CodeMaster

NATIONAL FLOOD INSURANCE PROGRAM

INTERNATIONAL CODE COUNCIL®

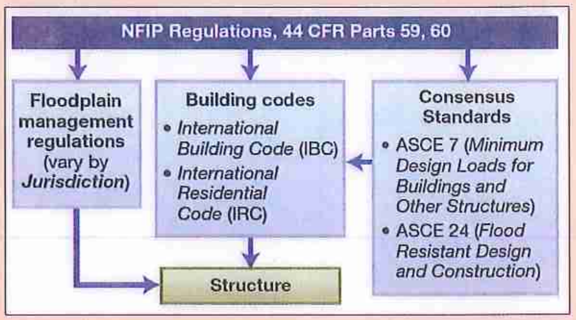
Flood Resistant Design

2009, 2012 IBC | 2009, 2012 IRC | ASCE 7-05, 7-10, 24-05

Preliminary Considerations

This CodeMaster identifies a 12-step procedure for designing a structure for flood loads in accordance with the requirements of the 2009 and 2012 *International Residential Code* (IRC), the 2009 and 2012 *International Building Code* (IBC), ASCE 7-05 and 7-10 *Minimum Design Loads for Buildings and Other Structures*, and ASCE 24-05 *Flood Resistant Design and Construction*.

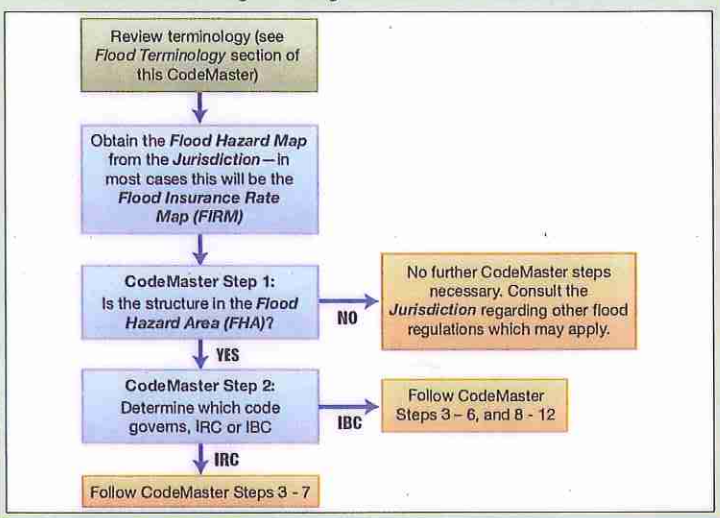
All steps will not be applicable in all cases, but following the applicable steps is necessary to meet the requirements of the ***National Flood Insurance Program (NFIP)*** – see *Code of Federal Regulations*, Title 44, Parts 59 and 60.



SECRETS OF THE CODEMASTER: Contact the ***Jurisdiction*** to determine if and how their floodplain management regulations and building code requirements vary from the flood resistant design and construction requirements contained in the IRC and IBC. Also inquire if IBC Appendix G (Flood Resistant Construction) has been adopted.

This CodeMaster applies to new construction, which also includes existing structures that are ***Substantially Damaged*** or ***Substantially Improved***.

The flow chart below will guide designers in their use of this CodeMaster.



Flood Terminology

This terminology section has been provided so that the designer can easily refer back to these terms and acronyms. These terms have been placed in bold, italics where used in this CodeMaster as a reminder that they are defined here.

Base Flood: The flood having a 1-percent chance of being equaled or exceeded in any given year. Also known as the "100-year flood". IBC Section 1612.2.

Base Flood Elevation (BFE): The elevation of the ***Base Flood***, relative to the datum used on the ***Flood Hazard Map***. IBC Section 1612.2.

Basement: The portion of a structure having its floor subgrade (below ground level) on all sides. IBC Section 1612.2.

Breakaway Walls: Walls designed and constructed to fail due to ***Flood Loads*** during ***Base Flood*** or lesser conditions, without causing collapse, displacement or other structural damage to the elevated portion of the structure or foundation system. IRC Section R322.3.4; ASCE 24 Section 1.2.

Coastal A Zone (CAZ): A subset of the ***A Zone***, that indicates the area subject to Moderate Wave Action (coastal wave heights between 1.5 and 3.0 ft during the ***Base Flood***). The ***Coastal A Zone (CAZ)*** is not typically mapped as a ***Flood Zone*** on the ***Flood Hazard Map***, but will be the area between the ***Limit of Moderate Wave Action (LiMWA)*** and the ***V Zone*** (or shoreline if a ***V Zone*** is not mapped). IRC Section R322.2; ASCE 24 Section 1.2.

Coastal High Hazard Area (CHHA): V Zone areas shown on the ***Flood Insurance Rate Map (FIRM)*** as Zone VE, V1-30 or V. IRC Section R322.3; ASCE 24 Section 1.2.

Design Flood: The greater of: 1) the ***Base Flood***, and 2) the flood adopted by the ***Jurisdiction*** for regulatory purposes. IBC Section 1612.2.

Design Flood Elevation (DFE): The elevation of the ***Design Flood***, relative to the datum used on the ***Flood Hazard Map***. IRC Section R322.1.4; IBC Section 1612.2.

Digital Flood Insurance Rate Map (DFIRM): A ***Flood Insurance Rate Map (FIRM)***, produced in digital form. Most maps produced since 2000 have been ***DFIRMs***.

Dry Floodproofing: A combination of structural and non-structural techniques which result in a structure being watertight with walls substantially impermeable to the passage of water and with structural components having the capacity to resist ***Flood Loads*** under ***Design Flood*** conditions. IBC Section 1612.2.

Flood Damage-Resistant Material: Any construction material capable of withstanding direct and prolonged contact with floodwaters without sustaining any damage that requires more than cosmetic repair. IRC Section R322.1.8; IBC Section 1612.2. Also known as "Flood-Resistant Material".

Flood Hazard Area (FHA): The area subject to flooding during the ***Design Flood*** and shown on the ***Flood Hazard Map*** adopted by the ***Jurisdiction***. ***Flood Hazard Areas*** have been mapped in riverine, lake, coastal, and other areas subject to flooding. The ***Flood Hazard Area (FHA)*** will be as large as or larger than the ***Special Flood Hazard Area (SFHA)***. IRC Section R322.2; IBC Section 1612.2.

Flood Hazard Map: The map adopted by the ***Jurisdiction*** delineating ***Flood Hazard Areas (FHA)***. Typically, the ***Flood Insurance Rate Map (FIRM)*** is the official ***Flood Hazard Map***. It is sometimes referred to as the "Flood Map".

Flood Hazard Zones: Areas designated on the ***Flood Hazard Map*** to indicate the nature and severity of flood hazards. Zones are generally designated as:

- ***V Zones:*** Zones VE, V1-V30, and V, collectively referred to as ***V Zones***, velocity zones, or the ***Coastal High Hazard Area (CHHA)***. These zones are subject to high-velocity wave action from storms or seismic sources during the ***Base Flood***.
- ***A Zones:*** Zones AE, A1-A30, AO, and A, collectively referred to as ***A Zones***, that identify portions of the ***Special Flood Hazard Area (SFHA)*** that are outside ***V Zones***.
- ***B, C and X Zones:*** Zones that indicate flooding may occur outside the ***Special Flood Hazard Area (SFHA)*** during the 500-year or more severe floods. ***B and C Zones*** were delineated on older ***FIRMs***. ***X Zones*** are delineated on newer ***FIRMs***.

