

Flood Mitigation for Homeowners: A Technical Document on Elevating Residential Buildings

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I. Introduction and Purpose

This interactive document is designed to assist homeowners who have experienced at least one serious flooding event and are:

- 1) required to elevate their house by building code due to 'substantial damage' or
- 2) have chosen to elevate due to fear of future flooding and related costs, even if not required to do so by code. Some benefits are: avoiding another traumatic flood experience; reduced flood insurance premiums; neighborhood stability.

It is not a goal of this report to discuss in detail various funding programs, of which references will be listed in the appendix. It is noted that public and private funds can be separate or combined to cover the costs to elevate a residential structure. Each state and local community, sometimes with federal assistance, offer various methods and the selection of the best alternative depends upon the owner's financial status, available financial programs, recommendations from public emergency management departments, and most important, the owner's decision whether or not to continue living on flood prone property.

The decision whether to elevate, physically move the house, or demolish the structure is best determined by working with local community planning and building departments and calculating possible alternatives with a 'benefit-cost' analyses. For example, if most homeowners living in a flood prone neighborhood decide to relocate instead of elevate, an individual homeowner may decide it also best to relocate out of flood's way rather than continue to live in an elevated, and isolated, home without an adjacent neighborhood structure-even if it proves financially cost effective to elevate the house.

Data and recommendations relevant for this report are taken from:

- 1) case studies of elevated homes through field inspections and interviews
- 2) public documents from local, state and federal emergency management agencies
- 3) technical reports, since 1980
- 4) meetings with community planners, floodplain administrators, building inspectors
- 5) regulations on elevating with an updated 'elevation certificate form'

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I-1. Homeowner Questionnaire

This document includes a combination of information, case studies and short questionnaires to help guide you through a decision process. Let's begin with a simple questionnaire whose purpose is for you to become familiar with your flood issues:

1. How often has my house been flooded since I lived in it or since it was built?
2. How high in feet and inches from the floor was the floodwater in my home?
 - 2.1 In an unfinished basement, crawl space or attached garage:
 - 2.2 In a living space:
3. How long did flood water remain in the house?
4. Did I have to move out and if so, for how long?
5. What were some of my monetary expenses in terms of:
 - 5.1 repair and replacement costs
 - 5.1.1 to the house structure = \$
 - 5.1.2 less any insurance coverage @\$ _____ = net loss \$ _____
 - 5.1.3 to contents = \$
 - 5.1.4 any contents insurance coverage@ \$ _____ = net loss \$ _____
 - 5.2 cleanup costs @ \$
 - 5.3 living away from home costs that were not covered by grants @ \$
 - 5.4 loss of employment @ \$
 - 5.5 other losses? @ \$
6. What were some of the physical and emotional costs?
 - 6.1 Family stress and disruption to normal living
 - 6.2 Time and effort to temporarily move furnishings and other possessions
7. Was my home accessible during or immediately after the flood?
8. Do I know if my house structure is located in a mapped flood plain?
9. Do I know the base flood elevation (BFE) of the mapped 100-year floodplain and its relation to the floor level(s) of my house?
10. Do I have flood insurance?
 - 10.1 If so, why is my insurance premium a certain cost?

II. Flooding Conditions and Flood Proofing Alternatives

Flooding occurs in a wide variety of settings:

- Riverine flooding
- Coastal zone flooding with wave action
- High, saturated ground water
- Back up flooding from rivers, creeks, drainage basins
- Dams and levees breaking
- Clogged culverts causing water back up
- Back flow from sewer lines
- Downhill sheet flow after a heavy rain or snow melt
- Roof drainage into the house



Fig. I-1 A riverine flood of long duration can cause serious damages (FEMA,1999)

Flooding conditions can be: (FEMA, *Mitigation for Homeowners*)

- Shallow to deep water
- Short warning time
- High or low flow velocities
- Long or short duration
- High rates of rise and fall
- Wave action
- Debris potential
- Hazardous materials in the water



Flooded houses along the Flint River in Albany, Georgia. Photo by Andrew Roebuck/FEMA

Fig. I-1 A riverine flood with a long duration and slow velocity (FEMA, 1999)

II-1 Questionnaire:

1. What is the reason my house flooded? (river flooded, etc.)
2. Do I know where the water came from and where it entered my house?
Mark the location(s) on the drawing below:

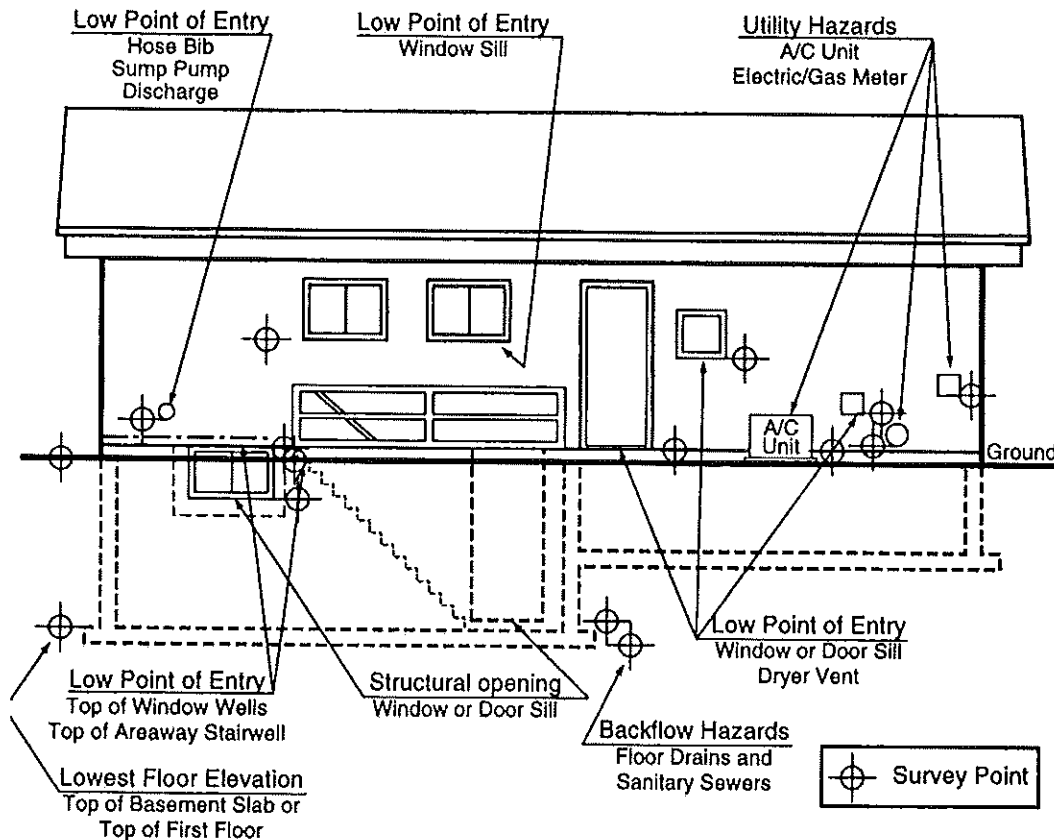


Figure II-1 Determining low point of water entry (FEMA, 1998)

3. Is it possible that I will experience flooding again?
4. Am I prepared for another flood event? Answer the below:
 - 4.1 Can I relocate damageable items quickly to a higher elevation?
 - 4.2 Could I move out of my home for an extended period?
 - 4.3 Are major utilities protected from water damage?
 - 4.3.1 Hot water heater
 - 4.3.2 Electrical panel box

5. Could flood waters cause structural walls to collapse?



Figure II-2. Exterior masonry wall collapsed due to water pressure (Photo by author)

There are different flood proofing, or ‘retrofitting’, methods available to the homeowner. This document will describe **elevation** in most detail but it is useful to know about other alternatives. (FEMA, 1995)

- **Elevation** of the house above probable, or ‘100 year’ Base Flood Elevation (BFE)
- **Relocation** to a site above flood danger; demolish or move the house to higher ground
- **Dry floodproofing** with closures and membranes to keep water from entering
- **Wet floodproofing** which allows water to enter the building with minimal interior damage
- **Floodwalls and levees** to keep floodwaters away from the building envelope

Elevation means raising all or part of the house structure with heavy duty jacks so that the lowest floor is at or above a designated flood protection level. Utilities are disconnected and a new or extended foundation wall, posts, piers or fill is constructed and the house is set on this new foundation. Elevated structures may be above a predicted flood level, but may now be subject to additional wind forces, undermined foundations and earthquake forces.



Fig.I-1 Large house elevated 4' with attractive landscaping (photo by author)

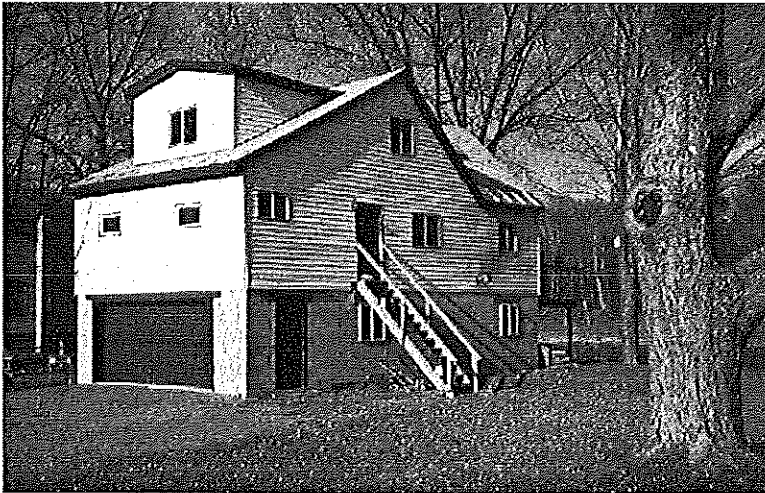


Fig.II-2 This modest house was elevated one full story; floodwaters freely enter and exit (photo by author)

Relocation means moving the house to a location that is less prone to flooding or erosion on another part of the same site or a new site. This is the surest way to reduce the risk of being flooded again but may be too expensive.

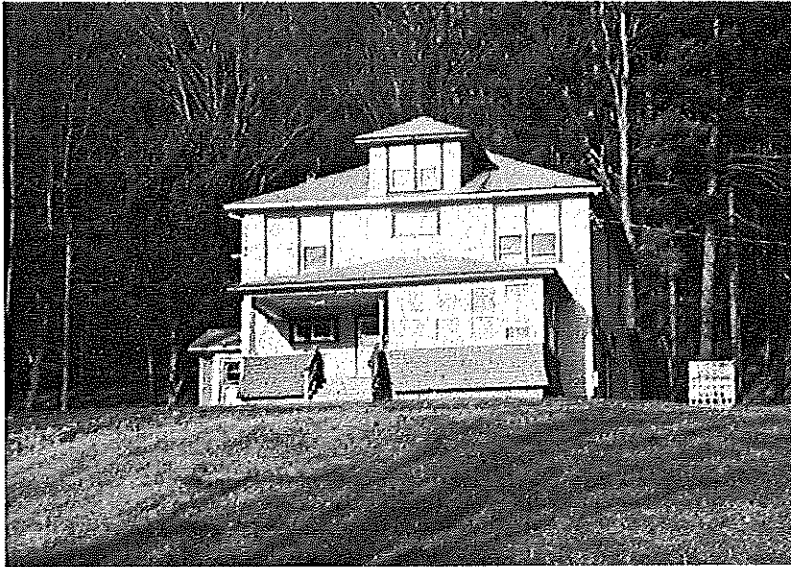


Figure II-3 This 1920's 2-story house was moved to higher ground and remodeled (photo by author)

Dry floodproofing means to seal that part of the building below the flood protection level so that area is watertight. Making the walls, doors and windows impermeable to water penetration using sealant systems, preventing back flow from sewer and drain lines, and closing vents are some methods to help seal the building. These are typically only appropriate where the floodwaters are less than three feet (3') deep because walls may collapse if water is higher than that. This method is not allowed under the National Flood Insurance Program (NFIP) for new or substantially damaged buildings located in a Special Flood Hazard Area.

