

# Chapter 7

## Flood Damage Reduction Strategies and Tools

### Chapter Overview

The two primary goals of floodplain management are (1) reduction of economic losses and threats to public health and safety from flooding, and (2) preservation and restoration of the natural and beneficial functions and resources within floodplains. Means of achieving the first goal is the focus of this chapter. The second goal will be addressed in a subsequent chapter.

There are three basic strategies that may be applied individually or in combination to reduce threats to life and property from flooding. They are:

- ∞ Modify the susceptibility to flood damage and disruption
- ∞ Modify the adverse impacts of floods on the individual and the community, and
- ∞ Modify floods

Under each “strategy” there are a number of “tools” that can be employed. They are depicted in Figure 7-1. This chapter will address these strategies and tools.

### Introduction

At a period when the nation is particularly aware of allocating scarce resources among competing economic, environmental, and social needs, public and private decisions affecting floodplains must give explicit consideration to the hazards to life and property. Proposed solutions to flood hazard problems must be evaluated in the context of all alternative strategies and of the technical, financial, and legal capabilities of all affected parties to carry out their responsibilities.

Legislative and administrative policies frequently cite two approaches – structural and nonstructural – for adjusting to the flood hazard. In this context, “structural” is usually intended to mean adjustments that modify the behavior of floodwaters through the use of measures such as dams, levees, and channel modifications. “Nonstructural” is usually intended to include all other adjustments (e.g., land-use regulations, flood insurance) in the way society acts when occupying or modifying a floodplain. Both structural and nonstructural tools are used for achieving desired future floodplain conditions. As stated above, there are three basic strategies that may be applied individually or in combination: (1) modifying the susceptibility to flood damage and disruption, (2) modifying (reducing) the adverse impacts of floods on the individual and the community, and (3) modifying the floods themselves.

Because the land and water resources of the floodplain and the flood-related problems and needs are highly varied, different strategies must be used to achieve desired objectives in different settings. Within these strategies are a large variety of options or “tools” for enabling desired uses or changing the uses of the floodplain. Each situation is different, but the basic objectives of floodplain management cannot be realized without also lowering the direct or indirect adverse

# **Management Strategies – Flood Loss Reduction**

## ***I. Modify Susceptibility to Flood Damage and Disruption***

- A. Floodplain Regulations**
  - 1. Zoning Ordinances
  - 2. Subdivision Regulations
  - 3. Building Codes
  - 4. Housing Codes
  - 5. Sanitary and Well Codes
  - 6. Other regulatory tools
- B. Development and Redevelopment Policies**
  - 1. Services and Utilities
  - 2. Land Rights, Acquisition, Open Space
  - 3. Redevelopment and Urban Renewal
  - 4. Evacuation/Relocation
- C. Disaster Preparedness, Assistance, and Recovery**
- D. “Floodproofing”**
- E. Flood Forecasting and Warning/Emergency Plans**

## ***II. Modify the Impact of Flooding on Individuals and the Community***

- A. Information and Education**
- B. Flood Insurance**
- C. Tax Adjustments**
- D. Flood Emergency Measures**
- E. Post-Flood Recovery**

## ***III. Modify Flooding***

- A. Dams, Reservoirs**
- B. Dikes, Levees, Floodwalls**
- C. Channel Alterations**
- D. High-Flow Diversions and Spillways**
- E. Land Treatment**
- F. Onsite Detention**
- G. Shoreline Protection Measures**

**Figure 7-1. Flood loss reduction management strategies.**

impacts of flood losses on the individual and the community to an acceptable level. In almost every community, some combination of strategies and tools is required to achieve the desired management objectives.

Although these strategies and associated tools for floodplain management may be used to guide public and private decision makers, there is a prerequisite and perhaps less obvious challenge, that of understanding the overall area's needs and goals. Meeting this challenge requires formulation of assumptions about the future development of the area and region as well as sensitivity to impacts beyond the immediate consequences of an action. For example, in the past, flood-modifying works frequently failed to account for indirect social costs (e.g., displacement) and environmental resources destroyed, although both represent costs passed on to the public. In recent decades there has been a trend toward increased reliance on nonstructural measures and less reliance on structural measures to address flood losses.

It must be realized, however, that some degree of flood loss potential remains, regardless of how carefully floodplain management programs are formulated. Appropriate selection from the following strategies and tools is predicated on these understandings.

### **Modify Susceptibility to Flood Damage and Disruption**

The strategy to modify susceptibility to flood damage and disruption consists of actions to avoid dangerous, uneconomic, undesirable, or unwise use of the floodplain. Responsibility for implementing such actions rests largely with the non-federal sector.

These actions include restrictions in the mode and the time of day and/or season of occupancy; in the ways and means of access; in the pattern, density and elevation of structures and in the character of their materials (structural strength, absorptiveness, solubility, corrodibility); in the shape and type of buildings and their contents; and in the appurtenant facilities and landscaping of the grounds. The strategy may also necessitate changes in the interdependencies between floodplains and surrounding areas not subject to flooding, especially interdependencies regarding utilities and commerce.

Implementing "tools" for these actions include land use regulations, development and redevelopment policies, floodproofing, disaster preparedness and response plans, and flood forecasting and warning systems. Land treatment measures, although discussed later in the strategy to "Modify Flooding," can also function to modify susceptibility to flood damage. Different tools may be more suitable to developed or underdeveloped floodplains or to more urban or rural areas.

### **Floodplain Regulations<sup>1</sup>**

Floodplain regulations are efficient tools for modifying future susceptibility to damage or loss, both on floodplains that are not fully developed and on highly developed floodplains where older structures are being rehabilitated. By providing direction to growth and change, regulations are particularly well-suited to preventing unwise floodplain occupancy. Land use regulations require that individuals recognize the general welfare when making decisions. Legal treatment of floodplain regulations and their adoption will be addressed in a subsequent chapter. A combination of regulatory tools is necessary to control development in floodplains, and they are frequently utilized in combination with other techniques.

