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OOD PLAIN MANAGEMENT

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Photographs

Cover — Milam Street became a canal in 1935 Houston flood.

Title page — Helicopter view shows standing water around Houston in 1973.

The middle photograph on page 7 and the lower photograph on page 8 courtesy of the Soil Conservation Service, U.S. Department of Agriculture.

LOOD PLAIN MANAGEMENT

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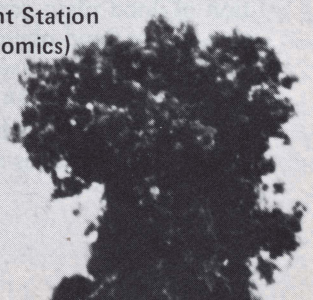

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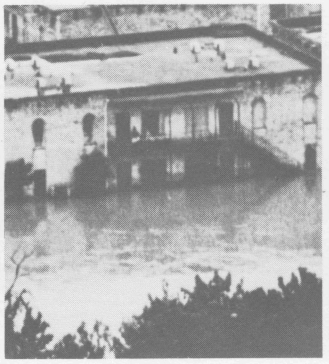

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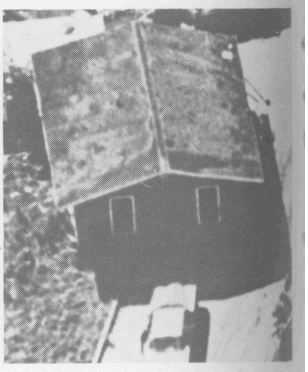

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Summary

Floods will continue to cause damage as long as development continues upon flood-prone lands. Inevitably flooding occurs, damage ensues, and personal suffering and loss create a public burden of rescue and relief operations at the expense of all taxpayers. Flood control projects cannot protect against all damage, and not all flood hazard areas are amenable to flood control projects. An alternative to the continued construction of engineering works for flood protection is the management of the flood plain, which, to be effective, must be brought about through political and legal means. The purposes are to minimize the consequences of flooding and to achieve in the long run the optimum use of flood plains.

The Small Watershed Program of the Soil Conservation Service has emphasized flood protection to agricultural land. Other agricultural program purposes, such as drainage and irrigation, have comprised a significant part of the program in regions where they are needed and adaptable. Flood records indicate that the frequency of natural overbank flows has not changed significantly since flood losses became so large as to justify Federal efforts to control them. Increases in agricultural flood damages are the result of a more intensive utilization of flood plain acreage. The practice of more intensive use of flood plain land can be expected to continue in agriculture because the flood plain is among the most productive land in an area.

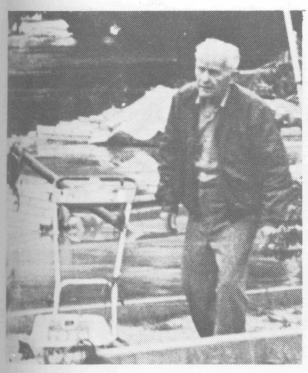
A method of analysis was developed so that agricultural flood damages can be estimated by a computer model for any specific area or field within a flood plain. With this knowledge regarding the incidence of flood damages, the relationship between a crop's expected flood damages and net returns can be estimated for any flood plain location. A program of agricultural flood insurance is now feasible along with profit maximizing or flood loss minimizing land uses. This degree of detail on the flood threat is needed for urban areas.

The flood damage hazard in the United States is highly concentrated. As few as 2 percent of all dwellings incur more than half of the annual flood damages. Less than 10 percent of all dwellings have any significant flood hazard, hence 90 percent or more are free from any serious or measurable flood hazard. Many people in high flood-risk areas are uninformed about the extent of risks of flood damage which they face.

Federal action against flooding has been escalating since 1966. Executive Order No. 11296 of that year requires Federal agencies to take the flood hazard into account in the uses of flood plain lands. In 1968, Congress established a voluntary National Flood Insurance Program to provide limited coverage to the victims of flood disasters. The Flood Disaster Protection Act of 1973 is an expanded flood insurance program, intended as a substitute and eventual replacement for Federal disaster relief for flood occurrences. It combines subsidized flood insurance for existing development with required insurance based on actuarial rates for future development in flood-prone areas.

An immediate problem for the Federal Insurance Administration (FIA) has been the documentation of the flood risk for purposes of ratemaking. The U.S. Corps of Engineers is making a limited number of flood plain information studies. Flood-prone areas are divided into zones reflecting varying degrees of flood risk from probable floods of specified magnitude. Where detailed studies are not made by a Federal agency, official flood maps are prepared for the FIA by a contractor.

Problems arise when the costs due to flood hazard are greater than the benefits due to location. Economic analyses indicate that an annual flood premium of about $2 per $100 property value approaches the limit of economic rationality for dwellings, and perhaps for other property also. When flood costs get to this general level, the implication is that land should be in some other use over the long run. In the short run, with the investment



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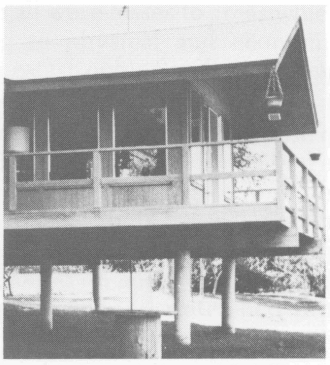

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in the present buildings already made and with subsidized flood insurance available, continued use of existing dwellings makes economic sense as public policy. The subsidy, to the owner and to the lender as well, may be necessary and desirable until the present buildings are no longer habitable.

The National Environmental Policy Act of 1969 requires persons doing planning for future development to evaluate the total environmental consequences of their planning decisions. The objective is to blend proposals by individual landowners and local groups with protection of the resource base to yield a desired complex of public values. A balance is sought between development and protection of the different ecological units of the landscape, such as streams, rivers, marshes, shorelands, flood plains, ground water recharge areas, woodlots, forests, and upland fields. The extent and frequency of flooding should serve as the basis for adjusting human activities.

Flood plain regulations reduce future damages by requiring that the flood plain be used for purposes that are not subject to flood damage or that suffer only minimal damage. Also, regulations provide for the necessary floodway capacity so that flows are not obstructed or flood heights increased significantly. Several devices are available to the community that wishes to achieve flood plain management.

Zoning is a legal tool used to implement and enforce detailed plans resulting from land use planning programs. Designated floodways may be reserved by establishing encroachment lines that clearly define flooding zones. Used by local governments to specify the manner in which land may be divided, subdivision regulations may prescribe the width of streets, curbs and gutters, lot sizes, elevations of land to avoid area flooding, size of floodways, and other requirements affecting the welfare and safety of the community. Building codes can contain provisions that assure the structural soundness of buildings during flood periods. Flood conscious governmental policies that limit the extension of public roads, utilities, and other services into flood-prone areas can play an important indirect role in shaping overall development. Private development often follows the extension of public services. Continuing study and review of flood plain management considerations is important in maintaining long-range appropriate land use.

Introduction

A large percentage of the Nation's population and tangible property is concentrated in flood-prone areas. These areas are comprised of flood plain land and thin coastal strips, and they total at least 5 percent of the Nation's territory (19). An indication of the magnitude of the flood threat by location is provided in Table 1 and Figure 1.

A streambed and the flood plain lands immediately adjacent are integral parts of every natural watercourse. The flood plain is formed from sediment deposits or removal accompanying the natural, intermittent overflow of the stream above its ordinary bed. Overbank flows are not abnormal. The flood plain acts as a natural reservoir and temporary channel for the excess water. Typically, a river uses some portion of its flood plain about once in 2 to 3 years. At average intervals of perhaps 25, 50, or 100 years, the river may inundate its entire flood plain to a considerable depth (13).

Records of floods permit estimation of frequency of flooding but not forecasting of the year a flood will occur on any watercourse. Flood records suggest that the frequency of natural overbank flows in the United States has not changed significantly in the years since flood losses became so large as to justify Federal efforts to control them. However, flood damages have been increasing in the United States in recent years. The primary cause is more intensive use of flood plains and consequent increases in dollar values of losses.

The full social costs of flood plain occupancy include immediate expenses of development. Also included are damages to be borne by the occupant or the expense of protective measures undertaken to reduce the frequency and extent of flood damage. Finally, costs include damages shared by society in disaster relief and rehabilitation (19).

Since 1936, the national approach to flood problems generally has been for the Federal government to assume the major obligation to protect developed areas from damaging floods. In addition, Federal agencies have cooperated with National, State, and local groups in providing relief and rehabilitation assistance at times of flood disasters. The U.S. Army Corps of Engineers estimates that the Federal government has invested more than $9 billion in flood control projects since 1936. But flood damages have been increasing each year since 1936, and the Corps estimates that flood losses now come to almost $2 billion annually (3).

TABLE 1 TOTAL FLOOD PLAIN ACRES AND URBAN ACRES IN FLOOD PLAIN (1973 Estimates)

Water-Resource Region	Total Flood Plain (1000 Acres)	Urban areas in flood plain (1000 Acres)	Percent of flood plain in urban areas
New England	1,350	223	16.5
Middle Atlantic	3,880	556	14.3
South Atlantic-Gulf	13,500	398	2.9
Ohio	9,000	700	7.8
Great Lakes	2,720	214	7.9
Upper Mississippi	10,300	64	.6
Souris-Red-Rainy	1,810	12	.7
Missouri	14,300	148	1.0
Arkansas-White-Red	10,500	77	.7
Lower Mississippi	35,660	130	.4
Rio Grande	130	21	16.2
Texas-Gulf	9,560	162	1.7
Colorado	570	113	19.8
Great Basin	500	59	11.8
California	3,070	354	11.5
Columbia-North Pacific	3,900	65	1.7
Alaska	8,000	5	.1
Hawaii	140	21	15.0
Puerto Rico & Virgin Islands	250	50	20.0
	129,140	3,372	2.6
	(201,780 Sq. Mi.)	(5,269 Sq. Mi.)	(2.6%)

Source: Corps of Engineers Internal Summary, 1973. The regions are delineated in Figure 1.

