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# Elevating of Structures for Flood Protection

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**Engineering Principles and Practices for  
Retrofitting Flood-Prone Residential Structure**

**Chapter 5E**

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# 5E Elevation

One of the most common of all retrofitting techniques is to raise an entire existing superstructure above the DFE. When properly done, the elevation of a house places the living area above all but the most severe floods.

The steps required for elevating a building are essentially the same in all cases. A cradle of steel beams is inserted under (or through) the structure; jacks are used to raise both the beams and structure to the desired height; a new, elevated foundation for the house is constructed; utility systems are extended and modified; and the structure is lowered back onto the new foundation and reconnected.

While the same basic elevation techniques are used in all situations, the final siting and appearance of the house will depend on the final elevation and type of foundation used. However, the actual elevation process is only a small part of the whole operation in terms of planning, time, and expense. The most critical steps involve the preparation of the house for elevation and the construction of a new, adequately designed, and elevated foundation. The elevation process becomes even more complex with added weight, height, or complex design or shape of the house. Brick or stucco veneers may require removal prior to elevation. Building additions may need to be elevated independently from the main structure.



## NOTE

FEMA strongly encourages that flood retrofits provide protection to the DFE (or BFE plus 1 foot, whichever is higher). However, in some situations, lower flood-protection levels may be appropriate. Homeowners and design professionals should meet with a local building official to discuss the selected retrofit measure and the elevation to which it will protect the home. The text and examples in this manual assume flood protection measures will be implemented to the DFE.

## 5E.1 Types of Residential Structures that Can Be Elevated

The elevation of houses over a crawlspace; houses with basements; houses on piers, columns, or piles; and houses on a slab-on-grade are examined here. In each of these situations, the designer must account for multiple (non-flood-related) hazards, such as wind and seismic forces. The various methods utilized to elevate different home types are illustrated in the pages that follow, providing the designer with an introduction to the design of these measures.

Houses that are elevated using solid foundation walls as opposed to piers, columns, or piles to raise the finished floor to or above the DFE must include openings to allow the automatic entry and exit of floodwater. Guidance on the design and installation of flood vents can be found in Section 5E.1.2.1.

### 5E.1.1 Houses Over a Crawlspace

These are generally the easiest and least expensive houses to elevate. They are usually one- or two-story houses built on a masonry crawlspace wall. This allows for access in placing the steel beams under the house for lifting. The added benefit is that, since most crawlspaces have low clearance, most utilities (heat pumps, water heaters, air conditioners, etc.) are not placed under the home; thus the need to relocate utilities may be limited. Houses over a crawlspace can be:

- elevated on extended solid foundation walls (see Figures 5E-1 through 5E-5); or
- elevated on an open foundation such as masonry piers (see Figures 5E-6 through 5E-8).



#### NOTE

Figures 5E-1 through 5E-5 illustrate the elevation of a home on extended solid foundation walls. Subsequent figures for various elevation techniques will include only those illustrations unique to that technique.



#### CROSS REFERENCE

Information on the design of foundation wall openings and adjustment of existing utility systems can be found in Chapter 5W.

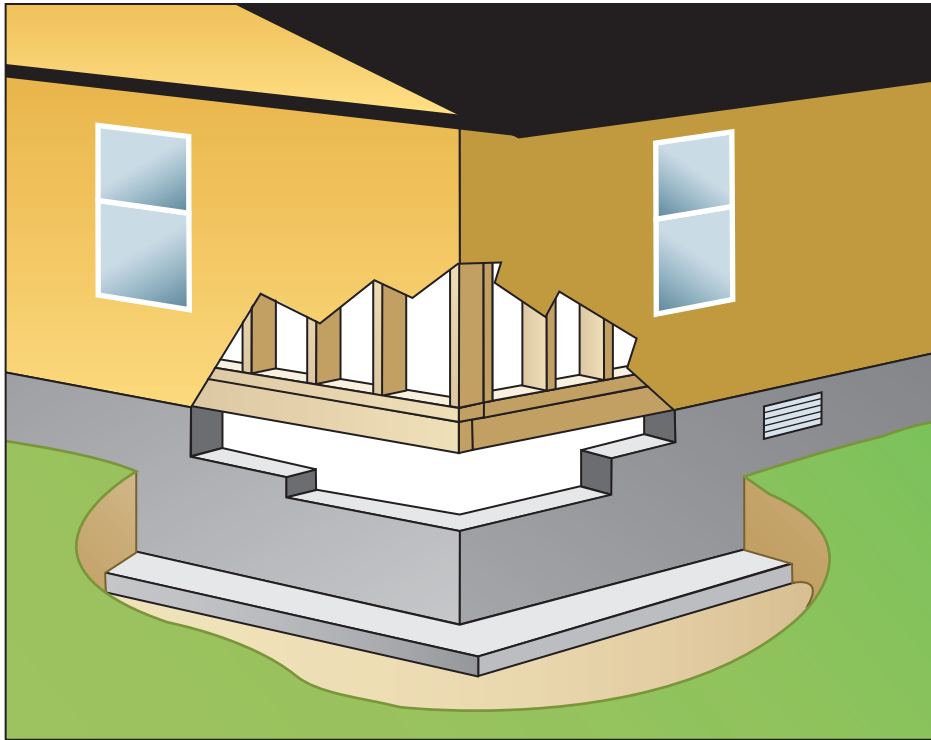


Figure 5E-1. Existing wood-frame house on crawlspace foundation to be elevated with extended walls and piers

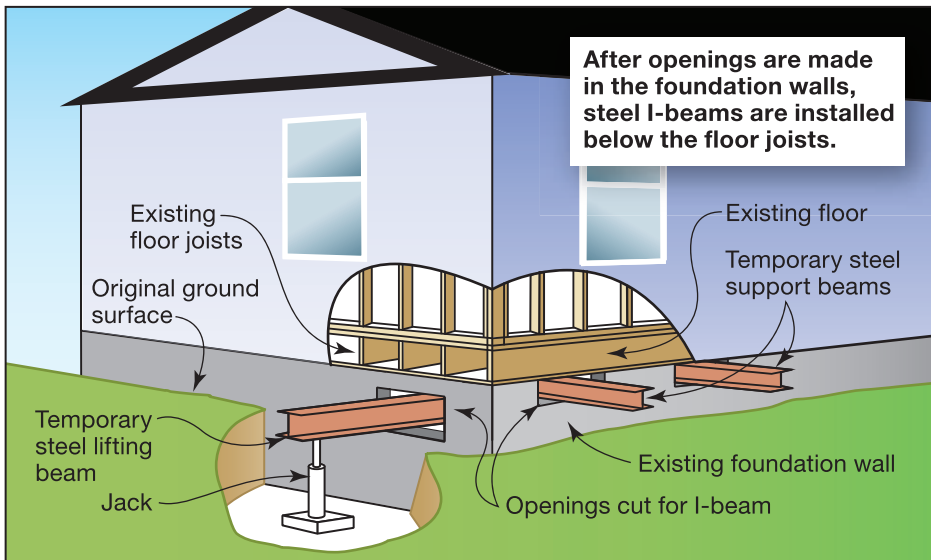


Figure 5E-2. Step 1 of elevating an existing wood-frame house on extended foundation walls and piers: Install network of steel I-beams

Figure 5E-3.  
Step 2 of elevating an existing wood-frame house on extended foundation walls and piers: Lift house and extend foundation walls and piers (reinforce as needed); relocate utility and mechanical equipment above flood level

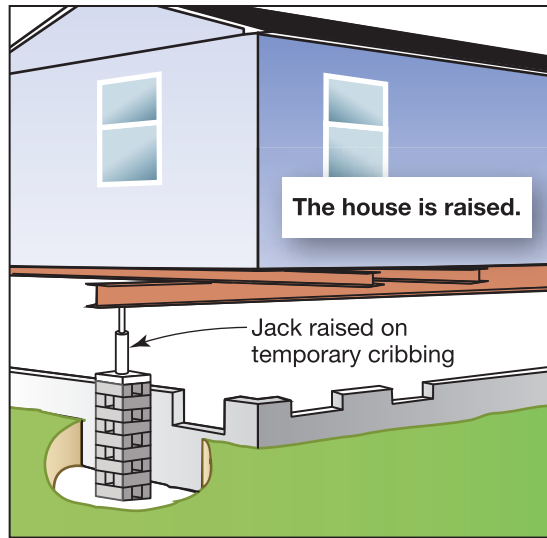
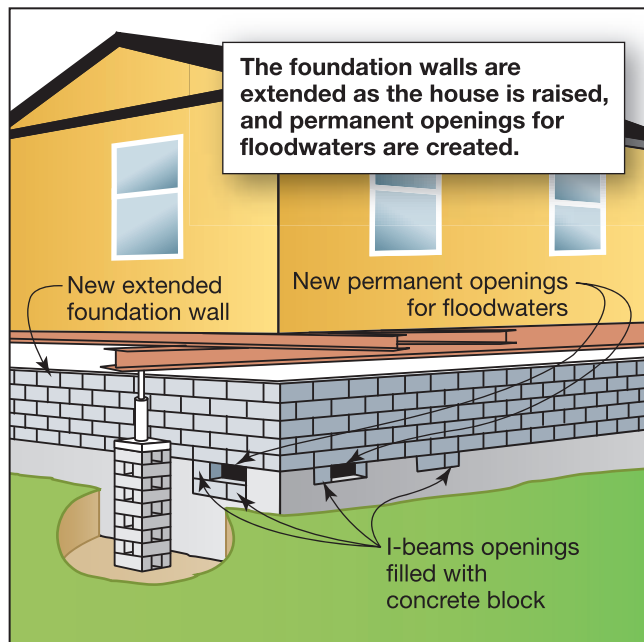


Figure 5E-4.  
Step 3 of elevating an existing wood-frame house on extended foundation walls and piers: Set house on new extended foundation and remove I-beams



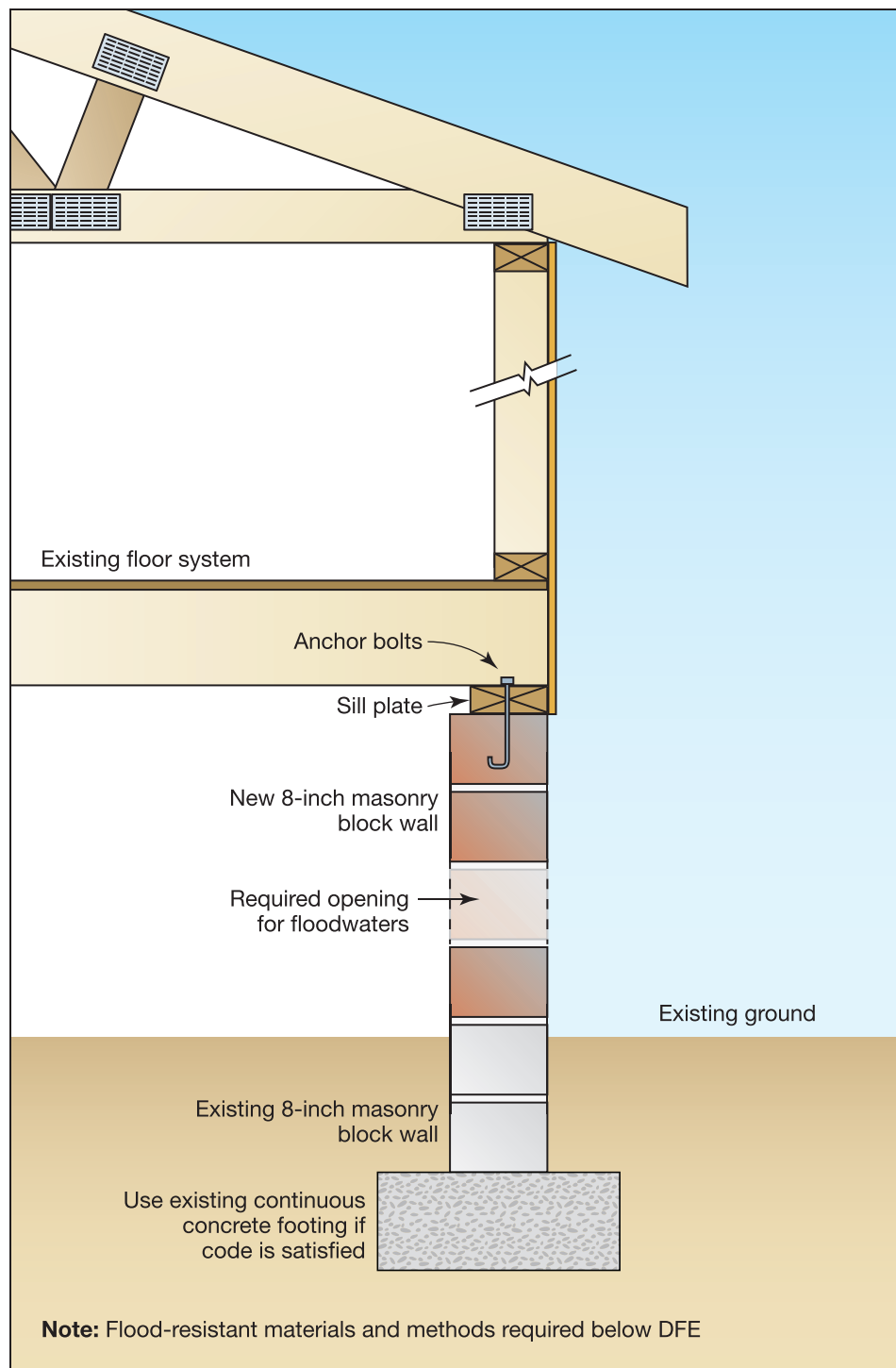


Figure 5E-5.  
Cross-section of elevated  
wood-frame house on  
extended piers and  
crawlspace walls

Figure 5E-6.  
 Step 1 of elevating an existing wood frame house on new or extended pier foundations: Install network of steel I-beams. Step 2 (not shown): Lift house, rebuilding or extending (reinforce as needed) piers; relocate utility and mechanical equipment above flood level.

