FLOOD PROOFING

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1.0 FLOOD PROOFING

1.1 Definition of Flood Proofing

Flood proofing is any combination of structural or nonstructural changes or adjustments incorporated in the design, construction, or alteration of individual buildings or properties that will reduce flood damages.

1.2 Overview of Flood-Proofing Methods

Some examples of flood proofing include the placement of walls or levees around individual buildings; elevation of buildings on fill, posts, piers, walls, or pilings; anchorage of buildings to resist floatation and lateral movement; watertight closures for doors and windows; reinforcement of walls to resist water pressure and floating debris; use of paints, membranes, and other sealants to reduce seepage of water; installation of check valves to prevent entrance of floodwaters at utility and sewer wall penetrations; and location of electrical equipment and circuits above expected flood levels.

1.2.1 Classification of Flood Proofing

Flood-proofing techniques can be classified on the basis of the type of protection that is provided as follows: (1) *permanent measures*—always in place, requiring no action if flooding occurs; (2) *contingent measures*—requiring installation prior to the occurrence of flood; and (3) *emergency measures*—improvised at the site when flooding occurs.

In the Denver metropolitan area, flood-proofing efforts should focus on permanent measures due to the rapid response of most of the Front Range stream systems. Contingent measures are more effective when combined with an early flood warning system or in areas not immediately adjacent to a stream channel.

1.2.2 FEMA Recommended Methods

The Federal Emergency Management Agency (FEMA) has published numerous references on the subject of flood proofing (FEMA 1984, 1986a, 1986b, 1991, 1993a, 1993b, 1993c, 1993d, 1993e, 1994, 1995, 1996). In several of these documents, FEMA outlines six methods of flood proofing as follows:

1. Elevation—Raising the structure so that the lowest floor is above the flood level.
2. Wet Flood Proofing—Making uninhabited portions of the structure resistant to flood damage and allowing water to enter during flooding.
3. Relocation—Moving the structure out of the floodplain to higher ground where it will not be exposed to flooding.
4. Dry Flood Proofing—Sealing the structure to prevent floodwaters from entering.
5. Levees and Floodwalls—Building a physical barrier around the structure to hold back floodwater.
6. Demolition—Tearing down the damaged structure and either rebuilding properly on the same

property or buying or building outside the floodplain.

1.3 Approach of *Manual* Relative to Flood-Proofing Guidance

Floodplain management includes all measurements for planning and actions that are needed to determine, implement, revise, and update comprehensive plans for the wise use of the floodplain and related water resources. This includes both corrective actions, as represented by most of the chapters of this *Manual*, and preventive actions as described in the POLICY and PLANNING chapters. Preventive measures cover a wide array of accepted and proven techniques ranging from floodplain regulation to flood forecasting to flood proofing. Due to the fact that flood proofing is often mentioned but little understood, this chapter is presented to assist drainage and flood control engineers in dealing effectively with existing development that is already flood prone.

1.4 Regulatory Considerations

Most regulations for flood proofing are based on the minimum standards of the National Flood Insurance Program (NFIP). The NFIP sets minimum regulatory standards for constructing, modifying, or repairing buildings located in the floodplain to keep flood losses to a minimum. The NFIP limits some flood proofing; for example, it prohibits obstructions, such as berms and floodwalls, in floodways.

The NFIP also requires flood proofing for a building that is substantially improved or substantially damaged. "Substantially damaged" is defined as "damage of any origin sustained by a structure whereby the cost of restoring the structure to its before damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred." Buildings that have been substantially damaged or are being substantially improved (renovated) must be elevated to or above the 100-year flood level. Nonresidential buildings must be elevated or dry flood proofed.

Other federal agencies, such as the U. S. Army Corps of Engineers (USACE), U. S. Geological Survey, and Natural Resources Conservation Service, also publish flood-proofing information, as do some state and local agencies. The USACE provides engineering and construction standards in the publication *Flood Proofing Regulations* (1995b). Additional USACE publications (1984, 1988, 1990, 1993, 1994, 1995a, 1996, 1998) provide information on case studies and detailed engineering applications of flood-proofing methods.

1.5 Flood Proofing In the Context of Overall Floodplain Management

Flood proofing is but one tool of an overall floodplain management strategy. With new development, the first option should always be to construct outside of the floodplain. If building outside of the floodplain is not practical for a site, then the structure should be constructed in compliance with local floodplain regulations. The remaining flood-proofing methods discussed in this chapter should be considered primarily for retrofitting existing structures.

2.0 WHEN TO FLOOD PROOF

2.1 How Flooding Can Damage Structures

To understand how flooding can damage a structure, there are six important flood characteristics: depth/elevation, flow velocity, frequency, rate of rise and rate of fall, duration, and debris load. The flood conditions at a particular site are determined largely by the combination of these characteristics.

2.1.1 Depth/Elevation of Flooding

The depth and elevation of flooding are so closely related that they can be viewed as a single characteristic for the purposes of this discussion. Flood depth is the height of the floodwater above the surface of the ground or other feature at a specific point. Flood elevation is the height of the floodwater above an established reference datum. The standard datums used by most federal agencies and many state and local agencies are the National Geodetic Vertical Datum (NGVD) and the North American Vertical Datum (NAVD); however, other datums are in use. The use of other datums is important because elevations of the ground, floodwaters, and other features cannot be meaningfully compared with one another unless they are based on the same datum.

When the elevation of the ground (or another surface such as the lowest floor of the building) and the elevation of the floodwater are both based on the same datum, the flood depth at any point is equal to the flood elevation at that point minus the elevation of the ground (or other surface) at that point. Figure FP-1 illustrates this relationship. An additional point to consider: ground elevations are established by surveys; flood elevations may be calculated, or they may be known from watermarks left by past floods.

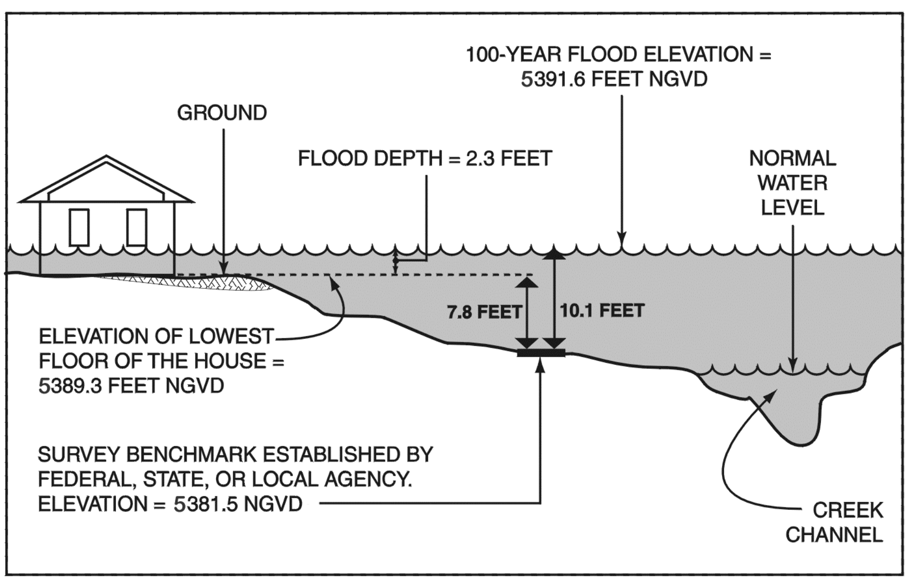

Figure FP-1—Schematic Representation of Flood Depth and Flood Elevation

The depth of flooding is important primarily because floodwaters, even when they are not moving, exert pressure on structural components such as walls and concrete floor slabs. The pressure exerted by still water is called hydrostatic pressure. It is caused by the weight of the water, so it increases as the depth of the water increases. As shown in Figure FP-2a, floodwater, including water that has saturated the soil under the building, pushes in on walls and up on floors. The upward force on floors is called buoyancy.

