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Design Guidelines for Flood Damage Reduction

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Federal Emergency Management Agency

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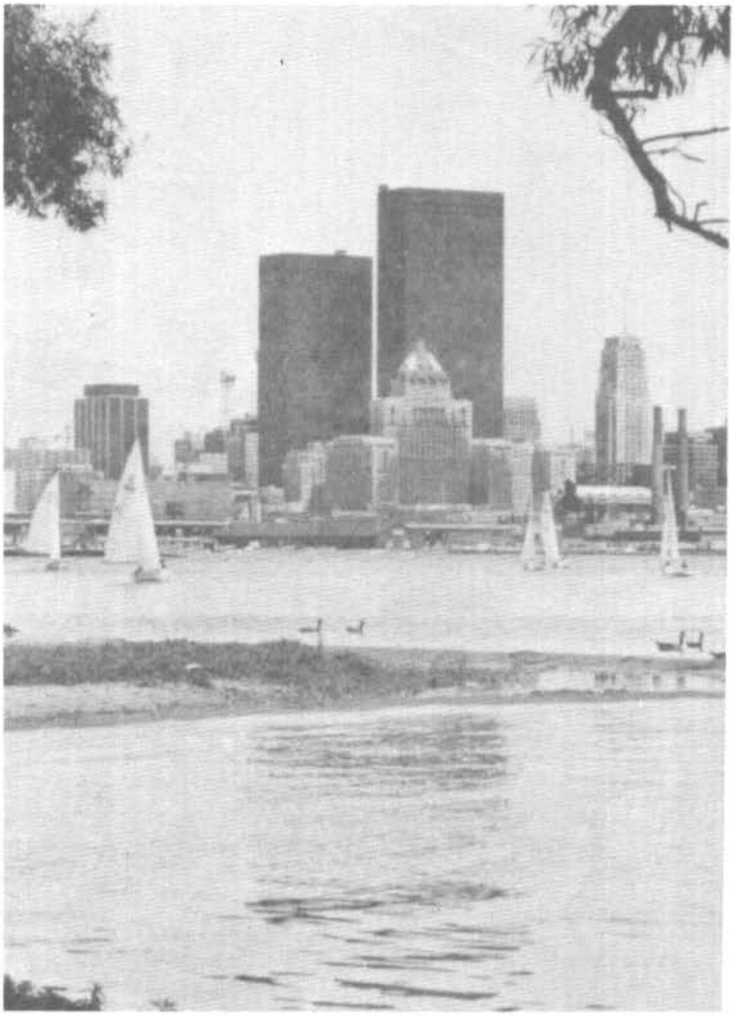
Preface

The Federal Emergency Management Agency, is charged with implementing the National Flood Insurance Act of 1968. Under this act FEMA is responsible for administering the National Flood Insurance Program and sponsoring other activities intended to reduce losses attributable to flooding. In pursuit of the latter goal FEMA has sought to:

- Encourage wise land-use and watershed management practices.
- Encourage better integration of natural and social systems.
- Encourage appropriate design and construction practices in flood-prone areas.

This manual has been prepared by the AIA Research Corporation as a special study for the FEMA to assist in meeting these objectives. The manual focuses on the need for improved building and site design in flood-prone areas—not, however, in isolation from effective floodplain management, which must accompany improved design if flood losses are to be reduced significantly.

Reduction of flood losses depends on damage mitigation activities by a variety of those involved in the use of our water and land resources. This responsibility falls to a large extent on those who design the built environment, since damage to buildings and their contents is the most common source of monetary loss in a flood disaster. For these designers to effectively contribute to flood damage reduction, they need specific information on the causes of flood damage and on ways to decrease losses through the design process. This manual has been prepared to provide that information.



Ron Vickers Ltd., AIA Journal

Chapter I

Introduction

The process of human development has been linked to oceans and rivers since the earliest phases of western civilization. Access to water has been essential for sanitation, transportation, energy, economic development, defense, recreation, and social amenity. The preeminence of these factors has fluctuated throughout history, but the reliance on water has continued.

Parallel to cultural evolution and its need for access to water has been the development of large segments of the built environment along seacoasts and riverbanks, with human settlement patterns having taken both social and economic advantage of the natural environment. However, this pattern has also led to a conflict between natural systems and social systems: The need for direct access to water has resulted in human occupation of low-lying areas that are subject to periodic inundation.

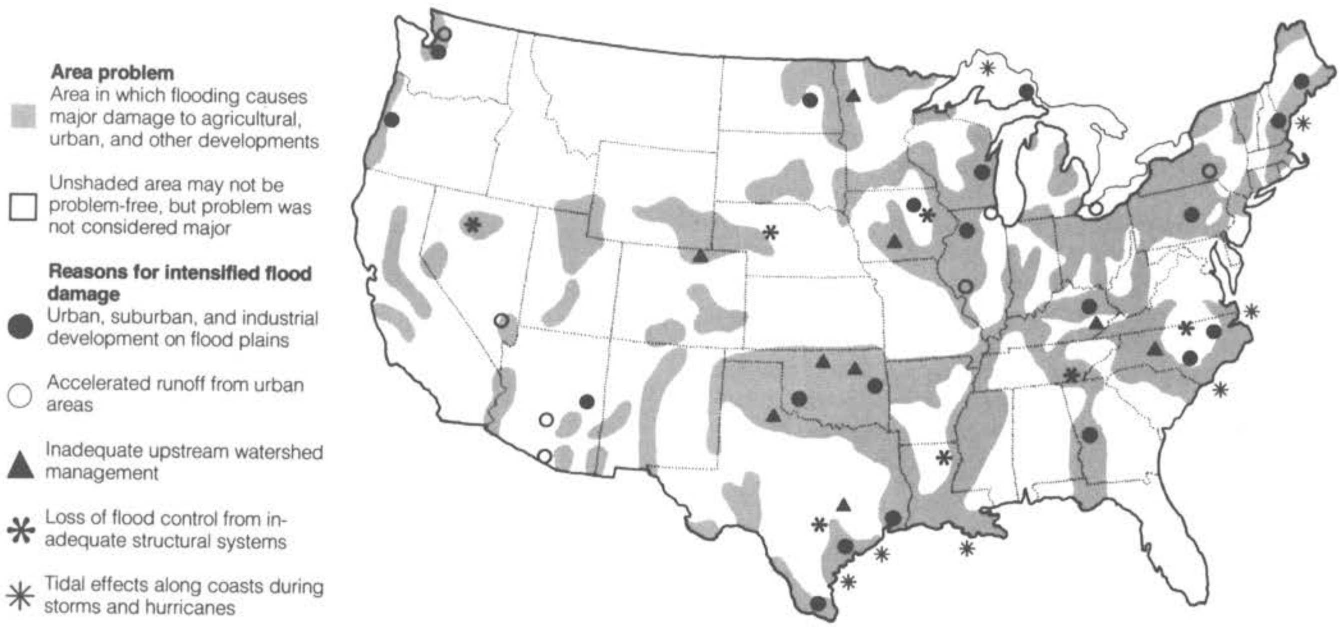
Flood Damage

Flooding occurs naturally as one part of the earth's hydrologic system. It is when this natural event is combined with the human tendency to live at the water's edge that the interaction of natural and social environments produces the potential for disaster. Unfortunately, this potential has been realized repeatedly throughout history, and the conflict is not yet resolved; losses due to flooding continue to increase.

PARNG Photo

Department of Housing and Urban Development

Cultural evolution led to the location of large segments of the built environment adjacent to water. This pattern can lead to disaster when flooding occurs.



Flooding Problems in the United States. This map shows the areas of the country in which flood damage is most prevalent and identifies some of the causes of flooding in the respective areas.

In the United States, approximately 160 million acres of land are in floodplains, with more than 6 million dwellings and a large number of nonresidential buildings located there. Periodic inundation of these floodplains is responsible for more damage to the built environment than any other type of natural disaster. The following figures indicate the seriousness of the problem.

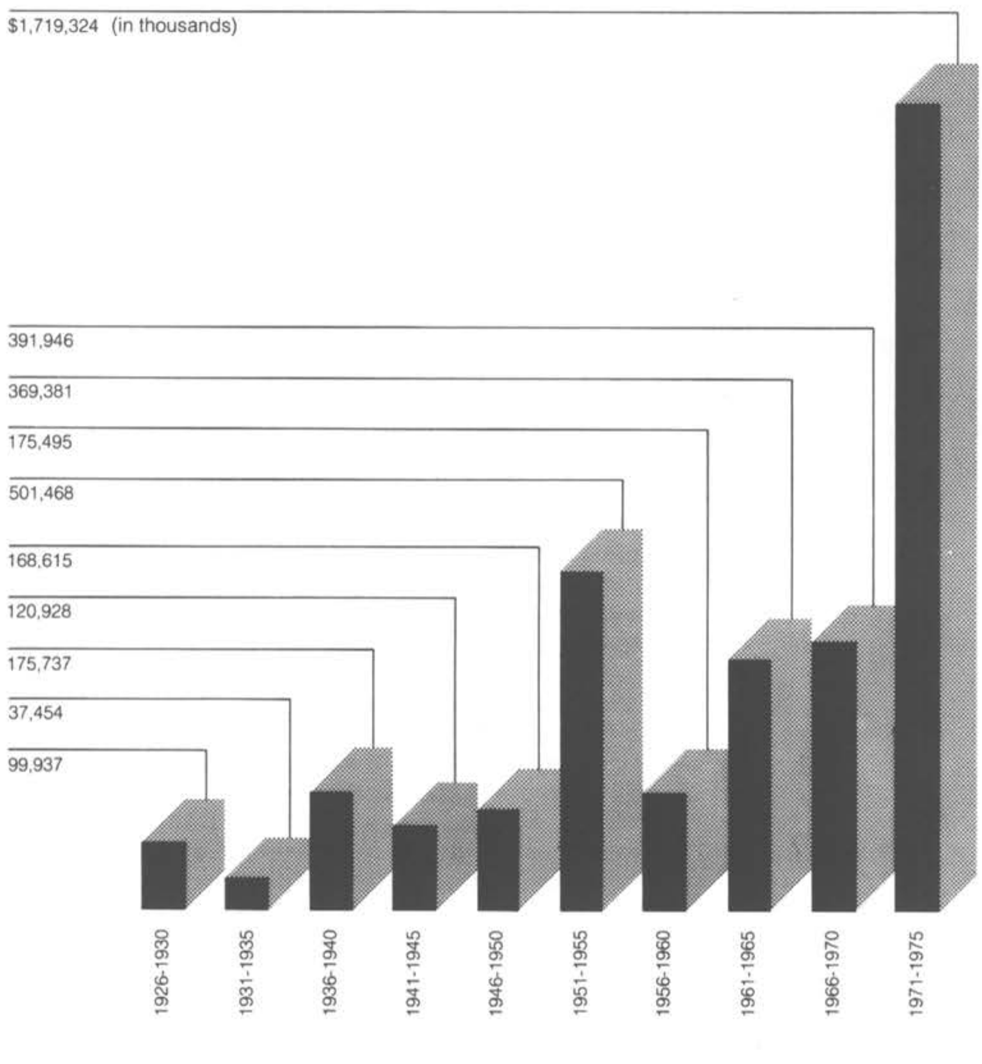
- In the six-year period between 1973 and 1979, there occurred 193 major natural disasters and 77 Presidentially declared emergencies; of these approximately 80 percent involved flooding.
- In 1978, the total flood damage—both economic and social—has been estimated to have been $3.8 billion.
- The estimated average property loss in the 1970's was over $1.7 billion annually.
- In 1978, 17 states suffered flood damage serious enough to be declared disaster areas.
- In 1979, Hurricane Frederic alone caused $1.8 billion in damages, much of it from flooding.

Response to Flooding

There have been many attempts to moderate the impact of flooding, with modern efforts dominated by structural flood control measures devised to reduce or eliminate flooding itself or to protect areas from the effects of flooding. However, the continuing damage due to flooding and current awareness of the nature of flooding have led to a shift toward a more comprehensive range of flood damage reduction methods. Attention has turned from total reliance on dams, levees, etc., to include nonstructural measures such as land and water resource management and techniques for floodproofing individual buildings.

The reason for the expanded view of damage mitigation strategies is twofold. First is the realization that floods cannot be totally eliminated. Second is the realization that better integration of the built environment with natural forces provides an environment that is both benign and rewarding.

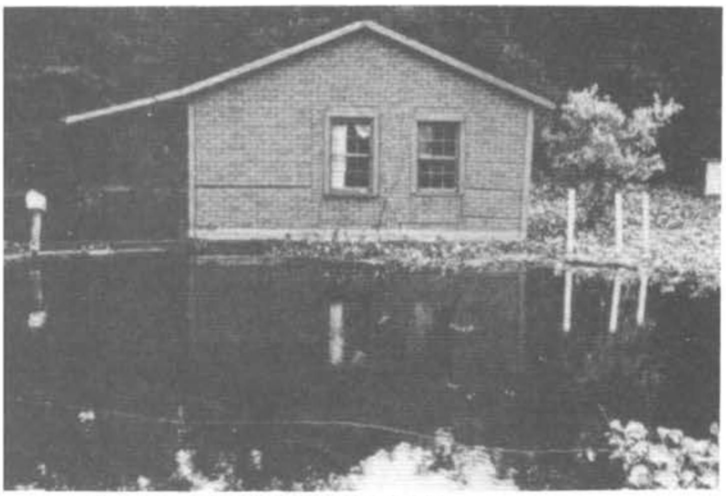
The need for a more comprehensive approach to flood damage reduction is recognized and supported by the various government agencies with a role in management of water resources and mitigation of natural disasters. Official policy of The American Institute of Architects (AIA) reflects this same awareness, as the following excerpt from the AIA's policy statement on the subject indicates.



Flood Losses. This table shows the average annual losses of property from flood in the United States, 1926-1975. The U.S. Water Resources Council, in preparing the data, concluded that the escalating flood damages resulted from continued development in floodplains and increases in the costs of making needed repairs.

Flood damage is more than dollars and cents. It affects thousands of people, causing loss of their homes, personal property, and often lives.

Department of Housing and Urban Development



Department of Housing and Urban Development

The AIA calls upon its members to exert leadership by alerting their clients to federal flood hazard boundary maps and data as to the human and material hazards and the potential environmental impacts of building in riverine floodplains, and by assisting clients in seeking alternative locations for building projects. However, when construction in riverine floodplains is undertaken, AIA calls upon its members to incorporate mitigating measures into both site development and building designs.

The premise underlying this statement is basic to this manual as well: The best way to reduce hazards in flood-prone areas is to eliminate buildings from them, thus transforming what would be human disasters into unexceptional natural events. However, such total prohibition is no more likely to be achieved than is complete control of flooding. It is inevitable that some buildings will continue to be located in flood hazard areas. This being the case, designers of the built environment are compelled to give consideration to flood hazards and ways to reduce them.

Purpose of the Manual

It is within this context that the present manual of design guidelines for flood damage reduction has evolved. The purpose of this manual is to assist designers in their task—in effect, to give them the basic information and the tools necessary to reduce the losses that continue to result from flooding. Specifically, the manual tries to meet this need by answering the following questions:

- What are flooding's inherent characteristics?
- How does flooding relate to the built environment?
- What steps have been taken to mitigate flood damage?

- What programs influence development in flood-prone areas?
- What essential information is needed to design in flood-prone areas?
- What design techniques are available to mitigate flood damage to the built environment?
- Where can the designer obtain additional information about flooding?

Organization of the Manual

In answering the above questions, the manual has been organized into three sections.

The first section, Chapters 2 and 3, provides background information on flooding to assist the designer in addressing the problems of designing in flood-prone areas. Chapter 2, **Flooding and the Built Environment,** discusses the natural characteristics of flooding and the interrelationships between flooding and the built environment. Chapter 3, **Policies, Programs, and Strategies for Flood Damage Reduction,** deals with the evolution and content of government flood-related programs and outlines general strategies for reducing flood losses.

The second section deals specifically with design issues. Chapter 4, **Design Analysis for Flood Damage Reduction,** details the range of information that is needed for pre-design analysis of projects in flood-prone areas, including a discussion of relevant regulations, hydrologic data, and physical site characteristics. The final chapter, **Design Techniques for Flood Damage Reduction,** outlines the various techniques that designers can use to mitigate the flood damage potentials identified in pre-design analysis.

Finally, the third section of the manual is a **Resource Index,** which provides additional sources of information that can be investigated by the designer when further detail is necessary. Included here are literature references on a wide range of flooding and development issues, as well as listings of key regional contact points for the variety of government agencies with an interest in flooding and development.

It is hoped that this manual proves to be a frequently used addition to the designer's reference shelf. It is intended to mark a beginning towards a more conscious inclusion of flooding issues in the routine procedures of design practice. If, beyond that, it helps the designer accept the challenge of finding creative and effective solutions to the problems of building in flood-prone areas, then both clients and the community will benefit.

American Institute of Architects Policy Statement

WHEREAS, flood plains adjoining inland rivers and coastal waters have been preferred locations for human settlements throughout history;

WHEREAS, current land use practices and increased urbanization have significantly increased human intervention within flood plain boundaries;

WHEREAS, construction in flood plains carries the risk of severe damage to such construction and its occupants and affects water quality, drainage patterns and balances between human and material systems;

WHEREAS, architects could be held liable for damages if they ignore flood plain information that is readily available, therefore, be it

RESOLVED, that architects should become involved in their local communities in order to develop wise flood plain management, regulations, and practices.

FURTHERMORE, The American Institute of Architects calls upon its members to exert leadership by alerting their clients to federal flood hazard boundary maps and data as to the human and material hazards and the potential environmental impacts of building in flood plains, and by assisting clients in seeking alternative locations for building projects. However, when construction in flood plains is undertaken architects shall incorporate mitigating measures into both site development and building designs.

Chapter 2

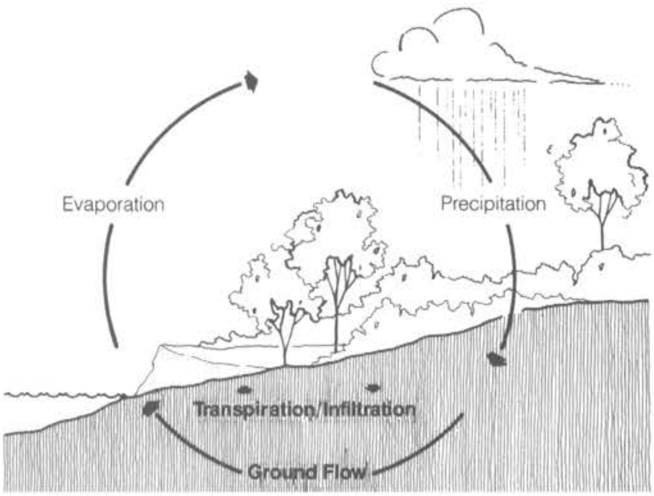
Flooding & the Built Environment

Building design does not occur in a vacuum. Rather, it is one of the interrelated elements in the larger sphere of the development process. Likewise, development is but one component of the environment as a whole. An understanding of these relationships is requisite to reducing flood damage through design of the built environment.

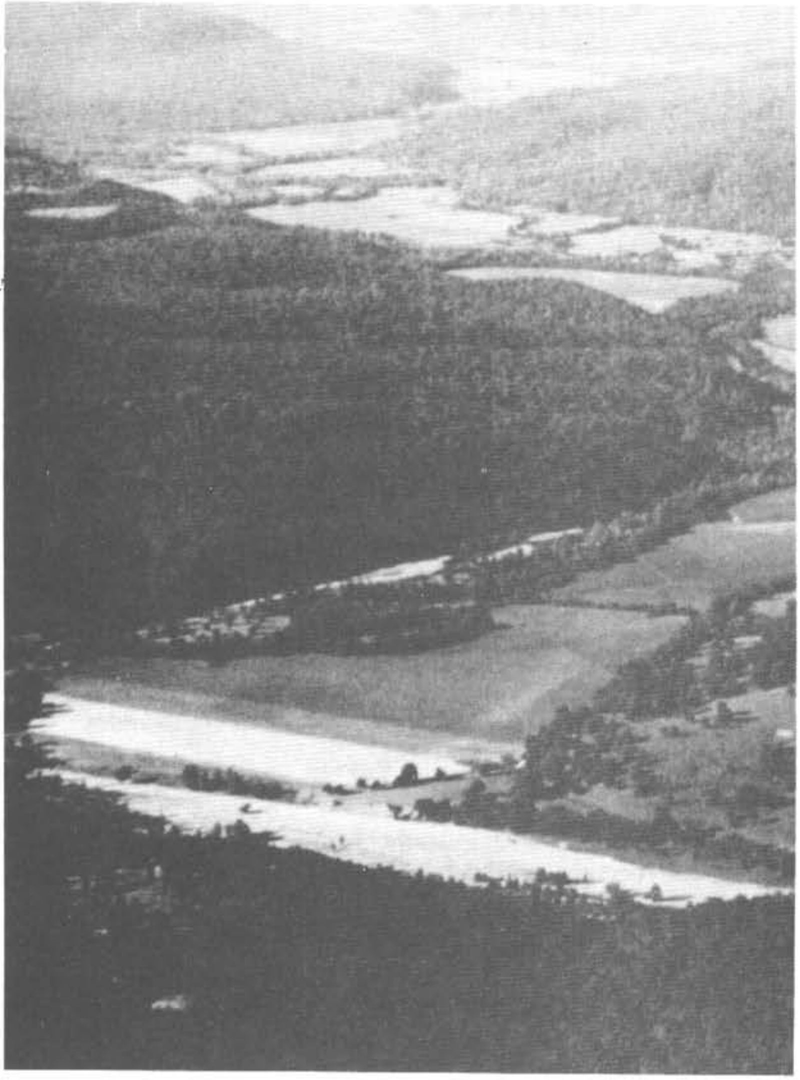
Of primary importance is the interdependence of the respective systems, natural and social. Buildings, as part of the social system, unavoidably affect and are affected by flooding, which is part of the natural system. Design in general, and design to reduce flood damage in particular, should respect this relationship and seek to achieve a balance among the various components.

The Natural System

Floods are natural—that fact must be stressed. Floods become a problem only when they coincide with human

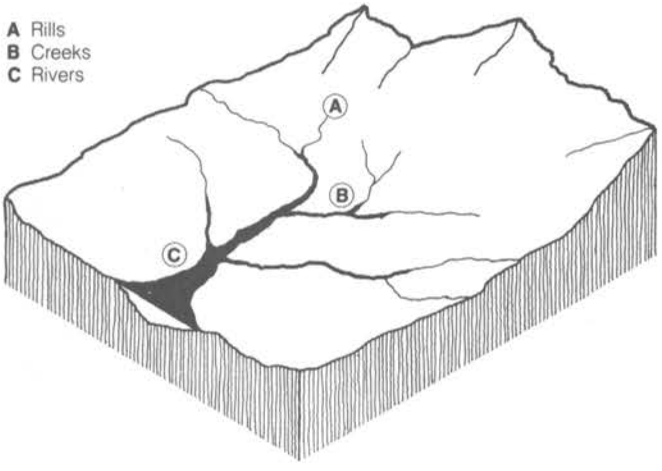


The hydrologic cycle constantly circulates water throughout the earth's environment.



National Park Service

The riverine watershed is a hierarchical drainage system that conveys water through the land-based portion of the hydrologic cycle.



habitation. To better understand this problem we look first at the natural system of which flooding is a part.

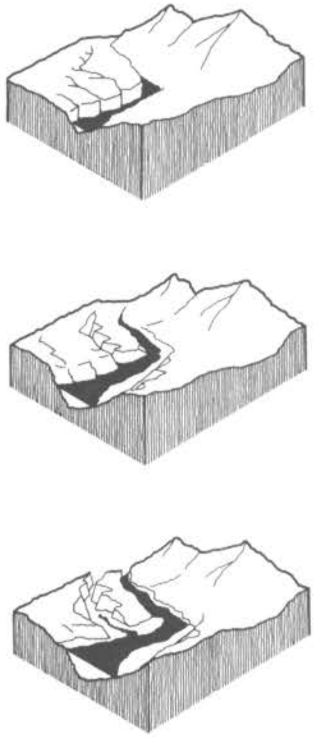
The Hydrologic Cycle

Flooding is part of the earth's natural hydrologic cycle. The cycle circulates water through a process of evaporation and transpiration, precipitation, water runoff, and stream flow. This process maintains an overall global balance between atmospheric moisture and water on the surface and in the ground. Often, however, local imbalances result in flooding.

Flooding results when the flow of water is greater than the normal carrying capacity of a stream, or where coastal waters exceed the normal high tide. This raises an important distinction between riverine and coastal flooding; though both are part of the global hydrologic system, the respective causes are dissimilar. Rivers flood when water overflows the channel because of excessive water runoff or blockage of the channel. Coastal flooding results from high water produced by storm systems or tsunamis (seismic sea waves).

Riverine Flooding

The magnitude, duration, and frequency of floods are influenced by a region's natural characteristics. One pri-



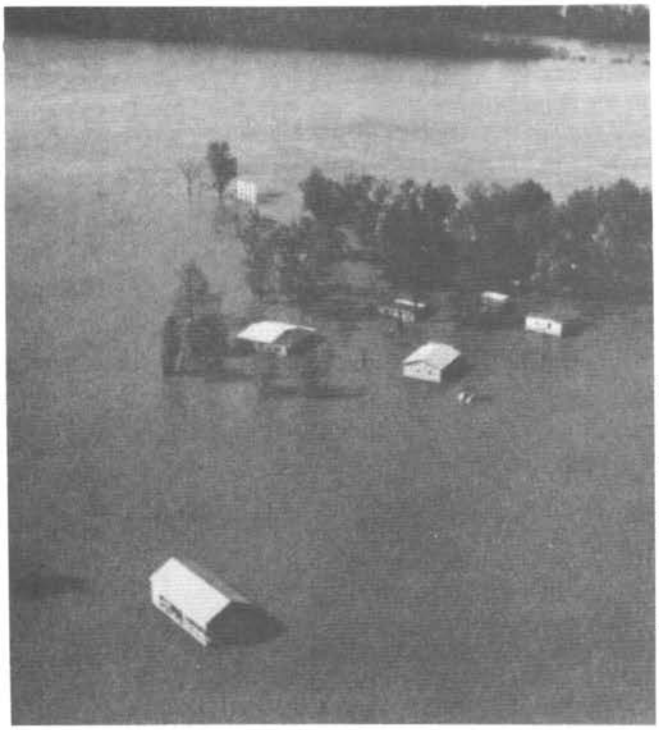
Riverine systems evolve to form distinct stream channels and floodplains. The drawings at left illustrate this gradual formation, while the photo at far left shows a well-defined channel and floodplain.

mary variable is the watershed, which is the natural drainage basin that conveys water runoff in the land-based portion of the hydrologic cycle. Water that is not absorbed by the soil and vegetation becomes surface water runoff, seeking the natural drainage lines according to local topography. These lines merge to form a hierarchical system of streams that includes rills, creeks, and rivers, each of successively larger capacity.

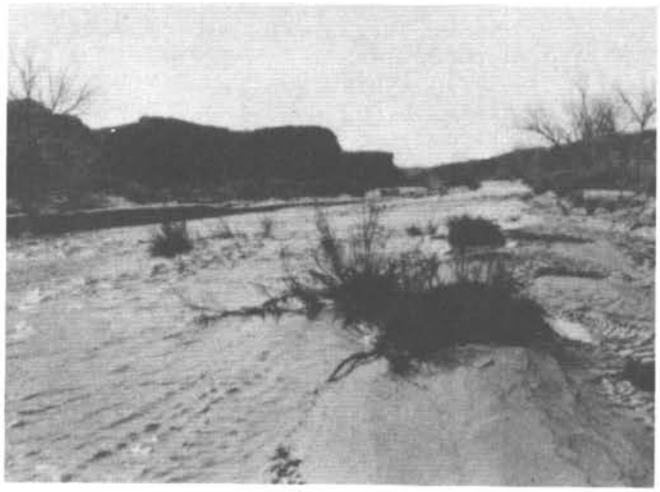
Streams have specific physiographic characteristics. The primary element is the stream channel, which carries the normal flow of water through the watershed system. The area of flat or gently sloping land adjacent to the channel is the floodplain. Flooding usually involves a build-up of water in the channel, followed by overflow of excessive quantities of water that inundate the floodplain. Generally, this rise in water surface elevation is quite slow in large streams and more rapid in smaller ones.

Flooding is part of the natural renewal of the earth's resources. Overflows play a positive role in the natural system by replenishing soil moisture and depositing fertile silt from the river channel onto the floodplain.

Flash Flooding. Flash flooding usually consists of a quick rise in water surface elevation, with abnormally high water velocity often creating a "wall" of water moving down the channel and floodplain. Flash floods usually



Department of Housing and Urban Development



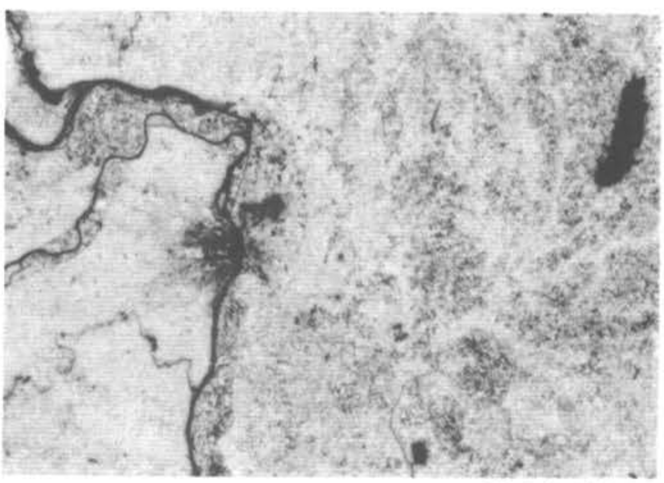
National Park Service

Flash flooding can occur in small, usually shallow or dry streams, such as arroyos in the southwestern part of the country.

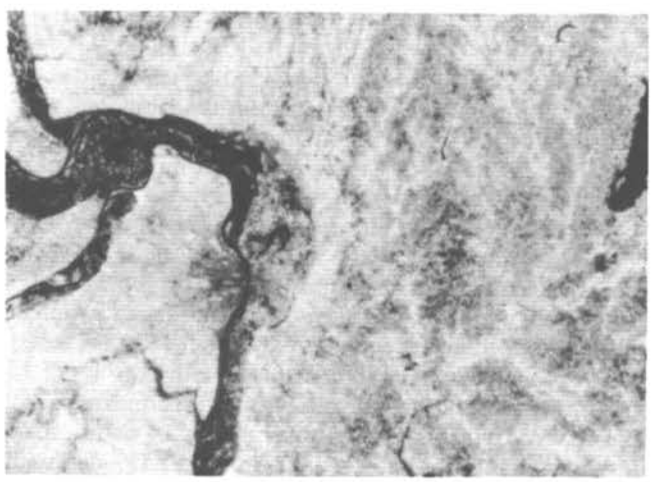
result from some combination of intense precipitation, steep slopes, a small drainage basin, and a high proportion of impervious ground surfaces. They are evident in many parts of the country and often occur in small streams that are otherwise shallow or dry, such as arroyos.

Shallow Flooding. Shallow flooding of several types occurs commonly throughout the country. Included in this category are unconfined flows over broad, relatively low areas such as alluvial plains; intermittent flows in arid or semi-arid regions that have not developed a system of well-defined channels; minor overbank flows that remain unconfined; overland flow of runoff in dense urban areas; and flows where heavy debris deposits cause constantly shifting channels, such as in alluvial fans. These types of flooding are also referred to as sheet flow, ponding, shallow overflow, and alluvial fan flow. It is very difficult to determine shallow flooding depths, the extent of such

Aerial photographs dramatize the potential for flood damage. The picture on the left shows the normal flow of a river through an urbanized region. At right is the same area during a flood.



U.S. Geological Survey



flooding, or the direction of flow, because shallow flooding is not readily analyzed in relation to more serious channel flooding.

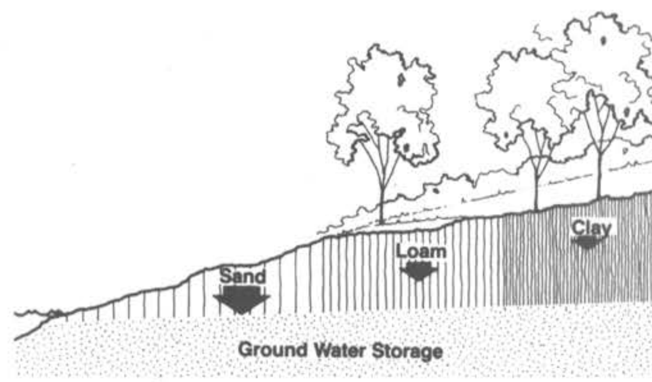
Flood Severity: Flood severity is determined first by the amount of water runoff to be conveyed through the watershed. Flooding is most likely to occur during times of heavy rainfall or snowmelt, when the amount of runoff is higher.

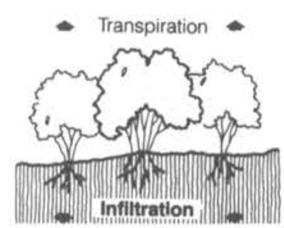
Soil characteristics, ground and surface water storage, and vegetation also influence flood levels. Soil permeability determines how much surface water can be absorbed rather than adding to runoff. Water runoff that collects in surface depressions will be released gradually into the ground and atmosphere and not contribute to flooding. Likewise, ground water that collects in cavities beneath the earth's surface helps reduce runoff and flooding. Finally, vegetation slows the rate of water runoff by holding moisture on leaves and in roots, and then releasing it to the air through evaporation and transpiration.

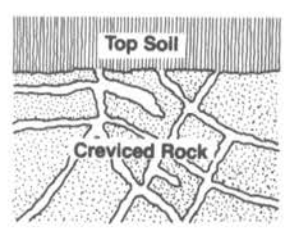
Thus, if a specific site has little permeable soil, no water storage capacity, and sparse vegetation, water either from a storm or from higher ground will flow directly across the surface of the site, adding to a build-up of water that may be in excess of the nearest stream's capacity. Obviously, the bigger this hypothetical site or region the greater the flooding impact throughout the watershed.

Coastal Flooding

Coastal flooding, on the other hand, has little to do with the movement of water through a watershed. Rather, it is due to the effects of severe ocean-based storm systems. Hurricanes, tropical storms, and extratropical storms such as "northeasters" are the principal causes, with flooding occurring when storm tides are higher than the normal







Variable soil porosity, as illustrated above, influences the degree of surface water absorption and runoff. Vegetation, left, holds water in leaves and roots, releasing it gradually through transpiration and infiltration. Water absorbed by the soil, below, is held as ground water in cavities below the water table.

U.S. Army Corps of Engineers

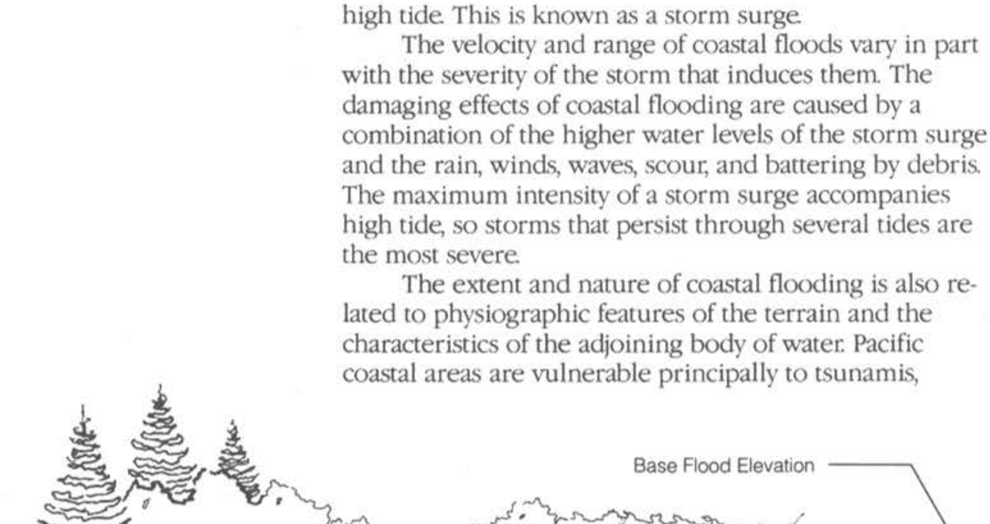
Coastal storms cause damage through the combined effects of wind, rain, wave wash, storm surges, scour, and battering by debris.

Wetland areas are frequently part of the coastal ecosystem. They can provide a reservoir for storage of flood waters and protect against storm-induced erosion.

high tide. This is known as a storm surge.

The velocity and range of coastal floods vary in part with the severity of the storm that induces them. The damaging effects of coastal flooding are caused by a combination of the higher water levels of the storm surge and the rain, winds, waves, scour, and battering by debris. The maximum intensity of a storm surge accompanies high tide, so storms that persist through several tides are the most severe.

The extent and nature of coastal flooding is also related to physiographic features of the terrain and the characteristics of the adjoining body of water. Pacific coastal areas are vulnerable principally to tsunamis,



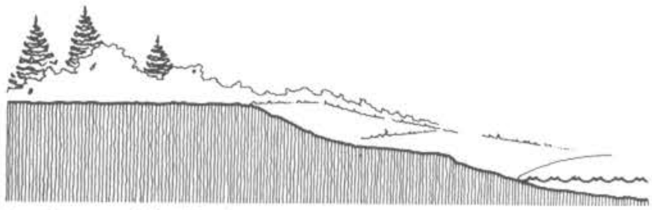
A typical coastal ecosystem consists of beach, dunes, and troughs between and behind the dunes. The beach and dunes are the more fragile components of this environment and should not be disturbed by development.

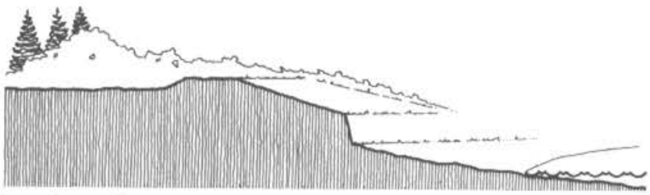
earthquakes, and other natural forces that can trigger excessive erosion, mud slides, and flash flooding. Great Lakes coastal areas are subject to erosion and severe winter storms. The Atlantic and Gulf Coasts are consistently exposed to the forces of hurricanes, lesser tropical storms, and northeasters. Each of these coastal areas suffers significant flooding, but it is the latter that has received the greatest amount of damage.

