

Elevating Homes for Flood Protection

By

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5 PDH HOURS



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.

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.

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:

CROSS REFERENCE

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

- 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).

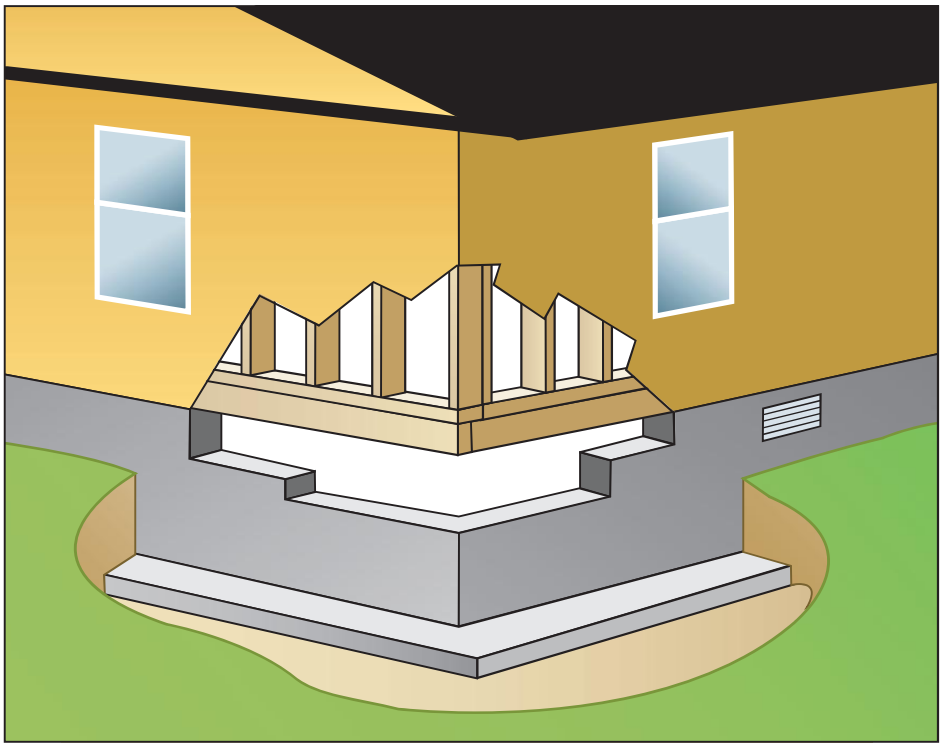


Figure 5E-1.
Existing wood-frame house on crawlspace foundation to be elevated with extended walls and piers

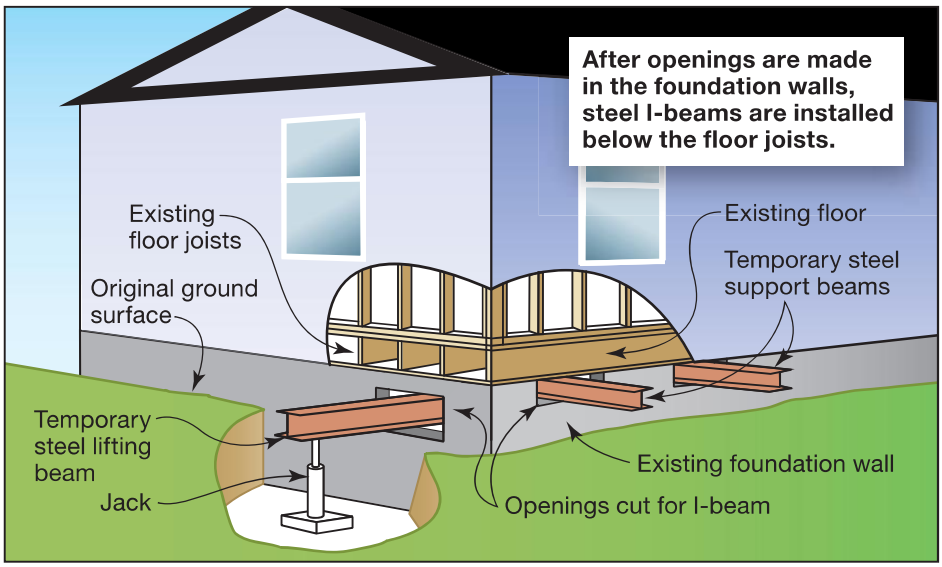


Figure 5E-2.
Step 1 of elevating an existing wood-frame house on extended foundation walls and piers: Install network of steel I-beams

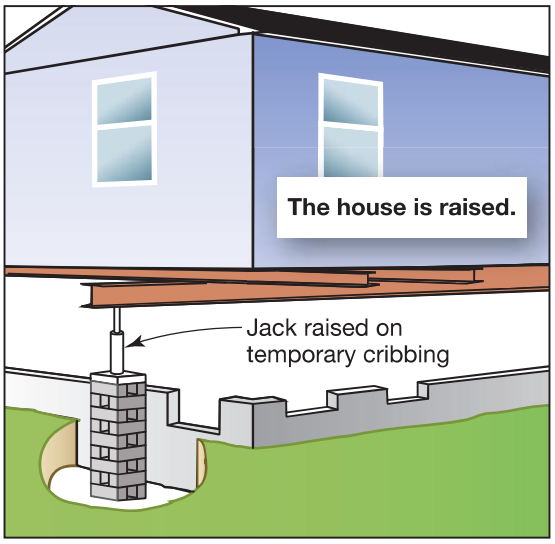


Figure 5E-3.
Step 2 of elevating an existing wood-frame house on extended foundation walls and piers: Lift house and extend foundation walls and piers (reinforce as needed); relocate utility and mechanical equipment above flood level

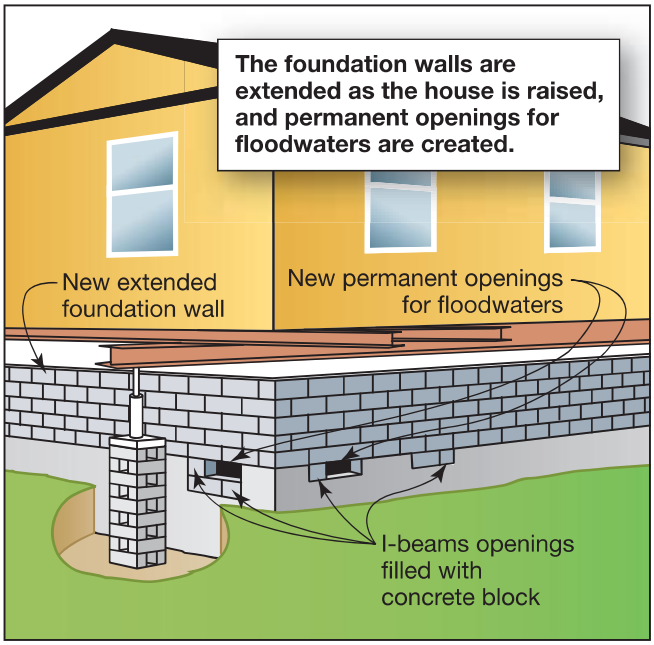


Figure 5E-4.
Step 3 of elevating an existing wood-frame house on extended foundation walls and piers: Set house on new extended foundation and remove I-beams

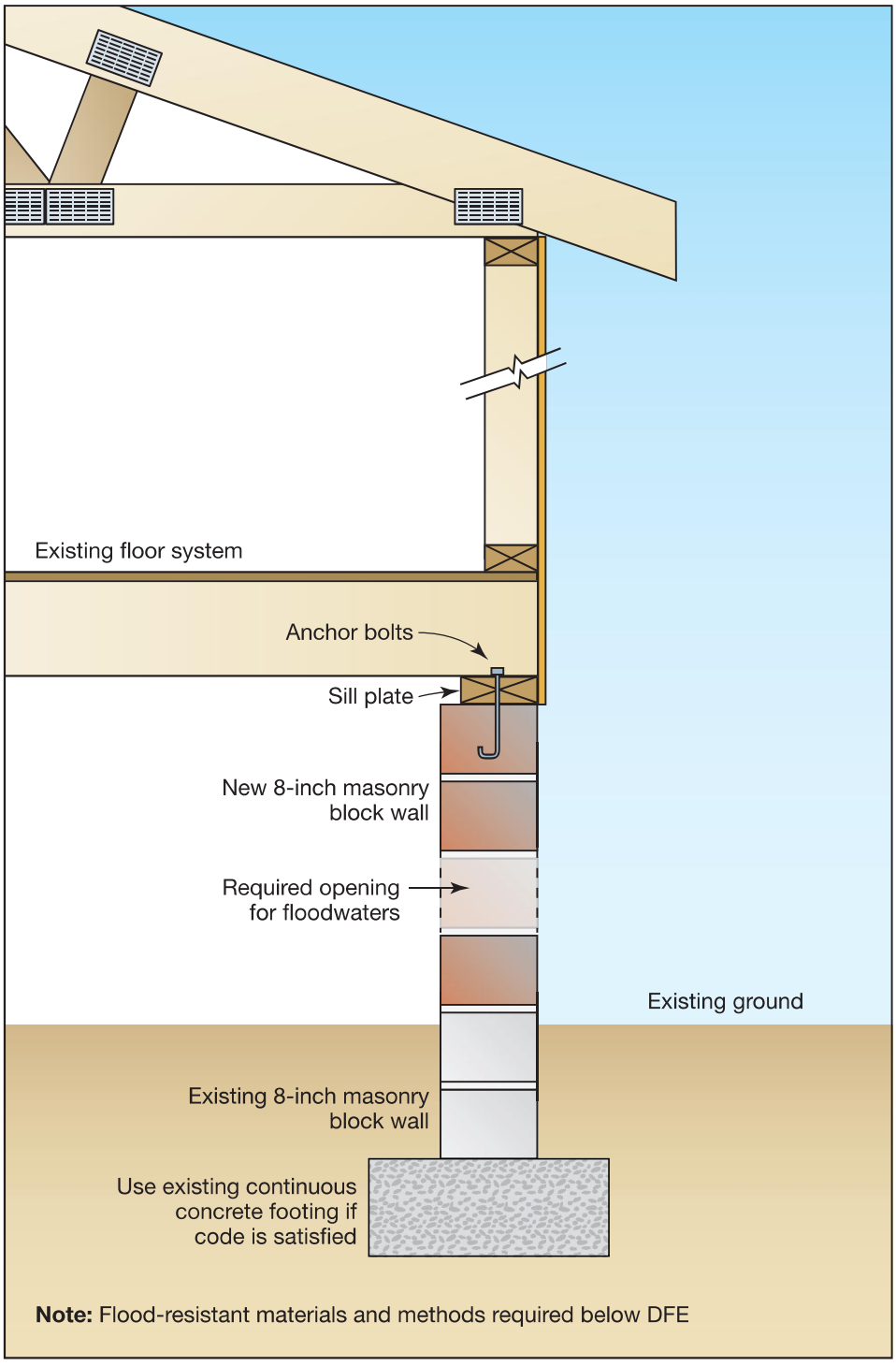


Figure 5E-5. Cross-section of elevated wood-frame house on extended piers and crawlspace walls

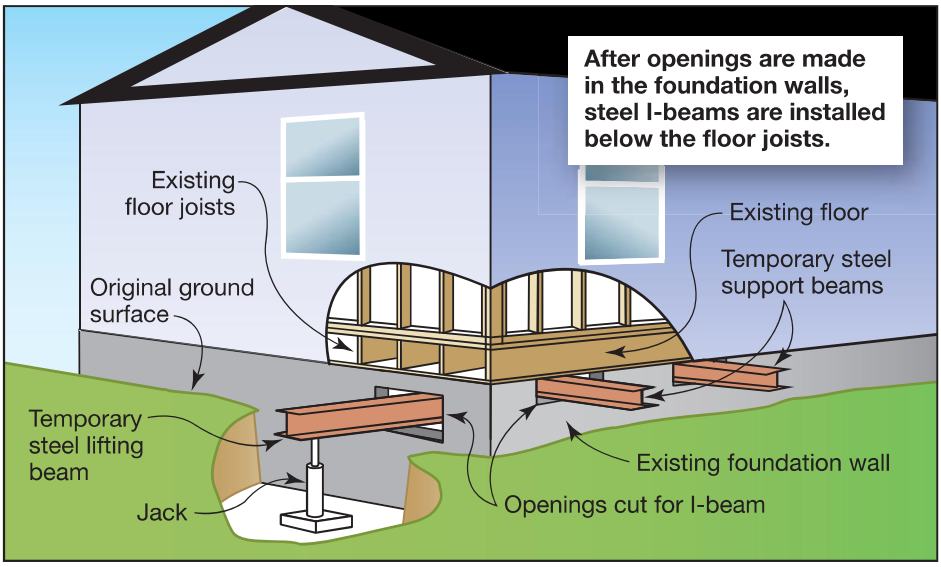


Figure 5E-6.
Step 1 of elevating an existing wood frame house on new or extended pier foundations: Install network of steel I-beams. Step 2 (not shown): Lift house, rebuilding or extending (reinforce as needed) piers; relocate utility and mechanical equipment above flood level.

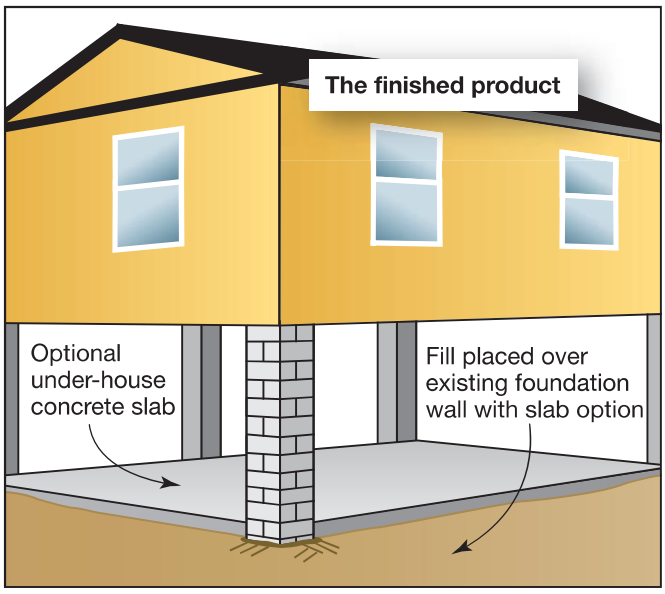


Figure 5E-7.
Step 3 of elevating an existing wood-frame house on new or extended pier foundation: Set house on new or extended piers

