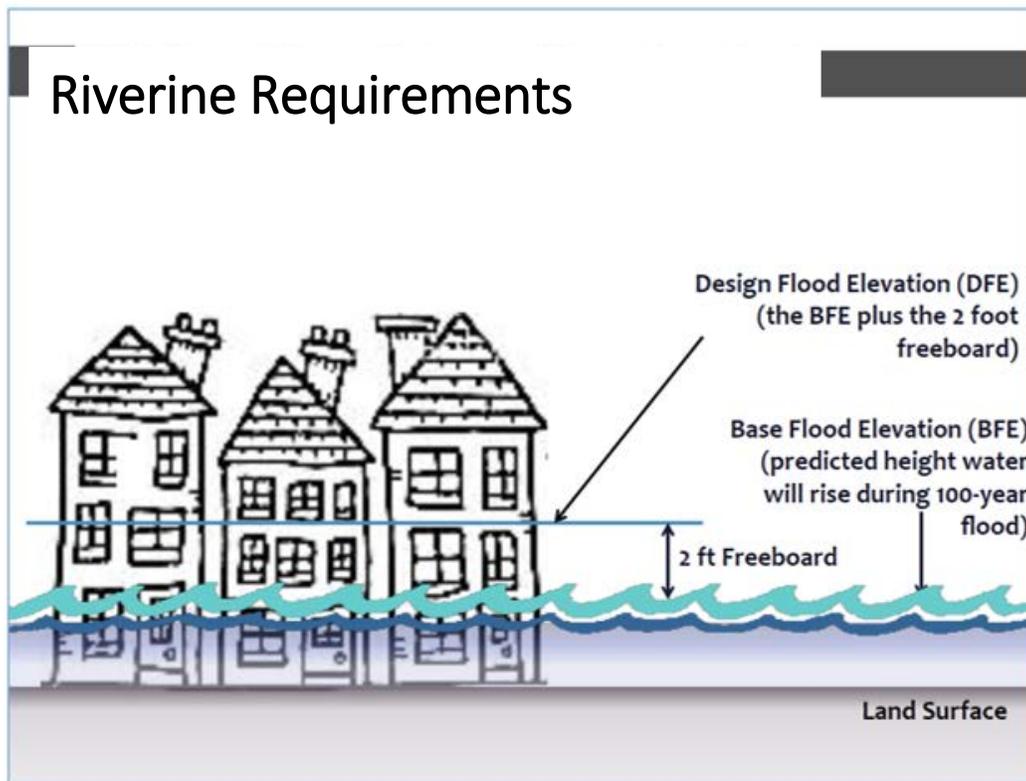
Target Design Flood Elevation in Riverine Floodplains

For commercial buildings in riverine floodplains, the City regulates to the 1% annual chance (100-year) flood elevation, or the base flood elevation (BFE), plus two feet of freeboard (“BFE+2”) (see Figure 4-1); or to the 0.2% annual chance (500 year) flood elevation. The higher elevation between these two is the target DFE. The flood elevation data in Table 2-1 was used to determine the target DFE for each structure.

Target Design Flood Elevation in Tidal Floodplains

For commercial buildings in the tidal floodplain, the City regulates to the 0.2% annual chance flood elevation (500-year) plus 2 feet freeboard. If required flood risk management is higher than what the dry flood proofing will allow, the City may consider wet flood proofing options in addition to the dry flood proofing. Although the City does not regulate the residential buildings, the team used the same ordinance requirements as the commercial structures to determine the target DFE. However, if it could not easily be met, the team developed FRAMs that could give the highest degree of flood risk management.

Figure 4-1: Standards for Design Flood Elevations for Riverine Commercial Buildings



Reference: PowerPoint Presentation by Kristin Baja and Lauren Schiszik, City of Baltimore, Department of Planning, May 25, 2017 (https://mht.maryland.gov/home_floodworkshop.shtml).

4.2 FLOOD RISK ADAPTIVE MEASURES IN HISTORIC AREAS

The typical recommendation for any modifications to a historic building is to minimize changes to the exterior and provide the reviewing historic preservation official detailed information regarding proposed changes to the structure (architectural drawings, details, renderings, product sheets and specifications prior) during the approval process. The level of detail provided in supporting documentation may heavily influence the speed and effectiveness of the review process. If possible, exterior modifications to the building should be done in a way that is least invasive to the original aesthetics of the building. Based on discussions with the historic preservation office personnel, below are some general guidelines to try to follow when considering FRAMs for historic buildings.

Passive Dry Flood Proofing Solutions- Flood Doors and Windows

Approval for replacement of historic doors with flood doors will depend on whether the existing door/window is considered historic, or original to the construction of the building. If the

door/window is the original door placed during original construction of the building, flood doors may not be a likely solution. If the historic door/window is not visible from the main street, it is more likely that door replacement would likely be approved. Replacement of historic door/window framing, especially if it has specific architectural detailing, will likely not be approved.

Active (non-passive) Dry Flood Proofing Solutions- Temporary Barriers

Approval for installation of temporary barriers will ultimately depend on how they will be mounted on the building due to concerns over damage to historic materials. The less obvious the mounting bracket in the door frame, the more likely it will be approved. Flood barriers also have a better chance of approval if they are applied to doors and window facing away from the main street.

Passive Wet Flood Proofing Solutions

Approval for installation of flood louvers/flood openings is more likely if they are mounted in a non-historic portion of a building. If they must be mounted on a historic portion of the building, the impact to the historical aesthetic must be minimized as much as possible. The property owner should work with the manufacturer to see if there is the possibility of coating the flood louver/opening to match the existing aesthetic of the building.

Passive Building Elevation Solutions

Approval for structural elevations is dependent on the desired height of elevation. Elevating too high may have an adverse impact on the building's context, how it relates to the landscape, and its location on the property and its neighbors. Impacts may be somewhat lessened by plantings, creative grading, or extending the building material of the first floor down to cover a foot or so of the foundation to make the elevation appear less drastic. Elevation can also alter the rhythm of the streetscape, especially if the rest of the houses along the street are all at the same height. It makes the house that rises above the rest more noticeable. On streets where houses are at different heights, that lessens the visual impact of an elevated structure. Some historic districts are protected in the community's zoning ordinance by a historic district overlay which may limit building heights. These options were not specifically recommended for these buildings, as many of them are row homes.

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5 ASSESSMENT RESULTS

5.1 TYPICAL BUILDING FEATURES

Based on the site visit and design considerations, the team developed potential concept plans for FRAMs for each of the nine sample buildings. Figures 5-1 through 5-3 show pictures of several key features typically found on Baltimore City buildings that routinely result in flooding. A description of how these features can be adapted to reduce flood risk accompanies each figure.

Figure 5-1: Two Parallel Basement Doors



These two paneled historic basement doors can often flood because they are even with or just above the sidewalk. In the interest of preserving the historical appearance of the building exterior, the recommended approach is to provide a certified flood proof basement door, and associated framing behind (or underneath) the existing basement doors, and leave the existing doors in place on top.

Figure 5-2: Basement Window Retrofit (Front)



The low basement window openings can allow flood waters to enter the buildings. To reduce the flood risk, retrofits on the building interior can be implemented that will not impact the exterior integrity and aesthetics of the structure. Structural glass installed in a new steel frame may be anchored to the existing masonry behind the historic windows.

Figure 5-3: Basement Windows and Wet Flood Proofing



These low area windows allow flooding of basements. In instances where basements are rarely used, wet flood proofing is the most logical and lowest-cost option. Wet flood proofing the basement area would protect the structure up to the finished first floor elevation. Some of the infilled windows could be fitted with flood louvers to allow the safe passage of water into the building without risk of damage to the structure.

5.2 SUMMARY OF CONCEPT PLANS

Detailed concept sheets that recommend flood risk adaptive measures were developed for each of the nine sample buildings and can be found in Appendix A *Concept Sheets*. The information included in each concept sheet is as follows:

- **General structure/building information** including floodplain, occupancy type, number of stories, and construction type
- **Building schematic** showing the typical exterior wall at grade with the reference flood elevations
- **Structure and flood elevation data** including low opening and first floor elevation, 1% and 0.2% annual chance flood elevations and the target DFE
- **Building photographs**
- **Analysis** describing in narrative form how the building or flooding characteristics suggest a particular flood proofing approach
- **Flood risk adaptive measures recommendations**, including a list of the specific measures that can be implemented as a part of the overall flood risk management approach

The information in this report serves as a resource for historic residential, commercial and public building owners in Baltimore City to better understand viable FRAM options. Using nine sample buildings, narrative analysis and recommendations linked to specific building characteristics and key features are presented to provide a more complete understanding of the primary considerations behind selecting FRAMs. The recommended measures include dry flood proofing and wet flood proofing, or a combination of both measures. Elevation is not specifically recommended as many of the residential buildings assessed are row homes. Table 5-1 shows the results of the FRAM assessment for the nine sample buildings, with the primary recommended solution.