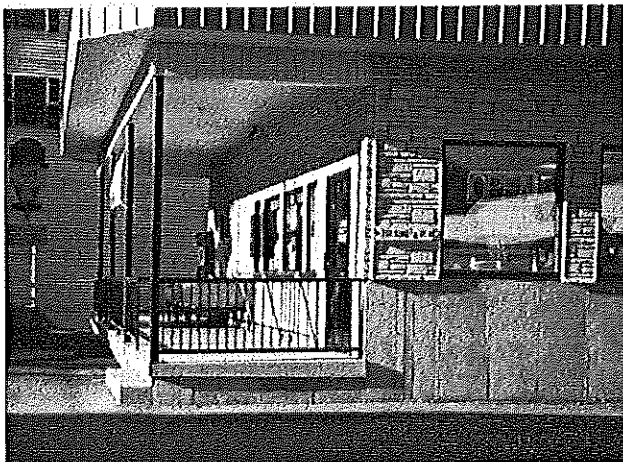
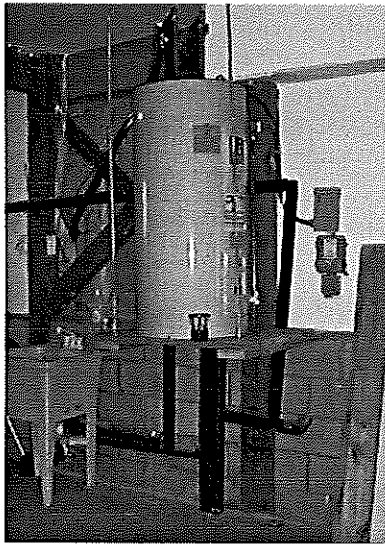


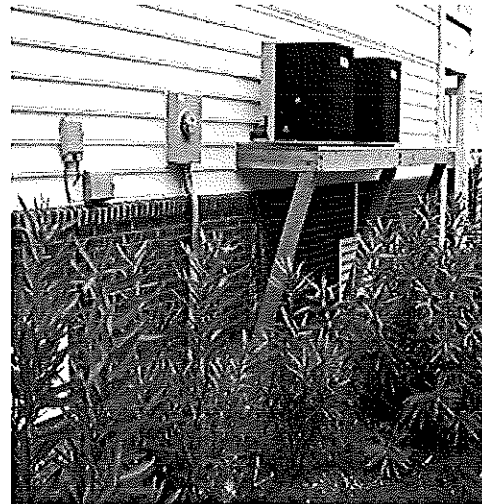
Fig. II-4 Lowest part of exterior walls and the doors form a seal below flood levels (photo by author)

Wet floodproofing is a method which allows water to enter a building, but essential building systems such as furnaces, hot water heaters and electrical panels are relocated or protected and space is available to relocate and store contents. This method may be the least cost flood protection method appropriate for structures with basements or crawl spaces that cannot be protected by other methods. During a flood the occupants usually have to leave the house until floodwaters recede.



Southport, NC. Elevating utilities, such as this hot water heater, on the ground floor or basement of a home often prevents costly replacement of items after a flood or other high water.

Photo By Dave Saville/FEMA News Photo



Southport, NC. Elevated utilities offer protection from flooding and high water.

Photo By Dave Saville/FEMA News Photo

Fig. II-5 and II-6 Elevating utilities above potential flood waters (FEMA, 1999)

Floodwalls and Levees mean constructing barriers between the house and the flooding source. Floodwalls are usually limited to four feet (4') in height and levees six feet (6'). Because of water pressure, costs, access, space and how they look. Zoning codes may restrict their size and location. Levees are typically compacted, impervious earth with 2:1 or 3:1 slopes and floodwaters no more than five feet (5') deep. Sandbags form temporary levees but are time consuming to build and water seepage will occur so pumps are often necessary to remove water seepage. Floodwalls are engineered barriers constructed of masonry or reinforced concrete but the wall foundations are vulnerable to seepage and erosion. A floodwall can surround an entire house or parts of a house and can be integrated with landscaping.



Figure II-7 Sandbagging can keep floodwaters out as a temporary measure (FEMA, 1999)

Substantial Damage/Substantial Improvement

It is important to determine whether or not your house structure has been *substantially* damaged in order to know whether or not the house must be brought up to 'code' and comply with floodplain regulations. This will also affect flood insurance rates. What does all this mean? A definition of substantial damage is "*Damage of any origin sustained by a structure whereby the cost of restoring the structure to its before damaged condition would equal or exceed 50% of the market value of the structure before the damage occurred*" (FEMA, 1998). The owner will need to calculate, usually with the help of a building official and contractor, the costs of damages to see whether or not there is 'substantial' damage.



Princeville, NC: This house -- one of the many buildings that were not strapped to their foundations -- apparently rose with the Hurricane Floyd floodwaters and eventually settled atop the family truck.

Photo by Dave Gatley/FEMA News Photo

Fig. II-8 Substantially damaged house from Hurricane Floyd in North Carolina (FEMA, 1999)

Before any repairs are begun you should ask these questions:

II-2 Questionnaire

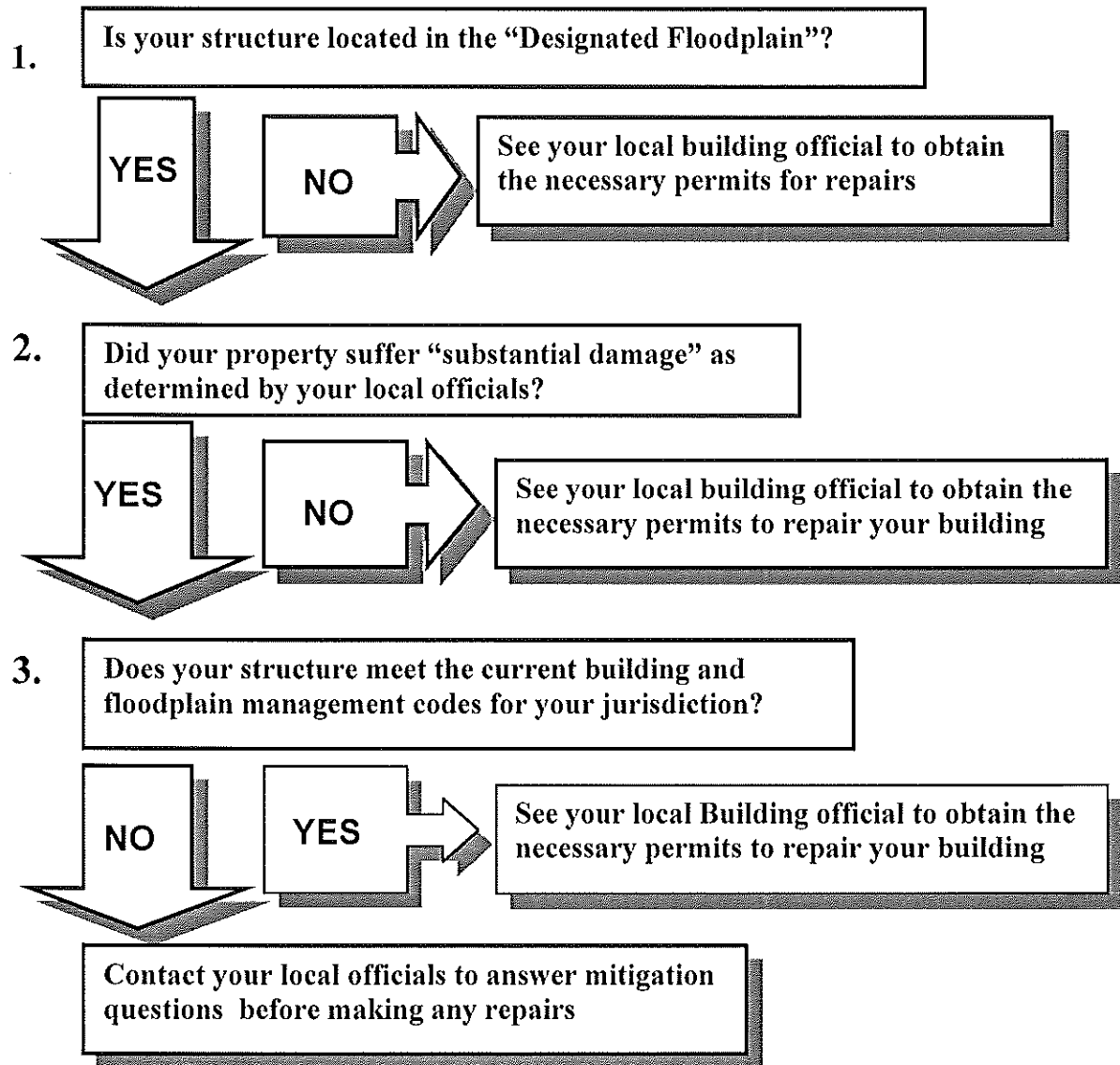
1. Have I called a local building official to inspect my house for damages or has the official been out to inspect my house and issued me an inspection tag?
2. If so, what type/color of tag was issued and do I understand the damage level?
A sample of 'Damage Levels and Conditions' follows: (See your local jurisdiction for the tag you will be issued)
3. Are there visible damages to the foundation walls or piers?
4. Are there visible damages to exterior walls?
5. Are there damages to interior walls and floors? On what levels? _____
 - 5.1 locations of wall, floor, and roof damages:
 - visible cracks
 - settling or buckling of flooring
 - collapse of floor, wall or roof system
 - water penetration through floors and walls
 - deterioration of materials; mold, mildew
 - other visible damages

DAMAGE LEVELS and CONDITIONS: Definitions of Damage Inspection Tags
(FEMA; City of Waverly, Iowa 1999)

Inspection Tag Color	Damage Level	Sample Conditions
WHITE Inspection required before re-entry	Undetermined	Damage Apparent
GREEN Preliminary inspection conducted	Minimum repairs needed	Broken windows and doors, damage to landscaping, porch and deck damage, carpets soaked on first floor, chimney damage, driveway damage
YELLOW Building inspected	Minor repairs needed	Interior floor and wall damage, minor damage to exterior walls, shingles/roofing damaged or missing, small trees fallen on structure
ORANGE Building inspected	Major repairs needed. Apparent damage in excess of 50%. Repairs not authorized until damage extent verified. May be Substantial (50% or more) Damage.	Water above 1st floor, house moved off foundation, walls collapsed, foundation, insulation and/or exterior wall damages. One or more rooms destroyed, exits blocked, utilities damage (furnace, water heater, well, septic system)
RED Building inspected	Substantial Damage. Destroyed; apparent extensive damage. No re-entry allowed	Structure collapsed or leveled, foundation and basement damage, water above the eaves, 2 nd floor missing,

BEFORE YOU BEGIN HOUSE REPAIRS

(Building Department City of Waverly, Iowa. 1999)



Floodproofing Matrix ‘decision’ sheets are shown in the appendix and helpful to decide which floodproofing alternative is possible and best (FEMA 312). Because this document has a focus on elevation the remaining sections will discuss methods and factors in elevating different house sizes and types.

III. Summary of Benefit-Cost Analyses and Elevation Certificate

The decision whether or not to elevate a house is based upon many factors:

1. Is your house in a floodplain or floodprone area?
2. Are you required to elevate by your local officials?
3. Have you ever seen elevated houses?
4. Do you consider elevation as a good idea?
5. Can you financially afford to elevate?
6. Have you applied for financial assistance?

Advantages and Disadvantages of Elevation (FEMA,1998)

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

Doing a 'Benefit-Cost Analyses' is necessary to determine if it pays off to elevate a house. Before doing this calculation, each homeowner needs to decide if elevation is possible. To help decide on the best methods you should complete the checklists in Chapter 4 of *Homeowner's Guide to Retrofitting* (FEMA Publ.312, June 1998).

Step 1: Determine the Hazards to Your House (there may be more than one)

Flood
Wind
Earthquake
Others

Assistance: Floodplain Manager, Local Planning and Building Departments.

Considerations: You need to be aware that an elevated house will be more vulnerable to high winds and earthquakes and new construction needs to take these multi-hazards into account. The foundation may need to be strengthened or replaced and connections between foundation, floors, walls and roofs may need to be increased beyond simply providing flood protection.

Step 2: Inspect Your House

Construction Type and size
Foundation Type
Lowest Floor Elevation
Overall Condition
Other

Assistance: Architect, Engineer, Builder, Certified House Inspector

Considerations: The construction types for most homes are wood frame, with or without masonry veneer; masonry; modular or manufactured home; combinations. Houses can be built on a basement, crawlspace, slab-on-grade, open foundation, or on a combination of these types.