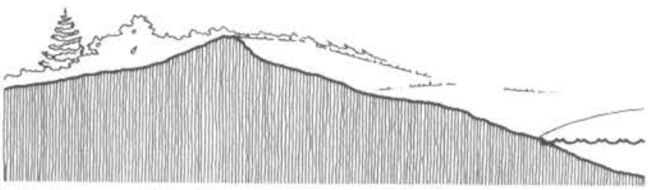
Balance of Coastal System. Most of the Atlantic and Gulf Coasts are made up of a succession of low-lying barrier islands, beaches, sand dunes, and bluffs. This collection of physiographic elements constitutes a fragile ecosystem that serves an important function in maintaining the natural environment.

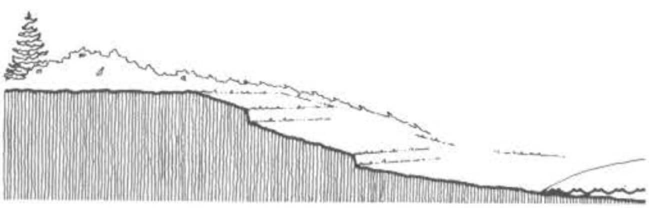
A dynamic balance of natural elements occurs as the movement of sand by wind, waves, and ocean currents maintains the beach and dune system. Dunes serve to catch and hold sand, thus keeping a constant supply to replenish the natural erosion of beach sand. This coastal system helps buffer the force of storm tides and surges. Wetlands, which are often an added element in the coastal system, provide flood water storage and protect against storm-induced erosion.

Physiographic characteristics vary along the length of the coast, and influence the type and extent of flooding. Beaches may be wide and flat, with low dunes, or they may be of medium-to-narrow width, with higher dunes and bluffs back from the water. The coast may be terraced, with height gradually increasing as the distance from the water increases. Or there may be a barrier dune or sand bar as a natural levee between water and land. These configurations will influence flooding by providing variable degrees of buffering.


Low Dunes and Flat Beach


Low Coastal Bluff and Narrow Beach


High Dune and Wide, Sloping Beach

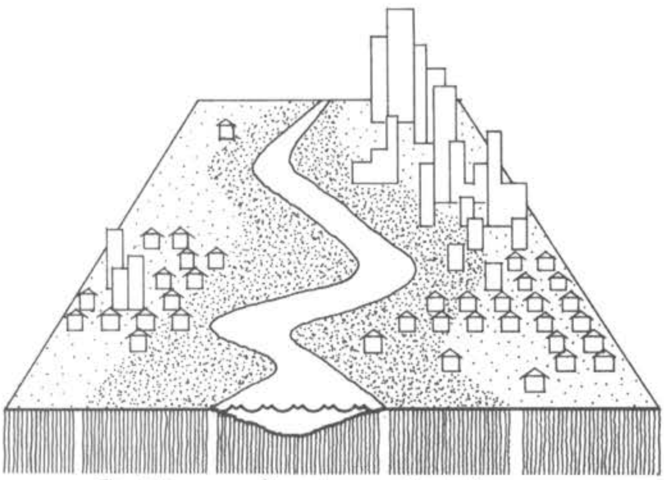

Terraced Coast

Variations in coastal topography can influence the extent of flooding because of their variable resistance to storm surges and tidal waves.

The Built Environment

As noted in the previous chapter, development along coasts and rivers is the result of a logical evolution, with human settlements benefiting both socially and economically from the natural system. The majority of this development occurs in urban areas, but is also apparent at the urban fringe, in small towns, and in rural areas. Development ranges from the single isolated building to the multi-building complex, and includes residential, commercial, and industrial building types.

However, this pattern has also led to a conflict between natural and social systems. The need and desire for direct access to water has resulted in human occupancy of low-lying areas, and this has put a large proportion of the built environment in flood-prone areas. The floodplain is transformed into a flood hazard area, and destruction of the human habitat becomes commonplace.

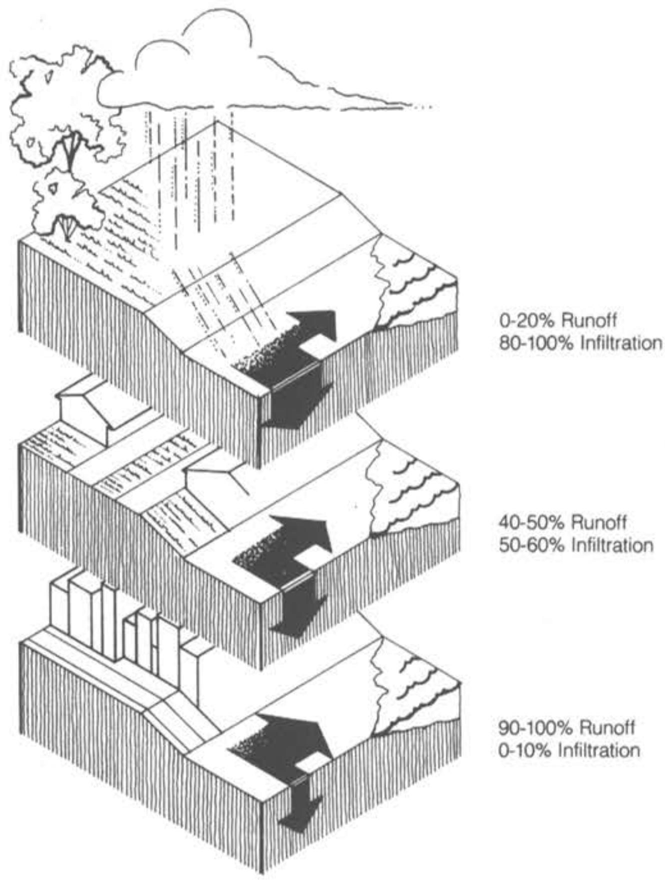


Development occurs in urban, suburban, small town, and rural settings, and buildings in many of these areas have been located on hazardous flood-prone sites.

Riverine Development

The introduction of built elements into flood-prone areas adds a range of factors, other than physiographic, that affect the degree of flooding. In riverine watersheds, development has consistently altered the natural topography, thus modifying drainage patterns and increasing storm water runoff. Development also displaces much of the natural vegetation that would otherwise absorb water, and decreases the permeability of soil by covering it with buildings or with nonporous surfaces (e.g., roads, sidewalks, and parking).

Ultimately, these development characteristics, either singly or in combination, cause a drastic increase in the amount and velocity of water runoff. Thus, during times of severe storms or heavy snowmelt the river system is quickly filled beyond its capacity and flooding results. The levels of flooding are increased not only by the abnormal runoff, but also because buildings located on the floodplain displace a volume of flood water. The more buildings on the floodplain, the greater is the displacement and the greater the level of flooding.



Development in the watershed alters natural drainage characteristics and decreases the permeability of soil, thus exacerbating the effects of flooding.

Coastal Development

In coastal areas development has similar effects because the delicate balance of shoreline elements is easily upset. The removal of beach sand and the leveling of dunes, along with the construction of seawalls, jetties, and piers, have been common practices in coastal construction. Yet, these measures weaken the shoreline's natural protection system by introducing static elements into the dynamic process that, left alone, is able to respond to constant wind and wave action. Such changes exacerbate the impacts of storm surges and high winds. Filling natural wetlands to increase developable land also eliminates such natural defenses against flooding.

Urbanization

The effects of development on flooding are most pronounced in the urban environment. If a building and its accessories, such as sidewalks, parking lots, and access roads, can increase water runoff, then the combined effect of many buildings, streets, parking lots, and sidewalks can increase it far beyond the capacity of the watershed system. The same is true of ocean-side cities and their effect on delicate coastal ecosystems.

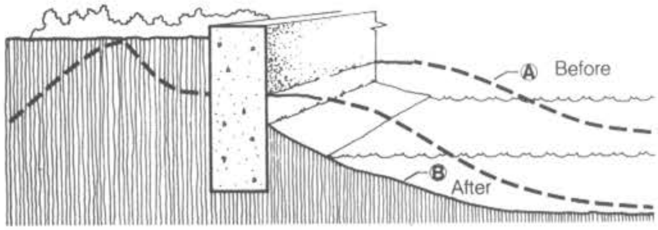
With the rapid expansion of cities since the late 1940's, ever-larger concentrations of land have been covered with buildings and pavement. As a result, surface drainage has been continually increased, and the capacity of the natural system to accommodate it has been exceeded repeatedly. And, the problem has not really been alleviated by flood control projects. On the contrary, flood control structures have encouraged much of the expansion onto floodplains, since these seemingly attractive building sites were thought to be protected.

Energy restrictions, economic forces, land speculation, increases in household formation, and the desire for amenities will bring continuing pressure for urban expansion. As this development occurs, people both in and out of the building process must be aware of the full costs and other effects arising from the necessary interdependence of natural and social systems.

Effects of Development

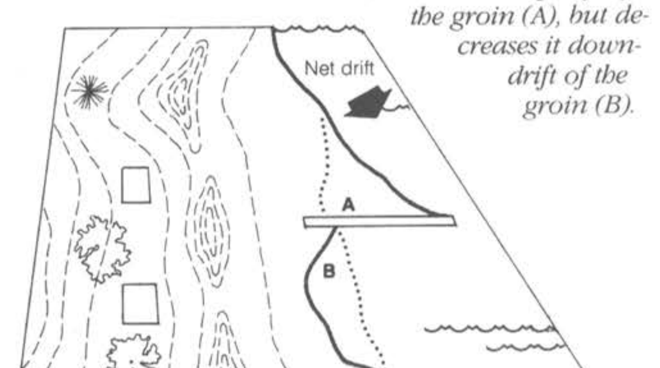
The dangers of development in floodplains take several forms. As discussed above, development can increase the severity of flooding. Also apparent is that buildings themselves, subject to the forces of flood waters, will be damaged. And, when damaged, parts of a building can break loose and act as battering rams when carried by the current of the stream or storm surge.

A less obvious danger can result from development in areas that are not subject to direct flood hazard. Virtually every site is part of a riverine watershed or coastal



Construction of seawalls alters the dynamic balance of the coastal ecosystem and causes erosion of the beach and seabed. The dotted line (A) represents the original profile with gently sloping beach and seabed. The profile after construction of the seawall (B) shows loss of beach area and steep slope of seabed.

Groins, constructed to stabilize the beach at one point, can have a reverse effect for adjacent areas. Shoreline erosion increases the beach area updrift of the groin (A), but decreases it downdrift of the groin (B).



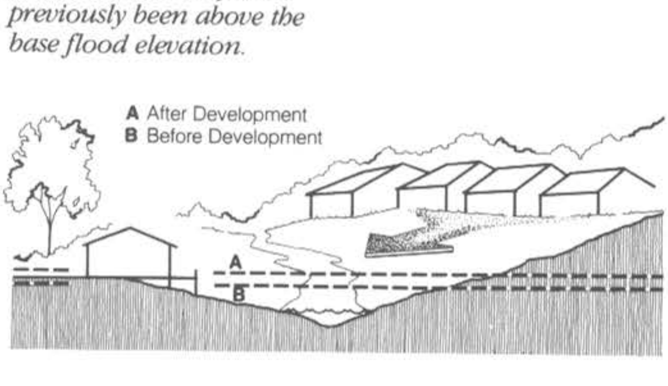
David Valdez, Department of Housing and Urban Development

U.S. Army Corps of Engineers

system. Even if the site itself is not likely to be flooded, development on it can have a major influence on flooding and flood damage at other locations. Any modification that increases runoff or disrupts natural protective systems will increase flooding at other locations, whether it be in the downstream portions of the watershed or inland portions of the coastal area.

Alteration of the natural balance on a single site may only have a small impact. But the cumulative impact of many individual sites or of large-scale developments, as is the rule more than the exception, can be massive. This is amply illustrated by the flash flood in Kansas City in 1977. Due to an unusually heavy thunderstorm, the rapid accumulation of runoff in a highly developed urban area created a six-feet-high wall of water in an otherwise dry creek bed. The result was over $30 million in damages and 24 lives lost.

Development at any place in the watershed can reduce the permeability of the soil, thus increasing runoff and flood levels. This increase in flood levels can then endanger properties that may have previously been above the base flood elevation.



Development Pressures

Human occupation of flood-prone areas brings with it inevitable losses of life and property and the disruption of commerce and services. Despite a long history of such losses, we continue to build and rebuild in hazardous locations. Ideally, this should not happen; however, the forces of development are as inevitable as the storms that produce flooding in the first place. In many cases people are unaware of the hazards of a given site or the effects of development on flooding at other sites. In yet other cases the risks are known, but locational advantages seem to override the hazard. Or the existing infrastructure in a flood-prone area is considered too enormous a capital investment to abandon. Too often, the speculative pressures of development override common sense.

Flooding is a normal occurrence, with the degree of

inundation influenced first by precipitation or storms, and then by such natural characteristics as topography, soil porosity, drainage, vegetation, and beach composition. Development in flood-prone areas often alters these natural features and can increase flood levels, chiefly by increasing the rate of water runoff.

To minimize adverse impacts, development should be prohibited or minimized in the most hazardous areas and carefully monitored to avoid undesirable effects in others. The design of the built environment should be carried out with complete knowledge of flooding characteristics and with conscious concern for maintaining the balance of environmental features.

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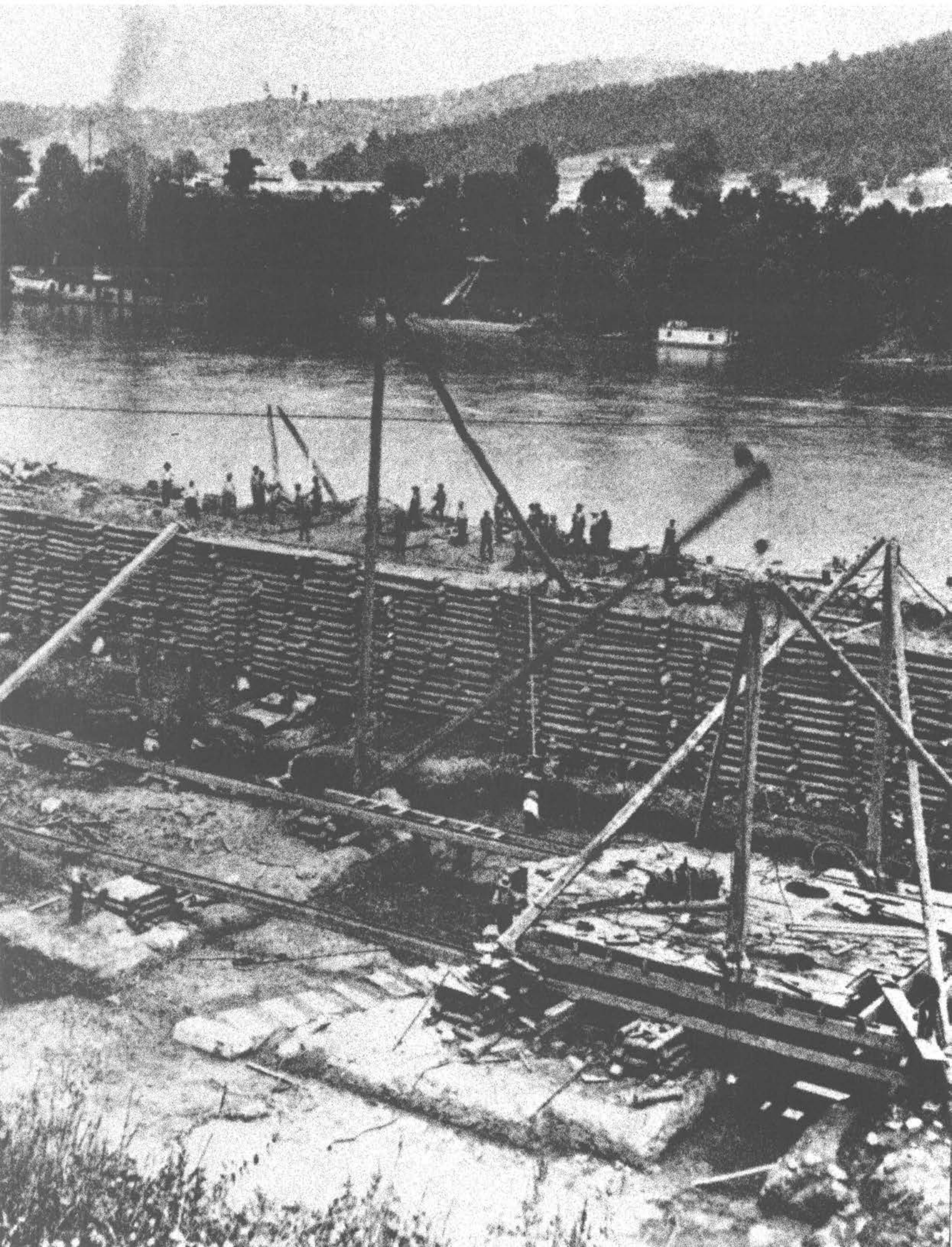
Department of Housing and Urban Development

Development in flood-prone areas frequently results in damage to buildings. The house at far left has been swept completely off its foundations by the force of a riverine flood. The house above has suffered similarly from coastal flood water. Shown at left-center is the inundation of a small town's entire central business district.



Chapter 3

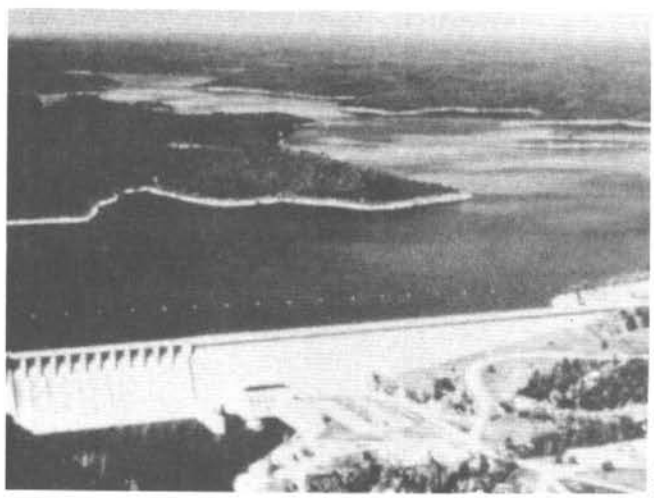
Policies, Programs, & Strategies for Flood Damage Reduction

Through time, the natural riverine and coastal systems have experienced increasing pressures from a rising population, the shift from an agrarian to an industrial society, and the limited amount of land close to water. Growing technological ability provided the means to translate these pressures into expanded development in flood-prone areas—even in the face of repeated disasters that showed that flooding cannot be controlled. The resultant cycle of destruction and rebuilding has been made more palatable for some due to the benefits of locating near the water. At the same time, there have been constant efforts to reduce the risk of flooding, with the federal government taking the initiative.

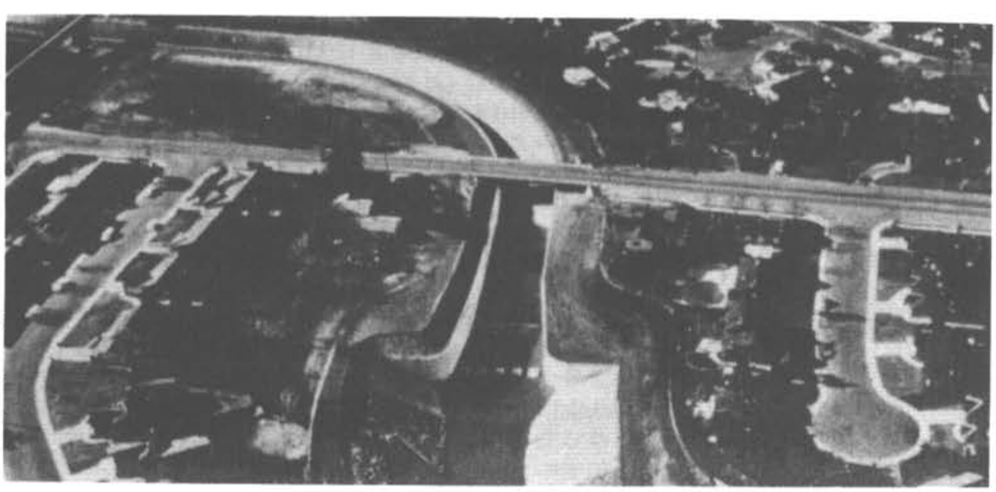
Evolution of Flood Policy

Early measures to reduce flood hazards in this country—most commonly, dikes and levees, seasonal evacuation, and buildings on stilts—were limited, and were usually the result of private or local initiatives. Since the 1920's, however, there has been a surge in technological advances and an active interest by the federal government.

In 1928, after a devastating flood of the lower Mississippi Valley, Congress passed the Lower Mississippi River Flood Control Act to provide federal funds for flood control in that region. The subsequent Flood Control Act of 1936 enlarged the scope of Congressional interest by declaring that flood damage was a national problem and should be addressed with federal funds. This legislation, which shaped policy for 30 years and remains an important influence on it, directed federal efforts towards preventing floods by *controlling* the flow of water in the nation's major river systems. This policy was implemented by the construction of structural modifications such as dams, levees and channel improvements.



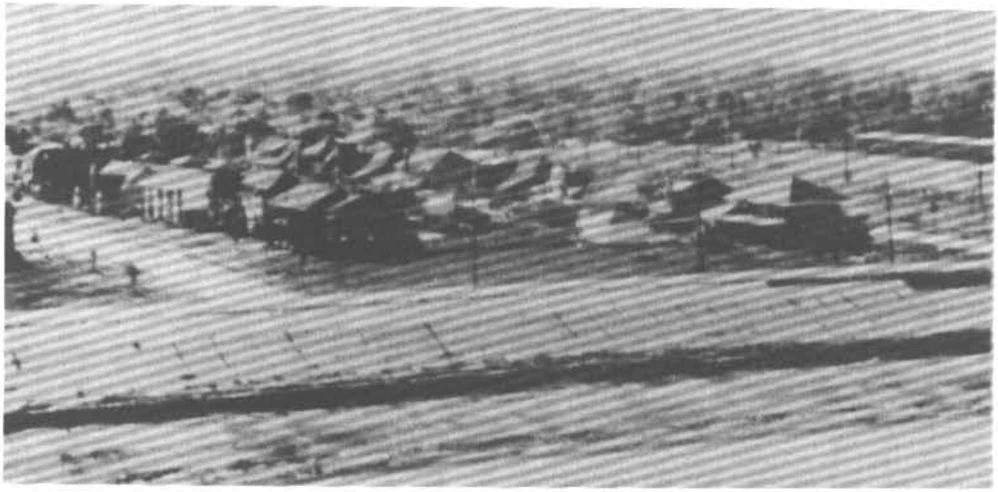
U.S. Army Corps of Engineers



U.S. Army Corps of Engineers

Flood control projects such as the dam and reservoir above and the channelization project at left have been constructed in an attempt to reduce flood damage by controlling stream flow.

Levee construction in 1890, U.S. Army Corps of Engineers



Levees are constructed to protect developed areas from flooding.

Between 1936 and 1965 the government constructed 260 reservoirs, 6,000 miles of levees, and 8,000 miles of channel improvements, with an expenditure of over $7 billion. This massive effort did provide protection for many previously vulnerable areas and had other positive benefits, yet did not reduce the expenditure for flood damages: In 1953 flood relief and rehabilitation required a federal expenditure of $53 million; by 1965 this figure had jumped to $237 million.

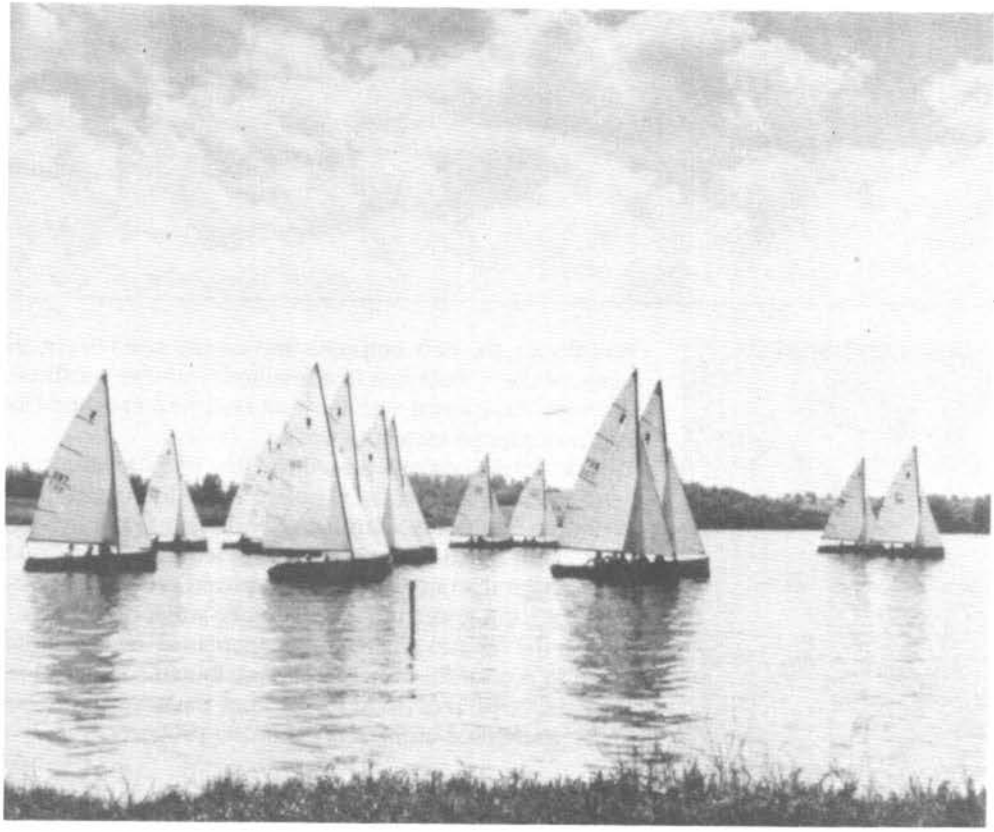
Policy Results

Federal programs to provide structural flood control projects have had numerous benefits. Increased control of river flow has often resulted in less inundation of major floodplains during times of heavy runoff. In effect, this has expanded the usable area of the floodplains, opening the way for increased economic opportunities in those areas. In addition, there have been significant increases in recreation opportunities at the many reservoirs and, in some cases, an increase in wildlife conservation habitats.

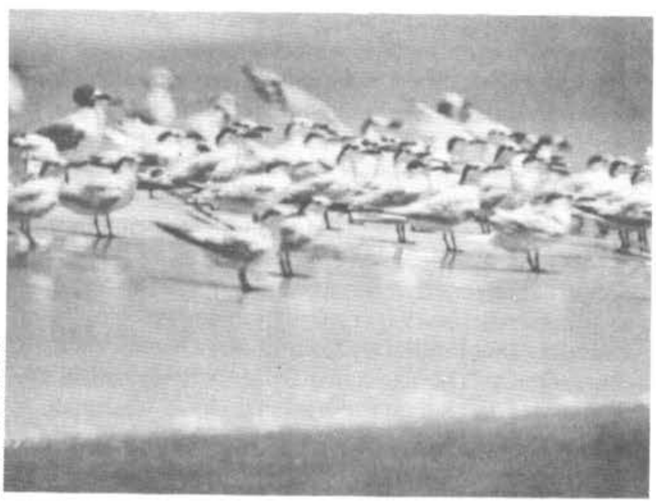
However, flood losses have climbed despite the structural program. It was found that preventive measures were not synonymous with elimination of flooding and that new development was frequently located in vulnerable locations. Thus when the limits of structural controls were exceeded and flooding did occur, damage resulted on a larger scale.

This was exacerbated by a simultaneous trend of rapid urban expansion. The growth of cities, already located in flood-prone areas, created development pressures for all available land. This pressure extended onto floodplains, which were perceived to be safe because of the structural flood control programs. These combined pressures caused insufficient attention to be directed at

Heritage Conservation and Recreation Service



National Park Service



Flood control projects can have numerous benefits. They often generate hydroelectric power and create recreation and conservation habitats.

U.S. Army Corps of Engineers

maintaining equilibrium in the total watershed system.

The federal program for structural control of flooding also failed to provide an effective deterrent to coastal flooding. The programs were aimed predominantly at the riverine environment, largely because little hurricane activity occurred during the period in which early flood-related legislation was passed. Consequently, little Congressional attention was focused on the unique problems of the coastal environment.

New Focus of Federal Policy

In the middle 1960's there was a reassessment of national policy and the beginning of a shift to a more comprehensive approach to flooding. Paramount was the recognition that structural works needed to be complemented by nonstructural measures. Rather than trying solely to prevent floods, the new emphasis was on the need to correct many of the imbalances that resulted from the conflicts between the natural and the built environments and that had precipitated escalating losses.

In 1965 Congress passed the first of a succession of laws updating federal flood policy. The effect of this policy evolution was not to eliminate flood control as a strategy, but to shift much of the emphasis of federal programs to nonstructural strategies. It also required greater involvement by local governments, put more attention on protecting the natural environment, increased the attention given to coastal flooding, and redistributed some of the financial burden of flood losses from the general public to the individual users of flood-prone property.

Executive Orders

Presidential Executive Orders concerning flooding were issued in 1967 and 1977. These interpret and reinforce the intent of the legislative acts as they are implemented by the appropriate executive agencies.

- E.O. 11296, issued in 1967, required evaluation of flood hazards in connection with any proposed action by a federal agency. The order was supplanted in 1977 by E.O. 11988, *Floodplain Management,* which advocates protection of floodplains as natural phenomena and provides explicit support for nonstructural measures wherever they are feasible.

It is significant that the Executive Order 11988 applies to all federally funded construction and development, including that funded by Community Development Block Grants. The Executive Order actually calls for higher standards than the National Flood Insurance Act, thus putting federal agencies in a leadership position regarding floodplain management.

- E.O. 11990, *Wetlands,* also issued in 1977, requires all agencies to act to minimize the destruction, loss, or degradation of natural wetlands.

Strategies for Flood Damage Reduction

As mentioned above, the emphasis of federal flood policy has shifted from almost exclusive use of structural control measures to equal consideration of nonstructural strategies. Included in this new approach are a number of methods, each supporting and supplementing the others.

It is now recognized that the various approaches must be combined to fit the unique circumstances of any given situation. Flood control is effective under some conditions, but cannot succeed alone. Water and land resources should be regulated to complement structural controls. Warning systems should be devised or refined. Individual buildings should be protected as necessary.

Recent Legislation

Water Resources Planning Act, 1965 (P.L. 89-90)
This law created the U.S. Water Resources Council, an independent executive agency that encourages the conservation, development, and use of water and related land resources on a comprehensive and coordinated basis. The chief tool in carrying out this mission is the establishment of the Unified National Program for Floodplain Management, which provides administrative guidelines that are applicable nationally to all levels of government and the private sector. This document, first issued in 1976 and revised and reissued in 1979, analyzes the basic principles of flooding and relates both riverine and coastal floodplains to the natural and social systems of which they are a part. Based on this analysis, it then outlines a series of management strategies, implementation techniques, and recommendations for an effective response to floods.

National Flood Insurance Act, 1968 (P.L. 90-448, Title 13)
This act set up a joint public/private National Flood Insurance Program (NFIP), with the important provision that insurance is available to individuals only if their community has an approved floodplain ordinance in conjunction with a floodplain management program. The effect is to shift part of the responsibility for flood damage reduction to local governments and to provide an incentive for floodplain regulation.

A 1969 amendment to this legislation made the NFIP more practicable by setting up an emergency insurance program for communities that lacked the information necessary for floodplain regulation. Once the required studies are completed and floodplain management is being implemented, the community moves to the regular insurance program. (These regulations are detailed in the following chapter.)

There are currently about 11,500 communities in the NFIP emergency program and over 5,000 in the regular program. Conversions from emergency to regular are occurring at a rate of approximately 1,000 communities a year.

Flood Disaster Protection Act, 1973 (P.L. 93-234)
In effect, this legislation changed the NFIP from a voluntary to a mandatory program. It achieved this by requiring purchase of flood insurance for any federal project and, more significantly, any project in a flood-prone area that relies on federal mortgage guarantees. This tied flood insurance to any building that was financed with assistance of Federal Housing Administration and Veterans Housing Administration loans, or for which a loan was guaranteed by the Federal Deposit Insurance Corporation or the Federal Savings and Loan Insurance Corporation. It also prohibited payment of disaster funds, except for emergency relief, in communities that were not participating in the NFIP.

Disaster Relief Acts, 1970 and 1974 (P.L. 91-606 and 93-228)
The first of these acts set up a disaster relief program to assist areas that have suffered major damage during a natural disaster. The program is managed by the Disaster Response and Recovery Office, a part of the Federal Emergency Management Agency (FEMA). The second act supplemented the first by requiring hazard mitigation actions, either before or after a disaster, as a condition for receipt of disaster relief funds.

The coordinated use of the full range of strategies is essential to achieving a significant reduction in flood losses. Following is a brief review of the nonstructural methods that have emerged in recent years.

Land-Use Planning and Management

The principal nonstructural strategy for reducing flood damage is to effect better use of water and land resources. This goal is achieved through comprehensive planning for and management of these resources throughout riverine watersheds and coastal environs.

Planning and management, as a strategy to reduce flood damage, addresses the critical need to better integrate the natural and built environments. This approach to the problems of flooding is based on the knowledge that, while floods cannot and should not be totally eliminated, the built environment can nevertheless be successfully developed if it respects the natural system.

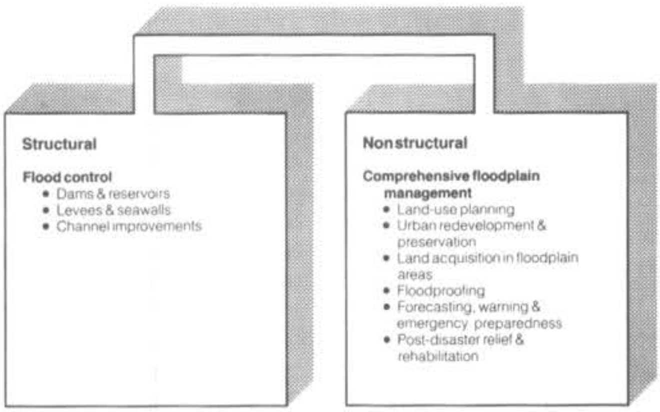
Planning and management, in practice, are based on compiling technical data on topography, drainage, soil composition, climate, and other natural characteristics and analyzing it in light of the physical, social, and economic aspects of the built environment. This analysis is then used to determine appropriate locations for both the encouragement and prohibition of building. Implementation then relies on regulations, such as zoning ordinances, subdivision regulations, and health and building codes, or on incentives that induce positive development practices. Floodplain management objectives can also be realized in conjunction with programs for urban revitalization and preservation, or through land acquisition by public bodies to control development.

Urban Redevelopment and Preservation

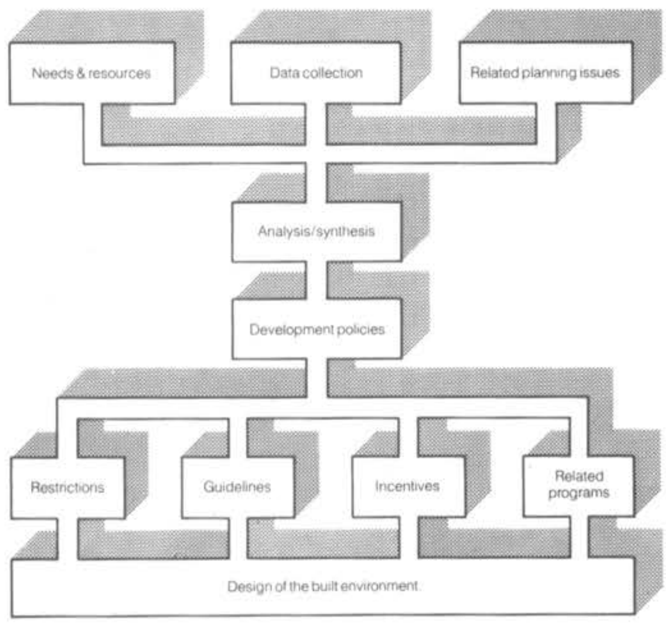
Renewal of the nation's cities is by its nature a continuous process. It offers the opportunity to rectify many of the earlier development practices that have contributed to flood damage. In some cases land that is particularly vulnerable to flooding can be cleared by "down-zoning" it to open space uses. In many cases, however, economic constraints or the historical significance of a building or district can make this impossible.

When renewal is to occur, design and development can make use of site design and floodproofing strategies to lessen the impact of flooding. Obviously, there is more latitude when working with a cleared site, but these strategies can also be applied to existing buildings.

Historical preservation is often a high priority in rehabilitation. Schemes to preserve important cultural artifacts require careful and creative use of damage reduction strategies to make a building safer from flood damage while respecting the integrity of the original design.



The floodplain planning process allows careful consideration of the various issues related to floods, resulting in the regulation and guidance of design and development.



Urban redevelopment and preservation in flood-prone areas offer opportunities to rectify many of the development practices that contributed to flood damage in the past. Such projects can use site design and floodproofing strategies to lessen the impact of flooding.

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Acquisition and Relocation

In many flood-prone areas existing development suffers repeated damage. Often such locations can be protected only by removing development, but this can rarely be accomplished without public ownership of the land. Public ownership is, likewise, the surest way to protect vacant land that is subject to development pressure.

A growing number of public bodies recognize the desirability of both acquiring such hazardous sites, either through negotiation or eminent domain, and relocating existing uses to safer sites. This strategy mitigates recurring losses, helps to restore natural processes in the floodplain, and promotes open space uses such as agriculture or recreation.

Federal authority to implement such policies exists in several forms. Section 1362 of the National Flood Insurance Act allows the Federal Emergency Management Agency (FEMA) to acquire certain flood-prone sites. To qualify, properties must meet several criteria—they must be insured, they must be substantially damaged or repeatedly flooded, and the relevant local government must be willing to take the property under its control. Implementation of Section 1362 has been slow, partly because of the constraints described above and partly because of a lack of funding. Fiscal year 1980 was the first time that funds were available specifically for Section 1362 acquisitions, with over $5 million used for that purpose in that year.

