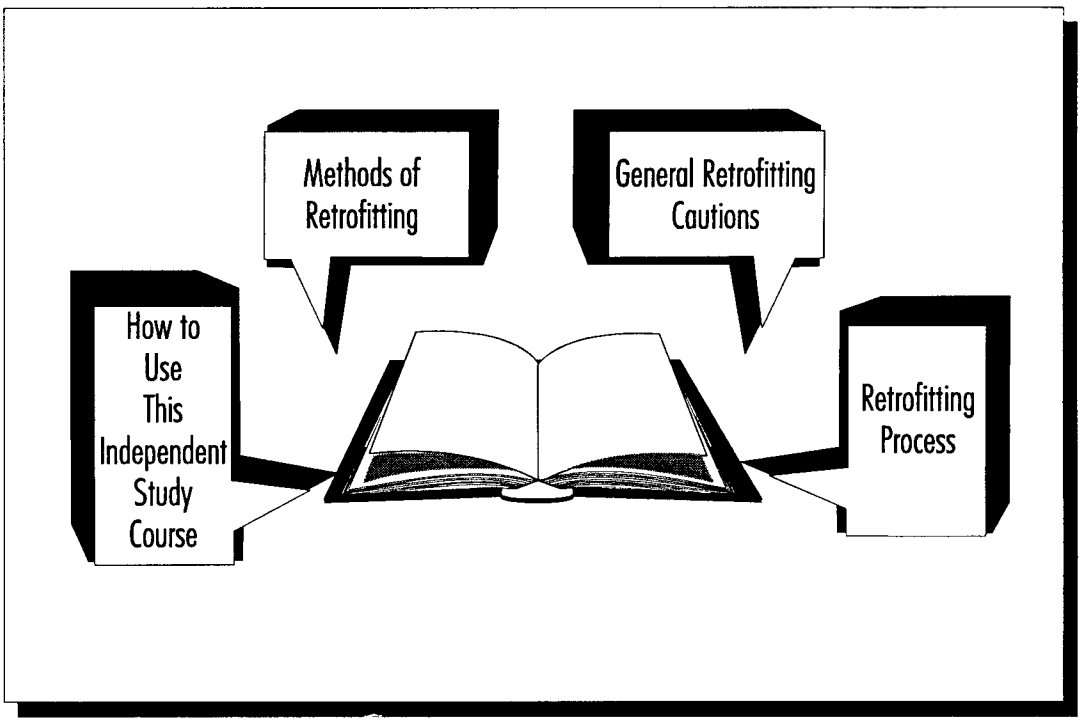
CHAPTER I

INTRODUCTION TO RETROFITTING



Featuring:

How to Use This Independent Study Course
Methods of Retrofitting
General Retrofitting Cautions
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Chapter I

INTRODUCTION TO RETROFITTING

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Chapter I: Introduction to Retrofitting

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PROFICIENCY CHECK

Answer the questions below to the best of your ability. When you are finished, turn the page to check your answers. If you have answered the questions thoroughly, you may turn to the end of this chapter and answer the summary questions.

Suppose you are meeting with a homeowner whose home has recently been flooded. Use the space below to plan your discussion with the homeowner about the concept of retrofitting.

1. What is retrofitting?

2. What are the retrofitting options called and what does each involve?

3. What are the general cautions regarding retrofitting?

4. List the sequence of steps involved in the implementation of any retrofitting option and tell the homeowner about the role he or she will play.

PROFICIENCY CHECK ANSWERS

Your answers should include most of the following information.

1. Retrofitting involves any combination of adjustments or additions to features of an existing structure that are intended to eliminate or reduce the possibility of flood damage.

2. Examples of retrofitting measures include:

   - Elevating a structure so that the lowest floor is at or above the designated flood protection level to prevent floodwaters from reaching damageable portions;
   - Relocating the structure to a place that is less prone to flooding and flood-related hazards, such as erosion;
   - Dry floodproofing, which involves sealing that portion of a building that is below the flood production level, making that lower level watertight;
   - Wet floodproofing, which involves modifying a structure to allow floodwaters inside the building in a way that minimizes damage to the structure and its contents; and
   - Floodwalls and levees, which are barriers that are constructed between the building and the source of the flooding to block floodwaters.

3. Some general cautions that should always be considered when implementing a retrofitting strategy include:

   - Careful attention and adherence to requirements under the NFIP, codes, and ordinances;
   - Retrofitting measures should be designed and constructed by experienced professionals;
   - Continued purchase of flood insurance may be necessary (floods may exceed the level of protection a retrofitting measure provides);

PROFICIENCY CHECK ANSWERS

3. continued

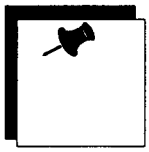
   - Retrofitting measures—except possibly relocation—do not eliminate the need for evacuation during floods;
   - Most retrofitting measures require maintenance; and
   - Some retrofitting measures require human intervention and, therefore, a plan of action.

4. A good retrofitting project should follow a process that involves the homeowner in the decision making from beginning to end. It should begin with careful exploration and fact finding, and proceed through analysis, detailed design, construction and, finally, a maintenance plan.

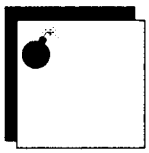
If your answers included all or most of the above points, turn to the end of this chapter and answer the Summary Questions.

If your answers did not include these points, it would be advisable for you to complete the programmed instruction for this chapter, which begins on the following page.

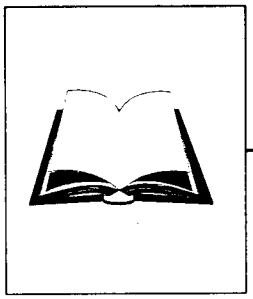
The following icons are used throughout this course.



Special Note: Indicates significant or interesting information



Bomb: Indicates special cautions need to be exercised



HOW TO USE THIS INDEPENDENT STUDY COURSE

GOALS

Part of the Federal Emergency Management Agency's (FEMA's) Mitigation Directorate's mission is the management of the National Flood Insurance Program (NFIP). This mission includes helping communities adopt and enforce regulations that meet the minimum floodplain management standards set by the NFIP. This *Independent Study Course* has been designed to increase understanding of the non-technical aspects of floodplain management, including the NFIP and minimum standards of floodplain management as it relates to the methods of retrofitting. This course also provides an introduction to factors that must be considered in the decision making process in order to select the most appropriate retrofitting measures for individual structures.

This *Independent Study Course* is a prerequisite to attendance at the Emergency Management Institute's more technical resident course of the same name.

This course consists of the first three chapters of the design manual entitled *Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures,* which is used in the resident course. These three chapters provide the user with an overall understanding of retrofitting and begin the process of a general evaluation of retrofitting alternatives that might be feasible for a given property.

Chapter I, Introduction to Retrofitting, gives a brief overview of the various retrofitting alternatives and the general retrofitting process. Chapter II, Regulatory Framework, discusses the National Flood Insurance Program (NFIP) community regulations and the permitting process, model building codes, and code capability with the NFIP. Chapter III, Parameters of Retrofitting, discusses factors that influence retrofitting deci-

sions, including homeowners preferences, regulations and permitting, and technical parameters.

The balance of the design manual, presented in the EMI resident course, gives detailed guidance on how to focus on the specific retrofitting solutions that are most applicable for the residential structure being evaluated, provides step-by-step design processes for each retrofitting measure, and offers a collection of information on the actual retrofitting of specific residential structures.

METHODS OF RETROFITTING

Retrofitting involves a combination of adjustments or additions to features of existing structures, that are intended to eliminate or reduce the possibility of flood damage. Examples of retrofitting include the following measures:

Elevation: The elevation of the existing structure on fill or foundation elements such as solid perimeter walls, piers, posts, columns, or pilings.

Relocation: Relocating the existing structure outside the identified floodplain.

Dry Floodproofing: Strengthening of existing foundations, floors, and walls to withstand flood forces while making the structure watertight.