Lovell (13) reports that Federal flood control programs have been credited with preventing $14.8 billion in flood losses. Under current conditions of project development, benefits attributable to flood control works are estimated in excess of $1 billion annually. Lovell lists existing flood control programs as including some 900 projects consisting of more than 260 lakes, 6,000 miles of levees and flood walls, and more than 8,000 miles of channel improvement work. Structural measures, although proven as efficient corrective action, have not been able to keep pace with the rapidly growing flood problems of our nation.

Flood control projects were not intended to protect against all damage, since the typical project was designed to afford protection against a specified flood level. Flood control construction agencies had little control over events which caused flood losses to continue to mount. The Task Force on Federal Flood Control Policy pointed out several types of development situations in flood plains (19). New construction occurred in areas which were not protected because of lack of local control, information, and (or) local cooperation. Many small towns, suburban areas, and seashore resorts fit this description. Sometimes flood-prone lands adjoining protected areas were built up. Along rivers, where some portion of the flood plain had been provided protection by reservoirs, adjacent but lower lying lands were developed. Most damaging of all were losses to areas which were protected according to physical and economic criteria but were visited by catastrophic floods exceeding protection limits.

The Task Force (19) found that the major purpose of engineering projects was changing from the protection of established property to the underwriting of new development. Increasingly, Federal funds were used to support projects justified on the basis of future development. A similar trend was found on approved Soil Conservation Service flood prevention and watershed protection projects.

Individual beneficiaries from engineering protection works were not, in many instances, bearing a share of the costs proportionate to their share of benefits. This latter factor, combined with the bias in favor of river control alternatives, relieved many individual flood plain occupants of fiscal responsibility for their actions. The general public bore all or a major part of flood protection works and subsidized the use of the flood plain.

Boulding (2) suggests that we need an entirely new philosophy for flood control, which may involve treating the river not as an enemy to be conquered but as a rather dangerous friend with whom one has to learn to live. It is perfectly possible to design cities on the flood plain to accommodate floods instead of taking on the impossible task of trying to prevent them.

Figure 1. The 18 water resource regions delineated by the Water Resources Council for the second national assessment.
Source: Our Land and Water Resources, Economic Research Service, U.S. Department of Agriculture, Misc. Pub. No. 1290, Washington, D.C., May 1974, p. 39.

Agricultural Flood Plain Management

The Flood Control Act of 1936, as amended in 1937, gave the U.S. Department of Agriculture authority to make preliminary examinations and surveys in the watersheds of all waterways in which U.S. Army Corps of Engineers' surveys were authorized. That legislation, however, did not provide for any structural works. The 1944 Flood Control Act authorized the first installation of improvements in 11 watersheds, but these projects, which then consisted mainly of accelerated land treatment, contained no structures. After 1948, U.S. Department of Agriculture watershed reports began to include proposals for structural measures.

Small Watershed Program

In 1954, the 83rd Congress passed P.L. 566, the Small Watershed Program, providing flood protection to farmland in upstream areas (11). Originally, this law authorized the Secretary of Agriculture to help local organizations plan and carry out works of improvement for flood prevention and such agricultural water management purposes as irrigation and drainage in upstream watersheds not exceeding 250,000 acres. The law was thus designed to fill the gap between water-related conservation practices on individual farms and large downstream river basin projects of the Corps of Engineers.

The scope of the Small Watershed Program has since been greatly enlarged by a series of congressional amendments. The first, in 1956, provided that the Federal government pay all construction and engineering costs for flood prevention and share in construction costs for agricultural water management. Currently, the Federal share for both drainage and irrigation is 100 percent of engineering costs and is limited to a maximum of 50 percent of construction costs. The Food and Agriculture Act of 1962 stipulated that cost sharing be consistent with similar government programs (11).

The 1956 amendment also expanded the program to include nonagricultural purposes, such as municipal and industrial water supply and streamflow regulation. But no Federal funds could be used for these purposes.

Three other amendments to P.L. 566 added to program authorizations. In 1958, fish and wildlife habitats improvement was added as a project purpose under the same Federal cost sharing provisions applicable to agricultural water management at that time. Recreation was added as a valid project purpose in 1962 where the need was demonstrated, and harvest provisions were added to fish and wildlife development. This amendment provides Federal cost sharing for recreation and fish and wildlife up to 50 percent of all costs including land costs. Then, in 1965, maximum flood prevention storage capacity was increased from 5,000 to 12,500 acre feet per structure.

The Small Watershed Program has emphasized flood protection to agricultural land throughout its lifetime even as other purposes were added or expanded by congressional amendments to the original law. Other agricultural program purposes, such as drainage and irrigation, have comprised a significant part of the program in regions where they are needed and adaptable. The net result is that the total program has been predominantly agricultural thus far (11).

The flood control programs of the Corps of Engineers and the Soil Conservation Service have protected some agricultural and nonagricultural areas from flooding. Despite these Federal flood control investments, flood losses have been increasing. Flood records show that the frequency of natural overbank flows has not changed significantly since flood losses became so large as to justify Federal efforts to control them. Therefore, increases in flood damages are not due to an increase in intensity and frequency of rainfall but are the result of a more intensive utilization of flood plain acreage. Studies indicate that flood plain encroachment occurs because of 1) ignorance of the flood hazard, 2) anticipation of further Federal protection, and 3) profitability to the private owner (19).

Alarm over the extent of agricultural flood damages and interest in flood protection programs are increasing as the flood plain becomes more intensively utilized. The increasing use of flood plain land can be expected to continue in agriculture since the flood plain is among the most productive land in an area. Usually as flood plain lands are converted to more intensive uses, vulnerability to flooding increases. This is explained through land use characterized by low per acre returns and a high degree of tolerance to floodwater, such as native pasture and woodland being replaced by row crops or alfalfa which have higher per acre returns but a low degree of tolerance to floodwater. Therefore, with more intensive use of flood plain, damages from flooding will continue to increase (5).

Flood Plain Evaluation

Increases in agricultural flood losses call for two distinct but related types of flood plain evaluation. There is flood protection to curb or reduce the increasing losses attributable to flooding. This type of evaluation involves

an economic appraisal of the reduction in flood damage resulting from alternative flood protection measures formulated for a particular watershed.

In addition to flood protection proposals, a thorough flood plain evaluation considers land use organization and the effect of alternative adjustments. Flood damage estimates for alternative land uses throughout a flood plain facilitate such an evaluation and aid entrepreneurs in their effort to develop an optimum cropping pattern. Knowledge of the incidence of flood damages permits calculating returns net of average annual flood damages and production costs by land use and flood plain location. By utilizing these data, flood plain land use and farm organization can be directed toward increasing profits or reducing the risk associated with flooding or some combination of both (5).

It is useful to identify both average annual flood damages and expected profit by land use throughout the flood plain since efforts to minimize or reduce flood damages will not necessarily yield a profit maximizing situation. For example, flood plain land use adjustments to attain large profit increases may be associated with increasing flood damages because an allocation of flood plain to higher value land uses may also result in greater flood losses. Conversely, increased flood damages could represent a reduced profit or an inefficient flood plain encroachment.

Estimating Flood Damages

Both types of flood plain evaluation discussed above require procedures for estimating flood damages. Governmental agencies working with flood losses and involved in watershed evaluation have formulated procedures for estimating losses resulting from floodwater. These procedures estimate flood damages with either a historical or a frequency method. The historical method computes damages based on the record of actual floods in the watershed and considers up to 150 separate storms. The frequency method calculates flood damages for as many as six flood sizes with the flood sizes selected to represent the distribution of floods in the watershed; i.e., annual flood, every 2 years, 5 years, etc., up to a 50- or 100-year flood (5).

Flood damage estimates are computed for an evaluation reach. Reaches are delineated such that hydraulic characteristics are similar throughout the reach. A flood damage value applies to the flood plain reach, with a cross section being the elevation profile of a flood plain at one point on the channel; i.e., elevations at points or stations across a flood plain at one channel location. The elevation of the flood plain within an evaluation reach is represented by measured points on one or more cross sections. The distance between cross sections frequently exceeds 3,000 feet. Evaluation reach data from which damage estimates evolve include cross section elevations, composite acre of the reach, crop yield, crop price, crop damage factors, and flood data. A composite acre is a hypothetical acre of flood plain composed of the

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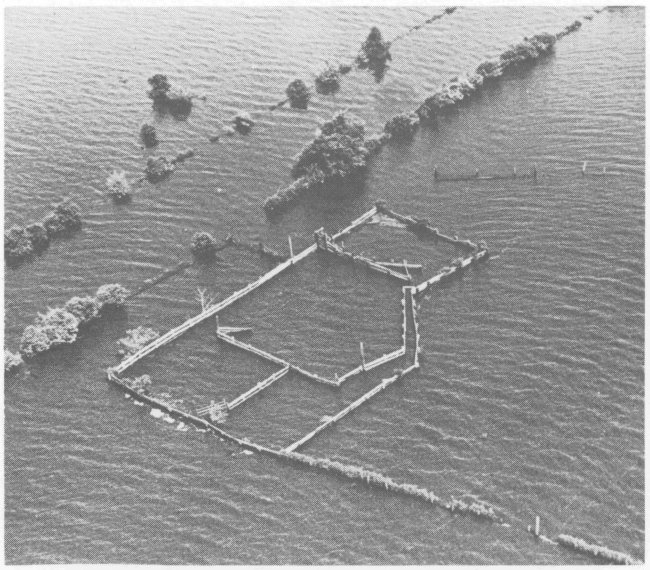

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The flood plain is among the most productive land in an area.

same percentage of each land use as in an evaluation reach. Crop damage factors are the percentage reduction in gross value for a given depth of inundation increment and season. Damages are computed by applying appropriate damage factors to the composite acre and expanding to the acres inundated.

