Figure 29
Windows and doors are added. The height of the raised front door shows the amount of elevation.

Figure 30
Interior partition walls and utilities are added.

Figure 31
This view from the rear of the house shows that the project is almost complete.

Figure 32
The final product: an attractive elevated house that meets local floodplain management requirements and is now much less vulnerable to flood damage. In addition, the house is now eligible for a lower rate of flood insurance coverage under the NFIP.

Case Study 2

The second house for which Technique 1 was used (Figures 33–38) is similar to the first, and the modifications made are much the same:

- The roof was removed.
- The walls were extended with masonry block.
- Compacted sand fill was placed over the old slab.
- A new slab was poured on top.
- Concrete bond beams and tie columns were installed.

Therefore, this case study focuses on construction details.

Figure 33
Wood framing for a new concrete staircase that will provide access to the elevated floor.

Figure 34
After the new concrete slab is poured, wood framing for interior walls is added.

Figure 35
The electrical system is upgraded to meet current code requirements.

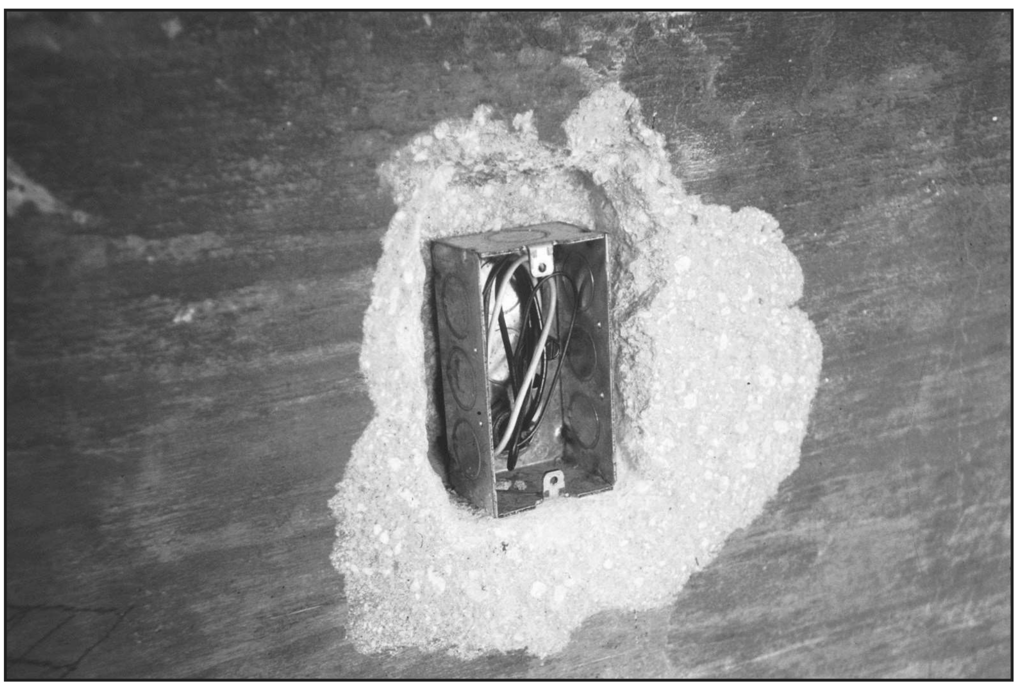

Figure 36
In this view from the front of the house, the amount of elevation is shown by the rows of concrete block on the tops of the original walls and by the raised window openings.

Figure 37
The project nears completion. In this house, as in Case Study 1, the level of the garage floor remains unchanged.

Figure 38
The elevated house is now complete.

Case Study 3

In the third house for which Technique 1 was used (Figures 39–44), the lowest floor was raised only about 1 foot. Otherwise, the work performed was essentially the same, with a few minor exceptions.

Figure 39
The roof of this house was removed as a single piece; the trusses were held together with bracing and portions of the original roof sheathing. This approach made it easier to reinstall the roof at the end of the project.

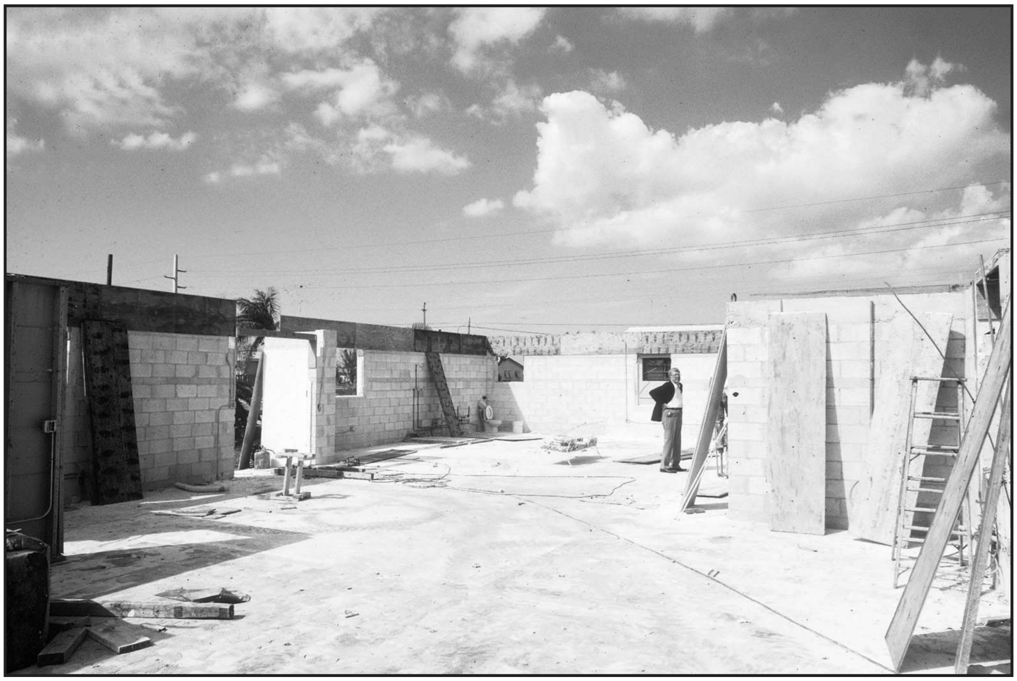

Figure 40
After the roof was removed and the storm-damaged interior gutted, the walls of the house were extended upward and a new bond beam added at the top.

