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FACTORS TO BE EVALUATED IN PLANNING FOR FLOOD-DAMAGE PREVENTION

A THESIS

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by

Jerrold Allen Moore

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FACTORS TO BE EVALUATED
IN PLANNING FOR
FLOOD-DAMAGE PREVENTION

Approved: _____

Date Approved by Chairman: May 31, 1958

FOREWORD

Contributions of This Study

The principal contributions this study aims to make are: (1) the identification and evaluation of flood and land-use factors which should be considered in planning for flood-damage prevention; and (2) the establishment of a procedural framework within which flood and land-use data can be analyzed and the interrelationships between them can be studied.

These steps are needed before effective flood-damage prevention programs can be applied to solve urban flood problems. Proper analysis of the interrelationships between flood and land-use factors points to the means by which flood-damage potential can be reduced. It is necessary to examine briefly the historical approaches to the prevention of flood damage, to study their achievements and shortcomings, and finally to outline the total range of flood-damage prevention measures and the situations to which they are applicable.

Robert W. Siler, Jr. presented a comprehensive introduction to this subject in Flood Problems and Their Solution Through Urban Planning Programs (Nashville: Tennessee State Planning Commission, 1955). Siler's study was originally prepared as a thesis submitted to the faculty of the Depart-

ment of City and Regional Planning of the University of North Carolina in partial fulfillment of the requirements for the degree of Master of Regional Planning.

As a result of his work, there was a foundation upon which to build in seeking to formulate a procedural framework for the consideration of factors which govern flood damage. This study is intended to complement Siler's work by further detailing some of the functions of urban planning with respect to the solution of flood problems.

The limitations in scope of this study should be recognized. Because of the complexity of urban planning, many factors that are closely associated with land use could be mentioned only in passing. For example, further study of the effects of flooding on transportation facilities needs to be made. A broad field of study that remains almost untouched is the political aspect of planning for flood-damage prevention.

However, the greatest contribution to be made in this field at the present time appeared to be in evaluating the interrelationships between floods and land use. This task was made considerably easier by the encouragement and assistance given the author by the Tennessee Valley Authority. This agency has been active in developing a method by which flood data can be furnished to communities in a form most useful for understanding the nature of local flood problems.

Their approach appears to be the most adequate method of presenting such data at the present time. The reports

published by the Authority are comprehensive and are oriented towards providing a basis for the solution of urban flood problems through the planning process.

Acknowledgments

The author wishes to express his gratitude to the Alfred Bettman Foundation and to the Graduate Division of the Georgia Institute of Technology for their invaluable financial assistance. Without this considerable help, his two years of advanced study at the Georgia Institute of Technology would not have been possible.

The Tennessee Valley Authority contributed a wealth of data, both published and unpublished. In addition, the illustrations included in this report were furnished by the Authority. Particular appreciation is felt for the substantial assistance extended by James E. Goddard, Chief, Local Flood Relations Branch, throughout the course of this study. Thanks are also given to Aelred J. Gray, Chief Community Planner, Government Relations and Economics Staff, and Edward J. Rutter, Head, Project Studies Section, Flood Control Branch, for reviewing each draft.

Miss Natelle Isley and Mrs. Anne Bailey of the Library of the School of Architecture furnished valuable assistance in locating and obtaining much of the research data used.

The author gratefully acknowledges the help and encouragement of Professors Howard K. Menhinick, Malcolm G. Little

and Carl E. Kindsvater during the preparation of this report.

This thesis is dedicated to my wife and three children, who have given so much and have asked for so little during the past six years. It is to them that most of the credit must be given for the successful completion of this work.

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SUMMARY

A brief review of the historical approaches to flood-damage prevention points out that: little thought has been given to the complementary advantages of a combination of measures that can be applied to the solution of a specific flood problem. As a result, the approaches to the solution of flood problems used in the past have not been completely successful in abating flood damage.

This failure is particularly evident in urban areas where unimpeded development of land subject to flooding has resulted in increased flood damage and loss of life during the last fifty years. If flood-damage prevention is undertaken as a part of the planning process, it can be used to place a limit on the development of flood-hazard land and to bring about satisfactory adjustments of existing land uses to flooding.

The principal contributions this study aims to make are: (1) the identification and evaluation of flood and land-use factors which should be considered, so that programs of flood-damage prevention can be effectively utilized; and (2) the establishment of a procedural framework within which flood and land-use data can be analyzed and the interrelationships between them can be studied.

The methods of analysis presented show that planning for flood-damage prevention should be pointed towards assist-

ing local governing bodies reach three decisions: (1) the delineation of flood-hazard areas; (2) the selection of land uses to be permitted in these areas; and (3) the selection of the means of flood-damage prevention to be utilized.

The delineation of flood-hazard areas is based upon an analysis of flood records and storm studies. This analysis can be used as the basis for the selection of a flood magnitude which can reasonably be expected to occur in a particular locality. The magnitude of this flood can then be used to delineate a floodway which should be kept as free as possible from encroachments and the temporary water-storage areas within which certain uses of land can be permitted that are not susceptible to extensive flood damage.

A comprehensive land-use plan summarizes the future requirements for land in a community and acts as a guide for development. The selection of land uses to be permitted in areas subject to flooding depends in part upon the necessity of utilizing this land as a community grows. An analysis of the effects of flooding on various uses of land can determine the appropriateness of the development of flood-hazard land for these uses.

Finally, the selection of the means of flood-damage prevention to be undertaken depends upon the nature and magnitude of a local flood problem. Each method has a specific role to play in reducing flood damage. Certain of these methods should be combined to form a program for flood-damage

prevention which is designed to fit specific situations. A summary of measures to reduce flood damage is outlined for developmental, preservation and redevelopmental programs.

CHAPTER I

THE NATURE OF THE FLOOD PROBLEM AND ATTEMPTED SOLUTIONS

The Nature of the Flood Problem

Magnitude of the Flood Problem

Increased flood damage on a national basis.--The adverse effects of flooding upon the social and economic well-being of the people in this country have recently become matters of much concern. During the past fifty years flood damage has increased greatly in many parts of the country. At the same time questions have been raised regarding the approaches which have been taken to mitigate this damage. Unless effective solutions can be formulated and proper adjustments made, flood damage can be expected not only to increase, but to reach staggering proportions in the future.

After a careful analysis of the increased costs of flood damage between 1903 and 1951, Hoyt and Langbein reported that:

> Of the increase in property damage by flood, we may ascribe about 45 per cent to the increase in property values, 25 per cent to an increase in the amount of flooding, and 30 per cent to an increase in building and other uses on flood-hazard lands. (1)

The 25 per cent increase ascribed to the amount of flooding does not necessarily mean that climatological changes are the cause. Rather, as meteorologic and hydrologic

records are extended, some of the great floods of record will be exceeded. As long as the "number of records that are broken does not increase out of proportion to the number of station-years of record," (2) this increase in amount of flooding has no significance from the standpoint of climate.

Thus, the magnitude of the flood problem is primarily the result of unimpeded encroachments by man upon flood plains. At the present time, "about 10,000,000 people in the United States prefer to reside and/or work on some 50,000,000 acres of land subject to occasional inundation." (3) Of this total, approximately 80 per cent live in cities and other urban areas.

Intensified use of land subject to inundation and increased property values in these areas have created a situation where greater damage and economic loss occur as a result of a given flood stage. Moreover, this situation has developed at a time when the importance of riverbank settlement has decreased. Technological advances now make it possible for many of the activities which were once dependent upon such a location to be conducted at sites some distance from the watercourse.

Regional differences.--Although the magnitude of flood damage is large on the basis of national averages, there are major differences in the magnitude and character of flood losses between different regions. The distribution of past losses shows that damage is concentrated in the Missouri and

Ohio River basins and in the North Atlantic States. The total cost of flood damage in these three areas since 1903 accounts for more than one-half of the losses which have been experienced in the entire nation. It is in these regions that the development of flood plains is the most intensive. Other regions experience proportionately less flood damage, because serious encroachments have not generally been made in hazard areas.

There is also a variation in the type of property damage in different regions. For example, in the Ohio basin and the North Atlantic States, damage to urban property has been extensive, and damage to transportation and utility facilities has been even greater. Contrasted to this is the situation in the Missouri basin, where the predominant type of flood loss has been in damage to agricultural property.

The magnitude and character of the flood problem varies considerably not only from region to region, but also from locality to locality. The unique features of the problem in each locality should be given proper consideration as solutions are formulated. In many situations, however, the first step towards undertaking satisfactory programs of flood-damage prevention must be recognition by the people that a flood hazard exists.

Recognition of the Flood Hazard

All too often recognition of the fact that a flood hazard exists in a locality comes only when rampaging waters

bring destruction. By that time it is too late for preventive measures; there remain the job of recovery and the need for action which can lessen the effects of future flooding. Unfortunately the adjustments which are necessary to mitigate future flood damage are seldom accomplished because:

> The flood hazard is underestimated by most flood-plain dwellers because of the infrequency of major floods, the frailties of human memory, and the reluctance of some people, for economic reasons or from sheer obstinancy, to admit that past floods may be repeated or exceeded. (4)

Flood-plain occupants cannot be expected to take full blame for this situation. Public officials and planners also are too often uninformed about flood-hazard conditions. It is with them that the responsibility rests for understanding the magnitude and extent of a local flood problem, and for using this understanding to develop adequate programs of flood-damage prevention. Recognition of the flood hazard and its implications in a given area can be gained only after a careful analysis of the flood and land-use factors involved. Once this has been done, future plans for development can be formulated, which make proper allowance for the deteriorating and often destructive aspects of flooding.

Increased local concern.--The series of major flood disasters in the United States during the past decade has resulted in a growing demand for a critical re-examination of those flood-damage prevention policies emphasized by Congress and various federal agencies. There is increased interest in and concern about flood problems at the state and local levels of

government. There are indications that these governing bodies, cognizant of some of the defects inherent in the federal programs, may be willing to make attempts to achieve satisfactory adjustments to local flood problems.

However, this interest and willingness to undertake programs of flood-damage prevention at the local level is merely the point of beginning. It is important that procedures be made available by which recognition of a flood hazard can be gained before disaster occurs. In addition, it is important that federal programs be established in such a way that local and state programs are encouraged in the future.

Formulation of Guiding Principles

There is needed, then, a formulation of guiding principles or criteria, which can lead to a full understanding of the nature of local flood problems and their solutions. Such principles can be derived in broad procedural form only, not as ready-made solutions which can be applied indiscriminately to the flood problems of a given area. Each locality has distinct and varied characteristics. The specific objectives to be achieved through the mitigation of flood damage will also vary. Consequently, allowances must be made within the over-all procedural framework to meet unique local and regional conditions as solutions to flood problems are formulated.

Effective utilization of flood plains.--The principles formulated for a comprehensive approach to the solution of flood problems need to give proper consideration to the feasibility of future flood-plain development, as well as attempts to adjust existing uses to flood hazards. There are certain uses of such land that are desirable and even necessary in some instances. Moreover, proper adjustments to flood conditions can result in the satisfactory occupancy of flood plains by many types of use. An analysis of these factors must take into account the effect of flooding on a particular use of land, and conversely, the effect of this use on the passage of flood discharges.

No longer is it practical to confine considerations of flood-plain use and the mitigation of flood damage to the protection of existing development. Flood-damage prevention is not an end in itself; it is a means by which the general level of safety, health, prosperity and welfare of the people in an area can be raised. This approach to the solution of flood problems emphasizes the effective utilization of the flood plains. Dr. Gilbert F. White expressed this idea in Human Adjustment to Floods by stating:

> Dealing with floods in all their capricious and violent aspects is a problem in part of adjusting human occupance to the flood plain environment so as to utilize most effectively the natural resources of the plain, and, at the same time, of applying feasible and practicable measures for minimizing the detrimental aspects of floods. (5)

Procedures for the formulation of guiding principles.--If planning is to fulfill its obligation in the field of water

and land resource development, including flood-damage prevention, the approach to the problems encountered must be broad enough to account for the full range of developmental possibilities. Incorporated within the planning process, flood-damage prevention can be used as a tool to achieve specific economic and social ends.

The first analysis to be made as a part of the planning process, then, is the determination of the social and economic objectives to be achieved. Once this has been accomplished, the alternatives that are available as means to achieve these ends can be identified. Finally, the effects of flooding can be evaluated by studying their impacts on both the objectives sought and the means by which they can be achieved.

It is through this process that guiding principles can best be formulated. Moreover, these principles can include the whole range of developmental considerations, such as the economics of developing land subject to inundation, as opposed to the economics of developing flood-free land; or the necessity of utilizing flood-hazard areas for community expansion. Many of these considerations have been ignored in previous attempts to find solutions to flood problems. Therefore, it is necessary to review briefly these previous attempts and then to outline a comprehensive approach which can overcome the inadequacies of these attempts.

Attempted Solutions

Restricted Nature of Previous Approaches

Historically, flood-damage prevention has taken two courses. From the first protection programs which were undertaken by the people of New Orleans in about 1718 (6), until Congress enacted the 1936 Flood Control Act (7), flood-damage prevention was primarily a local responsibility. During this period only isolated federal programs were undertaken in California, in Florida, and along the lower Mississippi.