Lacewell and Eidman (10) developed a method whereby flood damages can be estimated for a specific field with respect to the particular characteristics of that field; i.e., land use, productivity, depth of inundation, and location. More accurate estimates of the incidence of average annual flood losses help establish 1) more equitable assessments of the local costs of flood protection, 2) annual premiums for crop flood insurance, and 3) optimum cropping patterns. Benefits received by individual landowners from flood protection can be tied directly to reductions in depth of flooding on individual fields. Annual insurance premiums for specific fields can be related to the particular crop grown on the field. And the land use maximizing returns net of production costs and average annual flood damages can be identified for any flood plain location.

A general model was developed to estimate values associated with flooding on any specific area within a Soil Conservation Service project size watershed which is defined as less than or equal to a 250,000 acre drainage area. The values associated with flooding that the general model was developed to estimate are:

1. Acreage inundated by specific flood sizes with alternative systems of structures.
2. Flood damages for specific storms and average annual flood damages on any selected area within the flood plain of the watershed.
3. Average annual benefits from proposed systems of structures for specific fields and to land owners.
4. Flood damages with alternative land use patterns.

In the Lacewell and Eidman analysis (10), the general model was converted to an optimizing routine. The purpose of the modification was to develop a decision model for selecting that land use at each flood plain location which maximizes returns net of average annual flood damages and production costs. Additional data forthcoming from the modification are estimates of the optimum flood plain cropping patterns, associated net returns, and flood damages for alternative systems of structures as well as with no structures.

Using the Lacewell and Eidman method of analysis, flood damages can be estimated by a computer model for any specific area or field within a flood plain. With improved knowledge regarding the incidence of flood damages, the relationship between a crop's expected flood damages and net returns can be estimated for any flood plain location and in turn a profit maximizing as well as flood loss minimizing land use designated. Information of this type can be used for flood plain management and to effectively administer a flood insurance program for agriculture.

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Soil Conservation Service

Every watershed in Texas has flood problems to some degree.

Flood Hazard Studies

The Soil Conservation Service conducts flood hazard studies in Texas through a joint coordination agreement entered into in November 1973 between the Soil Conservation Service (SCS) and the Texas Water Development Board. The SCS is authorized to provide technical assistance to Federal, State, and local governing bodies in carrying out flood hazard studies under Public Law 556 as amended.

A typical SCS flood hazard study contains the following information:

1. A description of the watershed, including topographic and stream characteristics, present and anticipated future land use, cause and characteristics of flooding, past floods, and study procedure used.
2. A discussion of the principal aspects of a local flood plain management program.
3. A general map of the area showing watershed boundaries and the limits of the study reaches.
4. Flood hazard area maps showing the area subject to inundation by the 100-year and 500-year frequency floods under present conditions.
5. Profile drawings showing the 10-year, 50-year, 100-year, and 500-year frequency floods through the study reaches for existing conditions and the 100-year flood under anticipated future conditions.
6. Drawings of selected valley cross sections showing the elevations of the 10-year, 50-year, 100-year, and 500-year frequency flood events for existing conditions and the 100-year flood for anticipated future conditions.
7. Photographs of various locations showing the depth of flooding that would occur from the 100-year and 500-year frequency floods.
8. A map of the area showing soils, a narrative describing the soils, and interpretations on certain selected uses.
9. An accompanying brochure showing a summary of the study results and the need for a local flood plain management program (4).

Flood hazard studies are one of several alternatives that the Soil Conservation Service considers in trying to resolve flood problems in upstream watershed areas. Flood hazard studies do not reduce flood losses, but the land use and management requirements that can be developed from the studies control unwise development in the flood plains, thereby reducing the rate at which flood losses increase. Individual homeowners and local, State, and Federal governing bodies find these studies to be valuable tools in flood plain planning processes (4).

The SCS considers flood hazard studies to have three major uses. These are 1) to identify physical features and problems relating to flooding, 2) to make general suggestions to overcome the flooding problems through flood plain management, and 3) to identify soils and make interpretations for selected uses on these soils (4).

Factors Affecting Flooding

Every watershed in Texas has flood problems to some degree. Several factors affect flooding problems, and in most cases these are interrelated. If a watershed is located within or adjacent to a large metropolitan area, the land use patterns and physical features are in a state of dynamic change. As agricultural land is converted to urban land, highways, buildings, and parking lots proliferate. The direct result is an increased amount and rate of runoff, increased flow depths, and increased damages and monetary losses. Cities within or adjacent to a flood hazard analysis area are delineated on aerial photographs and described within the narrative of the study (4).

The general climatic zone in which a watershed is located partially determines what type of flooding problems will occur. The intensity, duration, distribution, and time of occurrence of rainfall are all significant factors concerning flooding. For this reason, a general description of the climate is included in flood hazard study reports.

Geology is another important element affecting flooding in a watershed. Storm runoff is affected by both surface and subsurface geologic materials. For example, a watershed that has rock exposed on the ground surface will produce much more runoff than a watershed that has a deep sand underlain by rock. A detailed geologic analysis is included in flood hazard studies.

Steepness of slope determines how fast the water will rise and fall and how large the peak discharges will be. For instance, in a watershed that has very steep slopes, the water will rise and fall very fast, and generally the peak discharges will be very high. The converse is true in watersheds with very flat slopes. This information is displayed in the narrative and tables of flood hazard studies (4).

The width of the flood plain generally determines how deep the water will get for a given flood. A watershed with narrow flood plains will tend to have deeper water from a given flood than one with wide flood plains. This is displayed in the study report document by use of water surface profiles and flood hazard area maps.

Stream densities and flow conditions tend to determine the volume of runoff and to a lesser extent the rate of runoff. A watershed with a dense pattern of perennial streams will tend to produce more runoff and a higher rate of runoff than one with few intermittent or ephemeral streams. This information is presented in narrative, table, and map form.

Present land use and treatment has a large effect on runoff and resultant flooding. An agricultural watershed with good conservation treatment will produce less runoff and lower peak discharges than one with poor conservation treatment. Urban watersheds with parks, greenbelt areas, and properly designed flood water removal systems will produce less runoff and smaller peak discharges than one with little vegetation and poorly designed flood water removal systems. Present land use is displayed in narrative and table form in the report document (4).

Anticipated land use can affect flooding adversely or favorably. If the projected conditions are for an agricultural watershed to evolve into an urban watershed, flooding and resultant damages can be expected to increase if development is uncontrolled and haphazard. If the anticipated conditions are for providing parks, greenbelt areas, and other less intense uses than are there at present, then flooding and damages can be expected to decrease. This information is displayed in narrative, profile, and map form.

Flood Plain Management Practices

The second major use of a flood hazard study report is the portraying of suggested general solutions to flood problems through flood plain management practices. Flood damages can be minimized by careful planning and proper flood plain management. Flood plain management programs should contain both preventive and corrective measures.

Preventive measures do not prevent flooding, but they do reduce the threat of damage and loss of life from flooding by discouraging unwise development in the flood plains. Preventive measures include but are not limited to such practices as encroachment lines, zoning, subdivision regulations, building codes, development policies, greenbelts, tax adjustments, flood insurance, and flood warning systems.

Corrective measures also do not eliminate flooding. These measures reduce the extent of flooding and flood damages. Corrective measures are usually physical in nature and include but are not necessarily limited to land treatment, floodwater retarding structures, channel rectification, permanent evacuation, and flood proofing (4).

The above items are presented in each flood hazard analysis as items for local consideration. Final decision as to what measures to apply are left to the judgment of the local governing body.

As a future tool to aid decision makers, a table of suggested flood plain uses is included in the study document. This tabulation presents some selected uses and provides both the suggested degree of protection required and the permissible location and lowest water entry elevation.

The third major use that can be made of a flood hazard study is from the information presented on identification and interpretation of soils. The soils that are considered in this section are the soils that lie within the 500-year flood plain. Technical descriptions, general agricultural uses, and locations of these soils are displayed in narrative and map form. These data are presented much like a standard county soil survey but in less detail (4).

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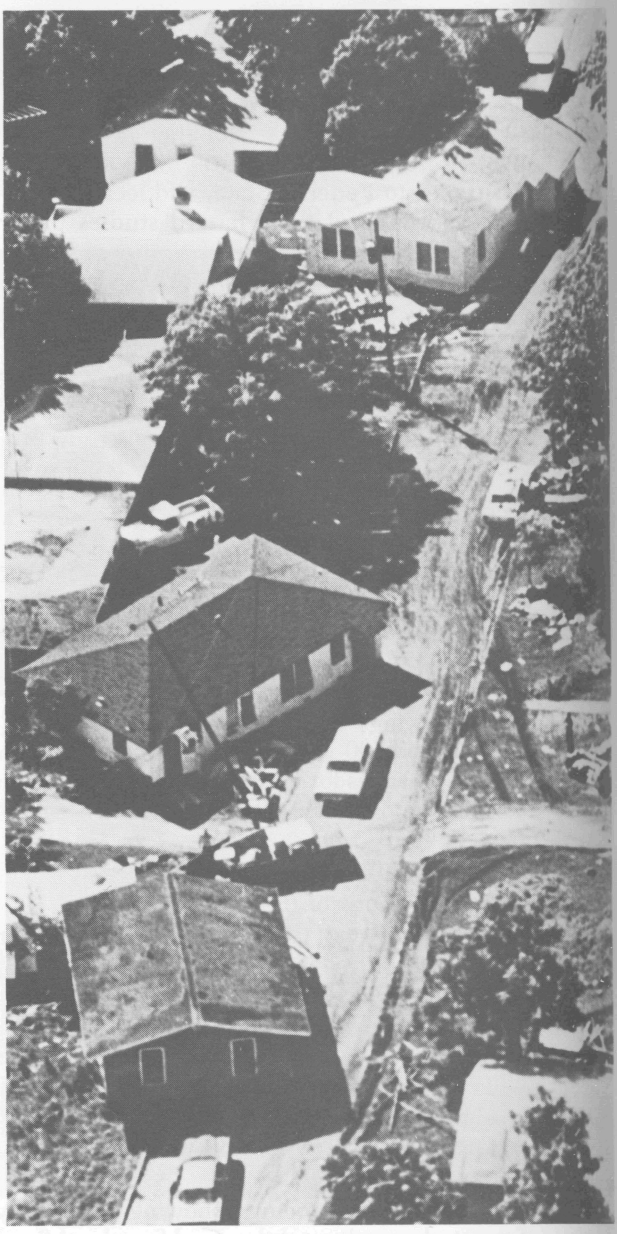

Floods of the same or larger magnitude as those that have occurred in the past can occur in the future.