Building owners considering implementation of FRAM solutions should consult with a professional Architectural Engineering (AE) firm to further investigate the structural feasibility of implementing adaptive solutions. Proper coordination with the City and State Historic Preservation Office should also be considered, when applicable. FRAMs can provide an effective option for reducing flood risk across a wide range of flood events and can significantly reduce damages during less severe floods and during larger floods if implemented in conjunction with larger scale watershed projects.

Table 5-1: Summary of Results

#	Flood Source	Usage	1% Annual Chance (100yr) Flood Elevation (ft.)	0.2% Annual Chance (500yr) Flood Elevation (ft.)	Target DFE (ft.)	Final DFE (ft.)	Primary Recommended FRAM
1	Tidal	Residential	5.3'	7.5'	9.5'	9.0'	Dry Flood Proof
2	Tidal	Residential	5.3'	7.5'	9.5'	8.0'	Dry Flood Proof and Convert Basement into Crawlspace
3	Tidal	Museum	5.3'	7.5'	9.5'	9.5'	Dry Flood Proof
4	Tidal	Commercial	5.3'	7.5'	9.5'	9.7'	Dry Flood Proof (completed)
5	Tidal	Commercial	5.3'	7.5'	9.5'	9.5'	Dry Flood Proof
6	Riverine	Government	12.6''	13.0'	14.6'	14.6'	Dry Flood Proof
7	Riverine	Commercial	12.8'	14.2'	14.8'	12.8'	Dry and Wet Flood Proof
8	Riverine	Commercial	145.9'	154.6'	147.9'	140.7'	Dry and Wet Flood Proof
9	Riverine	Residential	247.0'	252.3'	249.0'	246.1'	Dry and Wet Flood Proof

5.3 OTHER RESOURCES

Property owners considering implementing flood barriers and closure devices should learn about the National Flood Barrier Testing and Certification Program. The program has been developed by the Association of State Flood Plain Managers (ASFPM) in collaboration with Factory Mutual (FM) Approvals and the USACE National Nonstructural Committee. The program provides rigorous unbiased testing of commercially-available temporary barrier and closure device products, among other products to evaluate their material properties, manufacturing consistency, and ability to resist hydrostatic and hydrodynamic loads. More information on the program can be found at <http://nationalfloodbarrier.org/>.

Baltimore City building owners looking to implement products are encouraged to use certified products, in order to minimize risk that the product will fail to perform as designed when it is needed the most. Particular attention should be paid to the rigor of testing protocols performed on any flood proofing product that is being considered for implementation, whether certified by the National Flood Barrier Testing and Certification Program or otherwise. Property owners considering implementation of FRAMs should consult the appropriate historic preservation organizations and the product vendor prior to purchase.

Additional federal agency flood preparedness and flood proofing resources are listed below. Federal agencies such as the National Oceanic Atmospheric Administration (NOAA), National Weather Service (NWS), USACE and the Federal Emergency Management Agency (FEMA) provide these online resources for property owners to learn more about flood disaster readiness:

1. The NWS should be monitored (NOAA Weather Radio, website) when storms are approaching. The NWS homepage for text forecasts, warnings, and links to other information is located at <http://www.nws.noaa.gov>.
2. The National Hurricane Center (NHC) website can be used to track active tropical systems <http://www.nhc.noaa.gov>. For information regarding current watches, warnings, and alerts also visit <http://www.nws.noaa.gov/alerts>.
3. The USACE National Nonstructural Committee website provides links to numerous flood proofing/flood risk adaptive measures and flood damage reduction publications located at <http://www.usace.army.mil/Missions/Civil-Works/Project-Planning/nfpc/>.
4. FEMA provides advice on flood preparedness at this website location <http://www.ready.gov/floods>.

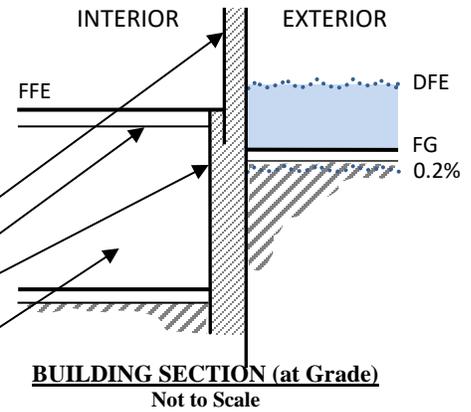
Appendix B contains a *Glossary of Terms* which serves as a resource for flood risk related terms.

APPENDIX A

Building Concept Sheets for Flood Risk Adaptive Measures

Building #1 Structure Information/Data:

Floodplain: Baltimore Harbor/Tidal
 Occupancy type: Row Home A (Residential)
 No. of Stories: 3
 Building Construction:
 Exterior Walls: Brick Masonry.....●
 Floor Construction (1st Flr): Wood Frame.....●
 Foundation: Masonry/Concrete●
 Grade/Crawlspace/Basement: Basement (6.3' height to underside of floor framing)



Structure/Flood Elevations Table:

FG	LO	FFE	ΔFFE-FG	1%	0.2%	Target DFE	ΔDFE-FG	ΔDFE-FFE
7.8'	8.3'	9.0'	1.2'	5.3'	7.5'	9.5'	1.7'	0.5'

Abbreviations: FG – Finished Grade; LO – Low Opening; FFE – First Floor Elevation; Δ – Delta/Difference;
 1%/0.2% - Annual chance of exceedance of the given flood elevation; DFE – Design Flood Elevation

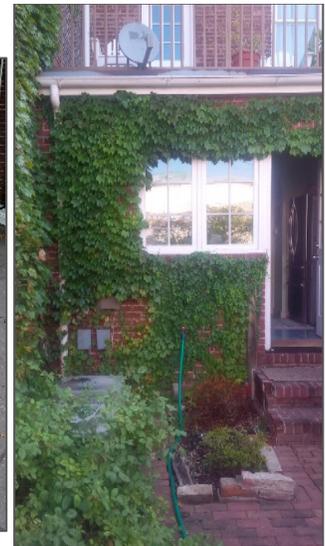
Structure Photographs:



1. North Elevation (Front)



2. Foundation wall and basement access (Front)



3. South Elevation (Rear)



4. Basement Interior



5. First floor framing

Analysis:

- The First Floor Elevation (FFE) of this structure (9.0') is more than 3.5' above the 1% annual chance exceedance (100 yr.) flood elevation, and 1.5' above the 0.2% annual chance exceedance (500 yr.) flood elevation.
- Protection above the finished first floor elevation was not considered, given that the risk of tidal flooding above that level is minimal. Baltimore City ordinance requirement for protection is to an elevation of 2' above the 0.2% annual chance exceedance flood in the tidal floodplain does not apply to residential structures.
- Reported flooding in 2003 in the rear corner of the house was likely due to poor localized drainage. This issue can be addressed by modifying the backyard area to ensure positive drainage away from the structure.
- Further investigation of the masonry wall in the rear of the structure is required to determine if a repair is recommended to ensure sufficient water tightness for dry flood proofing. The structure has multiple utility penetrations, so the repair could be as simple as sealing these penetrations. It is assumed that sealing of existing utility penetrations and a small amount of masonry wall repair would be required.
- Although not preferable for some residents because storage space is limited, one way to mitigate flooding is to wet flood proof the basement by relocating all contents above the design flood elevation and installing flood louvers in the foundation walls to allow the basement to flood.
- A more agreeable solution may be to dry flood proof the structure up to the finished first floor elevation. This approach comprises of providing certified flood proof doors or temporary barriers over low openings, and making other provisions to ensure that water will not enter the building below the design flood elevation. Provisions include sealing utility penetrations and repairing the existing wall in the rear of the structure to ensure water tightness. One set of certified flood proof doors would be required at the basement bulkhead door location on the front of the structure. In the interest of preserving the historical appearance of the building exterior, the recommended approach is to provide a certified flood proof door, and associated framing behind the existing doors, and leave the existing doors in place on top. Additional consideration must be given to the potential for a small amount of seepage into the basement even with the implementation of these flood proofing measures on the building exterior. Installation of a sump pump or utilization of a portable skimmer pump in the basement area is recommended.
- Given that this structure abuts structures on either side, successful flood risk mitigation may require all three property owners to adopt similar flood proofing measures to ensure that water penetration on one structure does not compromise the other through the shared walls. For the purposes of this report, it is assumed that water penetration through the shared basement walls would be minor, and can be handled by the recommended pumping provisions.