Flood Insurance Rate Map (FIRM): The official map upon which the Federal Emergency Management Agency (FEMA) has delineated both the ***Special Flood Hazard Area (SFHA)*** and the applicable risk premium zones ***(Flood Hazard Zones)***. The newest ***FIRMs*** are produced as ***Digital Flood Insurance Rate Maps (DFIRMs)***. IBC Section 1612.2.

CodeMaster developed by:
S C I
Structures & Codes Institute
A subsidiary of S.K. Ghosh Associates Inc.
www.skghoshassociates.com
ISBN 978-1-936039-07-4

Tel: (847) 991-2700
Fax: (847) 991-2702
skghosh@aol.com

Flood Insurance Study (FIS): The official report provided by the FEMA, containing the ***Flood Insurance Rate Map (FIRM)*** or another ***Flood Hazard Map***, and containing ***Base Flood Elevations (BFE)***, ***Stillwater Elevations (SWEL)***, and supporting technical data. IBC Section 1612.2.

Flood Loads: Structural loads caused by standing or moving water. These include: hydrostatic loads, hydrodynamic loads, wave loads, and floodborne debris impact loads.

Flood Opening: Openings through the walls surrounding an enclosed area below the ***Lowest Floor***, which equalize water levels inside and outside the enclosure.

Floodway: The channel of the river, creek, or other watercourse and the adjacent land areas that need to be reserved in order to discharge the ***Base Flood*** without cumulatively increasing the water surface elevation more than a designated height. IBC Section 1612.2.

Freeboard: An additional height that structures need to be elevated above the ***Base Flood Elevation (BFE)***. ***Jurisdictions*** often adopt ***Freeboard*** as a factor of safety to account for uncertainties in the determination of flood elevations, to provide an increased level of flood protection, and/or to reduce flood insurance premiums for structures in ***Flood Hazard Areas***. Some ***Jurisdictions*** incorporate ***Freeboard*** into the definition of the ***Design Flood Elevation (DFE)***. ***Freeboard*** may vary with structure type and ***Flood Hazard Zone***.

Free of Obstructions: Characteristic of the area below the ***Lowest Floor*** of a structure elevated on an open foundation, constructed without attached objects or components that interfere with the free passage of flood flow and waves. Insect screening, lattice, ***Breakaway Walls***, and certain foundation bracing are not considered obstructions by the ***National Flood Insurance Program (NFIP)***, but some ***Jurisdictions*** may limit these elements below the ***Lowest Floor***.

High Risk Flood Hazard Area: Flood Hazard Area (FHA) where one or more of the following hazards are known to occur: alluvial fan flooding, flash floods, mudslides, ice jams, high velocity flow, coastal wave heights greater than or equal to 1.5 feet, or erosion. ASCE 24 Section 1.2.

Jurisdiction: The governmental unit that has adopted a building code and/or floodplain management regulations. IRC Section R202 and IBC Section 202. Also known as the "Authority Having Jurisdiction".

Limit of Moderate Wave Action (LiMWA): A line shown on the newest coastal ***Flood Hazard Maps*** – the ***Digital Flood Insurance Rate Map (DFIRM)*** – indicating the limit of the 1.5 ft coastal wave height. The ***Coastal A Zone (CAZ)*** will be the area between the ***LiMWA*** and the ***V Zone*** (or the shoreline if a ***V Zone*** is not mapped).

Lowest Floor: The floor of the lowest enclosed area, including ***Basement***, but excluding any code-compliant, unfinished or flood resistant enclosure that is intended only for vehicle parking, structure access or limited storage, and excluding a code-compliant crawl space formed by foundation walls. IRC Section R322.1.5; IBC Section 1612.2.

National Flood Insurance Program (NFIP): A federal program enabling property owners in participating communities to purchase insurance protection against losses from flooding.

Special Flood Hazard Area (SFHA): The land area subject to flood hazards, shown on a ***Flood Insurance Rate Map (FIRM)*** as ***Zones*** A, AE, A1-30, A99, AR, AO, AH, V, VO, VE, or V1-30. IBC Section 1612.2.

Stillwater Elevation (SWEL): The water surface elevation used for design purposes. In riverine and lake areas, this will be a floodwater surface; in coastal areas, this will be the average water level after any waves that may be present are smoothed out.

Stillwater Flood Depth (d_s): The vertical distance from the ***Stillwater Elevation (SWEL)*** to the ground, after accounting for any erosion that is anticipated during the ***Design Flood***. Also known as "Flood Depth" and "Stillwater Depth".

Substantial Damage (SD): Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred. IBC Section 1612.2.

Substantial Improvement (SI): Any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the start of construction of the improvement. This term includes structures that have incurred ***Substantial Damage (SD)***, regardless of the actual repair work performed. The term does not, however, include: (1) certain improvements of a structure to correct existing violations of State or local health, sanitary, or safety code specifications or (2) alterations of a historic structure, provided that the alterations will not preclude the structure's continued designation as a historic structure. Consult the ***Jurisdiction*** regarding historic structures and ***SI*** and ***SD*** exceptions. IRC Section R112.2.1; IBC Section 1612.2.

STEP 1 — Determine if the Structure is in the Flood Hazard Area

Determine if the structure lies in whole or in part in the ***Flood Hazard Area (FHA)***, which means it is therefore subject to flooding during the ***Design Flood***. If so, then the structure needs to comply with the flood provisions of the applicable building code.

If the structure lies entirely outside the ***Flood Hazard Area (FHA)***, then it will not be subject to building code flood provisions unless the ***Jurisdiction*** has designated additional flood resistant design requirements outside the ***FHA***.

If the structure is not subject to building code flood provisions, you may stop here. The ***Jurisdiction*** should be consulted regarding other flood regulations which may apply.

STEP 2 — Determine Which Code Governs: IRC or IBC

Flood resistant design requirements vary depending on the applicable building code. The IRC governs one- and two-family dwellings and townhouses up to three stories in height (see IRC Section R101.2). If this limitation is not met, or if any of the other IRC limitations are not met (see Sections R301.2.4, R322.1, R301.2.1, R301.2.2, R301.2.3 and R403.1.8), then the IBC will govern.

STEP 3 — Determine Flood Hazard Zone

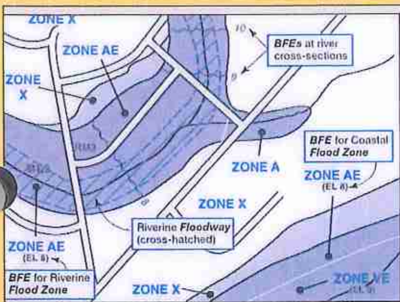
Use the ***Flood Hazard Map*** and other flood-related regulations or documents provided by the ***Jurisdiction*** to determine the ***Flood Hazard Zone(s)*** for the proposed structure footprint. When making this determination, the following questions should be considered.

- Is the structure partially or entirely in the ***Flood Hazard Area (FHA)***? If yes, in which ***Flood Hazard Zone(s)*** does the structure lie? ***A Zone***? ***Floodway***? ***Coastal A Zone (CAZ)***? ***V Zone***?
- Is the structure in the 500-year floodplain ***(Zones B, C or X)***? If yes, determine whether the ***Jurisdiction*** extends flood resistant design requirements into the 500-year floodplain or beyond.
- Is the structure partially or entirely in a ***High Risk Flood Hazard Area*** (IBC Section 1612.4, ASCE 24 Section 3)?
- Is the structure near or affected by levees or flood control structures? Consult the ***Jurisdiction*** regarding flood hazards, since older ***Flood Hazard Maps*** may overstate flood protection provided by the levee or flood control structure.