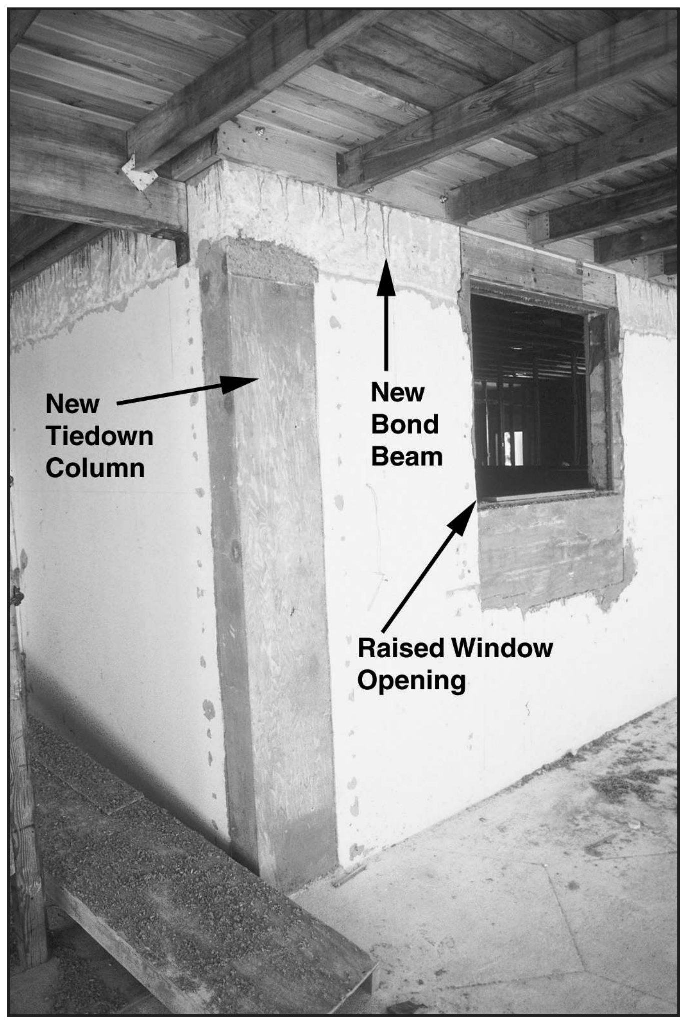

Figure 41
Note the new bond beam at the top of the extended wall, the new concrete tiedown column at the corner, and the raised window opening.

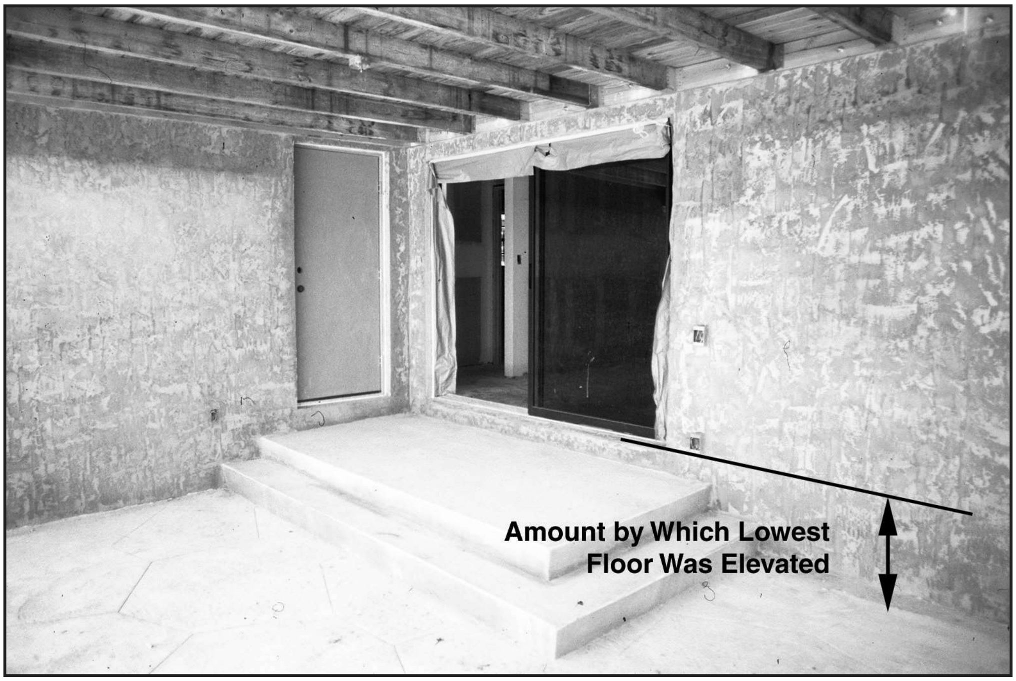

Figure 42
This view from the back of the house shows the height of the elevated slab floor.

Figure 43
The owner of this house decided to use light-gauge metal framing for the new interior walls.

Figure 44
The final product. As in the first two houses, the garage floor remains at the original level. The relatively small amount of elevation required for this house has altered its appearance very little.