The 1936 Act declared that flood destruction was a national problem and established the interest of the Federal Government in the mitigation of flood damage. Since that time, most flood-damage prevention measures have been instituted under federal programs. However, emphasis is once more being placed upon the need for local action to produce more nearly adequate solutions for local flood problems, by those who are genuinely concerned about the course taken by the federal programs.

The lack of local participation in flood-damage prevention during recent years has left a gap which needs to be filled. It is the gap which has permitted unimpeded development of flood plains, regardless of the relationship between the needs of the stream to use the flood plain in times of abnormal flow and the use to which this land is put. The comparatively few local attempts at solution have, in general, been characterized by their restricted approach to the problem, as have the federal programs.

The Federal Flood-Control Programs

The approach taken to flood-damage prevention by the Federal Government has been one of providing protective works to lessen the flood hazard in areas where property values are high enough to justify such construction. This approach can be criticized primarily because "the provision of even a modicum of flood control invites continued and accelerated use of the protected area," and because "people tend to confuse a degree of flood protection with the elimination of floods." (8)

The major federal flood-control program has been carried out by the U. S. Army Corps of Engineers. Flood-damage prevention also comes under the jurisdiction of other federal agencies such as the Tennessee Valley Authority, the Bureau of Reclamation and the Department of Agriculture.

Lack of a comprehensive water resource policy at the national level to guide federal and local units as they undertake measures for flood-damage prevention increases the possibility that such programs will come to be viewed as ends in themselves. The attitude of "if we wait long enough, any project can be justified" is brought out in the following statement by George R. Schneider:

> At the rate of recent appropriations for new flood control work the present program will require almost 20 years for completion. Long before that time the growth of the U. S. will have made more works necessary ... flood control is an example of action and reaction. (9)

With the present number of authorized but not constructed projects totalling more than 700 and estimated costs approximating $9 billion (10), the size of the program staggers the imagination. When the cost of providing additional protective works to meet future demands, caused by further flood-plain encroachment, is added to this, the vastness of the undertaking makes its practicality questionable.

Protective works can play an important role in achieving a reduction of flood damage. In 1948 the Corps of Engineers estimated that the effect of these protective works which had previously been constructed along major streams was to reduce average annual damage from more than $800 million to approximately $400 million (11). These estimates were based on the degree of flood-plain development at that time. Flood damages along smaller streams are not included in this estimate.

However, this means of flood-damage prevention should be studied along with other remedial measures in relation to the objectives to be achieved. The over-all objective of flood-damage prevention is to reduce flood-damage potential, thereby lessening economic loss and social disruption. It would seem, then, that to satisfactorily achieve these ends, federal agencies should utilize all the measures of abating flood damage which may be applicable to a particular situation.

Land-Use Regulations

A general lack of flood data, few legal precedents, and the failure to fully understand the nature of the flood hazard are the principal reasons for the lack of an extensive application of land-use regulations in flood-hazard areas. Where the application of regulations has been attempted, vague provisions and statements of intent raise questions concerning the principles upon which these measures are based. Aside from the fact that local conditions make certain differences in regulation necessary, the range and type of provisions found in zoning ordinances which regulate the use of flood plains indicates that inadequate attention has been given to critical analysis of the factors involved.

Zoning.--Among the most stringent of such regulations is the Azusa, California (1949) Zoning Ordinance. Under its provisions the following uses are prohibited: all buildings or structures; mining and/or removal of rock, sand, and gravel, or manufacturing any products from the same for commercial purposes. By contrast, the zoning ordinance of Jefferson County, Wisconsin, enacted in 1937, provides only that no building may be constructed with its basement below the high water mark of the Rock River.

Between the two extremes cited, there are several regulations, enacted by counties primarily, that are comprehensive in nature (12). Particularly important is the

fact that these ordinances reflect an analysis of the values to be gained by proper use of the flood plain in addition to the damage to be prevented.

Subdivision regulations.--Subdivision regulations have been used even less than zoning ordinances as a flood-damage prevention measure. In several regulations, the problem of restricting the development of hazard areas is handled under "suitability-of-land" provisions. An example of such a provision is found in the 1955 DeKalb County, Georgia Subdivision Regulations, which read as follows:

> Land subject to flooding and land deemed to be topographically unsuitable shall not be platted for residential occupancy, nor for such other uses as may increase danger to health, life, or property or aggravate erosion or flood hazard. Such land within the plat shall be set aside for such uses as shall not be endangered by periodic or occasional inundation or shall not produce unsatisfactory living conditions.

Subdivision regulations reflect, in some cases, the concept that land subject to flooding must bear the cost of flood protection. Such provisions require the subdivider to install approved protective works or furnish a performance bond in lieu of the actual works. The full cost of development is thus paid by the developer, and the community is protected from demands to subsidize the occupancy of this land at a later date.

Evacuation of Hazard Areas

Complete removal of flood-plain uses has been advocated from time to time, but little has been accomplished.

Although the 1938 Flood Control Act (13) authorized the expenditure of funds for relocation as an alternative to the construction of protective works, there have been few instances where this authorization has been utilized.

Leavenworth, Indiana and Shawneetown, Illinois were given assistance for resettlement in areas free from inundation after the Ohio River flood in 1937 (14). Other than these two examples, the authority granted in the 1938 Act appears to have been used only in connection with the relocation of communities in areas to be inundated by reservoir projects (15).

Urban Renewal

Urban renewal was utilized in Scranton, Pennsylvania to adjust land uses to flood hazards. Its use in that particular situation emphasized three important facts: (1) urban renewal provides, for the first time, a feasible method of changing land use in hazard areas; (2) it is an effective procedure for achieving protection from future floods; and (3) the immediate action taken by the Federal Government indicates that such programs can be implemented soon enough to meet emergency needs (16). This approach, however, has not been utilized to its utmost as a means of damage prevention.

Need for a Comprehensive Approach

This brief review of the historical approaches to flood-damage prevention brings out, in part, the defects of

both local and federal programs. Major emphasis has been placed upon the construction of protective works and land-use regulations, while relocation and urban renewal procedures have been utilized to a lesser extent. The important point, however, is that in nearly every instance of attempts to reduce flood damage, only one method has been utilized. There has not been enough thought given to the complementary advantages of a combination of measures which could be applied to the solution of a given flood problem.

Whether a flood-damage prevention program is undertaken in a community by federal, state or local agencies, or a combination of these, each possible method of solution should be given consideration. Then programs can be formulated which are comprehensive in nature; i.e., all of the methods of reducing flood damage that are applicable to a local situation can be coordinated.

CHAPTER II

FLOOD AND LAND-USE FACTORS

General Considerations

Although the flood problem is one of great magnitude, effective solutions can be formulated if flood damage is recognized as a combination of natural forces and land use. Floods are natural phenomena, to be sure, but flood damage occurs only when man places improvements in the path of these flows.

Recognition of the flood hazard in a locality can be brought about by a careful analysis of the flood and land-use factors concerned. These factors are too often analyzed separately; flooding as it relates to property damage, and land-use as it relates to community expansion. Little thought is given to the evaluation of sach set of factors as it relates to the other.

The first step in planning for flood-damage prevention still must be the isolation and identification of these factors on a separate basis. Once this is done, however, it is necessary to bridge the gap between floods and land use by determining their interrelationships. It is in this manner that planning for future community development can take into account the degree of hazard associated with the utilization of areas subject to flooding.

Flood Factors

Collection and Analysis of Data

Hydrology, in its broadest sense, is the science that deals with the natural processes which result in the reduction and replenishment of the earth's water resources. With respect to flood-damage prevention, it is necessary to consider only a limited number of the factors involved in these processes. More specifically, the hydrologic factors which govern the runoff characteristics of a watershed during floods need to be considered.

Flooding is related not only to storm characteristics, but also to watershed features. The watershed features which are of particular importance are the character of the terrain, the capacity of a stream channel and the extent to which its flood plain is utilized during periods of overflow. The investigation of these factors lies outside the realm of the planner; it is the job of the hydrologist to identify and evaluate the role of each with respect to local flood conditions. The planner is primarily concerned with the results of these investigations, which yield important facts about the flood characteristics of a watershed.

Sources of information.--Most planning staffs do not have the adequately trained personnel needed to conduct a thorough investigation of flood factors. In addition, few technical flood reports present the necessary data in a form useful

to planners. There are, however, at least three examples of flood reports that provide the type of information necessary for understanding the nature of a local flood problem.

The first of these is the comprehensive study of local flood problems which was published in 1952 by the Santa Clara County, California Planning Commission (17). It includes the results of an investigation of the factors which contribute to land inundation in the Santa Clara Valley. Besides presenting the data in a manner which leads to an understanding of the flood problem, this report stresses the interrelationship between floods and land use. The solutions proposed are tailored to fit the unique drainage problems in the valley, of which land subsidence and tidal flooding are contributing factors.

The second example is the approach used by the Tennessee Valley Authority. Communities in the Valley which need assistance in attacking their flood problems can obtain hydrologic data from the Authority. These comprehensive data concerning historical as well as possible future floods are presented in reports which can be utilized by the community as a basis for further consideration of local flood problems. The program "is based on genuine teamwork in which TVA--the federal agency--provides the hydrological facts, the state planning agencies furnish the personnel skilled in planning and in state customs and laws, and the local community makes the final decisions." (18) Reports have

been prepared for some thirty-four communities in the Valley, since the program was initiated in 1953.

The third, but slightly different type of report from which limited, though useful, data can be obtained, is illustrated by a recent publication of the Indiana Water Resources Study Committee (19). The report and its technical appendix present the results of a comprehensive hydrologic analysis of every watershed in the State of Indiana. Although it was oriented to the beneficial use of water resources, data from such a report can be adapted and used in planning for flood-damage prevention. However, for this latter purpose, supplementary information in the form of channel cross sections, flood hydrographs, flood profiles and storm studies are needed.

In areas where adequate flood studies are not available, they should be initiated to provide the necessary basic data. In every case, the fullest possible use should be made of state and federal agencies which are concerned with the collection of flood data and the analysis of flood factors.

Types of data required.--To be most useful, the flood data collected must include a wide range of information which can be used as a basis for understanding the nature of the flood problem in a particular area. The specific facts needed can be summarized as follows:

1. Extent of inundation.
2. Depth of inundation.

3. Duration of inundation.
4. Rate of rise of flood waters.
5. Velocity of flood waters.
6. Frequency of flooding.
7. Topographic maps.
8. Channel cross sections.
9. Regional flood.
10. Maximum probable flood.

From the data collected the unique characteristics of flooding in an area can be determined. An analysis of the first six items in this list should be made for the highest flood of record, the regional flood and the maximum probable flood. These characteristics are shown in summary form, by Figures 1-4, on pages 20 through 23. A more detailed presentation of these factors is included in the work by Siler (20).

Channel and Flood-Plain Characteristics

The physical characteristics of a stream's channel and flood plain determine the quantity of water that can pass a given point per unit of time, the velocity of flow, and the height floods will reach. The basic determinants are the cross-sectional area, slope and roughness of the channel and plain. These determinants of flow are all interrelated and interdependent. However, the cross-sectional area is the feature most likely to be altered by man.

Comparatively few natural stream channels can pass high floods without overflowing and utilizing the flood plain as flowage and storage areas. In most instances the flood plain assumes an important role during periods of high water. To function in the manner in which nature

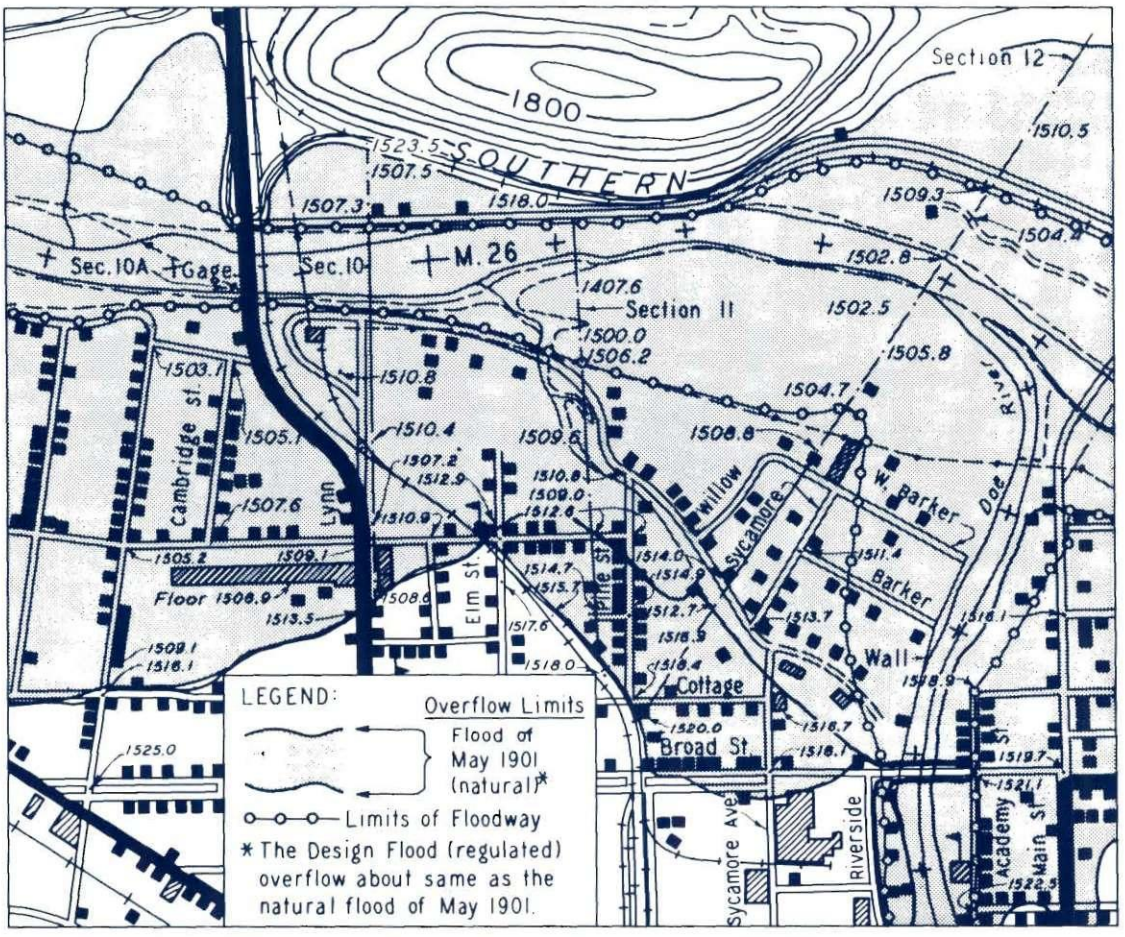


Figure 1. Areas Inundated by Floods and Limits of a Proposed Floodway.