Design and construction requirements vary by ***Flood Hazard Zone***. More restrictive requirements apply in the ***Floodway***, ***V Zone***, ***Coastal A Zone (CAZ)***, and other ***High Risk Flood Hazard Areas***.

SECRETS OF THE CODEMASTER: The location of the structure (not the site) determines specific flood resistant design and construction requirements. If any part of the structure lies in the ***Flood Hazard Area (FHA)***, then the entire structure is considered "in" and needs to be designed accordingly.

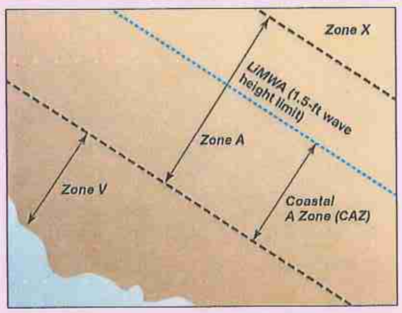
SECRETS OF THE CODEMASTER: Structures located in more than one ***Flood Hazard Zone*** are governed by the design and construction requirements for the more hazardous zone (IRC Sections R322.1, R322.2, R322.3; IBC Section 1612.1).



Sample (Old Style) ***Flood Insurance Rate Map (FIRM)*** Showing ***Flood Zones*** and ***BFEs*** for a Riverine ***Flood Hazard Area (FHA)*** at Top of Map and a Coastal ***FHA*** at Bottom of Map [Note: ***Base Flood Elevation (BFE)*** is discussed in Step 4].

Sample (New Style) ***DFIRM*** for a Riverine Area

SECRETS OF THE CODEMASTER: The ***Coastal A Zone (CAZ)*** is referenced by building codes and standards, but is not shown on the ***Flood Insurance Rate Map (FIRM)***. The ***CAZ*** lies between the ***Limit of Moderate Wave Action (LiMWA)*** line (if delineated on the ***FIRM***) and the ***V Zone***. Some ***Jurisdictions*** may delineate or define a ***Coastal A Zone (CAZ)*** even where a ***LiMWA*** is not drawn on the ***FIRM***. IRC structures need to meet ***CAZ*** requirements of the code where the ***LiMWA*** has been delineated (IRC Section 322.2). IBC structures are governed by ASCE 24 (IBC Section 1612.4), which requires designers to determine if a site will be subject to ***CAZ*** conditions (ASCE 24 Section 4.1.1).



Coastal A Zone (CAZ)

SECRETS OF THE CODEMASTER: The IBC requires compliance with ASCE 24 and ASCE 7. Many flood-related design requirements are not addressed explicitly in the IBC, but are captured by the IBC Section 1612.4 reference to ASCE 24.

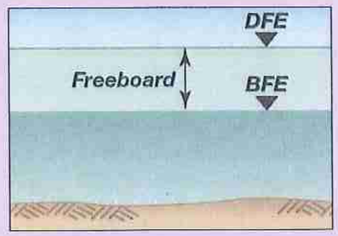
STEP 4 — Determine Design Flood Elevation (DFE)

The ***Design Flood Elevation (DFE)*** needs to be determined in accordance with the following since the ***DFE*** governs many aspects of flood resistant design and construction:

- Determine the ***Base Flood Elevation (BFE)*** at the structure location.
  - If the ***Flood Hazard Map*** shows a number in parentheses immediately below the ***Flood Zone*** within which the structure lies, use that number as the ***BFE*** for that ***Flood Zone***. Coastal and lake ***Flood Hazard Maps*** will use this mapping style.
  - ***Flood Hazard Maps*** for riverine areas typically do not have ***BFEs*** in parentheses below ***Flood Zones***, but do have ***BFEs*** designated beside river cross-section locations. In these cases, interpolation between cross-sections is used to identify the ***BFE***, unless the ***Jurisdiction*** requires selection of the upstream (higher) ***BFE***.
  - If more than one ***BFE*** exists at the structure location, select the highest ***BFE***.
- Consult the ***Jurisdiction*** to determine if its floodplain regulations require design to a more severe flood or require ***Freeboard*** above the ***BFE***.
- Review the adopted building code to determine if ***Freeboard*** is required. ***Freeboard*** may vary with structure type and ***Flood Hazard Zone*** (IRC Sections R322.2.1 and R322.3.2; IBC Section 1612.4; ASCE 24 Sections 2 and 4).

Consult the ***Jurisdiction*** if there is no ***BFE*** shown on the ***Flood Hazard Map*** at a site (IRC Section R322.1.4.1; IBC Section 1612.3.1). In areas designated as ***Zone AO***, the ***BFE*** is the elevation of the highest existing grade at the structure's perimeter plus the depth number (in ft) specified on the map.

SECRETS OF THE CODEMASTER: If a ***Jurisdiction*** only regulates to minimum ***National Flood Insurance Program (NFIP)*** requirements, the ***DFE*** is identical to the ***BFE***. The ***DFE*** will be higher than the ***BFE*** if a ***Jurisdiction*** chooses to: 1) adopt a ***Flood Hazard Map*** that delineates a flood that is more severe than the ***Base Flood***, 2) add ***Freeboard*** via its regulations or building code, or 3) otherwise exceed minimum ***NFIP*** elevation requirements.



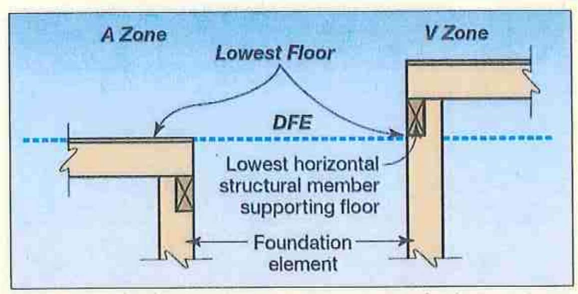
One Common Relationship Between ***Base Flood Elevation (BFE)***, ***Design Flood Elevation (DFE)*** and ***Freeboard***

STEP 5 — Determine Minimum Elevation of Lowest Floor

The IRC and IBC require the ***Lowest Floor*** to be elevated to or above the ***Design Flood Elevation (DFE)***. The minimum required ***Lowest Floor*** elevation varies by code and ***Flood Hazard Zone*** (see Steps 7 and 8).

Unless the ***Jurisdiction*** specifies higher elevation requirements, the following applies:

- In ***A Zones***, the top of the floor (walking surface) is the lowest floor reference and needs to be elevated to or above the ***DFE*** (IRC Section 322.2.1; IBC Section 1612.4; ASCE 24 Section 2.3).
- In ***V Zones***, the bottom of the lowest horizontal structural member (e.g., joist, beam, girder) supporting the ***Lowest Floor*** (excluding pile caps, grade beams, bracing, etc.) is the ***Lowest Floor*** reference, and needs to be elevated to or above the ***DFE*** (IRC Section 322.3.2; IBC Section 1612.4; ASCE 24 Section 4.4).



Location of ***Lowest Floor*** Relative to ***Design Flood Elevation (DFE)***

- In ***Coastal A Zones (CAZ)***, the ***Lowest Floor*** reference will vary by the governing code. The IRC uses the top of the ***Lowest Floor*** (IRC Section R322.2.1), while the IBC (Section 1612.4) and ASCE 24 (Section 4.4) use the bottom of lowest horizontal structural member supporting the ***Lowest Floor***.

Additional guidance on identifying the ***Lowest Floor*** is contained in FEMA's F-441 *Insurance Agent's Lowest Floor Guide*.