Federal Flood Insurance

In 1966, President Johnson transmitted to Congress the Report of the Task Force on Federal Flood Control Policy and issued Executive Order No. 11296 (19). This order required the agencies responsible for a wide range of Federal programs affecting the use of flood plain lands to take the flood hazard into account in their administration of those programs. This order has had comparatively little effect according to the National Water Commission (16) because the necessary flood plain maps and management plans are not available for the flood plain areas in which the agencies operate. A considerable degree of uncertainty exists as to the hazard at a designated location in a particular flood plain.

Before 1968, the sole relief available to the victims of flood destruction had been special Federal disaster loans. Because of the high risks and the lack of underwriting standards, flood insurance had not been made available through the private insurance industry (24).

In 1968, Congress passed the National Flood Insurance Act that offered a voluntary insurance program to provide limited indemnification to the victims of flood disasters. The two principal objectives of the 1968 Act were 1) to make available to residents of flood-prone areas flood insurance at reasonable premium rates through the means of a Federal subsidy and 2) to require local jurisdictions to enact land use and control measures designed to guide the rational use of the flood plain as a condition for the availability of federally subsidized flood insurance (24).

Despite the efforts of the Federal Insurance Administration to carry out the Congressional intent for land use and control measures as provided by the act, it became obvious that without mandating provisions to bring about these measures, no real accomplishment could be expected in this respect (24).

The Flood Disaster Protection Act of 1973 is an expanded flood insurance program. It is specifically intended as a substitute and an eventual replacement for Federal disaster relief for flood occurrences. This act will make property owners more aware of flood hazards and will permit them to contribute to their own protection. Property owners also will be more fully indemnified when a flood loss occurs.

Requirements

The act requires the purchase of flood insurance in connection with receiving any form of Federal financial assistance for acquisition or construction purposes in any area identified by the Secretary of Housing and Urban Development as having special flood hazards. This financial assistance includes loans, grants, guarantees, and similar forms of direct and indirect assistance from Federal agencies such as FHA and VA mortgage insurance. It also includes similar forms of assistance from federally insured or regulated lending institutions, such as banks, savings and loans institutions, and credit unions. Acquisition or construction purposes include all forms of construction, reconstruction, repair, or improvement to real estate for both private and public recipients (24).

In return for making low-cost insurance available for existing property in flood plains, the Flood Disaster Protection Act of 1973 places certain obligations upon communities entering the program. They are required to adopt and enforce land use and other control measures that will guide new development in flood-prone areas so that future flood damage is avoided or reduced. In most communities, the flood problems have not been previously documented.

Requests for flood plains studies are made by local governments through the Texas Water Development Board under the continuing authority granted by Section 206 of the 1960 Flood Control Act as amended. Studies are made and reports are prepared under the direction of the U.S. Army Corps of Engineers using a standard format.

The study area is divided into reaches having hydrologic characteristics fairly representative for the entire length of each reach. Flood frequency data for the various streams in the study are developed from discharge-frequency relationships based on regionalized hydrologic analyses. Using the peak discharges obtained in the hydrologic analyses, water surface profiles are determined.

Floods of the same or larger magnitude as those that have occurred in the past can occur in the future. Discussion of future floods in the studies is limited to those that have been designated as the 10-year, 50-year, 100-year, and 500-year frequency floods. Frequency curves of peak flows are constructed on the basis of available information, and flood flows up to the magnitude of the 500-year flood are computed from these curves. Frequency curves thus derived reflect the judgment of engineers who have studied the area. Floods larger than the 500-year flood are possible but are extremely rare.

The 100-year frequency flood is defined as a flood having an average frequency of occurrence of once in 100 years at a designated location, although the flood may occur in any year and possibly in successive years. It has a one-percent chance of being equalled or exceeded in

any year. Perhaps more significantly, it has about a 25-percent chance of being equalled or exceeded during a 30-year mortgage period.

Area maps, profiles, and selected cross sections are provided in each report to define the limits of flooding that would occur during the 100-year flood and a 500-year flood. In addition, profiles for 10-year and 50-year floods may be shown (3).

The hazards to life and extent of damage caused by any flood depend on the topography of the area flooded, depth and duration of flooding, velocity of flow, rate of rise, and developments on the flood plain. Velocities greater than 3 feet per second combined with depths of 3 feet or more are generally considered hazardous to life as well as property. Water flowing in excess of 4 feet per second is capable of transmitting sediment and causing severe erosion of streambanks and fill around bridge abutments. Where velocities drop below 2 feet per second, debris and silt deposits can build up, extending the flood damages and creating adverse health conditions (3).

By definition, a floodway is the channel of a watercourse and that portion of the adjoining flood plain required to provide for the passage of the 100-year frequency discharge (discharge having a one-percent chance of occurrence in any given year) with an insignificant increase in the water surface above that of the pre-flooding condition. Unless state or local requirements indicate a specific allowable increase, an insignificant increase is considered not more than a foot at any location. As a further definition, the "flooding fringe" is the portion of the 100-year flood plain located between the floodway boundary and outline of the 100-year flood (3).

City engineering staffs are given the opportunity to review and comment on the drawings showing the limits of the floodway. Although great care is taken in defining the floodway base line (centerline) and encroachment limits, the floodway delineations require additional adjustments. City officials are informed that the actual legal definition of the floodway for purpose of incorporation into zoning ordinances or other uses is their responsibility (3).

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An estimated 1,200 communities in Texas have present or po tential flooding problems.

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Flood Insurance in Texas

An estimated 1,200 communities in Texas have present or potential flooding problems (12). Lists of communities with newly identified special flood hazard areas are regularly published in the Federal Register in advance of the effective date of the identification.

About 600 Texas communities have received designation by the Federal Insurance Administration (FIA) as having flood-prone areas. This is done in the form of a Flood Hazard Boundary Map. This map delineates the areas of special flood hazard subject to inundation by the 100-year flood. The community can challenge the accuracy of the map and has 6 months to provide data showing that it is not flood-prone or has corrected the flood hazard. Together with the map, FIA sends a letter of transmittal explaining the map, application forms, and program information to community officials (24).

The community must commit itself to flood plain management that protects new construction from future flooding. Flood plain management means the operation of an overall program of corrective and preventive measures for reducing flood damage including emergency preparedness plans and any regulations aimed at the future use of the flood plain. Such regulations refer to specific local codes and ordinances which provide standards for the location and design of new development within flood-prone areas. These regulations typically take the form of zoning, subdivision or building regulations, or special purpose flood plain ordinances. To participate in the National Flood Insurance Program, a community must adopt flood plain management regulations that meet minimum standards published by the Federal Insurance Administration (24).

The Texas Water Development Board has been designated as the state agency to coordinate activities of the flood insurance program. The Board assists communities in adopting required flood plain management regulations and in qualifying for the program. It is the responsibility of the local community to adopt and administer these flood plain management regulations. The regulations do not apply retroactively to existing structures in the flood plain unless a structure is substantially impaired to the extent of half or more of its market value. And they do not apply to new construction outside of the special flood hazard areas (24).

Communities entering the flood insurance program usually do so in two phases. They first become eligible for the sale of flood insurance in the Emergency Program. Under this program, only half of the program's total limits of coverage are available, and all such insurance is sold at subsidized premium rates. To qualify for this program, a community must require building permits for all new construction and substantial improvements and review the permit to assure that sites are reasonably free from flooding. For its flood-prone areas, the community must also require 1)proper anchoring of structures, 2) the use of construction materials and methods that will minimize flood damage, 3) adequate drainage for new subdivisions, and 4) new or replacement utility systems located and designed to preclude flood loss (24). The Texas Water Development Board listed 438 cities and 40 counties in Texas in the Emergency Program as of August 31, 1976.

Any property owner whose building is located in a community that has been approved for the sale of flood insurance may purchase a policy. Owners or tenants may also purchase insurance on building contents. Policies may be purchased from any licensed property and casualty insurance agency or broker as soon as the community qualifies for the sale of flood insurance. Direct flood and flood-related losses are covered by the insurance. This includes losses from river and stream floodway, coastal flooding, flooding along the shores of lakes, and flood-related erosion as a result of storm activity. Wharves, piers, bulkheads, growing crops, land, shrubbery, livestock, roads, bridges, motor vehicles, and similar items are not covered (24).

When a community enters the Regular Program, it must require that all new construction in identified areas of special flood hazard be elevated or flood-proofed to the level of the base flood. Additional standards are required within any designated floodway or coastal high hazard area. The available limits of insurance coverage are double those available under the Emergency Program. The second half of coverage at actuarial (non-subsidized)rates is available together with the subsidized first half of coverage for all existing structures. All coverage under the Regular Program for new structures in the flood hazard areas is made at actuarial rates reflecting the degree of flood risk for each property (24). The Texas Water Development Board reports that 66 cities and 11 counties in Texas were approved for the Regular Program as of August 31, 1976.