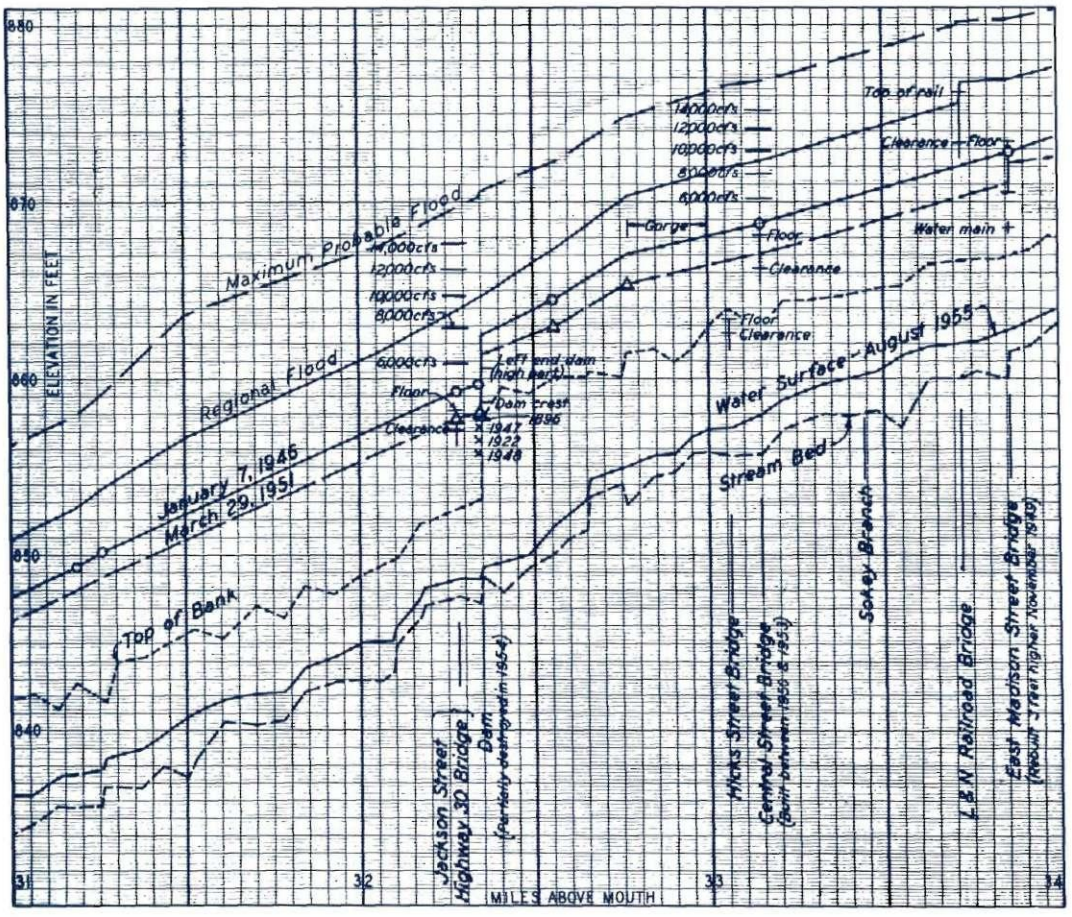


Figure 2. Profile of Various Flood Elevations.

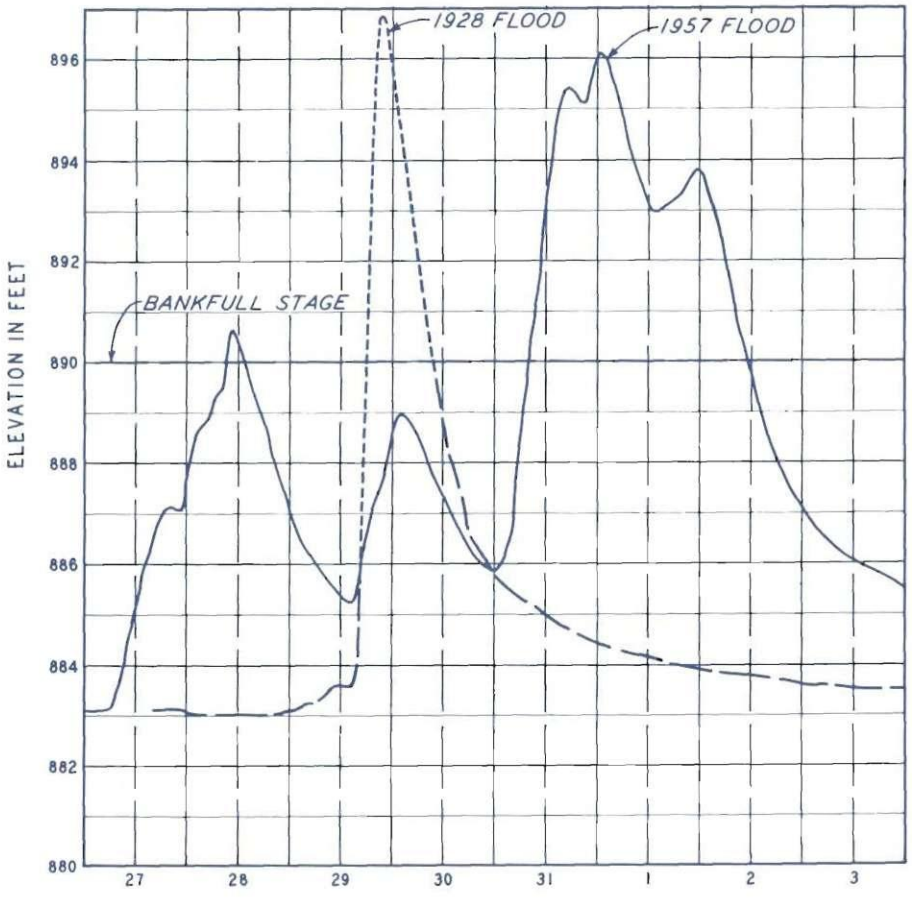


Figure 3. Rates of Rise and Fall and Duration of Floods.

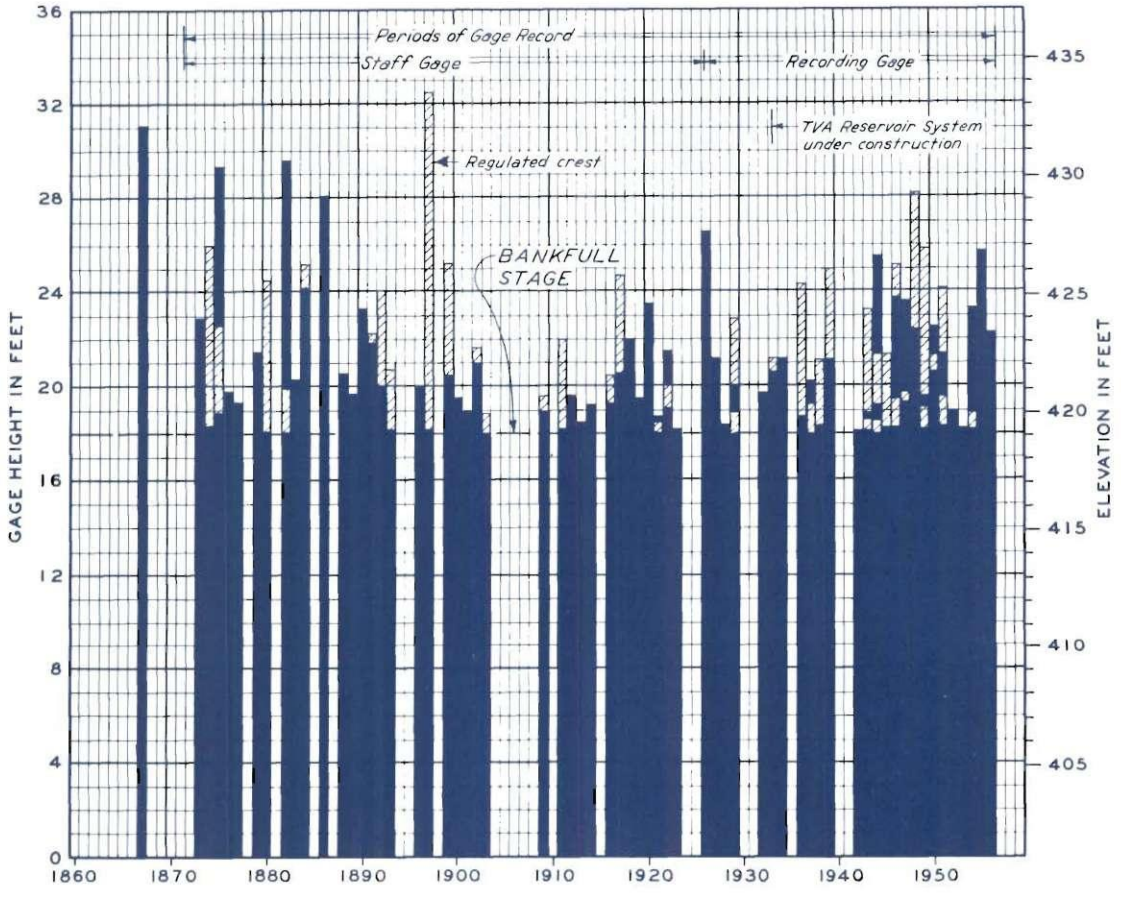


Figure 4. Dates and Respective Heights of Floods.

intended, the channel and portions of the flood plain must be kept relatively free from obstructions which impede flow or significantly reduce overbank storage.

Effects of obstruction on flow.--Of importance, therefore, is the determination of the effects of obstructions, particularly of man-made obstacles, on the passage of flood waters. Those obstructions which have the most adverse effects upon discharges are restrictions, such as limited bridge openings and earth-fill embankments.

In addition to these permanent or immovable obstructions, consideration should be given to such movable objects as buildings, fences, bridge floors and the like that can be washed loose and become lodged in restricted openings to further limit flow. Examples of obstructions to flow are shown on Figure 5, page 25.

In many localities, such impediments have the serious and detrimental effect of raising upstream flood heights and thereby increasing the flood hazard in those areas. Data should be gathered and evaluated concerning the effect of obstructions located in the flood plain. Although the effects of flood-plain obstructions on flow are engineering considerations, proper land-use planning can play a role in minimizing the number and character of obstacles placed in the path of flood flows.

Flood Frequency and Magnitude

Flood frequency.--At the present time flood records are too

Buildings crowding banks and protruding into the channel reduce capacity of the stream and increase flood heights.

Highway fills across plains coupled with bridges having inadequate openings obstruct flow and increase elevations of flood waters upstream. Effect was more than four feet here during this flood.

Figure 5. Examples of Obstructions to Flow.

short to permit reliable studies and conclusions with respect to the frequency of floods of different magnitudes. "It is most important to realize that floods of certain magnitudes don't occur in regular cycles of 10 years, 25 years, 31 years or any other cycle." (21) Floods that reach a given height once in fifty years could be called 50-year floods. This indicates only that there is a probability of 1 in 50 that this size flood will occur in any year.

There is a relationship between flood frequency and magnitude, with floods of lower magnitude being those of greater frequency. However, this relationship cannot be correctly stated in more specific terms unless the period of flood records is quite long. It is important, therefore, to evaluate flood data on the basis of flood magnitudes that have occurred and those which can be reasonably expected in a particular area.