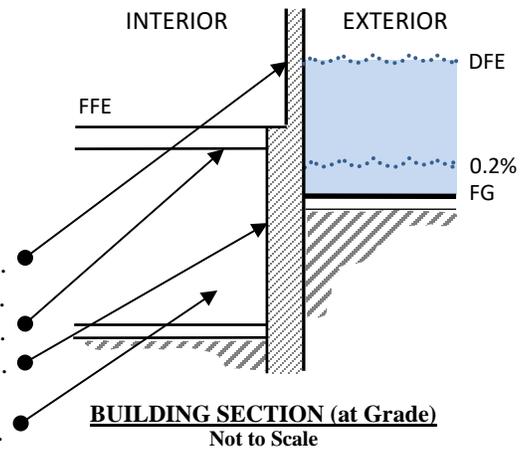
Recommendations:

1. **DRY FLOOD PROOF** the exterior of the structure up to the height of the finished first floor, to the final DFE of 9.0’.
 - a. **Install** certified flood proof bulkhead doors on existing basement entrance, and **replace** original doors on top for preservation of historical aesthetics.
 - b. **Replace** seals on existing utility penetrations in the rear of the house where water penetration in past flood events was reported.
 - i. Assume four 6” penetrations to be **resealed**.
 - c. **Replace** section of exterior masonry wall on rear of structure where water penetration during past flooding events was reported, from existing grade up to finished first floor elevation.
 - i. Assume 30 ft.² of masonry wall **removal** and **replacement** to match existing structure.
 - d. **Install** two skimmer pumps on basement interior in order to remove seepage which may occur, with portable generation capacity required to operate the pumps.
 - e. **Install** a backflow preventer on the existing sewage line connection.
2. **MODIFY LOCAL DRAINAGE AT REAR OF THE STRUCTURE** to ensure positive drainage away from the house.
 - a. **Remove** existing pavement in the rear of the structure, and **regrade** to ensure drainage away from the structure, and **replace** pavement in-kind.
 - i. Assume 100 ft.² of pavement **removal**, minor **regarding**, and pavement **replacement**

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Building #2 Structure Information/Data:

Floodplain: Baltimore Harbor/Tidal
 Occupancy type: Row Home B (Residential)
 No. of Stories: 3
 Building Construction:
 Exterior Walls: Brick Masonry with Siding (front)....
 Wood Frame (rear addition).....
 Floor Construction (1st Flr): Wood Frame.....
 Foundation: Masonry
 Grade/Crawlspace/Basement: Basement (4.75 ft. height to underside of floor framing)



Structure/Flood Elevations Table:

FG	LO	FFE	ΔFFE-FG	1%	0.2%	Target DFE	ΔDFE-FG	ΔDFE-FFE
6.8'	8.0'	8.0'	1.2'	5.3'	7.5'	9.5'	2.7'	1.5'
Abbreviations: FG – Finished Grade; LO – Low Opening; FFE – First Floor Elevation; Δ – Delta/Difference; 1%/0.2% - Annual chance of exceedance of the given flood elevation; DFE – Design Flood Elevation								

Structure Photographs:



1. Front entrance and foundation



2. Basement wall and first floor framing

Analysis:

- The finished first floor elevation of this structure (8.0') is 0.5' higher than the 0.2% annual chance exceedance (500 yr.) flood elevation; therefore, protection above the finished first floor elevation was not considered. Baltimore City ordinance requirement for protection is to an elevation of 2' above the 0.2% annual chance exceedance flood does not apply to residential structures. Reported historical flooding of the basement is likely due to localized drainage effects.
- Given the poor observed condition of the basement walls in the front of the structure, dry flood proofing of the basement walls in their current condition would potentially require extensive structural retrofits to ensure sufficient capacity to safely resist the applied hydrostatic loads. Further structural analysis is required to determine the extent of the required retrofits. The cost of these retrofits is likely to exceed the potential benefit for flood risk management, and is not recommended for this structure.

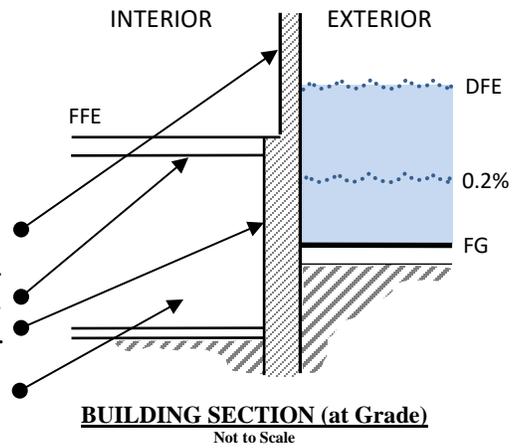
- The building tenant has already relocated all major utility equipment to the upper floors of the structure and uses the space for minimal storage only, making the basement a good candidate for being converted to a crawlspace and dry flood proofed. Under this approach, the existing basement slab would be broken up to allow for the passage of water, and an approximately 2' height of gravel or other structural fill placed in the basement area. The remaining crawlspace would be approximately 2.8' to the underside of the first floor framing, to allow for adequate ventilation and access. A permanent sump pump should be installed at the new crawlspace ground elevation to remove any seepage which may enter through the foundation walls during a high-water event. The electrical meter and switch panel which are located in the basement should be relocated to the first floor or higher.
- It is assumed that even though the basement walls are in visibly poor condition, no structural retrofits are required for the successful implementation of dry flood proofing in conjunction with partial filling. The partial filling of the basement significantly reduces the hydrostatic load which may be placed on the walls. Based on what could be observed during the site visit, the walls exhibit no out-of-plane bending, which suggests that the existing flexural capacity is sufficient. Testing is recommended to measure the permeability of the existing wall materials, to determine whether tuckpointing or other wall repair measures are required for effective dry flood proofing.

Recommendations:

1. **CONVERT EXISTING BASEMENT TO CRAWLSPACE** to reduce the foundation wall span height and allow for effective dry flood proofing, resulting in a final DFE of 8.0'
 - a. **Relocate** the existing electrical meter and switch panel to the first floor or higher.
 - b. **Remove** existing stairs down to basement; modify the access hatch as necessary.
 - c. **Break up** existing basement floor slab (assume 6" thick, 16'x20' dimensions)
 - d. Partially **fill** basement with suitable fill to a height of 2' above the existing floor elevation.
 - i. $320 \text{ ft}^2 \times 2 \text{ ft.} = 640 \text{ ft}^3$ of fill
2. **DRY FLOOD PROOF** the new crawlspace of the structure, providing a level of protection of 8.0', the elevation of the finished first floor.
 - a. **Install** an interior sump pump in the crawlspace area for removal of seepage during a high-water event.

Building #3 Structure Information/Data:

Floodplain: Baltimore Harbor/Tidal
 Occupancy type: Preserved historic home, museum
 No. of Stories: 3
 Building Construction:
 Exterior Walls: Brick Masonry
 Floor Construction (1st Flr): Wood Frame.....
 Foundation: Stone Masonry
 Grade/Crawlspace/Basement: Basement (7.0 ft. height to underside of floor framing)



Structure/Flood Elevations Table:

FG	LO	FFE	Δ FFE-FG	1%	0.2%	Target DFE	Δ DFE-FG	Δ DFE-FFE
5.9'	6.6'	8.4'	2.5'	5.3'	7.5'	9.5'	3.6'	1.1'
Abbreviations: FG – Finished Grade; LO – Low Opening; FFE – First Floor Elevation; Δ – Delta/Difference; 1%/0.2% - Annual chance of exceedance of the given flood elevation; DFE – Design Flood Elevation								

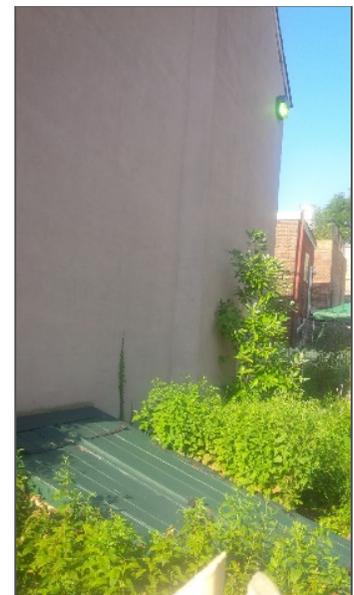
Structure Photographs:



1. East Elevation (Front)



2. Entrance and low opening (Front)



3. North Elevation (Side)



4. West Elevation (Partial, Rear)



5. Basement wall and electrical (Interior)

Analysis:

- According to the building survey, the finished first floor elevation of this structure (8.4') is 0.9' higher than the 0.2% annual chance exceedance (500 yr.) flood elevation. Baltimore City ordinance dictates a minimum level of protection of 2' higher than the 0.2% annual chance exceedance flood elevation for structures in the tidal floodplain; therefore the design flood elevation for this structure is 9.5'. This requires an additional 1.1' height of protection above the finished first floor.
- One of the primary concerns in selecting a flood proofing strategy for this structure is the historic value of the building and the relatively stringent requirements of preserving the historic integrity and aesthetics of the building exterior. This constraint may severely limit the flood proofing strategies that can practically be recommended. It is assumed, for the purposes of this report, that modifications that are visible from the building exterior are unacceptable due to these requirements. Therefore wet flood proofing of the basement area was not considered.
- The existing exterior masonry walls appear to be in good condition and would be suitable for dry flood proofing. The design flood elevation determined by the Baltimore City ordinance dictates that protection be provided on the two single doors that provide primary first floor access, and all other low openings. The other openings that must be considered for protecting the structure are the two basement windows on the front (east side) of the structure and the two basement access bulkhead doors on the east and north sides of the structure.
- To protect the two single doors, there are three alternative solutions: The owner could replace the doors and frames with a certified flood proof door product; install stoplog framing on the building exterior on either side of the door frame for drop in closure panels; or acquire a certified temporary flood barrier product that can be placed in front of the openings before a high-water event. Although temporary barriers are not the typical preferred approach, historical preservation considerations may preclude the possibility of attachment of stoplog framing to the structure or the replacement of the doors as required by the first two approaches. Use products that have been tested and certified under the National Flood Barrier Testing and Certification Program, if possible. A plan must be developed for the on-site storage and implementation of these barriers when required.
- For the existing bulkhead doors, new certified flood proof bulkhead closures should be framed into the masonry in the basement entry opening beneath the existing wooden bulkhead doors, such that the existing doors can remain in place and the new doors and framing are not visible from the exterior.
- Providing protection for the three existing basement windows is less straightforward, but can be accomplished entirely through retrofits on the building interior that will not impact the exterior integrity and aesthetics of the structure. Structural glass installed in a new steel frame may be anchored to the existing masonry behind the historic windows. The masonry immediately surrounding the window must be evaluated in order to design a connection between the masonry and the new window frame that can develop sufficient capacity. The historic windows would potentially be damaged in a high-water event given that they are not protected, but the new structural window would minimize water penetration into the basement area.
- Interior pumps and emergency power are required in order to handle seepage which might occur in a high-water event through the masonry walls or flood proofed openings. Additionally, existing utility penetrations through the basement wall, particularly in the rear of the structure, must be inspected for water tightness, and the opening resealed if necessary. The existing electrical panel and meter in the basement area should be relocated to the first floor of the building to minimize the risk of damage during a high-water event.

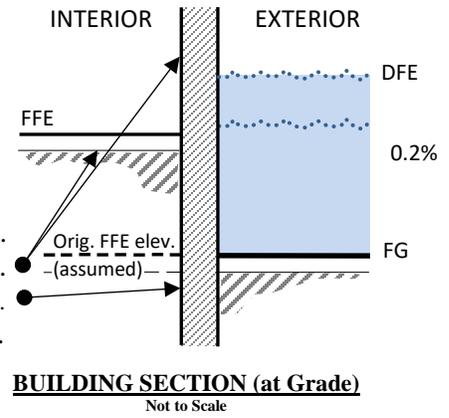
Recommendations:

1. **DRY FLOOD PROOF** the exterior of the structure up to the design flood elevation, 9.5'.
 - a. **Acquire** two certified temporary flood barriers for use on the two single doors on the first floor.
 - b. **Install** certified flood proof bulkhead doors on two existing basement entrances, keeping original doors on top for preservation of existing historical integrity and aesthetics.
 - c. **Install** three structural glass windows and associated framing anchored to masonry on interior side, approximately 4' x 2' each, rated for sustained hydrostatic pressure as required.
 - d. **Replace** seals on existing utility penetrations on the rear of the house.
 - i. Assume six 6" penetrations to be resealed.
 - e. **Create** interior floor drain system along exterior walls to direct seepage which may occur to a sump pump. As an alternative, three skimmer pumps in basement interior may be used in order to remove seepage, with portable generation capacity required to operate the pumps.
 - f. **Relocate** existing electrical panel and meter from the basement to the first floor or higher.
 - g. **Install** a backflow preventer on the existing sewage line connection.

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Building #4 Structure Information/Data:

Floodplain: Baltimore Harbor/Tidal
 Occupancy type: Office Building (Business) A
 No. of Stories: 3
 Building Construction:
 Exterior Walls: Brick Masonry.....
 Floor Construction (1st Flr): Raised concrete slab on grade (assumed)...
 Foundation: Concrete/Masonry.....
 Grade/Crawlspace/Basement: Grade.....



Structure/Flood Elevations Table:

FG	LO	FFE	ΔFFE-FG	1%	0.2%	Target DFE	ΔDFE-FG	ΔDFE-FFE
2.4'	7.7'	7.7'	5.3'	5.3'	7.5'	9.5'	7.1'	1.8'
Abbreviations: FG – Finished Grade; LO – Low Opening; FFE – First Floor Elevation; Δ – Delta/Difference; 1%/0.2% - Annual chance of exceedance of the given flood elevation; DFE – Design Flood Elevation								

Structure Photographs:



1. North Elevation (Main Entrance)



2. Flood barrier framing at entrance



3. East Elevation



4. East Wall (typical masonry condition)

Analysis:

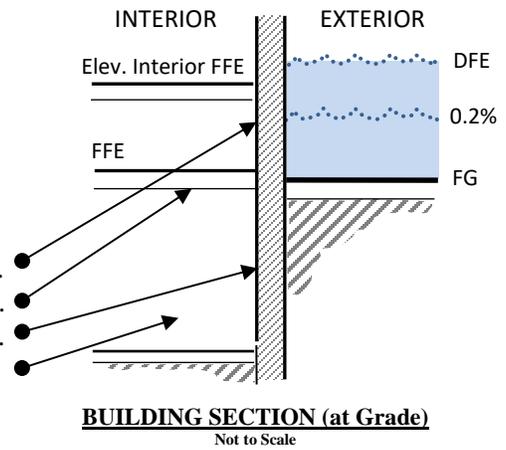
- Dry flood proofing measures have already been applied to the building exterior in the form of steel angle framing for stoplog or panel closures across the exterior entrances. The level of protection at the protected openings is approximately elevation 10.3', which exceeds the DFE established by the Baltimore City ordinance. The height of the closure system at the at-grade openings exceeds what is normally recommended for typical building construction without specific engineering analysis showing that the walls can withstand the additional hydrostatic load. However, it is assumed that the first floor slab, which is approximately 3.3' above exterior grade, provides sufficient lateral support for the wall so that the current level of protection of the system in place is reasonable. It is assumed that the system that is currently in place has been designed, thoroughly tested, and certified by a professional engineer.
- There are approximately 15 single windows on the north and east of the building that appear to be unprotected by the existing flood proofing system. However, field measurements of these openings relative to the finished floor elevation indicate that the sill elevation is approximately 9.7', just above the DFE. This sill elevation of the low unprotected opening controls the level of protection offered by the dry flood proofing system in place. It is unclear why the barrier framing extends beyond this elevation at some protected openings. Regardless, if properly designed and implemented, the existing flood barrier system on this building is sufficient to protect at the DFE established by Baltimore City ordinance.
- Based on the information gathered during the site visit, it is unclear where the closure barriers are stored, and how well they are organized and labeled for quick deployment. Regardless of how well-designed the flood protection system is, it is equally important to have a well-practiced deployment plan in place to ensure that the system will perform as designed.
- Localized masonry repair is recommended in some areas to minimize seepage through the walls into the foundation. An estimated 35% of the exterior masonry wall below the dry flood proofed elevation is recommended for tuckpointing or brick replacement to reduce the risk of damage to the building foundation over time.

Recommendations:

1. **EXTERIOR WALL REPAIR** to minimize the long-term risk of foundation damage due to water infiltration below the existing slab on grade.
 - a. Masonry *tuckpointing* on 10% of the building exterior up to the finished first floor elevation:
 $(260' \text{ flood proofed perimeter}) * (3.3' \text{ height}) * (0.1) = 84.5 \text{ ft.}^2$
 - b. Full masonry unit and mortar *replacement* on 25% of the building exterior up the finished first floor elevation: $(260' \text{ flood proofed perimeter}) * (3.3' \text{ height}) * (0.25) = 211.3 \text{ ft.}^2$
2. **INVESTIGATE CORRODED CLOSURE BARRIER FRAMING** at building entrance on the north elevation, and other locations as necessary.
 - a. Determine the extent of the corrosion in the sill plate, and either *reseal* the connection to prevent further water intrusion or *replace* the plate as necessary.

Building #5 Structure Information/Data:

Floodplain: Baltimore Harbor/Tidal
 Occupancy type: Office Building (Business) B
 No. of Stories: 4
 Building Construction:
 Exterior Walls: Brick Masonry.....
 Floor Construction (1st Flr): Concrete
 Foundation: Masonry.....
 Grade/Crawlspace/Basement: Basement.....