Earlier acquisition and relocation projects have been carried out using a variety of other funding sources. A project to relocate the business district of Soldier's Grove, Wisconsin, out of a riverine floodway has been initiated using discretionary funds available to the Departments of Interior and Housing and Urban Development and a grant from the Economic Development Administration. Section 73 of the 1974 Water Resources Development Act (P.L. 93-251) provides for acquisition and relocation, and

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several programs are underway. For example, in Prairie du Chien, Wisconsin, the U.S. Army Corps of Engineers is in the process of moving both residential and commercial buildings out of a highly vulnerable floodplain.

The scope of acquisition can vary widely. Following the devastating flash flood of 1972 in Rapid City, South Dakota, the entire floodway of Rapid Creek was acquired and cleared for open space. A local effort in Baltimore County, Maryland, purchased more than 200 dwellings that were located in the floodplain of several suburban streams. In Littleton, Colorado, the Corps of Engineers purchased 750 acres of land downstream from a reservoir to protect it from urban expansion. Other such projects are gaining momentum as funding sources are identified.

Floodproofing

Despite floodplain management and related programs to remove structures from hazardous locations, buildings will inevitably continue to be located in such areas. It is necessary that these buildings be protected from flood damage. Floodproofing, working in conjunction with floodplain management, provides this kind of protection.

Floodproofing encompasses any technique intended to protect buildings from flooding, and typically includes elevating buildings above the flood hazard level, providing watertight closures for doors and windows, and using floodwalls around ground level openings or, alternatively, eliminating such openings. Also included are the use of water-resistant materials, structural reinforcement to withstand water pressures, and placement of mechanical elements in the upper parts of buildings.

Floodproofing is applicable to historic buildings, to essential uses that are not suitable for alternative locations, and to areas in which the capital investment in the existing urban infrastructure requires continued occupation of a hazardous location. In these situations flood-

U.S. Army Corps of Engineers

Some existing development cannot be effectively protected from flooding. Recently, federal programs have been used to acquire these properties and relocate them in safe areas. Above is a portion of Prairie du Chien, Wisconsin (within circle), that was relocated by the Corps of Engineers.

proofing can be indispensable. Floodproofing is especially suitable where moderate flooding with low stage, low velocity, and short duration is experienced.

Forecasting, Warning, and Emergency Preparedness

Forecasting, warning, and emergency preparedness measures are integral parts of a well-balanced floodplain management system. For example, adequate warning allows time for the preparation of temporary floodproofing closures and the evacuation of people and building contents from hazardous locations. This is, in part, a technical issue of concern to meteorologists and hydrologists and, in part, an administrative issue requiring a system of emergency planning, organization, communication, and public education.

U.S. Geological Survey

Small-scale dikes can be constructed as part of an emergency preparedness plan. The sand-bag dike is protecting the houses from flood damage.

Relief and Rehabilitation

Relief and rehabilitation are, in the first instance, not methods of reducing flood damage, but ways of dealing with damage after other measures have been insufficient. Relief and rehabilitation assistance can include direct clean-up operations as well as loans, grants, and tax reductions to facilitate rebuilding and relocating where necessary. Federal agencies are the primary source of this aid, with private support available from organizations such as the Red Cross.

Rehabilitation can provide important damage mitigation opportunities. When rehabilitation is necessitated by flood disaster, future flood losses can be reduced by ameliorating many of the problems that contributed to destruction. There are often strong local pressures to rebuild as quickly as possible, particularly where economic livelihood is involved. And such pressures are justified. Yet, just as often there are long-term economic and social reasons for breaking the cycle of repeated destruction and ensuring that earlier development mistakes are not duplicated.

Post-disaster rehabilitation is most effective if it responds quickly to the needs of local residents but minimizes future destruction. This requires that redevelopment proceed according to sound principles of floodplain management, taking advantage of the various methods for reducing flood damage that apply to new development.

Experience has shown that any needed improvements in structural flood control devices should be seen as supplementary to the nonstructural measures now available. Changes in land use, acquisition and relocation of flood-prone properties, and appropriate floodproofing protection for buildings should all be used in the rebuilding effort. This comprehensive approach requires planning and coordination, which is properly the role of

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government agencies, but also needs the cooperation and support of all participants in the redevelopment process.

The issues and methods discussed in this and the preceding chapter must be integrated into the process of development. The remaining chapters will tie flood problems more specifically to one of the crucial components of development, design of the built environment.

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Unified National Program for Flood Plain Management. Washington, D.C.: U.S. Water Resources Council, 1979.

When flooding occurs, relief programs include the inevitable clean-up as well as assistance to victims of the disaster.

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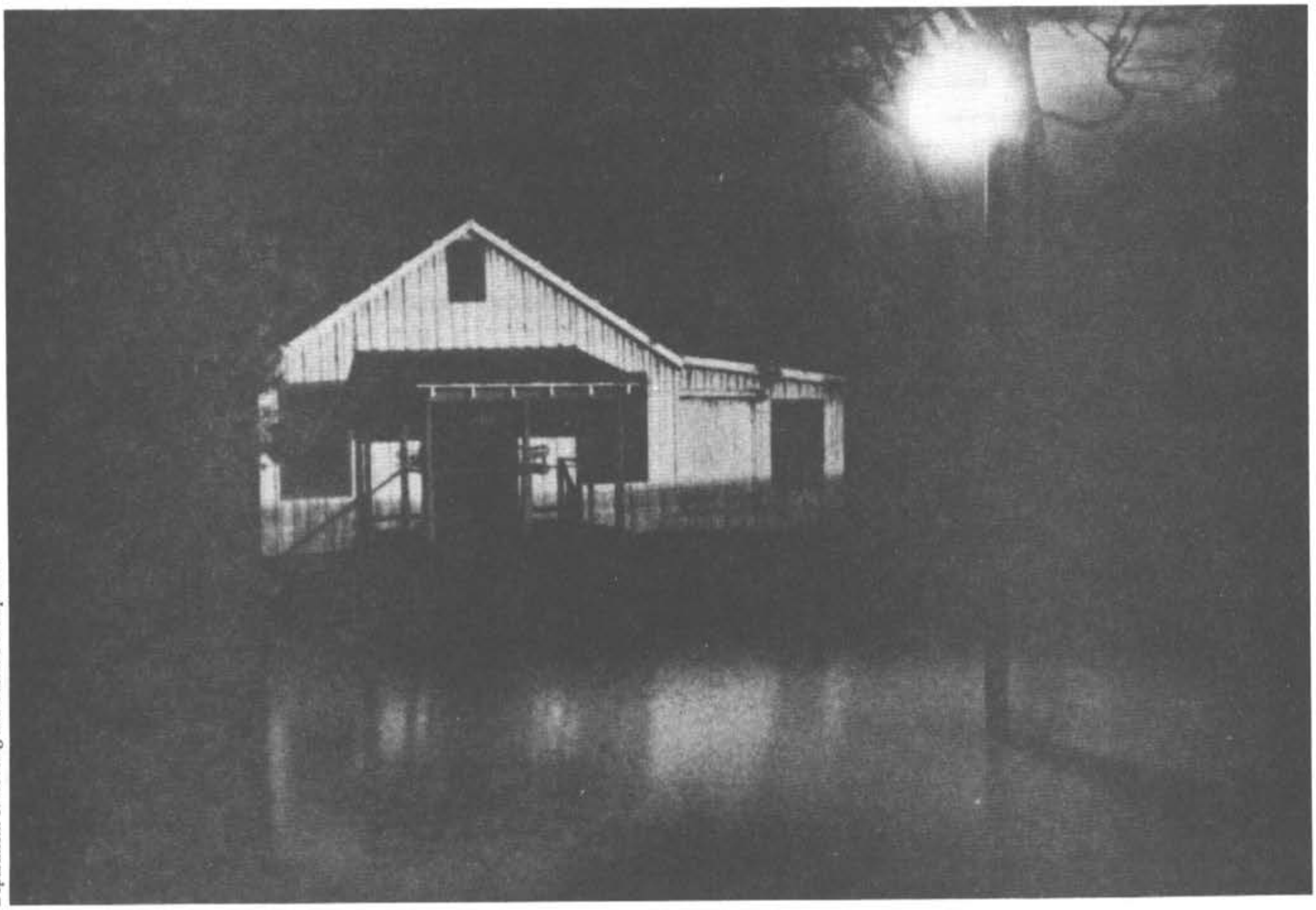
Chapter 4

Design Analysis for Flood Damage Reduction

Achieving a significant reduction in current levels of flood damage requires attention to all aspects of the development process, from structural flood control to floodplain management to design of the built environment. Designers are principally involved in the latter, with their necessary response being the explicit inclusion of damage reduction strategies in the design process. Such action requires that they first be aware of regulatory restrictions and guidelines, site-specific flooding characteristics, and appropriate techniques for mitigating flood damage through project design.

Previous chapters discuss the general relationship between flooding and the built environment. This chapter examines the specific information the designer needs for projects in flood-prone areas. This information is used in pre-design project analysis, both to ascertain basic flood hazards and to ensure that the project meets relevant regulatory requirements. The concluding chapter explores the associated techniques that are applied during development of the actual design.



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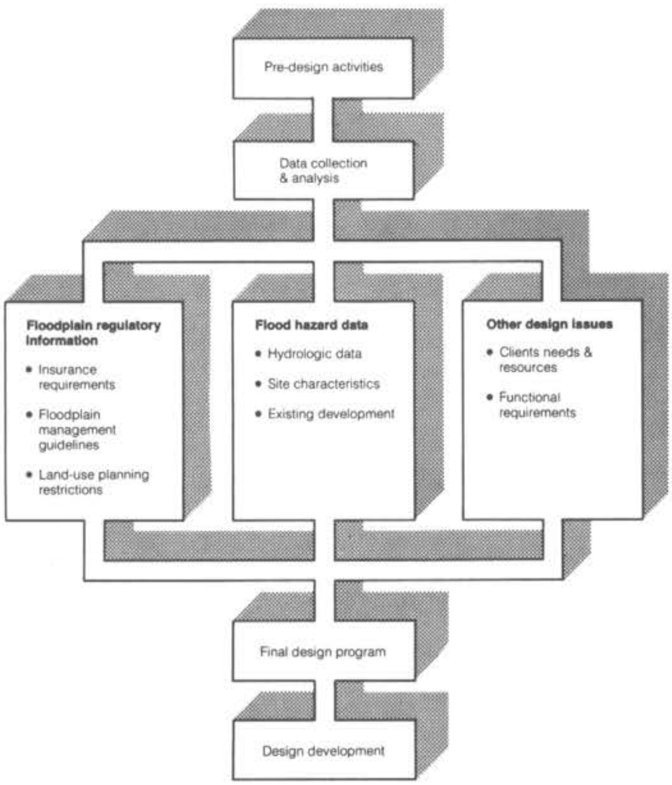


The design process must include analysis of floodplain regulatory information and flood hazard data.

The development process involves a wide range of decisions that directly influence the subsequent design of any project. The designer's role in making these decisions varies according to the nature of any given project, but generally centers on project analysis and evaluation. This phase culminates in the design program, which identifies problems and issues and sets out the requirements and criteria that will guide the generation of appropriate design responses. It is essential that analysis of flooding issues be part of this pre-design phase.

As with any aspect of a design problem, the starting point in analyzing the potential effects of flooding on a project is the collection and analysis of pertinent data. This research adds the necessary technical information to the client's initial program of needs and resources, thus making the connection between the individual site and the larger context of natural systems and the existing built environment.

Project analysis first requires knowledge of what data to collect, why it is important, and where it can be obtained. Analysis should identify the interaction of components in the natural and built environments and the relationship of these components to design of the proposed project.

The following sections identify the data relevant to flood damage reduction, outline the importance of the data, and review potential data sources. Pertinent data is categorized first according to the variety of flood-related regulatory programs and then according to specific flood hazard data.

Regulatory Information

A number of local, state, and federal requirements apply to development in flood-prone areas, foremost of which are a variety of programs for floodplain management. Part of the pre-design collection and analysis of information should include identification of these regulatory requirements and assessment of their constraints and opportunities.

National Flood Insurance Program

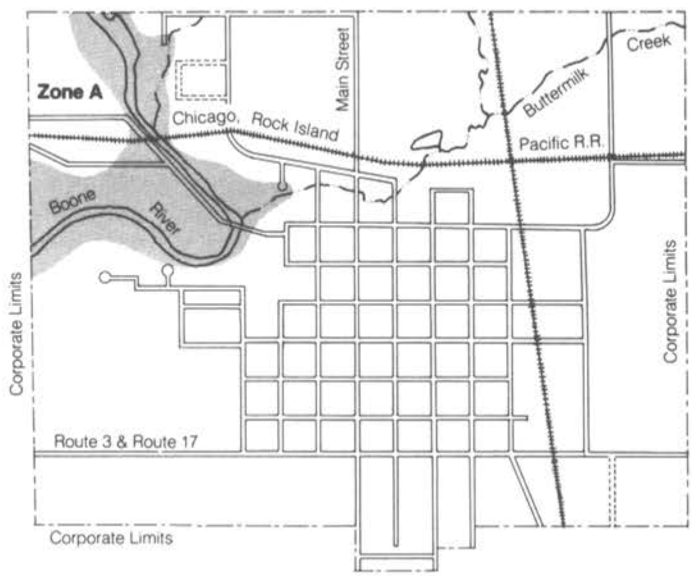
A primary impetus for mitigating flood damage comes from the National Flood Insurance Program (NFIP), which was established by Congress in 1968 to reduce the losses associated with flood damage. Administered by the Federal Emergency Management Agency (FEMA), this program's primary component is a stipulation that flood insurance is available only in communities that have satisfied federal requirements for floodplain management. This stipulation serves as an incentive to local governments to undertake appropriate planning measures to reduce flood losses by regulating development in hazardous areas. In addition to the planning incentive, the intent of the NFIP is expressed through insurance rate differentials and financial restrictions on federally guaranteed loans.

Emergency Program. Insurance regulations governing the NFIP vary according to the status of an individual community's floodplain regulatory process. When the available data on local flood hazards is insufficient to support final regulations, the community enters the "emergency phase," which provides limited insurance coverage with a large subsidy. A community may enter this emergency phase prior to completion of a detailed flood hazard survey. The local government, relying on an initial Flood Hazard Boundary Map, must adopt preliminary regulations to encourage proper development practices in flood-prone areas.

Regular Program. After the completion of detailed surveys (which are funded by FEMA), the resulting technical studies allow more comprehensive regulations. These technical reports identify pertinent information such as base flood elevations, areas inundated by various magnitudes of flooding, floodway boundaries, and coastal high hazard areas. This information is provided in the form of Flood Insurance Rate Maps, Flood Boundary Maps, and Floodway Maps.

Flood Hazard Boundary Map FHBM

City of Floodville, Pennsylvania Flood County



Zone A Areas of Special Flood Hazard

Note: These maps may not include all Areas of Special Flood Hazard in the community. After a more detailed study, the areas shown on this map may be modified and other areas added.

Flood Hazard Boundary Maps like this one are used as the basis of preliminary floodplain regulations in the emergency phase of the National Flood Insurance Program.

ELEVATION REFERENCE MARKS

REFERENCE MARK	ELEVATION (FEET NGVD)	DESCRIPTION OF LOCATION
RM1	889.70	U.S. Geological Survey standard brass disk, stamped „Erie 1934" set in top of concrete post flush with ground located in the city park, 4.7 feet north of the centerline of Third Street, 146 feet east of the centerline of Butler Street.
RM2	890.23	Top of southwestern bolt on the top flange of fire hydrant at northeast corner of the intersection of Fifth Street and Massachusetts Street.
RM3	889.36	Top of railroad spike projecting from north side of power pole, approximately one foot above the ground, located at northwest corner of intersection of Seventh Street and Massachusetts Street.
RM4	891.21	Top of west bolt on the top flange of fire hydrant at southeast corner of the intersection of Wilder Street and Butler Street.
RM5	894.25	Top of southeastern bolt on the top flange of fire hydrant at southwest corner of intersection of State Street and Butler Street.
RM6	902.12	Top of southwestern bolt on the top flange of fire hydrant at southeast corner of intersection of Railroad Street and Butler Street.
RM7	889.53	Chiseled cross on east end of south headwall of Second Street over the Tributary to Puckets Run Creek.
RM8	892.68	Top of railroad spike head projecting from north side of power pole, approximately one foot above the ground, located at southeast corner of intersection of Canville Street and the Missouri, Kansas, Texas railroad tracks.

Flood Insurance Rate Map

KEY TO MAP

- 500-Year Flood Boundary
- 100-Year Flood Boundary
- Zone Designations* With Date of Identification e.g., 12/2/74
- 100-Year Flood Boundary
- 500-Year Flood Boundary
- Base Flood Elevation Line With Elevation in Feet** — 513
- Base Flood Elevation in Feet Where Uniform Within Zone** — (EL 987)
- Elevation Reference Mark — RM7x
- River Mile — • M1.5

**Referenced to the National Geodetic Vertical Datum of 1929

*EXPLANATION OF ZONE DESIGNATIONS

ZONE	EXPLANATION
A	Areas of 100-year flood; base flood elevations and flood hazard factors not determined.
AO	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; average depths of inundation are shown, but no flood hazard factors are determined.
AH	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; base flood elevations are shown, but no flood hazard factors are determined.
A1-A30	Areas of 100-year flood; base flood elevations and flood hazard factors determined.
A99	Areas of 100-year flood to be protected by flood protection system under construction; base flood elevations and flood hazard factors not determined.
B	Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood. (Medium shading)
C	Areas of minimal flooding. (No shading)
D	Areas of undetermined, but possible, flood hazards.
V	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined.
V1-V30	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors determined.

NOTES TO USER

Certain areas not in the special flood hazard areas (zones A and V) may be protected by flood control structures.

This map is for flood insurance purposes only; it does not necessarily show all areas subject to flooding in the community or all planimetric features outside special flood hazard areas.

For adjoining map panels, see separately printed Index To Map Panels.

INITIAL IDENTIFICATION – JUNE 28, 1974

CONVERSION TO REGULAR PROGRAM – FEBRUARY 16, 1979

Refer to the CONVERSION TO REGULAR PROGRAM date shown on this map to determine when actuarial rates apply to structures in the zones where elevations or depths have been established.

To determine if flood insurance is available in this community, contact your insurance agent, or call the National Flood Insurance Program, at (800) 638-6620, or (800) 424-8872.

ELEVATION REFERENCE MARKS

REFERENCE MARK	ELEVATION (FEET NGVD)	DESCRIPTION OF LOCATION
RM1	889.70	U.S. Geological Survey standard brass disk, stamped „Erie 1934" set in top of concrete post flush with ground located in the city park, 4.7 feet north of the centerline of Third Street, 146 feet east of the centerline of Butler Street.
RM2	890.23	Top of southwestern bolt on the top flange of fire hydrant at northeast corner of the intersection of Fifth Street and Massachusetts Street.
RM3	889.36	Top of railroad spike projecting from north side of power pole, approximately one foot above the ground, located at northwest corner of intersection of Seventh Street and Massachusetts Street.
RM4	891.21	Top of west bolt on the top flange of fire hydrant at southeast corner of the intersection of Wilder Street and Butler Street.
RM5	894.25	Top of southeastern bolt on the top flange of fire hydrant at southwest corner of intersection of State Street and Butler Street.
RM6	902.12	Top of southwestern bolt on the top flange of fire hydrant at southeast corner of intersection of Railroad Street and Butler Street.
RM7	889.53	Chiseled cross on east end of south headwall of Second Street over the Tributary to Puckets Run Creek.
RM8	892.68	Top of railroad spike head projecting from north side of power pole, approximately one foot above the ground, located at southeast corner of intersection of Canville Street and the Missouri, Kansas, Texas railroad tracks.

Flood Boundary and Floodway Map

KEY TO MAP

- 500-Year Flood Boundary
- 100-Year Flood Boundary
- FLOOD FRINGE
- FLOODWAY
- 100-Year Flood Boundary
- 500-Year Flood Boundary
- Approximate 100-Year Flood Boundary
- Cross Section Line — (A)—(A)
- Elevation Reference Mark — RM7x
- River Mile — • M1.5

NOTES TO USER

Boundaries of the floodways were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations without regard to economic, legal, or political factors.

This map was prepared to support minimum flood plain management regulations; it may not show all areas subject to flooding in the community or all planimetric features outside special flood hazard areas.

For adjoining map panels, see separately printed Index to Map Panels.

Upon completion of technical floodplain studies, designation of appropriate flood boundaries, and adoption of floodplain regulations that meet NFIP minimum standards, a community is eligible for the NFIP "regular phase." Regulatory standards for the regular phase are more specific and more stringent than for the emergency program (see accompanying box for details of NFIP regulations). Entry into the regular program qualifies local property owners for full flood insurance coverage at actuarial rates that vary according to the degree of risk.

Insurance Rate Differentials. The variable rate structure for flood insurance premiums is another important component of the regular program of the NFIP. Flood hazard areas are divided into different zones, based on the degree of hazard. The rate for insurance then varies according to the zone and to the elevation of the building in relation to the base flood elevation.

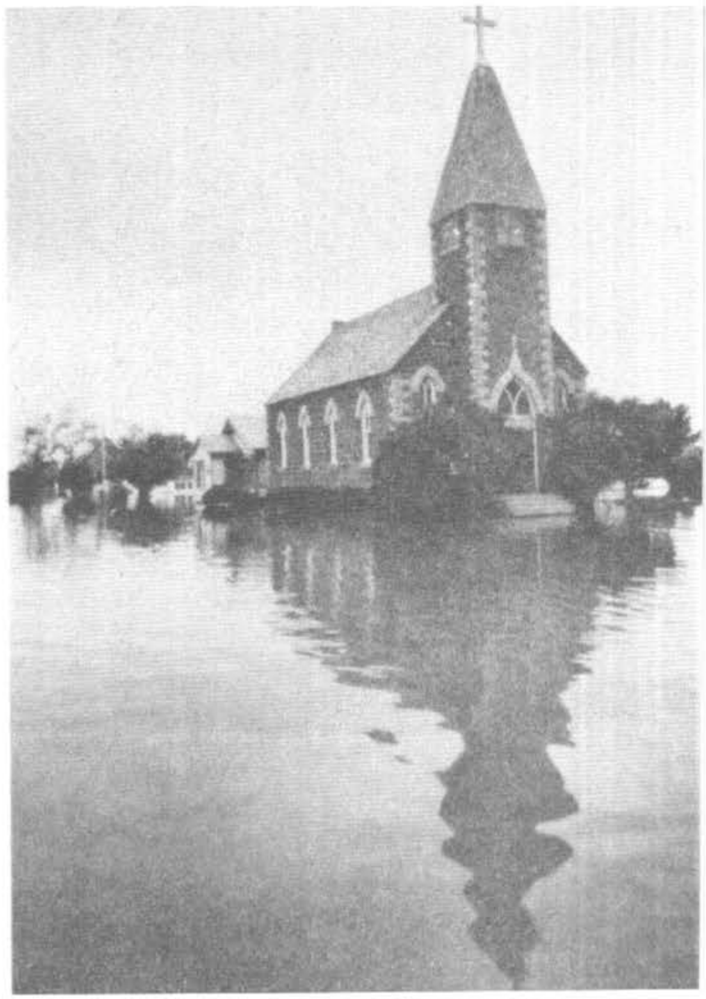
This variable rate structure adds a dimension to the restrictive element of the program by providing an incentive in fringe areas to increase safety beyond the regulatory minimum. Designers should be cognizant not only of the minimum standards, but also of the immediate and longterm economic benefits to the client that are provided by the rate differentials.

Local Planning and Floodplain Management

With the NFIP as incentive, nearly 17,000 communities around the country have begun to implement floodplain management through their local planning process. The principal tool for achieving this objective is the traditional zoning ordinance, which is used to prohibit and regulate development in designated flood hazard areas. Zoning is supplemented by subdivision regulations, which provide an administrative review to ensure that a project meets specified development standards. Of particular interest in this regard is the provision of public facilities, roads, and utilities in a manner that will not contribute to flood problems.

Innovative Planning Tools. In addition to traditional zoning and subdivision regulations, some communities use innovative planning techniques to address the specific problems of flooding. Notable here is the

After completion of detailed surveys, floodplain management regulations are implemented using Flood Insurance Rate Maps (opposite page, above) and Flood Boundary and Floodway Maps (opposite, below).



Department of Housing and Urban Development

American Red Cross

National Flood Insurance Program

The National Flood Insurance Program (NFIP) makes flood insurance available to individual property owners if, and only if their local government jurisdiction (i.e., city or county) participates in the NFIP and implements a program for floodplain management.

NFIP—Emergency Phase

When a local government enters the initial emergency phase of the NFIP it must adopt regulations to provide preliminary control of development in flood-prone areas. These regulations must:

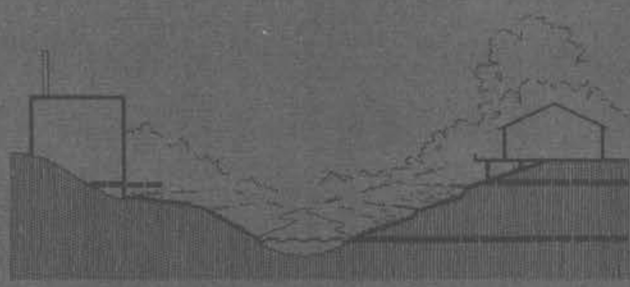
- Require building permits for all proposed construction.
- Require a review of building permit applications to ensure that new construction or substantial improvements* to existing buildings are reasonably safe from flooding.
- In flood-prone areas, as defined by a Flood Hazard Boundary Map, require:
  - —Design and anchoring to prevent flotation, collapse, or lateral movement of the structure.
  - —Use of construction materials and utility equipment that are resistant to flood damage.
  - —Use of construction methods and practices that minimize flood damage.
- Require a review of subdivision proposals and other proposed new developments to ensure that:
  - —All such proposals are consistent with the need to minimize flood damage.
  - —All public utilities and facilities, such as sewer, gas, electric, and water systems are located and constructed to minimize or eliminate flood damage.
  - —Adequate drainage is provided to reduce exposure to flood hazard.
- Require that new or replacement water supply systems and/or sanitary sewage systems be designed to minimize or eliminate both infiltration of flood waters into the systems and discharges from the systems into flood waters, and require that on-site waste disposal systems be located to avoid impairment of them, or contamination from them, during flooding.

NFIP—Regular Phase

After detailed surveys and technical studies have provided more precise information on flooding characteristics, the local community must transfer to the regular phase of the NFIP. This move requires adoption of more stringent measures governing development in flood-prone areas and must include the following minimum regulations, which supplement those of the emergency phase.

- Residential buildings, either new construction or substantial improvements to existing structures, must have the lowest floor, including basements, above the regulatory base flood elevation (BFE).
- Nonresidential buildings, either new construction or substantial improvements to existing structures, must have the lowest floor above the BFE or be floodproofed up to the same elevation.
- A regulatory *floodway* must be designated, and in this area no new construction or substantial improvement to existing buildings can be permitted.
- Fill or encroachments are prohibited from the designated floodway.
- Mobile homes cannot be placed within the designated floodway, except in existing mobile home parks.

Flood magnitudes are frequently described in relation to the frequency with which a certain level of flooding is likely to occur.



Buildings in a riverine setting should be located above the Base Flood Elevation (BFE).

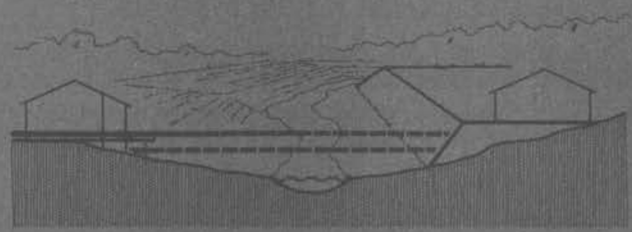
Coastal High Hazard Areas

Coastal High Hazard Areas are analogous to riverine floodways in that these areas are immediately adjacent to water and are subject to the greatest threat during flooding. In such coastal areas, designated as V-zones on Flood Insurance Rate Maps (FIRMs), the following regulations must be adopted to supplement other requirements of the NFIP.

- New buildings or substantial improvements to existing buildings must be elevated above the regulatory BFE, which in V-zones is determined by the height of the wave crest that accompanies the storm surge. Such buildings also must be located landward of mean high tide.
- New construction must be anchored securely enough to pilings or columns to withstand high velocity waters and hurricane wave wash.
- New construction must be provided with open space below the lowest floor to allow unobstructed flow of flood water. This space must be free of obstruction or with open lattice walls that

use of performance standards, where development limits are based on measurable impacts. In a project in a flood fringe area where certain kinds of development are acceptable, development densities might be tied to maintaining minimum elevations, to a minimum impervious surface ratio to control water runoff, or to providing stormwater detention systems on the site.

Another technique that can be useful for a flood-prone area is Planned Unit Development (PUD). This method of cluster development is used predominantly for large-scale residential and/or commercial projects, and requires a special planning ordinance. With PUD, part of a given site is built on at a higher density than would otherwise be permitted, thus leaving the remainder of the site as open space. In a flood-prone area, the development could be clustered on the part of the site



Buildings in coastal areas should be located behind the dune or in the trough between dunes, and should be raised above the BFE.

The addition of fill material can impede the flow of flood water and may increase flooding levels, thus causing damage to buildings previously above the BFE.

will collapse under abnormally high tides without jeopardizing the main structure.

- Land fill cannot be used for structural support.
- Sand dunes and mangrove stands cannot be altered if they provide wave or flood protection.

As is often the case, regulations change as continuing research provides better information on the characteristics of flooding. This has happened regarding designation of the BFE in Coastal High Hazard Area V-zones, which until recently were determined by the elevation of the storm surge alone. They are now calculated on the basis of the wave crest height, which is the height of waves on top of the storm surge. The new regulations take effect in each local jurisdiction as soon as the FIRMs for respective areas have been updated to show the new BFE. In the interim the wave crest height can be estimated on a case-by-case basis with the help of FIA officials or their representatives. In any event, it is essential that designers consult with local officials to ascertain the status of regulations in their area before beginning any project. Existing variable insurance rates already provide an incentive to locate buildings at the higher elevations, but once the new requirements are in effect substantial insurance savings will accrue to conforming structures. A Federal Emergency Management Administration publication, *The Coastal Construction Manual*, takes these new requirements into account and should be used as a guide for designing in coastal areas.

Definition of Terms Used in NFIP

Base Flood Elevation—Base Flood Elevations (BFE) are associated with an intermediate level of flooding that is significantly less than the greatest floods that could occur. Flood magnitudes are expressed in various ways, the most common being to describe them in relation to the frequency with which a certain level of flooding is likely to occur. For example, a level of flooding that, according to statistical probability, will be equaled or exceeded every 50 years is termed a "50-year flood"; the flood level likely to be equaled or exceeded every 100 years is termed a "100-year flood"; and the level likely to be equaled or exceeded every 500 years is termed a "500-year flood." It is important to remember that these designations are based on probability.

The regulatory BFE is based on the probable 100-year flood or, in coastal areas, the wave crest height of the 100-year storm tide. These also are referred to as floods with a one-percent chance of occurrence in any given year. However, these designations should not be interpreted literally, since floods do not occur in predictable cycles. Another way to express flood probability is to say that a 100-year flood has a 26 percent chance of occurring during the life of a 30-year mortgage. It is also noteworthy that a local jurisdiction may adopt requirements more stringent than the NFIP.

Coastal High Hazard Areas—the area immediately adjacent to the ocean and subject to high velocity waters, including but not limited to hurricane wave wash, storm surges, and tsunamis. National Flood Insurance Program regulations for Coastal High Hazard Areas, also known as V-zones, apply where tides, storm waves, and local geographic characteristics combine to produce a breaking wave of three feet or more.

Encroachment—any physical object in a floodplain that hinders the passage of water or otherwise affects flood flows.

Flood proofing—any combination of structural provisions and/or other modifications incorporated in individual buildings or properties subject to flooding, primarily for the reduction or elimination of flood damages (see Chapter 5 for details).

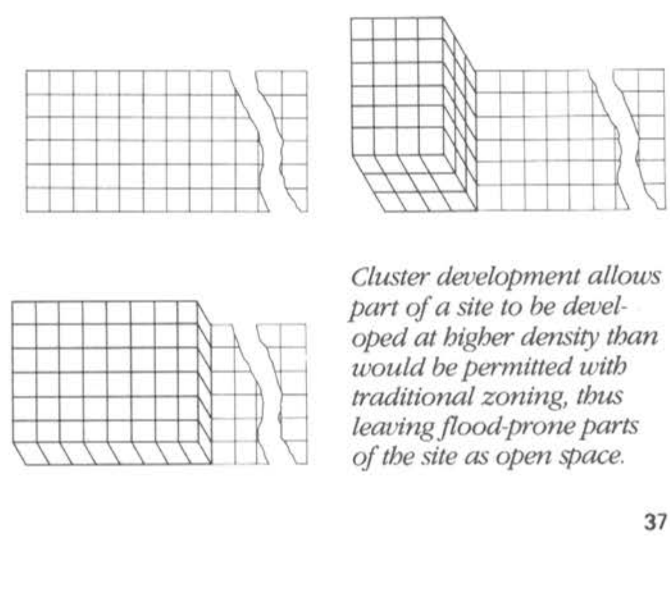
Floodway—the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.

Substantial Improvements—any improvement costing more than 50 percent of a structure's current market value.

that is safe, leaving the flood-prone part free of buildings but still usable as recreation space or parking.

Any of various local planning techniques can be used to control development to reduce flood damage. The designer should refer to these regulations to identify both restrictions that will apply to proposed buildings and opportunities that may be presented by planning regulations such as the PUD ordinance. The local planning agency is also a primary information resource for the designer. In addition to zoning maps, it will often provide access to other data that is useful in identifying flood hazards, such as is contained in the variety of technical floodplain studies.

Building Codes. Building codes are used infrequently to address the specific problems of flood damage. However, there are elements of design that



Cluster development allows part of a site to be developed at higher density than would be permitted with traditional zoning, thus leaving flood-prone parts of the site as open space.

Though this house remained intact, the force of a coastal flood knocked it off its foundation, causing extensive damage.

conceivably can be included in building codes in regard to flooding. For example:

- Codes may prohibit basements in certain areas or can require that basements be floodproofed to protect against damage.
- Structural reinforcements, waterproofing, or other protective measures may be required for structures with the first floor or basement below the base flood elevation.
- Buildings may be required to be anchored to prevent flotation during flooding.
- Building materials for use in flood-prone areas may be specified.

One of the national model codes does make general references to flood-related standards. The Building Officals and Code Administrators (BOCA) model code includes sections requiring structural integrity of foundations, walls, floor slabs, and retaining walls that might be subjected to water pressure. This model code (see the Resource Index for specific sections of the BOCA model code) is used in many parts of the country, often being adopted by reference. Other communities may have similar or more stringent requirements, and the designer should consult with local or state building officials to ascertain what codes are in effect.

State Programs

Some states have regulations applying to development in floodplains, along river channels, or in coastal zones. These regulations may be parallel to local requirements or in addition to them. The appropriate state government departments responsible for floodplain management, water resources, building codes or coastal zone management should be consulted prior to design of any project in a flood hazard area (state agencies are listed in the Resource Index).

Each state has designated a State Coordinating

Agency to assist in the implementation of the NFIP. This agency is a focal point for information on flood insurance, floodplain management, and coordination of the diverse state agencies with responsibilities for riverine and coastal floodplains. The authority of each state's coordinating agency varies, and can best be determined through direct contact. These agencies can be important sources of physical data, information on community eligibility for flood insurance, state regulations, references to other agencies, and, in some instances, technical assistance (State Coordinating Agencies are listed in the Resource Index).

Regional Jurisdictions

Several regional jurisdictions, both governmental and quasi-governmental, have taken an interest in floodplain management. Foremost of these is the Tennessee Valley Authority (TVA), the federally owned corporation established in 1933 to conduct a unified program of resource development for the economic growth of the Tennessee River Valley. It has played a leading role in both structural and nonstructural aspects of floodplain management, and is a particularly valuable source of physical data and technical assistance to professionals and communities in the region.

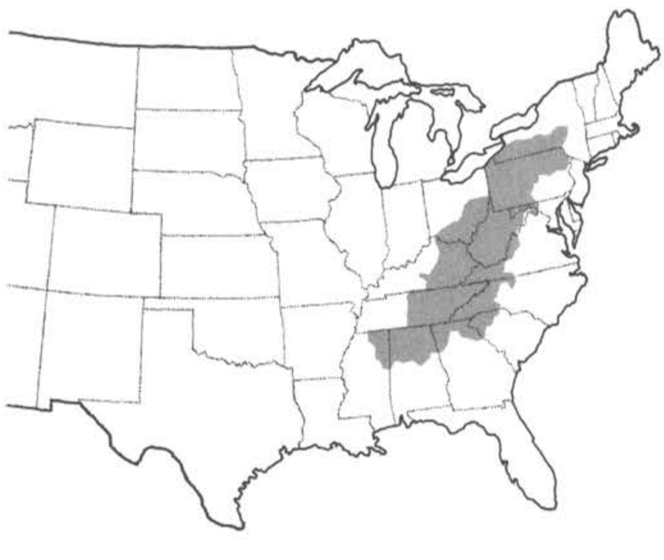
Within the thirteen-state Appalachian region, the Appalachian Regional Commission has been established as a cooperative federal-state entity to analyze regional problems and coordinate federal and state initiatives in Appalachia. It has addressed flooding and other natural hazards problems, and is a valuable source of economic, physical, and social data for its region.

Nine federal and state River Basin Commissions conduct a similar range of policy, planning, research, and coordinating activities in their respective regions, working closely with the U.S. Water Resources Council.*

Federal Agency Requirements

A variety of federal programs other than the NFIP deal with flooding issues. For example, the U.S. Army Corps of Engineers requires permits for development adjacent to major river channels or flood control projects. For many projects it is necessary to submit an Environmen-

Tennessee Valley Authority jurisdiction



Appalachian Regional Commission jurisdiction

**Delaware River Basin Commission, Great Lakes Basin Commission, Mississippi River Commission, Missouri River Basin Commission, New England River Basin Commission, Ohio River Basin Commission, Pacific Northwest River Basin's Commission, Susquehanna River Basin Commission, and Upper Mississippi River Basin Commission* tal Impact Statement prior to project approval by a governing body or agency. And, on all projects funded directly by the federal government, Presidential Executive Orders require special consideration of flooding issues (E.O. 11988) and protection of wetlands (E.O. 11990). Such requirements should be checked by referring to the appropriate federal agency (see Resource Index for list of agencies and their regional offices).

