# Chapter 8
# Other Measures That Reduce Existing-Condition Damage Susceptibility

## 8-1. Overview

Existing-condition damage susceptibility, and hence EAD, can be reduced with so-called "nonstructural" measures described in this chapter. The measures include floodproofing, relocation, and flood-warning/preparedness (FW/P) plans. Requirements for the measures are summarized in Table 8-1.

## 8-2. Requirements for Floodproofing

*a. Applicability.* Floodproofing measures are appropriate for damage reduction for single-story, residential structures. In special cases, these measures have been used for other structures, but the economic and physical feasibility of such applications is limited. Floodproofing does not reduce damage to utilities, infrastructure, lawns, and other exterior property. These measures are limited generally to property frequently flooded. Floodproofing is generally less disruptive to the environment than other measures that require significant construction.

*b. Overview of floodproofing.*

(1) Floodproofing includes (a) use of closures and small walls to keep out floodwaters and (b) raising existing structures in-place to reduce damage. The measures are spatially distributed, so do not provide the same uniform protection possible with, for example, a reservoir. Floodproofing reduces damage to existing individual structures or parcels of land by altering damage susceptibility.

(2) Closures, like those shown in Figure 8-1, reduce damage by keeping the floodwater out of the structure. This figure shows window closures, but similar closures can be provided for doors and other openings. Closures may be temporary or permanent. The figure shows temporary closures; these are bolted into place during a flood threat and removed afterwards. In addition to the closures, depending on site conditions, the following may be required: a waterproofing sealant applied to the walls and floors to reduce seepage, a floor drain and sump pump to accommodate seepage, and a valve to eliminate flooding in the structure due to sewer backflow.

(3) Similar damage reduction can be achieved with a small wall or levee built around one or several structures. Such a wall is designed for compatibility with local

**Table 8-1**
**Checklist for Measures that Reduce Existing-Condition Damage Susceptibility**

| Hydrologic Engineering Study Components | ✓ | Issues |
|---|---|---|
| Layout | | Based on qualification of flood hazard, identify structures for which measures are appropriate |
| Economics | | Determine with-project modifications to stage-damage function for all existing and future conditions |
| | | Quantify uncertainty in stage-damage function |
| | | Formulate and evaluate range of floodproofing, relocation, and/or FW/P plans, using risk-based analysis procedures |
| Performance | | Determine expected annual exceedance probability |
| | | Determine expected lifetime exceedance probability |
| | | Determine operation for range of events and sensitivity analysis of critical assumptions |
| | | Describe consequences of capacity exceedances |
| | | Determine event performance |
| | | Formulate OMRR&R plan and prepare O&M manual to include surveillance and flood fighting |
| Design | | Develop, for all these measures, FW/P plans |
| Environmental and Social | | Evaluate aquatic and riparian habitat impact and identify enhancement opportunities |
| | | Anticipate and identify incidental recreation opportunities |

