


3.0 An Overview of the Retrofitting Methods

This guide describes six retrofitting methods for you to consider as you think about how to protect your home from flooding:

Elevation – Raising your home so that the lowest floor or lowest horizontal member is at or above the regulated flood level. You can accomplish this in several ways. (Chapter 5)

Relocation – Moving your home to higher ground where it will reduce the exposure to flooding. (Chapter 6)

Demolition – Tearing down your damaged home and either rebuilding on the same property or buying or building a home elsewhere. (Chapter 6)

Wet Floodproofing – Making portions of your home resistant to flood damage and allowing water to enter during flooding. (Chapter 7)

Dry Floodproofing – Sealing your home to prevent floodwaters from entering. (Chapter 7)

Barrier Systems – Building a floodwall or levee around your home to restrain floodwaters. (Chapter 8)

This chapter describes the six methods in detail. Keep in mind that only elevation, relocation, allowable wet floodproofing, and demolition can be used to meet the minimum requirements of the NFIP. Barrier systems, dry floodproofing, and some wet floodproofing may be used to minimize damages, but are not recognized as meeting the minimum requirements of the NFIP. Remember that purchasing flood insurance for your home is important, even if you mitigate using one of these methods.

While the aforementioned mitigation methods protect the actual structure, this guide also describes retrofitting options for equipment and utilities to consider as you think about how to protect your home from flooding:

Equipment/Utilities – Equipment/Utilities – Retrofitting existing building equipment and utility systems may involve a combination of elevating and/or protecting in place. (Chapter 9)

For each method, you will find a section that explains how the method works and where it should and should not be used, lists its advantages and disadvantages, and provides a relative cost estimate. But first, you should be aware of some general cautions about retrofitting.

WARNING

In the areas listed below, the risks to lives and property are usually greater than in other flood-prone areas:

- Coastal High Hazard Areas (insurance Zone V, VE, and V1–V30) shown on a FIRM (Figure 2-13)
- Coastal A zones (portion of Zone A seaward of the limit of moderate wave action (LiMWA))
- Floodways shown on a FIRM (see Figure 2-13)
- Alluvial fan flood hazard areas (certain Zone AO with depths and velocities) shown on a FIRM
- Areas subject to flash floods
- Areas subject to ice jams
- Areas subject to extremely high-velocity flood flows

Modifying a home to protect it from flood damage in these areas requires extreme care and may also require complex, engineered designs. If your home is in one of these areas, relocation or demolition (as described later in this chapter and in Chapter 6) may be a more conservative option rather than any of the other retrofitting methods discussed in this guide. If you have any doubt about whether your home is in an area of unusually severe hazard, consult your local officials.

3.1 Cautions

3.1.1 Substantial Improvement/Substantial Damage

NOTE

Substantial Improvement and **Substantial Damage** are defined in Section 2.5 and Appendix B.

As noted in Chapter 2, your community's floodplain management ordinance, regulation, or provisions of the building code includes restrictions on the types of changes that may be made to a home that is being **Substantially Improved** or that has sustained **Substantial Damage**. These restrictions prohibit or limit the use of some retrofitting measures. Two of the six methods described in this guide—dry floodproofing and levees/floodwalls—can reduce future damage but may not be used to bring a Substantially Improved or Substantially Damaged home into compliance with your community's floodplain management ordinance, regulation, or provisions of the building code. Instead, in accordance with your community's requirements, you must do one of the following:

- Move the home out of the regulatory floodplain
- Elevate the home so that its lowest floor is at or above the BFE
- In conjunction with elevation, wet floodproof the areas of the home below the BFE and use them only for parking, building access, or storage

- Demolish the home and either rebuild or buy a home elsewhere

Additional requirements apply to the use of wet floodproofing. These are described later in this chapter and in Chapter 7.

3.1.2 Basements

Another important floodplain management requirement concerns basements. If your home has a basement below the BFE and your local officials determine that it is being Substantially Improved or is Substantially Damaged, *the basement must be eliminated*. You can usually do this by backfilling it with compacted soil or other suitable material. For floodplain management purposes, the NFIP regulations define a basement as "any area of the building having its floor subgrade on all sides." Your community's floodplain management ordinance, regulation, or provisions of the building code may include a more restrictive definition of basement.

Note that the NFIP definition of "basement" does not include what is typically referred to as a "**walkout-on-grade**" basement, whose floor would be at or above adjacent grade on at least one side of the building. Depending on your community's floodplain management ordinance, regulation, or provisions of the building code, the requirement to eliminate the basement in a Substantially Improved or Substantially Damaged home *may not* apply to a walkout-on-grade basement. Instead, you may be able to wet floodproof the area. However, a wet floodproofed walkout-on-grade basement may be used only for parking, building access, or storage.

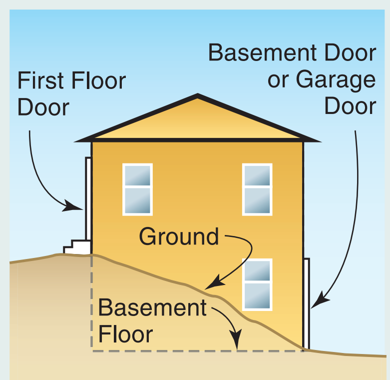
Your local officials can tell you more about these requirements and others that may be specified by local building codes and ordinances (see Chapter 4).

3.1.3 Flood Protection Elevation and Risk

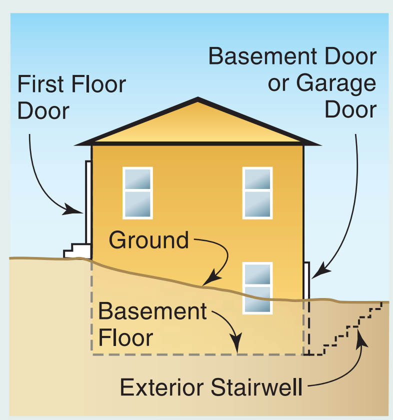
When you retrofit your home, one of the most important things you will do is choose a level of flood protection. In other words, will you protect your home from the base flood, the 0.2-percent-annual-chance flood, or some other flood? In some instances, this decision will be entirely yours; in others, it will depend largely on the regulatory requirements of your community, your State, or both. If your retrofit project is being funded through a Federal, State, or local agency, you may also be subject to different regulatory requirements. For the purpose of this publication, the **flood protection elevation** is considered the flood protection level you choose for your home.

DEFINITION

Walkout-on-grade is a term commonly used to describe a basement whose floor is at ground level on at least one side of a home. The term "walkout" is used because most basements of this type have an outside door or doors (entry door, garage door, or both) at ground level (see figure below). Note that if a basement floor is below grade on all sides (a basement as defined by the NFIP regulations) the basement may still have an outside door, but the door will be below ground level and stairs will be required for access.



Walkout-on-Grade Basement



SubGrade Basement

DEFINITION

Flood protection elevation – The elevation you choose to protect your home against the flood hazard. Although it is feasible for you to have a flood protection elevation less than the DFE, protecting your home to at least the DFE is recommended.

Design flood elevation (DFE) – The elevation of the design flood relative to the datum specified on the community's FIRM or flood hazard map. The design flood is the greater of the following two flood events: (1) the base flood, affecting those areas identified as special flood hazard areas on the community's FIRM; or (2) the flood corresponding to the area designated as a flood hazard area on a community's flood hazard map or otherwise legally designated. The I-Codes, ASCE 7, and ASCE 24 use the term DFE. In many communities, the DFE is identical to the BFE. Communities may designate a design flood (or DFE) in order to regulate based on a flood of record, to account for future increases in flood levels based on upland development, or to incorporate freeboard.

Base flood elevation (BFE) – The elevation of the base flood relative to the datum specified on a community's FIRM. The base flood has a 1 percent chance of being equaled or exceeded in any given year. BFEs are shown on FIRMs for many SFHAs. Relative to NFIP requirements, the BFE is the minimum elevation to which the lowest floor of a building must be elevated or floodproofed (Zone A). In Zone V, the bottom of the lowest horizontal structural member must be elevated to or above the BFE; floodproofing is not permitted in Zone V. Many SFHAs are shown on FIRMs without BFEs; in these areas, community officials and permit applicants are required to obtain and use information from other sources, or must estimate or develop BFEs at specific locations.

Freeboard – An added margin of safety, expressed in feet above a specific flood elevation, usually the BFE. In States and communities that require freeboard, buildings are required to be elevated or floodproofed to the higher elevation. For example, if a community adopts a 2-foot freeboard, buildings are required to be elevated or floodproofed to 2 feet above the BFE.

As you will see in this chapter, different retrofitting methods protect your home in different ways. For example, when you elevate your home, you protect it by raising its lowest floor to a specified elevation. When you dry floodproof your home, you use sealants, shields and other measures to protect the part of your home below a specified elevation by preventing water from entering the building. Because some seepage is anticipated, sump pumps are used to control the seepage and flood-damage-resistant materials are used to prevent damage where seepage is likely to occur. The home's structural components must have the capacity to resist increased flood loads resulting from dry floodproofing. To wet floodproof, you allow floodwaters to enter your home, but prevent damage below a specified elevation by using flood-damage-resistant materials and construction techniques. When you protect your home with a levee or floodwall, the top of the levee or floodwall is constructed to a specified elevation. To meet the requirements of the NFIP and potentially reduce your flood insurance premium, FEMA recommends protecting your home to the DFE.

If your home is being Substantially Improved or has been Substantially Damaged, your community's floodplain management ordinance, regulation, or provisions of the building code will specify a DFE that is at least equal to the BFE (the elevation of the 1-percent-annual-chance flood). Communities may require a higher DFE if they wish, or they may be required to do so by State law. Some States and communities require a higher DFE by establishing freeboard requirements, as discussed in Section 3.1.4. Your local officials can advise you about this.

On the other hand, if NFIP compliance is not required (the building does not have to meet the requirements of Substantial Improvement/Damage), then you may choose to have a flood protection level less than the DFE.

Although you cannot use a flood protection elevation lower than that required by your community, you are probably free to use a higher elevation if you wish to provide a greater level of flood protection. Depending on your situation, your choice of flood protection method and optimal elevation will be based largely on the cost to elevate to different elevations, the risk reduction provided by different elevations, and the annual cost of insurance premiums at different elevations.

In general, you will find that the cost of retrofitting increases as your flood protection elevation increases. For example, protecting your home to the elevation of the 2-percent-annual-chance flood with one of the methods described in this guide will probably cost you less than protecting it to the BFE with the same method (although the additional cost to protect to the BFE may be small). Although using a lower flood protection elevation may result in a less expensive retrofitting project, it exposes your home to a greater risk of flood damage and higher insurance rates. So in choosing a flood protection elevation, you must consider not only how much you are willing to pay, but also the level of risk you are willing to accept, including the potential for damage, financial loss, and emotional distress. For example, recent studies have shown that adding 1 to 3 feet of freeboard above the BFE to an elevation project can pay for itself within a few years through a 25 to 60 percent annual reduction in flood insurance premiums.

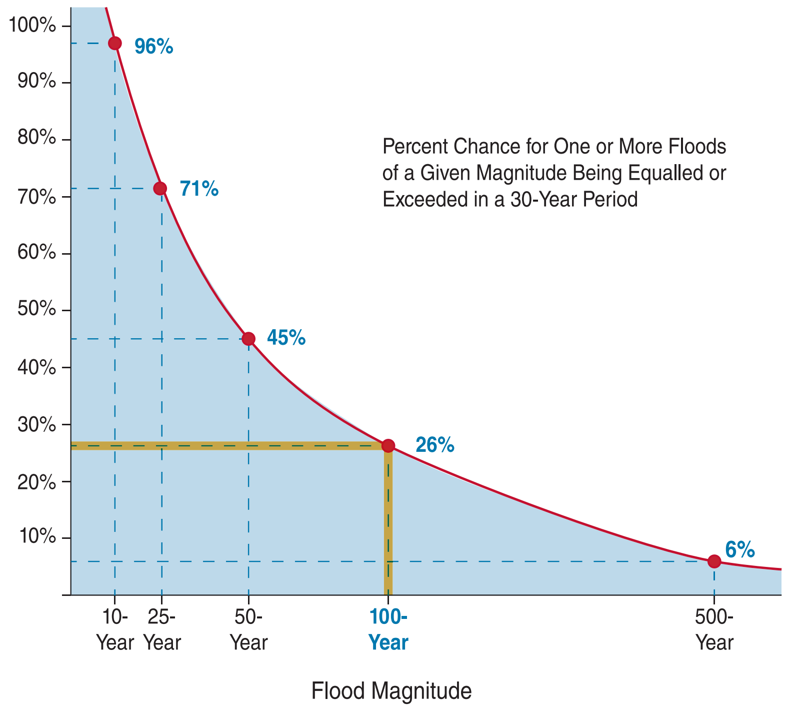
NOTE

A single-story home that is valued at $150,000 and located in Zone AE can have differing insurance premiums based on the level of protection. If the home is elevated to the BFE and does not have an enclosure, the annual premium would be approximately $1,294. If the same home is elevated to 2 feet above the BFE, the annual premium would be approximately $389. The increase in the flood protection level would result in a 70 percent savings in annual insurance premiums that would be passed onto the homeowner.