Highest flood of record.--The highest flood of record is the maximum flood that has occurred during the period for which records are available. The length of flood records varies considerably from locality to locality. Moreover, the number and size of floods that have been recorded in a particular area may not even be similar to those experienced in adjacent watersheds.

The highest flood of record merely represents an historical fact. It may or may not be a good indication of flood magnitudes which can be expected to occur in the future. Therefore, this flood should be compared to floods

that have occurred in the immediate region, as well as to the maximum probable flood.

Regional flood.--It is useful to evaluate the occurrence of large floods in the general vicinity of the watershed under study. Quite often flood histories show that storms have been experienced which brought heavy precipitation and resulting high floods to nearby watersheds. It is reasonable to expect that such storms can occur in the future over any watershed in a limited geographic region of similar physiographic and climatic characteristics. It is, therefore, desirable to consider the magnitude of these floods in determining the size of flood which can be expected to occur in a specific location.

Discharges for these known floods can be plotted as shown on Figure 6, page 28. Each flood should be given a reference number so that it can be associated with the location, date and drainage area in which it occurred. If the highest flood of record in the locality being studied is also plotted, a comparison can easily be made between the magnitude of floods which have been experienced in a locality and the maximum known floods which have occurred in the general vicinity.

This analysis yields the magnitude of the regional flood which can be expected to occur in a particular locality. Once this determination is made, the other characteristics of this flood can be obtained. This regional flood,

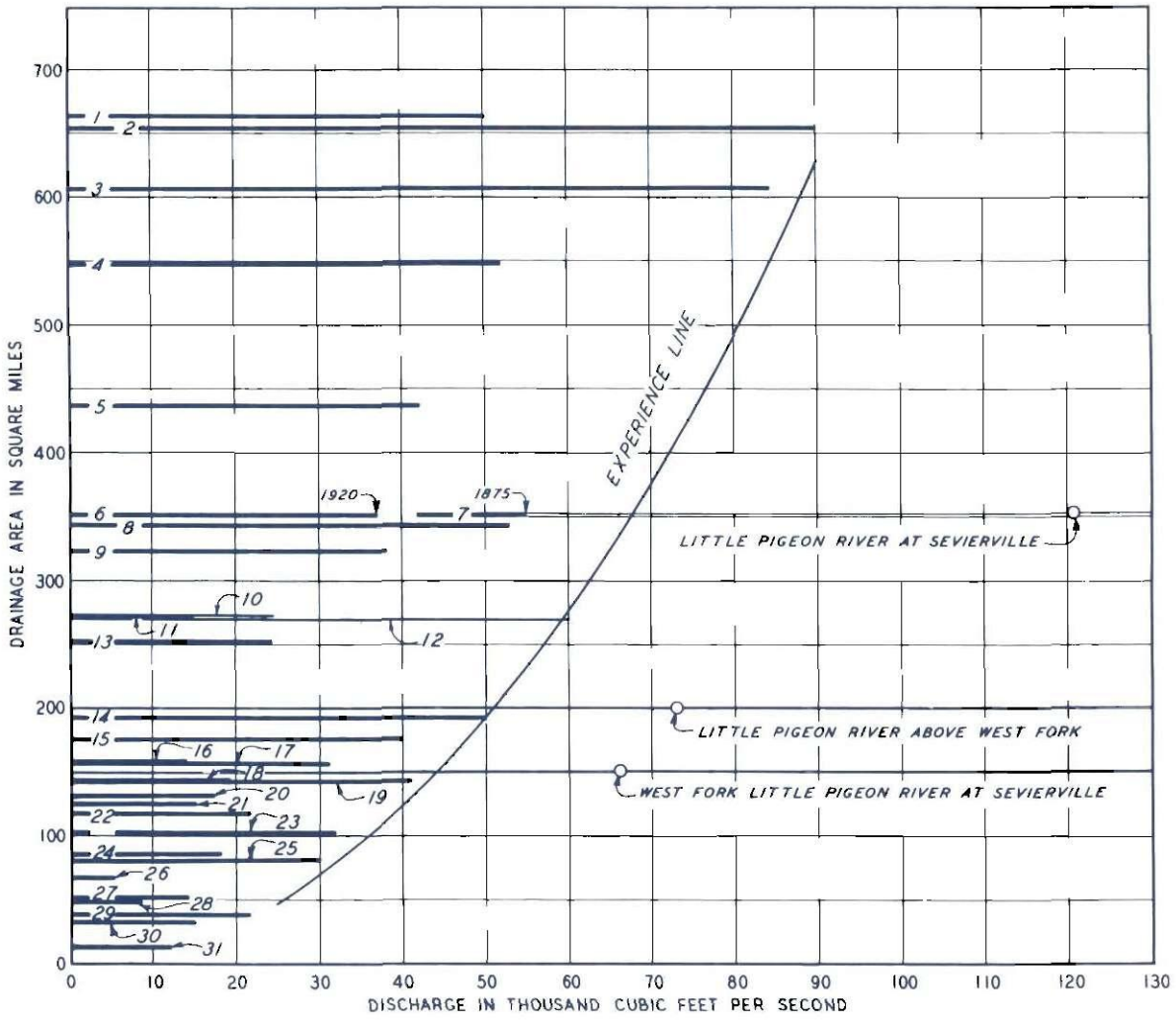


Figure 6. Floods of Record Within a Region.

however, is rarely as great as the maximum probable flood that could occur, but its frequency would be greater than the higher flood.

Maximum probable flood.--The maximum probable flood is the greatest flood which can be reasonably expected, taking into account pertinent conditions of location, meteorology, hydrology and terrain. It can be calculated from appropriate great floods that have occurred elsewhere, or by transposing observed great storms. This flood could result from a critical combination of meteorologic and hydrologic events which could occur within a broad geographic region.

Such a combination of events occurred before and during the devastating Kansas River flood in 1951. This flood resulted from two months of greater than normal precipitation over the entire basin. The period of excessive rainfall was "culminated in the four days, July 9 to 13, during which 10 inches or more of rain fell on more than 10 per cent of the watershed with a peak downpour of 17 inches." (22) High runoff resulted in the inundation of valuable agricultural land and parts of many cities in the valley. The two Kansas Citys were the hardest hit when the flood peaked there on July 14, causing damages estimated at nearly one-half a billion dollars (23).

Catastrophes such as this can be expected to occur only infrequently in a long period of record. They can occur, however, in any given year or even in successive

years. Although it is unlikely, great floods such as these may be exceeded at some later date.

The reason for this uncertainty lies in the fact that hydrology is not an exact science by which future combinations of events can be forecast with a high degree of confidence. Because of this, the limitations of any data collected must be recognized. Judgment values must often supplement hydrologic facts in actual practice.

Delineation of Flood-Hazard Areas

Problems of delineation.--Siler points out that:

> Delineation of the flood area and its classification by permitted uses and required standards would be a relatively simple task if information and techniques were available for the accurate prediction of the frequencies and magnitudes of future floods. (24)

If such were the case, the determination of the recurrence interval of a flood of given magnitude would provide a legislative body with the information needed to guide its decision concerning the delineation of flood-hazard areas.

The fact remains that the information that can be obtained is the only basis upon which principles can be formulated. Recognizing this consideration, the approach must be one where:

> Cautious use of such records of past flood damage, stream flow and rainfall as are available, coupled with careful observation in the field of terrain, watershed development, and all other factors likely to affect flood flows, may permit determination of at least the most hazardous areas. (25)

This introduces an additional element of caution associated with flood-hazard area delineation. It is the fact that:

> Inherent in the establishment of any area as unsafe because of possible flooding is the implication that the areas which are not thus delineated are secure from possible damage from floods. The degree to which the danger of this implication exists depends on the criteria used in establishing the limits of flooding. (26)

Therefore, delineation of hazard areas must be undertaken with full recognition of the data limitations and the possible consequences of improper evaluation of factors concerned. Delineation must also be made according to the differences in hazard within the total area subject to flooding. This determination is usually more difficult than defining the limits of the total hazard area.

Differences in the degree of hazard.--For most practical purposes the flood-hazard area can be defined by the magnitude of the maximum probable flood. The degree of flood hazard is the greatest in the stream channel and varies according to the physical features of the flood plain out to the limits of the area inundated by the maximum probable flood. Although larger floods are possible, they would occur so infrequently that the outer limits of this area may be considered the point of zero hazard.

Floodway and floodway fringe.--Within the flood-hazard area, the floodway and floodway fringe should be delineated. The floodway is the minimum area required for the passage of flood flows without unduly affecting flood heights upstream.

The floodway fringe is the area bordering the floodway, but within the total area that would be inundated by a selected flood. The floodway fringe does not contribute appreciably to the passage of flood flows.

It is the floodway required by nature which should receive careful consideration in planning for flood-damage prevention. Once it has been properly delineated, measures can be undertaken to keep it as free as possible from encroachments.

The initial step in determining the extent of the floodway is the selection of the flood magnitude which is to be used as a base. This index point logically becomes the maximum probable flood, since it is the greatest discharge that can reasonably be expected. The extent of the floodway can be determined by the relationship of known flood flows to the magnitude of the maximum probable flood.

The floods to be analyzed include:

1. Maximum probable flood.
2. Regional flood.
3. Highest flood of record.

The highest flood of record and the regional flood may be, but seldom are, of equal magnitude. Moreover, they do not necessarily approach or equal the maximum probable flood. Where these three discharges are found to be of nearly the same magnitude, it is reasonable to base the delineation of the floodway upon one of these high flows.

However, if the maximum probable flood is considerably greater than either or both the regional flood and the

highest flood of record, further analysis is required to reasonably delineate the floodway. In this instance, delineation could be based upon either the regional flood or the greatest flood of record.

Stage-area relationships.--In many instances justification for selecting a given flood magnitude cannot easily be shown. To aid in the determination of the floodway in such situations, the relationships between flood heights and areas inundated can be utilized.

The areas inundated by each discharge being considered could be plotted from the flood data. In plan, this would result in a map having a somewhat similar appearance to that of a contour map. For further study of stage-area relationships, the height of each flood should be plotted on the cross sections obtained for the stream channel and flood plain. This method is illustrated by Figures 7 and 8 on pages 34 and 35.

In this manner, the effects of successively higher floods in an area can be readily visualized. A determination can then be made of the advisability of selecting a flood of a given magnitude to be used as the basis for the delineation of the floodway. For example, the same magnitude of discharge could have quite different effects if the flood plain were broad and level than if the flood plain were narrow with sharply rising edges.

Required legislative determination.--Flood data can only point out the facts concerning historical overflows, and