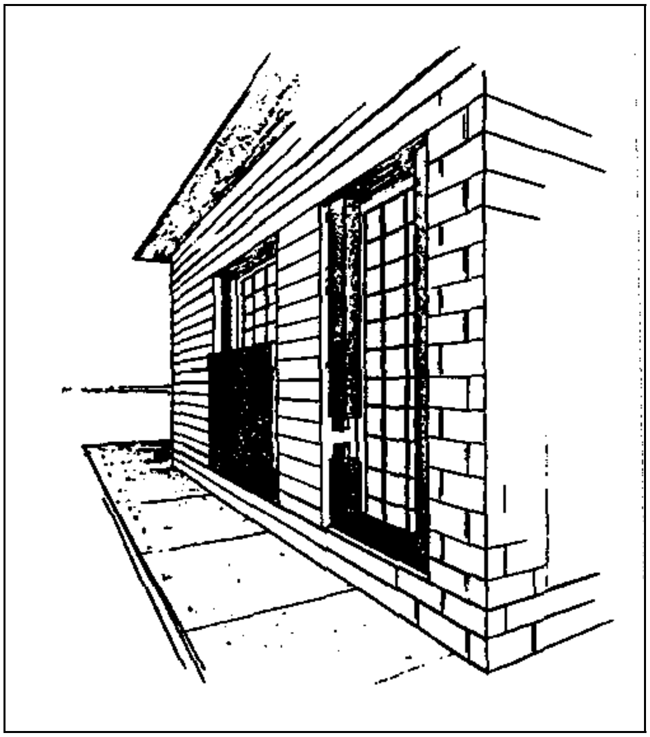

**Figure 8-1. Floodproofing with closures (from USACE 1978)**

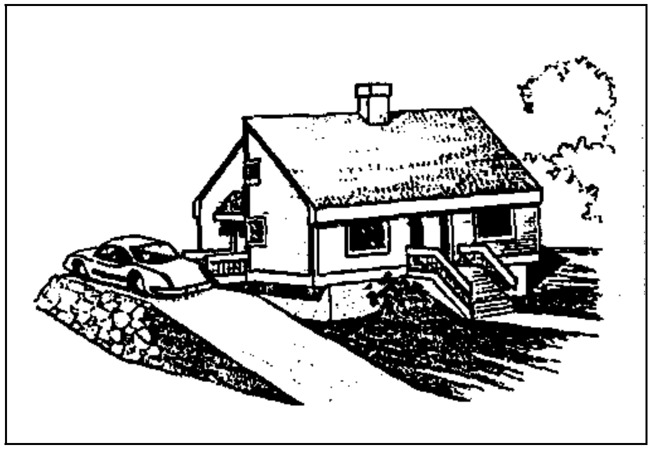

**Figure 8-2. Floodproofing by raising an existing structure in-place (from U.S. Dept. of Housing and Urban Development 1977)**

**Table 8-2**
**Actions Required to Raise a Structure In-Place (from USACE 1978)**

| |
|---|
| 1. Disconnect all plumbing, wiring, and utilities that cannot be raised with the structure. |
| 2. Place steel beams and hydraulic jacks beneath the structure and raise to desired elevation. |
| 3. Extend existing foundation walls and piers or construct new foundation. |
| 4. Lower the structure onto the extended or new foundation |
| 5. Adjust walks, steps, ramps, plumbing, and utilities. Regrade site as desired. |
| 6. Reconnect all plumbing, wiring, and utilities. |
| 7. Insulate exposed floors to reduce heat loss and protect plumbing, wiring, utilities, and insulation from possible water damage. |

landscaping and aesthetics, and generally is less than 1 meter high. Walls may be brick, stone, concrete, or some other material designed to withstand lateral and uplift forces associated with floodwaters. As with a major levee, runoff in the interior area must be managed; often a small pump is adequate.

(4) Figure 8-2 shows an existing structure after it was raised in-place to reduce damage. The hazard is not eliminated here, but the damage is reduced. Now when a flood occurs, the depth of water at the site, relative to the original ground level, is the same, but the depth of flooding in the structure is less. In Figure 8-2, the structure is a single-story wooden-frame residential structure that was constructed originally with a crawl space and no basement. Specific actions required to raise this structure are listed in Table 8-2. While it is possible to raise almost any structure, raising a structure such as that illustrated is most likely to be economically justified and physically feasible. Note that in the figure, fill was used to raise the car-parking pad.

*c. Flood damage reduction assessment.*

(1) Floodproofing alters the stage-damage relationship for structures. The manner in which it does so depends on the measures used. Figure 8-3 illustrates the alteration when a closure or small wall is used. The existing condition, without-project stage-damage function is the solid line curve; the modified function is the dotted curve. Without the closure or wall, damage begins when stage reaches $S_1$, as shown in the figure. With the closure or wall in place, the onset of damage is raised to stage $S_2$. Of course, if the stage exceeds $S_2$, the closure or wall is overtopped, and damage is essentially that which would be incurred without the measure. In the figure, this is represented by the sharp increase in with-project damage for stage greater than $S_2$.

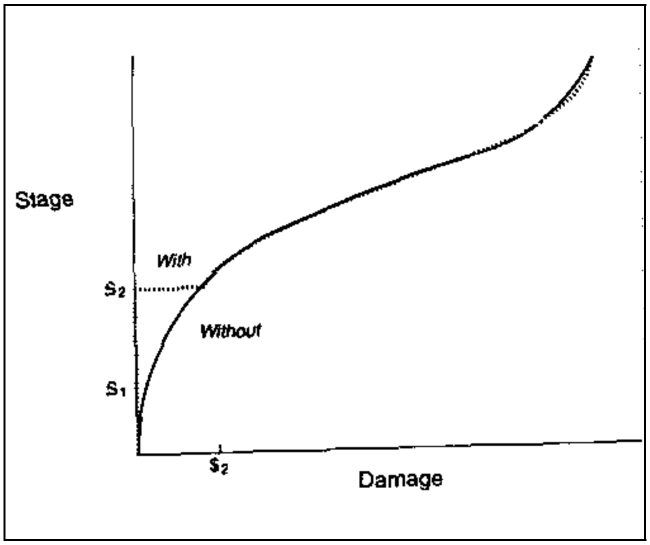


**Figure 8-3. Stage-damage function modification due to floodproofing with closure, wall**

(2) Figure 8-4 illustrates the alteration when an existing structure is raised in-place. Again, the existing condition, without-project stage-damage function is the solid line curve, and the modified function is the dotted curve. For the existing, without-project condition, damage begins when stage reaches $S_1$. When the structure is raised, the stage-damage function is shifted upward a distance equal to the increased elevation, but the function retains essentially the same shape. Thus the onset of damage is raised to stage $S_2$, and the damage incurred at all stages equals