One way to see the relationship between your flood protection level and risk is to look at the probabilities associated with floods of various magnitudes during a period of 30 years, which is also the same length of a standard mortgage (Figure 3-1). The percentages shown along the vertical axis of the graph in Figure 3-1 are the probabilities that a flood will be equaled or exceeded during a 30-year period. This probability decreases as the magnitude of the flood increases. So the probability of a flood with an elevation equal to or greater than the flood protection elevation you choose decreases as your flood protection elevation increases. For example, compare the risks associated with the 2-percent-annual-chance (50-year) flood and the base flood. If you choose a flood protection elevation equal to the elevation of the 2-percent-annual-chance (50-year) flood, the probability that a flood as high as or higher than your flood protection elevation will occur during a 30-year period is 45 percent. But if you choose a flood protection elevation equal to the 1-percent-annual-chance flood (100-year flood or base flood), the probability drops to 26 percent. Although the base flood serves as the basis for NFIP insurance rates and regulatory floodplain management requirements, the relative frequency of any given flood (e.g., 2- year or 10-year) serves as a useful reference point when selecting a retrofitting option, evaluating cost effectiveness, and comparing relative risk.

Regardless of the flood protection elevation you choose or are required to use, you must realize that a larger flood is always possible and that there will always be some risk of damage. If you don't have flood insurance, you should purchase a policy; if you have flood insurance, you should maintain your policy, even if you have protected your home to or above the BFE. Once a home has been retrofitted to meet the NFIP requirements for Substantially Improved structures, it will probably be eligible for a lower flood insurance rate depending on the level of protection of your flood retrofit. Note that dry floodproofing of residential structures is not permitted to meet NFIP requirements, and is not recognized for flood insurance premium reduction purposes. Also, unless a floodwall or levee is accredited, it is not recognized for flood insurance premium reduction purposes.

Figure 3-1. This graph shows the relationship between flood recurrence intervals and the probability of an event occurring within a 30-year period.



3.1.4 Freeboard and Flood Mapping Uncertainties

If you are protecting your home by elevating it, dry floodproofing it, or building a levee or floodwall, you should include a minimum of 1 foot of freeboard in your flood protection elevation, even if your community does not require you to do so. For example, if you are elevating your home to protect it from the base flood, your flood protection elevation should be equal to the BFE plus 1 foot.

Freeboard is recommended because of uncertainties regarding expected flood elevations. These uncertainties exist for several reasons, but the two primary reasons are limitations of the analytical methods used in floodplain studies and potential effects of future **watershed** development, such as the construction of buildings and roads.

> **DEFINITION**
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> The **watershed** of a stream is the geographic area that contributes surface water, from rain or melting snow, to that stream.

FEMA and other agencies that perform floodplain studies use a variety of standard engineering methodologies to determine flood frequencies and flood elevations. These methods involve the use of historical data, field measurements, and assumptions and judgments, all of which can affect the accuracy of the results. Some amount of uncertainty regarding the results is, therefore, unavoidable, and the potential for flood elevations higher than those expected should always be accounted for in retrofitting. For example, FEMA's FIRMs include areas subject to the 0.2-percent-annual-chance flood (designated on FIRMs as Zone B or shaded Zone X) and areas outside of the 0.2-percent-annual-chance flood (designated on FIRMs as Zone C or unshaded Zone X). Homes constructed in Zones B, C, or X are not considered to have a high risk of flooding by the NFIP, but that does not mean that they are not subject to flooding. In fact, 25 to 30 percent of all flood insurance claims are for flood damages that occur in one of these zones.

Another example of uncertainties in mapping exists in coastal areas. Coastal FIRMs show Coastal High Hazard Areas (designated on FIRMs as Zones V, VE, and V1–V30), which are subject to waves of 3 feet or higher. However, historic observations have shown that many coastal homes located outside of Zone V areas still experience significant damage from moderate wave heights of 1.5 to 3 feet. For this reason, FEMA is working to update many coastal FIRMs to include SFHAs seaward of the LiMWA, also known as Coastal A Zones. Zone A in coastal areas is divided by the LiMWA. The LiMWA represents the landward limit of the 1.5-foot wave. The area between the LiMWA and the Zone V limit is known as the Coastal A Zone for building code and standard purposes and as the Moderate Wave Action (MoWA) area by FEMA flood maps. Again, this area is subject to wave heights between 1.5 and 3 feet during the base flood. The area between the LiMWA and the landward limit of Zone A due to coastal flooding is known as the Minimal Wave Action (MiWA) area and is subject to wave heights less than 1.5 feet during the base flood. Although not an NFIP requirement, FEMA recommends that homes located in Coastal A Zones meet the same requirements as homes constructed in Zone V areas. Figure 3-2 is a typical paper FIRM showing the delineations between Zone V, the MoWA area, the LiMWA, Zone A, and the MiWA area. Figure 3-3 is an example of a transect perpendicular to the shoreline showing the delineations between Zone V, the MoWA area, the LiMWA, Zone A, and the MiWA area.

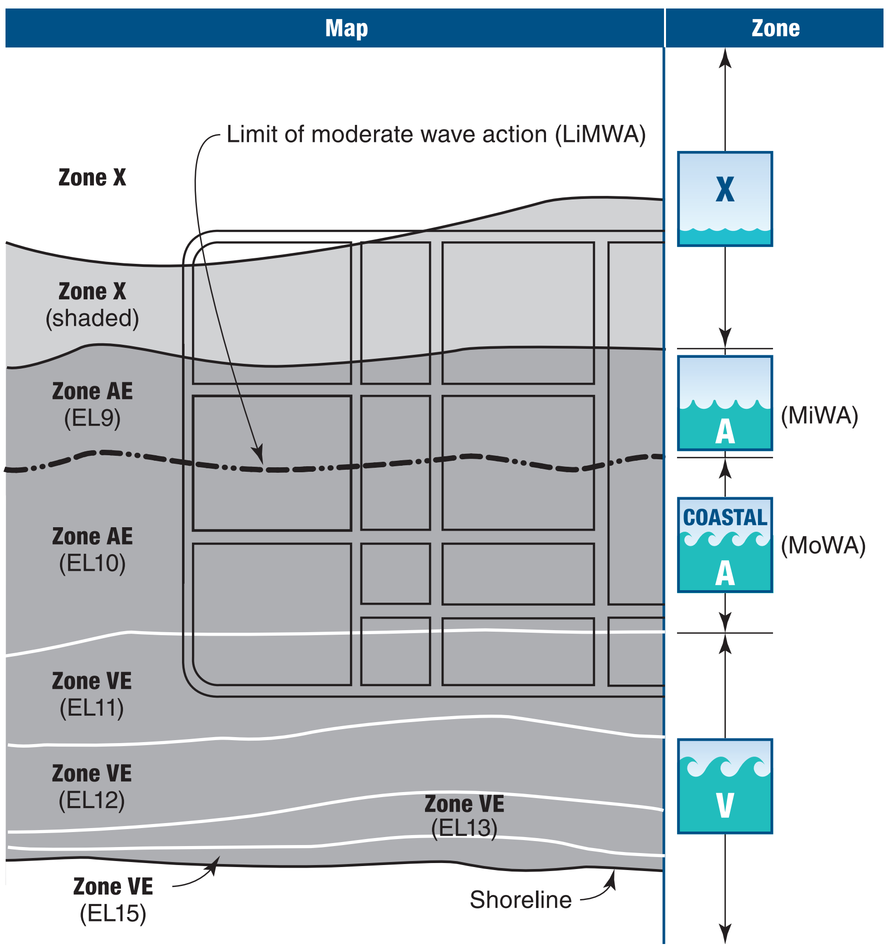


Figure 3-2. Portion of a paper FIRM showing coastal flood insurance rate zones. The icons on the right indicate the associated flood hazard zones for design and construction purposes. The LiMWA is not shown on older FIRMs, but is shown on newer FIRMs.

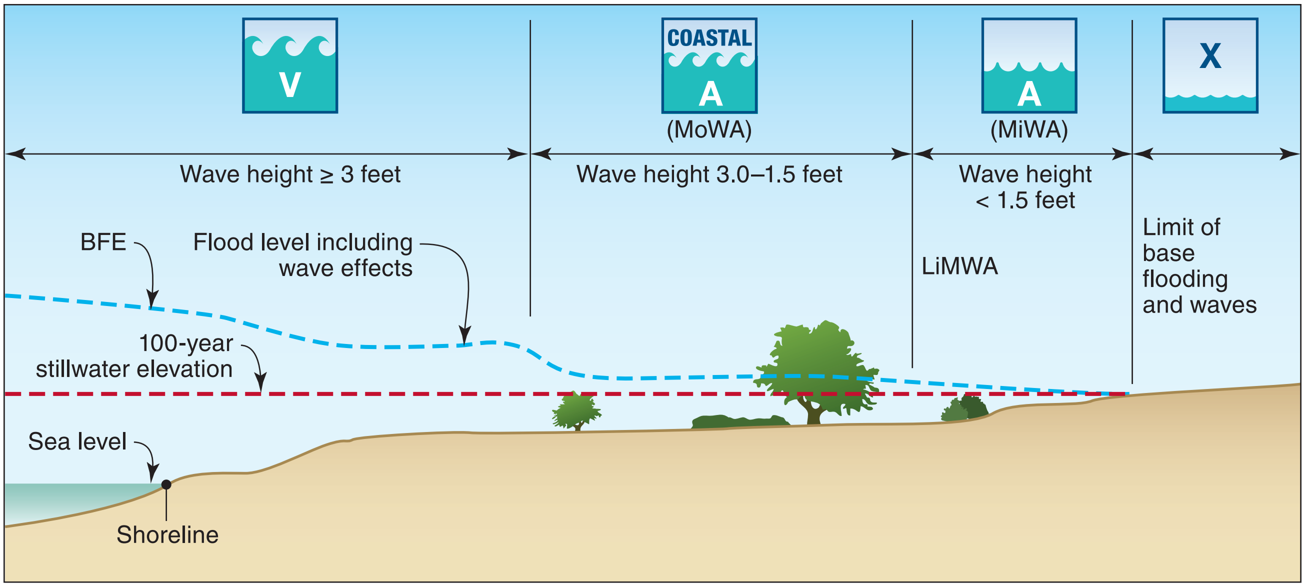


Figure 3-3. Typical transect perpendicular to the shoreline showing the delineations between Zone V, the MoWA area, the LiMWA, Zone A, and the MiWA area.

Development in a watershed can increase the size and frequency of floods in that watershed. In general, watershed development reduces the amount of open ground available to absorb water from rain and melting snow and, therefore, increases the amount of water that makes its way into streams. As a result, in a developing watershed, an amount of rainfall that might have caused minor floods in the past may cause larger floods and higher elevations in the future.

FEMA's floodplain studies are based on the watershed conditions existing at the time the studies are performed. They do not account for potential increases in watershed development or any other changes that might affect the sizes of future floods. The reason for this approach is that one of the primary purposes of FISs and FIRMs is to provide the technical basis for establishing flood insurance rates. Therefore, the flood hazards must be shown as they are, not as they might be. Also, attempting to predict the level of future watershed development in every study and determine the effects not only would be extremely difficult but also would require additional assumptions and judgments that could increase uncertainty. However, in many watersheds, some amount of development is inevitable. So, providing freeboard is a prudent means of protecting against the increased flood elevations that may result.

3.1.5 Human Intervention

Retrofitting methods fall into two general categories: those that depend on **human intervention**, which are referred to as "active" methods, and those that do not, which are referred to as "passive" methods. For example, elevating your home does not require human intervention to be effective. But what if you have a floodwall with an opening for your car? In addition to requiring interior drainage, a floodwall with an opening will protect your home only if you can close the opening before flooding occurs. So your floodwall will have to be fitted with a gate (or some other type of closure mechanism), and every time flooding threatens, you will have to be warned far enough in advance so that you can close the gate in time.

DEFINITION

Human intervention is any action that a person must take to enable a flood protection measure to function as intended. This action must be taken every time flooding threatens.

The need for adequate warning time and human intervention makes active methods less reliable than passive methods. You should try to avoid active methods when you choose a retrofitting method for your home, keeping in mind that active methods cannot be used to bring a home into compliance with the NFIP. If your retrofitting project includes active methods, you must have a plan that describes what actions you will take to make the measures work and when you will take those actions.

WARNING

Some communities may restrict or prohibit the use of active retrofitting methods for flood protection.

