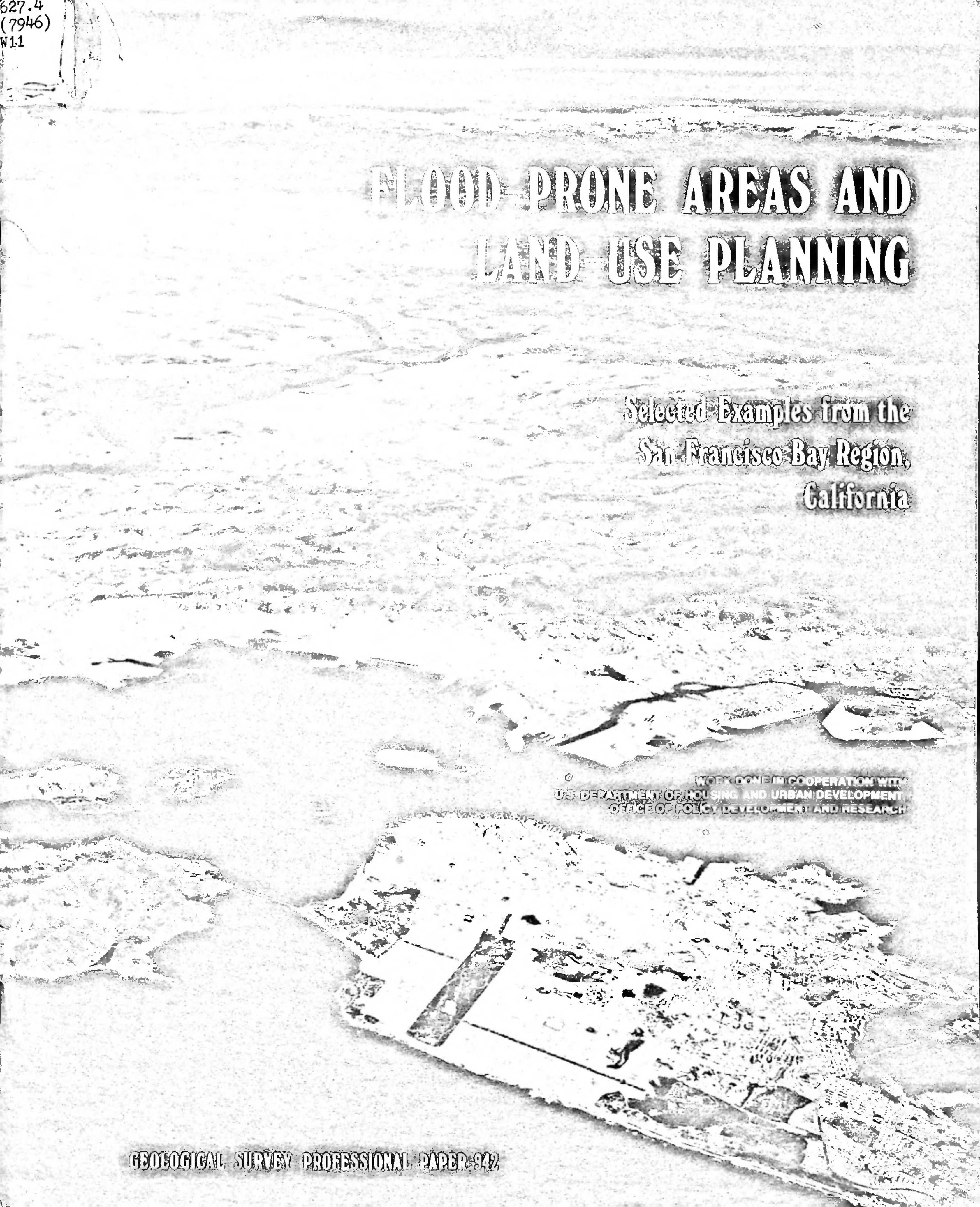

FLOOD-PRONE AREAS AND LAND-USE PLANNING

Selected Examples from the San Francisco Bay Region, California

WORK DONE IN COOPERATION WITH
U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
OFFICE OF POLICY DEVELOPMENT AND RESEARCH

GEOLOGICAL SURVEY PROFESSIONAL PAPER 942

COVER PHOTOGRAPH of San Francisco Bay Region taken April 14, 1972, at altitude of 65,000 feet from U-2 aircraft. Courtesy National Aeronautics and Space Administration (Ames Research Center, Moffett Field, Calif.) Front shows city of San Francisco and Golden Gate at bottom, San Francisco Bay and city of Oakland in middle, Sacramento-San Joaquin Delta and crest of Sierra Nevada at top. Back shows Bolinas Lagoon and trace of San Andreas fault at bottom, San Pablo Bay in middle, Sacramento valley and crest of Sierra Nevada at top.

Flood-prone areas and land-use planning—Selected examples from the San Francisco Bay Region, California

By A. O. WAANANEN, J. T. LIMERINOS, and W. J. KOCKELMAN,

U.S. GEOLOGICAL SURVEY, and

W. E. SPANGLE and M. L. BLAIR, WILLIAM SPANGLE & ASSOCIATES

GEOLOGICAL SURVEY PROFESSIONAL PAPER 942

Jointly supported by the U.S. Geological Survey and the Department of Housing and Urban Development, Office of Policy Development and Research, as part of a program to develop and apply earth-science information in support of land-use planning and decisionmaking

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FOREWORD

This report is a product of the San Francisco Bay Region Environment and Resources Planning Study, an experimental program designed to facilitate the use of earth-science information in regional planning and decisionmaking. The study is supported jointly by the U.S. Geological Survey, Department of the Interior, and the Office of Policy Development and Research, Department of Housing and Urban Development. The Association of Bay Area Governments participates in the study and provides a liaison and communication link with other regional planning agencies and with county and local governments.

Although the study focuses on the 9-county 7,400-square-mile San Francisco Bay region, it bears on an issue that is of national concern. This issue—how best to accommodate orderly development and growth while conserving our natural resource base, insuring public health and safety, and minimizing degradation of our natural and manmade environment—is difficult and complex. The complexity, however, can be greatly reduced if we understand the natural characteristics of the land, the processes that shape it, its resource potential, and its natural hazards. These subjects are chiefly within the domain of the earth sciences: geology, geophysics, hydrology, and the soil sciences. Appropriate earth-science information, if available, can be applied rationally in guiding growth and development, but the existence of the information does not assure its effective use in the day-to-day decisions that shape development. Planners, elected officials, and the public rarely have the training or experience needed to recognize the significance of basic earth-science information, and many of the conventional methods of communicating earth-science information are ill-suited to their needs.

It was hoped that the study would aid the planning and decisionmaking community by (1) identifying important problems that are rooted in the earth sciences and related to growth and development in the bay region; (2) understanding the relationships between the problems; (3) providing the earth-science information that is needed to solve these problems; (4) interpreting and publishing findings in forms understandable to and usable by nonscientists; (5) establishing new avenues of communication between scientists and users; and (6) exploring alternate ways of applying earth-science information in planning and decisionmaking.

Since the study was started in 1970, it has produced more than 100 reports and maps. These cover a wide range of topics: flood and earthquake hazard reduction, unstable slopes, engineering characteristics of hillside and lowland areas, mineral and water-resources management, solid and liquid waste disposal, erosion and sedimentation problems, bay water circulation patterns, and others. The methods used in the study and the results it has produced have elicited broad interest in a wide range of applications from planners, government officials, industry, universities, and the general public.

The present report, "Flood-Prone Areas and Land-Use Planning—Selected Examples from the San Francisco Bay Region, California," examines the problem of flooding in the San Francisco Bay region, describes the preparation and use of various types of flood maps and flood information reports, lists sources of information on flooding and flood plains, discusses flood-loss prevention and reduction measures, and discusses the role of comprehensive planning in flood-plain management.

Adequate information on flood-prone areas and flood hazards is essential to effective planning and management. Many sources of such information are available, and representative samples of importance in planning are discussed in this report. How this information is used by agencies involved in managing flood plains is shown by a case study involving Napa County. The section also shows the interplay among these agencies.

The methods of gathering and using flood-plain information for planning in the San Francisco Bay region are applicable in other parts of the country. The examples given in this report are selected to show both the wide range of tools available to the planner, and how those tools may be applied to deal most effectively with flood hazards.

Robert D. Brown Jr.
Project Director
San Francisco Bay Region Study

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CONVERSION FACTORS

[Factors for converting English units to metric units are shown to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values for the English units]

English	*Multiply by—*	*Metric*
acres	4.047×10^{-3}	km² (square kilometres)
acre-ft (acre-feet)	1.233×10^{-3}	hm³ (cubic hectometres)
	1.233×10^{3}	m³ (cubic metres)
ft (feet)	3.048×10^{-1}	m (metres)
ft³/s (cubic feet per second)	2.832×10^{-2}	m³/s (cubic metres per second)
in. (inches)	2.540×10^{1}	mm (millimetres)
mi (miles)	1.609	km (kilometres)
mi² (square miles)	2.590	km² (square kilometres)

DEFINITION OF TERMS

Physiographic, hydrologic, hydraulic, and selected administrative terms used in this report are defined as follows:

Acre-foot is the quantity of water required to cover 1 acre to a depth of 1 foot, and is equivalent to 43,560 cubic feet, 325,871 gallons, or 1,233 cubic metres.

Area plan establishes policy, expanding upon and consistent with a comprehensive plan, for a part of a planning jurisdiction, such as a watershed or a central business district.

Channel is an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. River, creek, run, branch, and tributary are some of the terms used to describe natural channels.

Comprehensive plan is a document setting forth official governmental policy for the long-term future development of an area considering all major determinants of growth and change—economic, political, social, and physical.

Cubic foot per second is the rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second, and is equivalent to 7.48 gallons per second, 448.8 gallons per minute, or 0.02832 cubic metres per second.

Discharge is the volume of water (or more broadly, total fluids) that passes a given point within a given period of time.

Drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide.

Flood, or flooding, is the general and temporary condition of partial or complete inundation of normal dry land areas from (a) the overflow of streams, rivers, and other inland water, or (b) abnormally high tidal water or rising coastal waters resulting from severe storms, hurricanes, or tsunamis. Also, any relatively high streamflow overtopping the natural or artificial banks in any reach of a stream; or a relatively high flow as measured by either gage height or discharge quantity.

Flood discharge is a quantitative measure of the rate of flow at a point during a flood event; it is usually expressed in cubic feet per second or cubic metres per second.

Flood frequency is the average interval of time between floods equal to or greater than a specified discharge or stage; it is generally expressed in years (see recurrence interval).

Flood-frequency curve is a graph which shows the probability of any given discharge being exceeded in any year, or which shows the recurrence interval, or return period, within which, on the average, a given discharge will be exceeded once by the annual peak discharge.

Flood-hazard map is a map, based on a thorough technical study of waterways in a given locality, of sufficient scale and clarity to permit ready identification of individual sites as being either within or outside an area having special flood hazards.

Flood insurance is the insurance coverage for both floods and mudslides obtained under the National Flood Insurance Program.

Flood peak is the highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge.

Flood plain is the land area adjoining a river, stream, watercourse, ocean, bay, or lake that has been or may be covered by floodwater. (This definition of flood plain may differ from that used in geologic and geomorphic writing.)

Flood-plain management is the operation of an overall program of corrective and preventive measures for reducing flood damage, including but not limited to emergency preparedness plans, flood-control works, and land-use and control measures.

Flood profile is a graph of elevation of the water surface of a river in flood in relation to the distance along the stream. A flood profile may be drawn to show elevation at a given time, crests during a particular flood, or stages for floods of any designated frequency.

Flood-prone area map, as used in this report, is a map based on limited studies that indicates areas likely to be flooded by virtue of their location adjoining a river, stream, bay, or other watercourse or water body.

Floodproofing is any combination of structural and nonstructural measures, changes, or adjustments to properties and structures which reduce or eliminate flood loss of lands, water and sanitary facilities, structures, and contents of buildings.

Flood stage is the stage at which overflow of the natural banks of a stream begins to cause damage in the reach in which the elevation is measured.

Flood wave is a distinct rise in stage culminating in a crest and followed by recession to lower stages. A flood wave may move downstream at a velocity greater than the average velocity of flow in a stream.

Floodway is the channel of a river or other watercourse and the adjacent land areas required to carry and discharge a flood of a given magnitude.

Functional plan describes facilities and operations for a specific function of government such as transportation, flood control, or flood-plain management; it is more specific and usually is shorter in range than a comprehensive plan.

Gage height is the water-surface elevation referred to some arbitrary gage datum. Gage height is often used interchangeably with the more general term "stage" although gage height is more appropriate when used with a reading on a gage.

Gaging station is a particular site on a stream, canal, lake, or reservoir where systematic observations of gage height or measurements of discharge are obtained.

General plan is another term for a comprehensive plan.

Infiltration is the flow of a fluid into a substance through pores or small openings, as the infiltration of water from precipitation or overland flow into the underlying soil.

Land-use plan is a key component of a comprehensive plan including objectives, policies, and proposals for the type, pattern, and intensity of land use in a planning area; it is also called a land-use element.

Mudslide is the general and temporary movement down a slope of a mass of rock or soil, artificial fill, or a combination of these materials, caused or precipitated by the accumulation of water on or under the ground.

National Flood Insurance Program is the Federally subsidized program established by the National Flood Insurance Act of 1968 (U.S. Congress, 1968) that provides previously unavailable flood-insurance protection to property owners in flood-prone areas. Insurance protection is provided only in return for the participating communities' implementation of a flood-plain management program.

One-hundred-year flood (100-year flood) is the level of flooding that will be equaled or exceeded once in 100 years and has a 1-percent chance of occurring each year, on the average.

Peak discharge is the highest rate of streamflow at a point during a rise in the stream. Peak discharge is usually expressed in cubic feet per second or cubic metres per second. A peak discharge that is the greatest in a 12-month period—usually October through September—is an annual peak discharge; a peak discharge that causes flooding is a flood discharge.

Peak stage is the maximum water-surface elevation during a rise in a stream and generally is coincident with the peak discharge.

Recurrence interval, or return period, of a flood of a given magnitude is the average interval of time within which the given flood will be exceeded once by the annual maximum discharge.

Regulatory flood discharge is the flood discharge selected to provide the basis for delineating that part of the flood plain that is to be managed or regulated to reduce flood damage (often the 100-year flood).

Regulatory flood fringe is the shoreward part of the regulatory flood plain that would carry shallow slow-moving water when inundated by the regulatory flood discharge.

Regulatory flood level or **profile** is the stage along the stream that corresponds to the regulatory flood discharge.

Regulatory flood plain is that part of the flood plain that would be inupdated by the regulatory, or 100-year, flood discharge and consists of a regulatory floodway and a regulatory flood fringe.

Regulatory flood profile; see regulatory flood level.

Regulatory floodway includes the incised stream channel and the unobstructed part of the flood plain that would carry deep fast-moving water when inundated by the regulatory flood discharge.

Runoff is that part of the precipitation that appears in surface streams. It is the same as "streamflow" unaffected by artificial diversions, storage, or other works of man in or on the stream channels.

Stage is the height of a water surface above an established datum plane; also see gage height.

Stage-discharge relation is the relation between gage height and the quantity of water flowing in a channel.

Storm runoff is that portion of the total runoff that reaches the point of measurement within a relatively short period of time after the occurrence of precipitation. Also called direct runoff.

Storm water is the excess water running off from the surface of a drainage area during and immediately after a period of rain or snowmelt. It is that portion of the rainfall and resulting surface flow that is in excess of that which can be absorbed through the infiltration capacity of the surface of the basin. See storm runoff.

Streamflow is the discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

Stream valley includes both the incised stream channel and its flood plain.

Watershed management is the analysis, protection, development, operation, or maintenance of the land, vegetation, and water resources of a drainage basin for the conservation of all its resources for the benefit of man and other living creatures.

Water-surface elevation is the height in relation to mean sea level expected to be reached by floods of various magnitudes and frequencies at pertinent points in the flood plains of coastal or riverine areas.

FLOOD-PRONE AREAS AND LAND-USE PLANNING—SELECTED EXAMPLES FROM THE SAN FRANCISCO BAY REGION, CALIFORNIA

By A. O. Waananen, J. T. Limerinos, and W. J. Kockelman
U. S. Geological Survey
and
W. E. Spangle and M. L. Blair
William Spangle & Associates

ABSTRACT

Flood-plain occupance and use is often based on the economic advantages of level ground, fertile soils, ease of access, and available water supplies, without full consideration of flood risk. Structural measures have provided substantial protection in many areas, but full protection of flood plains from all floods is economically infeasible, and flood losses have been increasing. Thus, planning for flood-plain use to minimize flood damage is urgently needed. Flood-prone area maps and other flood information facilitate effective land-use planning by providing a regional overview of the potential flood hazard or detailed information for local planning. Various measures are available for reducing flood losses through protection, removal, or conversion of existing development, discouragement of development in high-risk areas, and regulation of uses on flood plains.

Many Federal, State, and local governmental agencies are involved in flood-plain management and regulation, but often without coordinated authority and scope. The common goal of flood-plain regulation and use is protecting life, minimizing public expenditures, and reducing flood loss. A comprehensive program combining structural and nonstructural measures can yield substantial benefits and may present a practical approach for managing a flood plain.

A review of flood-plain planning, management, and regulation in the San Francisco Bay region, as shown by a study of Napa County, demonstrates complex multijurisdictional involvements. Yet, need exists for more adequate comprehensive planning and coordination to provide for sound development and use of flood plains.

INTRODUCTION

Floods are natural and recurrent events. They become a problem when man competes with rivers for the use of the flood plains—the high-water channels of rivers.

Flood plains are occupied by man because they are usually accessible and profitable to develop. But continued use may be possible only at a price—to sustain flood loss or provide flood-control facilities. Full flood control often is not possible or feasible; yet, abandonment of the flood plain may not be reasonable because the flood plain is a valuable resource and, in many areas, will continue to be occupied. The nature and extent of flood-plain use should be compatible with the risk involved and the degree of protection that would be practicable.

The alleviation or reduction of flood loss has been achieved traditionally through construction of protective works such as dams, dikes, levees, channel improvements, and seawalls. These structural measures have partially reduced hazards. But increasing development of urban flood plains, as reported by White (1960, 1975), has resulted in the paradox of continuing expenditures for flood control and rising flood losses.

Recognition of the mounting flood losses despite flood-control efforts in the United States was contained in the report "A Unified National Program for Managing Flood Losses" prepared by a special Task Force on Federal Flood Control Policy (U.S. Congress, 1966a). The President, in his letter transmitting the report to the Speaker of the House of Representatives, observed that:

> Nature will always extract some price for use of her flood plains. However, this Nation's annual flood damage bill *** is excessive ***. Beyond the dollar loss the accompanying toll in personal hardship cannot be calculated. In addition, opportunities are being lost to use flood plain lands effectively for recreation and wildlife purposes.
>
> The Federal interest in this matter is beyond doubt. The Federal effort to cope with the problem will be unsparing. But I cannot overemphasize that very great responsibility for success of the program rests upon State and local governments, and upon individual property owners in hazard areas. The key to resolving the problem lies, above all else, in the intelligent planning for and State and local regulation of use of lands exposed to flood hazard.

The Task Force report cited the increasing damage potential under existing policies through inadvertent encouragement of uneconomic use of flood plains. It presented recommendations for modifying and broadening policies and programs for flood control and flood-plain management so that any future flood-plain development would yield benefits in excess of costs. Executive Order 11296 (U.S. President, 1966), issued in response to these recommendations, directed the heads of the Federal executive agencies to provide leadership in preventing uneconomic uses and development of the Nation's flood plains. This order further instructed Federal agencies to evaluate flood hazards associated with Federal development proposals and instructed Federal grant, loan, and mortgage insurance agencies to evaluate flood hazards insofar as practical to preclude the uneconomic, hazardous, and unnecessary use of flood plains.

Federal and State policies on flood management are now shifting from protective measures to a balance between structural and regulatory controls. Flood-plain management, including land-use regulation, can effectively reduce flood losses. Land-use regulations can be used alone or in combination with protective works. Information on the extent of the flood hazard, land use, and development is essential for effective application of regulatory controls.

The move toward flood-plain management and the need for flood-plain information has been intensified by Federal legislation such as the National Flood Insurance Act of 1968 (U.S. Congress, 1968) and the Flood Disaster Protection Act of 1973 (U.S. Congress, 1973).

The delineation on suitable maps of areas susceptible to flooding can provide a means for identifying and evaluating flood risk. Such information can be helpful to elected officials, administrators, planners, designers, engineers, and developers concerned with the effective and wise management and use of flood plains.

Comprehensive discussions of the management and regulation of flood plains, including legal aspects, are presented in the reports "Regulations for Flood Plains," by Kusler and Lee (1972), and "Regulation of Flood Hazard Areas to Reduce Flood Losses," by the U.S. Water Resources Council (1971, 1972). White (1975) presents a comprehensive discussion of the state of the art in flood-hazard reduction, with emphasis on research needs. Further, consideration of nonstructural alternatives to reduce flood losses is required by Section 73 of the Water Resources Development Act of 1974 (U.S. Congress, 1974c).

The purpose of this report is to describe the development and use of flood-prone area maps for the San Francisco Bay region, the application of these maps and other flood-plain information in regional and local land-use planning and in the use, regulation, and management of flood plains, and the measures which can prevent or reduce flood loss through control of flood-plain use and protective measures. The maps and related materials described are intended to serve as tools useful to regional and local planning and decisionmaking agencies. Part of the information and techniques presented can also be used by those involved in the reduction of flood losses in communities throughout the nation. The section "Planning for Flood-Loss Reduction in the Napa Valley" describes how earth-science information has been used in one area of the Bay region and shows the practical benefits and difficulties of applying such information.

THE SAN FRANCISCO BAY REGION

The San Francisco Bay region is composed of nine counties contiguous to San Francisco Bay (fig. 1). It includes all stream basins draining into San Francisco, San Pablo, and Suisun Bays within these counties, and coastal basins draining into the Pacific Ocean along about 150 mi (241 km) of coast from about Pigeon Point on the south to the north boundary of Sonoma County. The region encompasses an area of 7,416 mi² (19,207 km²).

The population of the region was more than 4.8 million in 1975. Major urban centers include the Oakland, San Francisco, and San Jose metropolitan areas. Highly developed manufacturing, industrial, and service activities dominate the economy. Agriculture and related activities, shipping, and distribution are also major segments of the economy of the area.

Transportation facilities are extensive. A highly developed Federal, State, and county highway and road system provides access to all parts of the region and adjacent areas. Three major railroads serve the region. Airlines provide passenger and cargo service throughout the world. Seven major seaports permit ocean-going vessels to serve important industrial and agricultural centers and transport commercial cargoes.

Drainage from the Sacramento and San Joaquin Rivers flows through the region. The eastern part of the region includes part of the Sacramento-San Joaquin delta area east of Suisun Bay and part of the lower Sacramento River basin south of Putah Creek. The Gualala, Russian, and Napa Rivers and Ala-

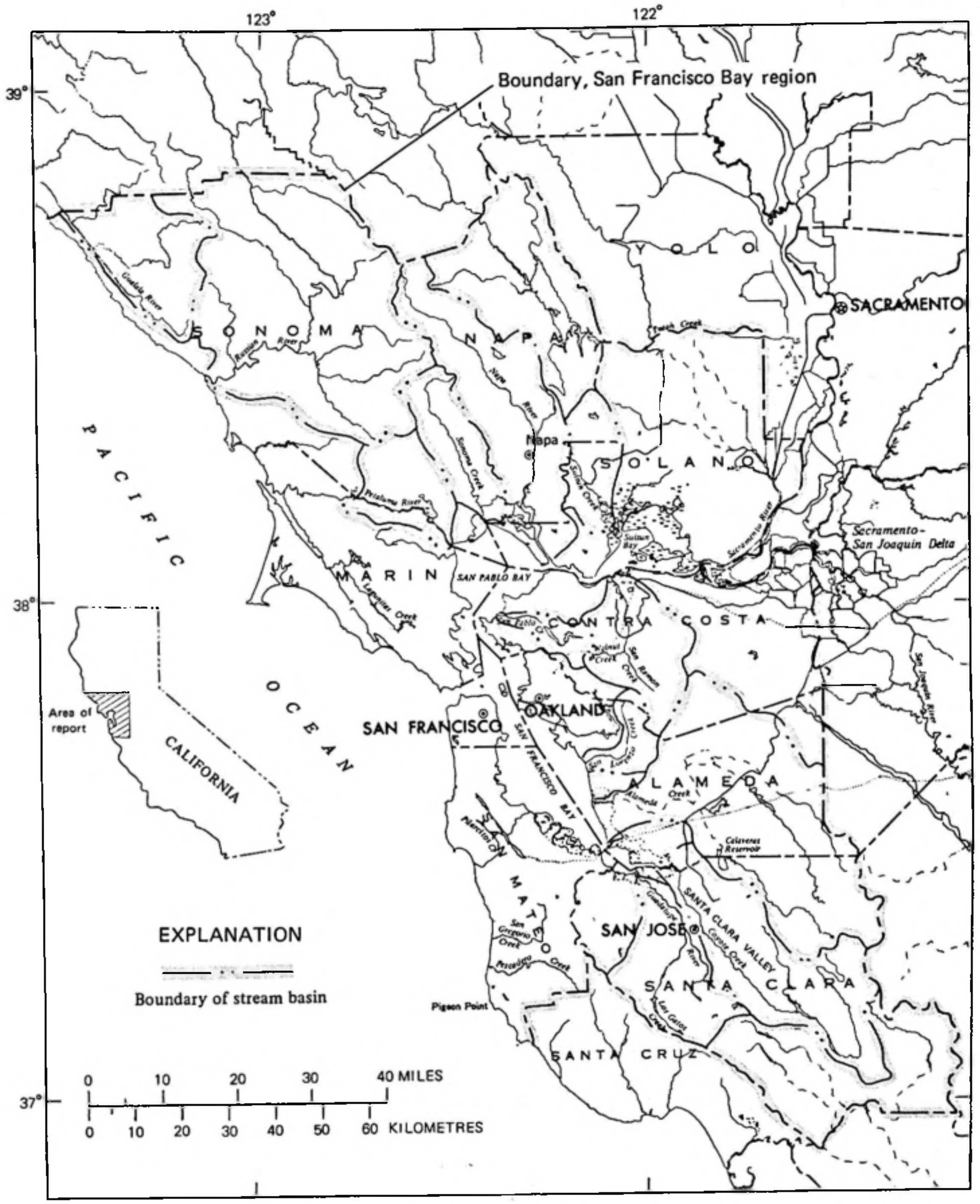


FIGURE 1.—Principal streams and drainage basins in the San Francisco Bay region.

meda and Coyote Creeks are the principal streams in the region; their combined drainage area is about 42 percent of the land area of the region. Other streams include the Petaluma River and Sonoma and Suisun Creeks in the north, San Ramon-Walnut, San Lorenzo, and San Pablo Creeks in the east, and Los Gatos Creek, through Guadalupe River, in the south; all are tributary to Suisun Bay, San Pablo Bay, and San Francisco Bay. Coastal streams that flow directly into the Pacific Ocean include the Gualala and Russian Rivers and Lagunitas Creek north of San Francisco and Pilarcitos, San Gregorio, and Pescadero Creeks south of San Francisco.

Topography.—The San Francisco Bay region lies completely within the Coast Ranges geomorphic province of California, and in part has moderate to high relief with peaks ranging up to more than 4,300 ft (1,300 m) in elevation. The Coast Ranges extend from Santa Barbara County on the south to Humboldt County on the north and form a nearly continuous barrier between the Pacific Ocean and the Great Central Valley. The only significant break in this barrier is in the San Francisco Bay region where the Carquinez Strait between San Pablo and Suisun Bays and the Golden Gate at San Francisco provide gaps through which the Sacramento and San Joaquin River flows are discharges (fig. 1). Mountains are present on the peninsulas north and south of the Golden Gate at San Francisco and along the east side of San Francisco Bay. The region also contains several alluviated valleys of moderately large size.

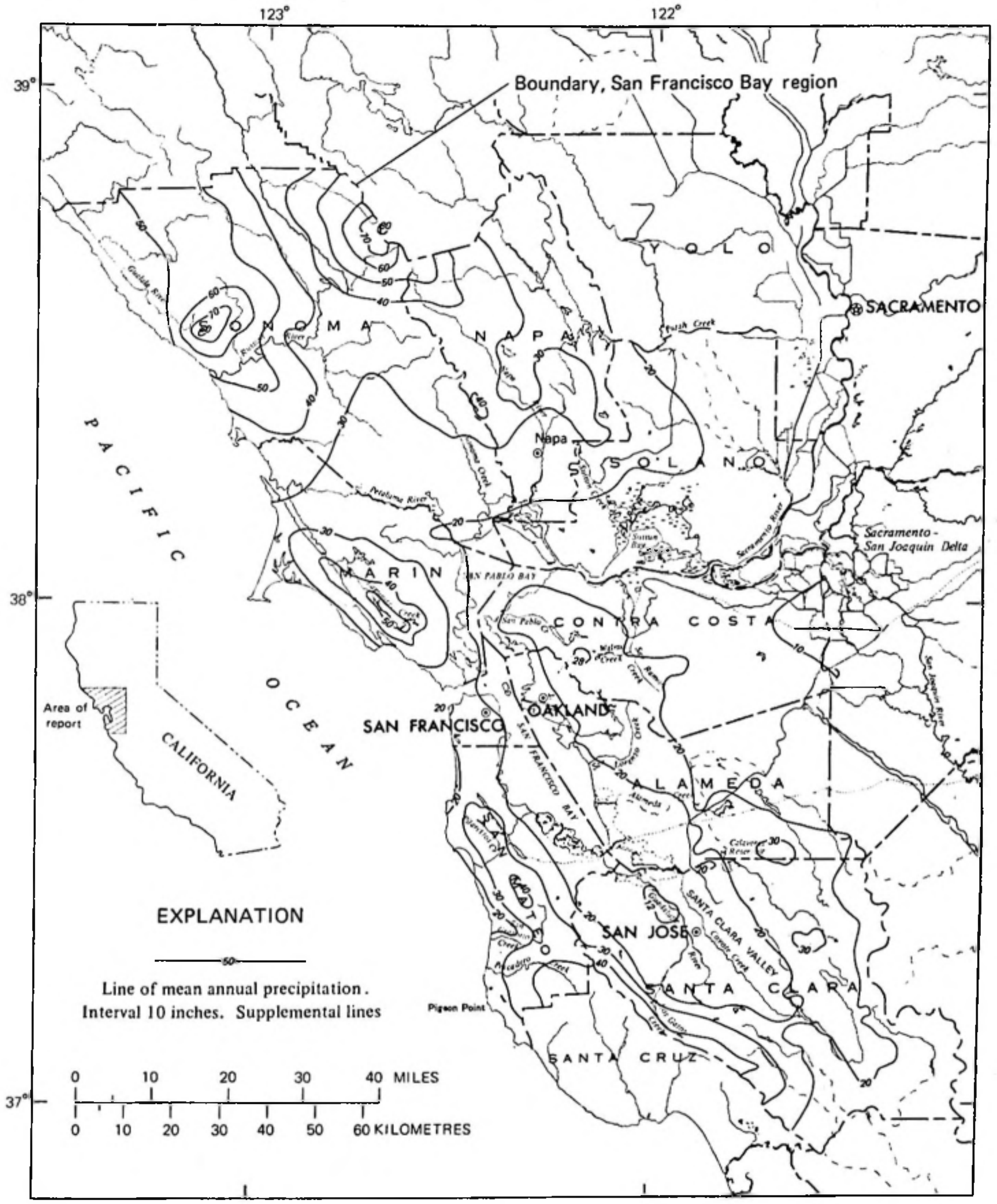
Owing to the hilly and mountainous character of many parts of the San Francisco Bay region settlement and development has tended to concentrate in the foothills, river valleys, and coastal areas. Urban and suburban development has been extensive in the areas bordering San Francisco Bay, the Santa Clara Valley south of the bay, the San Ramon-Walnut Creek Valley east of the bay, and stream valleys in the north bay area, as well as in the adjacent foothills.