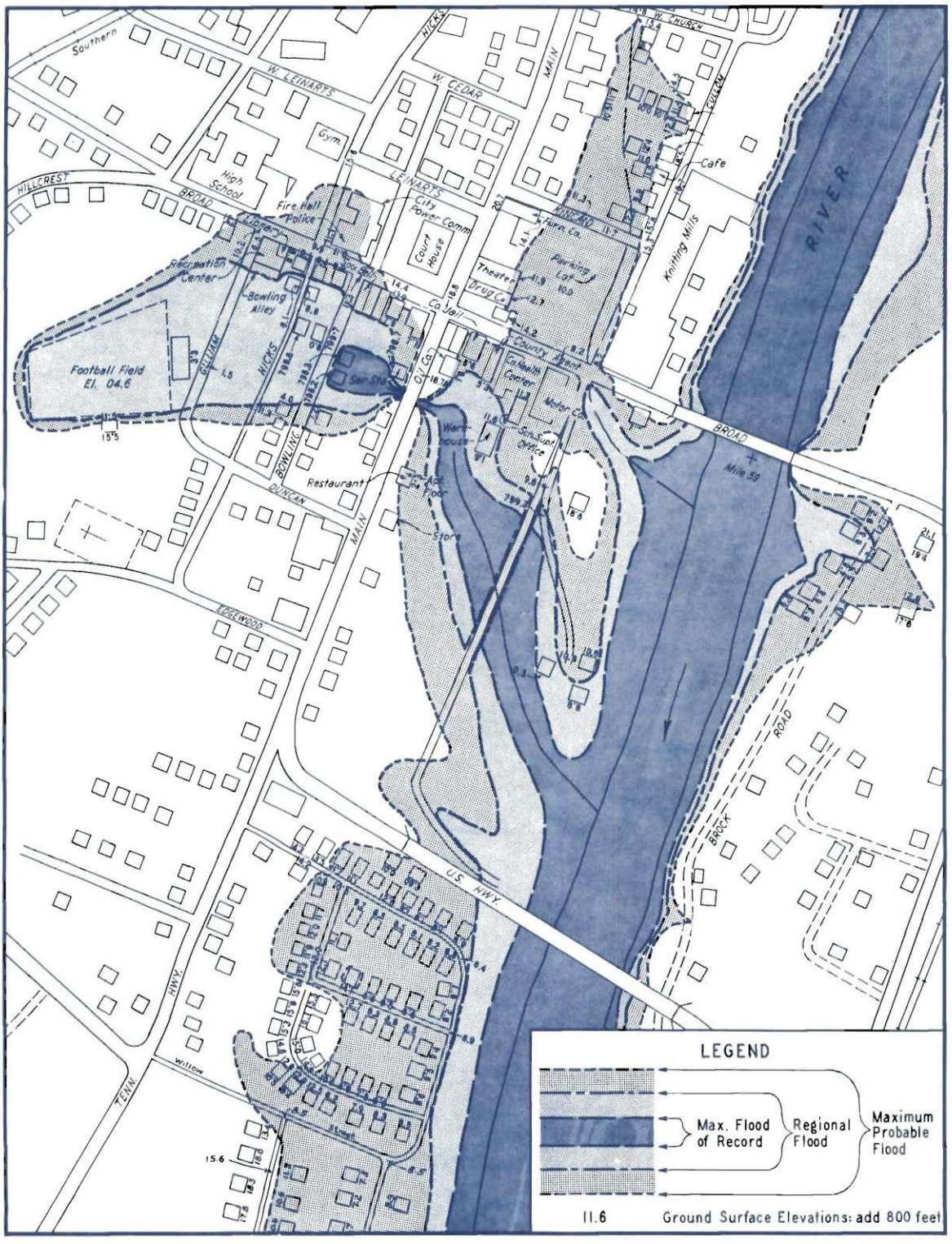
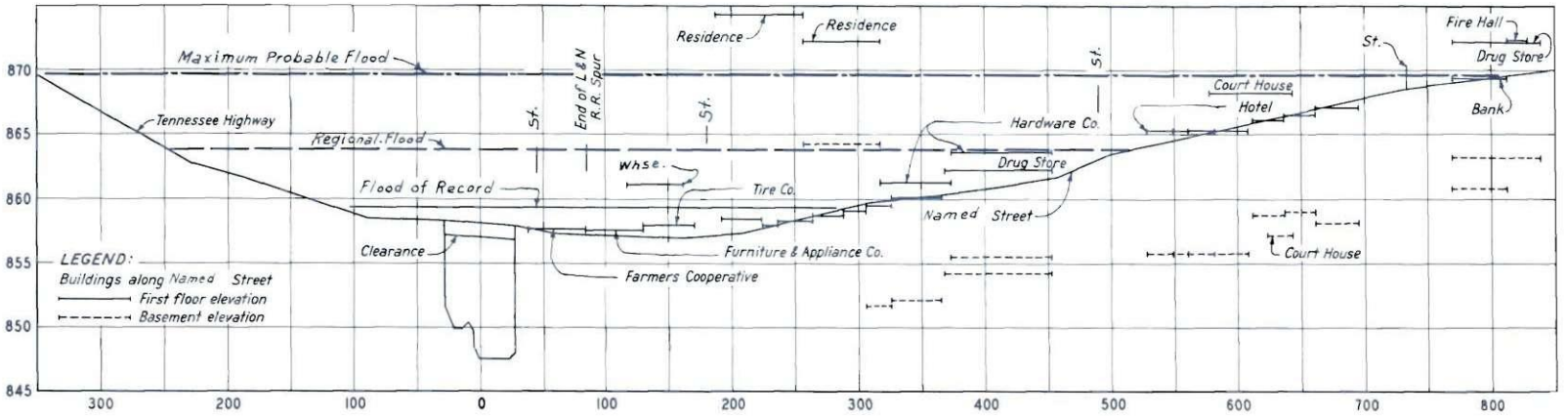


Figure 7. Stage-Area Relationships in Plan.



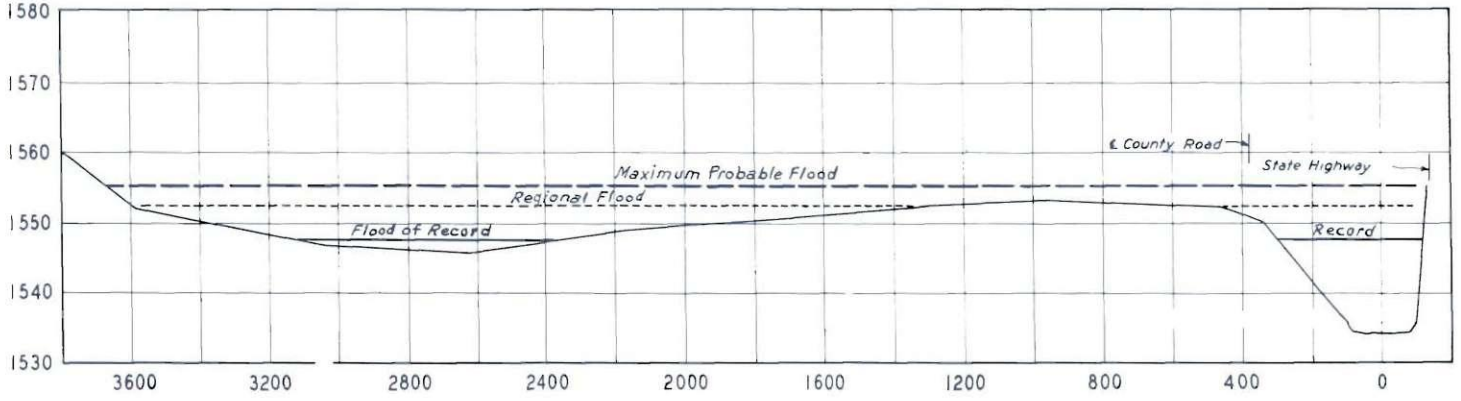


Figure 8. Stage-Area Relationships in Cross Section.

indicate the size of floods that can be reasonably expected at some unknown date in the future. When properly collected and thoroughly analyzed these data lead to an understanding of the nature of a local flood problem, from the hydrologic standpoint.

In the end, the selection of the magnitude of the flood to protect against or make adjustment for becomes a matter of decision-making on the part of the local governing body. This flood magnitude in turn is the basis for defining the limits of the required floodway and the floodway fringe. The flood magnitude and other flood characteristics indicate the hazard potential associated with floodplain occupancy.

This determination establishes the basis upon which public policy can be formulated with respect to hazard areas. It then becomes a matter of relating these flood factors to the use of land, and of determining the objectives to be achieved through flood-damage prevention measures.

Land-Use Factors

Land-Use Determinants

"Urban land use is a term commonly used to refer to the spatial distribution of city functions...." (27) The pattern of residential, commercial, industrial and public uses of land is the result of the interaction of three major forces. These forces are social, economic and public

interest in nature and can be referred to as the determinants of land use.

The interrelationship of these factors is extremely complex and is often not readily susceptible to identification and analysis. Moreover, in a dynamic society the relationships between these forces are fluid; the old relationships are modified and new relationships are evolved to meet the needs of a changing environment. Although the complexity of interrelating these forces cannot be stated in specific terms, elements of each determinant should serve as guideposts for the technical studies made in the course of planning for the use of land.

Land-use planning in the past can be viewed as somewhat restrictive in nature, placing emphasis upon the public interest determinant. There is a "need for a balanced consideration of economic, socially rooted, and public interest factors throughout the land use planning process." (28) As yet there has been little done towards establishing the systematic framework within which each of these factors can be evaluated and properly weighed. Until this is accomplished, the balance between economic, social and public interest determinants remains an objective to be sought, but one which may be difficult to achieve.

Land-Use Planning

Narrowing the consideration of land-use factors from concepts to methods of identification and analysis, it is

necessary to outline the studies which are needed to provide the basis for the formulation of a comprehensive land-use plan. This land-use plan is the framework, or guide, within which each proposal for the use of land can be evaluated with respect to over-all community development.

General studies.--The comprehensive land-use plan is formulated and kept up to date on the basis of population, economic and employment studies which are guideposts in determining the amount and nature of future urban growth. Results of these studies enable the planner to estimate the future land-use needs of a community.

These future requirements are then studied in relation to existing development. The net result in the case of a dynamic city is the need for additional land to meet future growth demands. A further breakdown of these anticipated requirements is made according to the type of use; estimates of the amount of land needed for residential, commercial, industrial and public development are obtained.

This does not mean to imply that it is possible to determine that at some pre-assigned date there will be a demand for a given amount of land to be used in a specific manner. To the contrary, as a community grows, these requirements must be met on a continuing basis, with the land-use plan serving as the guide to development.

Urban land studies.--The two ways to meet these future demands are through utilization of presently vacant land or

by re-ordering existing land uses by redevelopment. An evaluation can be made of the comparative desirability or feasibility of putting such lands to their best use. Such an evaluation can be made on the basis of data collected as the result of the following studies:

1. Topographic mapping.
2. Existing land-use survey.
3. Vacant land survey.
4. Structural and environmental quality survey.
5. Cost-revenue studies of land use.
6. Land value studies.
7. Studies of aesthetic features of the urban land.
8. Studies of attitudes and preferences regarding land use.

A full discussion of the collection and analysis of data with respect to these studies is presented in the work by F. Stuart Chapin, Jr. (29) Once this step has been taken, a sketch plan can be prepared showing a desirable pattern of land uses. After further refinement and public discussions, the land-use plan can be completed. This process should result in "the best practical, most economical, and attractive design for all uses, fitted to the topography and the existing land use pattern and articulated with the circulation system." (30)

Objectives of land-use planning.--The objectives sought through the formulation and implementation of a comprehensive land-use plan can be stated here in broad terms only. Specific objectives to be achieved will vary among different cities. These goals should be identified by the planning commission, but it is the role of the planner to present the alternatives which should be given consideration.

In general the objectives of land-use planning are: (1) to promote the economic, social and cultural values which create a desirable environment for living; (2) to promote the health, safety, and general welfare of the people; (3) to achieve an efficient and economical distribution of land uses; (4) to coordinate the use of land with transportation networks to facilitate the movement of people and goods; (5) to coordinate the development of the community with the development of adjoining cities, unincorporated areas of an urban character and rural areas; and (6) to provide the basis for expenditures for public improvements.

These objectives are manifested by the planning of residential areas which are free from excessive traffic, noise or smoke, floods and other hazards, and which are located in such a manner that ready access is available to schools, shopping areas and recreation facilities; by the planning of commercial areas to which easy access is possible in the movement of people and goods; by planning for the location of industries in such a manner that their objectionable features can be minimized; and so on to infinity.

CHAPTER III

RELATIONSHIPS BETWEEN LAND-USE AND FLOOD FACTORS

Objectives of Land-Use Planning Related to Flood Hazards

Land-use planning with respect to flood-hazard areas has two primary objectives: (1) to bring about the most effective use of the flood plain, consistent with over-all community development; and (2) to promote the health and safety of the present occupants of land subject to flooding.

Planning for the future utilization of land subject to inundation involves an evaluation of both flood and land-use factors. Basic land-use considerations are thus tempered by the implications of the risks involved by the occupancy of hazardous areas.

Provision of the Required Floodway

Construction and reconstruction of homes, factories and businesses in flood plains and even into stream channels has inevitably failed to make compensation for the disruption of the normal function of streams and their flood plains. The problem becomes one of re-ordering the uses in areas subject to inundation so that the floodway required by nature can be provided. The problem of adjusting existing

uses to flood hazards is of considerable magnitude, as pointed out in Chapter I, but a primary goal of planning is limiting further, unwise development in flood-hazard areas, particularly within the floodway.

It is in this respect that planning can make its greatest contribution if flood-damage prevention is ever to become more than a case of "action and reaction." For it is only through the planning process that the economic, social and public interest determinants of land use can be considered and related to flood hazards. Before any program to mitigate flood damage can be formulated, full consideration of future development, feasibility of existing uses, and the possible need to redevelop certain areas must be given to flood-hazard areas.

Future Development in Flood-Hazard Areas

Vacant Land Classification

The potential development of urban land is generally associated with the utilization of presently vacant land. Thus, as a part of the land-use planning process, the suitability for development of the vacant areas in a community should be determined. The location, amount and characteristics of this land can be determined by a vacant-land survey, which is usually made in conjunction with a land-use survey.

In considering vacant land, a mere summation of the areas available is not sufficient. A classification of this

land according to its location, topographic and drainage features, the size of tracts and the availability of utility and transportation facilities to service it is necessary. By classifying land according to these characteristics, its suitability for development can be determined for various uses.

Standard system of classification.--Chapin (31) suggests a simplified classification system for vacant land based on physiographic features and use potential reflected by the improvements available. Broad classifications of "prime" or "marginal" land are made depending upon the suitability of land to be developed without extensive site modifications. Subcategories are then established to reflect the availability of improvements.

Implicit in his classification is the assumption that all land subject to inundation requires extensive site modification to meet suitability requirements, and is, therefore, marginal. This assumption suffices to categorize adequately land frequently or continuously inundated. However, it in no way takes into consideration differences in flood magnitudes, and the varying topographic features of the flood plain, which determine the degree of hazard associated with flood-plain utilization.

Classification according to the degree of flood hazard.--A classification is needed, then, that reflects not only the physiographic features, but also the degree of risk involved

with the development of flood-hazard land. Once again, if the determination of future frequencies and magnitudes of floods could be predicted with certainty, this problem could be readily overcome.