Technique 2 – Convert the Existing Lower Area of the House to Non-Habitable Space and Build a New Second Story for Living Space.

Case Study 4

The owner of this house (Figures 45–50) chose to build the new second story with reinforced concrete block.

Figure 45
Concrete bond beams similar to those shown earlier were used in this house, but here they were installed on the tops of both the original first-story walls and the new reinforced concrete block second-story walls.

Figure 46
Concrete tiedown columns, such as the one to the left of the window in this photograph, were also used in this house.

Figure 47
The tiedown columns extend down from the new second-story walls and into the original first-floor walls. The columns tie the first and second stories together and provide a continuous load path that helps the house resist the forces of high winds.

Figure 48
Wood 2 by 4 studs were used to frame the interior walls of the second story.

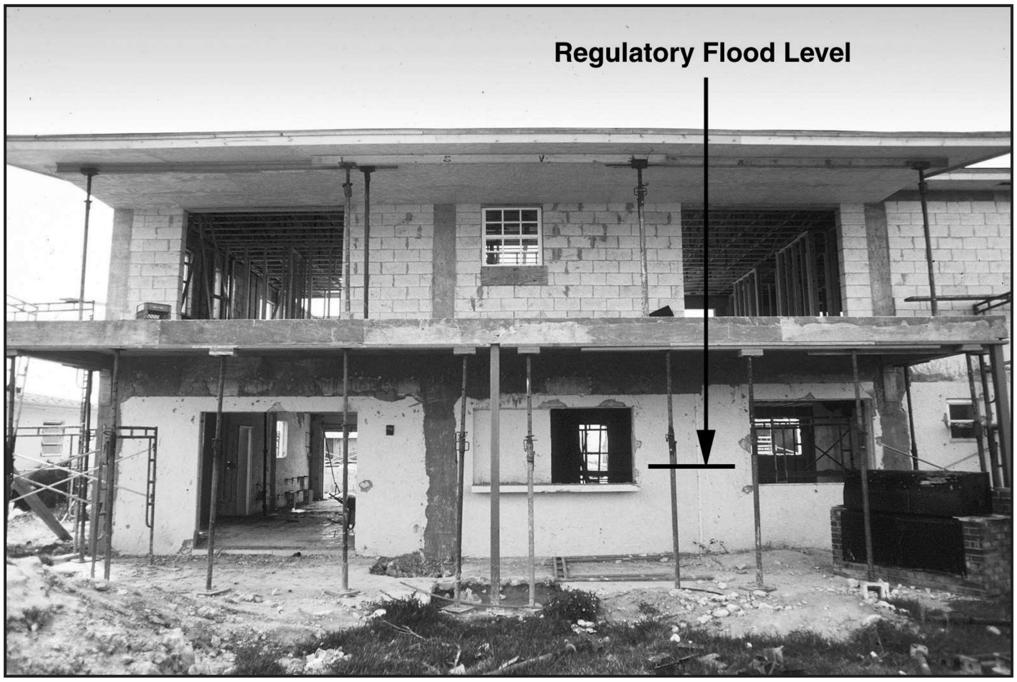

Figure 49
The house nears completion.

Figure 50
Not only does the completed house meet the requirements of local codes and the NFIP regulations, it now includes a substantial amount of parking and storage space below the new living level. In addition, because the lowest floor is now over 4 feet above the regulatory flood elevation, the house is eligible for NFIP flood insurance at a greatly reduced rate of coverage.

Case Study 5

Concrete bond beams and tiedown columns were used in this house (Figures 51–60) as well, but the owner decided to use metal-frame construction rather than concrete block for the new second story.

Figure 51
The storm-damaged first story has been gutted in preparation for construction.

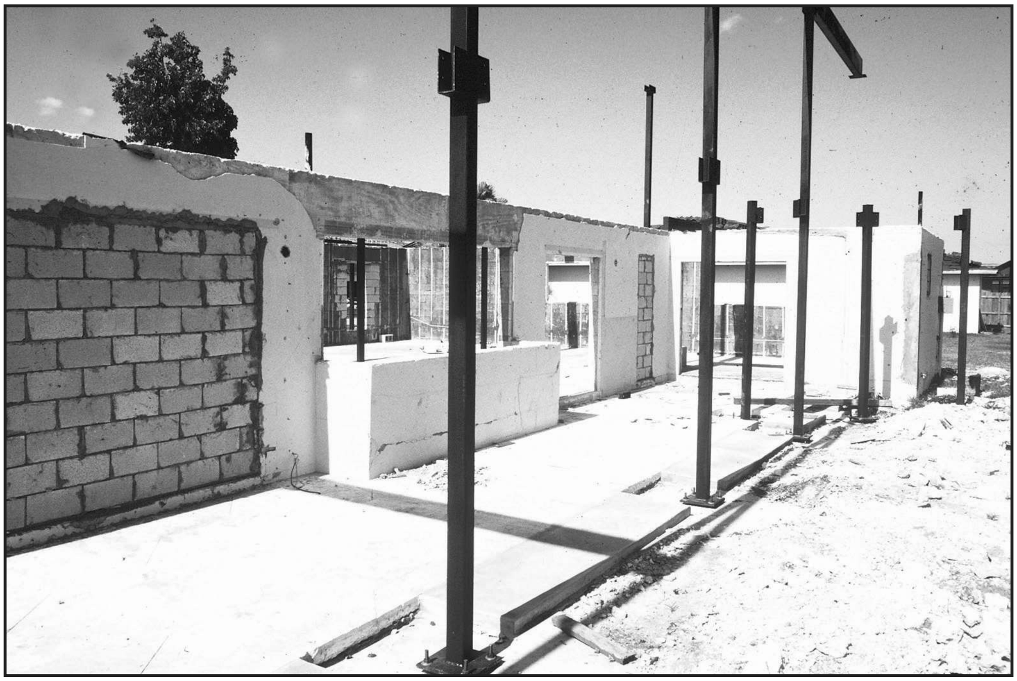

Figure 52
The existing first-story walls have been strengthened by the addition of concrete block. Metal columns and beams have been added to help support the new second story.