Climate.—The climate of the San Francisco Bay region is marked by wide contrasts within short distances. The Pacific Ocean and the topography are the two major features that influence the climate. Precipitation in the region is highly seasonal; almost 90 percent of the annual precipitation occurs during the 6-month period November through April, and the summer months are dry. Concentration of rainfall in wet months can result in serious floods from intermittent streams which seem to be of small consequence during the dry season. Most of the precipitation occurs in a series of general storms that reach all parts of the region, but the storm centers usually pass to the north of the region, and the result is a general tendency for precipitation to decrease from north to south.

Elevation has a strong local influence on the depth of precipitation and, because elevations range from sea level to more than 4,300 ft (1,300 m), there is a wide range in mean annual precipitation—from 10 in. (250 mm) in low-lying valley areas in the east to 80 in. (2,000 mm) in some mountain areas in the north. The distribution of mean annual precipitation in the San Francisco Bay region is shown in figure 2. Temperatures are generally mild, notably through the winter season, reflecting the moderating influence of the Pacific Ocean. Thus precipitation in the region occurs principally as rain. However, at elevations above 2,000 ft (610 m), the winter precipitation sometimes occurs as snow; but, the snowfalls are generally light, and the snow does not remain on the ground for more than a few days. Snow thus does not have a significant role in the hydrology of the region. Intense local convective storms are almost unknown in the region. Sustained heavy rains during general storms are the principal cause of riverine flooding in the San Francisco Bay region.

Flooding problems.—The San Francisco Bay region periodically experiences damaging floods. These floods usually are of riverine origin and affect flood-plain lands adjacent to the streams. Occasionally extreme high tides in the bay and coastal areas, or combinations of high tides, winds, and floods in the streams, cause coastal flooding and inundation of lands adjacent to San Francisco Bay. The resulting annual flood loss in the region is estimated to average more than $22 million (1965 prices), based on studies by the California Region Framework Study Committee (1971). These losses occur even though millions of dollars have been expended on flood-loss reduction measures. On a National basis, despite a Federal investment of more than $9 billion in flood-protection and prevention measures since 1936, the annual flood loss was estimated to average more than $1.7 billion, as of 1966 (U.S. Water Resources Council, 1968, p. 5-2-6), and as much as $2 billion in 1972 (U.S. Office of Emergency Preparedness, 1972, v. 1, p. 15).

Flood-control and flood-management measures such as reservoirs, levees, and channel improvements provide flood protection for many areas. But flood protection can seldom be complete. There is always a probability that a greater flood will occur than has been experienced in recorded history. Par-



Hydrology from S. E. Rantz (1971)

FIGURE 2.—Mean annual precipitation in the San Francisco Bay region.

tial protection from flooding may encourage greater use and development of the flood plain. Then, when a flood exceeds that for which protection is provided, losses may be greater than if no protection had been provided. Further, average annual flood loss from lesser floods has not been reduced as the continuing demands for land development have brought about further encroachment on and more intensive use of the flood plains. Annual flood loss has increased in the San Francisco Bay region and throughout the Nation (U.S. Congress, 1966a) as a result of increases in property values, in the magnitude of floods, and in building and other uses on flood-plain lands.

Extensive flooding occurred throughout the San Francisco Bay region in 1955 and 1958 and in parts of the region in 1940, 1952, 1963, and 1964. Losses from the four later floods were about $23 million in 1955, $14 million in 1958, $4 million in 1963, and $17 million in 1964, estimated at the time of occurrence, or reported by the California Region Framework Study Committee (1971, p. SF-2). These floods include some of the greatest in the region since the turn of the century. On an areawide basis, they have a probability of being exceeded once in 50 years, on the average (2 percent chance of being exceeded in any one year). An appreciation of the flood hazard in the region may be gained from the realization that planning for flood-plain management is usually based on the flood level that would be exceeded once in 100 years, on the average. The 100-year floodflows would be about 20 percent greater than the maximum flows that have occurred in this century. Potential losses from the 100-year flood in all streams in the region would exceed $200 million (1965 prices), based on estimates by the California Region Framework Study Committee (1971).

Relationships and benefits of study.—The delineation of flood-prone areas represents an interpretation of water-resources data useful in land-use planning and decisionmaking. This study is part of the San Francisco Bay Region Environment and Resources Planning Study, and is directed toward minimizing flood losses. The identification of areas that may be subject to flooding from either riverine or tidal sources, as shown by flood-prone area maps and flood-inundation studies, is important to the wise use and development of such areas. Awareness of potential flooding can lead to a more complete appraisal of the extent of possible flooding at specific sites and to improved decisions on site selection, design, and protection. Further, in flood-prone areas, regional and local administrators and planners would be alerted to the desirability of considering and evaluating alternative uses of flood plains.

The San Francisco Bay region study of flood-prone areas and land-use planning should provide an example to other metropolitan areas throughout the Nation of potential uses of flood information and inundation maps in regional and local land-use planning and decisionmaking. The section "Planning for Flood-Loss Reduction in the Napa Valley" shows the practical application of this information. Similar applications can be made in other areas throughout the Nation. Techniques for developing the maps may vary, however, depending on the hydrologic and hydraulic data available.

ACKNOWLEDGMENTS

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Acknowledgment is made of the extensive data, maps, and reports on floods and flood damage, flood-control projects, flood-plain information, land-use and watershed planning, and flood-plain management, prepared by Federal, State, county, and local agencies and by numerous public and private agencies and organizations, that were used in the preparation of maps of flood-prone areas and the studies leading to this report. The cooperation of regional and local agencies in the San Francisco Bay region such as the Association of Bay Area Governments, and agencies of the city of Napa and Napa County, are gratefully acknowledged. S. E. Rantz, U.S. Geological Survey, provided helpful guidance in the initiation of the report and in earlier studies related to the preparation of maps of flood-prone areas.

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FLOODS AND THE FLOOD PLAIN

By A. O. Waananen

The occurrence of floods is a part of a natural pattern of water circulation from the seas to the atmosphere, to the ground, and back to the seas again called the hydrologic cycle (fig. 3). In this cycle water from the surface of the oceans and other water bodies evaporates into the atmosphere. This vapor is condensed by various processes and falls to the earth as precipitation. Part of the precipitation that falls on the land surface is retained temporarily in the soil, in surface depressions, and on vegetation and other objects until it is returned to the atmosphere by evaporation and transpiration. The remainder moves through surface and underground channels to rivers, lakes, and eventually the sea, and is likewise subject to evaporation and transpiration. Precipitation in its various forms is the source of freshwater on the earth's surface. Through the hydrologic cycle freshwater thus becomes a renewable resource.

Floods are natural and normal events. Streams have, from time immemorial, periodically overflowed their banks and inundated their natural flood plains and floodways. In many areas the rich fertile soils deposited by such overflows, and the replenishment of soil moisture by the floodflows, have sustained an abundant agriculture. In semiarid areas such overflows may constitute the only source of enrichment and irrigation. Prior to intensive development periodic flooding was accepted as a natural, if at times frightening, event. After the floods the streams usually would revert to their normal channels, leaving the flood plains suitable again for agriculture and other compatible uses.

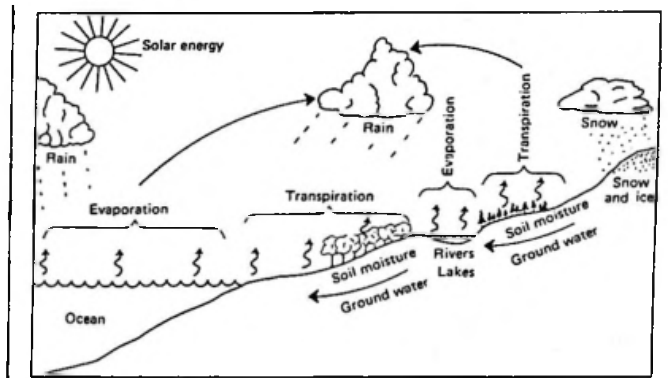


Figure 3.—The hydrologic cycle.

Typically, a stream will overflow its normal channel about once in 2 or 3 years and invade low places on its flood plain. The overflow occurs when the volume of water entering a stream channel exceeds the hydraulic capacity of the channel. Greater floods occur at less frequent intervals, with concomitant increase in the area affected; but, only about once in a century or longer, a great flood will submerge all the alluvial deposits in the stream valley. Floods vary in size, area inundated, duration, and frequency depending on natural and certain manmade conditions. The natural conditions include the total quantity, intensity, and geographical distribution of rainfall and snowmelt, storm patterns, antecedent moisture conditions, temperature, and season of the year, as well as the physical features of the watershed, such as topography, soils, geology, and drainage pattern. The manmade conditions include the various rural and urban land uses, storage, diversion, and regulation of streamflows, as well as changes in drainage and other factors that affect storm-water runoff.

MAJOR FLOODS IN THE REGION

The San Francisco Bay region is rarely subjected to areawide floods. The mountains and bays subdivide the region into relatively small and independent valleys thus eliminating the cumulative effect that might be found in a single-stream system. Floods on the various streams in the region are caused by intense rains and usually are of short duration. Runoff is derived almost entirely from rain, as the snow that does fall is not extensive.

Outstanding floods have occurred. Records extending back to 1787 mention storms during the winter 1798–99 that were reported to have lasted for 28 days, and rains in January and February 1819 caused floods that changed the courses of many streams.

Floods in 1861–62 affected extensive areas in California, and in many areas they were of such magnitude that they represent the greatest floods known. In the San Francisco Bay region considerable damage was caused in the towns of Napa, Alvarado, and San Leandro and in San Mateo and Santa Clara Counties (fig. 1). Floods on the Napa River and Petaluma Creek in January 1881 exceeded any other known flood. During the 1889–90 season record precipitation occurred at many points in the region. The flood of January 1890 near San Jose was the greatest since 1862 and may not have been equaled since. The 1890 flood in Napa River at Napa was reported to be only a foot lower than the record height set in 1881. Flows in the Russian River in 1890 exceeded the levels set in 1861 and approached those of the great flood of 1879 in this basin; the basin experienced another great flood in 1895. In March 1907 floods in Los Gatos Creek and other streams in the Santa Clara Valley were especially severe, and lands near San Jose were flooded. Alameda Creek reached levels as high as those in 1895. Flooding was also severe in the Russian River basin. In addition, many other floods of moderate extent have been experienced and reported in some part of the San Francisco Bay region since 1849, as reported in U.S. Geological Survey Water-Supply Paper 843, "Floods of December 1937 in Northern California," (McGlashan and Briggs, 1939, p. 434–437), and in reports on floods subsequent to 1937.

The floods of December 1955 generally were the greatest floodflows of the present century over the San Francisco Bay region except for those in San Lorenzo Creek at Hayward in 1962 and Coyote Creek at Madrone in 1911. Other notable recent floods occurred in 1952, 1958, 1963, 1964, and 1969 and affected different parts of the region. The December 1964 and January–February 1963 floods were severe principally in the northern part of the region, while the January 1969 floods were limited to the southern part.

The flood of December 23, 1955, was the highest in Alameda Creek in the record of peak discharge that started in 1916, and probably the highest since the flood of November 1892. The four highest floods in Alameda Creek near Niles occurred in 1950, 1952, 1955, and 1958 despite a storage capacity of 96,800 acre-ft (119 hm^3) in Calaveras Reservoir which was completed in 1925.

Precipitation records and historical accounts appear to indicate that the San Francisco Bay region has not experienced a major or areawide flood since 1889–90. Only the flood of December 1955 has approached the 1889–90 flood in magnitude and areal extent.

Many severe floods of limited extent have occurred in different parts of the region. Conservation and flood-control reservoirs in many of the basins in the region have reduced the peak discharges that otherwise would have occurred. Floodwaters from many storms have been retained in reservoirs operated by the Santa Clara Valley Water District (formerly Santa Clara County Flood Control and Water District) since about 1935 for subsequent release at controlled rates to percolation basins for replenishment of ground-water supplies. But most of the streams in the region have insufficient storage or no storage for the control or attenuation of major floods.

CHARACTERISTICS OF FLOODFLOWS

Two characteristics of floodflows—the frequency of occurrence and the relation between the quantity of flow and the water-surface elevation—are of particular significance to the use of flood-plain lands. These characteristics are described in the following sections.

FLOOD FREQUENCY

In any evaluation of flood hazard or flood potential the probability of recurrence of floods of a given magnitude must be estimated. The probability of occurrence of floods of various magnitudes at a site may be determined by statistical analysis of annual peak discharges for all years of record at the site, whether or not all of these events caused inundation. Peak discharge is the highest rate of flow in a stream and generally occurs coincident with the greatest water-surface elevation during a rise in the stream. The annual peak discharge, by conventional usage in most areas, is the greatest flow in a 12-month period—usually October through September (the so-called water year).

The magnitude of the annual peak discharge at a site varies from year to year, and it is customary to compare those magnitudes in terms of their probability of occurrence. The comparison is made by means of a flood-frequency curve for the site which shows the probability of any given discharge being exceeded in any year. A common practice is to refer to a peak discharge of a given magnitude in terms of its recurrence interval—the inverse of the probability of occurrence. The recurrence interval, or return period, is the average interval of time within which a given peak discharge will be exceeded once by the annual peak discharge. Thus, a peak discharge that has a 2 percent (1 in 50) chance, or probability, of being exceeded in any year is a 50-year flood peak, while the peak discharge that has a 1 percent (1 in 100) chance is a 100-year flood peak.

A flood-frequency curve is illustrated in figure 4, which shows a typical curve for a basin in the San Francisco Bay region that has a drainage area of 5 mi^2 (13 km^2) and mean annual precipitation of 40 in. (1,000 mm), Figure 4 shows the 50-year flood discharge at the hypothetical site to be 1,740 ft^3/s (49.3 m^3/s). Thus, a flood discharge of 1,740 ft^3/s (49.3 m^3/s) has a 2 percent chance of being exceeded in any year; or it may recur at intervals of 50 years, on the average. Similarly, the magnitude of the 100-year flood discharge is 2,090 ft^3/s (59.2 m^3/s). These values show the ratio of the 100-year to the 50-year flood discharge to be 1.2, rather than 2, the relation of the time intervals. The ratios between flood discharges of various recurrence intervals depend primarily on the regimen of storm precipitation and thus vary from region to region. The average ratio between the 100- and 50-year flood discharges in the San Francisco Bay region is 1.20, but it ranges from 1.25 for basins with a mean annual precipitation of 10 in. (250 mm) to 1.10 for basins with a mean annual precipitation of 80 in. (2,000 mm).

Recurrence intervals are average periods based on historical data; because the occurrence of floods is erratic the 50-year floodflow may not necessarily occur in any given 50-year period, or floods of this magnitude may occur several times during that period. A similar relation is true for a peak discharge of any given recurrence interval.

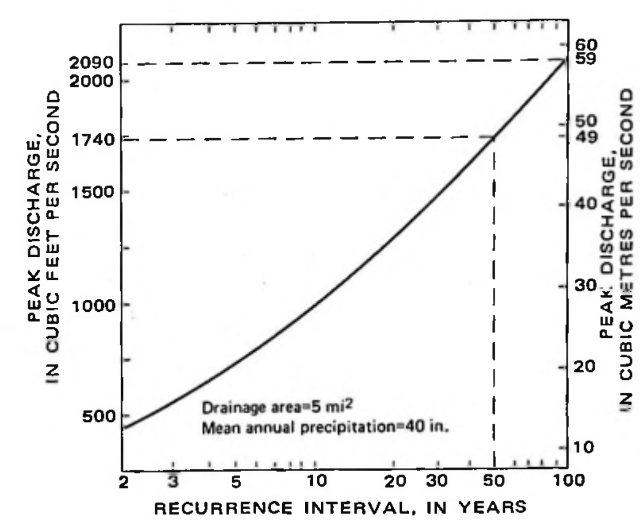


FIGURE 4.—Flood-frequency curve for a hypothetical basin in the San Francisco Bay region.

STAGE-DISCHARGE RELATION

For every peak discharge there is a corresponding peak stage, or water-surface elevation. The stage depends not only on the magnitude of the discharge, but also on the physical features of the stream valley. Pertinent physical features include ground or streambed slope in the direction of flow, cross-sectional size and shape of the stream channel and the valley, and the roughness and alinement of the streambed, banks, and overflow area. The slope of the water-surface profile during periods of high water usually is approximately parallel to the average slope of the channel, with no abrupt changes in elevation in the water-surface profile if the flow is not obstructed or constricted. However, some pronounced changes in cross-sectional size and shape are common in a reach or length of stream valley. Stream valleys, for example, may range from wide, flat flood plains to steep-sided canyons. Such pronounced differences in shape and ground elevation, combined with the relatively uniform water-surface levels, may cause wide variations in the extent of flooding and the depth of flow in the main channel and on the flood plain. This is illustrated in figure 5, which shows two valley sections and the profiles of the streambed and of the water surface for the 10- and 100-year flood discharges in a reach. The sections show that the channel is more deeply incised at section A than at section B. Flow velocities in an unobstructed waterway are usually greater in the part of the section with the greater depths.

The relation between stage and discharge is normally used as a basis for computing or determining streamflows. Conversely, this relation provides a means for determining the water-surface elevation at a site or in a reach corresponding to floodflows of designated frequency, such as the 10- or the 100-year flood.

CHARACTERISTICS OF THE FLOOD PLAIN

The flood plain is the normally dry land area adjoining rivers, streams, lakes, bays, or ocean that is likely to be flooded. Most commonly flooding of these lands results from the overflow of streams and rivers or from abnormally high tidal water or rising coastal water resulting from severe storms, hurricanes, or tsunamis (seismic sea waves). Along streams the flood plain may include the full width of narrow stream valleys or broad areas along the streams in wide, flat valleys. The hydrologist and the hydraulic engineer often use the term flood to de-

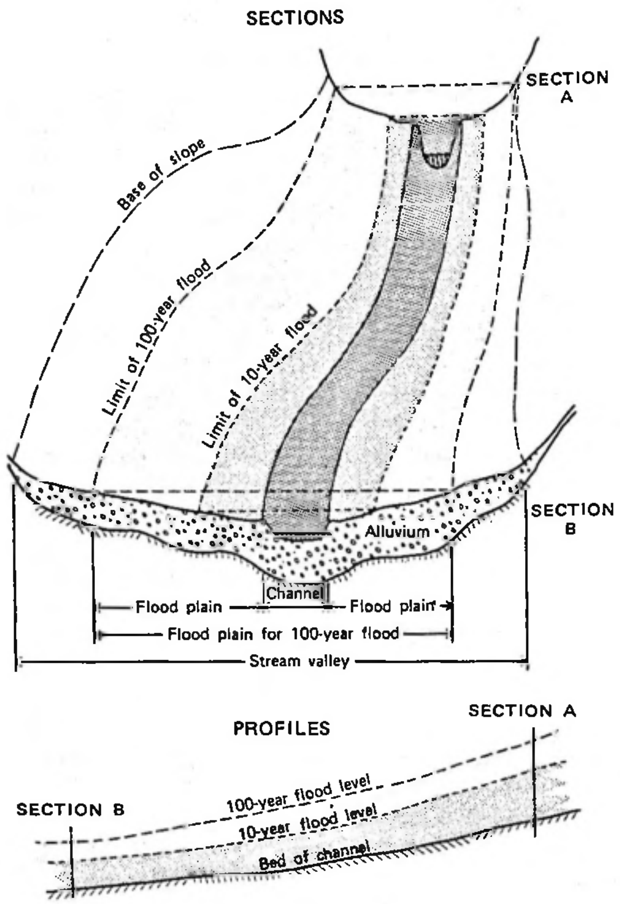


FIGURE 5.—Typical sections and profiles in an unobstructed reach of stream valley.

scribe a relatively high streamflow that overtops the banks of a stream or channel or a relatively high flow as measured by either the elevation of the water surface or the volume of flow (see "Definition of Terms").

The principal characteristics of a stream valley are shown in figure 5. The channel and flood-plain sections are integral parts of the natural conveyance system of a stream. The erosive power of a stream carves a channel large enough to carry the most frequent flow. Occasionally heavy rains or melting snow contribute a flow greater than the capacity of the channel. Then the flood plain carries the flow in excess of channel capacity. Flows that occur at intervals of 3-5 years may overtop the natural banks and occupy low-lying sections adjacent to the stream that constitute part of a natural floodway. Greater floods, which occur at less frequent intervals, extend over the remainder of the flood plain. During these greater floods the floodway may transport the principal part of the floodflows. In fringe areas on the flood plain the flooding usually consists of shallow inundation with low flow velocities. In the San Francisco Bay region some overflow generally occurs at intervals averaging from 3-8 years in streams not markedly affected by urban development.

Any encroachment on the flood plain interferes with the natural flow pattern during high stages. The areal extent of inundation of the flood plain is therefore related to the magnitude of the flood discharge and the physical characteristics—both natural and manmade or man-influenced—of the stream valley, which includes both the incised stream channel and its flood plain. Uses of the flood plain, such as for agriculture and recreation, that involve little physical change have minor effects on the stage and the extent of inundation. But the modification of natural drainage systems and the concentration of various structures that are part of the pattern of urban, suburban, industrial, and commercial development present obstructions to or alterations of flow that may affect the stage, depth, and extent of flooding.

Occupance of the flood plain can thus result in two kinds of flood losses. An individual who uses the flood plain for any development invites flood losses to himself; the potential for loss depends on the vulnerability of his specific use. But, more importantly, his entry on the flood plain may create problems and costs to others by causing higher flood stages through impedance or obstruction of the normal pattern of floodflow and reduction of flood-plain storage capacity. The increased flood depths would affect not only his flood-plain neighbors but could also affect residents outside the area who would otherwise not be flooded. Hillside developments may also affect flood-loss potential as a result of accelerated runoff discharged to flood-plain areas downstream.

The periodic inundation of flood-plain lands may result in losses to occupants including loss of life and property, hazards to health and safety, disruption of commerce and governmental services, and expenditures for flood protection and relief. These losses may be caused by both the cumulative effect of obstructions in flood plains that cause increased flood heights and velocities and uses of areas that are vulnerable to floods or present health and safety hazards because they are inadequately elevated or protected from flood damage.

The problems resulting from flood-plain occupance and use have led to the development of plans and means for reducing or alleviating flood damage. Measures generally applied fall into the two broad categories—structural and nonstructural. Structural measures include reservoirs, levees, floodways, and channel improvements; nonstructural measures (flood-plain management practices) generally include flood-plain regulation or control of land use. The purpose of flood-plain regulation is to promote beneficial use of flood plains with a minimum of flood damage and expense for flood protection. Nonstructural measures may be used effectively in combination with structural measures to achieve maximum benefits. The development and application of flood-plain regulations are described in the section "Planning for Flood-Loss Reduction."

A basic feature of flood-plain regulation is the establishment of a regulatory flood discharge, commonly the 100-year flood. The topography of the flood plain, the magnitude of the floodflow, and the corresponding water-surface elevation and profile would determine the areal extent of the inundation. The part of the flood plain affected by this discharge can be described as the regulatory flood plain. It would include the channel, floodway, and fringe area required to transport the regulatory flood discharge. Figure 6 shows the flood-hazard areas of a regulatory flood plain along a river. A regulatory floodway would include the channel of a stream and the unobstructed adjacent land areas necessary to convey floodflows for a selected flood discharge without substantially increasing flood heights above unrestricted levels. The width of a regulatory floodway could be reduced for the same size flood, if some backwater effects are permissible, through channelization or installation of dikes, levees, or other constrictive embankments or fill.

Coastal areas may be subject to high hazard from high energy winds and wave action, in addition to inundation, with resultant possible destruction of structures and facilities or severe erosion.

Comprehensive discussion of the regulation of flood plains and flood-hazard areas is presented in reports by Kusler and Lee (1972) and the U.S. Water Resources Council (1971, 1972).

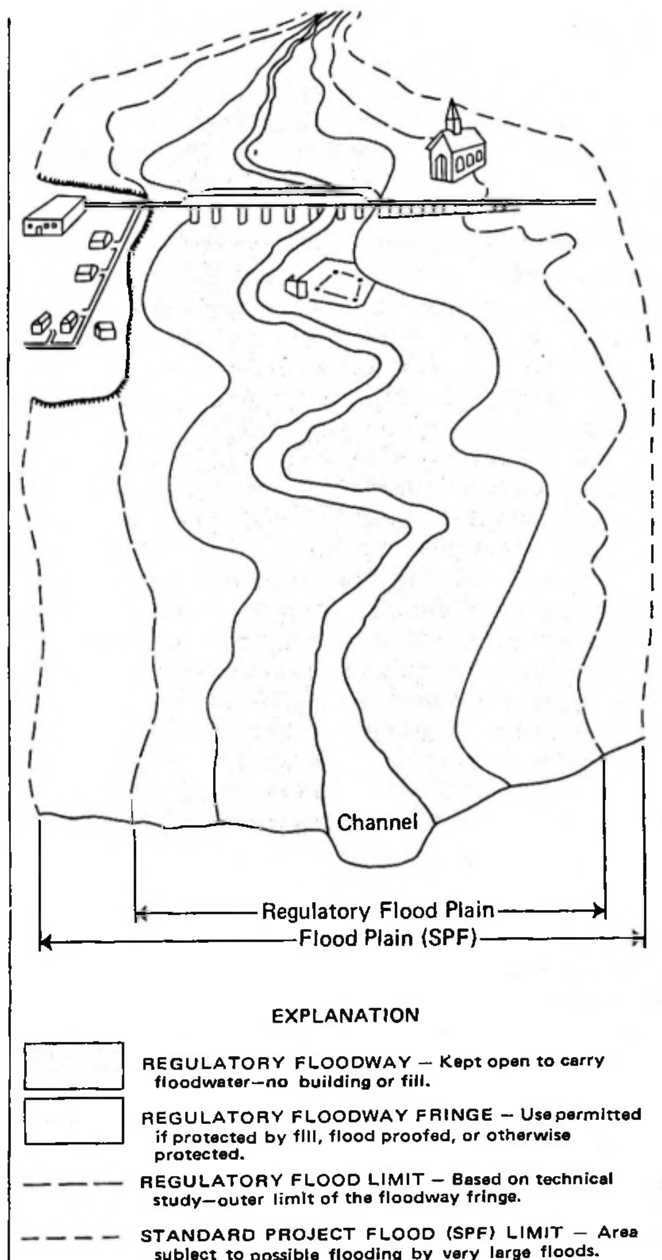


FIGURE 6.—Riverine flood-hazard areas of a regulatory flood plain. (Adapted from U.S. Water Resources Council, 1971.)

MANMADE INFLUENCES ON POTENTIAL FLOODING

The use of the flood plain by man has been accompanied by a variety of changes in the characteristics of the flood plain and floodflows. Under natural conditions the flood stage, or level of flooding, depends on both the peak discharge and the physical features of the stream valley. Under the changed conditions resulting from manmade influences the nature and extent of developments on the flood plain and upstream affect both the peak discharge and the three pertinent physical features—slope, cross-sectional area, and the roughness and alinement of the water course—that govern the stage-discharge relation and the consequent peak (flood) stage. These manmade influences thus affect the potential for flooding and damage. Some changes, such as those resulting from urban development, may be inadvertent and have adverse effects. Others, such as reservoirs and channel improvements, are intentional and are directed toward alleviating the flood hazard. Some projects reduce flood hazards in addition to serving the primary or multiple-purpose uses for which they were constructed.

INFLUENCE OF URBANIZATION ON POTENTIAL FLOODING

A characteristic of urban growth is the continuing increase in the extent and intensity of flood-plain use. The level and fertile lands and the ease of access and transportation initially made the flood plain attractive. With continued growth an increasingly greater part of the flood plain and adjacent foothill areas was used for homes, industry, and associated commercial and municipal purposes. Such resulting urban development usually leads to pre-emption of the flood plains of streams and encroachment on the natural floodways, often without regard to the periodic flood hazards and concomitant dangers to property, health, and life.

The principal hydrologic effect of urbanization is an increase in the peak flows and the corresponding peak stages for floods of all recurrence intervals. As increasingly large percentages of the drainage basins of streams are made impervious by roofs and paving, and as drainage channels are lined, paved, or replaced by pipe, both the infiltration of rain and the lag time, or time response of runoff to rainfall, are decreased. The result is usually a greater and earlier concentration of storm runoff in a channel and greater peak flows than would occur under natural conditions. The magnitude of the increase in flow depends also on the location of the impervious areas in the basin and the manner in which the runoff from the impervious surfaces reaches the collector channels. Storm runoff from developed areas in the lower part of a basin may cause sharp, short-duration peak flows that precede the runoff from the upper basin, while accelerated and intensified runoff from such areas in the upper basin may coincide with and accentuate downstream peak flows. The peak flows thus may be augmented in most basins but reduced in some.

The increases in flow resulting from urban development, in relation to natural flows in streams, usually are greatest for the smaller peak flows that have short recurrence intervals, and for which the peak flows may be increased manifold. The greater floods, those with long recurrence intervals, generally reflect basin-wide runoff after substantial saturation, a condition which would also occur under natural conditions. The saturation effect is similar to the urbanization effect, a reduction in infiltration and an increase in runoff. Thus the magnitude of the urban influence is less for the greater floods. The average ratios of peak flows for urbanized and unurbanized basins for the 50- and 100-year floods in the San Francisco Bay region are shown in figure 7. Floodflows from basins that are 80 percent urbanized, for example, are about twice those from the unurbanized basins, and the ratios are only slightly smaller for the longer recurrence interval. Urbanization is but one complex factor affecting the ratios. Other studies have shown that ratios are also smaller for drainage basins with the greater mean annual precipitation; the effect of mean annual precipitation is significant, however, only for peak flows with recurrence intervals less than 50 years.

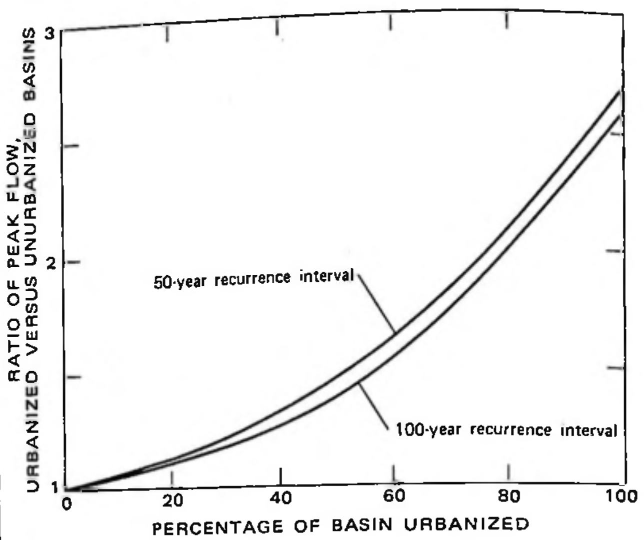


FIGURE 7.—Ratios of peak flows for the 50- and 100-year floods in urbanized and unurbanized basins in the San Francisco Bay region.

Thus, for any site downstream from an area that has become urbanized, the increased peak discharge at the upstream urbanized area will be reflected in increased peak discharge downstream. If the site is downstream from an area that has been leveed (see succeeding section "Structural Measures") the increase in flow velocity at the leveed area will increase the downstream velocity of the flood peak. The change in timing of the flood peak may cause an increase in the peak discharge at the downstream site. Upstream channel improvements that increase the velocity of the streamflow generally have a tendency to increase peak flows downstream.