Structure/Flood Elevations Table:

FG	LO	FFE	Δ FFE-FG	1%	0.2%	Target DFE	Δ DFE-FG	Δ DFE-FFE
5.4'	5.5'	5.5'	0.1'	5.3'	7.5'	9.5'	4.1'	4.0'

Abbreviations: FG – Finished Grade; LO – Low Opening; FFE – First Floor Elevation; Δ – Delta/Difference;
 1%/0.2% - Annual chance of exceedance of the given flood elevation; DFE – Design Flood Elevation

Structure Photographs:



1. West Elevation from SW corner



2. South Elevation from SW corner



3. Main Lobby Interior with raised floor



4. Basement storage and wall-mounted utility

Analysis:

- An additional 0.4' of protection above the raised finished first floor elevation, or approximately 4.1' above exterior grade, is required in order to protect up to the 9.5' DFE established by Baltimore City ordinance. The most logical approach to provide this level of protection is to dry flood proof the structure around the building perimeter using certified flood proof doors or stoplog closures and the associated framing as appropriate on all openings below the DFE. The openings to be dry flood proofed are seven on the west side, five on the south side, and one on the east side.
- There are two single doors and one double door which may be replaced with certified flood proof doors, but the remainder of the low openings are either large at-grade windows or single or double doors with adjacent at-grade windows. For these openings, stoplog closures are the most appropriate method of dry flood proofing. There are several window openings on the south elevation of the structure that are assumed to be above the DFE and therefore require no protection, although this assumption must also be verified prior to final design. Particularly with such a large number of openings to be protected with stoplog closures, it is crucial for the building owner to have a sound plan in place for storage and prompt installation of the closures when required. With implementation of the measures set forth in the above analysis, the building would be protected to the DFE of 9.5'.
- The 4.1' height of protection is higher than is typically recommended for dry flood proofing; however, based on the wall type and structural condition, it is reasonable to assume that this height of protection may be achieved on the structure without significant structural retrofits. The licensed structural designer who designs the stoplog closure system must also verify that the system will not pose a threat to the overall structural integrity of the building.
- The building tenant did not report any issues with historical flooding of the basement; however, implementation of best practices of elevating critical equipment as high as possible and providing pumps with emergency backup power to alleviate seepage is recommended. All electrical panels in the basement, including any which may not have been noted during the site visit, should be elevated to the first floor or higher.

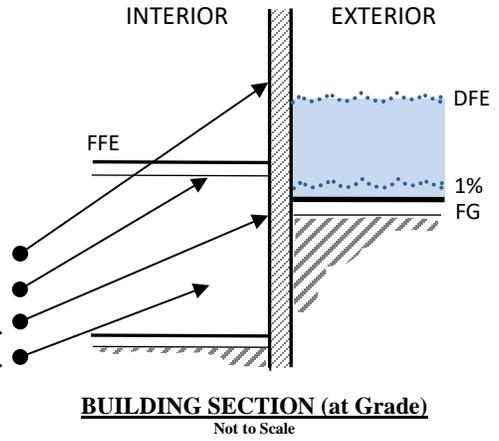
Recommendations:

The following assumptions were made in the development of these recommendations and should be confirmed before moving forward with design:

- a) The implementation of certified flood proof doors, where applicable, are preferable to stoplog closures for ease of use.
 - b) The existing masonry walls are sufficiently watertight to utilize dry flood proofing without additional coatings or treatment.
 - c) The exterior masonry walls have sufficient flexural capacity to resist hydrostatic loads to a height of 4.1' above existing grade.
 - d) Implementation of this strategy will not increase water infiltration into the basement; therefore the user's existing mitigation measures in this area are sufficient.
1. **DRY FLOOD PROOF** the exterior of the first floor of the building up to the DFE, 9.5'.
 - a. **Install** certified flood proof doors at the two applicable single door locations and one applicable double door location on the west elevation.
 - b. **Install stoplog closures** and associated framing on the building exterior for the following number and size of openings (assume 4.1' height of protection for all closures): (1)-16' span, (7)-12' span, (2)-10' span
 - c. **Install interior skimmer pumps** and sufficient emergency generation capacity (assume one pump per stoplog closure) to reduce the risk of damage due to seepage during a high-water event.
 - d. **Relocate** existing electrical panel and meter from the basement to the first floor or higher.
 - e. **Install** a backflow preventer on all existing sewage line connections.

Building #6 Structure Information/Data:

Floodplain: Jones Falls/Riverine
 Occupancy type: Office Building (Government) C
 No. of Stories: 4
 Building Construction:
 Exterior Walls: Masonry.....
 Floor Construction (1st Flr): Concrete.....
 Foundation: Masonry.....
 Grade/Crawlspace/Basement: Basement/Sub-Basement.....



Structure/Flood Elevations Table:

FG	LO	FFE	Δ FFE-FG	1%	0.2%	Target DFE	Δ DFE-FG	Δ DFE-FFE
(varies)	~10'	13.3'	(varies)	12.6'	13.9'	14.6'	(varies)	1.3'

Abbreviations: FG – Finished Grade; LO – Low Opening; FFE – First Floor Elevation; Δ – Delta/Difference;
 1%/0.2% - Annual chance of exceedance of the given flood elevation; DFE – Design Flood Elevation

Structure Photographs:



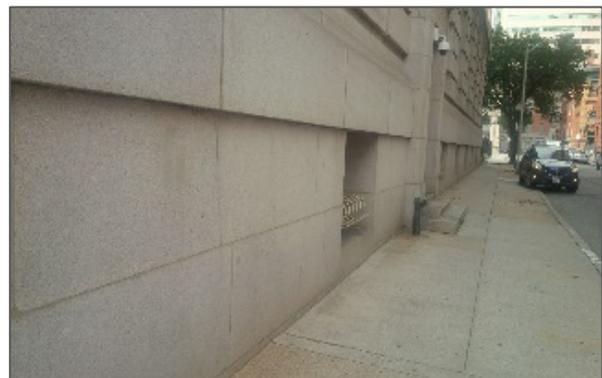
1. East Elevation



2. Basement Wall (Interior)



3. South Elevation



4. Exterior masonry wall (North side)

Analysis:

- The finished first floor elevation at the main entry is approximately 1.6' below the DFE established by the Baltimore City ordinance. All of the windows and doors around the perimeter of the structure are below this elevation and will require protection if this level of protection is to be reached. The windows on the north elevation and the northern half of the east elevation are at approximately the first floor elevation. The windows on the southern half of the east elevation, as well as the south elevation and west elevation, access the basement level and are approximately 2'-3' below the finished floor elevation. Further survey data is required to determine the exact number, size, and elevation of the windows and other low openings around the building. Given that the basement level is currently fully utilized for office space, it is assumed that wet flood proofing the basement of the structure is not a desirable strategy.
- The masonry walls appear to be in good condition and are very suitable for dry flood proofing. The wall construction appears to be very stout and should be able to resist the hydrostatic load up to the DFE without structural retrofit. In order to implement dry flood proofing on the structure, all building openings below the DFE must be protected with stoplog barriers or panels as appropriate. The windows that were accessible for observation on the site visit appear to be two typical sizes, which would simplify the design process. As visible in the site visit photos, the windows are currently covered with a metal grate for security. In selecting a flood proofing approach for the window, accommodations for the existing grate must be considered.
- The total number of doors and windows to be protected is estimated based on observations of the building areas that were accessible during the site visit. There are a total of 12 windows that are approximately 3.5' square, 20 windows that are approximately 3.5' x 5', two single doors, and three double doors. As mentioned above, there appear to be two areas on the west elevation where there is a recess in the building envelope. Further inspection is required in order to make a final recommendation for these locations, but the preliminary recommendation is to place closure barriers and the associated framing across the estimated 15' openings to these recessed areas, to protect all of the openings located in the recessed areas. After further investigation, there may be a possibility of designing a closure at the vehicle access point near the southwest corner of the building, which could provide protection for the entire south elevation.
- Based on the described and observed flooding conditions in the sub-basement near the southwest corner of the building, it is recommended to remediate this issue. Continued inundation of the basement area could eventually lead to potential structure impacts or health concerns over time. The recommended approach is to excavate around the building perimeter in the area where seepage is reportedly occurring and apply a waterproof sealant to the exterior of the foundation walls.

Recommendations:

The following assumptions were made in the development of these recommendations and should be confirmed before moving forward with design:

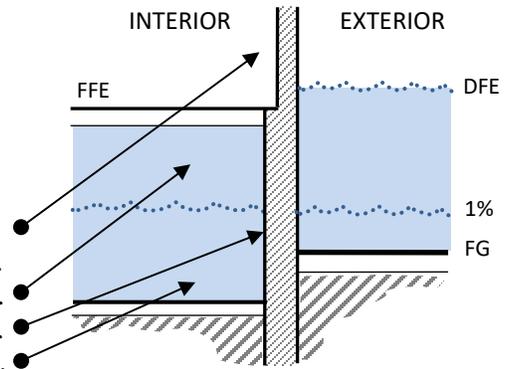
- a) The exterior masonry is in good condition and requires no repair to ensure adequate water tightness and structural capacity for dry flood proofing.
- b) The windows on the west elevation, which could not be observed on the site visit, are similar in construction to those on the east elevation.
- c) Implementation of the recommended dry flood proofing approach will not increase water infiltration into the basement; therefore the existing mitigation measures in place in this area are sufficient.

