1 Introduction

Flooding is the most common natural hazard in the United States and results in more fatalities and higher losses on average than any other natural hazard. Since 2001, the average annual flood losses in the United States were more than $10.4 billion, and from 1978 to mid-2012, the National Flood Insurance Program (NFIP) paid more than $41.3 billion in flood insurance claims.

Flood hazard mitigation can be achieved in several ways and is often different for buildings that are used for non-residential purposes such as business or industry, as compared to residential buildings such as homes and apartments. To that end, in 1986, the Federal Emergency Management Agency (FEMA) published FEMA 102, *Floodproofing for Non-Residential Structures* (FEMA 1986). The publication provided guidance to local officials, building owners, designers, contractors and other individuals or organizations interested in the design and implementation of floodproofing retrofits in non-residential structures. The guidance in FEMA 102 covers a broad range of floodproofing techniques that can be used in new and existing non-residential buildings to reduce or eliminate the potential for damage from flooding.

FEMA 102 is currently one of only a few documents in the FEMA Library that provides design professionals and community officials with guidance on floodproofing non-residential buildings. However, since its publication in 1986, floodproofing techniques and technology have evolved such that updated guidance on the subject is needed.

This document, FEMA P-936, *Floodproofing Non-Residential Buildings*, provides current guidance on floodproofing retrofits for non-residential buildings. It is similar to FEMA 102 but has a slightly different objective, which is described in the following section.

1.1 Objective and Scope

The primary objective of this publication is to provide guidance on floodproofing existing non-residential buildings in riverine areas and coastal areas that are not subject to wave action. Floodproofing will be most successful in areas subject to relatively shallow flood depths. The floodproofing concepts in this document may be applicable to:

- Core areas of critical facilities
- Buildings subject to frequent, low-level flooding for a level of protection lower than the base flood elevation (BFE)
- New construction

Additionally, a portion of the document describes dry floodproofing specific to new construction.

The publication focuses primarily on dry floodproofing but provides an overview of other retrofit methods that can be used in conjunction with or independent of dry floodproofing, including:

- Wet floodproofing
- Floodwalls
- Levees
- Protection of utilities
- Emergency floodproofing measures

The publication is intended to assist local government officials, engineers, architects, and property owners involved in the planning and implementation of floodproofing retrofits. Retrofits may be proposed voluntarily by the owner to reduce damage or may be necessary to meet building codes or floodplain management regulations. See Chapter 2 for information on floodplain management regulations related to the NFIP.

The following topics are not covered in detail:

- Residential construction, including large apartment and condominium complexes with multiple buildings, retirement homes, and nursing homes
- Operational considerations of floodproofing critical facilities
- Elevation
- Relocation
- Wave loads and Coastal A Zones

Building location, size, construction, function, and historic preservation factors dictate which floodproofing measure or measures will provide the most protection. The more complex the building, the more complex it is to protect. Combining methods of floodproofing is sometimes the best way to provide maximum protection (see Section 4.5).

1.2 Definitions and Key Concepts

Floodproofing is defined as any combination of structural or nonstructural adjustments, changes, or actions that reduce or eliminate flood damage to a building, contents, and attendant utilities and equipment (44 Code of Federal Regulations [CFR] §59.1 and American Society of Civil Engineers [ASCE] 24, *Flood Resistant Design and Construction* [2005]). Floodproofing can prevent damage to existing buildings and can be used to meet compliance requirements for new construction of non-residential buildings.

The concepts of the floodproofing measures used in this manual are defined as follows:

- **Dry floodproofing.** A combination of measures that results in a structure, including the attendant utilities and equipment, being watertight with all elements substantially impermeable to the entrance of floodwater and with structural components having the capacity to resist flood loads.
- **Wet floodproofing.** The use of flood-damage-resistant materials and construction techniques to minimize flood damage to areas below the flood protection level of a structure, which is intentionally allowed to flood.

- **Floodwall.** Constructed barrier of flood-damage-resistant materials to keep water away from or out of a specified area. Floodwalls surround a building or area and are off-set from the exterior walls of the building.
- **Levee.** Manmade barrier, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water so as to provide protection rom temporary flooding.