An associated effect of increased floodflows resulting from urban development is an increase in flood stage, as determined from the stage-discharge relation. Further, developments on the flood plain and encroachment on the floodway may obstruct floodflows and reduce floodwater storage sufficiently to cause backwater, flow retardation, and increased flood depths in the channel and the flood plain.

Urban development also has other effects in addition to the impact on peak flows. Total yield and annual runoff usually increase as the shortened time of surface runoff reduces infiltration opportunity. Low flows increase as a result of the discharge of wastewater from lawn irrigation and industrial and municipal operations, and effluent from sewage treatment plants and septic tanks. In contrast, recharge to the underlying ground-water basins, decreases owing to reduced infiltration.

WATERSHED MANAGEMENT

Watershed management generally refers to practices and measures designed to improve land use, alleviate flooding, and reduce erosion and sedimentation. These benefits may be achieved through combinations of land treatment and structural measures. The land-treatment measures may consist of agricultural practices to enhance the vegetative cover designed to reduce overland flow and runoff and to control erosion, stabilization of stream channels, drainage mains and laterals, and irrigation-water management. The methods include revegetation of bare soil, elimination of overgrazing, contour plowing, strip cropping, terracing, and mulch tillage. The objectives are accomplished by increasing the volume of surface storage for water, the rate of infiltration of water into the soils, and the capacity of the soil to store water. While these practices are effective in reducing the magnitude of the more frequent peak flows, the effect on the peak flows of major floods is minor. The practices do, however, reduce erosion and the subsequent volume of sediment in streams, with consequent reduction in flood damage.

Some agricultural practices, such as harvesting timber or substituting shallow-rooted grasses that have an economic grazing potential for noneconomic deep-rooted grasses, tend to increase peak discharge. The rate of runoff from logged areas, for example, may be increased with resultant higher peak flows. Because deep-rooted vegetation draws water from greater soil depths than shallow-rooted vegetation, the soil penetrated is left with a greater capacity to accept infiltration from rain during subsequent storms. The substitution of shallow-rooted vegetation may result in some increase in runoff. The effect would be significant primarily for the small, more frequent peak flows.

STRUCTURAL MEASURES

Constructing and operating reservoirs for water supply, flood control, power, irrigation, and conservation, developing and operating watershed-management programs, and constructing channel improvements for flood control and navigation all have an influence on flood discharge and stage. The general impact of these operations and measures is a reduction in the magnitude of floodflows.

Reservoirs.—Operating storage reservoirs that have gates to control the release of water will reduce downstream peak discharge when storage space is available at the time of peak inflow to the reservoirs. These reservoirs may provide full control, or serve multipurpose needs. Even reservoirs that are full and spilling at the time of peak inflow may reduce the peak discharge downstream by attenuating the floodflow.

Detention (ungated) reservoirs will normally have a similar effect on downstream peak discharge. However, discharge openings in detention reservoirs should be designed to ensure that the reduced peak outflows from such reservoirs will not be synchronized with other peak flows downstream in such a way that the combined flows produce greater peak discharge than would result from the natural, unsynchronized discharges had the reservoirs not been built.

Channel improvements.—The stage corresponding to a given discharge may be reduced by structural measures such as channel improvements that increase channel capacity by increasing the cross-sectional area of a stream channel or the stream velocity. These improvements may include straightening, realining, and eliminating bends in the channel, installing stabilization structures, changing floodway and bank vegetation, and paving. The area of a section may be increased by deepening or widening the main channel. Removing snags, trees, and brush increases the effective cross-sectional area, but a greater effect is an increase in velocity through reduction of flow-retarding influences.

The velocity of flow may be increased in many instances without reducing the cross-sectional area. Straightening and realining the channel and eliminating bed and bank irregularities will remove impediments to flow. Eliminating bends will reduce the effective length and increase the slope of a channel because the drop in streambed elevation in the reach occurs in a shorter distance. An increase in slope causes a corresponding increase in the velocity of flow. Deepening a channel will increase the hydraulic capacity more than widening and will also increase the velocity. Thus, for the same increase in section area, channel deepening is more effective in reducing stage. Reducing stage by improving the channel will be reflected in lower stages that extend a short distance upstream from the improved reach of channel, but will have little effect downstream.

In some instances improving the channel may have adverse effects. Straightening an alluvial channel by removing bends, and possibly increasing flow velocities, for example, may result in erosion and sedimentation problems. Paved channels could provide the ultimate in eliminating flow-retarding influences, but the measure may not be fully acceptable because of esthetic, ecological, and other environmental considerations, such as interference with natural alluvial deposition and ground-water recharge. Although channel modifications may benefit lands adjacent to the treated reach, they will tend to pass the flood problems on downstream.

Levees.—Levees are embankments along streams or on flood plains that confine river and overbank flows to a definite width for the protection of lands that are landward from the levee. The major or principal levees are usually designed to provide protection from the 100-year and greater floods. Levees reduce the cross-sectional area of flow and increase the velocity of flow within the constricted (leveed) reach of channel and flood plain. The stage of the flood discharge may be raised in and upstream from the leveed reach, but it will be little affected downstream.

OBSTRUCTIONS

The stages reached in streams and on the flood plain during major floods may be affected by several factors. Bridges that have limited waterway openings and raised approach embankments present impediments to flow that raise stream stages at the bridge. The effects sometimes extend for some distance upstream. Obstructions in the floodway and on the flood plain such as commercial and industrial buildings and residences may also cause substantial reductions in cross-sectional area and raise the flood stage. Flow velocities may be reduced immediately downstream from such obstructions but may be accelerated in the intervening flow paths. An obstruction in the floodway such as an isolated building may cause a local rise in water level immediately upstream. Concentrated development in urban areas may cause sufficient resistance to flow to cause a substantial increase in flood stage and associated greater damage from inundation.

DELINEATION OF FLOOD PLAINS

By J. T. Limerinos

Areas subject to flooding are commonly identified in reports on floods and in studies of measures for the alleviation or control of flooding. Reports on major floods prepared by various governmental agencies may include maps showing the extent of inundation from the floods. Studies of flood-control or flood-management projects similarly include appraisals of the probable extent of the areas subject to inundation from floods of designated recurrence intervals before and after installation of the proposed measures.

Flood-plain information in more detail is also available for many areas in several series of maps and information reports prepared by Federal, State, and local agencies. These maps generally provide sufficient information for identifying areas of potential flood hazards; for some areas the data in the flood-plain information reports may permit detailed evaluation of the hazards. This information is useful to planners, developers, public agencies, and private citizens concerned with future land development and use.

Flood-plain inundation maps provide basic information useful in developing land-use plans and policies for flood plains and adjacent areas and in formulating regulations for managing flood plains.

Some of the principal types of maps and reports that identify and delineate areas subject to inundation from floods and the sources of this information are described in the following sections.

FLOOD-PLAIN INUNDATION MAPS

Two general types of flood-plain inundation maps—flood-prone area and flood-hazard maps—have been issued by the U.S. Geological Survey. Maps of flood-prone areas show the areas likely to be flooded by virtue of their proximity to a river, stream, bay, ocean, or other watercourse or water body, as determined from readily available information. Flood-hazard maps show the extent of inundation as determined from a thorough technical study of flooding in a given locality. The detail and accuracy may be sufficient for readily identifying the relation of special flood hazards to individual building sites.

Flood-plain inundation maps have also been prepared by other governmental and private agen-

cies. Inundation maps are an integral part of comprehensive flood-plain information reports prepared by the U.S. Army Corps of Engineers and of watershed work plans and water- and land-management reports prepared by soil conservation agencies. Flood plains of many streams have been mapped by local agencies and special districts.

MAPS OF FLOOD-PRONE AREAS

A report by the Task Force on Federal Flood Control Policy (U.S. Congress, 1966a), included a recommendation that flood-prone area maps be prepared to assist in minimizing flood losses by quickly identifying areas of potential flood hazards. As part of a national program the U.S. Geological Survey in 1969 began compiling a series of maps for California to identify flood-prone areas and to alert owners, planners, public agencies, and developers to the areal extent of flood hazards. The maps prepared in 1969 showed areas "occasionally flooded," the delineated areas generally being those inundated by the greatest recent floods. Maps prepared since 1969 show the approximate limits of flooding for the 100-year flood. Through 1974 nearly 500 map sheets had been prepared for California; 119 of these are for the San Francisco Bay region (see table 10 and fig. 28).

The flood-prone area maps were prepared on topographic quadrangle maps which include contour lines—imaginary lines connecting points on the ground surface that have the same elevation—showing the configuration and elevation of the land surface. Each quadrangle covers an area encompassed by 7 1/2 minutes of latitude and longitude, or approximately 57 mi^2 (148 km^2). The scale of these maps is 1:24,000, or 1 in. equals 2,000 ft (10 mm equals 240 m). The areas subject to flooding were delineated from readily available information for quick appraisal rather than by detailed field surveys. The information included data on flood inundation, flood frequency, peak stage and discharge, and the results of some hydrologic and hydraulic studies. Estimated 100-year flood levels were used to identify flood limits at specific points along the margin of the flood plain. Lines denoting the limit of inundation were then drawn in general conformance with the stream slope and the topographic contours of the land surface. More detailed information than is shown on the flood-prone area maps usually is required for purposes such as structural design, economic studies, or formulation of land-use plans and regulations. A part of the flood-prone area map prepared for the Napa Quadrangle is shown in figure 8.

The maps of flood-prone areas in the San Francisco Bay region are listed in table 10.

A regional map of flood-prone areas in the San Francisco Bay region in California, prepared by Limerinos, Lee, and Lugo (1973) as part of the San Francisco Bay Region Study, provides an overview of areas subject to the 100-year flood. The map was prepared at a scale of 1:125,000, or 1 in. equals approximately 2 mi (10 mm equals 1,250 m), by transferring and compositing information from the 1:24,000-scale flood-prone area maps available for the entire area. The three-sheet map covers the 7,400 mi^2 (19,000 km^2) in the nine-county region, as shown in figure 9. A section of the map, for the Napa area in Napa County, is shown in figure 10. The topographic contour interval for this map is large—40 ft (12 m) in the flatlands and 200 ft (61 m) elsewhere—but the small map scale precludes greater refinement. The small scale of the map, however, permits coverage of extensive areas on a few map sheets of manageable size, thus furnishing a convenient and illuminating appraisal of the areas in the region that are vulnerable to flooding.

A regional flood-prone area map provides the regional and county-level planners and decisionmakers with information useful in formulating broad policies to guide the future development of flood plains. The inundation map may be used, for example, in conjunction with a regional map of present land use and other information in developing a regional land-use plan. The map may also serve to identify problem areas where detailed study of the flood hazard would be desirable; thus, the map may also be an aid in local planning.

The small scale of a regional map and the generalized delineation of the areas subject to inundation may not permit sufficient identification of flood problems at specific sites to be helpful for direct use in local land-use planning and decisionmaking. Thus, when construction or occupancy is planned on or adjacent to the flood-prone areas shown on the map, a more rigorous description of the flood hazard should be established through comprehensive flood studies. The regional and the standard quadrangle maps of flood-prone areas may be helpful, however,

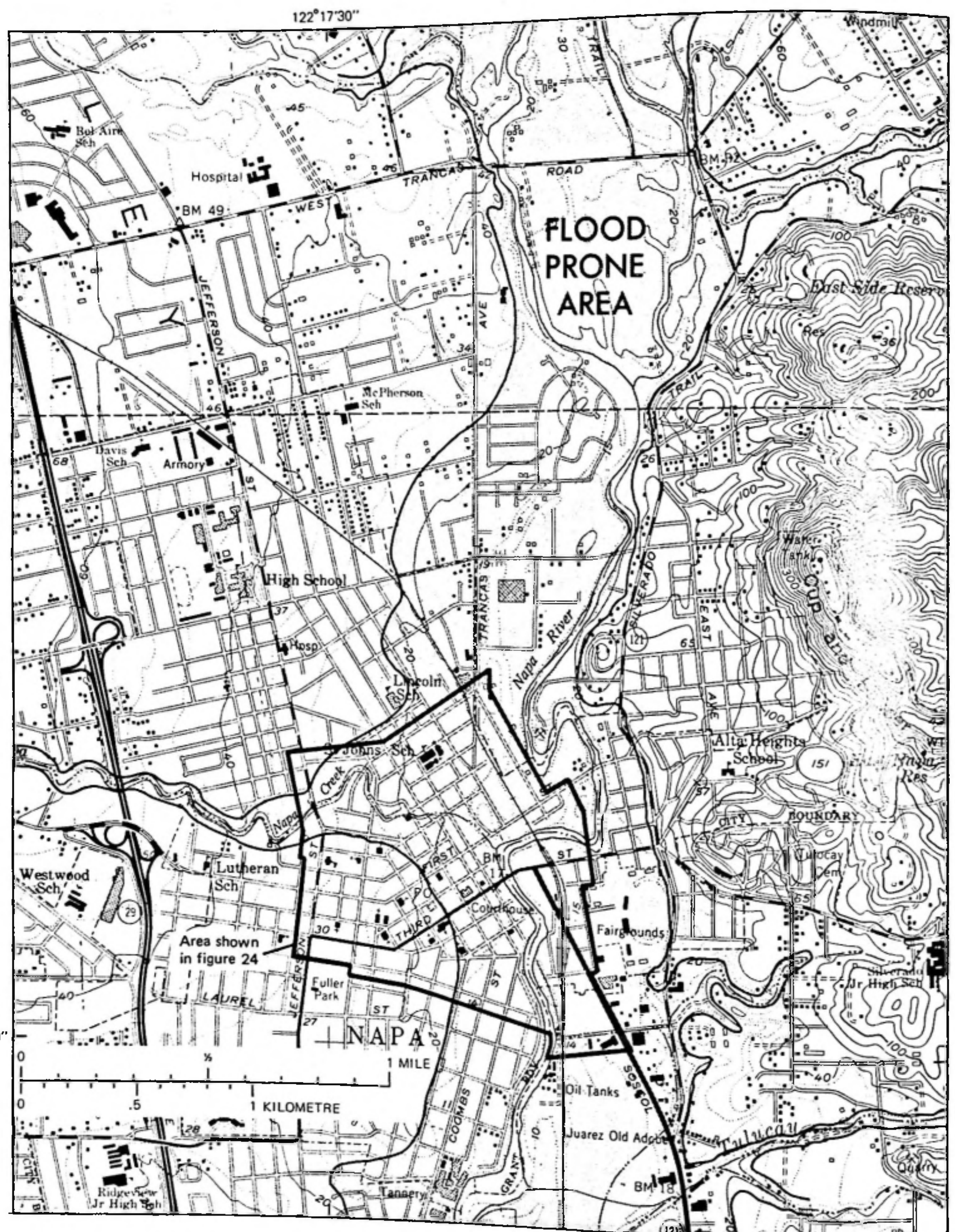


FIGURE 8.—Part of the flood-prone area map for the Napa area. (Area of fig. 24 not shown on original map.)

to the local planner in instances when time and funding restrictions preclude the more rigorous flood-hazard mapping studies.

The flood-prone areas delineated on the regional and quadrangle maps for the San Francisco Bay region included areas contiguous to the ocean and the bay that have a potential flood hazard associated with high tides. The tidal elevations, in relation to sea level, were based on data compiled by the U.S. Coast and Geodetic Survey, as interpreted and reported by the U.S. Army Engineer District, San Francisco, Corps of Engineers. (Tide data for San Francisco Bay are usually reported locally in relation to datum at mean lower low water, MLLW.) Inundation resulting from tsunamis, or earthquake-generated ocean waves, was not considered in the study of flood-prone areas. Although no devastating tsunami has been recorded in the San Francisco Bay region, and the likelihood of one is small, the possibility still exists. Ritter and Dupre (1972) have evaluated the impact of a possible damaging tsunami, as shown on two maps entitled "Maps Showing Areas of Potential Inundation by Tsunamis in the San Francisco Bay Region, California." A tsunami having a wave height of 20 ft (6 m) with a runup of 10 ft (3 m) could be disastrous to people participating in shoreline-recreational activities. Shore, dock, and harbor facilities, marinas, and boats also might suffer extensive damage from inundation and from swift currents in the bay generated by tsunamis. A 20-ft (6-m) tsunami also could inundate many inhabited areas—suburban, commercial, and industrial—around the perimeter of the bay, with attendant potential hazard and damage.

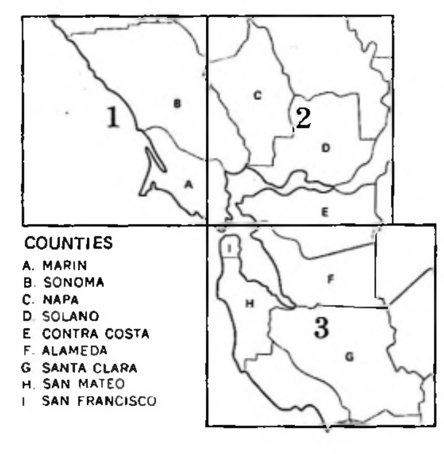


FIGURE 9.—Areas encompassed by the regional flood-prone area map sheets for the San Francisco Bay region.

FLOOD-HAZARD MAPS

A flood-hazard map, as prepared by the Geological Survey, generally is a detailed map based on a thorough technical study that shows the extent of areas subject to potential hazard from severe floods. Map scales may range from 1:1200 (1 in. equals 100 ft or 10 mm equals 12 m) to 1:24,000 (1 in. equals 2,000 ft or 10 mm equals 240 m), and contour intervals from 1 to 20 ft (0.3 to 6 m), depending on the type and density of the existing or planned flood-plain development. The large scale maps generally are helpful for developing plans and programs for flood-plain management.

The cost of a flood-hazard map and the associated study increases greatly with increase in map scale and corresponding refinement of the study. Thus, cost may preclude preparing maps at large scale for all the flood plains in a large area. The larger-scale maps may be essential, however, for areas where the existing or potential development on the flood plain is significant. Where little structural development exists or is planned the smaller map scales, such as 1:24,000 and contour intervals of 5 ft (1.5 m), may be adequate. Then, individual sites or local areas can be studied and mapped in greater detail for definition of the potential hazard with respect to depth and duration of inundation and flow velocity.

In 1954 the Geological Survey began publishing a series of hydrologic investigations atlases for the presentation of hydrologic information. This series has been used extensively for documenting floods and flooding in urban areas, river basins, and coastal areas (Bue, 1967). The maps presented are useful in evaluating flood potential and hazard.

The atlases generally use topographic quadrangle maps or aerial photomosaics as bases. The extent of inundation from floods of record is usually delineated on the basis of detailed surveys and investigations. Photomosaics permit ready identification of specific sites, structures, properties, and extent of inundation but lack technical data on land-surface elevations and depth relations. Topographic maps provide the specific data on land elevations and location basic to engineering studies and determination of the depths of flooding. The extent of inundation may be determined from aerial photographs taken during major flood or from field and office studies of peak stages and water-surface profiles. The atlases usually include, in addition to the map, a brief test that presents information on peak stages and discharges, floods frequency, water-surface profiles, depth of flooding, and the extent of

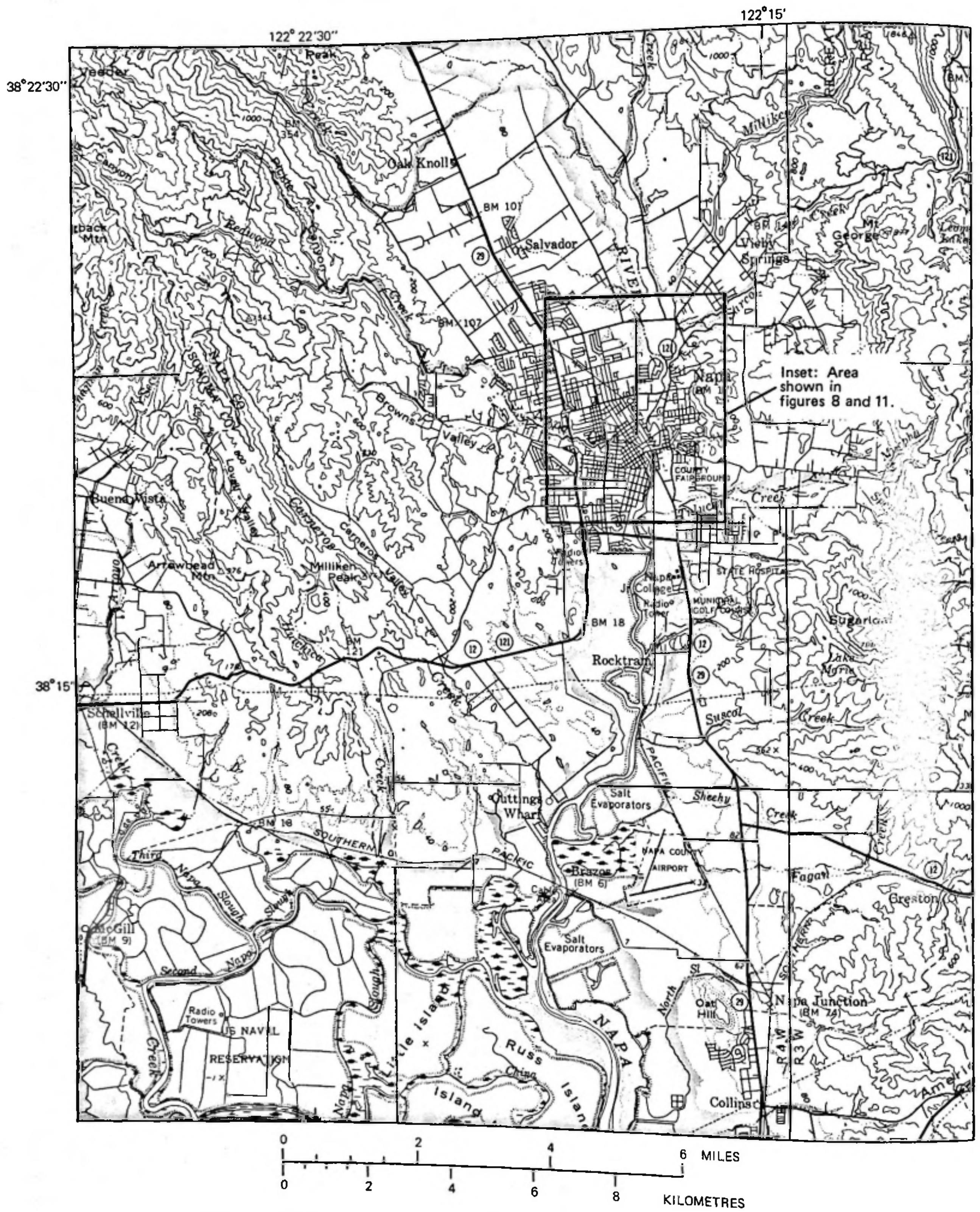


FIGURE 10.—Regional flood-prone area map for the Napa area. (From Limerinos, Lee, and Lugo, 1973.)

regulation. Some also include data on flood history and flow velocity. Illustrations may include flood-flow hydrographs or stage-duration curves, discharge-frequency curves, graphs of annual peak discharges, and suitable photographs.

Maps showing areas subject to flooding at selected frequencies are most meaningful in evaluating flood-protection proposals, establishing flood-insurance rate zones, and developing flood-plain management programs. The extent of areas subject to inundation by the 100-year flood is sometimes delineated in the atlases by extending the flood-depth relations shown by the stage- and discharge-frequency curves and the water-surface profiles. Depth of flooding may be estimated from the water-surface profiles and ground elevation or from the spot water-surface elevations and depth to the general ground surface shown on some atlases.

Seven hydrologic atlases related to floods have been published for areas in California, including two in the San Francisco Bay region (table 10). Hydrologic Investigations Atlas HA-54, "Floods at Fremont, California," by Young (1962), delineates the flooding in 1955 and 1958 in Alameda Creek in the vicinity of Fremont in Alameda County. Atlas HA-348, "Floods on Napa River at Napa, California," by Limerinos (1970), delineates the flooding in 1940 and 1955 in Napa River in Napa County.

A section of the map in the Napa River atlas (HA-348) is reproduced in figure 11. The area encompassed by figure 11 (same as fig. 8), is indicated, for comparison, on the section of the regional flood-prone area map shown in figure 10. The inundation by the floods of 1940 (recurrence interval, 40 years) and 1955 (recurrence interval, 8 years) is shown in figure 11. The map was prepared on the basis of detailed field surveys, inspection, and hydraulic studies. Circled figures at points along the main stream denote river miles measured from Dutton Landing (Brazos). The map (1:24,000; contour interval, 5 ft or 1.5 m) is generally adequate to identify the hazards in the lightly developed areas upstream from river mile 9.5, if little structural development is planned for those areas. More detail at a larger scale may be desirable for planning and design in the highly developed areas downstream from river mile 9.5.

Flood-hazard maps require updating when changes have occurred in the channel, on the flood plain, and in upstream areas. These changes may include structural modifications in the channel and in upstream areas such as deepening, widening, or realining. Development on the flood plain, obstructions, or other land-use changes in the basin, may affect the streamflow, water-surface elevations, and flow velocities. The usual effect is a change in the flood profile. In some instances, recomputation of the 100-year flood profile may be appropriate.

FLOOD-PLAIN INFORMATION REPORTS

A series of flood-plain information reports prepared by the U.S. Army Corps of Engineers presents a comprehensive appraisal of the flood hazard in the areas studied. The studies were authorized initially in the Flood Control Act of 1960 (U.S. Congress, 1960) to provide technical information to local planning agencies. The authorization was amended and extended by the Flood Control Act of 1966 (U.S. Congress, 1966b) in response to recommendations by the Task Force on Federal Flood Control Policy (U.S. Congress, 1966a). Under the 1966 Act the Corps of Engineers is authorized to compile and disseminate information on floods and flood damages, including identification of areas subject to inundation by floods of various magnitudes and frequencies, and general criteria for guiding Federal and non-Federal interests and agencies in the use of flood-plain areas. The principal purpose of the studies, guides, and flood-plain management services provided by the Corps of Engineers is to furnish local agencies appropriate information and guidance for development of plans and regulations for improved management and use of flood-plain lands. The surveys and studies are made and guides are prepared in response to approved requests.

A flood-plain information report typically includes maps or aerial photomosaics, flood profiles, charts, tables, photographs, narrative material on the extent, depth, and duration of past floods, and similar data on floods that may reasonably be expected in the future. The maps generally are of sufficient detail and scale for ready identification of areas subject to hazard from the 100-year flood (intermediate regional flood) and a possible greater flood (standard project flood). Depths of flooding may be determined from flood profiles and ground elevations. The reports may cover small or large basins or parts of basins.

Ten flood-plain information studies have been completed for selected streams in the San Francisco Bay region, as shown in table 10; studies on other streams are in progress.

Some flood reports published by the Corps of Engineers for specific floods, such as the floods of December 1955 (U.S. Army Corps of Engineers, 1956) and December 1964 (U.S. Army Corps of Engineers,

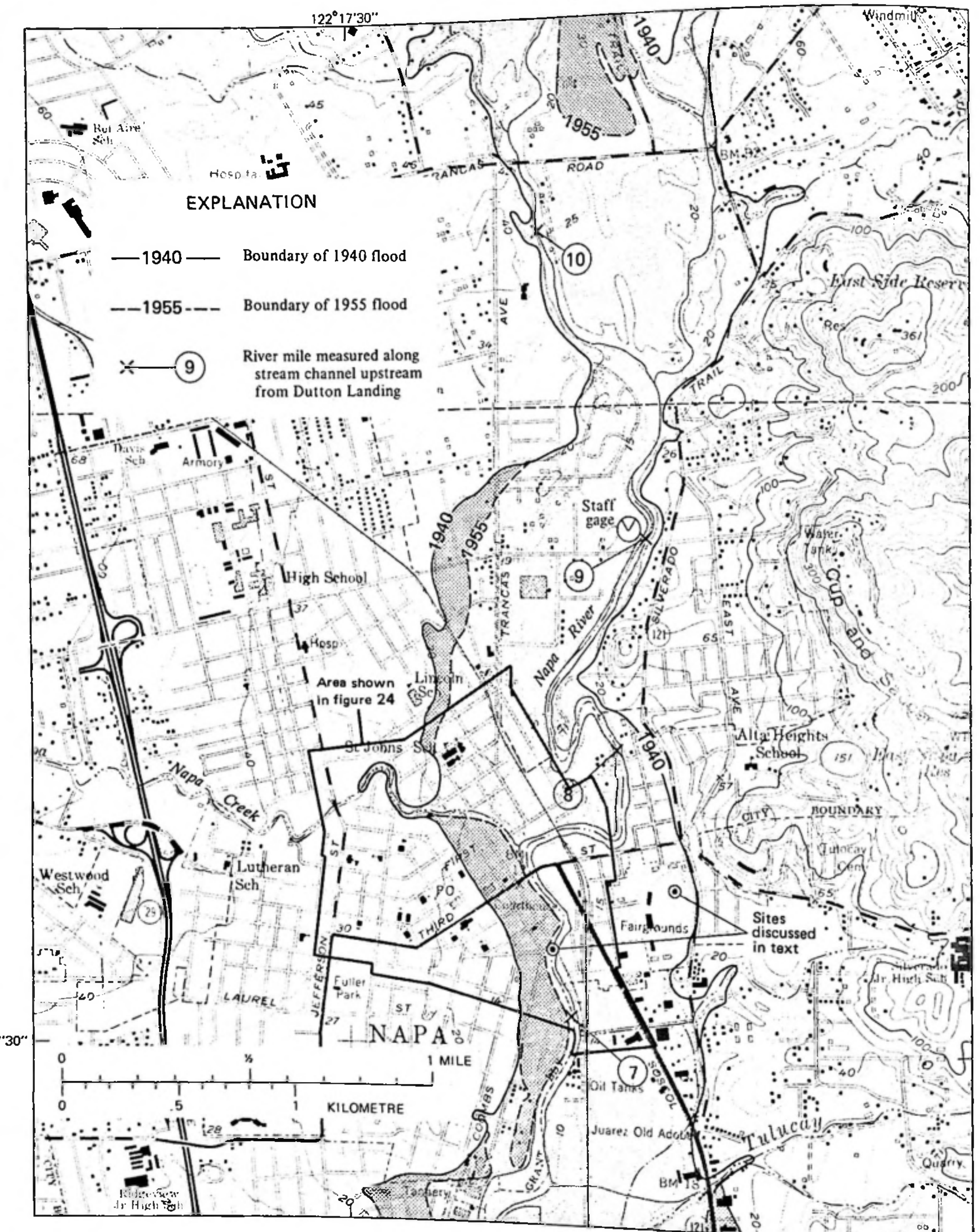


FIGURE 11.—Flood-hazard map for the Napa area. (From Limerinos, 1970. Area of fig. 24 not shown on original map.)

1965a), include generalized maps of the extent of flooding or maps showing elevations and location of high-water marks. Similarly, survey reports of the Corps of Engineers for flood control and allied purposes frequently contain maps giving generalized information on areas subject to inundation (table 10). Data from these reports and maps were utilized in the preparation of the maps of flood-prone areas issued by the Geological Survey; the individual reports are not listed herein.

The U.S. Soil Conservation Service, California Department of Conservation, and local resource conservation districts (often soil conservation districts) provide flood-plain information in their studies and reports on watershed work plans for watershed protection and flood prevention and on watershed investigations. These studies were authorized in Public Law 83-566, the Watershed Protection and Flood Prevention Act of 1954 (U.S. Congress, 1954). Projects authorized under Public Law 83-566 are listed in table 10. The objective of the studies is to formulate plans for improvements to alleviate flooding and to reduce erosion and sedimentation. The reports may include maps that indicate the probable limits of flooding, as well as information on flood depth, flow velocities, and agricultural damage from floods. Copies of the reports and other unpublished information may be consulted at district offices or the Soil Conservation Service and cooperating agencies.