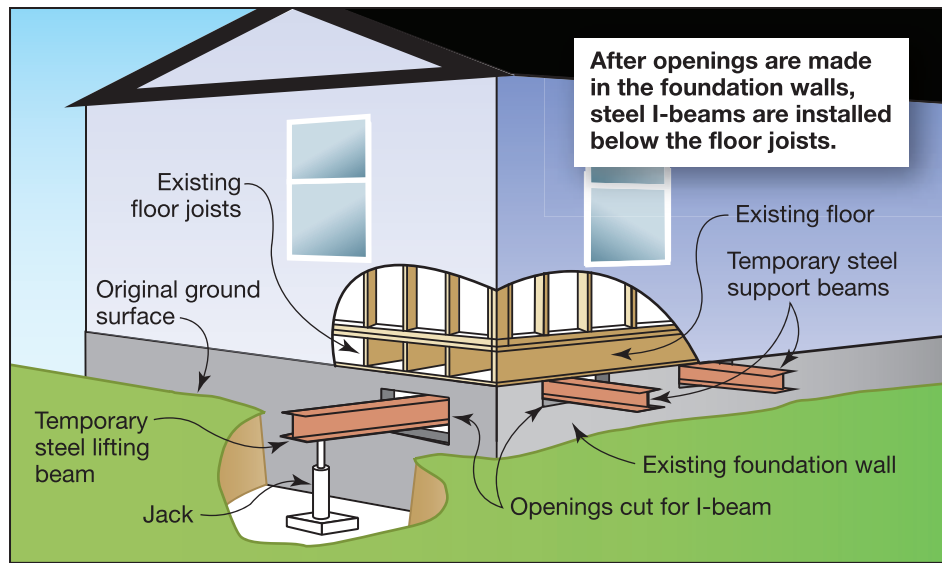
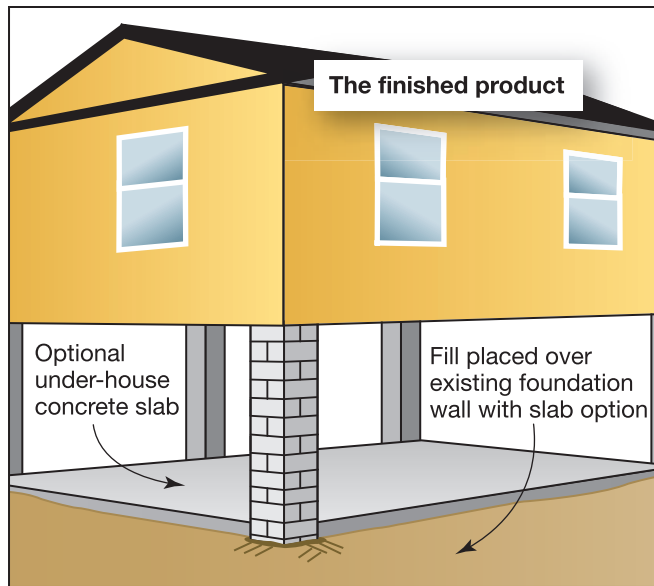
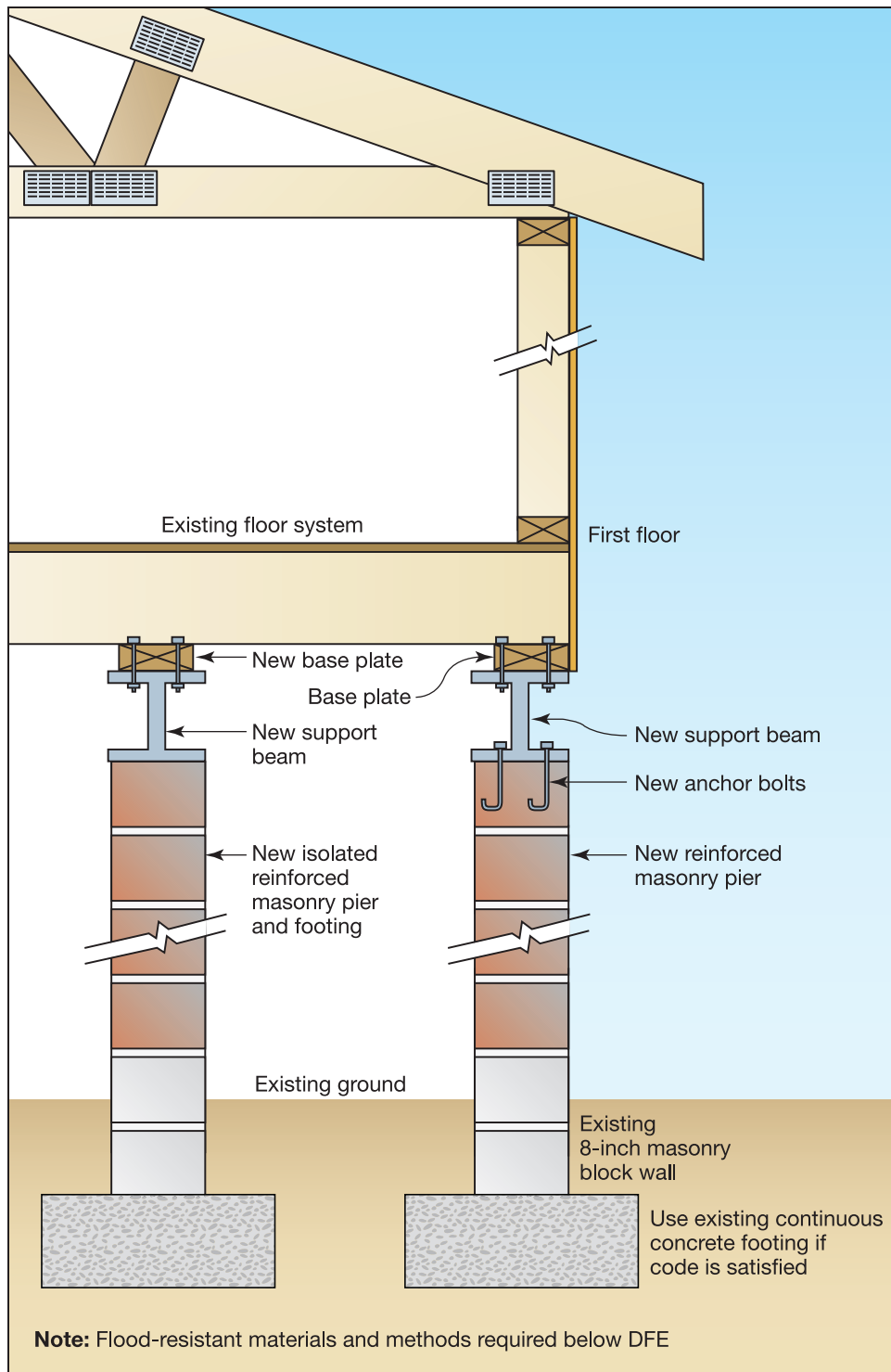


Figure 5E-7.  
 Step 3 of elevating an existing wood-frame house on new or extended pier foundation: Set house on new or extended piers







### 5E.1.2 Houses Over Basements

These houses are slightly more difficult to elevate because their mechanical and HVAC equipment is usually in the basement. In addition, basement walls may already have been extended to the point where they cannot structurally withstand flood forces. Houses over basements can be:

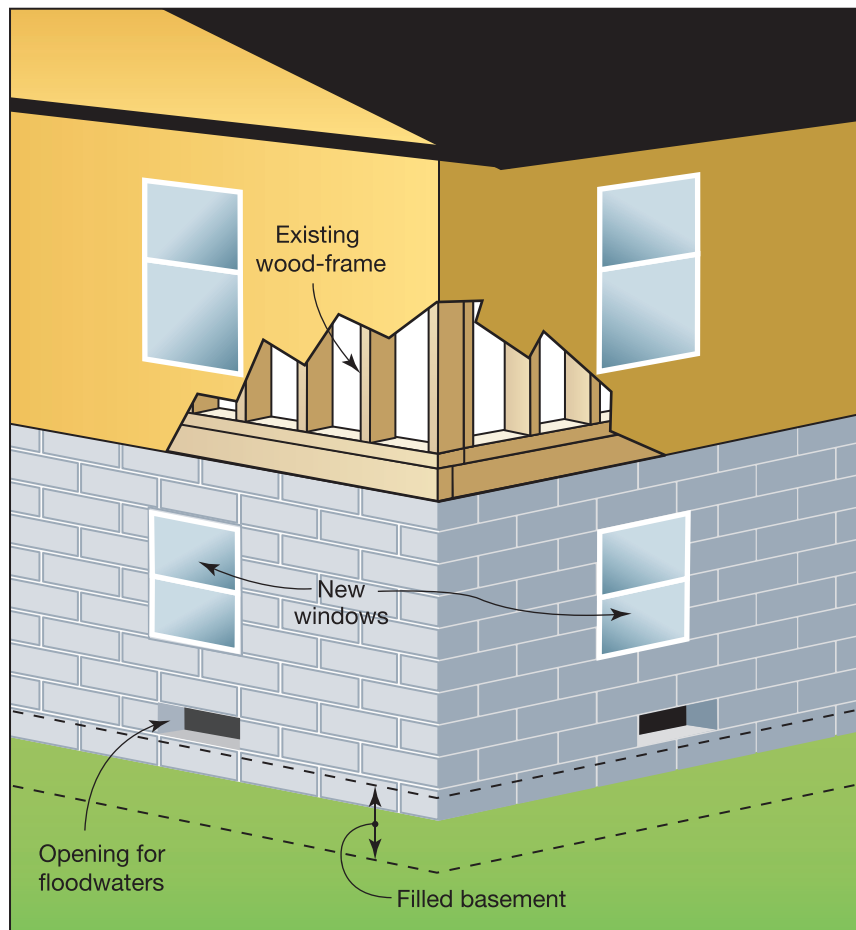
- elevated on solid foundation walls by creating a new masonry-enclosed area on top of an abandoned and filled-in basement (see Figures 5E-9 and 5E-10); or
- elevated on an open foundation, such as masonry piers, by filling in the old basement (see Figures 5E-11 and 5E-12).



#### CROSS REFERENCE

FEMA's post- and pre-FIRM requirements do not allow basements below the BFE for substantially damaged/improved and post-FIRM applications. For more information on what retrofitting measures are allowable under FEMA guidelines, refer to Chapter 2, Regulatory Requirements.

Figure 5E-9. Elevated wood-frame house with new masonry-enclosed area on top of an abandoned and filled-in basement; utility and mechanical equipment must be relocated above the flood level



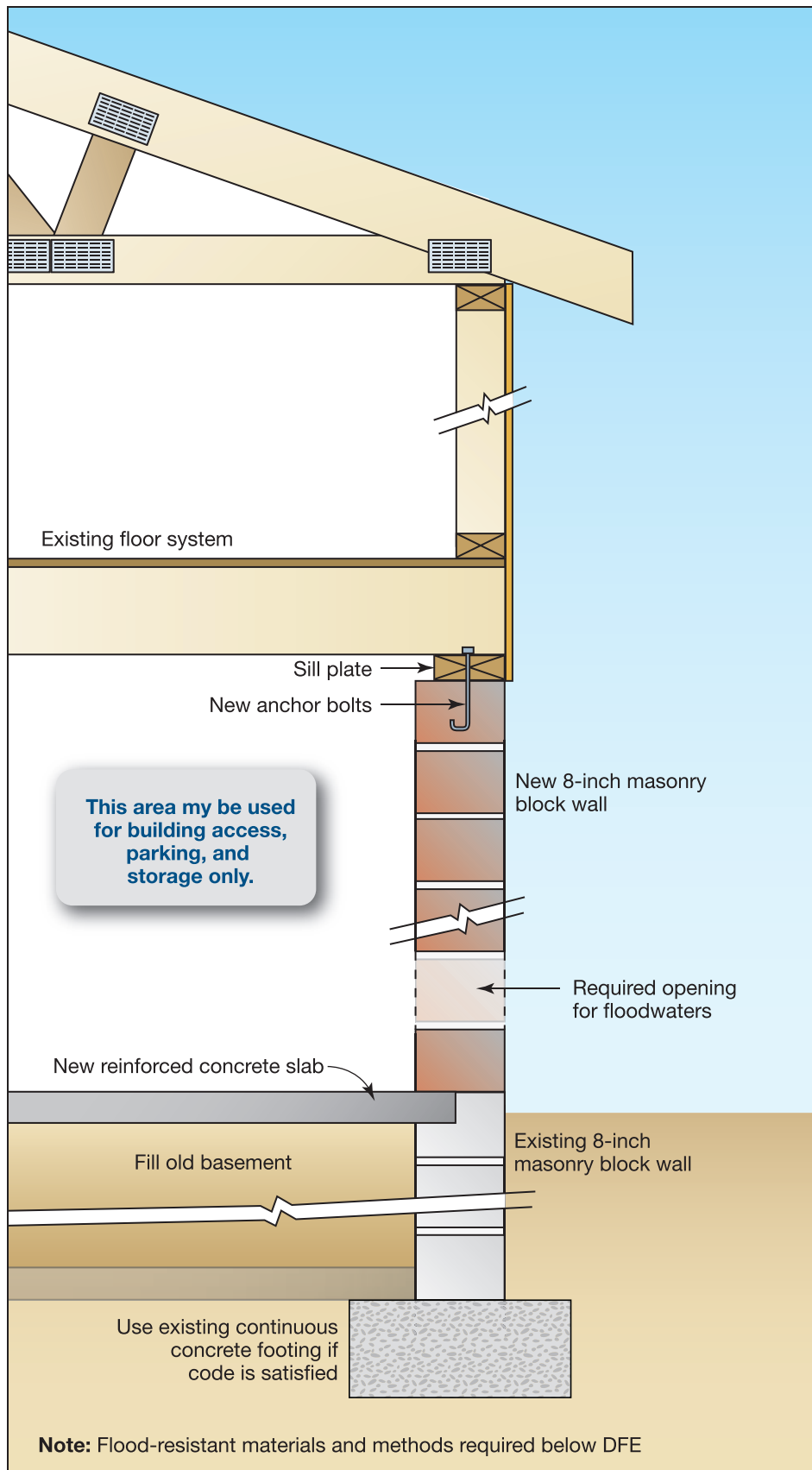
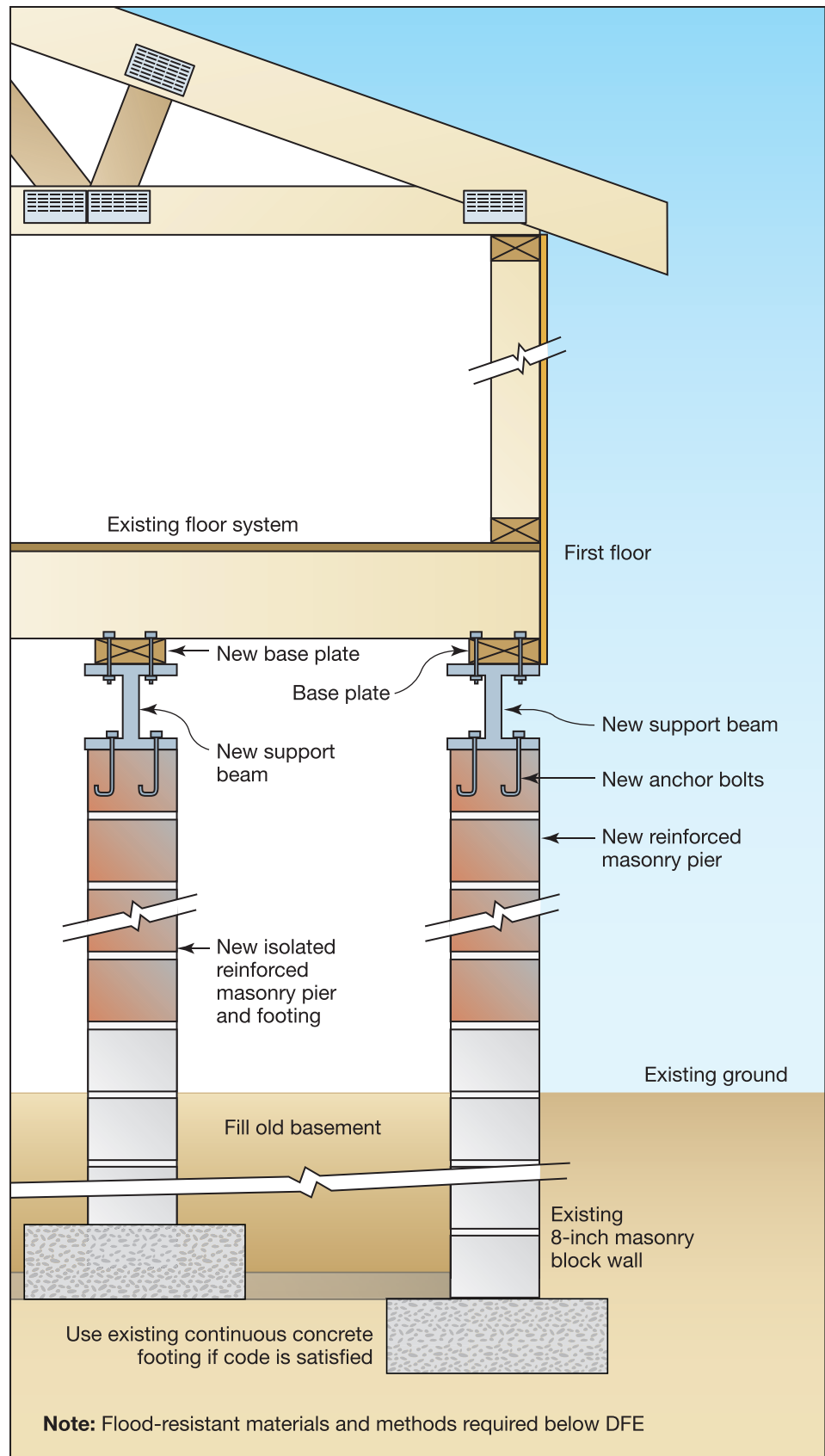


Figure 5E-10. Cross-section of elevated wood-frame house with extended masonry-enclosed area on top of an abandoned and filled-in basement

Figure 5E-11.  
Cross-section of elevated  
wood-frame house on  
top of the existing filled-  
in basement



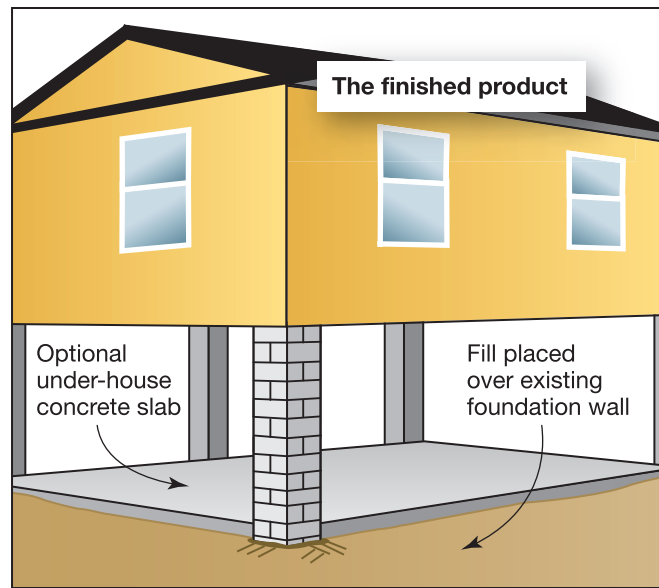


Figure 5E-12. Elevated wood-frame house set on new reinforced piers on top of the existing filled-in basement

### 5E.1.2.1 Design of Openings in Foundation Walls for Intentional Flooding of Enclosed Areas Below the DFE

It is important that the foundation walls contain openings that will permit the automatic entry and exit of floodwater for buildings that are constructed on extended solid foundation walls or that have other enclosures below the DFE (see Figure 5E-13).