As shown in Figure FP-2b, water that has saturated the soil poses a special hazard for basement walls. Because hydrostatic pressure increases with the depth of the water, the pressure on basement walls is greater than the pressure on the walls of the upper floor, as indicated by the arrows in the figure. This pressure is made even greater by the weight of the saturated soil that surrounds the basement. The walls of buildings built according to standard construction practice are not designed to resist this pressure. Once the pressure exceeds the strength of the walls (including basement walls), it can push them in, cause extensive structural damage, and possibly cause the building to collapse.

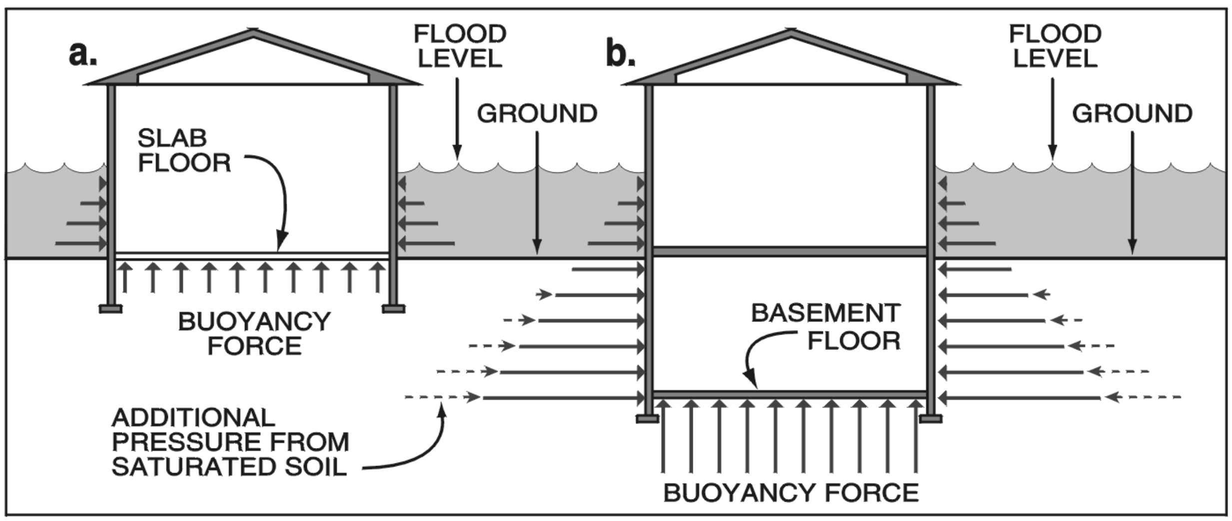

Figure FP-2 (a and b)—Hydrostatic Pressure Diagram With Dry Flood Proofing

Note that in the preceding illustration of hydrostatic pressure, no water is shown inside the building. If water is allowed to enter, the hydrostatic pressures on both sides of the walls and floor become the same, or equalized, and the walls are much less likely to fail (Figure FP-3).

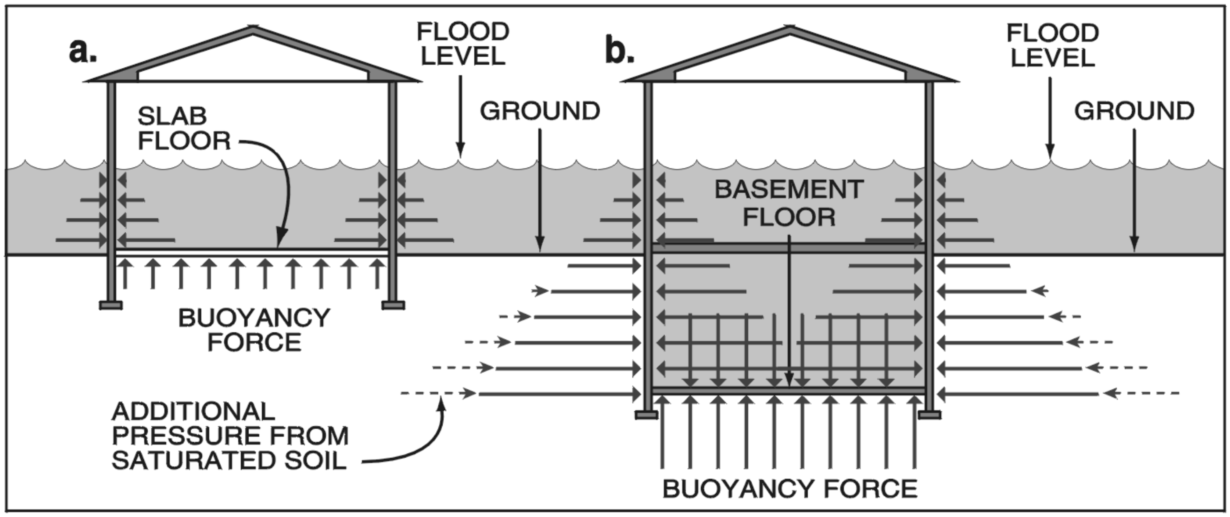

Figure FP-3—Hydrostatic Pressure Diagram With Wet Flood Proofing

2.1.2 Flow Velocity

Flow velocity is the speed at which floodwaters move. It is usually measured in feet per second (ft/sec). Flow velocities during riverine floods can easily reach 5 to 10 ft/sec, and in some situations may be even greater. Expressing velocities in ft/sec is common in floodplain studies and engineering analyses. Here, it may be helpful to relate ft/sec to a more familiar unit of measure. For example, 10 ft/sec is roughly equal to 7 miles per hour.

The velocity of riverine floodwaters depends on a number of factors; one of the most important is the slope of the stream channel and floodplain. As one might expect, floodwaters will generally move much faster along streams in steep mountainous areas than streams in flatter areas. Even within the same floodplain, however, flow velocity can still vary. As water flows over the ground, its velocity depends largely on the roughness of the ground surface. For example, water will flow more swiftly over parking lots, roads, and other paved surfaces and will flow more slowly over ground covered with large rocks, trees, dense vegetation, or other obstacles. Also, flow velocities in the floodplain will usually be higher nearer the stream channel than at the outermost fringes of the floodplain, where water may flow very slowly or not at all.

If a building is in an area where floodwaters are flowing, especially if they are moving more than about 5 ft/sec, the flow velocity is important for several reasons. Flowing water pushes harder on the walls of a building than still water. So instead of just the hydrostatic pressure caused by the weight of the floodwater resting against the walls, there is the additional pressure of moving water, referred to as hydrodynamic pressure. As water flows around the building, it pushes against the side that faces the flow (the upstream side). As it flows past the sides, it creates friction that can tear at wall coverings, such as siding. On the side of the building that faces away from the flow (the downstream side) the water may tend to create a suction that pulls on walls. In some situations, the combination of these forces can destroy one or more walls, cause the building to shift on its foundation, or even sweep the building away.

