Siting, Design, and Construction in Coastal Flood Zones

FEMA

Purpose and Intended Audience

The purpose of this advisory is to discuss siting, design, and construction practices in Coastal Flood Zones including Coastal A Zones, where wave and flood conditions during a flooding event will be less severe than in V Zones but can still cause significant damage to foundations and buildings (Figure 1). The authors anticipate that Puerto Rico officials will add to existing building codes requirements that buildings located in a Coastal A Zone be treated the same as those in the V Zone.

The intended audience for this document includes building owners and design professionals who are planning new building or rebuilding projects in coastal areas, as well as floodplain managers and community regulators involved in developing and enforcing building codes and ordinances in coastal floodplains.

Unless otherwise noted, all photographs are from FEMA Mitigation Assessment Team (MAT) observations in Puerto Rico following Hurricanes Irma and Maria in 2017.

Figure 1. Failure of structure subject to surge, waves, and erosion.

Figure 2. Severely damaged structure in Coastal Zone in Punta Santiago.

FEMA MATs have observed many instances of damage from small waves consistent with Coastal A Zone conditions along shorelines of communities impacted by Hurricane Maria.

Key Issues

- Correct design and construction practices can minimize damage to buildings, particularly by elevating the building higher than the minimum required elevation.
- Once flood levels exceed the lowest floor elevation of a building, the extent of damage increases dramatically, especially in areas subject to coastal waves (Figure 2).
- Foundations in coastal areas should be designed to elevate buildings above the Design Flood Elevation (DFE) in accordance with American Society of Civil Engineers *Standard for Flood Resistant Design and Construction* (ASCE 24-14, 2014), while withstanding flood forces, high winds, scour and erosion, and floating debris in *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE 7-16, 2017).
- Foundations used for inland construction are generally not suitable for coastal construction. Some examples of foundation systems that have a history of poor performance in erosion prone areas are slab-on-ground, spread footings, and mat (or raft) foundations.
- Open foundations (pile or pier) designed to resist all base flood conditions, including waves, high velocity flow, erosion and scour, and flood-borne debris should be used in V and Coastal A Zones.
- Land purchase and siting decisions for buildings should take into consideration the long-term impacts of storm surge, waves, and erosion and not be based only on the present-day shoreline location and conditions.

- Conformance with local/state shoreline setback lines does not mean buildings will be safe.
- Siting, design, and construction to exceed the minimum regulatory requirements can cost slightly more initially but can save the owner money in the long term. Homeowners should consider exceeding minimum requirements to take into account storms with impacts greater than the 1-percent-annual-chance level, as well as future climate impacts such as sea-level rise and long-term erosion.
- Buildings in V Zones must be elevated on open foundation systems and be free of obstructions. Areas below elevated buildings in V Zones can only be used for parking, storage, and building access. Any building elements and enclosures below the elevated building must be designed and constructed to break away from the structure and not transfer any loads to the elevated building nor the foundation system. Refer to the *Home Builder's Guide to Coastal Construction* (FEMA P-499, 2010), Technical Fact Sheet 8.1, for more on this subject. Breakaway walls, including garage doors, must be built with flood-resistant materials and be certified by a registered professional engineer. Utilities should not be attached to, or pass through, breakaway walls, and should be elevated. It is recommended that breakaway walls be designed to break into smaller sections, and to use screening, open lattice, slats, or louvers in place of solid breakaway walls. Areas below elevated buildings in Coastal A Zones should follow the same requirements as those areas for buildings located in V Zones.
- Many post-storm investigations have shown that typical A Zone residential and light commercial construction techniques (e.g., wood-frame, light gauge steel, and masonry walls on shallow footings or slabs) are subject to damage or destruction even when exposed to waves less than three feet high (Figure 3). Laboratory tests confirm field observations that breaking wave heights as small as 1.5 feet will cause failure of these types of walls (Figure 3) and foundations (Figure 4).
- Other flood hazards associated with coastal waves (e.g., floating debris, high velocity flow, erosion, and scour) also damage V Zone and A Zone type construction in coastal areas (Figure 5).