3.1.6 Other Considerations

The retrofitting measures discussed in this guide may be the best means of protection for a home in an area where a large flood control project or major waterway improvement, is not feasible, warranted, or appropriate. You should keep the following in mind whenever you consider a retrofitting project:

- Communities participating in the NFIP require permits for all development within the regulatory floodplain. Under your community's floodplain ordinance or law, any changes to buildings and other structures are considered "development." These changes include improvements and repairs of existing buildings and other structures. Also, communities usually require building permits for many of the activities associated with the retrofitting methods described in this guide. In communities that have adopted a floodplain ordinance or law, health code, and building code, the permits required by these ordinances, laws, and codes may be issued separately or as one combined permit. You may need a permit for the following:

    - Modifying your existing home or building a new home on a flood-prone site. A floodplain permit and possibly a building permit will be required.
    - Moving a home on public rights-of-way. If you relocate your home, you will probably need a permit, not only from your community but also from your State, as well as from any other communities through which the home will pass on its way to the new site. A relocation project may also require a permit for the foundation at the new site.
    - Demolishing a damaged home and restoring the site after demolition, including grading, planting vegetative cover, capping and abandoning utilities, and removing or securing underground septic and fuel storage tanks.

    You may wish to obtain the permits necessary for your retrofitting project yourself or arrange for your retrofitting contractor or design professional to obtain them. But remember, you must have the necessary permits in hand before you begin your project. As discussed in Chapter 4, your local officials are the best source of information about State and local permit requirements.

CROSS REFERENCE

Your design professional or contractor should review some or all of the applicable versions of the following nationally recognized codes and standards:

- International Code Council, *International Building Code* (IBC)
- International Code Council, International Existing Building Code (IEBC)
- International Code Council, *International Residential Code* (IRC)
- ASCE, *Minimum Design Loads for Buildings and Other Structures* (ASCE 7)
- ASCE, *Flood Resistant Design and Construction* (ASCE 24)
- See Appendix A for more information.

- In addition to meeting the requirements of the floodplain management ordinance and building codes, you may need to comply with the requirements of *other Federal, State, and local laws and ordinances, such as those dealing with zoning setbacks and wetlands*. Again, your local officials are the best source of information about these requirements.
- If your retrofitting project will involve financial assistance from a Federal agency and your property is 50 years old or older, you must work with that agency to *ensure that your project complies with the National Historic Preservation Act* (16 U.S.C. 470). The act requires that, before releasing any Federal assistance, the agency determine whether the property is eligible for inclusion in the National Register of Historic Places and if so, whether your project will have any effect on the historic character of the property. This requirement may not apply in some emergency situations or if the agency has made prior arrangements with historic preservation officials. For more information, contact your SHPO (Appendix E).
- Most retrofitting measures should be *designed and constructed by experienced professionals*, such as contractors, engineers, and architects. Using professionals helps you make sure that the work is done properly, that code and regulatory requirements are met, and that, once completed, the retrofitting measures will work.
- Most retrofitting measures cannot be simply installed and forgotten. You will need to *periodically inspect and maintain them* to be sure that they will continue to work over time, especially if they require human intervention or depend on certain materials.
- Even though retrofitting will help protect your home from flooding, *you should never remain in your home during flooding*. Stay informed about flooding conditions by monitoring local radio and television stations. Be prepared to evacuate when necessary.
- Elevating your home may reduce the cost of your NFIP flood insurance policy. Relocating a home to a site outside the regulatory floodplain eliminates the mandatory flood insurance purchase requirement and significantly reduces the cost of flood insurance for an owner who wishes to purchase a policy.

3.2 Construction Terminology

In the remainder of this guide, you will find many references to common types of home construction, such as frame or masonry, and common types of home foundations, such as slab-on-grade or crawlspace. Even if you are already familiar with these and other home construction terms, take a minute to review the following information before you move to the descriptions of the retrofitting methods.

3.2.1 Construction Type

The most common home construction types are (Figure 3-4):

Frame – walls constructed of wood or light-gauge metal studs, with wood, vinyl, or aluminum siding

Masonry veneer – frame walls with a non-structural, decorative, exterior layer of brick, stone, or concrete block instead of siding

Masonry – walls constructed of brick, stone, or concrete block

Modular home – frame home assembled on site on a permanent foundation from separate sections manufactured elsewhere (subject to local building codes)

Manufactured home – prefabricated frame home constructed on a transportable frame that can be placed on a permanent or temporary foundation (subject to Federal and State standards)

Some homes consist of combinations of two or more of these construction types.

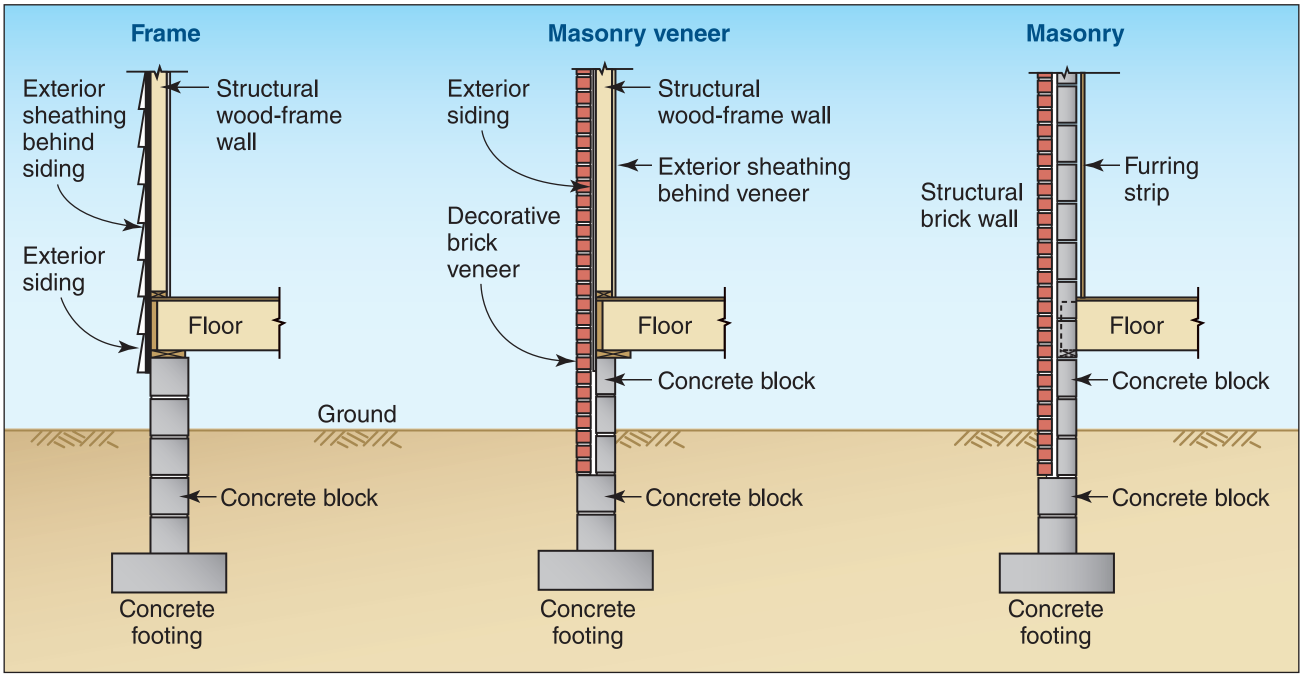


Figure 3-4. Typical cross-sections of three common construction types: frame, masonry veneer, and masonry. The foundation shown here for all three construction types consists of concrete blocks and a concrete footing. The same construction types are also found on basement and slab-on-grade foundations.

3.2.2 Foundation Type

Most homes of the construction types listed above are built on the following types of foundations (Figure 3-5):

Basement – with masonry or **cast-in-place** concrete walls

Crawlspace – with masonry or cast-in-place concrete walls

Slab-on-grade – either a slab with a masonry or concrete foundation or a thickened slab (see Figure 5-5 in Chapter 5)

Open foundation – usually concrete or masonry piers, but sometimes wood, concrete, or metal posts, columns, or piles

Some homes are built on more than one type of foundation. Various combinations of basement, crawlspace, and slab-on-grade foundations are common. Manufactured homes are occasionally installed on basement or crawlspace foundations but are more often supported either by stacks of concrete blocks or by foundation systems designed specifically for manufactured homes.

DEFINITION

Concrete poured into forms at the construction site is referred to as **cast-in-place** concrete.

WARNING

The relative costs in this chapter are provided only as examples of what to expect when choosing a retrofitting method. Be sure to get a complete, written cost estimate from your contractor and design professional before you begin any retrofitting project (see Chapter 4).

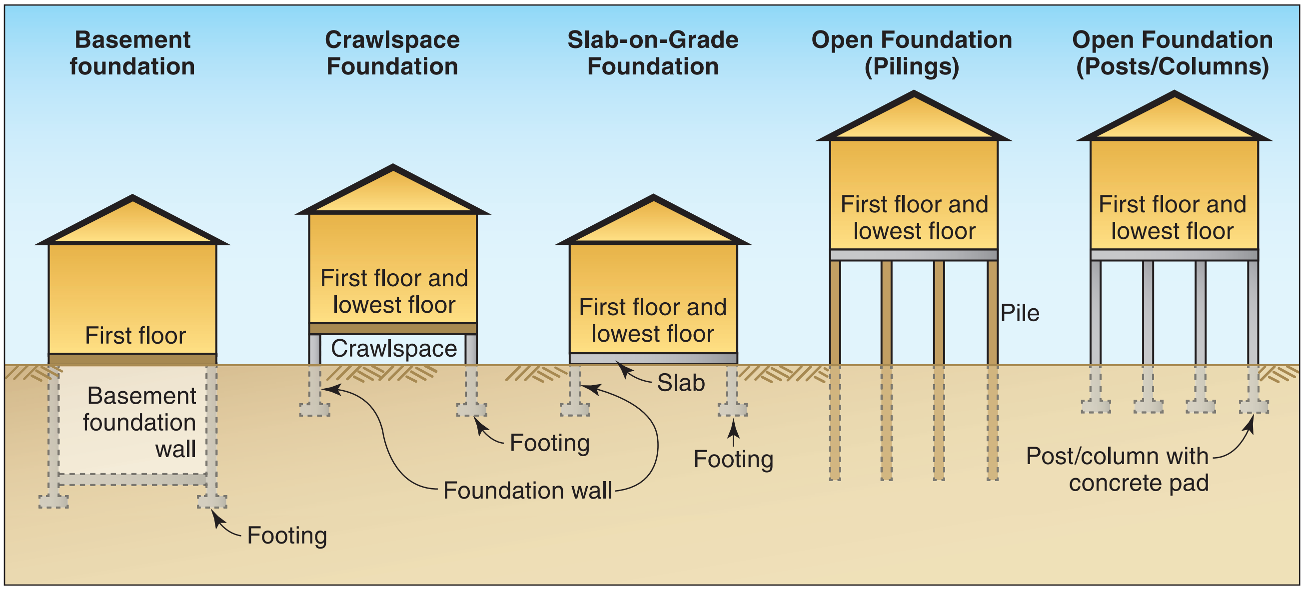


Figure 3-5. Home foundation types.

3.3 Retrofitting Methods and Costs

The following sections give an overview of the six retrofitting methods, explain how they work and where they are appropriate, and list their advantages and disadvantages. With this information, you will be ready for Chapter 4, *Deciding Which Method Is Right for Your Home*.

3.3.1 Elevation

Elevating a home to prevent floodwaters from reaching living areas is an effective retrofitting method. The goal of the elevation process is to raise the lowest floor to or above the DFE. You can do this by elevating the entire home, including the floor, or by leaving the home in its existing position and constructing a new raised floor within the home. The method used depends largely on construction type, foundation type, and flooding conditions. Chapter 5 presents more detailed information on elevation.

During the elevation process, most homes (including manufactured homes) are separated from their foundations, raised on hydraulic jacks, and held by temporary supports while a new or extended foundation is constructed below. This method works well for homes originally built on basement, crawlspace, and open foundations. As explained later in this section, the new or extended foundation can consist of continuous walls or separate piers, posts, columns, or piles.

NOTE

When you elevate your home, the existing foundation will need to be extended or demolished and rebuilt. This decision will depend on the condition of the existing foundation and its ability to carry additional loads.

CROSS REFERENCE

FEMA P-550, *Recommended Residential Construction for Coastal Areas: Building on Strong and Safe Foundations* (FEMA. 2009), offers more detail about these foundation types and elevation.

For homes with slab-on-grade foundations, elevation can be done in one of two ways. One approach is to leave the home attached to the slab foundation and lift both together. After the home and slab are lifted, a new foundation is constructed below the slab. The other approach is to detach the home from the slab and elevate the home, leaving the slab foundation in place. After the home is lifted, a new, elevated floor is constructed.