Figure 53
As the second story takes shape, its size in relation to the size of the original house becomes apparent.

Figure 54
Metal framing is used for the new second story, including the walls and roof support system.

Figure 55
Metal framing also supports the floor of the new second story.

Figure 56
One advantage of metal framing is its relatively light weight. An additional advantage is that the screws used to attach metal-frame components provide strong connections.

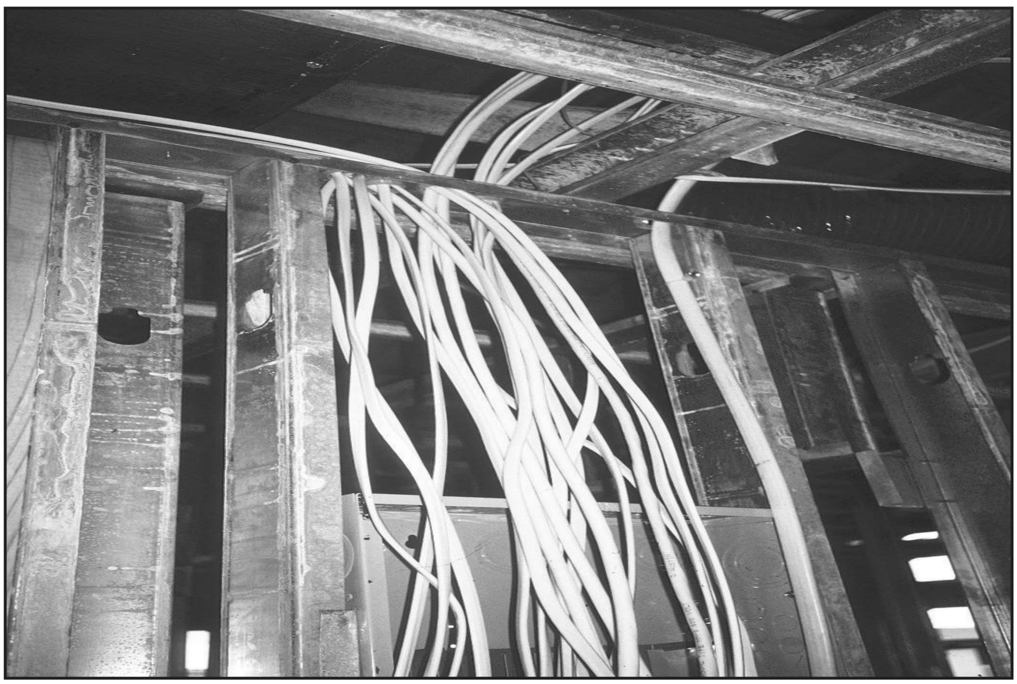

Figure 57
The project progresses with wiring and other utility work. As in each of the other house elevation projects, all current building code requirements must be met.

Figure 58
The new second story nears completion. The roof is made of formed metal panels.

Figure 59
The exterior walls consist of prefabricated concrete panels. Innovative techniques such as those employed in this project are helping homeowners who need practical and economical methods of repairing and protecting their houses.

Figure 60
The completed house has the appearance of a typical two-story residence. As in the house in Case Study 2, the lower floor is used only for parking, storage, and building access; the new second story provides the living space.

Case Study 6
The third house for which Technique 2 was used (Figures 61–64) differs from the first two in that the owner decided to build a wood-frame second story.

Figure 61
The wood-frame second story takes shape.

Figure 62
After the wood framing was completed, the roof and exterior wall sheathing were added.

Figure 63
The new second-story walls are securely connected to the original first-floor walls with galvanized metal hurricane straps.

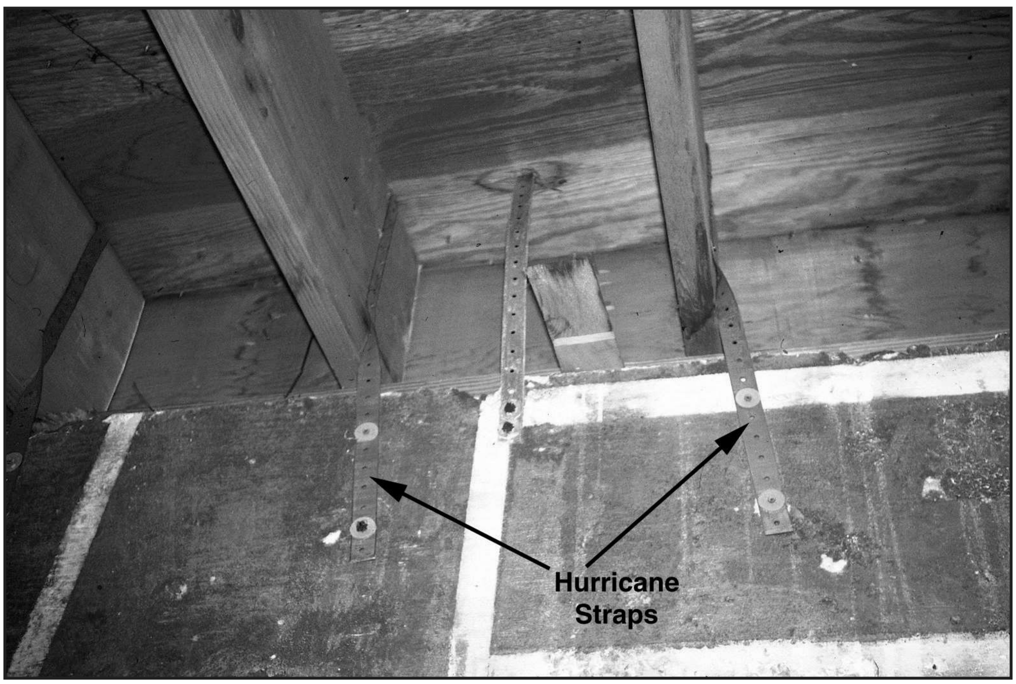

Figure 64
From the outside, the completed house, with its stucco walls, looks like a conventional masonry house.