Figure 3. Failure of wood-frame wall, brick veneer, and windows due to 4 feet of stillwater flooding and small waves. Hurricane Katrina in Mississippi.

Figure 4. Failure of A Zone type foundation in a coastal area, not subject to Zone V conditions.

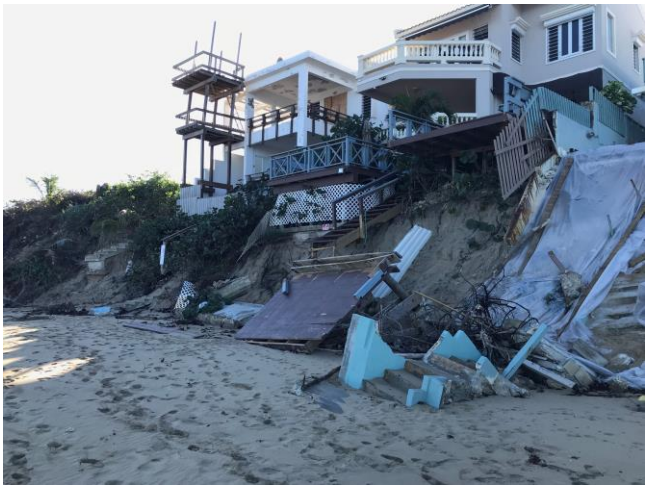

Figure 5. Structure being undermined by erosion experienced during Hurricane Maria at Shacks Beach.

This Recovery Advisory Addresses

- Definition of Coastal Flood Zones.
- Coastal Flood Advisory Mapping Information.
- Siting Structures in Coastal Flood Zones.
- V Zone and Coastal A Zone Design and Construction Guidance.

Definition of Coastal Flood Zones

FIRMs show V Zones, A Zones, and, on newer maps, the Limit of Moderate Wave Action (LiMWA). The LiMWA is mapped where wave heights during the base flood event are 1.5 feet. The area between the LIMWA and the V Zone is known as the Coastal A Zone and is referenced in building codes and standards. In the Coastal A Zone, wave heights are between 1.5 and 3 feet. The current FIRMs for Puerto Rico do not show the LiMWA; however, it will be shown on updated maps. FIRMs also show other zones, such as AO and VE; for a glossary, refer to *Managing Floodplain Development Through the NFIP* (FEMA, 1998), Appendix D.

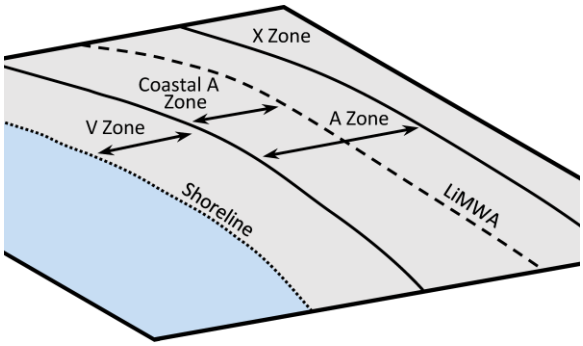

Figure 6. Perspective view showing the Coastal A Zone, V Zone, and LiMWA.

In Coastal Flood Zones, the principal source of flooding is astronomical tides, storm surge, seiches or tsunamis, and wave hazards, not riverine flooding. In relation to coastal construction requirements, there are three relevant coastal flood zones: the V Zone, the Coastal A Zone, and the A Zone (Figures 6 and 7).

The V Zone, also known as the Coastal High Hazard Area, is an area of high velocity wave action from storms and is typically subject to the most severe erosion potential and the most damaging waves. The V Zone is defined by wave heights 3 feet or greater or the combination of wave runup heights 3 feet or greater than the storm surge level and wave runup elevation 3 feet or greater than the ground elevation.