Flowing water can also cause erosion and scour. Erosion is the removal of soil that lowers the ground surface across an area. Scour is the removal of soil around objects that obstruct flow, such as foundation walls. Both erosion and scour can weaken the structure by removing supporting soil and undermining the foundation. In general, the greater the flow velocity and the larger the building, the greater the extent and depth of erosion and scour. Also, any objects being carried by floodwaters will be moving at roughly the same speed as the water. The dangers associated with these objects are discussed in Section 2.1.6.

2.1.3 Flood Frequency

Flood frequencies are usually determined through statistical and engineering analyses performed by floodplain management agencies and other organizations who need information on which to base engineering designs and flood insurance rates. The results of those analyses define the probability, expressed as a percentage, that a flood of a specific size on a specific stream will be equaled or exceeded in any year.

The 100-year flood is particularly important for homeowners because it is the basis of National Flood Insurance Program (NFIP) flood insurance rates and regulatory floodplain management requirements. In the NFIP, the 100-year flood is referred to as the base flood, the 100-year flood elevation as the base flood elevation (BFE), and the floodplain associated with the base flood as the special flood hazard area (SFHA). Other federal agencies, such as the USACE, use the 100-year flood for planning and engineering design, as do many state and local agencies.

2.1.4 Rate of Rise and Rate of Fall

Floodwaters with high flow velocities, such as those in areas of steep terrain, and water released by the failure of a dam or levee usually rise and fall more rapidly than slower-moving floodwaters, such as those in more gently sloping floodplains. In the floodplains of streams with high rates of rise, homeowners may have only a few hours' notice of a coming flood or perhaps none at all. If the flood protection method chosen depends partly on action the homeowner must take each time flooding threatens (i.e., contingent measures), warning time is especially important.

Rate of rise and rate of fall are important also because of their effect on hydrostatic pressure. As explained in the discussion of flood depth/elevation, hydrostatic pressure is most dangerous for a building when the internal and external pressures are not equalized. This situation occurs when the level of water inside is significantly higher or lower than the level outside. When floodwaters rise rapidly, water may not be able to flow into a building quickly enough for the level in the building to rise as rapidly as the level outside. Conversely, when floodwaters fall rapidly, water that has filled a building may not be able to flow out quickly enough, and the level inside will be higher than the level outside. In either situation, the unequalized hydrostatic pressures can cause serious structural damage, possibly to the extent that the building collapses.

2.1.5 Duration

Duration is related to rate of rise and rate of fall. Generally, water that rises and falls rapidly will recede more rapidly, and water that rises and falls slowly will recede more slowly.

Duration is important because it determines how long the structural members (such as the foundation, floor joists, and wall studs), interior finishes (such as drywall and paneling), service equipment (such as furnaces and hot water heaters), and building contents will be affected by floodwaters. Long periods of inundation are more likely to cause damage than short periods. In addition, long duration flooding can saturate soils (Figure FP-2), increasing the pressure on the foundation. Duration can also determine how long a building remains uninhabitable.

2.1.6 Debris Impact

Floodwaters can pick up and carry objects of all types (from small to large, from light to heavy) including trees, portions of flood-damaged buildings, automobiles, boats, storage tanks, mobile homes, and even entire buildings. Dirt and other substances such as oil, gasoline, sewage, and various chemicals can also be carried by floodwaters. All of these types of debris add to the dangers of flooding. Even when flow velocity is relatively low, large objects carried by floodwaters can easily damage windows, doors, walls, and more importantly critical structural components of a building. As velocity increases, so does the danger of greater damage from debris. If floodwaters carrying large amounts of dirt or hazardous substances enter the building, cleanup costs are likely to be higher and cleanup time greater.

2.2 When Flood Proofing is Not Appropriate

Many factors influence the decision-making process for determining the feasibility of flood-proofing options. However, there are certain situations in which flood proofing should not be considered, with the exception of relocation and/or demolition. For example, structures located within a regulatory floodway cannot be retrofitted with substantial improvements that would result in any increase in flood levels during the base flood discharge. Under these conditions, the structure should be relocated out of the floodway and, preferably, out of the floodplain.

2.3 Typical Causes of Flooding Problems

Flooding in the Denver metropolitan area typically results from heavy rains during the spring and summer months. Intense rainfall can lead to flooding in several ways and is exacerbated by the increasing percentage of impervious cover associated with urban development. The time of concentration is reduced as water is conveyed via a network of gutters and storm sewers yielding increased peak flows in the drainageways. Flooding can occur at any point in the drainage system and is aggravated if debris inhibits the flow.

2.3.1 Inadequate Street Conveyance

As discussed in the STREETS/INLETS/STORM SEWERS chapter, the minor drainage system should be designed to convey between the 2- and 10-year design storms. Over time, the street conveyance capacity can diminish due to pavement overlays reducing the gutter depth and altering the design slopes. As a result, even during minor storms, flows can pond or exceed the gutter capacity resulting in localized flooding.

2.3.2 Inadequate Storm Sewer Conveyance

Older sections of the metropolitan area predate drainage criteria. In many cases, the storm sewer capacity is limited to the 2-year or less frequency design.

2.3.3 Inadequate Drainage Channel Conveyance

Prior to current floodplain and drainage criteria, development often encroached on natural drainageways resulting in the reduced capacity of open channel conveyance. Over-bank flooding is the most dangerous type due to the combination of velocity and depth of the floodwaters.

2.3.4 Sewage Backup

Flooding can often inundate and overload sanitary sewer systems and combined sanitary/storm sewer systems. As a result, water can flow backward through sewer lines and out through toilets or floor drains. The best solution to this problem is usually to install a backflow valve.

3.0 FLOOD PROOFING METHODS

3.1 Overview of Six Methods Identified by FEMA

The following sections describe the retrofitting methods, explain how they work and where they are appropriate, and list their advantages and disadvantages.

3.1.1 Elevation

Elevating a building 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 flood protection elevation (FPE) as shown in Figure FP-4. This can be done by elevating the entire building, including the floor, or by leaving the building in its existing position and constructing a new, elevated floor within the building. The method used depends largely on construction type, foundation type, and flooding conditions.