1. **DRY FLOOD PROOF** the exterior of the structure up to the height of the DFE, 14.6'.
 - a. **Install** certified flood barriers on the 32 window openings below the final level of protection, located on all sides of the building exterior. Existing grating in front of windows is to remain.
 - i. 12 windows – 3.5' x 3.5'
 - ii. 20 windows – 3.5' x 5'
 - b. **Design** stoplog closures and install the required framing for the following sizes of openings at the specified depth of protection: (1)-6' span and (1)-3' span at 2' height of protection; (1)-3' span, (2)-6' span, and (2)-15' span at 4.5' height of protection
 - c. **Replace** seals on existing utility penetrations below the final level of protection to ensure sufficient water tightness for dry flood proofing.
 - i. Assume (10)-4" penetrations to be resealed
 - d. **Install** approximately 12 skimmer pumps in the basement interior in order to remove seepage which may occur, with portable generation capacity required to operate the pumps.
 - e. **Relocate** existing utilities and critical equipment from the basement to the first floor or higher to whatever extent possible.
 - f. **Install** a backflow preventer on the existing sewage line connection.
2. **REMEDiate SEEPAGE IN SUB-BASEMENT**
 - a. **Excavate** around the building perimeter in the affected area, up to approximately 10' away from the structure or as necessary to perform the work.
 - b. **Apply a waterproof sealant product** to the exterior of the foundation walls.
 - c. **Replace** pavement in-kind or as desired after backfill.

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Building #7 Structure Information/Data:

Floodplain: Jones Falls/Riverine
 Occupancy type: Office Building (Business) D
 No. of Stories: 3
 Building Construction:
 Exterior Walls: Brick Masonry.....
 Floor Construction (1st Flr): Concrete.....
 Foundation: Masonry.....
 Grade/Crawlspace/Basement: Basement.....



BUILDING SECTION (at Grade, south elevation)
 Not to Scale

Structure/Flood Elevations Table:

FG	LO	FFE	Δ FFE-FG	1%	0.2%	Target DFE	Δ DFE-FG	Δ DFE-FFE
7.5' (E elev) 13.5' (W elev)	8.5'	14.5'	7.0' (E elev) 1.0' (W elev)	12.8'	14.2'	14.8'	7.3' (E elev) 1.3' (W elev)	0.3'

Abbreviations: FG – Finished Grade; LO – Low Opening; FFE – First Floor Elevation; Δ – Delta/Difference;
 1%/0.2% - Annual chance of exceedance of the given flood elevation; DFE – Design Flood Elevation

Structure Photographs:



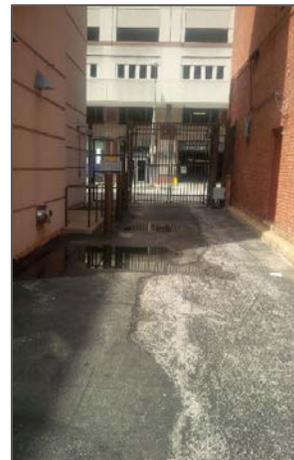
1. West Elevation



2. South Elevation



3. Close-up of basement windows (South elevation)



4. Alley on north side at new egress

Analysis:

- The finished first floor elevation of the building is approximately 14.5' based on the measurements taken during the site visit, 0.3' lower than the DFE established by the Baltimore City ordinance. GPS survey data from the building survey were unreliable for this building, so the elevation of the first floor is based on LIDAR data and field measurements of the first floor relative to adjacent grade. It is recommended to confirm the building elevations prior to final selection of the flood proofing approach, given that the estimated finished floor elevation is so close to the DFE and the final elevation may drastically impact the flood proofing approach. For the purposes of this report, it is assumed that the level of protection above the finished floor elevation that may be required will be less than 6" above the low first floor opening, and can therefore be protected against by sandbags or similar temporary non-engineered means. Provisions must be made by the building owner to ensure that sandbags are securely stored and can be implemented quickly in the case of an impending high-water event. The remainder of the analysis section for this structure addresses the flood proofing measures to be taken in the basement area only.
- The openings into the basement vary in elevation along the length of the building, from approximately 8.5' at the southeast corner to approximately 13' at the southwest corner. The openings vary in size, and have all been infilled with various materials, including brick masonry and wood in different locations (Photo 3). In some locations, the infill also has openings for equipment ventilation. It is assumed that in all cases this infill does not have sufficient structural capacity to resist a hydrostatic load applied to the exterior, as would be required for dry flood proofing.
- Given the relatively low priority usage of the basement area, wet flood proofing is the most logical and lowest-cost option. Wet flood proofing the basement area would protect the structure up to the finished first floor elevation. Some of the infilled windows would be fitted with flood louvers in order to allow the safe passage of water into the building without risk of damage to the structure. As observed during the site visit and reported by the building tenant's representative, the basement is used for paper storage and also houses some mechanical equipment. Depending on the importance of this storage and the desired level of protection, these items may either be relocated to elevated shelves and platforms within the basement area, or relocated to a higher floor of the structure. Approximately 4' of elevation above the basement floor is required to reach the 1% annual chance exceedance (100 yr.) flood, the recommended minimum in this case. The installation of interior sump pumps at low areas within the basement, if not already present, is recommended for removal of water after a high-water event. In the case of any mechanical and electrical equipment in the basement, it is highly recommended to relocate to a higher floor of the building to elevate above the DFE.

Recommendations:

The following assumption was made in the development of these recommendations and should be confirmed before moving forward with design:

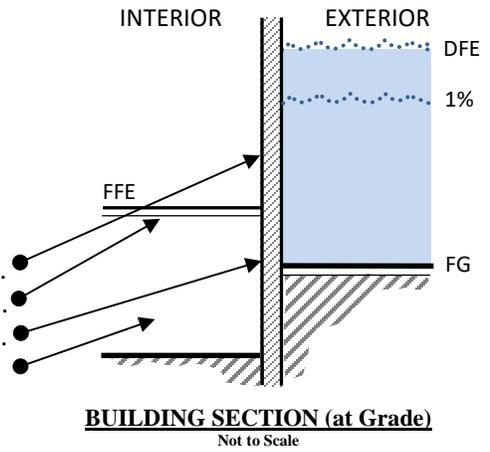
- a) The finished floor elevation, which was estimated based on LIDAR data and field measurements, is sufficiently accurate to validate the analysis and recommendations.
1. **DRY FLOOD PROOF** the exterior of the structure up to the DFE, 12.8'.
 - a. **Acquire and store sandbags** as necessary to provide an approximately 6" height of protection above the finished floor elevation at all first floor door openings
 - b. **Install** one skimmer pump per protected door opening in order to remove seepage which may occur, with portable generation capacity required to operate the pumps.
 2. **WET FLOOD PROOF** the basement of the structure.
 - a. **Elevate** storage in the basement on steel platforms to provide a slightly increased level of protection over the existing condition.
 - i. Assume 3 tons of structural steel required for platforms for elevated basement storage.
 - b. **Relocate** all mechanical and electrical equipment located in the basement to the first floor or higher.

- c. ***Install*** approximately 8 flood louvers in the existing basement wall on the south elevation of the structure.
- d. ***Install*** two interior sump pumps in the basement area for operation after a high-water event.
- e. ***Install*** a backflow preventer on the existing sewer line.

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Building #8 Structure Information/Data:

Floodplain: Jones Falls/Riverine
 Occupancy type: Mixed-use commercial (Business)
 No. of Stories: Varies (≤ 4)
 Building Construction:
 Exterior Walls: Masonry.....
 Floor Construction (1st Flr): Concrete.....
 Foundation: Masonry.....
 Grade/Crawlspace/Basement: Basement (unfinished).....