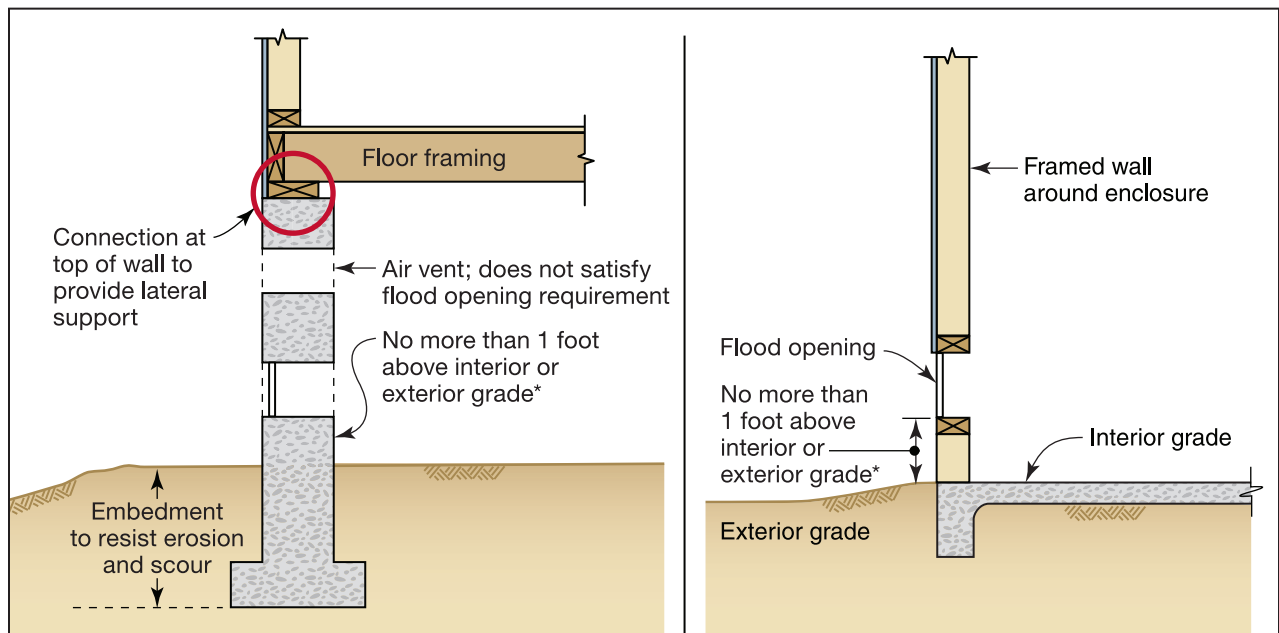


Figure 5E-13. Typical opening for solid foundation wall

These openings allow floodwater to reach equal levels on both sides of the walls and thereby lessen the potential for damage from hydrostatic pressure. While not a requirement for existing buildings built prior to a community's joining the NFIP, NFIP regulations require these openings for all new construction and substantial improvements of existing buildings in SFHAs.

The minimum criteria for design of these openings are:

- a minimum of two openings must be provided on different sides of each enclosed area, having a total net area of not less than 1 square inch for every square foot of enclosed area subject to flooding; this is not required if openings are engineered and certified;
- the bottom of all openings shall be no higher than 1 foot above grade; and
- openings may be equipped with screens, louvers, or other coverings or devices, provided those components permit the automatic entry and exit of floodwater and do not reduce the net open area to less than the required open area.



### CROSS REFERENCE

For additional information on the regulations and design guidelines concerning foundation openings, please refer to FEMA's NFIP Technical Bulletin 1-08, Openings in Foundation Walls for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program (FEMA, 2008).

It is important to make sure that none of the flood openings will be obstructed during a flood event. In wet floodproofed buildings, openings are sometimes obstructed by drywall or other wall coverings (Figure 5E-14), which can result in significant damage if the opening does not operate as intended. Figure 5E-15 shows an NFIP-compliant house with attached garage with flood openings to prevent the build-up of hydrostatic loads on the foundation walls.



Figure 5E-14. A house where flood openings have been covered by insulation and drywall

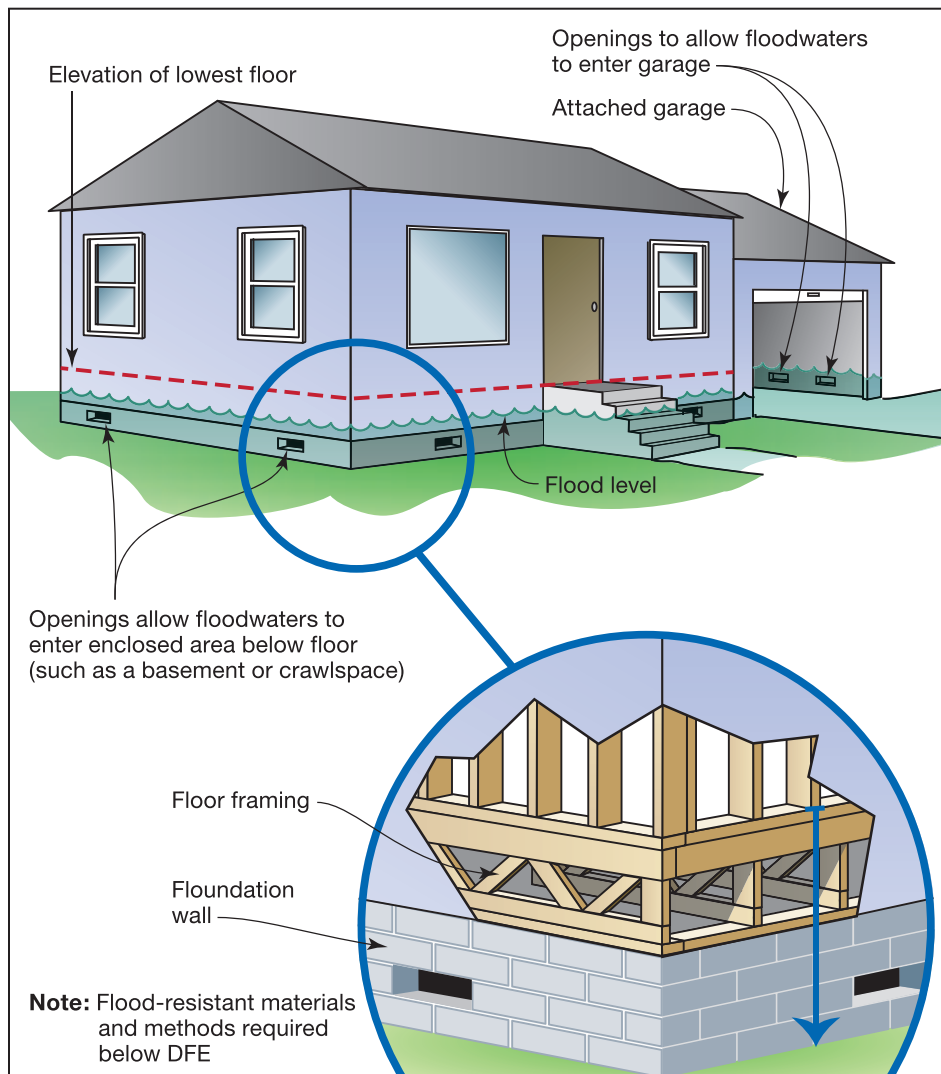


Figure 5E-15.  
NFIP-compliant house built  
on solid foundation walls  
with attached garage

### 5E.1.3 Houses on Piers, Columns, or Piles

The process of elevating a house on existing piers, columns, or piles is slightly more complex in that temporary relocation of the house may be part of the elevation process. With the use of this type of foundation, the house may need to be lifted off the existing foundation and temporarily relocated on site. The existing foundation is then removed and/or reconstructed, and the house is reset on the new foundation. In some instances, raising the home above the working area (instead or relocating off to the side) may provide sufficient room to install new pier and column foundations and to extend existing piers or columns upward.

### 5E.1.4 Slab-on-Grade Houses

Although slab-on-grade houses may be the most difficult to raise, a number of elevation options exist with regard to raising the structure with or without the slab and using a first floor composed of wood or concrete. If the slab is to be raised with the house, a trench is normally dug under the house to provide a space for inserting lifting beams. However, intrusive techniques that place beams through the structural walls have

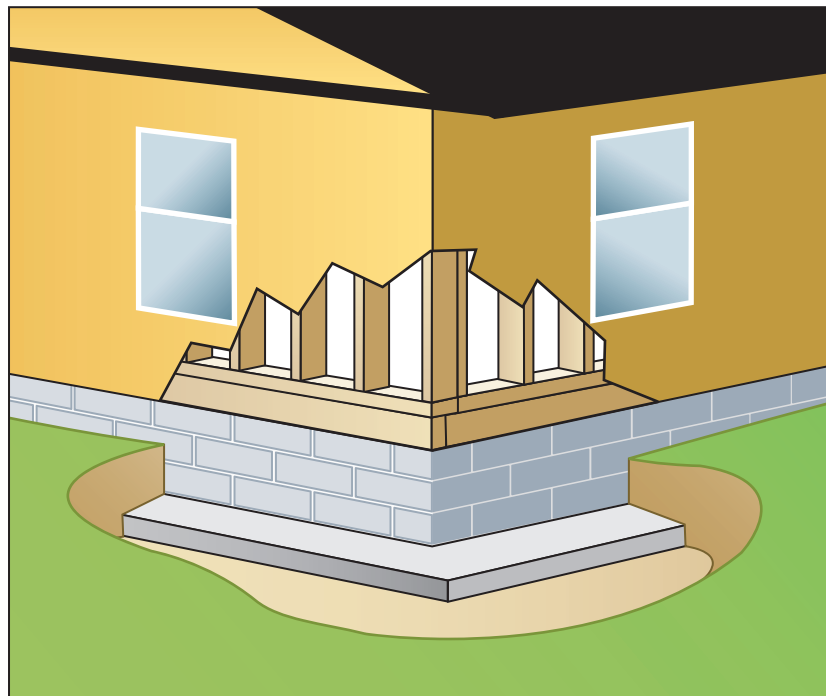
proved to be successful in elevating some slab-on-grade homes, as well. If the existing slab is to remain in place, the house must be detached from the slab, the structure must be raised separately from the slab, and a new floor system must be built along with an elevated foundation.

#### 5E.1.4.1 Elevating a Slab-on-Grade Wood-Frame House

The following procedures apply to elevating a wood-frame house with a slab-on-grade foundation:

- Elevating without the slab, using a new first floor constructed of wood trusses (see Figures 5E-16 through 5E-20); and
- Elevating with the slab intact (see Figures 5E-21 through 5E-23). The basic order of steps required for raising a slab on grade house with slab intact is illustrated in Figures 5E-21 through 5E-23; implementation demands highly specialized skill and equipment that are beyond the scope of this manual.

**Figure 5E-16.**  
Existing wood-frame house with slab and stem-wall foundation



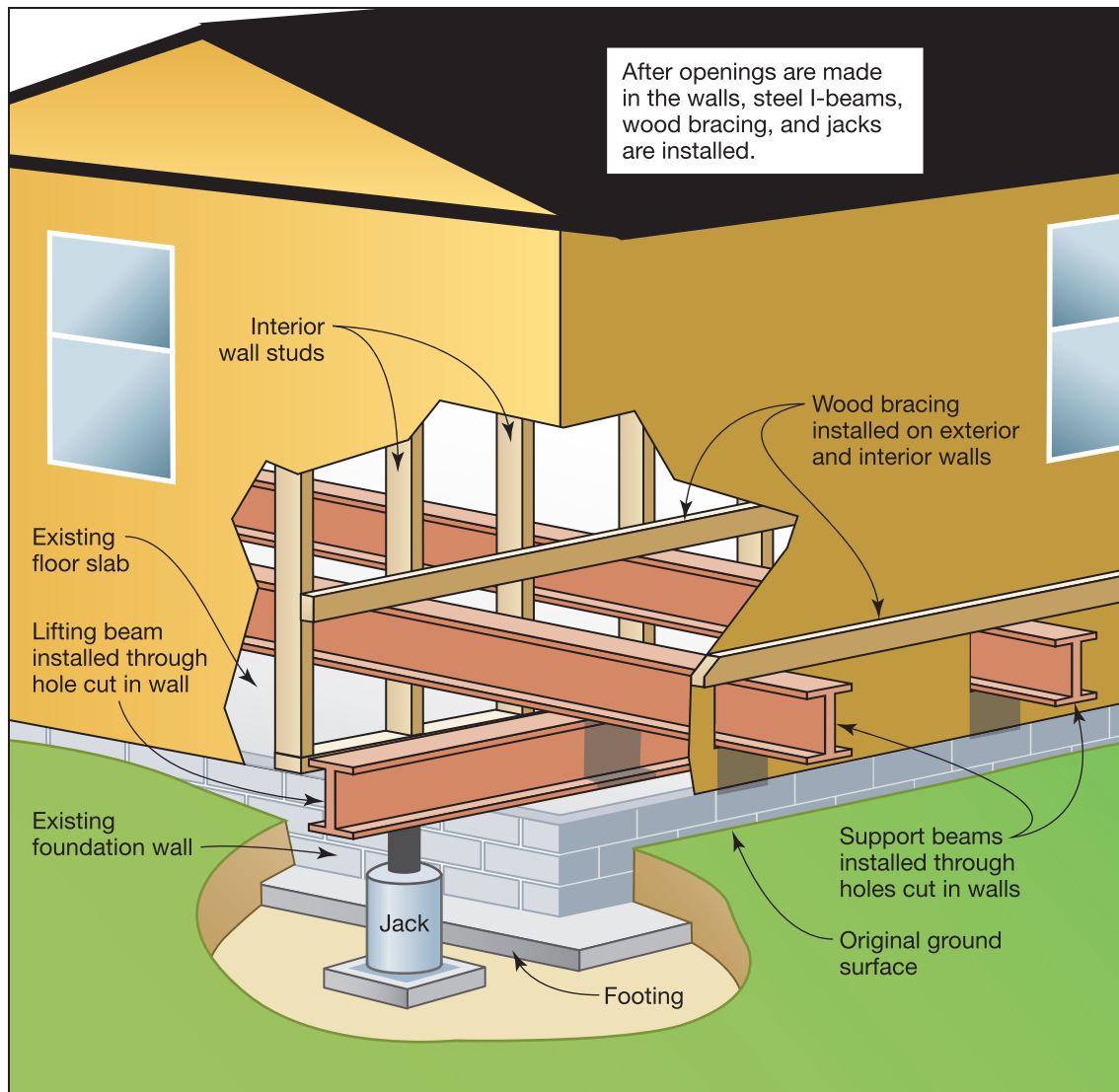


Figure 5E-17. Step 1 of elevating an existing wood-frame house without the slab using a new first floor constructed of wood trusses: Install steel I-beam network and prepare to lift walls