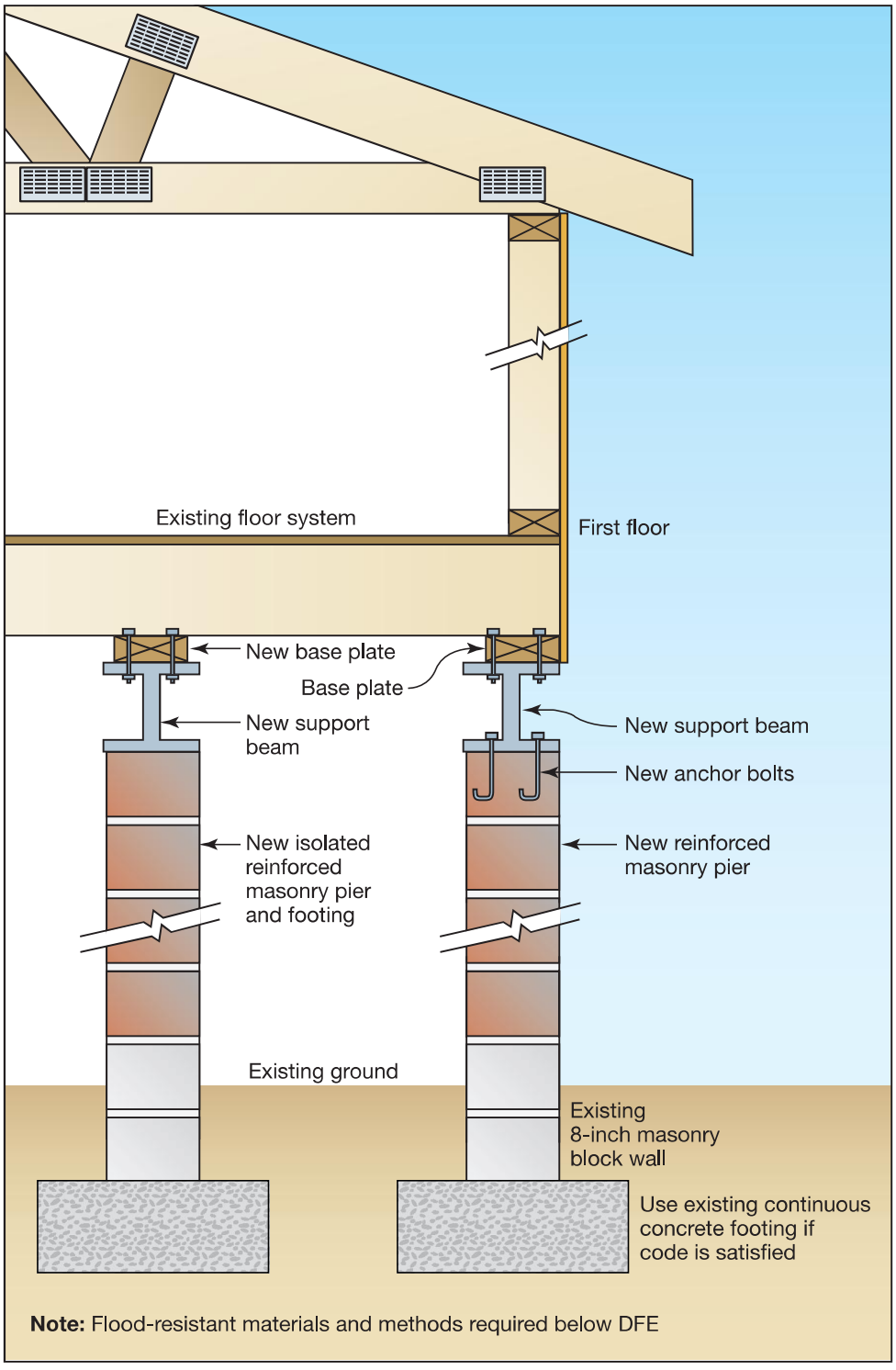


Figure 5E-8. Cross-section of elevated wood-frame house on new or extended pier foundation

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.

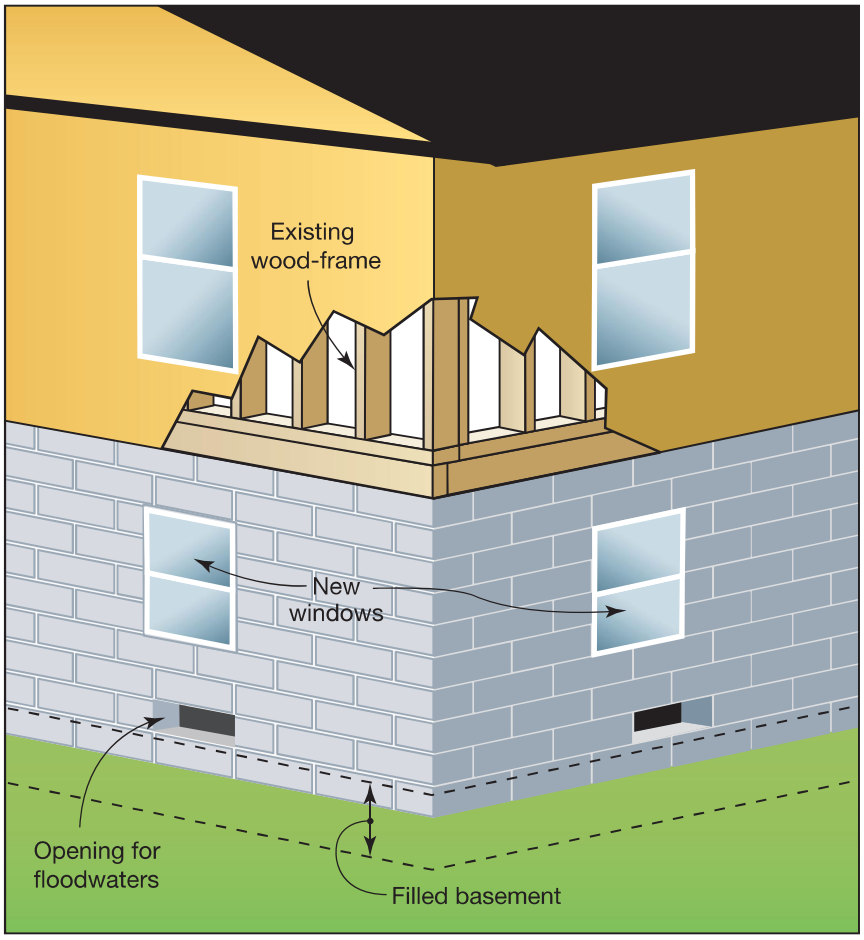


Figure 5E-9. Elevated wood-frame house with new masonry-enclosed area on top of an abandoned and filled-in basement; utility and mechanical equipment must be relocated above the flood level

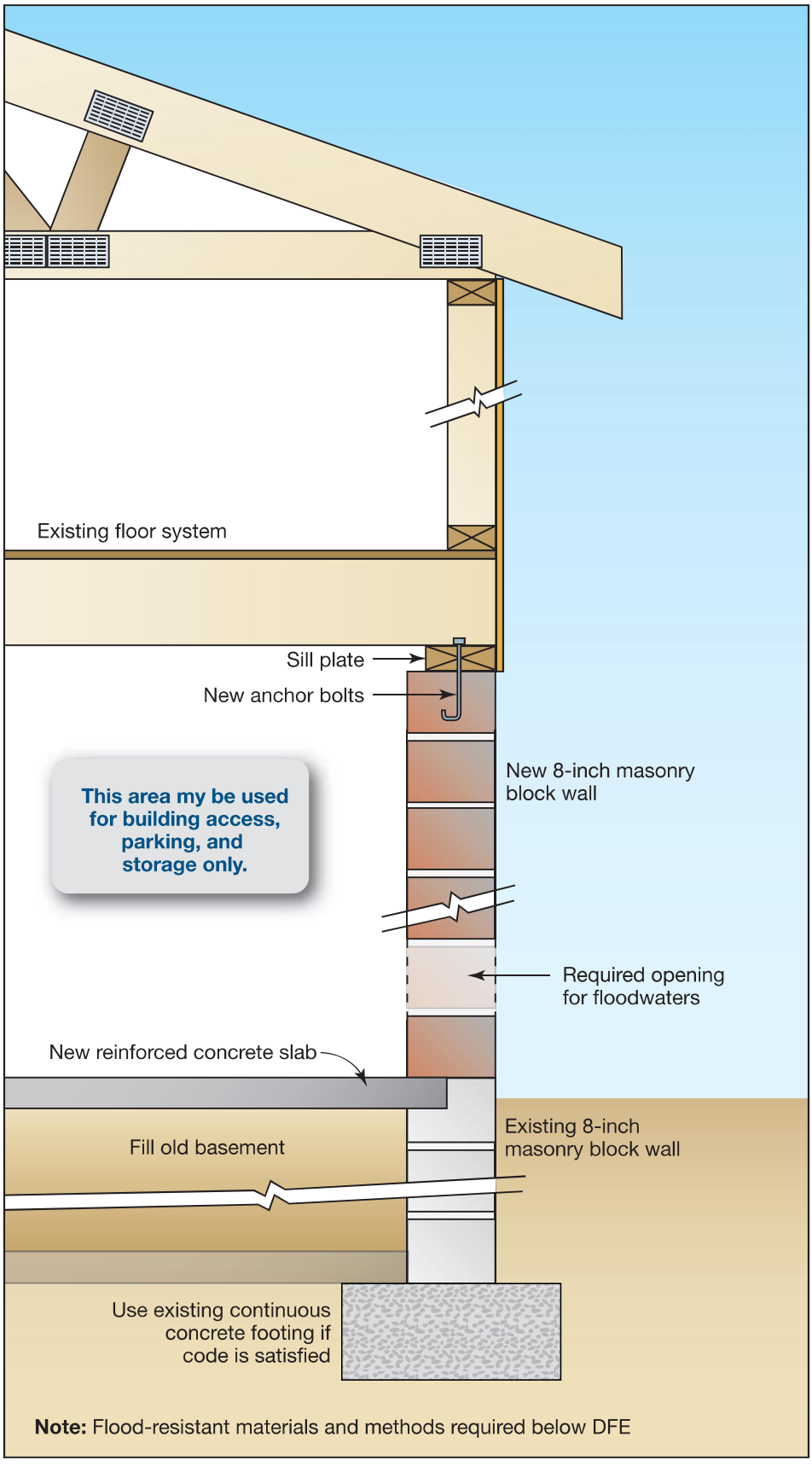
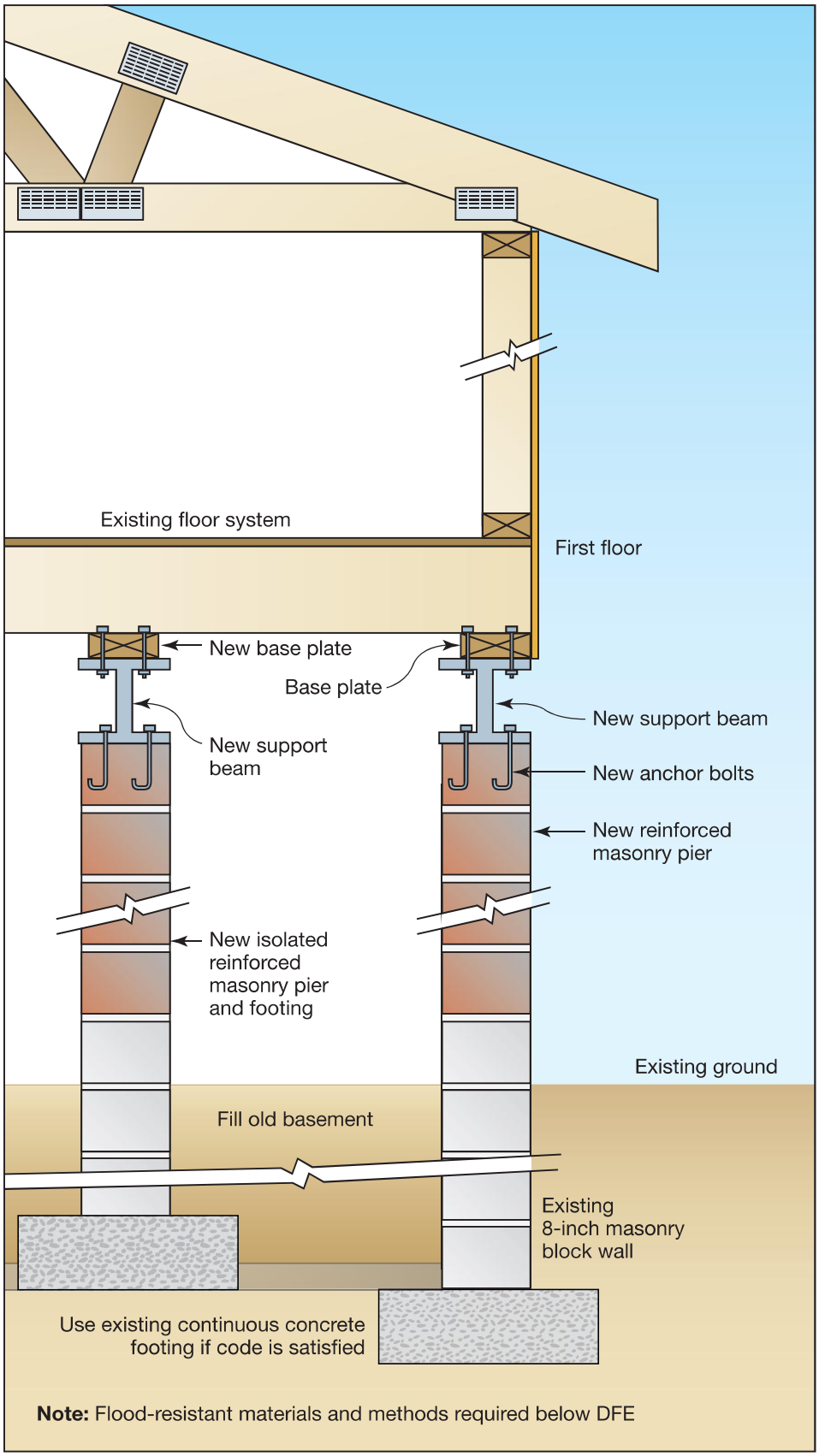


Figure 5E-10. Cross-section of elevated wood-frame house with extended masonry-enclosed area on top of an abandoned and filled-in basement

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



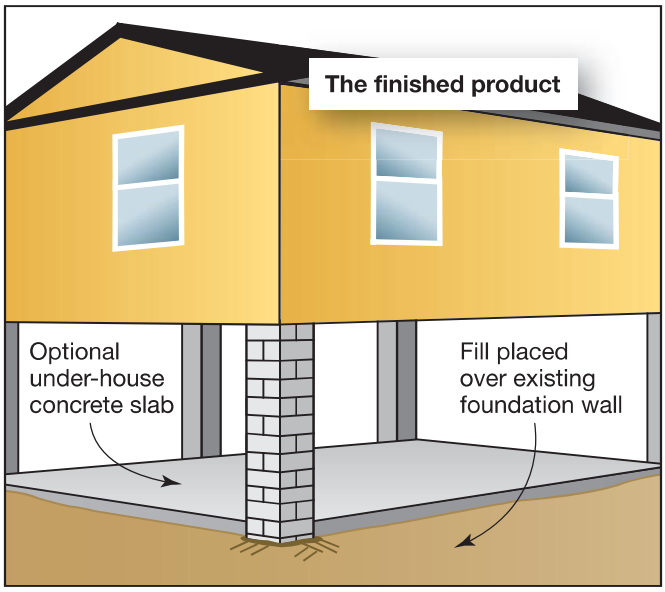


Figure 5E-12. Elevated wood-frame house set on new reinforced piers on top of the existing filled-in basement

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).