It is the judgment of the degree of risk in such areas that may determine whether land modifications are necessary to obtain suitable building sites. Terrain features in a portion of the hazard area may be such that the risk involved is felt to be sufficiently small to make unnecessary extensive modifications of the site. However, there remains a certain amount of risk involved in the use of this location. Such land cannot be then correctly classified as either marginal or prime.

Therefore, in areas subject to inundation, a refinement of this classification is necessary. The answer lies in the methods used to delineate flood-hazard areas. The limits of the flood-hazard area are established by the maximum probable flood. Within this area the floodway and floodway-fringe areas are delineated by the magnitude of a flood selected by the local governing body as the flow to protect against or for which land-use adjustments should be made.

At the risk of oversimplification, it appears that one additional category could be added to Chapin's classification to account for these functional characteristics of flood-hazard land. This can be accomplished by upgrading

the term "marginal" and adding the classification "sub-marginal" to describe areas frequently or continuously inundated, such as swamps and tidal basins, and the floodway.

That portion of the flood plain between the floodway and hazard-area limits would be classed as "hazard-marginal." Whether extensive site preparation is or is not deemed necessary, the classification "hazard-marginal" would carry the connotation of risk involved in the development of such land. Only that land which is free from flooding and which does not require extensive site preparation can be classed as prime. This would be land having an elevation above the height of the maximum probable flood.

After classifying the vacant land in the community on the basis of physiographic and risk characteristics, the next step is the evaluation of the availability of utility and transportation facilities. Each area can be given a rating based on the presence of water, sewer, gas, electricity, highway and railroad improvements either crossing the land or near its boundaries.

Conceivably, the existence of these improvements could upgrade hazard-marginal land to the point where it should receive equal consideration with prime land to which such facilities are not available. This determination, however, depends upon public policy with respect to the use of these areas.

Determination of Appropriate Flood-Plain Uses

Advisability of the utilization of flood-hazard areas.--The feasibility of including vacant flood-plain land in plans for future community development depends in part upon whether a given use of land is highly susceptible to flood damage. It becomes a matter of choosing between alternative locations for given uses; balancing the advantages and risks of flood-plain occupancy with the availability of suitable sites elsewhere.

During the formulation of the land-use plan, the advisability of and need for developing certain parts of flood-hazard areas should be studied. The vacant-land survey and the subsequent classification of such land in an urban area will point out the desirability of using hazard-marginal and possibly sub-marginal land for future expansion. However, at the present time few communities require additional area badly enough to justify the development of sub-marginal land.

Exclusion of residential development.--In general the public interest overrides the development of flood-hazard land for residential or other purposes where the health and safety of the occupants would be endangered. This is particularly true for floodway areas. Furthermore, if such uses are permitted in the floodway-fringe areas and the remainder of the flood-hazard area, adequate safeguards in the form of design criteria should be enforced to render structures safe from floods.

Industrial location.--Recent trends in industrial development point to the fact that large tracts of easily assembled land are desirable and even necessary for modern methods of industrial operation. New plants often occupy only a small portion of the total site. The bulk of this area is usually devoted to parking, loading facilities and landscaping. This less intensive development immediately reduces the potential hazard from that which exists in older, more intensive industrial developments in the same type of area. Conversely, the capital investment in the new facilities is proportionately greater. Destruction or extensive flood damage might, therefore, result in relatively greater economic loss.

Unless economic and location factors greatly overbalance the risk of potential flood damage, industrial development of flood-hazard areas should be limited to certain types of industry and to areas beyond the limits of the floodway. Examples of such industries include pulp and textile mills or chemical and metal-processing plants which require large quantities of water and discharge great amounts of effluent. Quarrying operations, which utilize the land resources of the plain, are other examples.

Water-transportation terminal facilities are another type of land use which must be located in the flood-hazard area of navigable streams. Minimization of flood damage to these facilities depends to a great extent upon the efficient removal of goods from the terminal, so that raw

materials and merchandise are not stored within hazard areas for long periods of time.

Commercial uses.--Wholesale and distribution uses which require the stocking of large quantities of goods are particularly susceptible to water and silt damage. Site needs for these uses are flexible enough that locations free from flooding can usually be found.

Certain commercial activities are being increasingly oriented to drive-in customers. As such, they have become open-type uses to a great extent. That is, structural floor areas are small with respect to total site requirements. Examples of these uses which could be located in flood-hazard areas are commercial recreation facilities, parking lots and structurally-open parking garages, drive-in theaters and used-car lots.

Even though shopping centers are examples of extensive development, contemporary slab-on-ground construction and large areas of plate glass make such uses undesirable from the standpoint of structural and merchandise damage. Shopping centers should be convenient to residential areas, and therefore, their location in hazard areas will not usually be a major problem if residential uses are prohibited in such areas.

Central business district expansion in areas subject to inundation is undesirable as a general rule. However, if a given location has sufficient value to the developer,

the risk of occupancy may have little effect in curtailing construction. Measures of structural adjustment or design should be enforced to lessen the adverse effects of flooding in such instances.

Public uses.--Increasing urbanization has resulted in a lack of open space in many areas. The need for park and recreation areas convenient to the people for leisure time activities is likely to increase in the future. Many communities have recognized the importance of the recreational resources of flood plains and have acquired these areas for such uses. Flood-plain land can be left as natural parks or developed as golf courses, picnic areas and even stadium areas. Milwaukee County, Wisconsin has incorporated streams and their overflow areas as a part of its parkway system.

Finally, an evaluation of land use must include an analysis of public works and improvements and their relation to the local flood problem. The planning of public improvements, such as water and sewerage treatment plants, transportation facilities and public buildings, requires the same type of consideration that is accorded private development, with respect to flooding.

The proper location of these facilities, so that the least amount of disruption of service can be assured for the community during floods, is important. Partial or complete disruption of service affects the lives of many who are often far removed from the hazard area. The failure of a bridge can result in the loss of time and money to many

people. Flooded water treatment plants cause a shortage of potable water. Inundated public offices can result in the destruction of valuable and irreplaceable records.

In summary, these are some of the factors which should be given consideration in determining the role that flood-hazard areas are to play in the future development of a community. Both a system of land classification and a procedure for evaluating development in flood-hazard areas were presented. The latter can be utilized in analyzing existing development in flood-hazard areas. Both methods can be utilized in re-use planning.

Analysis of Existing Uses in Flood-Hazard Areas

Methods of Analysis

An evaluation of existing land uses in flood-hazard areas is important from the standpoint of determining the type and amount of adjustment which should be made to mitigate flood damage. Within these areas, there may be uses which can and should play a major role in the continued prosperity of the city; uses which can no longer be justified from either an economic or social viewpoint; uses which impede flood discharges or are subject to extensive flood damage; and uses which place a financial burden on the community, because they fail to adequately compensate for services provided.

The analysis of the amount and nature of future

land-use needs in a community provides the framework within which the existing uses of flood-hazard land, which are a desirable part of the urban environment, can be identified. At the same time those uses which are not in accord with an efficient and amenable development of this land can be determined. The methods which can be used to identify these relationships between existing and suggested future land uses include analyses of: (1) property valuation trends; (2) structural and environmental quality; (3) cost-revenue relationships; and (4) stage-damage relationships.

Property valuation trends.--Trends in property values, based upon market value appraisals, can be useful in determining the desirability of using areas subject to inundation from the standpoint of the developer. This determination not only identifies the market forces operating, but it also points to the popularly accepted degree of risk associated with flooding.

Building permits in these areas should be examined and the costs of development compared to market value. This cross check can be used to determine the accuracy of valuations. Moreover, the trends in type and amount of development in flood-hazard areas can be established.

These areas are often among the substandard, or blighted, sections of a community. The deteriorating effects of repeated inundation can be responsible in whole or in part for blight in hazard areas. Repeated flood

damage or the risk of future economic loss may lead to an unwillingness on the part of the hazard-area owners and occupants to maintain or repair their properties. Deterioration can thus be the result of water and silt damage which compounds the normal effects of weathering; or it can be the result of neglect.

Low market values and tax assessments in hazard areas may compensate for the financial risk taken by the development of this land. This condition may encourage land uses which cannot effectively utilize the resources of the stream and its flood plain, but which would locate in these areas because of low land and tax costs.

Structural and environmental quality.--The extent of blight in areas subject to inundation can be assessed on the basis of the physical condition of structures and the presence of hazards and nuisances. Of particular importance is the determination of the characteristics of residential development within flood-hazard areas.

A great deal of attention has been given to the formulation of criteria for the evaluation of housing conditions. Although the specific criteria for comparative purposes must be those acceptable in a given community, housing conditions can generally be divided into three major categories: standard, substandard and dilapidated.

The first of these applies to houses judged as safe and sanitary for human occupancy. The substandard classification is used to identify housing in which there is a lack

of sanitary facilities. Dilapidated structures are those which have inadequate structural features from the standpoint of appearance and safety.

However, little has been done towards establishing similar criteria for evaluating the condition of commercial and industrial structures. The system of classification to be used must be worked out on the basis of vacancies, obsolescence and structural deterioration.

Segments of flood-hazard areas can be delineated according to degrees of blight as established by an analysis of structural and environmental conditions. This delineation can be used to determine, in turn, those areas in which redevelopment is necessary and those areas in which preservation measures are needed.

Cost-revenue relationships.--Cost-revenue relationships are determined by a comparison between the cost of furnishing public services to an area and the tax revenues derived from the use of that land. When an area does not pay its proportional part of the cost of public services, it is subsidized by the remainder of the community.

This is generally true of residential areas, whether they are located in flood-hazard areas or in areas free from floods. Commercial and industrial land uses usually furnish the tax revenues necessary to make up for the difference between the cost of supplying public services to residential areas and the revenues received from these

areas. However, industrial and commercial uses in flood-hazard areas may also be subsidized because of low tax assessments, as noted previously. A check should be made of the cost-revenue relationships of these land uses to determine the extent to which they are supported by other areas.

Perhaps a more important type of subsidy, from the standpoint of the occupants, is the aid given stricken areas in times of flood disaster. The local government carries a big share of the load of cleaning up and returning activities to normal. Besides this cost, there are also lost tax revenues in many cases when structures are destroyed or operations are discontinued in a community by commercial- and industrial-use owners.

Costs of providing public services to an area can be estimated from records of capital and operating expenditures. Estimates of recovery costs may be based upon the experiences associated with previous flooding; or they can be made by assuming the amount and character of flood damage which could occur as the result of a selected flood, and the costs assumed necessary to return conditions to normal. Revenues derived from property within these areas can be obtained from records of ad valorem taxes and special assessments.

These costs and revenues can then be compared to cost-revenue relationships for flood-free areas of a similar

character within the community. In this way, the determination of the financial feasibility of existing land uses in flood-hazard areas can be made.

Stage-damage relationships.--The technique of relating flood heights to property damage is utilized by the Corps of Engineers and other agencies in determining benefit-cost ratios for protective works. Whether the amount of detail involved with such a procedure is justifiable depends upon the resources of the community. However, if it is believed that protective works may become a part of the over-all program, such detailed information should be obtained and used to determine the stage-damage relationship for various flows.

If the construction of protective works is not anticipated, estimates of damage could be obtained from the land-use data at hand, according to the nature of the use as represented by structural characteristics and the type of equipment, merchandise or furnishings in and near the structure itself. A helpful guide can be estimates of damage incurred during previous floods, adjusted to a common base of value and development.

Two methods can be used to summarize this evaluation. The first is a series of overlays outlining the degrees of damage potential by color or pattern concentration. The second is the stage-damage curve, which is constructed using flood stages as abscissa values and cost of damage potential as ordinate values. Both methods of

presentation will clearly show the cumulative effects of greater floods.

The relationships between flood heights and property damage can point to those portions of the flood-hazard area in which adjustments in land use are needed to reduce the amount of flood damage. These characteristics can also point to the methods which can be used to mitigate flood damage, whether they include simple measures such as providing sliding panels to cover doors and windows, or clearance and redevelopment procedures.

Redevelopment Considerations

Importance of Redevelopment as a Flood-Damage Prevention Measure

The evaluations discussed in the preceding sections point out the manner in which flood factors and land-use considerations can be related within the framework of comprehensive land-use planning. In many instances redevelopment may be the only measure which can be used to create a better urban environment and, at the same time, significantly reduce flood damage.

Opportunity to modify land uses.--As Chapin points out: "In those portions of the urban area identified for clearance and redevelopment, there is a full measure of freedom for modifying the land use pattern." (32) This factor has generally been neglected during formulation of flood-damage prevention programs in the past. For example, protective

works often prolong the life of uses which can no longer be justified when analyzed in terms of a community's future growth and prosperity. The economic basis for the benefit-cost ratio analysis, utilized at the present time to justify the construction of protective works, does not take this factor into consideration.

In re-planning flood-hazard areas, the same considerations should govern the selection of recommended re-uses as those which are applied to the development of vacant land. These, to review briefly, include uses which can properly utilize the resources of the stream and flood plain; uses which are not subject to extensive flood damage; and uses which are compatible with development in adjacent areas.