Wet Floodproofing: Making utilities, structure components, and contents flood- and water-resistant during periods of flooding within the structure.

Floodwalls/Levees: The placement of floodwalls or levees around the structure.

Retrofitting measures can be passive or active in terms of necessary human intervention. Active or emergency retrofitting measures are effective only if there is sufficient warning time to mobilize labor and equipment necessary to implement the measures. Therefore, every effort should be made to design retrofitting measures that are passive and do not require human intervention.

QUESTION I-1

Indicate whether or not statements 1 and 2 are true or false:

1. This course addresses both passive and active retrofitting measures that may be technically feasible and cost-effective for one- to four-family residential structures that are located in coastal areas subject to velocity and wave action.

2. Retrofitting a residential structure to withstand floodwater-generated forces results in a structure that is better able to withstand non-flood-related forces, as well.

3. Give a brief description of retrofitting and list the five categories of retrofitting techniques presented in this manual.

ANSWER I-1

1. False. The course does not address coastal areas with velocity and wave action.

2. False. Retrofitting measures that are not specifically designed to withstand other non-flood-related forces may improve, impair, or have no effect on the structure's ability to withstand those forces.

3. Your answer should address the following key points.

Retrofitting is a combination of adjustments or additions to features of an existing structure designed to reduce or eliminate the possibility of flood damage. The five categories of retrofitting presented in this course are:

- elevation,
- relocation,
- dry floodproofing,
- wet floodproofing, and
- floodwalls/levees.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

ELEVATION

Elevating a structure to prevent floodwaters from reaching damageable portions is an effective retrofitting technique. The structure is raised so that the lowest floor is at or above a designated flood protection elevation (FPE). Heavy-duty jacks are used to lift the existing structure. Cribbing supports the structure while a new or extended foundation is constructed below. In lieu of building new support walls, open foundations such as piers, columns, posts, and piles are often used. Elevating a structure on fill is also an option in some situations.

While elevation may provide increased protection of a structure from floodwaters, other hazards must be considered before implementing this strategy. Elevated structures may encounter additional wind forces on wall and roof systems and the existing footings may experience additional loading. Extended and open foundations (piers, piles, posts, and columns) are also subject to undermining, movement, and impact failures caused by seismic activity, erosion, ice or debris flow, mudslide, and alluvial fan forces, among others.

Cost is an important factor to consider in elevating structures. As an example, lighter wood-frame structures are easier and often cheaper to raise than masonry structures. Masonry structures are not only more expensive to raise, but are also susceptible to cracks.

Base Flood is defined as the flood having a 1% chance of being equaled or exceeded in any given year. The Base Flood Elevation (BFE) is the elevation to which floodwaters rise during a Base Flood.

Flood Protection Elevation (FPE), also referred to as the Flood Protection Level (FPL), is the elevation (height) to which a retrofitting measure is designed. Typically, the FPE is a function of the expected flood elevation (normally the BFE) plus a minimum freeboard value of 1.0 foot.

Elevation on Solid Perimeter Foundation Walls

Elevation on solid perimeter foundation walls is normally used in areas of low to moderate water depth and velocity. After the structure is raised from its current foundation, the support walls can often be extended vertically using materials such as masonry block or cast-in place concrete. The structure is then set down on the extended walls. While this may seem to be the easiest solution to the problem of flooding, there are several important considerations.

Depending on the structure and potential environmental loads (such as flood, wind, seismic, and snow), new and larger footings may have to be constructed. It may be necessary to reinforce both the footings and the walls using steel reinforcing bars to provide needed structural stability.

Deep floodwaters can generate loads great enough to collapse the structure regardless of the materials used. Constructing solid foundation walls with openings or vents will help alleviate the danger by allowing hydrostatic forces to be equalized on both sides. For new and substantially damaged buildings, openings are required under the NFIP.

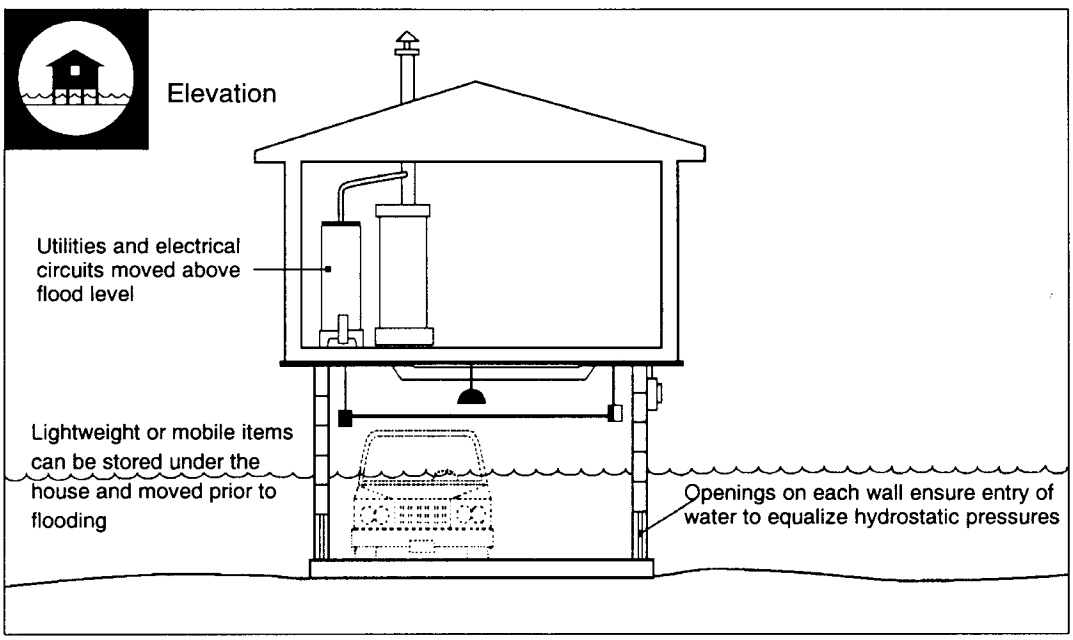


Figure I-1: Elevation on Solid Perimeter Foundation Walls.

Figure I-2: Elevation of Existing Residence on Extended Foundation Walls

QUESTIONS I-2

Indicate whether the following statements are true or false.

1. Structures should be raised so that the lowest floor is at or above the flood protection elevation. Designers typically, as a factor of safety, include one foot freeboard at a minimum above the flood elevation.

2. Elevation of solid perimeter foundation walls usually involves extending masonry block or poured concrete walls.

3. It is critical that the perimeter walls form a solid enclosure and do not allow floodwaters to enter the structure.

ANSWER I-2

1. True.

2. True. It may also involve building new and larger footings and reinforcement of both the footings and walls with steel reinforcing bars.

3. False. Because floodwaters generate hydrostatic forces, solid perimeter foundation walls often must be constructed with vents or openings to allow the hydrostatic forces to equalize on both sides of the walls.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Elevation on Open Foundation Systems

Open foundation systems are vertical structural members that support the structure at key points without the support of a continuous foundation wall. Open foundation systems include piers, posts, columns, and piles.

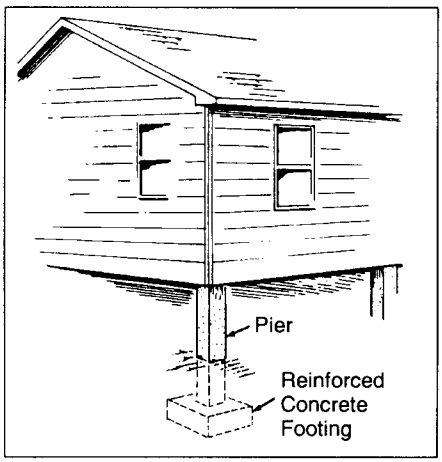


Figure I-3: Elevation on Piers

Elevation on Piers

The most common example of an open foundation is piers, which are vertical structural members that are supported entirely by reinforced concrete footings. Despite their popularity in construction, piers are often the elevation technique least suited for withstanding significant horizontal flood forces. In conventional use, piers are designed primarily for vertical loading; when exposed to flooding, they may also experience horizontal loads due to moving floodwater or debris impact forces. Other environmental loads, such as seismic force, can also create significant horizontal force. For this reason, piers used in retrofitting must not only be substantial enough to support the vertical load of the structure, but also must be sufficient to resist a range of horizontal forces that may occur.