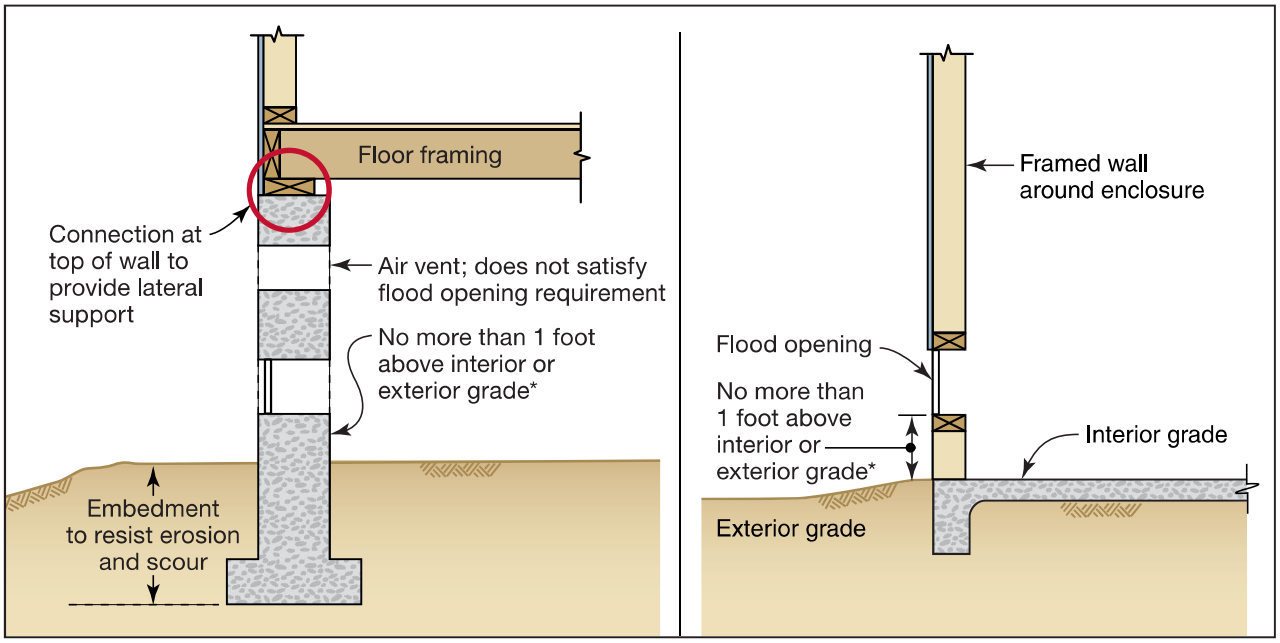


Figure 5E-13. Typical opening for solid foundation wall

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

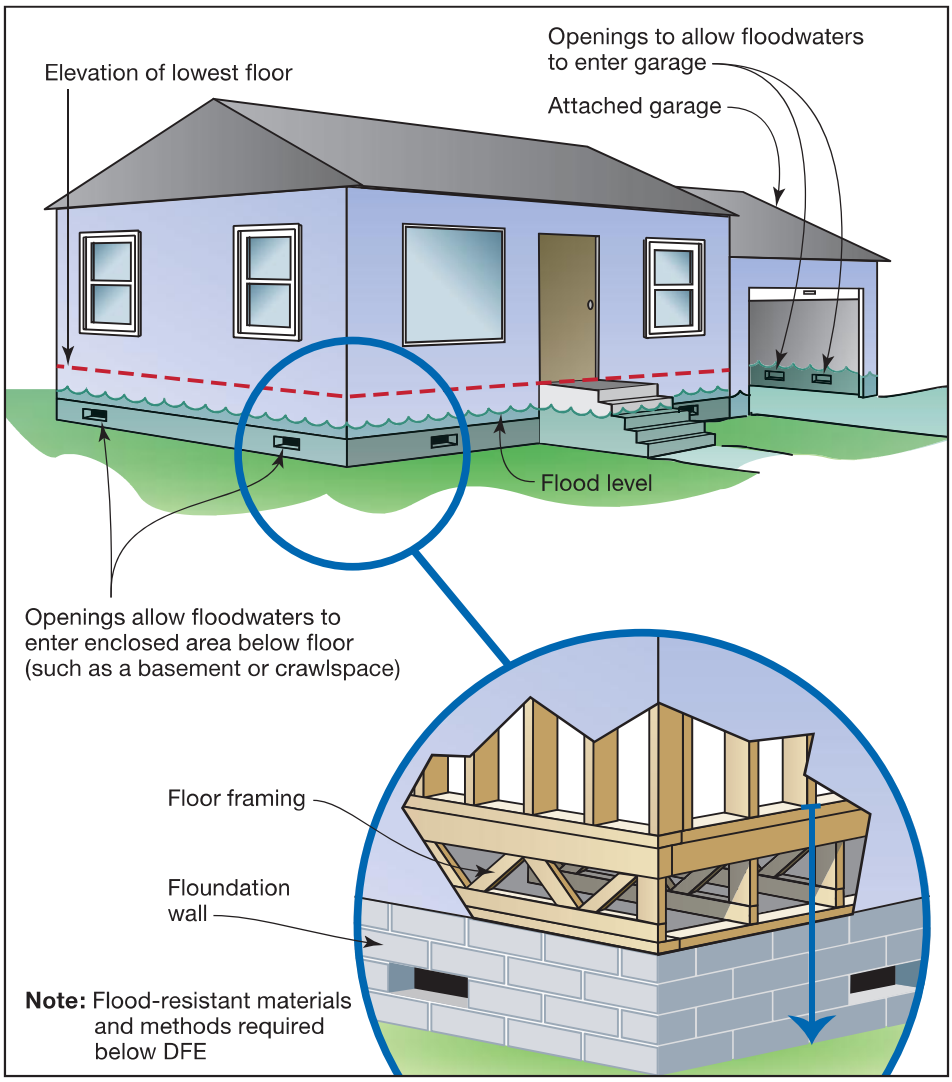


Figure 5E-15. NFIP-compliant house built on solid foundation walls with attached garage

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

The process of elevating a house on existing piles, piers, or columns 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.

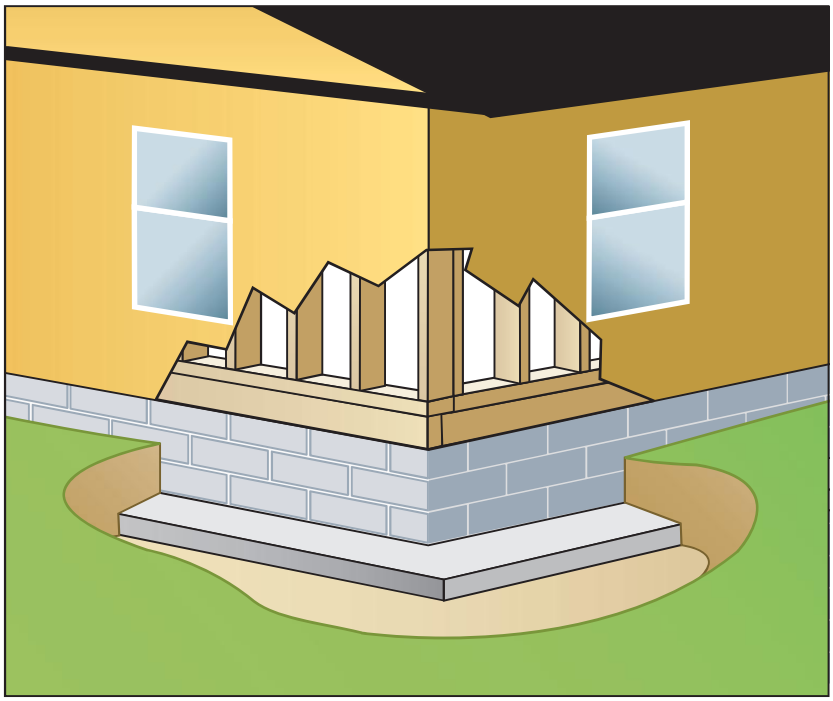


Figure 5E-16. Existing wood-frame house with slab and stem-wall foundation

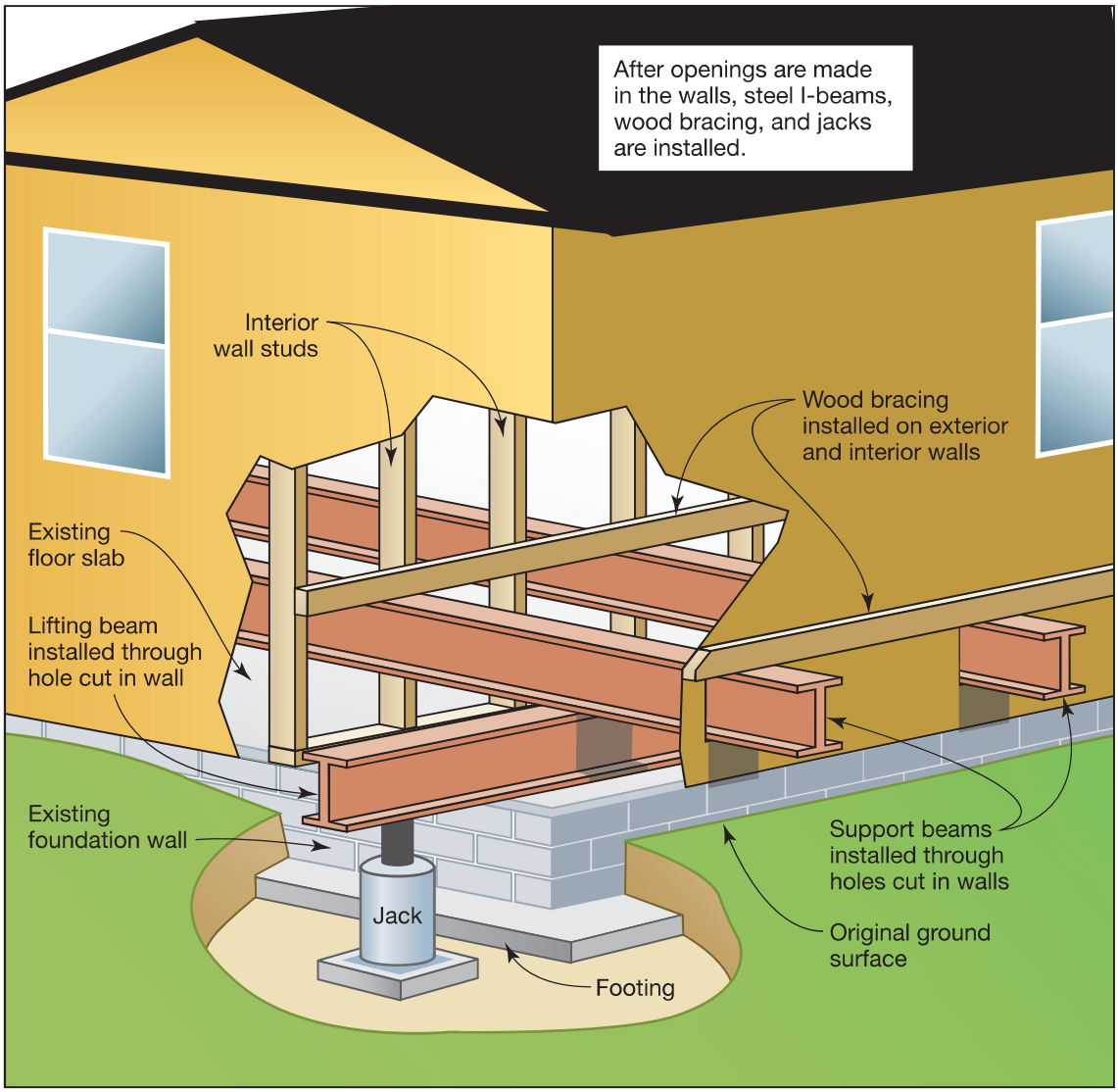


Figure 5E-17. Step 1 of elevating an existing wood-frame house without the slab using a new first floor constructed of wood trusses: Install steel I-beam network and prepare to lift walls

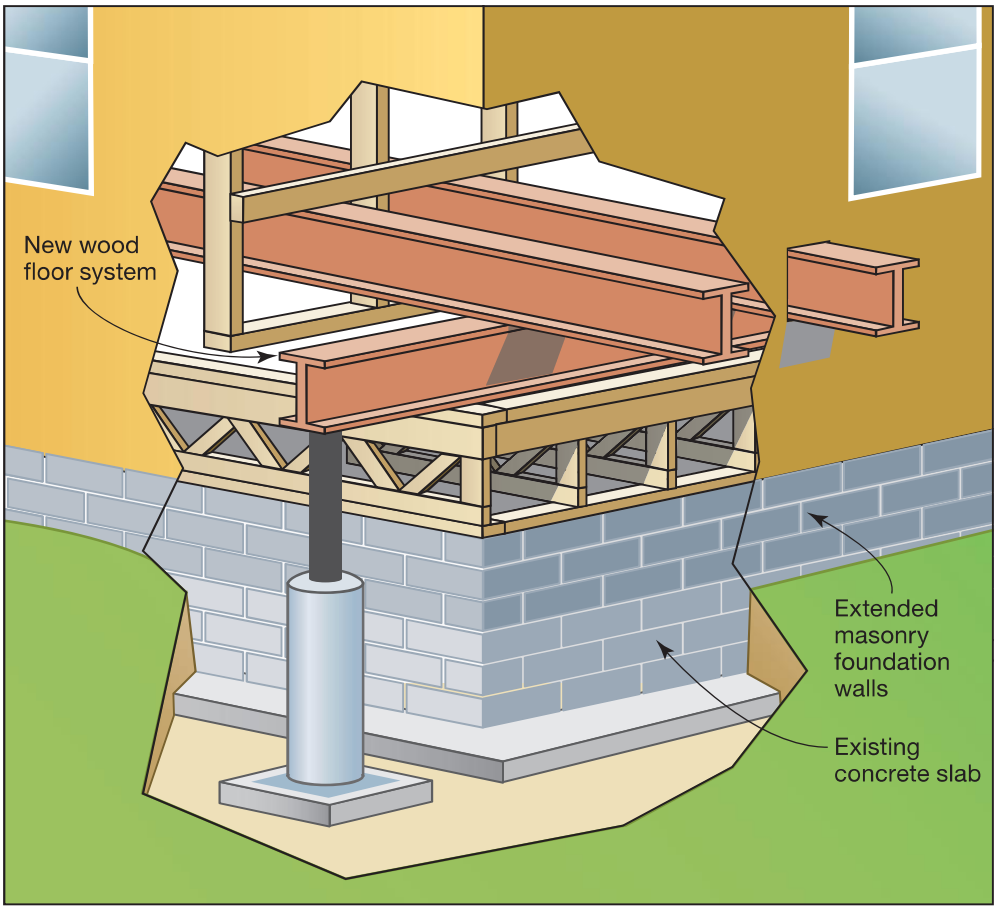


Figure 5E-18. Step 2 of elevating an existing wood-frame house without the slab using a new first floor constructed of wood trusses: Lift house, extend masonry foundation wall, and install wood floor trusses; relocate utility and mechanical equipment above flood level