Figure 5E-18.  
 Step 2 of elevating an existing wood-frame house without the slab using a new first floor constructed of wood trusses: Lift house, extend masonry foundation wall, and install wood floor trusses; relocate utility and mechanical equipment above flood level

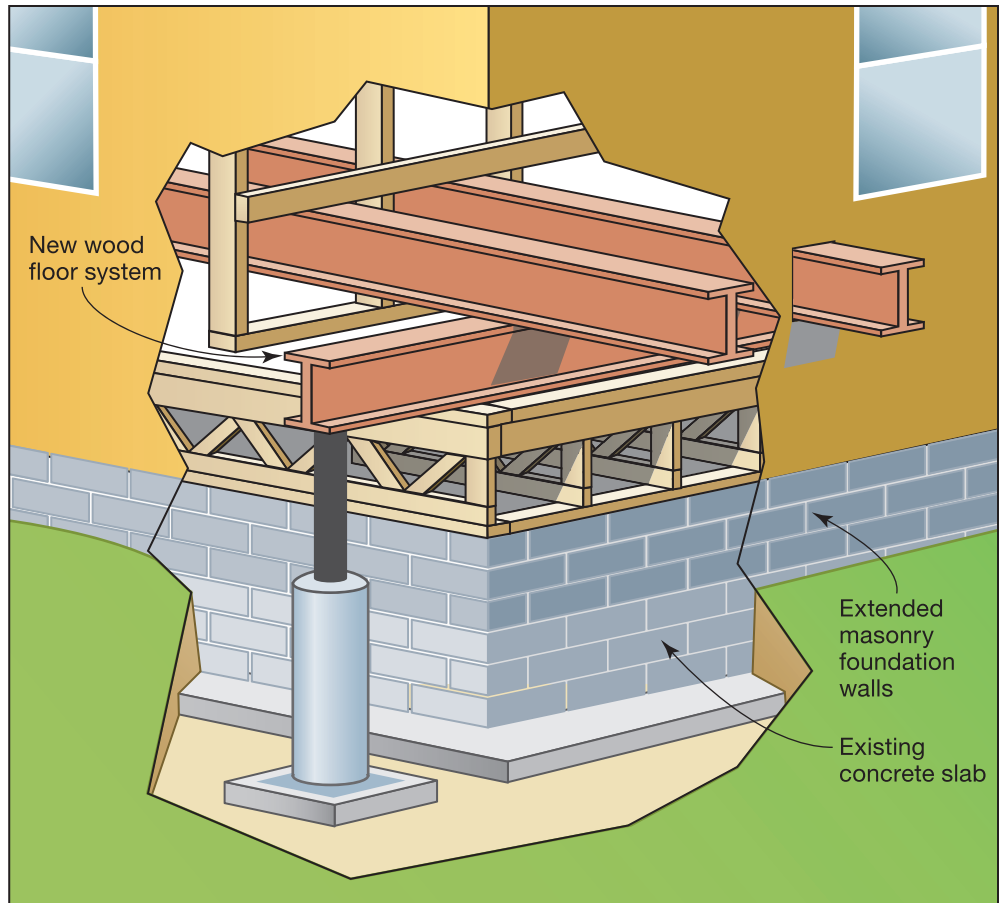
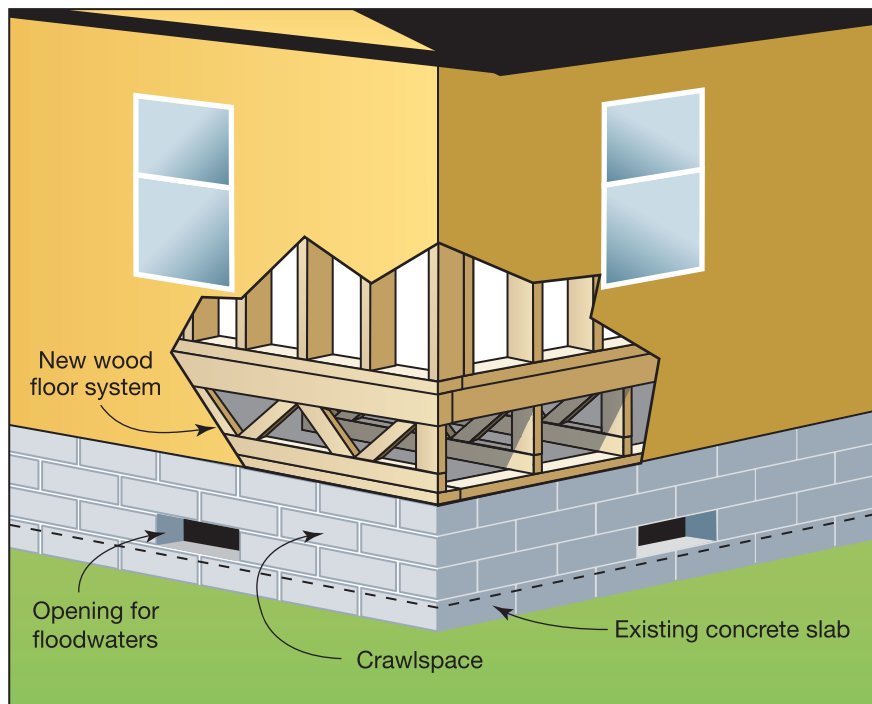
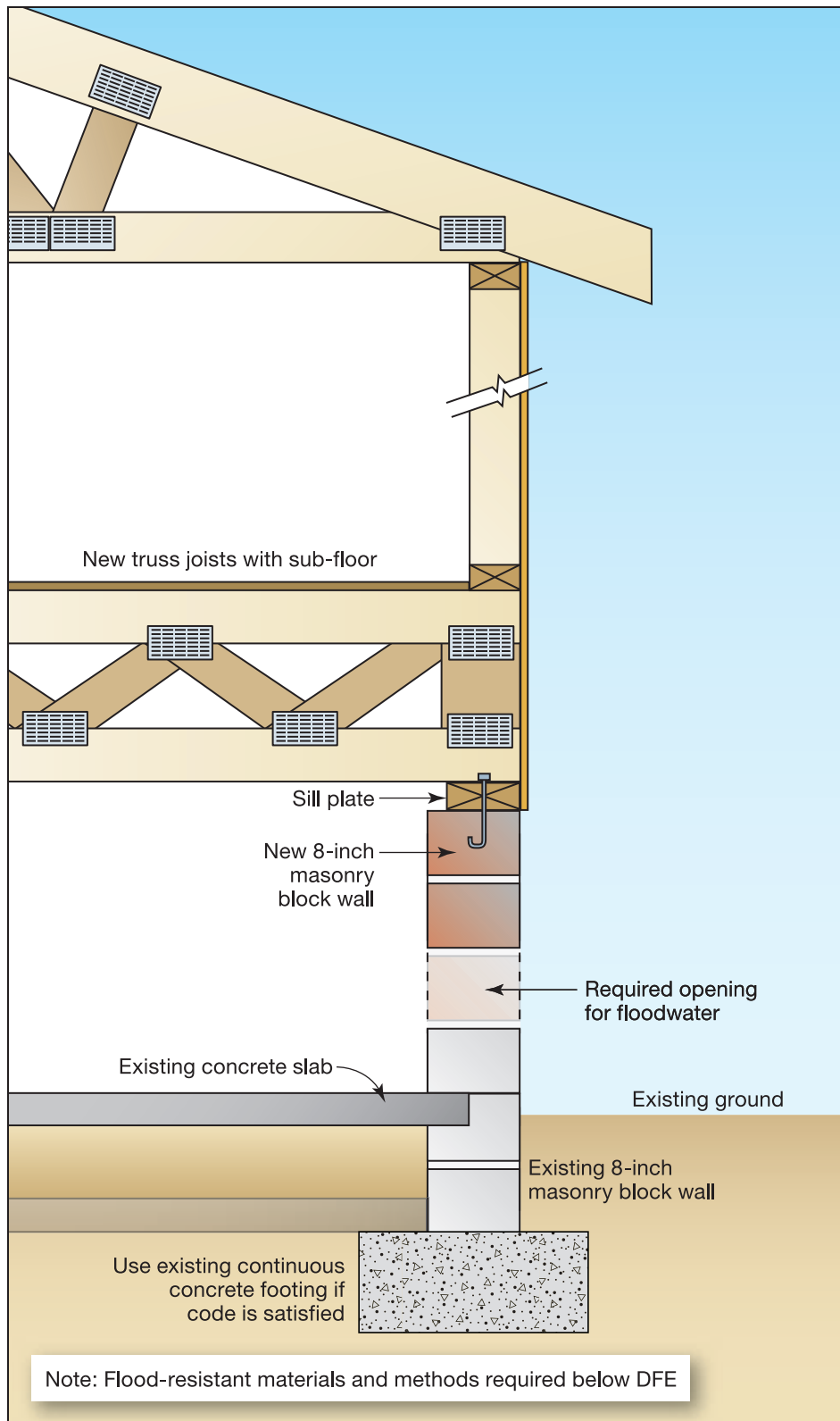


Figure 5E-19.  
 Step 3 of elevating an existing wood-frame house without the slab and with extended stem wall using a new first floor constructed of wood trusses: Set house on new foundation and remove I-beams





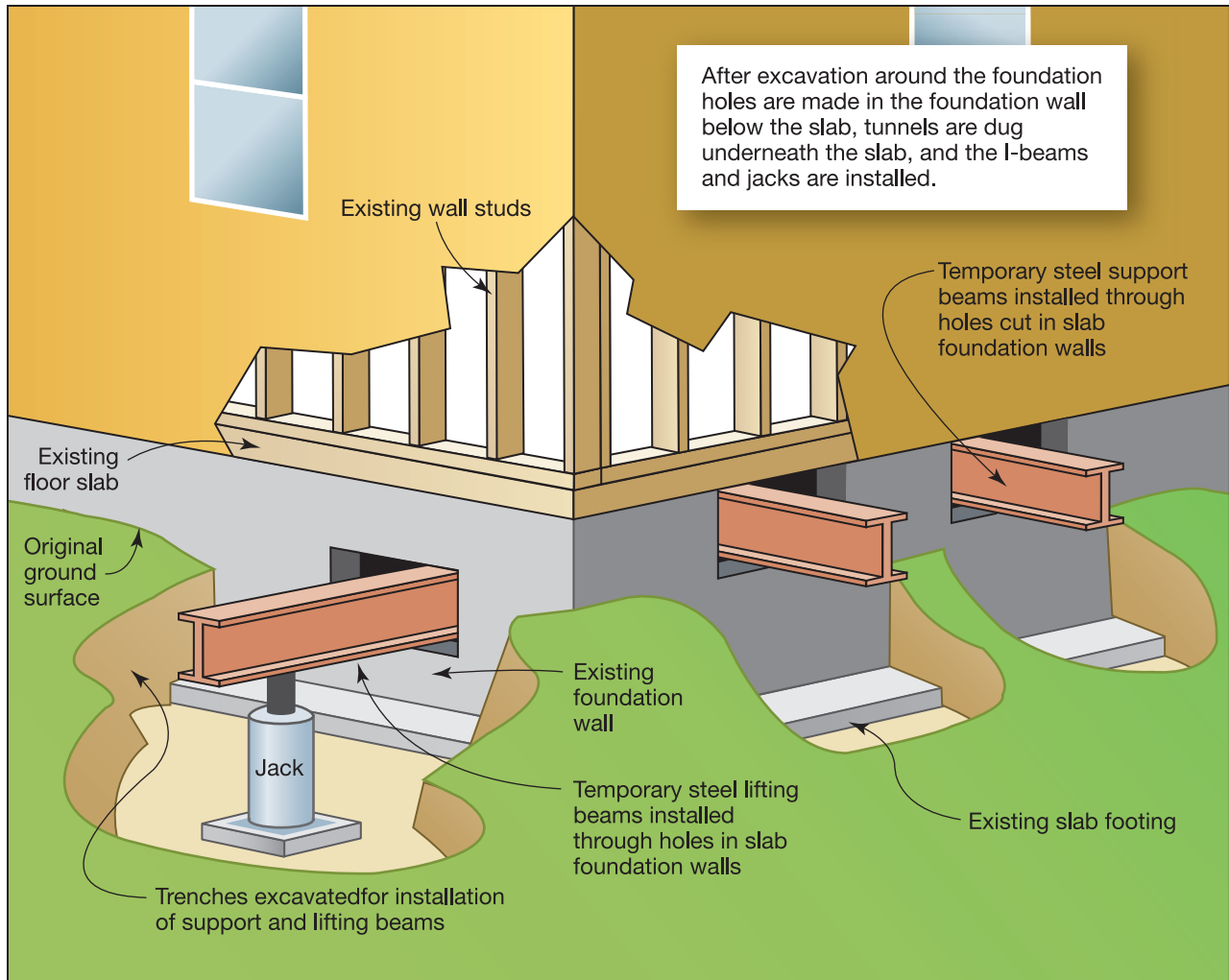


Figure 5E-21. Step 1 of elevating an existing wood-frame house with stem wall foundation and the slab intact: Excavate under existing slab and install network of steel I-beams. Step 2 (not shown): Raise the wood-frame house with the slab intact, extend foundation stem walls, and install new piers.