Floodplain regulations which are part of broader land use regulations can be applied effectively only by state and community action. They are often required under ongoing federal programs (e.g., National Flood Insurance Program) as a prerequisite to other assistance. Administration of

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<sup>1</sup> Land-use regulations for floodplain management, introduced here, will be covered in greater detail in Chapter 15.

floodplain regulations adds only a small incremental cost where other ordinances are already being administered and these costs are characteristically small in relation to the flood damage problem.

To some degree, individual opportunity foregone is a cost of all land use regulations. The net economic cost, i.e., reflecting externality costs, of reducing the intensity of use may be large or small. This cost depends on the availability of alternatives to a floodplain location.

To be effective regulations must be based on sound and suitable technical data, must be equitably applied, and should permit reasonable use of the land (not necessarily highest economic return). Provisions have to be made to handle “nonconforming uses,” i.e., construction or use that occurred before adoption of regulations and that now do not conform to the regulations.

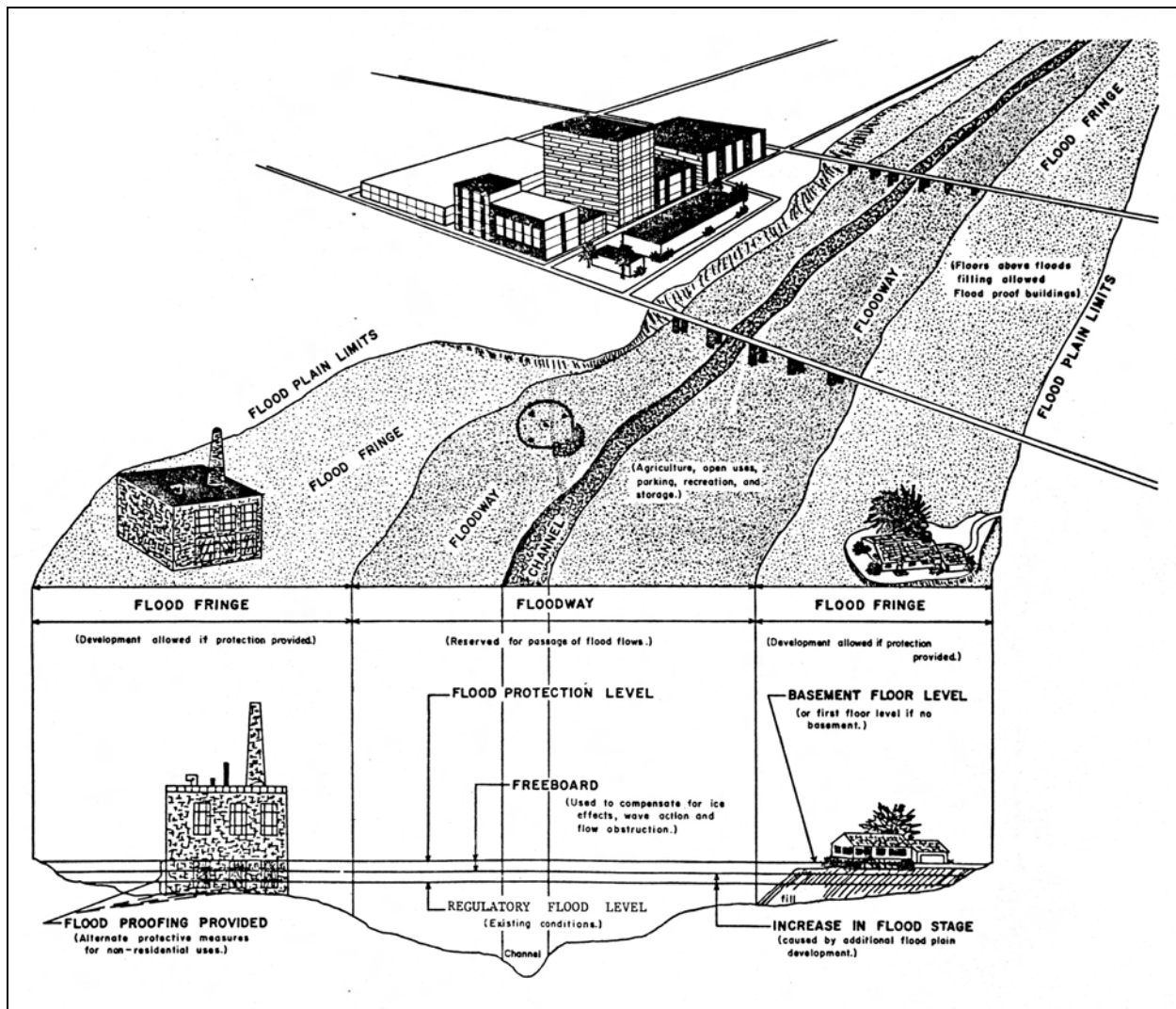
The regulatory aspects of floodplain management programs are sensitive to political pressures for change in favor of individuals, but they can be effective when equitably reinforced at all government levels. Several types of “police power” regulation are in use in some states and nearly all localities to regulate land uses in flood hazard areas.

A number of states require their local units of government to regulate floodplain development consistent with minimum state objectives and standards. They and other states may also provide advice and assistance in understanding, interpreting and enforcing regulations. Many state boards of health regulate the use of private and public waste disposal systems. Some prohibit private systems in areas subject to high groundwater or flooding.

The principal local control of flood hazard areas is through zoning, subdivision regulations, building and housing codes, and sanitary codes with specific flood hazard provisions.

Zoning divides a government unit into specified areas for the purpose of regulating (a) the use of structures and land, (b) the height and bulk of structures, and (c) the size of lots and density of use. Zoning may be used to set special standards for land uses in flood hazard areas including specification of minimum floor elevations to place them above expected flood levels. Floodplain zoning is commonly single district (all of the designated floodplain in a special district) or two district (division of the floodplain into the “floodway” and “flood fringe”).