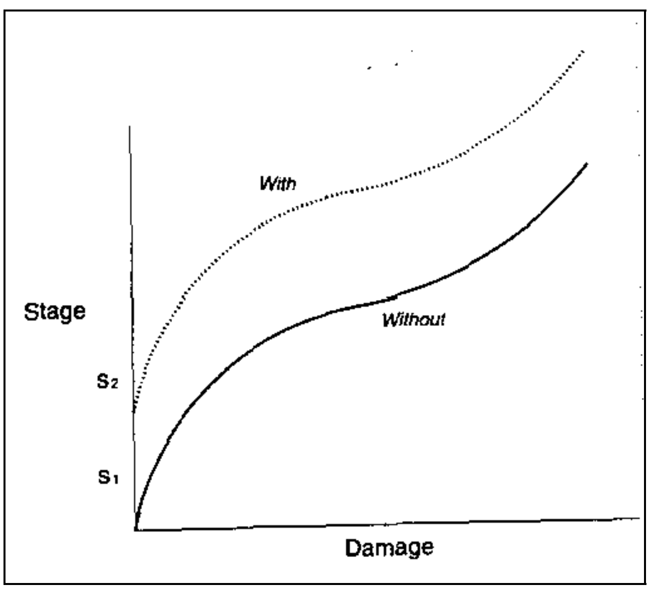


**Figure 8-4. Stage-damage function modification due to floodproofing by raising in-place**

the damage previously incurred at that stage less the distance the structure was raised.

*d. Technical considerations.*

(1) Reports from HEC (USACE 1978, 1985) describe various nonstructural measures in detail and identify critical technical considerations for formulating plans that include these measures. Some of the important considerations identified there are summarized in Table 8-3.

**Table 8-3**
**Performance Requirements for Floodproofing**

| Floodproofing Method | Performance Requirement |
|---|---|
| Window or door closure | Provide adequate forecasting and warning to permit installation of closures. |
| | Identify *all* openings for closure, including fireplace cleanouts, weep holes, etc. |
| | Ensure structural adequacy to prevent failure due to hydrostatic pressure or floating of structure. |
| | Ensure watertightness to minimize leakage. |
| | Arrange adequate, on-going public training to ensure proper operation. |
| Small wall or levee | Requirements similar to those for major levee, but on a smaller scale, including (1) providing for closure of openings in wall or levee; (2) ensuring structural stability of levee or wall; providing for proper interior drainage. |
| | Arrange adequate, on-going public training to ensure proper operation. |
| | Plan for emergency access to permit evacuation if protected area is isolated by rising floodwaters. |
| Raising in place | Protect beneath raised structure, as hazard is not eliminated. |
| | Ensure structural stability of raised structure. |
| | Plan for emergency access to permit evacuation if protected area is isolated by rising floodwaters. |

(2) A critical task is to characterize floods to permit design of alternative measures that satisfy the performance constraints. In doing so, estimates of depths, velocities, and sediment and debris loads of flowing water, and the forces due to these must be provided. The fluvial- and

alluvial-process models described in Appendix B may provide the necessary information.

(3) A complete plan that incorporates floodproofing must include an emergency evacuation plan. This can only be formulated properly by using hydrologic engineering input. Inundated areas for identifying escape routes and estimating flow velocities for evaluating the safety of the evacuation routes must be identified. For example, if a small 2-foot-high levee is proposed for a group of residences, the velocities associated with flows corresponding to depths greater than 2 feet should be determined and the likelihood of evacuation by foot, vehicle, or boat evaluated.

## 8-3. Requirements for Relocation

*a. Applicability.* Relocating contents within an existing structure at its current location is effective in any case, but the damage reduction possible is limited. The residual damage is likely to be great. Permanently removing the contents or the structure and contents from a flood hazard area similarly reduces damage in any case, but is likely to be costly and, thus, economically feasible only for higher value structures. Permanent relocation is physically feasible for a limited class of structures (USACE 1978).

*b. Overview of relocation.*

(1) The term relocation, as used in this manual, means moving property so it is less susceptible to damage. This may be accomplished by (a) relocating contents within an existing structure at its current location or (b) removing the contents or the structure and contents from a flood hazard area.

(2) Examples of relocation of contents within a structure are shown in Table 8-4. These are relatively simple measures that can be undertaken by any property owner. The relocation can be temporary or permanent. Effectiveness depends on the type of contents and flood hazard.