The A Zone is an area landward of the V Zone where wave heights are less than 3 feet. The depth of storm surge flooding is less in the A Zone than in the V Zone; however, there is still potential for damaging waves and scour. It has been shown that wave heights between 1.5 and 3 feet can still cause significant damage to residential structures; hence, FEMA maps the LiMWA to identify this area. Building codes now define the Coastal A Zone as the area landward of the V Zone where the potential for wave heights between 1.5 and 3 feet exist. Generally, at least 2 to 4 feet of stillwater depth is necessary to support these wave heights. The Coastal A Zone can be identified using the FIRM as the area between the LiMWA and the V Zone.

Coastal A Zone design and construction practices described herein are required by the International Code Council *International Building Code* (ICC IBC, 2018), through its reference to ASCE 24-14, and by the 2015 and 2018 editions of the ICC *International Residential Code* (ICC IRC, 2015 and 2018). As Puerto Rico adopts these new codes, higher standards in Coastal A Zones will be enforced. In addition, the National Flood Insurance Program (NFIP) encourages communities to adopt these practices, and Community Rating System (CRS) credits may be available for doing so.

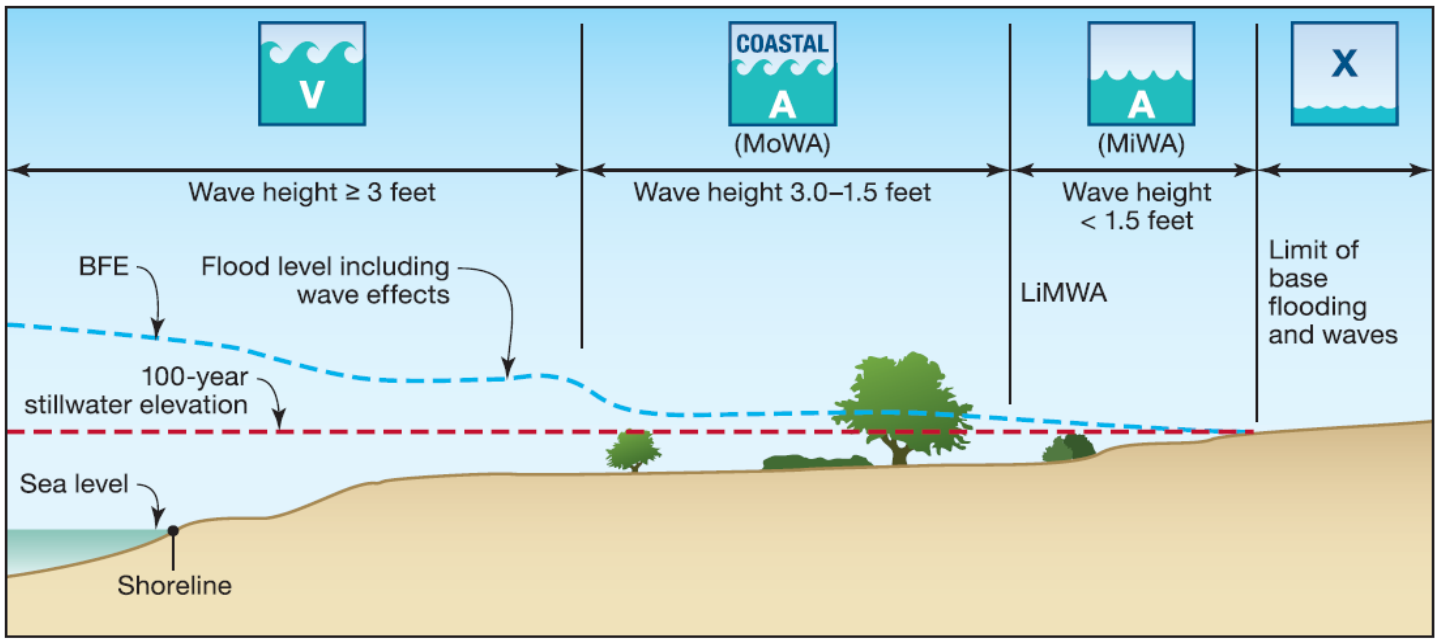

Figure 7. Cross-section showing 1-percent-annual-chance stillwater elevation, stillwater depth, BFE, LiMWA, and flood hazard zones. From the Coastal Construction Manual (FEMA P-55, 2011), Figure 3-53.