FLOOD-INSURANCE STUDIES

The National Flood Insurance Act of 1968 (U.S. Congress, 1968) was enacted to provide previously unavailable flood-insurance protection to property owners in flood-prone areas. Qualification for inclusion in the flood-insurance program included agreement by a community to adopt and enforce land-use control measures consistent with designated criteria. The program is administered by the Federal Insurance Administration, U.S. Department of Housing and Urban Development.

Initially flood-insurance coverage under an emergency program was extended to communities that had established eligibility. Subsequent detailed flood-insurance ratemaking studies provide a basis for actuarial insurance rates and coverage under a regular program. The detailed studies, performed for the Federal Insurance Administration by Federal agencies and other organizations, include development of inundation maps, water-surface profiles for designated floods, floodway delineation, and depth-damage curves. The Federal Insurance Administration then furnishes flood-insurance rate maps to insuring agencies and the local communities. These usually delineate areas of special flood hazard (inundation by the 100-year flood) and elevations of the 100-year flood levels within these areas.

The flood-insurance rate maps and topographic maps define the extent of the flood-hazard area and the depths of flooding on the flood plain. The reports on the detailed studies are filed in each community studied but generally are not distributed.

The Flood Disaster Protection Act of 1973 (U.S. Congress, 1973) requires the purchase of flood insurance after March 2, 1974, or 1 year after the community's identification as being flood prone, as a condition for receiving any form of Federal or Federally related financial assistance for acquisition or construction purposes in an identified flood-plain area having special flood hazards that is located within any community currently participating in the National Flood Insurance Program. Flood-hazard insurance would be required when a community enters the program, and special flood-hazard areas have been identified on flood-hazard boundary maps. These flood-hazard boundary maps are the first maps prepared in the identification process, and they show the location of special hazard areas. They are separate from the Geological Survey's maps of flood-prone areas and have been prepared by the Federal Insurance Administration specifically for insurance purposes. These maps provide only an approximate delineation of the extent of the 100-year flood, and they do not provide information on water-surface elevations usable in estimating depths of flooding. Copies are filed in each eligible community and with insuring agencies.

Communities in the San Francisco Bay region participating in the National Flood Insurance Program are shown in table 10. The coordination of flood-insurance studies in California has been provided by the California Department of Water Resources through the Flood Control Development Branch of the Division of Resources Development.

OTHER FLOOD-PLAIN MAPPING

The flood plains of many streams in the San Francisco Bay region have been mapped by county flood control and water conservation districts, municipal agencies, and other departments and agencies. Some maps show the extent of inundation by major floods, or probable inundation by floods of designated recurrence intervals. Other maps have been prepared in connection with special studies for flood control and drainage, zoning, planning, and development.

The map scales and detail are generally adequate to provide information comparable to that from the flood-hazard and flood-plain inundation maps. The maps may be particularly helpful in studying small local areas in and near cities and the adjacent suburban areas.

Flood-plain maps prepared by county and local agencies generally are not published but may be available for consultation in the offices of the issuing agency.

INTERPRETATION OF FLOOD-PLAIN MAPS AND INFORMATION FOR SITE EVALUATION

Planning for the use and management of flood-plain lands includes consideration of the magnitude and extent of the flood risk. The several types of flood-plain maps and information reports available identify flood-prone areas and provide estimates of the depth of flooding in some areas.

The accuracy of the delineations of flood-prone areas depends on the quality and scale of the flood maps. The regional maps (scale 1:125,000) of flood-prone areas generally are useful for broad area appraisal of possible flood hazard. The standard quadrangle maps (scale 1:24,000) used for both the flood-prone area and flood-hazard maps may provide sufficient detail for specific site location and hazard evaluation, especially in nonurban areas. Adequate appraisal of the vulnerability of a particular building site may require maps of larger scale and greater detail. The use of flood-hazard maps such as those in the hydrologic atlases in flood-risk evaluation and in planning for urban development and other land use is illustrated in a report, "Flood-Hazard Mapping in Metropolitan Chicago," by Sheaffer, Ellis, and Spieker (1970).

The flood-hazard maps for the San Francisco Bay region presented in hydrologic atlases and flood-plain information reports permit some evaluation of flood risk. However, these maps are available for only a few areas. The following appraisal of flood risk at a site in Napa, Calif., illustrates use of a flood-hazard map.

The hydrologic atlas for the lower Napa River area, by Limerinos (1970), provides information appropriate for flood-hazard evaluation. Figure 11 shows part of the flood-prone area within the city of Napa. The flood hazard might be evaluated, for example, for a site such as the fairgrounds, 0.3 mi (0.5 km) east of the Napa River at about river mile 7.3, the distance upstream from Dutton Landing. The ground elevation at the site is about 15 ft (4.6 m) above mean sea level.

One of the graphs in the atlas is a profile of the water-surface elevations along the Napa River downstream from Dry Creek for the floods of February 1940 and December 1955. This profile (fig. 12) indicates an elevation of 16.5 ft (5.03 m) for the flood of February 27, 1940, at river mile 7.3, and presumably also at the fairgrounds. Flood depths at the fairgrounds thus would be about 1.5 ft (0.5 m). A second graph in the atlas is a flood-frequency curve for Napa River (fig. 13) at a gaging station upstream at river mile 13.9 (not shown in fig. 11). The curve indicates a recurrence interval of about 40 years for the 1940 flood. Flood-plain lands within the limits of flooding by the 1940 flood thus are subject to inundation to the levels shown by the flood profile (fig. 12) about once in 40 years, on the average.

The 100-year flood generally has been accepted as the base flood for flood-hazard evaluation, flood insurance, and flood-plain planning. The potential hazard from a flood of this magnitude therefore needs to be evaluated.

The extent and depth of inundation from [illegible] 00-year flood in Napa River may be estimated [illegible] the increase in water-surface elevation above th[illegible] the 1940 flood. The stage difference at the gagin[illegible]n at river mile 13.9 is about 1.5 ft or 0.5 m (19[illegible]d, 57.5 ft or 17.5 m; 100-year flood, 59.0 ft or 18.[illegible] fig. 13). Owing to greater flood-plain width dow[illegible]am the stage difference in the vicinity of Thir[illegible]eet and the fairgrounds may be only about two-t[illegible]s of that at the gage, as shown by the 1940 and 1955 flood profiles in figure 12. The 100-year flood elevations in the city of Napa accordingly would be approximately 1 ft (0.3 m) higher than the 1940 levels. The corresponding depth of flooding at the fairgrounds would be 2.5 ft (0.8 m).

In a similar manner the flood maps in the Corps of Engineers flood-plain information reports provide information for flood-risk evaluation in the areas covered by the reports. The maps provide data on ground elevations and show the limits of flooding from the Intermediate Regional Flood (IRF), equivalent to the 100-year flood, and from a greater Standard Project Flood (SPF). Water-surface profiles for these floods along the major streams are included. The potential for flooding at a site from the 100-year flood (IRF) can be determined readily from the map, and the depth of flooding can be estimated from the ground elevations and flood profiles.

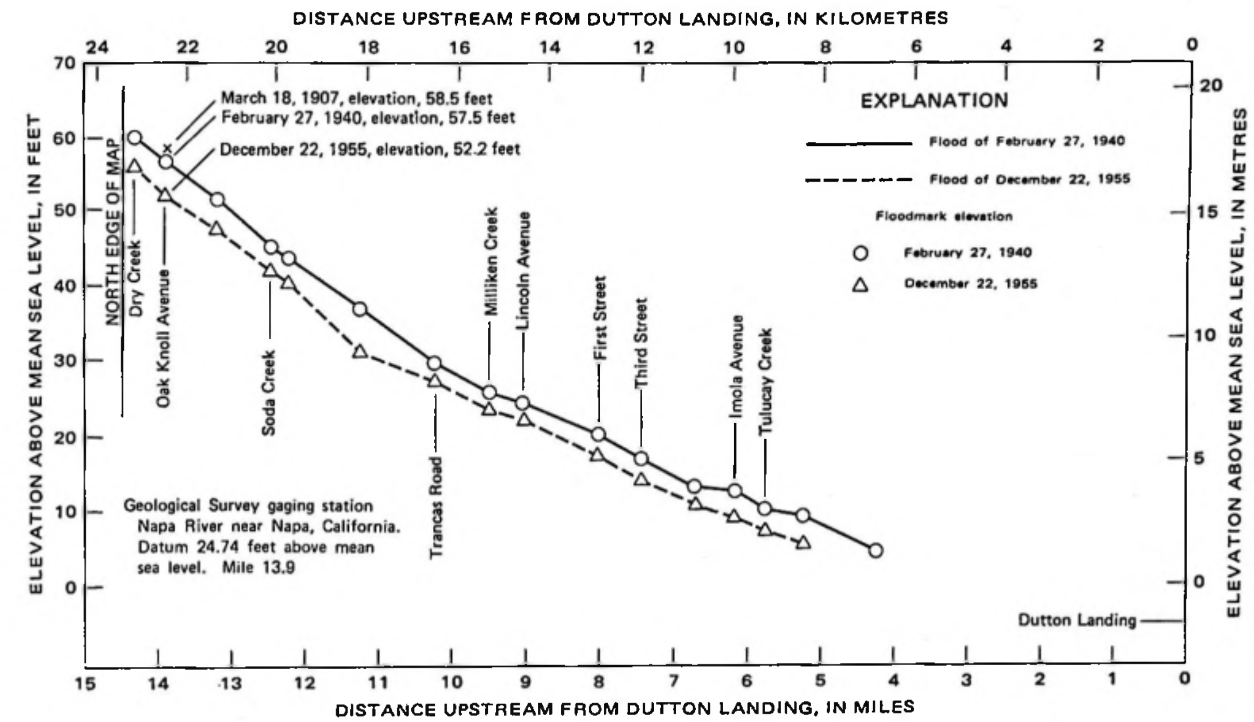


FIGURE 12.—Profiles of floods on Napa River downstream from mouth of Dry Creek. (From Limerinos, 1970.)

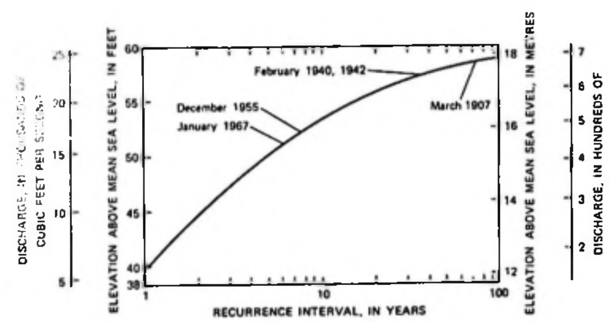


FIGURE 13.—Frequency of floods above 39-foot elevation at gaging station on Napa River near Napa, California. (From Limerinos, 1970.)

SOURCES OF FLOOD-PLAIN MAPS AND INFORMATION

The Geological Survey and other Federal, county, and local agencies have prepared flood-plain inundation maps and other flood studies for many areas in the San Francisco Bay region. Information on flooding and flood hazards has been presented in pertinent maps and reports. The principal sources of the maps and flood information are indicated in table 9; the maps and reports available are listed in table 10.

FLOOD-LOSS PREVENTION AND REDUCTION MEASURES

By W. J. KOCKELMAN

The need for preventing and reducing flood loss has grown with increasing use of, and encroachment upon, flood plains. Many methods and devices, both structural and nonstructural, are available for the prevention and reduction of flood loss. These methods and devices may be used in a variety of combinations to provide relief from existing and potential flood problems. Effective programs for flood-loss prevention[1] should be based on an adopted comprehensive plan, although individual methods and devices are often applied without a plan. The comprehensive planning process is discussed in the following section, "Planning for Flood-Loss Reduction." Any flood-loss prevention program is most effective if based on an adopted comprehensive plan or flood-plain management program that is being firmly implemented.

[1]Flood-loss prevention and flood-loss reduction are mutually inclusive terms as used in this report. Prevention is usually the desired goal; however, it is recognized that under certain circumstances reduction may be the more feasible goal.

A regional land-use plan can serve as a general framework for subregional, watershed, and community land-use plans. An adopted regional land-use plan that recommends protecting flood plains from incompatible development and establishes specific land-use regulations, if implemented, could prevent flood loss, protect certain important elements of the natural resource base, including water quality, and partially satisfy a need for park and open-space lands.

PROTECTION OF EXISTING DEVELOPMENT

Coordinating land-use and water-use plans would assure, for instance, that plans for using flood plains for park and recreational purposes would include concurrent establishment of water-quality standards that would accommodate recreational uses. Therefore, land- and water-use plans should be prepared together and carefully adjusted to the capability of the resource base to sustain the proposed land and water uses. Because water-use plans are best prepared for a watershed, the mutual adjustment of land-use and water-use plans may be best accomplished as part of a comprehensive watershed planning program.

Once land-use and related water-use plans have been prepared, adopted, and implemented, many methods and devices are available for preventing or reducing flood loss. These include the protection, removal, discouragement, and regulation of certain types of development on flood plains. These methods and devices are listed in table 1 and are briefly described in the following sections.

Development has occurred and will continue to occur on flood plains within the San Francisco Bay region. Such development, though often convenient, advantageous, and profitable to some individuals and economic sectors of a community, sometimes imposes a heavy burden on society. For economic and humanitarian reasons, local, State, and Federal governmental agencies may find it necessary to protect existing developments on flood plains. This protection may be provided by flood-control works, flood warning and evacuation, and floodproofing.

Flood-control works.—Loss from floods often leads to persistent demands for public-works programs to provide protection for existing developments through construction of structures and improvements such as dams, ditches, canals, sluices, holding basins, and detention reservoirs; channel deepening, straightening, widening, and paving; bypass or diversion channels, dikes, revetments, floodwalls, levees, and underground drainage facilities; or combinations of several of these.

Construction of flood-control works can be self-defeating. As the urban development of flood plains continues, the number of persons and the value of property in areas subject to flooding tend to increase at rates greater than that at which protection can be provided. Most flood-control works are extensive and costly. For example, to be effective, levees must be of substantial construction, continuous throughout areas with low banks, set back to allow for high-water flows, and may need to be supplemented by drainage of interior areas.

TABLE 1.—*Flood-loss prevention methods and devices*

Purpose	Method or device
Protection of existing development.	Flood-control works:
	Reservoirs
	Channel improvements
	Diversions
	Floodwalls and levees
	Flood warning and evacuation
	Floodproofing
Removal or conversion of existing development.	Public acquisition
	Urban redevelopment
	Public-nuisance abatement
	Nonconforming uses
	Conversion of use
	Public-facility reconstruction
Discouragement of development.	Public information
	Warning signs
	Recordation of hazard
	Tax-assessment practices
	Financing policies
	Public-facility extensions
	Flood-insurance costs
Regulation of flood-plain uses.	Zoning ordinance districts
	Special flood-plain regulations
	Subdivision ordinances
	Sanitary ordinances
	Building ordinances

The costs of constructing single-purpose flood-control structures and improvements may be greater than the benefits from reduced flood-loss risk. However, multipurpose structures and improvements, such as low-flow augmentation or recreation, that provide benefits in addition to flood control may prove economically feasible when evaluated within the context of a comprehensive watershed plan. Environmental, recreational, and esthetic costs and benefits should be considered even though their evaluation might be difficult.

Actions and improvements by upstream communities often impose expenditures on downstream communities for public works. Channel improvements, for example, may increase flood peaks downstream and require public expenditures for downstream flood-control works. Some facilities for flood control, such as dams and levees, may encourage development of flood plains in anticipation of additional works being constructed. The public may believe that the flood problem has been eliminated, rather than simply abated, by newly constructed works. Also, such works may not prevent losses from great and infrequent floods that exceed the design flood, often with catastrophic effects. The intelligent management and regulation of the flood plain is still required in conjunction with public works.

Several Federal programs are available to assist communities in the construction, repair, or rehabilitation of structures and other improvements to protect existing development. These Federal programs include the Snagging and Clearing for Flood Control, Flood Control Works, Emergency Bank Protection, and Small Flood Control Projects programs authorized under the Flood Control Acts of 1937, 1941, 1946, and 1948. These programs are discussed in the "Catalog of Federal Domestic Assistance" (U.S. Office of Management and Budget, 1974).

Flood warning and evacuation.—Reliable and timely flood warnings would permit temporary evacuation of people and some personal properties from flood plains to reduce loss of life and property damage. In areas where the time interval between the onset of rainfall and flooding is short, such information relayed immediately to residents on the flood plain can result in saving of life and movable property.

The Joint Federal-State River Forecast Center at Sacramento, Calif., a cooperative program of the National Oceanic and Atmospheric Administration and the California Department of Water Resources, monitors weather conditions and river stages in the Pacific Coast area. For the San Francisco Bay region, the Center issues forecasts of river stages for Walnut Creek and the Napa and Russian Rivers during the flood season. The Center also provides information to the National Weather Service Forecast Office at Redwood City for other streams in the San Francisco Bay region.

The National Weather Service River District Office at San Francisco International Airport relays forecasts and issues flood warnings, when necessary, to the appropriate county flood-control districts, State and Federal agencies, and the American Red Cross. When flash floods are occurring or imminent, the Forecast Office at Redwood City issues flash-flood watches and flash-flood warnings to Weather Service offices, various public agencies, and the news media. Flash floods are not a common phenomenon in the San Francisco Bay region.

Floodproofing.—Floodproofing prevents or reduces flood loss to existing structures that cannot be economically removed from, or that need to be maintained on, the flood plain, such as certain public utilities, navigation facilities, depots, and warehouses. Floodproofing should be considered, however, only where floods are likely to be of short duration and have low stages and velocities.

Floodproofing measures range from structural modifications and installation of special equipment or materials to operational and management safeguards. Many of these measures are discussed and illustrated in "Introduction to Floodproofing" (Sheaffer and others, 1967) and "Flood-Proofing Regulations" (U.S. Army Corps of Engineers, 1972c). Structural modifications and special installation methods are the most effective as they are not dependent on warning, judgment, decision, and action immediately prior to a flood.

The feasibility of modifying structures and installing protective equipment or applying special materials would depend on the materials, age, design features, and the existing and proposed use of the structures to be floodproofed. Structural modifications include reinforcing basement walls and floor underpinnings to withstand the hydrostatic pressures of floodwaters; permanently sealing exterior openings to basements; using masonry construction; erecting low floodwalls; installing water-tight bulkheads, shutters, and doors; and elevating the lowest floor and access roads to at least 2 ft (0.6 m) above the 100-year flood.

Installing special equipment or applying special materials may include using special cements for flooring; providing adequate electric fuse protection; anchoring buoyant tanks; sealing of the outside walls of basements; installing automatic sump pumps, sewer-check valves, seal-tight windows and doors, and door and window flood shields; and using wire-reinforced glass. Care must be exercised, however, to avoid high hydrostatic pressures which might cause structural damage.

Operational and management safeguards include taking special actions during, or in anticipation of, floods such as waterproofing valuable items and merchandise or removing them from areas subject to flood loss; protecting or removing electrical equipment; discontinuing personal use of areas subject to flooding; postponing orders of freight shipments; operating emergency pump equipment and sewer valves; and placing movable bulkheads against doors and windows. Though floodproofing on-site soil absorption systems for sewage disposal is sometimes suggested, substituting alternative disposal systems, such as public sanitary sewer systems or holding tanks, would be more effective.

REMOVAL OR CONVERSION OF EXISTING DEVELOPMENT

Recurrent and frequent damage or hazard to life from flooding may be avoided by permanently evacuating the flood plain. This may be accomplished by removing structures or converting them to some use less vulnerable to damage by floods. The feasibility of such action depends on the value of the structures, their adaptability to floodproofing, their effect upon the movement, depth, and storage of floodwaters, and sufficient citizen interest and concern to support the necessary action by local public officials. Special attention should be given to removing structures within floodways because of their effect on flood stage and flood velocity. Methods for removal or conversion include public acquisition, urban redevelopment, public-nuisance abatement, nonconforming-use provisions in zoning ordinances, conversion of use, and reconstruction of existing public facilities.

Public acquisition.—One approach to removing or converting flood-plain development is for a governmental agency to acquire the developed land. The flood plains can be acquired through negotiation, condemnation, tax-delinquency default, dedication, devise, or donation. The governmental agency can then control development in the public interest. It may elect to sell or lease part or all of the acquired lands, restricting any development or uses that would be vulnerable to flood damage. If agricultural land has been acquired, it might then be leased for appropriate agricultural uses, thus permitting part of the acquisition costs to be recovered.

Under the Federal Land and Water Conservation Fund Act of 1965 and the Federal Housing and Community Development Act of 1974, grants are available to assist communities in acquiring flood plains for park and recreation purposes. These grant programs are discussed in the "Catalog of Federal Domestic Assistance" (U.S. Office of Management and Budget, 1974).

Acquiring less-than-fee interest in flood plains costs the public less than purchasing the land because only certain property rights need to be purchased. Such interest may be in the form of scenic easements for vista protection, conveyance of development rights to assure continuance of private parks and open spaces, and grants of public access and development rights for construction and use of park facilities. By purchasing easements or development rights, flood-plain development can be limited to certain uses, while the owner receives fair compensation for the release of these rights. Easement lines need not be based on documented flood data because the boundaries of the lands to be acquired can be determined by agreement. The use of easements should include periodic inspection and enforcement of the land use by the agency holding the easement. Easements should be obtained in perpetuity, or for as long as the flood hazard exists.

Urban redevelopment.—Flood plains can be redeveloped publicly or privately by purchasing land that has been determined to be blighted or to have deteriorated and then clearing and redeveloping the land.

The California Community Redevelopment Law (California Health and Safety Code, 1976c) authorizes the creation of public redevelopment agencies. The law provides for the preparation and adoption of redevelopment plans; acquisition, clearance, disposal, reconstruction, and rehabilitation of blighted areas; and relocation of persons displaced by a redevelopment project. Redevelopment agencies generally are empowered to issue bonds, receive a portion of taxes levied on property in the project and use Federal grants or loans available under the Urban Growth and New Community Development Act of 1970 and the Federal Housing and Community Development Act of 1974. These programs are discussed in the "Catalog of Federal Domestic Assistance" (U.S. Office of Management and Budget, 1974).

Public-nuisance abatement.—Buildings and structures subject to periodic flood loss often go unrepaired after a flood, thus initiating a cycle of deterioration. These buildings and structures can be removed or razed by local units of government applying their public-nuisance abatement powers. For example, Section 203 of the Uniform Building Code, prepared by the International Conference of Building Officials (1973), which many cities and counties have adopted, provides:

> All buildings and structures which are structurally unsafe or not provided with adequate egress, or which constitute a fire hazard, or are otherwise dangerous to human life, or which in relation to existing use constitute a hazard to safety or health, or public welfare, by reason of inadequate maintenance, dilapidation, obsolescence, fire hazard, disaster damage, or abandonment*** are***unsafe buildings. All such unsafe buildings are hereby declared to be public nuisances and shall be abated by repair, rehabilitation, demolition, or removal***.

Nonconforming uses.—The adoption and enforcement of zoning ordinances, discussed in a following section, may make some existing uses of the flood plains nonconforming. These are uses in existence at the time of the adoption of a zoning ordinance that do not conform to the use restrictions of the ordinance. For example, if residential uses of flood plains are prohibited by a zoning ordinance, residences existing on the flood plain at the time of adoption of the ordinance would become nonconforming.

Zoning ordinances may provide that nonconforming uses may be continued but not extended or enlarged and, if discontinued for some designated period, any future use must conform with the ordinance. The total structural repairs or alterations over the lifetime of a nonconforming use may also be limited to a percentage of the assessed or market value. State enabling legislation may also permit eliminating nonconforming uses by providing for the amortization of such uses over a reasonable period of time.

Conversion of use.—Land uses, improvements, and structures that are vulnerable to flood damage can be voluntarily converted to uses less vulnerable to loss by floods. Farm feed-storage buildings, for example, could be converted to sheds for farm equipment that would not be damaged by floodwaters or disrupt farm operations by being temporarily unavailable; tilled lands might be used for pasture or sown to crops that are less susceptible to flood loss; and urban redevelopment areas could be used for parking lots or recreation areas.

Public-facility reconstruction.—Reconstructing public facilities located on the flood plain, such as roads, bridges, utilities, and community facilities, that are subject to renewal by reason of functional or structural obsolescence may afford opportunity to reduce the risk of flood loss. This might be done by elevating roads and utilities above flood peaks, floodproofing, or relocating them in areas not subject to flooding.

DISCOURAGEMENT OF DEVELOPMENT

Several methods or devices are available to discourage development on flood plains. They include public-information programs, warning signs, recordation of hazard, tax-assessment practices, financing policies, and public-facility extension policies. Flood-insurance requirements and costs may be an additional deterrent.

Public information.—Public-information programs can help to bring important flood information to the attention of the public. Prudent citizens, when advised of flood hazards, would be reluctant to risk property losses and expose their families to the danger and trauma that may accompany floods. As any program of land-use control will depend on the support of an informed public, using educational measures is important.

Preparing, announcing, and disseminating flood-hazard information are effective means for informing the public. Flood-prone area maps, flood-hazard maps, and flood-plain information reports, such as those described in the preceding section, "Delineation of Flood Plains," are some of the ways to provide the needed information.

Warning signs.—Warning signs draw public attention to flood hazards, especially the attention of potential land purchasers and developers who inspect sites prior to purchase. Such signs may be most effective if they are readily visible to buyers, developers, and the public, are based upon adequate flood data, and are posted where the 100-year flood boundaries intersect public rights-of-way. Warning signs might take other forms also, such as rubber-stamp impressions on subdivision plats and on building and zoning permits stating that the sites are in areas subject to flooding at a given frequency or recurrence interval.

Recordation of hazard.—Recordation provides a possible means for alerting land purchasers, local assessors, and lenders to potential flood hazards. This might be done by filing flood-hazards maps with the appropriate county recorder, together with listings of the subdivisions or the sections, as identified under the public lands survey system, and requesting entry into tract indexes. Abstracts of titles for affected properties and subsequent conveyances then would contain an entry referencing the hazards. Adopting local subdivision ordinances that require potential flood boundaries to be shown would automatically result in the filing of pertinent flood-hazard data with the county recorder along with the subdivision plat.

Tax-assessment practices.—Real-property assessment is an important factor influencing land-use patterns. In urban and urbanizing areas, the appraisals, assessments, and tax rates on real property reflect the high demand for land. Owners of flood plains may seek to relieve tax burdens by selling the less agriculturally productive flood plains for development. The public-information, warning, and recordation programs can alert potential purchasers and local property-tax assessors to those lands subject to flood hazards. A lower assessment and reduced demand can result in less economic pressure on the owner to convert flood plains to urban use.

When constructing public works for flood-loss prevention becomes necessary, the costs of these flood-control works may be assessed in whole or in part against those lands that will benefit from the works.

Financing policies.—Almost all building or construction today involves loans or mortgages by private lenders, many of which are insured by the Federal Housing Administration, Farmers Home Administration, or the Veterans Administration. Compliance by private lenders and Federal agencies with policies denying loans or loan insurance for construction on flood plains would discourage flood-plain development.

Public-facility extensions.—The availability of utilities and other community facilities in flood plains may attract subdividers, developers, and home purchasers. Metropolitan and municipal utilities could design and install water-supply and sewerage systems that would not have the capacity to serve urban developments proposed on flood plains. Local governing bodies and agencies could adopt and announce policies that they will not authorize, finance, or construct community facilities, such as roads and schools, to serve areas subject to flooding. These actions should be taken well in advance of developmental pressures; but they can also be used with removal and regulatory methods and devices.

Flood-insurance costs.—Flood insurance traditionally has not been available from private sources because floods lack the essentially random nature necessary to a sound insurance program. The American Insurance Association (1956) has reported that:

> flood insurance covering fixed-location properties in areas subject to recurrent floods cannot feasibly by 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.

Flood insurance apparently can be sold at feasible rates only with sizable government subsidies. Unless premiums are related to the risk involved, the cost of flood insurance may be considered a taxation measure.

The National Flood Insurance Program attempts to discourage development in flood-hazard areas. This program requires the purchase of flood insurance as a condition for receiving any form of Federal financial assistance for construction or acquisition in identified flood-hazard areas. This program is discussed in the section "Governmental Organization for Flood-Loss Reduction in the San Francisco Bay Region."

REGULATION OF FLOOD-PLAIN USES

It is costly to undertake public-works programs for the protection of development, difficult to remove or convert existing development, and probably unrealistic to assume that all future development on the flood plain will be discouraged by indirect action. Prohibiting and regulating uses vulnerable to flood loss under local police powers, however, provides an efficient and economical method for preventing or reducing flood loss. For example, the California Legislature has declared that the primary responsibility for planning, adopting, and enforcing land-use regulations to manage flood plains rests with local government (California Water Code, 1971).

Generally, floodways should be restricted to open-space uses, such as parks, grazing, some types of agriculture, drive-in theaters, parking lots, and outside storage areas, and to selected structures that can withstand flood velocities without obstructing the movement of floodwaters. The flood plains should also be limited to open-space uses, but certain uses that are not flood-vulnerable might be permitted if so regulated that reductions in floodwater storage capacity and increases in flood stage are minor. Isolated filling operations on flood plains might be allowed, but numerous individual fills may have substantial adverse effects on storage capacity and flood stage. Therefore, the U.S. Army Corps of Engineers has stated in one of its flood-plain information reports that, "The best rule is to avoid any filling of the flood plain*** " (U.S. Army Corps of Engineers, 1966, p. 26).

Devices for prohibiting or regulating flood-plain development include establishing regulatory zones compatible with the flood hazards involved and incorporating flood-plain regulations in zoning, subdivision, sanitary, and building ordinances. An extensive discussion of state enabling legislation, selected legal issues, program administration, and local ordinances relating to flood-plain regulations is contained in the U.S. Water Resources Council report "Regulation of Flood Hazard Areas to Reduce Flood Losses" (1971, 1972). Examples of zoning districts and special flood-plain, subdivision, sanitary, and building regulations, which can be incorporated into existing local ordinances, are set forth in Appendices H through L of the "Floodland and Shoreland Development Guide" (Southeastern Wisconsin Regional Planning Commission, 1968). Planning-related aspects of these regulatory devices are discussed in the section "Planning for Flood-Loss Reduction."

Zoning ordinance districts.—Zoning ordinances, adopted and administered by local governmental agencies, can regulate and restrict the use of land, water, air, and structures in the public interest. The ordinances usually consist of a text setting forth regulations that apply to each zoning district and a map delineating the boundaries of each district to which the regulations apply.

Zoning is a widely accepted and effective technique for controlling flood-plain development. This device can provide direct benefits by restricting future development of vacant lands in flood plains to avert potential damage and by limiting expansion of existing development in flood-hazard areas.

The California Legislature has provided for the adoption and administration of zoning ordinances by counties and cities and specifically declared its intention that counties and cities may exercise the maximum degree of control over local zoning matters (California Government Code, 1976a).

The most common general zoning districts which contain uses compatible with flood hazards are agricultural, open-space, conservancy, and park districts. These districts permit such uses as general farming, woodlands, wildlife refuges, and public and private recreation. The general zoning regulations can be supplemented by incorporating flood-plain regulations into the zoning ordinance text to prohibit none agricultural, open-space, conservancy, and park uses which would be vulnerable to flood damage. For example, the use of flood plains for agricultural purposes can be regulated to prohibit farm dwellings, the permanent sheltering or restrictive confinement of animals, and tillage of the floodways without soil conservation practices.

Flood plains which can be zoned for commercial and industrial use because of proximity to existing development can be regulated to permit only parking and outside storage and to prohibit the storage of buoyant, toxic, flammable, and explosive materials. Selected parts of flood plains adjacent to proposed residential development may be placed in a planned residential district. Regulations can then be imposed so that such flood plains are reserved or dedicated for public or private neighborhood parks to serve the adjoining residential development.