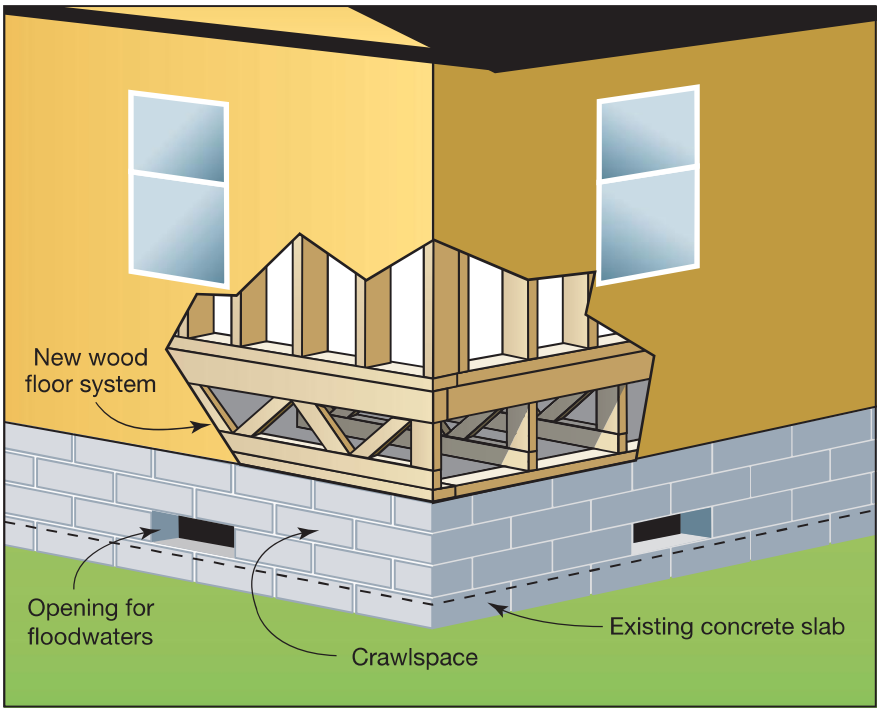


Figure 5E-19. Step 3 of elevating an existing wood-frame house without the slab and with extended stem wall using a new first floor constructed of wood trusses: Set house on new foundation and remove I-beams

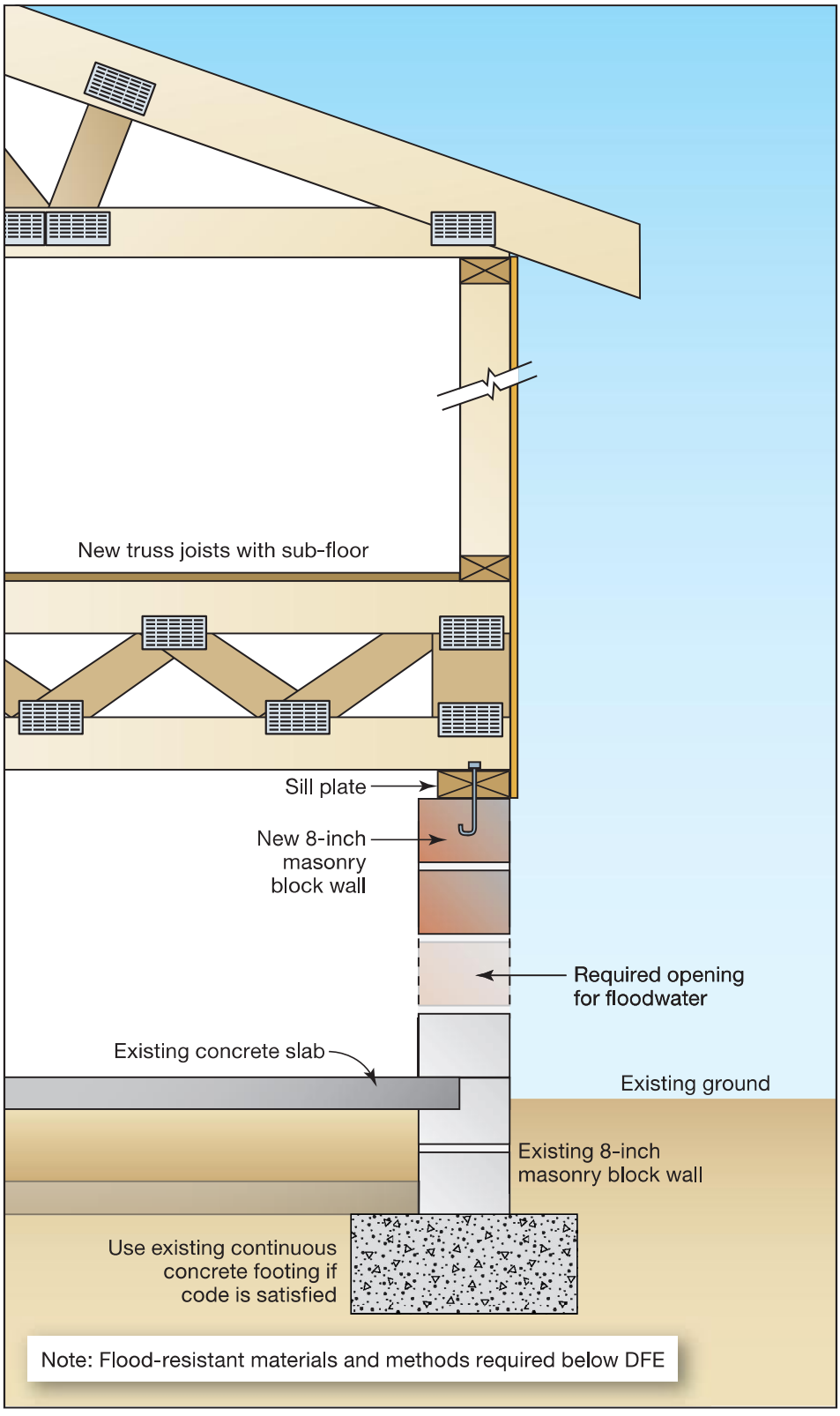


Figure 5E-20. Cross-section of elevated wood-frame house (slab not raised) with extended stem-wall foundation and newly installed wood truss floor

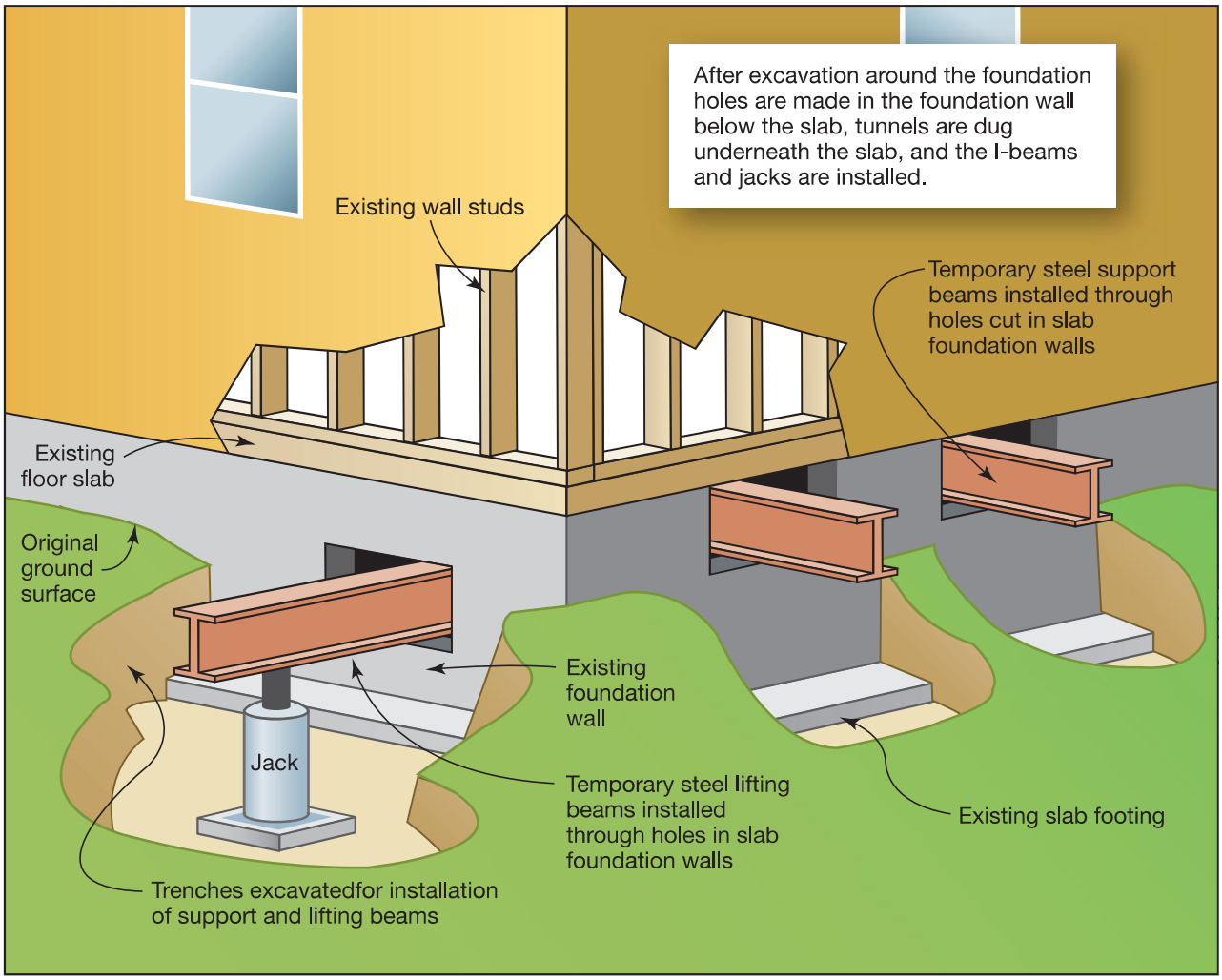


Figure 5E-21. Step 1 of elevating an existing wood-frame house with stem wall foundation and the slab intact: Excavate under existing slab and install network of steel I-beams. Step 2 (not shown): Raise the wood-frame house with the slab intact, extend foundation stem walls, and install new piers.

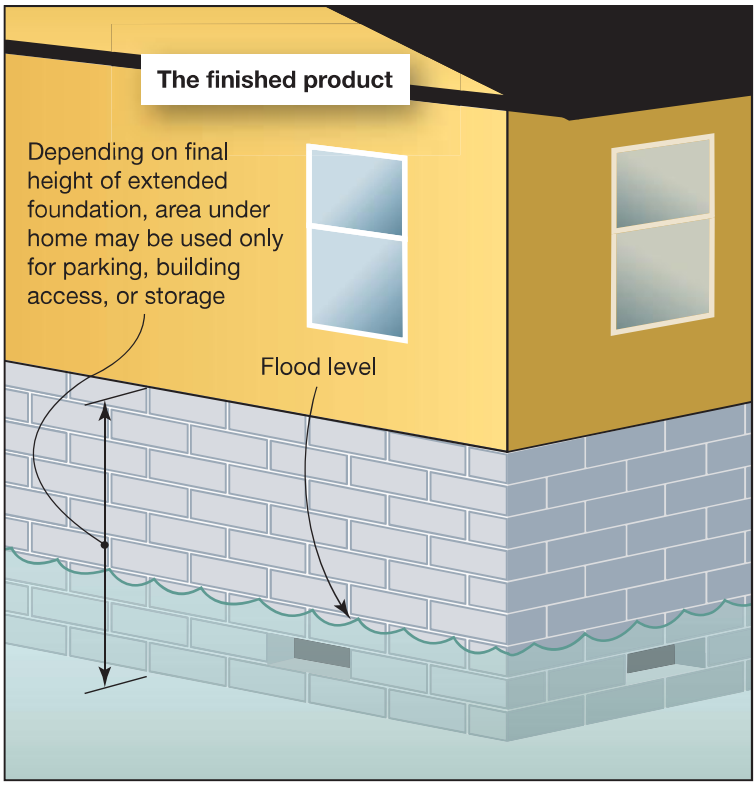


Figure 5E-22. Step 3 of elevating an existing wood-frame house with stem wall foundation and the slab intact: Set the house on the new foundation and remove the I-beams

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

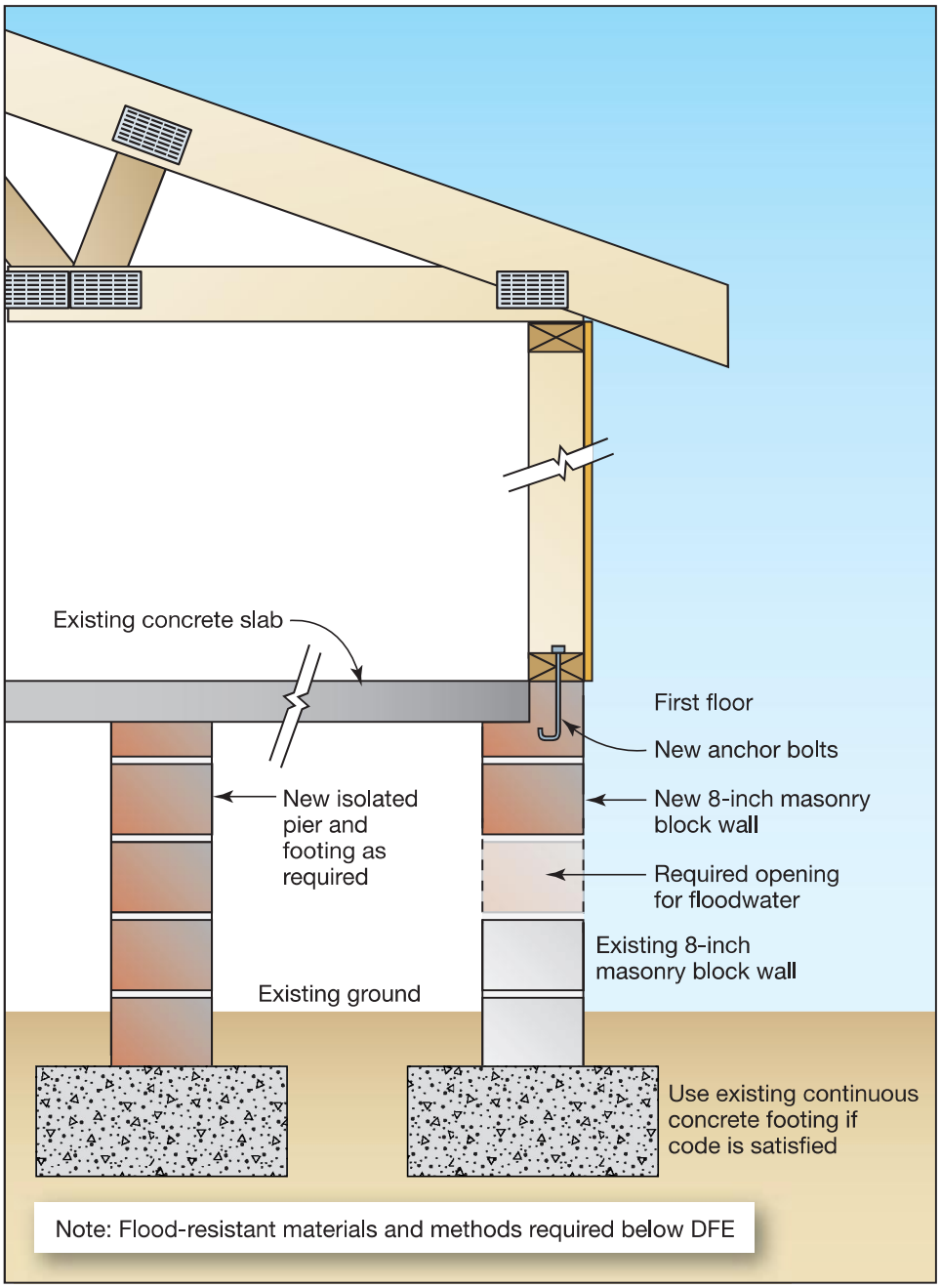
The following alternatives apply to elevating a masonry house with a slab-on-grade foundation:

- 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).