Implementation of Redevelopment Measures

The 1949 Housing Act (33) presents the opportunity to communities for redeveloping their blighted areas. After land is assembled and cleared it can either be retained for public purposes or sold for private re-use. In areas subject to flooding, the redevelopment plan can bring about the land-use adjustments needed to reduce flood damage. The redevelopment plan can be legally enforced for a period of 40 years from the date of its adoption. Deed restrictions can also be placed on the land to insure conformity with the plan during this period.

It is important that renewal plans for flood-hazard areas be prepared and be available for implementation.

Then, if a disaster occurs before actual clearance operations are begun, a guide for the rehabilitation and adjustment of uses is at hand. Expenditures for the repair of damaged properties in areas designated for redevelopment could be discouraged or prohibited and additional costs of acquisition avoided.

Required Legislative Determination

The selection of uses which are to be permitted in areas of flood hazard is a necessary legislative determination. The formulation of a comprehensive land-use plan for the community is the general, unofficial determination of these uses. It serves to guide the selection of specific uses in flood-hazard areas. This determination of public policy will be manifested by the provisions of land-use regulations, redevelopment plans, construction of protective works, and the use of other means to mitigate the effects of flooding on a community.

CHAPTER IV

ELEMENTS OF A COMPREHENSIVE FLOOD-DAMAGE PREVENTION PROGRAM

Effective Application of Individual Elements

General Considerations

The preceding chapters dealt primarily with the nature of the flood problem; first on a general basis and then on a more specific basis, outlining the factors affecting local flood problems. Evaluations made up to this point were concerned with establishing methods by which flood and land-use factors can be studied, and an understanding of the nature of local flood problems can be gained. Two legislative determinations, which are required as a basis for the implementation of a flood damage prevention program, were identified.

Required legislative determination.--The third, and final, legislative determination which is necessary is the selection of those elements of a comprehensive damage-prevention program that are applicable to a given situation. If a program is to be successful those elements should be selected which can be used to achieve the greatest reduction in damage potential.

Not all of the means of mitigating flood damage will be applicable to the solution of flood problems in a single

urban area. Careful consideration should be given to the advantages and limitations of each measure as they relate to the objectives sought. These objectives were presented in the previous chapters, and attention will now be given to fitting the means to these ends.

Public Information

Value of gaining public support.--Perhaps the critical consideration in the implementation of flood-damage prevention program is obtaining public understanding of the nature and magnitude of a local flood problem and the reasons for proposed action. The effectiveness of a program depends not only upon the proper technical determinations, but also upon the acceptance of these proposals by the people affected. The attitudes and desires of the people can and should have a great deal of bearing upon the elements to be incorporated in a program. The following example serves to illustrate the point that public understanding can be a useful aid to proper administration of flood-damage prevention measures.

The town of Athens, Tennessee asked for and received from the Tennessee Valley Authority a report concerning the nature and magnitude of their local flood problem. With the assistance of the area-planner from the Tennessee State Planning Commission, the local planning commission drew up and recommended enactment of land-use regulations to restrict continued encroachment in areas subject to flooding. These

measures were subsequently adopted by the city council. Shortly afterward, it was brought to the attention of the planning commission that a developer had placed 60,000 cubic yards of earth fill in the area classified as the Floodway District. This action, in direct violation of the adopted regulations, restricted the cross-sectional area of the stream in such a manner that flood heights could be increased. Additional flood heights would endanger residential property located upstream from as well as on the opposite side of the stream from the fill.

The important fact to be noted is that the residents of the area which would be subject to increased flooding were the ones who brought the violation to the attention of the planning commission. The commission asked for and received from the Tennessee Valley Authority and the Tennessee State Planning Commission an analysis of the effects of this embankment on flood stages. This analysis showed that if the stream channel were improved, the removal of only a portion of the fill would eliminate the adverse effects on flood heights. The planning commission recommended to the city council that it consider ordering removal of the entire obstruction, thereby restoring the floodway to its natural character; or, as a minimum alternative, that the channel be improved and a specific amount of the embankment removed. At the time of this writing final action has not been taken to assure the proper passage of flood waters.

A means of controlling development.--An encouraging trend in working toward the solution of local flood problems is the stand taken by various lending agencies regarding loans and guarantees of loans for residential construction in areas known to be subject to flooding. In the Tennessee Valley, the Federal Housing Administration, Veterans' Administration, Urban Renewal Administration and Public Housing Administration have utilized flood data from Tennessee Valley Authority reports in making decisions concerning their participation in such developments. In addition, information concerning the nature of the flood hazard should be made available to all other public or private agencies which are normally involved with the development of land.

Where desirable elements of a flood-damage prevention program cannot be used, because of a lack of legislative authority or municipal finances, public information may be the only way to combat unwise development of hazard areas. In other instances, because of political considerations, this means may be more effective than restrictions upon the use of land in the form of land-use regulations.

Regulatory Measures

Zoning.--Zoning can be most effectively applied to flood-hazard areas to: (1) avert potential damage by restricting the future utilization of vacant land; (2) limit the intensification of uses in already built-up areas; and (3) limit the repair and reconstruction of damaged or destroyed

structures after a flood is experienced.

The application of zoning provisions to flood-hazard areas should be a part of the comprehensive zoning regulations for the community. An example of this procedure is illustrated by Figure 9 on page 64, which shows the inclusion of a floodway district and floodway-fringe areas as a part of the comprehensive zoning map.

To be valid, zoning provisions must relate the appropriateness of the control to the potential hazard. By following the procedure presented to arrive at the delineation of the floodway, there seems to be little doubt that this determination would be declared reasonable by the courts. It has been ruled in many zoning cases that the judgment of the court will not be substituted for that of the legislative body, unless the action is so grossly arbitrary that it must be declared unconstitutional.

It is when too much emphasis is placed upon zoning to eliminate potential flood damage that arbitrary provisions will be drawn. Care must be exercised in equating the functional characteristics of flood-hazard areas with the public interest. The inclusion of a definite statement of intent in the ordinance will clarify the objectives to be achieved by regulating the use of land in hazard areas.

Provisions are also necessary to insure compatibility between land uses in hazard areas and adjacent development. As Siler points out, "The fact that a flood area is an excellent location for a stockyard does not constitute a

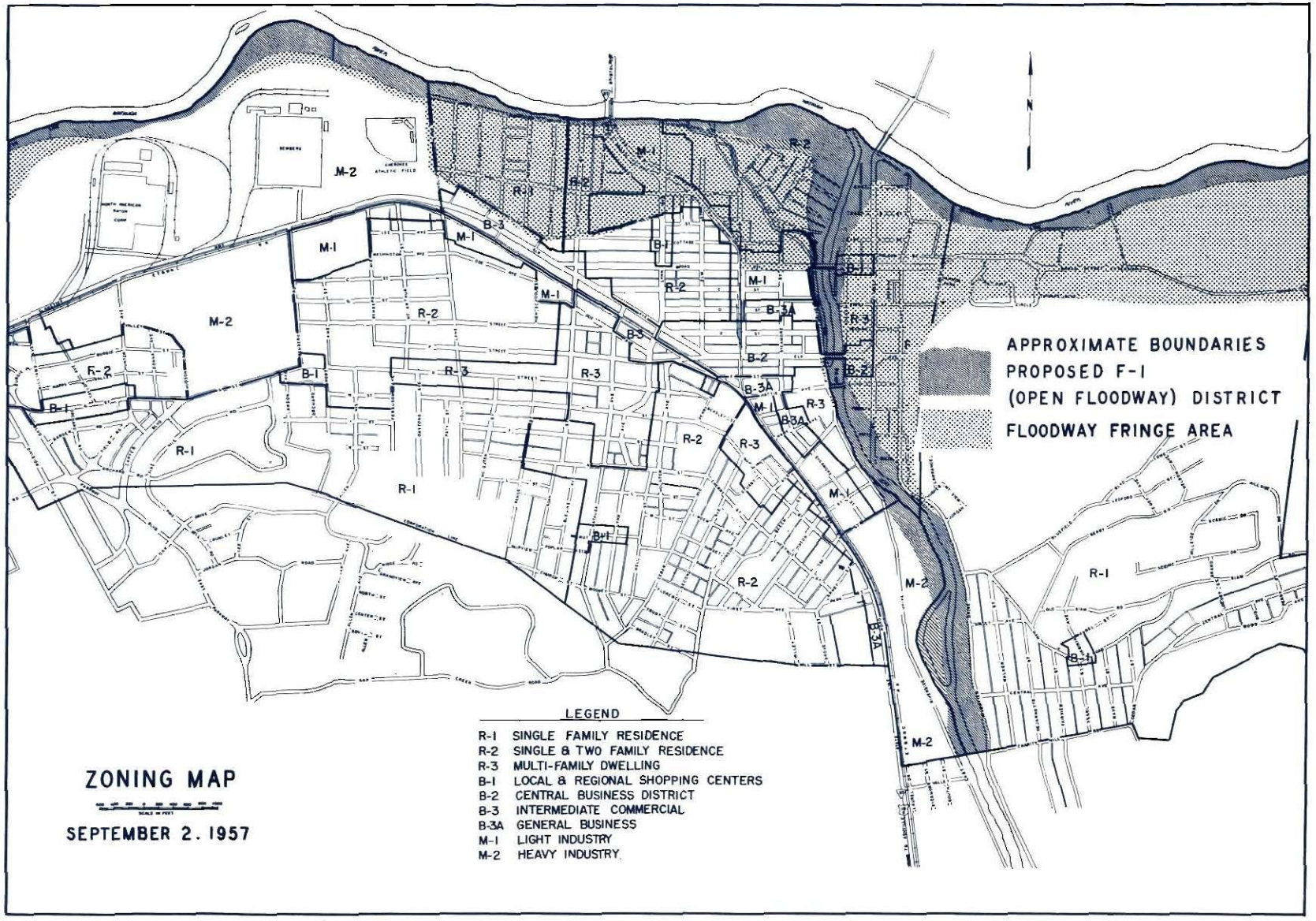


Figure 9. Zoning Map Including Floodway District and Floodway-Fringe Areas.

license for the developer to ignore the presence of nearby residences." (34) Thus, there must be a method for judging proposed uses of flood plains and for applying regulations uniformly.

One method would be to spell out in detail the requirements for uses in different sections of the flood-hazard area. The amendments to the Lewisburg, Tennessee zoning ordinance adopted in 1957 present another method of approaching this problem (35). Within the Lewisburg Floodway Districts, open-type uses such as loading and unloading areas, parking lots, used-car lots, recreation facilities, and storage yards are permitted subject to the approval of the planning commission.

To guide the Lewisburg Planning Commission in its determination of permitted improvements, conditions are outlined which must be met by the developer. These include the prohibition of residential structures and land filling; that structures permitted must be designed and constructed in such a manner that they offer a minimum obstruction to the flow of water; and that structures shall be firmly anchored to prevent their floating away from their foundations.

In this instance, delineation of the floodway and the establishment of the Floodway Districts were based upon the maximum probable flood. Elevations of inundation were established as a part of the regulation by incorporating

the high-water profile chart of Big Rock Creek as a part of the ordinance.

This is a necessary procedure; it is one which distinguishes the delineation of flood-hazard areas from the delineation of ordinary zoning districts. Only in lagoon or lake areas can a constant elevation be used for regulatory purposes. Stream beds and flood waters often experience a considerable differential in elevation through the area for which regulations are formulated. Particularly in ponding areas it is important that flood elevations be determined, so that building and land-fill grades can be established. It then becomes necessary for the local government to provide a system of bench marks in the field, from which elevations in an area can be obtained and related to the flood elevation.

Subdivision regulations.--Subdivision regulations can be effectively applied to prevent the construction of residences within flood-hazard areas. Where the regulations establish reasonable standards to protect against a menace to health and safety, they can be expected to be upheld by the courts. Moreover, in each residential district there should be a building site on every lot with an elevation above that of the flood used to delineate the floodway. Where the limits of this flood encompass a portion of the proposed development, this fact should be clearly shown on the plat.

Subdivision regulations should include an additional requirement governing the acceptance of dedicated streets.

Connector and major streets need to be provided at elevations higher than that of the flood which was selected to delineate the floodway. The purpose of this requirement is to prevent the isolation of areas which are safe from flooding, but to which access could be cut at other points. Minor streets could be allowed at elevations as low as two feet below the controlling flood elevations. This permits some flexibility in site design and at the same time allows safe evacuation of areas during flooding.

Official-map procedures.--Public uses of land are often the best uses in floodways. However, acquisition of large tracts is likely to be more costly than many communities can afford. Where possible, official-map procedures should be employed to reserve portions of the flood plain for public use. These lands can then be acquired gradually by eminent domain. The repetition of this procedure over a period of time could result in eventual acquisition of a large amount of flood-hazard land.

Building codes.--Building codes should include criteria for the design of substructures and structural members of buildings and other structures located in hazard areas. These criteria should be based upon the forces which would result from the computed or measured water velocity of the discharge used to define the floodway. Particularly important is the provision of standards to assure sufficient anchorage to prevent structural failure.