SECRETS OF THE CODEMASTER: In addition to elevating the ***Lowest Floor***, building codes also require the use of ***Flood Damage-Resistant Materials*** below the ***DFE*** or other elevations specified by the code (IRC Section R322.1.8; IBC Sections 801.5, 1612.2, 2009 IBC Section 1403.5 [2012 IBC Section 1403.6]; ASCE 24 Section 5). Additional information is contained in *NFIP Technical Bulletin 2, Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas*.

SECRETS OF THE CODEMASTER: Designers and owners should consult qualified insurance agents to understand how certain minimum design requirements – including ***Lowest Floor*** elevation – can affect the cost of federal flood insurance. Designers should investigate and discuss flood insurance premium implications of design alternatives with owners before designs are finalized.

STEP 6 DETERMINE PERMISSIBLE FOUNDATION TYPES

Foundation types permitted by the IRC and IBC vary by ***Flood Hazard Zone*** and applicable code. However, all foundations need to elevate the ***Lowest Floor*** to the required elevation and need to be designed, connected, and anchored to resist flotation, collapse or permanent lateral movement during the ***Design Flood*** (IRC Section R322.1.2; IBC Section 1612.1).

- In ***A Zones***, slab-on-fill, solid perimeter wall (creating a crawl space), pile and column foundations are permitted (IRC Section R322.2; IBC Section 1612.4; ASCE 24 Sections 2.4, 2.5, 2.6). Grades in a crawl space need to meet certain requirements (IRC Section R408.7; IBC Section 1805.1.2.1). Limitations for crawlspace construction in some flood hazard areas are contained in *NFIP Technical Bulletin 11, Crawlspace Construction for Buildings Located in Special Flood Hazard Areas.*
- In ***A Zones, Flood Openings*** need to be installed in any walls or partitions enclosing space below the ***DFE*** (IRC Section R322.2.2; IBC Section 1203.3.2 and ASCE 24 Section 2.6.1). Additional information is contained in *NFIP Technical Bulletin 1, Openings in Foundation Walls and Walls of Enclosures Below Elevated Buildings in Special Flood Hazard Areas.*
- In ***V Zones***, structures need to be elevated on open (pile or column) foundations (IRC Section 322.3.3; IBC Section 1612.4; ASCE 24 Section 4.5). Note that the IBC (via ASCE 24) permits the use of shear walls as foundation walls. Fill cannot be used for structural support in ***V Zones*** (IRC Section 322.3.2.3; IBC Section 1612.4; ASCE 24 Section 4.5.4).
- In ***V Zones***, the area below the ***DFE*** needs to be ***Free of Obstructions*** (2012 IRC Section R322.3.3). Although the 2009 IRC and the IBC do not use the term ***"Free of Obstructions"***, equivalent performance is required by the codes (2009 IRC Section R322.3.4; 2009 and 2012 IBC Section 1612.4; ASCE 24 Section 4.5.1). Additional information is contained in *NFIP Technical Bulletin 5, Free of Obstruction Requirements for Buildings Located in Coastal High Hazard Areas.*
- In ***Coastal A Zones (CAZ), A Zone*** foundation types are permitted by the IRC (Section R322.2), but IBC Section 1612.4 and ASCE 24 Section 4.5 require ***V Zone*** foundations.

STEP 7 DETERMINE AND APPLY IRC FLOOD PROVISIONS

The table below lists the principal flood resistant design provisions contained in the IRC that need to be checked for applicability. If the IBC governs, go to Step 8.

Topic	IRC Section
Basic Flood Resistant Requirements	R322.1.1, R322.1.2, R322.1.3
Flood Loads and Conditions	R301.1, Table R301.2(1), R322.1.2, R322.3.3
Lowest Floor Elevation	R309.3, R322.2.1, R322.3.2
Foundation	R322.2.3, R322.3.3, R401
Use of Fill	R322.1.4.2, R322.3.2(3) and (4), R401.2, R506.2.1
Basements	R322.2.1, R322.3.2
Use of Enclosed Area Below the ***Design Flood Elevation (DFE)***	R309.3, R322.2.2, R322.3.5
Flood Openings in Below-***DFE*** Enclosures	R322.2.2, R408.7
Breakaway Walls	R322.1.6, R322.3.4
Flood Damage-Resistant Materials	R322.1.8
Mechanical, Electrical Equipment and Systems, Plumbing, Fuel Gas	R322.1.6, M1301.1.1, M1401.5, M1601.4.9, M1701.2, M2001.4, M2201.6, G2404.7, P2601.3, P2602.2, P2705.1, P3001.3, P3101.5
Dry Floodproofing	Not Permitted
High Risk Flood Hazard Areas	See ***Floodway, V Zone*** requirements and ***Coastal A Zone*** requirements: R301.2.4, R301.2.4.1, R322.1, R322.1.1, R322.2, R322.3
Substantial Damage and ***Substantial Improvements***	R102.7.1, R105.3.1.1, R112.2.1, R322.3.1
Documentation, Inspections and Certifications ***Lowest Floor*** Elevation, ***Flood Openings***, ***Dry Floodproofing***, ***Breakaway Walls***, ***V Zone*** Design	R106.1.3, R109.1.3, R322.1.4.1, R322.1.4.2, R322.1.10, R322.2.2, R322.3.3, R322.3.4, R322.3.6, 2012 IRC Section R109.1.6.1

Designers should consult with the ***Jurisdiction*** to see if additional flood requirements apply to structures governed by the IRC and if a detailed assessment of ***Design Flood*** conditions is required (if so, see Step 9).

SECRETS OF THE CODEMASTER: IRC Sections R301.2.4.1 and R322.1.1 permit use of ASCE 24 as an alternate for structures constructed in whole or in part in a ***V Zone***. The same 2012 IRC sections permit use of ASCE 24 as an alternate for structures constructed in delineated ***Coastal A Zones (CAZ)***.

STEP 8 DETERMINE AND APPLY IBC FLOOD PROVISIONS

The table below lists the principal flood resistant design provisions contained in the IBC that need to be checked for applicability. If the IRC governs, go to Step 7.

Topic	IBC Section	ASCE 24 Section ASCE 7 Section
Basic Flood Resistant Requirements	1612.1, 1612.4	ASCE 24: 1.5
Flood Loads and Conditions	2009 IBC Section 1605.2.2 (2012 IBC Section 1605.2.1), 1605.3.1.2, 1612.4, 3102.7	ASCE 24: 1.6 ASCE 7: 2.3.3, 2.4.2, 5.3.1, 5.3.2, 5.4
Lowest Floor Elevation	1603.1.7, 1612.4	ASCE 24: 2.3, 4.4
Foundation	1612.4, Chapter 18	ASCE 24: 1.5.3, 2.5, 4.5
Use of Fill	1804.4	ASCE 24: 1.5.4, 2.4, 4.5.4
Basements	1612.2	ASCE 24: 1.2, 1.5.2, 2.3
Use of Enclosed Areas Below the ***Design Flood Elevation (DEF)***	see ASCE 24	ASCE 24: 2.6, 4.6
Flood Openings in Below-***DEF*** Enclosures	1203.3.2(5)	ASCE 24: 2.6.1, 2.6.2, 4.6.2
Breakaway Walls	2009 IBC Section 1403.6 (2012 IBC Section 1403.7), 1612.5.2.3	ASCE 24: 1.2, 4.6 ASCE 7: 5.3.3
Flood Damage-Resistant Materials	801.5, 1403.5 (2012 IBC Section 1403.6), 1612.2	ASCE 24: 1.2, 5.0
Mechanical, Electrical Equipment and Systems, Plumbing	2009 IBC Section 1403.6 (2012 IBC Section 1403.7), 3001.2	ASCE 24: 4.6.1, 7.0
Dry Floodproofing	1612.2	ASCE 24: 1.2, 1.5.2, 6.0, 7.1
High Risk Flood Hazard Areas	see ASCE 24	ASCE 24: 3.0, 4.0
Substantial Damage and ***Substantial Improvements***	1612.1, 1612.2, 3403.1 3403.2, 3404.2, 3405.5, 3412.2.4.1	ASCE 24: 1.1, 1.2, 1.5.1
Documentation, Inspections and Certifications ***Lowest Floor*** Elevation, ***Flood Openings, Dry Floodproofing, Breakaway Walls, V Zone*** Design	107.2.5, 110.3.3, 1603.1, 1603.1.7, 1612.3.1, 1612.5, 2012 IBC Section 110.3.10.1	Not Applicable

Application of the IBC flood provisions require that ***Design Flood*** conditions and ***Flood Loads*** be determined (see Steps 9 – 11). (Note that for structures in areas subject only to riverine and/or lake flooding, Steps 9.6 and 10.4 do not apply).