Coastal Flood Advisory Mapping Information

After severe coastal storms like Hurricanes Irma and Maria, FEMA issues Advisory Flood Mapping for areas where the existing FIRMs no longer adequately represent the actual base flood risk, or where additional information is needed to advise the rebuilding process. These Advisory Maps are intended to offer guidance on elevating new and reconstructed buildings. For Puerto Rico, the existing FIRMs lack the LiMWA line identifying the Coastal A Zone. They also lack detailed BFEs for many streams. Critical facilities such as fire stations and emergency services, need to be built to the 0.2-percent-annual-chance level and are not included on current FIRMs; hence, 0.2-percent-annual-chance Advisory BFEs are in preparation. The Advisory Flood Mapping for Puerto Rico includes the following information:

- LiMWA lines and Coastal A Zone areas based on the 1-percent-annual-chance flood event.
- New 1-percent-annual-chance coastal floodplain boundaries, delineated to the latest topographic information.
- New 0.2-percent-annual-chance coastal flood zones and floodplains with elevations for critical facility guidance.
- LiMWA lines and Coastal A Zone areas based on the 0.2-percent-annual-chance flood event.
- Identification of areas vulnerable to storm erosion.
- Long-term erosion setback lines for 30-year and 60-year erosion areas.
- New stream floodplains and elevations for both the 1-percent- and 0.2-percent-annual-chance levels.

Advisory mapping provides interim information for reconstruction efforts and can be used until updates to the Flood Insurance Studies (FISs) and FIRMs are made. The Advisory Mapping is a combination of the effective FIRM information and the updated mapping listed above. Figure 8 shows an example of the Advisory Mapping for Puerto Rico.

Use of advisory maps is mandatory only when a State, Territory, or community adopts them. Advisory Mapping information for Puerto Rico is available at http://jp.pr.gov/sigepr/advsmap.

Other Flood Hazards

FIRMs do not account for all the factors that can influence flood hazards over time. The following factors should also be considered:

- Shoreline erosion, wetland loss, subsidence, and relative sea level rise
- Shoreline development and adjacent building practices
- Upland development or topographic changes
- Stormwater management and drainage
- Degradation or settlement of levees and floodwalls
- Changes in storm climatology (frequency and severity)
- The effects of multiple storm events

Terminology

Flood Insurance Rate Map (FIRM): The official map of a community produced by FEMA. The FIRM shows Base Flood Elevations, Special Flood Hazard Areas, and risk premium zones.

Special Flood Hazard Area (SFHA): The land areas subject to a 1-percent-or-greater-annual-chance of flooding, where floodplain management regulations must be enforced, and mandatory flood insurance purchase requirements apply. These areas are indicated on FIRMs as Zone AE, A1-A30, A99, AR, AO, AH, V, VO, VE, or V1-30. Mapped zones outside of the SFHA are Zone X (shaded or unshaded, subject to or beyond 0.2-percent-annual-chance flooding) or Zone B/Zone C on older FIRMs.

Base Flood Elevation (BFE): The elevation to which flood waters are anticipated to rise during the base flood (1-percent-annual-chance) event with wave effects included in coastal areas. The BFE is the basis of insurance and floodplain management requirements.

Design Flood Elevation (DFE): Flood Elevation on which building design requirements are based. The DFE may include additional elevation (freeboard) above the BFE.