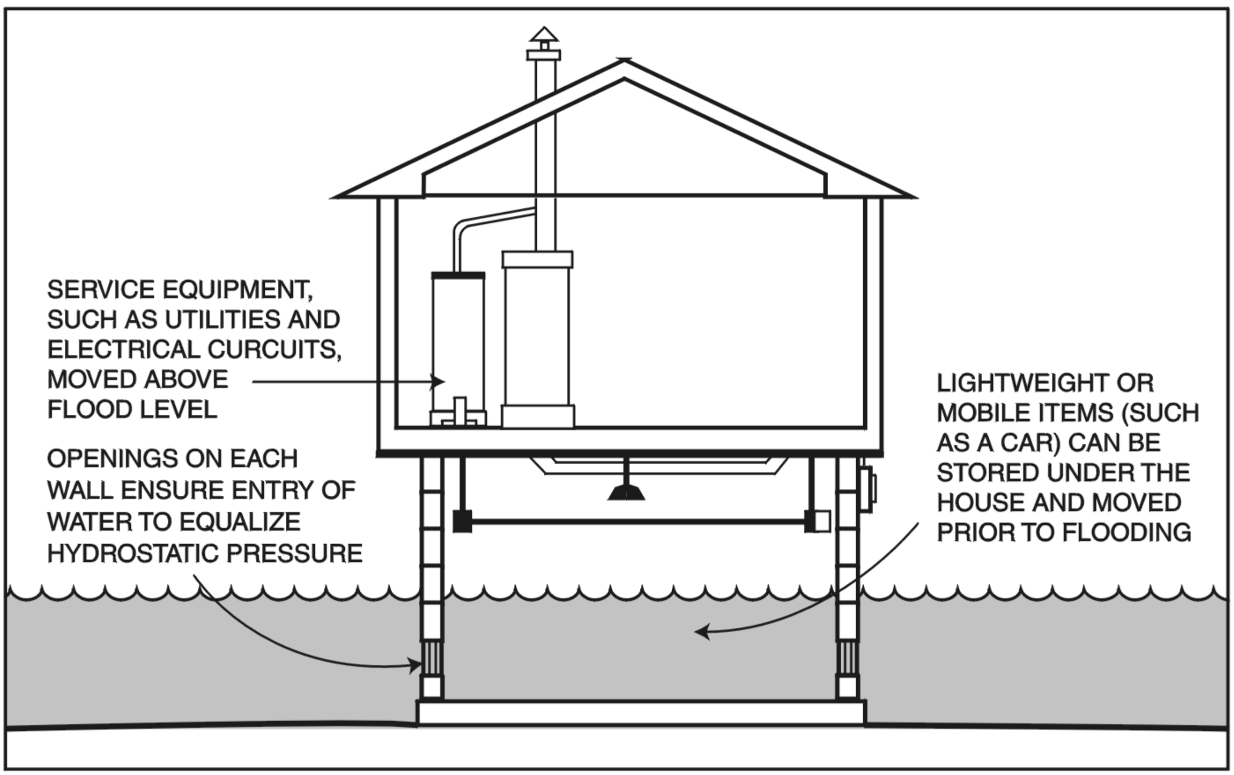

Figure FP-4—Example of a Structure Elevated on Continuous Foundation Walls

During the elevation process, most buildings 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 buildings originally built on basement, crawl space, 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 pilings.

A variation of this method is used for buildings on slab-on-grade foundations. In these buildings, the slab forms both the foundation and the floor of the building. Elevating these buildings is easier if the building is left attached to the slab foundation and both are lifted together. After the building and slab are lifted, a new foundation is constructed below the slab.

Alternative techniques are available for masonry buildings on slab-on-grade foundations. These techniques do not require the lifting of the building. Instead, they involve raising the floor within the building or moving the living space to an upper story.

Although elevating a building can help protect it from floodwaters, other hazards need to be considered before choosing this method (Table FP-1). The walls and roof of an elevated building may be more susceptible to wind forces because they are higher and more exposed. 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 and wind forces.

Table FP-1—Advantages and Disadvantages of Elevation

Advantages	Disadvantages
• Elevation to or above the FPE allows a substantially damaged or substantially improved building to be brought into compliance with the community's floodplain management ordinance or law. • Elevation reduces the flood risk to the building and its contents. • Except where a lower floor is used for storage, elevation eliminates the need to move vulnerable contents to areas above the water level during flooding. • Elevation often reduces flood insurance premiums. • Elevation techniques are well known, and qualified contractors are often readily available. • Elevation does not require the additional land that may be needed for construction of floodwalls or levees. • Elevation reduces the physical, financial, and emotional strain that accompanies floods.	• Cost may be prohibitive. • The appearance of the building may be adversely affected. • Access to the building may be adversely affected. • The building must not be occupied during a flood. • Unless special measures are taken, elevation is not appropriate in areas with high-velocity flows, waves, fast-moving ice or debris flow, or erosion. • Additional costs are likely if the building must be brought into compliance with current code requirements for plumbing, electrical, and energy systems. • Potential wind and earthquake loads must be considered.

3.1.2 Wet Flood Proofing

Wet flood proofing a building is done by modifying the uninhabited portions (such as a crawl space or an unfinished basement) so that floodwaters will enter but not cause significant damage to either the building or its contents. The purpose of allowing water into portions of the building is to ensure that the interior and exterior hydrostatic pressures will be equal (Figure FP-5). Allowing these pressures to equalize greatly reduces the likelihood of wall failures and structural damage. Wet flood proofing is often used when all other retrofitting methods are either too costly or are not feasible, but it is practical in only a limited number of situations. The advantages and disadvantages of wet flood proofing are summarized in Table FP-2.

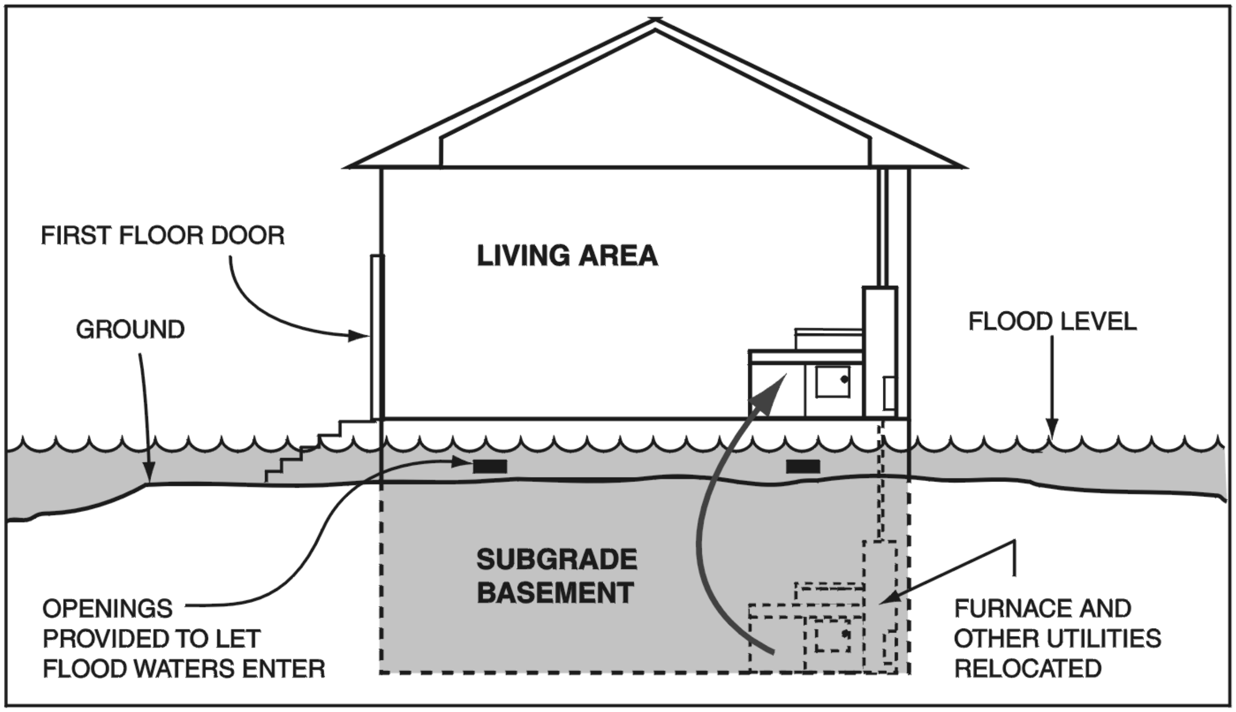

Figure FP-5—Example of a Building With a Wet Flood-Proofed Subgrade Basement

Because wet flood proofing allows floodwaters to enter the building, all construction and finishing materials below the FPE must be resistant to flood damage. For this reason, wet flood proofing is practical only for portions of a building that are not used for living space, such as a basement as defined by the NFIP regulations, a walkout-on-grade basement, crawl space, or attached garage. It would not be practical for most slab-on-grade buildings, in which the living space is at or very near the ground level. Whether or not wet flood proofing is appropriate for a building will depend on the flood conditions, the FPE selected, the design and construction of a building, and whether the building has been substantially damaged or is being substantially improved.