- The most appropriate elevation technique for frame houses is to elevate on extended foundation walls or open foundations, depending upon location.
- For masonry house, either 1) extend the walls of the house upward and raise the lowest floor, or 2) abandon the lowest floor and move the living area to the upper floor with access by stairways. The lowest, flood-prone floor will have to have 'break away openings to allow floodwater to freely enter and exit.
- Slab-on-grade houses are more difficult to elevate than houses on basement or crawlspace foundations.
- Houses with basements usually have furnaces, hot water heaters and other utilities in the basement which need to be elevated or relocated.
- Houses with basements that elevate may need an engineering study to establish the safety of keeping the basement, due to exterior water pressures that may cause the walls to collapse.
- The difference between the Flood Protection Level (FPE) and the lowest floor elevation determine the distance the house has to be elevated. It is critical to know which floor is the 'lowest'. The lowest floor could be a basement, the floor of an attached garage, or the first level 'finished living room'. It may be necessary to get an official survey that will cost several hundred dollars. Assistance from a local building official will help determine. If your house has been substantially damaged or being substantially improved your FPE

must be at least equal to the Base Flood Elevation (BFE) on the flood maps. Consult with your public officials.

- Before any retrofitting work is started you will need a detailed inspection, including your notes on the extent of any previous damages and repairs. A contractor or design professional should conduct this inspection.

Step 3: Check with Your Local Officials

Hazards

Regulations and Codes

Technical Guidance

Financial Assistance

Assistance: Local Planning and Building Departments

Considerations: Officials will have copies of the Flood Insurance Study (FIS) and Flood Insurance rate Map (FIRM) published by FEMA. Other information, such as flood flow velocity, may be necessary to determine the best structural system for elevating. They will help you determine if elevation is allowed and if Federal, State and local financial assistance is available. Use the guide in FEMA #312 when you meet with local officials.

Step 4: Consult a Design Professional and a Contractor

Qualifications

Site Inspection

Cost estimate

Design

Schedule

Assistance: Architects, engineers, licensed building contractors

Considerations: You need to determine what types of services are necessary for your elevation project and how to evaluate and select design professionals and contractors. Beware of special deals, unknown contractors, pressure to sign a contract, asked to pay cash or a large up-front deposit. Check with the Better Business Bureau, State licensing authorities, FEMA, State and local emergency managers and other reliable references for licensed contractors and licensed design professionals. Get the list of requirements for selecting the right contractor from FEMA #312.

- Normal Services of a design professional are to evaluate the condition, strength and stability of the foundation to see whether it can support increased loads and resist any wind or earthquake loads; designing the new or improved foundation system
- Normal services of a house elevation contractor, together with electrical and plumbing sub-contractors are to disconnect utilities, jack up the house, increase the foundation height, re-connect utilities.

Table III-1 Here is a guide of work items and expenses for elevation:(COE, 1995)

Work item	Equipment		Labor		Materials		\$ Total
	qty	\$	qty	\$	qty	\$	
1. Coordinate work with other public agencies and utility companies.							
2. Obtain permit(s)							
3. Inventory and inspect premises before and after job							
4. Insurance							
5. Security							
6. Warranty							
7. Disconnect and restore utilities: gas, water, electric, sewer, etc.							
8. Elevate house: placement of beams, cribbing, jacking, etc.							
9. Elevate central heating and A/C and associated equipment (ducts, condenser)							
10. Elevate deck							
11. Lengthen downspouts							
12. Brickwork? Remove and dispose existing brick, add new brick, etc.							
13. Prepare and augment foundation to support house at new elevation: add courses of block,, new vents, new access door, new foundation piers, etc.							
14. Augment steps, porches, stoops, etc. to restore full accessibility.							
15. Insulate under-house pipes against freezing if necessary, due to more open foundation.							
16. Lodging for occupants as premises are vacated.							
17. Restore landscaping and clean-up: seeding, grading, ..							
18. Additional landscaping							
19. Replacement and reinforcement of flooring members before raising house							
20. Other (specify)							
21. profit							

TOTAL \$ _____ (with Company name and Signatures)

What is an Elevation Certificate?

If your home is located in a community participating in the National Flood Insurance Program (NFIP), this means you can buy flood insurance and some lending institutions require this as part of a home mortgage. This insurance is not the same as a regular 'homeowners policy'. If there is a local floodplain ordinance in effect, and to ensure compliance with this ordinance, you may need to complete a two-page NFIP *Elevation Certificate*. This certificate is required for 'post-FIRM' buildings constructed after the publication date of the Flood Insurance Rate Map (FIRM) for your community. The *Elevation Certificate* is not required for 'pre-FIRM' buildings unless your house is being rated under 'post-FIRM' insurance rules.

The *Elevation Certificate* provides elevation information necessary for:

- compliance with local floodplain ordinances
- determination the proper flood insurance premium rate
- request for a Letter of Map Amendment

The *Elevation Certificate* form is to be completed by you and a community official or land surveyor, engineer or architect who is authorized to certify elevation information. This depends upon what 'flood zone' your house is located so you need to meet with your local floodplain manager or building official to determine which Zone. A full description of the *Elevation Certificate* is in the instructions; here is an outline of the instructions for Elevation Certificate FEMA Form 81-31 (August 1999):

- Section A- Property Owner Information
- Section B- Flood Insurance rate Map Information
- Section C- Building Elevation Information; Survey Required
- Section D- Surveyor, Engineer, or Architect Certification
- Section E- Building Elevation Information-Survey Not Required
- Section F- Property Owner Certification
- Section G- Community Information (optional)

Benefit-Cost Analyses

Because this document assumes the best choice for floodproofing your home is to elevate the building, this section describes only in general terms the 'benefit-cost analyses'.

Steps of a 'benefit-cost analyses' include: (FEMA 259, 1995)

1. evaluating the hazards
 - estimating expected frequency and severity of flooding
2. estimating the costs of potential (future) damages if no actions are taken
 - estimate damages as a function of flood depth and previous data
3. identifying costs associated with (elevation) alternatives
 - each retrofit measure is assigned costs for construction, engineering/architectural fees, temporary living expenses, loss of income, etc. (see table)
4. estimating benefits for each (elevation) alternative
 - probable costs based upon data from previous floods or hypothetical floods of different intensities

5. computing benefit/cost ratio and net present value
 - computing a benefit-cost ratio where the benefits, over time, are greater than the costs to retrofit (elevate) the house
7. selecting the best (elevation) method
 - comparing the alternative methods to elevate a house and ranking them demonstrates which alternative is best, based upon benefit-cost, however, an alternative that costs less to build may not be the best one! Other technical, economic or subjective factors can influence your decision. For example, It may be better to relocate the home rather than elevate, even if elevation is less costly.

FEMA has a computer program to calculate benefit-costs and use of this program will assist the homeowner (FEMA 259, January 1995). To obtain a copy of the Flood Insurance Study (FIS) for your community, call FEMA at 1-800-358-9616. The Flood Insurance Administration has also published a guide *FIA Depth-Damage Data Table* to help estimate potential damages, by % of replacement value. For example, if flood depth of a \$60,000 1-story house without a basement house is 2 feet, estimated damages are 22% of \$60,000 or \$13,200 to the house structure, not including contents.

Flood Insurance Administration (FIA) Depth-Building Damage Data

Flood Depth	Building Damage Percent by Building Type (based upon replacement value)					
	1 Story without Basement	2 Story without Basement	Split Level without Basement	1 or 2 Story with Basement	Split Level with Basement	Mobile Home
-2	0	0	0	4	3	0
-1	0	0	0	8	5	0
0	9	5	3	11	6	8
1	14	9	9	15	16	44
2	22	13	13	20	19	63
3	27	18	25	23	22	73
4	29	20	27	28	27	78
5	30	22	28	33	32	80
6	40	24	33	38	35	81
7	43	26	34	44	36	82
8	44	29	41	49	44	82
9	45	33	43	51	48	82
10	46	38	45	53	50	82
11	47	38	46	55	52	82
12	48	38	47	57	54	82
13	49	38	47	59	56	82
14	50	38	47	60	58	82
15	50	38	47	60	58	82
16	50	38	47	60	58	82
17	50	38	47	60	58	82
18	50	38	47	60	58	82

Figure V-5: FIA Depth-Damage Data Table

Table III-2 Flood Insurance Administration "Depth-Damage" data estimates (FEMA, 1988)

The estimates above are for each flooding event. Flood frequency must be determined to calculate multiple flooding events or "avoided losses".

Selecting the best method of elevation

If the benefit-cost analysis proves elevating the house is cost effective, we must decide which elevation technique to use and how high to elevate. This means conducting a second analysis with additional factors:

- Present worth of benefits:
Dollar value of annual damages avoided by elevating, least cost method
- Total project costs for each elevation method
Construction costs and the owner's budget, including financial assistance
- Review of benefit-cost ratios for each elevation alternative
- Technical Feasibility
Project objectives need to be stated. For example, elevating the house four (4') may meet the objectives to raise the first floor above the flood hazard or base flood elevation (BFE) but raising it 8' may allow for under-floor temporary storage, parking or other uses that comply with the floodplain ordinance. Raising it higher will increase the cost but improve the function.
- Aesthetics
Elevating a house means the addition of stairs and other elements to the interior and exterior of the elevated house to make it function and provide an appearance the owner desires. This will take designing the elements, such as interior and exterior stairways, to function and be pleasing. Some of these elements will be shown in Section VI "case Studies.
- Human intervention requirements and annual maintenance
Elevating the house means that some elements need to be operated during times of probable flooding: stairways kept clear; storage, cars and other items in the flood prone level below the elevated living floors need to be temporarily moved; occupants may need to be evacuated from a flooded site for some time with limited access while flood waters stay high; utilities need servicing in the event occupants are away; electrical panel boxes need to be shut off; refrigerators and furnaces may be without power during any weather condition freezing weather without heat means water lines may have to be drained.

The homeowner should consult with a architect or engineer to decide the best elevation alternative. In FEMA Publ. 259 there is a 'Preference Ranking Worksheet' useful for this process and in adding up the detailed costs for each alternative. It will be necessary to have construction estimates prepared by house moving/raising contractors. Because there is a tendency to inflate costs during periods of greatest construction activity, owners need to have at least two (2) estimates from licensed, reputable contractors.

Let's look at some rough cost estimates (FEMA 1998): (Case studies in section VI show real costs).

COST OF ELEVATING A HOUSE 2 FEET

CONSTRUCTION TYPE	EXISTING FOUNDATION	RETROFIT	COST (per square foot of house footprint)
FRAME (For frame house with brick veneer on walls, add 10 percent)	Basement or Crawlspace	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation	\$17
	Slab-on-Grade	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation ¹	\$47 ¹
MASONRY	Slab-on-Grade	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation	\$47 ¹
	Basement, Crawlspace, or Slab-on-Grade	Extend Existing Walls 2 Feet and Create New Elevated Living Area	\$35

¹ Price shown is for raising the house with the slab attached.

Table III-3 Approximate costs to elevate a house (FEMA #312, 1998)

A sample cost estimate (1998 averages and need to be adjusted for local conditions)

House size: 1500 square feet
House structure: Wood frame, brick veneer over crawl space
Foundation wall: Old: continuous masonry; new addition, continuous masonry
Raise the house: 8 feet or 4 feet

Using the table above, let's calculate raising the house 8 feet.

Cost of elevating two 2 feet \$17.00 per s.f. x 1500 s.f. = \$25,500
Cost of elevating additional 6 feet = 6 x \$0.75 x \$1500 s.f. = \$ 6,750

TOTAL = \$32,250 + 10% for brick veneer =
\$32,250 + \$3225 = **\$35,475** or \$ 23.65 per s.f. of house footprint

Comparing future 'avoided' damages to the cost to elevate 8 feet gives a rough idea of 'benefit cost'. For example, if the above 1500 s.f. house has a pre-flood market value of \$80,000 and flooded 4 feet above the 1st floor during each flood, with the base flood elevation (BFE) at 3 feet above the first floor:

Potential damages of 28%/flood (table III-2) x \$80,000 = \$22,400 damages each flood
Three future flooding events @5 years between floods x \$22,400= \$67,200/15 years.

The \$35,475 cost to elevate this house is more than \$22,400 potential damage for one flood, but only 52% of damage costs for three floods. With three or more future flood probabilities, the calculation clearly indicates it is cost-effective to elevate, perhaps not the full 8 feet, but at least 1 foot above the BFE. The cost to elevate 4 feet is \$30,525 but does not provide lower level storage and/or parking space. Savings not mentioned are lower flood insurance premiums by elevating the house, plus away from home living expenses due to the occupants having to evacuate their home for a period of time.