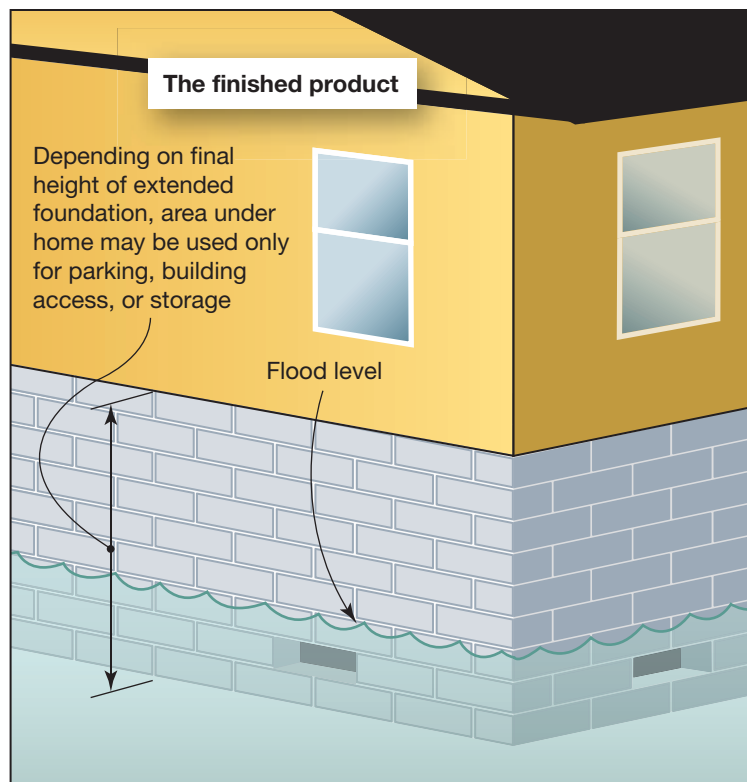


Figure 5E-22.  
Step 3 of elevating an existing wood-frame house with stem wall foundation and the slab intact: Set the house on the new foundation and remove the I-beams

#### 5E.1.4.2 Elevating a Slab-on-Grade Masonry House

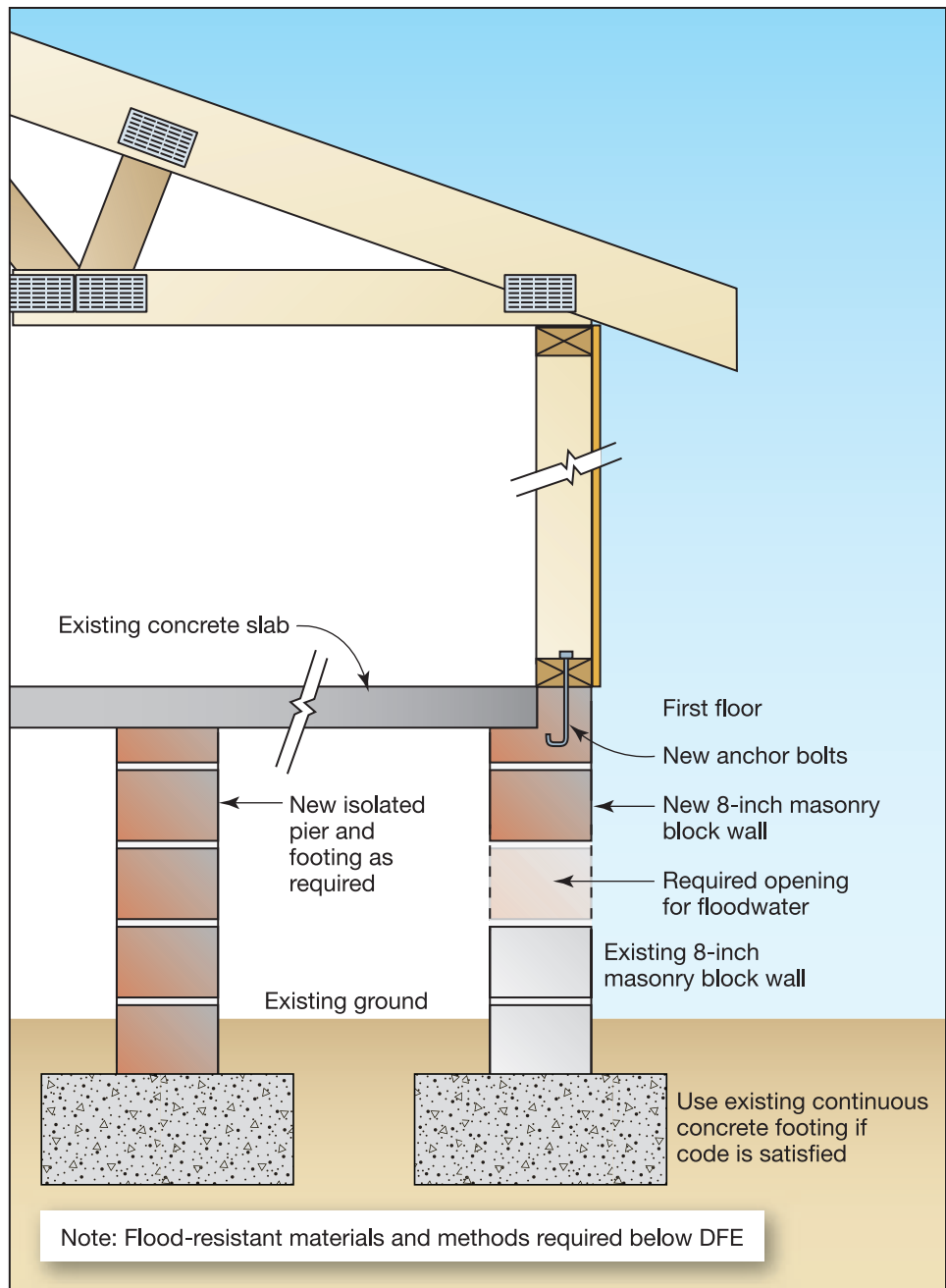
The following alternatives apply to elevating a masonry house with a slab-on-grade foundation:

- elevate a slab-on-grade masonry structure with the slab intact;
- elevate a slab-on-grade masonry structure without the slab, and using a first floor constructed of wood framing;
- install an elevated concrete slab within an existing masonry structure;
- install an elevated wood-frame floor system within an existing masonry structure;
- create a new masonry livable area on top of an existing one-story masonry structure; and
- create a new wood-frame livable area on top of an existing one-story masonry structure.

#### 5E.1.5 Heavy Building Materials/Complex Design

The elevation process becomes even more complex with added weight, height, or complex design of the house. Brick or stucco veneers may require removal prior to elevation. Combination foundations (i.e., slab-on-grade and basement) should be evaluated jointly, as well as separately, and the worst case scenario utilized for design purposes. Building additions may need to be elevated independently from the main structure. Due to the extreme variability of structural conditions, a structural engineer should evaluate the suitability of lifting this type of home.

Figure 5E-23.  
Cross-section of elevated  
wood-frame house with  
stem wall foundation and  
the slab intact



The entire elevation design process is illustrated with a detailed example of the design for a crawlspace house (Figure 5E-24).

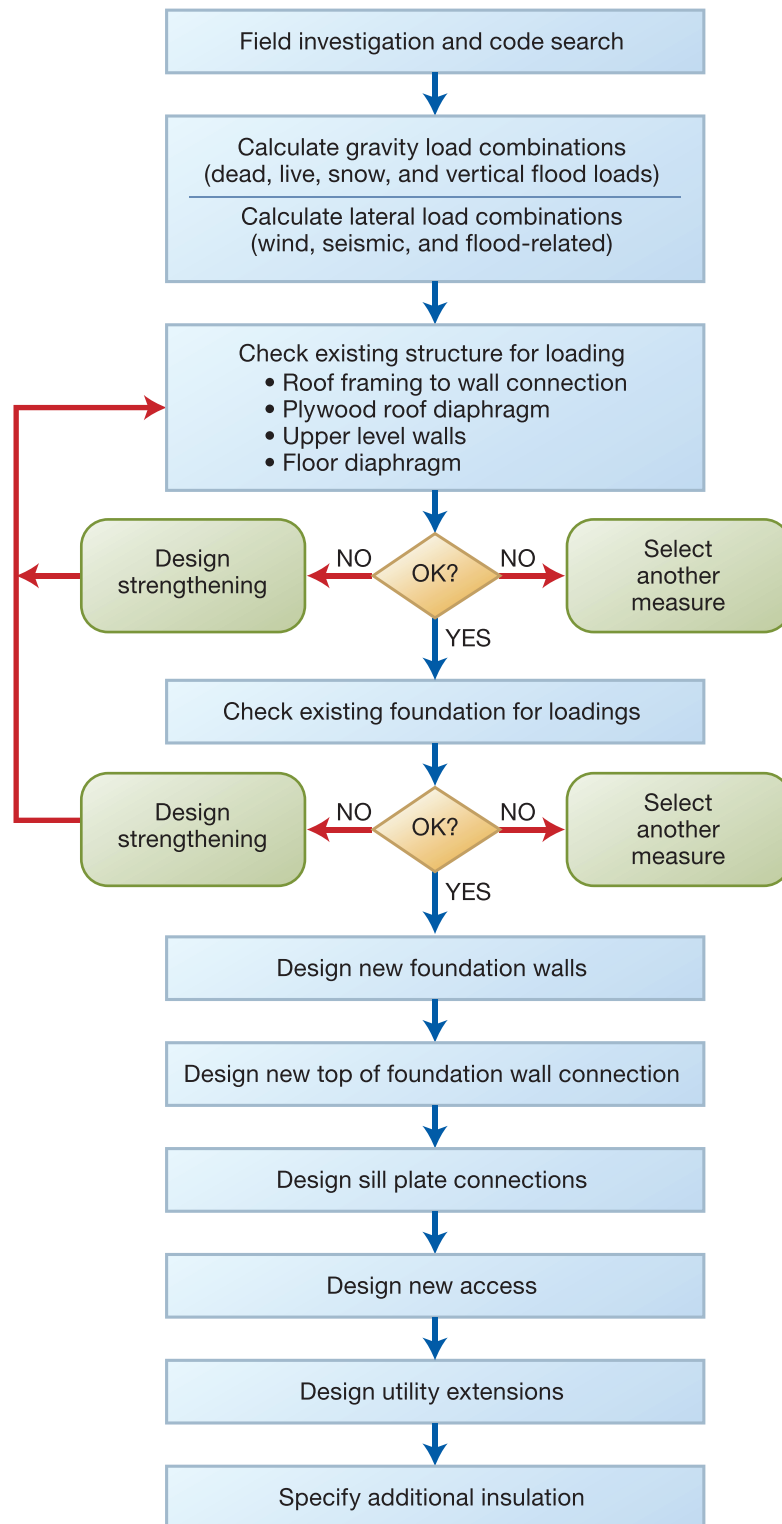


Figure 5E-24.  
Design process for  
an elevated house on  
foundation walls

## 5E.2 Field Investigation Concerns

To determine whether elevation is an appropriate retrofit technique for a particular building, a field investigation should be performed. In addition to a site visit and inspection, a data review and code search should be conducted.

### 5E.2.1 Property Inspection and Existing Data Review

During the field investigation, the designer should inspect the property and review existing data to confirm the applicability of the selected alternative and to confirm specific design guidance such as the height of elevation and type of foundation to be utilized. The designer should utilize the guidance presented in Chapter 5. Much of the data has been previously discussed in Chapters 3 and 4. At a minimum, the designer should collect information on the checklist in Figure 5E-25.

### 5E.2.2 Code Search

During the field investigation, the designer should also conduct a search of local floodplain ordinances, local and State building codes, restrictions to deeds, restrictions in subdivisions, and zoning regulations. In addition, a visit with the local building official should be planned to determine any special requirements for the locality. During the code search, the following should be determined:

- elevation and foundation requirements per the floodplain ordinance and flood hazard map;
- requirements of the building code that governs the elevation project;
- design wind speed;
- design seismic zone;
- ground snow loads;
- frost depths;
- restrictions on height (overall building, portions of building relative to materials in use, allowable height/thickness ratios); and
- restrictions on foundations.

Elevation Field Investigation Worksheet	
Owner Name: _____	Prepared By: _____
Address: _____	Date: _____
Property Location: _____	
Does site topography data cover required area? <input type="checkbox"/> Yes <input type="checkbox"/> No	
Additional data required:	
Any construction access issues?	
Site and building utilities identified?	<input type="checkbox"/> Yes <input type="checkbox"/> No
Potential utility conflicts identified?	<input type="checkbox"/> Yes <input type="checkbox"/> No
Describe conflicts: _____	
Review homeowner preferences: _____	
Can aesthetics reconcile with site and building constraints? <input type="checkbox"/> Yes <input type="checkbox"/> No	
How?	
Confirm type and condition of existing framing:	
<input type="checkbox"/> member sizes	<input type="checkbox"/> spans
<input type="checkbox"/> connections	<input type="checkbox"/> supports
Confirm type and condition of foundation:	
<input type="checkbox"/> type	<input type="checkbox"/> depth
<input type="checkbox"/> size	
Confirm types and condition of existing construction materials:	
<input type="checkbox"/> roof	<input type="checkbox"/> floor
<input type="checkbox"/> walls	<input type="checkbox"/> foundation
Confirm soil information:	
<input type="checkbox"/> type	<input type="checkbox"/> depth of rock
<input type="checkbox"/> bearing capacity	<input type="checkbox"/> susceptibility to erosion and scour
Confirm characteristics of flood-related hazards:	
<input type="checkbox"/> base flood elevation (BFE)	<input type="checkbox"/> velocity
<input type="checkbox"/> design flood elevation (DFE)	<input type="checkbox"/> frequency
<input type="checkbox"/> duration	<input type="checkbox"/> potential for debris flow
Confirm characteristics of non-flood-related hazards:	
<input type="checkbox"/> wind	<input type="checkbox"/> seismic
<input type="checkbox"/> snow	<input type="checkbox"/> other
Review accessibility considerations:	
<input type="checkbox"/> access/egress	<input type="checkbox"/> special resources for elderly, disabled, children
Architectural constraints noted: _____	
Is clearance available to install lifting beams and jacking equipment? <input type="checkbox"/> Yes <input type="checkbox"/> No	
Check local codes/covenants for height or appearance restrictions:	
<input type="checkbox"/> deed/subdivision rules	<input type="checkbox"/> local building codes
Restrictions: _____	

Figure 5E-25. Elevation Field Investigation Worksheet



## 5E.3 Design

The design process for an elevated structure shown in Figure 5E-24 consists of the following steps:

**Step 1:** Calculate the vertical loads.

The computation of vertical loads, which includes building dead and live loads (gravity loads) and buoyancy forces, was presented in Chapter 4.

**Snow Loads:** There are no “typical” equations for houses, since the calculation of snow loads depends on the building code in use, the geographic area in which the house is located, and the size and shape of the house and roof. The governing building code will clearly spell out the correct procedure to follow. Most procedures are simple and straightforward. Some houses will be more complex due to their shape or the quantity of snow that must be allowed for. However, the general procedures are as follows:

- consult snow maps in the building code and/or local requirements with the local building official to determine the ground snow load;
- determine the importance factors;
- analyze the surrounding terrain, trends in snow patterns, and slope of roof to determine the exposure factors;
- determine the snow load;
- determine the considerations for drifting snow by examining any adjacent house or structure, a mountain above the house, or higher roofs; and
- determine the considerations for sliding snow by examining the steep slope on the roof or higher roofs.

**Step 2:** Calculate the lateral loads.

The calculation of building lateral loads includes wind, seismic, and flood-related loads. One objective of the wind and seismic analysis is to determine which loading condition controls the design of specific structural components.

**Wind Analysis:** There are no “typical” equations for houses, since the calculation of wind loads depends upon the building code in use and the size and shape of the house. The governing building code will clearly spell out the correct procedure to follow. Most procedures are simple and straightforward. Some houses will be more complex due to their shape. However, the general procedure, as discussed in Chapter 4, is presented below.



### CROSS REFERENCE

To illustrate the design process, a worked example is shown in Appendix C for Steps 1-7. Information on Step 9 is presented in Chapter 5F. The designer should refer to local codes for guidance on Steps 8 and 10. The example demonstrates numerous considerations necessary for an elevation project, but is not technically exhaustive.



### NOTE

If the governing building code does not provide applicable guidance on loading associated with flooding, wind, seismic, or snow, refer to ASCE 7.

- determine the wind speed and pressure by consulting wind maps within the building code, and checking local requirements with the local building official;
- determine the importance factors and the exposure category;
- determine the wind gust and exposure factors and analyze the building height and shape, whether the wind is parallel or perpendicular to the roof ridge, and whether it is windward or leeward of roofs/walls;
- determine the wind load; and
- distribute the load to resisting elements based upon the stiffness of shear walls, bracing, and frames.

**NOTE**

ASCE 7 and the IRC provide basic wind speed maps showing wind velocities and frequencies. If the local code enforced is the IRC, the designer should refer to the IRC wind speed map (Figure 4-19). If no local code is in force, the designer should refer to ASCE 7, Minimum Design Loads for Buildings and Other Structures.

**Seismic Analysis:** There are no “typical” equations for houses since the calculation of seismic loads depends upon the building code in use and the size and shape of the house. The governing building code will clearly spell out the correct procedures to follow. Some houses will be more complex due to their shape. However, the general procedures, as discussed in Chapter 4, are presented below.

- calculate the dead loads by floor, including permanent dead loads (roof, floor, walls, and building materials) and permanent fixtures (cabinets, mechanical/electrical fixtures, stairs, new locations for utilities, etc.);
- determine if the snow load must be included in the dead load analysis; most building codes require the snow load to be included for heavy snow regions and will list these requirements;
- determine the seismic zone and importance factors;
- determine the fundamental period of vibration (height of structure materials used in building);
- determine the total seismic lateral force by analyzing site considerations, building weights, and the type of resisting system;
- distribute the loads vertically per the building code, keeping in mind the additional force at the top of the building; and
- distribute the loads horizontally according to the building code and the stiffness of resisting elements. The code-prescribed minimum torsion of the building (center of mass versus center of rigidity), shear walls, bracing, and frames must be considered.