Unlike other types of construction in which elevation can be relatively straightforward, elevating slab-on-grade homes with the slab intact is technically challenging and often not feasible. When a slab-on-grade home is elevated with the slab intact, the slab, which was previously continuously supported by the soils beneath it, must function as a structural element. It must span the distance between the portions of the foundation that support the elevated home. Typically, these slabs often are either unreinforced or only lightly reinforced with welded wire fabric and are essentially non-structural. These slabs may not be able to support the loads of an elevated home. Consequently, the slab foundation should be thoroughly evaluated by a registered design professional before choosing this mitigation option.

Alternative techniques are available for masonry homes on slab-on-grade foundations. As described later in this section, these techniques do not require the lifting of the home. Instead, they involve raising the floor within the home or moving the living space to an upper story. Guidance for elevating slab-on-grade masonry homes can be found in FEMA P-347, *Above the Flood: Elevating Your Floodprone House* (FEMA. 2000).

Although elevating a home can help protect it from floodwaters, you need to consider other hazards before choosing this method. Elevating the home can make it more susceptible to damage from earthquakes. In addition, both continuous wall foundations and open foundations can fail as a result of damage caused by erosion and the impact of debris carried by floodwaters. If portions of the original foundation, such as the **footings**, are used to support new walls or other foundation members, or a new second story, they must be capable of safely carrying the additional loads imposed by the new construction and the expected flood, wind, and earthquake forces.

Method #1: Elevating on Continuous Foundation Walls

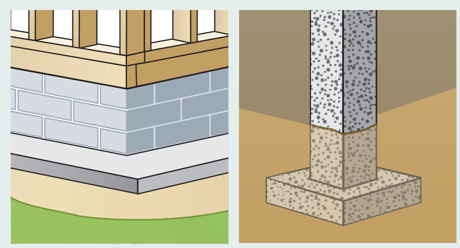
Although this method is usually used in flood hazard areas where the risks of wave action and high-velocity flow are low (Figures 3-6 and 3-7), continuous foundation walls in low-velocity flow areas with wave action can also be susceptible to structural damage. Open foundations should be considered as a reasonable mitigation option. After the home is detached from its foundation and raised on jacks, the existing foundation is often saved and the

CROSS REFERENCE

FEMA has produced a videotape titled *Best Build 3: Protecting a Flood-Prone Home*, which illustrates the retrofitting methods described in this guide (see Appendix A).

DEFINITION

A **footing** is the base of a foundation. Footings are usually made of concrete and may be reinforced with steel bars. Foundation walls are supported on continuous footings; separate foundation members, such as piers, are supported on individual footings.



Continous footing   Individual footing

NOTE

Elevation on open foundations is required by the NFIP in Zone V areas (even when the ground elevation lies above the BFE) and is strongly recommended for Coastal A Zones. Some States and communities have formally adopted open foundation requirements for Coastal A Zone construction.

foundation walls are extended. The new portions of the walls are usually made of masonry block or cast-in-place concrete. Although this method may be the easiest way to elevate a home, it can involve some additional construction modifications or reinforcements.

Figure 3-6. Typical cross-section of home elevated on continuous foundation walls.

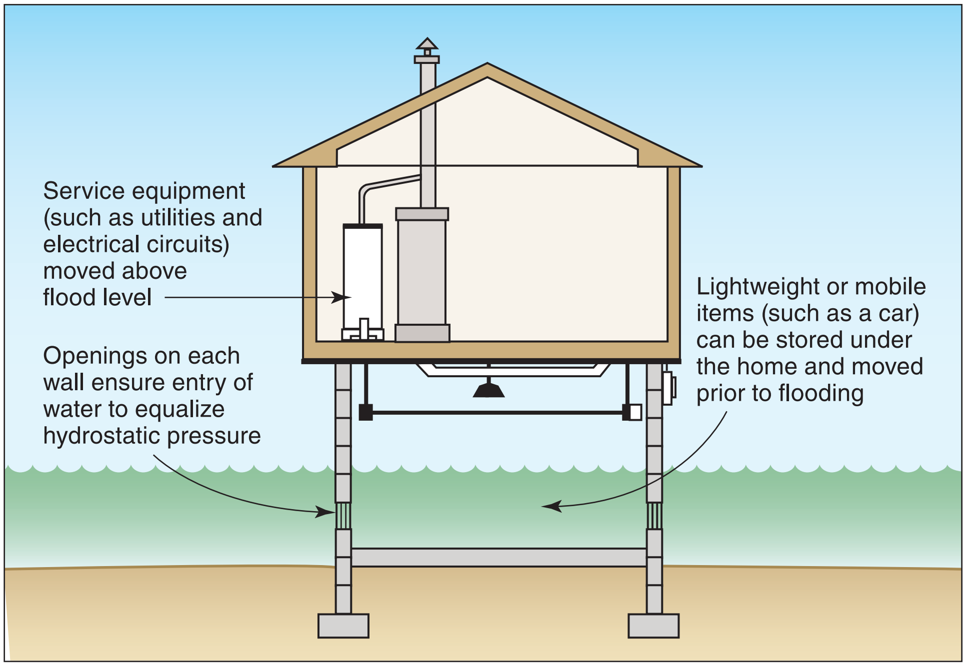


Figure 3-7. Before (left) and after (right) photos of a retrofitted home elevated on extended continuous foundation walls.

Depending on the size of your home, the amount of elevation, and the magnitude of the potential environmental loads (such as those from floods, wind, earthquakes, and snow), your contractor may have to modify or reinforce the footings and foundation walls to ensure the structural stability of the home. The original footings may have to be replaced with ones that have a higher capacity for environmental loads. Both the footings and the foundation walls may need to be reinforced with steel bars.

This type of foundation creates what is referred to under the NFIP as an "enclosure." The enclosure must be constructed of flood damage-resistant materials, have all service equipment elevated above the DFE, and be used only for parking, access, or storage. NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements* (FEMA. 2008), defines a "flood [damage]-resistant material" as "any building product [material, component, or system] capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage."

"Prolonged contact" means at least 72 hours, and "significant damage" means any damage requiring more than cosmetic repair. Technical Bulletin 2 provides a detailed list of appropriate flood damage-resistant materials and also classifies flood damage-resistance of materials as acceptable or unacceptable based on water resistance and ability to be cleaned.

The enclosure must also be constructed with openings to allow equalization of hydrostatic pressure to comply with NFIP and building code requirements. As explained in Chapter 2, unequalized hydrostatic pressure exerted by floodwaters can collapse walls, regardless of the construction materials used. The NFIP may require that openings be installed in the foundation walls so that water can flow into and out of any enclosed area below the newly elevated home. NFIP Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures* (FEMA. 2008), provides guidance on the NFIP regulations concerning openings in foundation walls. When the water levels on both sides of the foundation walls are the same, the hydrostatic pressure is equalized. If you are elevating your home as part of a Substantial Improvement or in connection with repairs of Substantial Damage, your community's floodplain management ordinance, regulation, or provisions of the building code will require that you install openings in all areas below the BFE. Consult your local officials about local requirements for openings.

Method #2: Elevating on Open Foundations

Unlike continuous foundations, open foundations consist of individual vertical structural members that support the home only at key points. Because they present less of an obstacle to flood flows than continuous walls, open foundations can be used in areas where there are risks of wave action and high-velocity flood. Most open foundations consist of piers, posts, columns, or piles.

Piers. Piers (or columns) are commonly built with masonry block or are made of cast-in-place concrete (Figure 3-8). Piers can be made from wood and steel as well. The bottom of each pier sits on a concrete footing. Pier foundations are used in conventional construction; they are not just a means of elevating a flood-prone home. In conventional use, they are designed primarily for vertical loading—to hold the weight of the home. They are not normally designed to resist large horizontal forces, such as those associated with moving floodwaters, waves, impacts from floodborne debris, wind, and earthquakes. As a result, pier foundations are generally used where the risks of wave action and high-velocity flow are low to moderate and the potential for earthquakes is low.

If you decide to elevate your home on a pier foundation, you should expect your contractor to reinforce the piers and footings with steel reinforcing bars and to connect the piers to the footings so they will not separate under flood or other forces. Adequate connections between the piers and the home are also necessary so that the home and foundation will resist lateral loads from floods, winds, and earthquakes, and uplift from buoyancy.

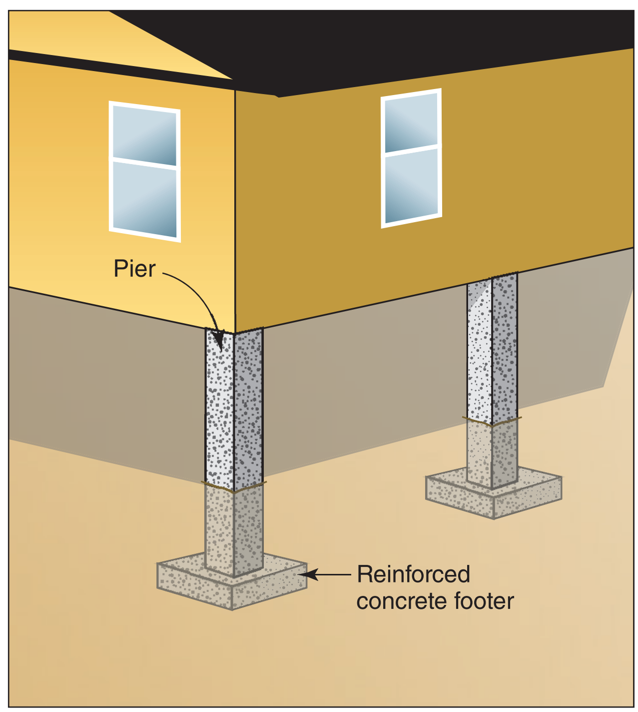


Figure 3-8. Home elevated on reinforced concrete piers.

Posts. Posts are usually made of wood or steel (Figure 3-9). They are generally square but may also be round. Posts are set in holes, and their ends are encased in concrete, or supported on concrete pads (as in the figure). After posts are set, the holes are filled with concrete, dirt, gravel, or crushed stone.

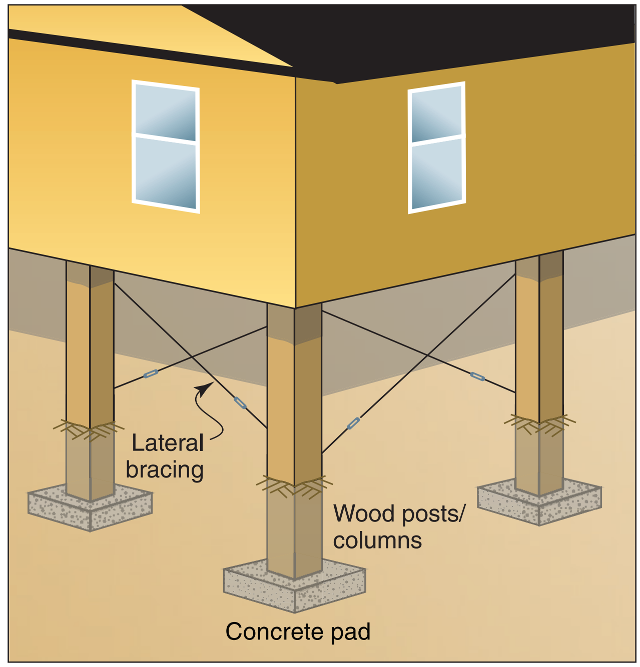


Figure 3-9. Home elevated on posts

Posts can be connected to each other with bracing made of wood, steel rods, or guy wires. The type is usually determined by cost, flood conditions, expected loads, the availability of materials, and local construction practice. Like piers, posts are generally used where the risks of wave action and high-velocity flow are low to moderate.

One primary difference between piers, and posts is the dimension of the element – piers are larger in cross section because they usually are CMU (concrete masonry unit) or concrete block and are usually shorter than posts. Posts are braced together because they are usually taller and more slender with less stability than piers.

Piles. Piles are usually made of wood, but fiber-reinforced polymer, steel, or **precast** concrete piles are also common in some areas (Figure 3-10). Piles are similar to posts but, instead of being set in holes, they are driven into the ground or jetted in with streams of water. Also, piles are embedded deeper in the ground than either piers or posts. As a result, pile foundations are less susceptible to the effects of high-velocity flow, waves, debris impact, erosion, and scour than the other types of open foundations. Piles differ from piers and posts also in that they do not rest on footings. Instead they are driven until they rest on a solid support layer, such as bedrock, or until they are embedded deep enough that the friction between the ground and the piles will enable them to resist the loads that are expected to act on them.