III. Basic Construction and Foundation Systems

Much of the decision about *whether* and *how* to elevate a house, providing it is looks cost effective, has to do with the house value, size, construction and foundation systems. The bearing capacities of the original foundation and soils must also be taken into account with engineering services.

Below are diagrams of construction and foundation types, followed by several methods to elevate a house.

Common construction types: (also may be in combinations of several types)

- frame: walls constructed of wood or light gage metal studs, with wood or other siding
- masonry veneer: frame walls with non-structural exterior layer of brick, stone, etc.
- masonry: walls constructed of load bearing brick or concrete block
- modular home: frame home constructed on site from pre-made sections
- manufactured home; prefabricated frame house on a transportable frame

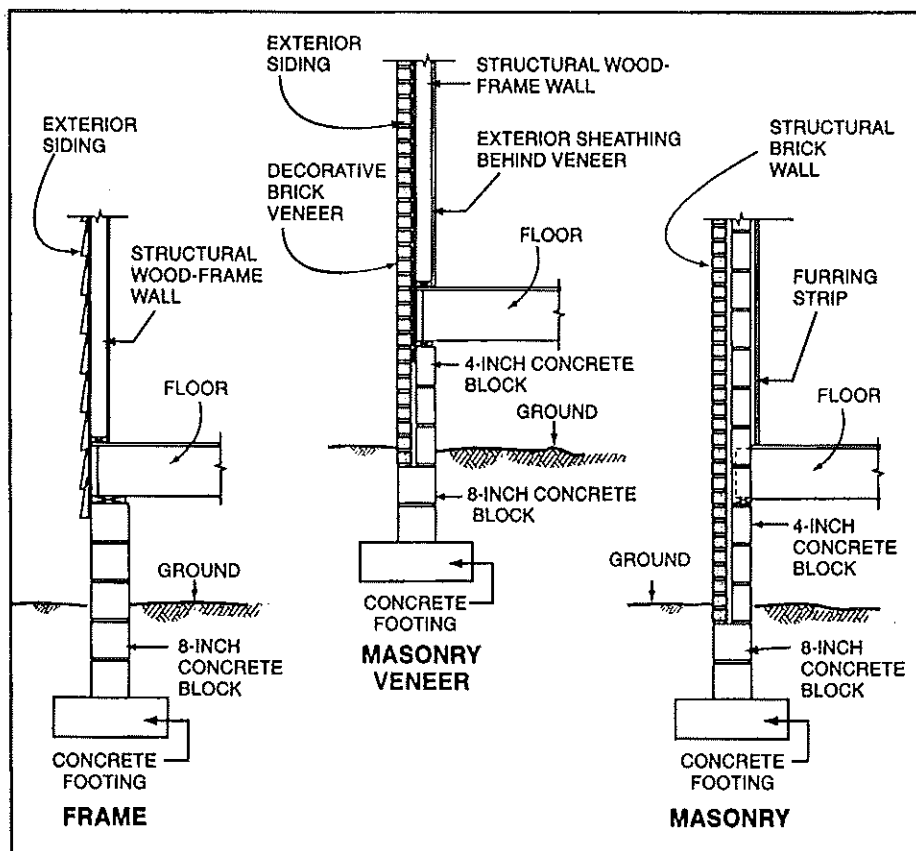


figure IV-1 Three common construction types, all with masonry foundations and concrete footings. The same types are found with basement and slab-on grade foundations. (FEMA, 1998)

Most houses are built on the following types of foundations (FEMA, 1998)

- **basement:** with masonry (concrete block, clay tile, or cast-in-place concrete walls)
- **crawlspace:** masonry or cast-in-place concrete perimeter walls, interior piers
- **slab-on-grade:** either a thickened slab or slab with masonry or concrete foundation
- **open foundation:** concrete or masonry piers or posts; wood pilings

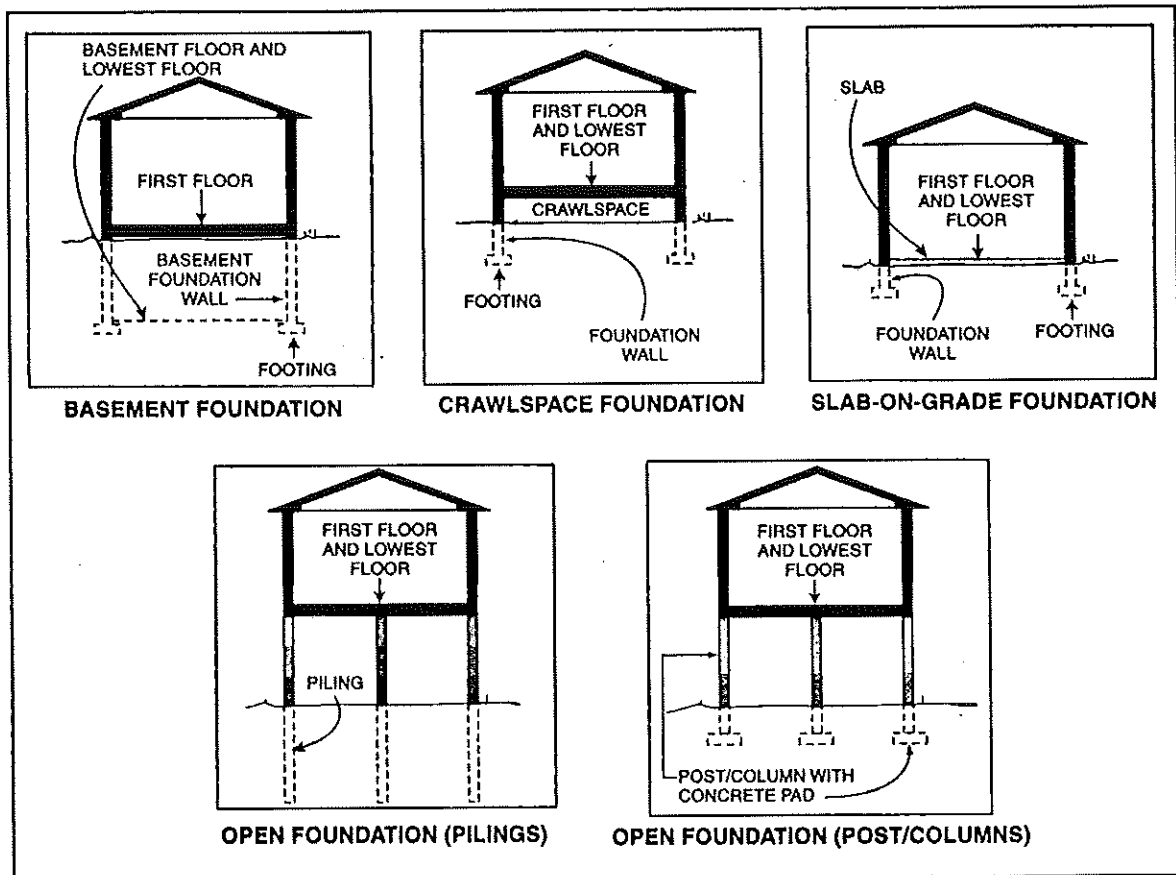


figure IV-2 Basic residential foundation systems (FEMA 1988)

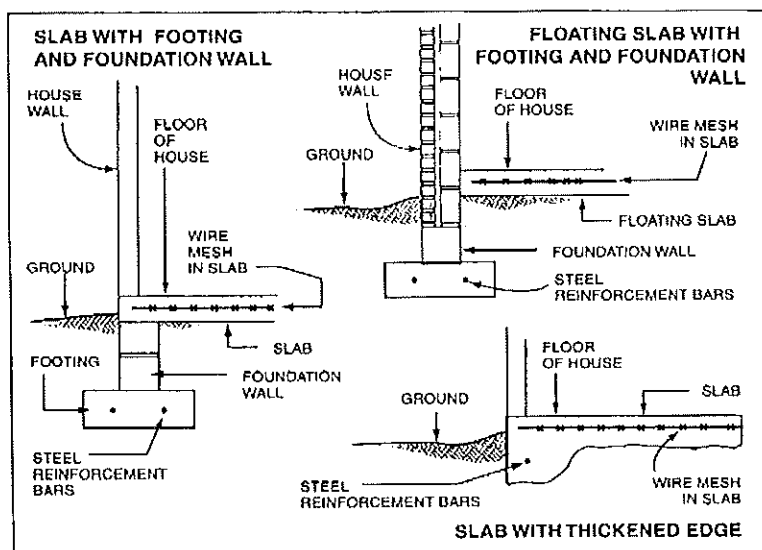
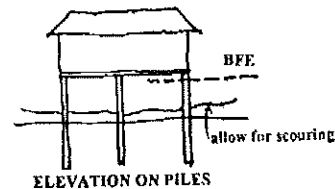
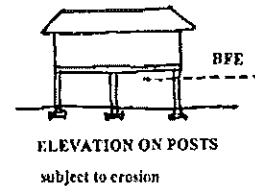
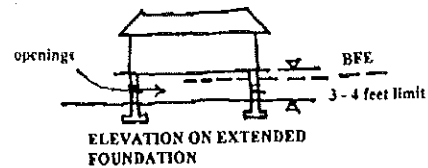
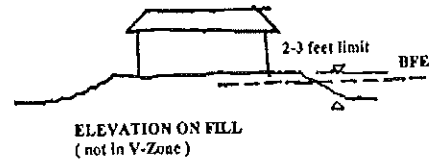


figure IV-3 Slab foundation systems (FEMA 1988)

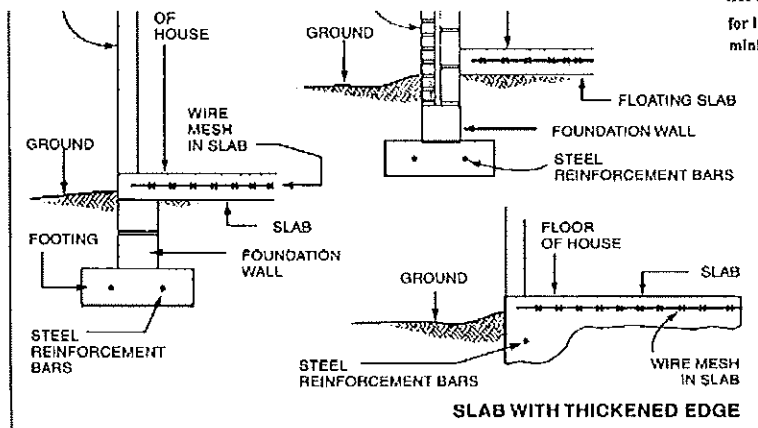
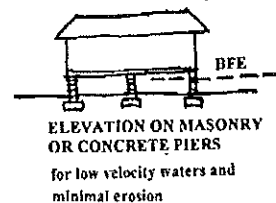
Elevation Strategies (AIA, 1995)

This section will summarize different elevation strategies. Selection of the best one to use depends upon many factors: original building construction system and quality, soil and hydrological data, local building codes, and cost.



ELEVATION on MASONRY or CONCRETE PIERS
Suitable in areas away from a river or coastline where flood waters move with low velocity. Built from concrete block, poured in place concrete, or bricks.