Administration of riverine floodplain zoning ordinances is simplified by the designation of floodway or floodplain encroachment limits. Floodway limits are designated, as part of the planning process, so that any development that is permitted in the remainder of the floodplain (i.e., within the flood fringe) will not result in a flood stage increase over a prescribed amount (usually one foot) of a specified frequency flood (usually the 1 percent annual chance flood) at any location along the studied stream. These measures are illustrated in Figure 7-2.



**Figure 7-2. Illustration of floodplain regulation terms.**

Although the floodway concept does not apply in coastal areas, there is a parallel for high hazard coastal and lakeshore areas where the major forces of tides and waves come into play and where erosional changes are at a maximum during flooding. The National Flood Insurance Program designates such areas as “coastal high hazard areas” on maps they prepare for coastal communities.

Subdivision regulations guide the division of large parcels of land into smaller lots for the purpose of sale or building. Often the community’s jurisdiction is extended beyond its boundaries by subdivision-enabling legislation. Such extension provides coverage usually unavailable through zoning.

Subdivision regulations guide the process of land division to ensure that lots are suitable for intended use without putting a disproportionate burden on the community. They also control improvements such as roads, sewers, water, and recreational areas. Subdivision regulations often require (a) installing adequate drainage facilities, (b) showing the location of flood hazard areas on the plat, (c) avoiding encroachment into floodplain areas, (d) determining the most



appropriate means of elevating a building above the regulatory flood height in accordance with sound engineering practice, and (e) placing streets and public utilities relative to the selected flood protection elevation. These provisions are illustrated in Figure 7-3.

Building Codes regulate neither the location nor the type of development; rather, they control building design and use of construction materials. Building codes can reduce flood damages to structures by setting specifications to (a) require suitable anchorage to prevent flotation of buildings during floods; (b) establish minimum protection elevations for the first floors of structures; (c) require electrical outlets and mechanical equipment to be above regulatory flood levels or be appropriately “floodproofed” (described later); (d) restrict use of materials that deteriorate when wetted; and (e) require an adequate structural design, one that can safely withstand the effects of water pressure and flood velocities. General floodproofing requirements (as performance standards) are sometimes included in floodplain zoning ordinances rather than in building codes. Building codes have an added value in that they also may be used to require flood protection to below-ground spaces in areas beyond the regulatory area but still within the zone of sewer backup and flood-elevated groundwater.

Housing Codes like building codes, set minimum standards for construction, but they also set minimum standards for maintenance of structures. These may be used to require repair of flood-damaged structures in a manner that will ensure the safety of occupants and prevent blight.

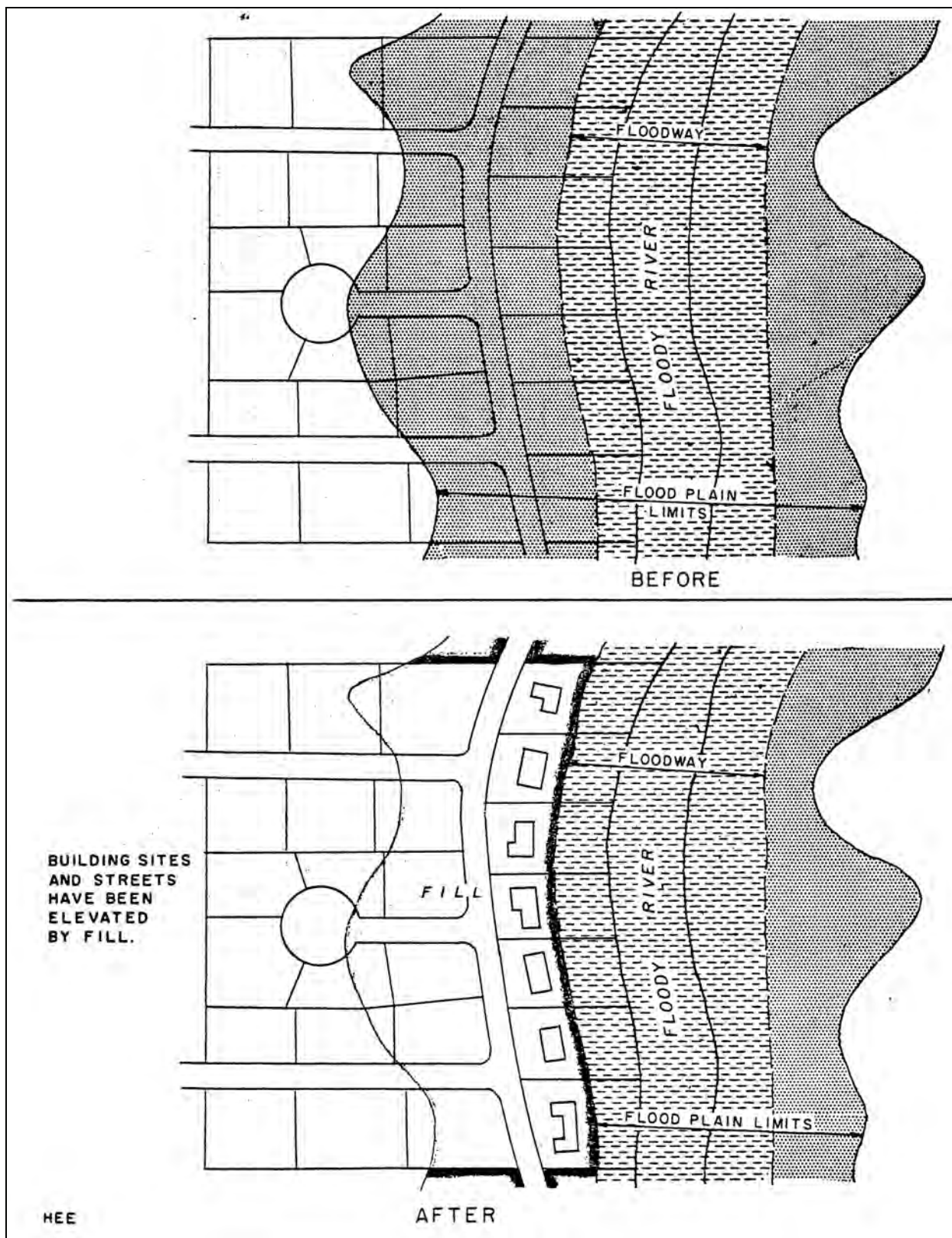
Sanitary and Well Codes establish minimum standards for waste disposal and water supply. Sanitary codes commonly prohibit onsite waste disposal facilities such as septic tank systems in areas of high groundwater and flood hazards. Sometimes elevation or floodproofing requirements are established for public sewer systems. Well codes often establish special floodproofing requirements for facilities located in flood hazard areas in order to reduce their potential for contamination during flooding.