STEP 9 — Determine Design Flood Conditions

Flood resistant design requires that design flood conditions be determined. Step 9 divides the various ***Design Flood*** conditions into substeps, describes how each ***Design Flood*** condition will be used, and provides additional guidance.

Design Flood Condition	Used For	Step	Additional Guidance
Stillwater Elevation (SWEL)	Calculating ***Stillwater Flood Depth, d_s***	9.1	Obtain from ***FIS/FIRM*** or site-specific determination
Anticipated Eroded Ground Elevation	Calculating ***Stillwater Flood Depth, d_s***	9.2	Some sites will not be subject to erosion during ***Design Flood***
Stillwater Flood Depth, d_s	Calculating hydrostatic and hydrodynamic loads, coastal wave heights	9.3	Obtain by subtracting anticipated eroded ground elevation from ***SWEL***
Flood Velocity, V	Calculating Hydrodynamic Loads	9.4	Estimated from ***FIS*** or site-specific determination; ASCE 7 C5.4.3
Floodborne Debris	Calculating debris impact loads	9.5	ASCE 7 C5.4.5
Coastal Wave Height	Calculating breaking wave loads (coastal design only)	9.6	ASCE 7: 5.4.4

STEP 9.1 — Determine Stillwater Elevation (SWEL)

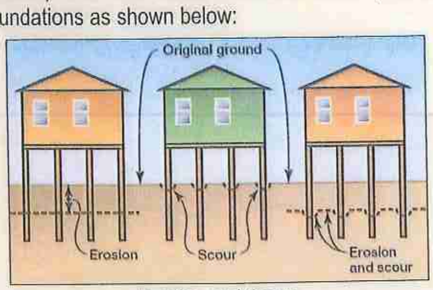
The ***Stillwater Elevation (SWEL)*** is the water surface elevation used for design purposes. The ***SWEL*** needs to be referenced to the same datum used to establish the ***Base Flood Elevation (BFE)*** and ***Design Flood Elevation (DFE)***. The ***Flood Insurance Rate Map (FIRM)*** and the ***Flood Insurance Study (FIS)*** need to be reviewed, and the ***Jurisdiction*** needs to be consulted regarding the nature of flooding (riverine/lake versus coastal) and ***SWEL*** determinations. The ***Jurisdiction*** has the authority to require use of data from other sources or to require development of flood elevation data (IRC Section R322.1.4.1; IBC Section 1612.3.1).

Unless the ***Jurisdiction*** has adopted a more severe flood as the ***Design Flood***, the ***Stillwater Elevation (SWEL)*** used for design purposes will be as follows:

- Riverine and lake: the ***BFE*** published in the ***Flood Insurance Study (FIS)*** and shown on the ***Flood Insurance Rate Map (FIRM)***.
- Coastal: the 100-year ***Stillwater Elevation (SWEL)*** published in the ***Flood Insurance Study (FIS)***.

STEP 9.2 — Adjust Ground Elevation for Erosion and Scour

In both riverine and coastal areas, floods may erode soil over large areas ("erosion") and can cause localized scour ("scour") around structure foundations as shown below:



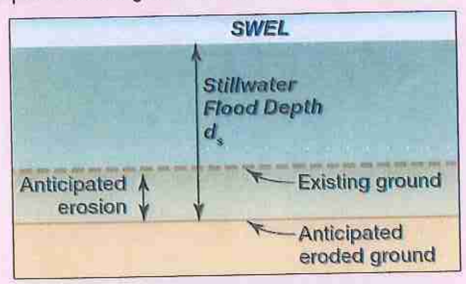
Erosion and Scour

- If erosion has occurred in the vicinity of the structure site during past floods or if the soils are known to be highly erodible, the ground elevation needs to be adjusted (lowered), which will increase the ***Stillwater Flood Depth, d_s*** and associated ***Design Flood Loads*** (IBC Section 1612.4; ASCE 7 Section 5.3.2).
- If local scour has occurred or is likely around structures at or near the site during floods, scour needs to be anticipated and accounted for during foundation design (IBC Section 1612.4; ASCE 7 Section 5.3.2). Note that local scour will affect the required foundation depth, but will not affect the ***Stillwater Flood Depth, d_s*** (which is based on the eroded ground elevation); therefore, it will not affect ***Flood Loads*** calculated using ***d_s***.

Guidance regarding the amount of the adjustments for erosion and local scour may be limited – check with the ***Jurisdiction***, use historical evidence, and consult geotechnical experts. FEMA's *Coastal Construction Manual* will provide guidance on estimating scour and erosion in coastal areas.

STEP 9.3 — Calculate Stillwater Flood Depth, d_s

- For sites not subject to erosion during the ***Design Flood***, subtract the existing ground elevation from the ***Stillwater Elevation (SWEL)*** determined in Step 9.1.
- For sites subject to erosion during the ***Design Flood***, subtract the anticipated eroded ground elevation from the ***SWEL***.



Stillwater Flood Depth, d_s

SECRETS OF THE CODEMASTER: Calculating ***d_s*** is one of the most important flood calculations that will be made because most ***Flood Loads*** depend on the result.

STEP 9.4 — Estimate Flood Velocity, V

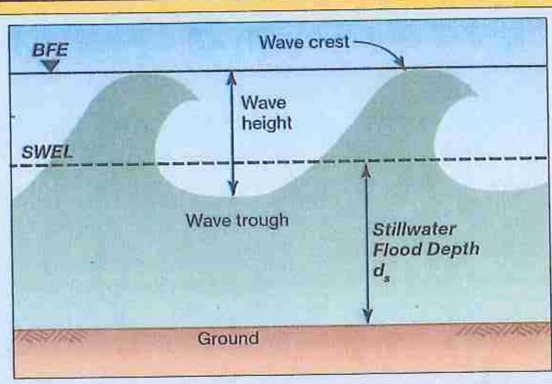
Flood velocity needs to be estimated based on historical evidence, data in the ***Flood Insurance Study (FIS)***, flood model results, or approximations developed using simplified methods. Estimating flood velocity will be one of the more difficult aspects of flood resistant design. The ***Jurisdiction*** or hydraulic/coastal experts should be consulted for help.

STEP 9.5 — Characterize Floodborne Debris

The type, size, weight and velocity of debris likely to be propelled by floodwaters need to be estimated. Guidance can be found in the Commentary to Chapter 5 of ASCE 7.