Special flood-plain regulations.—Regulations in zoning ordinances concerning the use of flood plains supplement the basic use and site regulations and can be designed to:

1. Prohibit flood-vulnerable uses and structures within the flood plain and its floodway, including on-site sewage disposal facilities, residential uses, sheltering and confining of animals, and the storing of buoyant, toxic, flammable, and explosive materials.
2. Regulate other uses and structures within the flood plain to require floodproofing without impeding drainage, reducing storage capacity, increasing flood peaks, or raising flood stages.
3. Prohibit uses and structures within the floodway, including filling, dumping, bridge embankments, permanent structures, and private roads that would obstruct the floodway, raise flood stages, increase flood velocities, or retard the movement of floodwaters.
4. Prohibit dumping, filling, and erecting any structures within the channel that might obstruct floodwaters, and prohibit the building of bulkheads, wharves, and piers except by special permit.

Subdivision ordinances.—Regulating the design and improvement of subdivisions is a less frequently used method for controlling flood-plain development. The California Legislature has provided that every city and county "***shall by ordinance regulate and control subdivisions" (California Government Code, 1976b). These ordinances may prohibit subdividing lands not suited to the intended uses, subdividing flood plains, and altering flood plains and floodways. They may require flood-protection measures for building sites and improvement of streets and building sites prior to dedication and sale.

The approval of subdivisions, acceptance of public rights-of-way, and extension of utilities, coupled with the developer's investments in road and site improvements and the erection of dwellings, creates a dilemma for local officials. This dilemma concerns the legality, reasonableness, and economy of subsequently applying zoning and other regulations that would prohibit further development on lands already subdivided and partially improved. This problem could be avoided by prohibiting the creation of new building sites in areas subject to flooding.

Such prohibition can be accomplished by a subdivision ordinance that is designed to:

1. Prohibit the creation of building sites on flood plains subject to the 100-year flood.
2. Require the delineation and designation of flood-prone areas on subdivision plats and certified survey maps.

3. Require dedication or reservation of flood-prone lands for public or private parks or other community purposes.
4. Require that public and private roads, bridges, and other facilities be designed and constructed to withstand flood velocities; prevent isolation, utility outages, and disruption of transportation; and not obstruct the movement of floodwaters, increase flood velocities, or raise flood stages.
5. Require dedication of, or easements along, those drainageways necessary for adequate watershed drainage.

Sanitary ordinances.—Sanitary ordinances are public laws adopted by local units of government to protect the health of the citizens within their jurisdiction. For example, the California Legislature has provided that cities "***shall take such measures as may be necessary to preserve and protect the public health, including the regulation of sanitary matters" (California Health and Safety Code, 1970).

These ordinances can be used to eliminate the health problems resulting from the disruption of private sewage-disposal systems or contamination of private water-supply systems caused by flood inundation. On-site soil absorption sewage-disposal systems, for example, including septic tanks, absorption fields, and seepage beds and pits, do not function during floods and may become inoperative or clogged after floodwaters have receded. Such problems can be avoided by a sanitary ordinance that is designed to:

1. Require a permit prior to installing any system or constructing or modifying any building, and require the application for such permit to show the flood-plain boundaries.
2. Prohibit on-site soil absorption sewage-disposal systems and private water-supply systems on lands subject to flooding.
3. Require the replacement of on-site soil absorption sewage-disposal systems on flood plains with alternate systems, such as public sanitary sewerage or flood-proofed holding tanks.

Building ordinances.—Building ordinances are public laws adopted by local units of government to ensure the safety of structures within their jurisdiction. Section 17958 of the California Health and Safety Code (1975b) provides that "***every city or county shall adopt ordinances or regulations imposing the same requirements as are contained in the regulations adopted pursuant to Section 17922***." Section 17922 of the California Health and Safety Code (1976b) provides for imposing "***substantially the same requirements as are contained in the most recent edition of the ***Uniform Building Code of the International Conference of Building Officials."

These ordinances can be used to ensure that the structures and their contents are protected from flood loss, do not aggravate flood problems, and provide sound and safe occupancy during floods. The opportunity to protect structures from flood loss can be increased by a building ordinance that requires:

1. Foundations, base supports, footings, and other anchorages that can withstand flood velocities and hydrostatic pressures.
2. Use of materials that will not be damaged if submerged.
3. Elevation of floors and electrical equipment at least 2 ft (0.6 m) above the level of the 100-year flood. In addition, the ground level around buildings should be at least 1 ft (0.3 m) above the 100-year flood for at least 15 ft (4.6 m) out from the exterior walls.
4. Appropriate floodproofing measures, including structural modifications and installation of special equipment.
5. Bridge and culvert openings adequate to pass high-flood discharges and designed for maximum passage of debris.

A good example of minimum building standards and requirements that could be used to supplement existing building codes is contained in "Flood-Proofing Regulations" (U.S. Army Corps of Engineers, 1972c).

PLANNING FOR FLOOD-LOSS REDUCTION

By W. E. Spangle and M. L. Blair

In general, planning is the process of devising and carrying out a course of action to reach an identified objective. As an organized governmental activity, planning is directed toward improving the quality of decisionmaking and may result in several kinds of plans serving different purposes. The principal kinds of plans discussed in this report include:

Comprehensive plan.—A plan for the long-term future development of an area considering all major determinants of growth and change—economic, political, social, and physical. When adopted by the governing body having planning authority, the plan becomes the official policy of the agency. A comprehensive plan is often called a general plan or master plan. In California, each city and county is required

by State law to prepare and adopt a "comprehensive, long-term general plan for the physical development of the county or city" (California Government Code, 1966). Unless otherwise specified or made clear by the context, the terms "plan" and "planning," as used in this report, refer to comprehensive (or general) plans and planning.

Land-use plan.—A key component of a comprehensive plan providing a link between more general goals and policies and the pattern of land development. A land-use plan includes objectives, policies, and proposals for the type, pattern, and intensity of land use. The land-use plan may be called a land-use element, as in the Federal Comprehensive Planning Assistance Program in Section 701 of the Housing and Community Development Act of 1974 (U.S. Congress, 1974b) and in the California Planning and Zoning Law (California Government Code, 1976d).

Functional plan.—A plan for facilities and operations for a specific function of government such as transportation, water development, flood control, or flood plain management; it is more specific and usually shorter range than the comprehensive plan.

Area plan.—A plan, expanding upon and consistent with the comprehensive plan, for a part of a planning jurisdiction, such as a watershed, central business district, or other particular area.

THE PLANNING PROCESS

Planning is described herein as a six-step process: (1) Identifying problems and defining goals and objectives; (2) collecting and interpreting data; (3) formulating the plan; (4) evaluating impacts; (5) reviewing and adopting the plan; and (6) implementing the plan. These steps, as depicted in figure 14, are closely interrelated. Plan formulation often indicates the need for additional information. Additional information may alter the concept of the objectives and problems, and plan implementation may reveal the need for additional information or modification of the plan.

Under our democratic form of government, public participation is essential throughout the planning process. In fact, most planning efforts funded by Federal programs are required to provide for significant public participation. "Public" may refer to elective or appointed political bodies, special-interest groups, or interested individuals. Success in implementing a plan depends on widespread public support which is difficult to achieve if major segments of the public are excluded from participating in the planning process.

Decision occur throughout the process, ranging from the decision to engage in a planning effort, to the final approval of a plan and adoption of implementing regulations, programs, and procedures. Elected public officials have final responsibility for most key policy decisions, although persons in non-elective positions actually make many important day-to-day decisions. It is particularly important that public input precede major policy decisions made by elected officials.

The steps in the planning process compose a rational, systematic approach to informed decision-making generally applicable to land-use, functional, and area planning as well as comprehensive planning. Ideally, the product of the process is an orderly, logical, and internally consistent plan, or a set of plans and programs, to guide public and private decisions.

Land-use planning is directly relevant to reducing flood losses. The extent of loss from flooding is a direct consequence of the use of land. Through a land-use planning and decisionmaking process, agreement concerning an acceptable level of risk from flooding can be reached, appropriate uses of flood-prone areas can be determined, and adverse effects of flooding can be mitigated. A land-use plan prepared by planners in collaboration with earth scientists, hydrologists, and other specialists thus provides an excellent framework for developing specific programs to reduce flood losses.

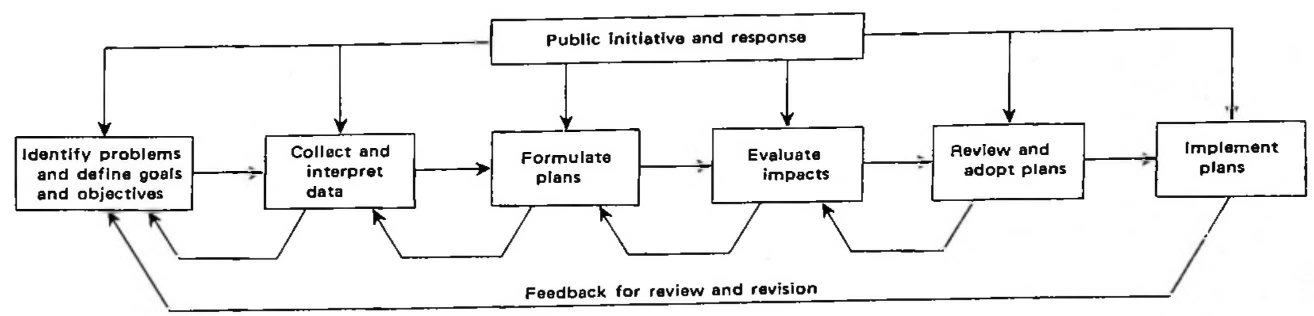


Figure 14.—The planning process.

Logical decisions concerning flood-loss reduction are likely to result when flooding problems are considered in each step of the land-use planning process. The outline below lists, under each step of the planning process, tasks or actions ordinarily needed for effective land-use planning and decision-making in flood-prone areas. In many cases, specific procedures to be followed are defined by State law.

Identify problems and define goals and objectives.—Obtain readily available data for preliminary identification of flooding problems.

Review the data in relation to existing development, current land-use plans and policies, projected growth trends, and anticipated changes.

Based on community consideration of the acceptable level of risk, develop a tentative set of objectives and priorities related to reduction of future flood losses. A usual objective is to prevent losses from floods of varying severity up to that of the 100-year flood.

Collect and interpret data.—Evaluate adequacy of available hydrologic and engineering data for land-use planning and develop a program for compiling needed new data.

Arrange with earth scientists and engineers for needed hydrologic studies including maps of flood-prone areas, flood profiles, and discharge-frequency relationships. Map information should relate in scale and detail to the physical characteristics of the flood plain and stream basin and the degree of development of the area, present and potential.

Estimate the probable future demand for land considering projections of population growth and distribution, economic activity, social and cultural needs, and transportation requirements.

Use flooding information in combination with other data to prepare land-capability maps showing the relative natural capability of each land unit to accommodate each contemplated use.

Formulate plans.—Consider feasible alternative arrangements of land uses, based on land-capability maps, appropriate projections, and economic, social, and political analyses.

Prepare and test alternative land-use plans incorporating as much detail as necessary to provide a policy guide for future actions and decisions.

Prepare functional water-resources plans for stream basins with flooding problems that provide enough depth and detail to guide the selection of appropriate flood-loss reduction measures.

Evaluate impacts.—Evaluate alternative land-use plans for environmental, economic, and social impacts.

Evaluate the impact of alternative land-use patterns on the extent and severity of flooding.

Evaluate the impact of alternative land-use patterns in terms of potential flood loss.

Review and adopt a plan.—Present alternative plans for review and selection by the appropriate legislative body.

Schedule and hold public hearings.

Adopt plan with such modifications as may be needed to respond to information provided and opinions expressed at public hearings.

Implement the plan.—Prepare and seek adoption of regulations and any land-acquisition and capital-improvement programs needed to carry out the plan.

Establish guidelines and a procedure for evaluating the effect of development proposals on flood potential.

Develop procedures and staff or consultant capability for reviewing hydrologic, soils, and geologic reports, environmental impact assessments, and project proposals.

Arrange for modification of previous steps as new or more detailed data become available.

The generalized model of the planning process and list of actions undertaken in each step are necessarily idealized and simplified. Actual practices vary widely depending on the responsibility, authority, and financial position of the planning agency; the diversity of the planning area; scope of the planning effort; and availability of data. For example, planning by regional councils of government (COGs) is likely to emphasize the development of objectives, policies, and criteria for use in reviewing projects and plans because the COG's primary source of power derives from Federally mandated review processes. Local planning, on the other hand, is more likely to emphasize the development of objectives, policies, and criteria to serve as a basis for land-use and development regulation—primarily a local responsibility.

In addition, planning practices are not static. Planning is in a state of flux, with planners, legislators, and citizens searching for new ways to make the process more effective. The scope of planning is expanding and its role changing, fresh approaches are being tried, and new relationships—local, metropolitan-regional, State, and Federal—are emerging.

FLOOD-PRONE AREAS—PLANNING FOR APPROPRIATE LAND USES

In planning for flood-loss reduction, the local and regional land-use planner is particularly

concerned with defining appropriate land uses for flood-prone areas. The determination of appropriate land uses is a technical-social-political process involving personal and corporate aspirations and legal rights, as well as public goals and objectives. A well-conceived and implemented land-use plan can lead to significant reduction in flood losses with relatively small public cost, particularly in areas where little or no development of the flood plain has occurred.

More is at stake in deciding land uses in flood-prone areas than the potential reduction of flood losses. The flood plain is an important environmental and ecological resource meriting attention in its own right. Flood-prone areas often provide wildlife habitats, water-recharge areas, fertile soils, scenic areas, and lands suitable for recreation and park uses. Thus, the land-use planner must evaluate proposed land uses in terms of both the potential flood risk and the beneficial use of the natural attributes of the flood plain.

Planning for appropriate flood-plain uses must also be done in the context of land-use planning for the entire drainage basin. The extent and frequency of flooding and the resource potential of the flood plain may be affected by land-use decisions in upstream areas. In situations where the drainage basin extends beyond a local planning agency's jurisdiction, effective planning for flood-prone areas requires interjurisdictional coordination or multijurisdictional (regional) planning.

If development is proceeding in a stream basin or if flood-control works are being considered, plans more specific than local land-use plans are often needed to focus directly on the flooding problem. Such plans, usually called functional plans, consider in depth the land-use/hydrologic relationships in the stream basin. Functional plans can provide a bridge between land-use plans and engineering plans for flood-control works or specific flood-plain management regulations. Such functional planning may be carried out by a public works department or a flood control district, or by the general planning agency. The comprehensive plan and planning information should provide a framework for the functional planning effort whether or not the planning agency is directly involved.

More than one governmental agency is frequently involved in planning for a given stream basin. The plans of the various agencies differ in scope and specificity, but should be mutually consistent. A regional land-use plan ordinarily provides broad policy guidance for evaluating future urban development, open space, large scale commercial and industrial development, and major public facilities including transportation facilities.

Ideally the regional plan provides a framework for more detailed county and city land-use planning in which both urban and nonurban uses are usually considered in more detail and attention is given to local conditions and problems. A regional plan might recommend open-space uses for flood-prone areas; a county or city plan would typically specify the particular open-space use, such as grazing or water-related recreation.

In undeveloped flood-prone areas, nonintensive land uses should be given high priority. Because flood plains are usually flat and are often overlain with fertile alluvial soils, agricultural uses are frequently appropriate. When natural and economic factors favor agricultural uses, more specific determinations need to be made concerning the kind of agricultural use. Grazing may have a different impact on flood-loss potential than crop cultivation. The impacts of crop cultivation can also vary depending on the kind of crop, the growing season, the structures needed (irrigation structures, storage structures, fencing), the use of pesticides, erosion potential, and land-treatment practices. Where crop production is permitted on the flood plain, maintenance of riparian cover adjacent to the streambanks can prevent undue erosion or bank collapse and loss of wildlife habitats. Farm buildings or other structures should be located outside the floodway to avoid obstructing the flow of floodwater.

Agricultural use of flood-prone areas reduces flood-loss potential below that of urban uses, but does not eliminate it. In fact, flood-control works are often proposed and constructed to protect agricultural lands from flooding. Such projects should be evaluated for both short- and long-term effects. Periodic flooding and deposition of sediment is a natural process which forms the rich alluvial soils of flood plains. While the loss of a crop may cause immediate economic hardship to the region, the farmer, or the locality, the replenishment of the soil by flooding may be a vital long-term benefit.

Agriculture is only one of many open-space uses which may be appropriate for flood-prone areas. Recreation, especially water-related activities such as fishing, boating, and swimming, often has little flood-loss potential and may provide valuable public benefits. Open-space and other low-intensity uses of flood-prone areas may be appropriate to preserve scenic, archeological, and scientific resources or to conserve mineral and timber resources for future use.

Uses such as parking lots, drive-in theaters, or uses involving structures with relatively little flood-loss potential may be appropriate for flood-prone areas. However, the impact of such uses on the natural functions of the flood plain must be carefully evaluated. In particular, the extent of impervious surfaces (roofs and paving) must be strictly limited in ground-water recharge areas if such areas are to continue to function. Determining the appropriate uses for specific flood-prone areas thus involves achieving beneficial use from its natural features as well as minimizing flood-loss potential.

Planning for developed flood-prone areas is more difficult. Detailed plans for conversion of developed flood-prone areas to less intensive uses can be prepared to guide day-to-day decisions concerning changes in land use within the flood plain. Such plans can also provide the basis for decisions concerning reconstruction and extension of public facilities and utilities and public acquisition of land for park or other open-space purposes. Well conceived and publicized plans for conversion of an area can also affect private investment decisions. Detailed plans prepared to guide gradual conversion of use of the flood plain can also serve effectively in guiding recovery activity following a damaging flood. The availability of such a plan can speed recovery, provide a rational basis for administering State or Federal disaster assistance, and encourage rebuilding in a way that minimizes future flood losses.

Flood-loss potential may also be reduced through planned redevelopment of the flood-prone area. Redevelopment permits public acquisition and clearance of parcels in a blighted area. Parcels acquired are then made available for re-use according to a specific redevelopment plan. Redevelopment can be an effective method of reducing flood-loss potential under certain circumstances. If the redevelopment area includes both flood-prone and flood-free lands, the plan can specify intensive development of the flood-free area and nonintensive uses compatible with the flood risk for the flood-prone area. Where urban uses are planned for a flood-prone area, the redevelopment plan may require floodproofing or related safeguards for new structures and those structures which are to remain.

In many developed flood-prone areas, particularly those with economically viable uses and sound structures, clearance may not be socially or economically feasible. In such areas, safeguards such as floodproofing and measures to limit occupancy can reduce potential flood losses to some extent. For major reduction in flood-loss potential, flood-control works will probably be required. If flood-control works are constructed, it is important that flood-plain uses be regulated to prevent an increase in damage potential from floods greater than the design flood. Even with flood-control structures designed for the 100-year flood, it is usually wise planning to restrict occupancy of flood plains to uses which can accept occasional flooding.

ROLE OF LAND CAPABILITY STUDIES

The evaluation of land capability can assist planners and decisionmakers in assessing alternative land uses in flood-prone areas. In any area the natural features and processes present a range of advantages and disadvantages for different land uses. Land-capability studies systematically record judgments about the relationship between the physical characteristics of land and particular land uses. Such studies provide at least a generalized view of the relative physical merits of lands in a study area for particular uses.

Information delineating flood-prone areas is important in assessing land capability for most land uses. In fact, a capability study may be designed to eliminate, on a first cut, lands subject to flooding from consideration for residential or intensive urban uses. Considering only the objective of reducing flood losses, flood plains would almost always have a high capability rating for low intensity, open-space uses. If flood-prone area information is combined with data describing other natural features often occurring in flood plains (for example, good agricultural soils, fish and wildlife habitats, ground-water recharge areas, and scenic sites), the high capability of the flood-plain lands for low intensity uses may be reinforced.

Flood-prone areas are typically part of larger flatland areas which, if flooding is not considered, often have high physical capability for urban uses as well as agriculture and other open-space uses. Resolving the conflicts among the competing land uses is rarely done on the basis of natural factors alone. Economic, social, and political data are needed in this process. Although an area may have poor physical capability to support intensive uses, other factors, such as location and accessibility, land cost, absence of alternative lands, or overriding public need, may indicate that it be intensively developed. In cases where intensive development of a flood plain is warranted, flood-control works to reduce the flood-loss potential may be appropriate.

The use of flooding information in a land capability study is illustrated in the Ohio Department of Natural Resources (1974) report "Big Darby Creek Corridor Study." The purpose of the study was to prepare a land-use plan for a stream corridor in central Ohio "to permit the best use of flood plains while avoiding flood hazardous construction on them***(and)***to properly evaluate and use the recreation and natural preservation potential of scenic river valleys" (preface). For the capability analysis, the corridor was divided into 2.35-acre (0.0095-km^2) grid cells. Each grid cell was given a numerical rating for physical variables such as soils, slope, vegetation, flood plains, ground-water availability, sand and gravel deposits, and surface water. The variables selected and the ratings assigned differed with each land use considered. The individual ratings were added for each cell giving an overall rating of relative capability for the land use. The total ratings were then divided into three capability classes, A, B, and C, and one "incapable" class. A cell was classed as "incapable" if it had "severe limitations" in certain physical variables. For example, in evaluating capability for residential development, an "incapable" classification was automatically given to cells within the flood plain.

The capability classifications provided key input to a suitability analysis which considered transportation, existing land use, utility availability, and other cultural aspects of the stream corridor. In the system used, cells classed as "incapable" for a particular use were also automatically considered "unsuitable." Cells in the A, B, and C capability classes were rated for suitability and classed as A, B, or unsuitable. The suitability classification was applied directly in plan formulation. The resulting plan, incorporating objectives and policies derived from public participation in the planning process, recommended primarily park and recreational uses in the flood plain and local adoption of flood-plain zoning and subdivision regulations.

A somewhat different approach to land capability analysis has been taken by the Association of Bay Area Governments (ABAG) in a recent study (1976). ABAG, supported by the San Francisco Bay Region Study (SFBRS), developed a method for expressing land capability in terms of the dollar costs associated with hazard mitigation measures, potential property damage from natural hazards, and loss of natural resources. The method was tested in a demonstration area in a part of the Santa Clara Valley.

The ABAG study focuses on geologic and hydrologic hazards and resources, making excellent use of many SFBRS products. Natural factors considered in evaluating land capability include earthquakes, flooding, bearing materials, slope stability, erosion/sedimentation, and natural resources. Land uses considered include agricultural or rural, semirural residential, single-family residential, multifamily residential, regional commercial, downtown commercial, industrial manufacturing, and freeways.

The total expected cost associated with each natural constraint and resource for each land use was calculated. For stream flooding, expected costs are assigned to areas within the 100-year flood plain as mapped by Limerinos, Lee, and Lugo (1973) at a scale of 1:125,000. Insurance rates developed for the National Flood Insurance Program are used to estimate all future expected costs per acre associated with flooding. Table 2 lists these costs for each land use.

TABLE 2.—*Expected costs associated with stream flooding*
[From Association of Bay Area Governments, 1976, p. 113]

Land use	Expected cost per acre
Rural or agricultural	$200
Semirural residential	700
Single-family residential	9,000
Multifamily residential	40,000
Regional shopping centers	40,000
Downtown commercial	50,000
Industrial	40,000
Freeways	0

Cost information for all natural resources and problems for each 24.9-acre (0.10-km^2) grid cell was aggregated for each land use. The resulting number indicates, for each cell, "the dollar cost per acre expected to be incurred by developing that cell with that land use" (Association of Bay Area Governments, 1976, p. 168). The range of total costs was divided into six capability levels and a land capability map for each use was printed by computer. The study shows that the expected costs associated with flooding are quite high for most land uses, but less significant than the costs associated with other problems, particularly dike failure, landslides, and soil creep.

IMPLEMENTATION OF LAND-USE PLANS FOR FLOOD-LOSS REDUCTION

Plan implementation with a focus on flood-loss reduction is primarily a function of local government. It can be accomplished in a variety of ways depending on the degree of existing development, the natural characteristics of the flood plain, the kind and level of detail of flood information, and the policies and proposals of the land-use plan.

Three categories of plan implementation actions may be effective in reducing flood losses:

1. Establishing and administering regulations on land-use and development through zoning, subdivision, building and housing codes, and grading and sanitary ordinances (most effective in undeveloped areas);
2. The execution of programs directly by the government which has jurisdiction in the planning area, including actions such as land acquisition for public sites and construction of public facilities; and
3. The review of projects, both public and private, as required by the National Environmental Policy Act of 1969 (U.S. Congress, 1970), various State environmental laws, and the U.S. Office of Management and Budget Circular A-95 (1969).

Effective plan implementation depends on the active support of residents and organizations within a planning jurisdiction. The implementing process is intensely political, involving public decisions which have direct impact on the legal rights, economic and social status, and living and working environment of individuals in a community. Measures to insure public participation in decisions concerning implementing programs and regulations are critical to the realization of plan objectives.

LAND-USE AND DEVELOPMENT REGULATION

Land-use regulation is largely a prerogative granted by the States to local units of government. Although case law and planning legislation differ from state to state, general legal principles pertain to all efforts to control land-use and development. These principles may be summarized as follows:

1. Because the authority to regulate the use of private land derives from a local jurisdiction's "police power," regulations, to be legal, must promote the "health, safety, morals, and general welfare" of the community.
2. Regulation of land use must be "reasonable." While the concept of "reasonableness" has been variously interpreted, it still remains the most crucial test of the legality of a regulation. Prevailing considerations in court determinations of reasonableness include the existence of a rational basis for the regulation and equity in its application.
3. Regulations are viewed more favorably by the courts if they are the product of a consistent, well-thought-out planning program which reflects explicit, community-determined goals.

Zoning.—A zoning ordinance divides a jurisdiction into districts or zones and establishes for each district requirements governing the use of land and the bulk, height, coverage, and use of structures. Certain zoning classifications and procedures may reduce allowable intensity of development in flood plains and (or) require concentrating structures on a portion of a site out of the flood plain thus reducing flood-loss potential. Some of the more commonly applied zoning techniques include planned unit development (PUD), planned community zoning, cluster zoning, agricultural zoning, and flood-plain zoning.

Planned unit development or planned community zoning allows development of a large parcel as a single unit according to a plan approved by the legislative body. This technique provides the developer the flexibility to plan for the economic use of a large area within constraints posed by natural features and processes. It also gives the public agency the opportunity to review all aspects of the proposal and place legally binding conditions on the development of the property. Flood-prone areas are typically left as open space.

Cluster zoning specifies the density of permitted development (the number of dwelling units per unit of land) and requires that the houses be placed close enough together to leave a considerable portion of the site in open space. Under this device, flood-prone areas may be left in open space with little or no loss of development potential of a large parcel.

Agricultural zoning restricts use to specified agricultural uses. Agricultural zoning applied to flood-prone areas can be effective in reducing losses particularly if farm structures are prohibited in the flood plain and appropriate measures are taken to prevent encroachment on the stream channel and to reduce erosion.

Flood-plain zoning restricts the use of officially designated flood-prone areas. The zoning is often applied to the 100-year flood plain although different restrictions may apply to different parts of the flood plain depending on flood frequency or loss potential. The floodway may be under more severe use limitations than the less frequently flooded fringes of the flood plain (figs. 5 and 6).

Subdivision regulations.—The process of dividing undeveloped land into buildable parcels is governed by subdivision regulations. These typically prescribe lot sizes and relationships, requirements for the dedication of lands for public use, limitations on use of hazardous areas, standards for street improvements, standards for storm drainage, and requirements for other public utilities and facilities. Subdivision regulations also prescribe procedures for review and approval of proposed subdivisions.

In the San Francisco Bay region, the local flood control and water conservation district typically reviews subdivision proposals involving flood-prone areas and recommends steps to reduce potential flood losses. These may include dedication of easements along water courses for public access, parks, or some other legitimate public purpose; prohibition of stream channel encroachments; relocation of utilities, roads, or other public facilities; protection of riparian vegetative cover; and elevation of structures above the flood level. Recommendations of the flood control districts are advisory, but the local legislative body has the power, under State law, to attach any of these conditions to the approval of a subdivision or to deny approval of a subdivision proposal for failure to comply with such conditions. Where there is no flood control district, the responsibility for review and recommendations regarding flood problems and solutions usually rests with the city or county engineer.

Building and sanitary codes.—Building and sanitary codes are regulations adopted by local units of government to ensure the safety of structures and residents within their jurisdictions. Such regulations can be effectively used to reduce health hazards and damages from flooding. Typical local ordinance provisions were described in a preceding section "Flood-Loss Prevention and Reduction Measures."

Administration of land-use regulations.—Development proposals are evaluated for compliance with appropriate policies, plans, and regulations according to procedures which are ordinarily specified in the regulatory ordinances. When ordinances contain detailed restrictions on land use and development, administration is straightforward. For example, administering flood-plain zoning that prohibits construction within a flood plain specifically delineated in the ordinance involves reference to a map to determine whether or not a proposed structure is within the designated flood plain.

Regulations which indicate desired results in more general terms permit greater discretion and require greater expertise at the time of review of development proposals. Planned unit development regulations which call for avoiding natural hazards, for example, can be appropriately administered only if the agency staff has detailed information concerning the physical characteristics of the site or requires that such information be provided by the developer. In either case, the agency staff should have sufficient information to set proper data requirements for the developer, and sufficient expertise to review the developer's reports.

The administration of land-use and development regulations is a staff function of the reviewing agency, and the staff ordinarily makes ministerial decisions. But, in cases where discretion is allowed, the decision to approve or deny a development proposal is usually made by the local planning commission or legislative body. In these cases, the responsibility of the staff is to provide the decision-making body with all relevant and legally required information.

PROGRAM DEVELOPMENT AND EXECUTION

Program development and execution involves the systematic use of governmental powers and resources to achieve public objectives. Programs describe the direct actions a public agency intends to undertake including land acquisition, construction of public facilities, and provision of public services. A typical example is a local capital improvement program which schedules, over a multiyear period, the capital expenditures proposed for each project or activity. Constructing a flood-control project, for example, requires scheduling land acquisition and construction components in a logical sequence related to availability or commitment of funds.

A funding schedule or program is also needed to carry out public acquisition of flood-plain lands. Within limits established by Federal and State law, public agencies may acquire land for public purposes. Many agencies may acquire land through eminent domain (condemnation at fair market value). Public land may be maintained in open-space uses such as parks, natural preserves, or parking lots, or, in some cases, sold or leased for appropriate private development or use.

Land acquisition programs may be critical to flood-loss reduction in both developed and undeveloped flood-prone areas. In undeveloped flood-prone areas, public acquisition of land may be effectively used if the land is suitable for a public use such as recreation or wildlife conservation, or if regulation to reduce flood-loss potential would discriminate against individual land owners. In developed flood-prone areas, public acquisition and clearance of land may be appropriate where incentives are lacking, or cannot be reasonably provided, for private redevelopment to uses less vulnerable to flooding.

Construction of public facilities strongly affects realization of a land-use plan. The timing and location of utility extension, street and highway construction, and park and school development, for example, all influence the timing and location of urban development. Development of flood-prone areas can be discouraged by restricting utility extensions, transportation access, and public services consistent with an adopted land-use plan. If construction of flood-control projects is needed to reduce flood losses, programming the actions of several governmental agencies—Federal, State, and local—may be involved.

PROJECT REVIEW

Planning agencies are regularly called upon to review proposals for projects within or having potential impact on their planning areas. Even in the absence of specific procedures or requirements, careful review for consistency with the general plan is a matter of good planning practices. In recent years, through Federal requirements for the assessment of environmental impact and the U.S. Office of Management and Budget A-95 review (1969), such review has become increasingly formalized. These review processes are the major plan-implementing techniques of many regional agencies.