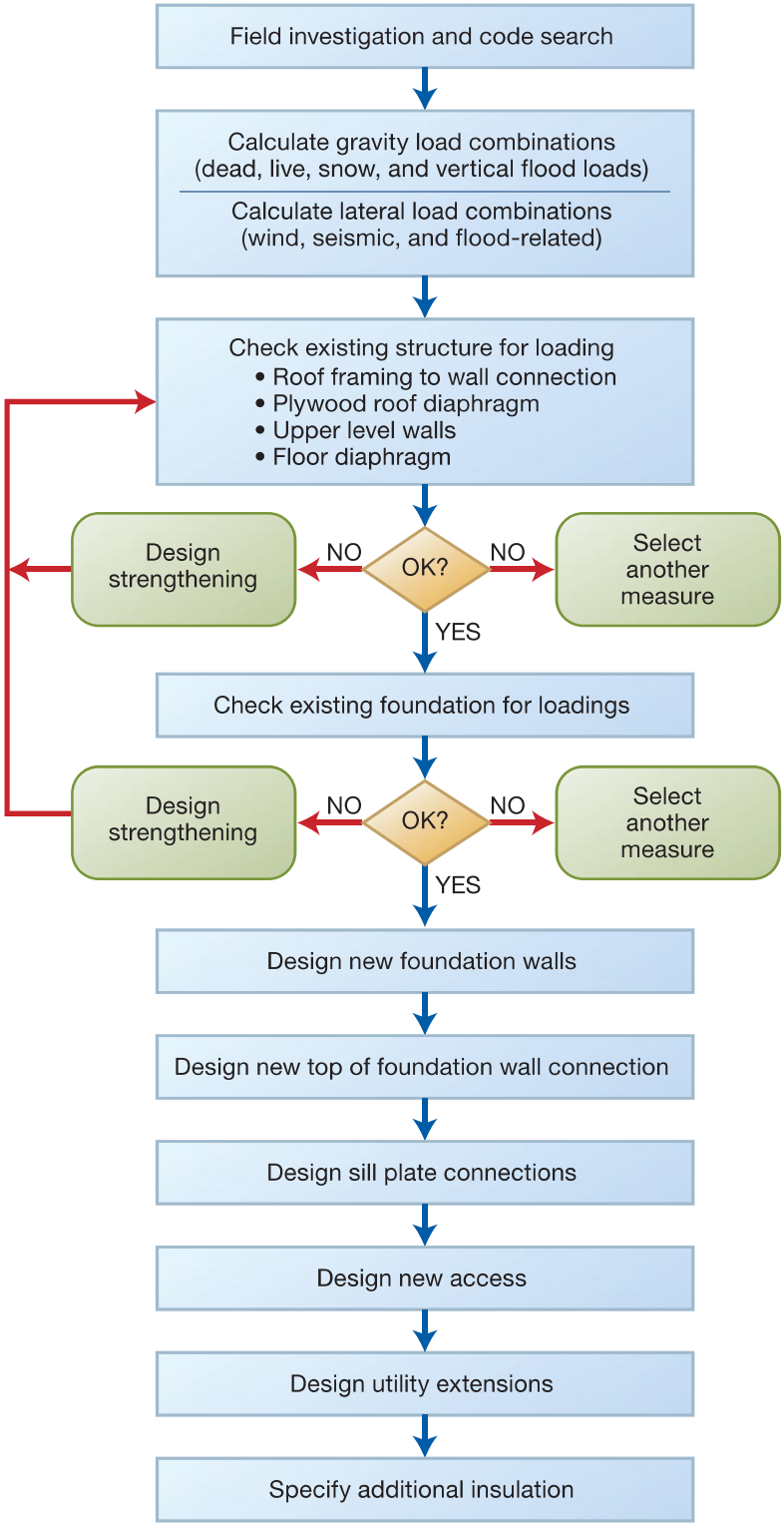


Figure 5E-24. Design process for an elevated house on foundation walls

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? ☐ Yes ☐ No

Additional data required:

Any construction access issues?

Site and building utilities identified? ☐ Yes ☐ No

Potential utility conflicts identified? ☐ Yes ☐ No

Describe conflicts: _____

Review homeowner preferences: _____

Can aesthetics reconcile with site and building constraints? ☐ Yes ☐ No

How?

Confirm type and condition of existing framing:

☐ member sizes ☐ spans ☐ connections ☐ supports

Confirm type and condition of foundation:

☐ type ☐ depth ☐ size

Confirm types and condition of existing construction materials:

☐ roof ☐ floor ☐ walls ☐ foundation

Confirm soil information:

☐ type ☐ depth of rock ☐ bearing capacity ☐ susceptibility to erosion and scour

Confirm characteristics of flood-related hazards:

☐ base flood elevation (BFE) ☐ velocity ☐ design flood elevation (DFE) ☐ frequency

☐ duration ☐ potential for debris flow

Confirm characteristics of non-flood-related hazards:

☐ wind ☐ seismic ☐ snow ☐ other

Review accessibility considerations:

☐ access/egress ☐ special resources for elderly, disabled, children

Architectural constraints noted: _____

Is clearance available to install lifting beams and jacking equipment? ☐ Yes ☐ No

Check local codes/covenants for height or appearance restrictions:

☐ deed/subdivision rules ☐ 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.

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.

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.

- 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 Case Studies

This chapter presents case studies based on structural and nonstructural retrofitting measures. The studies illustrate many of the procedures presented in the previous chapters and actual design practices. The cases include scenarios that examine elevation, relocation, dry and wet floodproofing, and small floodwalls and levees.

The case studies that follow are fictionalized scenarios developed to illustrate the retrofit option selection and design process. Narratives, graphics, photos, and calculations are fabricated and not based on actual individuals or structures.

6.1 Case Study #1: Residential Retrofit in Riverine Floodplain Using Elevation or Relocation

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

6.1.1 Description of Property

Harry S. Truman
55555 Cedar River Road, Mount Vernon, IA 55555

The Truman family has owned a large plot of land near Mount Vernon, Iowa, since the early 20th century. The 200+ acre plot slopes up from the Cedar River to a hilly, wooded area. Their current home, a one-story, wood-frame structure, was built in the 1960s, and is considered pre-FIRM construction. It has experienced varying levels of flooding from the Cedar River since its construction. A sunroom addition was built onto

the back of the structures in the 1980s. The structure is located in the SFHA (100-year floodplain) but, due to the sloping nature of the site, most of the rest of the plot is located outside the SFHA.

Harry Truman, the current owner, has decided that he would like to retrofit his home to resist flood damage. The local floodplain ordinance does not allow elevation on fill, and he does not like the idea of an open foundation. Mr. Truman indicated he would like to pursue retrofitting options that would allow him to obtain a reduced NFIP flood insurance rate. If possible, Mr. Truman would like to apply for HMA grant assistance.

6.1.2 Structure Information

55555 Cedar River Road is a one-story, wood-frame structure on a crawlspace and is a structure of good quality (Figure 6-1).

Other structure information includes:

- Footprint: 1,800 square feet
- Foundation:
  - Perimeter crawlspace foundation walls are reinforced and grouted CMU block, 8 inches thick, supported by a 2-foot wide x 1-foot thick reinforced concrete wall footer
  - Twelve interior piers at 10-foot spacing are reinforced and grouted double-stack CMU block, supported by 2-foot x 2-foot x 1-foot footer
  - Perimeter foundation walls and interior piers extend 2 feet below grade to the top of the footers, and 2 feet above grade
  - There are no flood vents in the above-grade portion of the perimeter foundation walls
- Structure:
  - First floor elevation of 694.2 feet (reference NAVD88), measured at the top of the lowest finished floor
  - Top of crawlspace of 692.2 feet (reference NAVD88)
  - Wood-frame structure
  - Wood siding
  - Wood-frame interior walls with gypsum board sheathing
- Roof:
  - Gable roof without overhangs over main structure (40 foot x 40 foot plan area)
  - Flat roof without overhangs over sunroom (10 foot x 20 foot area)
  - Asphalt shingle roof covering over entire roof
- Interior:
  - Wood stud interior walls with gypsum board sheathing
  - Hardwood floors

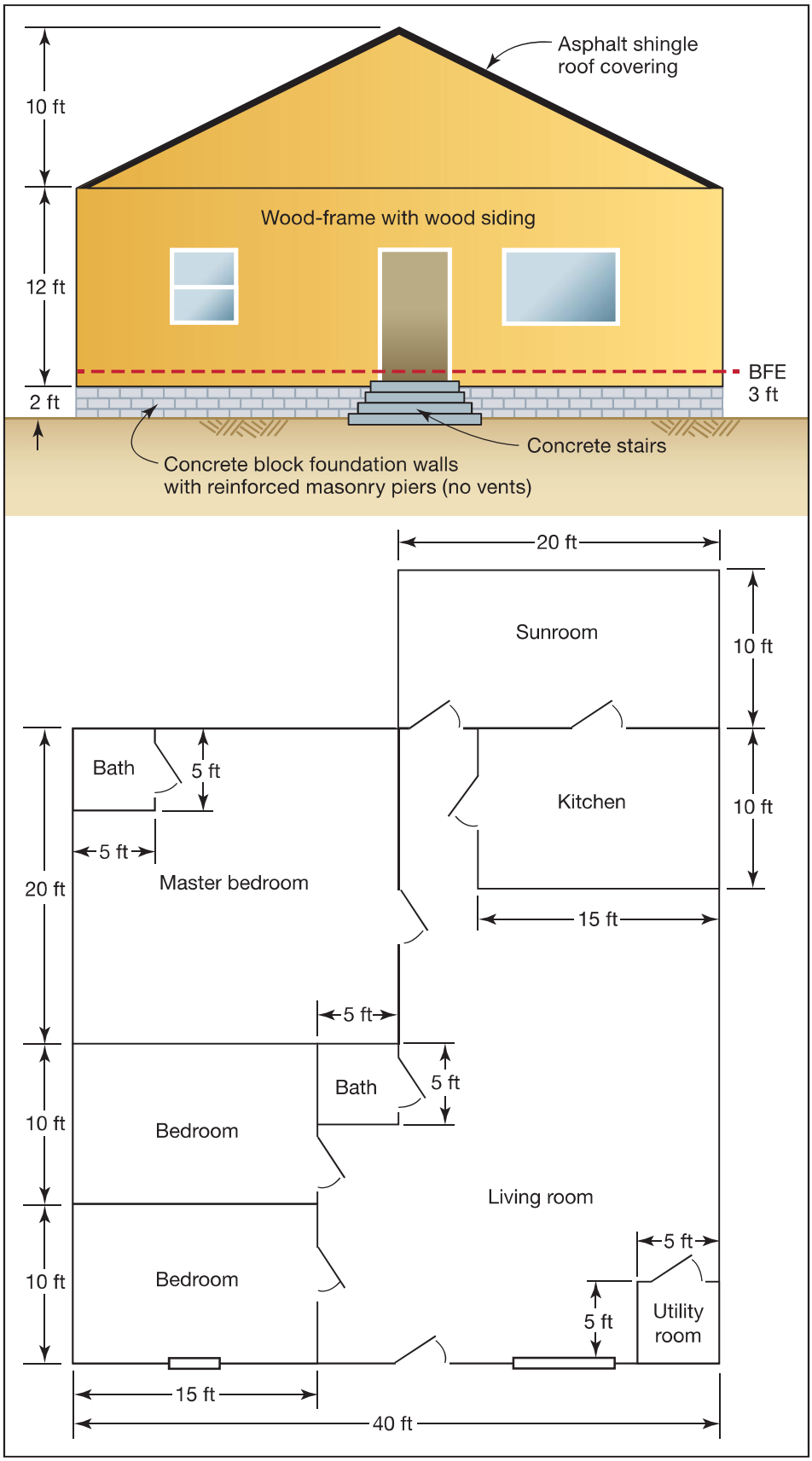


Figure 6-1.
The Truman house

Plot

The 200+ acre plot slopes from an elevation of approximately 690 feet near the river to near 730 feet in the woods. The 10-foot contour map shows the approximate size and topography of the plot and is included at the end of this case study. 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 Truman home has a building replacement value of approximately $105.00 per square foot, based on popular cost estimating guides.

Flood Hazard Data

The local floodplain management ordinance applies to all structures in the floodplain. Elevation on fill is prohibited, and a 1-foot freeboard is required for all new construction and substantial improvements.

The structure itself sits at the low point of the property and is in the SFHA, although most of the plot is outside of the regulatory floodplain. The flood map (FIRMette) is included at the end of this case study.

The applicable excerpts from the FIS show the flood elevations and discharges for the existing structure and are included in Section 6.1.5 and summarized in Table 6-1.

Table 6-1. Summary of Flood Elevations and Discharges for the Truman House

	Streambed	10-year	50-year	100-year	500-year
Elevation (ft)	671.2	694	696.3	697.8	700
Discharge (cfs)	NA	53,500	77,900	87,900	112,900

cfs = cubic feet per second

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.

Note that since there are no flood vents, the top of the lowest floor is considered to be the top of the crawlspace floor. In this case, the top of the crawlspace floor is equivalent to the LAG.

The flow velocity under base flood conditions is assumed to be 2.0 ft/sec.

6.1.3 Retrofit Options Selection

During an initial interview with Mr. Truman, potential retrofit options were discussed (Figure 6-2). 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, elevation and relocation are viable options for the structure and will reduce NFIP flood insurance rates.

Owner Name: Harry S. Truman Prepared By: Jane Q. Engineer

Address: 55555 Cedar River Road Date: 9/1/2011

Property Location: Mount Vernon, Iowa

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
Floodproofing Measures									
Measure Allowed or Owner Requirement		X					X	X	X
Homeowner Concerns									
Aesthetic Concerns			X	X	X				
High Cost Concerns	X		X	X	X	X			
Risk Concerns									
Accessibility Concerns	X		X	X	X				
Code Required Upgrade Concerns									
Off-Site Flooding Concerns									
Total "X's"	2	NA	3	3	3	1	NA	NA	NA

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 6-2. Preliminary Floodproofing/Retrofitting Preference Matrix for the Truman house

Cost was a concern for all potential retrofit options. Mr. Truman was also concerned about building accessibility for an elevation project. Mr. Truman was particularly concerned about how his home might look with an open foundation.

Based on the retrofit option screening matrix, the two most viable options were elevation by extending the foundation walls and relocation. Calculations and considerations are provided for both relocation and elevation.

Relocation

The only way to completely eliminate the flood risk to Mr. Truman's home is to move the entire structure out of the SFHA. Because his plot is so large, and ample buildable space exists outside of the SFHA, relocation is a good option to consider. Refer to Table 1-2 of this document for the advantages and disadvantages of relocation. The relocation process would include:

- selecting the new structure site;
- designing, excavating for, and constructing the new foundation;
- installing new utility connections at the new site;
- disconnecting utilities at the existing site;
- lifting the existing structure on hydraulic jacks;
- transporting the structure from the original site to the new site;
- lowering the structure and securing it onto the new foundation ;
- connecting utilities; and
- demolishing and filling the old foundation.

Note-Relocation is more likely to be found to be a cost-beneficial option when the owner has a suitable relocation site on the same tract of land. Purchase of a site is avoided and contact with public rights of way and utilities are minimized or avoided.

A preliminary cost estimate shows that the cost of relocation would likely be approximately $120,000. A preliminary BCA shows a BCR of 1.18. Therefore, relocation would be cost-beneficial as well as effective at eliminating future flood damage.

Elevation by Extending the Perimeter Foundation Walls

Elevating the structure on the existing perimeter foundation walls is also a viable retrofit option. Refer to Table 1-1 of this document for the advantages and disadvantages of elevation. The elevation process would include:

- designing the extended foundation;
- disconnecting utilities;
- lifting the existing structure on hydraulic jacks;
- extending the foundation walls;

- installing flood vents;
- lowering the structure;
- reconnecting utilities; and
- constructing a new deck and stairs.