Combination of Techniques 1 and 2

Case Study 7

Many owners of substantially damaged houses in the areas affected by Hurricane Andrew took advantage of the opportunities afforded by their elevation projects to make additional improvements. For example, the owner of the next house (Figures 65–72) used a combination of Techniques 1 and 2. In addition to extending the walls of the house upward and raising the lowest floor above the BFE, he built a new second-story addition over the garage. The addition was not a necessary part of the elevation process, but it does provide additional living space well above the flood level.

Figure 65

After the house was gutted, the walls were extended upward with reinforced concrete block. In this view from behind the house, the rear wall of the new second story can be seen on the left and the extended first-story wall on the right. Note the new raised window opening in the extended wall, just above the original opening.

Figure 66
The new second-story walls as seen from inside the garage.

Figure 67
The extended first-story walls.

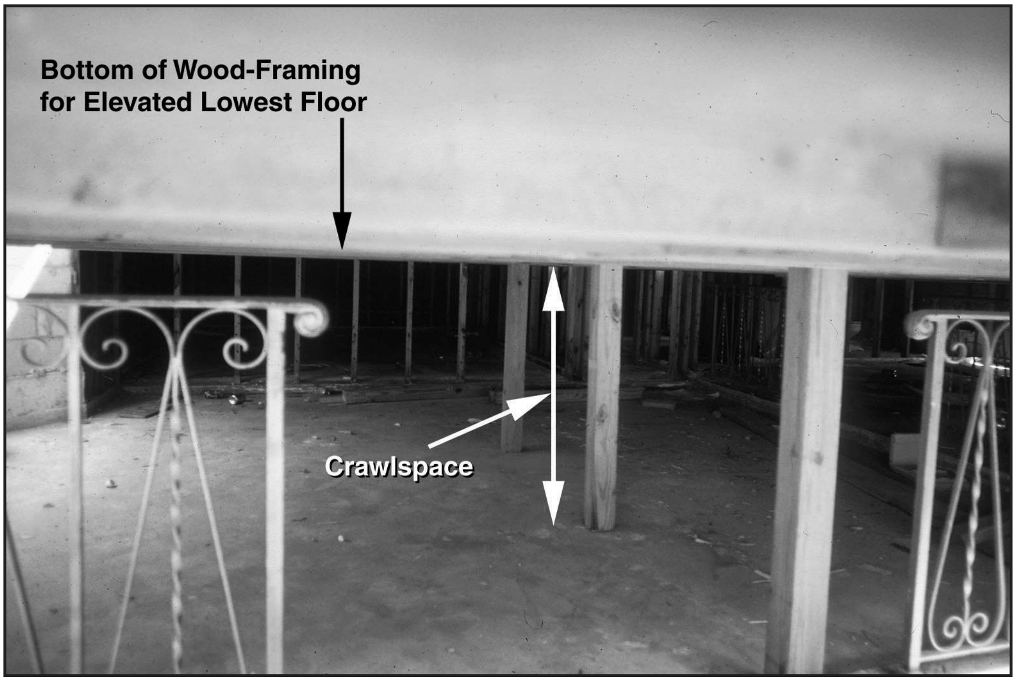

Figure 68
Rather than install a new concrete slab on compacted fill, the owner of this house chose to build a new wood-frame floor above the old concrete slab. This method creates a crawlspace below the new floor.

Figure 69
Wood framing is used for the new second story.

Figure 70
Metal hurricane straps are used to tie the structural members together and create a continuous load path from the roof to the foundation.