Because driving and **jetting** piles requires bulky, heavy construction machinery, an existing home must normally be moved off its existing foundation and set on **cribbing** until the operation is complete. As a result, elevating a home by placing it on a pile foundation will usually require more space and cost more than elevating with another type of foundation. Pile foundations are used primarily in areas where other elevation methods are not feasible, such as where floodwaters are deep and the risks of wave action and high-velocity flow are great. For example, pile foundations are used extensively in oceanfront areas exposed to high-velocity flow, waves, and high winds (Figure 3-11).

DEFINITION

Concrete materials such as posts, beams, and blocks that are brought to the construction site in finished form are referred to as **precast**.

Jetting is a process in which the hole for the installation of a pile is made by a high-pressure stream of water from a nozzle attached to the bottom of the pile.

Cribbing usually consists of a framework of crisscrossed timbers that provides temporary structural support.

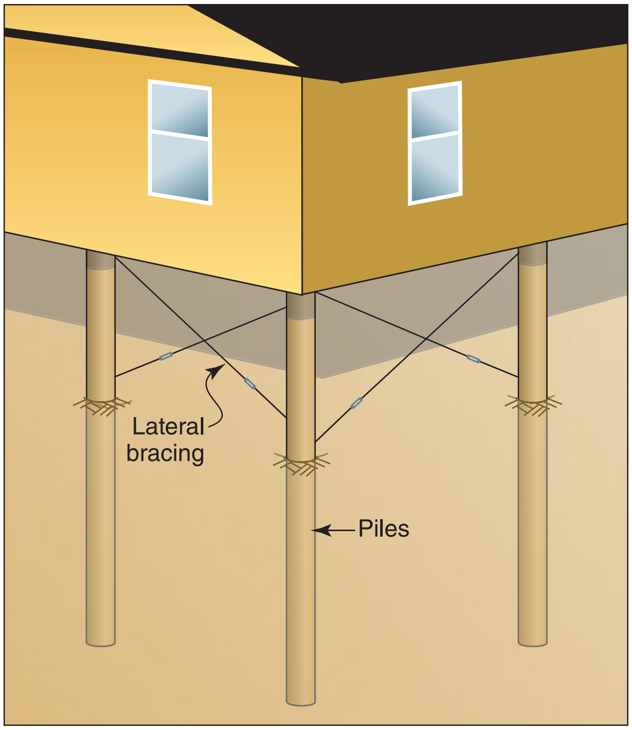


Figure 3-10. Home elevated on piles.

Figure 3-11. Example of well-elevated and embedded pile foundation tested by Hurricane Katrina. Note adjacent building failures (Dauphin Island, AL, 2005).

Methods #3 and #4: Elevating by Extending the Walls of the Home or Moving the Living Space to an Upper Floor

For masonry homes on slab-on-grade foundations, two alternative elevation methods are available. One is to remove the roof, extend the walls of the home upward, replace the roof, and build a new, raised floor at the DFE (Figure 3-12). This technique works best where the floor needs to be raised less than 4 feet to reach the DFE. The floor can be either a new slab or a new wood-framed floor. For a new slab, fill dirt is placed on top of the old slab and the new slab is built on top. If a new wood-framed floor is built, the space between it and the old slab is left open and becomes a crawlspace (and must be retrofitted with openings to allow floodwaters in the crawlspace).

CROSS REFERENCE

As discussed in Section 2.6, the cost of elevating a Substantially Damaged home may be eligible for a flood insurance claim under ICC coverage.

Figure 3-12. The owner of this flood-prone home in south Florida decided to build a new wood-framed second story on top of the masonry first story. The new second story is well above the BFE.

The second technique is to abandon the entire lower floor, or lower enclosed area, of the home and move the living space to an existing or newly constructed upper story. This technique works best for multi-story homes where the DFE is more than 4 feet above the level of the lower floor. The abandoned lower floor or enclosed area is then used only for parking, building access, or storage.

These techniques, like the others, have their limitations. The portions of the home below the DFE will be exposed to flooding and must, therefore, be made of flood damage-resistant materials. That is why this method is applicable to masonry homes rather than frame homes, which would be much more easily damaged by flooding. The area below the DFE cannot be used for living space; it may be used only for parking, building access, or storage. In addition, all appliances and utilities must be moved to the upper floor. Also, openings must be cut into the walls of the lower floor to allow water to enter during flooding so that the hydrostatic pressure on the walls will be equalized. In essence, the lower floor is wet floodproofed (see Section 3.4.1).

Adding a new second story to a single-story home may require that the foundation be strengthened so that it can support the additional load. You must consult an engineer if you plan to use this method. The second story can be frame or masonry (to match the lower floor). The method you choose will depend on the advice of your engineer, cost, appearance, the availability of materials and experienced contractors, and the risks of other natural hazards such as hurricanes and earthquakes.

Table 3-1 presents the advantages and disadvantages of elevation.

The relative costs shown in Table 3-2 are for elevating frame, masonry veneer, and masonry homes of various foundation types. The costs for extending utilities and adding or extending staircases are included. The costs shown for elevating frame, masonry veneer, and masonry homes on existing slab-on-grade foundations are based on the assumption that the home is raised with the existing slab attached.

Table 3-1. Advantages and Disadvantages of Elevation

Advantages	Disadvantages
• Brings a Substantially Damaged or Improved building into compliance with the NFIP if the lowest horizontal structural member of the lowest floor is elevated to the BFE • Reduces flood risk to the structure and its contents • Eliminates the need to relocate vulnerable items above the flood level during flooding • Often reduces flood insurance premiums • Uses established techniques • Can be initiated quickly because qualified contractors are often readily available (unless project is implemented immediately after a disaster) • Reduces the physical, financial, and emotional strains that accompany flood events • Does not require the additional land that may be needed for floodwalls or levees	• May be cost-prohibitive • May adversely affect the structure's appearance • May adversely affect access to the structure • Cannot be used in areas with high-velocity water flow, fast-moving ice or debris flow, or erosion, unless special measures are taken • May require additional costs to bring the structure up to current building codes for plumbing, electrical, and energy systems • Requires consideration of forces from wind and seismic hazards and possible changes to building design

NFIP = National Flood Insurance Program; BFE = base flood elevation

Table 3-2. Relative Costs of Elevating a Home

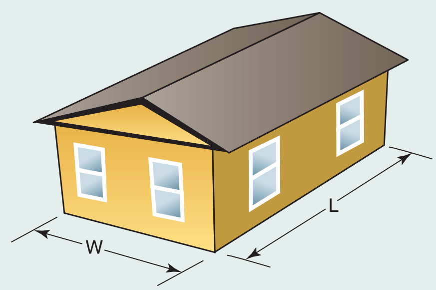
Construction Type	Existing Foundation	Retrofit	Relative Cost
Frame	Basement, crawlspace, or open foundation	Elevate on continuous foundation walls or open foundation	Lowest
Frame with masonry veneer		Elevate on continuous foundation walls or open foundation	
Load bearing masonry		Extend existing walls and create new elevated living area	
Frame	Slab-on-grade	Elevate on continuous foundation walls or open foundation	
Frame with masonry veneer		Elevate on continuous foundation walls or open foundation	
Load bearing masonry		Elevate on continuous foundation walls or open foundation	Highest

Occasionally, slab-on-grade homes are raised without the slab. Although this method can be less expensive than raising the home with the slab, it involves detaching the home from the slab and requires extensive alterations to interior and exterior walls.

The cost of abandoning an existing lower level will depend on whether the home already has an upper level that can be used for living space. If an upper level is available, abandoning the lower floor would involve primarily elevating or relocating utilities, adding openings in the lower-level walls, and ensuring that all construction materials below the BFE are flood damage resistant. This method is well-suited to a home with a walkout-on-grade basement, which can be wet floodproofed and used for parking, building access, or storage. The cost of adding a new frame upper level and raising the roof to accommodate the new level would vary, depending upon the amount of interior finishing and other factors.

DEFINITION

The footprint of a house is the land area it covers (see figure). This area is equal to the length of the house multiplied by its width. Note that the footprint is not necessarily equal to the total square footage of the house.



Footprint = L x W

3.3.2 Relocation and Demolition

Relocation is the retrofitting measure that can offer the greatest security from future flooding. It involves moving an entire structure to another location, usually outside the floodplain. Relocation as a retrofitting measure not only relieves anxiety about future flooding, but also offers the opportunity to reduce future flood insurance premiums. Demolition is tearing down a damaged home. A new compliant home can be rebuilt on site, rebuilt on another property, or the owner can simply move in to another structure elsewhere. These retrofitting methods are discussed below.

Relocation

Moving your home to high ground, outside the flood hazard area, is the most effective of the retrofitting methods described in this guide. Retrofitting literature commonly refers to this method as relocation. Chapter 6 presents more detailed information on relocation. When there is enough space and the ground is high enough, you may even be able to move your home to another location on the same piece of property.

Relocating a home involves detaching it from the foundation, raising it with jacks, and placing it on a wheeled vehicle that delivers it to the new site. The original foundation is demolished and a new foundation is built at the new site. The home is installed on the new foundation and all utility lines are connected. Relocation is particularly appropriate in areas where the flood hazard is severe, such as where flood conditions are characterized by one or more of the following:

- Deep water
- Rapid rates of rise and fall
- Short warning time
- Wave action
- High-velocity flow
- High debris potential
- Long duration
- Erosion

Relocation is also appropriate for homeowners who want to be free of worries about damage from future floods that may exceed a selected flood protection elevation.

Although similar to elevation, relocation requires additional steps that usually make it more expensive. These include moving the home, buying and preparing a new site (including building the new foundation and providing the necessary utilities), and restoring the old site (including demolishing the old foundation and capping and abandoning old utility lines).

Homes of all sizes and types can be relocated, either as a unit or in segments. One-story frame homes are usually the easiest to move, particularly if they are built on a crawlspace or basement foundation that provides easy access to the floor framing. Masonry homes can also be moved, but usually with more difficulty and at a higher cost.

Professional home movers can advise you about the things you need to consider when deciding whether to relocate. The structural integrity of your home will have to be checked. Also, you may need to find a place where you can store furniture and other belongings temporarily. However, in most instances, the contents of your home may remain in the home while it is being moved. Keep in mind that there must be a clear route to the new site. Narrow roads, restrictive overpasses, and bridges with low weight limits may make it impossible for your home to be moved to the new site. Also, many States and communities have requirements that govern the transport of homes and other buildings on public rights-of-way. For information about structural movers in your area, visit http://www.iasm.org. Table 3-3 presents the advantages and disadvantages of relocation.

Table 3-3. Advantages and Disadvantages of Relocation

Advantages	Disadvantages
• Allows Substantially Damaged or Improved structure to be brought into compliance with the NFIP • Significantly reduces flood risk to the structure and its contents • Uses established techniques • Can be initiated quickly because qualified contractors are often readily available (unless project is implemented immediately after a disaster) • Can eliminate the need to purchase flood insurance or reduce the premium because the home is no longer in the floodplain • Reduces the physical, financial, and emotional strains that accompany flood events	• May be cost-prohibitive • Requires locating a new site • Requires addressing disposition of the flood-prone site • May require additional costs to bring the structure up to current building codes for plumbing, electrical, and energy systems • May take a long time, depending on time required to find desired property, purchase it, and develop it with desired utilities • May be cost-prohibitive to relocate, as well as to develop the site with desired utilities (water, sewage, electrical, natural gas, cable, telephone etc.)

NFIP = National Flood Insurance Program

Table 3-4 shows the relative costs of relocating homes of different construction and foundation types. In addition to moving and construction costs, it is important to account for the additional relocation project costs of any new property that must be purchased.

WARNING

The relative relocation costs shown here are based on a small home. Because relocation costs do not increase proportionally with the size of a home, the cost per square foot of moving a larger home may be less than that shown here.

Table 3-4. Relative Costs of Relocation

Construction Type	Existing Foundation	Retrofit	Relative Cost
Frame	Crawlspace, or open foundation	Relocate existing home and install the home on a new foundation at the new site, hook up utilities, and restore the old site	Lowest
Frame with masonry veneer			
Load bearing masonry			
Frame	Basement		
Frame with masonry veneer			
Load bearing masonry			
Frame	Slab-on-grade		
Frame with masonry veneer			
Load bearing masonry			Highest

Demolition

Demolition is tearing down a damaged home. A new compliant home can be rebuilt on site, rebuilt on another property, or the owner can simply move in to another structure elsewhere. This retrofitting method may be the most practical of all those described in this guide when a home has sustained extensive damage, especially severe structural damage. Chapter 6 presents more detailed information on demolition.

Whether you intend to rebuild or move, you must tear down your damaged home and then restore the site. Site restoration usually involves filling in a basement, grading, and landscaping. As a result, you will need the services of a demolition contractor. The contractor will disconnect and cap all utility lines at the site and then raze the home with a bulldozer or other heavy equipment. If you decide to rebuild on the old site or somewhere else on the same property, your construction contractor may be able to do the demolition and site restoration work as part of the home construction.