The BFE is 697.8 feet NAVD88, and the first floor elevation (i.e., the top of the lowest floor) is 694.2 feet. The elevation of the LAG is 692.2 feet. The BFE is at a depth of 697.8 feet – 692.2 feet = 5.6 feet. Therefore, the floodproofing depth H = 5.6 feet + 1 feet = 6.6 feet.

Installing NFIP-compliant flood vents in the foundation walls will ensure that the crawlspace is no longer considered the "lowest floor" and that the lowest floor elevation will actually be the top of the floor of the living area. Because the crawlspace is already 2 feet high, the perimeter walls would only need to be extended an additional 4.6 feet to place the first floor elevation 1 foot above the BFE (i.e., 6.6 feet above the LAG).

A preliminary cost estimate shows a retrofit cost of approximately $100,000. This cost yields a BCR of 1.08. Therefore, elevation would be effective and cost-beneficial.

The elevated structure would look as shown in Figure 6-3. A hydrostatic force computation worksheet is presented in Figure 6-4.

Note that the concrete staircase has been replaced with wooden stairs that allow water to flow through the base.

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

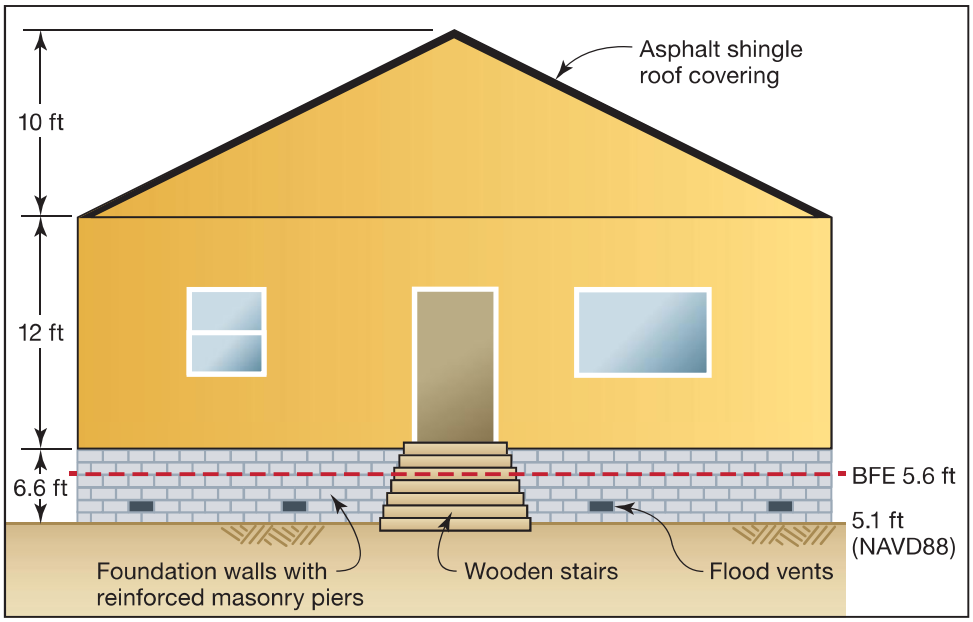


Figure 6-3. The Truman house after elevation, including extended foundation walls and flood vents

Hydrostatic Force Computation Worksheet

Owner Name: Harry S. Truman Prepared By: Jane Q. Engineer

Address: 55555 Cedar River Road Date: 9/1/2011

Property Location: Mount Vernon, Iowa

Constants

γ_w = specific weight of water = 62.4 lb/ft^3 for fresh water and 64.0 lb/ft^3 for saltwater

Variables

H = floodproofing design depth (ft) = 6.6 ft

D = depth of saturated soil (ft) = 2 ft

S = equivalent fluid weight of saturated soil (lb/ft^3) = NA

Vol = volume of floodwater displaced by a submerged object (ft^3) = 2,167 ft^{3,a}

Summary of Loads

f_{sta} = 0 lb/ft

f_{dif} = 0 lb/ft

f_{comb} = 0 lb/ft

F_{bouy} = 135,236 lb

Equation 4-4: Lateral Hydrostatic Force

$$f_{sta} = \frac{1}{2} P_h H = \frac{1}{2} \gamma_w H^2 = 0 \text{ lb/ft}$$

Equation 4- 5: Submerged Soil and Water Force

$$f_{dif} = \frac{1}{2}(S - \gamma_w) D^2 = 0 \text{ lb/ft}$$

Equation 4-6: Combined Lateral Hydrostatic Force

$$f_{comb} = f_{sta} + f_{dif} = 0 \text{ lb/ft}$$

Equation 4-7: Buoyancy Force

$$F_{buoy} = \gamma_w (Vol) = (62.4 \text{ lb/ft}^3)(2{,}167 \text{ ft}^3) = 135{,}236 \text{ lbs}$$

[a] Volume of water displaced is equal to the volume of the foundation walls, footers, floor system, and interior piers:

Walls: Perimeter = 40 ft + 40 ft + 40 ft + 10 ft + 20 ft + 10 ft + 20 ft = 180 ft; height = 4 ft (above grade) + 2 ft (below grade) = 6 ft; thickness = 16 in = 1.33 ft; 6 corners subtract 6(1.33 ft)(1.33 ft)(6 ft) = 63.7 ft^3; vents: 1 in^2 of open area for 1 ft^2 of enclosed area 1800 in^2 of open area 12.5 ft^2 of open area subtract 1.33 ft * 12.5 ft^2 = 16.6 ft^3

V_{walls} = (180 ft)(6 ft)(1.33 ft) – 6(1.33 ft)(1.33 ft)(6 ft) – (12.5 ft^2)(1.33 ft) = 1,355.7 ft^3

Footers: Perimeter = 180 ft; width = 2 ft; thickness = 1 ft; corners subtract 6(2 ft)(2 ft)(1 ft) = 24 ft^3

$V_{footers}$ = (180 ft)(2 ft)(1 ft) – 6(2 ft)(2 ft)(1 ft) = 336 ft^3

Floor: The floor joists and subfloor must be included in Zone A because the top of the lowest floor is at 4 ft. 2 in.x10 in. floor joists at 16 in. o.c (40 ft x12 in./ft)/16 in. ≈ 30 joists in main structure. Volume of one joist in main structure = 2 in. x (ft/12 in.) x 10 in. x (ft/12 in.) x 40 ft = 5.56 ft^3. In sunroom, (20 ft x 12 in./ft)/16 in. = 15 joists. Volume of one joist in sunroom = 2 in. x (ft/12 in.) x 10 in. x (ft/12 in.) x 10 ft = 1.39 ft^3. Total volume of joists = 30 x 5.56 ft^3 + 15 x 1.39 ft^3 = 187.65 ft^3. Subfloor 0.5 in. plus 0.25 in. hardwood floor volume of floor = (0.5 in. + 0.25 in.) x (1 ft/12 in.) x 1800 ft^2 = 112.5 ft^3

V_{slab} = 187.65 ft^3 + 112.5 ft^3 = 300.15 ft^3

Interior Piers: 12 piers. Each 16 in^2, 6 ft tall with a 2 ft x 2 ft x 1 ft footer.

V_{piers} = 12(1.33 ft)(1.33 ft)(6 ft) + 12(2 ft)(2 ft)(1 ft) = 175.4 ft^3

$V_{water} = V_{walls} + V_{footers} + V_{slab} + V_{piers}$ = 1,355.7 ft^3 + 336 ft^3 + 300.15 ft^3 + 175.4 ft^3 = 2,167 ft^3

Figure 6-4. Hydrostatic Force Computation Worksheet for the elevated Truman house (refer to Figure 4-9)

6.1.4 Load Calculations

The following paragraphs provide calculations for flood loads, dead loads, live loads, and load combinations, as well as bearing capacity, sliding, uplift, and overturning checks 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 4 feet. The perimeter wall extends 2 feet underground and is supported by a 1-foot-deep footer; therefore, the saturated soil depth D (measured from the ground surface to the top of the footer) is 2 feet (see Figure 4-8). Because openings were installed in the crawlspace, there are no hydrostatic forces.

The flow velocity is 2.0 ft/sec. An equivalent hydrostatic force computation worksheet is presented in Figure 6-5.

Equivalent Hydrostatic Force Computation Worksheet

Owner Name: Harry S. Truman Prepared By: Jane Q. Engineer

Address: 55555 Cedar River Road Date: 9/1/2011

Property Location: Mount Vernon, Iowa

Constants

γ_w = specific weight of water = 62.4 lb/ft^3 for fresh water and 64.0 lb/ft^3 for saltwater

g = acceleration of gravity = 32.2 ft/sec^2

Variables

H = design floodproof depth (ft) = 6.6 ft

V = velocity of floodwater (10 ft/sec or less) = 2 ft/sec

P_{dh} = hydrostatic pressure due to low velocity flood flows = (lb/ft^2)

b = width of structure perpendicular to flow (ft) = 40 ft

Summary of Loads

f_{dh} = 40.0 lb/ft

f_{sta} = 0 lb/ft

f_{dif} = 0 lb/ft

f_{comb} = 19.38 lb/ft

Equation 4-8: Conversion of Low Velocity Flood Flow to Equivalent Head

$$dh = \frac{C_d V^2}{2g} = (1.25)(2 \text{ ft/sec})^2/(2)(32.2 \text{ ft/sec}^2) = 0.0776 \text{ ft}$$

Develop C_d: b/H = 40 ft/4 ft = 10 From Table 4-5; C_d = 1.25

Equation 4-9: Conversion of Equivalent Head to Equivalent Hydrostatic Force

$$f_{dh} = \gamma_w (dh) H = P_{dh} H = (62.4 \text{ lb/ft}^3)(0.0776 \text{ ft})(6.6 \text{ ft}) = 40.0 \text{ lb/ft}$$

Equation 4-10: Combined Lateral Hydrostatic Force

$$f_{comb} = f_{sta} + f_{dif} + f_{dh} = 0 \text{ lb/ft} + 0 \text{ lb/ft} + 40.0 \text{ lb/ft}$$

Figure 6-5. Equivalent Hydrostatic Force Computation Worksheet for the Truman house (refer to Figure 4-11)

The design flood depth is 4 feet; therefore, C_D = 0.75. C_B = 1.0. An impact force computation worksheet is presented in Figure 6-6.

Impact Force Computation Worksheet

Owner Name: Harry S. Truman Prepared By: Jane Q. Engineer

Address: 55555 Cedar River Road Date: 9/1/2011

Property Location: Mount Vernon, Iowa

Variables

W = weight of the object (lb) = 1,000 lbs

V = velocity of water (ft/sec) = 2 ft/sec

C_D = depth coefficient (see Table 4-6) = 0.75

C_B = blockage coefficient (taken as 1.0 for no upstream screening, flow path greater than 30 feet; 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)

Summary of Loads

F_i = 1,200 lbs

Equation 4-13: Normal Impact Loads

$F_i = W V C_D C_B C_{Str}$ = (1000 lbs)(2 ft/sec)(0.75)(1)(0.8) = 1,200 lbs

Figure 6-6. Impact Force Computation Worksheet for the Truman house (refer to Figure 4-12)

Flood Force Summary:

Horizontal Force:

f_{comb} = 40.0 lb/lf

F_i = 1,200 lbs

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

F = (40.0 lb/lf)(40 ft) + 1,200 lbs= 2,800 lbs

Vertical Force:

F_{buoy} = 135,236 lbs

Load Calculations: Dead Loads

The dead load is the self-weight of the structure. Table 6-2 illustrates the dead load calculations using the conservative unit weights listed in Chapter 4 as well as a less conservative approach.

Table 6-2. Summary of Dead Load Calculations for the Truman House

Element	Area (ft^2)	Chapter 4 Unit Weight (lb/ft^2)	Chapter 4 Total Weight (lbs)
Exterior walls: drywall, 4 in. batt insulation, wood siding	(4)(40 ft)(12 ft) + (2)(10 ft)(12 ft) = 2,160	11	23,760
Interior walls: wood stud, 2 ft x 4 ft, ½ in. drywall	(12)(5+5+20+20+15+10+10+5+5+10+15 +10) = 1,560	8	12,480
Floor frame: wood frame, 2 ft x 10 ft interior, unfinished floor	1,800	10	18,000
Floor cover: hardwood	1,800	3	5,400
Ceiling: drywall	1,800	10	18,000
Roof: sloping timbers, sheathing, 10 in. batt insulation	(2)(40)(102 + 202)1/2 + (10)(20) = 1,992[a]	15	29,880
Roof cover: asphalt shingles	1,992	4	7,968
TOTAL	**Over the 1,800 ft^2 structure**	**61**	**115,488**

[a] Roof area is taken to be the area of the sloping sections of the roof, calculated as twice the area of one side of the roof. Each side of the roof is taken to be rectangular, with dimensions of 40 ft (along the base) and [(10)2 + (20)2]1/2 = 22.4 ft (the hypotenuse of the triangle formed by the vertical section of the roof structure).

[b] Foundation walls are considered to be a single layer, reinforced CMU wall (8-in. thick) with a unit weight of 75 lb/ft^2. Walls after mitigation extend 4 ft above ground and 2 ft below ground. The area is therefore [4 (40 ft)(6 ft)] – [4x(0.67 ft)(6 ft)] (to account for corners) = 944 ft^2.

[c] Foundation piers are considered to be double stack, reinforced CMU piers (16 in. x 16 in.). The unit weight of a 16-in. thick pier is taken to be twice the unit weight of an 8-in. thick reinforced CMU pier. The area is therefore 12 (1.333 ft)(6 ft) = 96 ft^2.

[d] Unit weights for reinforced concrete are given in lb/ft^3. The footing volume is taken to be [4 (40 ft)(2 ft)(1ft)] – [4 (2 ft)(1 ft)(1 ft)] = 312 ft^3.

[e] See (d). The interior footing volume is taken to be 12 (2 ft)(2 ft)(1 ft) = 48 ft^3.

Load Calculations: Live Loads

Live Load (Vertical)

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

L = 40 lb/ft^2 x (1,800 ft^2) = 72,000 lbs

Roof Live Load (Vertical)

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

L_r = 20 lb/ft^2 x (1,800 ft^2) = 36,000 lbs

Snow Load (Vertical)

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

S = 20 lb/ft^2 (1,800 ft^2) = 36,000 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. Therefore, assume a wind pressure of 30 lb/ft^2 acting uniformly over the entire aboveground structure:

Area = Elevated Crawlspace area + Exterior Wall area + Vertical Roof area

$\Rightarrow A$ = (4 ft)(40 ft) + (12 ft)(40 ft) + (10 ft)(40 ft) = 160 ft^2 + 480 ft^2+ 400 ft^2 = 1040 ft^2

W = 30 lb/ft^2 x (1,040 ft^2) = 31,200 lbs

Earthquake Load

Earthquake forces are assumed to be negligible for this location. Therefore, E = 0.

Load Combinations

To determine the worst-case horizontal and vertical loading scenarios, ASCE 7-10 load combinations are used (Allowable Stress Design). Table 6-3 presents a summary of the horizontal and vertical load combinations.