STEP 9.6 — Estimate Coastal Wave Height

Wave heights will likely be of importance in areas subject to coastal flooding, especially sites close to the shoreline. Coastal wave heights are limited by ***Stillwater Flood Depth, d_s***, and the presence of obstructions (e.g., vegetation or structures). Coastal wave heights decrease as ***Stillwater Flood Depth, d_s*** decreases and as the number, size, and density of obstructions increase. Coastal wave height information may be available from government agencies, coastal experts, universities, or the ***Jurisdiction***. Absent other information, coastal wave heights used for design can be approximated using information contained in the ***Flood Insurance Study (FIS)*** and the ***Flood Insurance Rate Map (FIRM)***.

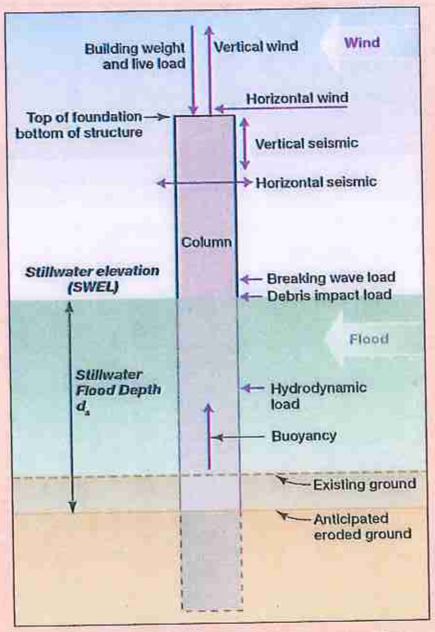


Coastal Wave Height

STEP 10 CALCULATE DESIGN FLOOD LOADS

Flood Loads depend on the flood conditions present at the structure site and on the size and shape of the affected structural elements.

<u>**NOTE for Steps 10.1 through 10.4:**</u> Many structures will not be exposed to all the ***Flood Loads*** described in Steps 10.1 through 10.4. Designers need to determine which ***Flood Loads*** will be present during a design-level event, and then complete Steps 10.1 through 10.4, as applicable.

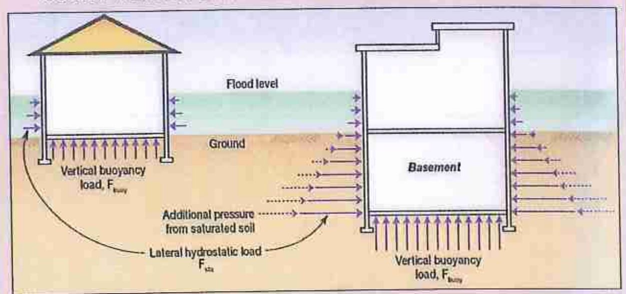


Flood and Other Loads Acting on a Foundation Column

STEP 10.1 CALCULATE HYDROSTATIC LOADS, F_{sta} AND F_{buoy}

Hydrostatic loads are caused by standing or slowly moving floodwaters.

- Lateral hydrostatic loads, F_{sta}, need to be calculated for any enclosed space below the ***Design Flood Elevation (DFE)***, unless it is equipped with ***Flood Openings*** as specified by IRC Section R322.2.2 or IBC Section 1203.3.2 (and ASCE 24 Sections 2.6.1, 2.6.2, 4.6.2). Lateral hydrostatic loads need not be considered for below-***DFE*** enclosure walls that have properly installed ***Flood Openings*** that allow water to flow in and out, preventing unbalanced lateral hydrostatic loads. See *NFIP Technical Bulletin 1, Openings in Foundation Walls and Walls of Enclosures.*
- Vertical (buoyant) hydrostatic loads, F_{buoy}, need to be calculated for any component of the structure that extends below the ***Stillwater Elevation (SWEL)*** (except for ***Breakaway Walls*** – see 4^{th} bullet). The submerged weights of structural components are less than their weights in air, so buoyancy effects need to be considered when resistance to uplift, overturning and sliding is determined (ASCE 7 Section 3.2.2).
- Lateral and vertical (buoyant) forces in ***Dry-Floodproofed*** areas and ***Basements*** are very large and need to be considered carefully in design. Caution: ***Basements*** are not allowed by the ***National Flood Insurance Program (NFIP)***, except for ***A Zone*** non-residential spaces that are dry floodproofed in accordance with ASCE 24 Section 6.
- In ***V Zones***, lateral and vertical hydrostatic loads need not be considered for below-***DFE Breakaway Walls*** as specified in IRC Section R322.3.4 or ASCE 24 Section 4.6.1.

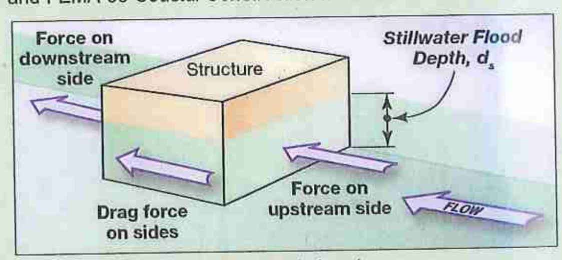


Hydrostatic Loads

STEP 10.2 CALCULATE HYDRODYNAMIC LOAD, F_{dyn}

Hydrodynamic loads are caused by floodwaters flowing past a fixed object, such as a structure or foundation element. The net hydrodynamic load, F_{dyn}, needs to be calculated in accordance with the following:

- Hydrodynamic loads increase with the size of the object around which floodwaters pass and with the square of the flood velocity. Hydrodynamic loads also vary with the shape of the object and associated drag coefficients.
- Calculation methods are contained in numerous references, including ASCE 7 Section 5.4.3, FEMA-259 *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Buildings*, and FEMA-55 *Coastal Construction Manual*.



Hydrodynamic Loads

STEP 10.3 CALCULATE FLOODBORNE DEBRIS IMPACT LOAD, F_i

Floodborne debris impact loads, F_i, occur as large objects propelled by moving floodwaters strike a structure. Floodborne debris impact loads vary with the type, size, weight, and velocity of the debris and by the blockage effects of upstream vegetation and structures. Guidance on calculating floodborne debris impact loads is contained in the Commentary to Chapter 5 of ASCE 7.

STEP 10.4 CALCULATE COASTAL WAVE LOAD, F_{brk}

Coastal wave loads occur as wind- or seismically-generated waves propagate across the water surface and strike a structure. The coastal wave load used for design purposes, F_{brk}, needs to be calculated in accordance with the following:

- Coastal wave loads need to be calculated in ***V Zones*** and ***Coastal A Zones (CAZ)*** (IBC Section 1612.4; ASCE 7 Section 5.4.4), and at coastal sites mapped as ***A Zones*** (outside the ***V Zone*** and ***CAZ***). Designers of structures outside the ***V Zone*** and the ***CAZ*** need to check the ***Flood Insurance Study (FIS), Flood Hazard Map***, and other available information to determine whether coastal waves will be present during design flood conditions.

- Coastal wave loads are typically calculated for columns and walls. The methods in ASCE 7 Section 5.4.4 assume breaking waves strike those structural elements.

SECRETS OF THE CODEMASTER: ASCE 7 Section 5.4.4 permits three methods for calculating wave loads: 1) analytical methods contained in that section of ASCE 7 (which are simple and conservative), 2) more advanced numerical procedures, and 3) laboratory (physical model) tests.

STEP 11 — Determine Flood Load F_a for Load Combinations

IBC Section 1605.3.1.2 and 2009 IBC Section 1605.2.2 (2012 IBC Section 1605.2.1) specify load combinations for structural design when there are flood loads. The load combinations for structures in ***Flood Hazard Areas (FHA)*** require calculation of the ***Flood Load***, F_a. F_a is calculated using combinations of individual ***Flood Loads*** determined in Steps 10.1 through 10.4.