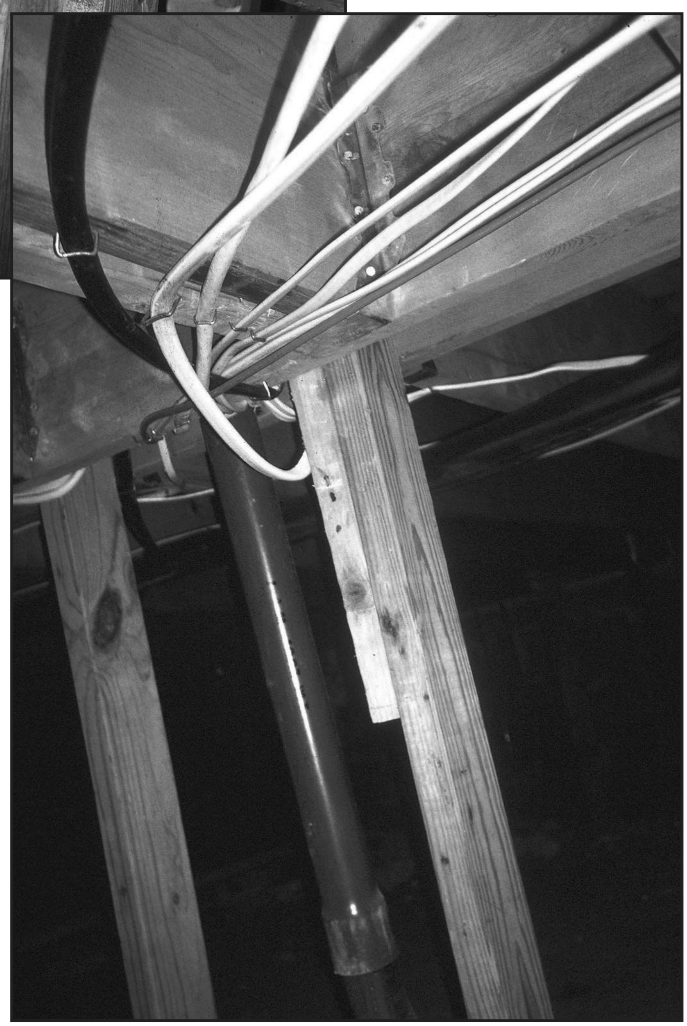

Figure 71
All plumbing and electrical renovation work must be performed according to state and local code requirements.

Figure 72
The completed house is compliant with local floodplain management requirements, is more resistant to flood damage, and provides additional living area above the flood level.

Technique 3 – Lift the Entire House, With the Floor Slab Attached, and Build a New Foundation To Elevate the House.

Case Study 8
Unlike Techniques 1 and 2, which build up from the existing foundation and walls, Technique 3 lifts the entire house with hydraulic jacks and builds a new foundation below it (Figures 73–85).

Figure 73
Like the houses shown previously, this one-story house, with its concrete block walls, concrete slab foundation, and attached garage, is typical of the houses in the area affected by Hurricane Andrew.

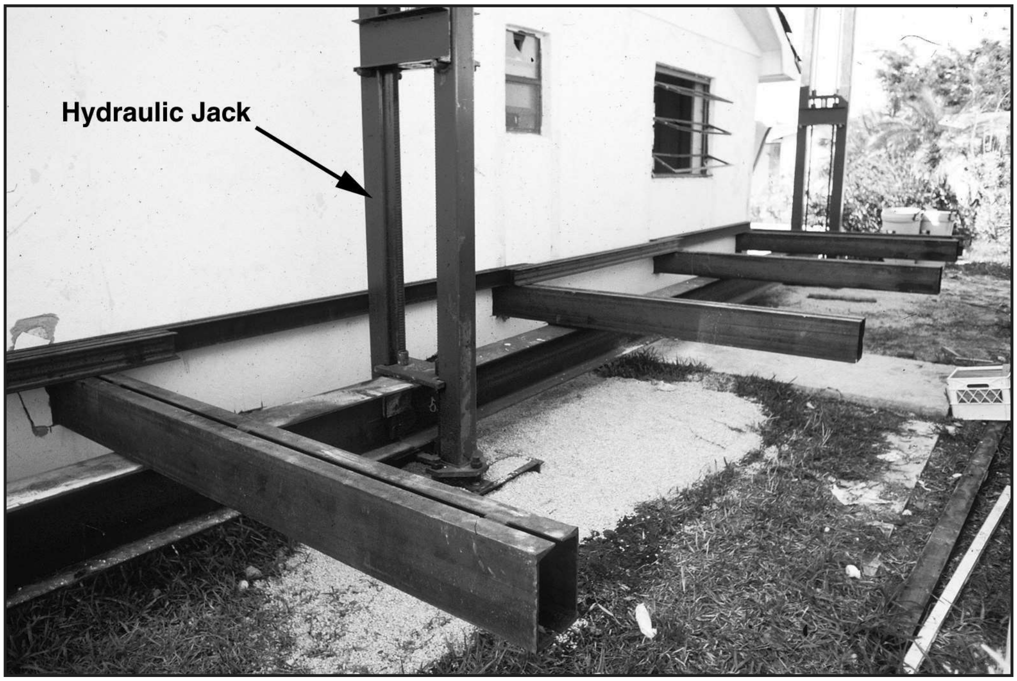

Figure 74
In this variation of Technique 3, steel beams are inserted through the walls of the house rather than under the slab. The beams span the length and width of the house and cross one another inside to create a grid. Outside the house, the beams rest on larger beams that will be raised with hydraulic jacks.

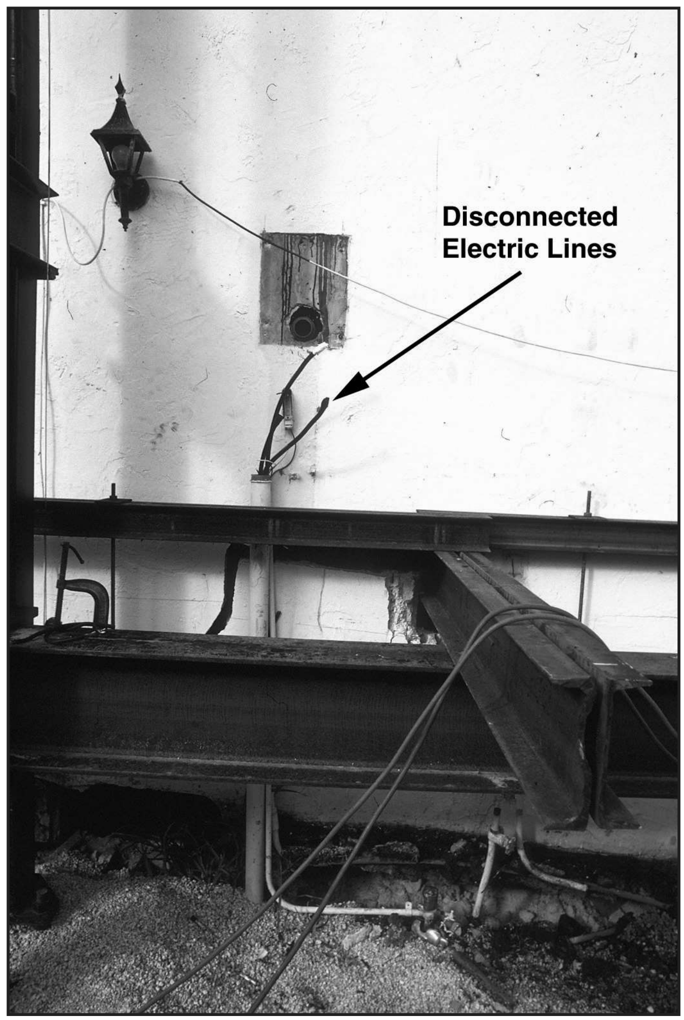

Figure 75
Electrical lines and other utilities were disconnected early in the project.

