Fact Sheet 3.0: Buildings, Systems and Equipment

The Fact Sheets in this section present mitigation methods for public buildings and internal systems to make them more resilient to floods and hurricanes so that critical community lifelines can be maintained.

Hurricane and Flood Impacts

Hurricanes and floods can result in damage to public buildings. This loss of building function has the potential to negatively impact communities because some government and public service functions could be reduced temporarily. Ideally, communities will incorporate mitigation elements into renovations of these buildings before disasters occur to decrease impacts that floods and hurricanes could have on providing services to the public. However, if mitigation cannot be done before a disaster impacts a public building it should be incorporated during the repair process to make sure these facilities can withstand disasters in the future to allow communities to be more resilient.

Mitigation Fact Sheets

The Fact Sheets in this series discuss building elements that may be impacted during a flood or hurricane, including building systems, which include mechanical (heating, ventilation, and air conditioning), electrical, and plumbing systems and associated equipment, which includes things like piping, wiring, fixtures and other accessories. There are eight Fact Sheets in this series, covering four topics:

1. **Foundations**: Building foundations help to distribute the weight of the building to the earth below. Foundations generally are classified as shallow or deep and closed or open. Without a proper foundation, a building can suffer damage from erosion, scour or settlement.

2. **Walls and Openings**: The exterior walls of buildings include joints and openings such as doors and windows. These all provide points of entry for wind-driven rain and flood water to pass into the building. They also can be susceptible to damage from wind-borne debris. Implementing mitigation measures can help prevent wind- and flood-related damage.

3. **Roof Systems**: Roof systems generally are classified as sloped or low-sloped, with sloped roofs having a pitch of 1V:4H or greater and low-sloped roofs having a pitch of less than 1V:4H, although this can vary slightly based on the type of roof covering. Roofs can be subject to damage from wind, wind-driven rain and wind-borne debris.

4. **Building Utility Systems**: For these fact sheets, building utility systems include heating, ventilation and air conditioning (HVAC); electrical; plumbing; and conveyance systems. These systems heat and cool buildings, provide water and power, expel wastewater, and move people and equipment between levels of the building. Each of these systems can be susceptible to damage by flood, and exterior components also can be susceptible to wind damage.

Mitigation Solutions

There are many recommended mitigation measures or best practices for small public buildings (Figure 3.0.1) and large public buildings (Figure 3.0.2) in areas prone to floods or hurricanes.

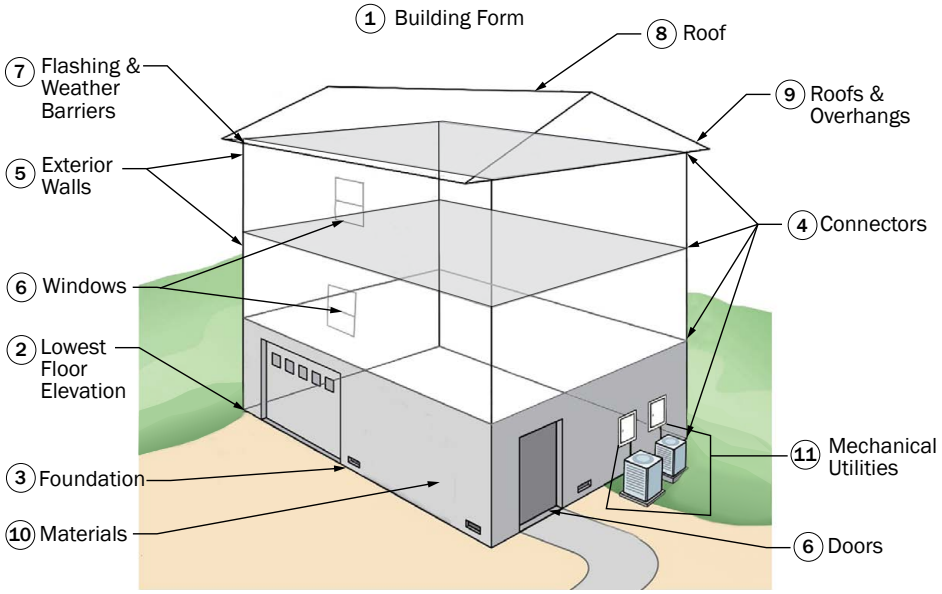


Figure 3.0.1. Small public building elements (before mitigation).