Piers are generally used in shallow depth flooding conditions with low velocity ice, debris, and water flow potential, and are normally constructed of either masonry block or cast-in-place concrete. In either case, steel reinforcing should be used for both the pier and its support footing. The reinforced elements should be tied together to prevent separation. There must also be suitable connections between the superstructure and piers to resist seismic, wind, and buoyancy forces.

QUESTION I-3

Indicate whether or not the following statements are true or false:

1. Piers are normally constructed of masonry block or cast-in-place concrete and are supported by reinforced concrete footings.

2. Piers are the most commonly used elevation support because they are excellent at resisting horizontal flood forces.

ANSWER I-3

1. True.

2. False. Piers are commonly used, but they are most effective in supporting vertical loading and are the least effective structural support in withstanding horizontal flood forces.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Elevation on Posts or Columns

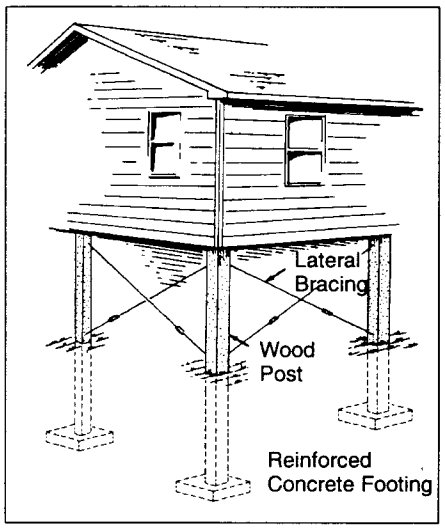


Figure I-4: Elevation on Posts

Elevation on posts or columns is frequently used when flood conditions involve moderate depths and velocities. Made of wood, steel, or precast reinforced concrete, posts are generally square-shaped to permit easy attachment to the house structure. Set in pre-dug holes, posts are usually anchored or embedded in concrete pads to handle substantial loading requirements. Concrete, earth, gravel, or crushed stone is usually backfilled into the hole and around the base of the post.

Columns differ from posts in the size of their application. Posts are small columns.

While piers are designed to act as individual support units, posts normally must be braced. There are a variety of bracing techniques such as wood knee and cross bracing, steel rods, and guy wires. Cost, local flood conditions, loads, the availability of building materials, and local construction practices influence which technique is used.

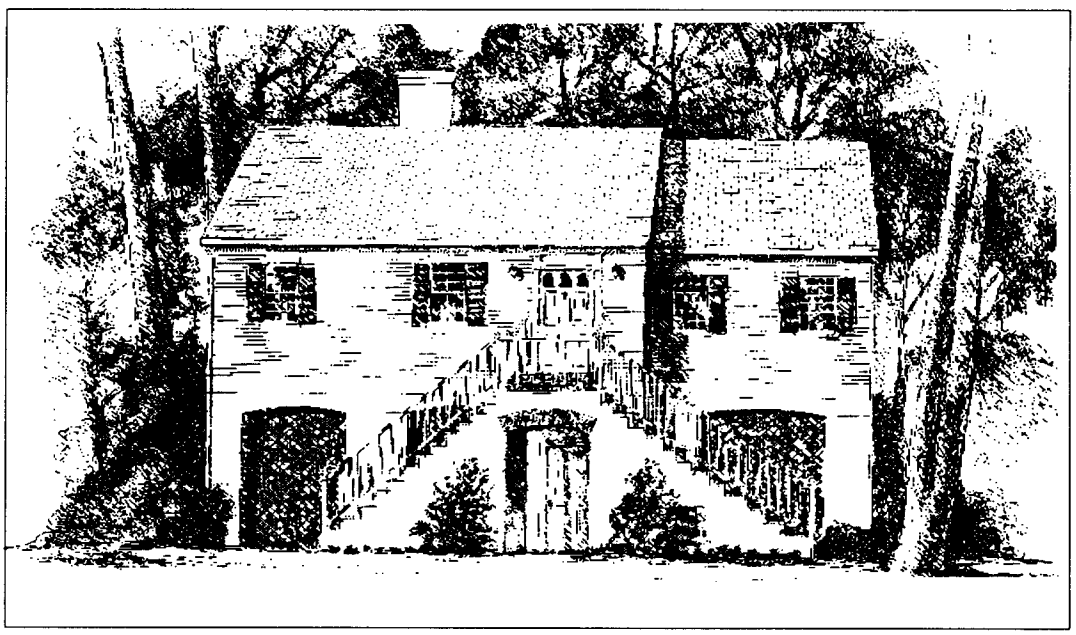


Figure I-5: Structure Elevated on Posts

Elevation on Piles

Piles differ from posts in that they are generally driven, or jetted, deeper into the ground. As such, they are less susceptible to the effects of high-velocity floodwaters, scouring, and debris impact. Piles must either rest on a support layer, such as bedrock, or be driven deep enough to create enough friction to transfer anticipated loads to the surrounding soil. Piles are often made of wood, although steel and reinforced precast or pre-stressed concrete are also common in some areas. They may require bracing similar to the methods described for posts.

Because driving piles generally requires bulky, heavy construction machinery, an existing house must normally be moved aside and set on cribbing until the operation is complete. This additional cost often precludes the use of piles in areas where alternative elevation methods for retrofitting are technically feasible.

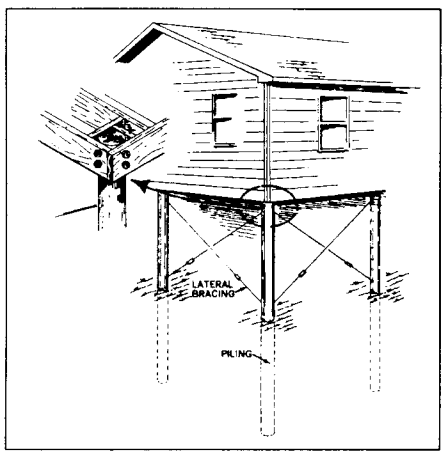


Figure I-6: Elevation on Piles

Several innovative methods have been developed for setting piles. These include jetting exterior piles in at an angle using high-pressure water flow, and trenching, or auguring, holes for interior pile placement. Augured piles utilize a concrete footing for anchoring instead of friction forces. This measure requires that the existing home be raised several feet above its final elevation to allow room for workers to install the piles.

Figure I-7: Structures Elevated on Piles

QUESTION I-4

1. Describe the flooding conditions under which posts or columns would most often be preferable over piers or elevation on solid perimeter foundation walls.

Indicate whether or not the following statements are true or false:

2. Piles are often less susceptible to the effects of high-velocity floodwaters, erosion, scour, and debris impact than any other method of elevation.

3. Piles are often made of wood, steel, reinforced, precast concrete or prestressed concrete.

4. Piles do not require bracing because they are driven, or jetted, deeper into the ground than other structural supports used in elevation.

ANSWER I-4

1. *Your answer should address the following key points:*

   Elevation on posts or columns is preferable when flooding conditions involve moderate depths and water flow velocities. Elevation on piers or solid perimeter foundation walls is recommended only in areas of shallow flooding or low velocity water flow.