A-95 review.—A-95 review is a procedure designed to coordinate Federally funded projects with State and local planning objectives. Under this procedure, notification of application for Federal funds for a wide variety of projects must be submitted to designated State and regional clearinghouse agencies for review for consistency with State, area-wide, and local plans and programs. The clearinghouse agency forwards the notification to agencies potentially affected by the project for their review and comment. The comments are only advisory, but a Federal agency must defend in writing any decision to fund a project which has received a negative review. This assures at least consideration of the review comments of affected public agencies.

Environmental impact assessment.—The National Environmental Policy Act of 1969 [NEPA] (U.S. Congress, 1970) requires that an environmental impact statement (EIS) be prepared for proposals for legislation and other Federal actions significantly affecting the quality of the human environment. The statement must include the environmental impact of the proposed action, any adverse environmental effects which cannot be avoided should the proposal be implemented, alternatives to the proposed action, the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

Environmental impact assessment requirements, similar to those set forth in the Federal legislation, were adopted by California in the Environmental Quality Act of 1970 (California Public Resources Code, 1976). This act requires an environmental impact report (EIR) for all public and private projects which may have significant environmental impacts, and which involve a discretionary decision by a public agency. Other states have adopted similar requirements since 1970.

The requirement for environmental impact assessment, whether Federal or State, is, in effect, superimposed on the normal review process of the jurisdiction in which a project is proposed. Projects subject to environmental impact assessment are still reviewed for conformity with the general plan and regulations of the appropriate jurisdiction. Local regulations may require more environmental information than is required by Federal or State law.

GOVERNMENTAL ORGANIZATION FOR FLOOD-LOSS REDUCTION IN THE SAN FRANCISCO BAY REGION

By M. L. Blair and W. E. Spangle

Planning and decisionmaking related to flood-loss reduction in the San Francisco Bay region is carried out and influenced by a diverse group of governmental agencies. Typically, efforts to reduce flood losses are initiated by local government. If flood-loss reduction is to be accomplished primarily through regulation, local decisions dominate the effort. However, if major flood-control works are to be constructed, State and Federal agencies are usually more directly involved. Because flood-loss reduction often involves a combination of regulatory and structural measures, the interplay of government agencies can become very complex.

Even when no flood-control works are anticipated, flood-loss reduction is influenced by Federal, State, and regional agencies. Federal and State agencies affect local decisionmaking through requirements for funds, criteria for programs, shared responsibility for functions such as transportation, and regulations such as those relating to local planning or environmental quality.

Local governmental agencies are increasingly dependent on Federal and State funds to carry out

their responsibilities. This means that local plans and programs are often framed with an eye to Federal and State program funding requirements as well as to locally expressed objectives and concerns. The fact that, until recently, Federal funding has been more readily available for flood-control structures than for purchase of land or development rights in flood-prone areas has influenced local decisions concerning flood-loss reduction measures. Key governmental programs which influence planning for flood-loss reduction and selected governmental agencies most often directly involved in the planning and decisionmaking process are described in the following sections.

FEDERAL PROGRAMS

NATIONAL FLOOD INSURANCE PROGRAM

The National Flood Insurance Program was enacted through passage of the National Flood Insurance Act of 1968 (U.S. Congress, 1968) and is administered by the Federal Insurance Administration (FIA) in the U.S. Department of Housing and Urban Development. The program was established to promote the public interest by providing appropriate protection against flood losses through the availability of flood insurance coverage and the requirement of sound flood-plain management regulatory measures to minimize the exposure of lives and property to flood risk. The economic justification for the program, which initially requires extensive public subsidies to bring premiums in line with what the public can afford, is the reduction of the need for and dependence on increasing flood disaster relief appropriations through safer construction practices in flood-hazard areas.

The program was amended by the Flood Disaster Protection Act of 1973 (U.S. Congress, 1973) under which available limits of flood insurance coverage were substantially increased. Further, such coverage became a statutory requirement to secure eligibility for Federal financial assistance for acquisition or construction purposes within the identified special flood-hazard areas of the Nation. Federal agencies responsible for the supervision of lending institutions are required to direct such institutions to require flood insurance in connection with real estate, mobile home, or personal property loans in identified flood-hazard areas. State-owned properties may be covered by approved self-insurance plans.

Section 202 of the Act prohibits Federal financial assistance for acquisition or construction purposes and Federally related financing by private lending institutions for properties in identified special flood-hazard areas, unless the community in which the area is located is participating in the program within one year of its notice of identification as being flood prone.

The Federal Insurance Administration is charged with the responsibility to identify all the Nation's flood-plain areas that have special flood hazards. Such an area is defined as being that area of the flood plain which, on the average, is likely to be flooded once every 100 years (that has a one percent chance of flood occurrence in any given year). The Federal Insurance Administration (written commun., 1977) has identified 96 communities in the San Francisco Bay region that are eligible for the sale of flood insurance. Flood-hazard areas have been identified in all but two of these communities (see table 10). The eligible communities are all participating in the emergency flood insurance program in which the limits of coverage are one-half of that of the regular program, and the premiums are subsidized. Upon completion of flood-insurance ratemaking studies, each community will be transferred to the regular program with full insurance coverage available at actuarial rates based on the degree of flood risk.

The specificity of the flood-plain management requirement of the National Flood Insurance Program is directly related to the degree of technical data which FIA has made available to a participating community. When a community has submitted an application to participate in the NFIP but has not yet received a Flood Hazard Boundary Map (FHBM) delineating the special flood hazard area, it is required to adopt and enforce general flood-plain management measures (Federal Insurance Administration, 1976) which are applicable throughout its entire jurisdiction. These measures are performance standards; the development of specific implementation criteria is left to the discretion of the community, which has the best knowledge of its own flood problem and administrative resources. At all times, however, technical assistance is available from both FIA and the coordinating officials designated to carry out such responsibilities by each State government. Since some of the following requirements are paraphrased by the FIA, and since the map zones in which each of them apply are omitted for the sake of brevity, the appropriate section of the regulations (Federal Insurance Administration, 1976) is noted and should be referred to for the specific regulatory language and area of applicability.

When the FHBM is not yet available, the community must meet the following requirements of Section 1910.3.a:

1. Require permits for all proposed construction or other development[2] (including placement of prefabricated buildings and mobile homes) to determine if it lies within a flood-prone area (1910.3.a.1).

2. Review such development proposals to assure that all necessary Federal or State permits have been obtained (e.g., Section 404 permits under the Federal Water Pollution Control Act Amendments of 1972) (1910.3.a.2).

3. Review all permit applications to assure that all new construction and substantial improvements be: (a) Anchored to prevent displacement or collapse. (b) Constructed with materials and utility equipment which are resistant to flood damage. (c) Constructed according to methods and practices that minimize flood-damage potential (1910.3.a.3).

4. Review subdivision proposals and other proposed new development to determine whether such proposals will be reasonably safe from flooding. If a subdivision proposal or other proposed new development is in a flood-prone area, any such proposal shall be reviewed to assure that: (a) Such proposals are consistent with the need to minimize flood damage within the flood-prone area. (b) New or replacement utilities are located and constructed in a manner which will minimize or eliminate flood damage. (c) Adequate drainage is provided to reduce exposure to flood hazards (1910.3.a.4).

5. Require new or replacement water systems to be designed to minimize or eliminate infiltration of flood waters into the systems and discharges from the systems into flood waters (1910.3.a.5).

6. Require new or replacement sanitary sewage systems to be designed to minimize or eliminate infiltration of flood waters into the systems and discharges from the systems into flood waters, and require that on-site waste-disposal systems be located to avoid impairment of them or contamination from them during flooding (1910.3.a.6).

After receiving its FHBM, the community must continue to enforce the same controls within the area defined on the map, as well as the following additional requirements of Section 1910.3.b:

1. Require that all subdivision proposals and other proposed new developments greater than 50 lots or 5 acres, whichever is the lesser, include base flood-elevation data (1910.3.b.3).

2. Obtain, review, and reasonably utilize base flood-elevation data from alternative sources, prior to its being provided by FIA through its Flood Insurance Rate Study, as criteria for requiring that all new residential structures and substantial improvements to existing structures have their lowest floor (including basement) elevated to or above the base flood level, and new nonresidential structures and substantial improvements to existing ones have the lowest floor (including basement) elevated or floodproofed to or above the base flood level (1910.3.b.4).

3. Obtain and record the lowest floor level when a permit is issued for new construction and substantial improvements for use in the determination of applicable flood insurance risk premium rates (1910.3.b.5).

4. In riverine situations, notify adjacent communities and the State Coordinating Office prior to any alteration or relocation of a watercourse and submit copies of such notifications to FIA (1910.3.b.6).

5. Require that the flood carrying capacity within the altered or relocated portion of any watercourse be maintained (1910.3.b.7).

6. Require that mobile homes meet FIA anchoring standards to resist flotation, collapse, or lateral movement (1910.3.b.8).

7. Require that an evacuation plan for all mobile home parks and subdivisions be filed with appropriate Disaster Preparedness Authorities (1910.3.b.9).

Up to this point, the community has been participating in the Emergency Flood Insurance Program and has received none of the advanced technical data (base flood data, floodway, or coastal high-hazard area delineation) which becomes available upon conversion to the Regular Program with the completion of the Flood Insurance Rate Study and its accompanying Flood Insurance Rate Map (FIRM). After a community converts to the Regular Program, it must meet the requirements of either Section 1910.3.c, d, or e, depending upon the type of information which the study provides. If the study provides only base flood data, the community must adhere to Section 1910.3.c; if it provides a floodway delineation which is typical in riverine situations, as well as the base flood data, Section 1910.3.d must be adhered to; if it provides a coastal high-hazard area delineation for coastal areas subject to wave action, Section 1910.3.e must be adhered to; and in certain circumstances where communities include both riverine (floodway) and coastal high-hazard areas, Sections 1910.3.d and 1910.3.e must be adhered to.

The requirements of Section 1910.3.c include those of Section 1910.3.b, as well as the following additional requirements:

1. Require that all new construction and substantial improvements of *residential* structures have the lowest floor (including basement) elevated to or above the base flood level, unless an exception for the allowance of basements and/or storm cellars is granted to the community by the FIA (1910.3.c.2).

2. Require that new construction and substantial improvements of *nonresidential* structures have the lowest floor (including basement) elevated to or above the base flood level, or floodproofed to or above that level (1910.3.c.3).

3. Require that, where floodproofing is used for structures in lieu of elevation, a registered professional engineer or architect certify that the floodproofing methods used are adequate to withstand flood depths, pressures, impact and uplift forces, and other forces associated with the base flood and record such certifications or submit to FIA for approval of local regulations containing detailed floodproofing specifications which meet the watertight performance standards (1910.3.c.4).

4. For new mobile home parks and subdivisions, expansion to existing ones, and in those where access, utilities, and pads are substantially improved, require that stands and lots are elevated so that the lowest floor of the mobile home will be at or above the base flood level, that adequate surface drainage and access for haulers is provided, and that where piles or columns are used for elevation, lots are large enough to permit steps, and piling foundations are stabilized and reinforced (1910.3.c.5).

5. Require that mobile homes which are not to be located in mobile home parks or subdivisions meet the foregoing requirements (1910.3.c.6).

6. In areas subject to shallow flooding, require that all new construction and substantial improvements have the lowest floor (including basement) elevated above the crown of the nearest street to the height specified on the FIRM (1910.3.c.7).

7. Require that nonresidential structures in areas subject to shallow flooding be either floodproofed or meet the foregoing requirement (1910.3.c.8).

8. Until a regulatory floodway is designated, require that, prior to such designation, no new construction or other development is permitted which, when combined with all other existing and anticipated development, will increase the water-surface elevation of the base flood more than one foot at any point within the community (1910.3.c.9).

The requirements of Section 1910.3.d include the requirements of Sections 1910.3.c.1–8, as well as the following:

1. Select and adopt a regulatory floodway based on the principle that the area chosen for the regulatory floodway must be designed to carry the waters of the base flood without increasing the water surface elevation of that flood more than one foot at any point (1910.3.d.2).

2. Prohibit encroachment, including fill, new construction and substantial improvements, and other development within the adopted regulatory floodway that would result in any increase in flood levels in the community during the occurrence of the base flood discharge (1910.3.d.3).

3. Prohibit the placement of any mobile homes, except in an existing mobile home park or subdivision, within the adopted regulatory floodway (1910.3.d.4).

The requirements of Section 1910.3.e include those of Section 1910.3.c.1–9 for the portions of the flood-hazard area outside of the coastal high-hazard area as well as the following additional requirements which apply within the coastal high-hazard area:

1. Obtain the elevation of the lowest habitable floor of all new or substantially improved structures, for the determination of applicable flood insurance risk premium rates, and maintain records of all such information (1910.3.e.2)

2. Provide that new construction is located landward of the reach of mean high tide (1910.3.e.3).

3. Provide that (i) all new construction and substantial improvements are elevated on adequately anchored piles or columns, and securely anchored to such piles or columns so that the lowest portion of the structural members of the lowest floor (excluding piles or columns) is elevated to or above the base flood level, and (ii) that a professional engineer or architect certify that the structure is securely anchored to adequately anchored piles or columns in order to withstand velocity waters and hurricane wave wash (1910.3.e.4).

4. Provide that all new construction and substantial improvements have the space below the lowest floor free of obstructions or be constructed with "breakaway walls" intended to collapse under stress without jeopardizing the structural support, so that the impact on the structure by abnormally high tides or wind-driven water is minimized. Such temporarily enclosed space cannot be used for human habitation (1910.3.e.5).

5. Prohibit the use of fill for structural support (1910.3.e.6).

6. Prohibit the placement of mobile homes, except in existing mobile home parks and mobile home subdivisions (1910.3.e.7).

7. Prohibit man-made alteration of sand dunes and mangrove stands which would increase potential flood damage to existing structures (1910.3.e.8).

The implementation of a flood-plain management regulatory effort based on the design and high-hazard area criteria discussed above as required under the National Flood Insurance Program will have significant effects on land-use planning in many San Francisco Bay region communities. Large areas of the region are subject to either tidal or riverine flooding—including many highly urbanized areas. Planners in these areas need detailed, up-to-date information about the flood-insurance requirements of the Federal Insurance Administration. Because the regulations are subject to change, the planner is well advised to contact the Federal Insurance Administration for current requirements pertaining to his jurisdiction.

FEDERAL DISASTER ASSISTANCE PROGRAM

Federal disaster assistance supplements the resources of State and local governments to alleviate the suffering and damage caused by emergencies and major disasters, as defined by the Disaster Relief Act of 1974 (U.S. Congress, 1974a). This Act, implemented by the Federal Disaster Assistance Administration (1975) contains three significant provisions in Federal preparedness and disaster assistance relating to flood-prone areas. First, financial and technical assistance, funded by the Federal government, is offered to the States to develop plans, programs, and regulations for hazard reduction, disaster preparedness, and disaster relief. Second, buildings and mobile homes located within identified flood-prone areas which are to be replaced, repaired, or restored with Federal disaster assistance funds must conform to the National Flood Insurance Program prior to receipt of that assistance. The major effect of the program on flood-loss reduction efforts is to reinforce the provisions of the National Flood Insurance Program that discourage flood-plain development. Also, Section 314 of Public Law 93-288 (U.S. Congress, 1974a) requires insurance for other hazards on properties assisted under Section 402 or 419 of the Act, provided that such insurance is reasonably available, adequate, and necessary. Third, as a condition of any loan or grant, the State or local government must agree that the natural hazards in the areas in which the funds of the grants

[2] The term "development" is defined to mean "any manmade change to improved or unimproved real estate including, but not limited to, buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations."

or loans are to be used will be evaluated. The State and local government must also agree that appropriate action will be taken to mitigate these hazards, including safe land-use and construction practices.

U.S. ARMY CORPS OF ENGINEERS

As set forth in the Flood Control Act of 1936 (U.S. Congress, 1936), the U.S. Army Corps of Engineers has a major responsibility for flood control throughout the United States. The Corps studies flood problems, recommends solutions, and constructs and maintains flood-control projects. The Corps undertakes major flood-control projects specifically authorized by Congress and small flood-control projects that do not require Congressional authorization. The purpose of major flood-control projects is to prevent flood losses by construction of channel improvements, levees, or dams. Most major projects involving construction of dams are multipurpose, also serving needs for "hydroelectric power, irrigation, navigation, municipal and industrial water supplies, water-quality control, recreation and enhancement of fish and wildlife resources" (U.S. Army Corps of Engineers, 1975d, p. 215).

Small flood-control projects provide flood-control structures at a Federal cost usually less than $1 million per project. Both major and small flood-control projects are preceded by thorough hydrologic studies, cost/benefit analyses of alternative solutions to flood problems, and detailed project reports. The costs of Corps projects are shared between the Federal and local governments. States may assume some or all of the local costs.

The Water Resources Development Act of 1974 (U.S. Congress, 1974c), authorizing Corps projects for the coming year, requires, for the first time, that nonstructural alternatives to reduce flood losses be analyzed in flood-control studies. The local share of the cost of nonstructural alternatives, such as land acquisition and relocation of buildings, is the same as for structural projects. Three nonstructural projects are authorized by the Act, representing a significant change in the Corps' traditional approach.

Under the Flood Plain Management Services Program, the Corps prepares flood-plain information reports at the request of local agencies, undertakes hydrologic studies for the Federal Insurance Administration, and provides technical assistance to government agencies in flood-plain planning and management. Corps of Engineers flood-control studies, flood-plain information reports, and projects in the San Francisco Bay region are listed in table 10.

COMPREHENSIVE PLANNING ASSISTANCE PROGRAM

The Comprehensive Planning Assistance Program, authorized by Section 701 of the Housing and Community Development Act of 1974 (U.S. Congress, 1974b), currently provides grants to finance comprehensive planning programs. The purpose of this assistance is to increase the capacity of States, regional governmental bodies, units of general local government, and other eligible grant recipients to plan and manage all the resources available to them in order to achieve the following goals:

1. Community betterment, in both rural and urban areas, that is responsive to the needs of the public;
2. Adequate housing, public facilities, and public services that are required to support an improved quality of life;
3. Conserving and protecting the environment and natural resources for future generations; and
4. Coordination and management of all functional planning activities.

Currently, grants usually cover two-thirds of project costs. The Secretary of Housing and Urban Development may allocate assistance directly to eligible recipients or through States (U.S. Department of Housing and Urban Development, 1974).

All agencies applying for grants must have an adopted land-use element by August 22, 1977 (U.S. Department of Housing and Urban Development, 1975, p. 36862). The element is to identify areas where growth should and should not take place giving comprehensive consideration to environmental factors.

In addition, the regulations require that assisted planning activities be conducted in accord with the National Environmental Policy Act of 1969 (U.S. Congress, 1970) through the inclusion of environmental planning in the comprehensive planning process. Specifically each agency shall (U.S. Department of Housing and Urban Development, 1975, p. 36860):

1. Identify salient elements of the natural and manmade environments, their interrelationships, and major problems and/or opportunities they present for community development;
2. Assess those environmental factors which will: (i) Minimize or prevent undue damage, unwise use, or unwarranted pre-empting of natural resources and opportunities; (ii) Recognize and make prudent allowance for major latent environmental dangers or risks (e.g., floods, mud slides, earthquakes, air and water pollution); and (iii) Foster the human benefits obtainable from use of the natural environment by wise use of the opportunities available (e.g., use of natural drainage systems for park and recreational areas).

Under these regulations, problems of flooding must be considered in the development of land-use plans.

COMMUNITY DEVELOPMENT BLOCK GRANT PROGRAM

The Community Development Block Grant Program, administered by the Department of Housing and Urban Development, was instituted by the Housing and Community Development Act of 1974 (U.S. Congress, 1974b). Under this program, Federal funds are made available to local governments for a wide variety of community activities, many of which were previously funded under separate programs. Among the activities eligible for grants are the conservation of open space, natural resources, and scenic areas; provision of recreational opportunities; and installation of flood and drainage facilities (U.S. Department of Housing and Urban Development, 1976). Funds are also available to meet emergency community development needs in Federally declared disaster areas.

U.S. SOIL CONSERVATION SERVICE AND RESOURCE CONSERVATION DISTRICTS

The U.S. Soil Conservation Service (SCS) is concerned primarily with watershed management and land-treatment practices to reduce soil erosion and sedimentation; it is also involved in flood-control projects through Public Law 83-566 (U.S. Congress, 1954). Under this law, Federal funds are provided for flood-control projects in small watersheds. The projects are undertaken cooperatively with local sponsors and may have water supply, recreation, or erosion-control functions. The projects are financed partly by State or local funds. Six small watershed projects, as identified in table 10, have been authorized by Congress for the San Francisco Bay region; one, the Ulatis Creek project, has been completed.

County flood control and water conservation districts together with resource conservation districes serve as local sponsoring agencies for all authorized small watershed projects in the San Francisco Bay region. In California, resource conservation districts (RCD), like soil conservation districts throughout the United States, are served by SCS field offices, each headed by a district conservationist. Resource conservation districts may be formed under provisions set forth in the California Public Resources Code (1970) for "the control of runoff, the prevention or control of soil erosion, the development and distribution of water, and the improvement of land capabilities." Eight SCS field offices, located in Concord, Dixon, Half Moon Bay, Livermore, Morgan Hill, Napa, Santa Rosa, and Petaluma serve the 15 resource conservation districts in the San Francisco Bay region (fig. 15).

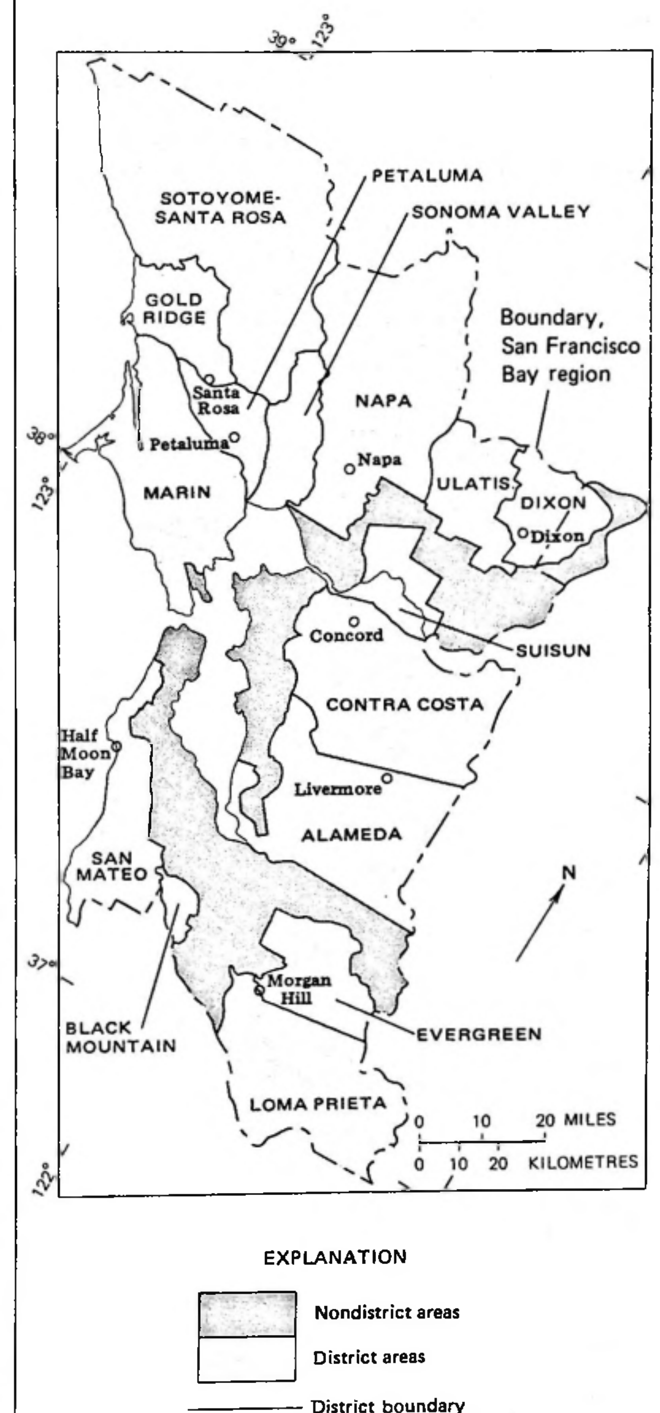


FIGURE 15.—Resource conservation districts and U.S. Soil Conservation Service field offices, San Francisco Bay region.

REGIONAL AND LOCAL PROGRAMS

FLOOD CONTROL DISTRICTS

Flood-plain regulations in the Bay region are often drafted and administered by county flood control districts. All the San Francisco Bay region counties except San Francisco have such districts, but as each district was established by separate State legislation, the powers and form of organization are not uniform. For example, the Santa Clara Valley Water District is governed by a separately elected board, while the other districts are governed by the local County Board of Supervisors sitting as the district governing board. All the districts are empowered by their establishing legislation to levy taxes, acquire property and water rights, enter into contracts, issue bonds, establish zones for levying assessments, and exercise the power of eminent domain in carrying out their functions.

The districts usually are responsible for drainage, flood control, water-supply development, water conservation, and several other functions related to the use of the county's water resources. They maintain channels, remove debris and other obstructions to waterflow, and provide emergency services in the event of a flood. The primary functions actually performed by the eight districts in the region are shown in table 3.

The flood control districts typically draft and administer regulations responsive to the California Cobey-Alquist Flood Plain Management Act (California Water Code, 1976), which requires prohibition of development within the right-of-way of a proposed flood-control project. In addition, the districts may administer county, and sometimes city, flood-plain regulations. In most San Francisco Bay region counties, permits from the district are required for encroachment on or obstruction of stream channels.

TABLE 3.—*Primary functions of flood control districts in the San Francisco Bay region*

Name of district	Date established	Plan, construct, maintain flood control facilities	Conserve, import, develop water supply	Monitor water quality	Project review	Land use and development regulations administered by district
Alameda County Flood Control and Water Conservation District.	1949	x	x	x	x	Permit for work within easements, rights-of-way owned by District. Building permit denial in flood-prone areas along certain creeks. Two city ordinances regulating "designated floodways" for proposed flood-control projects.
Contra Costa County Flood Control and Water Conservation District.	1951	x			x	Permit for work within stream channels in unincorporated areas. Subdivision regulations setting minimum drainage standards, requiring easements. Permit for grading, soils and engineering geology reports. Prohibition on obstructing water flow, damaging levees, work in county easements.
Marin County Flood Control and Water Conservation District.	1953	x			x	Flood-plain zoning applied in Novato area—primary and secondary zones. Permit for work in channels in unincorporated and some incorporated areas. Prohibition on obstructing water flow.
Napa County Flood Control and Water Conservation District.	1951	x	x	x	x	Permit for encroachment on channels including 50-foot strip on either side of channel operated and maintained by District. Limited flood-plain zoning applied to right-of-way of proposed U.S. Army Corps of Engineers project on the Napa River.
San Mateo County Flood Control District.	1959	x			x	Permit for construction activities in San Francisquito Creek channel and 15 feet from San Mateo County side.
Santa Clara Valley Water District.	1951	x	x	x	x	Permit for construction within "designated floodway" or within 50 feet of top of streambank in both unincorporated and incorporated areas. Policy for dedication to District of land in "designated floodway."
Solano County Flood Control and Water Conservation District.	1951	x	x		x	Permit for construction in channels or altering existing water drainage in unincorporated areas. Subdivision regulations setting drainage criteria. Limited flood-plain zoning.
Sonoma County Water Agency.	1949	x	x		x	Limited flood-plain zoning. Permit for construction in or near any drainageway.

REGIONAL AGENCIES

Regional agencies influence flood-loss reduction through an extension of their planning, project review, and regulatory powers. These agencies include the Association of Bay Area Governments, the San Francisco Bay Conservation and Development Commission, and the California Coastal Zone Conservation Commission.

The Association of Bay Area Governments (ABAG) is the only regional agency covering the entire nine-county San Francisco Bay region with responsibility for comprehensive planning. Established in 1961 to develop plans and policies pertinent to region-wide problems, ABAG is a voluntary association of city and county governments. Implementation of ABAG's regional plans and policies depends on decisions by State and Federal agencies, other regional agencies, and local units of government. However, ABAG can indirectly influence local decisions through its designation by the Federal government as the A-95 Review clearinghouse agency for the San Francisco Bay region. In this capacity, ABAG reviews requests for Federal funds available through most Federal programs. A major function is the review of local applications for Community Development Block Grants. ABAG reviews proposed Federal projects for conformity with adopted regional plans. ABAG also reviews Federally required environmental impact statements and most State-required environmental impact reports. In the usual situation in which many projects are competing for limited funds, a negative finding by ABAG, although advisory, is likely to be heeded by the funding agency.

The San Francisco Bay Conservation and Development Commission (BCDC) was created by the State legislature to prepare a comprehensive plan for San Francisco Bay and its shores. The plan was adopted by the State legislature, and BCDC became a permanent agency charged with carrying out the plan. The adopted plan has legal status and serves as a guide in the review of projects. BCDC shares jurisdiction over land-use decisions with the cities and counties which retain normal land-use and building permit controls. However, with certain minor exceptions, a permit from BCDC is required for all projects within its area of jurisdiction (the water of San Francisco Bay and up to 1,000 ft or 305 m inland from the Bay shoreline). Thus, in effect, it holds veto power over any project proposal in conflict with the San Francisco Bay Plan.

With respect to flooding the plan states as a major policy (Bay Conservation and Development Commission, 1969, p. 17):

> To prevent damage from flooding, buildings on fill or near the shore-line should have adequate flood protection as determined by competent engineers. As a general rule, buildings near the shoreline should be at least nine feet above mean sea level (standard U.S.G.S. datum) or should be protected by dikes of an equivalent height and by any necessary pumping facilities. In the southern half of the South Bay, this height should be at least ten feet. Exceptions to the general height rule may be made for developments specifically designed to tolerate periodic flooding.

The California Coastal Zone Conservation Commission (CCZCC) and six subordinate regional commissions have powers comparable to BCDC's over California's coastal areas. In 1972 California voters adopted, by initiative, legislation creating these commissions. The CCZCC, working with the regional commissions, was charged with preparing a plan for managing the California coastal zone. While the plan was being prepared, the commissions controlled development, through a permit process, to ensure consistency with the objectives of the establishing legislation and the emerging plan policies. Coastal areas of the San Francisco Bay region are represented by two regional commissions: Central (San Mateo County) and North Central (San Francisco, Marin, and Sonoma Counties). The plan was presented to the Governor and State Legislature in December 1975 for adoption and implementation. Under the terms of the initiative, the CCZCC and the six regional commissions were to expire on January 1, 1977, unless legislation was enacted to create successors to them.

In September 1976 the California Coastal Act of 1976 was enacted (California Public Resources Code, 1976b), establishing the California Coastal Commission and six regional coastal commissions as successors to the commissions created by the 1972 initiative. Under the terms of the Act, the six regional commissions will expire 30 days after the last required local coastal program has been certified, but no later than January 1, 1981.

The California Coastal Plan is interesting in its emphasis on the beneficial effects of flooding. According to the plan, these effects include (California Coastal Zone Conservation Commission, 1975, p. 83):

> the maintenance of salmon and steelhead spawning ground;
> the continued supply of beach sands;
> the removal of vegetation choking the river channel, restoring the channels capacity to contain minor flood flows;

the long-term deposition along the floodplain of sediments that provide highly fertile soils;
flushing of undesirable salts from the surface layers of soils, and
the preservation of valuable plant communities on overflow lands, such as giant redwood groves.