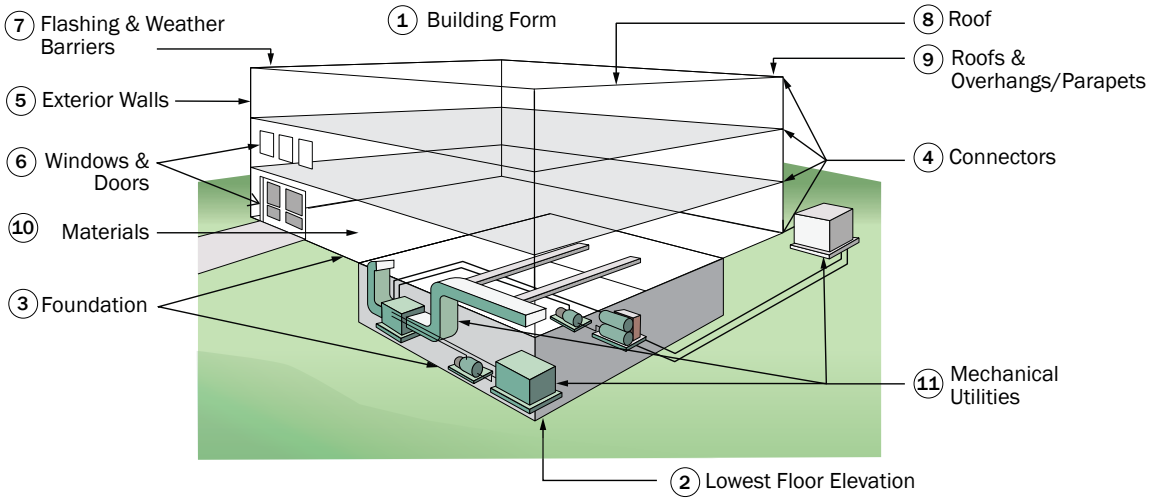


Figure 3.0.2. Large public building elements (before mitigation).

The numbered items below relate to the numbering in Figure 3.0.1 and Figure 3.0.2. They list the recommended mitigation measures for each of the numbered building elements:

1. **Building Form**. Flat or low-sloped roofs covering open spaces such as porches and carports, overhangs, and gable ends are subject to increased wind pressure in high winds. Buildings that are both tall and narrow are subject to overturning. These problems can be overcome through the design process, but each issue must meet specific design requirements. During the design process, consider moderate-sloped hip roofs with a 4:12 or 6:12 slope.

2. **Lowest Floor Elevation**. In coastal buildings, elevate the bottom of the lowest horizontal structural member (LHSM) supporting the lowest floor above the Design Flood Elevation (DFE), or highest flood level, in the Coastal A and V Zones. Building foundations in A Zones should be elevated to comply with the local floodplain management ordinance, including codes, specifications and standards such as ASCE 24. Critical public buildings will require more freeboard to reduce damage during the predicted 0.2%-annual-chance (500-year) flood event, which will increase resilience. Lastly, uses for areas that are below the base flood elevation (BFE) are limited to parking, storage, and access and should remain unfinished, using only flood-damage-resistant materials. (See NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements, for additional information.)*

3. **Foundation**. Make sure the foundation is deep enough to resist the effects of scour and erosion; strong enough to resist wave, current, flood, and debris forces; and capable of transferring wind forces on upper stories to the ground. A coastal foundation should include piles, piers, or columns and be open to allow the free flow of flood waters and waves. NFIP Technical Bulletin 2, *Flood Damage Resistant Material Requirements, and* NFIP Technical Bulletin 5*, Free of Obstruction Requirement*s, provide additional information.

4. **Connections**. Key connections to ensure a continuous load path from the roof to the foundation include roof sheathing, roof-to-wall, wall-to-wall, and wall-to-foundation connections. Be sure these connections are built according to the design. Bolts, screws and ring-shank nails are common requirements. Define standard connection details and nailing on the plans. Connectors in coastal environments should be corrosion-resistant consistent with NFIP Technical Bulletin 8, *Corrosion Protection of Metal Connectors in Coastal Areas.*

5. **Exterior Walls**. Use structural sheathing in high-wind areas for increased wall strength. Use tighter than typical nailing schedules for attaching sheathing. Take care not to over-drive pneumatically driven nails. This can result in loss of shear capacity in shear walls. Refer to FEMA P-424, *Design Guide for Improving School Safety,* for more detailed information.