CROSS REFERENCE

As discussed in Section 2.6, the cost of demolishing a Substantially Damaged home may be an eligible flood insurance claim under ICC coverage.

Remember, all demolition, construction, and site restoration work must be done according to the regulatory requirements of your community. Permits may be required for all or part of this work. If you decide to rebuild on the site of your old home, you must rebuild in compliance with your community's floodplain management ordinance or law and other ordinances and codes, which means ensuring that the lowest floor of your new home is at or above the DFE. You can do this by elevating your new home on an extended foundation as described in Section 3.3.1 or on compacted fill dirt if your property is located in Zone A. If your property is located in Zone V area, you must elevate your home on piles or columns. A better approach is to build your home on an alternative building site outside the regulatory floodplain, where you can use standard construction practices, including the construction of a basement. Remember, if you rebuild on the same site, within the regulatory floodplain, your community's floodplain management ordinance, regulation, or provisions of the building code will not allow your new home to have a basement (as defined by the NFIP regulations) if it is located below the DFE. Figure 3-13 shows a home damaged by Hurricane Irene that is slated for demolition.

Figure 3 13. Many homes in the Town of Prattsville, NY, were slated for demolition during the recovery effort following Hurricane Irene.

The advantages and disadvantages of demolition vary depending on which of the following three options you choose:

1. Rebuilding on the existing site
2. Rebuilding on an alternative site on a different part of your property, which may be outside the regulatory floodplain
3. Moving to a home on another property, which may be outside the regulatory floodplain

CROSS REFERENCE

See Section 7.1.7 for a discussion of flood damage-resistant materials.

The advantages and disadvantages of option 1 are similar to those listed in Table 3-1 for the elevation method. The advantages and disadvantages of options 2 and 3 are the same as those listed in Table 3-3 for the relocation method, with the following exceptions: If you choose option 2, you will avoid the need to buy another lot and dispose of your existing property.

If you decide to demolish your damaged home and rebuild somewhere on your existing property (option 1 or 2 above), your costs will include tearing down the damaged home, building the new home to the community's specified elevation, reconnecting utility lines, and restoring the site around the new home. If you decide to move to a home outside the regulatory floodplain (option 3), your costs will include tearing down the damaged home, buying or building a home elsewhere, capping and abandoning the old utility lines, and restoring the old site.

The cost of tearing a home down, which is not a complex or difficult job, will be almost entirely for the disposal of the resulting debris. This cost can vary widely, depending on the amount of debris and whether a dumping fee is required at the disposal site. The major costs associated with the demolition method will be for building or buying a home and will, therefore, depend on how and where you build or on the type of home you buy. Be sure to get a complete cost estimate before you begin a demolition project. Table 3-5 shows approximate costs for tearing down your home and rebuilding on the same site.

Table 3-5. Relative Costs of Demolition and Rebuilding

Construction Type	Proposed Foundation Type	Relative Cost
Frame	Closed Foundation	Lowest
	Open Foundation	
Frame with Masonry Veneer	Closed Foundation	
	Open Foundation	
Load bearing masonry	Closed Foundation	
	Open Foundation	Highest

3.4 Floodproofing

Wet floodproofing allows floodwaters to enter your home while using various techniques to minimize flood damage and protect critical systems and contents. Wet floodproofing techniques include raising utilities and important contents to or above the flood protection level, installing and configuring electrical and mechanical systems to minimize disruptions and facilitate repairs, installing flood openings or other methods to equalize the hydrostatic pressure exerted by floodwaters, and installing pumps to gradually remove floodwater from basement areas after the flood.

The purpose of dry floodproofing your home is to make it watertight (substantially impermeable) to floods of limited duration (a few hours) and depth (typically less than 2-3 feet). Dry floodproofing reduces the potential for flood damage by reducing the probability that your home's interior will be inundated. It can be an appropriate alternative for flood mitigation when relocating or elevating buildings is not cost effective or technically feasible.

3.4.1 Wet Floodproofing

Wet floodproofing a home is modifying the uninhabited portions of the home (such as a crawlspace, basement, or other enclosure) so that floodwaters will enter but not cause significant damage to either the home or its contents. The purpose of allowing water into portions of the home is to ensure that the interior and exterior hydrostatic pressures will be equal. Allowing these pressures to equalize greatly reduces the likelihood of wall failures and structural damage. Wet floodproofing may be used when other retrofitting methods are either too costly or are not feasible. If you intend to wet floodproof your basement, a licensed engineer or design professional is needed to determine the structural integrity of the walls. Wet floodproofing is practical in only a limited number of situations. Chapter 7 presents more detailed information on wet floodproofing.

Because wet floodproofing allows floodwaters to enter the home, all construction and finishing materials below the DFE should be resistant to flood damage. For this reason, wet floodproofing is practical only for portions of a home that are not used for living space, such as a basement as defined by the NFIP regulations, an enclosure such as a walkout-on-grade basement or a crawlspace, or an attached garage. Figure 3-14 illustrates a home with a wet floodproofed subgrade basement. Wet floodproofing this home protects it from hydrostatic pressure, but not hydrodynamic pressure and floodborne debris. To minimize damages, service equipment must be elevated above the flood level and the walls of the basement must be built with flood damage-resistant materials.

Figure 3-15 illustrates a home in which the lower level was modified to create an enclosure that is built with flood damage-resistant materials, service equipment was elevated above the flood level, and the lower level is used solely for parking, access, and storage. As illustrated in Figure 3-15, openings must be placed in the walls to relieve hydrostatic pressure. If the lowest elevated floor is above the community's DFE and the enclosure is protected as described above, the home would meet the minimum requirements of the NFIP.

WARNING

Wet floodproofing mitigation methods can lead to NFIP compliance only if the area is limited to parking, access, or storage; designed to allow for automatic entry and exit of flood waters; and uses only flood damage-resistant materials below the DFE. If your home is being Substantially Improved or has been Substantially Damaged, your community's floodplain management ordinance or law will restrict your use of wet floodproofing to attached garages and enclosed areas below the BFE that are used solely for parking, building access, or storage. For more information, consult your local officials. Note that basements (any area of the building having its floor subgrade on all sides) cannot be wet floodproofed to meet NFIP requirements.

Wet floodproofing would not be practical for most slab-on-grade homes in which the living space is at or very near the ground level. Whether or not wet floodproofing is appropriate for your home will depend on the flood conditions, the flood protection elevation you have selected, the design and construction of your home, and whether you are required to bring your home into compliance because it is being Substantially Improved or has been Substantially Damaged.

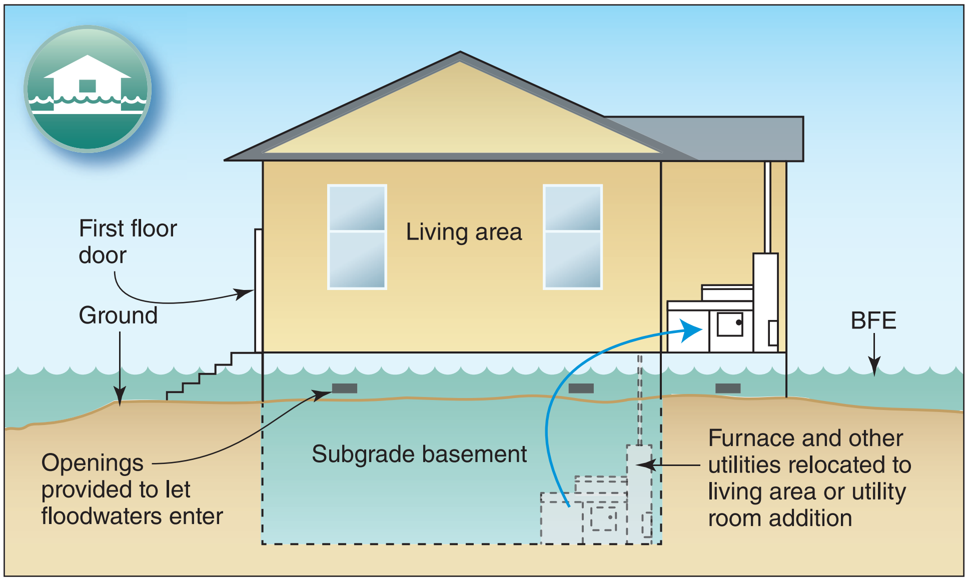
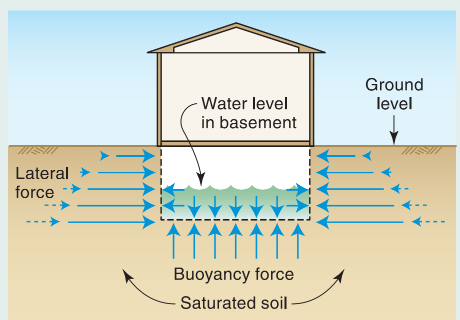


Figure 3-14. A home with a wet floodproofed subgrade basement. Note: Wet floodproofing a basement is not permitted to achieve NFIP compliance. If Substantial Improvement or Substantial Damage requirements are triggered, the basement would need to be filled.

WARNING

After floodwaters recede from around a home with a wet floodproofed basement, you will need to pump out the water that filled the basement during the flood. However, you must take certain precautions before you pump out the water. If the soil surrounding the basement walls and below the basement floor is still saturated with water, removing the water in the basement too quickly can be dangerous. As the water level in the basement drops, the outside pressure on the basement walls and floor becomes greater than the inside pressure (see figure). As a result, the walls can collapse and the floor can be pushed up or cracked (see Section 2.3.1). If you are unsure whether pumping out your basement is safe, contact a licensed dewatering contractor. Note that basements (any area of the building having its floor subgrade on all sides) cannot be wet floodproofed to meet NFIP requirements.



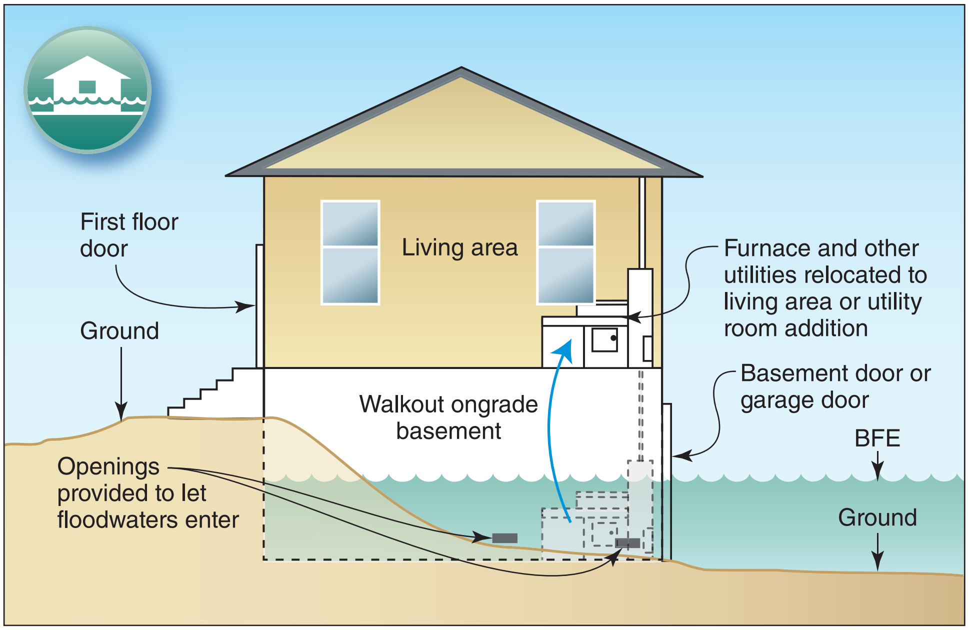


Figure 3-15. A home with a wet floodproofed enclosure. Note: Interior grade must be at or above the exterior grade along the entire length of the lowest side to prevent being a basement.

If you are considering wet floodproofing, keep the following in mind:

- Your home should have space above the DFE in which you can temporarily or permanently store items that could be damaged by floodwaters.
- If your furnace, water heater, or other service equipment is below the DFE, it should be protected as well. You may be able to move the equipment to another floor, elevate it, or protect it in place (see Chapter 9).
- Any construction and finishing materials below the DFE that are not flood damage-resistant should be removed or replaced with materials that are flood damage-resistant.
- If a flood occurs, you will not be able to live in your home as long as floodwaters remain.
- Wet floodproofing does not alleviate the threat of damage from high-velocity flood flow and wave action.
- Your community's floodplain management ordinance, regulation, or provisions of the building code will not allow you to wet floodproof your basement as defined under the NFIP if your home has been Substantially Damaged or is being Substantially Improved.