Terminology

- **Passive/active measures.** Floodproofing measures are either passive or active depending on whether they require human intervention. Passive measures do not require human intervention and are recommended whenever possible. Active (or emergency) measures require human intervention and are effective only if there is enough warning time to mobilize the labor and equipment necessary to implement them and to safely evacuate.
- **Substantially impermeable.** According to the U.S. Army Corps of Engineers (USACE), a wall is considered substantially impermeable if it limits water accumulation to 4 inches in a 24 hour period. In addition, sump pumps are required to control any seepage and flood-resistant materials must be used in all areas where sepage is likely to occur. This standard is the minimum requirement; lower seepage rates are possible and strongly encouraged by FEMA, particularly in new construction (USACE 1995).

1.3 Limitations of Floodproofing and Precautionary Measures

The limitations of floodproofing and precautionary measures to consider when floodproofing include:

- **Residual risk.** Residual risk is the remaining exposure to loss after all other known risks have been eliminated or minimized. Although residual financial risk can be minimized by purchasing flood insurance, building owners/managers with property in flood-prone areas should be aware that all risk cannot be eliminated by implementing physical measures such as floodproofing. The level of protection that is selected should be consistent with the ability to absorb the impacts of the residual risk. ASCE 24 and many floodplain management regulations incorporate freeboard to reduce the risk. However, the designer and building owner should be aware that floodwater levels can exceed even elevations that include freeboard and should therefore determine methods of addressing the residual risk, including:

Terminology

Freeboard is any additional height above the BFE used as a measure of safety in setting the minimum elevation of a building or floodproofing measure applied to a building.

  - **Flood damage potential.** Floodproofing does not eliminate the potential for all flood damage. For example, wet floodproofing can reduce the load on structural systems, but extended inundation may still compromise structural materials.
  - **Performance of building above floodproofing design level.** The areas above the protection levels of both dry and wet floodproofing are still at risk of damage from higher-than-expected floodwater levels, contamination, toxic materials near or inside the building, and mold from higher-than-normal humidity.

- **Space below the floodproofing design level.** Floodproofing retrofits are implemented to prevent damage to existing buildings and are not intended to create usable space below the flood protection level.
- **Occupation of floodproofed buildings.** Floodproofed buildings are not meant to be occupied during a flood. Flood warning time should be adequate and evacuation plans should be developed to ensure that occupants are not stranded in the building during a flood. Dry floodproofing actually increases the risk to occupants if floodwaters rise higher than the floodproofing design level because severe structural damage can occur. Further, the interior of the building will likely be subject to inundation, which may occur rapidly.

1.4 Assumptions

The guidance on floodproofing existing buildings in this publication is based on the following assumptions:

- The building does not have any unresolvable issues related to strength or materials that preclude dry floodproofing.
- Flood characteristics (e.g., depth, duration, velocity) on the building site are well defined and are reasonably predictable.
- Dry floodproofing is most likely to be successful for buildings subject to flooding depths, including freeboard, that do not exceed three feet, although it is recognized that floodproofing to a greater depth is feasible and may be appropriate, depending on the project.
- The building is in a riverine flood hazard area or in coastal areas subject to flood conditions without waves.
- Flood protection measures will be implemented to the flood protection level (or local regulatory flood elevation if compliance is required) not exceeding a height of three feet. FEMA strongly encourages flood retrofits to provide protection to the flood protection level or BFE plus one foot, whichever is higher, in accordance with *International Building Code* (IBC [2012]) and ASCE 24. Lower flood protection is sometimes appropriate, but the insurance implications should be considered. Building owners and design professionals should meet with a local building official to discuss the selected retrofit measure and the flood protection level.

All designs should be prepared or verified by a registered design professional before being implemented.

1.5 Evaluation of Floodproofing Options

The owner and designer should evaluate all possible methods of flood hazard mitigation before implementing mitigation options on a building. If relocating or elevating a building is not feasible or cost-effective, floodproofing may be an appropriate alternative. Table 1-1 presents important points to consider for various floodproofing measures, including dry floodproofing, wet floodproofing, floodwalls, and levees. These points of consideration are based either on established standards in ASCE 24, on regulatory documents, or on best practice guidance. Italic text indicates a consideration that is based on best practice guidance. The building and site characteristics may not be compatible with certain floodproofing measures, so the unique characteristics for each project should be taken into account.