—
BT
AN



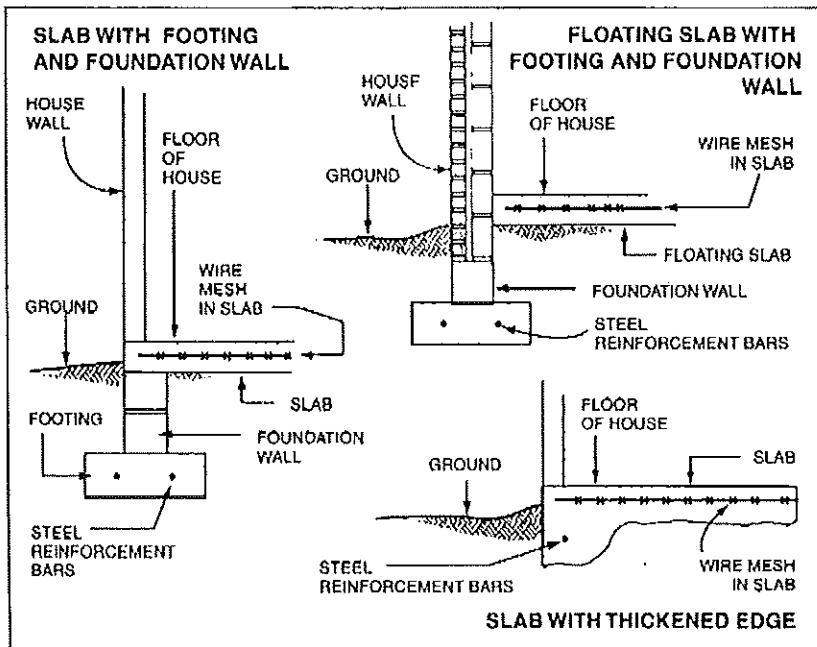
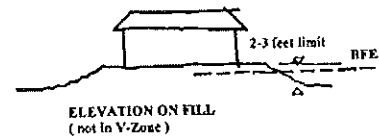
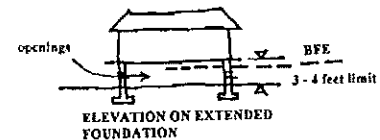


Figure IV-3 Slab Foundation Systems (FEMA 1998)

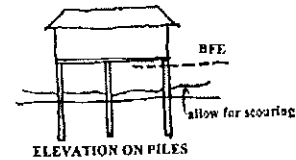
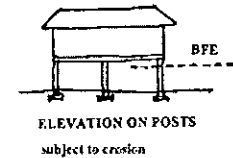
ELEVATION ON FILL-Economical for 2-3 feet, not permitted in coastal zones due to wave action, generally not allowed in floodways or flood zones unless there will be no increase in flood elevation.



ELEVATION ON EXTENDED FOUNDATION WALLS- A common method, usually cannot extend more than 4 feet above grade; need openings in foundation walls to equalize water pressure. Higher walls will allow for a new living area over an abandoned first floor.



ELEVATION ON POSTS AND PILES- Wood, concrete or steel posts in pre-dug holes or piles driven into the ground. Driven piles are stronger than posts in coastal and high-velocity zones and may need cross-bracing. Steel piles will corrode in coastal zones.



ELEVATION ON PIERS- Made from concrete blocks, poured in place concrete, and brick. Suitable in areas with low velocity and minimal erosion- not suitable in coastal areas.

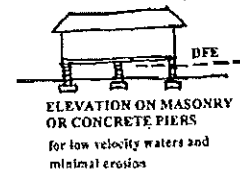


Figure IV-4 Elevation Strategies (AIA 1995)

The next pages show two charts to help decide which elevation methods are best, depending upon if the home has been 1) substantially damaged / substantially improved or 2) NOT substantially damaged or substantially improved (see Section ..)

1st Condition: Substantial Damage / Substantial Improvement (FEMA 1988)

The National Flood Insurance Program limits your choice based upon the location and flooding characteristics. Cost factors, local regulations, laws and codes may further restrict your choice.

2nd Condition: NO Substantial Damage / NO Substantial Improvement

The National Flood Insurance Program regulations do not prohibit the use of any of the methods, however, local laws, codes and ordinances may. A short description of each factor:

Federal, State, Local Restrictions: building codes, zoning and floodplain ordinances, deed restrictions, historic building regulations, covenants

Appearance: Elevating a house 1 or 2 feet will make little difference but higher on walls or piers and adding stairways and other elements will. Consult with a design professional and local contractors and building officials.

Cost: Height and type of elevation methods will affect cost in terms of labor and materials. Elevating a frame house without masonry is less expensive than one with masonry. The foundation type is important to evaluate: elevating a slab on grade is more expensive than elevating a wood floor over a crawl space.

Accessibility: How easy is it to reach and enter the house after retrofitting the house? Interior or exterior stairs required to access an elevated house may be unacceptable.

Code-required Upgrades: regulations may require an elevated house to meet new standards for plumbing, heating/ventilating/air conditioning and electrical panel boxes. New energy efficiency standards may have to be met. Upgrades will add to the cost but also improve the property value.

Human Intervention: Homeowners need adequate warning of a coming flood and be prepared to take action before flood waters arrive. For example, closing drains with manual back flow (gate)valves, operating a closure mechanism for a wall opening, and moving temporary storage and vehicles away from flood risk areas.

Other: Homeowners must consider if financial assistance is available from local, State or Federal sources; the time required to complete the project while living away from the house; The current value of the house vs. cost to retrofit, using the benefit-cost analysis.

The first step with either matrix on the next page is to mark an “X” in the box labeled ‘Prohibited...’ for methods not acceptable or that do not meet your needs. The next step is to evaluate the remaining methods (those without an “X” under their names). Discuss your concerns with local officials, design professional and contractors. Total up the “X’s” and the methods with the least Total “X’s” is the best choice.

1) RETROFITTING METHODS FOR**Condition: Substantially Damaged / Substantially Improved Houses (FEMA 1988)**

EVALUATION FACTORS	ELEVATION ON EXTENDED FOUNDATION WALLS	ELEVATION ON OPEN FOUNDATION: PIERS, POSTS, PILES	NEW LIVING AREA OVER ABANDONED FIRST FLOOR
Prohibited by Federal, State or Local regulations or Eliminated by Homeowner			
Appearance			
Cost			
Accessibility			
Code-required upgrades			
Human Intervention			
Other			
TOTAL X'S			

2) RETROFITTING METHODS FOR:**Condition: NO Substantial Damage or Substantial Improvement (FEMA 1988)**

EVALUATION FACTORS	ELEVATION ON EXTENDED FOUNDATION WALLS	ELEVATION ON OPEN FOUNDATION: PIERS, POSTS, PILES	NEW LIVING AREA OVER ABANDONED FIRST FLOOR
Prohibited by Federal, State or Local regulations or Eliminated by Homeowner			
Appearance			
Cost			
Accessibility			
Code-required upgrades			
Human Intervention			
Other			
TOTAL X'S			

Elevation Design Process

After all the approvals and regulations are met, elevating a house structure can be a complicated process. The existing building needs to have a good engineering study so soils and new foundations and connections will structurally support the changes. The table below provides general guidance about the steps in elevating a house.

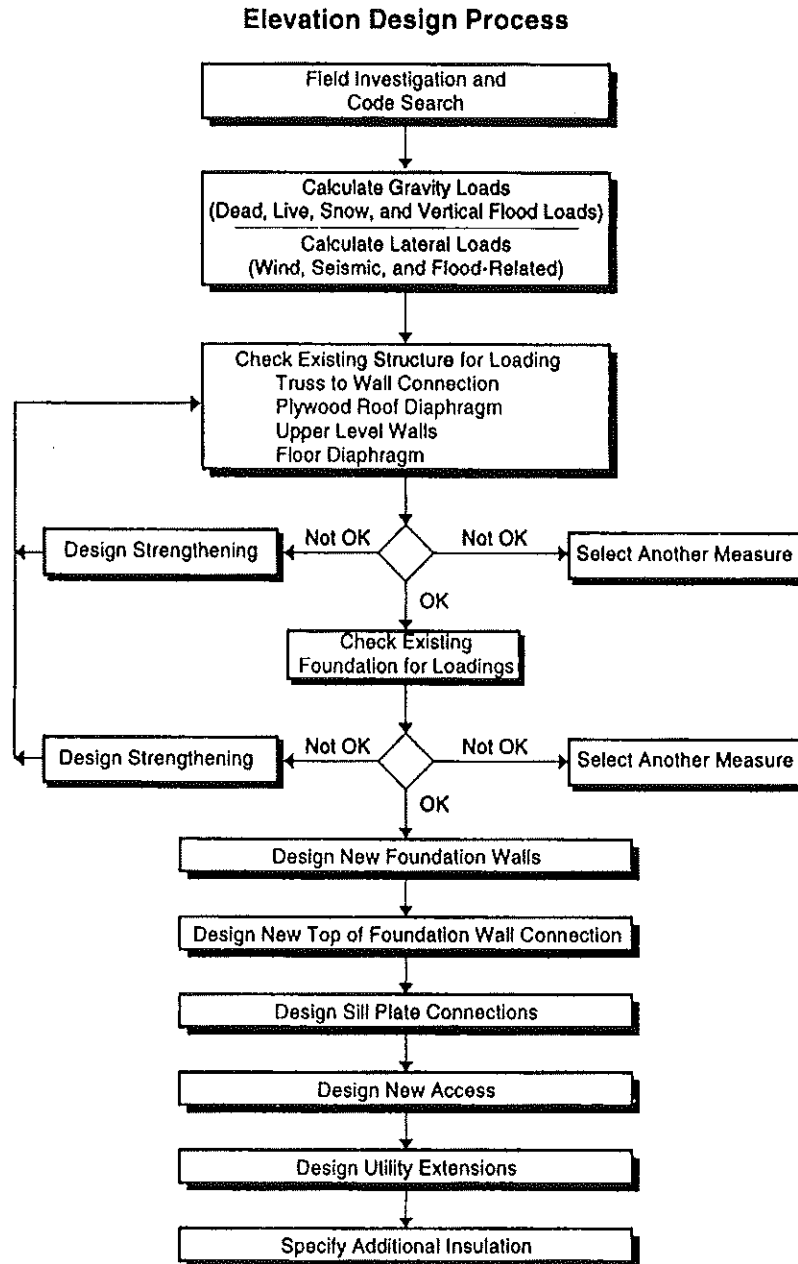


Table V-1 Design and construction steps to elevate a house. For an elevation sample house calculation, see Chapter VI in FEMA Publ. 259. (FEMA 1995)

Elevation Techniques for Various Residential Building Types

Examples 1-4 below describe basic elevation construction steps.

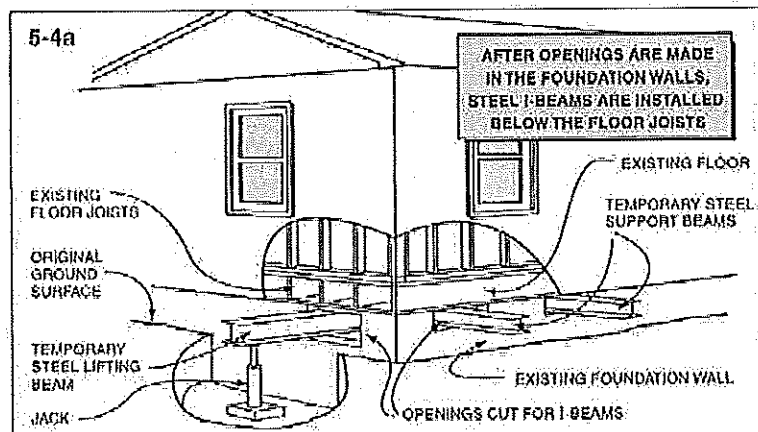
1. 1-2 story wood frame house over a basement or crawl space



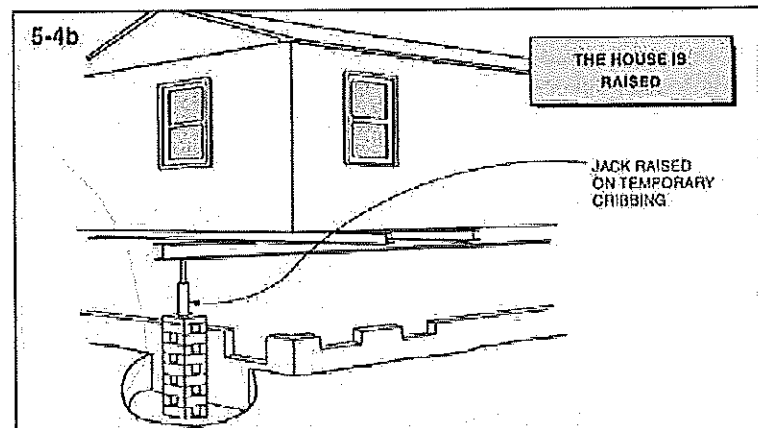
Figure V-1 Elevated houses over basements. Note new stairways and openings in foundation walls (author)

- Construction steps:
1. Turn off utilities and disconnect lines
 2. Excavate around foundation, strengthen as necessary
 3. Cut holes in original foundation walls, install lifting beams
 4. Raise house with jacks
 5. Extend foundation walls to desired height, install wall openings
 6. Lower house on new foundation, reconnect utility lines