**Table 8-4**
**Examples of Relocation (from USACE 1978)**

1. Protecting HVAC equipment, appliances, shop equipment by raising off floor.

2. Relocating property to higher floors.

3. Relocating commercial and industrial products, merchandise, equipment to higher floor or higher building.

4. Relocating finished products, materials, equipment, other movable items now located outside to higher ground.

5. Protecting electrical equipment by raising on pedestal, table, platform.

6. Anchoring property that might be damaged by floodwater movement.

(3) Removing contents or a structure is an effective, if costly, solution to the flood-damage problem in any circumstance. To accomplish this, a building site outside the flood hazard area must be located and purchased or leased. In the case of moving a structure, the new site must be prepared; the structure must be raised, transported, and installed at the new site; contents must be moved; and the old site restored. For relocating contents only, a structure outside the hazard area must be built or leased, and contents must be moved.

*c. Flood damage reduction assessment.* Relocation reduces flood damage by reducing the damage incurred at a given stage. In the extreme, if all structures and their contents are moved from the flood hazard area, the stage-damage function is reduced to zero damage for all stages in the range of practical interest. More practically, if selected structures or contents are relocated, the stage-damage function will be modified to reflect the lowered value of property that would be inundated at a given elevation. In general, the damage for a specified stage will be reduced; the exact form of the modified with-project stage-damage function depends on location and value of property relocated.

*d. Technical considerations.*

(1) Hydrologic engineering plays a critical role in formulating relocation plans. Properties subject to inundation and reduced-hazard elevations to which contents must be moved or sites to which structures should be moved must be identified. If a significant number of structures or goods stored outside are moved, the hydraulic properties of the floodplain may change, and the impact using alluvial or fluvial process models, such as those described in Appendix B, must be assessed.

(2) If relocation of contents is a temporary flood damage reduction measure, the plan must include a forecast and warning component. The requirements are presented in paragraph 8-4.

## 8-4. Requirements for Flood Warning-Preparedness Plans

*a. Applicability.* A FW/P program may be implemented as (1) a stand-alone measure when other measures are not feasible, (2) an interim measure until others are in-place, or (3) a component of other measures. FW/P as a stand-alone measure provides only minimum damage reduction. Even with the most efficient forecast and best-planned response system, the possibility of significant damage continues to exist in a managed manner. A FW/P plan has no significant environmental impact in most cases.

*b. Overview of flood warning and preparedness plans.*

(1) A FW/P plan reduces flood damage by providing the public with an opportunity to act before stages increase to damaging levels. The savings due to a FW/P plan may be due to reduced inundation damage, reduced cleanup costs, reduced cost of disruption of services due to opportunities to shut off utilities and make preparations, and reduced costs due to reduction of health hazards. Further, FW/P plans may reduce social disruption and risk to life of floodplain occupants.

(2) A FW/P plan is a critical component of other flood damage reduction measures, as pointed out elsewhere in this manual. In addition, the Corps Flood Plain Management Services (FPMS) staff may provide planning services in support of local agency requests for assistance in implementation of a FW/P plan; this is authorized by Section 206 of the Flood Control Act of 1960.

*c. Flood damage reduction assessment.* A FW/P plan reduces inundation damage by permitting the public to relocate property, close openings, close backflow valves, turn on sump pumps, and take other actions that will lower the damage incurred when water reaches a specified stage. Estimating the form of the modified, with-project stage-damage function requires estimating the accuracy of a forecast and how the public will respond to a warning. Day (1973) suggested a method for estimating the benefit, but the hydrologic engineering study should make estimates appropriate for each particular application.

*d. Technical considerations.* Table 8-5 shows the components of a complete FW/P plan. If the plan is to function properly, it must include each of these components. Formulation and subsequent design of the flood threat recognition subsystem is part of the hydrologic engineering study. Likewise formulation of the emergency-response plan requires information from the hydrologic engineering study as does delineation of inundated areas and identification of escape routes. USACE (1986) provides guidance.

**Table 8-5**
**Components of a FW/P System (adapted from USACE 1988a)**

| Component | Purposes |
|---|---|
| Flood-threat-recognition subsystem | Collection of data and information; transmission of data and information; receipt of data and information; organization and display of data and information; prediction of timing and magnitude of flood events. |
| Warning-dissemination subsystem | Determination of affected areas; identification of affected parties; preparation of warning messages; distribution of warning messages. |
| Emergency-response subsystem | Temporary evacuation; search and rescue; mass care center operations; public property protection; flood fight; maintenance of vital services. |
| Postflood recovery subsystem | Evacuee return; debris clearance; return of services; damage assessment; provisions for assistance. |
| Continued system management | Public awareness programs; operation, maintenance, and replacement of equipment; periodic drills; update and arrangements. |