Structure/Flood Elevations Table:

FG	LO	FFE	Δ FFE-FG	1%	0.2%	Target DFE	Δ DFE-FG	Δ DFE-FFE
134.5'	137.7'	137.7'	3.2'	145.9'	154.6'	147.9'	13.4'	10.2'

Abbreviations: FG – Finished Grade; LO – Low Opening; FFE – First Floor Elevation; Δ – Delta/Difference;
 1%/0.2% - Annual chance of exceedance of the given flood elevation; DFE – Design Flood Elevation

Structure Photographs:



1. East Elevation (South half)



2. Loading dock on east side



3. Large door closure (North side)



4. Typical single door closure



5. West Elevation (North half)



6. Door to basement – (damaged in recent flood)



7. Partially rebuilt flood wall (East side)



8. West Elevation

Analysis:

- The finished first floor elevation of the structure, 137.7', is 10.2' below the DFE established by Baltimore City ordinance for commercial structures in the riverine floodplain. Protecting the structure to this level is not possible by flood proofing means similar to those recommended for other structures contained in this report. The following are options for reducing the flood risk to the structure that may be considered individually or in combination, but, due to their scale or nature, are not described in further detail in the analysis and recommendations contained in this report:
 - Increase hydraulic conveyance in the adjacent channel by increasing the width of the channel and making overbank modifications, and modifying features which may reduce conveyance, such as the low bridge which provides access to the building site.
 - Construct a structural flood wall around the full perimeter of the structure and adjacent parking lot to protect up to the DFE, with gate closures to provide vehicle and pedestrian access to the building, provided that such an approach does not violate pertinent floodplain building codes.
 - Wet flood proof the entire first floor of the structure, which would require significant modifications to the interior finishes in some areas, and may significantly impact which tenants are suitable for these spaces.
 - Acquisition of the structure and property and repurposing for more suitable use.
- The remainder of the analysis and recommendations sections are concerned with protecting the structure to the highest level achievable by dry flood proofing means, apart from requirements dictated by the Baltimore City ordinance. Although these measures offer a level of protection, which is far short of even the 1% chance annual exceedance flood, they will nevertheless reduce the risk of flood damage to the structure.
- The design of the existing dry flood proofing system in place on the structure must be evaluated in detail to determine whether or not it is suitable for the conditions to which it has been applied. The materials and connection details used in the existing system suggest that it may have been improperly designed. In the event that the existing system is found to be unsuitable, it should be replaced with a certified flood proof product which is similar in concept. The protected height will be approximately 3' above the first floor slab elevation, constrained by the flexural capacity of the existing walls. As shown by the recent flood event, the lead time available for implementation of the system in anticipation of a flood event may be relatively small, and the plan for storage and installation of the closure barrier members must be developed with this time constraint in mind.
- As an alternative, certified flood proof doors could be installed at all door locations. The use of flood proof doors would remove the need for pre-flood actions to protect the openings where they are used, which may be of particular value on this project given past flood events. For the purposes of this report, it is assumed that the use of certified flood proof doors wherever applicable is preferable to stoplog closure barriers. The new level of protection is assumed to be 3' above the finished floor elevation, until structural inspection and analysis of the exterior walls is performed to determine whether a higher level of protection is achievable. If limited to 3' above the finished floor elevation, the final level of protection, 140.7', will still be approximately 5.2' below the 1% annual chance exceedance flood elevation.
- Although the basement is unoccupied, the depth of flooding to which the basement will be exposed likely makes it unsuitable for wet flood proofing. Given that there is only one exterior entrance to the basement, dry flood proofing the basement area is a suitable approach. A certified flood proof door would be installed on the existing door opening, and tied in to the surrounding masonry to ensure sufficient strength under significant hydrostatic load.

Recommendations:

The following assumptions were made in the development of these recommendations and should be confirmed before moving forward with design:

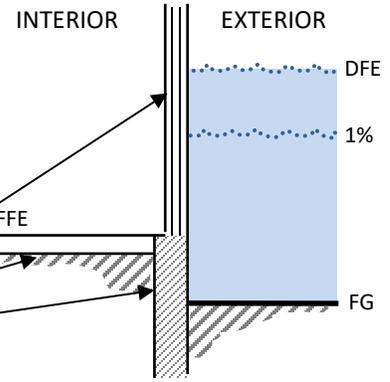
- a) The exterior masonry is in good condition and requires no repair to ensure adequate water tightness for dry flood proofing to the height specified.
- b) Existing flood barrier framing is insufficiently designed and needs to be replaced.
- c) There are six single doors, four double doors, and two garage doors in the north half of the structure, the applicable portion for dry flood proofing.

1. **DRY FLOOD PROOF** the exterior of the northern half of the structure up to the height of 3' above the finished floor slab, elevation 140.7'.
 - a. Install certified flood proof doors on the six single doors, four double doors, and two garage doors below the final level of protection.
 - b. Replace seals on existing utility penetrations below the final level of protection to ensure sufficient water tightness for dry flood proofing.
 - i. Assume quantity 10, 6" penetrations to be resealed.
 - c. Provide approximately 12 skimmer pumps in the first floor interior in order to remove seepage which may occur, with portable generation capacity required to operate the pumps.
 - d. Install a backflow preventer on the existing sewage line connection.
2. **DRY FLOOD PROOF** the unoccupied basement of the structure.
 - a. Install one certified flood proof door on the basement access door.
 - b. Install one interior skimmer pump in the basement area in order to remove seepage which may occur, and sufficient portable generation capacity for operation.

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Building #9 Structure Information/Data:

Floodplain: Gwynns Falls/Riverine
 Occupancy type: Single-Family Dwelling (Residential)
 No. of Stories: 2
 Building Construction:
 Exterior Walls: Wood Frame
 Floor Construction (1st Flr): Wood Frame
 Foundation: Masonry
 Grade/Crawlspace/Basement: Grade



BUILDING SECTION (at Grade)
 Not to Scale

Structure/Flood Elevations Table:

FG	LO	FFE	Δ FFE-FG	1%	0.2%	Target DFE	Δ DFE-FG	Δ DFE-FFE
~241'	243.1'	243.1'	~2'	247.0'	252.3'	249.0'	~8'	5.9'

Abbreviations: FG – Finished Grade; LO – Low Opening; FFE – First Floor Elevation; Δ – Delta/Difference;
 1%/0.2% - Annual chance of exceedance of the given flood elevation; DFE – Design Flood Elevation

Structure Photographs:



1. North Elevation



2. North Elevation close-up (West half)



3. Southwest corner



4. Patio and rear entrance

Analysis:

- The low opening and finished first floor elevation of this structure are approximately 4' below the 1% annual chance of exceedance (100 yr.) flood elevation. The minimum recommended action for this structure is to ensure that utility equipment is elevated to the highest elevation possible within the building to minimize damage in the case of a high-water event. The Baltimore City ordinance which requires protection to an elevation of 2' above the 1% annual chance exceedance flood does not apply to residential structures. The recommendations for this structure were developed to protect the structure to the highest level feasible.
- Due to first floor usage, wet flood proofing is not a viable solution for the majority of the first floor of this structure. Wet flood proofing of the garage area (Photo 2) may be implemented in conjunction with dry flood proofing the remainder of the structure, as described below. To the furthest extent possible, important storage in the garage should be placed on elevated shelving units in order to minimize damage from potential flooding.
- An active dry flood proofing system may be used to protect the structure as high as the low window elevation, or to the maximum allowable height based on a structural investigation of the condition and flexural capacity of the exterior walls, whichever is lower. As compared to the buildings of masonry construction presented in this report, the wood frame construction of this structure is relatively ill-suited to dry flood proofing. Wood frame walls have less flexural capacity to resist hydrostatic load, and are generally more prone to seepage and damage from extended periods of inundation. Protection of this structure up to the 1% annual chance of exceedance (100 yr.) flood elevation is not feasible by dry flood proofing, but a system as described here would still offer a significant increase over the current level of protection. A certified temporary flood barrier product will be required across all at-grade openings, including the double doors to the back patio (Photo 4) and the interior single door (assumed) from the garage into the main structure.
- The garage shall be wet flood proofed as indicated above; therefore the dry flood proofed perimeter will not include the garage exterior. The temporary barriers will be deployed in advance of an anticipated flood event to protect the vulnerable openings. Additionally, installation of a waterproof membrane around the building exterior up to the flood proofed height is recommended to reduce seepage. The membrane may be installed beneath the existing siding in order to minimize aesthetic impact. This long-term approach is likely more desirable for a residential tenant than the short-term alternative of hanging heavy duty plastic sheeting around the perimeter immediately before a flood event, with sandbags required to minimize seepage beneath the sheeting.
- The only solution that provides a level of protection at or above the 1% annual chance of exceedance (100 yr.) flood elevation is to elevate the entire structure on extended foundation walls or raised fill. Although there is a much higher upfront cost associated with this approach, it more effectively minimizes the long-term risk of flood damage to the structure and interior contents, and once in place, requires no pre-flood actions. Residential construction is particularly well-suited to this flood proofing strategy, and should be strongly considered by the building owner.
- For the recommendations below, it is assumed that the combination wet/dry flood proofing approach described above will be adopted.

Recommendations:

The following assumptions were made in the development of these recommendations and should be confirmed before moving forward with design:

- a) The exterior wood frame wall is in good condition and requires no retrofit in order to ensure sufficient structural capacity to resist the applied hydrostatic load associated with dry flood proofing. However, the installation of a water resistant membrane either below the siding or on the building exterior is recommended to minimize seepage.
- b) The building owner has sufficient advance warning and physical capability to install the dry flood proofing measures described in anticipation of a high-water event.
- c) The floor and wall finishes in the garage area are sufficiently water-resistant and durable for effective wet flood proofing.