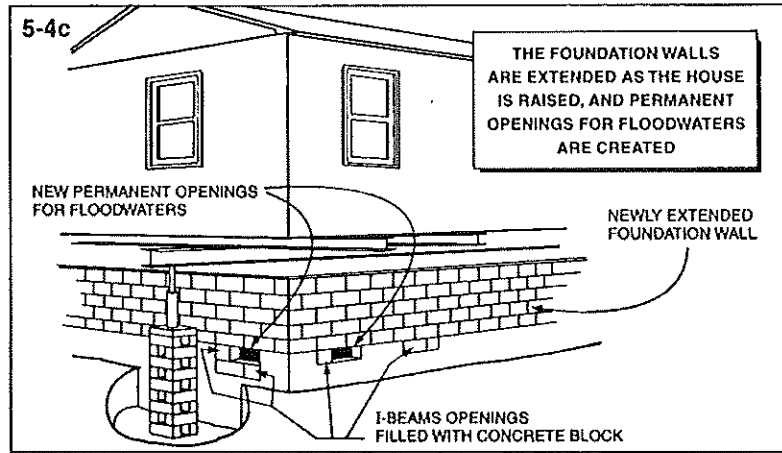
Steps 1, 2, 3
Prepare to lift house



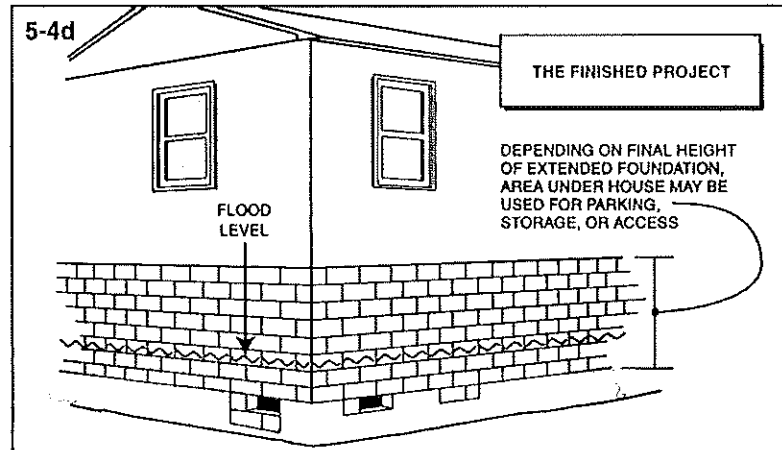
Step 4
Raise house with jacks



Step 5
Extend foundation walls
with openings for flood
waters



Step 6
Lower house onto
foundation and
reconnect utilities



2. House elevated on fill is similar to elevating house over crawl space



Figure V-2 House with basement elevated on fill (photo by author)

- Construction steps:
1. Turn off utilities and disconnect lines
 2. Excavate around original foundation
 3. Cut holes in foundation, install lifting beams
 4. Raise house with hydraulic jacks
 5. Fill materials brought to desired elevation
 6. Construct new foundation, lower level slab and walls
 7. Lower house on new foundation, reconnect utilities

3. Elevating Slab-on Grade Houses

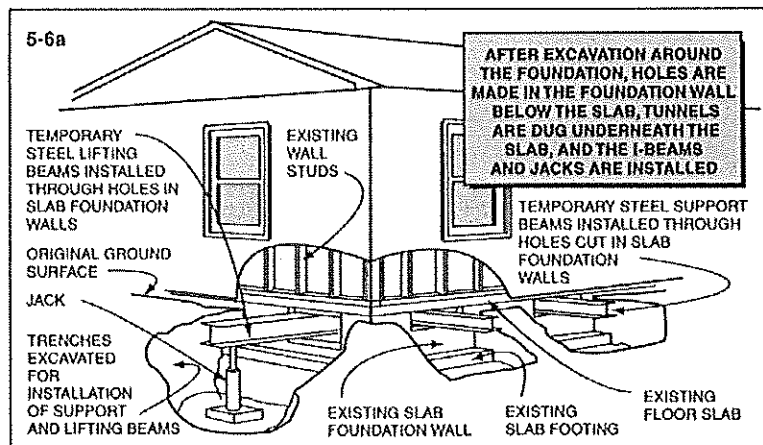
3.a Raising a slab-on-grade house with slab intact



Figure V-4 House raised and moved with slab intact over new masonry foundation (USCOE, 1990)

- Construction steps:
1. Turn off utilities and disconnect lines
 2. Dig trenches around foundation and tunnel under slab
 3. Install lifting beams and jacks below slab
 4. Raise house with jacks, slab attached
 5. Construct new foundation walls, interior piers, stairways
 6. Lower house on new foundation, reconnect utilities

Steps 1, 2, 3 Turn off utilities, excavate and tunnel under foundation for lifting beams and jacks



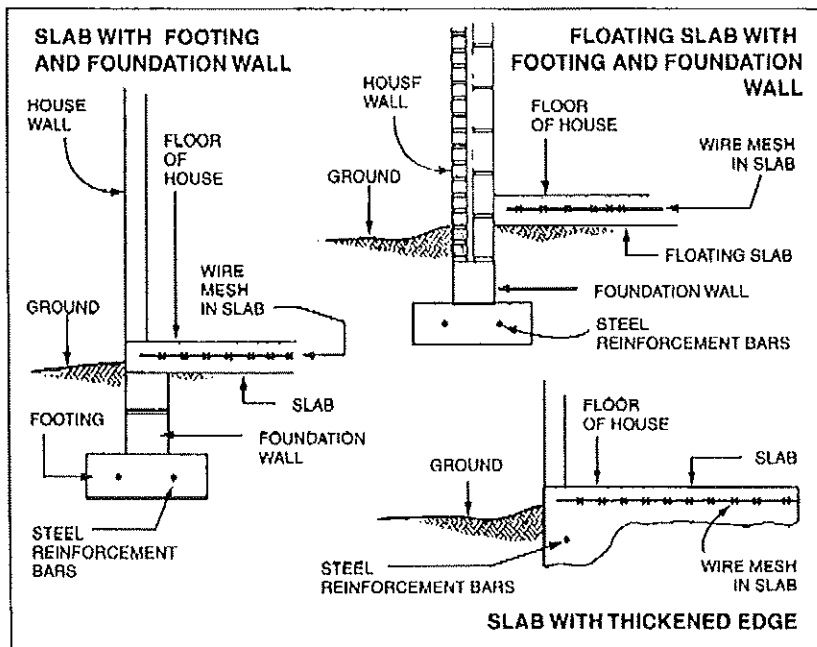
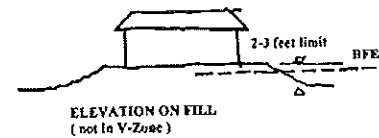
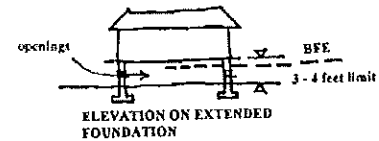


Figure IV-3 Slab Foundation Systems (FEMA 1998)

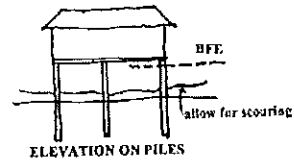
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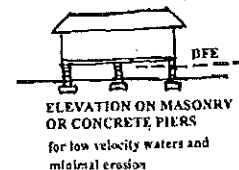


Figure IV-4 Elevation Strategies (AIA 1995)

The next pages show two charts to help decide which elevation methods are best, depending upon if the home has been 1) substantially damaged / substantially improved or 2) NOT substantially damaged or substantially improved (see Section ..)

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Human Intervention: Homeowners need adequate warning of a coming flood and be prepared to take action before flood waters arrive. For example, closing drains with manual back flow (gate)valves, operating a closure mechanism for a wall opening, and moving temporary storage and vehicles away from flood risk areas.

Other: Homeowners must consider if financial assistance is available from local, State or Federal sources; the time required to complete the project while living away from the house; The current value of the house vs. cost to retrofit, using the benefit-cost analysis.

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1) RETROFITTING METHODS FOR

Condition: Substantially Damaged / Substantially Improved Houses (FEMA 1988)

EVALUATION FACTORS	ELEVATION ON EXTENDED FOUNDATION WALLS	ELEVATION ON OPEN FOUNDATION: PIERS, POSTS, PILES	NEW LIVING AREA OVER ABANDONED FIRST FLOOR
Prohibited by Federal, State or Local regulations or Eliminated by Homeowner			
Appearance			
Cost			
Accessibility			
Code-required upgrades			
Human Intervention			
Other			
TOTAL X'S			

2) RETROFITTING METHODS FOR:

Condition: NO Substantial Damage or Substantial Improvement (FEMA 1988)

EVALUATION FACTORS	ELEVATION ON EXTENDED FOUNDATION WALLS	ELEVATION ON OPEN FOUNDATION: PIERS, POSTS, PILES	NEW LIVING AREA OVER ABANDONED FIRST FLOOR
Prohibited by Federal, State or Local regulations or Eliminated by Homeowner			
Appearance			
Cost			
Accessibility			
Code-required upgrades			
Human Intervention			
Other			
TOTAL X'S			

Elevation Design Process

After all the approvals and regulations are met, elevating a house structure can be a complicated process. The existing building needs to have a good engineering study so soils and new foundations and connections will structurally support the changes. The table below provides general guidance about the steps in elevating a house.

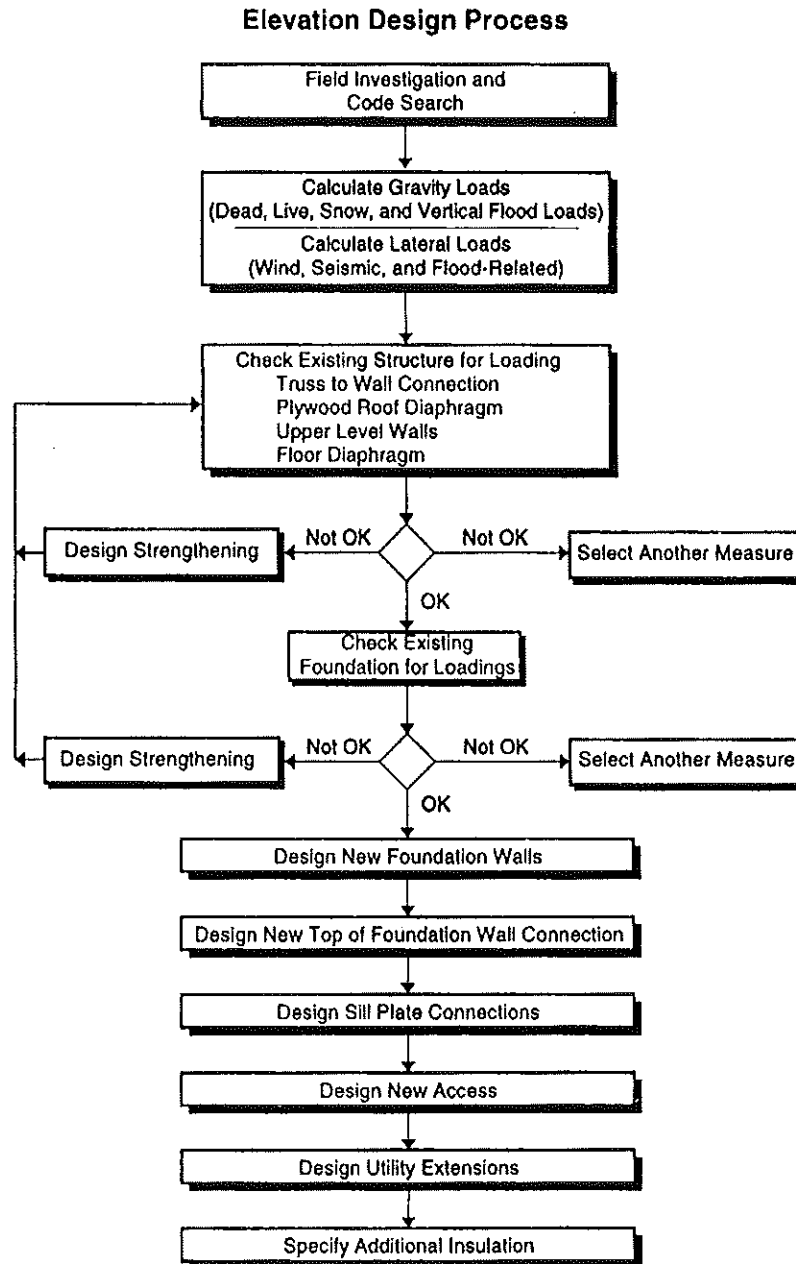


Table V-1 Design and construction steps to elevate a house. For an elevation sample house calculation, see Chapter VI in FEMA Publ. 259. (FEMA 1995)

Elevation Techniques for Various Residential Building Types

Examples 1-4 below describe basic elevation construction steps.