The information presented in Table 2 was prepared and distributed by the U.S. Department of Housing and Urban Development to summarize flood insurance ratemaking under the Emergency and Regular Programs. The table sets forth the available limits of coverage as well as appropriate premium rates under the program. Under the Emergency Program only the first layer or subsidized flood insurance is available. With the Regular Program, full coverage (first and second layer) is available. Actuarial rates are paid for all coverage on new construction and on substantial improvements in the flood hazard areas. On existing structures and on new construction outside the flood hazard area, actuarial rates are paid for the second layer of coverage and either the subsidized or the actuarial rates for the first layer, whichever is lower (24).

A Flood Insurance Rate Map is furnished to the community by the Federal Insurance Administration. This map is the result of an engineering study and is used to further refine the boundary lines of flood hazard areas. These reflect the flood elevations that would occur during a flood with a one-percent chance of occurrence in any given year. The actuarial or non-subsidized premium rates reflecting degree of flood risk are determined from this information. Local officials are consulted on available data to verify or correct potential flood levels, and a public meeting is held to obtain additional information. Flood elevations on the rate map may be appealed by citizens for 90 days after the maps are published, and any appropriate technical data can be submitted for substantiation (24).

Communities that have been identified as having one or more areas of special flood hazard by publication of the Flood Hazard Boundary Map have until December 31, 1976 or one year from notification, whichever is later, to qualify for the program. If the community has not qualified, no Federal or federally related financial assistance may legally be provided for the construction or acquisition of buildings in the community's identified special flood hazard areas. Such assistance will remain unavailable until the community has qualified. The financing of buildings outside these areas is not affected.

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Many people in high flood-risk areas are uninformed about the extent of risks of flood damage which they face.

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TABLE 2. AVAILABLE LIMITS OF COVERAGE AND PREMIUM RATES OF THE FLOOD INSURANCE PROGRAM[1]

	Emergency program[2] First layer		Regular program[3] Second layer		
	Limit	Subsidized rates (Per $100)	Limit	Actuarial rates	Total limits of coverage
Single family residential	$ 35,000	25c	$ 35,000	Varies	$ 70,000
Other residential	100,000	25c	100,000	"	200,000
Non-residential	100,000	40c	100,000	"	200,000
Contents, residential (per unit)	10,000	35c	10,000	"	20,000
Contents, non-residential (per unit)	100,000	75c	100,000	"	200,000

[1]Source: U. S. Department of Housing and Urban Development.
[2]Only the first layer of coverage is available under the emergency program.
[3]Full coverage is available under the regular program for all structures in the community.

Economic Considerations

In its concern for the general welfare, the Federal government has a proper interest in measures to hold flood damages to an economic minimum. It has a responsibility to discourage flood plain development which would impose a later burden on the Federal taxpayer and which would benefit some citizens only at the expense of others.

Under previous policies, flood plain property owners in unprotected or partially protected areas bore only a portion of the cost, their price being exacted when damage occurred. Some shouldered full losses; others relied on public relief and assistance in rehabilitation. They paid a minor fraction, through payment of general taxes, of the public cost of relief and rehabilitation. The general public, by bearing all or a major part of the cost of flood protection works and thus lessening the individual's damage costs, further subsidized flood plain occupants in their use of the flood plain.

Flood insurance is intended to provide financial assistance to flood disaster victims in restoring their property. In addition, flood insurance is to be a mechanism to help prevent unwise use of land where flood damages mount steadily and rapidly.

Many factors affect average annual flood damages for any property in any location, but the two most important characteristics of the flood-risk zone in which the property is located are the frequency of flooding and the depth of flooding. The hydrologic approach is based upon flood magnitude-frequency and depth-damage relationships.

The flood damage hazard in the United States is highly concentrated. As few as 2 percent of all dwellings can expect to have more than half of the total average annual flood damage. Less than 10 percent of all dwellings have any significant flood hazard, and the other 90 percent or more are free from any serious or measurable flood hazard. If everyone contributed equally to a flood insurance program, through a uniform premium rate, this would be quite inequitable in view of the wide range in degree of flood risk (19).

Many people in high flood-risk areas are relatively unconcerned about the risks of flood damage which they face. They are grossly over-optimistic about the probability that their property will not be flooded, or they expect public help to bail them out when the inevitable flood disaster strikes. There is a maximum limit to the amount any large group of flood plain occupants will pay for flood insurance, even with the subsidies extended under the present program (19).

Managing the Flood Hazard

The prime measure to reduce flood damage hazard is to avoid unwarranted occupancy of the flood-prone areas. If the new occupant of such areas bears the full cost of flood insurance premiums, then he has to weigh the advantages of occupancy against the costs of flood plain occupancy. In some circumstances, it may be economic to occupy an area with relatively high hazard of flood damage, such as summer homes along the coast. The sea frontage makes these locations valuable but at the same time makes the risks of damage high. In many situations, the full costs of occupying high-hazard areas are greater than the probable advantage. Under those circumstances, flood insurance premiums that place the full cost on those benefiting from the location can operate to keep unwarranted occupancy to a minimum (19).

Alternatives exist that allow use of flood-prone areas. By careful site planning, land development, and site preparation and by special flood-proofing measures, the monetary damage from floods can be reduced considerably. In the case of industrial and commercial property, special measures can be taken to protect machinery, equipment, supplies, and stock from damage. Some of these measures can be taken on older buildings, although both physical and economic possibilities are greater for new buildings.

Flood-prone areas, both riverine and coastal, are often valuable regardless of the risk of flooding. Many industries needing a lot of water, or having the need for major discharge of wastes into water, want locations bordering streams or the Gulf. The amenity or recreation value of a flood plain location for a vacation or permanent home is also important. In some cities, the flood-prone area may be well located with respect to the rest of the city. In these and other situations, people may wish to locate their primary home, their vacation home, or their business in a location subject to flood hazard (19).

Problems arise, however, when the costs due to flood hazard are greater than the benefits due to location. If everyone were perfectly informed and if circumstances never changed, presumably no one would ever be located where costs exceeded benefits. Many persons have, in fact, located where flooding costs proved to be far higher than they expected when they located there. Sometimes a location that was valuable when a building was first erected is no longer so valuable when conditions have changed.

Flood Insurance on Developed Flood Plain

Flood insurance premiums can be useful in identifying for the potential buyer or builder the true flood risk. For the examples that follow, it is assumed that a flood insurance premium is set at the average annual flood damages per $100 of building and contents. Actually, a flood insurance premium that is not subsidized will exceed average annual flood damages since flood damages and all overhead costs of the program must be included in the premium, hence the effect of flood insurance on property values is greater than that of the actual flooding risk.

The value of property in a flood plain considering flooding risk can be estimated using the following equation:

$$V = L + B + F - \frac{A\left(\frac{B+F}{100}\right)}{i} \qquad (1)$$

where

V = value of land, buildings, and contents considering flooding
L = land value with no flooding risk
B = building value in absence of flooding
F = furnishings or building contents value in absence of flooding
A = average annual flood damages per $100 building and contents value
i = interest or discount rate.

Basically, the calculation takes property value in the absence of flooding and subtracts the expected present value of all future flooding damages.

Assume a development in the flood plain which has a land value of $10,000 and flood damageable property in building and furnishings of $40,000. This would give a total value of $50,000 for land, building, and furnishings if the development was not subject to flooding. However, the location in a flood plain means a flood risk is assumed, and this risk can be reflected in reduced property value.

The magnitude of the reduction in property value is directly related to the flood risk; i.e., the greater the flood risk, the greater the loss in property value. In the example, if average annual flood damages were $1 per $100 flood damageable property value, the total property value would be reduced $4,000 calculated as $\left(\frac{\$1 \times 400}{10\%}\right)$ leaving $46,000 property value rather than $50,000. This, of course, is calculated using a 10 percent discount rate. At $5 average annual flood damages per $100 property value, the reduction in property value due to flooding risk would be $20,000, or the $50,000 value would be reduced to $30,000.

Figure 2 shows the percent reduction in flood damageable property value that is associated with alternative flooding risks (average annual flood damages). A 10 percent discount rate is used to develop the graph. With average annual flood damages of $10 per $100 of building and contents, the value of the building and contents is

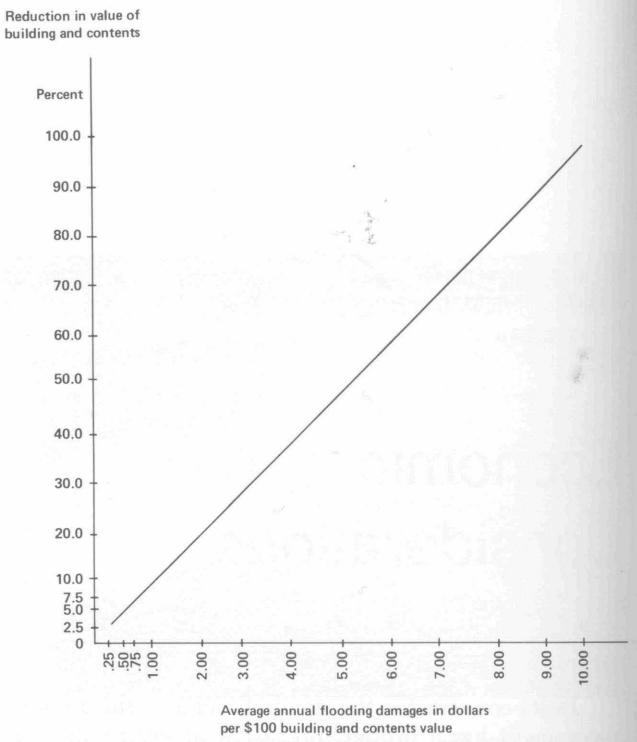

Figure 2. Percent reduction in value of building and contents by level of flood risk.

zero due to the serious magnitude of flooding risk. This would logically mean that the land value would also be zero for building; i.e., land use would have to be something other than homesites to have any value.