Table FP-2—Advantages and Disadvantages of Wet Flood Proofing

Advantages	Disadvantages
• No matter how small the effort, wet flood proofing can, in many instances, reduce flood damage to a building and its contents. • Because wet flood proofing allows internal and external hydrostatic pressures to equalize, the loads on walls and floors will be less than in a dry flood-proofed building (discussed later in this section). • Costs for moving or storing contents (except basement contents) after a flood warning is issued are covered by flood insurance in some circumstances. • Wet flood-proofing measures are often less costly than other types of retrofitting. • Wet flood proofing does not require the additional land that may be needed for floodwalls and levees (discussed later in this section). • The appearance of the building is usually not adversely affected. • Wet flood proofing reduces the physical, financial, and emotional strains that accompany floods.	• Wet flood proofing may be used to bring a substantially damaged or substantially improved building into compliance with a community's floodplain management ordinance or law <u>only</u> if the areas of the building below the FPE are used solely for parking, storage, or building access. • Preparing the building and its contents for an impending flood requires human intervention and adequate warning time. • The building will get wet inside and possibly be contaminated by sewage, chemicals, and other materials borne by floodwaters. Extensive cleanup may be necessary. • The building must not be occupied during a flood, and it may be uninhabitable for some time afterward. • It will be necessary to limit the uses of the floodable area of the building. • Periodic maintenance may be required. • Pumping floodwaters out of a wet flood-proofed basement too soon after a flood may lead to structural damage.* • Wet flood proofing does nothing to minimize the potential damage from high-velocity flood flow and wave action.

* **WARNING.** After floodwaters recede from the area around a building with a wet flood-proofed basement, the owner will usually want to pump out the water that filled the basement during the flood. If the soil surrounding the basement walls and below the basement floor is still saturated with water, however, 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 flood becomes greater than the inside pressure. As a result, the walls can collapse and the floor can be pushed up or cracked.

<u>3.1.3 Dry Flood Proofing</u>

In some situations, a building can be made watertight below the FPE, so that floodwaters cannot enter. This method is called dry flood proofing. Making the building 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 FPE must be equipped with permanent or removable shields, and backflow valves must be installed in sewer lines and drains (Figure FP-6). The flood characteristics that affect the success of dry flood proofing are flood depth, flood duration, flow velocity, and the potential for wave action and flood-borne debris.

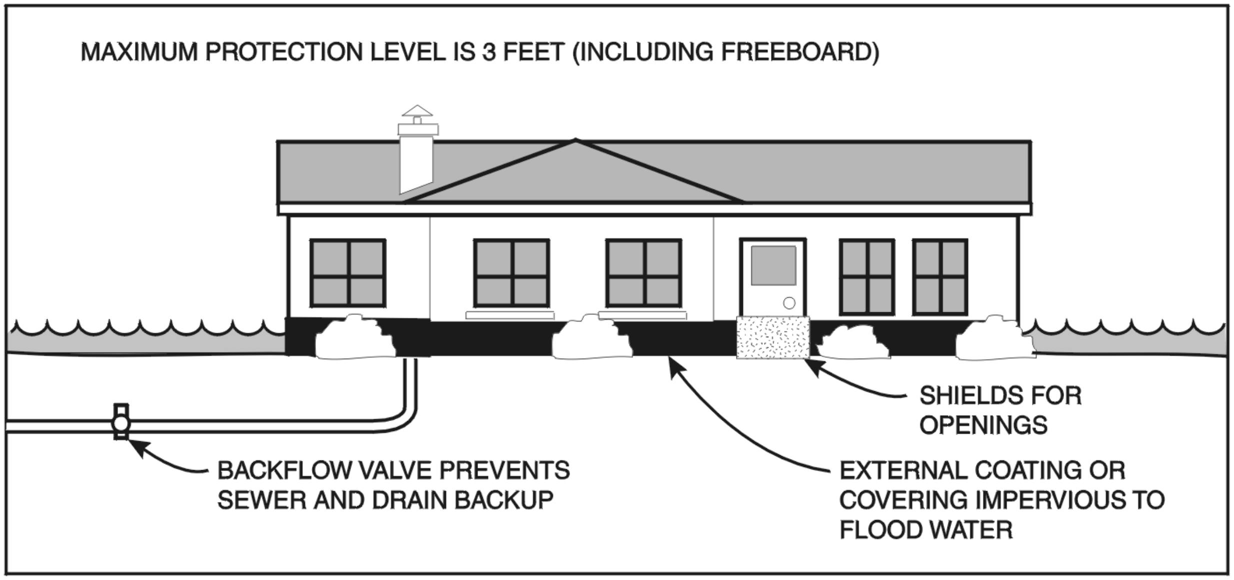

Figure FP-6—Example of a Dry Flood-Proofed House

Flood depth is important because of the hydrostatic pressure that floodwaters exert on walls and floors. Because water is prevented from entering a dry flood-proofed building, the exterior pressure on walls and floors is not counteracted as it is in a wet flood-proofed building. The ability of building walls to withstand the pressure exerted by floodwaters depends partly on how the walls are constructed. Typical masonry and masonry veneer walls, without reinforcement, can usually withstand the pressure exerted by water up to about 3 feet deep. When flood depths exceed 3 feet, unreinforced masonry and masonry veneer walls are much more likely to crack or collapse. An advantage of masonry and masonry veneer walls is that their exterior surfaces are resistant to damage by moisture and can be made watertight relatively easily with sealants. In contrast, typical frame walls are likely to fail at lower flood depths, are more difficult to make watertight, and are more vulnerable to damage from moisture. As a result, wet flood proofing is not recommended for buildings with frame walls that will be damaged by moisture.

Dry flood proofing may not be used to bring a substantially damaged or substantially improved building into compliance with a community's floodplain management ordinance or law. The advantages and disadvantages of dry flood proofing are summarized in Table FP-3.

Table FP-3—Advantages and Disadvantages of Dry Flood Proofing

Advantages	Disadvantages
• Dry flood proofing reduces the flood risk to the building and its contents. • Dry flood proofing may be less costly than other retrofitting methods. • Dry flood proofing does not require the additional land that may be needed for levees and floodwalls (discussed later in this chapter). • Dry flood proofing reduces the physical, financial, and emotional strains that accompany floods.	• Dry flood proofing may not be used to bring a substantially damaged or substantially improved building into compliance with a community's floodplain management ordinance or law. • Ongoing maintenance is required. • Flood insurance premiums are not reduced for residential structures. • Installing temporary protective measures, such as flood shields, requires human intervention and adequate warning time.* • If the protective measures fail or the FPE is exceeded, the effect on the building will be the same as if there were no protection at all. • If design loads are exceeded, walls may collapse, floors may buckle, and the building may even float, potentially resulting in more damage than if the building was allowed to flood. • The building must not be occupied during a flood. • Flood shields may not be aesthetically pleasing. • Damage to the exterior of the building and other property may not be reduced. • Shields and sealants may leak, which could result in damage to the building and its contents. • Dry flood proofing does nothing to minimize the potential damage from high-velocity flood flow and wave action.