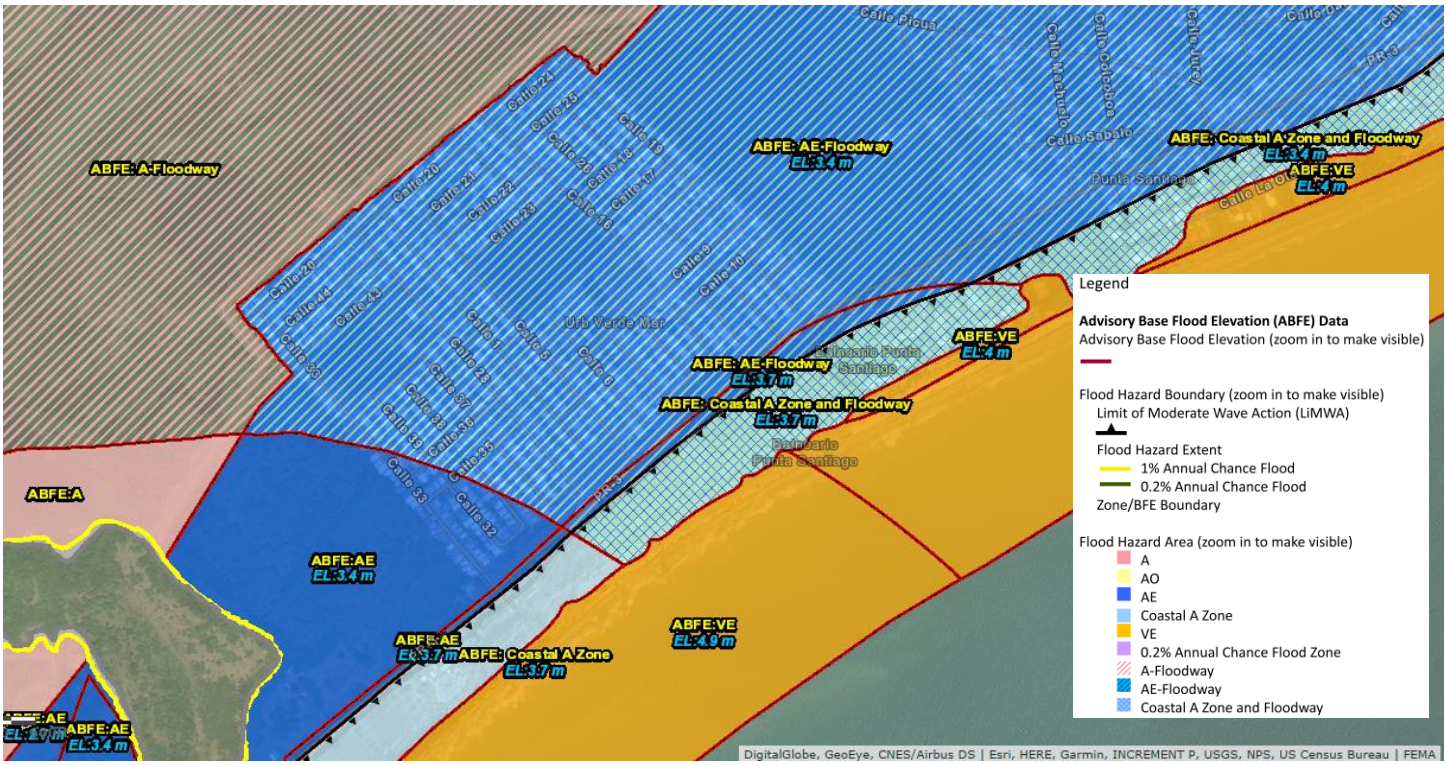

Figure 8. Example of Advisory Map information for Puerto Rico.

Siting Structures in Coastal Flood Zones

A well-built but poorly sited building can be undermined and will likely fail (Figure 9). Even if a building is set back or situated farther from the coastline, it will not perform well if it is incapable of resisting high winds, waves, storm surge, and other hazards that occur at the site (Figure 10).

Figure 9. Structures located close to shore and subject to scour and erosion.

Figure 10. Structure foundation survived but could not resist high winds.

The single most common and costly siting mistake made by designers, builders, and owners is to fail to consider future erosion and slope stability when an existing coastal building is purchased, or when land is purchased and a new building is built. Purchase decisions or siting, designing, and construction decisions based on present-day shoreline conditions often lead to future building failures.

Builders, Designers, and Owners Should

Siting should consider both long-term erosion and storm impacts. Siting should consider site-specific experience wherever possible.