Flood Hazard Data

Flood hazard data identifies essential flood-related factors for both the general region and the specific site. This basic data helps determine the degree of hazard that is likely at any proposed site, identifies the expected impacts of proposed development on future flooding severity, and provides the necessary information for evaluating and choosing mitigation strategies.

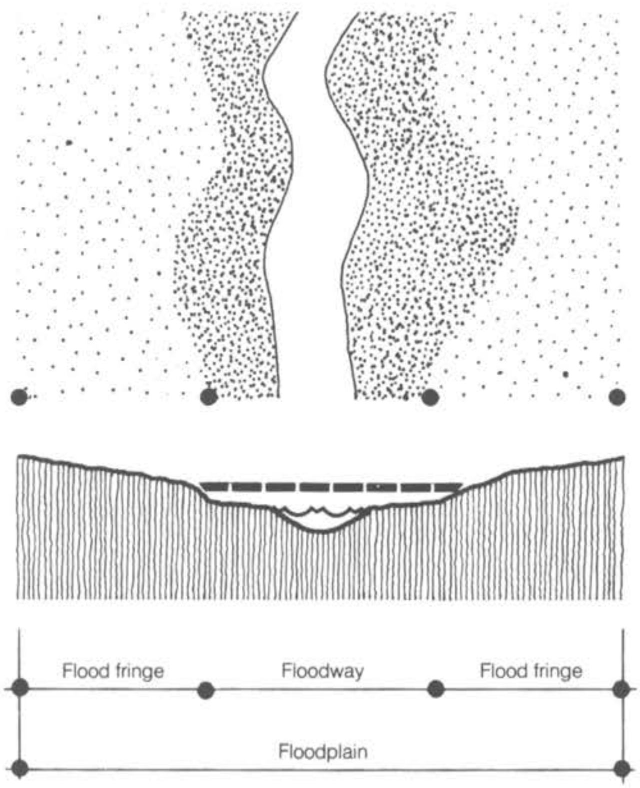
Hydrologic Data

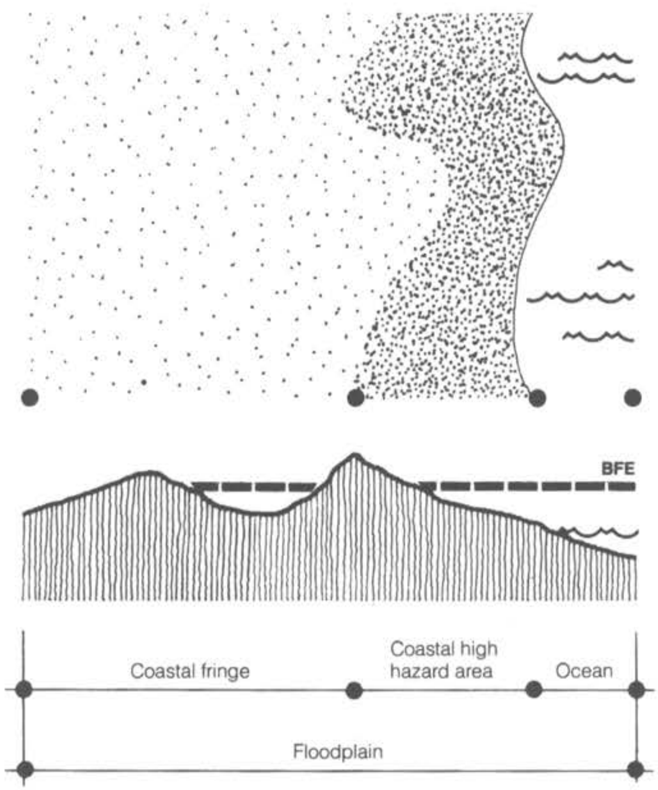
Much of the data relevant to damage mitigation concerns the flow of water associated with the various stages in the hydrologic cycle. A variety of components of the natural system—both riverine and coastal—combine to cause flooding. The designer must analyze these components to understand the threat from flooding that is to be mitigated in design.

Hydrologic data is available from numerous sources. Various governmental agencies carry out floodplain technical studies, the scope and content of which varies according to the needs of each agency. General information on flooding characteristics, as well as detailed analysis of flood boundaries, levels, velocities, etc. are avail-

Agencies / Data type	Coastal Surveys & reports	Flood control measure	Flood hazard reports	Flood insurance studies	Floodplain information reports	Flood records & probabilities	Floodplain technical studies	Hydrologic atlases	National Flood Insurance program regulations	State floodplain regulations	Technical assistance	Topographic maps	Zoning ordinances & maps
Local government planning agency or municipal engineer			●	●			●		●	●			●
State floodplain mangement coordinating agency			●	●			●		●	●	●		
State office of coastal zone management	●						●			●			
Federal emergency management agency			●	●					●		●		
National Oceanic and Atmospheric Administration (Department of Commerce)	●		●	●		●							
Soil Conservation Service (U.S. Dept. of Agriculture)		●	●	●		●							
U.S. Army Corps of Engineers (Department of Defense)		●	●	●	●	●					●		
U.S. Geological Survey (Department of the Interior)			●	●		●	●	●				●	
Regional authorities (e.g. TVA)		●	●	●		●	●				●	●	

Federal, state, and local sources of information on flooding and floodplain management (see Resource Index for detailed listings of information sources).





The regulatory floodplain consists of two components. The riverine floodplain (left) consists of the floodway and the flood fringe. Corresponding designations for the coastal floodplain (right) are the coastal high hazard area and the coastal fringe.

able for all areas of the country and for many specific sites. The accompanying matrix identifies relevant agencies and notes the flood-related data that each agency is usually able to provide.

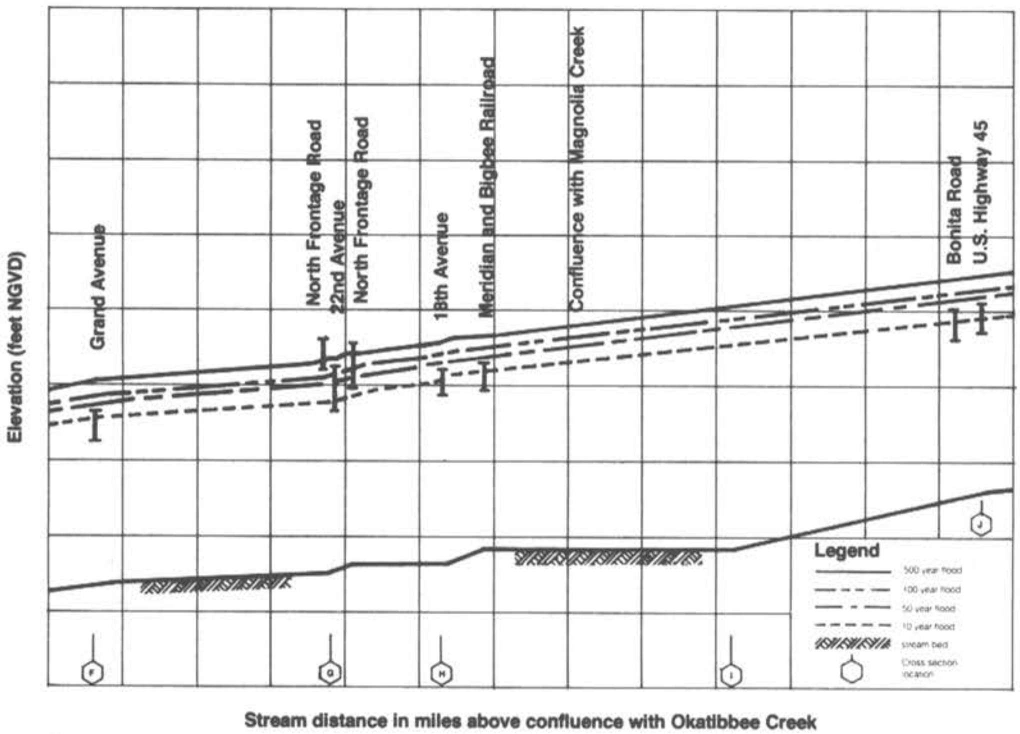
In cases where agencies cannot provide the information or where existing reports do not include a particular site, hydrologic specialists can develop the required information through site-specific surveys. Some large design firms have staff engineers capable of completing hydrologic studies, or such specialists can be retained as consultants for specific projects as required.

Data concerning hydrologic conditions at the proposed site should include the following elements.

Flood Hazard Boundaries. Boundaries for the different degrees and types of flooding, including floodways, floodway fringe, coastal high hazard areas, coastal fringe, and shallow flooding areas, must be identified. Flood hazard boundaries are most significant because they determine the specific flood hazard zones that are part of a proposed development site or that will influence development on the site. In addition, boundaries indicate where floodplain management regulations and flood insurance requirements apply to the site. Flood hazard boundary data can be obtained from floodplain maps or be developed from topographic maps, zoning maps, aerial photographs, and related hydrologic data.

Flood Depths. Flood depths are determined by the difference between water surface elevation at times of flooding and normal ground surface elevations. This information is important both in determining the elevations at which flood damage is likely to occur and in defining the appropriate building elevations for flood insurance and floodplain management regulations. Flood depths also influence the hydrostatic forces that are in effect during flooding, including the horizontal loads that can cause lateral displacement or overturning, and the vertical loads that can cause uplift, flotation, or downward pressure on roofs. Flood depth data is available from various technical studies that include flood elevations, water surface profiles, or stream and coast cross-sections. In the absence of official reports, information on flood depths can be obtained from site survey and historical records.

Flood profiles—Sowashee Creek



Stream distance in miles above confluence with Okatibbee Creek

A flood profile (or water surface profile) such as this one identifies the elevation of various levels of flooding for a specific stream channel.

Flood Water Velocity The average and maximum velocity of flood water is important in determining hydrodynamic forces, which influence horizontal loads in excess of hydrostatic loads. Velocity also affects the magnitude of debris impact loads (i.e., force of floating objects carried by flood waters), and can increase ero-

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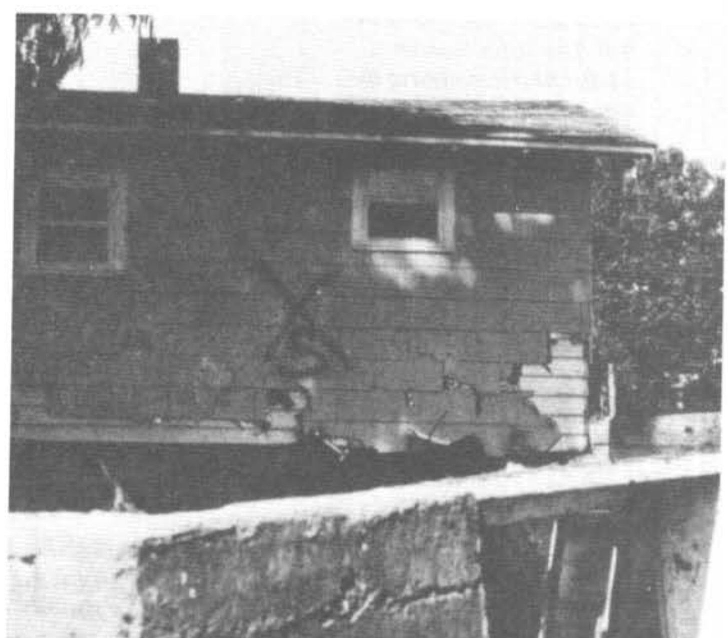
Flood water velocity produces lateral forces that can cause scour and result in collapse of foundations (above left), increase the magnitude of debris impact loads (below left), and dislocate buildings from their foundations (below).

U.S. Army Corps of Engineers



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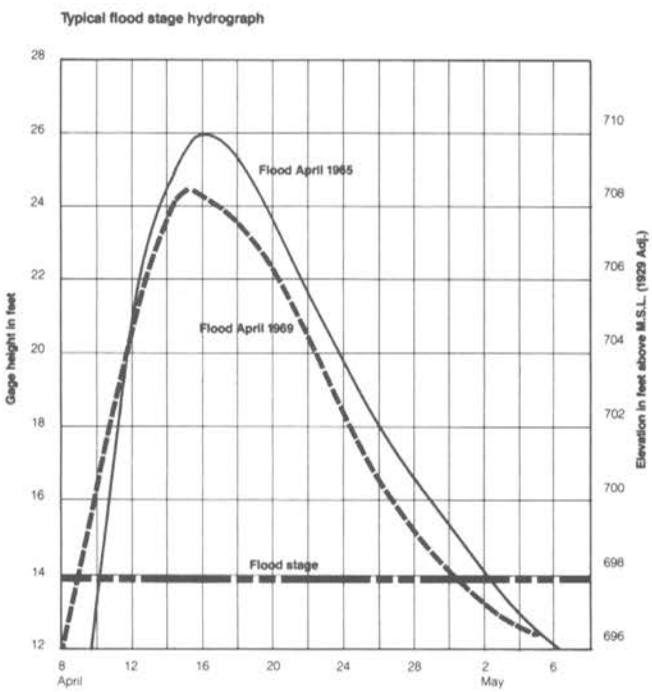
sion and affect soil stability on slopes. Data on water velocity is available from the various floodplain technical studies or can be determined by special hydrologic studies.

Advance Warning. The amount of advance warning prior to flooding is determined largely by the speed with which flood waters rise, which depends on the rate at which water enters the system and the topography of the watershed. The topography of the watershed influences warning time by affecting the rate of storm water runoff. A watershed with flash flooding characteristics will allow very little warning, while a larger and flatter drainage basin will usually result in slower rise and more warning time. Warning time is important in planning for emergency evacuation, as well as in determining the feasibility of incorporating waterproofing tech-



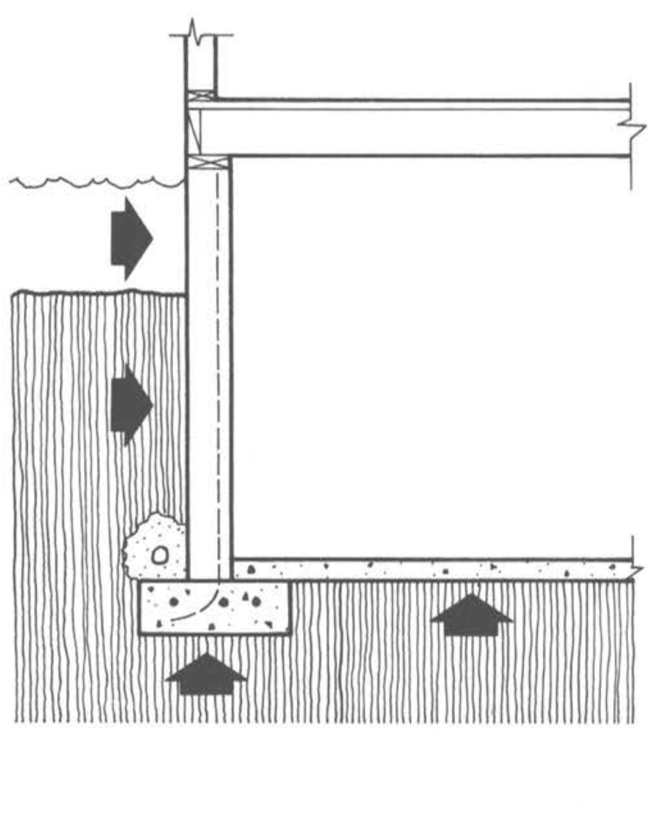
A hydrograph charts water depth in relation to time, indicating the rate at which flood water will rise and fall. This information is useful in determining the amount of advance warning likely and the duration of flooding.

niques that require time to install. It is also a factor in designing systems for wet floodproofing and influences the design of drainage systems.

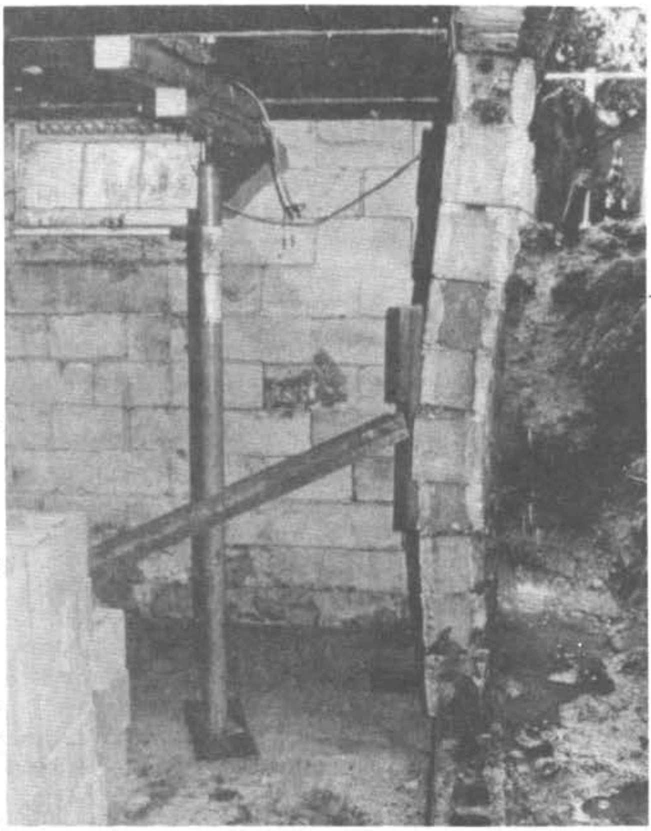
Data on rates of rise and fall of water is typically presented in the form of a hydrograph, which charts water depth over time, and is part of many of the technical reports. In addition to the usual sources, data on warning time may be available from local civil defense offices or the historical records of local police or fire departments.

Duration of Flooding. The duration of flood inundation, which is a function of the rate of rise and fall of water, has several important influences on design. Duration influences the saturation of soils and building materials, the amount of seepage, and the length of time that facilities might be inaccessable or inoperable, which might have major economic impacts. These factors can affect design decisions on building orientation, configuration, and use of the various floodproofing techniques. The various floodplain technical studies and historical records are the sources for this information.

Frequency of Flooding. The frequency with which flooding occurs is of course a major factor in determining building locations. It can also be important in considering techniques for floodproofing, particularly those that require installation prior to each flood event. For



Water pressure, both above and below the ground, is increased by the rise of flood water. This pressure causes increased stress on buildings' foundations, footings, and floor slabs.



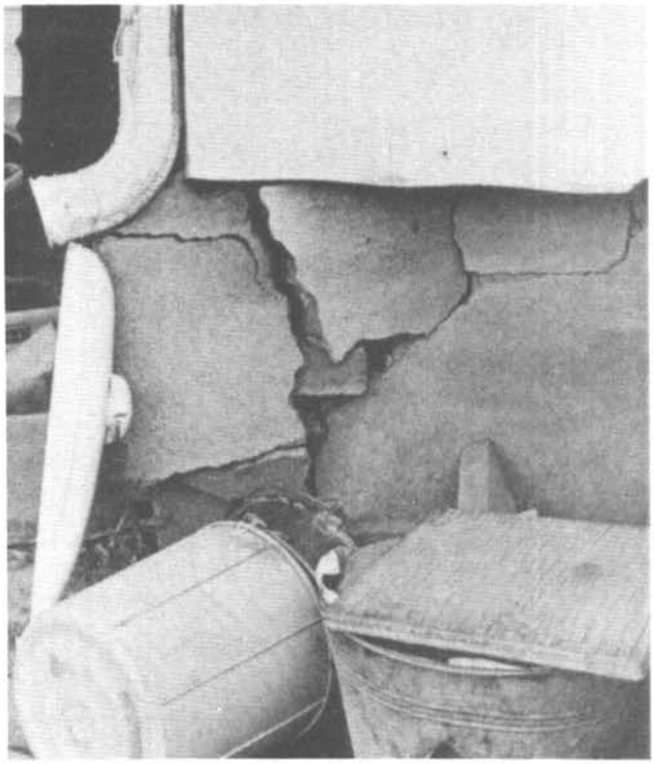
David Valdez, Department of Housing and Urban Development

example, frequent use of temporary protective coverings over vulnerable doors and windows requires that such coverings be easy to put in place and remove. Frequency of flooding also indicates the need for special access to or from the site if flooding is anticipated to be a common occurrence.

Climate and Weather. Climate and weather are factors in predicting the frequency and type of precipitation that might be common to a particular area, which, in turn, influences flooding severity. For example, a propensity for cloudbursts or heavy snowfall will indicate a need for dealing with quick water build-up in the design of a given project. Seasonal variations might also be a consideration in this respect. Data on climate and weather is obtainable from the records of the local office of the National Weather Service, as well as from local newspapers, police, and civil defense officials.

Ground Water Levels. Ground water levels interact with the effects of precipitation and storm water runoff to help determine the water pressure on footings, foundation walls, and floor slabs during flooding. With high ground water levels, the uplift forces associated with flooding will occur more quickly and more frequently, and should be accommodated in the design of all structures on the proposed site.

Flood Control Measures. Existing flood control works will have been accounted for in the basic flood hazard data such as flood boundaries and flood depths. However, the designer still needs to be aware of the limits of the control works and of the effects on the proposed site if water does exceed the design limits. Beyond these issues, the designer should know of any proposed flood control structures that will alter local flooding characteristics. If such devices are proposed,



Department of Housing and Urban Development

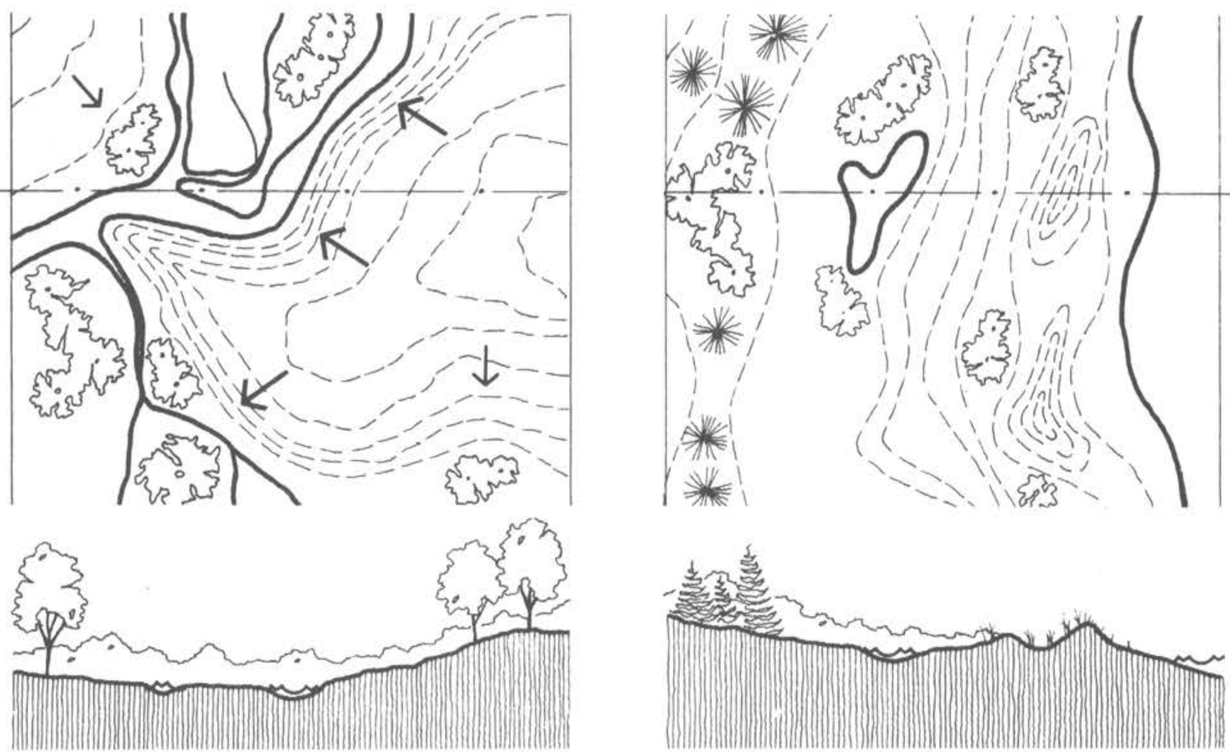
These examples of structural damage illustrate the possible effects of water pressure associated with flooding.

information from the relevant implementing agency or from the Federal Emergency Management Agency (FEMA) can help determine the probability of the control project being implemented and can give an estimate of its expected effects and completion date.

Site Characteristics

In addition to hydrologic data, a number of specific site characteristics affect flooding and the choice of strategies for flood damage reduction. As with hydrologic data, local planning offices and various federal agencies are primary sources of information on site characteristics. In addition to these resources, much of the site analysis depends on site surveys, both visual and technical, by design staff and professional consultants. Relevant site characteristics include the following.

Physiographic Features. Physiographic features on the site, such as the location of stream channels or meandering channels, drainage patterns, wetlands, sinkholes, and erosion patterns affect flooding. These natural features should be identified to indicate which areas of the site should be avoided or protected during development. Such features will affect orientation, distribution, and density of built elements on the site, and will help identify advantages and constraints to be considered in site development. Physiographic features can be



Physiographic features must be analyzed to determine which areas of the site should be avoided or protected during development. In both riverine (left) and coastal (right) environments attention should focus on stream channels, drainage patterns, wetlands, and existing vegetation.

Soil Types

Division	Soil Description	Value As A Material Foundation	Drainage
Gravel and Gravelly Soils	Well graded gravel, or gravel/sand mixture; little or no fines	Excellent	Excellent
	Poorly graded gravel, or gravel/sand mixtures; little or no fines	Good	Excellent
	Silty gravels, gravel/sand/silt mixtures	Good	Poor
	Clayey sands, sand/clay mixtures	Good	Poor
Sand and Sandy Soils	Well graded sands, or gravelly sands; little or no fines	Good	Excellent
	Poorly graded sands, or gravelly sands; little or no fines	Fair	Excellent
	Silty sands, sand/silt mixtures	Fair	Fair
	Clayey sands, sand/clay mixtures	Fair	Poor
Silts and Clays	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity	Fair	Poor
	Inorganic silts of low to medium plasticity, gravelly sands, silty clays, lean clays	Fair	Impervious
	Organic silt/clays of low plasticity	Poor	Impervious
	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor	Poor
	Inorganic clays of high plasticity, fat clays	Very Poor	Impervious
	Organic clays of medium to high plasticity, organic silts	Very Poor	Impervious
Highly Organic Soils	Peat and other highly organic soils	Not Suitable	Poor

Soil characteristics must be analyzed to determine the soil's drainage characteristics and its value as foundation material.

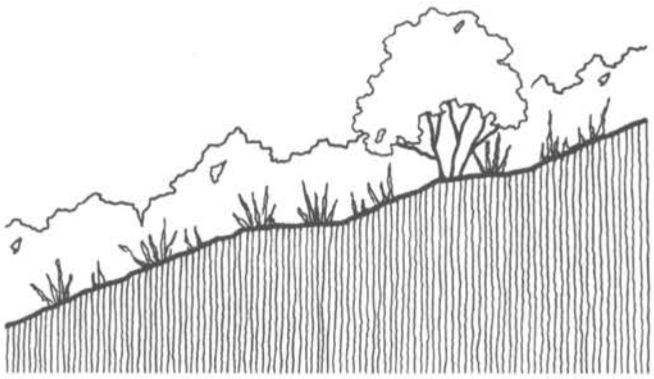
identified by referring to topographic maps and floodplain technical studies, as well as by conducting detailed site surveys.

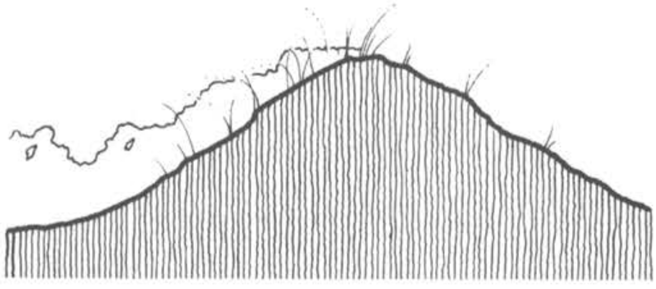
Site Topography. Identification of topographic elements such as slopes and ground elevations is most important in determining the buildable portion of a site. Topographic data also indicates erosion potential and the need for, and feasibility of, using fill material to enhance the site for construction.

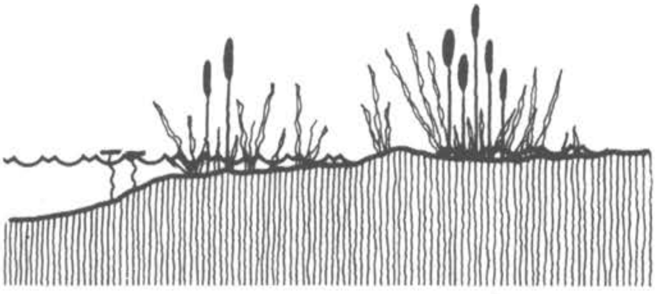
Soil Characteristics. Soil characteristics affect flood damage reduction in several ways. The permeability of soil determines the degree of water absorption, which influences the rate of storm water run-off, erosion, and ground water storage. Soil characteristics also determine the feasibility and design specifications for the use of land fill to elevate buildings, the use of backfill around foundations, and the construction of earth berm levees on the site. Finally, soil analysis will indicate the necessary depths for footings and pilings, as well as piers and columns used to elevate buildings.

Soil data can often be obtained from the U.S. Department of Agriculture's Soil Conservation Service in the form of maps, elevations, tables, and reports, or can be collected by design staff and consultants as part of site-specific surveys.

Stability of Slopes. The combination of topography and soil characteristics determines the stability of slopes on the site and affects design decisions in several ways. Slope stability affects the choice of the actual building site, the use of fill material, and the design of founda-







Vegetation is an important part of controlling water runoff. It helps prevent erosion and reduces the flow of surface water on slopes (top). It also stabilizes dune composition in coastal areas (center) and protects wetland areas (bottom).

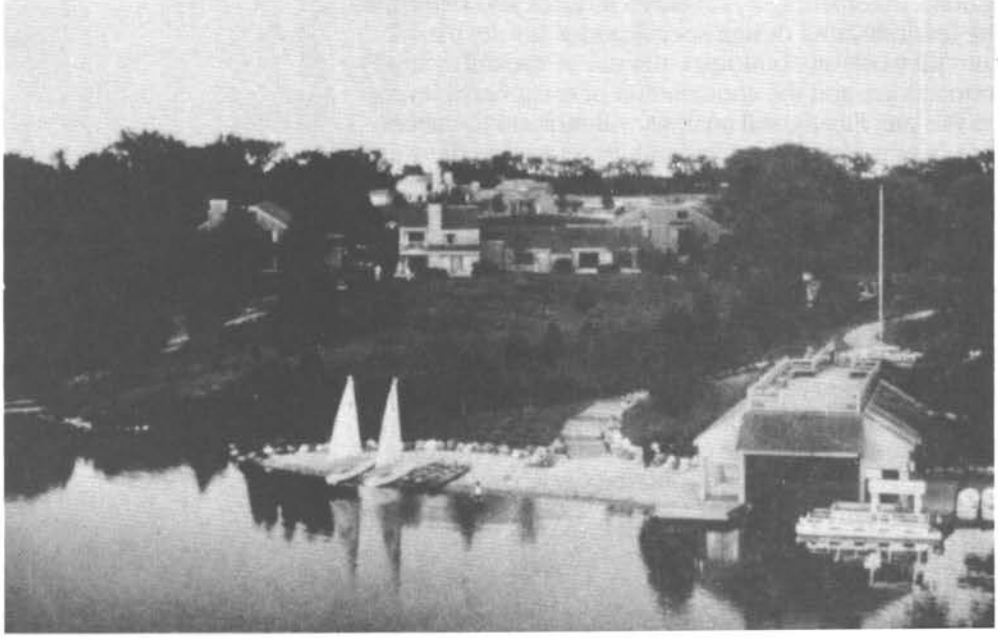
tions, footings, and pilings. Slope stability also influences erosion, which determines the need to use protective techniques such as terracing, planting, or other forms of ground cover.

Vegetation. Both existing and potential vegetation on a proposed site affect the choice of flood damage reduction strategies. Vegetation aids in the control of storm water runoff and helps discourage erosion. Site surveys carried out by design staff or consultants should identify how existing vegetation is related to flooding and how vegetation can be used in site development to minimize flood-related losses.

Water Storage. Water storage, either temporary or permanent, is another factor in controlling storm water runoff. Storage devices can be used to hold excess runoff until it can be released gradually into the watershed system, thereby avoiding the rapid accumulations that cause flooding. Additionally, stored water can aid in recharging ground water levels and, in some instances, provide environmental amenity. Site analysis should identify where water collects on the site prior to development, such as in natural surface depressions, and should indicate how water can be detained after development. This information can be obtained from topographic maps, surface profiles, and site surveys.

Existing Development

Existing development at the site and in the surrounding region also influences design in flood-prone areas. The intensity and type of development adjacent to the proposed site will influence the movement of water through the hydrologic cycle, and thus influence flooding at the site. With a high level of development intensity in the region there is likely to be more surface runoff of



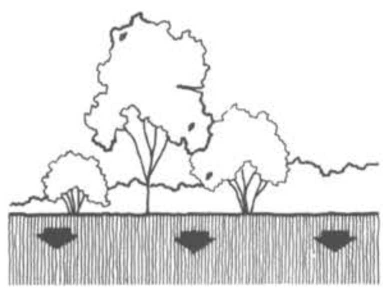
Water storage can be an important aid in controlling water runoff.

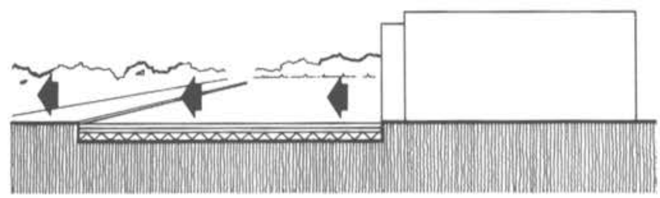
storm water, which will increase the volume of water entering the site from upstream.

Likewise, the designer must gauge the impact of the proposed project on the existing built environment and the cumulative impact of existing and new development on the natural environment. Analysis of these elements in relation to flood potential can increase the designer's sensitivity to the importance of maintaining a balance with the natural system, and can help minimize flood losses, both on-site and downstream.

Existing Infrastructure. In addition to general consideration of the existing development, specific attention should be given to the location and design of existing streets and utilities. The location of utilities is one aspect to consider in making buildings waterproof and affects maintenance of essential services during floods. Streets and utilities are important in determining site use layouts, and should be analyzed in reference to building locations and access to and from the site during floods.

After all information regarding flooding, regulatory requirements, and related design requirements is collected, it is synthesized in the design program: flood-related constraints are identified, building requirements are outlined, and the buildable portions of the site are determined. The next step is to develop design alternatives, drawing on the full range of available techniques for reducing flood damage, within the context of the overall design program.





Permeability influences water runoff. An undeveloped site (top) is highly porous and allows water to percolate into the soil. Developed sites with most of their surfaces covered with nonporous materials (bottom) do not allow this percolation, resulting in greater runoff.