6. **Windows and Doors**. In high-wind areas, use windows and doors capable of withstanding increased wind pressures. In wind-borne debris areas, use impact-resistant glazing or shutters. Use door shields to prevent water intrusion when used with water-resistant foundation and wall membranes. Refer to Fact Sheet 3.2, *Wall Systems and Openings, and* FEMA P-543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds*, for additional information.

7. **Flashing and Weather Barriers**. Use stronger connections and improved flashing for roofs, walls, doors and windows and other openings. Install secondary moisture barriers, such as house wrap or building paper, to reduce water intrusion from wind-driven rain. Refer to FEMA P-424, *Design Guide for Improving School Safety*, for more-detailed information.

8. **Roof**. In high-wind areas, choose appropriate roof coverings and pay attention to detailing. Avoid roof tiles in hurricane-prone areas. Install secondary water barriers to provide extra protection. Secure rooftop equipment to resist design wind loads or place equipment in a rooftop penthouse. Refer to FEMA P-424, *Design Guide for Improving School Safety,* and Hurricanes Irma and Maria in the U.S. Virgin Islands Recovery Advisory 2, *Attachment of Rooftop Equipment in High-Wind Regions*, for additional information.

9. **Porch Roofs and Roof Overhangs**. Design and tie down porch roofs, roof overhangs, and columns to resist uplift forces in accordance with FEMA P-55, *Coastal Construction Manual.*

10. **Materials**. Use flood-resistant materials below the DFE. All exposed materials should be moisture- and decay-resistant. Metals should have enhanced corrosion protection. See NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements*, and ASCE 24, *Flood Resistant Design and Construction.*

11. **Mechanical and Utilities**. Mechanical, electrical and plumbing (MEP) systems and equipment should be raised to avoid flood damage and strategically located to avoid wind damage. Utility lines should be installed to minimize potential flood damage.

What Should Communities Expect from a Mitigated Building?

A public building can be mitigated successfully if it can resist damage from a variety of natural hazards over time, such as wind, flooding, hurricanes, erosion and scour. This does not mean that a public building will remain undamaged over its intended lifetime. It means that the impacts of a design-level flood, storm, wind, or erosion event (or a series of small events with combined impacts equivalent to a design event) will be limited to the following:

- The building **foundation** should remain intact and functional.
- The **envelope** (walls, openings, roof, and lowest floor) should remain structurally sound and capable of withstanding wind, rain, and debris.
- The **lowest floor elevation** should be sufficient to prevent floodwaters from entering the elevated building envelope during the design event.
- The **utility connections** (e.g., electricity, water, sewer, natural gas) should remain intact or be restored easily.
- The building should be **accessible**, **habitable**, and **safe** with minimal repairs following a design-level event.
- Any damage to **enclosures** below the Design Flood Elevation (DFE), or the highest flood level, should not damage the foundation, the utility connections, or the elevated portion of the building.
- Building **contents** will remain safe with minimal damage.

Exceeding Minimum Requirements Can improve Building Performance

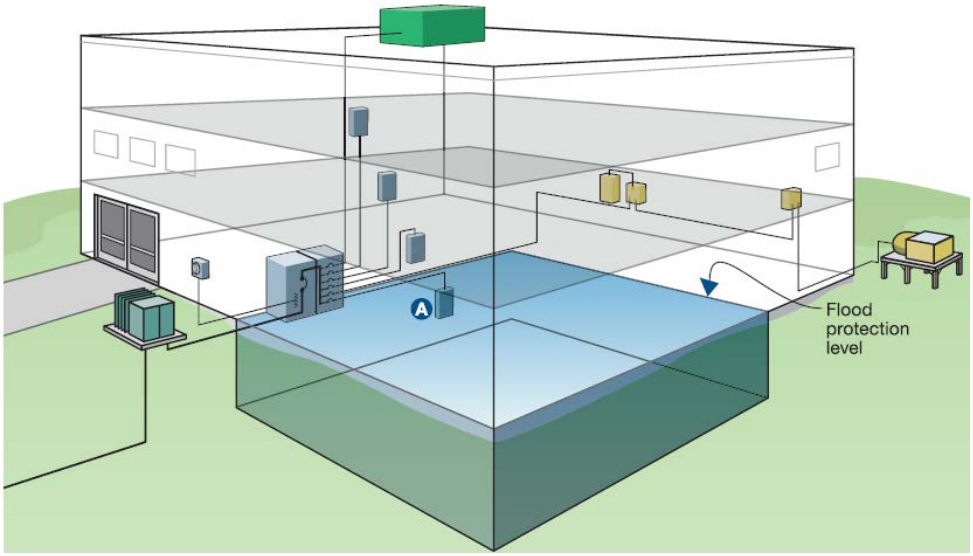
States and communities enforce regulatory requirements that determine where and how buildings may be sited, designed and built under Executive Order 11988, *Floodplain Management*. Federal agencies funding or permitting key public buildings are required to avoid building in areas that are in the 0.2%-annual-chance (or 500-year probability) flood event. See the FEMA fact sheet, Critical Facilities and Higher Standards, for additional information.