2. True.

3. True.

4. False. Piles may require bracing, regardless of the depth to which they are driven.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

Table I-1

Advantages and Disadvantages of Elevation

Advantages	Disadvantages
• **If elevated to the BFE, allows for a substantially damaged or improved structure to be brought into compliance with the NFIP**	• Cost may be prohibitive
• Reduces flood risk to the structure and its contents	• The appearance of the structure may be adversely affected
• Eliminates the need to relocate vulnerable items above the flood level in the house during conditions of flooding	• The structure should not be occupied during a flood
• Often reduces flood insurance premiums	• Access to the structure may be adversely affected
• Techniques are well-known and qualified contractors are often readily available	• Not appropriate in areas with high-velocity water flow, fast-moving ice or debris flow, or erosion unless special measures are taken
• Reduces the physical, financial, and emotional strain that accompanies flood events	• Additional costs may be incurred to bring the structure up to current building codes for plumbing, electrical, and energy systems
• Does not require the additional land that may be needed for floodwalls or levees	• Forces due to wind and seismic hazards must be considered

QUESTION I-5

If properly designed and constructed, does elevation to or above the base flood elevation of a new or substantially damaged or improved structure comply with the NFIP regulations?

ANSWER I-5

Yes.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

RELOCATION

Another retrofitting method is to move the structure to a location that is less prone to flooding and flood-related hazards such as erosion. This method is commonly referred to in retrofitting literature as relocation. The structure may be relocated to another portion of the current site or to a different site. The surest way to eliminate flood damage to a structure is to remove it from the floodplain and relocate it to a flood-free location. The procedure normally involves placing the structure on a wheeled vehicle. The structure is then transported to a new location and set on a new foundation.

Relocation is an appropriate measure in high hazard areas where continued occupancy is unsafe and/or owners want to be free from flood worries. It is also a viable option in communities that are considering using the resulting open space for more appropriate floodplain activities. Relocation may offer an alternative to elevation for substantially damaged structures that are required under local regulations to meet NFIP requirements.

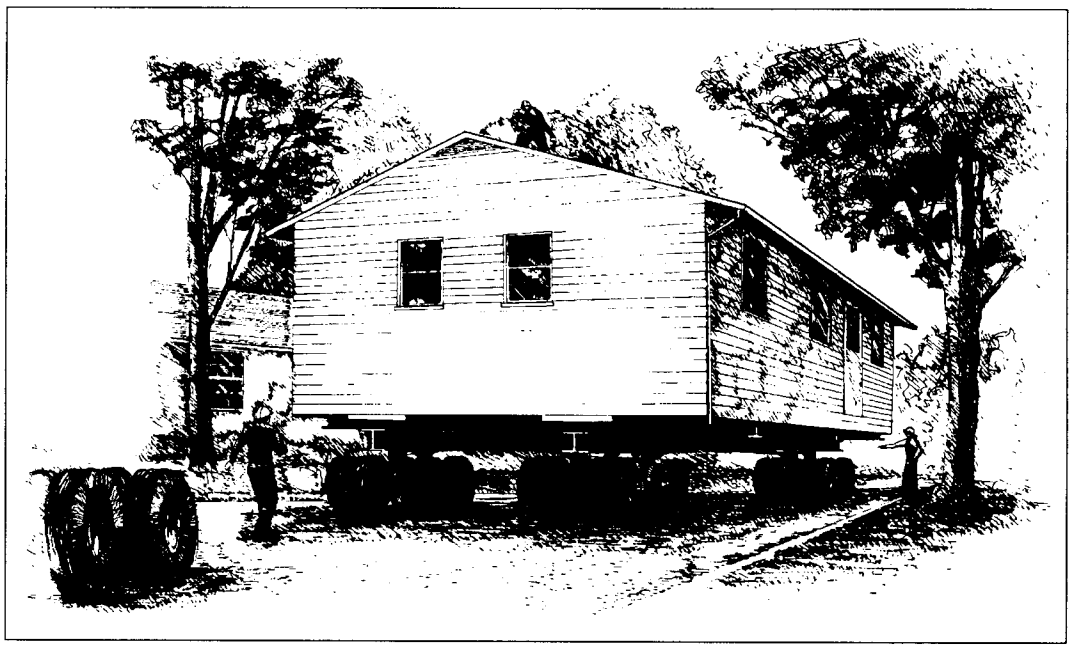


Figure I-8: Structure Placed on a Wheeled Vehicle for Relocation to a New Site

While similar to elevation, relocation of a structure requires additional steps that normally increase the cost of this retrofitting method. These additional costs include moving the structure, purchase and preparation of a new site to receive the structure (with utilities), construction of a new foundation, and restoration of the old site.

Most types and sizes of structures can be relocated either as a unit or in segments. One-story wood-frame houses are usually the easiest to move, particularly if they are located over a crawl space or basement that provides easy access to floor joists. Smaller, lighter wood-frame structures may also be lifted with ordinary house-moving equipment and often can be moved without partitioning. Houses constructed of brick, concrete, or masonry are also movable, but usually with more difficulty and increased costs.

Structural relocation professionals should help owners to consider many factors in the decision to relocate. The structural soundness should be thoroughly checked and arrangements should be made for temporary housing and storage of belongings. Many states and communities have requirements governing the movement of structures on public rights-of-way.

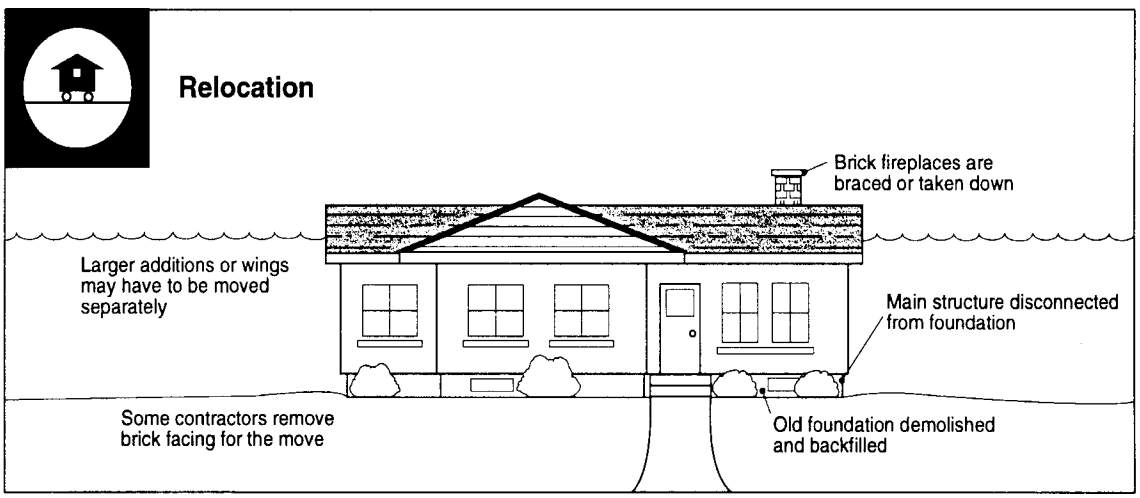


Figure I-9: Structure to be Relocated

Table I-2

Advantages and Disadvantages of Relocation

Advantages	Disadvantages
• **Allows for substantially damaged or improved structure to be brought into compliance with the NFIP**	• Cost may be prohibitive
• Significantly reduces flood risk to the structure and its contents	• A new site must be located
• Relocation techniques are well-known and qualified contractors are often readily available	• Disposition of the flood-prone lot must be addressed
• Eliminates need to purchase flood insurance or could reduce the premium	• Additional costs may be incurred to bring the structure up to current building codes for plumbing, electrical, and energy systems
• Reduces the physical, financial, and emotional strain that accompanies flood events	

QUESTION I-6

Indicate whether or not the following statements are true or false:

1. Although relocation is an appropriate measure in high hazard areas, it is not a technically feasible measure for brick, concrete, or masonry structures.

2. Relocation outside the Special Flood Hazard Area (SFHA) allows a substantially damaged or improved structure to be brought into compliance with the NFIP.

ANSWER I-6

1. False. Relocation is a technically feasible retrofitting measure for brick, concrete, and masonry structures, but usually entails more difficulty and increased costs.