Literature Resources

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Summary Table:
Design Analysis for Flood Damage Reduction

Regulatory Information

Information Required	Purpose or Implications of Data	Possible Forms of Data	Potential Sources of Data
• National Flood Insurance Program (NFIP)	• Requires local communities to implement floodplain regulations. • Sets minimum standards for floodplain regulations. • Prohibits federal funding for projects in violation of floodplain regulations. • Prohibits federal loan guarantees for projects in violation of floodplain regulations. • Establishes flood insurance rate differentials for properties in flood-prone areas.	• Program regulations • Insurance rate information and tables • Flood Insurance Studies • Flood Maps Section 1362 Guidelines	• Federal Insurance Administration • Federal Emergency Management Agency • State Floodplain Management Coordinating Agency • Local Government Planning Agency
• Local Government Planning Programs	• Implements floodplain regulations. • Determines local floodplain regulations based on NFIP guidelines (includes zoning and subdivision regulations, performance standards, Planned Unit Development ordinances, building codes, etc.) Note: Local regulations can be set at a higher standard than NFIP minimum standards, depending on local needs and circumstances.	• Planning and Zoning Ordinances • Zoning Maps • Building Codes	• Local Government Planning Agency • Local Government Engineer • Building Code Officials
• State Floodplain and Coastal Zone Programs	• Provides statewide floodplain development regulations and guidelines. • Regulates development in coastal zones. • Coordinates implementation of NFIP in local jurisdictions and in areas where multiple state agencies have an interest in flooding. • Clearinghouse for Floodplain Management Information.	• State program regulations • State development guidelines	• State Floodplain Management Coordinating Agency • State Office of Coastal Zone Management • State Office of Natural or Water Resources
• Regional Planning Restrictions or Guidelines	• Can provide additional regulations and guidelines for regional jurisdictions. • Coordinates activities of different agencies within the region. • Source of information and, in some cases, technical assistance.	• Program regulations • Development guidelines	• Regional Authorities (e.g., Tennessee Valley Authority, Appalachian Regional Commission, etc.) • Regional Planning Commissions • River Basin Commissions
• Federal Agency Requirements and Guidelines (other than NFIP)	• May include regulations relating to development in flood-prone areas (e.g., Corps of Engineers permits for development on navigable rivers). • May involve federal funding, the use of which is restricted in flood-prone areas. • Projects may require federal approval for development in flood-prone areas (e.g., Environmental Impact Statements).	• Program regulations	• U.S. Army Corps of Engineers • Environmental Protection Agency • Federal Emergency Management Agency • State Floodplain Management Coordinating Agency • Local Planning Agency

Hydrologic Data

Information Required	Purpose or Implications of Data	Possible Forms of Data	Potential Sources of Information
• Flood Hazard Boundaries	• Determines where floodplain regulations, insurance, and federal financing restrictions apply. • Determines specific flood hazard zones. • Determines variable flood insurance rate zones.	• Flood Hazard Boundary Maps • Flood Insurance Rate Maps • Flood Boundary and Floodway Maps • Hydrologic Atlases • Local Zoning Maps • Flood Insurance Studies	• Local Government Planning Agency • Local Government Municipal Engineer • State Floodplain Coordinating Agency • State Office of Natural Resources • Federal Insurance Administration • Federal Emergency Management Agency • U.S. Army Corps of Engineers • U.S. Geologic Survey • Regional Authorities —Tennessee Valley Authority —Appalachian Regional Commission —River Basin Commissions • Hydrologic Engineering Consultants • Surveys by Professional Staff
• Flood Depths	• Indicates elevations at which flood damage is likely to occur. • Determines appropriate building elevations for meeting floodplain regulations and flood insurance restrictions and rates. • Indicates hydrostatic loads in flood-prone areas.	• Flood Elevations • Water Surface Profiles • Stream and Coast Cross-sections • Flood Insurance Studies	
• Flood Water Velocity	• Determines hydrodynamic loads in flood-prone areas. • Determines debris-impact loads in flood-prone areas. • Indicates potential for erosion and slope deterioration.	• Floodplain Technical Studies • Hydrologic Studies • Flood Insurance Studies	
• Warning Time	• Indicates importance of emergency evacuation as part of the design program. • Influences design of floodproofing techniques such as floodshields. • Influences design of drainage systems. • Influences design of wet floodproofing techniques.	• Hydrographs • Floodplain Technical Studies • Historical Records • Flood Insurance Studies	

Hydrologic Data

Information Required	Purpose or Implications of Data	Possible Forms of Data	Potential Sources of Information
• Duration of Flooding	• Affects seepage into buildings and saturation of soils and building materials. • Affects the length of time facilities might be inaccessible or inoperable. • Affects building design relative to orientation, configuration, and choice of floodproofing techniques.	• Floodplain Technical Studies • Historical Records • Flood Insurance Studies	• U.S. Department of the Interior Water and Power Resources Service (operates west of the Mississippi River.)
• Frequency of Flooding	• Influences site choice. • Affects choice of floodproofing techniques, especially those that require installation before every flood. • Indicates need for special access.	• Floodplain Technical Studies • Historical Records	
• Climate and Weather	• Indicates frequency and type of precipitation and, in turn, the type and magnitude of flooding that is likely.	• Weather Service Records • Historical Records	
• Ground Water Level	• Influences potential water pressure on footings, foundations, and floors. • Affects site design techniques for controlling water runoff.	• Geologic Surveys • Soil Analysis Reports	
• Structural Flood Control Measures (e.g., dams, levees, channel improvements)	• Existing measures can affect site if the limits of the flood control device are exceeded. • Proposed measures can, when implemented, alter basic flood data.	• Feasibility Studies • Design Specifications • Probability Reports	

Site Characteristics

Information Required	Purpose or Implications of Data	Possible Forms of Data	Potential Sources of Information
• Physiographic Features	• Affects location and magnitude of flooding on the site. • Identifies areas of the site that should be avoided or protected. • Affects orientation, distribution, and density of built elements on the site. • Identifies physical constraints and advantages for site development.	• Topographic Maps • Floodplain Technical Studies • Site Surveys	• Local Government Planning Agency • Local Government Municipal Engineer • State Floodplain Coordinating Agency • State Office for Natural Resources • Soil Conservation Service, U.S. Department of Agriculture • U.S. Geologic Survey • Regional Authorities • Hydrologic and Civil Engineering Consultants • Surveys by Professional Staff • U.S. Department of the Interior Water and Power Resources Service(operates west of the Mississippi River.)
• Topography	• Influences siting of buildings. • Indicates erosion potential. • Indicates need for, and feasibility of using, fill material on the site. • Indicates appropriate site design techniques for controlling water runoff.	• Topographic Maps • Floodplain Technical Studies • Site Surveys	
• Soil Characteristics	• Soil porosity influences the rate of water runoff and flooding potential. • Determines the feasibility and design specifications for use of fill material to elevate buildings, the use of backfill around foundations, and construction of earth berms. • Indicates required depth for footings, pilings, or columns.	• Soil Maps • Soil Analysis Reports • Site Surveys	
• Slope Stability	• Affects choice of building sites, the use of fill material, and the design of foundations, footings, and pilings. • Influences erosion. • Indicates the need for terracing or ground cover to protect slopes.	• Analysis of combined effects of topography and soil characteristics • Site Surveys	
• Vegetation	• Aids in control of water runoff, and thus can be a factor in reducing flooding levels.	• Site Surveys	
• Water Storage	• Aids in control of water runoff, and thus can be a factor in reducing flooding levels. • Recharges ground water supplies.	• Geologic, soil, and hydrologic surveys • Site Surveys	

Chapter 5

Design Techniques for Flood Damage Reduction

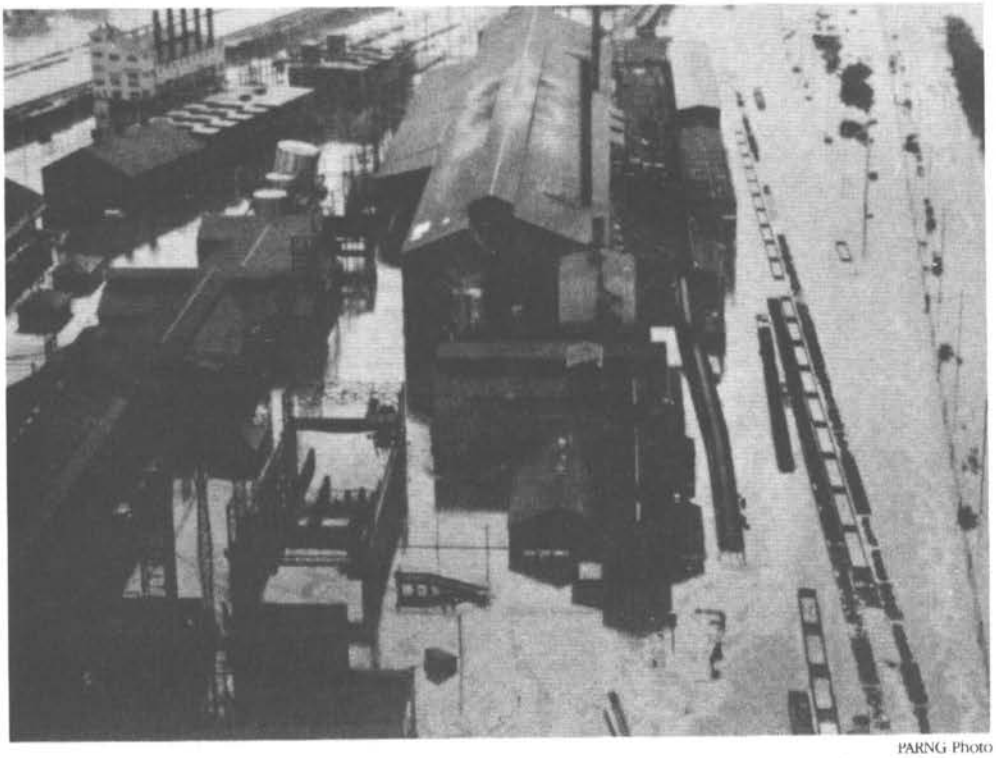
The pre-design analysis outlined in the previous chapter enables the designer to incorporate data on flood-related restrictions and opportunities into the client's basic program of the needs and requirements that the design must meet. At this point the focus shifts to generating design alternatives and, ultimately, to detailed design decisions.

Type of Project

The type of design project has a direct bearing on flood damage mitigation strategies. The variations most relevant to flooding include multiple versus single buildings, new versus existing buildings, and building use.

Multiple Buildings. The complexity of siting decisions is affected by whether a project involves a single building or multiple buildings. With a single building it is a matter of siting the building on that part of the site least likely to suffer flooding. With multiple buildings, site use can vary from clustering all buildings on one part of the site to dispersing the buildings throughout the site but locating each of them above base flood elevations.

New or Existing Buildings. New construction offers wide latitude in making site decisions and in deciding on the use of flood-related design techniques. Conversely, projects involving expansion, improvement, preservation or rehabilitation of existing buildings require special consideration of design alternatives. Site choice is predeter-



Flooding can affect all types of development. It can damage either new or existing buildings, and is a relevant design factor for industrial, commercial, and residential uses. In some projects flooding must be considered in relation to multiple buildings, while others may involve only a single building.

PARNG Photo

Gordon H. Schenck, Jr.

Case Summary: Corte Madera Creek Marin County, California

A Flood Control Study

Sponsored by:
U.S. Army Corps of Engineers
San Francisco District

Prepared by:
Royston Hanamoto,
Beck & Abey
San Francisco, California

With the assistance of:
Pflueger Architects
Water Resources Engineers
KCA Engineers, Inc.
Lord & LeBlanc
Tetra Tech, Inc.
William Liskamm

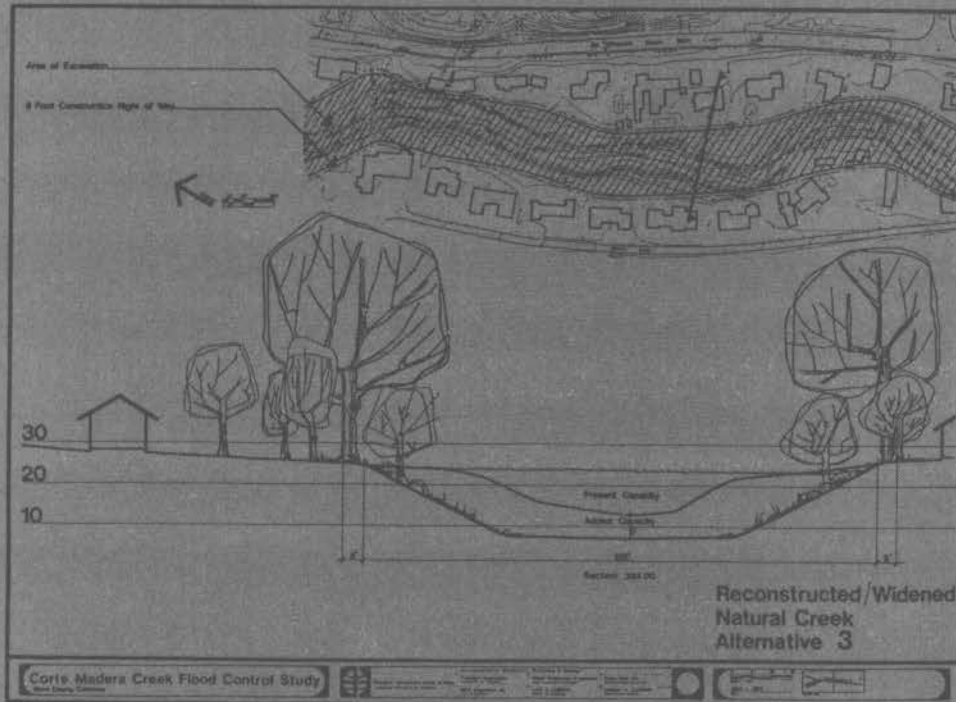
Corte Madera Creek, located in Marin County, California, is one of several major channels that drain 28 square miles of the eastern slopes of Mt. Tamalpais. The 70-acre area studied in the project coincides with the floodplain of Corte Madera Creek. The 100-year floodplain, which varies in width from 100 to 4000 feet, is populated by housing, schools, roads, and commercial facilities.

The study was undertaken to investigate alternative methods of providing flood control for an area in which existing buildings were located on hazardous, flood-prone sites. The principal goal was to make the immediate area safe from flooding without destroying the natural quality and character of the creek. In achieving this end, strategies adopted were to avoid increasing the flood hazard for downstream residents and to preserve the area's ecological system.

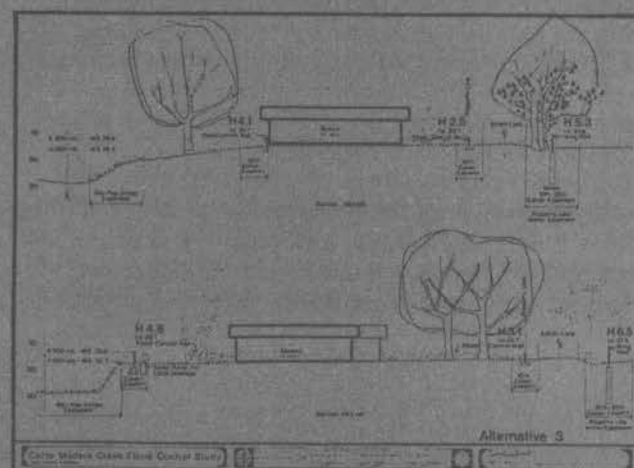
During the course of the study a number of alternatives encompassing a variety of flood damage reduction techniques were analyzed. Included among the alternative strategies were proposals to:

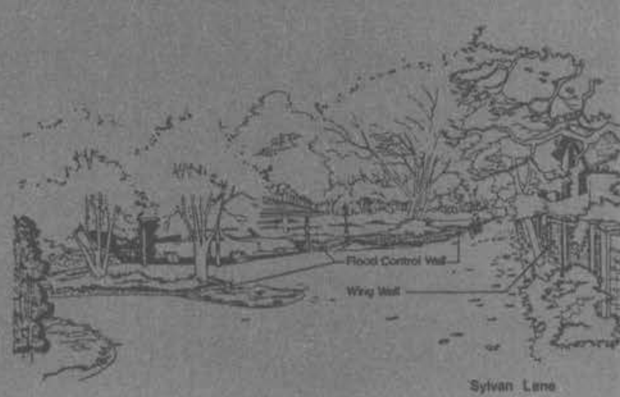
- Reconstruct the creek using concrete channel linings to contain the flow of flood water.
- Enlarge the creek and clear it of vegetation and debris to improve water flow.
- Build flood walls and berms along the banks of the creek.
- Provide overflow culverts under either the existing creek bed or an adjoining street.
- Remove some of the existing houses to create a waterfront park that would accommodate flood waters.

After evaluating the advantages and disadvantages of the various proposals, the study recommended an approach that combined several techniques. It was agreed that the stream channel should be widened and deepened to improve the flow of water, but that trees, shrubs, and ground cover should be retained or restored instead of using concrete linings. To further protect creekside residents from the 100-year flood, it was proposed that several houses be elevated above the base flood elevation and that protective walls be constructed along some sections of the creek. This solution provided the necessary degree of protection yet maintained the natural character of the stream, which was valued highly by the community.



The final proposal recommends widening and deepening the creek bed to meet the requirements of the 100-year flood. After excavation the creek bed is to be restored to its natural condition with trees, shrubs, and ground cover.





Channel improvements are to be combined with floodwalls at strategic points to protect existing properties.

mined unless relocation is feasible. Older buildings often have structural limitations and seldom prove to be feasible candidates for elevation above the base flood level. Additional constraints arise if the project involves a historical building that cannot be altered to the extent of reducing its historical integrity. All such issues affecting existing buildings must be analyzed in relation to strategies for flood damage reduction.

Type of Use. Residential, commercial, industrial, and public building projects have different factors influencing the choice of techniques for flood damage reduction. First, in meeting National Flood Insurance Program (NFIP) regulations, residential structures are required to be above the base flood elevations, while other uses have the option of being either elevated or floodproofed to the same level. Second, the type of use also influences site decisions. For example, the use of clustering techniques will be different for residential buildings than for commercial or industrial uses. Third, the type of use can affect the site layout in terms of required access to buildings during flooding, and will influence the methods for controlling water runoff.

Finally, different uses influence floodproofing techniques. Waterproofing is generally more relevant for commercial buildings that have easily damaged materials and finishes, valuable records, and vulnerable contents. Wet floodproofing might be more appropriate for an industrial building that is easier to clean and has more easily protected contents.

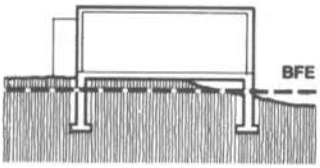
Applicability of Design Techniques

As previous chapters have made clear, buildings ideally will be located so that they are not subject to flooding. Yet there are still a variety of situations where this ideal is impractical or unnecessary and that call for special measures to reduce flood damage. For example, when:

- The project site is not itself in a flood hazard area, but is where development might increase flood levels elsewhere.
- Buildings are located in a fringe area that is subject to only mild flooding.
- Buildings can be cost-effectively floodproofed to achieve an acceptable level of safety.
- The project includes existing buildings that, due to historical or economic significance or an existing urban infrastructure, must remain in a flood-prone area.
- Existing buildings are to be removed from a flood hazard area, but the period of amortization will require temporary protection.

U.S. Army Corps of Engineers

Buildings must be located on the part of the site that analysis of basic flood data has indicated is above the Base Flood Elevation (BFE).



Site Design Techniques

Site design techniques for flood damage reduction fall into two categories—distribution and density of built elements on the site and control of storm water runoff. These categories represent different types of problems to be addressed in site design in relation to mitigating flood damage both on the site and throughout the region. The range of available techniques should be used in varying combinations to fit the unique circumstances of each site and the associated design program.

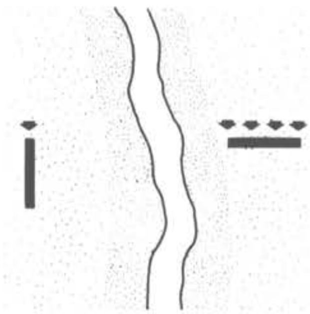
Distribution and density is, foremost, a question of how to locate and orient buildings on the site. Related concerns are the determination of circulation and access routes and the alteration of site topography through excavation and use of fill material.

Siting Individual Buildings. The primary objective in siting individual buildings is to locate structures so that they will be safe (or can be made safe) from flooding. In practice this means locating on that part of the site that analysis of basic flood data has indicated is above the base flood elevation. However there are other factors to be considered.

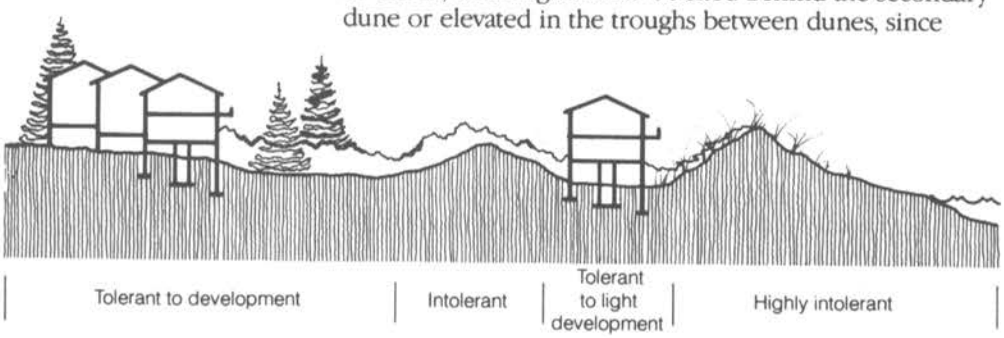
Nonresidential structures can use a combination of elevation and waterproofing to achieve the required degree of safety, as long as they are not located in the floodway or coastal high hazard area. For all structures, the designer should consider the potential for going beyond regulatory minimums, thus providing greater protection wherever possible. Some sites, for instance, allow buildings to be located completely outside the flood fringe, and this should be done wherever possible.

Buildings should also be oriented so that foundations and floodproofed walls minimize obstruction of flood flows. Natural drainage lines and other natural features that help control storm water runoff should be preserved. These measures avoid raising the level of flood waters and minimize negative impacts on downstream property.

Coastal areas require additional safeguards in locating buildings. There must be no construction on beaches or dunes; buildings should be sited behind the secondary dune or elevated in the troughs between dunes, since



Where some construction is allowed in the flood fringe, buildings should be oriented to minimize obstruction of flood flows.



Buildings in coastal areas must be sited in areas that are tolerant to development in order to minimize damage to both the buildings and the natural balance of the coastal ecosystem.

Cluster development to reduce flood damage

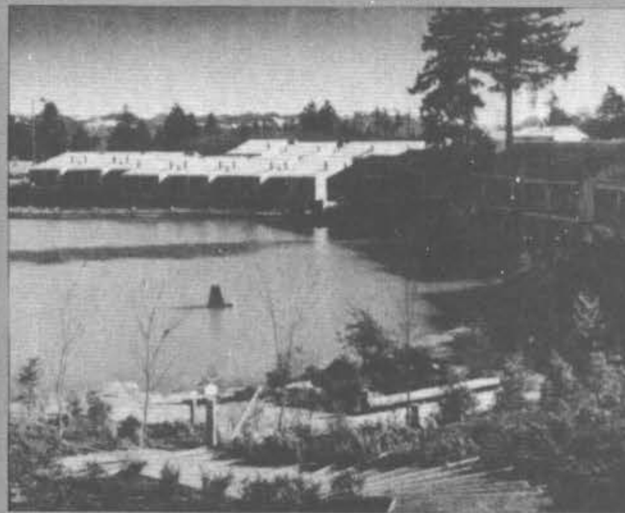
Cluster development is frequently used in situations that are not ideally served by traditional zoning and subdivision layouts. It provides flexible alternatives for developing parcels of land that are affected by such special circumstances as flooding. Clustering techniques require specific local zoning laws, which are usually enacted as Planned Unit Development (PUD) ordinances.

Using cluster techniques, part of a site can be developed at higher densities than would be permitted under traditional zoning, leaving the remainder of the site as open space. In a flood-prone area, buildings can be clustered on the part of the site that is safe from flooding, leaving the flood-prone area free of buildings. The remaining open space is then available for low-intensity uses, such as recreation, conservation, or parking, depending on the nature of the project.

Foremost of the flood-related benefits of cluster development is that buildings are not located on the flood-prone portions of the site. Clustering also minimizes streets, thus reducing the use of impervious surfaces that increase the rate of water runoff. In addition, open space protects existing drainage courses and permits continued infiltration of water in areas left undeveloped.

Cluster techniques offer advantages beyond reduced flood damage. The need for less extensive street and utility systems results in lower construction and maintenance costs. Shorter roadways also reduce the energy required both for construction and for driving the distance of the streets after they are in use. Such savings can have a major significance in large projects.

The drawings at left illustrate how flood damage reduction can be achieved using cluster development in a residential setting. The first drawing shows a hypothetical site subdivided, using traditional zoning, into single detached dwellings on large individual lots. As can be seen, four of the lots would be affected by potential flooding and there would be considerable damage to the natural terrain and a high proportion of impervious surfaces.

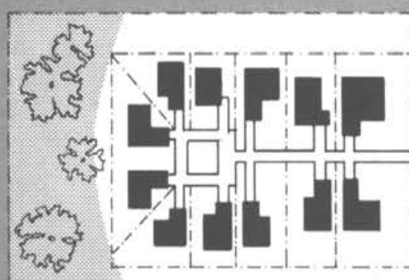


James K. M. Cheng, AIA Journal

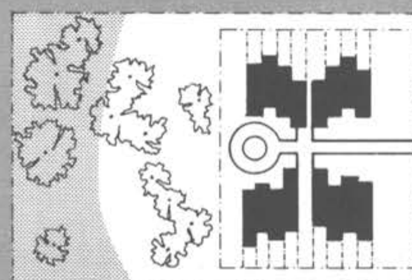
The second illustration shows the same detached dwellings, but on smaller lots. Consequently, all dwellings are located outside the flood-prone area and there is more open space and a lower proportion of impervious surface on the site. The result is protected building sites and better control of water runoff.

The third drawing takes the cluster technique a step farther by using attached, townhouse-style dwellings. This provides even more open space and minimum street coverage.

Conventional site plan using large lots and single detached dwellings.



Another example of single detached dwellings, but clustered on smaller lots.

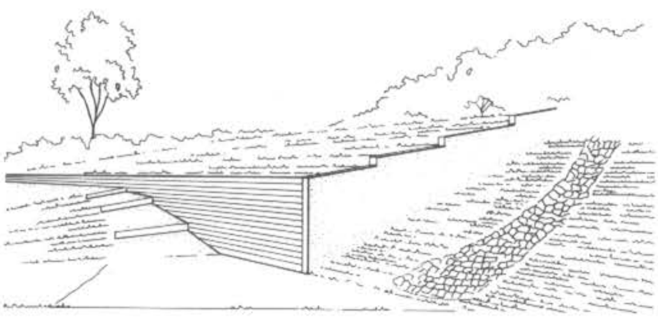


Clustered site plan using attached dwellings and small lots, with a large portion of the site left as open space.

these areas are generally more tolerant to alteration. It is also important that the stabilizing composition and vegetation of dune systems not be disrupted. Access to beaches should be carefully controlled, using elevated walkways to avoid damaging the dunes. And, buildings should not be located, nor should any fill material be used, in wetland areas.

Siting Multiple Buildings. Where multiple buildings are to be placed on the site, the objective when locating structures is the same as with an individual building. The approach to achieving this objective, however, can vary with project circumstances. One approach is to disperse buildings throughout the site, applying the criteria discussed above to each building.

An alternative to dispersal, where local zoning ordinances allow, is grouping buildings in clusters on the higher



Alteration of site topography should include measures to control water runoff. Slopes can be protected by using ground cover, retaining walls, terraces, and channels to direct the flow of water.

parts of the site, leaving the more vulnerable areas open. (See box.) This approach not only reduces direct flood damage but also allows greater flexibility in protecting the natural features on the site and controlling water runoff.

Large open areas can be used in a number of ways, depending on the nature of the project. They can be retained as agricultural or conservation preserves or developed as low-intensity recreation areas. Smaller parcels also have conservation and recreation potential, and can be effective buffers between conflicting land uses. With any of these uses, open space can serve as an amenity that enhances the value of developed property. Another alternative is to develop open areas as parking or temporary storage for transportable goods.

Restructuring Topography. On some sites it may be possible to use fill material—from either on-site or off-site—to create locations for buildings that are above the base flood elevation and meet other development criteria. This method would be aimed at the same objectives as described above, only being used where it will not increase flood levels due to displacement. Site restructuring also can be used to improve drainage and control runoff.

Special consideration should be given to soil conditions and slope stability, as well as flood water velocities and duration, to ensure that erosion does not add to flooding problems and endanger the structural integrity

Philip Schmidt, Department of Housing and Urban Development

Even when buildings are above flood levels, the improper location of streets can result in blocked access routes and damage to vehicles.

of the building. When restructuring topography, exposed cut and fill slopes, as well as borrow and stockpile areas areas, should be protected. Runoff should be diverted from the face of slopes, and slopes should be stabilized with ground cover or retaining walls.

Circulation and Access. Every site must connect with a road system for access to the surrounding infrastructure, and larger development projects require circulation within the site. The objective in site design is to meet the program needs for circulation and access while maintaining safe access during flooding and avoiding damage to natural features that aid in the control of runoff and flooding.

Roads should be minimized to reduce the amount of surface paving. Site layout should locate roads to approach buildings from the direction away from the floodplain so that access routes will be less likely to be blocked by the flow of flood waters and debris. This approach will protect natural features in the floodplain and will minimize obstruction of the floodway. To reduce potential erosion, siltation, and runoff problems, roads should not disrupt drainage patterns, and road crossings should be perpendicular to streams, with adequate bridge openings and culverts to permit the unimpeded flow of water. If roads are to be raised, the slope of embankments should be minimized and open faces stabilized with ground cover or terracing.

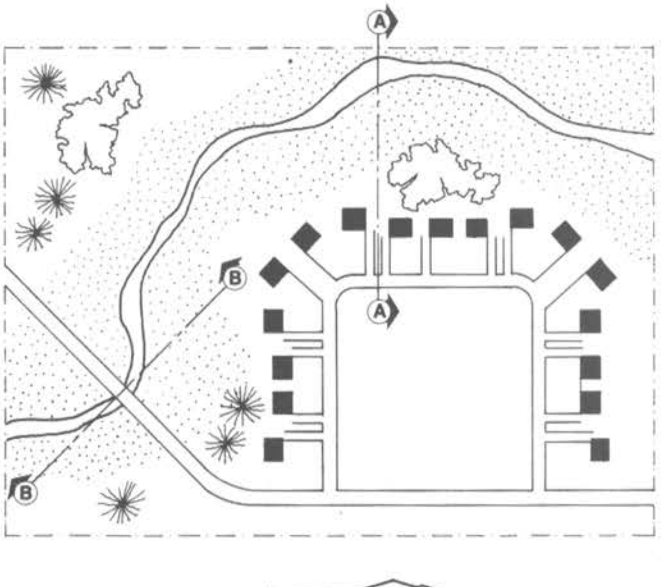
Control of Storm Water Runoff

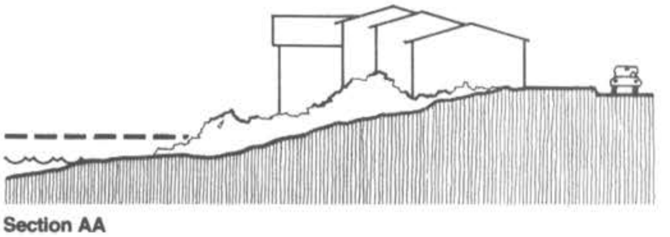
Water enters a given site either from precipitation or as runoff from upstream portions of the watershed. What happens to this water is a major determinant of both the degree of flooding and the potential of damage from flooding. If, through development of a site, there is an increase in the volume or velocity of storm water runoff, there will be an increase in flooding levels. Thus, as an ideal, runoff rates after development should not exceed the rates before development. This ideal may not always be possible or practical and may not be required by regulations, but should remain the objective of good site planning and design.

Site design techniques should work to protect the individual site, as well as minimizing increased flood levels elsewhere. There are a number of key factors that influence storm water runoff, and the combination of these must be considered in the site design process.

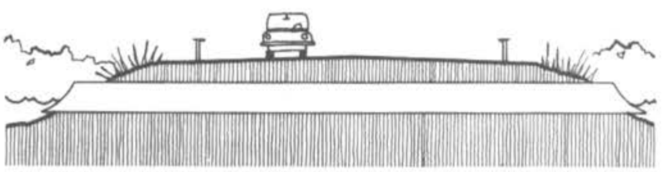
Soils. Soil porosity is one component in controlling water runoff. Soil composition needs to be firm enough to adequately support buildings but at the same time permeable enough to allow percolation of water to recharge the water table and to allow water to drain away from buildings. Balanced soil composition slows water runoff, increases infiltration, and helps prevent the build-up of

Streets should be located to approach buildings from the direction away from the floodplain so that access is less likely to be blocked and vehicles are not damaged by flood water. Road crossings should be perpendicular to streams, with adequate culverts or bridge openings to permit unimpeded flow of water.



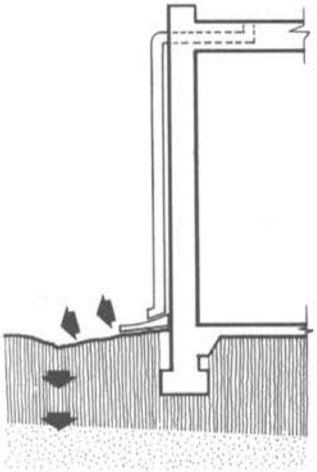


Section AA



Section BB

Water runoff should be routed away from the building's foundation before being allowed to percolate into the subsoil and water table.



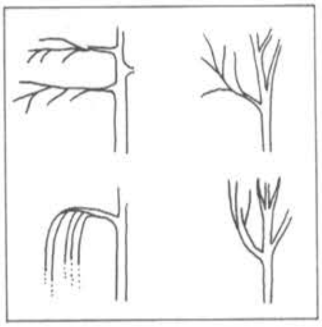
extreme water pressure on foundation walls, footings, and floors.

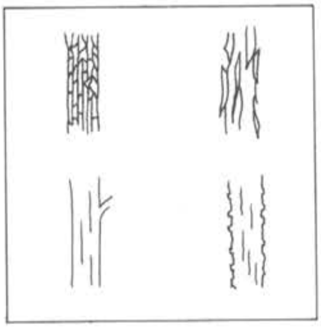
The type of soil on the site dictates the appropriate response for site development. Soils that remain saturated with water tend to corrode foundations. Heavy clay soils require the addition of sand to improve their drainage, the provision of good surface drainage, or a bed of gravel between soil and foundation to prevent foundation corrosion. Sand and silt, though porous, are unsuitable for stable foundations. They necessitate pilings to anchor the structure to deeper bearing soil.

Vegetation. Vegetation aids in slowing the rate of storm water runoff by holding water, both internally and externally, thus allowing it to filter into the ground or evaporate gradually. In addition, vegetation makes an important contribution by helping to prevent erosion and sedimentation that exacerbate flooding.

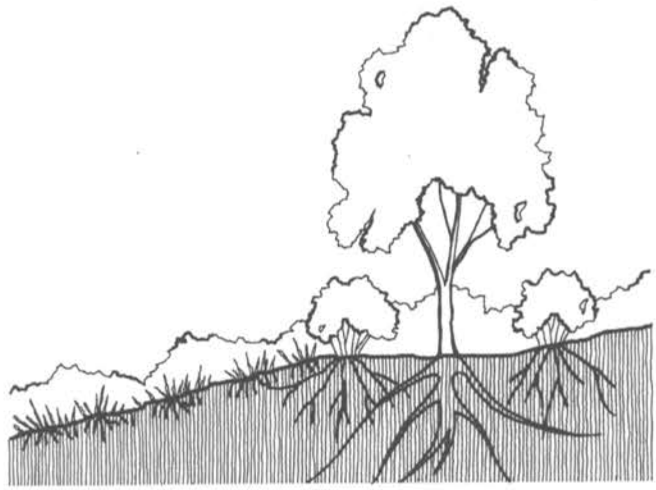
Attention should focus on retaining natural vegetation wherever practicable, and on introducing planting in locations that will be most affected by runoff. The selection of plants should emphasize compatibility with natural conditions and the ability to hold the maximum amount of water. Leaf type, branching characteristics, and the texture of bark all affect water-holding capacity. A fibrous root structure can help control erosion.

Dune Stabilization. Protection of the dune structure is a vital part of flood damage reduction in coastal areas. Dunes should be preserved in order to fulfill their role in maintaining the balance of the coastal ecosystem. In addition to keeping all buildings off dunes, natural vegetation should be retained to stabilize the dunes' sandy composition. Dunes should not be cut or breached by site development features such as walkways. The construction of jetties, groins, and similar structures should likewise be carefully controlled to prevent disturbance of the





Vegetation is useful in controlling runoff and stabilizing slopes. Foliage and roots hold water and prevent erosion. Plant leaves vary in their ability to hold water. Horizontal branching is most effective in preventing water runoff down the tree truck and erosion at the base of the tree. Rough bark holds and slows water running down the tree trunk and prevents erosion at the base of the tree.



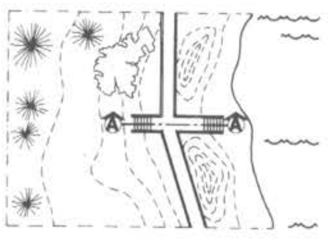
natural balance of the beach and dune system.

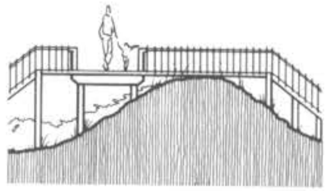
Impervious Surfaces. Nonporous surfaces contribute to the volume and velocity of water runoff, adding to the level of flood waters and increasing the chance of flash flooding. This is especially important on steep slopes and in the urban environment, where a large proportion of the surface has already been covered by buildings, streets, and parking areas.

Site design should maximize the preservation of open space and vegetation and avoid large continuous expanses of impervious surfaces. Large parking areas should be punctuated with planting. Streets, walkways, and parking areas should be constructed of porous paving materials wherever possible. Gravel, for instance, is highly porous, and bricks and flagstones can allow infiltration between joints. When soil conditions vary on the site, buildings should be located on the less porous soils, leaving areas with better filtration as open space.

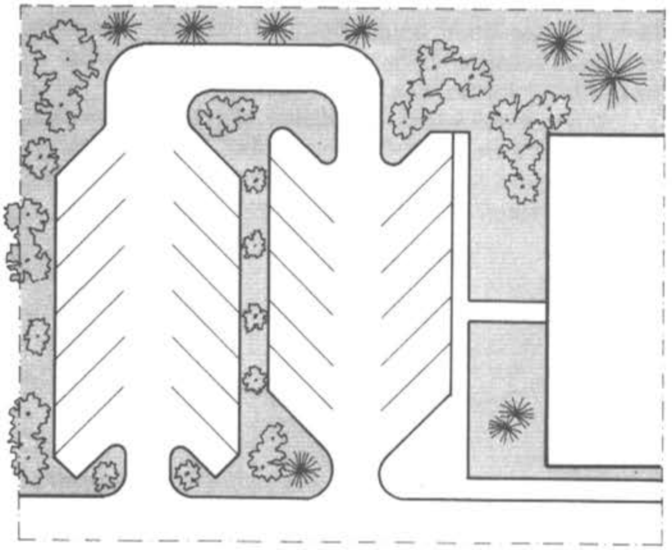
Water Storage. Water storage can be either temporary or permanent, depending on local ground water supplies, geology, and climate. Temporary storage can take a variety of forms, including the preservation of natural surface depressions in the landscape. Such "dry pond" storage helps to detain water after a storm, with gradual drainage, percolation, and evaporation to reduce the volume and velocity of runoff. This technique also helps replenish ground water supplies and can boost property values by increasing the site amenity and providing recreation space.

Temporary water storage can also be designed into parking areas by creating depressions in paved surfaces that, in combination with drainage channels, allow gradual runoff. In some situations large expanses of flat roof





Dunes should not be cut by site-development structures. Access to beaches can be provided by catwalks, stairs, and ramps that protect the fragile composition of the dune system.



Large expanses of nonporous surfaces, such as those used for parking lots, increase runoff. Parking areas should be designed to minimize impervious surfaces, using vegetation to maintain or improve natural drainage characteristics.

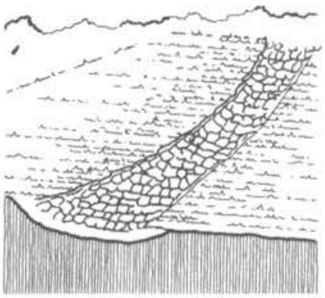
can be used to detain water, but this requires special attention to the roof's structural ability to support the weight of collected water and reliable waterproofing measures. Both of these methods can be helpful in offsetting the effects of existing impervious surfaces in urban areas where there is little open space to absorb runoff.

Permanent water storage in the form of ponds or lakes can be used in circumstances where a consistent supply of water and sufficient space exist. Ponds and lakes can add to site amenity and offer added potential for recreation and conservation habitats, though they do require regular maintenance.