Other Regulatory Tools are available to reduce flood losses and promote sound management of flood prone lands. Special statutes may require that sellers or real estate brokers disclose flood hazards on marketed lands. Interstate Land Sales Registration statements of natural hazards protect buyers or potential buyers unfamiliar with the area. Official maps designate areas where structural development is planned for reservoirs, dikes, levees, parks, or other public areas.

### **Development and Redevelopment Policies**

Other public actions not necessarily employing the police power can modify susceptibility to flood damage and guide development in a manner that takes into account the flood hazard and natural characteristics of the floodplain. Such actions may be applied at the local, state, and federal levels through the design and location of utilities and services, through policies of open space acquisition and easement, and through redevelopment or permanent evacuation. These measures are normally required in any viable community, but in this context they should reflect the flood hazard. They can often be more effective than local land use regulations.

Design and Location of Services and Utilities reduce flood loss potentials by guiding private and public developments (hence public services and utilities) to low risk areas or areas not subject to flooding. Local governments can exercise discretion in extending roads or sewer and water mains or their access in flood hazard areas. Locating libraries, schools, post offices, and other public and government facilities away from the flood hazard area not only lessens the possibility of flood damages to such buildings but prevents them from otherwise encouraging private development in areas prone to flooding.



**Figure 7-3. Typical floodplain subdivision before and after site preparation.**

Land Rights, Acquisition, and Open Space Use lessen the potential for flood losses and their consequences. Land is purchased directly, or control is purchased through easements or

development rights, for the purpose of precluding future uses incompatible with floodplain management programs and for the purpose of providing open space. In the short run, acquisition may be a costly substitute for regulation but the best tool in certain circumstances, and it may be the only acceptable approach if the proposed use has a specific non-flood-related purpose, such as for public use areas. Easements are being used in some situations to continue agricultural or undeveloped use of the land, particularly where development pressures are high. Regulations cannot be used to change ownership from private to public.

Redevelopment may offer a tool for improving floodplain areas blighted for reasons that may or may not include exposure to flooding. Usually the motives for redevelopment are broader than just flood damage reduction. However, the principles of floodplain management can be accomplished in the process. Disaster assistance, urban redevelopment, economic development, and other community development activities should be coordinated in such situations. The opportunities for and justification of redevelopment should not be overlooked. Redevelopment may help to achieve at least some of the floodplain management objectives by improving both economic efficiency and the natural environment.

Permanent Evacuation, like redevelopment, of which it may in fact be part, is increasingly being carried out in the aftermath of federally-declared flood disasters. Several thousand flood-damaged structures were acquired and removed from the floodplain after the 1993 Midwest flood and after Hurricane Floyd caused extensive flooding in eastern North Carolina in 1999. The cleared land, intended for open space uses, was transferred to local governments with permanent restrictions on resale or placement of any future structures. Principally the federal government provided funding, usually on a 75-25 or 90-10 cost-share ratio with state and local governments. In other instances structures and facilities are relocated from floodways and other perilous flood prone areas. In a number of cases, permanent evacuation of floodplain areas may be the only economically feasible alternative.

### **Disaster Preparedness**

Preparedness plans and programs provide for pre-disaster mitigation, warning and emergency operations. Training at all levels, public information activities, and readiness evaluations are all tools available within disaster preparedness. Coordination of local, state and federal disaster preparedness plans and programs is essential. Success is closely associated with the degree to which individuals, local governments, and states protect themselves by taking appropriate hazard mitigation measures and obtaining flood insurance coverage to supplement or replace government assistance.

### **Disaster Assistance**

Disaster assistance may be provided by federal, state, or local governments and certain nonprofit organizations to repair, replace, or restore facilities damaged or destroyed by a disaster. In today's political climate, federal assistance is usually available to assist state and local governments in the recovery effort. Relief and recovery efforts from the public and private sectors help individuals, business owners, and the community after a flood. Initial measures include cleanup and resumption of services, followed by longer-term recovery measures.

Post disaster evaluation may provide the opportunity for the implementation of innovative hazard mitigation strategies. Usually a percentage (10-15) of total disaster funds made available by the federal government is designated for mitigation measures. Flexibility may exist to construct other needed facilities in lieu of restoring the damaged or destroyed facilities. Permanent restorative work to rebuild damaged facilities should be in conformity with applicable codes, specifications, plans, and standards. Acquisition of properties that have been frequently or extensively damaged also should be considered.



## **Disaster Recovery**

While it is most desirable to develop preparedness and recovery programs prior to flood disasters, the opportunity should be seized when such disasters occur to design recovery and redevelopment activities that will reduce or eliminate future flood hazards. This is particularly important during the brief “window of opportunity” after a disaster when public interest, political support, and the availability of outside assistance are at their highest levels.