2. True.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

DRY FLOODPROOFING

Another approach to retrofitting is to seal that portion of a structure below the flood protection level, making that area watertight. The objective of this approach is to make the walls impermeable to the passage of floodwaters. Creating an impervious membrane, such sealant systems can include wall coatings, waterproofing compounds, impermeable sheeting, or walls with supplemental impermeable wall systems, such as cast-in-place concrete. Doors, windows, sewer and water lines, and vents are closed with permanent or removable shields or valves.

The expected duration of flooding is extremely critical when using sealing systems because seepage can increase over time, rendering the floodproofing ineffective. Waterproofing compounds, sheeting, or sheathing may fail or deteriorate if exposed to floodwaters for extended periods. Sealant systems are also subject to damage (puncture) in areas that experience water flow of significant velocity, or ice or debris flow.

Dry floodproofing is usually appropriate only where floodwaters are less than three feet deep, since most walls and floors in residential structures may collapse under higher water levels. Research in this area has been conducted by the U.S. Army Corps of Engineers and is available in a document titled *Floodproofing Tests*, August 1988.

Dry floodproofing is not allowed under the NFIP for new and substantially damaged or improved residential structures located in a Special Flood Hazard Area. Additional information on dry floodproofing can be obtained from FEMA Technical Bulletin 3-93, titled *Non-Residential Floodproofing Requirements and Certification for Buildings Located in Special Flood Hazard Areas in Accordance with the NFIP*. Non-residential techniques are also applicable in residential situations.

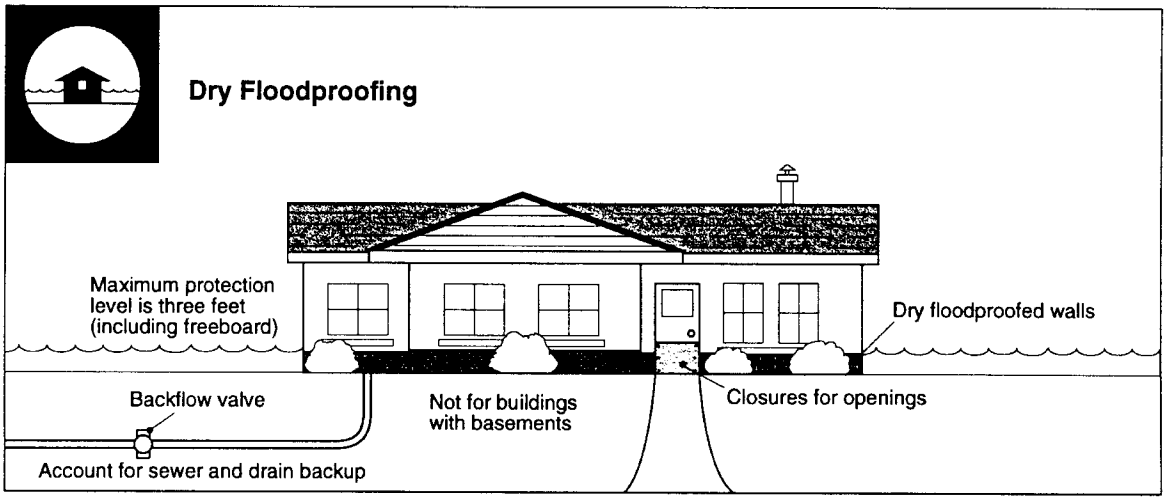


Figure I-10 Dry Floodproofed Structure

Even brick or concrete block walls should not be floodproofed above a height of three feet (without an extensive engineering analysis) due to the danger of structural failure from excessive hydrostatic and other flood-related forces.

The designer should consider incorporating freeboard into the three-foot height constraint as a factor of safety against structural failure. Other factors of safety might include additional pumping capacity and stiffened walls. Other factors of safety might include additional pumpimg capacity and stiffened walls.

Dry floodproofing is also not recommended for structures with a basement. These types of structures can be susceptible to significant lateral and uplift, or buoyancy, forces. When dry floodproofing a wood-frame structure, only buildings constructed of concrete block or faced with brick veneer should be considered. Weaker construction materials, such as wood-frame with siding, will often fail at much lower water depths from hydrostatic forces.

Table I-3

Advantages and Disadvantages of Dry Floodproofing

Advantages	Disadvantages
• Reduces risk to the structure and contents if the design flood level is not exceeded	• **Does not satisfy the NFIP requirement for bringing substantially damaged or improved structures into compliance**
• May be less costly than other retrofitting measures	• Requires on-going maintenance
• Does not require the extra land that may be needed for floodwalls or levees	• Flood insurance premiums are not reduced for residential structures
• Reduces the physical, financial, and emotional strain that accompanies flood events	• Usually requires human intervention and adequate warning time for installation of protective measures
• Retains the structure in its present environment and may avoid significant changes in appearance	• Measures can fail or be exceeded by large floods, in which case the effect will be as if there were no protection
	• If design loads are exceeded, walls may collapse, floors may buckle, the structure may even float, potentially resulting in more damage than just letting the house flood
	• The structure should not be occupied during a flood
	• Shields are not always aesthetically pleasing
	• The damage to the exterior of the structure and other property may not be reduced
	• May be subject to leakage, which could cause damage to the structure and its contents

QUESTION I-7

1. Briefly describe what dry floodproofing entails.

2. List some of the drawbacks to the effectiveness of this measure.

3. *Indicate whether the following statement is true or false:*

   Dry floodproofing satisfies the NFIP requirement for bringing substantially damaged or improved residential structures into compliance.

ANSWER I-7

Your answers should address the following key points:

1. Dry floodproofing involves sealing the portion of a structure that is below the flood protection level to make the structure watertight. Walls are coated with waterproofing compounds or impermeable sheeting or protected with supplemental impermeable wall systems such as cast-in-place concrete. Doors, windows, sewer lines, water lines, and vents are closed with permanent or removable shields or valves.

2. Waterproofing compounds, sheeting, or sheathing may fail or deteriorate if exposed to floodwaters for extended periods. Sealant systems are also subject to damage (puncture) in areas that experience water flow of significant velocity, or ice or debris flow. In addition, use of dry floodproofing techniques in situations where more than three feet of water exists may lead to collapse of the structure.

3. False. Dry floodproofing does not satisfy the NFIP requirement for bringing substantially damaged or improved residential structures into compliance.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

WET FLOODPROOFING

Another approach to retrofitting involves modifying a structure to allow floodwaters to enter a structure in a way that minimizes damage to the structure and its contents. This type of protection is classified as wet floodproofing.

Wet floodproofing is often used when all other techniques are not technically feasible or are too costly. It is generally appropriate if a structure has available space in which to relocate and/or temporarily store damageable items. Utilities and furnaces may also need to be relocated or protected along with other non-movable items by using flood-resistant building materials. Wet floodproofing may also be appropriate for structures with basements and crawl spaces that cannot be protected technically or cost-effectively by other retrofitting measures.

Wet floodproofing is not allowed under the NFIP for new and substantially damaged or improved structures located in a Special Flood Hazard Area. Refer to FEMA's Technical Bulletin #7-93, titled *Wet Floodproofing Requirements for Structures Located in Special Flood Hazard Areas in Accordance with the NFIP.*

Compared with the more extensive flood protection measures described in this manual, wet floodproofing is generally the least expensive. The major costs of this measure involve the rearrangement of utility systems, installation of flood resistant materials, acquisition of labor and equipment to move items, and organization of cleanup when floodwaters recede. Major disruptions to structure occupancy often result during conditions of flooding.