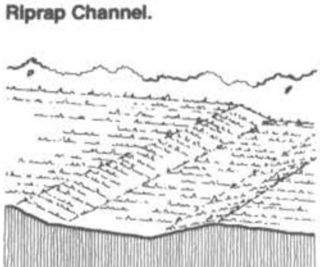
Open Channels. Open channels can serve as both small-scale storage devices and a means of directing runoff away from vulnerable areas. Their primary purposes are to divert water away from areas likely to erode, such as large, gently sloping areas and shorter steep slopes, and to collect and transport water runoff to larger drainage courses. Channels with grass cover are appropriate where the channel gradient is low; they can serve as percolation trenchs by allowing gradual infiltration while water is being transported. Linings are necessary in channels where vegetation cannot be established because flow is of long duration, runoff velocities are high, erodable soils exist, or slopes are steep. Concrete and asphalt paving or riprap are the most commonly used channel linings. However, such linings can increase the velocity of runoff, and thus should be designed with velocity checks to control the rate of water flow.

Streets and Curbs. Streets and curbs are frequently added during development, and the layout and gradient should be designed to complement runoff control systems. Streets, by decreasing the area of permeable surface, can create excessive runoff and contribute to localized flash flooding. Their design should avoid these problems, and should work to collect and convey water runoff at controlled velocities and to safe outlet points.

Storm Sewer System. Installation of a storm sewer system is often part of site development in large projects, usually parallel to the street and curb system. Storm sewers should interconnect with other drainage devices to

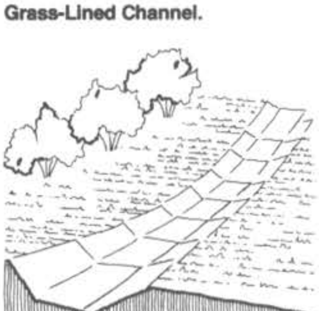


Riprap Channel.

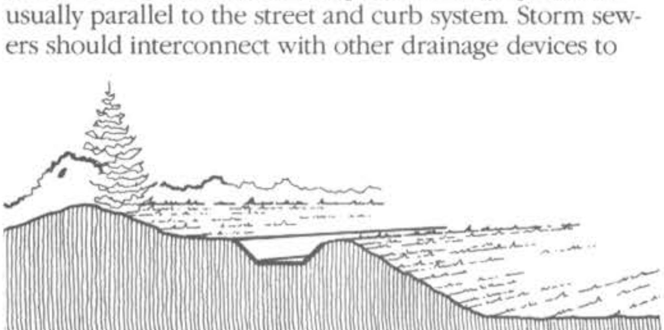


Grass-Lined Channel.

Open channels can be used to divert runoff around the face of vulnerable slopes and to direct the flow to larger drainage courses. Various linings can be used depending on the steepness of the channel. Porous linings offer the advantage of allowing gradual infiltration while water is being transported.



Concrete Channel.



Channel running across the slope to divert water.

Case Summary: Kiawah Island, South Carolina

Developer and Planner:
Kiawah Beach Company
Charleston, South Carolina

Kiawah Island, located 24 miles southwest of Charleston, South Carolina, is one of the many barrier islands found between North Carolina's Outer Banks and Northern Florida. Approximately 10 miles long and 3 miles wide, the island has 4100 acres of ground 3 feet or more above mean sea level. It consists of 11 miles of beach-front shoreline, dune ridges, salt marshes, tidal ponds, and forest vegetation.

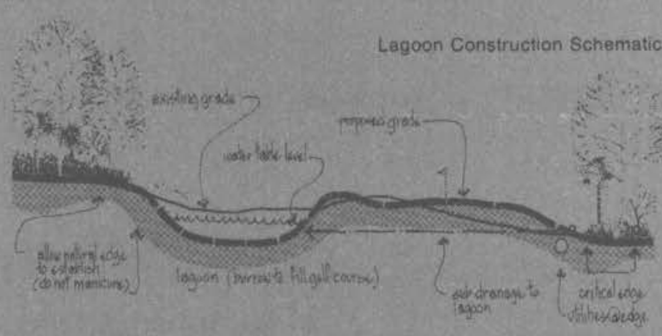
The Kiawah Beach Company has proposed a planned development district on the island, using the 4100 acres as a residential resort community with a broad range of recreational opportunities and support activities. Planning for the project has included extensive analysis of the site's natural environment and careful consideration of how it can be accommodated as the land is developed.

Site analysis encompassed detailed examination of existing environmental features, geologic processes, climate, hydrology, soils, and vegetation. From the analysis, planners concluded that "the susceptibility to flood is perhaps the single most important hazard to coastal development." In response, the development plan included the following flood-related elements.

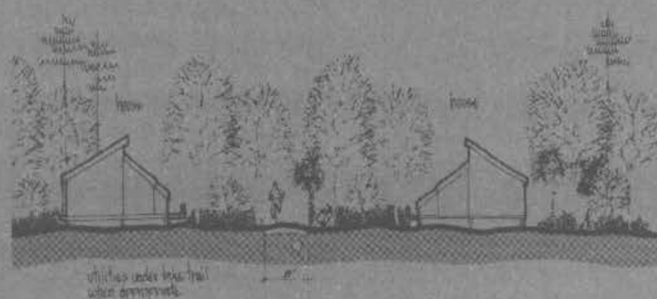
- The expected flood elevations resulting from 25-, 50-, and 100-year storms, as determined by the National Oceanic and Atmospheric Administration, were mapped. To qualify for the National Flood Insurance Program, Charleston County has adopted the 100-year flood level as the minimum flood elevation for all new buildings and has established 6.5 feet above mean sea level as the minimum for any road.

All proposed Kiawah Island development will conform to these standards.

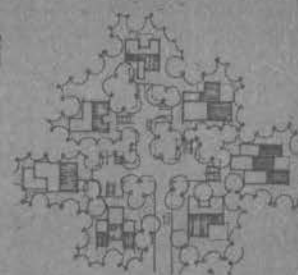
- Because the average annual rainfall for Kiawah is 49 inches it is important to have an adequate storm drainage system. The existing topography lends itself to the development of a good natural drainage system. The island is penetrated by a series of low areas that can be readily developed into an efficient network of lagoons. These will handle storm water runoff from adjacent higher areas as well as store water until it can be released gradually into the surrounding waters. The use of existing low areas allows the lagoons to be developed with minimum earthwork and thus with the least possible damage to the adjacent vegetation. The absence of deep cuts and steep banks also reduces the potential for erosion. The excavated material can be used for nearby building sites and recreation facilities and the completed lagoons will provide added site amenity.
- The success of the storm drainage system is not solely determined by the engineered structures. The protection of natural ground covers, trees, and shrubs, in combination with the sandy soils, provides for natural percolation of runoff into the ground water table.
- The most predominant land use on the island will be residential. The land use plan encourages clustering of residences to achieve construction and land economies but, of equal importance, restricts disturbance of natural areas and hence minimizes erosion and consequent flooding potential.



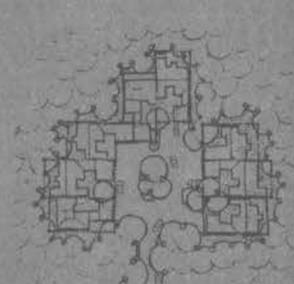
A system of lagoons will be constructed to complement the island's natural drainage system. These will retain storm water, allowing gradual runoff and percolation.



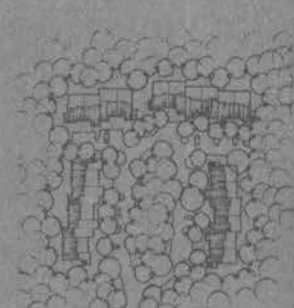
Buildings will be elevated where necessary to ensure that the lowest floor level is above the regulatory base flood elevation.



Detached single family cluster

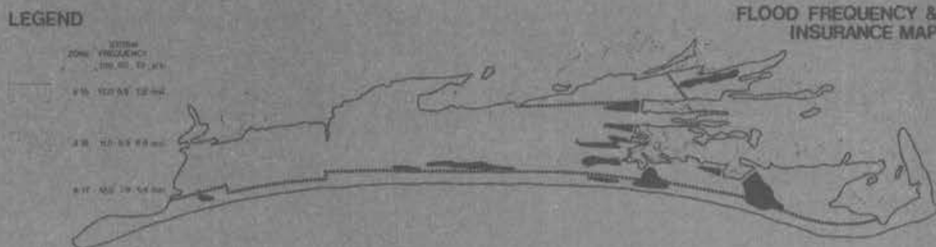


Attached single family cluster

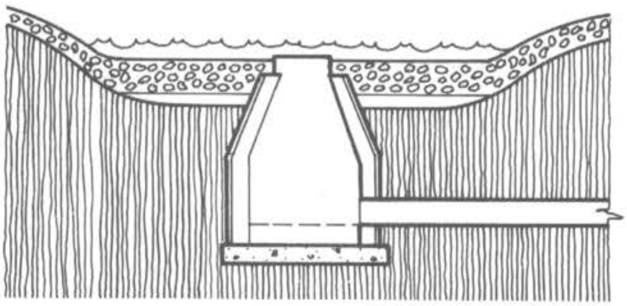


Townhouse cluster

The land use plan relies on clustering to achieve construction and land economies and to reduce the potential of erosion, excessive runoff and flooding. Shown are three examples of how dwellings can be clustered.



Expected flood frequencies were mapped for the project and development proposals were designed to conform with all flood-related regulations.



Sediment traps, installed at storm sewer inlets, help prevent sediment deposits and maintain the steady drainage of storm water.

decrease the velocity of storm water runoff and to release water at controlled points and rates of flow. Lines and access points need to be sized and distributed to accommodate the runoff likely to be associated with the site and not cause backup of water and the resulting overspill of flash flooding. The capacity of the storm sewer system can be impaired by sediment deposits within the systems; to avert this problem, drain inlets should be designed with sediment traps and filters.

Building Design Techniques

In the design of buildings that must be located in a flood hazard area, several problems should be addressed in reducing the threat of flood damage. These include:

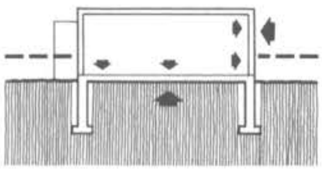
- Entrance of water through building openings
- Damage to building finishes and contents
- Seepage through walls, floors, and foundations
- Water pressure on foundations, walls, and floor slabs
- Back-up of water through sewer systems
- Access to and from buildings during floods.

To deal with these problems adequately the designer can incorporate a variety of flood damage reduction techniques in building design. These techniques interact with site design features and, as with site design, the techniques used for any given project will vary with individual circumstances, needs, and resources.

Floodproofing. The term floodproofing is used here to describe any method of making buildings resistant to flood damage. Floodproofing strategies are particularly appropriate where moderate flooding (i.e., low flood stage, low velocities and short duration) is likely, or where buildings' uses require riverine or coastal locations. The principal approach to achieving this objective is to protect buildings from water by keeping their interiors dry during flooding. This can involve raising buildings above flood levels or waterproofing the portions of the building that are below flood levels.

Keeping flood water out of buildings requires special structural support. During flooding, water entering the building serves to equalize water pressure that builds up on the exterior. If this equalization is eliminated by waterproofing, then the building is likely to collapse. If a strategy is adopted that keeps water out, then the building must also be made structurally capable of withstanding these exterior water pressures.

The "dry" floodproofing approach, as described above, is the most common and widely applicable way to protect buildings and their contents from flood damage. An alternative that can be used in some situations is "wet" floodproofing, which involves purposely allowing water to flow into a building when flood levels rise, thereby equalizing water pressures and avoiding major structural



Flooding causes the build-up of exterior water pressure, which must be equalized to avoid major structural damage to buildings located in flood-prone areas.

Benefit/Cost Analysis

Studies published by the Federal Emergency Management Agency indicate that floodproofing buildings in both riverine and coastal environments can be cost effective. One study analyzed four different flood damage reduction strategies, as applied to a small commercial building.* The four methods tested were:

- Wet Floodproofing
- Elevating the building on fill material
- Partially elevating the building on fill and equipping it with watertight closures
- Elevating the building on columns

Analysis found that wet floodproofing was not economically justifiable in this case study, but that all three dry floodproofing techniques were cost effective. Elevating the prototype building on fill was most favorable, with benefit/cost ratios of 5.96 for reduction of insurance premiums (see below) and 3.46 for reduction of flood losses.

In another study the costs and benefits of elevating a 2500-square-foot model house in a coastal high hazard area were analyzed. The study concluded that,

> In high hazard areas of the Atlantic and Gulf of Mexico coasts, new homes elevated to the wave crest level associated with 100-year storm surge are economical for individual homeowners, both in terms of reduced flood losses and of reduced insurance premiums.**

Three techniques for elevating the house were analyzed, and one, the use of a rigid frame design, proved to be most advantageous. It was least expensive, had the highest safety factor, and the highest benefit/cost ratios for reduction of both flood losses (between 3.1 and 8.2) and flood insurance premiums (between 5.9 and 9.5).

Unquestionably, the most effective means of reducing flood losses is to locate out of flood hazard areas. However, where this is not possible, floodproofing alternatives should be explored. As noted above, the added costs of floodproofing can be offset by reduced flood insurance premiums and reduced flood losses over the life of the structure.

Reduced Insurance Premiums. Actuarial rates for insurance premiums are keyed to elevation above or below the base flood elevation (BFE), and according to risk zones. For example, if a one-to-four family house is being built in flood risk zones A8 to A14, the flood insurance premium can vary as follows.

- $0.10 per $1000 coverage when the first floor elevation is three feet **above** the BFE
- $1.60 per $1000 coverage when the first floor elevation is **equivalent to** the BFE (the minimum standard)
- $9.30 per $1000 coverage when the first floor elevation is three feet **below** the BFE.

Thus it is clear that the cost savings to the client can be significant, even with only a three-foot increase over the minimum standard. In view of both the cost savings and the added margin of safety in the extra elevation, the designer should work with the client to elevate above the minimum level wherever possible.

Benefit/Cost Ratios:

Alternative methods of Coastal Construction; Gulf Shores, Alabama

Wave Crest Elevation (Feet)	18	17	16	15	14
Storm Surge Elevation (Feet)	11	11	11	11	11
Difference (Feet Below Wave Crest Elevation)	−7	−6	−5	−4	−3
Benefits derived from reduced average annual flood damage					
Rigid Frame System	74.9	9.5	16.6	8.2	5.9
Semi-Rigid Frame System With Grade Beam (Czerniak Method)	33.2	4.1	4.1	2.8	1.8
Semi-Rigid Frame System With Grade Beam (Griffith Method)	24.5	3.0	3.3	2.2	1.4
Benefits derived from reduced flood insurance premiums					
Rigid Frame System	8.2	6.2	6.2	4.5	3.1
Semi-Rigid Frame System With Grade Beam (Czerniak Method)	3.6	2.7	2.2	1.5	1.0
Semi-Rigid Frame System With Grade Beam (Griffith Method)	2.7	1.9	1.8	1.2	0.9

Benefit/Cost:

Alternative Floodproofing Methods for a Small Commercial Building; Jersey Shore, Pennsylvania

	No Floodproofing	Wet Floodproofing	Raised on Fill	Partially Raised with Watertight Closures	Raised on Columns
Floodproofing Benefits Derived from Reduced Annual Flood Losses	0	0.25	3.46	1.39	1.53
Floodproofing Benefits Derived from Reduced Insurance Costs	—	—	5.96	2.31	2.48

*Sheaffer and Roland, Inc., *Economic Feasibility of Floodproofing: Analysis of a Commercial Building* (Washington, D.C.: Federal Emergency Management Agency, 1979) pp. 18-23.

**Sheaffer and Roland, Inc., *Elevating to the Wave Crest Level: A Benefit/Cost Analysis* (Washington, D.C.: Federal Emergency Management Agency, 1980) pp. 34-47.

Case Summary: Naval Submarine Support Base Kings Bay, Georgia

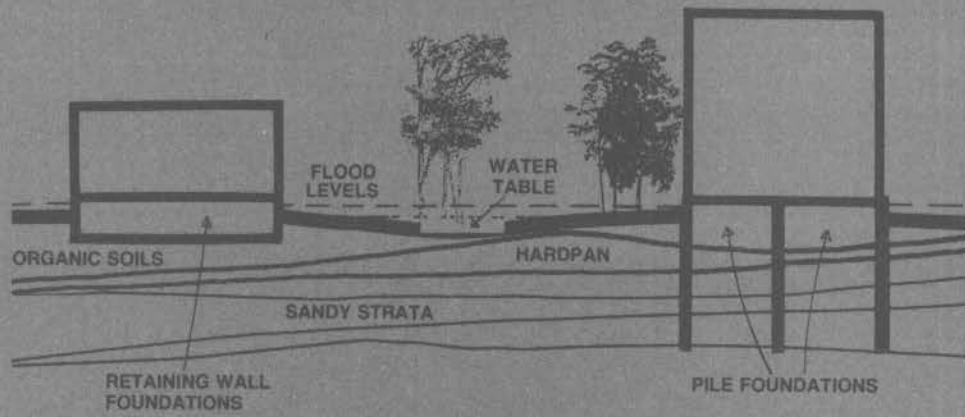
Planning and Design:
Zimmerman, Evans and Leopold, Inc.
Atlanta, Georgia

AECK Associates, Inc.
Atlanta, Georgia

This project called for developing a complete master plan for a 12,000-acre submarine support base for the U.S. Navy. The plan, which is structured to maintain maximum flexibility within designated land use areas, will be used by the Navy to establish broad planning and design policies for the base and to guide program implementation.

One of five functional areas in the plan is the Personnel Support Area. It includes military housing, a recreation complex, administration and training facilities, and related commercial facilities. Site planning concepts were developed to respond to the unique constraints of the site. This included planning for land areas inside the 100-year flood boundary. Specific guidelines relating to flood damage reduction include:

- Buildings will be elevated to minimize the impact on existing drainage systems.
- Buildings will be elevated above the 100-year flood levels.
- Pedestrian walkways will be elevated on timber or concrete piles to protect environmentally sensitive coastal areas.



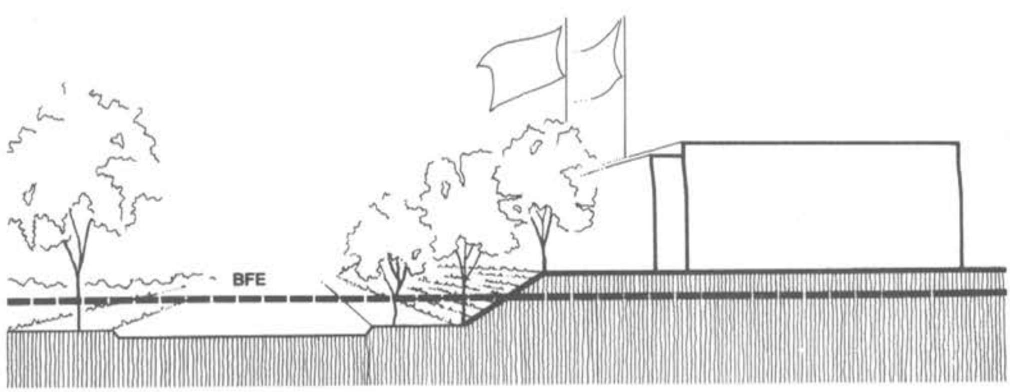
Buildings are to be elevated to reduce flood damage and to minimize the effects on the existing natural environment.

damage. This technique also focuses on minimizing damage to the interior of the building when water does enter.

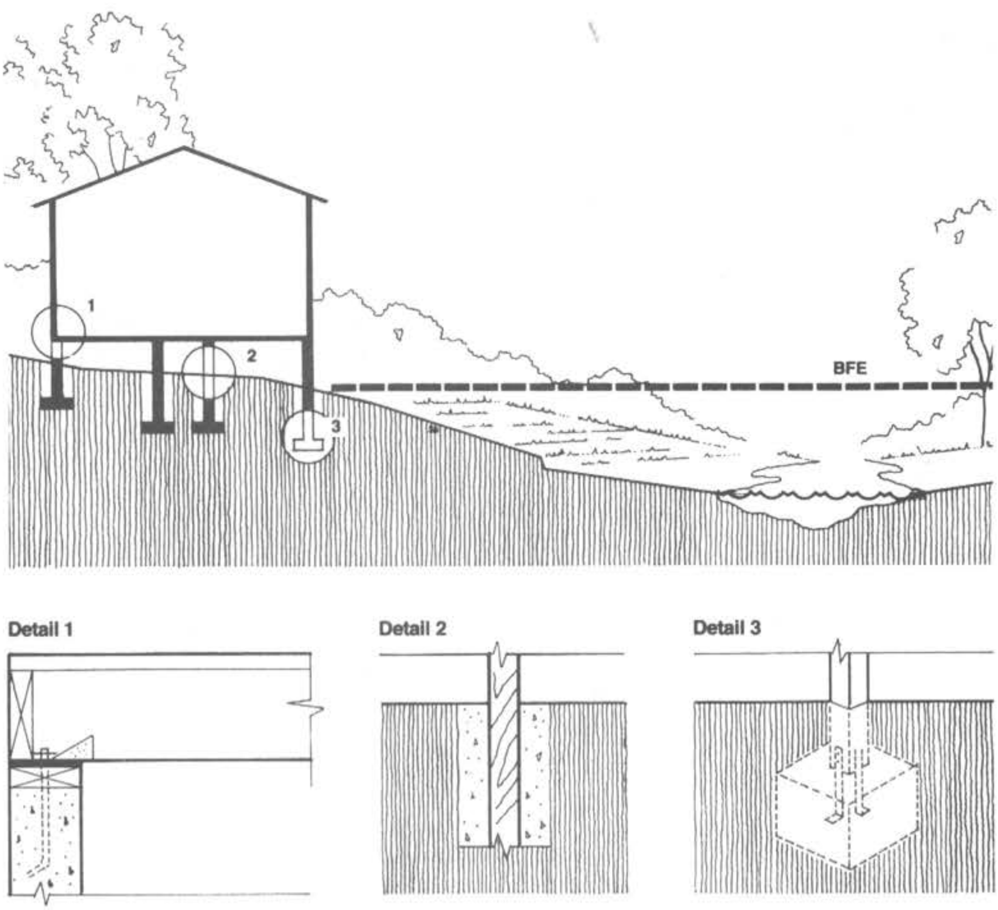
The following discussion of specific techniques assumes adoption of the dry floodproofing approach to mitigating flood damage. Wet floodproofing is discussed after the other methods as a separate technique.

Elevating Buildings. Elevating buildings above the base flood level is a common technique for reducing flood damage. Flood insurance requirements mandate that residential buildings in flood-prone areas be elevated and that other types of buildings be elevated and/or floodproofed. It is a particularly useful technique where site elevations are consistently below the base flood elevation, and offers the greatest assurance of keeping a building dry during flooding.

One method of raising buildings is to use fill material to achieve the desired elevations. This technique interacts with the various site design issues, and requires consideration of the type of fill, compaction and settlement of fill, protection against erosion, and the effect of



Buildings can be raised above the BFE by the use of fill material.



Buildings can be raised above the BFE on posts, piers, or columns. They must be securely anchored to the stilts, which in turn must be anchored to footings. Stilts should be secured in the ground by backfilling.

altered land forms on the flooding levels elsewhere in the watershed system.

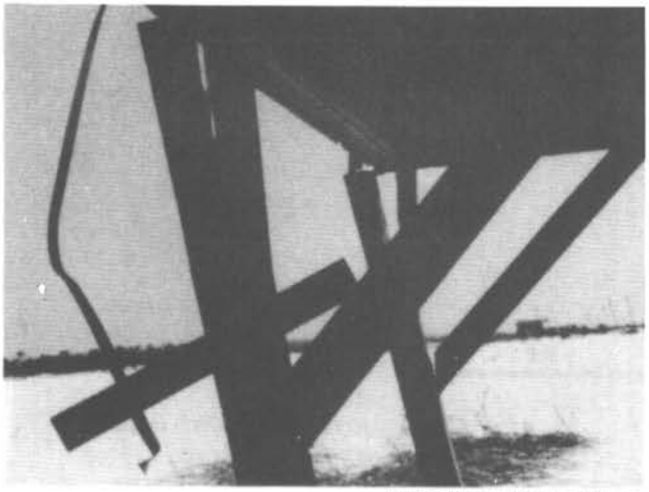
Another approach to elevating buildings is to raise them on some form of stilts, such as piers, posts, or columns. This method puts the building above the base flood level and leaves the ground level predominantly open. The open ground offers the advantage of not impeding the flow of flood water or displacing a significant volume of water, thus being less likely to increase downstream or upstream flood levels.

In using stilts, the designer must consider the size and spacing of stilts to ensure adequate support with minimum obstruction. Stilts should penetrate to bearing soil and be firmly anchored to ensure that they will be able to resist vertical and horizontal water pressure and debris impact loads.

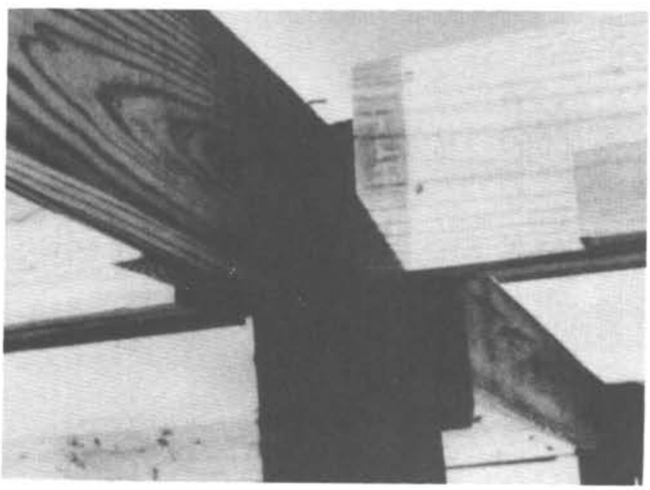
Extended foundation walls can also be used to elevate buildings above flood levels. However, the vertical surfaces of walls can obstruct the flow of water and are

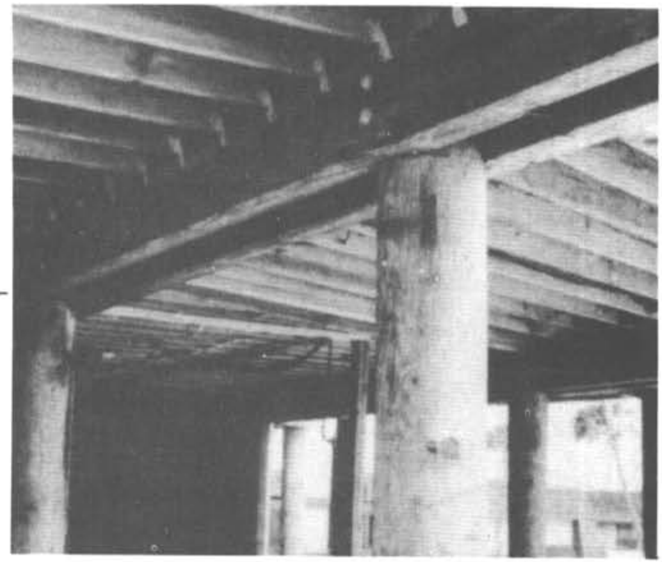
This beach house has been elevated on concrete piers to minimize flood damage.

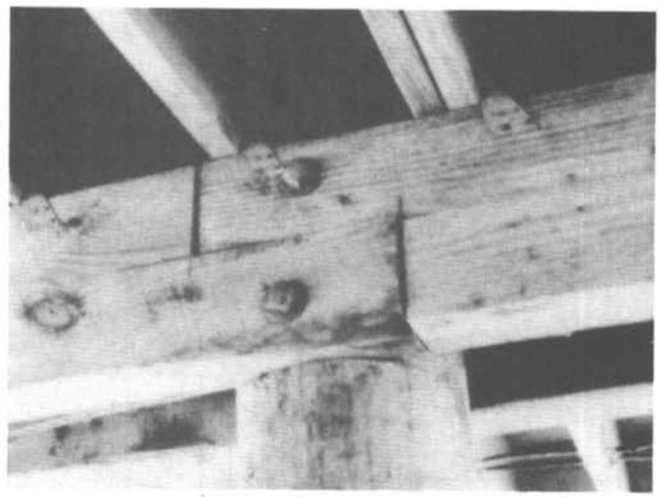
Department of Housing and Urban Development



Raymond R. Fox, Dames and Moore







Above, left, are examples of how the forces of flood water can damage a building if it is not securely anchored to piers, foundations, and footings. Above, right, are examples of anchoring systems designed to resist the forces of flooding.

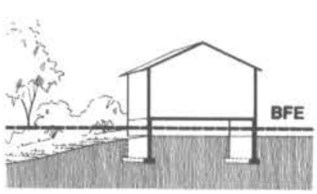
subject to greater lateral water pressure. Longer walls should be located parallel to the flow of flood water to minimize these dangers. All foundation walls that might be subjected to flooding should be anchored to prevent displacement or flotation.

In some cases it can be advantageous to use a combination of methods. For example, a building can be raised on fill at one end and on stilts at the other. This would be beneficial in providing ground floor access at the end of the building that is away from the floodplain while minimizing obstruction of water at the end nearer the stream channel. Techniques for elevating buildings can also be combined with waterproofing techniques in some circumstances.

In using any of the methods for elevating a structure, the designer must consider access to and from the building during flooding and the protection of utility lines and points of entry.

Spatial Organization. The internal spaces of buildings located in or partially in a floodplain should be organized to minimize damage in the event of inundation. The most vulnerable elements of the building should be located above flooding levels. This would typically include placing all mechanical equipment on the upper floors or roof of the building. Depending on the respec-

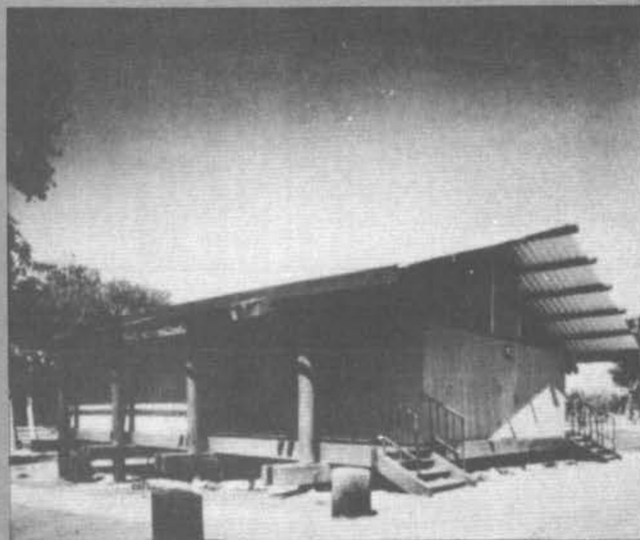
Buildings can be elevated on extended foundation walls. Vertical walls should be sited to minimize obstruction of water flow during flooding.



Case Summary: Featherly Regional Park Orange County, California

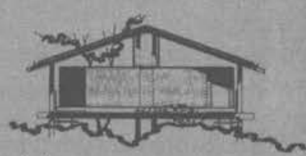
Designer:
Dan L. Roland and Associates
Anaheim, California

Featherly Regional Park is a 156-acre facility located in Orange County, California. The park is traversed by the Santa Ana River, which flows throughout the year. The majority of the park site is subject to flooding during the rainy season. The purpose of the project was to provide camping and picnicking areas as well as administration, concession, and toilet facilities. The design solution included elevation of permanent buildings on poles. This minimized soil disturbance, preserved existing vegetation important in reducing soil erosion, and reduced the effects of flood damage to the buildings.

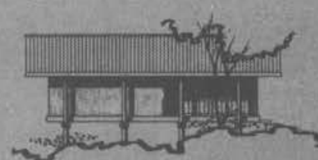


Dan L. Roland and Associates

Support facilities for the park were designed to be elevated on posts to minimize their impact on the natural environment and to reduce the effects of seasonal flood damage.



END ELEVATION



SIDE ELEVATION

tive elevations, machinery and similar equipment should be raised off the floor or anchored to prevent flotation. Particularly valuable and vulnerable contents, such as computer equipment, should be located in areas above flood levels or otherwise securely protected from inundation (e.g., raised on stilts or surrounded by a waterproof enclosure). Spatial configuration should also allow for access to, from, and within the building during flooding.

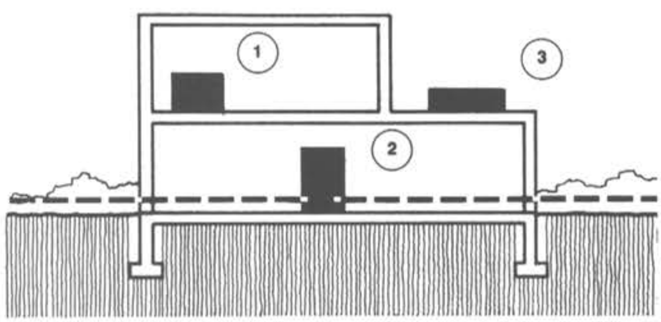
Elimination or Protection of Openings. The most vulnerable components of the basic building fabric are the points where walls below flood levels are penetrated. These points include doors and windows, as well as utility inlets and, in some cases, underground tunnels to adjacent buildings. Such points should be either located above flood levels or thoroughly waterproofed.

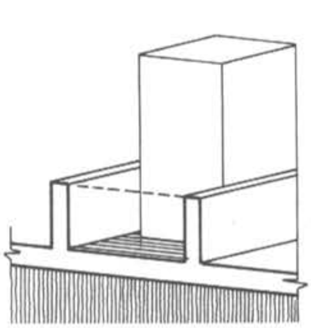
Ideally, all doors and windows should be above the base flood elevation, with access provided via ramps, stairs, or fill. Rubber gaskets can sometimes be used to seal openings below the base flood elevation, and waterproof conduits can be used to protect utility lines.

Openings for doors and windows unavoidably located below flood levels can be protected by flood shields that would be put in place upon receipt of flood warnings. These shields can cover openings ranging from small areas to large display windows. They can sometimes be incorporated in the building's structure, out of the way when not needed and, using hinges and rollers, put in place when necessary. They can also be separate from the structure and stored when not in use. Adequate warning time is a prerequisite to the effectiveness of shields.

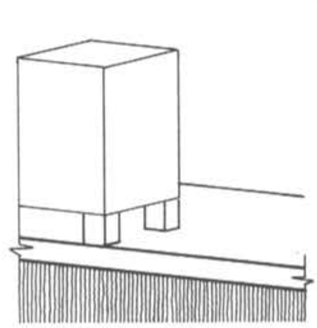
Openings below the base flood elevation in existing buildings can often be eliminated, with alternative entry points provided at higher levels. Windows below flood level can sometimes be replaced by glass bricks, which al-

The internal configuration of buildings in flood-prone areas must be organized to minimize damage to contents in the event of flooding. Computers, financial records, and other vulnerable contents (1) should be placed on upper floors. Mechanical equipment (2) should be located on upper floors or on the roof. Machinery or other contents that must be in vulnerable locations (3) should be protected, either by surrounding it with a watertight enclosure (3A) or raising it above flooding levels (3B).

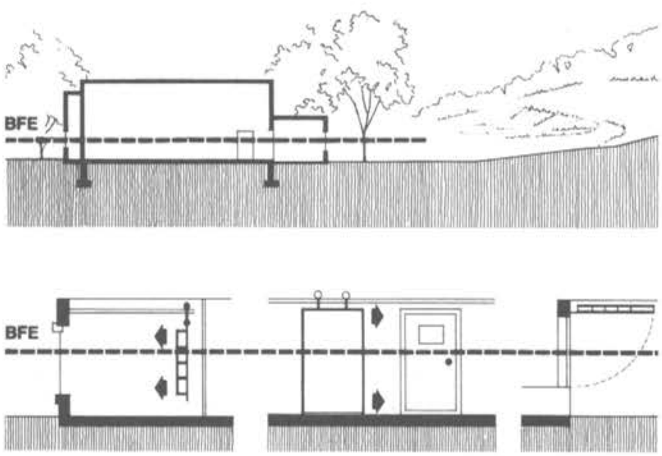




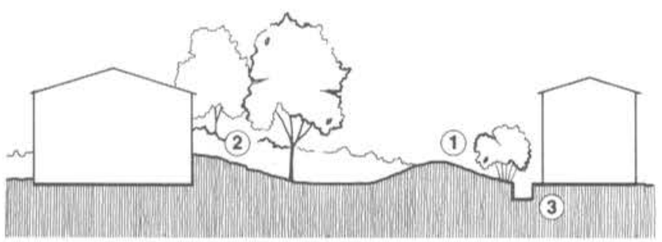
Detail 3A



Detail 3B



Doors and windows below the BFE can be protected by flood shields that can be put into place on receipt of flood warnings. The examples below use rollers and/or hinges.



On-site flood control measures, such as earth berms, can be used to protect buildings from flooding. They can be free standing (1) or directly against the building (2). When berms or other types of flood walls are used it is important to install sump pumps (3) to ensure that dry conditions are maintained within the enclosure.

Water pressure caused by flooding affects both vertical and horizontal structural members. This pressure must be countered, either by structural reinforcing or by allowing an equivalent amount of water into the structure, to avoid major structural damage.

low light but can withstand moderate amounts of water pressure during flooding.

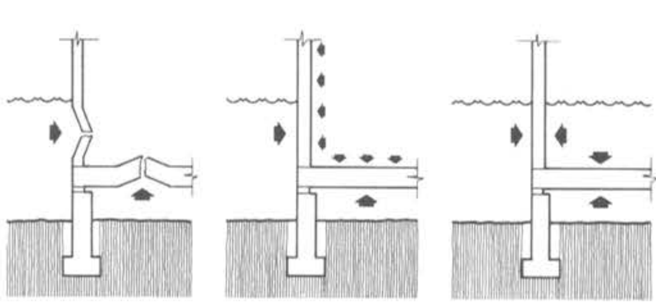
On-Site Flood Control. Levees and retaining walls can be used as on-site flood control measures to keep water away from all or part of a building. These can be in the form of earth berms—either free-standing or directly against the building—which can also provide access routes. Retaining walls can be incorporated into buildings as fences or patio enclosures to protect openings that are below the base flood level, and provide privacy and amenity as well.

Such control measures should be designed to resist lateral and vertical water pressures, protect against erosion, and not obstruct the flow of water.

Enclosures designed to protect openings should be combined with sump pumps to ensure that dry conditions are maintained within the protected area. Emergency power supplies should always be available for operating the pump during storms, when normal power is likely to be disrupted. Levees and walls can be combined with flood shields to maximize their effectiveness, and can be appropriate for any size or type of building. Their use should be carefully coordinated with site design issues.