Table 3-6. Advantages and Disadvantages of Wet Floodproofing

Advantages	Disadvantages
• Reduces the risk of flood damage to a building and its contents, even with minor mitigation • Greatly reduces loads on walls and floors due to equalized hydrostatic pressure • May be eligible for flood insurance coverage of cost of relocating or storing contents, except basement contents, after a flood warning is issued • Costs less than other measures • Does not require extra land • Reduces the physical, financial, and emotional strains that accompany flood events	• Does not satisfy the NFIP requirement for bringing Substantially Damaged or Improved structures into compliance • Usually requires a flood warning to prepare the building and contents for flooding • Requires human intervention to evacuate contents from the flood-prone area • Results in a structure that is wet on the inside and possibly contaminated by sewage, chemicals, and other materials borne by floodwaters and may require extensive cleanup • Does not eliminate the need to evacuate during floods • May make the structure uninhabitable for some period after flooding • Limits the use of the floodable area • May require ongoing maintenance • May require additional costs to bring the structure up to current building codes for plumbing, electrical, and energy systems • Requires care when pumping out basements to avoid foundation wall collapse

NFIP = National Flood Insurance Program

DEFINITION

The **lowest adjacent grade** is the lowest ground surface that touches any of the exterior walls of your home.

Wet floodproofing is generally less expensive than the other flood protection methods described in this guide. Table 3-7 shows the relative approximate costs of wet floodproofing homes on basement and crawlspace foundations to heights between 2 feet and 8 feet. In a home with a basement, this height is measured from the basement floor. In a home with a crawlspace, this height is measured from the **lowest adjacent grade** to the home. The relative costs include those for adding wall openings for the entry and exit of floodwaters, installing pumps, rearranging or relocating utility systems, moving large appliances, and making it easier to clean up after floodwaters recede. The relative costs shown for basements in Table 3-7 are valid only for unfinished basements. Wet floodproofing a finished basement would involve the removal of all non-flood damage-resistant materials and replacing finish materials with flood damage-resistant materials. As a result, wet floodproofing costs for finished basements would be higher and would vary, depending on the amount of finish material to be removed or replaced.

Table 3-7. Relative Costs of Wet Floodproofing

Construction Type	Existing Foundation	Retrofit	Relative Cost
Frame, frame with masonry veneer, or load bearing masonry	Crawlspace	Wet floodproof crawlspace to a height of 2 ft to 4 ft above LAG*	Lowest
	Basement	Wet floodproof unfinished basement to a height of 2 ft to 4 ft above the basement floor	↓
	Basement	Wet floodproof unfinished basement to a height of 8 ft above the basement floor	Highest

* LAG – Lowest Adjacent Grade

3.4.2 Dry Floodproofing

In some situations, a home can be made watertight below the DFE, so that floodwaters cannot enter. This method is called "dry floodproofing." Section 7.2 presents more detailed information on dry floodproofing. Making the home watertight requires sealing the walls with waterproof coatings, impermeable membranes, or supplemental layers of masonry or concrete. Also, doors, windows, and other openings below the DFE must be equipped with permanent or removable shields, and backflow valves must be installed in sewer lines and drains.

The flood characteristics that determine whether dry floodproofing is effective are flood duration, flow velocity, and the potential for wave action and floodborne debris. You should consult a design professional before undertaking a dry floodproofing project. Figure 3-16 shows a typical dry floodproofed home and Table 3-8 presents the advantages and disadvantages of dry floodproofing.

Flood protection elevation is important to know because of the hydrostatic pressure that floodwaters exert on walls and floors. Because water is prevented from entering a dry floodproofed home, the exterior pressure on walls and floors is not counteracted as it is in a wet floodproofed home (see the discussion on pages 3-26 and 3-27). The ability of a home's walls to withstand the pressure exerted by floodwaters depends partly on how the walls are constructed. Typical frame and masonry veneer walls are likely to fail at lower flood depths, are more difficult to make

WARNING

Dry floodproofing may not be used to bring a Substantially Improved or Substantially Damaged home into compliance with your community's floodplain management ordinance or law unless the home is located in a community granted with a floodproofing exception.[1] Dry floodproofing residential buildings will not reduce flood insurance premiums.

WARNING

Even concrete block and brick walls should not be dry floodproofed above a height of 3 feet, unless an engineering analysis has been performed that shows that the walls will withstand the expected hydrostatic and hydrodynamic loads and debris impact forces. The effects of buoyancy on slab floors must also be considered.

[1] Use FEMA Form 086-0-24, Residential Basement Floodproofing Certificate: This is a form that is provided to communities participating in the National Flood Insurance Program that have been granted an exception by FEMA to allow the construction of floodproofed residential basements in Special Flood Hazard Areas.

watertight, and are more vulnerable to damage from moisture. As a result, dry floodproofing is not recommended for homes with frame and masonry veneer walls.

Even if frame and masonry veneer walls are reinforced to withstand the pressure of deeper water, the effects of buoyancy must be considered. The buoyancy force exerted by water may be enough to crack a slab floor or push it up.

WARNING

Because dry floodproofing requires human intervention, you must be willing and able to install all flood shields and carry out all other activities required for the successful operation of the dry floodproofing system. As a result, not only must you be physically capable of carrying out these activities, you must be home or able to get home in time to do so before floodwaters arrive.

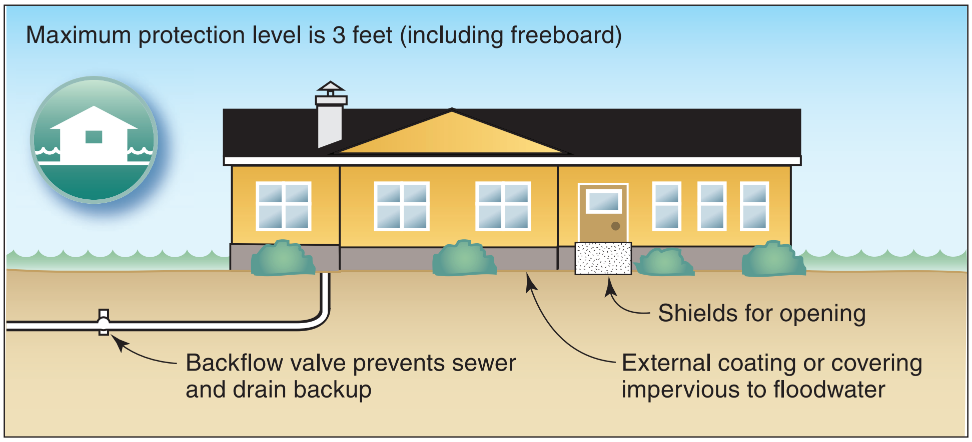


Figure 3-16. A typical dry floodproofed home.

Table 3-8. Advantages and Disadvantages of Dry Floodproofing

Advantages	Disadvantages
• Reduces the flood risk to the structure and contents if the design flood level is not exceeded • May be less costly than other retrofitting measures • Does not require the extra land that may be needed for floodwalls or reduced levees • Reduces the physical, financial, and emotional strains that accompany flood events • Retains the structure in its present environment and may avoid significant changes in appearance	• Does not satisfy the NFIP requirement for bringing Substantially Damaged or Improved residential structures into compliance • Requires ongoing maintenance • Does not reduce flood insurance premiums for residential structures • Usually requires human intervention and adequate warning time for installation of protective measures • May not provide protection if measures fail or the flood event exceeds the design parameters of the measure • May result in more damage than flooding if design loads are exceeded, walls collapse, floors buckle, or the building floats • Does not eliminate the need to evacuate during floods • May adversely affect the appearance of the building if shields are not aesthetically pleasing • May not reduce damage to the exterior of the building and other property • May lead to damage of the building and its contents if the sealant system leaks • Involves increased costs for a design professional • At times, may require invasive retrofits • Does not minimize the potential for damage from high-velocity flood flow and wave action

NFIP = National Flood Insurance Program

Duration of flooding is critical because most sealing systems will begin to allow some seepage after prolonged periods of exposure to water. If your home is in an area where floodwaters remain high for 24 hours or longer, you should use a different retrofitting method. Dry floodproofing is not appropriate in areas with a risk of high-velocity flood flow, wave action, or both. Either condition may render dry floodproofing totally ineffective and cause severe damage.

Floodproofed homes are not meant to be occupied during a flood. Flood warning time should be adequate and evacuation plans should be developed to ensure that occupants are not stranded in the home during a flood. Dry floodproofing actually increases the risk to occupants if floodwaters rise higher than the floodproofing design level because severe structural damage can occur. Further, the interior of the home will likely be subject to inundation, which may occur rapidly.

Dry floodproofing is not recommended for homes with basements. Saturated soils pressing against basement walls can damage them or cause them to fail. The buoyancy force exerted by saturated soils below the basement can cause the basement floor to fail or even push the entire home up.

Sealant systems, especially those that rely on membranes and coatings, can be punctured by ice and other types of debris. If your home is in an area where floodwaters are known to carry debris, you should select a different retrofitting method.

The total cost for dry floodproofing a home will depend largely on the size of the home, the type and condition of the wall system, the flood protection elevation, types of sealant and shield materials used, number of plumbing lines that have to be protected by check valves, and number of openings that have to be covered by shields. Table 3-9 shows approximate costs for elements of a dry floodproofing project.

Table 3-9. Relative Costs of Dry Floodproofing

Component	Height of Dry Floodproofing	Relative Cost
Waterproof Membrane (above grade)[1]	3 Feet	Lowest
Asphalt (two coats on foundation up to 2 feet below grade)[1]		
Sprayed-on Cement (above grade)[1]		Highest
Wood Flood Shield		Lowest
Metal Flood Shield		Highest

[1] Cement, asphalt, and membrane are alternative sealant methods.

3.4.3 Barrier Systems

Levees and floodwalls are types of flood protection barriers. A levee is a compacted earthen structure; a floodwall is an engineered structure usually built of concrete, masonry, or a combination of both (concrete masonry unit [CMU]). When these barriers are built to protect a home, they are usually referred to as "residential," "individual," or "onsite" levees and floodwalls. The practical heights of these levees and floodwalls are usually limited to 6 feet and 4 feet, respectively. These limits are the result of the following considerations:

- As the height of a levee or floodwall increases, so does the depth of water that can build up behind it. Greater depths result in greater water pressures, so taller levees and floodwalls must be designed and constructed to withstand the increased pressures. Meeting this need for additional strength greatly increases the cost of the levee or floodwall, usually beyond what an individual homeowner can afford.

WARNING

Levees and floodwalls may not be used to bring a Substantially Improved or Substantially Damaged home into compliance with your community's floodplain management ordinance or law and do not eliminate the insurance requirement on the home for federally backed mortgages.

- Because taller levees and floodwalls must be stronger, they usually require more space than is likely to be available on an individual lot. This is especially true of levees.
- Levees require a large land area for construction. For example, the levee in Figure 3-20 is 4 feet tall and about 27 feet wide.

Chapter 8 presents more detailed information on levees and floodwalls. Figure 3-17 shows a home protected by a levee and floodwall; Figure 3-18 shows a home protected by a levee. Remember that levees and floodwalls should be designed by a licensed engineer.

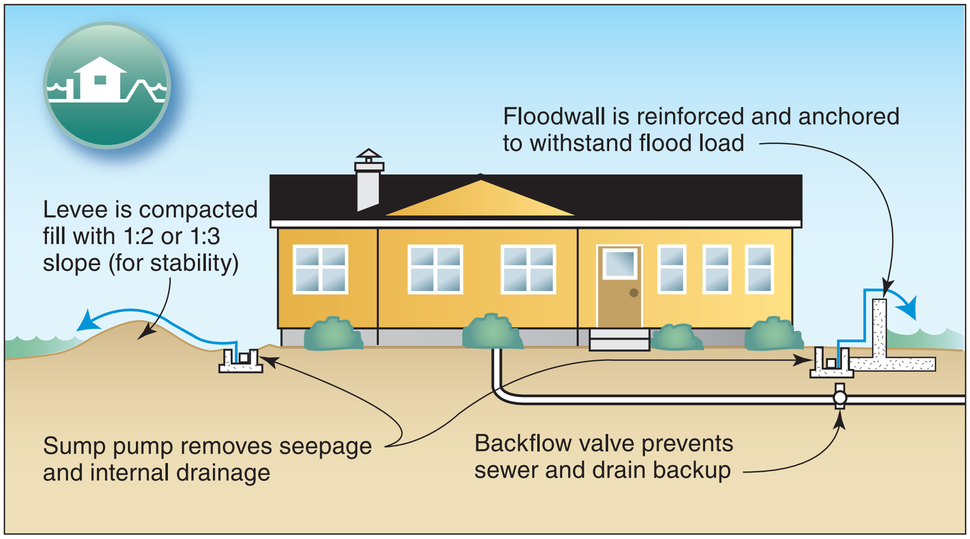


Figure 3-17. A home protected by a levee (left) and a floodwall (right).

Figure 3-18. A home protected by a levee.

Both levees and floodwalls should provide at least 1 foot of freeboard. For example, if you are building a levee to protect your home from the base flood, the top of the levee should be at least 1 foot above the BFE.