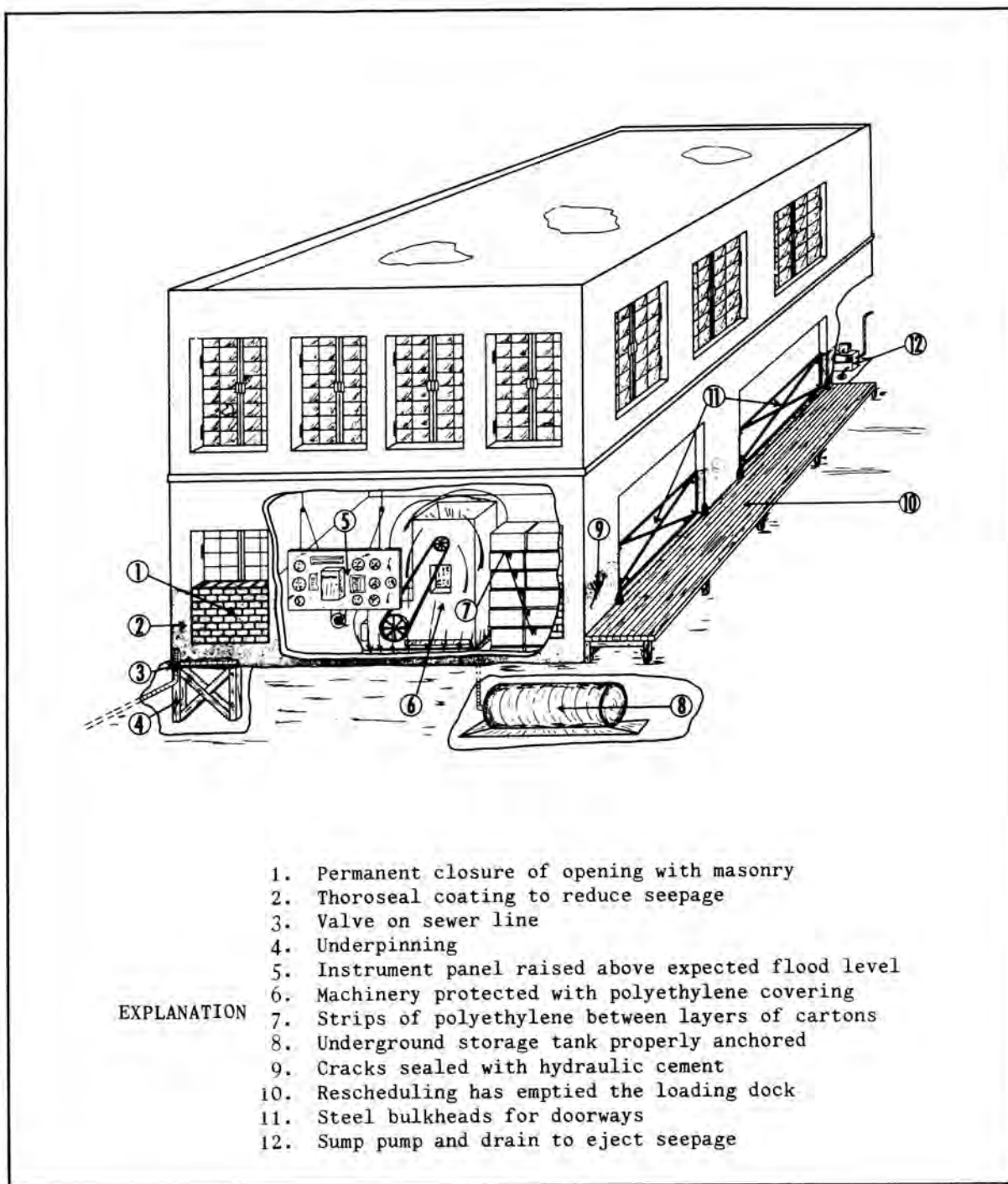
## **Floodproofing**

Floodproofing can provide for development in lower risk floodplain areas by keeping damage within acceptable limits. It can be chosen by an individual or government agency for existing structures as well as new construction.

Floodproofing consists of modifications of structures, their sites, and building contents to keep water out or reduce effects of water entry. Such adjustments can be installed when buildings are under construction or during repair, remodeling, or expansion of existing structures.

Floodproofing may be permanent (e.g., bricked-in openings) or it may be contingent on some action at the time of the flood. The adjustment may be by elevation (on fill or open work such as piling), by appropriately constructed ring dikes or their equivalent, or by water proofing (closure, seals, pumps, valves or pipes), or other measures. Some possible measures are illustrated in Figure 7-4.

Like other methods of adjusting to floods, floodproofing has limitations. It can generate a false sense of security, and residual losses may be very high. A primary purpose of floodproofing structures is to reduce property losses and to provide for early return to normalcy after floods have receded rather than for continuous occupancy. Only very substantial and self-contained structures should be occupied during a flood. Unless correctly used, floodproofing can increase unwise use of floodplains. Applied to structurally unsound buildings, it can result in more damage than would occur without floodproofing, in part because of the false sense of security and resultant inappropriate actions and decisions. The application of economic criteria is more likely to justify floodproofing for commercial structures than for residential structures. Usually it is applied to individual structures, but it is only partially effective unless it is also applied to means of access. Access to buildings should be passable at least in floods up to the magnitude used in setting floodproofing elevations. Floodproofing should never protect some property owners while aggravating the hazard for others.



**Figure 7-4. Possible floodproofing measures.**

The U.S. Army Corps of Engineers established a National Floodproofing Committee around 1990 to advance knowledge and application of floodproofing. The committee has developed and published a number of manuals on the subject. Among Corps publications is a detailed manual on

floodproofing concepts, in model building code format. The manual cover is reproduced as Figure 7-5. Some of its contents will be utilized in a more detailed discussion of floodproofing in Chapter 16.