* **WARNING.** Because dry flood proofing requires human intervention, one must be willing and able to install all flood shields and carry out all other activities required for the successful operation of the dry flood-proofing system. As a result, not only must one be physically capable of carrying out these activities, one must be in the building or able to go there in time to do so before floodwaters arrive.

3.1.4 Relocation

Moving a building to high ground, outside the flood hazard area, is the most effective of the retrofitting methods described in this *Manual*. Retrofitting literature commonly refers to this method as relocation. When space permits, it may even be possible to move a building to another location on the same piece of property.

Relocating a building usually involves jacking it up and placing it on a wheeled vehicle, which delivers it to the new site. The original foundation cannot be moved, so it is demolished and a new foundation is built at the new site. The building is installed on the new foundation and all utility lines are connected.

Relocation is particularly appropriate in areas where the flood hazard is severe. Relocation is also appropriate for those who want to be free of worries about damage from future floods that may exceed a selected FPE.

Although similar to elevation, relocation requires additional steps that usually make it more expensive. These include moving the building, 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 properly capping and abandoning old utility lines). The advantages and disadvantages of relocation are summarized in Table FP-4.

Table FP-4—Advantages and Disadvantages of Relocation

Advantages	Disadvantages
• Relocation allows a substantially damaged or substantially improved building to be brought into compliance with a community's floodplain management ordinance or law. • Relocation significantly reduces flood risk to the building and its contents. • Relocation can either eliminate the need to purchase flood insurance or reduce the amount of the premium. • Relocation techniques are well known, and qualified contractors are often readily available. • Relocation reduces the physical, financial, and emotional strains that accompany flood events.	• Cost may be prohibitive. • A new site (preferably outside the flood hazard area) must be located and purchased. • The flood-prone lot on which the building was located must be sold or otherwise disposed of. • Additional costs are likely if the building must be brought into compliance with current code requirements for plumbing, electrical, and energy systems.

3.1.5 Levees and Floodwalls

Levees and floodwalls are types of flood protection barriers. A levee is typically a compacted earthen structure; a floodwall is an engineered structure usually built of concrete, masonry, or a combination of both (Figure FP-7). When these barriers are built to protect a building, they are usually referred to as residential, individual, or on-site 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.

- Because taller levees and floodwalls must be stronger, they must also be more massive, so they usually require more space than is likely to be available on an individual lot. This is especially true of levees.

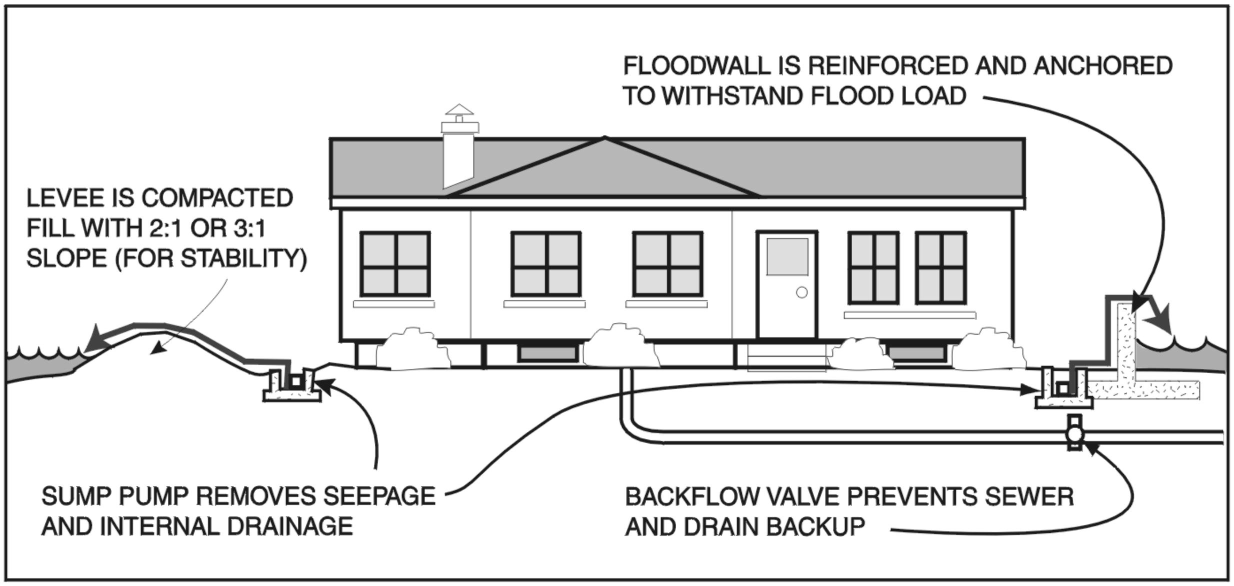

Figure FP-7—Example of Levee and Floodwall Protection

Both levees and floodwalls should provide at least 3 feet of freeboard. For example, if building a levee to protect a building from the base flood, the top of the levee should be 1 foot above the FPE.

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 flow velocities could erode the surface of a levee, the side of the levee exposed to floodwater is usually protected with riprap or with other erosion-resistant material. Levees can surround a building, or they may be built only across low areas and tied into existing high ground.

A floodwall can surround a building, or, depending on flood depths, site topography, and design preferences, it can protect isolated openings such as doors, windows, and basement entrances, including entry doors and garage doors in walkout-on-grade basements. 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 much 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 that provides the same level of protection; however, 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 flow velocities 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.

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.

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

3.1.6 Demolition

Demolition, as a retrofitting method, is tearing down a damaged building and either rebuilding properly somewhere on the same property or moving to a building on other property outside the regulatory floodplain. This retrofitting method may be the most practical of all those described in this *Manual* when a building has sustained extensive damage, especially severe structural damage.

Whether rebuilding or moving, the damaged building must be torn down and the site restored. Site restoration usually involves filling in a basement, grading, and landscaping. As a result, the services of a demolition contractor will probably be needed.

All demolition, construction, and site restoration work must be done according to the regulatory requirements of the community. Permits may be required for all or part of this work. If the new structure is built on the site of the old building, it must be rebuilt properly, which means ensuring that the lowest floor of the new building is at or above the FPE and that the new building is located outside the floodway. This can be accomplished by elevating the new building on an extended foundation as described in Section 3.1.1 or on compacted fill dirt. If the property includes an alternative building site outside the regulatory floodplain, a better approach is to build on that site, where standard construction practices, including the construction of a basement, can be used. If the building is reconstructed on the existing site within the regulatory floodplain, the community's floodplain management ordinance or law will not allow the new building to have a basement (as defined by the NFIP regulations).

The advantages and disadvantages of demolition depend on the decision of where to rebuild the structure (Table FP-5). If one of the flood-proofing methods is used, such as relocation or elevation, then the advantages and disadvantages of those methods will apply.