Designers can help facility owners and communities evaluate their options to make informed decisions about mitigation options. Note that critical facilities, such as hospitals, have their own code requirements. Some buildings have performance standards per ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, or *ASCE 24, Flood Resistant Design and Construction*, for different risk categories based on the building's use or purpose. Hurricane or tornado shelters must be built to ICC 500 Storm Shelter or FEMA Safe Room standards contained in FEMA P-361, *Safe Rooms for Tornadoes and Hurricanes.*

Building Contents, Equipment and Furnishings

Building contents and equipment can be elevated or relocated to protect against flood damage (Figure 3.0.3 and Figure 3.0.4). Finishes can be replaced with materials made to resist flood damage. When advanced notice of a storm allows for it, relocating critical and expensive equipment—for instance, moving fire and rescue equipment away from a fire station that is close to the coast or in a flood-prone area—not only prevents damage but also allows the equipment to be used during critical emergency response operations.

When repairing a non-Substantially Damaged building (i.e., a building for which the total cost of repairs is less than 50% of the structure's market value before the disaster) with significant interior damage, or during a planned renovation, using flood damage-resistant materials for interior elements like flooring, doors, cabinets, etc., can prevent or significantly reduce damage from flooding. Rearranging a building's space—for example, moving critical equipment to a second or third floor above the flood level—can reduce flood damage and allow continued operation.



A *Note: The basement panel will remain vulnerable to flooding, so it should be electrically isolated from the rest of the electrical system.*

Figure 3.0.3. Large public building elements with primary electrical system components mitigated.

Utility Flood Protection Level

FEMA P-348, *Protecting Building Utility Systems from Flood Damage,* defines the flood protection level as "… the elevation required by the NFIP, building codes, or locally adopted regulations. In addition, flood protection level refers to the level selected to provide the desired level of protection when compliance with code or regulation is not required and designers and owners elect to elevate or protect building utility systems." The flood protection level is the same as the design flood elevation. These may differ from the base flood elevation, which is the elevation to which a flood is expected to rise during the 1%-annual-chance flood, also called the 100-year flood. The flood protection level (or design flood elevation) is generally the base flood elevation plus freeboard.

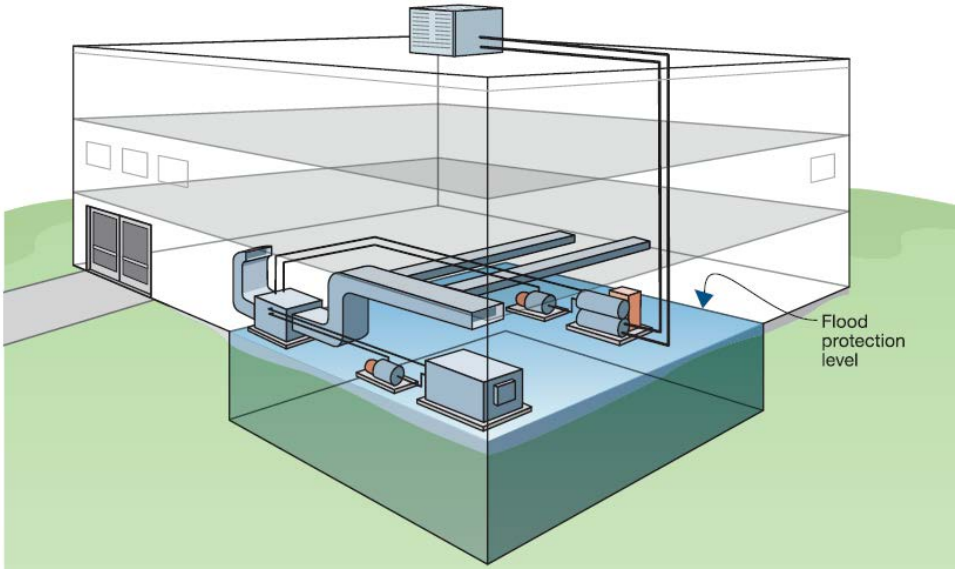
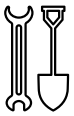


Figure 3.0.4. Flood risk for large public building reduced by relocating primary HVAC components from a subgrade basement level to a higher floor.