Figure 76
Inside the house, workers drill holes in the concrete slab ...

Figure 77
... install anchors ...

Figure 78
... and use hangers to attach the anchors to the grid of steel beams.

Figure 79
The anchors and hangers connect the slab securely to the beams, enabling the beams to raise the slab along with the rest of the house.

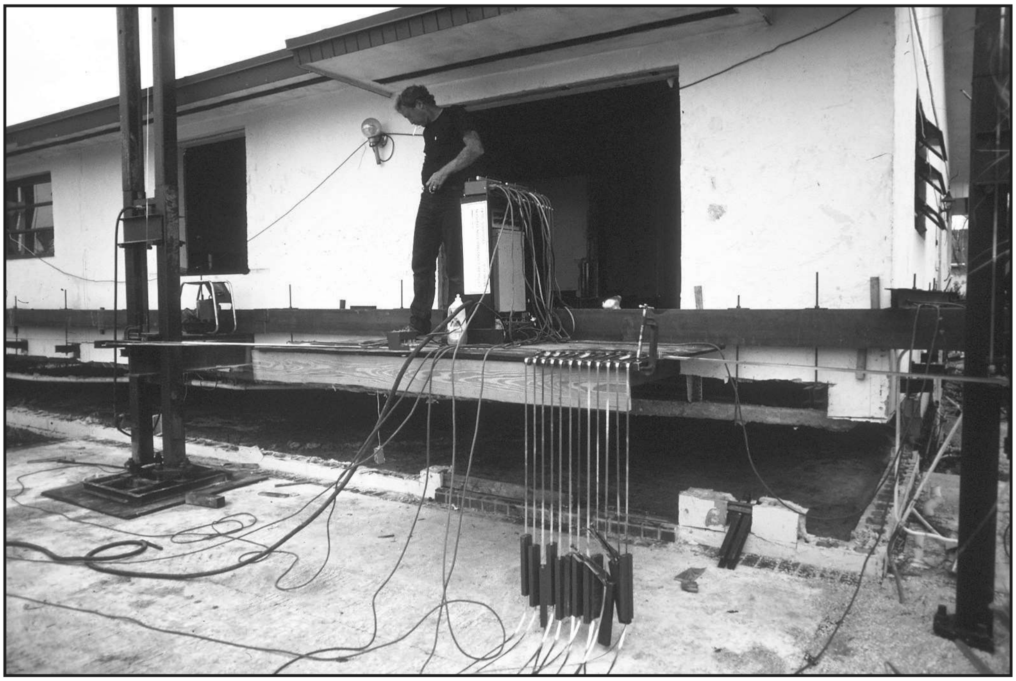

Figure 80
Lifting the house, while simple in theory, is complicated by the need to ensure an equal amount of lift at each jack throughout the process. Too much or too little lift at even one jack can cause the slab and walls to crack. The elevation contractor for this project used a sophisticated jacking system that provided the required level of control.

Figure 81
The house and slab were raised one full story.

Figure 82
While the jacks and beams supported the house, new steel foundation members were installed below.

Figure 83
Concrete blocks were brought to the site ...

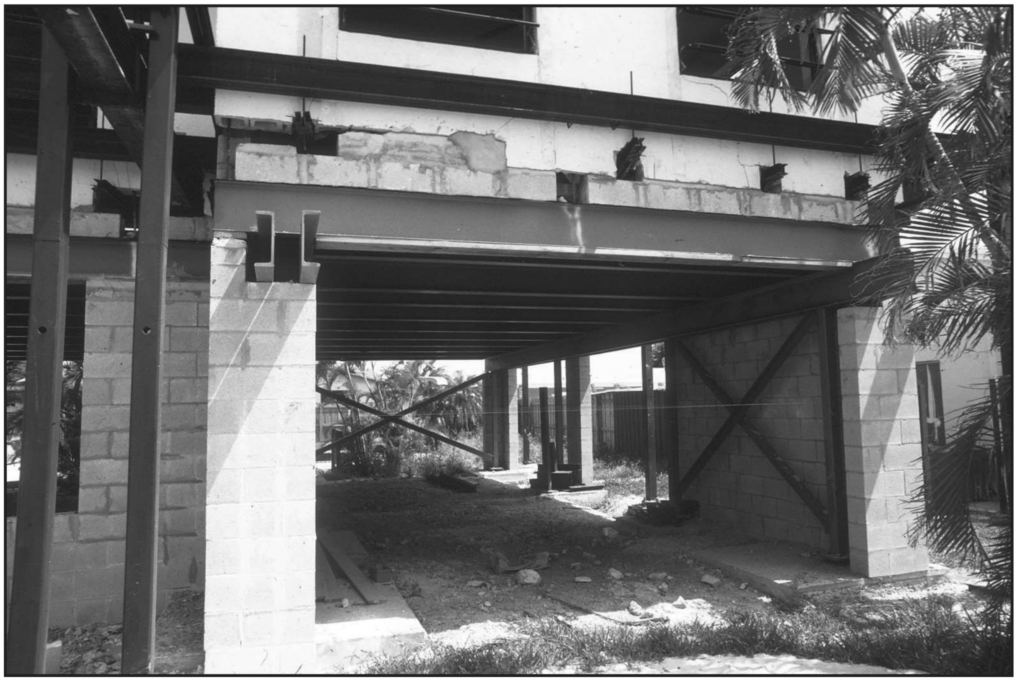

Figure 84
... and used to build the lower-level walls.