Table FP-5—Advantages and Disadvantages of Levees and Floodwalls

Advantages	Disadvantages
• The building and the area around it will be protected from inundation, and no significant changes to the building will be required. • Floodwaters cannot reach the building or other structures in the protected area and, therefore, will not cause damage through inundation, hydrodynamic pressure, erosion, scour, or debris impact. • The building can be occupied during construction of levees and floodwalls. • Levees and floodwalls reduce the flood risk to the building and its contents. • Levees and floodwalls reduce the physical, financial, and emotional strains that accompany flood events.	• Levees and floodwalls may not be used to bring a substantially damaged or substantially improved building into compliance with a community's floodplain management ordinance or law. • Cost may be prohibitive. • Periodic maintenance is required. • Human intervention and adequate warning time are required to close any openings in a levee or floodwall. • If a levee or floodwall fails or is overtopped by floodwaters, the effect on the building will be the same as if there were no protection at all. • An interior drainage system must be provided. • Local drainage can be affected, possibly creating or worsening flood problems for others. • The building must not be occupied during a flood. • Access to the building may be restricted. • Levees and floodwalls do not reduce flood insurance rates. • Floodplain management requirements may make levees and floodwalls violations of codes and/or regulations. • A large area may be required for construction, especially for levees. • Hydrostatic pressure on below-ground portions of a building may still be a problem, so levees and floodwalls are not good retrofitting methods for buildings with basements.

3.2 Engineering Aspects

Engineering aspects of flood proofing include evaluating the site and building characteristics, determining the flooding characteristics, and analyzing the potential loads on the structure during a flood event.

3.2.1 Analysis of Flood Hazards

Determining the potential depth of flooding is the first and most logical step in assessing flood hazards, since it is often the primary factor in evaluating the potential for flood damage. The depth of flooding is also critical in determining the extent of retrofitting that will be needed, and which method(s) will be the most appropriate for a given site. Detailed flood information is given in Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs) where such studies are available, and can be obtained from the District or local community in the form of Flood Hazard Area Delineations (FHADs).

The next step is to calculate the forces acting upon a structure during a flood. These forces include hydrostatic, hydrodynamic, and impact loads. Hydrostatic forces include lateral water pressure, saturated soil pressures, combined water and soil pressures, equivalent hydrostatic pressures due to low velocity flows (< 10 ft/sec), and buoyancy pressures. Hydrodynamic forces consist of frontal impact by the mass of moving water against the projected width and height of the obstruction represented by the structure, drag effect along the sides of the structure, and eddies or negative pressures on the downstream side of the structure. Impact loads are imposed on the structure by objects carried by moving water.

3.2.2 Site Characteristics

Important site characteristics to evaluate include the location of the structure relative to sources of potential flooding and geotechnical considerations. The site location should be evaluated with respect to mapped floodplains and floodways and the potential for local flooding from stormwater conveyance elements.

Soil properties during conditions of flooding are important factors in the design of any surface intended to resist flood loads. These properties include saturated soil pressures, allowable bearing capacity, potential for scour, frost zone location, permeability, and shrink-swell potential.

3.2.3 Building Characteristics

The building should be evaluated with respect to the type of construction and the condition of the structure. The type of foundation, foundation materials, wall materials, and the method of connection all play a role in deciding which retrofitting method will be most applicable. Operations involving a building in poor condition may easily wind up further damaging the building and costing more than its original value.

3.3 Selection of Flood-Proofing Techniques

In addition to the engineering aspects, the selection of the flood-proofing technique is a function of several factors that are dependent on the owner of the structure.

3.3.1 Regulatory Considerations

Federal, state, and local regulations may restrict the choice of retrofitting measures. Such regulations may include state and local building codes, floodplain management ordinances or laws, zoning ordinances, federal regulations concerning the alteration of buildings classified as historic structures, deed restrictions, and the covenants of homeowners associations.

State and local regulations may require that a retrofitted building be upgraded to meet current code requirements that were not in effect when the building was built. Portions of the electrical, plumbing, and heating/ventilation/air conditioning systems could be affected. For example, the electrical panel might have to be upgraded from fuses to circuit breakers. These changes are required for the safety of the homeowner. Other code-required upgrades include those necessary for increased energy efficiency. Any required upgrade can add to the scope and cost of the retrofitting project.

3.3.2 Appearance

The final appearance of a building and property after retrofitting will depend largely on the retrofitting method used and the FPE. For example, elevating a building several feet will change its appearance much more than elevating it only 1 or 2 feet, and a building elevated on an open foundation will not look the same as one elevated on extended foundation walls. However, a change in appearance will not necessarily be a change for the worse.

3.3.3 Accessibility

Accessibility refers to how easy or difficult it is to routinely reach and enter the building after the retrofitting project is completed. The retrofitting methods described in this *Manual* affect accessibility in different ways. For example, elevating a building will usually require the addition of stairs, which may be unacceptable to some. Wet flood proofing will have little, if any, effect on accessibility. The effect of relocation on accessibility will depend on the location and configuration of the new site.

3.3.4 Human Intervention Required

For retrofitting methods that require human intervention, owners must be willing, able, and prepared to take the necessary action, such as operating a closure mechanism in a floodwall or placing flood barriers across the doors of a dry flood-proofed building. Also, the owner must always have adequate warning of a coming flood and must be present or near enough to reach the building and take the necessary action before floodwaters arrive. If these conditions cannot be met, retrofitting methods that require human intervention should be eliminated from consideration.

3.3.5 Benefit/Cost Analysis

The cost of retrofitting will depend largely on the retrofitting method used and the FPE. For some methods, the construction type (frame, masonry, etc.) and foundation type (crawl space, slab, etc.) will also affect the cost. In general, costs will increase as the FPE increases, but there may be tradeoffs between alternative methods. For example, elevating may be less expensive than relocating when a building is raised only 1 or 2 feet but may become more expensive at greater heights. The benefits considered in a flood-proofing measure are the future damages and losses that are expected to be avoided as a result of the measure.

3.3.6 Other

Building owners may need to consider other factors, such as the availability of federal, state, and local financial assistance; the current value of the building versus the inconvenience and cost of retrofitting; the amount of time required to complete the retrofitting project; and the need to move out of the building during construction (including the availability and cost of alternative housing).

4.0 PROVIDING ASSISTANCE TO PROPERTY OWNERS

4.1 Decision Making Process for Property Owners

The decision of which flood-proofing method to use will be based primarily on legal requirements, the technical limitations of the methods, and cost. Other considerations might include such things as the appearance of the building after retrofitting and any inconvenience resulting from retrofitting.

4.1.1 Determine Flood Hazards

Information about flooding in the area is available from the District and local officials. Local officials, design professionals, and contractors can use this information, along with the flood hazard information developed by FEMA and other agencies and organizations, to provide advice about retrofitting options.

4.1.2 Inspect Structure

The structure should be inspected to determine the construction method and the type of foundation. Four characteristics of a building that are particularly important in retrofitting are construction type, foundation type, lowest floor elevation, and condition. Key to the inspection is performing a "Low Point of Entry" determination as illustrated in Figure FP-8.