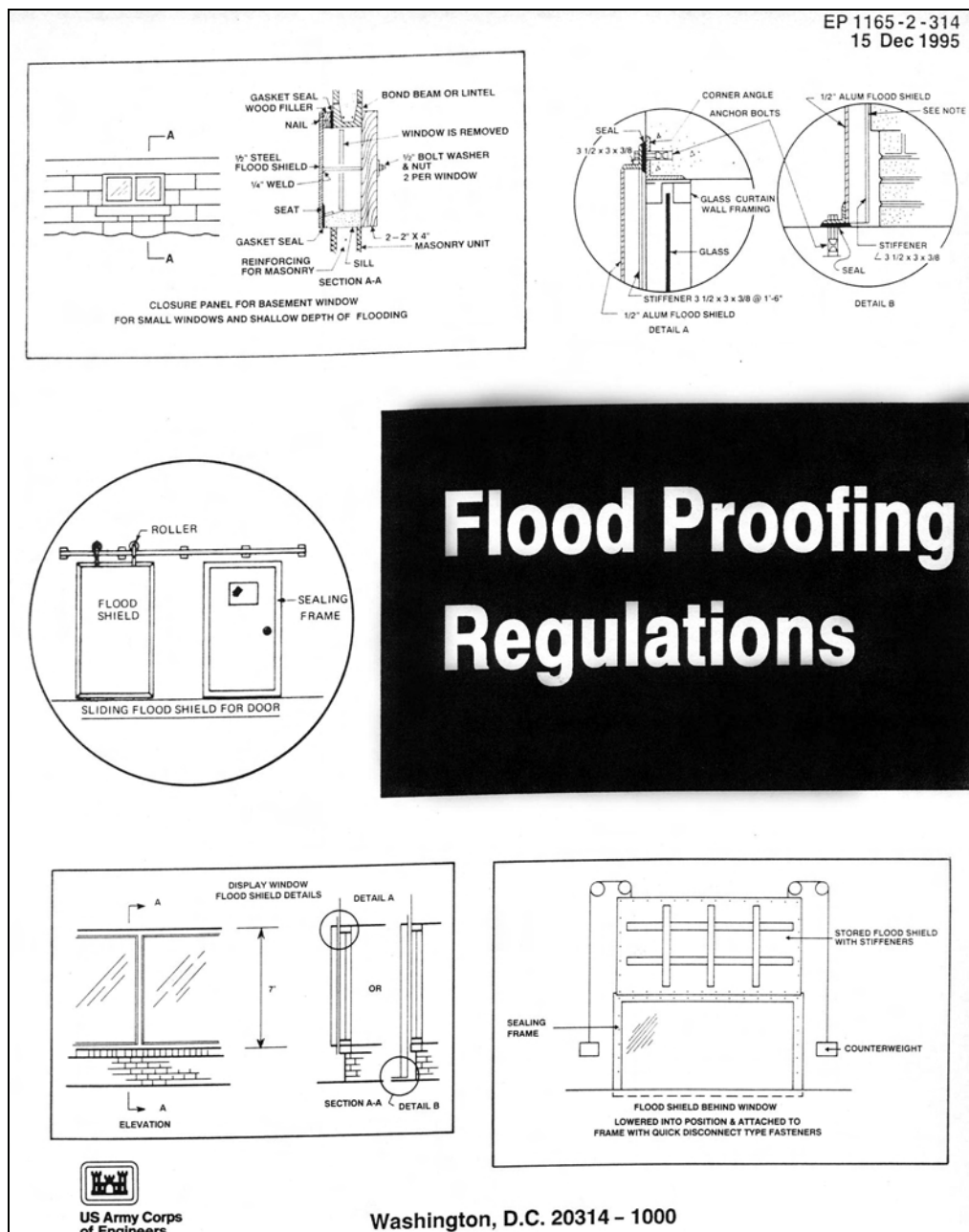


Figure 7-5. U.S. Army Corps of Engineers manual.

### Flood Forecasting and Warning Systems and Emergency Plans

Flood forecasting systems have been established for the major river systems in the United States. These systems provide information on the time of occurrence and magnitude of flooding to be expected. On major rivers where the flood crest moves slowly, warnings are provided several days to a few weeks in advance of the event. For smaller tributaries, warning times decrease to a matter of a few hours and probably not more than a day or two at a maximum. On short headwater streams with steep channel gradients, flash flood warnings may be possible only a few

hours or even a few minutes in advance of the event. Community warning systems can be established for such conditions, but the short interval available for warning and response demands even tighter advance planning and preparedness than is required for areas with longer warning periods.

The effectiveness of flood watches (possibility of flooding) and warnings (imminent or occurring) depends upon the effectiveness of their dissemination to the public, the time available, and the actions taken in response. At a minimum, local officials, police, fire and rescue squads, and radio and television stations are notified. They are also issued on weather Internet sites. Warnings must be effectively presented.

The success of flood forecasting and flood warning systems depends upon having an emergency action plan and attendant implementing organization in place before a flood occurs. The flood prone community must look upon the emergency action plan as its plan since only the local community can make the plan work. The emergency action plan must recognize that as the length of warning period decreases, the opportunity for emergency action including temporary evacuation diminishes accordingly. In many cases contingency and emergency floodproofing and the removal of goods and inhabitants are possible with sufficient warnings, but flash floods may permit only the evacuation of inhabitants.

### **Modify the Impact of Flooding on Individuals and the Community**

A second strategy for mitigating flood losses consists of actions designed to assist individuals and communities in their preparatory, survival, and recovery responses to floods. Tools include dissemination of information and education, arrangements for spreading the costs of the loss over time, and purposeful transfer of some of the individual's loss to the community. The distinction between a reasonable and unreasonable transfer of costs from the individual to the community, as described under the preceding section on regulations, is a key element.