Icons

The Fact Sheets include points to consider about developing and implementing each mitigation option. Icons represent these common considerations, which are summarized in Table 3.0.1.

Table 3.0.1. Icons Used to Represent Considerations about Hazard Mitigation Strategies

Icon	*Considerations about Hazard Mitigation Strategies*
	**Cost** — The cost to carry out the mitigation option may be high, which could make using the option cost prohibitive.
	**Engineering** — A qualified engineer would likely need to design the mitigation option.
	**Environmental and Historic Preservation** — The mitigation option likely will need to comply with local, state and/or federal environmental and historic preservation requirements.
	**Floodplain Management** — Carrying out the mitigation option might impact the floodplain, triggering compliance with floodplain management requirements.
	**Operations and Maintenance** — The mitigation option might require additional operations and maintenance activities beyond those currently being performed.
	**Permitting** — Evaluate the local, state or federal permits required to carry out the mitigation option.

REFERENCES:

Recommended practice and guidance concerning listed topics can be found in the following FEMA publications and trade publications:

American Society of Civil Engineers (ASCE). 2016. ASCE 24 Flood Resistant Design and Construction. Available at: https://ascelibrary.org/doi/book/10.1061/asce24

Federal Emergency Management Agency (FEMA). 1993a. NFIP Technical Bulletin 3, *Non-Residential Floodproofing—Requirements and Certification.* Available at: https://www.fema.gov/emergency-managers/risk-management/building-science/national-flood-insurance-technical-bulletins

FEMA. 1993b. NFIP Technical Bulletin 7, *Wet Floodproofing Requirements for Structures Located in Special Flood Hazard Areas.* Available at: https://www.fema.gov/emergency-managers/risk-management/building-science/national-flood-insurance-technical-bulletins

FEMA. 2007. FEMA 551, *Selecting Appropriate Mitigation Measures for Floodprone Structures.* Available at: https://www.fema.gov/sites/default/files/2020-08/fema_551.pdf

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FEMA. 2009. FEMA P-762, *Local Officials Guide for Coastal Construction* Available at: https://www.fema.gov/sites/default/files/documents/fema_p-762-local-officials-guide-coastal-construction.pdf

FEMA. 2010. FEMA P-499, *Homebuilder's Guide to Coastal Construction.* Available at: https://www.fema.gov/sites/default/files/2020-08/fema499_2010_edition.pdf

FEMA. 2011. FEMA P-55, *Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas.* Available at: https://www.fema.gov/media-library/assets/documents/3293

FEMA. 2012. FEMA P-259, *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures.* Available at: https://www.fema.gov/sites/default/files/2020-08/fema259_complete_rev.pdf

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FEMA. 2016. FEMA P-787, *Catalog of FEMA Building Science Branch Publications and Training Courses—Fifth Edition.* Available at: https://www.fema.gov/sites/default/files/2020-07/fema_earthquakes_p-787-catalog-of-fema-building-science-branch-publications-and-training-courses-fifth-edtition_20161014.pdf

FEMA. 2019. NFIP Technical Bulletin 8, *Corrosion Protection of Metal Connectors in Coastal Areas* Available at: https://www.fema.gov/emergency-managers/risk-management/building-science/national-flood-insurance-technical-bulletins

FEMA. 2020. NFIP Technical Bulletin 5, *Free of Obstruction Requirements* Available at: https://www.fema.gov/emergency-managers/risk-management/building-science/national-flood-insurance-technical-bulletins

FEMA. No Date. Fact Sheet, *Critical Facilities and Higher Standards.* Available at: http://data.wvgis.wvu.edu/pub/RA/_resources/CF/FPM_1_Page_CriticalFacilities_and_Higher_Standards.pdf

International Code Council (ICC). 2018. *International Building Codes and I-Codes Summary of Changes to Flood Provisions.*

U.S. Army Corps of Engineers (USACE). 1995. *Flood Proofing Regulations* EP 1165-2-314. Available at: https://www.publications.usace.army.mil/Portals/76/Publications/EngineerPamphlets/EP_1165-2-314.pdf