1. 1-2 story wood frame house over a basement or crawl space

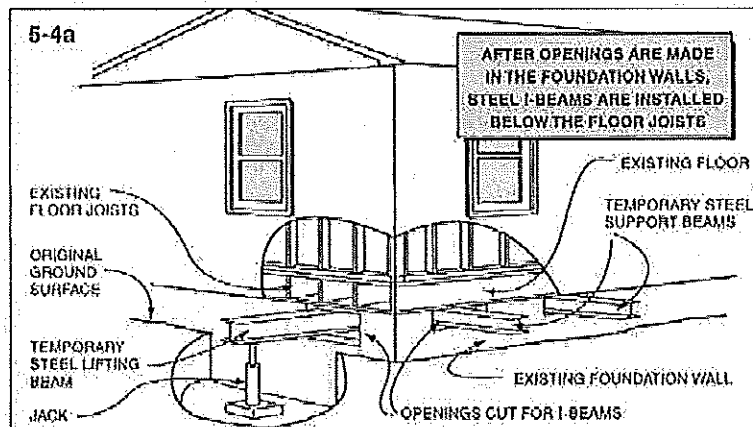


Figure V-1 Elevated houses over basements. Note new stairways and openings in foundation walls (author)

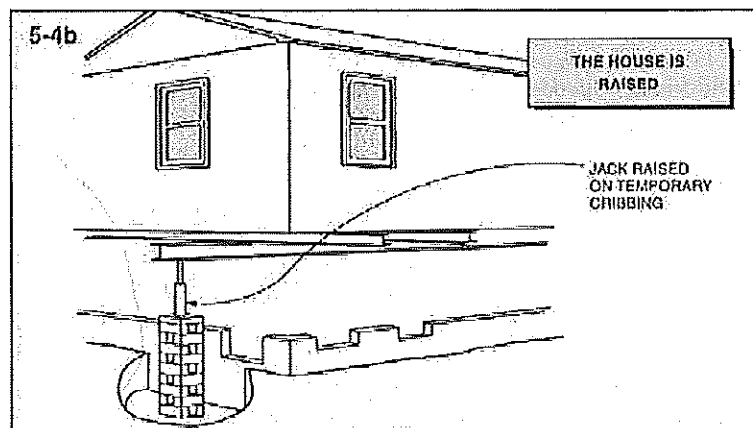
Construction steps:

1. Turn off utilities and disconnect lines
2. Excavate around foundation, strengthen as necessary
3. Cut holes in original foundation walls, install lifting beams
4. Raise house with jacks
5. Extend foundation walls to desired height, install wall openings
6. Lower house on new foundation, reconnect utility lines

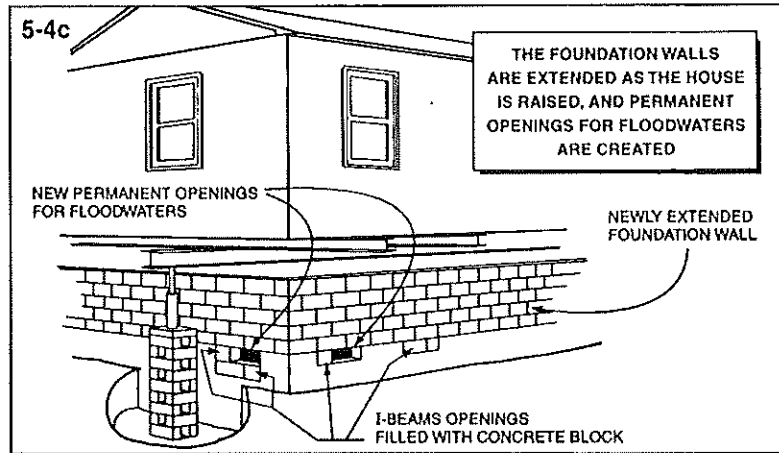
Steps 1, 2, 3
Prepare to lift house



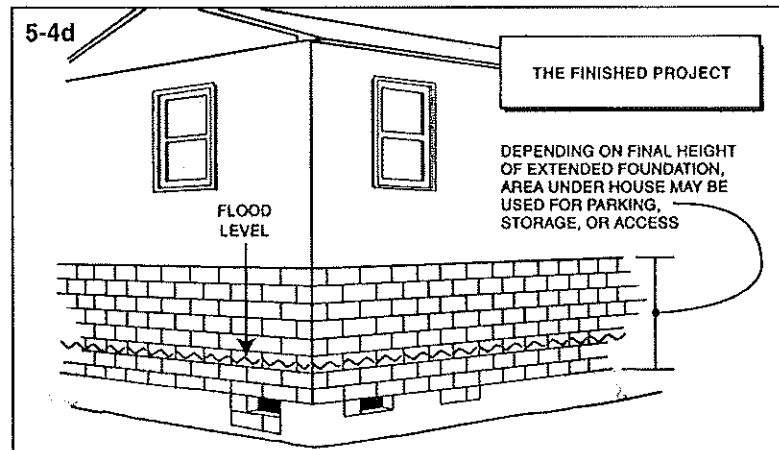
Step 4
Raise house with jacks



Step 5
Extend foundation walls
with openings for flood
waters



Step 6
Lower house onto
foundation and
reconnect utilities



2. House elevated on fill is similar to elevating house over crawl space



Figure V-2 House with basement elevated on fill (photo by author)

- Construction steps:
1. Turn off utilities and disconnect lines
 2. Excavate around original foundation
 3. Cut holes in foundation, install lifting beams
 4. Raise house with hydraulic jacks
 5. Fill materials brought to desired elevation
 6. Construct new foundation, lower level slab and walls
 7. Lower house on new foundation, reconnect utilities

3. Elevating Slab-on Grade Houses

3.a Raising a slab-on-grade house with slab intact

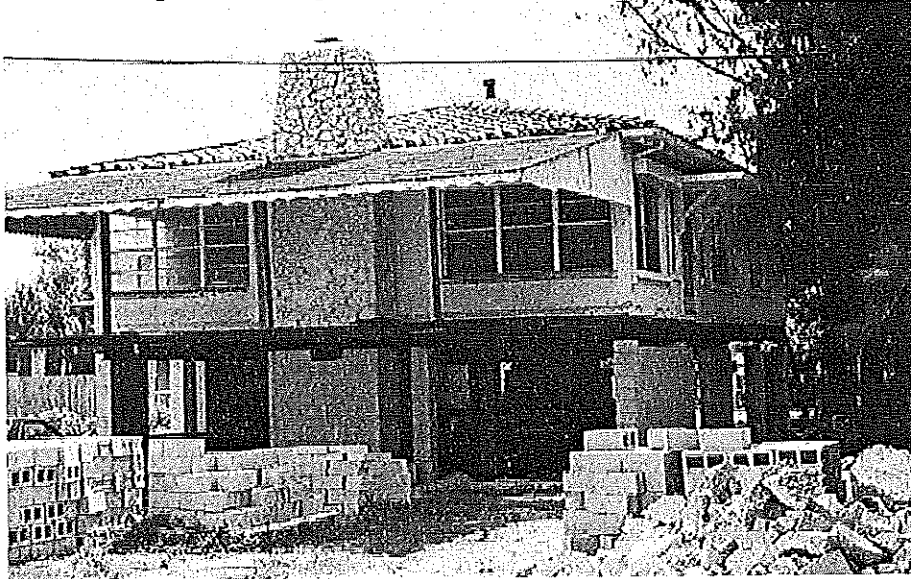
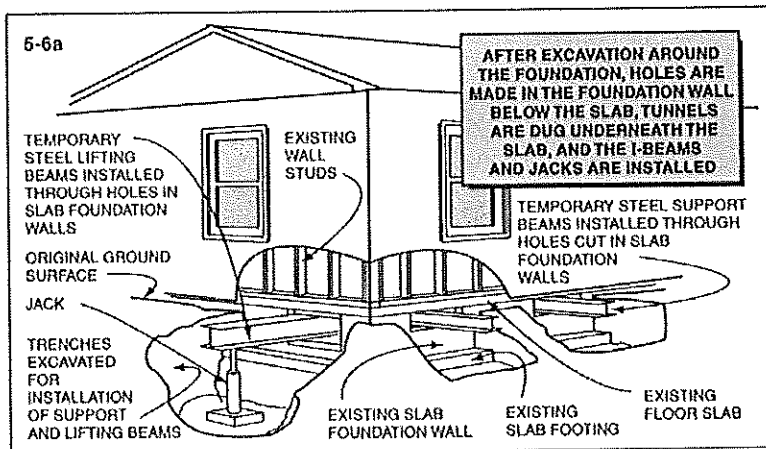


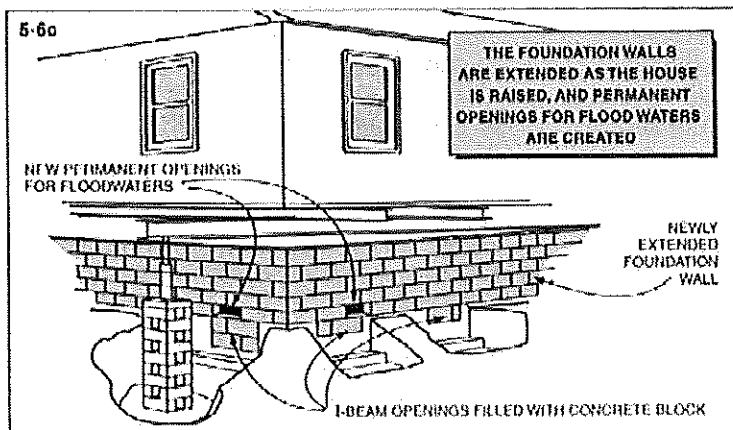
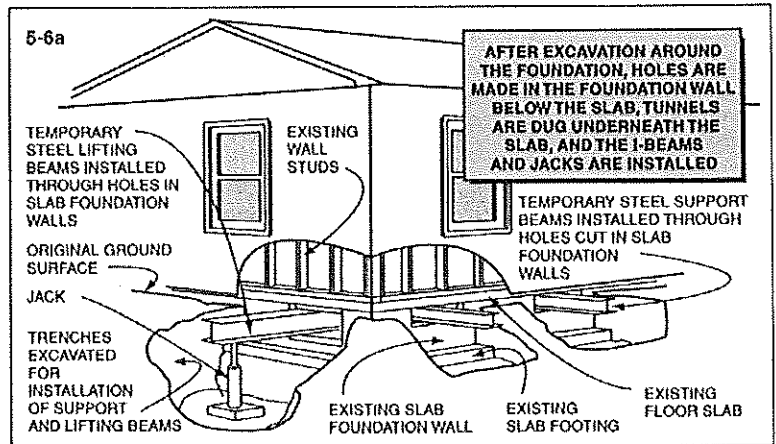
Figure V-4 House raised and moved with slab intact over new masonry foundation (USCOE, 1990)

- Construction steps:
1. Turn off utilities and disconnect lines
 2. Dig trenches around foundation and tunnel under slab
 3. Install lifting beams and jacks below slab
 4. Raise house with jacks, slab attached
 5. Construct new foundation walls, interior piers, stairways
 6. Lower house on new foundation, reconnect utilities

Steps 1, 2, 3 Turn off utilities, excavate and tunnel under foundation for lifting beams and jacks

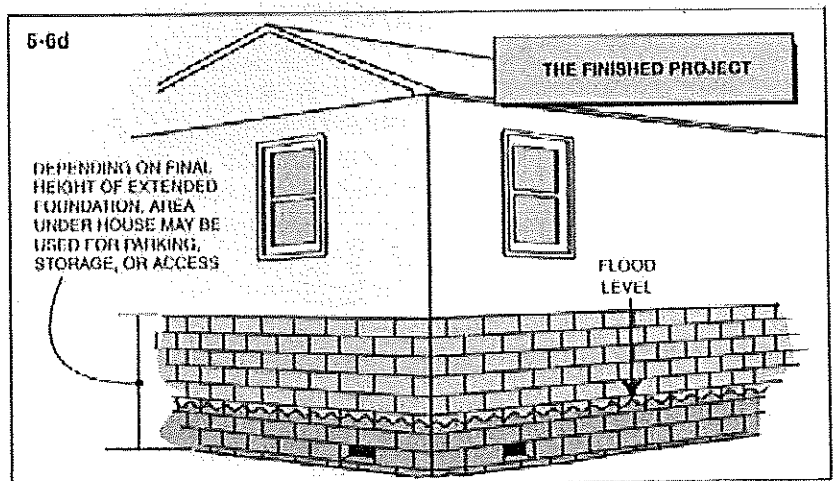


Step 4
Raise house with jacks to
desired flood protection level



Step 5
Extend foundations walls on
existing or new foundation with
openings for flood waters

Final Step 6
Reconnect utilities, build
stairways, add wall finishes,
complete landscaping.
Space under new floor can
be used for storage.