Table 1-1. Consideration of Floodproofing Measures for Non-Residential Buildings

Type of Mitigation	Building or Site Attribute	Issues for Consideration
Dry Floodproofing	Building strength	• The superstructure and foundation should be able to adequately resist flood-related forces (hydrostatic, hydrodynamic, buoyancy, soil and debris impact) and the non-flood-related forces (e.g., wind, seismic) that are expected at the site. The superstructure and foundation should be evaluated by a registered design professional. • *If the structure is not capable of resisting the expected forces, additional retrofits to the structure may be necessary before floodproofing work begins.*
	Warning time	Warning time may be required to activate or deploy a given floodproofing measure before floodwaters begin to impact the site. Adequate warning time estimates should include time for evacuation, notification of key personnel, travel time to the site if key personnel are not located on site, implementation of the measure, and evacuation of key personnel.
	Flood characteristics	*Dry floodproofing is not recommended where flooding is expected to persist for a long period (longer than 12 hours). Prolonged contact with floodwaters increases the chance of seepage and structural failure in floodproofed buildings. Additionally, frequent flooding can adversely affect the building's structural integrity over time.*
	Level of protection	*Dry floodproofing is most likely to be successful in cases where flood depths do not exceed three feet, although floodproofing to a greater flood depth may be possible. If NFIP compliance is required, building code requirements or local regulations govern the level of protection.*
	Building location (Coastal A Zone and Zone V)	Dry floodproofing is not permitted: • In Zone V under NFIP • In Coastal A Zone or Zone V per ASCE 24 • In Zone V if the community enforces building codes based on the IBC
	Operational considerations	Dry floodproofing measures require periodic inspection and maintenance plans to ensure that they are kept in working order.
	Seepage considerations	Measures to remove water that will infiltrate the building are necessary for a dry floodproofing measure to be successful.
	Utilities	• *Alternate power may be required to operate sump pumps if normal power sources are unavailable during a flooding event.* • *Underground utilities may need to be effectively sealed to prevent backflow of floodwaters into the building.* • Electrical utilities below the flood protection level must be protected against floodwaters.
	Substantial Improvement/Damage	Dry floodproofing is permitted under the NFIP compliance regulations for buildings that are undergoing Substantial Improvement or have incurred Substantial Damage only if the buildings are non-residential. It is not permitted for residential buildings with Substantial Improvement/Damage or new construction. However, it is permissible for non-Substantial Improvement/Damage retrofit of residential buildings. It is not recommended for wood-frame construction or for areas where flood levels are greater than two to three feet.

Table 1-1. Consideration of Floodproofing Measures for Non-Residential Buildings (continued)

Type of Mitigation	Building or Site Attribute	Issues for Consideration
Wet Floodproofing	Building strength	• The superstructure and foundation should be able to adequately resist flood-related forces other than hydrostatic load (i.e., hydrodynamic, buoyancy, soil and debris impact) and the non-flood-related forces (e.g., wind, seismic) that are expected at the site. The superstructure and foundation should be evaluated by a registered design professional. • If the building is not capable of resisting the expected forces, additional retrofits to the building may be necessary.
	Warning time	Warning time may be required to activate or deploy a given floodproofing measure before the floodwaters begin to impact the site. Adequate warning time estimates should include time for evacuation, notification of necessary individuals, travel time to the site if key personnel are not located on site, implementation of the measure, evacuation of key personnel.
	Flood-damage-resistant materials	Any materials used below the BFE in wet floodproofing measures must be flood-damage resistant.
	Operational considerations	Wet floodproofing mitigation measures require periodic inspection and maintenance plans to ensure they are kept in working order.
	Utilities	Utilities below the flood protection level must be designed, constructed, and installed to prevent floodwaters, including any backflow through the system, from entering or accumulating within the components. *They should also be designed to prevent damage to the system as a result of factors such as buoyancy and corrosion.*
Floodwalls/Levees	Level of protection	*Floodwalls, levees, and other flood protective works should not be considered as protective of buildings during the design flood unless these works are shown on a community's flood hazard map as providing protection.*
	Warning time	Warning time may be required to activate or deploy a given floodproofing measure before the floodwaters begin to impact the site. Adequate warning time estimates should include time for evacuation, notification of key personnel, travel time to the site if key personnel are not located on site, implementation of the measure, and evacuation of key personnel.
	Substantial Improvement/Damage	Accredited levees result in removal of the Special Flood Hazard Area (SFHA) designation in the areas they protect. However, small levees protecting a single or limited number of buildings are generally not accredited, and their construction does not satisfy Substantial Improvement/Damage requirements or bring new buildings into compliance. To meet 44 CFR §65.10 requirements for levee accreditation, operations and maintenance must be under the jurisdiction of an approved government agency.
	Utilities	• *Underground utilities should be considered in the design of floodwalls to prevent backflow of floodwaters into the building.* • *If a levee or floodwall is breached, the resulting flow may be high velocity, possibly causing scour and dislocation.* • *Underground utilities may threaten the stability of the levee itself, if they run underneath the structure.*