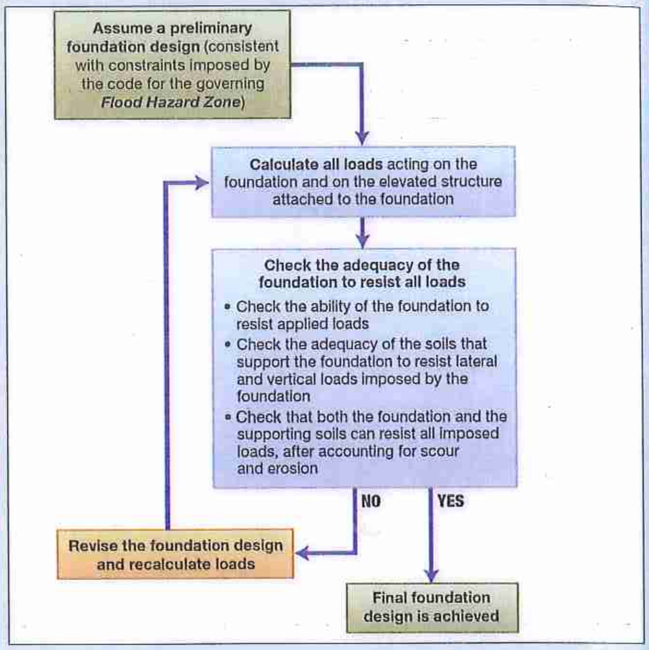
SECRETS OF THE CODEMASTER: ASCE 7 does not specify how individual ***Flood Loads*** should be combined into F_a. The following table, adapted from FEMA's *Coastal Construction Manual*, provides guidance. Designers also need to reduce dead loads to account for the effects of vertical buoyant forces, F_{buoy}, when load combinations are calculated.

Flood Zone	Foundation Type	F_a =
V Zone, or ***Coastal A Zone (CAZ)***, or ***A Zone*** subject to coastal waves	Pile or Column	Greater of F_{brk} or F_{dyn} (on front row of piles/columns only) + F_{dyn} (on all other piles/columns) + F_i (on one pile/column)
V Zone, or ***Coastal A Zone (CAZ)***	Solid Foundation Wall	Solid foundation walls are not permitted in ***V Zones*** or ***Coastal A Zones (CAZ)*** by the IBC or ASCE 24 (Section 4). Solid Foundation walls are not permitted in ***V Zones*** by the IRC. For IRC structures in ***CAZ***, $F_a = (F_{brk} + F_i)$ or $(F_{dyn} + F_i)$, whichever is greater
A Zone (riverine or lake flood source)	Pile or Column	$F_{dyn} + F_i$ (on one pile/column)
A Zone (riverine or lake flood source)	Solid Foundation Wall (with ***Flood Openings***)	$F_{dyn} + F_i$
A Zone (riverine or lake flood source)	Solid Foundation Wall (***Dry Floodproofed***, no ***Flood Openings***)	$F_{sta} + F_{dyn} + F_i$

STEP 12 — Design the Foundation

The basic design process for the structure's foundation is as follows:

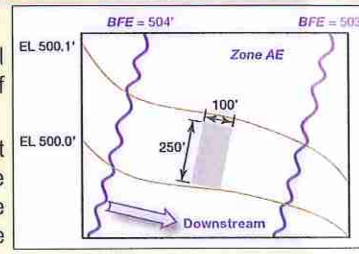
- The owner and designer need to first agree on the basic structural characteristics necessary to design the elevated portion of the structure (e.g., size, use/occupancy, number and height of stories, type of construction).
- Lateral and vertical loads (from all hazards and conditions affecting the elevated structure, e.g., wind, snow, seismic, dead, live, etc.) need to be determined, along with the reactions the loads impose on the top of the foundation.
- Loads acting directly on foundation elements – including ***Flood Loads*** – need to be determined, and a preliminary foundation design needs to be developed.
- This will be an iterative process and it will be repeated until an efficient design – capable of resisting all loads on the foundation and elevated structure and meeting owner requirements -- is achieved.
- Prescriptive foundation designs have been developed for some ***Flood Hazard Areas (FHA)*** and may assist designers with the foundation design process (see FEMA P-550, *Recommended Residential Construction for Coastal Areas: Building on Strong and Safe Foundations*).



Flood Resistant Foundation Design Process

Example

Given:



- Proposed 1-story commercial structure, with a footprint of 100 ft by 250 ft.
- The structure footprint and existing grades are superimposed on the ***Flood Hazard Map*** (see figure).
- All ground elevations and ***Base Flood Elevations (BFEs)*** are relative to the National Geodetic Vertical Datum (NGVD).
- The site is subject to riverine flooding and is located outside the ***Floodway***.
- The ***Jurisdiction*** requires 2 ft of ***Freeboard*** above the ***BFE***.

Find: Design Flood Conditions and Loads

Step 1: Determine if the structure is in the ***Flood Hazard Area***: The ***Flood Hazard Map*** indicates that the building is in the ***Flood Hazard Area***.

Step 2: Determine Which Code Governs: IRC or IBC: In this case, the IBC governs because it is a commercial structure.

Step 3: Determine ***Flood Hazard Zone(s)***: The ***Flood Hazard Map*** indicates that the entire building is located within ***Zone AE***.

Step 4: Determine ***Design Flood Elevation (DFE)***: Determine highest ***BFE*** at footprint – using interpolation, the ***BFE*** is determined to be 503.5 ft NGVD. Check IBC and contact ***Jurisdiction*** for ***Freeboard*** requirements. IBC (via ASCE 24 Table 2-1) requires 1 ft of ***Freeboard*** for Category II structures. The ***Jurisdiction*** requires 2 ft. Therefore, ***DFE*** = 503.5 ft + 2 ft = 505.5 ft.

Step 5: Determine Minimum Elevation of ***Lowest Floor***: Per IBC Section 1612.4 and ASCE 24 Section 2.3, the ***Lowest Floor*** (top of floor) is set at the DFE = 505.5 ft NGVD.

Step 6: Determine Permissible Foundation Types: IBC (via ASCE 24 Section 1.5.3) permits any code-compliant foundation in ***A Zones***. For this example, a preliminary foundation design is assumed to be constructed of 12 in thick masonry foundation walls (700 ft of wall forming a crawl space) and 16 in square interior masonry piers (216 piers).

Step 8: Determine and Apply IBC Flood Provisions: See Table in Step 8.

Step 9.1: Determine ***Stillwater Elevation (SWEL)***: Because the ***Jurisdiction*** did not adopt a more severe flood than the ***Design Flood***, the ***SWEL*** is equal to the ***BFE*** at the location of the structure, which is 503.5 ft NGVD.

Step 9.2: Adjust Ground Elevation for Erosion and Scour: A geotechnical study and local experience suggest 6 in of erosion will occur during the ***Design Flood***. Therefore, 0.5 ft needs to be subtracted from existing ground elevations to account for erosion, and the lowest adjusted ground elevation at the structure location is calculated as 500.0 ft NGVD – 0.5 ft = 499.5 ft NGVD.

Step 9.3: Calculate ***Stillwater Flood Depth, d_s***: The maximum ***Stillwater Flood Depth*** at the structure is calculated by subtracting the lowest adjusted ground elevation from the ***SWEL***, as follows: 503.5 ft NGVD – 499.5 ft NGVD = 4.0 ft.

Step 9.4: Estimate Flood Velocity, V: Data from hydraulic studies supplied by the ***Jurisdiction*** indicate a flood velocity, V, of 2.5 ft/sec is expected during the ***Design Flood***.