### **Information and Education**

Flood hazard information is a prerequisite to sound floodplain management. The development of needed technical information and public education, especially by or for the officials and planners who will have the major task of interpreting and applying it, are essential in an effective floodplain management program. Although available in many forms and from many sources, such information is neither of uniform quality nor available for all areas. Vital information includes the hydrology and hydraulics of small, large, and very large floods on the areas subject to inundation, on the floodplain's resource attributes, on the role of the floodplain within its region, and on the potential impact of land use decisions on expected flooding. From this information, responsible government and private decision makers can formulate alternative floodplain management approaches. Better information on property at risk and probabilities of various levels of damage or loss can help to translate the hazard into terms that stimulate appropriate local action. Federal, state, and local agencies and private consultants are all providing this sort of information, with major emphasis on the more technical aspects of risk analysis provided principally by the federal agencies.

With this said, a major conundrum is *how to organize information into educational programs that target citizens in flood risk areas of our country?*

What we have today is a widespread problematic interpretation of the term "100-year flood." One authority noted that every floodplain manager he's talked to has a story about how people misunderstand it.

University of Arizona hydrologist Dr. Victor Baker even calls it "the most spectacular failure of public communication for any scientific concept of our time." Some floodplain experts have



now come to use the term “one percent” but it is not widely known or used by the public, banks, realtors, etc. He notes that this term swirls in a larger maelstrom of floodplain demarcation, property rights and political chess that usurp precious time and attention from developing a more informed citizenry.

### **Flood Insurance**

Insurance is a mechanism for spreading the cost of losses both over time and over a relatively large number of similarly exposed risks. Until 1969, insurance against flood loss was generally unavailable. Under the National Flood Insurance Program (NFIP), initiated in 1968 and significantly expanded in 1973, the federal government makes flood insurance available for existing property in the flood hazard area. In return, participating localities must enact and enforce floodplain management regulations designed to reduce future flood losses and regulate new development in the designated flood hazard area in accordance with the calculated risk. The regulations must, at a minimum, be consistent with NFIP criteria.

By emphasizing the long-term advantages of wise floodplain use and by providing a mechanism for widespread risk sharing, the National Flood Insurance Program provides persuasive strength and beneficial emphasis to local floodplain management. First layer insurance coverage is made available at subsidized rates to property owners whose location decisions and building construction were completed before identification of the specific nature and extent of their flood hazard. First and second layer insurance coverage is made available at actuarial rates to property owners of new buildings. Insurance may not be sold in areas designated under the Coastal Barrier Resources Act (covered in a subsequent chapter). Specific information is provided to potential owners of floodprone properties about the economic costs of locational decisions, and thus serves to discourage unwise construction in hazardous floodplain areas. The program’s floodplain management provisions help reduce flood losses and the dependency upon public support. The NFIP will be covered in more detail in Chapter 10.

### **Tax Adjustments**

Tax adjustments at the federal, state, or local level can play an important role both in influencing decisions about floodplain occupancy and in providing relief to individuals. Tax provisions can be used to encourage appropriate use and discourage inappropriate use. It is highly important that the tax structure recognize the regulatory aspects of the program so that the latter are reinforced, e.g., low density use achieved by regulations can be supported by low tax for such use. Amortization provisions can be applied to nonconforming uses. Financial relief can be found in provisions for claiming losses in federal and state income taxes and through special allowances on real estate taxes that may be enacted by local officials following a flood.

### **Flood Emergency Measures**

Preparation for floods and flood-fighting plans, including contingency and emergency floodproofing, can be completed in anticipation of flooding for areas where flood warning time permits these actions. They must be properly integrated with emergency evacuation plans of the type mentioned in the previous section. Temporary earthen dikes are an example of an emergency measure. Flood fighting has been effective in helping communities to survive a flood. But opportunities for successful flood fighting are limited by flood characteristics; the physical nature of some flood problem areas; and the large manpower, fiscal, supply, and equipment requirements. It should also be recognized that one of the functions of overall floodplain management is to reduce the need for this type of emergency action, which at best is stopgap.



**Photograph of flood fight activities –  
1997 flood. U.S. Army Corps of  
Engineers**

### **Post-Flood Recovery**

Like other aspects of floodplain management, post-flood recovery requires a plan. Public facilities and services are restored and aid given to individuals. Aid from public and quasi-public agencies is often in the form of donations of food and clothing or grants and loans (which may be counterproductive if used to rehabilitate damaged structures or property located in high hazard areas). Relief may also be in the form of tax adjustments. Although relief does not directly reduce flood losses, it does reduce the overall loss impact by shortening the period of disruption and by accelerating the return to normalcy. Under various federal legislation, property owners in a flooded community may be required to purchase and maintain flood insurance as a condition for obtaining federal financial assistance.

It is essential that plans for post-flood recovery proceed with reuse and/or reconstruction in a way that will minimize future flood exposure. Following a Presidentially declared disaster, funds are made available for mitigation as part of the recovery process. They can be used to implement long-term area and watershed plans for reducing flood losses.

### **Modify Flooding<sup>2</sup>**

The traditional strategy of modifying floods relies upon the construction of dams, dikes, levees, floodwalls; channel alterations; high-flow diversions and spillways; and land treatment measures. These tools permit changes in the volume of runoff; in the peak stage of the flood; in the time of rise and duration; in the extent of the area flooded; in the velocity and depth of floodwaters; and consequently in the amount of debris, sediment, and pollutants that floods carry. While the effectiveness of these tools in protecting property and saving lives has been demonstrated repeatedly, sole reliance upon a flood modification strategy is neither practical nor desirable.

Flood modification (structural) measures acting alone leave a residual flood loss potential within the remaining floodplain and add the risk of rare but potentially devastating damages from structural failure or from uncontrolled flows of major storms. Unless accompanied by appropriate nonstructural measures, the structural measures could lead to a false sense of security and encourage floodplain landowners to develop inappropriate uses of their lands. For this reason, some form of land use regulations and other appropriate nonstructural measures should accompany the implementation of structural measures. (Initially introduced here, measures to modify flooding will be covered in greater detail in Chapter 16.)

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<sup>2</sup> Initially introduced here, measures to modify flooding will be covered in greater detail in Chapter 16.