Viewing the same type analysis somewhat differently, assume a family buys a new house and a lot for $32,000, paying 10 percent down, and puts $8,000 worth of furniture in it. The land may have been worth $8,000 and building cost, including builder's profit, $24,000. Under usual home financing terms, the monthly payments, including taxes and amortization of the loan, are about $300. Such houses have been found in some cities in the zone with most frequent flood hazard. The average annual flood damage in such areas might easily reach to $10 per $100 property value (building and contents). This is $4,000 or $333 monthly, or more than the whole home financing cost in the absence of a flood risk. Aside from the question of the occupant's willingness to pay any such cost, it is not economical for him to do so, nor is it economical for the public that he should be in a place where flooding costs are so high.

In the short run, with the investment in the present buildings already made and subsidized flood insurance available, continued use of existing dwellings makes economic sense from a public policy viewpoint. Although the owner with a high mortgage may not be willing or able to pay actuarial flood insurance rates, it is better for him or someone else to use the dwelling than to abandon it. The subsidy may be necessary and desirable until the present buildings are no longer habitable. If exposed to heavy flood losses, houses will age quickly.

Flood Insurance on Undeveloped Flood Plain

The preceding discussion related to a building in the flood plain. On bare flood plain land the effect of flooding risk on land value where development is planned can also be calculated with Equation 1. The one important difference is that development has *not* occurred. This means that the value of buildings and contents planned for the flood plain cannot reasonably be decreased due to flooding risk. A homeowner would not rationally expend money on land, building, and contents in a flood plain when upon completion of construction the property would be worth thousands of dollars less. Therefore, all the loss in value to undeveloped flood plain property attributable to flood risk must be applied to the land. Further, flood insurance is not subsidized for new developments in the flood plain, hence the property owner rate is actuarial rate or a close approximation of actual flood risk.

To illustrate, consider a home that is planned in the flood plain where the land is valued at $10,000 in the absence of flooding and a $38,000 building and contents structure is contemplated. If average annual flood damages after construction are $1 per $100 building and contents value, the loss in property value would be $3,800. This $3,800 loss in value due to flood risk would reasonably be deleted from the $10,000 land value, leaving a $6,200 land value. For greater flood risks, the land value is further reduced to zero and beyond for this type of development. The value for recreation or water storage purposes is not considered in this problem.

The level of average annual flood damages per $100 building and contents value where land value becomes zero is important. Average annual flood damages where land value is zero can be calculated as

$$\frac{A\left(\frac{B+F}{100}\right)}{i} = L \quad (2) \qquad A = \frac{100L\,i}{B+F} \quad (3)$$

In the example where land value was $10,000 in absence of flooding and a $38,000 building and contents structure is contemplated, with average annual flood damages of $2.632 per $100 building and contents value, the value of the land would be zero.

The level of average annual flood damages where land value is zero is especially important in evaluating new developments in a flood plain. Table 3 indicates average annual flood damages where land value would be zero given alternative building and contents values for a planned development and land values in the absence of flooding. A 10 percent discount rate was used in the calculations. With larger building and contents value relative to land value, the amount of average annual flood damages where land value is reduced to zero becomes smaller.

For example, if the value of building and contents were going to be $20,000 and land value in the absence of flooding was $10,000, average annual flood damages would have to be $5 per $100 building and contents value to reduce land value to zero. However, if building and contents value were increased to $50,000, average annual flood damages where a $10,000 land value would be reduced to zero occurs at $2 per $100 property value.

Figure 3 follows the same principle but in a more general form. Average annual flood damages per $100 building and contents value is presented where land value in a flood plain would be zero given alternative land values (in the absence of flooding) as a percent of total property value. Data in Figure 3 may be useful to flood plain developers, flood plain owners, and those contemplating building in a flood plain.

Overall programs, public and private, for management of land and other resources in flood-prone areas, must take into account these differences in risk, and the relevant insurance premiums can be a valuable guide to decisionmaking. Given the hazard of flooding, as measured by the insurance premium, what is the best use of

TABLE 3. AVERAGE ANNUAL FLOOD DAMAGES WHERE LAND VALUE IS ZERO[1]

Value of building and contents	Land value in absence of flooding								
	1,000	2,000	3,000	4,000	5,000	10,000	20,000	50,000	100,000
1,000	10.00	20.00	30.00	40.00	50.00	100.00	200.00	500.00	1,000.00
2,000	5.00	10.00	15.00	20.00	25.00	50.00	100.00	250.00	500.00
5,000	2.00	4.00	6.00	8.00	10.00	20.00	40.00	100.00	200.00
10,000	1.00	2.00	3.00	4.00	5.00	10.00	20.00	50.00	100.00
15,000	.67	1.33	2.00	2.67	3.33	6.67	13.33	33.33	66.67
20,000	.50	1.00	1.50	2.00	2.50	5.00	10.00	25.00	50.00
25,000	.40	.80	1.20	1.60	2.00	4.00	8.00	20.00	40.00
30,000	.33	.67	1.00	1.33	1.67	3.33	6.67	16.67	33.33
40,000	.25	.50	.75	1.00	1.25	2.50	5.00	12.50	25.00
50,000	.20	.40	.60	.80	1.00	2.00	4.00	10.00	20.00
100,000	.10	.20	.30	.40	.50	1.00	2.00	5.00	10.00
200,000	.05	.10	.15	.20	.25	.50	1.00	2.50	5.00
250,000	.04	.08	.12	.16	.20	.40	.80	2.00	4.00

[1] Average annual flood damages per $100 building and contents value. Calculations are based on a 10 percent discount rate. The calculation is

$$\text{Average annual flood damages} = \frac{\text{land value}}{(\text{building and contents value}) \cdot 0.1}$$

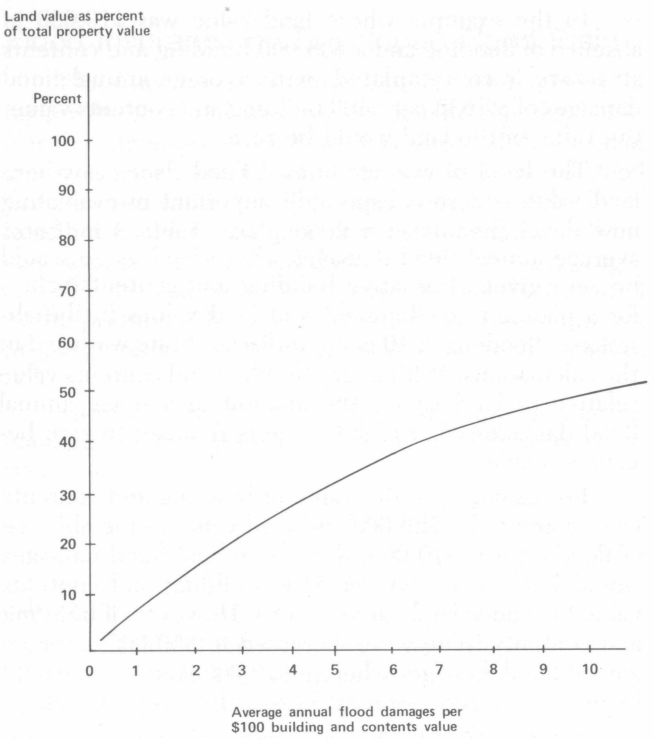

Figure 3. Average annual flood damage level where land value is zero with land value at alternative proportions of total property value.

a particular tract of land? It is highly unrealistic to talk about flood plains or flood-prone areas as if all parts of each plain or area were alike. Actually, the hazard varies greatly between zones, and in some instances the zones are quite narrow.

With compulsory flood insurance set at the approximate flood risk rate, flood plain development is expected to be guided to more socially desirable ends. But flood insurance is not the only flood plain land use planning technique that should be used in guiding development of bare flood plain or shifting uses in developed flood plain.

The best management program for a particular flood-prone area may be a system of flood protection works, but the limit to their rational cost is suggested by the difference in insurance premiums with and without them. If flood damage is unavoidable, then insurance is a means of protecting against such losses. Where the unavoidable loss is high, the best long-run solution may well be a shift in land use from residential to industrial, or to recreational, or simply as overflow land to help contain floods. If the city has long-range economic and land use plans and if it takes actions to implement these plans over a period of years, substantial changes in land use can be made over such a period. Zoning, building permits, extension of public services, and other public actions can gradually shift use out of one area and into another. If such public plans are sound and well known, they provide guides to private investment which can work toward the same end.