- Consult local and state agencies, universities, coastal engineering experts, and consultants for detailed, site-specific erosion and hazard information.
- Look for historical information on erosion and storm effects. How have older buildings in the area fared over time? Use the experience of others to guide siting decisions.
- Consider future sea level rise projections and impacts to flooding, erosion, and shoreline position.
- Understand the level of risk associated with purchasing land or building along the coastline.

Common Siting Problems

- Building on a small lot between a road and an eroding shoreline should be avoided, as the small lot does not allow for a setback distance from the shoreline.
- Building on odd-shaped lots forces buildings close to the shoreline and increases their vulnerability.
- Siting a building near the edge of a bluff increases the likelihood of building loss, because of increased wind exposure, bluff erosion, and changes in bluff stability resulting from development activities (e.g., clearing vegetation, constructing new buildings, landscaping, and altering surface drainage and groundwater flow patterns).
- Siting near a tidal inlet with a rapidly changing shoreline may expose the building to increasing flood and erosion hazards over time.
- Siting a building immediately behind an erosion control structure may lead to building damage from wave runup and/or overtopping and limits the owner's ability to repair or maintain the erosion control structure.
- Siting a new building within the footprint of a pre-existing building does not prevent future loss nor damage.

Siting on a property involves working to minimize the risk to coastal buildings (Figure 11). The following practices will help reduce the risks:

- Locating development on the least hazardous portion of a site
- Rejecting the site and finding another location
- Transferring development rights to another parcel better able to accommodate development
- Combining lots or parcels to create additional space or setbacks
- Reducing the footprint of the proposed building and shifting it away from the flood hazard
- Shifting the location of the building on the site by modifying or eliminating ancillary structures and development
- Seeking variances to lot line setbacks along the landward and side property lines (in the case of development along a shoreline)
- Moving roads and infrastructure
- Modifying the building design and site development to facilitate future relocation of the building on the same site
- Altering the site to reduce vulnerability, if allowed by the community
- Constructing protective structures, if allowed by the community