Table 1-1. Consideration of Floodproofing Measures for Non-Residential Buildings (continued)

Type of Mitigation	Building or Site Attribute	Issues for Consideration
Floodwalls/Levees (continued)	Seepage potential and local/internal drainage	• *The longer the duration (i.e., the longer floodwaters are in contact with the floodwall), the greater the potential for seepage, and the greater the need for seepage control measures such as backfill, cutoff walls, or pumps.* • *Local drainage systems should be designed to minimize the rainfall runoff of floodwaters within the protected area.* • *The soil type surrounding the building is a key consideration in floodwall design. The soil mineralogy and deposition can vary widely in coastal deposits. This variability affects both permeability and strength properties, and should be carefully evaluated. Seepage potential is lower for less permeable soils, which reduces the required floodwall drainage design flow volume and rate. However, less permeable soils must be checked for adequate stability and strength to resist static and dynamic flood forces.*
	Floodwall openings	*Floodwalls with fewer/smaller openings are simpler to design and require less warning time to install protective floodwall closures, but can limit site access.*
	Location and topography	*Levees require a significant amount of surrounding vacant land and are not typically suitable for densely developed communities.* *If the natural topography is such that only one or two sides of a building need to be protected, a levee may be feasible.*
	Regulatory requirements	Federal, State, and local laws and regulations should be reviewed to determine whether floodwall or levee construction is permissible, restricted, or prohibited. For example, certain criteria restrict floodwall or levee construction within FEMA-designated floodways. Additionally, when floodprone property is acquired via a FEMA mitigation grant program, deed restrictions on land use prohibit most development, including the construction of levees, on the property.

1.6 Icons

Throughout this manual, the following icons are used, indicating:

Special Note: Significant or interesting information

Terminology: Definition or explanation of pertinent terms

Cross Reference: Reference to another relevant part of the text or another source of information

Equation: Use of a mathematical equation

Warning: Special cautions need to be exercised

1.7 Organization

The information in this manual is organized as follows:

- **Chapter 1: Introduction** – Definition of floodproofing, limitations and assumptions in floodproofing non-residential buildings, and an evaluation of floodproofing measures.
- **Chapter 2: Design Considerations for Floodproofing** – Factors that influence the decision to implement a floodproofing measure.
- **Chapter 3: Dry Floodproofing Measures** – General design considerations for dry floodproofing, as well as a discussion of the types of dry floodproofing measures.
- **Chapter 4: Other Floodproofing Measures** – Floodwalls, levees; floodproofing utilities, wet floodproofing, and emergency floodproofing; pros and cons of each measure; other factors to consider when selecting a floodproofing measure; and how to combine floodproofing measures.
- **Appendix A: FEMA Assistance** – Overview of FEMA's Hazard Mitigation Assistance grant programs.
- **Appendix B: Understanding the FEMA Benefit-Cost Process** – Importance of the Benefit-Cost Analysis (BCA) in FEMA assistance, data required to run a BCA module, and resources with additional information.
- **Appendix C: Checklist for Vulnerability of Flood-prone Sites and Buildings** – A tool that can be used to help assess site-specific flood hazards and building vulnerability.
- **Appendix D: References** – Cited references.
- **Appendix E: Resources** – Resources with additional information, including vulnerability and maintenance checklists.
- **Appendix F: FEMA Region Contact Informattion** – Mailing addresses and phone numbers for the FEMA Regions.