Recognizing that development in flood-hazard areas not only removes these benefits, but is exposed to loss from flooding, the plan contains the following policy statement (p. 84):

To avoid the need for new flood control works and interference with natural watershed processes that adversely affect coastal resources such as sand supply and anadromous fisheries, development in flood-hazard areas shall be regulated as follows:

a. Criteria for New Developments in Unprotected Flood-Hazard Areas. Only new developments that can sustain periodic flooding and that will not create public burdens by aggravating the flood problem, impeding floodwater storage capacity, or increasing pressure for new flood control projects shall be allowed in presently unprotected flood-hazard areas (those subject to inundation by a 100-year flood), consistent with the existing Federal insurance program. Examples of permissible uses include agriculture and recreation, with necessary incidental structures.
b. Restrict Use of Flood-Hazard Areas during Flood-Prone Periods. During flood-prone periods, flood-hazard areas shall not be used for log decks or storage of materials that can be carried downstream by flood waters unless mitigation (such as anchoring devices or berms) is adequate.
c. Review Inland Flood-Hazard Area Projects That Could Affect Coastal Zone. It is recommended that the Legislature establish procedures to ensure opportunities for public review of proposed inland flood-hazard area projects that could adversely affect lives and property in the coastal zone.

PLANNING FOR FLOOD-LOSS REDUCTION IN THE NAPA VALLEY

By M. L. Blair

Planning for flood-loss reduction, through structural or nonstructural measures, usually involves several agencies with differing powers and responsibilities. The pattern of relationships among the agencies is highly variable and often difficult to trace. Therefore, examining the actual responses of agencies to a particular flooding problem can be more instructive than attempting to generalize from very diverse situations. This section describes planning and decisionmaking related to flood-loss reduction in the Napa Valley area of the northern San Francisco Bay region. This area was selected for detailed study because it has agricultural, urban, and urbanizing lands subject to severe flooding; agencies at all jurisdictional levels have been involved in planning for the flood-prone areas; and several different approaches have been tried or proposed to reduce flood losses.

This study describes the plan formulation and implementation efforts at the regional, county, and city levels with respect to the flood-prone areas of the Napa Valley. The case study format necessarily emphasizes what has been done rather than what ought to be done. However, in describing the efforts of the agencies involved, the effectiveness of various actions within a specific context is made clear. Because flooding problems are widespread and variable, and there are many possible responses, a description of actual responses to a particular problem can illuminate possibilities and problems which may pertain to many different situations.

DESCRIPTION

The Napa River rises just north of Calistoga in northern Napa County and flows south through the Napa Valley to San Pablo Bay—a distance of 39 mi (63 km). Numerous tributaries flow into the river which broadens onto tidal sloughs about 9 mi (14 km) north of San Pablo Bay. North of the city of Napa, the valley floor is flanked by a series of foothills that reach a maximum elevation of 4,343 ft (1,323 m) at Mount St. Helena on the county line 7 mi (11 km) north of Calistoga. The location of Napa County in the San Francisco Bay region is shown in figure 1. The location of the Napa Valley Planning Area is shown in figure 16.

With the exception of the flat tidal marshes that, north of San Pablo Bay, the river valley is entirely within Napa County. The valley, however, is a natural feature significant to the entire San Francisco Bay region because of the economic importance of its renowned vineyards, the significance of its large nonurban areas to a regional system of open space, and its attractiveness as a locale to accommodate a substantial share of projected regional population growth. Figure 17 is an aerial view of the Napa River as it winds through the city of Napa.

Although only a 1-hour drive from San Francisco, the valley is bypassed by the Bay area freeway network and has experienced far less rural-residential development and suburbanization than neighboring counties. Napa, Yountville, St. Helena, and Calistoga, the only incorporated cities in Napa County, are all located in the Napa Valley and have a combined population of approximately 52,400 (44,200 in Napa). Another 34,600 people live in the unincorporated areas of the county, for a total county population of 87,000 (Napa County Conservation, Development and Planning Department, 1974a). Napa County plans and regulations are presently designed to accommodate a population of 115,000 by

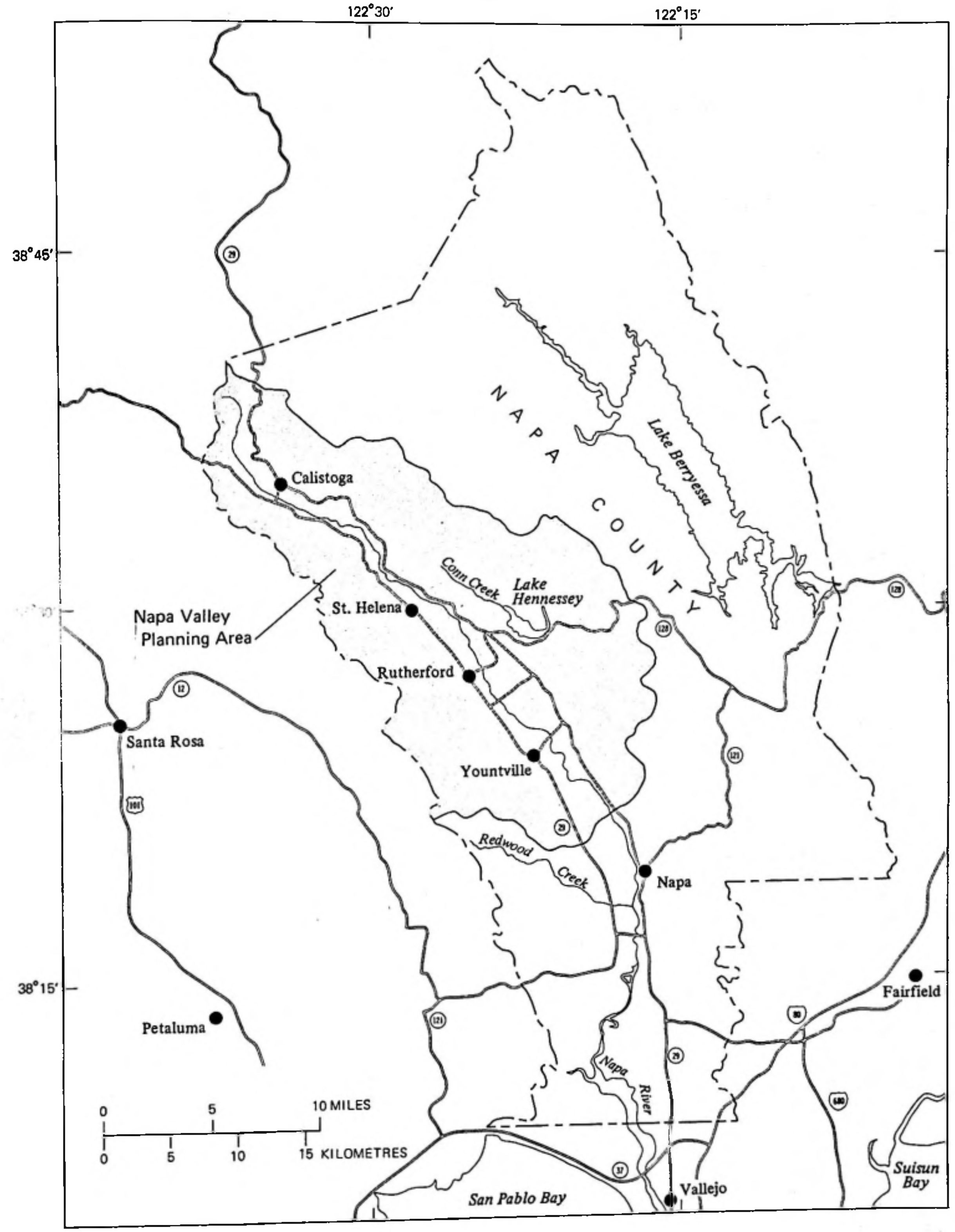


Figure 16.—Napa County and Napa Valley planning area.

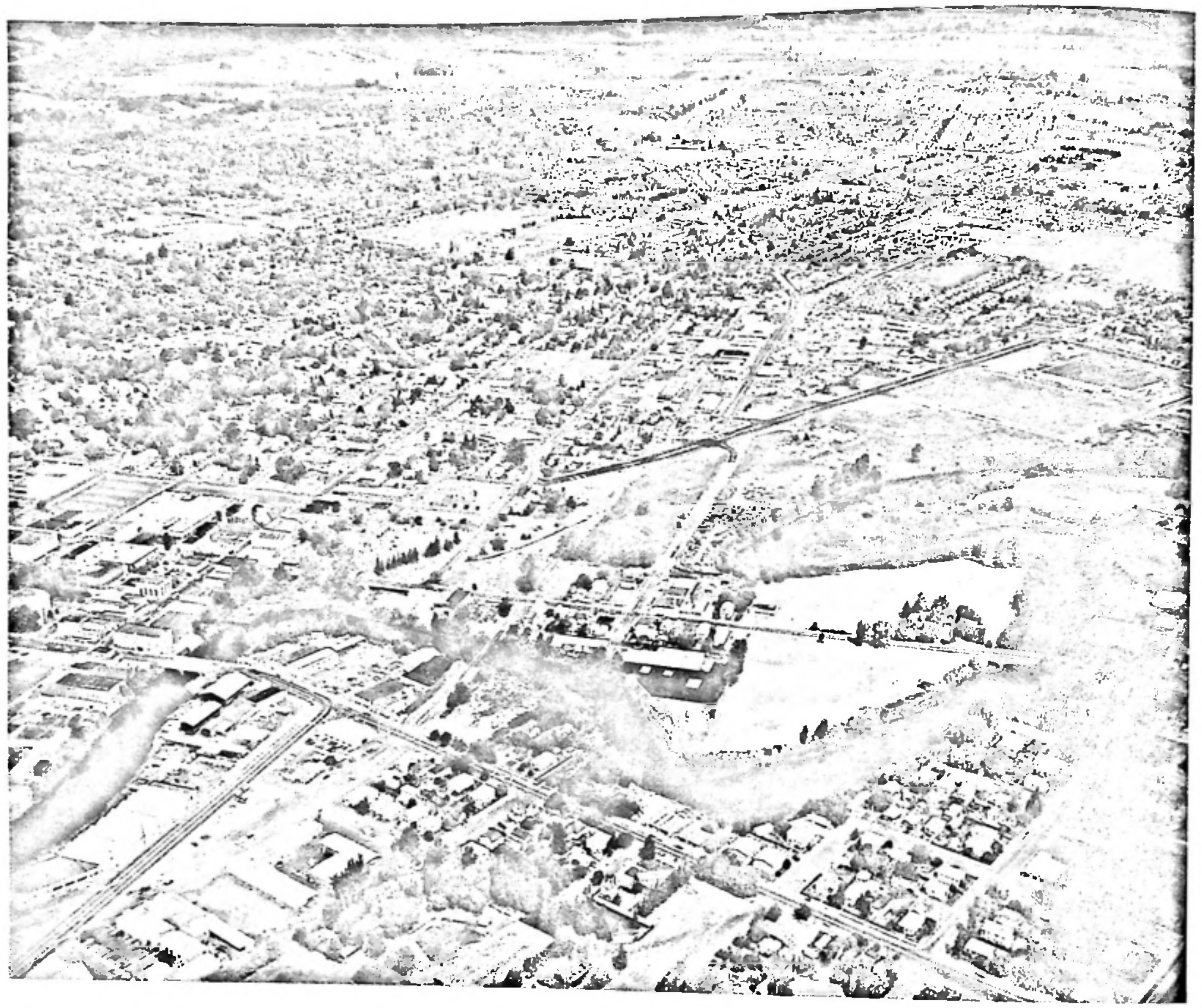


FIGURE 17.—Napa River, city of Napa. (Photograph by U.S. Army Corps of Engineers.)

the year 2000. Regional and local plans indicate that population growth is to be accommodated in or near the existing cities along the Napa River, especially the city of Napa.

The soils, climate, and topography of Napa Valley are exceptionally well-suited to the cultivation of grapes. Some of California's finest wines are produced in the valley, and the value of land for viticulture has in recent years exceeded its value for subdivision development. Although this situation may be temporary, it is presently (1976) in sharp contrast to the economic situation which contributed to the suburbanization of prime agricultural land in other areas of the Bay region such as the Santa Clara Valley.

FLOODING PROBLEMS IN THE NAPA VALLEY

Flooding along the Napa River is a persistent problem. The city of Napa has experienced damaging floods 18 times since 1900, or an average of more than once every 4 years (fig. 18). According to Limerinos (1970),

> Flooding of low-lying areas in the city occurs when streamflow exceeds 12,000 cfs (cubic feet per second) or at stages above an elevation of about 47 feet above mean sea level (gage height, 23 feet) at the gaging station (at Oak Knoll Avenue) on Napa River near Napa, Calif.

The date, elevation, and discharge of the major floods, in order of magnitude, are shown in table 4.

The extent of flooding in the valley, caused by storms of the same magnitude, may vary for several

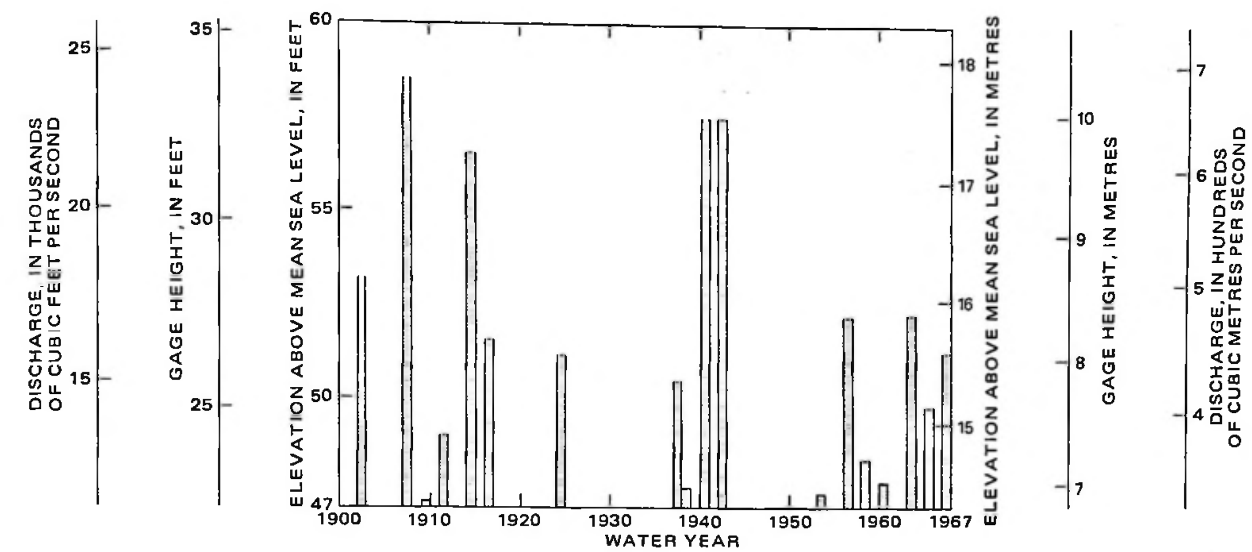


FIGURE 18.—Annual floods above 47-foot elevation, 1900–1967, Napa River near Napa, California. (From Limerinos, 1970.)

reasons. First, tidal action can affect flood elevations in the lower end of the valley. A high tide can increase the height of a flood up to Trancas Road[3] in the north side of the city (Limerinos, 1970). Second, although of limited capacity and not operated for flood control, several small water-supply reservoirs on the tributaries can retain a portion of the runoff if a storm occurs at a time when the reservoirs are not full. Limerinos reported that:

> At the onset of the storm that caused the December 1955 flood, the water level in Lake Hennessey was 14 feet below the spillway elevation, and a considerable part of the flood runoff was stored in the reservoir. On January 31, the water level was only 1 foot below the spillway elevation, and most of the ensuing flood runoff spilled. This caused extensive damage along Conn Creek and increased the flow of the Napa River through Napa.

Third, the construction of levees and other channel modifications or the presence of debris or channel obstructions can affect the extent of damage from a given storm. Fourth, runoff characteristics of the 220-mi² (570-km²) drainage basin upstream from the Oak Knoll Avenue gaging station above Napa also affect the degree and frequency of flooding from a given storm. If the storm occurs when the soil is saturated from the rain of preceding storms, the amount of runoff increases. The effect is similar in areas where the drainage basin has been denuded of natural vegetation or cleared for cultivation, subdivision development, highway construction, or other purposes.

TABLE 4.—*Major floods at the U.S. Geological Survey gaging station Napa River near Napa, California, 1900–1967*[1]
[From Limerinos, 1970]

Date of flood	Stage (feet)	Elevation above mean sea level (feet)	Discharge (cubic feet per second)
March 18, 1907	[2]33.8	[2]58.5	[2]23,800
February 27, 1940	32.8	57.5	22,500
February 6, 1942	[2]32.8	[2]57.5	[2]22,500
December 31, 1913	[2]31.8	[2]56.5	[2]21,500
February 24, 1902	[2]28.5	[2]53.2	[2]18,000
January 31, 1963	27.5	52.2	16,900
December 22, 1955	[2]27.5	[2]52.2	[2]16,800
January 3, 1916	[2]26.8	[2]51.5	[2]16,200
January 21, 1967	26.5	51.2	15,800
February 12, 1925	[2]26.4	[2]51.1	[2]15,700

[1]No significant floods have occurred since 1967.
[2]Estimated.

The U.S. Army Corps of Engineers (1965b) estimated the damage from flooding on the Napa River for three recent floods (table 5).

Response to the problem of flooding in the Napa Valley is shared, often without formal coordination, by a variety of governmental agencies. ABAG, the Napa County Conservation, Development and Planning Department, and the incorporated cities are involved in general planning for all or part of the Napa Valley. Detailed water-resources planning with emphasis on providing flood protection has been done by the Corps of Engineers, the Soil

[3]Although shown on Geological Survey maps as Trancas Road, and often referred to as Trancas Avenue, the official city name is Trancas Street.

Conservation Service, and the Napa County Flood Control and Water Conservation District. The plans, programs, and functions of these agencies with respect to the flood-prone areas in Napa County and the nature of hydrologic information used at each jurisdictional level for various purposes are described in the following sections.

TABLE 5.—*Estimated loss from three floods on the Napa River*
[From U.S. Army Corps of Engineers, 1965b]

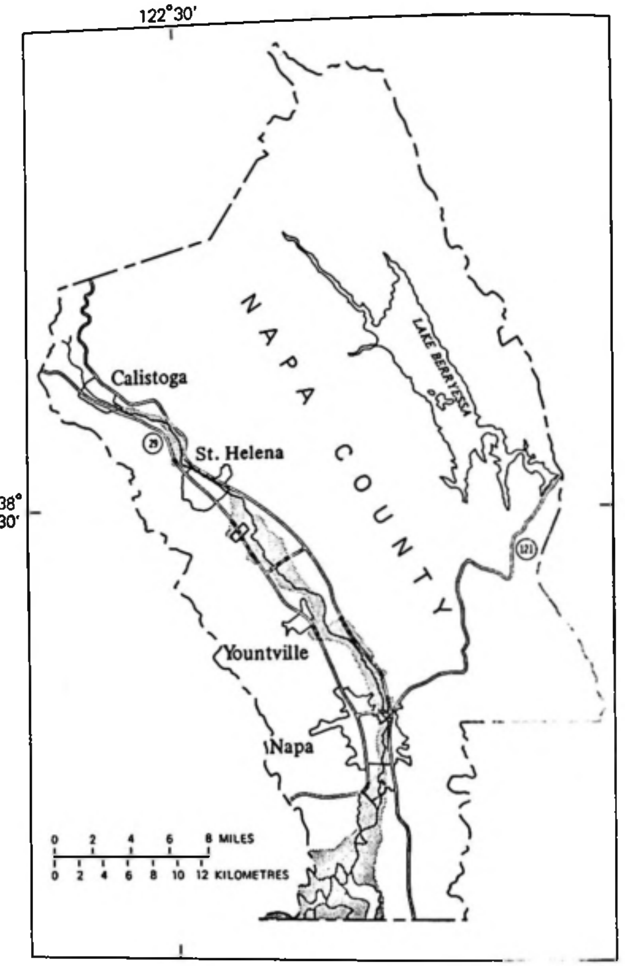
Type of flood loss	Loss, in dollars, at 1963 price levels		
	1955	1958	1963
Commercial	$198,000	$17,000	$237,000
Residential	61,000	23,000	136,000
Agricultural	187,000	288,000	198,000
Roads and bridges	170,000	28,000	80,000
Public utilities	24,000	---	16,000
Federal property	1,000	---	---
Total	$641,000	$356,000	$667,000
Area flooded (in acres)	11,900	9,300	7,200

PLANNING FOR NAPA VALLEY—REGIONAL PERSPECTIVE

Regional planning for the Napa Valley provides policies and procedures related to urban and open-space uses of the valley lands. ABAG's "Regional Plan 1970:1990" discusses the relationship between the physical character of the land and the pattern of urban development in the following terms (1970, p. 4):

> It is on the Bay plain area that circles the Bay, and the larger valleys of Santa Clara, Napa, Sonoma, Petaluma, Livermore, and Ygnacio that the greatest amount of urban development has occurred. These valley lands, separated only by intervening ridges, are being steadily converted from agricultural to urban use to serve the needs of a growing population. Due to the difficulty of building on steeper slopes, those valley lands that remain unurbanized are prime targets for future urban development. The region will have to choose either to retain the prime agricultural lands and unique natural settings that these lands provide, or to allow them to be transformed by urbanization.

The flatlands of the Napa Valley have excellent agricultural soils (Class II and III according to the Soil Conservation Service soil capability rating system) and are prone to flooding; but, because of low slope and stable soils, they are considered reasonably well suited for urban development. Figures 19, 20, and 21 show the relationship of these characteristics for the Napa Valley. The geographic coincidence of these features is typical of the Bay region. It is within this general framework of conflicting potentials and problems that regional plans attempt to provide policy direction.



EXPLANATION

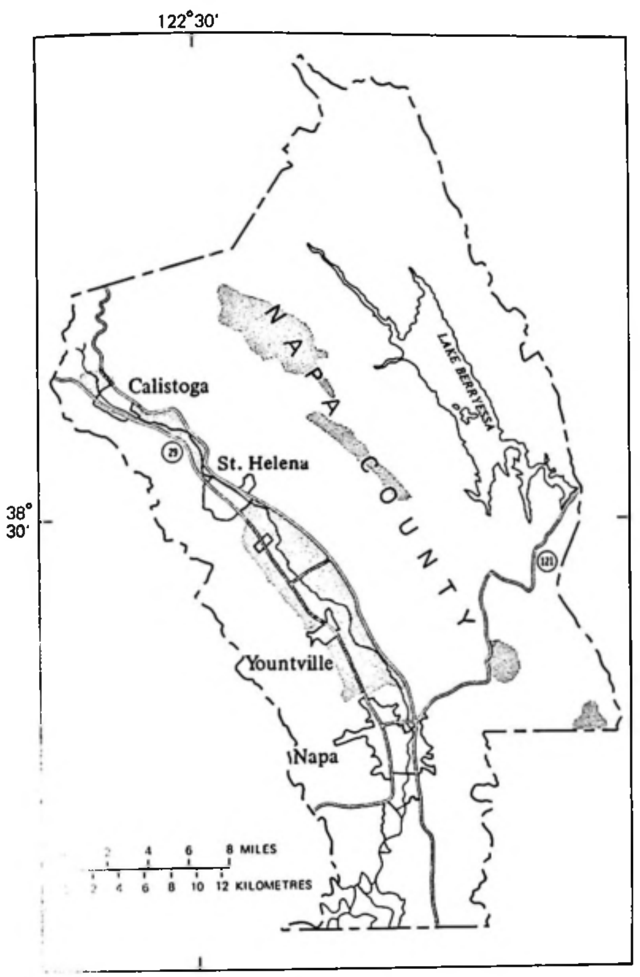
Flood plains

FIGURE 19.—Flood plains in Napa County. (From Napa County Conservation, Development and Planning Department, 1973.)

PLAN FORMULATION

ABAG's regional plan (1970) provides a policy framework for considering the future growth of the Bay region. A major plan policy is that new urban growth should be accommodated in two ways: by the infilling and controlled extension of existing cities and by the development of entirely new, self-contained communities. The land-use implications of this and other ABAG policies adopted by 1970 are presented graphically on the land-use diagram, figure 22, which indicates infilling and extension of existing urban areas in Napa County.

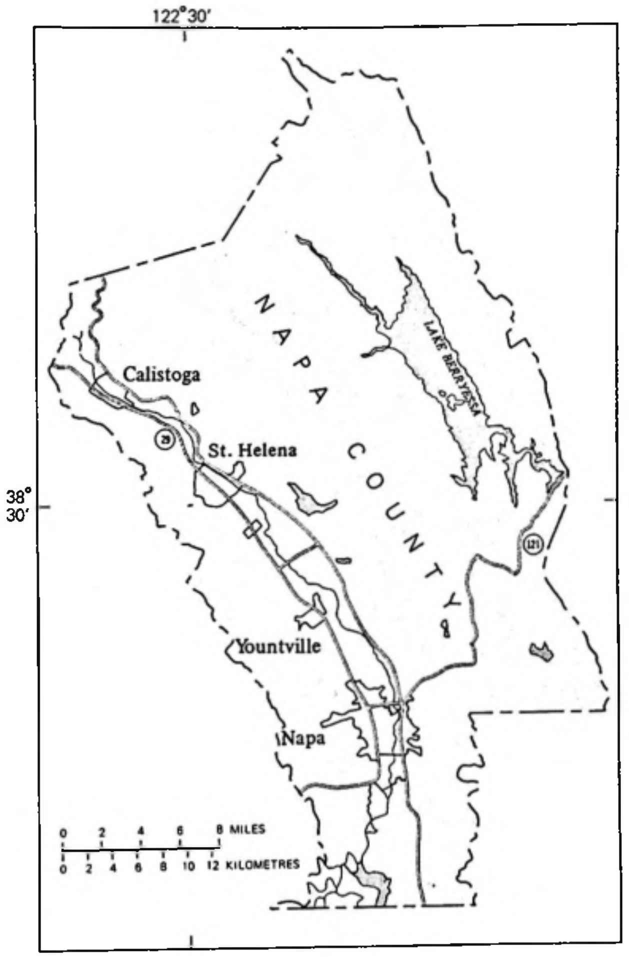
Nonurban lands are classed in the ABAG plan as either permanent open space or lands for controlled development. Lands in the controlled development category are to be held in reserve to provide land for urban development beyond 1990, if needed.



EXPLANATION

Prime agricultural lands

FIGURE 20.—Prime agricultural lands in Napa County. (From Napa County Conservation, Development and Planning Department, 1973.)



EXPLANATION

Hills and mountains

Flat land

Water

FIGURE 21.—Urban areas and areas with slopes less than 15 percent in Napa County. (From Napa County Conservation, Development and Planning Department, 1975.)

According to the plan, major flood plains and drainage channels should be accorded priority for public acquisition to avoid the costs of further flood-control protection and to provide a means of linking the region's open-space areas. Other open-space lands, like those with exceptional qualities for the specialized agriculture of the Napa Valley, are to be preserved by regulation. The plan diagram thus shows the area north of the city of Napa as permanent open space, primarily on the basis of agricultural value of the land. The open-space strip along Napa River in the city of Napa provides flood protection and links open-space areas above and below the city.

Thus, the regional plan policies recognize and address, in general terms, the flooding problem of the Napa Valley and the conflict arising from the high potential of the land for both urban and agricultural uses. The ABAG plan clarifies the potentials and conflicts on a regional level and provides a conceptual framework to guide local land-use planning and decisionmaking. Detailed data were not needed for formulating the plan. The Geological Survey regional map of flood-prone areas (Limerinos, Lee, and Lugo, 1973), for example, can be used effectively for planning at this degree of generality.

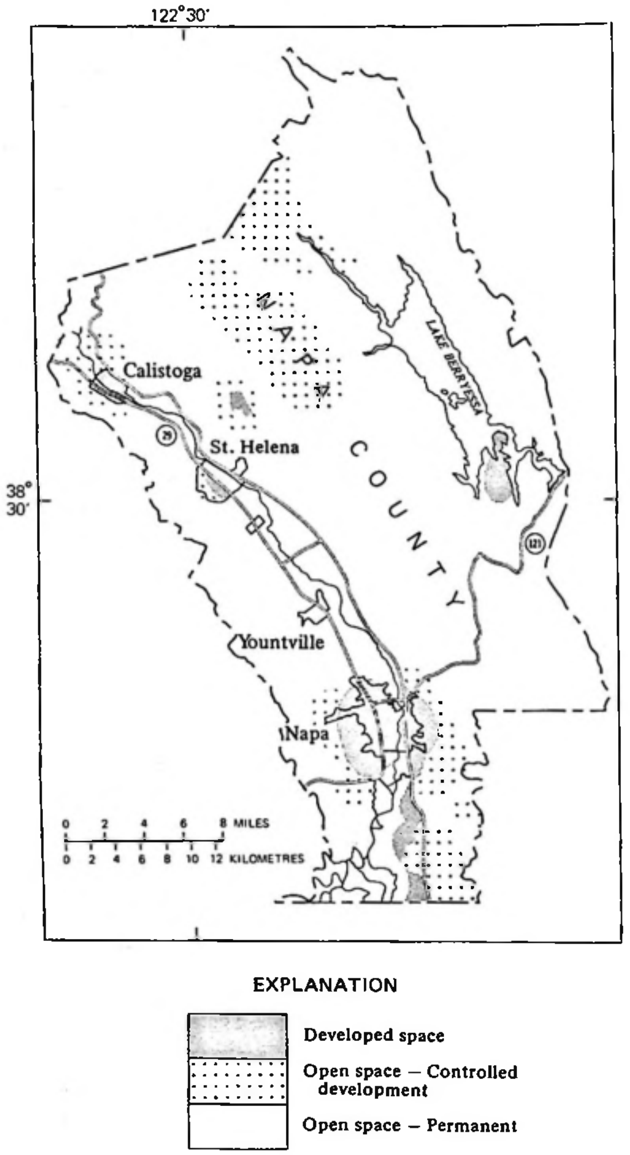


FIGURE 22.—Association of Bay Area Governments regional plan for Napa County. (From Association of Bay Area Governments, 1970.)

The open-space policies of the ABAG regional plan are amplified in the "Regional Open Space Plan—Phase II" (Association of Bay Area Governments, 1972). Six functional categories of open space were defined as shown in table 6. Lands designated permanent open space and controlled development in the Regional Plan were then assigned to the appropriate categories.

Map overlays were prepared showing lands in each open-space category to allow visual identification of lands serving multiple open-space purposes. Priority is given to these lands in the open-space preservation program. Flood plains were included in the public safety category (table 6). Significant parts of the Napa Valley fall into all six categories, and these areas are consequently given high priority for open-space preservation. Table 7 shows the acreages in Napa County recommended for open space, categorized according to function.

TABLE 6.—*Categories of land serving open-space purposes*
[From Association of Bay Area Governments, 1972, p. 4]

Category	Uses
Open space for managed resource production.	Prime agricultural lands and lands for specialty crops. Lands for grazing. Lands for mineral production. Lands for water supply. Water areas for fish and marine life production.
Open space for preservation of natural and human resources.	Lands, tidelands, marsh, and water areas for fish and wildlife refuge. Notable geological features. Historical and cultural sites and places. Areas to provide visual amenity.
Open space for health, welfare, and well-being.	Land to protect the quality of water resources, including ground water. Land for disposal of sewage, garbage, etc. Open areas to improve airshed quality.
Open space for public safety.	Flood control reservoirs, flood plains, drainage channels, and areas below dams. Unstable soil and fault areas. Airport flight path zones. Critical fire zones.
Open space for outdoor recreation.	Lands for developed recreation uses. Lands for water-oriented recreation. Lands for natural environmental experience. Lands for scenic and recreational travel.
Open space for shaping urban growth.	Lands to preserve community identity. Lands to prevent inefficient urbanization.

TABLE 7.—*Recommended acreage for each open-space category in Napa County.*
[From Association of Bay Area Governments, 1972, p. 6]

Open-space category	Acres
Total acres serving at least one purpose	399,850
Managed resource production	294,931
Preservation of natural and human resources	177,855
Health, welfare, and well-being	270,519
Public safety	31,585
Outdoor recreation	188,417
Shaping urban growth	161,813

The plan illustrates how information concerning areas subject to flooding can be combined with other data to arrive at a system of priorities for open-space preservation based on numerous factors.