**Flood-Related Forces:** The computation of flood-related forces was presented in Chapter 4 and includes the following:

- determine the DFE;
- determine the types of flood forces (hydrostatic or hydrodynamic);
- determine the susceptibility to impacts from debris (ice, rocks, trees, etc.);

- determine the susceptibility to scour;
- determine the applicability of and susceptibility to alluvial fans;
- determine the design forces; and
- distribute the forces to resisting elements based upon stiffness.

**Step 3:** Check ability of existing structure to withstand additional loading.

Chapter 4 presented general information on determining the ability of the existing structure to withstand the additional loadings imposed by retrofitting methods. The process detailed below is similar for each of the building types most people will encounter. First, the expected loadings are tabulated and compared against allowable amounts determined from soil conditions, local code standards, or building material standards. The following list of existing building components and connections should be checked.

**Roofs:** The plywood roof diaphragm, trusses, connections, and uplift on roof sheathing should be capable of resisting the increased wind and seismic loads. The Engineered Wood Association (<http://www.apawood.org>) has published several references that are useful in this calculation, including APA SR-1013, *Design for Combined Shear and Uplift from Wind* (APA, 2011) and APA Form T325, *Roof Sheathing Fastening Schedules for Wind Uplift* (APA, 2006).

These reference materials or the local building codes will give the designer the necessary plywood thicknesses and connection specifications to resist the expected loadings and/or will provide loading ratings for specific material types and sizes.

If the roof diaphragm and sheathing are not sufficient to resist the increased loading, the design can strengthen these components by:

- increasing the thickness of the materials; and/or
- strengthening the connections with additional plates and additional fasteners.

**Roof Framing-to-Wall Connections:** The roof framing connections to walls should be checked to ensure that they will resist the increased wind loads. Of critical importance are the gable ends, where many wind failures occur. The Engineered Wood Association has published several references that are useful in this calculation, including APA SR-1013, *Design for Combined Shear and Uplift from Wind* (APA, 2011) and APA Form L350, *Diaphragms and Shear Walls* (APA, 2007).

These reference materials or the local building codes will give the designer the necessary truss size, configuration, and connection specifications to resist the expected loadings, and/or will provide loading ratings for specific truss and connection types and sizes.

If the roof trusses and wall connections are not sufficient to resist the increased loading, the design can strengthen these components by:



### CROSS REFERENCE

For additional information on the performance of various building system products, refer to product evaluation reports prepared by the model code groups or the National Evaluation Service (NES).

- increasing the amount of bracing between the trusses; and/or
- strengthening the connections with additional plates and additional fasteners.

**Upper Level Walls:** The upper level walls are subject to increased wind pressure and increased shear due to increased roof loads. Both the short and long walls should be checked against the shear, torsion, tension, and deflection, utilizing the governing loading condition (wind or seismic).

The Engineered Wood Association has published several references that are useful in this calculation, including APA SR-1013, *Design for Combined Shear and Uplift from Wind* (APA, 2011) and APA Form L350, *Diaphragms and Shear Walls* (APA, 2007).

These reference materials or the local building codes will give the designer the necessary wall size and configuration and connection specifications to resist the expected loadings and/or will provide loading ratings for specific wall types, sizes, and connection schemes.

If the upper level walls are determined to be unable to withstand the increased loadings, the designer is faced with the difficult task of strengthening what amounts to the entire house. In some situations, this may be cost-prohibitive, and the homeowner should look for another retrofitting method, such as relocation. Measures the designer could utilize to strengthen the upper level walls include:

- adding steel strapping (cross bracing) to interior or exterior wall faces;
- adding a new wall adjacent to the exterior or interior of the existing wall;
- bolstering the interior walls in a similar fashion; and/or
- increasing the number and sizes of connections.

**Floor Diaphragm:** The floor diaphragm and connections are subject to increased loading due to wind, seismic forces, and flood. The existing floor diaphragm and connections should be checked to ensure that they can withstand the increased forces that might result from the elevation.

The Engineered Wood Association has published several references that are useful in this calculation, including APA Form Y250, *Shear Transfer at Engineered Wood Floors* (APA, 1999) and APA Form L350, *Diaphragms and Shear Walls* (APA, 2007).

These reference materials or the local building codes will give the designer the necessary floor size and configuration and connection specifications to resist the expected loadings, and/or will provide loading ratings for specific floor types, sizes, and connection schemes.

If the floor diaphragm or connections are determined to be unable to withstand the increased loadings, the designer could strengthen these components by:

- adding a new plywood layer on the bottom of the existing floor diaphragm;
- increasing the number and size of bracing within the floor diaphragm; and
- increasing the number and size of connections.

**Step 4:** Analyze the existing foundation.

The existing foundation should be checked to determine its ability to withstand the increased gravity loads from the elevation, the increased lateral loads due to soil pressures from potential backfilling, and the increased overturning pressures due to seismic and wind loadings. The designer should tabulate all of the gravity loads (dead and live loads) plus the weight of the new foundation walls to determine a bearing pressure, which is then compared with the allowable bearing pressure of the soil at the site. Not including expected buoyancy forces in this computation will yield a conservative answer.

If the existing footing is insufficient to withstand the additional loadings created by the elevated structure, the design of foundation supplementation should be undertaken. The foundation supplementation may be as straightforward as increasing the size of the footing and/or more substantial reinforcement. The designer may refer to the ACI manual for footing design, recent texts for walls and footing design, and applicable codes and standards.

**Step 5:** Design the new foundation walls.

The design of a new foundation, whether solid or open, is usually governed by the local building codes. These codes will have minimum requirements for foundation wall sizes and reinforcing schemes, including seismic zone considerations. The designer should consult the appropriate code document tables for minimum requirements for vertical wall or open foundation reinforcement.

**CROSS REFERENCE**

For wet floodproofing applications, where openings in foundation walls are necessary, refer to Chapter 5W, Wet Floodproofing.

For new slab applications where the lower level is allowed to flood and the slab is not subject to buoyancy pressures, the designer can use the Portland Cement Association document *Concrete Floors on Ground* (2008) as a source of information to select appropriate thicknesses and reinforcing schemes based upon expected loadings. The slab loadings will vary based upon the overall foundation design and the use of the lower floor.

**Step 6:** Design top of foundation wall connections.

Top of wall connections are critical to avoid pullout of the sole plate, floor diaphragm, and/or sill plate from the masonry foundation. A preliminary size and spacing of anchor bolts is assumed, and uplift, shear, and tension forces are computed and compared against the allowable loads for the selected bolts. Where necessary, adjustments are made to the size and spacing of the anchor bolts to keep the calculated forces below the allowable forces. Connections should be designed for all appropriate load combinations as discussed in Chapter 5.

**Step 7:** Design the sill plate connections.

The existing sill plate connections will be subject to increased lateral loads and increased uplift forces due to increased wind and buoyancy loading conditions. The sill plate is designed to span between the anchor bolts and resist bending and horizontal shear forces. The designer should refer to the appropriate wood design manual that provides recommended compression, bending, shear, and elasticity values for various sill plate materials. Using these values, the designer checks the connection against the expected forces to ensure that the actual forces are less than the allowable stresses. If the sill plate connection is insufficient to withstand expected loadings, the size of the sill plate can be increased (or doubled), and/or the spacing of the anchor bolts can be reduced.

**Step 8:** Design new access.

The selection and design of new access to an elevated structure is done in accordance with local regulations governing these features. Special homeowner requirements, such as for aesthetics, handicapped accessibility, and/or special requirements for children and the elderly, can be incorporated using references previously discussed in Chapter 3.

Incorporating the new access often applies to multiple egress locations and may present a unique challenge to the designer as greater area is required on the existing site to accommodate the increase in elevation from adjacent grade to egress. A particular obstacle may arise with attached garages where the living space is elevated and the garage slab remains at original grade as allowed for areas designated for building access, parking, and storage only. Besides the area and height constraints required for the additional stairs to the elevated egress, the designer must also resolve drainage and aesthetic issues created by the newly discontinuous roof system.

Connection of the new access to the house should be designed in accordance with the local codes. The foundation for the access measure will either be freestanding and subject to its own lateral stability requirements or it will be an integral part of the new elevated structure. In either case, analysis of the structure to ensure adequate foundation strength and lateral stability should be completed in accordance with local codes.

It should be noted that any access below the BFE should incorporate the use of flood-resistant materials. The designer should refer to FEMA's NFIP Technical Bulletin 2-08, *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program* (FEMA, 2008).

**Step 9:** Design the utilities extensions.

The field investigation will reveal the specific utility systems that will require relocation, extension, or modification. Whenever possible, utility systems should be relocated above the DFE. Local utility companies should be contacted about their specific requirements governing the extension of their utility service. In many instances, the local utility company will construct the extension for the homeowner. Critical issues in this extension process include:

- handling of utilities encased in the existing slab or walls;
- coordination of disconnection and reconnection;
- any local codes that require upgrades to the utility systems as part of new construction or substantial repair or improvement;
- introduction of flexible connections on gas, water, sewer, and oil lines to minimize potential for seismic damage;
- potential for relocation or elevation of electrical system components from existing crawlspace and/or basement areas; and
- design of separate GFI-type electrical circuits and use of flood-resistant materials in areas below the BFE.

**CROSS REFERENCE**

Guidance on the selection of an elevation or relocation contractor is provided in Chapter 5R, Relocation.



**Step 10:** Specify the increased insulation requirements.

Elevated floors and extended utility system components may increase the potential for heat loss through increased exposure and airflow and necessitate additional insulation. The designer should evaluate the energy efficiency of each aspect of the project, compare existing insulation (R-values) against the local building code, and specify additional insulation (greater R-value) where required.

## 5E.4 Construction Considerations

Following are some important points for consideration both prior to and during implementation of a structure elevation project.

Prior to elevating any house:

- obtain all permits and approvals required;
- ensure that all utility hookups are disconnected (plumbing, phone, electrical, cable, and mechanical);
- estimate the lifting load of the house; and
- identify the best location for the principal lift beams, lateral support beams, and framing lumber, and evaluate their adequacy (generally performed by a structural engineer or the elevation contractor).

### 5E.4.1 Slab-on-Grade House, Not Raising Slab with House

Procedures for elevating a slab-on-grade house without raising the slab:

- holes are cut for lift beams in the exterior and interior walls;
- main lifting beams are inserted;
- holes are cut for the lateral beams;
- lateral beams are inserted;
- bracing is installed to transfer the loads across the support walls and lift remaining walls;
- jacks are moved into place and structure is prepared for lifting;
- straps and anchors used to attach house to slab-on-grade are released;
- the house is elevated and cribbing installed;
- slab around edges is removed to allow for new foundation;
- the new foundation is constructed;
- new support headers and floor system are installed;
- any required wind and seismic retrofit is completed;

- house is attached to new foundation;
- all temporary framing is removed, holes are patched;
- all utilities are reconnected;
- new stairways and access are constructed; and
- all utilities below the DFE are floodproofed.

### **5E.4.2 Slab-on-Grade House, Raising Slab**

Procedures for elevating a slab-on-grade house and raising the slab:

- trenches are excavated for placement of all support beams beneath slab;
- lifting and lateral beams are installed;
- jacks are moved into place and the structure is prepared for lifting;
- the house is elevated and cribbing installed;
- the new foundation is constructed;
- any required wind and seismic retrofit is completed;
- house is attached to new foundation;
- support beams are removed;
- access holes are patched;
- all utilities are reconnected;
- new stairways and access are constructed; and
- all utilities below the DFE are floodproofed.

### **5E.4.3 House Over Crawlspace/Basement**

Procedures for elevating a house over a crawlspace or basement:

- masonry is removed as necessary to allow for placement of support beams;
- main lifting beams are installed;
- lateral beams are installed;
- jacks are moved into place and the structure is prepared for lifting;
- all connections to foundation are removed;



- house is elevated and cribbing installed;
- existing foundation walls are raised or demolished, depending on whether the existing foundation walls can handle the new loads;
- new footings and foundation walls are constructed if the existing foundation walls/footings cannot withstand the additional loading;
- basement is backfilled where appropriate;
- house is attached to new foundation;
- support beams are removed;
- access holes are patched;
- all utilities are reconnected;
- new stairways and access are constructed; and
- all utilities below the DFE are floodproofed.

#### **5E.4.4 House on Piers, Columns, or Piles**

If the house is to remain in the same location, the house will most likely need to be temporarily relocated to allow for the footing and foundation installation. If the house is being relocated within the same site, the footings should be constructed prior to moving the house. Procedures for elevating a house on piers, columns, or piles:

- main support beams are installed;
- lateral beams are installed;
- jacks are moved into place and the structure prepared for lifting;
- house is elevated and cribbing is installed;
- if the house is being relocated, see section 5R;
- existing foundation is demolished and removed and new pier and column foundation is installed or existing foundation elements are extended upward and reinforced as needed
- house is attached to new foundation;
- support beams are removed;
- all utilities are reconnected;
- new stairways and access are constructed; and
- all utilities below the DFE are floodproofed.

## 6.2 Case Study #2: Residential Retrofit in Coastal A Zone Using Elevation or Acquisition

This case study exercise examines the retrofit of a residential building in a coastal floodplain by means of elevation or acquisition. Details are provided in the subsections that follow.

### 6.2.1 Description of Property

Abe and Bea Chester  
1234 Bay Street, Norfolk, VA 12345

Abe and Bea Chester built their home in the 1960s before flood maps were developed for the area. The one-story, wood-frame structure does not have a basement. They live on Bay Street, close to the beach, in Norfolk, VA. Although they live outside of Zone V, they are still in the SFHA (Zone A) and would like to protect their home from flooding. They are not interested in moving the house itself, but they may be willing to move out of the neighborhood if they can get money to purchase another house. Because they live in Zone A and are subject to coastal flooding, they are interested in elevation on an open foundation. The local floodplain ordinance prohibits elevation on fill. The effective BFE is 4 feet above the first floor elevation.

The Chesters indicated they would like to pursue retrofitting options that would allow them to obtain a reduced NFIP flood insurance rate. If possible, the Chesters would like to apply for HMA grant assistance.

### 6.2.2 Structure Information

1234 Bay Street is a one-story, wood-frame structure and is a structure of average quality (Figure 6-18). See Section 6.2.5 for a tax card, including a floor plan of the structure.

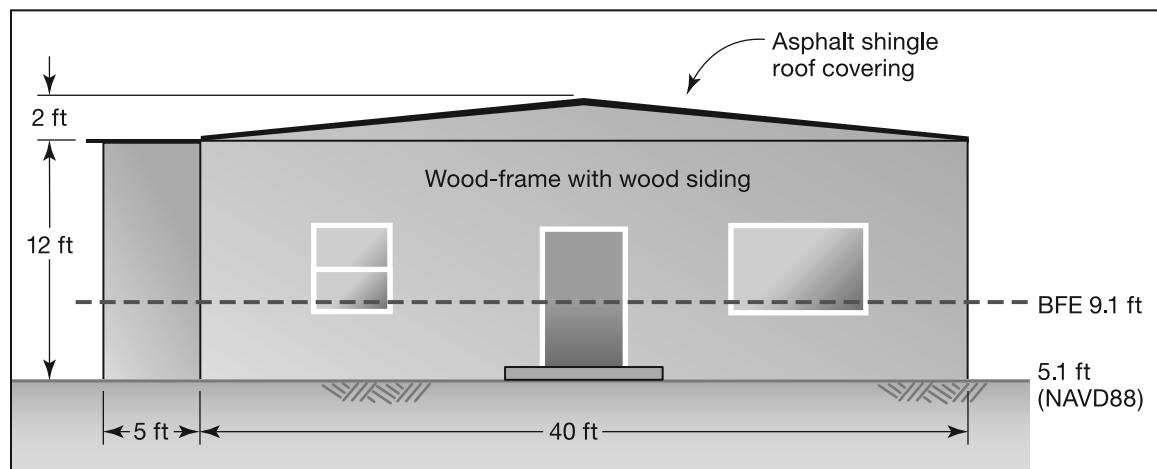


Figure 6-18. The Chester house, before mitigation

Other structure information includes:

- Footprint:
  - 1,025 square feet (see section 6.2.5)
- Foundation:
  - 6-inch-thick concrete slab on a 2-foot-wide x 1-foot-thick concrete wall footer
- Structure:
  - First floor elevation of 5.1 feet NAVD88, measured from the top of the lowest finished floor
  - Wood-frame structure
  - Wood siding
  - Wood-frame interior walls with gypsum board sheathing
- Roof:
  - Gable roof without overhangs over main structure (35-foot x 25-foot plan area)
  - Flat roof without overhangs over side areas (two 5-foot x 15-foot areas)
  - Asphalt shingle roof covering over entire roof
- Interior:
  - Wood stud interior walls with gypsum board sheathing
  - Hardwood floor coverings

### Plot

The Chesters' plot is essentially flat and relatively small. The entire plot is in the SFHA. The ground elevation is between 5.1 feet and 5.3 feet (NAVD88) over the entire plot. The site soils are primarily a mixture of silty sand and gravel (Soil Type SM).