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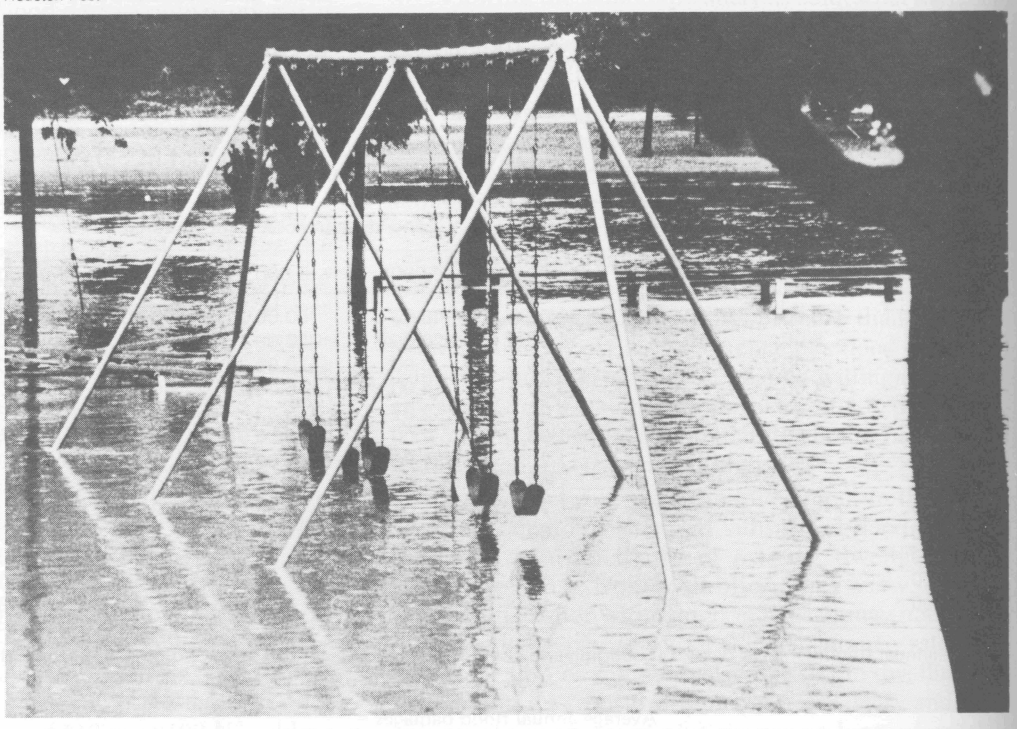

The extent and frequency of flooding should serve as the basis for adjusting human activities.

Environmental Considerations

Passage of the National Environmental Policy Act of 1969 caused those persons doing planning for future development, including uses of water resources, to evaluate more fully the total environmental consequences of their planning decisions. For the first time, a broad national policy for maintaining environmental quality was established. Natural environmental considerations were made a full partner with economic and technical matters. Federal agencies were required to include all environmental factors in their planning and decisionmaking. The action-forcing Section 102 (2) (c) of the Act requires Federal officials to include in every proposal for legislation and other major Federal actions significantly affecting the quality of the human environment statements on:

"1. The environmental impact of the proposed action.
2. Any adverse environmental effects which cannot be avoided should the proposal be implemented.
3. Alternatives to the proposed action.
4. The relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity.
5. Any irreversible and unretrievable commitments of resources which could be involved in the proposed action should it be implemented." (16)

The objective of comprehensive planning and management is to blend proposals by individual landowners and local groups with protection of the resource base to yield a desired complex of public values. A balance is sought between development and protection of the different ecological units of the landscape, for example, streams, rivers, marshes, shorelands, flood plains, ground water recharge areas, woodlots, forests, and upland fields (16).

Increasing problems are being encountered with watershed projects, but the most serious involve maintaining valuable wetlands and streams and their associated shorelands and flood plains from inappropriate physical developments. Vast amounts of drainage, including channelization, have been applied in a detrimental manner and lead to the degradation and destruction of ecological systems, environmental quality, and public values.

Reduction of height, extent, duration, and frequency of overflows as achieved through channelization often drastically reduce biological productivity of the stream channels treated. They not only threaten the survival of plants and animals that require periodic overflows of flood plains, but they also promote more intensive use of flood plains. All of these results degrade and destroy the bottomland ecosystems which depend upon periodic overflows for sediment and nutrient influx and deposition.

Downstream areas also are degraded. The increase in volume and velocity of water flows in excavated channels maximize their erosive force and permit them to carry a higher silt load, as well as the more abundant nutrients, downstream to community lakes, reservoirs, and other streams.

Channelization should be regarded as a technique which, when used in an ecologically insensitive manner, degrades and destroys ecological relations, environmental quality, and public values. With few exceptions, every stream periodically overflows its banks onto its flood plain to accommodate the flows it cannot carry in its channel. Areas adjacent to streams are natural flood storage sites and should not be protected completely from overflowing. The extent and frequency of flooding should serve as the basis for adjusting human activities. Only those encroachments which are compatible with maintaining stream channels, shorelands, water quality, open space, recreational opportunities, and fish and wildlife habitat should be permitted on flood plains (16).

Procedures currently used by economists and planners in small watershed projects to accumulate agricultural and nonagricultural benefits are promoting development. Wetlands, flood plains, woodlands, and other tracts are converted to intensive agricultural uses. Residential developments are encouraged in flood plains. With free technical assistance, 50-percent cost sharing for drainage, 100-percent taxpayer payments for channels associated with flood control, and 100-percent payments for administering construction contracts, landowners have plural incentives to discourage them from maintaining wetlands, woodlands, and other similar areas (15).

Ecological Management

Wetlands and streams with their associated shorelands and flood plains can be recognized as unique ecological systems. Wetlands should no longer be looked upon as wastelands. They are important features of the landscape which provide unique diversity and are of public value.

To maintain these essential areas, State and Federal resource agencies should inventory the land and water resources in each proposed watershed project in sufficient detail to permit designation of important features of the landscape for maintenance and ecological management.

1. Streams or sections of streams that are not to be impounded, channeled, or altered in any way should be delineated in each watershed. Every stream of local, state, regional, and national significance should be included. Degraded streams should be restored, whenever feasible, through ecologically sound modifications and management that reduce erosion, sedimentation, and pollution and improve their biological productivity.
2. Flood plains of all streams should be delineated using boundaries of the flood which, on the average, may be expected once in a hundred years. Within this defined area, man's activities should be planned and carried out according to standard development criteria based on flooding hazards. The development should be designed to prevent and minimize damages, expenses, and inconveniences to citizens. Only that development consistent with nature's requirements for conveying flood waters should be permitted. Planners and engineers must protect the bottomland environments from man's inappropriate degrading and destructive activities.
3. Wetlands that must be preserved or mitigated should be delineated. By knowing in advance the wetlands requiring preservation, the need for and expense of mitigation can be minimized through appropriate project design. Specific needs for mitigation can be determined as planning proceeds.
4. Sites that can hold excess runoff waters should be designated and maintained or developed to minimize flooding downstream within and outside a watershed, and when feasible, to enhance fish and wildlife habitat and public recreational opportunities.
5. Other unique features of the landscape should be delineated, such as ground water recharge areas and outstanding or rare plant communities (16).

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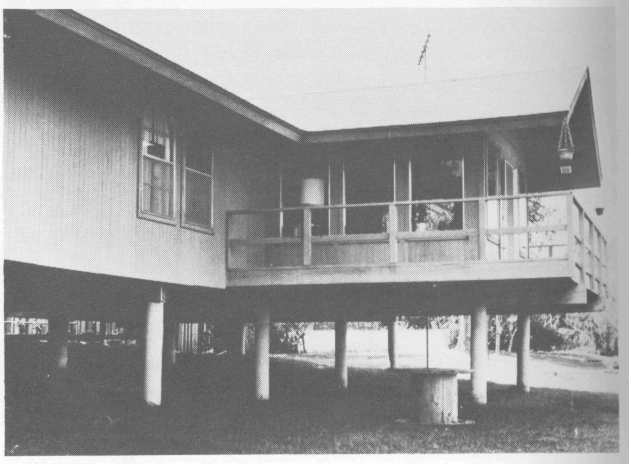
Flood damages can be minimized by careful planning and proper flood plain management.



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Policies and Tools of Management

The individual's right to land is not a right to charge his costs off to others. Individual land rights tend to lessen in direct proportion to increasing flood hazards. Costs always occur in the occupancy of a flood plain. The individual who builds on the flood plain bears some flood losses and shifts some of his costs to others. The added cost may come in the form of higher flood stages caused by impeding or obstructing the normal pattern of flood flow. Services, such as utilities and streets, may require flood proofing or suffer frequent flood losses. Other costs are for relief and rehabilitation as well as for the destructive effects of floating property that adds hazards to waters during floods. "The point is that it is reasonable to assume that the more frequently flooded portions of the flood plain — those defined within a 100-year floodway — have sufficient certainity of flooding that the consequences described above would be deemed nuisancelike by a court." (18)

Development of flood plain can be controlled by strict land use management. White (26) suggests this would be the single adjustment most likely to reduce national flood losses. Whether or not this control would yield the largest net benefits to the nation is not certain.

Flood Insurance

An effective, compulsory flood insurance program should result in maximum net benefits to the nation by causing rational economic flood plain use. This is based on the premise that actuarial flood insurance premiums are a reliable measure of flooding risk and can be expressed as an annual cost to which the flood plain occupant can relate. Basically in the long run, if each new development were required to pay an annual charge (insurance premium) in proportion to its hazard, the following would be expected:

"1. Society would be assured that occupants of new developments were assuming appropriate responsibility for locational decisions.
2. New development in the flood plain would be precluded unless the advantages were expected to equal or exceed the total social (public and private) cost.
3. There would be incentive to undertake all those flood damage reduction measures, public and private, the costs of which are less than the consequent reduction in damage potential since they would result in a greater reduction in occupancy charges (total social costs) than the outlays for such measures. Moreover, if the cost of occupancy charges were taken into account in the benefit-cost analysis of flood protection works, it would help to determine the economics of any such undertaking and of any increment in scale of such undertaking.
4. There would be support for appropriate regulation of flood plains to help, where possible, reduce the costs of flood plain occupancy.
5. In sum, an occupancy charge indemnification fund, or flood loss insurance, could be used in lieu of an uneconomic structural or other type of measure and to complement an economic flood protection measure." (19)

The degree of subsidy for flood insurance on existing property is quite high. Expected payouts of eleven-to-one are not unusual, with the property owner receiving $11 in compensation at the time of a flood loss for every dollar of premium paid. This figure may seem high, but it may not be higher than the existing subsidy that the same property owner could receive from existing cost-sharing arrangements for structural approaches (1).

Incentive must be provided so that uneconomic development of flood plains will stop. Urban expansion into flood plains in the United States lies between 1.5 and 2.5 percent annually, with much of the new development gaining no special benefits from flood plain location (26).