### **Dams and Reservoirs**

Storage of floodwaters in reservoirs causes the broadest range of flood-modifying effects such as reduction in flood flow rate, extent of area flooded, timing, etc. Except in the area immediately downstream from the dam, however, storage may not provide as high a degree of relief from flood damage in specific areas as may be achieved by other more localized tools. Flood storage may function alone, in groups, or with other tools.

Release of water detained by dams may be at a fixed rate, or it may be varied to accommodate changing downstream conditions during a flood. Dams and reservoirs also have potential for wide multiple-purpose uses that more localized measures may not achieve. In some already well developed valleys, storage provides the only significant means of reducing the flood damage potential for widespread areas short of removing the potential for damage from the floodplain.

In addition to the large areas of land that they occupy, reservoirs may also modify stream behavior and habitat in both beneficial and adverse ways. These facilities may reduce or contribute to downstream erosion, and sediment accumulation in the reservoir is a significant consideration in engineering design for long-term effectiveness.

### **Dikes, Levees, and Floodwalls**

Dikes, levees, and floodwalls protect a portion of the floodplain from flooding, up to a design level. These works may have adverse as well as beneficial effects. They can increase the height of the flood immediately upstream, across the stream, and downstream by reducing the amount of floodplain area available for overbank floodwater conveyance and/or storage. Their appeal lies in their direct and specific results. Sometimes emergency dikes or levees are built following a flood forecast. Although they may be effective for the emergency, they should not be considered as permanent flood protection measures. (Removal of emergency measures often does not occur because of cost and passing interest.)

Dikes, levees, and walls cannot feasibly be built high enough to provide protection against all floods, and the consequences of their overtopping and failure during a major flood may be grave. They may require expensive pumping facilities to handle the storm water collected behind the constructed barrier. They can cut off river views and access and are not as adaptable to multiple-purpose uses as are reservoirs. Experience shows that levees often have to be increased in height if channel aggradation takes place or if originally planned upstream storage reservoirs are not built because of loss of the sites to development or lack of public support for their construction.

### **Channel Alterations**

In some situations channel alterations (never use “improvements;” many say human modification of natural channels do not “improve” them) may be the only feasible structural tool for protecting the area subject to flooding. Because channel alterations can accelerate the quantity and/or velocity of flow through an area, they may increase the flood impacts on downstream reaches. Enlarging a channel and shortening its course disturbs the stream regimen and, in turn, the existing ecology. To assure proper channel functioning, snagging and clearing operations may be necessary. Maintenance costs may be high unless the channel and stream banks are stable. Use of concrete or stone where necessary for stabilization increases construction costs and may be esthetically undesirable in some locations.

### **High Flow Diversions**

High flow diversions typically redirect excess flows away from developed areas using natural or artificially constructed bypass channels or conduits. Physical opportunities for application of flood flow diversions are limited. Where such measures can be employed, they may be least

objectionable from an environmental standpoint if they minimize the destruction of the land-water interface in the natural channel. However, in some circumstances, such diversions may sharply alter downstream flow patterns and discharges, thereby producing unwanted environmental effects. Where communities are not adequately protected from flooding by diversion, additional measures may be required.

A noted example of a high flow diversion in the United States is the Bonnet Claire spillway on the Mississippi River above New Orleans which can divert floodwaters into Lake Pontchartrain, bypassing the city. In Canada, a diversion carries a major portion of floodwaters from the Red River of the North around Winnipeg, Manitoba.

### **Land Treatment Measures**

Land treatment measures modify floods by increasing infiltration and decreasing the amount and rate of runoff. These measures may also be viewed as modifying susceptibility to flood damage. They include vegetative cover, runoff interceptors and diversions, small detention and erosion control structures, terraces, and cropping management practices (which also serve to modify susceptibility to flood damage). They are effective in small headwater areas and function in combination with other measures to ameliorate flood conditions in larger watersheds. In most respects, land treatment measures produce changes in the broad range of flooding effects, although they become less effective as flood size increases. They can be especially important in reducing erosion and the resulting amount of sediment and pollutants carried downstream.

### **Onsite Detention Measures**

Whereas land treatment measures are appropriate primarily in non-urban areas, onsite detention measures can provide temporary storage of urban runoff waters, extending the period of runoff with the intent of reducing flood peaks. The temporary storage of runoff may also result in increased infiltration. These measures may take the form of earthen or paved holding areas integral to or adjacent to the site. A growing number of urban communities are including onsite detention requirements in land development ordinances. Common applications involve residential subdivisions, business parks, and shopping centers. Effective implementation of these measures includes providing for continuous maintenance, determining the drainage area to be served by a single structure, and determining the effects of detention on the timing of runoff in different segments of the watershed.

### **Shoreline Protection Measures**

There are four main categories of such measures. The first includes structures such as seawalls, bulkheads, and revetments, which are designed to protect development along coastal areas by restricting wave impacts. The second category is made up of breakwaters and jetties, which are designed either to protect harbors and navigation channels from wave action or to stabilize inlets. The third category includes groin fields or segmented offshore breakwaters, which provide shoreline protection by trapping sand. All of these structures have a tendency to induce erosion on their downdrift sides or in front of them if they have not been properly designed, constructed, or maintained.

The fourth category of shoreline protection measures includes quasi-natural methods such as beach nourishment and building sand dunes. These methods are often taken in an attempt to restore eroding beaches and also to protect existing development. They are generally more cost-effective than structural measures in the first three categories, but are sacrificial by design and must be periodically repeated, particularly after major coastal storms.

### **Chapter Homework Assignment**

List as many flood damage reduction methods you can find from the chapter materials and the classroom lectures and write a two to three sentence explanation of how they can be effective.



For example:

Zoning ordinances - Divides the floodplain into Floodway and Flood Fringe Districts. Within the floodway only those land uses which are not subject to damage by floodwaters and will not restrict its passage are permitted. Minimum floor elevations are established for buildings in the flood fringe area.