Building Materials. Even when using "dry" floodproofing approaches to reducing flood damage, some parts of a building may be exposed to water. If so, water-resistant building materials should be used. This could include the use of water-resistant lumber, floor coverings, adhesives, and paints, as well as masonry construction and finishes, and waterproof mechanical and electrical fittings. The use of water-absorbent materials such as gypsum board paneling should be avoided below flood levels.

Structural Walls. All structural walls should be designed to accommodate hydrostatic, hydrodynamic, and debris impact loads. The walls should be able to withstand the lateral forces from the predicted depth and velocity of flood waters, as well as the vertical forces from flood waters and rising ground water levels, which require secure anchoring to footings and foundations. Potential seepage requires the use of sealants, external wall coatings, and the secure joining of walls, floors, and foundations.



Floors. Floors should be designed to withstand the vertical pressures associated with flooding. This requires consideration of soil composition and ground water levels, as well as the likely flood levels in relation to building elevations. Floor design should provide adequate thickness and reinforcing to resist water pressure, and can include the provision of extra weight (e.g., concrete pads) to prevent flotation. Floors should be securely anchored to foundations, and joints between walls and floors should be securely tied and sealed to prevent displacement or seepage.

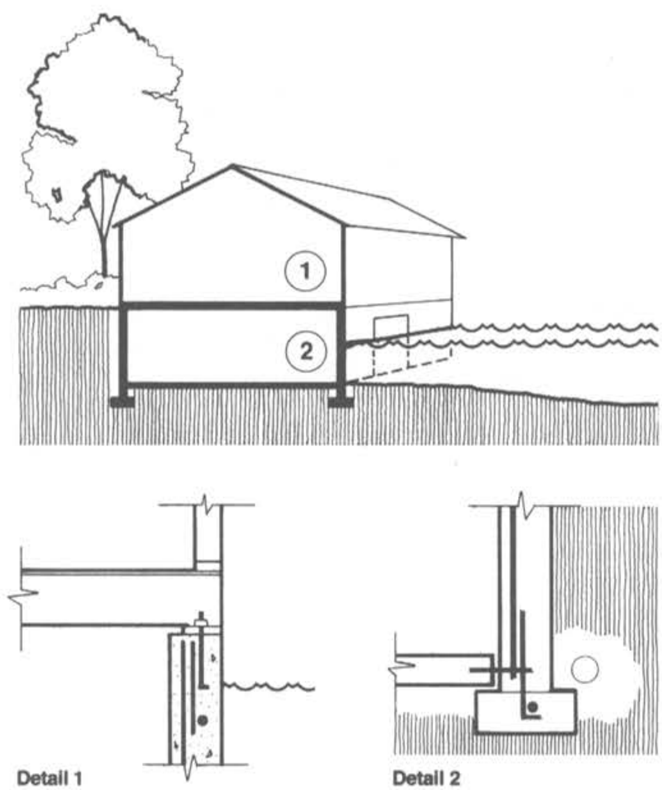
Footings and Foundations. Footings and foundations require special consideration in flood-prone areas. They should be at a sufficient depth and on bearing soil in order to provide the necessary lateral resistance to water pressure, and should also be able to resist vertical pressures. In some cases this may require additional anchorage with pilings or extra weighting with concrete pads. Also necessary is the protection of footings and foundations from erosion and scour, which is especially important where they will be subjected to extreme velocities, such as with coastal tides and storm surges.

Utilities. All utility lines should either enter the building above the base flood elevation or be waterproofed and secured to prevent displacement due to water pressure. When a utility line enters the building below the base flood level, it should be routed so that the interior outlet point is above the flood level. Internal and external fittings that are below flood levels should be thoroughly waterproofed, and control panels should be above the base flood elevation to allow access during flooding. Controls for lower floors and basements can often be isolated to allow them to be disconnected independently during flooding.

Mechanical Systems. All mechanical equipment and controls should be located above the base flood elevation to prevent damage and to allow access to the equipment during flooding. The duct work associated with the mechanical system should be elevated or otherwise protected from water damage.

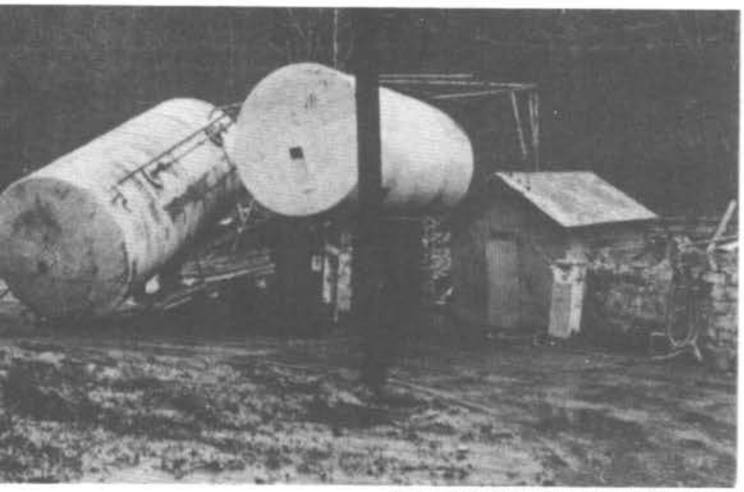
Plumbing. Floor drains and other plumbing will often be unavoidably located below the base flood level. They should be fitted with valves to prevent the backflow of water that would damage the interior of the building. Sump pumps should be installed to remove small quantities of water, with the drain outlet of the pump located above the base flood level and an emergency power source available.

Wet Floodproofing. As mentioned earlier, wet floodproofing is a special technique that can be used under certain circumstances to reduce flood damage. The distinguishing characteristic of wet floodproofing is that rather than trying to keep water out, water is purposely intro-



Secure connections between different parts of the building are necessary to prevent flood damage. The building must be firmly anchored to foundations (1) and foundations must be anchored to footings (2). The house below was not adequately anchored to its foundation.

Department of Housing and Urban Development



Department of Housing and Urban Development

All potentially damaging elements must be firmly anchored. Storage tanks can be damaged when torn from their mountings and can increase hazards if their contents are spilled or if they are carried away as debris.

duced into a building at times of flooding. This is done so that the water level inside will counteract the pressure of rising flood water on the outside, thus reducing the possibility of major structural damage. This technique is potentially useful where damage from exposure to water will be minimal and post-flood clean-up relatively easy.

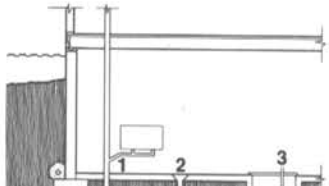
Wet floodproofing requires that all parts of the building below the base flood level be constructed and fitted with water-resistant materials and finishes. Surfaces should be nonporous in order to minimize absorption and facilitate cleaning (e.g., concrete, metal, plastic, or glass). Pumping clean water in as flood waters rise, rather than allowing flood water to enter, will simplify clean-up. All interior spaces must be allowed to fill with water, including any cavity walls, and must be able to drain and be cleaned after the water recedes.

It is essential in wet floodproofing that utility and mechanical systems be accessible and operable before, during, and after flooding. Thus they must be either above the base flood elevation or waterproofed and anchored. Fuel and chemical storage tanks must be elevated or located on upper floors above flooding levels, or evacuated prior to flooding. Valves that maintain equalized water pressure and clean-up equipment must be included in a wet-floodproofed building.

The many special requirements of wet-floodproofing and its limited effectiveness in reducing damage to contents limit the number of situations to which it can be applied. However it could be useful in some industrial buildings and may be appropriate for limited-use basement areas that are below the base flood elevation.

The foregoing techniques are not all-encompassing, but indicate the design issues involved in reducing flood damage, ranging from site selection to control of storm water runoff and from building configuration to structural requirements. They are outlined to provide an overview of the general information needed and the tools that are available for design in flood-prone areas. More detailed information is available from the literature references cited and from the relevant government agencies listed in the Resource Index.

The designer with a firm grasp of these flood-related issues and techniques is better prepared to generate appropriate design responses for each specific project and site. Increased knowledge allows the designer to accept the creative challenge of designing to meet programmatic and aesthetic standards while simultaneously reducing flood losses throughout the natural and built environment. The designer is thus able to meet professional responsibilities while benefiting both the client and the community.



Plumbing drainage lines (1 and 2) should be fitted with valves to prevent the backflow of flood water into the building. Sump pumps should be installed to remove small quantities of water that might build up, even in floodproofed buildings.

Heritage Conservation and Recreation Service

Literature Resources

Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas. Dames & Moore, Inc. Washington, D.C.: U.S. Department of Housing and Urban Development; Federal Emergency Management Agency, Federal Insurance Administration, 1981.

Elevated Residential Structures: Reducing Flood Damage Through Building Design. AIA Research Corporation. Washington, D.C.: Federal Insurance Administration, 1976.

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Introduction to Floodproofing. John R. Sheaffer. Chicago: Center for Urban Studies, University of Chicago, 1967.

Lakes and Ponds. Joachim Tourbier and Richard Westmacott. Washington, D.C.: Urban Land Institute, Technical Bulletin 72, 1976.

Manual for the Construction of Residential Basements in Non-Coastal Flood Environs. National Association of Home Builders Research Foundation, Inc. Washington, D.C.: Federal Insurance Administration, 1977.

Michigan Soil Erosion and Sedimentation Control Guidebook. Lansing, Michigan: Bureau of Water Management, Michigan Department of Natural Resources, n.d.

Residential Storm Water Management. New York, N.Y. and Washington, D.C.: American Society of Civil Engineers, National Association of Home Builders, and the Urban Land Institute, 1975.

The Role of Vegetation in Shoreline Management. Great Lakes Basin Commission. Chicago: U.S. Army Corps of Engineers, North Central Division.

Resource Index

Glossary

Actuarial Rates. Rates established by the Federal Insurance Administration pursuant to Flood Insurance Studies for individual communities. These rates are set in accordance with the National Flood Insurance Program (NFIP) and accepted actuarial principles. Subject to various other limitations, actuarial rates are applicable only after the publication and effective date of a community's Flood Insurance Rate Map (FIRM).

Base Flood Elevation (BFE). The elevation for which there is a one-percent chance in any given year that flood levels will equal or exceed it. The BFE is determined by statistical analysis of streamflow records for the watershed and rainfall and runoff characteristics in the general region of the watershed.

Coastal High Hazard Area. The portion of a coastal floodplain that is subject to high velocity waters caused by tropical storms, hurricanes, northeasters, or tsunamis. NFIP regulations for Coastal High Hazard Areas apply where tides, storm waves and surges, and local geographic characteristics combine to produce a breaking wave of three feet or more.

Debris Impact Loads. Loads induced on a structure by solid objects carried by flood water. Debris can include trees, lumber, displaced sections of structures, tanks, runaway boats, and chunks of ice. Debris impact loads are difficult to predict accurately, yet reasonable allowances must be made for them in the design of potentially affected structures.

Encroachment. Any physical object placed in a floodplain that hinders the passage of water or otherwise affects flood flows.

Existing Construction. Those structures already existing or on which construction or substantial improvement was started prior to the effective date of a community's floodplain management regulations.

First Floor. The floor that is level with or immediately above the main point of entry into the building. For residences, it is additionally that floor that comprises the main living area of the dwelling.

Flood or Flooding. A general and temporary condition of partial or complete inundation of normally dry land areas. Flooding results from the overflow of inland or tidal waters or the unusual and rapid accumulation of surface water runoff from any source.

Flood Fringe. The area within the floodplain (as determined by the reach of the one-percent-probability flood) that is outside the floodway.

Flood Hazard Boundary Map (FHBM). An official map of a community, issued or approved by the Federal Emergency Management Agency on which the boundaries of the floodplain and special flood hazard areas have been designated. This map is prepared according to the best flood data available at the time of its preparation, and is superseded by the Flood Insurance Rate Map after more detailed studies have been completed.

Flood Insurance Rate Map (FIRM). An official map of a community, issued or approved by the Federal Insurance Administration, that delineates both the special hazard areas and the risk premium zones applicable to the community.

Flood Insurance Study (FIS). A study, funded by the Federal Insurance Administration and carried out by any of a variety of agencies and consultants, to delineate the special flood hazard areas, base flood elevations, and NFIP actuarial insurance rate zones. The study is based on detailed site surveys and analysis of site-specific hydrologic characteristics.

Floodplain. Any normally dry land area that is susceptible to being inundated by water from any natural source. This area is usually low land adjacent to a river, stream, watercourse, ocean, or lake.

Floodplain Management. The operation of a program of corrective and preventive measures for reducing flood damage, including but not limited to flood control projects, floodplain land use regulations, floodproofing of buildings, and emergency preparedness plans.

Flood Profile. A graph showing the relationship of water surface elevation to a specific location, the latter generally expressed as distance above the mouth of a stream of water flowing in an open channel. It is generally drawn to show surface elevation for the crest of a specific magnitude of flooding, but may be prepared for conditions at any given time or stage.

Floodproofing. Any combination of structural provisions and/or other modifications incorporated into individual buildings or properties primarily for the purpose of reducing or eliminating flood damages.

American Red Cross

Floodway. The channel of a river or watercourse and the adjacent land areas that must be reserved to discharge the one-percent-probability flood without cumulatively increasing the water surface elevation more than a designated height, generally one foot.

Flood Boundary and Floodway Map. An official map of a community, issued or approved by the Federal Emergency Management Agency, on which floodplain and floodway boundaries have been designated.

Hydrograph. A graph that charts the passage of water as a function of time. It shows flood stages, depicted in feet above mean sea level or gage height, plotted against stated time intervals.

Hydrology. The science of the behavior of water in the atmosphere, on the earth's surface, and underground.

Hydrodynamic Loads. As flood water flows around a structure at moderate-to-high velocities it imposes loads on the structure. These loads consist of frontal impact by the mass of moving water against the structure, drag effect along the sides of the structure, and eddies or negative pressures on the structure's downstream side.

Hydrostatic Loads. Those loads or pressures resulting from the static mass of water at any point of flood water contact with a structure. They are equal in all directions and always act perpendicular to the surface on which they are applied. Hydrostatic loads can act vertically on structural members such as floors, decks, and roofs, and can act laterally on upright structural members such as walls, piers, and foundations.

Infiltration. The flow of fluid into a substance through pores or small openings. The word is commonly used to denote the flow of water into soil.

Mean Sea Level. The average height of the sea for all stages of the tide, usually determined from hourly height observations over a nineteen-year period on an open coast or in adjacent waters having free access to the sea.

New Construction. Structures on which construction or substantial improvement was started after the effective date of a community's floodplain management regulations.

One-Hundred-Year Flood. See Special Flood Hazard Areas.

Permeability. The property of soil or rock that allows passage of water through it.

Regulatory Floodway. Any floodway referenced in a floodplain ordinance for the purpose of applying floodway regulations.

Special Flood Hazard Areas. Areas in a community that have been identified as susceptible to a one-percent or greater chance of flooding in any given year. A one-percent-probability flood is also known as the 100-year flood or the base flood. Special Flood Hazard Areas are usually designated on the Flood Hazard Boundary Map (FHBM) as Zone A. After detailed evaluation of local flooding characteristics, the Flood Insurance Rate Map (FIRM) will refine this categorization into Zones A, A0, A1-30, and V1-30.

Transpiration. The process by which water vapor escapes from a plant through its leaf system and enters the atmosphere.

Watershed. An area from which water drains to a single point; in a natural basin, the watershed is the area contributing flow to a given place or a given point on a stream.

Water Table. The uppermost zone of water saturation in the ground.

Federal Emergency Management Agency Regional Offices

The Federal Emergency Management Agency (FEMA) was created in 1978 to provide a single point of accountability for all federal activities related to disaster mitigation and emergency preparedness and response. It was established as an independent agency in the executive branch to consolidate a variety of existing agencies and offices performing related functions. The Federal Insurance Administration (FIA), formerly a part of the Department of Housing and Urban Development, is only responsible for insurance activities. FEMA is responsible for administering the National Flood Insurance Program. This responsibility includes assisting state and local governments in the implementation of floodplain management programs and providing information on flooding to communities and individuals. Regional offices are the primary means by which FEMA's programs are carried out at the state and local level.

Federal Emergency Management Agency Regional Offices and Boundaries

Region I Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island & Vermont

442 J. W. MacCormack Office Building
Boston, Massachusetts
02109
(617) 223-2616

Region II New Jersey, New York, Puerto Rico & Virgin Islands

26 Federal Plaza
Rm. 1349
New York, New York
10007
(212) 264-4756

Region III Delaware, District of Columbia, Maryland, Pennsylvania, Virginia & West Virginia

Curtis Building
Sixth & Walnut Streets
Philadelphia, Pennsylvania
19106
(215) 597-9416

Region IV Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina & Tennessee

1375 Peachtree Street, N.W.
Suite 778
Atlanta, Georgia
31792
(404) 881-2391

Region V Illinois, Indiana, Michigan, Minnesota, Ohio & Wisconsin

1 North Dearborn Street
Chicago, Illinois
60602
(312) 353-0757

Region VI Arkansas, Louisiana, New Mexico, Oklahoma & Texas

Federal Regional Center
Rm. 206
Denton, Texas
76201
(817) 387-5811

Region VII Iowa, Kansas, Missouri & Nebraska

Federal Office Building
Rm. 405
Kansas City, Missouri
64106
(816) 374-2161

Region VIII Colorado, Montana, North Dakota, South Dakota, Utah & Wyoming

Federal Regional Center
Building 17
Denver, Colorado
80225
(303) 234-6582

Region IX Arizona, California, Hawaii & Nevada

211 Main St.
Rm. 220
San Francisco, California
94105
(415) 556-3543

Region X Alaska, Idaho, Oregon & Washington

Federal Regional Center
Bothell, Washington
98011
(206) 486-0721

Ted Carland, American Red Cross

U.S. Army Corps of Engineers District Offices

The Corps of Engineers is involved in a variety of flood-related activities, including research and development, planning, design, construction, operation and maintenance. It also engages in real estate activities related to rivers, harbors, and waterways and administers laws for protection and preservation of navigable waters and related resources such as wetlands.

The Corps is organized into 11 divisions and 36 districts based on riverbasins and watersheds. The districts are the principal planning and implementation offices of the Corps, and include an office of Floodplain Management Services. It is authorized to provide information, technical assistance, and guidance to nonfederal entities in identifying the magnitude and extent of flood hazards and in planning wise use of floodplains. It can identify areas subject to flooding and describe flood hazards at specific sites. This information is a basis for planning floodplain use, delineating boundaries for floodplain regulations, and setting appropriate elevations for floodproofing.

U.S. Army Corps of Engineers District Offices and Boundaries

Lower Mississippi Valley Division

Memphis
U.S. Army Engr. Dist.
668 Clifford Davis Federal Building
Memphis, Tn. 38103

New Orleans
U.S. Army Engr. Dist.
P.O. Box 60267
New Orleans, La. 70160

St. Louis
U.S. Army Engr. Dist.
210 Tucker Blvd. N.
St. Louis, Mo. 63101

Vicksburg
U.S. Army Engr. Dist.
P.O. Box 60
Vicksburg, Ms. 39180

Missouri River Division

Kansas City
U.S. Army Engr. Dist.
700 Federal Bldg.
Kansas City, Mo. 64106

Omaha
U.S. Army Engr. Dist.
6014 USPO & Courthouse
Omaha, Ne. 68102

North Atlantic Division

New England
U.S. Army Engineering Division,
424 Trapelo Road
Waltham, Ma. 02154

Baltimore
U.S. Army Engr. Dist.
P.O. Box 1715
Baltimore, Md. 21203

New York
U.S. Army Engr. Dist.
26 Federal Plaza
New York, NY 10007

Norfolk
U.S. Army Engr. Dist.
803 Front St.
Norfolk, Va. 23510

Philadelphia
U.S. Army Engr. Dist.

U.S. Custom House
2nd & Chestnut St.
Philadelphia, Pa. 19106

North Central Division

Buffalo
U.S. Army Engr. Dist.
1776 Niagaeh St.
Buffalo, NY 14207

Chicago
U.S. Army Engr. Dist.
219 S. Dearborn St.
Chicago, Il. 60604

Detroit
U.S. Army Engr. Dist.
P.O. Box 1027
Detroit, Mi. 48231

Rock Island
U.S. Army Engr. Dist.
Clock Tower Bldg.
Rock Island, Il. 61201

St. Paul
U.S. Army Engr. Dist.
1135 USPO & Custom House
St. Paul, Mn. 55101

North Pacific Division

Alaska
U.S. Army Engr. Dist.
P.O. Box 7002
Anchorage, Ak. 99510

Portland
U.S. Army Engr. Dist.
P.O. Box 2946
Portland, Or. 97208

Seattle
U.S. Army Engr. Dist.
P.O. Box C-3755
Seattle, Wa. 98124

Walla Walla
U.S. Army Engr. Dist.
Bldg. 602, City-County Airport
Walla Walla, Wa. 99362

Ohio River Division

Huntington
U.S. Army Engr. Dist.
P.O. Box 2127
Huntington, WV. 25721

Louisville
U.S. Army Engr. Dist.
P.O. Box 59
Louisville, Ky. 40201

Nashville
U.S. Army Engr. Dist.
P.O. Box 1070
Nashville, Tn. 37202

Pittsburgh
U.S. Army Engr. Dist.
Federal Bldg.
1000 Liberty Ave.
Pittsburgh, Pa. 15222

Pacific Ocean Division

Honolulu
U.S. Army Engr. Dist.
Bldg. 230, Fort Shafter
Honolulu, Hi. 96858

South Atlantic Division

Charleston
U.S. Army Engr. Dist.
P.O. Box 919
Charleston, SC 29402

Jacksonville
U.S. Army Engr. Dist.
P.O. Box 4970
Jacksonville, Fl. 32201

Mobile
U.S. Army Engr. Dist.
P.O. Box 2288
Mobile, Al. 36628

Savannah
U.S. Army Engr. Dist.
P.O. Box 889
Savannah, Ga. 31402

Wilmington
U.S. Army Engr. Dist.
P.O. Box 1890
Wilmington, NC 28402

South Pacific Division

Los Angeles
U.S. Army Engr. Dist.
P.O. Box 2711
Los Angeles, Ca. 90053

Sacramento
U.S. Army Engr. Dist.
650 Capital Mall
Sacramento, Ca. 95814

San Francisco
U.S. Army Engr. Dist.
211 Main Street
San Francisco, Ca. 94105

South Western Division

Albuquerque
U.S. Army Engr. Dist.
P.O. Box 1580
Albuquerque, NM 87103

Fort Worth
U.S. Army Engr. Dist.
P.O. Box 17300
Ft. Worth, Texas 76102

Galveston
U.S. Army Engr. Dist.
P.O. Box 1229
Galveston, Texas 77553

Little Rock
U.S. Army Engr. Dist.
P.O. Box 867
Little Rock, Ar. 72203

Tulsa
U.S. Army Engr. Dist.
P.O. Box 61
Tulsa, Ok. 74102

U.S. Department of Agriculture
Soil Conservation Service

The Soil Conservation Service (SCS) was established in 1935 to develop a national soil and water conservation program. SCS provides technical assistance to local conservation districts, sponsors of watershed protection projects, and other individuals and groups.

The SCS technical services include a number of flood-related activities. Soil surveys are made to determine soil use potentials and conservation strategies. SCS's plant materials centers are operated to assemble, test, and encourage the use of promising plant species in conservation programs. An inventory and monitoring system is maintained for planning the use of water and land resources. Snow surveys in western states are made to develop stream-flow forecasts. SCS's watershed studies provide a basis for developing coordinated water resource programs, and its floodplain management studies furnish technical data, assistance, and information for local floodplain management programs.

Soil Conservation Service Regional Boundaries

Northwest

S.C.S. Alaska Office
Suite 129, Professional Bldg.
2221 E. Northern Lights Blvd.
Anchorage, Alaska 99504
(907) 276-4246

S.C.S. Colorado Office
Room 313
2490 West 26th Avenue
P.O. Box 17107
Denver, Colorado 80217
(303) 837-4275

S.C.S. Idaho Office
Room 345
304 North 8th St.
Boise, Idaho 83702
(208) 384-1601 Ext. 1601

S.C.S. Montana Office
Federal Building
P.O. Box 970
Bozeman, Montana 59715
(406) 587-5271 Ext. 4322

S.C.S. North Dakota Office
Federal Building
Rosser Avenue & Third St.
P.O. Box 1458
Bismark North Dakota 58501
(701) 255-4011 Ext. 421

S.C.S. Oregon Office
Federal Office Building
1220 S.W. 3rd Avenue
Portland, Oregon 97209
(503) 221-2751

S.C.S. South Dakota Office
Federal Building
200 4th Street, S.W.
P.O. Box 1357
Huron, South Dakota 57350
(605) 352-8651

S.C.S. Utah Office
4012 Federal Building
125 South State St.
Salt Lake City, Utah 84138
(801) 524-5051

S.C.S. Washington Office
360 U.S. Courthouse
W. 920 Riverside Avenue
Spokane, Washington 99201
(509) 456-3711

S.C.S. Wyoming Office
Federal Office Building
P.O. Box 2440
Casper, Wyoming 82601
(307) 265-5550

Southwest

S.C.S. Arkansas Office
Federal Building, Room 5029
700 West Capitol Street
P.O. Box 2323
Little Rock, Arkansas 72203
(501) 378-5445

S.C.S. Arizona Office
3008 Federal Building
230 N. 1st. Ave.
Phoenix, Arizona 85025
(602) 261-6711

S.C.S. California Office
2828 Chiles Road
Davis, California 95616
(916) 758-2200 Ext. 210

S.C.S. Hawaii Office
300 Ala Moana Blvd.
Room 4316
P.O. Box 5004
Honolulu, Hawaii 96850
(808) 546-3165

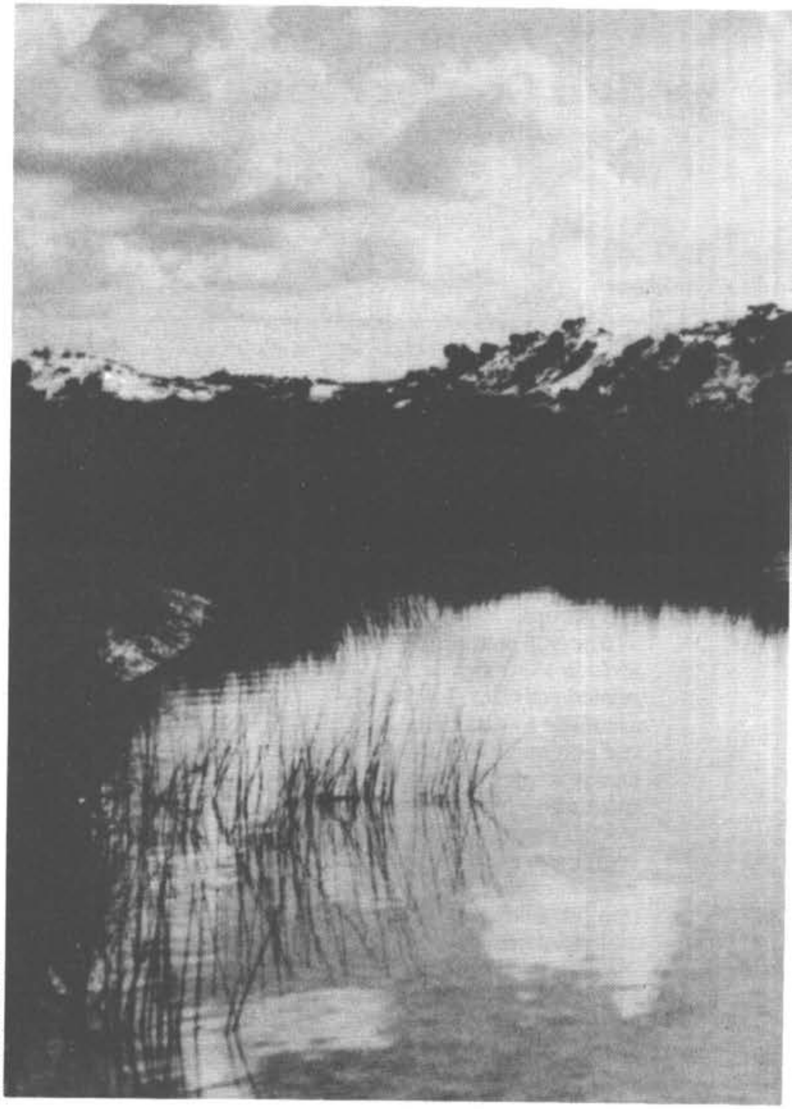
S.C.S. Louisiana Office
3737 Government Street
P.O. Box 1630
Alexandria, Louisiana 71301
(318) 448-3421

S.C.S. Nevada Office
U.S. Post Office Building
P.O. Box 4850
Reno, Nevada 89505
(702) 784-5304

S.C.S. New Mexico Office
517 Gold Avenue, S.W.
P.O. Box 2007
Albuquerque, New Mexico
87103
(505) 766-2173

S.C.S. Oklahoma Office
Agriculture Building
Farm Road & Brumley Street
Stillwater, Oklahoma 74074
(405) 624-4360

S.C.S. Texas Office
W.B. Poage Federal Building
101 S. Main Street
P.O. Box 648
Temple, Texas 76501
(817) 773-1711


National Park Service

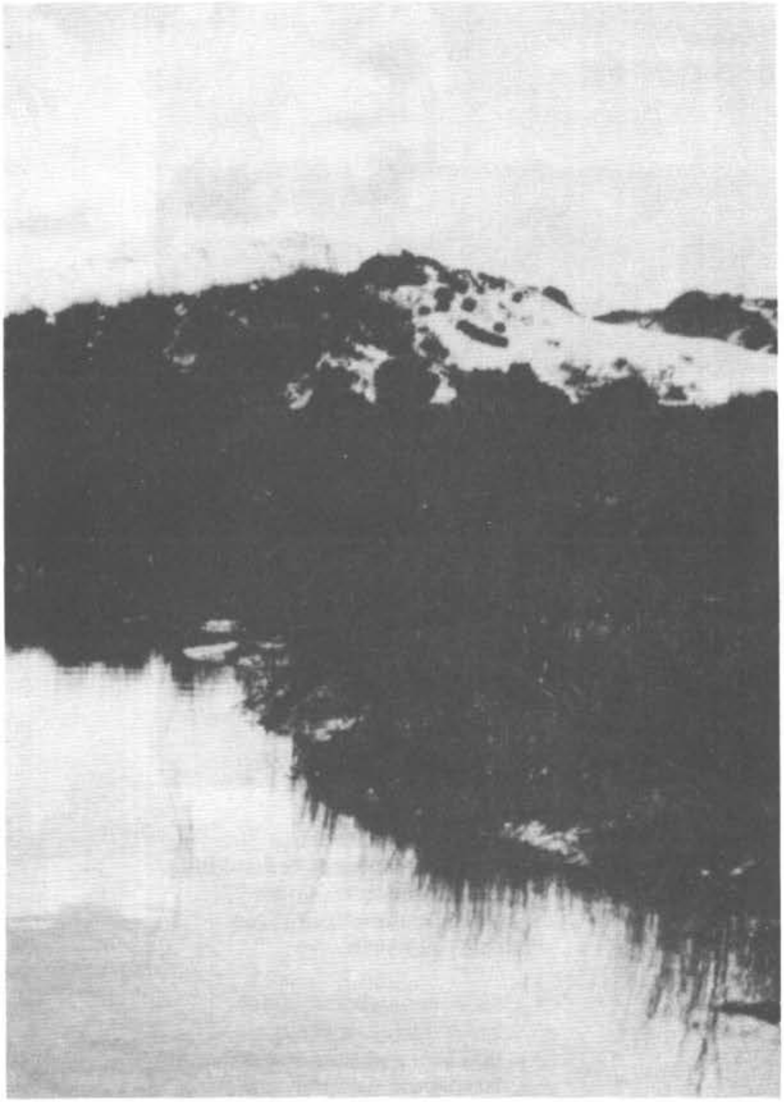
Midwest

S.C.S. Illinois Office
Federal Building
200 W. Church Street
P.O. Box 678
Champaign, Illinois 61820
(217) 356-3785

S.C.S. Indiana Office
Atkinson Square West
Suite 2200
5610 Crawfordsville Road
Indianapolis, Indiana 46224
(317) 269-3785

S.C.S. Iowa Office
693 Federal Building
210 Walnut St.
Des Moines, Iowa 50309
(515) 862-4260

S.C.S. Kansas Office
760 South Broadway
P.O. Box 600
Salina, Kansas 67401
(913) 825-9535



S.C.S. Michigan Office
Room 101
1405 South Harrison Road
East Lansing, Michigan 48823
(517) 372-1910

S.C.S. Minnesota Office
200 Federal Bldg., &
U.S. Courthouse
316 North Robert St.
St. Paul, Minnesota 55101
(612) 725-7675

S.C.S. Missouri Office
555 Vandiver Drive
Columbia, Missouri 65201
(314) 442-2271

S.C.S. Nebraska Office
Federal Building
U.S. Courthouse, Room 345
Lincoln, Nebraska 68508
(402) 471-5301

S.C.S. Ohio Office
Room 522
200 North High St.
Columbus, Ohio 43215
(614) 469-6785

S.C.S. Wisconsin Office
4601 Hammersvey Road
Madison, Wisconsin 53711
(608) 252-5351

Southeast

S.C.S. Alabama Office
Wright Building
138 South Gay St.
P.O. Box 311
Auburn, Alabama 36830
(205) 821-8070

S.C.S. Florida Office
Federal Building
Room 248
P.O. Box 1208
Gainesville, Florida 32602
(904) 377-8732

S.C.S. Georgia Office
Federal Building
355 E. Hancock Avenue
P.O. Box 832
Athens, Georgia 30603
(404) 546-2274

S.C.S. Kentucky Office
333 Waller Ave.
Lexington, Kentucky 40504
(606) 233-2749 Ext. 2749

S.C.S. Mississippi Office
Milner Building, Room 590
210 South Lamar St.
P.O. Box 610
Jackson, Mississippi 39205
(601) 969-4330

S.C.S. North Carolina Office
310 New Bern Ave.,
Federal Building
Fifth Floor, P.O. Box 27307
Raleigh, North Carolina 27611
(919) 755-4165

S.C.S. Puerto Rico Office
Caribbean Area
Federal Office Bldg.,
Room 633, 6th Floor
Hato Rey, Puerto Rico, 00918
(809) 753-4206

S.C.S. South Carolina
240 Stoneridge Drive
Columbia, South Carolina 29210
(803) 765-5681

S.C.S. Tennessee Office
675 U.S. Courthouse
Nashville, Tennessee 37203
(615) 749-5471

Heritage Conservation and Recreation Service

Northeast

S.C.S. Connecticut Office
Mansfield Professional Park
Route 44A
Storrs, Connecticut 06268
(203) 429-9361/9326

S.C.S. Delaware Office
Treadway Towers, Suite 2-4
9 East Loockerman St.
Dover, Delaware 19901
(302) 678-0750

S.C.S. Maine Office
USDA Building
University of Maine
Orono, Maine 04473
(207) 866-2132/2133

S.C.S. Maryland Office
Room 522, Hartwick Building
4321 Hartwick Road
College Park, Maryland 20740
(301) 344-4180

S.C.S. Massachusetts Office
29 Cottage St.
Amherst, Massachusetts 01002
(413) 549-0650

S.C.S. New Hampshire Office
Federal Building
Durham, New Hampshire 03824
(603) 868-7581

S.C.S. New Jersey Office
1370 Hamilton St.
P.O. Box 219
Somerset, New Jersey 08873
(201) 246-1205 Ext. 20

S.C.S. New York Office
U.S. Courthouse & Federal Bldg.
100 S. Clinton St., Room 771
Syracuse, New York 13260
(315) 423-5493

S.C.S. Pennsylvania Office
Federal Bldg. & Courthouse
Box 985, Federal Square Station
Harrisburg, Pennsylvania 17108
(717) 782-4403

S.C.S. Rhode Island Office
222 Quaker Lane
West Warwick, Rhode Island 02893
(401) 828-1300

S.C.S. Vermont Office
Burlington Square, Suite 205
Burlington, Vermont 05401
(802) 862-6501 Ext. 6261

S.C.S. Virginia Office
Federal Bldg., Room 9201
400 N. 8th St.
P.O. Box 10026
Richmond, Virginia 23240
(804) 782-2457

S.C.S. West Virginia Office
75 High St.
P.O. Box 865
Morgantown, West Virginia 26505
(304) 599-7151

U.S. Department of the Interior
Water and Power Resources Service

(Formerly, the Bureau of Reclamation)

Since 1902 the Department of the Interior has been authorized to construct and maintain facilities to develop water resources for the reclamation of arid and semiarid lands in 17 western states (see map). This responsibility has been fulfilled by the Bureau of Reclamation since 1907. In 1979 its name was changed to the Water and Power Resources Service. Included among the agency's activities are programs for water conservation and flood control, as well as studies of riverbasins and watersheds. The Service can provide water-related information and technical assistance for areas in the states in which it operates.

Bureau of Reclamation
Water and Power Resources Service Offices

Pacific Northwest
Regional Director, Federal Bldg.
and U.S. Courthouse
Box 043-550, West Fort St.
Boise, Idaho 83724

Mid-Pacific
Regional Director, Federal Bldg.
2800 Cottage Way
Sacramento, California
95825

Lower Colorado
Regional Director
P.O. Box 427
Administration Bldg.
Boulder City, Nevada
89005

Upper Colorado
Regional Director
P.O. Box 11568
125 So. State St.
Salt Lake City, Utah
84147

Southwest
Regional Director
Herring Plaza
Box H-4377
Amarillo, Texas
79101

Upper Missouri
Regional Director
P.O. Box 2553
Federal Bldg.
316 No. 26th St.
Billings, Montana
59103

Lower Missouri
Director
P.O. Box 25247
Building 20
Denver, Colorado
80225

U.S. Geological Survey State Offices

The U.S. Geological Survey (USGS) has existed since 1879, carrying out research throughout the country on topography, geology, and mineral and water resources. USGS has a number of interests, including resource conservation, geologic studies, mapping, and land and water analysis.

The USGS provides hydrologic data for optimum management of the nation's water resources. It collects data for the evaluation of water quality and quantity, conducts water resource appraisals of the characteristics of surface and ground water, coordinates other federal agencies' water-related research, and provides technical assistance on hydrologic issues to federal, state, and local agencies. As part of its mission, the USGS disseminates water data and research results through reports, maps, and computerized information services.