Administrative regulation of utility extensions.--Another method of controlling the unwise development of flood-hazard areas is administrative in nature. It is the formulation of a policy of selective utility extension. A firm public policy of withholding the provision of water, sewerage and other facilities to hazard areas would be a strong deterrent to unwise development. To be most effective, this policy should be formulated as the result of a comprehensive utility-improvement plan, which should in turn be based on the comprehensive land-use plan.

Preservation Measures

Protective works.--Protective works have a specific role to play in flood-damage prevention. They should be utilized where feasible to preserve development which is vital to the proper functioning of the economic and social life of a community. Moreover, the utilization of this measure is restricted by economic and technical considerations.

The Miami Conservancy District is one instance which can be cited where dam-sites are available near enough to urban areas to afford an adequate reduction of flood stages. Streams and rivers generally do not have the broad, level flood plains, such as that of the Mississippi, necessary for the proper utilization of a levee system. Financial and technical resources needed to initiate an extensive flood-damage prevention program, of which protective works are a major part, are often unobtainable. Moreover, few

cities can afford to wait for Congress to authorize and appropriate funds for the construction of local protective works. Finally, only a small proportion of the cities with flood problems have existing development values within hazard areas to justify the construction of protective works. It is in these situations that other measures of flood-damage prevention can be used to limit the type and number of encroachments in flood plains.

Structural adjustments.--Relatively simple and economical adjustments to flooding may be possible in many instances, especially in outlying sections of flood-hazard areas. One type of adjustment can be made to existing structures to protect interiors from water and silt damage. Such measures might include the installation of sliding panels, which could be used to cover doorways and windows; other, nonessential openings could be sealed; and substructures could be waterproofed. Another method of adjustment could include the relocation of merchandise and furnishings so that they would be above flood elevation, or could be readily moved out of danger.

Developmental Measures

Techniques of building design.--The application of building design techniques, taking into account the unique requirements of flooding, has not received the attention it deserves. The recent hurricane floods in New England proved once again that structures built on stilts, or pillars, can safely

withstand the adverse conditions of flooding. This principle has been applied in Europe and Asia within the flood plains of rivers. The United States High Commissioner's headquarters in Germany was constructed within the overflow area of the Rhine River. "It is built on concrete stilts; actually, the first- or ground-floor columns are left free of walls, and the open space is used for car-parking." (36) Uses of the building which would be subject to flood damage are restricted to the floors above flood level.

A great deal of flexibility in the use of flood-hazard areas can be realized if building design is properly adapted to flood conditions. Many of the presently objectionable features of flood-plain development could be overcome in this manner.

Site design.--The proposed redevelopment plan for the Cincinnati riverfront illustrates the effective use of site-design criteria in flood-hazard areas. The original proposal in 1946 (37) called for the inclusion of parkways, stadium, heliport, administration and service center, convention and recreation center, and apartment buildings. Structures were planned for location on high ground within the area, or were designed in such a manner that flooding would not result in serious damage. In addition, all major streets within the area were planned at elevations which would not be reached by high floods. Temporary curtailment of some activities would result from extremely high floods, but little damage could be expected.

This plan has recently been re-studied to meet changed conditions, which include the need for more of this land for a system of expressway distributors and a loss in area caused by the shifting of the Ohio River shoreline (38). The revised plan excludes the provision of the administration and service center, and the apartment group. However, the basic site-design elements have been retained, because of their importance to the successful implementation of the plan.

Protective works.--Little attention has been given to the construction of protective works to serve specifically as an aid to land development. Up until the present time, there have been only scattered instances of such action in this country. The reclamation of land through channel-improvement and drainage measures has been undertaken extensively in Florida. Protective works also play an important role in this developmental program. The Central and Southern Florida Flood Control District represents one of the largest programs of this type to be attempted in this country (39).

Isolated opportunities may also prove the usefulness of this measure in the future. For example, it might be in the public interest for a community to finance the works necessary to render an otherwise attractive industrial site free from floods up to a certain magnitude, if there were no prime industrial land available. Tax revenues to be derived and employment opportunities to be gained could certainly be valid arguments for such a procedure.

As a general rule, communities are not faced with critical land-resource problems at the present time. However, the current rate of urban expansion in some localities will inevitably create a shortage of land which can be readily developed. It is at this break-point that protective works may offer a feasible solution. The advantage of this procedure over building protective works for existing developments is that the future development of an area can be planned for the most proper and efficient uses at the outset.

Flood Insurance

The measures of flood-damage prevention discussed up to this point can be applied to reduce flood damage. However, these measures cannot completely remove the risk of flood damage; there is a degree of risk associated with the occupancy of flood plains, regardless of the preventive measures taken. A means which can be utilized to cover the risk of such occupancy is flood insurance. The objective of flood insurance "is to assure economic stability to justifiable enterprise in hazardous areas, and to provide an effective bar to improvident assumptions of risk." (40)

Position of stock insurance companies.--Floods are almost the only natural hazard which is not insurable at the present time. The results of studies of floods and flood damage merely reinforced the previous stands taken by the industry concerning the coverage of flood risks. This

position is as follows:

> Specific flood insurance covering fixed location properties in areas subject to recurrent floods cannot feasibly be written because of the virtual certainty of loss, its catastrophic nature and the reluctance or inability of the public to pay the premium charge required to make the insurance self sustaining. (41)

The major drawback to the issuance of flood insurance by private companies appears to be the magnitude of reserves which would be required initially. Because only those who might be affected by flooding would probably carry this insurance, a long period of time would be required before adequate reserves could be built up. There is no assurance that a major flood would not occur in the interim, which could bankrupt an insurance system.

Interest of the Federal Government.--To meet the above objections, and to determine the feasibility of writing flood insurance on an experimental basis, Congress enacted the Federal Flood Insurance Act of 1956 (P. L. 1016). It was felt that the Federal Government, as a permanent institution, could better withstand the adverse effects of possibly high early losses. Moreover, by subsidizing premium rates, the Federal Government could present flood insurance at reduced costs to occupants of land subject to flooding. This program did not get off the ground, however, because Congress failed to appropriate the necessary funds (42). Therefore, the future of a federal program of flood insurance is unknown at the present time.

Full cost of development.--It is reasonable to assume, however, that at some future date a form of flood insurance or amortization-of-loss measures will be applied to property in areas subject to flooding. This will likely come as a result of public pressures against further subsidy to flood-plain occupants in the form of protective works and disaster relief.

The risk of flood loss is a cost of development in flood-hazard areas. As such it should be borne by the developer, not the public. Thought of in this manner, insurance, or any other measure to assure that the full cost of development is placed on the developer, becomes what Hoyt and Langbein term "economic zoning." (43)

Proper flood-plain occupancy, which yields high economic returns because of the advantages of location or resources, can certainly bear this cost. At the same time, unwise development of these areas could be deterred by the cost entailed. By properly utilizing flood data published by the local governing body, lending agencies could play an important role in assessing the full cost of flood-plain development to the occupants.

Classification of Elements

The following is a functional and temporal outline of the measures that might be included in a comprehensive program of flood-damage prevention. It should be utilized as a check-list, rather than a formula for the solution of

flood problems, to guide a community in the selection of flood-damage prevention measures.

Development of vacant land.

Public Information.

Regulatory Measures.
- Zoning.
- Subdivision regulations.
- Official map procedures.
- Building codes.
- Administrative regulation of utility extensions.
- Deed restrictions.

Developmental Measures.
- Public land acquisition.
- Protective works.
- Site design criteria.
- Structural design critera.

Flood Insurance.

Existing developed areas.

Public Information.

Regulatory Measures.
- Zoning.
- Building codes.

Preservation Measures.
- Protective works.
- Structural adjustments.

Flood Insurance.

Redevelopment of built-up areas.

Public Information.

Regulatory Measures.
- Zoning.
- Subdivision regulations.
- Building codes.
- Deed restrictions.
- Administrative regulation of utility extensions.

Redevelopmental Measures.
- Public land acquisition.

Flood control structures.
Site design criteria.
Structural design criteria.

Flood Insurance.

Each method of implementation has a specific role to play and specific ends which it can accomplish. A comprehensive program for flood-damage prevention entails the utilization of the measures most applicable to the type of problem encountered and the specific objectives sought. Thus, there is no clearcut, model approach which can be applied to the solution of these problems. It is through the application of a general framework of principles that each situation can be evaluated and the proper solutions worked out.

CHAPTER V

FORMATION OF LOCAL PUBLIC POLICY FOR FLOOD-DAMAGE PREVENTION

Selection of Most Applicable Flood-Damage Prevention Measures

From the methods available for the implementation of flood-damage prevention, programs can be initiated which offer the greatest chance of success in achieving community objectives. These objectives can best be formulated through the planning process and expressed as a part of the comprehensive plan and public policy.

In this way, flood-damage prevention ceases to be an end in itself. It becomes a factor to be evaluated within the framework of comprehensive planning. The abatement of flood damage is a factor of considerable magnitude in some urban areas. Where solutions to this problem are needed, the answers will likely be the result of intelligent compromise; compromise between floods and the unlimited use of flood-hazard land; or compromise between the most efficient use of land and the economic and political considerations involved.

Cost of flood-damage prevention.--The unimpeded development of flood-hazard areas in the past is proving costly to communities, both in terms of subsidies and corrective measures. Few communities can afford to continue neglecting their

responsibilities for taking remedial action. The total cost in the end is bound to be considerably greater than the cost of carrying out proper land-use adjustments as quickly as possible.

However, since most cities are faced with financial problems, they ordinarily do not have the funds available to support comprehensive programs of flood-damage prevention. Protective works, public land acquisition and urban renewal are all costly in terms of capital expenditures. This is the reason why the federal flood-control program has appeared so attractive to communities for so long. The possibility of federal protection with little cost to the people immediately affected was, and still is in many instances, a deterrent to local governmental action in this field.

However, there is inherent slowness in the federal operation. In addition, there are many communities for which protective works cannot be economically justified, or are not technically feasible.

So public officials and professional people concerned with flood-damage prevention are looking for another "economical" solution to these problems. Land-use regulations are presently being advocated by some as the means which can be used to solve flood problems with the least expenditures of public funds. This approach does not completely take into consideration the objectives which can be achieved

through the regulation of flood-plain occupancy, nor the limitations of such procedures.

Alternatives of Urban Development

The search for a means of effectively and economically minimizing the adverse effects of flooding has been made without proper consideration for the desirability or necessity of utilizing land subject to flooding. This evaluation can be made if flood-damage prevention is undertaken within the framework of comprehensive planning, as stressed in the preceding chapters. By utilizing the land-use plan as the guide to over-all community development, the range of alternatives available for land development in a particular urban area can be considered.

Necessity of utilizing flood-hazard areas.--The concept that the cost of flood damage is a cost of doing business in land subject to inundation was presented in Chapter IV. It may be many years, however, before significant gains in flood-damage prevention can be obtained by this means of "economic zoning." In the meantime, there is another approach which might prove successful if properly utilized.

It is the alternative of public subsidy for the development of land which is not subject to inundation. If it is in the public interest to subsidize the occupants of flood plains, why is it not also in the public interest to spend public funds for the preparation of alternative sites which would be free from the danger of floods? At the

present time, there appear to be no serious objections, in principle, to the expenditure of public funds necessary to permit the utilization of flood plains with a reduced degree of risk. However, this approach to the problem is not consistent with the objections usually raised to the idea of subsidizing development of alternative locations.

Summary of Procedures

The formation of public policy with respect to flood-damage prevention can be aided greatly by the evaluation of relevant factors through the planning process. Basically there are three steps which should be taken in planning for flood-damage prevention:

1. Isolation and identification of the factors which govern flood damage;
2. Evaluation of these factors as they relate to present development and plans for future community expansion; and
3. Formulation of programs leading to satisfactory adjustments to flood conditions.

Implementation of a flood-damage prevention program can be carried out on the basis of public policy which will result from this analysis. The successful implementation of such a program requires a firm, yet flexible public policy regarding the role flood-plain land should play in the future development and redevelopment of a city.

Legislative determinations.--There are three legislative determinations which need to be made in the course of initiating a program of flood-damage prevention:

1. Delineation of the floodway, floodway-fringe and flood-hazard areas.
2. Selection of uses to be permitted in these areas.
3. Selection of damage-prevention elements to be included in the program.

The first of these determinations needs to be based on a reasonable interpretation of flood data. Adequate flood data is the essential element, if the nature of a local flood problem is to be fully understood.

The second determination depends upon the relationship between local flood characteristics and plans for community development. Particularly important as a basis for this determination is the analysis of the effects of flooding on the uses proposed for location in the hazard areas.

Finally, the selection of the elements to be included in a program for flood-damage prevention should be studied. The applicability of each to the problems of a community provides the basis for the selection of the methods to be used.

Utilization of the Procedures Established

The procedures outlined comprise a framework of guiding principles, within which specific local problems can be analyzed. It is not a rigid framework, because of the nature of the planning process and the range of specific problems it must encompass. This, however, is not a drawback to its effective use as a method of analyzing urban flood problems. Within this general framework it is possible to evaluate a

wide range of flood and land-use factors to determine the type of flood-damage prevention program most applicable to a particular situation.

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