For a levee to be effective over time, it must be constructed of soils that cannot be easily penetrated by floodwaters, it must have proper side slopes for stability, and it must be periodically inspected and maintained. In areas where high-velocity flows could erode the surface of a levee, the side of the levee exposed to floodwater is usually protected with a covering of rock, referred to as **riprap**, or with other erosion-resistant material. Levees can surround a home, or they may be built only across low areas and tied into existing high ground.

DEFINITION

Riprap refers to pieces of rock or crushed stone added to the surface of a fill slope, such as the side of a levee, to prevent erosion.

A floodwall can surround a home or it can protect isolated openings, such as doors, windows, and walkout-on-grade basements, depending on flood depths, site topography, and design preferences. When built with decorative bricks or blocks or as part of garden areas, floodwalls can become attractive architectural or landscaping features. But they can also be built solely for utility, usually at a lower cost.

Because a floodwall is made of concrete or masonry rather than compacted earth, it is more resistant to erosion than a levee and generally requires less space than a levee to provide the same level of protection. But floodwalls are usually more expensive. As a result, floodwalls are normally considered only for sites where there is not enough room for a levee or where high-velocity flows may erode a levee. Also, some homeowners prefer floodwalls because they can be more aesthetically pleasing and allow for the preservation of existing site features, such as trees.

WARNING

Special design considerations are necessary when levees or floodwalls are built to protect a home with a basement. Even though the surface water is kept from coming into contact with the home, the soil below the levee or floodwall and around the home can become saturated, especially during floods of long duration. The resulting pressure on basement walls and floors can cause them to crack buckle, or collapse.

As shown in Figure 3-17, an interior drainage system, including a sump pump, must be installed in the area protected by a levee or floodwall. The purpose of the system is to remove rainwater trapped inside the protected area and, during flooding, to remove water that enters through seepage or infiltration.

Including an opening in a levee or floodwall may also be necessary to provide access for a car or other vehicle. All openings must be equipped with closures similar to those used in dry floodproofing. Installing closures over openings in levees and floodwalls requires advance warning of flooding in most cases—in other words, levees and floodwalls generally require human intervention. One exception is a low, earthen levee that can be sloped to allow vehicle access.

Table 3-10 presents the advantages and disadvantages of levees and floodwalls. Figure 3-19 shows a home protected by a floodwall.

Table 3-10. Advantages and Disadvantages of Levees and Floodwalls

Advantages	Disadvantages
• Protects the area around the structure from inundation without significant changes to the structure • Eliminates pressure from floodwaters that would cause structural damage to the home or other structures in the protected area • Costs less to build than elevating or relocating the structure • Allows the structure to be occupied during construction • Reduces flood risk to the structure and its contents • Reduces the physical, financial, and emotional strains that accompany flood events	• Does not satisfy the NFIP requirements for bringing Substantially Damaged or Improved structures into compliance • May fail or be overtopped by large floods or floods of long duration • May be expensive • Requires periodic maintenance • Requires interior drainage • May affect local drainage, possibly resulting in water problems for others • Does not reduce flood insurance premiums • May restrict access to structure • Requires considerable land (levees only) • Does not eliminate the need to evacuate during floods • May require warning and human intervention for closures • May violate applicable codes or regulations • Individual residential levees or floodwalls cannot be used to bring a home with a first floor elevation below the BFE into compliance with the NFIP • May not be ideal for homes with basements because hydrostatic pressure on below-ground portions of the home can lead to structural failures • May require a professional determination that the BFE did not increase in the project area, which could make levees and floodwalls difficult and expensive to design

NFIP = National Flood Insurance Program

NOTE

The costs for levee construction can vary greatly, depending on the distance between the construction site and the source of the fill dirt used to build the levee. The greater the distance that fill dirt must be hauled, the greater the cost.

Figure 3 19. A home protected by a floodwall designed as a landscaping feature.

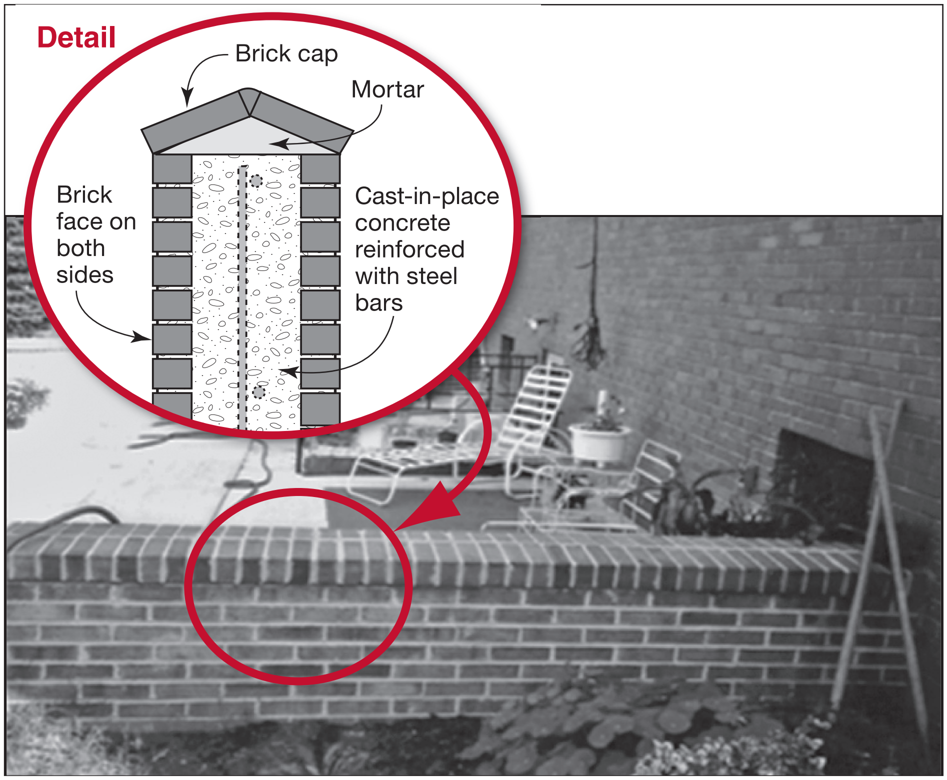


Table 3-11 shows the relative costs for levees and floodwalls of various heights. Additional costs for erosion protection using seeding or riprap, interior drainage, and installation of closures may be required for levees and floodwalls. Figure 3-20 illustrates the dimensions of these structures.

Table 3-11. Relative Costs of Levees and Floodwalls

Construction Type	Existing Foundation	Retrofit	Relative Cost
Frame, Masonry Veneer, or Masonry	Basement, Crawlspace, Open Foundation, or Slab-on-Grade	Levee constructed 2 feet above grade	Lowest
		Levee constructed 4 feet above grade	↓
		Floodwall constructed 2 feet above grade	↓
		Levee constructed 6 feet above grade	↓
		Floodwall constructed 4 feet above grade	Highest

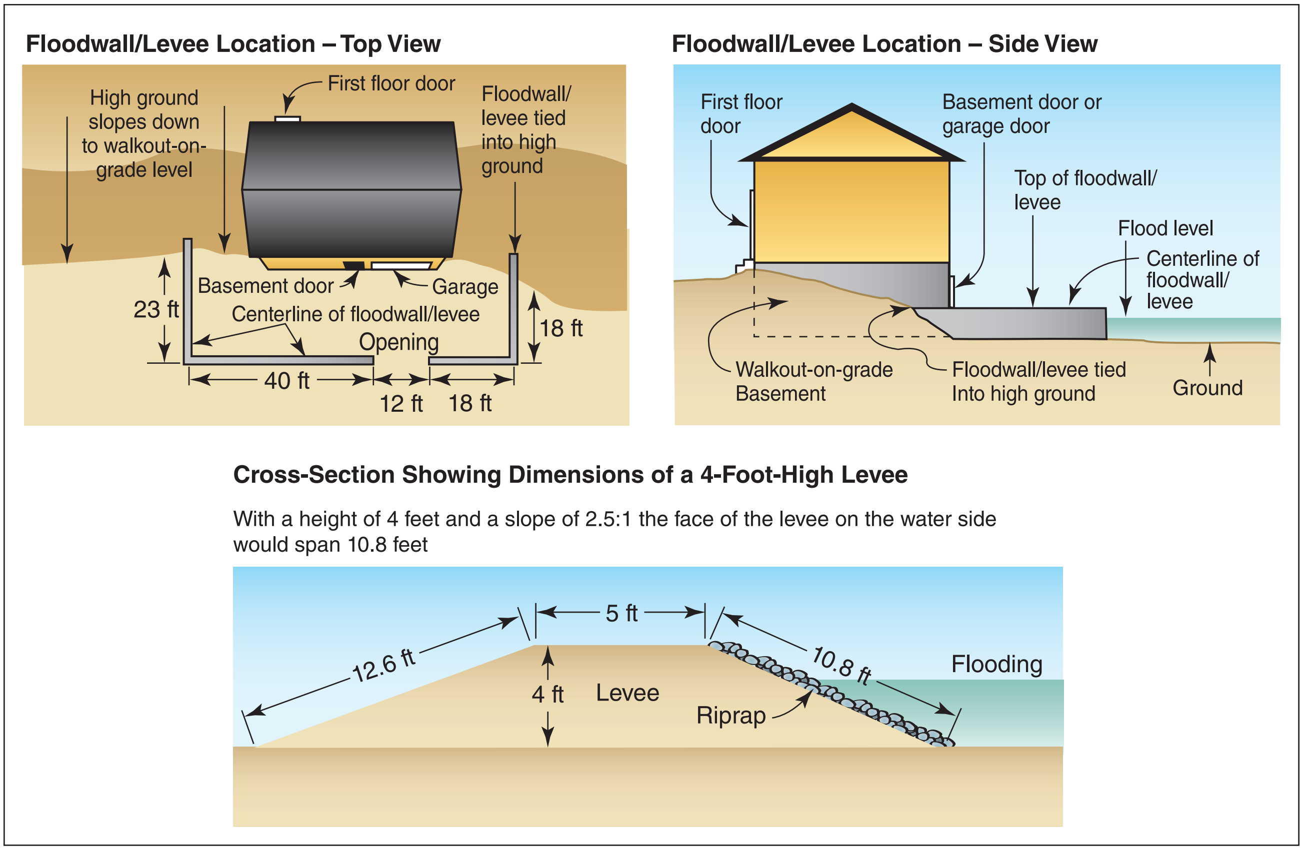


Figure 3-20. Example of floodwall and levee dimensions.

3.5 Summary

To protect your home from flooding, you may be able to use one or more of the retrofitting methods described in this chapter. However, some retrofitting methods are probably inappropriate for your home and some may not be allowed by your State or community. Also, if the Substantial Improvement and Substantial Damage requirements do not apply to your home, you may be faced with decisions about the level of protection you are willing to pay for and the level of risk you are willing to accept. Table 3-12 provides a comparison of the relative costs of each of the retrofitting methods listed in this chapter based on home construction type and foundation type.

Chapter 4 will help you decide on a method. Note that cost is not the only consideration when evaluating mitigation measures. Depending on your decision, you can move on to Chapter 5, 6, or 7 for a detailed look at your preferred method.

Table 3-12. Relative Costs of Various Retrofit Measures

Construction Type	Existing Foundation	Measure	Retrofit	Relative Cost
Frame, Masonry Veneer, or Masonry	Crawlspace or Basement	Wet Floodproofing 	Wet floodproof crawlspace to a height of 4 feet above lowest adjacent grade or wet floodproof unfinished basement to a height of 8 feet above basement floor	Lowest
Masonry Veneer or Masonry	Slab-on-Grade or Crawlspace	Dry Floodproofing 	Dry floodproof to a maximum height of 3 feet above lowest adjacent grade	
Frame, Masonry Veneer, or Masonry	Basement, Crawlspace, or Open Foundation	Barrier Systems 	Levee constructed to 6 feet above grade or floodwall constructed to 4 feet above grade	
Frame, Masonry Veneer, or Masonry	Basement, Crawlspace, or Open Foundation	Elevation 	Elevate on continuous foundation walls or open foundation	
Frame, Masonry Veneer, or Masonry	Basement, Crawlspace, or Open Foundation	Relocation 	Elevate on continuous foundation walls or open foundation	
Frame, Masonry Veneer, or Masonry	Slab-on-Grade	Elevation 	Elevate on continuous foundation walls or open foundation	
Frame, Masonry Veneer, or Masonry	Slab-on-Grade	Relocation 	Elevate on continuous foundation walls or open foundation	Highest
Frame, Masonry Veneer, or Masonry	Slab-on-Grade, Crawlspace, Basement, or Open Foundation	Demolition 	Demolish existing building and buy or build a home elsewhere	Varies