Load Summary:

Horizontal Loads

$D = L = L_r = S$ = E = 0

$F_a = F_{comb}$ = 2,800 lbs

W = 31,200 lbs

Table 6-3. Summary of Horizontal and Vertical Load Combinations for the Truman House

	Combination	Horizontal (lbs)	Vertical (lbs)
1.	D	0	115,560
2.	$D + L$	0	187,560
3.	D + (L_r or S or R)	0	151,560
4.	$D + 0.75L + 0.75(L_r$ or S or $R)$	0	196,560
5.	D + (0.6W or 0.7E) + 0.75F_a	20,820	14,133
6a.	$D + 0.75L + 0.75(0.6W) + 0.75(L_r$ or S or $R) + 0.75F_a$	16,140	95,133
6b.	$D + 0.75L + 0.75(0.7E) + 0.75S + 0.75F_a$	2,100	95,133
7.	$0.6D + 0.6W + 0.75F_a$	20,820	-32,091
8.	$0.6D + 0.7E$	0	69,336

Vertical Loads

D = 115,560 lbs
L = 72,000 lbs
L_r = 36,000 lbs
S = 36,000 lbs
W = 0 (conservative)
E = 0
$F_a = F_{buoy}$ = 135,236 lbs

Bearing Capacity Check

$P_{max} = A_{bearing} S_{bc}$
S_{bc} = 2,500 lb/ft^2 (Table 5-2)

The bearing area is the area of the footings:

$A_{bearing}$ = [4 (40 ft)(2 ft)] - [4 (2 ft)(2 ft)] + [12(2 ft)(2 ft)] = 352 ft^2
P_{max} = (2,500 lb/ft^2)(352 ft^2) = 880,000 lbs

Maximum vertical load:

335,688 lbs < P_{max} ✓

Sliding Check

The soil type is SM; from IBC 2009 (Table 1806.2), the coefficient of friction is 0.25. Worst case horizontal load combination 7: $0.6D + 0.6W + 0.75F_a$

Horizontal Resistive Force = Foundation Resistive Force + Resistive Force from Structure Self-Weight

Foundation Resistive Force $r = (k_p)(\gamma_{soil})(d^2/2)$, where:

$k_p = \tan^2(45^o + \phi/2)$, where ϕ is the soil angle of internal friction (assume $\phi = 30^o$)
$k_p = \tan^2(45^o + 30^o/2) = 3$
γ_{soil} = 77 lb/ft^3 (Soil Type SM; see Table 4-3)
d = depth of soil from top of soil to top of footer = 2 ft
Therefore, r = (3)(77 lb/ft^3)(2 ft)^2/2 = 462 lb/ft

Assume both side walls of the main structure resist sliding, therefore,

R_H = 2(40 ft)(462 lb/ft) = 36,960 lbs
Resistive Force from Structure Self Weight = 0.25 (0.6D) = 0.25 x 0.6 (115,560 lbs) = 17,334 lbs
Total Resistive Force = 36,960 lbs + 17,334 lbs = 54,294 lbs
Horizontal Load = 0.6W + $0.75F_a$ = 20,820 lbs < 38,203 lbs ✓

Figure 6-7 presents the moment diagram for the Truman house.

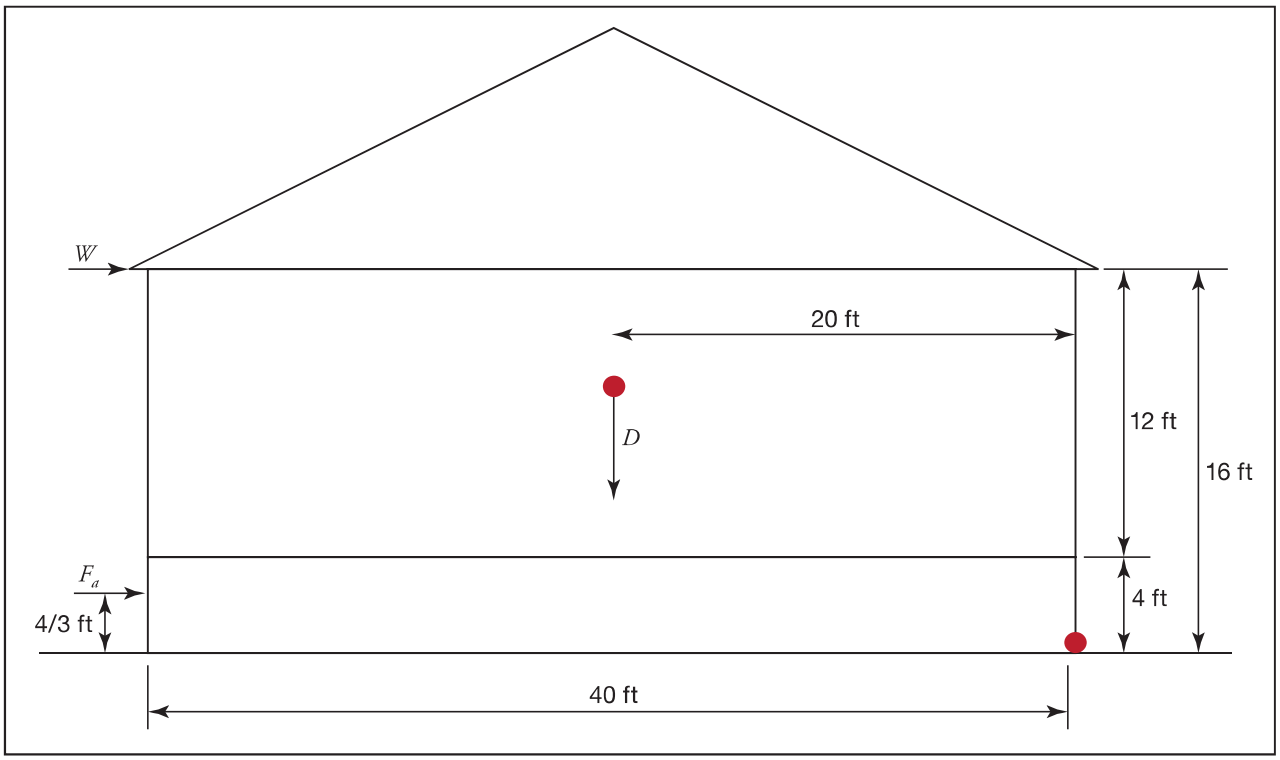


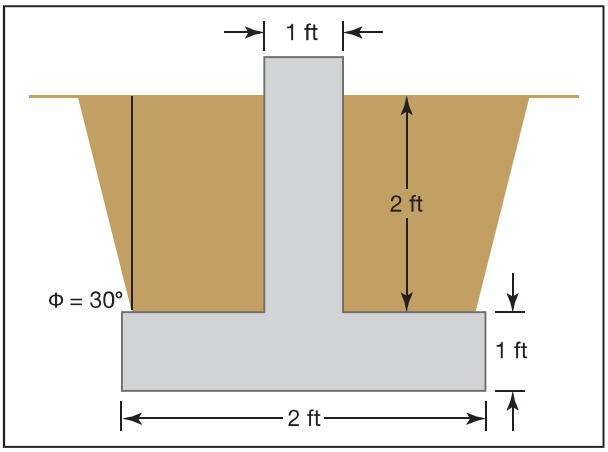
Figure 6-7. Moment diagram for the Truman house

Uplift Check

The worst case load combination for the uplift check would be $0.6D + 0.6W + 0.75F_a$.

The resistive force is equal to the weight of the concrete footer and soil above the footer that would need to be uprooted. Assuming a soil angle of internal friction of $\phi = 30^o$, a cross section of the displaced soil and footer is as follows in Figure 6-8:

Figure 6-8. Cross section of displaced soil and footer



To calculate the weight of the displaced concrete and soil, calculate the volume displaced. The perimeter of the house is given by (40 ft x 3 + 20 ft + 10 ft + 20 ft + 10 ft) = 180 ft.

The volume of the foundation walls is given by:

V_{walls} = (180 ft x 2 ft x 1 ft) – 6(2 ft x 1 ft) = 348 ft^3

The volume of the footers is given by:

V_{footer} = (180 ft x 1 ft x 2 ft) – 6(1 ft x 2 ft) = 348 ft^3

The total volume of concrete is: $V_{concrete}$ = 348 ft^3 + 348 ft^3 = 696 ft^3

The total weight of concrete is: $W_{concrete}$ = 150 lb/ft^3 x 696 ft^3 = 104,400 lbs

The cross-section of the displaced soil is given by the area of the trapezoid of soil failure minus the area of the wall. The smaller base of the trapezoid is 2 feet. The angle of internal friction is 30°, therefore the wider base of the trapezoid is 2 feet + 2[2tan(30°)] = 4.3 feet. Therefore the cross-sectional area of the displaced soil is:

A_{soil} = (2 ft + 4.3 ft) x 2 ft/2 – 2 ft x 1 ft = 4.3 ft^2

The volume of displaced soil is given by:

V_{soil} = (180 ft x 4.3 ft^2) – 6(4.3 ft^2) = 748.2 ft^3

The total weigt of soil is: W_{soil} = 77 lb/ft^3 x 748.2 ft^3.

Therefore, the total resistive force is: R_v = 104,400 lbs + 57,611 lbs = 162,011 lbs

Vertical uplift = $0.6W + 0.75F_a$ = 101,427 lbs < 162,011 lbs ✓

Overturning Check

M_W = (16 ft)W = 499,200 ft-lbs

M_F = –(20 ft)F_V + –(4/3 ft)F_H = –2,708,453 ft-lbs

$0.6M_W + 0.75M_F$ = (0.6)(+499,200 ft-lbs) + (0.75)(– 2,708,453) = –1,731,820 ft-lbs

M_D = (20 ft)D = 2,311,200 ft-lbs

$0.6M_D$ = 1,386,720 ft-lbs

M_{Rv} = (20 ft)R_V = 3,240,220 ft-lbs

$0.6M_W + 0.75M_F < 0.6M_D + M_{Rv}$ ✓

6.1.5 Supporting Documentation

This section includes additional information about the Truman house. The following maps and documents provide backup documentation for the values used in the Case Study 1 calculations, including:

- topographic map showing the location of the plot and ground elevation (Figure 6-9);
- FIRMette showing the location of the plot relative to the SFHA (Figure 6-10);
- summary of discharges, excerpted from the FIS, showing the 10-, 50-, 100-, and 500-year discharges at the Truman house (Figure 6-11);
- flood profile showing the 10-, 50-, 100-, and 50-year flood elevations at the Truman house (Figure 6-12);

- elevation certificate showing the first floor elevation (Figure 6-13);
- tax card providing building value and square footage (Figure 6-14); and
- BCA report excerpt summarizing the cost-effectiveness of elevation and relocation (Figure 6-15).



Figure 6-9. Topographic map showing the location of the Truman plot (in red). Please note these are 10-foot contours.

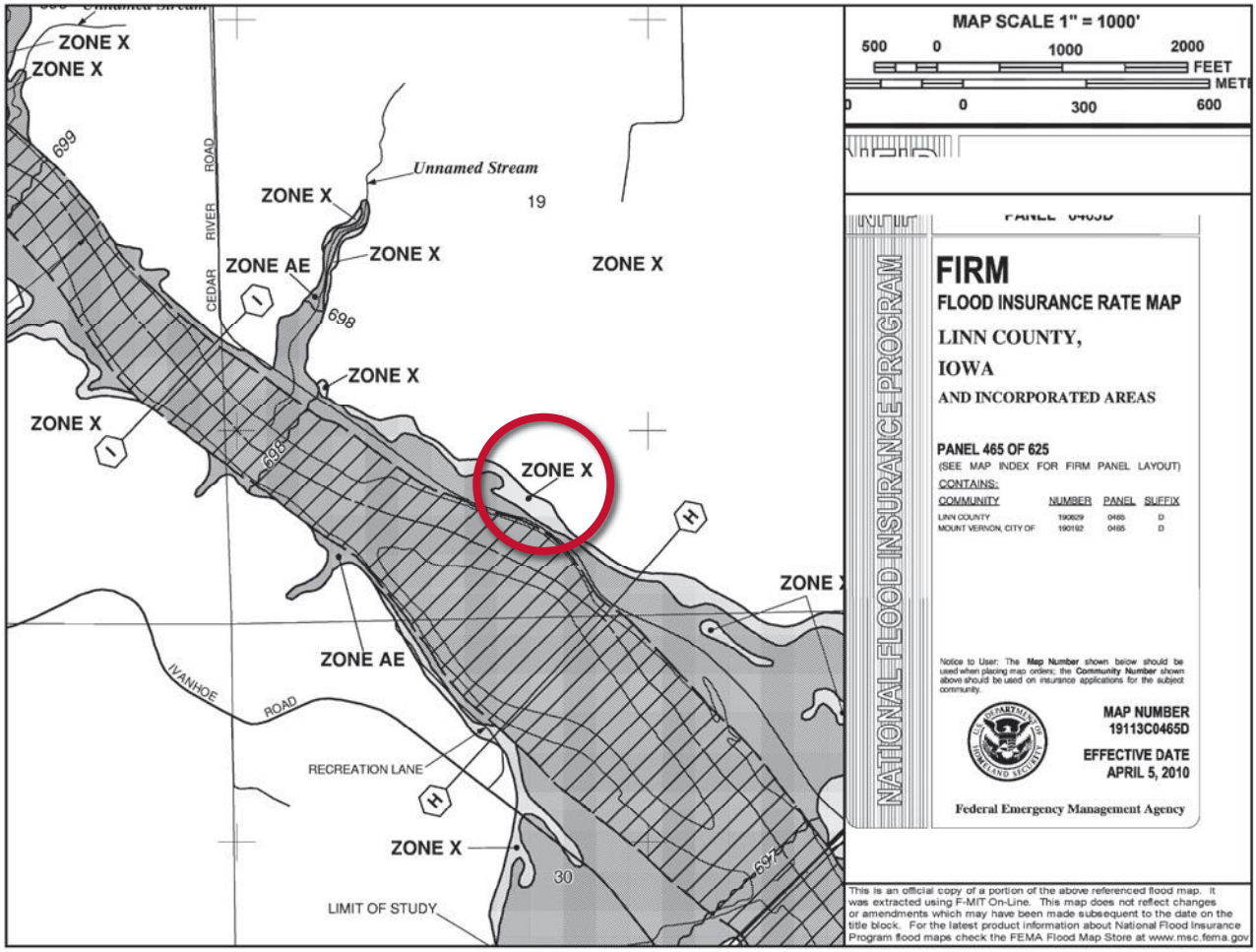


Figure 6-10. FIRM showing the location of the Truman plot (circled in red)

TABLE 3 – SUMMARY OF DISCHARGES

Flooding Source and Location	Drainage Area Sq. Miles	Peak Discharges (CFS) 10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
CEDAR CREEK					
At State Highway 1 bridge	6974	53500	77900	87900	112900
of Big Creek					
Just upstream of confluence of Morgan Creek	6458	53500	78100	88100	113100
At the gaging station in Cedar Rapids at 7th Avenue SW	6510	53000	77000	87000	112000
Just upstream of confluence of Otter Creek	6381	53700	78400	88400	113400
Just upstream of confluence of Opossum Creek	6243	53800	78500	88600	113600
WAPSIPINICON RIVER					
At south county boundary	1324	18350	30520	36000	49220
Just above confluence of Heatons Creek	1294	18090	30080	35480	48500
Just above confluence of Waltons Creek	1242	17810	29620	34940	47760
MARTINS CREEK					
At mouth	4.2	1255	2485	3152	4995
Just upstream of small tributary in the northwest quarter of Section 14, T83N, R6W	3.5	1225	2410	3055	4830
Just upstream of small tributary in the northwest quarter of Section 11, T83N, R6W	2.2	1010	2010	2565	4105