Step 9.5: Characterize Floodborne Debris: Commentary for Chapter 5 of ASCE 7 indicates woody debris in riverine areas will average 1,000 to 2,000 lb. Local experience confirms this. Ice is not expected at this site. Use W = 1,500 lb.

Step 9.6: Estimate Coastal Wave Height: For the purpose of this example, no waves are expected during the ***Design Flood***.

Step 10.1: Calculate Hydrostatic Loads, F_{sta} and F_{buoy}: Install ***Flood Openings*** in foundation walls per ASCE 24 Section 2.6.2.1 or 2.6.2.2 to eliminate lateral hydrostatic loads, F_{sta}, on foundation walls. Using ASCE 24 Section 2.6.2.1, the total net area of ***Flood Openings*** must be at least 25,000 sq in (1 sq in per sq ft of enclosed area; 100 ft x 250 ft enclosed area). If ASCE 24 Section 2.6.2.2 is used and detailed engineering calculations are performed, the 25,000 sq in net opening area can be reduced. After ***Flood Openings*** are included in the foundation wall design, $\mathbf{F_{sta} = 0}$ **lb**.

Next, compute the vertical buoyant force, F_{buoy}, on foundation walls and interior foundation piers. F_{buoy} can be calculated using $F_{buoy} = \gamma$ Vol, where γ is the specific weight of fresh water (62.4 lb/ft^3), and Vol is the volume of water displaced by the submerged portion of the foundation. (Note: For this example, F_{buoy} is calculated for those portions of the foundation above grade and below the ***SWEL*** and is equal to d_s = 4 ft. For actual designs, buoyant forces also need to be calculated on below-grade portions of foundations).

For each individual pier, F_{buoy} = 62.4 lb/ft^3 x (pier width squared) x (submerged pier height), or (62.4 lb/ft^3)(16/12 ft)(16/12 ft)(4.0 ft), or F_{buoy} = 443.7 lb/pier. With 216 piers, the total buoyant load on the piers is **F_{buoy} = (F_{buoy}/pier) (# of piers) = 95,839 lb**.

For each linear foot of foundation wall, F_{buoy} = 62.4 lb/ ft^3 x (wall thickness) x (submerged wall height), or (62.4 lb/ft^3)(1.0 ft)(4.0 ft), or F_{buoy} = 249.6 lb/LF. With 700 ft of foundation wall, **F_{buoy} (walls) = 174,720 lb**.

The total vertical buoyant force, F_{buoy} = F_{buoy} (piers) + F_{buoy} (walls) = 95,839 lb + 174,720 lb, or **F_{buoy} = 270,559 lb**.

Step 10.2: Calculate Hydrodynamic Load, F_{dyn}: Using basic fluid mechanics, compute the lateral hydrodynamic load $F_{dyn} = 0.5\ C_D\ \rho\ A\ V^2$, where C_D = drag coefficient, ρ = mass density of water (1.94 slugs/ft^3), A = the foundation wall area subject to flow (sq ft), and V = flood velocity (ft/sec). A is found by multiplying the building length by the ***Stillwater Flood Depth, d_s*** (250 ft x 4.0 ft = 1,000 sq ft). The drag coefficient C_D = 1.75 is obtained from a hydraulics textbook, and the flood velocity V = 2.5 ft/sec was determined in Step 9.4. The resulting calculation shows F_{dyn} = (0.5)(1.75)(1.94 slugs/ft^3)(1,000 ft^2)(2.5 ft/sec)^2, or **F_{dyn} = 10,609 lb**. Assume no hydrodynamic loads act on interior foundation piers.

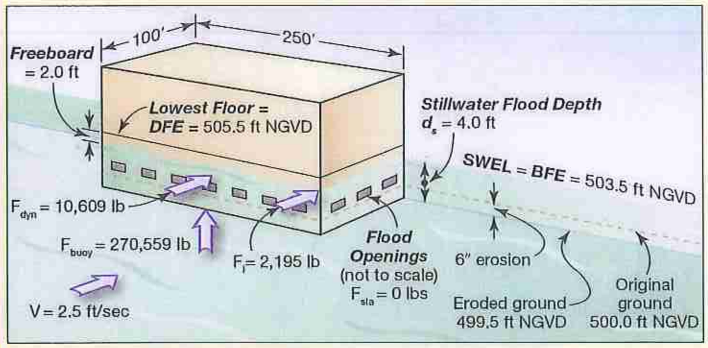
Step 10.3: Calculate Floodborne Debris Impact Load, F_i: Use Equation C5-3 and the procedure outlined in the Commentary of ASCE 7 Chapter 5, with a 1,500 lb object (Step 9.5) moving at V = 2.5 ft/sec (Step 9.4), a ***Stillwater Flood Depth, d_s*** = 4.0 ft (Step 9.3, which yields a depth coefficient C_D = 0.75 from ASCE 7 Table C5-2), an importance coefficient C_I = 1.0 (ASCE 7 Table C5-1), an orientation coefficient C_O = 0.8 (ASCE 7 Section C5.4.5), and assuming no debris blockage around the structure (C_B = 1.0 from ASCE 7 Table C5-3). Given an impact duration, Δt = 0.03 sec (ASCE 7 Section C5.4.5), and a structure natural period (computed outside this example) = 0.2 sec, the structure response ratio, R_{max} = 0.6 (by interpolation using ASCE 7 Table C5-4). Thus, $F_i = [\pi\ WVC_I\ C_O\ C_D\ C_B\ R_{max}]/[2g\Delta t]$, = [(3.1416)(1,500 lb)(2.5 ft/sec)(1.0)(0.8)(0.75)(1.0)(0.6)]/[(2)(32.2 ft/sec^2)(0.03 sec)], or **F_i = 2,195 lb.**

Step 10.4: Calculate Coastal Wave Load, F_{brk}: There will be no wave load because the structure is only subject to riverine flooding (see Step 9.6).

Step 11: Determine F_a for Load Combinations: Using the Table in Step 11, in an ***A Zone*** (riverine flood source), $F_a = F_{dyn} + F_i$ = 10,609 lb + 2,195 lb, or **F_a = 12,804 lb**. Designers also need to reduce the structure dead load by the total vertical buoyant force acting on the structure (Step 10.1) when load combinations are calculated.

Step 12: Design the Foundation: Use the procedure outlined in the flow chart in Step 12 to finalize the foundation design.

The building, site, and flood conditions and loads described by the steps above are illustrated in the following figure (other loads that may occur are not shown for clarity).



Flood Loads and Conditions at Example Building

Closing Comments

This CodeMaster has presented a step-by-step process for achieving flood resistant design. Some of the topics covered have been treated briefly, and a more detailed consideration of these issues will be required for actual design and construction.

Resources

FEMA. 2001. NFIP Technical Bulletin 11, *Crawlspace Construction for Buildings Located in Special Flood Hazard Areas.*

FEMA. 2008. NFIP Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures Below Elevated Buildings in Special Flood Hazard Areas.*

FEMA. 2008. NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas.*

FEMA. 2008. NFIP Technical Bulletin 5, *Free-of-Obstruction Requirements for Buildings Located in Coastal High Hazard Areas.*

FEMA. 2009. FEMA F-441, *National Flood Insurance Program, Insurance Agent's Lowest Floor Guide.*

FEMA. 2009. FEMA P-550, *Recommended Residential Construction for Coastal Areas: Building on Strong and Safe Foundations.*

FEMA. 2011. FEMA-55, *Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas.*

FEMA. 2011. FEMA-259, *Engineering Principles and Practices for Retrofitting Flood-Prone Residential Buildings.*