### Building Assessment

An updated tax card is included at the end of this case study as an alternate source of the building replacement value as well as to verify the building square footage data.

Additionally, an engineer's estimate is that the Chesters' home has a building replacement value of approximately \$80 per square foot, based on popular cost estimating guides.

### Flood Hazard Data

The local floodplain management ordinance applies to all structures in the SFHA. Elevation on fill is strictly prohibited, and a 1-foot freeboard is required for all new construction and substantial improvements. The flood map (FIRMette) is included in Section 6.2.5 to document the flood hazard data used below.

The applicable excerpts from the FIS show the flood elevations and the BFE for the existing structure and are included in Section 6.2.5. Table 6-4 shows the stillwater elevations and BFE of the property.

**Table 6-4. Stillwater Elevations for the Chester House**

Stillwater Elevations (ft)				
BFE	10-year	50-year	100-year	500-year
9.1	5.5	6.9	7.6	8.9

Note: All topographic maps and flood hazard data reference NAVD88.

A licensed surveyor filled out the elevation certificate, which references NAVD88 and is included at the end of this case study.

The base flood flow velocity is assumed to be 3.0 feet per second.

### 6.2.3 Retrofit Options Selection

During an initial interview with the Chesters, potential retrofit options were discussed (Figure 6-19). Immediately, elevation on fill was ruled out because it is prohibited by the local floodplain ordinance. Similarly, dry floodproofing, wet floodproofing, and floodwalls and small levees were ruled out because these measures will not bring a pre-FIRM home located in a SFHA into compliance with the NFIP. Therefore, acquisition (not included in matrix) and elevation were viable options for the structure and will reduce NFIP flood insurance rates.

Cost was a concern for all potential retrofit options. The Chesters were also concerned about building accessibility for an elevation project.

Based on the retrofit option screening matrix, the two most viable options were elevation on piers and acquisition/demolition.

#### Acquisition

The only way to completely eliminate the risk to the Chesters' home is to move the entire structure out of the SFHA. Because the Chesters aren't interested in this, but are willing to move, acquiring the house and demolishing it may be a viable option. The acquisition process would include:

- Using HMA or other funds to purchase the home from the Chesters
- Demolishing the existing structure
- Restoring the site to green space
- Maintaining the site as green space

Owner Name: <u>Abe and Bea Chester</u>		Prepared By: <u>Jane Q. Engineer</u>							
Address: <u>1234 Bay Street</u>		Date: <u>9/1/2011</u>							
Property Location: <u>Norfolk, VA</u>									
Floodproofing Measures									
Considerations									
	Elevation on Foundation Walls	Elevation on Fill	Elevation on Piers	Elevation on Posts and Columns	Elevation on Piles	Relocation	Dry Flood-proofing	Wet Flood-proofing	Floodwalls and Levees
Measure Allowed or Owner Requirement		X				X	X	X	X
Homeowner Concerns									
Aesthetic Concerns	X		X	X	X				
High Cost Concerns			X	X	X				
Risk Concerns	X		X	X					
Accessibility Concerns	X		X	X	X				
Code Required Upgrade Concerns									
Off-Site Flooding Concerns	X								
Total "X's"	<b>4</b>	<b>NA</b>	<b>4</b>	<b>4</b>	<b>3</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>

Instructions: Determine whether a floodproofing measure is allowed under local regulations or homeowner requirement. Put an "x" in the box for each measure that is not allowed. Complete the matrix for only those measures that are allowable (no "x" in the first row). For those measures allowable or owner required, evaluate the considerations to determine if the homeowner has concerns that would affect its implementation. A concern is defined as a homeowner issue that, if unresolved, would make the retrofitting method(s) infeasible. If the homeowner has a concern, place an "x" in the box under the appropriate measure/consideration. Total the number of "x's". The floodproofing measure with the least number of "x's" is the most preferred.

Figure 6-19. Preliminary Floodproofing/Retrofitting Preference Matrix for the Chester house

A preliminary cost estimate shows that the cost of acquisition would be approximately equal to the market value of the structure, plus \$15,000 for demolition and title fees. Based on the tax card (at the end of this case study), the 2011 market value of the structure and land is \$127,461. Based on a total cost of \$142,461, the BCR is 1.25 (see Section 6.2.5). Therefore, acquisition and demolition would be a cost-beneficial retrofit option.

### Elevation on Pile Foundation

If the Chesters decide that they are not interested in moving, elevating on timber piles may be a viable retrofit option. Because the Chesters live in a Coastal A Zone, piers and columns may not be appropriate because of hydrodynamic forces. Refer to Table 1-1 for the advantages and disadvantages of elevation. The elevation process would include:

- Designing the new pile foundation system
- Disconnecting utilities
- Lifting the existing structure on hydraulic jacks and moving it to install piles
- Demolishing the existing foundation
- Driving new piles
- Moving the structure back, lowering the structure, and connecting it to the piles
- Reconnecting utilities

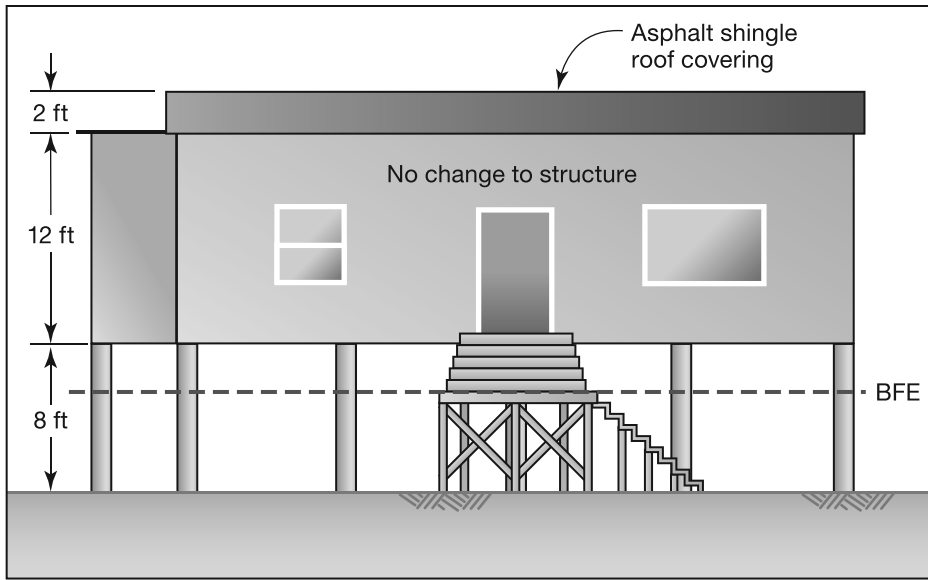
The BFE is 9.1 feet, and the LAG and top of the finished first floor are both 5.1 feet. Including the required 1 foot of freeboard, the floodproofing depth  $H$  is  $(9.1 - 5.1 + 1.0) = 5$  feet. Because the Chesters may want to use the empty space below their newly elevated house for parking, building access, or storage, they may choose to elevate the first floor to 8 feet rather than 5 feet.

A preliminary cost estimate shows a retrofit cost of approximately \$175,000. Therefore, the BCR is 0.86 (see Section 6.2.5). Consequently, elevation on piles as designed is not cost effective. The Chesters may decide not to pursue this option, or they may decide to alter the elevation design to lower costs. For illustrative purposes, load calculations for elevation on piles (as described) are shown in the following sections.

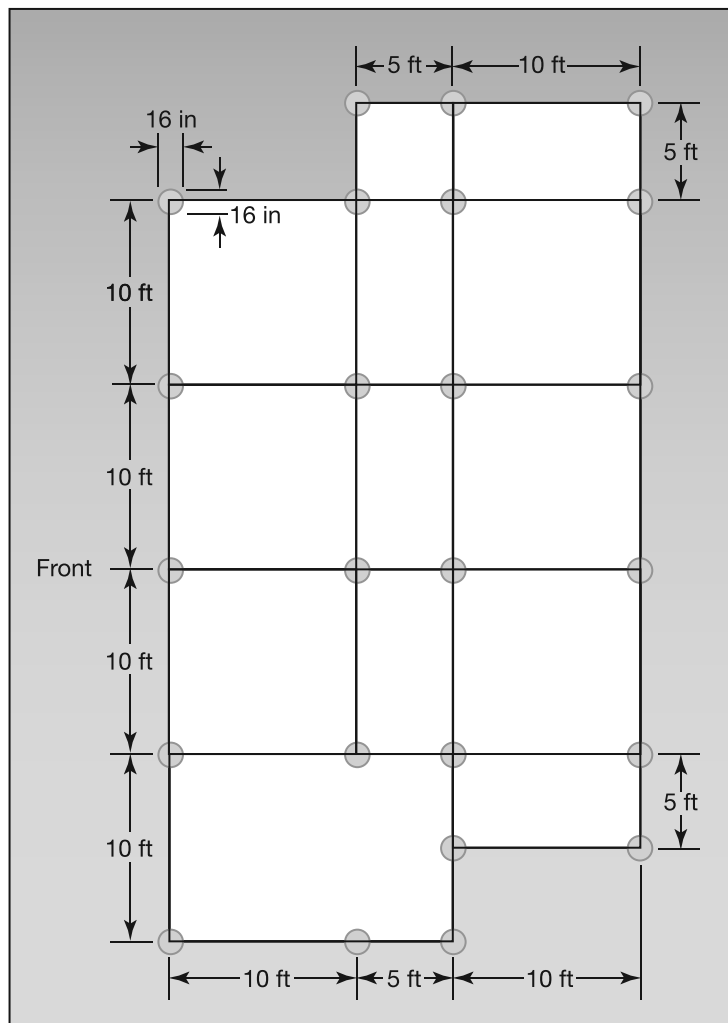
The elevated structure would look as shown in Figure 6-20.

The timber pile plan for the elevated structure is shown in Figure 6-21.

To ensure that the foundation is properly designed, the flood forces must be calculated and checked with other applicable loads.



**Figure 6-20.**  
The Chester house, after mitigation



**Figure 6-21.**  
Timber pile plan for the elevated Chester house

### 6.2.4 Load Calculations

The paragraphs that follow provide calculations for flood loads, dead loads, live loads, and load combinations associated with the elevation option.

#### Load Calculations: Flood Loads

The first step is to calculate hydrostatic forces. As determined above, the floodproofing depth  $H$  is 5 feet. Because the home is being elevated on an open foundation, the saturated soil depth is 0 feet. Because the home is being elevated on an open foundation, and because it is being supported on piles, no lateral hydrostatic or hydrodynamic forces are acting on the structure. Further, vertical hydrostatic (buoyancy) forces will be negligible.

The design flood depth is 5 feet, therefore  $C_D = 1.00$ . Assume  $C_B = 1.0$ . An impact force computation worksheet is presented in Figure 6-22.

Hydrostatic Force Computation Worksheet	
Owner Name: <u>Abe and Bea Chester</u>	Prepared By: <u>Jane Q. Engineer</u>
Address: <u>1234 Bay Street</u>	Date: <u>9/1/2011</u>
Property Location: <u>Norfolk, VA</u>	
<b>Variables</b>	<b>Summary of Loads</b>
$W$ = weight of the object (lbs) = 1,000 lbs	$f_i = 600$ lb
$V$ = velocity of water (ft/sec) = 3 ft/sec	
$C_D$ = depth coefficient (see Table 4-6) = 1.00	
$C_B$ = blockage coefficient (taken as 1.0 for no upstream screening, flow path greater than 30 ft; see Table 4-7 for more information)	
$C_{Str}$ = building structure coefficient	
= 0.2 for timber pile and masonry column supported structures 3 stories or less in height above grade	
= 0.4 for concrete pile or concrete or steel moment resisting frames 3 stories or less in height above grade	
= 0.8 for reinforced concrete foundation walls (including insulated concrete forms)	
Equation 4-13: Normal Impact Loads	
$F_i = W V C_D C_B C_{Str} = (1,000 \text{ lbs})(3 \text{ ft/sec})(1.0)(1.0)(0.2) = 600 \text{ lbs}$	

Figure 6-22. Impact Force Computation Worksheet for the Chester house (Refer to Figure 4-12)



Flood Force Summary:

*Horizontal Force:*

$$f_{comb} = 0 \text{ lb/lf}$$

$$F_i = 600 \text{ lbs}$$

The total flood force acting on the six piers of the front wall (perpendicular to flow) is:

$$F = 600 \text{ lbs}$$

*Vertical Force:*

$$F_{buoy} = 0 \text{ lbs}$$

### Load Calculations: Dead Loads

The dead load is the self-weight of the structure. Case Study #1 illustrates a detailed calculation of the dead load. For this case study, assume a dead weight of approximately 50 lb/ft<sup>2</sup> over 1,025 square feet.

$$D = 50 \text{ lb/ft}^2 \times (1,025 \text{ ft}^2) = 51,250 \text{ lbs}$$

### Load Calculations: Live Loads

*Live Load (Vertical)*

Per ASCE 7-10, assume a live load of:

$$L = 40 \text{ lb/ft}^2 \times (1,025 \text{ ft}^2) = 41,000 \text{ lbs}$$

*Roof Live Load (Vertical)*

Per ASCE 7-10, assume a roof live load of 20 lb/ft<sup>2</sup>. The roof live load acts on the horizontal projected area of the roof:

$$L_r = 20 \text{ lb/ft}^2 \times (1,025 \text{ ft}^2) = 20,500 \text{ lbs}$$

*Snow Load (Vertical)*

Assume a conservative snow load of 20 lb/ft<sup>2</sup>, per ASCE 7-10. The snow load also acts on the horizontal projected area of the roof.

$$S = 20 \text{ lb/ft}^2 (1,025 \text{ ft}^2) = 20,500 \text{ lbs}$$

*Wind Load (Horizontal)*

Appendix C contains a detailed discussion of wind load calculations, including a detailed example. Refer to Appendix C for wind load calculations; this case study uses a simplified approach. Using a simplified wind load, assuming that the structure is fully enclosed, assume a worst case scenario wind load acting perpendicular to the structure (i.e., on the entire face of the structure facing the river). Because the roof at the front (windward side) of the house is sloped and there are no overhangs, there is no vertical wind (uplift) component on the roof. There may be some uplift on the bottom of the structure, but it is not considered here. Therefore, assume a wind pressure of 30 lb/ft<sup>2</sup> acting uniformly over the entire aboveground structure:

$$\begin{aligned} \text{Area} &= \text{Pier surface area (6 piers)} + \text{Exterior Wall area} + \text{Vertical Roof area} \\ \Rightarrow A &= (6)(16 \text{ in.}/(12 \text{ in.}/\text{ft}))(5\text{ft}) + (45 \text{ ft})(16 \text{ ft}) + (1/2)(2 \text{ ft})(40 \text{ ft}) = 40 \text{ ft}^2 + 720 \text{ ft}^2 + 40 \text{ ft}^2 = 800 \text{ ft}^2 \\ W &= 30 \text{ lb}/\text{ft}^2 \times (800 \text{ ft}^2) = 24,000 \text{ lbs} \end{aligned}$$

*Earthquake Load*

Seismic forces are not considered for this example. Therefore,  $E = 0$ .