Alabama

University
District Chief
Alabama District Office USGS WRD
P.O. Box V
FTS 229-2957 COM 205-752-8104

Alaska

Anchorage
District Chief
District Office USGS WRD
Skyline Bldg., 218 E. Street
FTS 339-0150 COM 907-277-5526

Arizona

Tucson
District Chief
Arizona District Office USGS WRD
Fed. Bldg., 301 West Congress
FTS 762-6671 COM 602-792-6671

Arkansas

Little Rock
District Chief
Arkansas District Office USGS WRD
2301 Federal Bldg.
700 W. Capitol Ave.
FTS 740-5246 COM 501-378-5246

California

Menlo Park
District Chief
California District Office USGS WRD
855 Oak Grove Avenue
FTS 467-2328 COM 415-323-8111

Colorado

Lakewood
District Chief
Colorado District Office USGS WRD
Denver Fed Center MS 415
P.O. Box 25046
FTS 234-5092 COM 303-234-5092

Connecticut

Hartford
District Chief
Connecticut District Office USGS WRD
RM 235 Post Office Bldg.
FTS 244-2528 COM 203-244-2528

Delaware

Dover
Subdistrict Chief
Subdistrict Office USGS WRD
300 S. New St., Federal Bldg.
Rm. 1201
FTS 487-5128 COM 302-734-2506

Florida

Tallahassee
District Chief
Florida District Office USGS WRD
Suite F-240, 325 John Knox D.
FTS 946-4251 COM 904-386-111A

Georgia

Doraville
District Chief
Georgia District Office USGS WRD
6481 Peachtree Indust. Blvd. Suite 8
FTS 285-4858 COM 404-526-4858

Hawaii

Honolulu
District Chief
Hawaii District Office USGS WRD
5th Floor, 1833 Kalakawa Ave.
FTS 556-022USAKCOM 955-0251

Idaho

Boise
District Chief
Idaho District Office USGS WRD
P.O. Box 036, Rm 365 FEd. Bldg.
550 W. Fort St.
FTS 554-1750 COM 208-384-1750

Illinois

Champaign
District Chief
Illinois District Office USGS WRD
P.O. Box 1026, 605 N. Neil St.
FTS 958-9137 COM 217-359-3918

Indiana

Indianapolis
District Chief
Indiana District Office USGS WRD
1819 North Meridian St.
FTS 313-7101 COM 317-269-7101

Iowa

Iowa City
District Chief
Iowa District Office USGS WRD
Rm 269 Fed. Bldg., 400 S. Capitol St.
P.O. Box 1230
FTS 863-6521 COM 319-338-05A1

Heritage Conservation and Recreation Service

Kansas
Lawrence
District Chief
Kansas District Office USGS WRD
1950 Ave., "A" Campus West
Univ. of Kansas
FTS 752-2300 COM 913-864-4321

Kentucky
Louisville
District Chief
Kentucky District Office USGS WRD
572 Federal Bldg., 600 Federal Place
FTS 352-5241 COM 502-582-5241

Louisiana
Baton Rouge
District Chief
Louisiana District Office USGS WRD
P.O. Box 66492, 6554 Florida Blvd.
FTS 687-4281 COM 504-387-0181

Maine
Augusta
Subdistrict Chief
Subdistrict Office USGS WRD
State House Annex-Capitol Shopping Ctr.
FTS 833-6280 COM 207-289-3484

Maryland
Towson
District Chief
District Office USGS WRD
208 Carroll Building, 8600 La Salle Rd.
FTS 920-3311 COM 301-828-1535

Massachusetts
Boston
District Chief
Central New England District
Office USGS W C
Suite 1001, 150 Causeway St., 10th Floor
FTS 223-2822 COM 617-223-2822

Michigan
Okemos
District Chief
Michigan District Office USGS WRD
2400 Science Pkwy., Red Cedar Research
FTS 374-1561 COM 517-372-1910

Minnesota
St. Paul
District Chief
Minnesota District Office USGS WRD
Room 1033 P.O. Bldg.
FTS 725-7841 COM 612-725-7841

Mississippi
Jackson
District Chief
Mississippi District Office USGS WRD
430 Bounds Street
FTS 490-4600 COM 601-969-4600

Missouri
Rolla
District Chief
Missouri District Office USGS WRD
P.O. Box 340
FTS 276-9185 COM 314-364-36HO

Montana
Helena
District Chief
District Office USGS WRD
Rm 421 Fed. Bldg., 316 N. Park Ave.
P.O. Box 1696
FTS 585-5263 COM 406-449-5011

Nebraska
Lincoln
District Chief
Nebraska District Office USGS WRD
Rm 406 Fed. Bldg. & US CRTHS
100 Centenial Mall N.
FTS 867-5082 COM 402-471-5082

Nevada
Carson City
District Chief
Nevada District Office USGS WRD
229 Federal Bldg., 705 N. Plaza St.
FTS 598-5911 ASKCOM 702-882-1388

New Hampshire
Concord
Subdistrict Chief
Subdistrict Office USGS WRD
Rm 307 Federal Bldg 55 Pleasant St.
FTS 834-4740 COM 603-224-7273

New Jersey
Trenton
District Chief
District Office USGS WRD
Rm 420 Fed. Bldg., 402 E. State St.
P.O. Box 123A
FTS 340-3212 COM 609-599-3511

New Mexico
Albuquerque
District Chief
New Mexico District Office USGS WRD
P.O. Box 26659
FTS 474-2246 COM 505-766-3357

New York
Albany
District Chief
New York District Office USGS WRD
P.O. Box 1350, 343 PO & Court House
FTS 562-3107 COM 518-472-3107

North Carolina
Raleigh
District Chief
North Carolina District Office USGS WRD
P.O. Box 2857, Rm 440 Century Sta.,
P.O. Bldg
FTS 672-4510 COM 919-755-4510

North Dakota
Bismarck
District Chief
North Dakota District Office WRD
P.O. Box 778, Rm. 332 New Fed. Bldg.
FTS 783-4227 COM 701-255-4011

Ohio
Columbus
District Chief
Ohio District Office USGS WRD
975 West Third Ave.
FTS 943-5553 COM 614-469-5553

Oklahoma
Oklahoma City
District Chief
Oklahoma District Office USGS WRD
Rm 621, 201 N.W. 3rd St.
FTS 736-4256 COM 405-231-4256

Oregon
Portland
District Chief
Oregon District Office USGS WRD
830 NE Holladay St., P.O. Box 3202
FTS 429-4776 COM 503-234-3361

Pennsylvania
Carnegie
Hydrologist In Charge
Field Unit USGS WRD
Box 420
FTS 590-3468 COM 717-782-3468

Rhode Island
Providence
Subdistrict Chief
Subdistrict Office USGS WRD
224 Federal Building and
U.S. Post Office
FTS 838-4387

South Carolina
Columbia
District Chief
South Carolina District
Office USGS WRD
Suite 200, 2001 Assembly St.
FTS 677-5966 COM 803-765-5966

South Dakota
Huron
District Chief
South Dakota District
Office USGS WRD
P.O. Box 1412, Rm 231 Fed. Bldg.
FTS 782-2258 COM 605-352-8651

Tennessee
Nashville
District Chief
Tennessee District Office USGS WRD
A-413 Federal Bldg.
FTS 852-5424 COM 615-749-5424

Texas
Austin
District Chief
Texas District Office USGS WRD
649 Federal Bldg., 300 East 8th
FTS 734-5766 COM 512-397-5766

Utah
Salt Lake City
District Chief
Utah District Office USGS WRD
8002 Federal Bldg., 125 So. State St.
FTS 588-5663 COM 801-524-5663

Vermont
Montpelier
Hydrologist In Charge
Field Headquarters USGS WRD
8 E. State St., P.O. Box 628
FTS 832-2393 COM 802-223-8610

Virginia
Richmond
District Chief
Virginia District Office USGS WRD
Room 304, 200 West Grace St.
FTS 925-2427 COM 804-782-2427

Washington
Tacoma
District Chief
Washington District Office USGS WRD
Room 300, 1305 Tacoma Ave., South
FTS 390-6510 COM 206-593-6510

West Virginia
Charleston
District Chief
West Virginia District Office USGS WRD
3303 Fed. Bldg. & US Courthouse
500 Quarrier St E.
FTS 924-1310 COM 304-343-6181

Wisconsin
Madison
District Chief
Wisconsin District Office USGS WRD
Room 200, 1815 University Ave.
FTS 262-2488 COM 608-262-2488

Wyoming
Cheyenne
District Chief
Wyoming District Office USGS WRD
P.O. Box 2087, 4015 Warren Ave.
FTS 328-2111 COM 307-778-2220

State Coordinating Offices for the National Flood Insurance Program

Each of the states, in cooperation with the Federal Emergency Management Agency, has designated a specific agency to coordinate implementation of the National Flood Insurance Program. This agency provides a link between federal, state, and local levels of government and between different state agencies with flood-related responsibilities. The designated agency will typically be a department responsible for natural resources, emergency services, or physical development, and is a focal point for information relating to flood insurance and floodplain management. It can be an important source of physical data, information on community eligibility for flood insurance, relevant state regulations, references to other agencies, and, in some instances, technical assistance. The authority of each state's coordinating agency varies, and can best be determined through direct contact.

Alabama

Alabama Development Office
State Planning Division
State Capitol Bldg.
Montgomery, Alabama 36130
(205) 832-6400

Alaska

Department of Community & Regional Affairs
Pouch B
Juneau, Alaska 99811
(907) 276-1721

Arizona

Emergency Services Director
State of Arizona
Division of Emergency Services
5636 E. McDowell Rd.
Phoenix, Arizona 85008
(602) 258-8596

Arkansas

Division of Soil & Water Resources
State Department of Commerce
1818 W. Capitol Building A
Little Rock, Arkansas 72202
(501) 371-1611

California

State of California
Department of Water Resources
P.O. Box 388
Sacramento, California 95802
(916) 445-2985

Colorado

Colorado Water Conservation Board
Rm. 823
State Centennial Building
1313 Sherman Street
Denver, Colorado 80202
(303) 839-3441

Connecticut

Connecticut Department of Environmental Protection
State Office Bldg., Rm. 207
Hartford, Connecticut 06115
(203) 566-7245

Delaware

Office of Management, Budget, and Planning
Townsend Bldg., Third Floor
Dover, Delaware 19901

Florida

Department of Community Affairs
2571 Executive Ctr. Circle East
Howard Bldg.
Tallahassee, Florida 32301
(904) 488-7956

Georgia

Georgia Department of Natural Resources Environmental Protection Division
270 Washington Street, S.W.
Atlanta, Georgia 30334
(404) 656-5164

Hawaii

Hawaii Board of Land & Natural Resources
P.O. Box 621
Honolulu, Hawaii 96809
(808) 548-7642

Idaho

Idaho Department of Water Resources
Statehouse
Boise, Idaho 83720
(208) 384-2215

Illinois

Illinois Department of Transportation
Division of Water Resources
Local Floodplain Programs
300 North State Street
Room 1010
Chicago, Illinois 60610
(312) 793-3864

Indiana

Department of Natural Resources
608 State Office Building
Indianapolis, Indiana 46204
(317) 633-5267

Iowa

Iowa Natural Resources Council
Wallace State Office Building
Des Moines, Iowa 50319
(515) 281-5029

Kansas

Division of Water Resources
Kansas State Board of Agriculture
1720 South Topeka Avenue
Topeka, Kansas 66612
(913) 757-3717

Kentucky

Division of Water Resources
Kentucky Department of
Natural Resources
950 Leestown Road
Frankfort, Kentucky 40601
(502) 564-3980

Louisiana

Louisiana Department of Urban
& Community Affairs
5790 Florida Boulevard
Baton Rouge, Louisiana 70806
(504) 925-3718

Maine

Bureau of Civil Emergency
Preparedness
State House
Augusta, Maine 04330
(207) 622-6201

Maryland

Maryland Water Resources
Administration
Flood Control Section
Tawes State Office Building
D-2
Annapolis, Maryland 21401
(301) 269-3826

Massachusetts

Massachusetts Water
Resources Commission
State Office Building
100 Cambridge Street
Boston, Massachusetts 02202
(617) 727-3267

Michigan

Water Management Division
Michigan Department of Natural
Resources
Post Office Box 30028
Lansing, Michigan 48909
(517) 373-3930

Minnesota

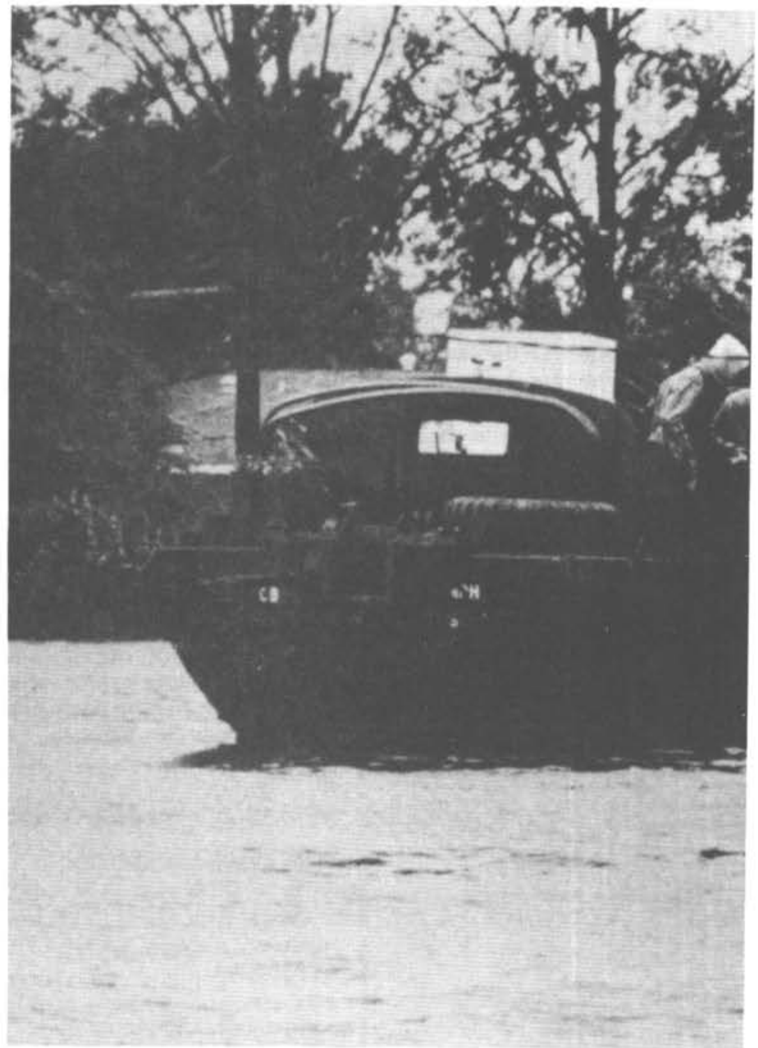
Minnesota Department of Natural
Resources
Land Use Management Section
Division of Waters
St. Paul, Minnesota 55101
(612) 296-4803

Mississippi

Mississippi Research & Development
Center
Post Office Drawer 2470
Jackson, Mississippi 39205
(601) 982-6376

Missouri

Disaster Planning & Operations
Office
Post Office Box 116
Jefferson City, Missouri 65102
(314) 751-2321



Department of Housing and Urban Development

Montana

Montana Department of Natural
Resources & Conservation
32 South Ewing Street
Helena, Montana 59601
(406) 449-2864

Nebraska

Nebraska Natural Resources
Commission
Post Office Box 94876
Lincoln, Nebraska 68509
(402) 471-2081

Nevada

Department of Conservation
& Natural Resources
Capitol Complex
201 S. Fall Street
Carson City, Nevada 89710
(702) 885-4380

New Hampshire

New Hampshire Office of State
Planning
2½ Beacon Street
Concord, New Hampshire 03301
(603) 271-2155

New Jersey
New Jersey Department of Environmental Protection
Post Office Box CN 029
Trenton, New Jersey 08625
(609) 292-2296

New Mexico
State Engineer's Office
Bataan Memorial Building
Santa Fe, New Mexico 87501
(505) 827-2135

New York
New York State Department of Environmental Conservation
Water Management
50 Wolf Road—Room 618
Albany, New York 12233
(518) 457-3157

North Carolina
Division of Community Assistance
Department of Natural & Economic Resource
P.O. Box 27687
Raleigh, North Carolina
(919) 733-2850

North Dakota
State Water Commission
State Office Building
900 E. Boulevard
Bismark, North Dakota 58501
(701) 224-2750

Ohio
Ohio Department of Natural Resources
Flood Plain Management Unit
Fountain Square & Building E
Columbus, Ohio 43224
(614) 466-6020

Oklahoma
Oklahoma Water Resources Board
12th Floor, Northeast
10th & Stonewall
Oklahoma City, Oklahoma 73105
(405) 271-2555

Oregon
Oregon Water Resources Department
Milcreek Office Park
Salem, Oregon 97310
(503) 378-3671

Pennsylvania
Department of Community Affairs
216 South Office Building
Capitol Complex—Room 506
Harrisburg, Pennsylvania 17120
(717) 787-7400

Puerto Rico
Puerto Rico Department of Natural Resources
Post Office Box 5887
Puerta de Trera, Puerto Rico 00906
(809) 726-5710

Rhode Island
Statewide Planning Program
Rhode Island Office of State Planning
265 Melrose Street
Providence, Rhode Island 02907
(401) 277-2656

South Carolina
South Carolina Water Resources Commission
Post Office Box 4515
3830 Fore Drive
Columbia, South Carolina 29240
(803) 758-2514

South Dakota
South Dakota Planning Bureau
State Capitol
Pierre, South Dakota 57501
(605) 224-3661

Tennessee
Tennessee State Planning Office
660 Capitol Hill Building
Nashville, Tennessee 37219
(615) 741-2211

Department of Housing and Urban Development

Pennsylvania

Division of Industrialized and Mobile Housing
Education Building, Room 503
P.O. Box 155
Harrisburg, Pennsylvania 17120
(717) 787-9682
(Mobile Homes)

Rhode Island

State Building Commissioner
State Building Commission
12 Humbert Street
North Providence, Rhode Island 02911
(401) 277-3032
(Mobile Homes)

Texas

Division of Disaster Emergency Services
Texas Department of Public Safety
5805 N. Lamar Boulevard
Post Office Box 4087
Austin, Texas 78773
(512) 475-2171

Utah

Utah Department of Public Safety
317 State Office Building
Salt Lake City, Utah 84114
(801) 533-5401

Vermont

Department of Water Resources
Vermont Agency of Environmental Conservation
State Office Building
Montpelier, Vermont 05602
(802) 828-2761

Virginia

Virginia State Water Control Board
Post Office Box 71143
Richmond, Virginia 23220
(804) 257-0056

Washington

Department of Ecology
St. Martin's College
Abbot Raphael Hall
Olympia, Washington 98504
(206) 754-2040

West Virginia

Disaster Recovery Office
1591 Washington Street, East
Charleston, West Virginia 23505
(304) 348-2246

Wisconsin

Department of Natural Resources
Flood Plain-Shoreline
Post Office Box 7921
Madison, Wisconsin 53707
(608) 266-0161

Wyoming

Wyoming Disaster & Civil Defense Agency
P.O. Box 1709
5500 Bishop Boulevard
Cheyenne, Wyoming 82001
(307) 777-7566

Flood-Related Building Codes

Building codes can be part of a community's legal mechanisms for reducing flood damage. The Building Officials and Code Administrators (BOCA) model code, which is used as a guide in many parts of the country, includes several sections meant to mitigate flood damage. Many communities may have similar requirements, and the designer should consult with local or state building officials to ascertain the flood-related codes that are in effect. Below are relevant excerpts from the BOCA model code, followed by a list of the state agencies that coordinate or enforce building codes within their respective jurisdictions.

Excerpts for the Building Code Officials and Code Administrators (BOCA) Model Code

Section 709.0 Special Loads

709.1 General: Provisions shall be made for all special loads herein prescribed and all other special loads to which the building or structure may be subjected.
709.2 Below Grade: All retaining walls and other walls below grade shall be designed to resist lateral soil pressures with due allowance for hydrostatic pressure and for all superimposed vertical loads.
709.3 Hydrostatic Uplift: All foundation slabs and other footings subjected to water pressure shall be designed to resist a uniformly distributed uplift equal to the full hydrostatic pressure.

Section 870.0 Retaining walls

870.1 General: Walls built to retain or support the lateral pressure of earth or water or other superimposed loads shall be designed and constructed of approved masonry, reinforced concrete, steel sheet piling, or other approved materials within the allowable stresses of accepted engineering practice. . . .
870.2 Design: Retaining walls shall be designed to resist the pressure of the retained material, including both dead and live load surcharges to which they may be subjected, and to insure stability against overturning, sliding, excessive foundation pressure, and water uplift.
870.3 Hydrostatic Pressure: Unless drainage is provided, the hydrostatic head of water pressure shall be assumed equal to the height of the wall.

Section 872.0 Waterproofing and Floodproofing

872.1 General: The exterior structural elements of all buildings herein specified shall be waterproofed in accordance with the approved rules.
872.2 Steel Frame: Exterior steel columns and girders, before embedment in masonry of the required fire-resistance rating specified . . ., shall be protected from moisture by approved waterproofing material, a parging coat of cement mortar or by a minimum of eight (8) inches of weather-tight masonry.
872.3 Chases: The backs and sides of all chases in exterior walls with less than eight (8) inches of approved masonry to the exterior surface shall be insulated and waterproofed.
872.4 Foundations: Exterior walls below grade and the cellar floors of all buildings for institutional and residential uses (use groups I and R) enclosing habitable or occupiable rooms or spaces below grade shall be made watertight, and when necessary shall be reinforced to withstand water pressure as prescribed in Sections 709.0 and 870.0. The basement walls of buildings in the residential use groups and the walls of all habitable and occupiable rooms and spaces below grade shall be protected with not less than a one (1) coat application of approved waterproofing paint, or a one-half (%) inch parging coat of portland cement mortar or other approved dampproof covering.
872.4.1 Subsoil Drains: Subsoil drains shall be provided around foundations enclosing habitable or usable spaces located below grade and which are subjected to ground water conditions. Drains shall be installed at or below the area to be protected and shall discharge by gravity or by mechanical means into an approved drainage system complying with the plumbing code listed in Appendix B (of the codes).
872.5 Types of Waterproofing: The processes and methods used to render buildings, structures or parts thereof watertight as herein required shall comply with accepted engineering practice covering types of waterproofing.
872.6 Floodproofing: Where a structure is located within a floodplain as determined by the building official or the governmental body having jurisdiction, such a structure must be designed to resist or overcome the anticipated flood conditions.

State Building Code Offices


U.S. Army Corps of Engineers

Alabama
Director of Technical Staff
State Building Commission
800 South McDonough Street
Montgomery, Alabama 36104
(205) 832-3404

Arizona
Division of Mobile and
Manufactured Housing Standards
1645 West Jefferson
Phoenix, Arizona 85007
(602) 255-4072
(Recreational Vehicles & Mobile Homes)

Arkansas
State Building Services
700 Medical Arts Building
12th and Marshall
Little Rock, Arkansas 72202

California
Division of Codes and Standards
Department of Housing and
Community Development
921 Tenth Street
Sacramento, California 95814
(916) 445-9471
(Recreational Vehicles)

Connecticut
State Building Inspection
Department of Public Safety
294 Colony Street
Meriden, Connecticut 06450
(203) 238-6011

Georgia
Comptroller General
State Capitol, Room 238
Atlanta, Georgia 30334
(404) 656-2056

Hawaii
Department of Labor and
Industrial Relations
825 Miliani Street
Honolulu, Hawaii 96813
(808) 548-3150

Idaho
Director and Fire Marshal
Department of Labor and
Industrial Services
317 Main Street, Room 400
Boise, Idaho 83720

Illinois
Institute of Natural Resources
325 Adams Street
Room 300
Springfield, Illinois 62706
(217) 785-2002

Indiana
State Building Commissioner
300 Graphic Arts Building
215 North Senate Avenue
Indianapolis, Indiana 46204
(317) 232-1400

Iowa
State Building Codes Commissioner
State Capitol Complex
523 East Twelfth Street
Des Moines, Iowa 50319
(515) 281-3807

Kansas
Architectural Services Divison
Department of Administration
State Office Building
10 East Harrison
Topeka, Kansas 66612
(913) 296-3811

Kentucky
Commissioner
Department of Housing
Route 127 South
Frankfort, Kentucky 40601
(502) 564-8044

Maine
Department of Business Regulation
Station 35
State House
Augusta, Maine 04333
(207) 289-3916

Maryland
Director
Codes Administration
Maryland Department of Economic
and Community Development
2525 Riva Rd.
Annapolis, Maryland 21401
(301) 269-2701

Massachusetts
State Building Code Commission
McCormack State Office Building
1 Ashburton Place
Room 1305
Boston, Massachusetts 02108
(617) 727-6916
(Mobile Homes)

Michigan
Bureau of Construction Codes
Department of Labor
7150 Harris Drive
Lansing, Michigan 48909
(517) 322-1701
(Mobile Homes)

Minnesota
Department of Administration
200 State Administration Building
St. Paul, Minnesota 55155
(612) 296-3862

Missouri
Division of Mobile Homes
Missouri Public Service Commission
P.O. Box 360
Jefferson City, Missouri 65102
(314) 751-2557
(Recreational Vehicles & Mobile Homes)

Montana
Administrator, Building Codes Division
Department of Administration
State of Montana
Capitol Station
Helena, Montana 59601
(406) 449-3933

Nebraska
Division of Housing and
Environmental Health
301 Centennial Mall South
Lincoln, Nebraska 68509
(402) 471-2541
(Recreational Vehicles & Mobile Homes)

Nevada
Manufactured Housing Division
Department of Commerce
201 South Fall Street
Room 325
Carson City, Nevada 89710
(702) 885-4298
(Recreational Vehicles & Mobile Homes)

New Hampshire
State Fire Marshal
Department of Public Safety
James Hayes Safety Building
Hayes Drive
Concord, New Hampshire 03301
(603) 271-3336

New Jersey
Division of Housing
363 West State Street
Trenton, New Jersey 08625
(609) 292-7898

New Mexico
General Construction Bureau
Bataan Memorial Building
Santa Fe, New Mexico 87503
(505) 827-5571

New York
Housing and Building Codes Bureau
Division of Housing and
Community Renewal
Two World Trade Center
New York, New York 10047
(212) 488-7080

North Carolina
Deputy Commissioner of Insurance
North Carolina Department of Insurance
P.O. Box 26387
Raleigh, North Carolina 27611
(919) 733-3901

Ohio
Board of Building Standards
P.O. Box 825
2323 West 5th Avenue
Columbus, Ohio 43216
(614) 466-3316

Oklahoma
Engineering Department
State Board of Public Affairs
Room 306, State of Capitol
Oklahoma City, Oklahoma 73105
(405) 521-2121

Oregon
Building Codes Division
Department of Commerce
401 Labor and Industries Building
Salem, Oregon 97310
(503) 378-3176

Pennsylvania
Division of Industrialized and Mobile Housing
Education Building, Room 503
P.O. Box 155
Harrisburg, Pennsylvania 17120
(717) 787-9682
(Mobile Homes)

Rhode Island
State Building Commissioner
State Building Commission
12 Humbert Street
North Providence, Rhode Island 02911
(401) 277-3032
(Mobile Homes)

Texas
Facilities Planning & Construction Division
1028 Stephen F. Austin State Office Building
Austin, Texas 78711
(512) 475-2270

Vermont
Department of Labor and Industry
120 State Street
Montpelier, Vermont 05602
(802) 828-2286

Virginia
Office of Uniform Building Code
Division of Building Regulatory Services
205 North Fourth Street
Richmond, Virginia 23219
(804) 786-5041

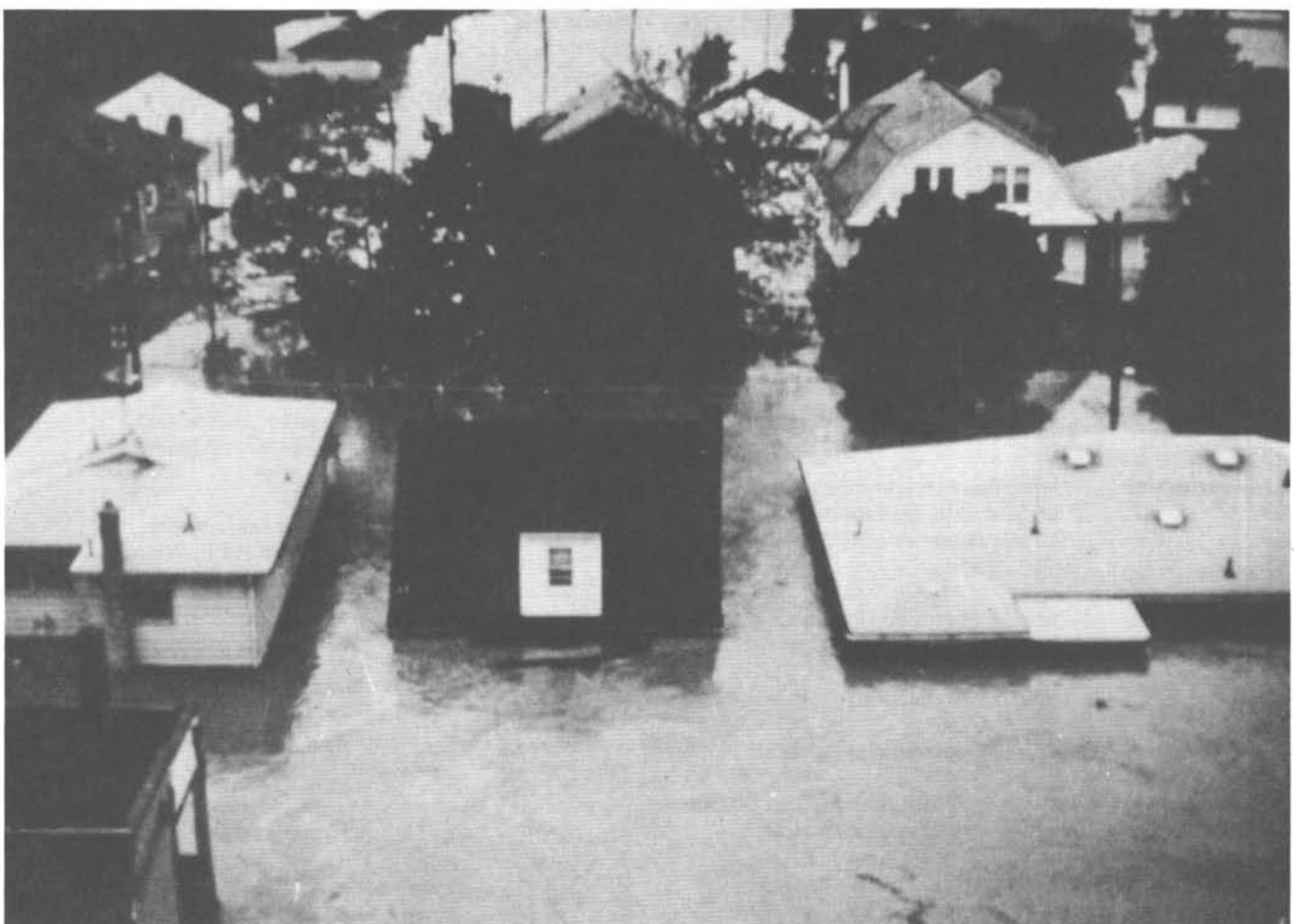
Washington
Department of Labor & Industries
Building Construction Safety Inspection Services
300 West Harrison Street
Room 504
Seattle, Washington 98119
(206) 464-7204

West Virginia
State Fire Marshal
2000 Quarrier Street
Charleston, West Virginia 25305
(304) 348-2191

Wisconsin
Safety and Building Division
Department of Industry, Labor & Human Relations
P.O. Box 7969
Madison, Wisconsin 53707
(608) 266-7319

Wyoming
State Fire Marshal
Department of Fire Prevention and Electrical Safety
720 West 18th Street
Cheyenne, Wyoming 82002
(307) 777-7288

Puerto Rico
Regulations and Permits Administration
P.O. Box 41179
Minillas Station
Santurce, Puerto Rico 00940
(809) 726-6200



U.S. Army Corps of Engineers

National Flood Insurance Program: Rules, Building and Insurance Rate Information

The National Flood Insurance Program (NFIP) is the principal administrative mechanism for reducing flood damage, providing an incentive to local governments to implement sound floodplain management controls. Using the limited availability of flood insurance as leverage, the NFIP has established requirements and guidelines for development in flood-prone areas. The rate structure of insurance premiums reinforces the intent of these regulations by charging higher insurance rates for buildings subject to greater hazard. Insurance rates are set on the basis of designated hazard zones and the elevation of the building or structure in relation to the Base Flood Elevation (BFE) in that particular zone. The effect of this differential rate structure is to provide an incentive to increase the safety of buildings beyond the minimum standards by giving significant financial benefits to buildings at higher elevations and in less hazardous zones. Insurance rates are an important element in analysis of life-cycle costs and can be the designer's best argument for proper siting and design of a proposed project.

It is thus vital that designers, before approaching any design, familiarize themselves with the nature and extent of the NFIP. This should specifically include those components of the NFIP rules and building and insurance rate information that can directly influence building design. This information can be obtained from local insurance agents, public officials and FEMA regional offices.

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National Park Service

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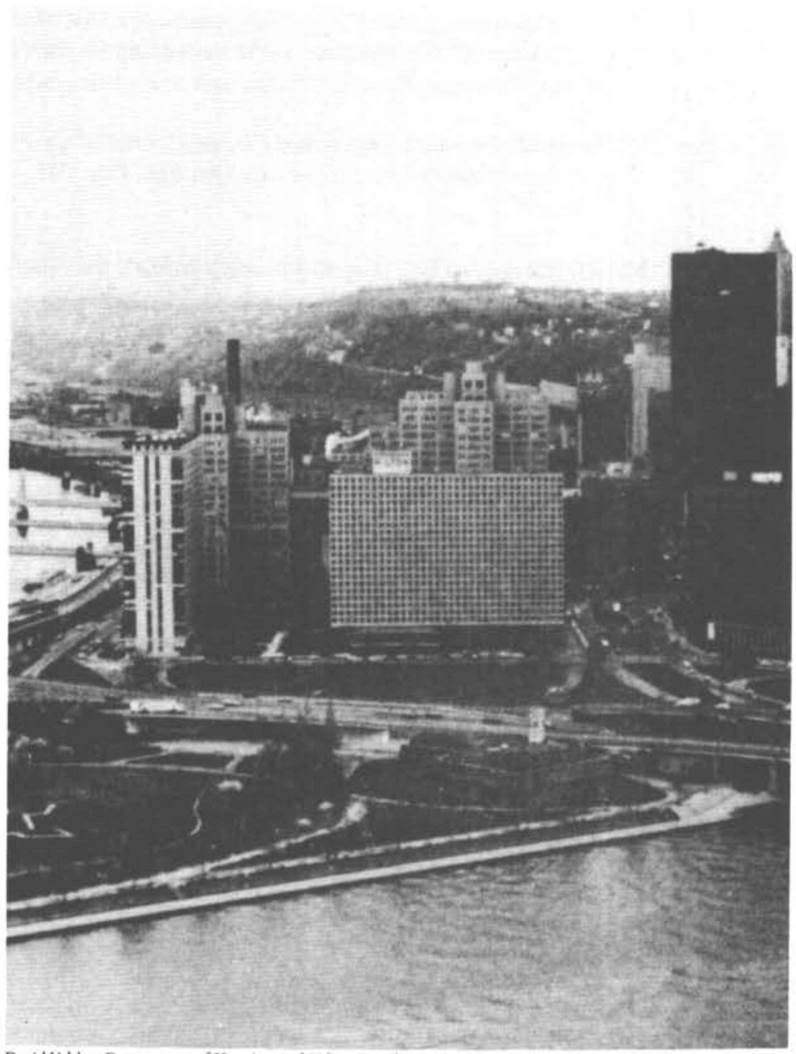

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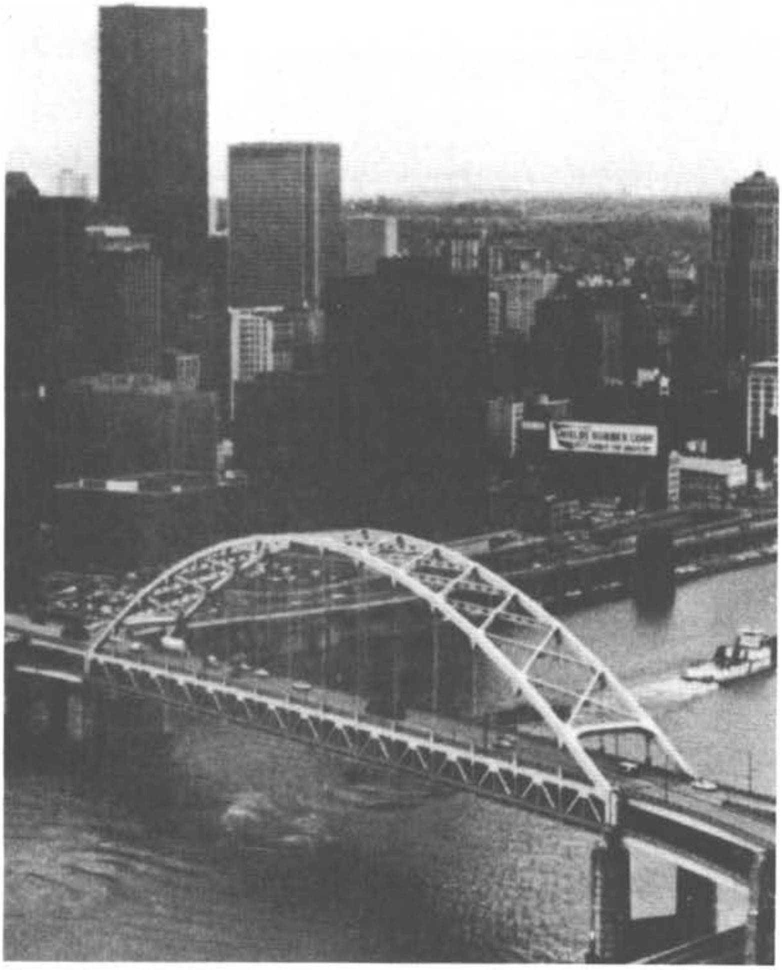

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