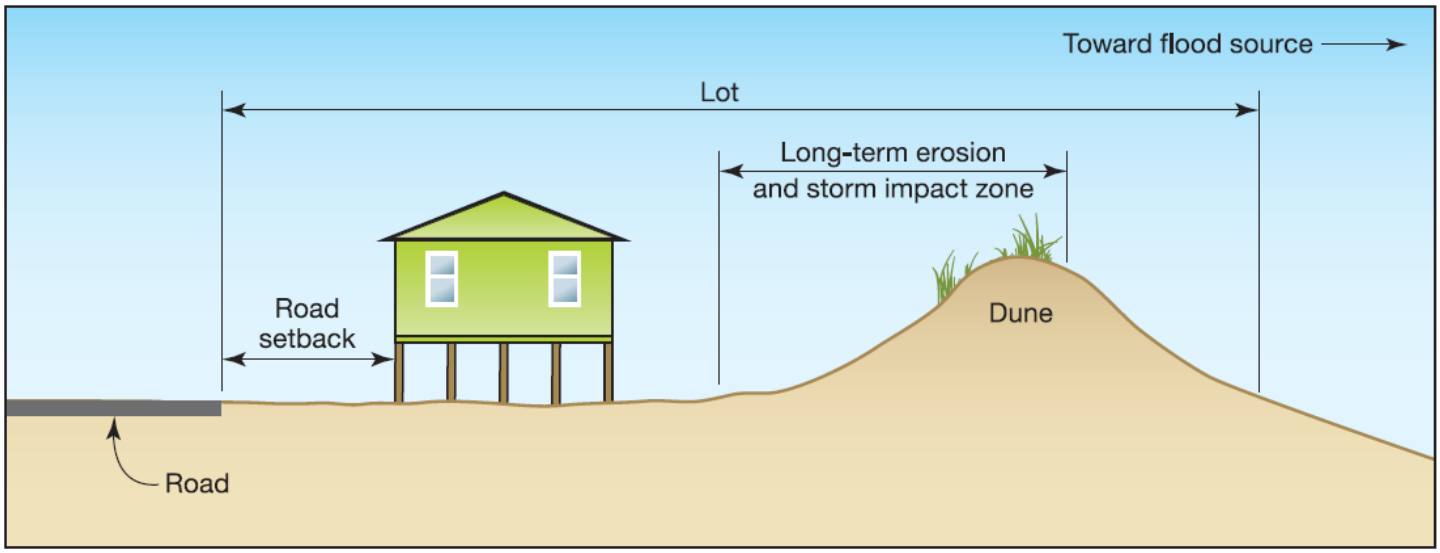

Figure 11. Recommended building location on a coastal lot. From FEMA P-55 (Figure 4-12).

V Zone and Coastal A Zone Design and Construction

Building in a coastal environment is different from building in an inland area:

- Flood levels, velocities, debris, and wave action in coastal areas tend to make coastal flooding more damaging than inland flooding.
- Coastal erosion can undermine buildings and destroy land, roads, utilities, and infrastructure.
- Wind speeds are typically higher in coastal areas and require stronger engineered building connections and more closely spaced nailing of building sheathing, siding, and roof shingles.
- Wind-driven rain, corrosion, and decay are frequent concerns in coastal areas.

In general, homes in coastal areas must be designed and built to withstand higher loads and more extreme conditions (Figure 12). Homes in coastal areas will require more maintenance and upkeep. Because of their exposure to higher loads and extreme conditions, homes in coastal areas will cost more to design, construct, maintain, repair, and insure.

Because of the presence of damaging waves, V Zone design, construction, and certification practices are required for Coastal A Zones by the IBC and are recommended by FEMA where they are not required by code. V Zone and Coastal A Zone construction should include the following elements:

- **Open Foundations:** Design open foundations (pile or pier) designed to resist all base flood conditions, including waves, high velocity flow, erosion and scour, and flood-borne debris.
- **Elevation:** Elevate the bottom of the lowest horizontal structural member supporting the lowest floor above the base flood wave crest elevation (Figure 13). Because waves and debris will impact the floor joists and other foundation elements during the base flood, consider elevating above current NFIP minimum requirements that allow the lowest floor's walking surface to be set at the wave crest elevation in A Zones. Puerto Rico currently requires 1 foot of freeboard in V Zones. The IRC requires 1 foot of freeboard in V Zones and Coastal A Zones.

Figure 12. A well-built coastal structure with its lowest member above the BFE.

- **Flood-Resistant Materials:** Use flood-resistant materials above the level of the walking surface of the lowest floor, in case flooding exceeds the lowest floor level and any freeboard incorporated into the building design.
- **Strong Connections and Continuous Load Paths:** Design connections between the foundation and the elevated building capable of withstanding simultaneous wind and flood forces. Post-hurricane investigations typically find many foundation-to-building connections to be deficient.
- **Freeboard:** Incorporate additional elevation above what is required (the BFE). Adding sufficient freeboard to allow parking beneath the building will not only reduce future flood damages but also lower flood insurance premiums.

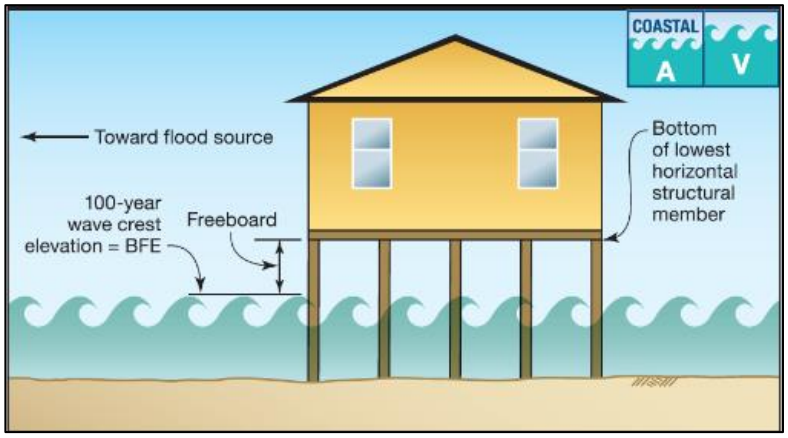

Figure 13. Recommended building standards in V Zones and Coastal A Zones. From FEMA P-55 (Figure 5-2).