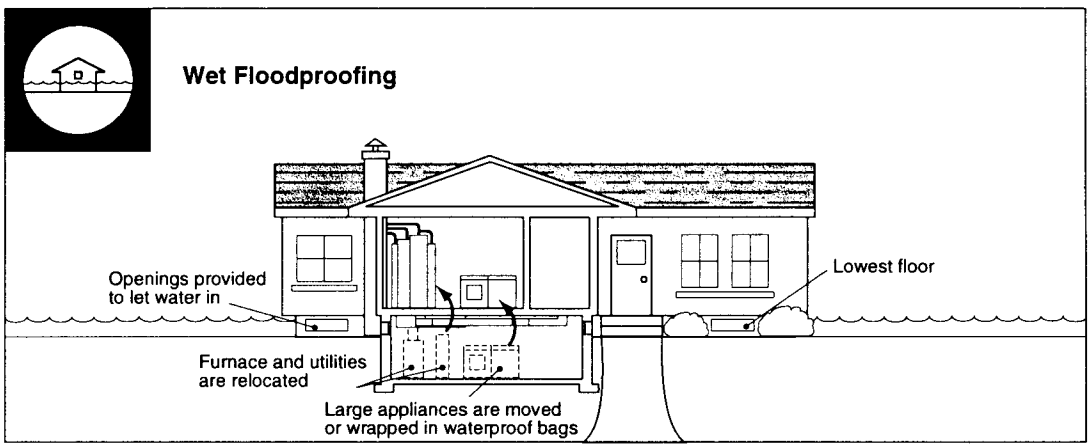


Figure I-11: Wet Floodproofed Structure

Table I-4

Advantages and Disadvantages of Wet Floodproofing

Advantages	Disadvantages
• No matter how small the effort, wet floodproofing can, in many instances, reduce flood damage to a building and its contents	• **Does not satisfy the NFIP requirement for bringing substantially damaged or improved structures into compliance**
• Compared to a dry floodproofing measure, loads placed on the walls and floors of a building may be greatly reduced due to equalized hydrostatic pressure compared to a dry floodproofing measure	• Flood warning is usually needed to prepare building and contents for flooding
• Costs for relocating or storing contents (except basement contents) after a flood warning is issued are normally covered by flood insurance	• The evacuation of contents from the flood-prone area is dependent on human intervention
• Wet floodproofing measures are often less costly than other measures	• The structure will get wet inside, and possibly will be contaminated by sewage, chemicals, and other materials borne by flood waters. Extensive cleanup may still be necessary
• Does not require extra land, which may be needed for floodwalls or levees	• The structure should not be occupied during a flood
• Reduces the physical, financial, and emotional strain that accompanies flood events	• The structure may be uninhabitable for a time after flooding
	• There may be a need to limit use of the floodable area of the building
	• There may be some ongoing maintenance requirements
	• Additional costs may be incurred to bring the structure up to current building codes for plumbing, electrical, and energy systems
	• To avoid foundation wall collapse, care must be taken when pumping out basements

QUESTION I-8

Choose the correct answer to complete the following statement:

1. Modifying a structure to allow floodwaters to enter a structure in a way that minimizes damage to the structure and its contents, known as wet floodproofing, involves:

   a. great cost
   b. temporary relocation of damageable items
   c. permanent relocation of damageable items
   d. the use of flood-damage-resistant building materials

Indicate whether the following statement is true or false:

2. Wet floodproofing does not satisfy the NFIP requirement for bringing substan tially damaged or improved structures into compliance.

ANSWER I-8

1. If your answer included b, c, and d, you are correct. Wet floodproofing is often the least expensive of the retrofitting measures.

2. True.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

FLOODWALLS AND LEVEES

Another retrofitting approach is the construction of localized barriers between the structure and the source of flooding. There are two basic types of barriers: levees and floodwalls. They can be built to any height but are usually limited to four feet for floodwalls and six feet for levees due to cost, aesthetics, access, water pressure, and space. Local zoning and building codes may also restrict use, size, and location.

A levee is typically a compacted earthen structure that blocks floodwaters from coming into contact with the structure. To be effective over time, levees must be constructed of suitable materials (i.e., impervious soils) and with correct side slopes for stability. Levees may completely surround the structure or tie to high ground at each end. Levees are generally limited to homes where floodwaters are less than five feet deep. Otherwise, the cost and the land area required for such barriers usually make them impractical for the average owner.

Floodwalls and levees are not allowed under the NFIP for new and substantially damaged or improved structures located in a Special Flood Hazard Area.

Floodwalls are engineered barriers designed to keep floodwaters from coming into contact with the structure. Floodwalls can be constructed in a wide variety of shapes and sizes but are typically built of reinforced concrete and/or masonry materials.

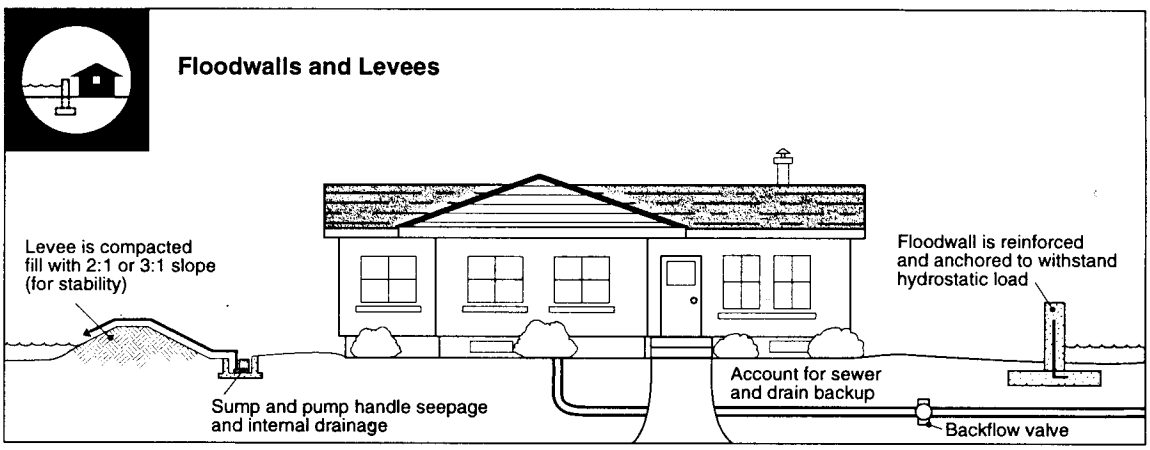


Figure I-12: Structure Protected by Levee and Floodwall

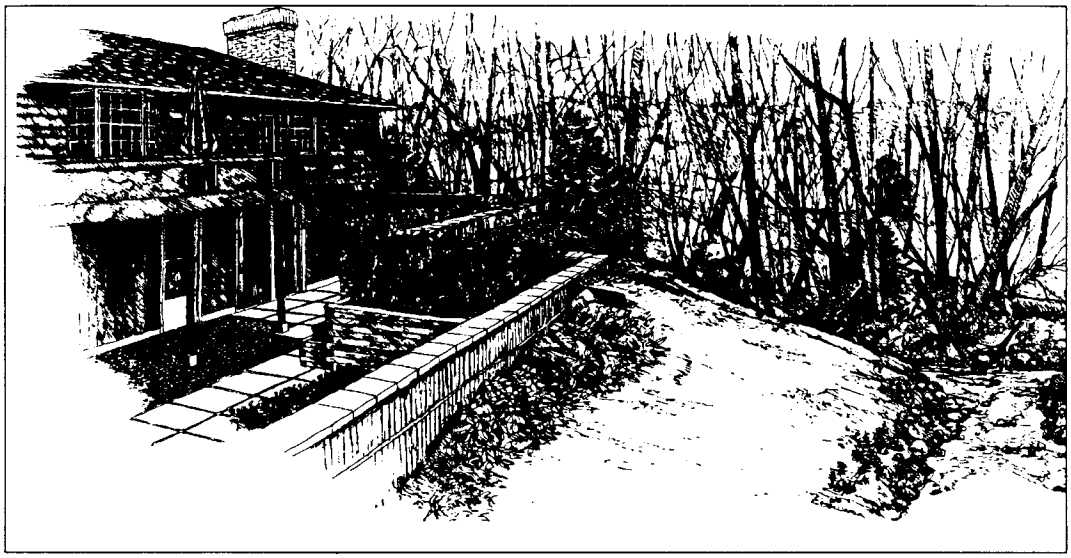


Figure I-13: House Protected by a Floodwall

Generally, residential floodwalls are only cost-beneficial at providing protection up to four feet and levees up to six feet, including one foot of freeboard.