The impact of flood insurance on new development is variable. There is no subsidy, but the procedure to establish flood insurance in an area identifies the degree of hazard and makes this information available on flood hazard boundary maps. This is to be translated into regulations that keep development off the highest risk portion of the flood plain. Development that does take place above the 100-year flood area has flood insurance available to it, and premiums would be expected to pay actual damages. Losses in potential capital gains in the flood-prone areas should be offset by actual increases in capital gains in areas outside the high risk zone (1).

The incentive to not locate in a flood plain when it is uneconomic can and will be provided by Federal flood insurance. Requirements to be covered by flood insurance have brought about an increasing use of land use management and flood-proofing in adjusting to flood hazards (26). According to the Texas Water Development Board as of April 30, 1976, persons in the eligible areas of the State had purchased 80,633 flood insurance policies. The total amount of flood insurance in force in Texas at that time was $2,157,936,000.

The actuarial base for the present flood insurance program is the likelihood of a 100-year flood, one which

has a one-percent chance of being equalled or exceeded in any one year. This size of flood has been selected as a flood hazard guideline which provides a reasonable level of freedom from damage or threat to life and health but is not so high as to be unnecessarily restrictive.

A one-percent chance of exceedence in any one year is equivalent to a 20- to 30-percent chance of exceedence in the common mortgage period. It seems rational to plan or insure against such a risk. A 100-year flood occurs every year in some region of the country and often occurs in several regions. In 1972 and 1973, more than 80 Presidential disaster declarations for public assistance were related to flooding. In more than 20 of these disasters, flooding equal to or greater than the 100-year flood was experienced at some location. In about 10 of these cases, extensive flooding occurred over large areas (3).

Flood insurance premiums provide economic guidelines to optimum use of the flood plain. This is because of the great variation in average annual flood damages (insurance premium) from one flood risk zone to another, which reflect the cost of living on the flood plain. Figure 4 indicates estimated average annual flood damages by flood risk zones. In zone A where a flood is expected once every 5 years (20-percent chance of flooding annually), average annual flood damages per $100 of value are about $3.60, compared with $2 in the 5- to 10-year expected occurrence interval. Expected flood damages continue to decline as the threat of flooding becomes less frequent (20).

Other Management Tools

Of course, flood insurance is but one of the management tools available for guiding flood plain land use. Traditionally, landowners have borne the loss of flood damages as part of normal operating costs, or they have utilized flood protection works at great public expense. Other forms of adjustment are possible, but they vary in political acceptability. Godwin and Shepard (7) find that the most restrictive policies are those that are least feasible politically.

Distributive policies, such as subsidies and construction projects, draw resources from the general public and distribute these resources to selected groups. Once enacted, these policies enjoy stability because they

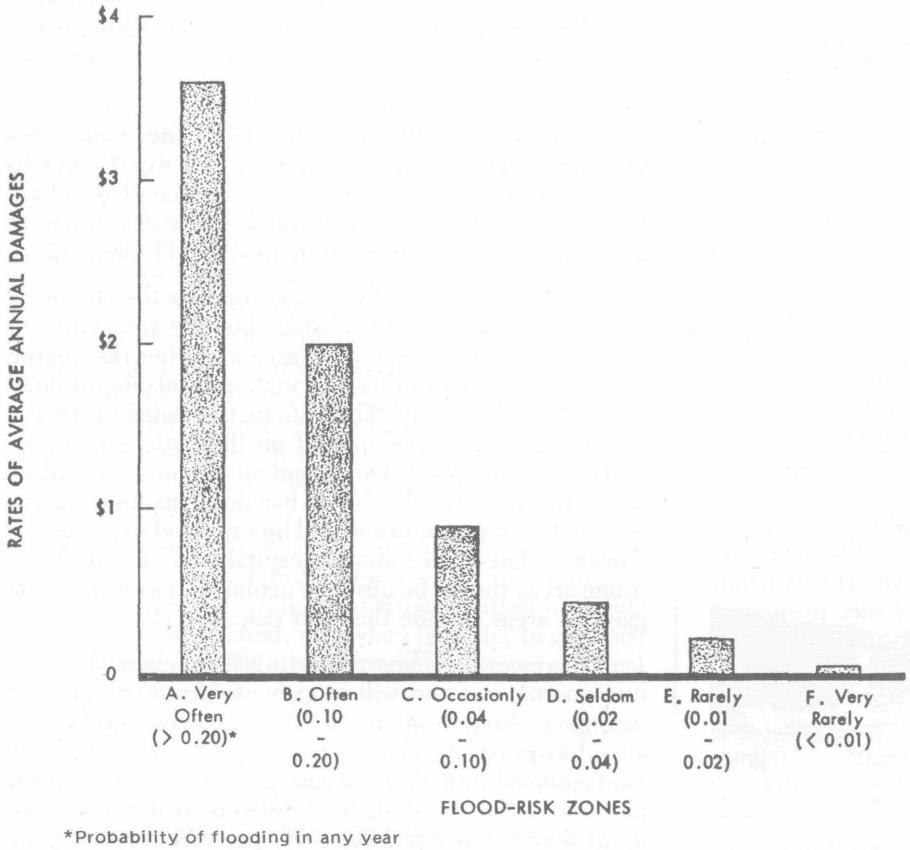

Figure 4. Average annual residential flood damages, per $100 property value, structure and contents, by risk zones, median of study areas.

Source Committee on Banking and Currency, U.S. Senate. 1966. Insurance and Other Programs for Financial Assistance to Flood Victims. U.S. Government Printing Office, Washington, D.C., p. 4.

create or strengthen a vested interest. If certain groups object to the benefits others are receiving, their interests can be included in later appropriations. The average citizen pays little and can be convinced of the public need. Structural measures for flood control fall in this category.

Self-regulatory policies are permissive or enabling measures which allow but do not compel certain actions. Until passage of the Flood Disaster Protection Act of 1973, the national flood insurance program was permissive. Most people did not buy the insurance because they did not perceive financial or other incentives to do so.

Redistributive policies extract resources from specific classes or groups and redistribute the benefits to other classes or groups. Both the individuals receiving benefits and those who must pay are aware of the policy. If developers anticipated structural measures protecting a flood plain and instead the land was zoned for public recreation purposes, there would be redistribution of benefits (7).

Finally, regulatory agencies redistribute power and authority through statutes vesting power in different units. They usually include clear inducements or sanctions and are powerful in their effects. Flood plain regulations reduce damages by requiring that the flood plain be used for purposes that are not subject to flood damage and by providing for the necessary floodway capacity so that flows are not obstructed or flood heights increased significantly. Several devices are available to the community which wishes to achieve flood plain management.

Zoning is a legal tool that can be used to implement and enforce detailed plans resulting from land use planning programs to ensure the most beneficial use of flood plain lands while safeguarding the safety, health, and welfare of the total community. Designated floodways may be reserved by establishing encroachment lines that clearly define floodway zones. Utilization of flood plain lands adjacent to the floodway is limited only by the degree of flood risk deemed allowable by local government and the requirements of a city's zoning criteria for the area (13).

Subdivision regulations can be used by local governments to specify the manner in which land may be divided. These regulations prescribe the width of streets, curbs and gutters, lot sizes, elevations of land to avoid area flooding, size of floodways, and other requirements affecting the welfare and safety of the community. They also provide an effective means of controlling construction and preserving floodways in presently undeveloped flood plain areas (13).

In addition to the more conventional construction standards set forth, building codes should contain provisions that assure the structural integrity of buildings during flood periods. Code requirements to reduce flood damage include elevation control, consideration of strength and deterioration susceptibility of materials, proper anchorage, and flood proofing criteria.

Flood proofing measures can be effectively applied to both existing and proposed structures in relatively low-risk hazard areas. These may include land filling and elevation of structures, site grading, and structural design changes that reduce flood damage vulnerability. Health regulations can serve to control the use of flood plains for solid waste disposal and the construction of water and sewage treatment facilities that may create health problems during floods.

Accurate, timely forecasting of floods and critical stream stages, coupled with temporary evacuation and other emergency actions, can often save lives and reduce property losses. In development of community plans for coping with natural disasters, provisions should be made for alerting area residents and coordinating operations of city-county-state public service agencies throughout the flood-fighting evacuation and for rescue activities which may be required during a flood emergency (13).

Although regulatory controls are valuable tools in comprehensive flood damage prevention planning, probably the most effective tool is in the area of development policies. "Flood conscious" governmental policies that limit the extension of public roads, utilities, and other services into flood-prone areas can play an important indirect role in shaping overall development. Private development often follows the extension of public services. By locating public facilities away from flood-prone areas, a soft-sell negative influence is projected, which encourages the occupancy of higher and safer ground. Other actions that can be taken by local governmental units include preservation of floodways through urban renewal, providing favorable tax adjustments to lands held for open-space uses, and taking necessary action to be included in the national flood insurance program. In the area of finance, lending institutions — both Federal and private — can influence flood plain development by withholding mortgage guarantees or other funding from those who contemplate projects that will intensify known flood problems (13).

The extent and degree of flooding should be considered in the adoption of any development plan. As previously indicated, data can be used to identify those areas where structural flood control measures are required. These measures may include appropriate channel improvements, planning for eventual removal of obstructive construction in floodways, eliminating future encroachment on floodways, designing all future or replacement stream crossing structures with adequate waterway openings, and flood proofing existing structures that must remain in the flood plains.

Continuing study and review of floodway requirements and other areal designations that may be defined in connection with flood plain zoning is particularly important in maintaining long-range land use. Community authorities should periodically review and adjust the provisions governing flood plain uses whenever new information indicates a change in their flood potential. Expansion of developments or the construction of flood control structures may sufficiently alter runoff conditions to warrant future reviews and possible amendment of controls (13).

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