- **Screen, Lattice, Louvers, or Solid Breakaway Walls:** Use screens, lattice, louvers, or solid breakaway walls if space below the elevated floor is enclosed. Refer to FEMA Technical Bulletin 9, *Design and Construction Guidance for Breakaway Walls Below Elevated Coastal Buildings* (FEMA TB-9, 2008).
- Detailed guidance for design and construction of residential structures in coastal areas can be found in the *Coastal Construction Manual* (FEMA P-55, 2011). This guidance provides comprehensive approaches to planning, siting, designing, construction, and maintaining buildings in a coastal environment.

Additional guidance for design and construction in coastal flood hazard zones can be found in FEMA P-499. This publication is a series of 31 fact sheets that provide recommended design and construction practices for foundations, connections, building envelopes, etc. FEMA P-499, Fact Sheet 1.2 summarizes recommended practices for different flood hazard zones, including the Coastal A Zone.

What Should Owners and Builders Expect From a "Successful" Coastal Building?

In coastal areas, a building can be considered a success only if it is capable of resisting damage from coastal hazards and coastal processes over a period of decades. This statement does not imply that a coastal residential building will remain undamaged over the intended lifetime. It means that the impacts of a design-level flood, storm, wind, or erosion event (or series of lesser events with combined impacts equivalent to a design event) will be limited to the following:

- The building foundation must remain intact and functional.
- The building (walls, openings, roof, and lowest floor) must remain structurally sound and capable of minimizing penetration by wind, rain, and debris.
- The lowest floor elevation must be sufficient to prevent floodwaters from entering the elevated building during the design event.
- The utility connections (e.g., electricity, water, sewer, natural gas) must remain intact or be easily restored following the design event.
- The building must easily be made accessible and usable following a design event.
- Any damage to enclosures below the DFE must not result in damage to the foundation, the utility connections, or the elevated portion of the building.

References and Useful Links

References

American Society of Civil Engineers (ASCE). 2014. *Standard for Flood Resistant Design and Construction*. ASCE 24-14. http://www.asce.org/templates/publications-book-detail.aspx?id=6963.

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FEMA. 2011. *Coastal Construction Manual*. FEMA P-55. https://www.fema.gov/media-library/assets/documents/3293. Note, the Coastal Construction Manual is available in Adobe Portable Document Format (PDF), on CD-ROM (FEMA 55CD), and as a print publication. The CD and print publication are available from the FEMA Distribution Center. Call 1-800-480-2520 and request either FEMA 55 or FEMA 55CD.

FEMA. 2013. *Operating Guidance for Processing Appeals and Revisions to the Limit of Moderate Wave Action (LiMWA) on Regulatory NFIP Products*. Operating Guidance 14-13. https://www.fema.gov/media-library-data/1386337289584-1e0087d5b299ddd9e9e7d93bdba88b16/Operating+Guidance+14-13-Operating+Guidance+for+Processing+Appeals+and+Revisions+to+the+LiMWA+on+Regulatory+NFIP+Products+(Oct+2013).pdf.

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International Code Council. 2018b. *International Residential Code*. ICC IRC. https://codes.iccsafe.org/public/document/IRC2018.

Useful Links

FEMA. "FEMA Puerto Rico." https://www.facebook.com/FEMAPuertoRico. *Note, this Facebook page was created for the Hurricanes Irma and Maria recovery process and is regularly updated with useful information.*

Puerto Rico Planning Board. "Planning Board Portal." [In Spanish.] http://jp.pr.gov/sigepr/advsmap.

For more information, see the FEMA Building Science Frequently Asked Questions Web site at https://www.fema.gov/frequently-asked-questions-building-science.

If you have any additional questions on FEMA Building Science Publications, contact the helpline at FEMA-BuildingScienceHelp@fema.dhs.gov or 866-927-2104.

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