A floodwall can surround an entire structure or, depending on the flood levels, site topography, and design preferences, it can protect isolated structure openings such as doors, windows, or basement entrances. Floodwalls can be designed as attractive features to a residence, utilizing decorative bricks or blocks, landscaping and garden areas, or can be designed for utility at a considerable savings in cost.

Because their cost is usually greater than that of levees, floodwalls would normally be considered only on sites that are too small to have room for levees or where flood velocities may erode earthen levees. Some owners may believe that floodwalls are more aesthetically pleasing and allow preservation of site features, such as trees. Special design considerations must be taken into account when floodwalls or levees are used to protect homes with basements because they are susceptible to seepage that can result in hydrostatic and saturated soil pressure on foundation elements.

Provisions for closing access openings must be included as part of the floodwall or levee design.

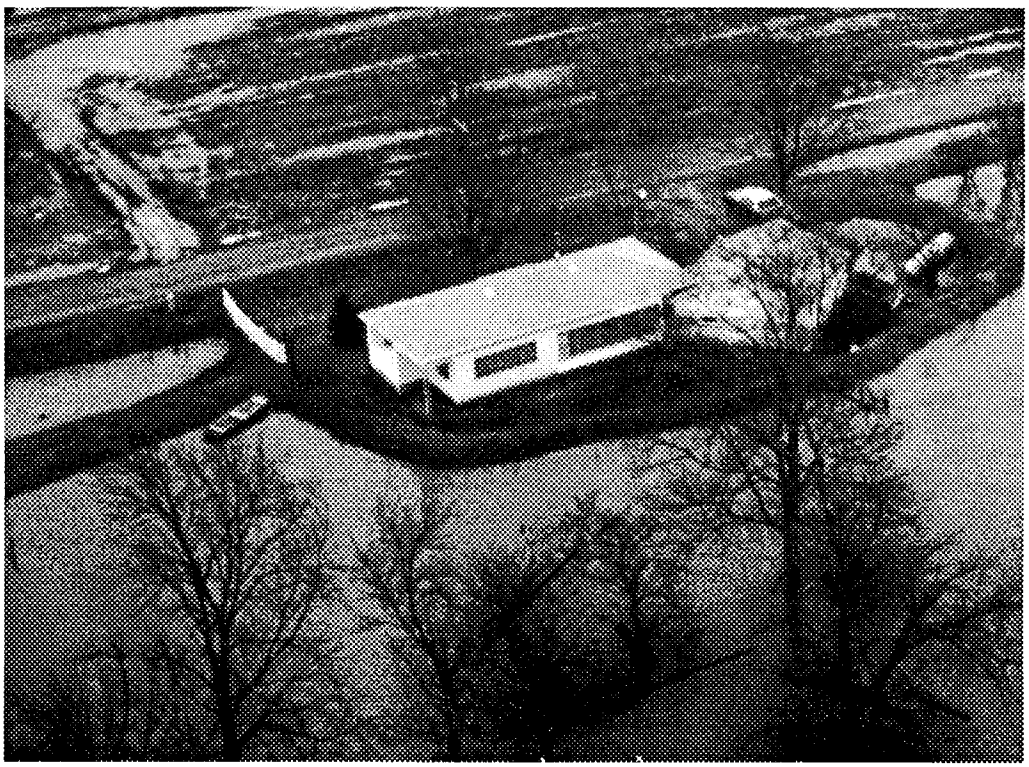


Figure I-14: House Protected by Levee

Table I-5

Advantages and Disadvantages of Floodwalls and Levees

Advantages	Disadvantages
• The area around the structure will be protected from inundation without significant changes to the structure	• **Does not satisfy the NFIP requirements for bringing substantially damaged or improved structure into compliance**
• There is no pressure from floodwater to cause structural damage to the home or other structures in the protected area	• Levees and floodwalls can fail or be overtopped by large floods or floods of long duration, in which case the effect will be as if there was no protection at all
• These barriers are usually less expensive to build than elevating or relocating the structure would be	• May be expensive
• Occupants do not have to leave the structure during construction	• Both floodwalls and levees need periodic maintenance
• Reduces flood-risk to the structure and its contents	• Interior drainage must be provided
• Reduces the physical, financial, and emotional strain that accompanies flood events	• Local drainage can be affected, possibly resulting in water problems for others
	• No reduction in flood insurance rates
	• May restrict access to structure
	• Levees require considerable land area
	• Floodwalls and levees do not eliminate the need to evacuate during floods
	• May require warning time and human intervention for closures
	• Floodplain management requirements may make floodwalls and levees violations of applicable codes and/or regulations

QUESTION I-9

1. Briefly describe the difference between a floodwall and a levee.

Indicate whether the following statement is true or false:

2. Floodwalls and levees satisfy the NFIP requirements for bringing substantially damaged or improved structures into compliance.

ANSWER I-9

1. A levee is typically a compacted earthen structure, while floodwalls are engineered barriers typically constructed of reinforced concrete and/ or masonry materials.

2. False. Floodwalls and levees do not satisfy the NFIP requirements for bringing substantially damaged or improved structures into compliance.

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

GENERAL RETROFITTING CAUTIONS

Appropriately applied retrofitting measures have several advantages over other damage reduction methods. Individual owners can undertake retrofitting projects without waiting for government action to construct flood control projects. Retrofitting may also provide protection in areas where large structural projects, such as dams or major waterway improvements, are not feasible, warranted, or appropriate. Some general cautions should always be considered in implementing a retrofitting strategy, however. These include:

- Substantial damage or improvement requirements under the NFIP, local building codes, and floodplain management ordinances render some retrofitting measures illegal.

- Codes, ordinances, and regulations for other restrictions, such as setbacks and wetlands, should be reviewed.

- Retrofitted structures should not be used nor occupied during conditions of flooding.

- Most retrofitting measures should be designed and constructed by experienced professionals (engineers, architects, or contractors) to ensure proper consideration of all factors influencing effectiveness.

- Most retrofitting measures cannot be installed and forgotten. Maintenance must be performed on a scheduled basis to ensure that the retrofitting measures adequately protect the structure over time.

- Floods may exceed the level of protection provided in retrofitting measures. In addition to implementing these protective measures, owners should consider continuing to purchase flood insurance. In some cases owners may be required by lending institutions to continue flood insurance coverage.

- When human intervention is most often needed for successful flood protection, a plan of action must be in place and an awareness of flood conditions is required.

RETROFITTING PROCESS

A good retrofitting project should follow a careful path of exploration, fact finding, analysis, detailed design, and construction steps. The successful completion of a retrofitting project will require a series of homeowner coordination and design input meetings. Ultimately, the homeowner will be living with the retrofitting measure, so every effort should be made to incorporate the homeowner's concerns and preferences into the final product. The primary steps in the overall process are shown in Figure I-15 and include:

HOMEOWNER MOTIVATION

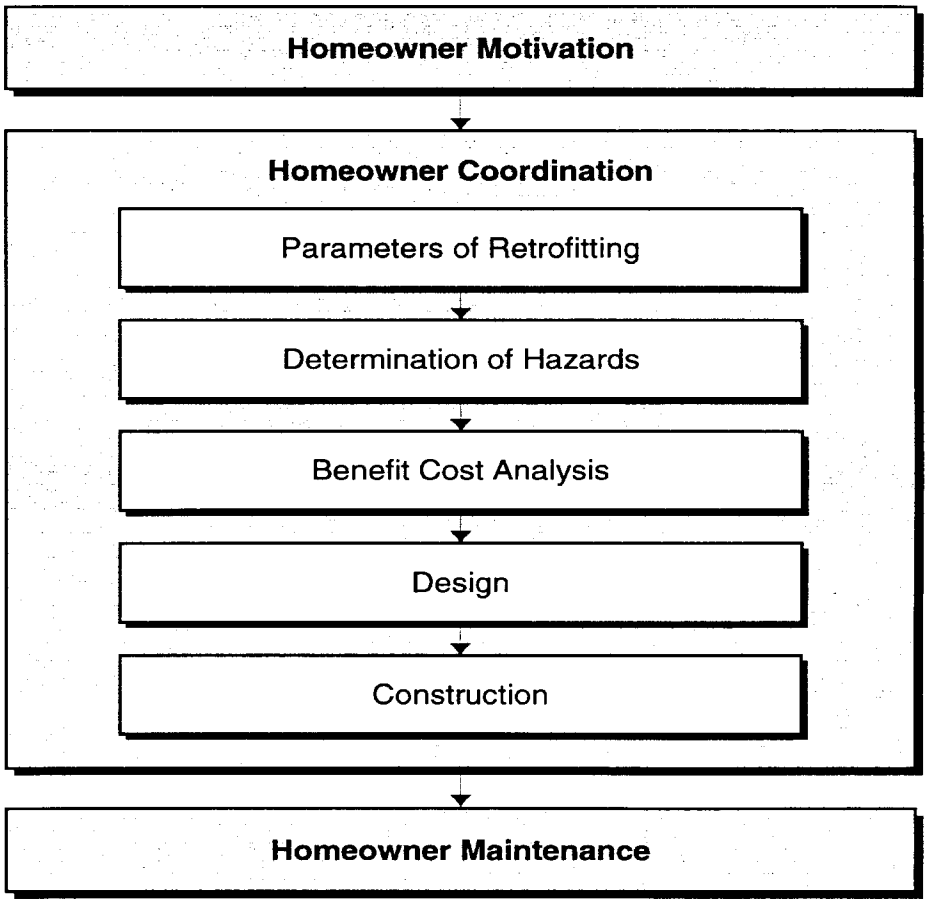
The decision to consider retrofitting options usually stems from having experienced or witnessed a flooding event in or near the structure in question; having experienced substantial damage from a flood or an event other than a flood; or embarking on a substantial improvement, which requires adherence to local floodplain regulations. The homeowner may contact other homeowners, local community officials, contractors, or design professionals to obtain information on allowable retrofitting techniques, available technical and financial assistance, and other possible options.

PARAMETERS OF RETROFITTING

The goal of this step is to conduct the necessary field investigations, regulatory reviews, and preliminary technical evaluations to select applicable and technically feasible retrofitting techniques that warrant further analysis.

DETERMINATION OF HAZARDS

This step involves the detailed analysis of flood, flood-related and non-flood-related hazards and the evaluation of specific sites and structures to be retrofitted.


Homeowner Motivation
Homeowner Coordination
Parameters of Retrofitting
Determination of Hazards
Benefit Cost Analysis
Design
Construction
Homeowner Maintenance

BENEFIT/COST ANALYSIS

This step is critical in the overall prioritization of the technically feasible retrofitting techniques, and it combines an objective economic analysis of each retrofitting measure considered with any subjective decision factors introduced by the homeowner or others.

DESIGN

During this phase, specific retrofitting measures are designed, construction details developed, cost estimates prepared, and construction permits obtained.

Within each of these steps, homeowners are involved in providing input into the evaluations, analyses, decisions, and design concepts to ensure that the final product meets requirements. Finally, maintenance of the constructed retrofitting measure is the responsibility of the homeowner.

CONSTRUCTION

Upon final design approvals, a contractor is selected and the retrofitting measure is constructed.

OPERATION AND MAINTENANCE

The development of a well-conceived operation and maintenance plan is critical to the overall success of the project.

QUESTION I-10

1. List the general cautions that should be observed when retrofitting.

2. Number the following steps in the retrofitting process in sequential order:

   Conceptual Design

   Benefit/Cost Analysis

   Homeowner Motivation

   Determination of Hazards

   Parameters of Retrofitting

   Construction

   Operation and Maintenance

   Design

ANSWER I-11

1. *Your answer should include the following key points:*

   - Substantial damage or improvement requirements under the NFIP, local building codes, and floodplain management ordinances render some retrofitting measures illegal.

   - Codes, ordinances, and regulations for other restrictions, such as setbacks and wetlands, must be taken into consideration.

   - Retrofitted structures should not be used nor occupied during conditions of flooding.

   - Most retrofitting measures should be designed and constructed by experienced professionals (engineers, architects, or contractors) to ensure proper consideration of all factors influencing effectiveness.

   - Most retrofitting measures cannot be installed and forgotten. Maintenance must be performed on a scheduled basis to ensure that the retrofitting measures adequately protect the structure over time.

   - Floods may exceed the level of protection provided in retrofitting measures. In addition to implementing these protective measures, owners should consider continuing to purchase flood insurance. In some cases owners may be required by lending institutions to continue flood insurance coverage to conform with NFIP regulations.

   - When human intervention is most often needed for successful flood protection, a plan of action must be in place and an awareness of flood conditions is required.

ANSWER I-11 (CONTD.)

2. *Steps should be numbered as follows:*

   4. Conceptual Design

   5. Benefit/Cost Analysis

   1. Homeowner Motivation

   3. Determination of Hazards

   2. Parameters of Retrofitting

   7. Construction

   8. Operation and Maintenance

   6. Design

If you answered correctly, please move on to the next section. If you answered incorrectly, please review this section before moving on.

SUMMARY QUESTIONS

Congratulations! You have completed the text review of Chapter I, Introduction to Retrofitting. All that remains to complete this segment of the Independent Study Course is to answer and check the Summary Questions that follow.

Complete the questions below.

1. Define retrofitting.

2. Identify and describe the retrofitting measures available.

3. List the general cautions which must be taken to help ensure a successful retrofitting project.

4. Identify the steps in the retrofitting process.

SUMMARY QUESTION ANSWERS

Your answers should contain the key points in the following answers below.

1.	Retrofitting	Retrofitting is any combination of measures taken on an existing structure to eliminate or reduce the possibility of flood damage. These measures may involve adjustments to the features of an existing structure, additions to the structure, or a combination of both.
2.	Elevation	Elevation is the raising of a structure on an extended support structure to place it above floodwaters and their resulting damage. The lowest floor is elevated at or above the designated flood protection level.
	Relocation	Relocation is the moving of a structure from a flood area to a new location that is less likely to be subjected to flooding or flood-related hazards, such as erosion.
	Dry Floodproofing	Dry floodproofing entails sealing that portion of a structure that is below the flood protection level to make it watertight. Sealing involves creating an impervious membrane through which floodwaters cannot pas. This measure may involve coatings, sheeting, shields, valves, and/or supplemental wall systems. This measure is used in areas of low level flooding.
	Wet Floodproofing	Wet floodproofing is the modification of a structure to allow floodwaters to pass through the building in such a way that damage to the structure and its contents is minimized.
	Floodwalls and Levees	Floodwalls and levees are barriers that are constructed between the structure and the source of flooding. They are constructed of a resistant material such as concrete, or of compacted soil, respectively.

3. Some general cautions that should always be considered when implementing a retrofitting strategy include:

   - Requirements under the NFIP, codes, ordinances, and regulations for other restrictions should be researched and adhered to.
   - Retrofitting measures should be designed and constructed by experienced professionals.
   - Floods may exceed the level of protection a retrofitting measure provides, possibly making continued purchase of flood insurance a necessity.
   - Retrofitting measures do not eliminate the need for evacuation during floods. Except possibly for relocation, most require maintenance. Certain measures require human intervention and a plan of action.

4. The process of retrofitting is conducted in conjunction with the homeowner at each step. From information gathered through interviewing the homeowner and surveying the site, the design professional conducts a preliminary evaluation of alternatives. This is followed by a determination of hazards and a benefit/cost analysis in order to arrive at the appropriate retrofitting measure. Once the design professional and homeowner have agreed upon the measure, it is designed and constructed. A maintenance plan is then put into effect.