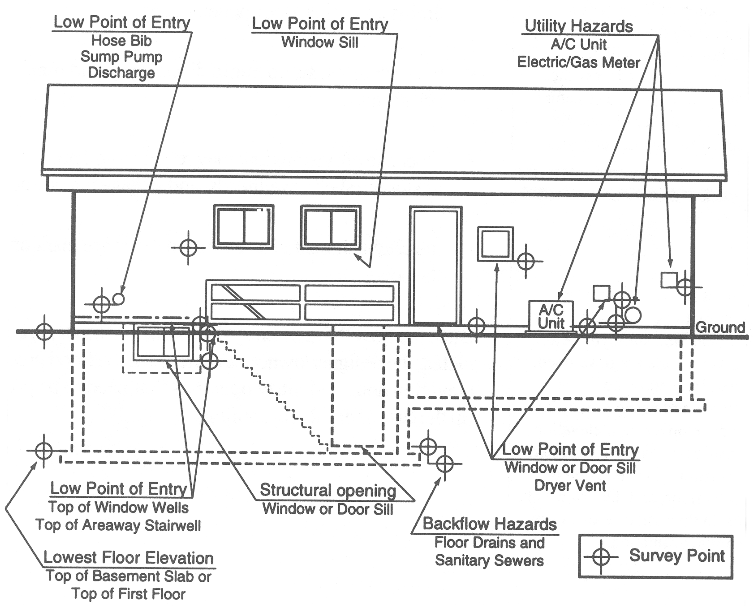

Figure FP-8—Example of a Low Point of Entry Survey

4.1.3 Contact Local Officials

The District and local officials have copies of the FIS and FIRM published for the community by FEMA. District or community officials can determine whether a building is in the regulatory floodplain and, if so, the FPE at the location of the building.

Local officials will provide federal, state, and local regulations, codes, and other requirements that can determine what retrofitting methods will be allowed. They can also provide information about federal, state, and local programs that provide financial assistance for homeowner retrofitting projects. If the property is 50 or more years old and receiving federal financial assistance for a retrofitting project, then the State Historic Preservation Office should also be contacted.

4.1.4 Consult With Professionals

The owner of a structure that needs flood proofing will need to consult with a design professional and a contractor in order to choose the appropriate flood-proofing method and ensure that the method is properly constructed. Table FP-6 shows the types of contractors and design professionals that may be required for each of the retrofitting methods.

4.2 Potential Sources of Financial Assistance at Federal, State, and Local Levels

FEMA and other federal agencies have a wide array of financial assistance programs that help states, communities, and individual property owners mitigate the negative effects of flood hazards. Property owners may be eligible to receive financial assistance through one or more of these programs that will help pay for the retrofitting project. If a presidential declaration of a major disaster has been issued for the area, property owners should seek information from FEMA and the state and local government representatives supporting the post-disaster recovery of the community.

The community's floodplain management ordinance or law includes requirements concerning construction in the community's regulatory floodplain. These requirements apply not only to new buildings but also to existing buildings that have been substantially damaged or that are being substantially improved. If the structure falls into one of the latter two categories, one of the following will be required:

- Elevate the building so that its lowest floor is at or above the FPE (Elevation).
- Move the building out of the regulatory floodplain (Relocation).
- Wet flood proof the part of the building that is below the FPE (Wet Flood Proofing). (This alternative is allowed only if the part of the building that is below the FPE is used solely for parking, storage, and building access and is not a basement as defined by the NFIP.)

Table FP-6—Requirements for Contractor and Design Professional Services

Method	Need for Contractor and/or Design Professional	Primary Services
Elevation	Design Professional	Evaluating the condition, stability, and strength of the existing foundation to determine whether it can support the increased load of the elevated building, including any wind and seismic loads
	Contractor: Building Elevation Contractor	Disconnecting utilities, jacking up the building, increasing the height of the foundation, and connecting utilities
Wet Flood Proofing	Design Professional	Designing any necessary replacements of vulnerable structural materials and relocated utility systems
	Contractor: General Construction Contractor	Replacing vulnerable structural and finishing materials below the FPE with flood-resistant materials, raising utilities and appliances to a location above the FPE, and installing openings required to allow the entry of floodwaters
Relocation	Design Professional	Designing any new building, foundation, and site improvements that may be required, such as new utility systems
	Contractor: Building Moving Contractor	Jacking up the building, moving it to the new site, and installing it on the new foundation
	Contractor: General Construction Contractor	Preparing the new site (including grading, foundation construction, and utilities) and cleaning up the old site (including demolition)
Dry Flood Proofing	Design Professional	For masonry walls to be dry flood proofed higher than 3 feet and for masonry veneer or frame walls to be dry flood proofed higher than 2 feet, evaluating the condition, stability, and strength of the existing walls to determine whether they can withstand the pressure from floodwaters at the FPE; designing or selecting flood shields for openings
	Contractor: General Construction Contractor	Applying waterproof sealants and membranes, installing flood shields over openings below the FPE, installing backflow valves in sewer and water lines, and, if necessary, bracing or modifying walls so that they can withstand the pressure from floodwaters at the FPE
Levees and Floodwalls	Design Professional	Assessing the adequacy of soils at the site and preparing the engineering design to ensure that the levee or floodwall, including any closures required, will be structurally stable under the expected flood loads and will be able to resist erosion, scour, and seepage
	Contractor: General Construction Contractor	Constructing the levee or floodwall
Demolition	Design Professional	Designing any new building, foundation, and site improvements that may be required, such as new utility systems
	Contractor: Demolition Contractor	Disconnecting and capping utility lines, tearing down the damaged building, hauling away debris, and cleaning up the old site
	Contractor: General Construction Contractor	Building the new building on the new site (May also be able to do all demolition work)

Communities with more restrictive floodplain management ordinances or laws may require a greater level of protection.

Although the substantial damage/substantial improvement requirement helps protect lives and property, it has at times placed an additional burden on property owners who were trying to repair their damaged buildings. Under the original terms and conditions of the NFIP Standard Flood Insurance Policy (SFIP), the owner of a substantially damaged building was reimbursed for the costs of repairing the damage but not for the costs of complying with state and local requirements concerning substantially damaged structures. For example, the homeowner would not have been reimbursed for the cost of elevating the building, even though state or local ordinances or laws required elevating.

In 1997, to provide relief for the owners of houses substantially damaged by flooding, Congress authorized the inclusion of Increased Cost of Compliance (ICC) coverage in the SFIP. With this change in effect, the SFIP reimburses homeowners not only for the cost of repairing flood damage but also for the additional cost, up to a maximum amount stated in the SFIP, of meeting certain state and local floodplain management requirements concerning substantial damage and repetitive losses. Other sources of assistance include:

- Small Business Administration (SBA)—In areas declared a major disaster area by the President, the SBA provides low-interest disaster assistance loans to individuals for both businesses and private residences. These loans cover the cost of rebuilding a damaged building, including the cost of bringing the building into compliance with applicable ordinances and laws. The loans can pay for retrofitting of substantially damaged buildings required by ordinances or laws (including elevating flood-prone buildings and rebuilding badly damaged flood-prone buildings at an alternative location), as well as some mitigation projects that are not required by ordinances or laws. At the applicant’s request, the amount of the loan may be increased by up to 20 percent for hazard mitigation measures not required by the community’s ordinances or laws.

- Department of Housing and Urban Development (HUD)—In an area declared a major disaster area by the President, HUD may provide additional, or allow for the reprogramming of existing, community development block grants. If a community wishes, these grants may be used for retrofitting substantially damaged or substandard buildings (including elevating flood-prone buildings and acquiring badly damaged flood-prone buildings).

- U.S. Army Corps of Engineers (USACE)—The USACE has the statutory authority to participate in flood protection projects that may include residential retrofitting (including elevating flood-prone buildings and acquiring badly damaged flood-prone buildings).

- Natural Resources Conservation Service (NRCS)—The NRCS has the statutory authority to participate in small watershed flood protection projects that may include residential retrofitting.

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