1. **DRY FLOOD PROOF** the exterior of the structure other than the garage, up to the height of 3' above the finished floor, elevation 246.1'.
 - a. **Purchase and store certified temporary flood proof barriers** appropriately sized for the dry flood proofed door openings, three single doors and one double door, designed for a 3' height of protection.
 - b. **Remove** existing siding up to flood proofed height, install a waterproof membrane material down to a recommended minimum of 1' below existing grade, and reinstall siding.
 - c. **Install** approximately four skimmer pumps in the first floor interior in order to remove seepage which may occur, with portable generation capacity required to operate the pumps.
 - d. **Install** a backflow preventer on the existing sewage line connection.
2. **WET FLOOD PROOF** the garage interior.
 - a. **Install** two flood louvers in the exterior walls of the garage to allow for the safe passage of water into the space.
 - b. **Build** shelving for elevated storage of important materials within the garage, if necessary.

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APPENDIX B

Glossary of Terms

100-Year Flood – The flood that has a 1% chance of occurring in any given year.

500-Year Flood – The flood that has a .2% chance of occurring in any given year.

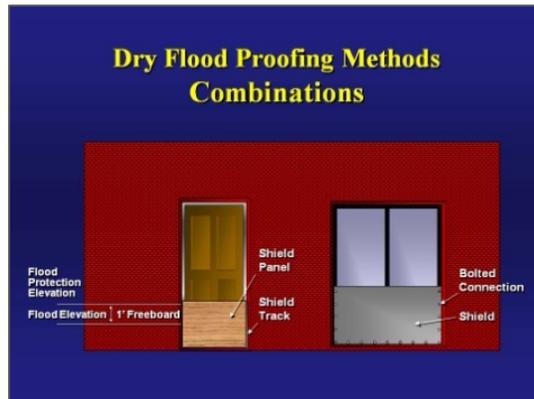
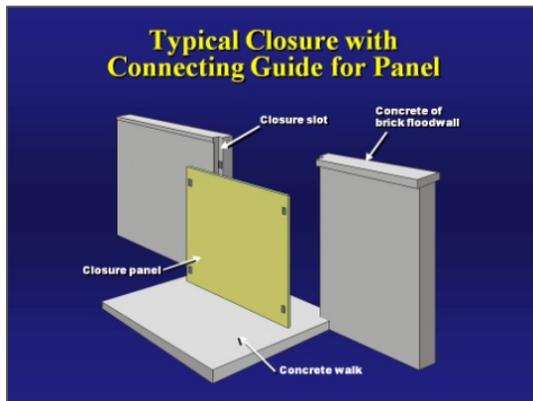
Base Flood Elevation (BFE) – Flood elevation for a 100-year (1% annual chance) flood event.

First Floor Elevations (FFE) – Many properties are within a flood zone, but the risk varies based on your location and the building's finished floor elevation, which is at or above the BFE as required by FEMA or local ordinance to reduce flood risks.

Base Flood Elevation plus 2 ft. of Free Board (BFE+2) – Flood elevation equivalent to the 100-year (1% annual chance) flood event plus 2 ft. of free board.

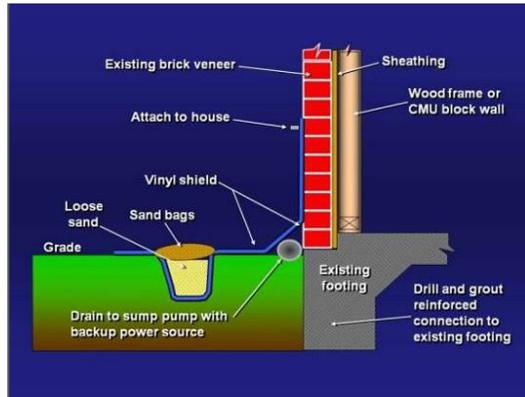
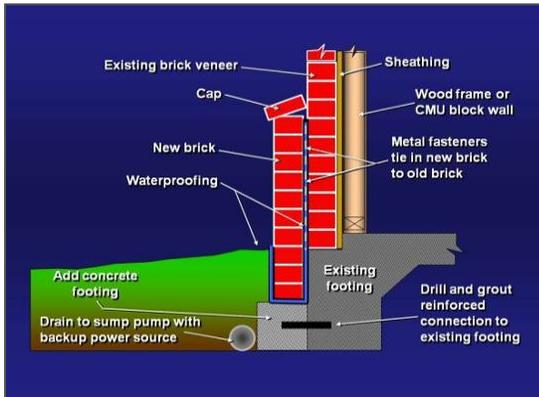
Closures / Shields – Closures, shown below, act to close the openings in flood barriers and prevent water from entering. They can be of a variety of shapes, sizes, and materials. In some cases closures are permanently attached using hinges so that they can remain open when there is not flood threat. They may also be portable, normally stored in a convenient location and slipped into place when a flood threatens.

Closure/ Shields

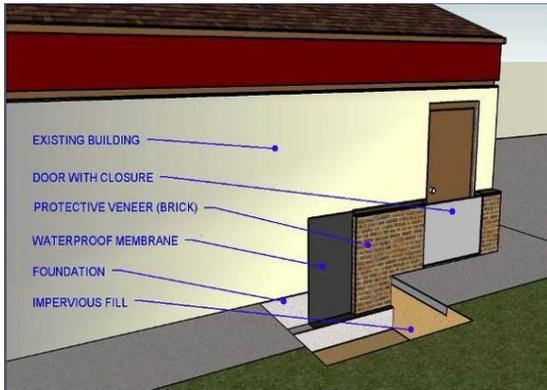


Dry Flood Proofing involves the temporary or permanent sealing of building walls with waterproofing compounds, impermeable sheeting, or other materials to prevent the entry of floodwaters into damageable structures. Dry flood proofing, shown below, are applicable in areas of shallow, low velocity flooding

Permanent Dry Flood Proofing

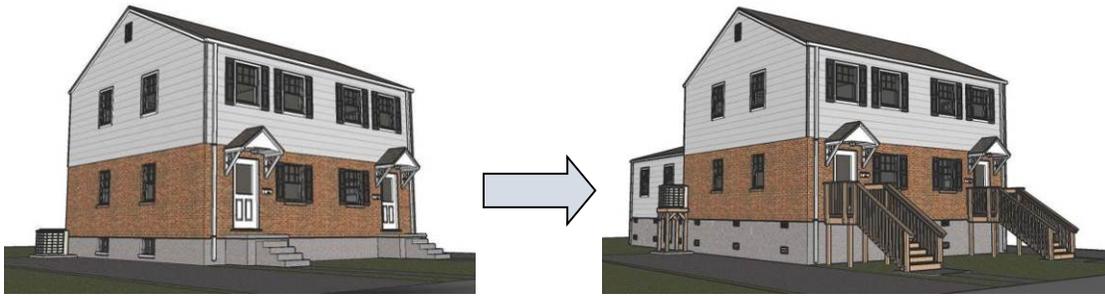


Temporary Dry Flood Proofing (Detail/Example)



Elevation involves raising the buildings in place so that the structure sees a reduction in frequency and/or depth of flooding during high-water events. Elevation, as shown below, can be done on fill, foundation walls, piers, piles, posts or columns. Selection of proper elevation method depends on flood characteristics such as flood depth or velocity.

Elevation (Graphic Illustration)



Federal Emergency Management Agency (FEMA) – The agency within the Emergency Preparedness and Response Directorate of the U.S. Department of Homeland Security. FEMA administers the National Flood Insurance Program and several flood mitigation planning and grant programs.

Flood - A *flood* is an overflow of water that submerges land or structures which is normally dry. It can be tidal, riverine or stormwater.

Flood Insurance provides insurance to assist in recovery from a flood event. Typically not include with homeowners insurance policy.

Flood Louver / Flood Openings – Flood louvers / flood vents are a permanent opening in a wall designed to allow unobstructed passage of water (automatically) in and out of a structure thereby preventing water pressure buildup (hydrostatic pressure) that can damage or destroy foundations and bearing walls.

Flood Risk - The likelihood and consequences that may arise from a flood event.

Flood Risk Management – Policies and programs for managing flood risk. This includes measures that reduce the flood hazard as well as measures that reduce the exposure and vulnerability of persons and property.

Lowest Adjacent Grade (LAG) – The lowest ground elevation adjacent to the structure.

National Nonstructural Committee (NNC) - The National Nonstructural Committee is part of the US Army Corps of Engineers and specializes in flood risk adaptive measures (which the term “nonstructural” refers to).

<http://www.usace.army.mil/Missions/CivilWorks/ProjectPlanning/nfpc.aspx>

Risk – Measure of the probability and severity of undesirable consequences.

Structural Measures – Historically, this term was used to distinguish flood risk reduction measures constructed to reduce the flood hazard (such as reservoirs and levees) from measures that might be directed to reducing consequences.

Wet Flood Proofing measures allow floodwater to enter the structure after vulnerable items such as utilities, appliances, and furnaces are waterproofed or relocated to higher locations. By allowing floodwater to enter the structure hydrostatic forces on the inside and outside of the structure can be equalized reducing the risk of structural damage.