**Load Combinations**

IBC section 1810.1 requires that deep foundations be designed on the basis of a detailed geotechnical analysis. For that reason, failure modes are not analyzed here. For illustrative purposes, ASCE 7-10 load combinations (Allowable Stress Design) are presented in Table 6-5.

**Table 6-5. Summary of Horizontal and Vertical Load Combinations for the Chester House**

Combination	Horizontal (lbs)	Vertical (lbs)
1. $D$	0	51,250
2. $D + L$	0	92,250
3. $D + (L_r \text{ or } S \text{ or } R)$	0	71,750
4. $D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$	0	97,375
5. $D + (0.6W \text{ or } 0.7E) + 0.75F_a$	14,850	51,250
6a. $D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R) + 0.75F_a$	11,250	97,375
6b. $D + 0.75L + 0.75(0.7E) + 0.75S + 0.75F_a$	450	97,375
7. $0.6D + 0.6W + 0.75F_a$	14,850	30,750
8. $0.6D + 0.7E$	0	30,750

Load Summary:

*Horizontal Loads*

$$\begin{aligned} D &= L = L_r = S = E = 0 \\ F_a &= F_{sta} = 600 \text{ lbs} \\ W &= 24,000 \text{ lbs} \end{aligned}$$

*Vertical Loads*

$$\begin{aligned} D &= 51,250 \text{ lbs} \\ L &= 41,000 \text{ lbs} \\ L_r &= 20,500 \text{ lbs} \\ S &= 20,500 \text{ lbs} \\ W &= 0 \text{ (conservative)} \\ E &= 0 \\ F_a &= F_{buoy} = 0 \end{aligned}$$

## 6.2.5 Supporting Documentation

This section includes additional information about the Chester house. The following maps and documents provide backup documentation for the values used in the Case Study 2 calculations, including:

- topographic map showing the location of the plot and ground elevation (Figure 6-23);
- DFIRM excerpt showing the location of the Chester house relative to the SFHA (Figure 6-24);
- elevation certificate showing the first floor elevation and BFE (Figure 6-25);
- tax card providing building value and square footage (Figure 6-26); and
- BCA report excerpt summarizing the cost effectiveness of elevation and acquisition (Figure 6-27).

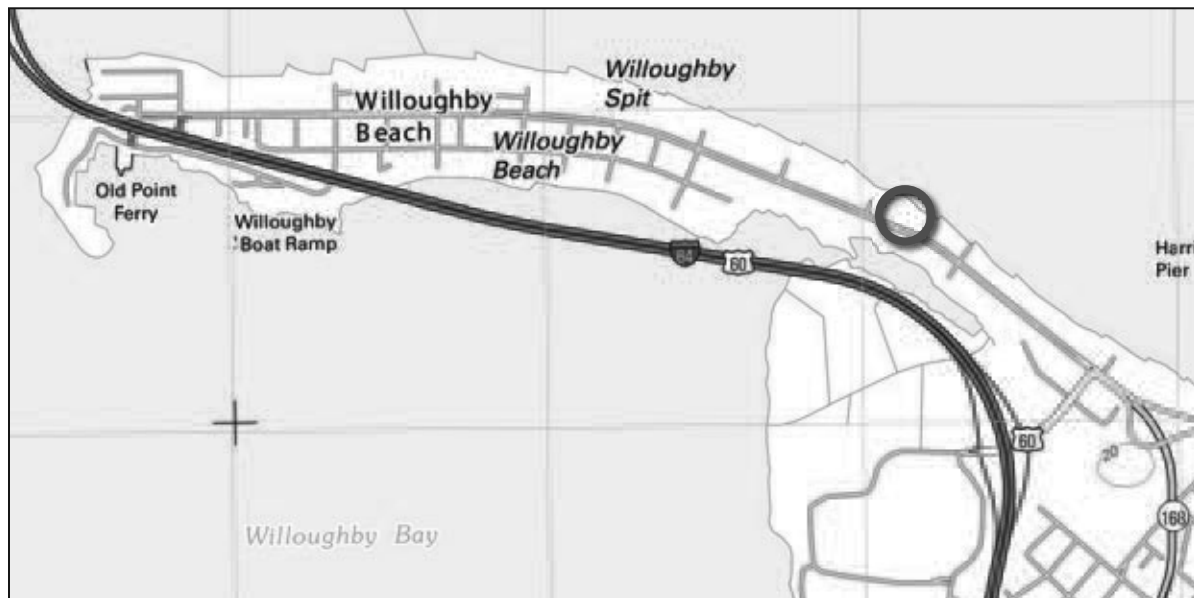


Figure 6-23. Topographic map for the Chester house (general location in red circle)



TABLE 1 - SUMMARY OF STILLWATER ELEVATIONS

Flood Source and Location	Elevation (Feet) NAVD 88			
	10-Percent-Annual-Chance	2-Percent-Annual-Chance	1-Percent-Annual-Chance	0.2-Percent-Annual-Chance
Chesapeake Bay and Tributaries Entire shoreline within community	5.5	6.9	7.6	8.9
Little Creek From the east corporate limits to approximately 0.3 mile west of the east corporate limits	5.6	7.2	7.8	9.2
From approximately 0.3 mile west of the east corporate limits and remaining shoreline	5.5	6.9	7.6	8.9
Mason Creek Entire shoreline	4.5	5.6	6.1	7.4

Figure 6-24. DFIRM excerpt and FIS excerpt: Summary of stillwater elevations for the Chester house

U.S. DEPARTMENT OF HOMELAND SECURITY  
Federal Emergency Management Agency  
National Flood Insurance Program

### ELEVATION CERTIFICATE

OMB No. 1660-0008  
Expires March 31, 2012

Important: Read the instructions on pages 1-9.

SECTION A - PROPERTY INFORMATION		For Insurance Company Use:
A1. Building Owner's Name Abe and Bea Chester		Policy Number
A2. Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No. 1234 Bay Street		Company NAIC Number
City Norfolk State VA ZIP Code 1234		

A3. Property Description (Lot and Block Numbers, Tax Parcel Number, Legal Description, etc.)

A4. Building Use (e.g., Residential, Non-Residential, Addition, Accessory, etc.) \_\_\_\_\_

A5. Latitude/Longitude: Lat. \_\_\_\_\_ Long. \_\_\_\_\_ Horizontal Datum:  NAD 1927  NAD 1983

A6. Attach at least 2 photographs of the building if the Certificate is being used to obtain flood insurance.

A7. Building Diagram Number \_\_\_\_\_

A8. For a building with a crawlspace or enclosure(s):

a) Square footage of crawlspace or enclosure(s) \_\_\_\_\_ sq ft

b) No. of permanent flood openings in the crawlspace or enclosure(s) within 1.0 foot above adjacent grade \_\_\_\_\_

c) Total net area of flood openings in A8.b \_\_\_\_\_ sq in

d) Engineered flood openings?  Yes  No

A9. For a building with an attached garage:

a) Square footage of attached garage \_\_\_\_\_ sq ft

b) No. of permanent flood openings in the attached garage within 1.0 foot above adjacent grade \_\_\_\_\_

c) Total net area of flood openings in A9.b \_\_\_\_\_ sq in

d) Engineered flood openings?  Yes  No

SECTION B - FLOOD INSURANCE RATE MAP (FIRM) INFORMATION					
B1. NFIP Community Name & Community Number Norfolk, VA 510104		B2. County Name NA		B3. State VA	
B4. Map/Panel Number 0020	B5. Suffix F	B6. FIRM Index Date 9/2/2009	B7. FIRM Panel Effective/Revised Date	B8. Flood Zone(s) AE	B9. Base Flood Elevation(s) (Zone AO, use base flood depth) 9.1

B10. Indicate the source of the Base Flood Elevation (BFE) data or base flood depth entered in Item B9.

FIS Profile  FIRM  Community Determined  Other (Describe) \_\_\_\_\_

B11. Indicate elevation datum used for BFE in Item B9:  NGVD 1929  NAVD 1988  Other (Describe) \_\_\_\_\_

B12. Is the building located in a Coastal Barrier Resources System (CBRS) area or Otherwise Protected Area (OPA)?  Yes  No

Designation Date \_\_\_\_\_  CBRS  OPA

SECTION C - BUILDING ELEVATION INFORMATION (SURVEY REQUIRED)	
C1. Building elevations are based on: <input type="checkbox"/> Construction Drawings* <input type="checkbox"/> Building Under Construction* <input checked="" type="checkbox"/> Finished Construction	
*A new Elevation Certificate will be required when construction of the building is complete.	
C2. Elevations – Zones A1-A30, AE, AH, A (with BFE), VE, V1-V30, V (with BFE), AR, AR/A, AR/AE, AR/A1-A30, AR/AH, AR/AO. Complete Items C2.a-h below according to the building diagram specified in Item A7. Use the same datum as the BFE.	
Benchmark Utilized _____ Vertical Datum <u>NAVD88</u>	
Conversion/Comments _____	
Check the measurement used.	
a) Top of bottom floor (including basement, crawlspace, or enclosure floor) <u>-4.1</u>	<input checked="" type="checkbox"/> feet <input type="checkbox"/> meters (Puerto Rico only)
b) Top of the next higher floor <u>5.1</u>	<input checked="" type="checkbox"/> feet <input type="checkbox"/> meters (Puerto Rico only)
c) Bottom of the lowest horizontal structural member (V Zones only) _____	<input type="checkbox"/> feet <input type="checkbox"/> meters (Puerto Rico only)
d) Attached garage (top of slab) _____	<input type="checkbox"/> feet <input type="checkbox"/> meters (Puerto Rico only)
e) Lowest elevation of machinery or equipment servicing the building (Describe type of equipment and location in Comments) <u>-4.1</u>	<input checked="" type="checkbox"/> feet <input type="checkbox"/> meters (Puerto Rico only)
f) Lowest adjacent (finished) grade next to building (LAG) <u>4.8</u>	<input checked="" type="checkbox"/> feet <input type="checkbox"/> meters (Puerto Rico only)
g) Highest adjacent (finished) grade next to building (HAG) <u>5.3</u>	<input checked="" type="checkbox"/> feet <input type="checkbox"/> meters (Puerto Rico only)
h) Lowest adjacent grade at lowest elevation of deck or stairs, including structural support _____	<input type="checkbox"/> feet <input type="checkbox"/> meters (Puerto Rico only)

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION	
This certification is to be signed and sealed by a land surveyor, engineer, or architect authorized by law to certify elevation information. I certify that the information on this Certificate represents my best efforts to interpret the data available. I understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001. <input type="checkbox"/>	
Check here if comments are provided on back of form. <input type="checkbox"/> Were latitude and longitude in Section A provided by a licensed land surveyor? <input type="checkbox"/> Yes <input type="checkbox"/> No	
Certifier's Name Joseph Kavalier	License Number 12345
Title Surveyor	Company Name Surveyors Inc
Address 1234 Survey Street	City Richmond State VA ZIP Code 54321
Signature _____	Date _____ Telephone _____

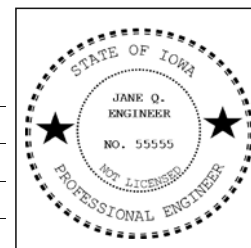


Figure 6-25. Elevation certificate excerpt for the Chester house

CITY OF NORFOLK ASSESSOR				
<b>Pin</b>	12345-67898-76543			
<b>Deed</b>	CHESTER ABRAHAM			
<b>Property Address</b>	1234 BAY STREET NORFOLK, VA 12345			
<b>Class</b>	RESIDENTIAL			
Current Value Information				
Land Value	Dwelling Value	Improvement Value	Total Value	
25,461	102,000	0	127,461	
Prior Year Value Information				
Year	Land Value	Dwelling Value	Improvement Value	Total Value
2011	25,461	102,000	0	127,461
2010	25,461	102,000	0	127,461
2009	27,508	105,333	0	132,841
2008	27,508	105,333	0	132,841
2007	27,508	105,333	0	132,841
Residential Building Information				
Occupancy	Style	Year Built	Total Living Area	
Single-Family/Owner Occupied	1 Story Frame	1983	1,275	
Yard Extra Information				
Description	Item Count	Year Built		
NA				
Land Information				
Lot Basis	Square Feet	Acres		
Lump Sum	5,400	0.124		
Tax History Information				
Tax Year	Assessed Value	Taxable Value	Gross Tax	Net Tax
2009	127,461	58,108	9,404	9,400
2008	132,841	53,136	8,502	8,540
2007	132,841	60,223	10,022	10,001
2006	132,841	61,132	11,276	11,200

Figure 6-26. Tax card for the Chester house (page 1)

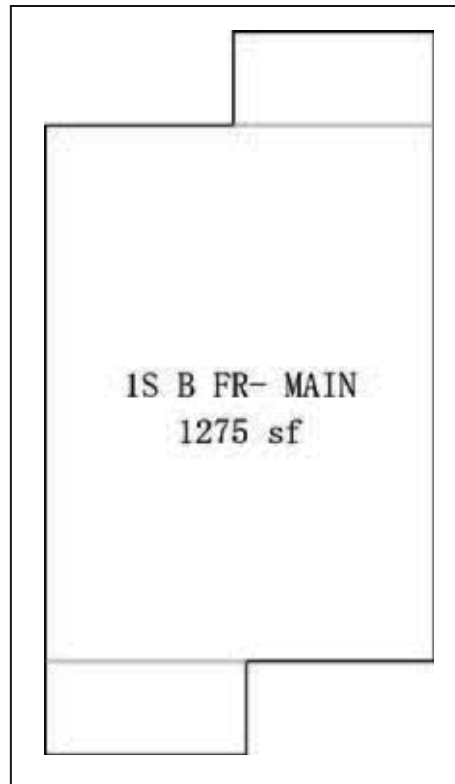


Figure 6-26 (concluded).  
Tax card for the Chester  
house (page 2)

16 Sep 2011	Project: <b>Case Study 2</b>	Pg 1 of 21
Total Benefits: <b>\$497,269</b>	Total Costs: <b>\$292,461</b>	BCR: <span style="border: 1px solid black; padding: 2px;">1.70</span>
Project Number:	Disaster #:	Program:
State: <b>Virginia</b>	Point of Contact:	Agency: <b>City of Norfolk</b>
		Analyst:

**Project Summary:**

Project Number: \_\_\_\_\_ Disaster #: \_\_\_\_\_  
 Program: \_\_\_\_\_ Agency: City of Norfolk  
 Analyst: \_\_\_\_\_  
 Point of Contact: \_\_\_\_\_ Phone Number: \_\_\_\_\_  
 Address: Virginia  
 Email: \_\_\_\_\_  
 Comments: \_\_\_\_\_

**Structure Summary For:**

1-Elevation, 1234 Bay Street, Norfolk, Virginia, 12345, Norfolk City

Structure Type: Building      Historic Building: No      Contact: \_\_\_\_\_  
 Benefits: \$227,014      Costs: \$150,000      BCR: 1.51

Mitigation	Hazard	BCR	Benefits	Costs
Elevation	Flood	1.51	\$227,014	\$150,000

2-Acquisition, 1234 Bay Street, Norfolk, Virginia, 12345, Norfolk City

Structure Type: Building      Historic Building: No      Contact: \_\_\_\_\_  
 Benefits: \$270,255      Costs: \$142,461      BCR: 1.90

Mitigation	Hazard	BCR	Benefits	Costs
Acquisition	Flood	1.90	\$270,255	\$142,461

**Figure 6-27. Sample BCA Report excerpt for the Chester house elevation and acquisition**



## 6.2.6 Real World Examples

Although the Chester house is fictional, elevation and acquisition are both commonly used flood mitigation measures. Figures 6-28 and 6-29 are examples of real structures that have been protected using the mitigation measures discussed in this case study.

These homes were elevated on timber piles.



Figure 6-28.  
House elevated on timber piles



Figure 6-29.  
Elevation on timber piles