3.b Raising a slab-on grade house without the slab attached

Steps- Lifting beams put through openings in walls above the slab, walls are braced and the house is raised on a new or extended foundation wall. The new floor can be wood frame or elevated concrete slab.

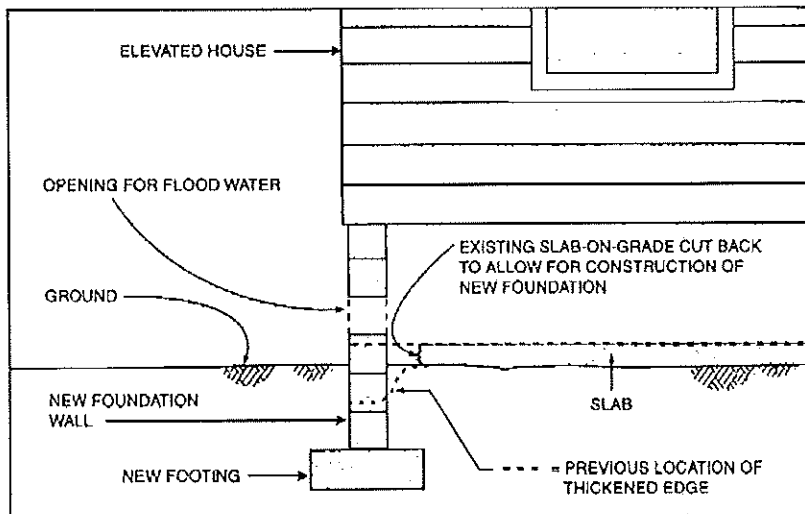
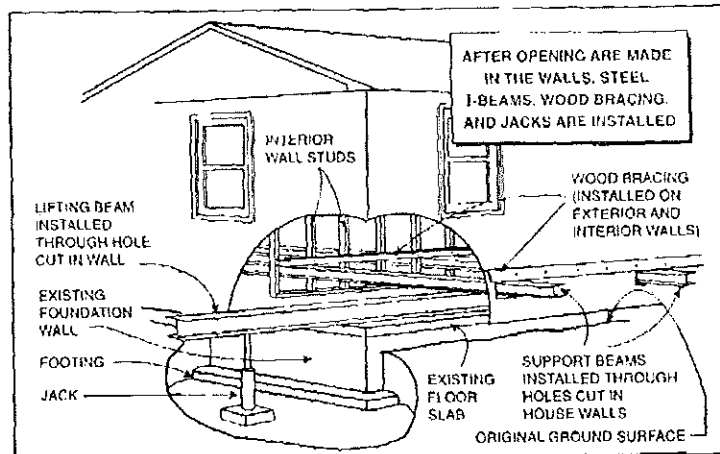
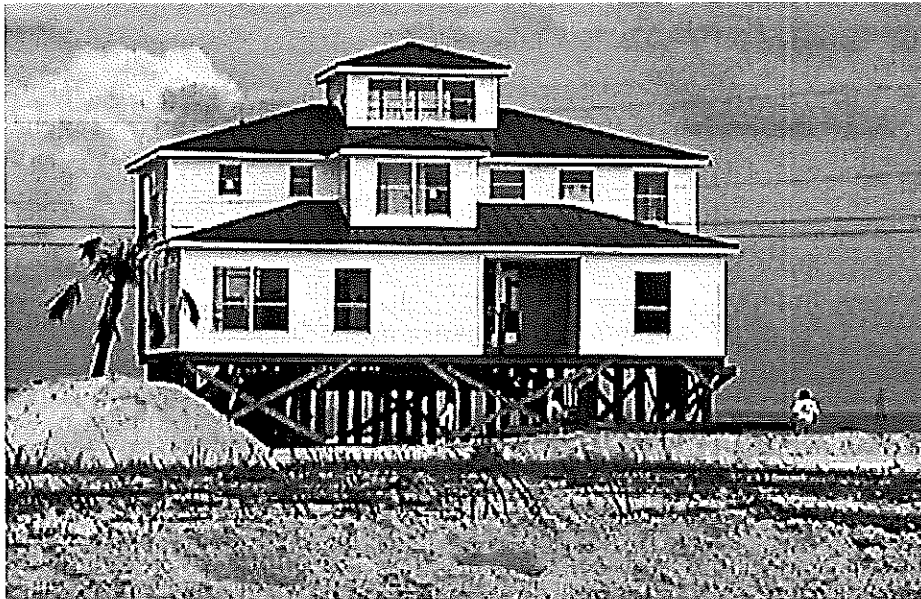


Figure V- Drawing of elevated house over the original slab-on grade, with a new foundation wall.

4. Open wood foundation on piers, pilings, or posts



Good mitigation efforts during planning and construction allowed many homes to survive the storm.
FEMA photo by John Pilger, EIPA

Figure V-3 New coastal house elevated on piers with cross-bracing (FEMA 1999)

- Construction Steps:
1. Turn off utilities and disconnect lines
 2. Excavate around foundation, cut holes in foundation and house walls to install lifting beams
 3. Raise house with jacks, move it off site to temporary location
 4. Demolish existing foundation, install new pilings, piers or posts
 5. Move house back, lower on pilings, reconnect utilities

Elevating houses on open foundations makes it critical to assess the flood/wind zone designations and the flooding and erosion hazards to determine which elevation alternatives are possible. The table below shows possible alternatives (FEMA 1994):

Flood Zones and Hazards		ELEVATION ALTERNATIVES			
Flood Insurance Zone Designation	Flooding and Erosion Hazards	No Action	Piles	Columns: (Piers, Posts)	Solid Foundation Walls
V Zone	Coastal High Hazard Areas subject to erosion	YES	YES	NO	NO
	Coastal High Hazard Areas not subject to erosion	YES	YES	YES	NO
A Zone	Coastal plain areas subject to tidal flooding	YES	YES	YES	YES
No Designation Or C or X Zone	Coastal Waterfront on bluffs subject to erosion	YES	NO	NO	NO

Cost Comparisons for Elevating Substantially Damaged Residential Buildings in Southeastern Texas for a 2,000 square foot wood frame structure (FEMA, 1994)

Note: Estimated costs are from 1994 and need to be adjusted for present time. These costs below are provided for general guidance only and do not include potential additional costs for compliance with wind requirements, new roofing systems, seismic strengthening, general contractor charges, or other costs such as electrical, plumbing, finishing, and other non-structural costs.

Height above grade home is being elevated ↓	ALTERNATIVES for a 2,000 square foot house						
	A 2 Raise existing wood floor on grade beams	B Raise existing wood floor on piers	C 2 Build new floor over existing slab- on grade foundation	D New slab & foundation walls on fill over existing slab & fdn.	E 2 Elevate existing slab on new grade beams	F Raise wood floor over steel beams on new piers	G 2 Abandon 1 st floor, build new 2 nd floor over slab-on grade
1 to 3 feet	\$10,000	\$7,600	\$13,200	\$13,200	\$19,100	\$7,600	N/A
4 feet	\$10,400	\$8,000	\$14,000	\$14,000	\$20,500	\$8,000	N/A
5 feet	\$10,500	\$8,500	\$14,700	\$14,700	\$21,300	\$8,500	N/A
6 feet	\$11,800	\$9,000	\$15,500	\$15,500	\$22,100	\$9,000	N/A
7 feet	\$12,500	\$9,400	\$17,400	\$17,400	\$23,100	\$9,400	N/A
8 feet	\$13,200	\$9,900	\$18,600	\$18,600	\$24,100	\$9,900	\$17,600
10 feet					\$26,700	\$10,800	\$19,200
12 feet						\$12,000	
14 feet						\$13,100	
16 feet						\$14,300	

2 = No finish in enclosed area

VI. Case Studies of Elevated Residential Buildings (one shown here-I will have about 6)

Case Study 1

1. Location/date: 608 Crestwood, Waverly, Iowa. House elevated 1999
2. House Type: Single story ranch with attached garage (330 sf)
3. Structural system: Wood frame over crawl space, concrete block foundation
3. House size: 1100 square feet living area plus garage = 1430 s.f.
4. Reason to elevate: Repetitive flooding from creek near Cedar River
5. Height of elevation: 32" or 4 courses of 8" high concrete blocks to achieve flood protection level above 100 -year base flood elevation (BFE)
6. Method to elevate: Raised on hydraulic jacks
7. Costs: Total about \$40,000. Gross unit cost = \$27.90 per s.f.
Total costs include electrical, insulation, foundation materials, interior repairs, new utilities (furnace, air conditioning, hot water heater) interior finishes.
Some Cost Line Items:
7.1 \$7500 to jack up house = \$5.20 s.f.
7.2 other:

After the 1999 flood and before elevating the house:

The owner said....

The building inspector said.....

The contractor said...



1999 floodwater level was to this level. House had to be raised up 32".

Deck was torn off foundations and a/c compressor replaced and still needs to be elevated

Figure VI-1 Case study 1. Flood damages following the 1999 flood (photo by author)

The same house after elevation, 1999. After disconnecting utilities, the lifting beams were placed through the old foundation wall and under the main floor. The house was then lifted by jacks and cribbing high enough so the new extended foundation walls could be built. Then the house was lowered and secured on the new walls.

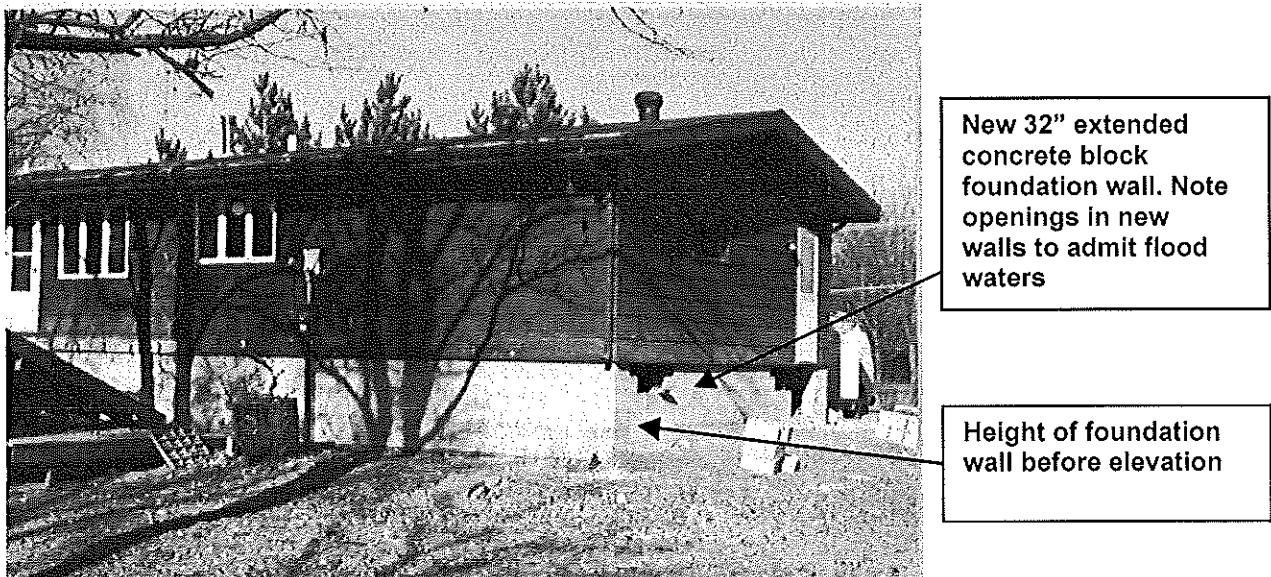


Figure VI-2 Case study 1. House after 32" elevation (photo by building inspector)

After elevating the house:

The owner said....

The contractor said....

The building inspector said...

(This is the end of 1st draft as of 12/26/99- this case study and others will contain more notes and technical drawings as available.

Additional case studies will follow this format. The last sections are a glossary of terms and appendix.)