Figure 6-11. FIS Excerpt: Discharge table for the Truman house (applicable discharges circled in red)

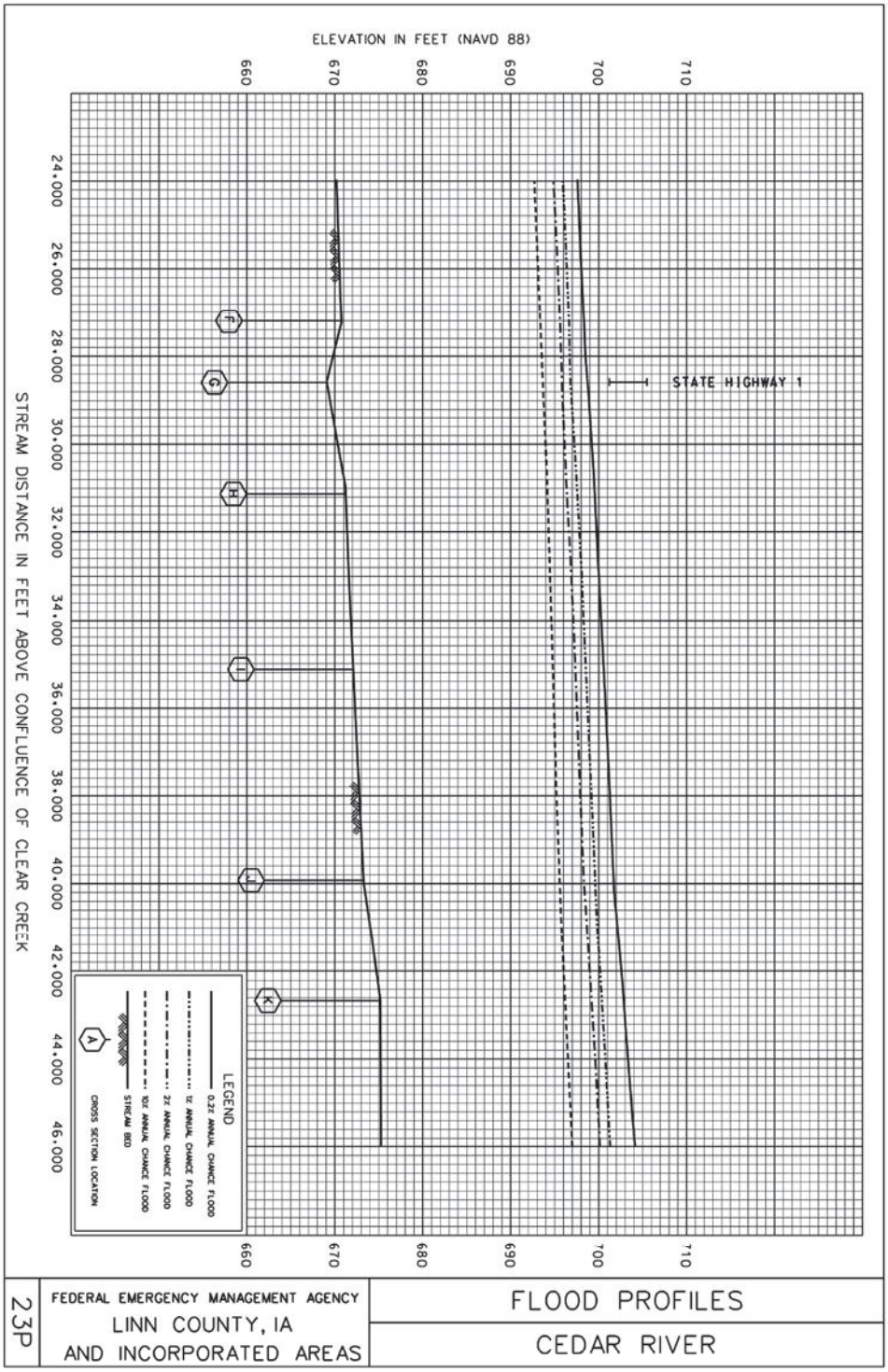


Figure 6-12.
FIS excerpt: Flood profile for the Truman house

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

ELEVATION CERTIFICATE

Important: Read the instructions on pages 1-9.

OMB No. 1660-0008
Expires March 31, 2012

SECTION A - PROPERTY INFORMATION

For Insurance Company Use:
Policy Number
Company NAIC Number

A1. Building Owner's Name Samuel Klayman

A2. Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No.
55555 Cedar River Road
City Mount Vernon State IA ZIP Code 55555

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

A4. Building Use (e.g., Residential, Non-Residential, Addition, Accessory, etc.) Residential
A5. Latitude/Longitude: Lat. NA Long. NA 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 8
A8. For a building with a crawlspace or enclosure(s):
a) Square footage of crawlspace or enclosure(s) 1800 sq ft
b) No. of permanent flood openings in the crawlspace or enclosure(s) within 1.0 foot above adjacent grade 0
c) Total net area of flood openings in A8.b 0 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	B2. County Name	B3. State
19113C	Linn County	IA

B4. Map/Panel Number	B5. Suffix	B6. FIRM Index Date	B7. FIRM Panel Effective/Revised Date	B8. Flood Zone(s)	B9. Base Flood Elevation(s) (Zone AO, use base flood depth)
465	D	April 5, 2010	April 5, 2010	AE	697.8

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

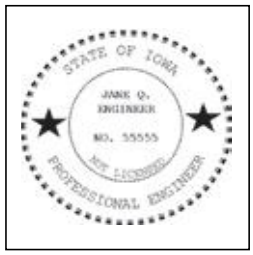
SECTION C - BUILDING ELEVATION INFORMATION (SURVEY REQUIRED)

C1. Building elevations are based on: ☐ Construction Drawings* ☐ Building Under Construction* ☒ 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 NAVD 88
Conversion/Comments _____

			Check the measurement used.	
a)	Top of bottom floor (including basement, crawlspace, or enclosure floor)	694.2	☒ feet ☐ meters (Puerto Rico only)	
b)	Top of the next higher floor	696.2	☒ feet ☐ meters (Puerto Rico only)	
c)	Bottom of the lowest horizontal structural member (V Zones only)	_____	☐ feet	☐ meters (Puerto Rico only)
d)	Attached garage (top of slab)	_____	☐ feet	☐ meters (Puerto Rico only)
e)	Lowest elevation of machinery or equipment servicing the building (Describe type of equipment and location in Comments)	696.2	☒ feet ☐ meters (Puerto Rico only)	
f)	Lowest adjacent (finished) grade next to building (LAG)	694.2	☒ feet ☐ meters (Puerto Rico only)	
g)	Highest adjacent (finished) grade next to building (HAG)	694.5	☒ feet ☐ meters (Puerto Rico only)	
h)	Lowest adjacent grade at lowest elevation of deck or stairs, including structural support	694.2	☒ feet ☐ 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.* ☐
Check here if comments are provided on back of form. Were latitude and longitude in Section A provided by a licensed land surveyor? ☐ Yes ☒ No



Certifier's Name Jane Q. Engineer License Number 5555555
Title Project Engineer Company Name Engineering Co, Inc
Address 555 Main Street City Springfield State IA ZIP Code 55555
Signature Date Telephone 555-555-5555

FEMA Form 81-31, Mar 09 See reverse side for continuation. Replaces all previous editions

Figure 6-13. Elevation certificate excerpt for the Truman house

LINN COUNTY ASSESSOR

Pin	55555-55555-55555
Deed	TRUMAN HARRY S
Property Address	55555 CEDAR RIVER RD MT VERNON
Class	RESIDENTIAL

Current Value Information

Land Value	Dwelling Value	Improvement Value	Total Value
1,434,098	163,795	0	1,597,893

Prior Year Value Information

Year	Land Value	Dwelling Value	Improvement Value	Total Value
2011	1,434,098	163,795	0	1,597,893
2010	1,434,098	163,795	0	1,597,893
2009	1,434,098	163,795	0	1,597,893
2008	1,434,098	163,795	0	1,597,893
2007	1,434,098	163,795	0	1,597,893

Residential Building Information

Occupancy	Style	Year Built	Total Living Area
Single-Family/Owner Occupied	1 Story Frame	1964	1,800

Yard Extra Information

Description	Item Count	Year Built
NA		

Land Information

Lot Basis	Square Feet	Acres
Lump Sum	9,280,000	213

Tax History Information

Tax Year	Assessed Value	Taxable Value	Gross Tax	Net Tax
2009	1,597,893	748,564	23,363	23,363
2008	1,597,893	728,462	20,791	20,600
2007	1,597,893	704,354	20,244	19,200
2006	1,356,789	618,145	17,533	17,000

Figure 6-14. Truman house tax card

16 Sep 2011 Project: **Case Study 1** Pg 1 of 21

Total Benefits: **$246,241** Total Costs: **$220,000** BCR: **1.12**

Project Number: Disaster #: Program: Agency: **City of Mount Vernon**

State: **Iowa** Point of Contact: Harry Truman Analyst:

Project Summary:

Project Number: Disaster #:

Program: Agency: City of Mount Vernon

Analyst:

Point of Contact: Harry Truman Phone Number:

Address: 55555 Cedar River Rd, Mount Vernon, Iowa, 55555

Email:

Comments:

Structure Summary For:

1-Elevation, 55555 Cedar River Road, Mount Vernon, Iowa, 55555, Linn

Structure Type: Building Historic Building: No Contact:

Benefits: $105,211 Costs: $100,000 BCR: 1.05

Mitigation	Hazard	BCR	Benefits	Costs
Elevation	Flood	1.05	$105,211	$100,000

2-Relocation, 55555 Cedar River Road, Mount Vernon, Iowa, 55555, Linn

Structure Type: Building Historic Building: No Contact:

Benefits: $141,030 Costs: $120,000 BCR: 1.18

Mitigation	Hazard	BCR	Benefits	Costs
Acquisition	Flood	1.18	$141,030	$120,000

Figure 6-15. Sample BCA report excerpt for the Truman house elevation and relocation projects

6.1.6 Real World Examples

Although the Truman house is fictional, elevation and relocation are both commonly used flood mitigation measures. Figures 6-16 and 6-17 are examples of real structures that have been protected using the mitigation measures discussed in this case study.

This structure was relocated to another property.



Figure 6-16. Relocation of an existing building to another location

This home was elevated on solid foundation walls in Louisiana.



Figure 6-17. Elevation of an existing home above the BFE

A Guide to Elevating homes for Flood Protection – Quiz

Updated: 3/7/2018

1) Which of the following is one of the most common retrofitting techniques of protecting a structure from flood damage?
a. To demolish the structure
b. To Use a floating foundation
c. To raise the entire existing superstructure above the DFE
d. To purchase flood insurance

2) Which of the following would be reasons that elevating a structure would be the preferred technique of flood protection for a house?
a. The permitting is simple
b. By design, the living area is undamaged after a flood
c. Elevating is the best technique for all situations
d. Elevating contractors are easier to find than other contractors

3) For which of the following foundation types is elevation considered an option?
a. Crawlspace foundations
b. Slab-on-grade foundations
c. Pile, pier and column foundations
d. All of the above

4) Houses over a crawlspace are generally the easiest and least expensive houses to elevate.
a. True
b. False

5) Which of the following should foundation walls for elevated houses have to permit the automatic entry and exit of floodwater?
a. French drains
b. Foundation walls with adequate openings
c. Breakaway foundation walls
d. A sump pump system with backup power

6) Which of the following are minimum flood design criteria for openings in foundations walls?
a. At least 2 openings must be provided on different sides of each enclosed area
b. The total net area of openings should be at least 1 square inch of opening per square foot of enclosed area subject to flooding
c. The bottoms of all openings shall be no higher than 1 ft. above grade
d. All of the above

7) The process of elevating a house on existing piles, piers or columns is much simpler than elevating a home on a crawlspace?
a. True
d. False

8) Slab-on-grade homes have been successfully elevated using which of the following methods?
a. Elevating the slab-on-grade structure with the slab intact
b. Elevating the slab-on-grade structure without the slab, constructing a new wood framed first floor
c. Creating a new wood-frame livable area on top of an existing one story masonry structure
d. All of the above

9) Elevating houses with heavy building materials and complex designs is more complicated than elevating houses with simple designs and light materials.
a. True
b. False

10) As part of the design process for an elevated house, the designer should do which of the following?
a. Calculate gravity load combinations
b. Check the existing structure for loading of different structural systems of the home
c. Design new foundation walls
d. All of the above

11) Which of the following should be determined during a code search?
a. Bids from subcontractors
b. Requirements of the building code that governs the elevation project
c. Required building permits
d. Calculation of foundation loads

12) There are no “typical” equations for wind loads on houses, since the calculation of winds loads depends upon which of the following?
a. The building code in use
b. The size of the house
c. The shape of the house
d. All of the above

13) Elevated houses are subject to increased wind loads due to the increased surface area of foundations walls.
a. True
b. False

14) When elevating wet floodproofed buildings, openings are sometimes obstructed by drywall or other wall coverings, which can result in buildup of what undesired effect?
a. Hydrostatic loads on the foundation walls
b. Hydrostatic pressure on the drywall covering potentially causing drywall failure
c. Uplift forces on the foundations
d. Additional dead load due to wet drywall

15) The roof framing-to-wall connections should be checked to ensure that they will resist the increased _____.
a. Seismic loads
b. Snow loads
c. Wind loads
d. Vertical loads

16) The existing foundation should be checked to determine its ability to withstand which of the following?
a. Increased gravity loads from materials added during elevation
b. Increased lateral loads due to soil pressure from potential backfilling
c. Increased overturning pressure due to seismic and wind loadings on a taller structure
d. All of the above

17) Top of wall connections are critical to avoid pullout of the _____.
a. Electrical utilities
b. Footings from the ground
c. Ridge from the rafters
d. None the above

18) Following are some important construction considerations prior to elevating any house.
a. Estimating the lifting load of the house
b. Documenting the original conditions of the house prior to elevating
c. Removing any tree limbs that might be hanging over the house
d. Ensuring that the new top of home elevation will not encroach on the glide path of local airports

19) 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 construction.
a. True
d. False

20) Elevated _____ and extended utility system components may increase the potential for heat loss through increased exposure and airflow and necessitate additional insulation.
a. Floors
b. Foundations
c. Walkways
d. Carports

21) Which of the following home/foundation types may require construction of new outside stairways and access after elevating?
a. Crawlspace foundations
b. Pile/pier foundations
c. Slab-on-gradehome
d. All of the above

22) When elevating a house on a masonry crawlspace foundation or a slab-on-grade with a masonry foundation wall, the existing masonry must be removed and replaced down to the foundation.
a. True
b. False

23) What must be done with utilities below the DFE after a house is elevated?
a. The utilities must be located by a utility locating service
b. The utilities must be restored to their original condition
c. The utilities must be abandoned
d. The utilities must be floodproofed

24) In the case study of the Chester residence, what type of licensed professional may place their seal on the Elevation Certificate?
a. A licensed architect
b. A licensed surveyor
c. A licensed professional engineer
d. All of the above

25) In the case study of the Chester residence, the home was evaluated for 2 techniques of protection against flooding. Elevation was determined not to be cost effective. Which option was chosen as the cost-beneficial retrofit option?
a. Dry floodproofing
b. Acquisition and demolition
c. Wet floodproofing
d. Relocation of the structure