Figure 85
The completed house, with lower-level space for parking and storage and upper-level living space, looks as if it were originally designed and built as a two-story structure.

Summary

The benefits of elevating make it an effective means of protecting a floodprone house.

In communities that participate in the NFIP, new, substantially improved, and substantially damaged houses must be elevated to or above the BFE. As shown by the eight house elevation projects presented in this publication, homeowners may have a choice of three techniques for elevating a slab-on-grade house to comply with local floodplain management requirements and reduce future flood damage.

Elevating provides a number of benefits:

- reduces future flood damage
- can lower flood insurance premium
- can add to the value of the house
- can increase space in the house usable for parking and storage
- can improve the appearance of the house
- helps protect contents
- helps reduce anxiety about future floods

Elevating a substantially damaged house can be expensive, but so can buying or building a comparable replacement house. The cost of elevating will depend of a number of things, including the following:

- size of the house
- type of foundation (e.g., slab-on-grade, crawlspace, basement)
- whether the house has wood-frame, masonry, or concrete walls
- the BFE, which determines the amount of elevation required.

Also, because the costs of labor and construction materials vary across the United States, the location of the house will affect the cost of elevating. However, regardless of these conditions, one of the best times to elevate a floodprone house is when repair or reconstruction is necessary after a flood or other damaging event. The benefits of elevating, coupled with the desire of many homeowners to remain in their neighborhoods, makes elevating an attractive solution to flood problems.

It is important to note that masonry-wall slab-on-grade houses, such as the eight case study houses presented in this publication, are among the most difficult to elevate. In general, masonry, wood-frame, and metal-frame houses on other types of foundations, such as crawlspaces, basements, pilings, piers, or posts, are easier and less expensive to elevate. Therefore, elevating will often be the most practical means of protecting a house from flooding and complying with floodplain management requirements.

Additional Information

NOTE

To learn more about flood hazards, floodplain management requirements, and building codes in your community, check with your local floodplain administrator, building official, city engineer, or planning and zoning administrator.

NOTE

A number of Federal and non-Federal programs provide financial assistance for retrofitting projects, including house elevation. FEMA's *Homeowner's Guide to Retrofitting* (FEMA 312) lists these programs and describes the types of assistance available.

Information about protecting floodprone houses is available from FEMA and other sources.

FEMA has produced many technical guides and manuals that provide additional information about methods of protecting floodprone houses, including elevation techniques. Some of these documents are intended primarily for homeowners and non-technical readers; others are designed specifically to meet the needs of engineers, architects, and building officials.

FEMA Guides and Manuals for Both Non-Technical and Technical Readers

Homeowner's Guide to Retrofitting– Six Ways to Protect Your House From Flooding

FEMA Publication No. 312

This handbook is intended for non-technical readers who would like more information about flood protection methods. Illustrated discussions of house elevation, wet floodproofing, house relocation, dry floodproofing, levees and floodwalls, and demolition are supplemented with cost estimates, checklists, and decision-making worksheets.

NFIP Technical Bulletin Series

TB-1 through TB-9

FEMA's NFIP Technical Bulletins are intended for a broad range of readers, including homeowners, local officials, and design professionals, who need guidance concerning NFIP regulatory requirements that apply to buildings in SFHAs. Topics addressed by the bulletins that may be of interest to readers of this publication include the requirement for openings in foundation walls below the BFE (TB-1), flood-resistant materials requirements (TB-2), wet floodproofing requirements (TB-7), and corrosion protection for metal connectors in coastal areas (TB-8).

Protecting Building Utilities From Flood Damage – Principles and Practices for the Design and Construction of Flood Resistant Building Utility Systems

FEMA Publication No. 348

This manual is intended for developers, architects, engineers, builders, code officials, and homeowners who are involved in designing and constructing building utility systems for residential and non-residential structures. The manual discusses flood-protective design and construction of utility systems for new buildings and modifications to utility systems in existing buildings.

FEMA Guides and Manuals for Engineers, Architects, Building Officials, and Other Technical Readers

Coastal Construction Manual – Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas

Third Edition
FEMA Publication No. 55

This three-volume manual is intended for architects, engineers, building professionals, and community officials who need technical guidance concerning the proper methods of planning, siting, designing, constructing, and maintaining residential buildings in coastal areas subject to flood, wind, and seismic hazards. The manual includes a summary of past coastal hazard events, such as hurricanes, northeasters, and tsunamis; a discussion of coastal hazards and regulatory requirements that affect coastal construction; and detailed design guidance, including formulas and example problems.

Engineering Principles and Practices for Retrofitting Flood Prone Residential Buildings

FEMA Publication No. 259

This manual is intended for architects, engineers, and building professionals who need technical guidance concerning flood protection techniques that can be applied to existing buildings. Detailed specifications, computation examples, and cost data are presented.

In addition, this publication on house elevation in south Florida is available on both CD-ROM and videotape. To order copies of FEMA publications, including videos and CD-ROMs, call the FEMA Publications Distribution Facility at 1-800-480-2520.

For more information about hazard mitigation and other subjects in emergency management, visit FEMA's web site:

www.fema.gov