Classifying the 4-million acres (16,200 km²) in the Bay region allocated to open space in the Regional Plan was accomplished with existing and readily available information. The classification can be refined as more detailed information becomes available. Information of a much more detailed nature will be needed to implement the open-space preservation program. Identification of specific land areas (with well-defined boundaries) to be preserved for open space is required. The plan, however, presents a broadly conceived target for preserving regionally significant open-space areas. Information developed and presented at a scale of 1:125,000, such as the regional flood-prone area maps (Limerinos, Lee, and Lugo, 1973), is usually adequate for this purpose.

PLAN IMPLEMENTATION

As a voluntary association, ABAG has very limited powers to implement its plans. Successful implementation really depends on the actions of Federal, State, and local governmental agencies. ABAG's implementing program, therefore, emphasizes measures to encourage other governmental units to act. ABAG proposes the following five actions to implement the "Regional Open Space Plan—Phase II" (Association of Bay Area Governments, 1972, p. 7).

1.—presenting the two five-year "exemplar" programs as developed;
2.—reviewing grant applications from jurisdictions within the region;
3.—encouraging the preparation of individual open space elements consistent with the Regional Open Space Plan—Phase II;
4.—developing a regional Open Space Preservation Information System (OSPIS);
5.—participating in a program of coordination and legislative advocacy for open space purposes.

The two exemplar programs—a minimal preservation program and an augmented preservation program—are proposed as alternative 5-year programs. Under the minimal program, 18,954 acres (76.7 km²) in Napa Valley (presumably prime agricultural land) would be preserved by local zoning, and development rights to 4,154 acres (16.8 km²) of the Napa River flood plain would be acquired for $7,504,000 (1972 estimates). Under the augmented program, the State would acquire development rights to an additional 10,954 acres (44.3 km²) of Napa River marshlands for an estimated $1,664,000 (Association of Bay Area Governments, 1972, p. 9).

The ABAG minimal program indicates that financial responsibility for acquiring development rights to the Napa River flood plain belongs to the region. However, ABAG has neither the authority nor the funds to acquire land or development rights to land. It may influence decisions through review of grant applications of local governments and special districts for State and Federal funds available for the purchase of open space.

Through the A–95 review process, ABAG may also review development projects involving Federal funds for conformity with its open-space plan. The agency reviews Federally required environmental impact statements. There is no requirement for ABAG review of environmental impact reports mandated for public and private projects by State law. However, most EIRs are voluntarily submitted to ABAG for review.

To assist in the review function, ABAG's recent report "Areas of Critical Environmental Concern" (Association of Bay Area Governments, 1975) sets forth policies concerning and criteria for identifying areas of regionally significant environmental concern which "because of intrinsic qualities demand special consideration in the comprehensive planning process" (p. 1). The report extends the earlier work on the "Regional Open Space Plan—Phase II" (Association of Bay Area Governments, 1972) by exploring "in much greater detail those land areas that merit protection because of intrinsic environmental characteristics" (unpaged).

With respect to stream flooding, the report sets forth the following regional policy (p. 43):

> Protect floodplains of streams that flow through more than one jurisdiction from development that will alter floodplain extent or that will be significantly damaged by flooding.

Lands within the 100-year floodplain are subject to the policy. The following statement is made concerning compatible uses:

> Within floodplains, uses should be limited to those types of activities which will be minimally damaged by flooding, such as certain types of agricultural uses, low intensity recreational uses and parking.

The map "Flood-Prone Areas in the San Francisco Bay Region, California" (Limerinos, Lee, and Lugo, 1973) is cited as a reference for identifying 100-year flood plains. It is emphasized, however, that the maps are not a part of the plan; they are listed to help identify locations where the policies might apply.

PLANNING FOR FLOOD-PRONE AREAS— NAPA COUNTY

The Napa River, its environs, problems, and potentials, dominates planning in Napa County. Almost all of the county's population lives in the river valley, and prospects for substantial development in other areas of the county are currently remote because of steep slopes, inaccessibility, and distance from major metropolitan centers. A possible exception to this general observation is the potential for additional recreational development in the Lake Berryessa area in northeastern Napa County.

Within the last few years, advocates of limited growth, preservation of environmental quality, and conservation have achieved a majority on the County Board of Supervisors. Recent elections in the city of Napa, including a 1973 plebiscite favoring a limited growth concept, indicate a similar trend. The new priorities of the residents of the county were revealed by the response to a survey on growth policies. The survey questionnaire was included with a summary of the county general plan sent to all registered voters in February 1974. The document outlined the impacts associated with three possible population levels (growth options) for the year 2000 (Napa County Conservation, Development and Planning Department, 1974a):

(Current population 87,000)	
Low growth	115,000
Medium growth	150,000
High growth	200,000

Over 76 percent of the respondents favored the low-growth alternative and associated policies to limit growth. As a result, new general plans are being developed for both the county and the city, reflecting the public consensus on growth limitation.

PLAN FORMULATION

The Napa County Board of Supervisors recently adopted the following new set of land-use planning goals (Napa County Conservation, Development and Planning Department, 1975):

Goal 1 To plan for agriculture and related activities as the primary land uses in Napa County and concentrate urban uses in the County's existing cities and urban areas.

Goal 2 To develop and implement a set of planning policies which combine to define a population size, rate of population growth and the geographic distribution of that population in such a manner that the desired quality of life is achieved.

Goal 3 To determine what the land is best suited for; to match man's activities to the land's natural suitability; to take advantage of natural capabilities and minimize conflict with the natural environment.

Goal 4 To work with cities, other governmental units, citizens, and the private sector to plan for services, facilities and accommodations, including housing, transportation, economic development, parks and recreation, open space, and other total County needs.

These goals, developed through extensive public participation, are a logical extension of work done on the Napa County Open Space and Conservation Plan and a subarea plan for the Napa Valley. The goals guided the preparation of a new land-use element and provide a framework for future revisions or additions to the County General Plan.

The Napa County land-use element, adopted in September 1975 by the Board of Supervisors, designates lands for urban growth sufficient to accommodate a population of 115,000 by the year 2000. The element explicitly recognizes constraints to urban development including potential flooding. Flood plains are designated as "limited development areas" to be retained in large parcel sizes primarily for agricultural use (Napa County Conservation, Development and Planning Department, 1975, p. 16).

The Napa Valley Area Plan, a subarea plan adopted by the Board of Supervisors in 1975, sets forth more specific goals and policies covering the use of flood plains. The goals are (Napa County Conservation, Development and Planning Department, 1974b, p. 22–23):

Restrict and regulate urban development in areas of flood risk.

Protect the vegetation and animal habitats of the waterways and flood plains as well as their hydraulic carrying capacity from encroachment of urban development.

Protect existing areas of urban development from flooding.

The related policies are:

Seasonal flooding from streams, deposits of rock and sediment and bank undercutting make some areas difficult to develop. Occasional high water levels in the lakes and reservoirs flood adjacent areas for short durations. Encourage development and implementation of flood plain management programs that protect homes and property, as well as stream side vegetation, and control obstruction of natural waterways.

Maintain watercourses and related vegetation as components of an open space system. Develop pedestrian and riding trails if compatible with riparian (stream side) vegetation and wildlife habitat. Develop public access at frequent intervals.

Maintain watercourses and vegetation within rural areas as components of an open space system and develop public access or roadside rests at cross roads where compatible with surrounding land uses.

The land-use implications of these and other plan policies are shown in the plan diagram (fig. 23).

The county-wide Conservation and Open Space Element, approved by the Board of Supervisors in June 1973, contains the same goals and policies for land use in flood plains as the adopted Napa Valley Area Plan, with the following additions (Napa County Conservation, Development and Planning Department, 1973, p. 22):

Investigate the feasibility of obtaining data to establish a floodway and restrictive zone outside the floodway for all unincorporated areas subject to flooding, based on a 100 year storm. Identification of flood prone areas will be accomplished by the Napa County Flood Control and Water Conservation District.

Adopt flood plain zoning in all applicable areas, and investigate the compatibility of zoning areas adjacent to flood plains for recreational uses. Flood plains along streams which feed Lake Berryessa, the Napa River, and the Suisun Marsh are zoned for agricultural uses in the majority.

Encourage provision for flood insurance. The Napa County Flood Control and Water Conservation District and the Napa County Board of Supervisors have obtained Federal Government approval of Napa County for flood insurance and have agreed, in return, to enact local land use and control measures for areas having special flooding problems. The controls are to be consistent with Federal criteria.

Establishing flood-plain boundaries can be quite general at this phase of planning. However, applying the policies, through either regulation or project review, ordinarily requires data which are both specific and accurate. The Geological Survey flood-prone area quadrangle maps of the Napa Valley (Cuttings Wharf, Napa, Rutherford, St. Helena, and Yountville, scale 1:24,000) showing the areal extent of the 100-year flood (fig. 28 and table 10) can be used in framing general plan policies (U.S. Geological Survey, 1971).

The success of these county planning efforts depends in large measure on the continued economic viability of grape cultivation in the Napa Valley. In recent years, public decisions to limit population growth, preserve agriculture, and limit flood-plain development have been consistent with private land-use decisions based on land-use economics.

PLAN IMPLEMENTATION

The county of Napa has the same powers to implement plans—zoning ordinance, subdivision regulations, building codes, project review, for example—as a city. However, the county's authority extends only to the unincorporated areas. Most of Napa County's unincorporated area is undeveloped except for agriculture, small towns, or other low-intensity uses. Thus the county is developing and applying policies in essentially nonurban areas.

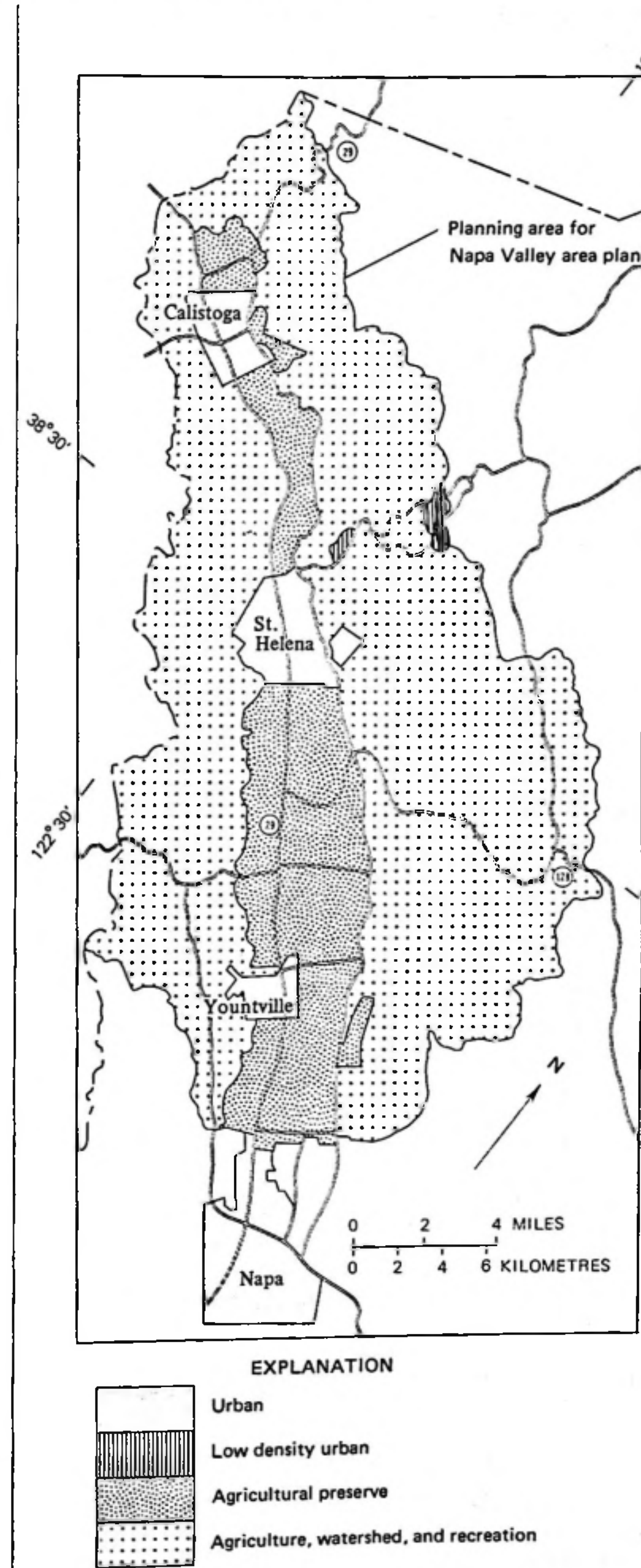


FIGURE 23.—Napa Valley Area Plan. (From Napa County Conservation, Development and Planning Department, 1974b.)

Napa County's implementation program has six main aspects: flood-plain zoning, establishment of agricultural preserves, regulation of watercourse obstruction and riparian cover, watershed protection, flood insurance, and project review procedures.

Flood-plain zoning.—In 1967, the Board of Supervisors adopted a very limited flood-plain zoning ordinance to meet the requirements of the original Cobey-Alquist Flood Plain Management Act (later amended, California Water Code, 1976). The ordinance prevents encroachment in the designated floodway for which a flood-control project is proposed or anticipated. The ordinance provides for three zoning districts to be applied to flood-prone areas to regulate uses according to the severity of flood hazard (Napa County Board of Supervisors, 1967): FP-1 applies to the stream channel and portions of the flood plain required to carry the floodflow. Permitted structures and uses include parks, farming, grazing, utility pipelines, and boating facilities, and campgrounds from May to November. FP-2 applies to areas flooded by overflow and backwater relatively free of current. Uses normally permitted in the zoning districts with which the FP-2 district is combined are allowed as long as the ground-floor level of structures is above the flood-profile level. FP-3 applies to properties in a flood zone which are protected by flood-control works. All uses permitted in the zoning districts with which the FP-3 district is combined are allowed with no additional restrictions.

To date (1976) only the FP-1 zoning has been applied. The area now covered by this zoning includes the unincorporated areas along Napa River from Trancas Road south to Edgerly Island. In general, the district conforms to the proposed right-of-way for a Corps of Engineers flood-control project. The ordinance as it is now applied regulates only a small portion of the county's flood-prone lands. The currently zoned districts are designated on a map on file with the Napa County Flood Control and Water Conservation District.

The county has adequate information provided by a flood-insurance study and the Geological Survey study by Limerinos (1970) to apply flood-plain zoning to the entire 100-year flood plain of the Napa River and its major tributaries. The flood-insurance study delineates the 100-year flood plain at a scale of 1:12,000 and includes flood profiles which permit estimation of depth of flooding at different points in the flood plain. This is important when considering various flood-loss prevention measures such as floodproofing requirements. The study by Limerinos (1970, scale 1:24,000) shows the areas flooded in 1940 and 1955, provides information concerning the flood profiles of the 1907, 1940, and 1955 floods, and gives a flood-frequency curve. This information is especially useful in applying differential restrictions to different areas of the flood plain based on the probability of a flood of a given frequency occurring in a given year.

Agricultural preserves.—The county has three types of agricultural preserves. The Agricultural Preserve District (AP) is intended to apply to fertile valley and foothill areas in which agriculture is and should continue to be the predominant use. It requires a minimum lot size of 20 acres (0.08 km^2), permits extensive agriculture and processing in addition to grazing and cultivation, and has been applied primarily to the Napa Valley (Napa County Board of Supervisors, 1968).

The Agricultural Preserve Interim District (API) is intended to preserve agricultural uses until an area is ready for urbanization. It requires a minimum lot size of 20 acres (0.08 km^2), and it is applied primarily in hillside areas (Napa County Board of Supervisors, 1969).

The Agricultural Preserve Extensive District (AP-E) is intended to apply primarily to grazing land with mostly non-prime soils. It requires a minimum lot size of 100 acres (0.40 km^2) and mimimum zoning district size of 320 acres (1.3 km^2). All lands in AP-E districts are under Williamson Act contracts (Napa County Board of Supervisors, 1969).[4]

North of the city of Napa, most of the valley has been zoned Agricultural Preserve (AP) since 1968. This zoning establishes agriculture as the primary use of the valley area including the flood plain. The AP zone was challenged in the courts by the Napa Valley United Farmers, but it was upheld by the Superior Court of the county of Napa, in a decision on February 17, 1971, as a proper exercise of police powers which benefited not only the public at large, but also those whose land was regulated (Overview Corporation, 1973, p. 20).

Because much of the 100-year flood plain along the Napa River is in agricultural use, better information concerning the impact of flooding on different crops and types of farming and grazing would be useful to the county in determining appropriate flood-plain uses. More needs to be known about the effects of different land-management practices on the amount of loss sustained from a given flood. However, it is generally accepted that many agricultural uses are appropriate for flood-prone areas. Unless the cost of losses from flooding in agricultural areas is excessive, or erosion and sedimentation problems are particularly severe, a single zone that covers the 100-year flood plain and permits only agricultural and other open-space uses may be sufficient for nonurban areas. It is desirable to prohibit construction of farm buildings, grading, or other farm-related activities within the floodway.

[4]The Williamson Act, also called the California Land Conservation Act of 1965 (California Government Code, 1976c), permits landowners to enter into contracts with cities and counties in which the landowners agree to maintain land in agricultural use in exchange for tax assessment based on the economic return from agricultural use of the land.

Watercourse obstruction/riparian cover ordinance.—In February 1974 the Napa County Board of Supervisors adopted Ordinance 447 (Napa County Board of Supervisors, 1974a). The purposes of the ordinance include reducing flood losses caused by channel obstructions or water-borne debris, preserving wildlife habitats, and preventing stream-bank erosion. A permit is required from the Planning Commission before anyone may deposit or remove any material within a watercourse; excavate within a watercourse; construct, alter, or remove any structure within, upon, or across a watercourse; plant or remove any vegetation within a watercourse; or alter any embankment within a watercourse. Except for the Napa River, the permit requirement applies to the stream channel and a 50-ft (15-m) wide strip measured landward from the top of each bank of the stream. For the Napa River the requirement applies to a 100-ft (30-m) strip along either side of the river from the county's southern boundary to St. Helena. The ordinance does not apply in the incorporated areas. A map showing streams covered by the ordinance is on file in the Flood Control and Water Conservation District office.

This ordinance was intended to alleviate some of the potential problems associated with agricultural use of the flood plain. It provides the means whereby the county may prohibit cultivation of farmland immediately adjacent to the banks of the river. Cultivation to the river's edge removes riparian cover which may cause increases in bank erosion and collapse, significant increases in river sedimentation, and loss of wildlife habitats. In addition, the ordinance regulates the deposition of debris in the river channel. Debris carried by flood waters is a major source of damage to agricultural lands.

Watershed protection.—The extent of flooding may be affected by man's use of watershed lands. Thus, control of use of the watershed lands can significantly affect potential damage from flooding. Most unincorporated areas in Napa County which are not in the Agricultural Preserve District are in the Agriculture, Watershed, and Recreation (AWR) District pending completion of the county general plan revision. Minimum lot size in this district is 40 acres (0.16 km^2). The adopted Napa Valley Area Plan (Napa County Conservation, Development and Planning Department, 1974b) recommends retention of the minimum parcel size of 40 acres (0.16 km^2) in the AWR zone, with the possibility of reducing the minimum lot size to as small as 5 acres (0.02 km^2) under certain conditions. Residential development could be permitted on parcels less than 40 acres (0.16 km^2) after review based on consideration of water and sanitation conditions, slope, access, fire hazards, environmental impacts, and growth policies and related factors (Napa County Board of Supervisors, 1974b).

In the Napa Valley watershed, five public reservoirs, with a combined firm annual yield of 23,000 acre-ft (28 hm^3) of water, provide most of the county's water supply. The assurance of both quality and quantity of this local water supply is critical for both domestic and agricultural users. Stringent watershed protection measures are easily justified in this case to protect public health, safety, and welfare. Proper watershed management is also important in controlling erosion and sedimentation.

Flood insurance.—On December 10, 1970, the Napa County Board of Supervisors adopted Resolution 70-155 (Napa County Board of Supervisors, 1970) requesting that flood insurance be made available to property owners in the county. The resolution stated that the county would meet the following land-use and control standards established by the Federal Insurance Administration (Federal Insurance Administration, 1971):

(1) Require building permits for all proposed construction or other improvements in the community;

(2) Review all building permit applications for new construction or substantial improvements to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a location that has a flood hazard, any proposed new construction or substantial improvement (including prefabricated and mobile homes) must (i) be designed (or modified) and anchored to prevent flotation, collapse, or lateral movement of the stucture, (ii) use construction materials and utility equipment that are resistant to flood damage, and (iii) use construction methods and practices that will minimize flood damage;

(3) Review subdivision proposals and other proposed new developments to assure that (i) all such proposals are consistent with the need to minimize flood damage, (ii) all public utilities and facilities, such as sewer, gas, electrical, and water systems are located, elevated, and constructed to minimize or eliminate flood damage, and (iii) adequate drainage is provided so as to reduce exposure to flood hazards; and

(4) Require new or replacement water supply systems and/or sanitary sewage systems to be designed to minimize or eliminate infiltration of flood waters into the system and discharges from the systems into flood waters, and require onsite waste disposal systems to be located so as to avoid impairment of them or contamination from them during flooding.

The standards for land-use and control measures become more stringent as more detailed information is provided to the community by the Federal Insurance Administration.

As presently enacted and administered, the National Flood Insurance Program provides Napa County with an incentive to prevent inappropriate use of flood-prone areas while providing insurance protection to owners of flood-prone property which is already developed.

Project review.—Information defining the extent of areas subject to flooding at a given frequency is very important in the process of reviewing development proposals for conformity with adopted plans and regulations and for assessing environmental impact. Any proposal for development within the 100-year flood plain, as delineated on the 1:12,000 scale maps used in administering the flood insurance program, is reviewed for the county by the Napa County Flood Control and Water Conservation District. Detailed delineation of areas likely to be flooded, and information on the nature and frequency of flooding, water elevation, and speed of movement, are all important in the review of specific projects. Requirements which can legally be imposed for floodproofing or raising the floor level, for example, require site-specific information concerning the nature and depth of potential floodwaters. The Geological Survey's maps of flood-prone areas do not serve this purpose. However, if the District did not have the more detailed information provided by the flood insurance study, the Geological Survey maps could serve as the basis for determining which developments have potential flooding problems and should be reviewed by the District. Where subdivision is proposed, detailed information can be required from the subdivider under the California State Subdivision Map Act of 1974 (California Government Code, 1976e) to assure that a project is properly designed with respect to the flood risk.

The Napa County Flood Control and Water Conservation District makes its recommendations to the County Planning Commission and the Board of Supervisors based on the maps and flood profiles available from the flood insurance study. The District recommendations are also sent directly to the applicant for a subdivision or building permit. The District usually indicates the elevation of the 100-year flood and recommends that the ground floor of a structure be 1 ft (0.3 m) above that elevation. The recommendations are advisory; the authority to impose requirements rests with the Board of Supervisors.

THE NAPA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

The Napa County Flood Control and Water Conservation District is a countywide district with the County Board of Supervisors acting as the governing board. In addition to responsibilities for flood control, the District acts as the contracting agency for Napa County for water from the State Water Project, plans for and develops adequate water supply from all sources within the county, is involved with assuring adequate water quality, supervises water and sanitation systems of other special districts which are governed by the Board of Supervisors, and provides technical assistance to the Board with respect to flood insurance.

The District participates in the review of development proposals and the development of land-use plans and regulations in flood-prone areas by providing technical assistance and advice. Its role in land-use decisions, however, is strictly advisory. The District has direct permit power over activities in and along the stream channels it operates and maintains. The District, in cooperation with the County Planning Commission, exercises considerable control over construction or other development in and along all major streams in the county in connection with the Water Course Obstruction and Riparian Cover Ordinance (Napa County Board of Supervisors, 1974a).

PLANNING FOR FLOOD-PRONE AREAS—CITY OF NAPA

The city of Napa is located in the Napa Valley upstream from the marshlands and diked lands which extend to San Pablo Bay (fig. 18). Nearly half the county's population lives in the city of Napa, the governmental and urban center of the county. Much of the flood damage in Napa County occurs in the city of Napa. A major portion of the downtown area is within the 100-year flood plain of the Napa River and is also subject to flooding from Napa Creek which flows through downtown Napa into Napa River (fig. 8).

PLAN FORMULATION

The city, like the county, has experienced a political changeover as a result of changes in public attitudes towards growth and environmental quality. The 1968 General Plan for the city (Napa City Planning Department, 1968) is now considered inadequate to address today's concerns, and the city council is presently (1976) reviewing a revised general plan (fig. 24, Napa City Planning Department, 1975). The revised plan stresses the establishment of a "residential urban limit line" to confine future development to locations close to the presently developed parts of the city. This is a reduction from 55 mi² (142 km²) to 18 mi² (47 km²) in the area considered appropriate for residential development.

Planning for the flood-prone areas within the city of Napa is, and has been, based on the assumption that flood-control works will be constructed which will eliminate, to a large degree, the flood hazard within the city. The new plan calls for continuation of a redevelopment project featuring a major government, business, and retail center within the 100-year flood plain. The plan diagram shows a linear park along the river, but the 100-year flood plain extends well beyond the limits of this park. Major areas of proposed high density residential use (10 to [illegible] units per acre) and major commercial and industrial areas are shown within the 100-year flood plain along the river. The intensity of land use increases from the foothills to the river with the most intense development along the river in the flood plain or along Highway 29—the major north-south route through the city.

PLAN IMPLEMENTATION

The city of Napa has adopted flood-plain zoning virtually identical to that of the county and has applied it to the areas needed to construct the proposed Corps of Engineers Napa River flood control project. The city's efforts to plan, and implement plans, for the flood-prone areas are embedded in multijurisdictional programs for redevelopment and flood control. An effort has been made to coordinate the provision of flood control with redevelopment, transportation, and open-space planning in the city. The main features of this effort are discussed below.

A solution to Napa's flooding problems is the flood control project proposed by the U.S. Army Corps of Engineers (1973f, p. 60, 61):

> Authorized by the 1965 Flood Control Act, the project provides for channel enlargement and realinement, construction of levees, floodwalls, and public boat-launching facilities in an 11-mile reach downstream from Trancas Road in the city of Napa to Edgerly Island.
>
> The Federal first cost of the project is estimated at $25,300,000 (July 1972). The estimated cost to local interests is $9,680,000.

The planning process involved in developing the flood-control project is somewhat unusual. The Corps of Engineers originally proposed to construct a straight-walled channel through the center of the city of Napa to carry flood waters. Local authorities viewed the Corps project as an opportunity to revitalize the water-front area of the city and create an esthetically pleasing and useful linear parkway through the city. They requested that the Corps of Engineers alter its plans to provide a somewhat wider but less austere channel. The reach of the project through central Napa was redesigned with a series of steps rather than a straight wall. A landscaped linear park with walkways, bike trails, picnic areas, and benches along either side of the channel became an integral part of the project design.

The flood-control project became part of a broader effort to redevelop downtown Napa, upgrade transportation, and provide recreational facilities. This integrated approach involved coordination of planning and implementation of activities of the Napa County Flood Control and Water Conservation District, city of Napa, Corps of Engineers, Department of Housing and Urban Development, Soil Conservation Service, California Department of Water Resources, and California State Division of Highways (now Department of Transportation). Figure 25 shows the location of the project and related elements. A major part of the cooperative project was to be Federally sponsored urban renewal for the deteriorating downtown area of Napa, much of which is flood prone. Open space in addition to the linear park would be provided at selected locations along both sides of the channel in both the rural and urban areas of the project.

As originally conceived, the responsibility and financing for the project involved five agencies.

The Corps of Engineers was to design and construct the flood channel improvements including boat launching facilities at selected locations and the landscaping required for the linear park. Recreational facilities in the linear park were to be financed jointly with Federal and local funds.

The California Department of Water Resources was authorized by State legislation to finance the

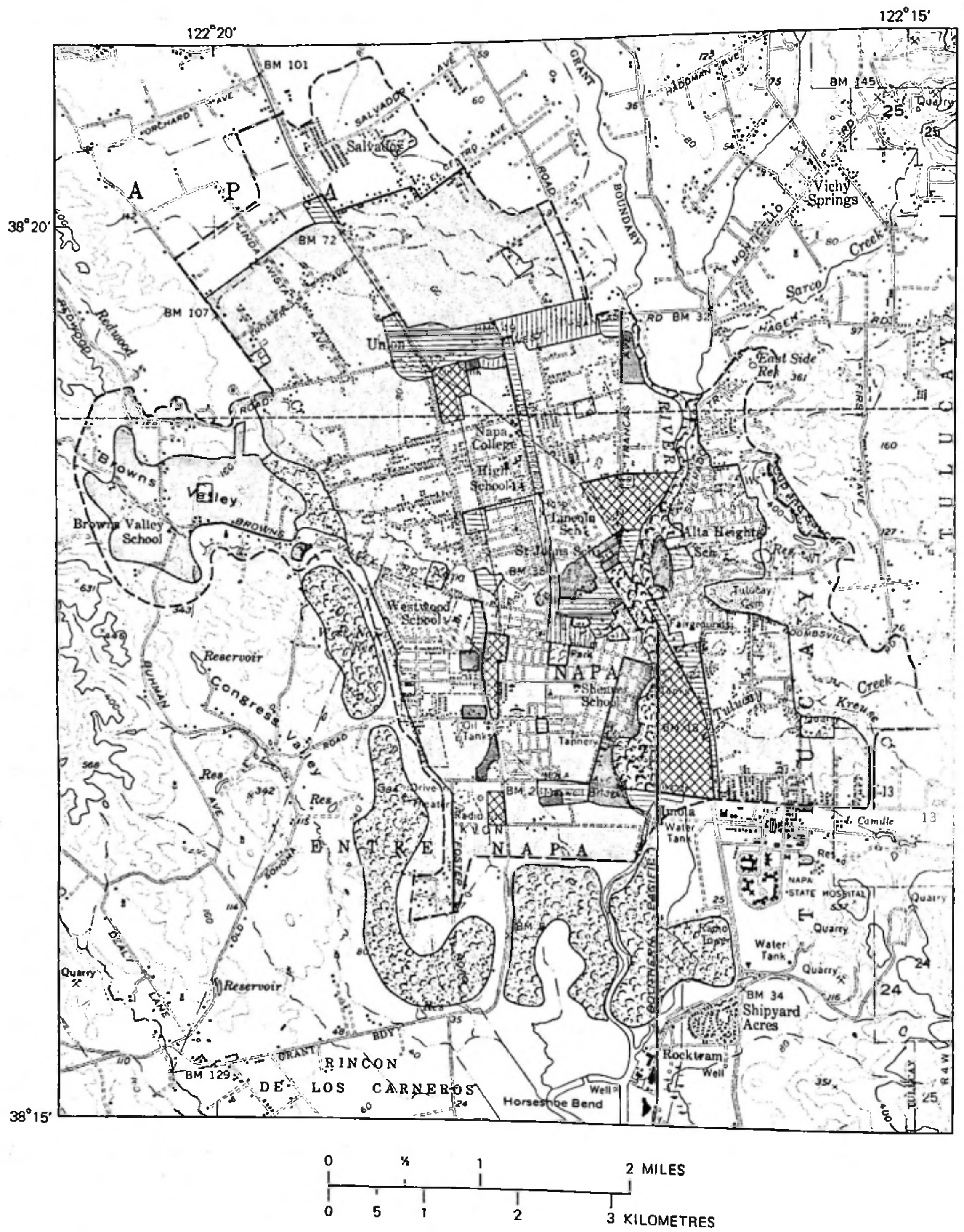
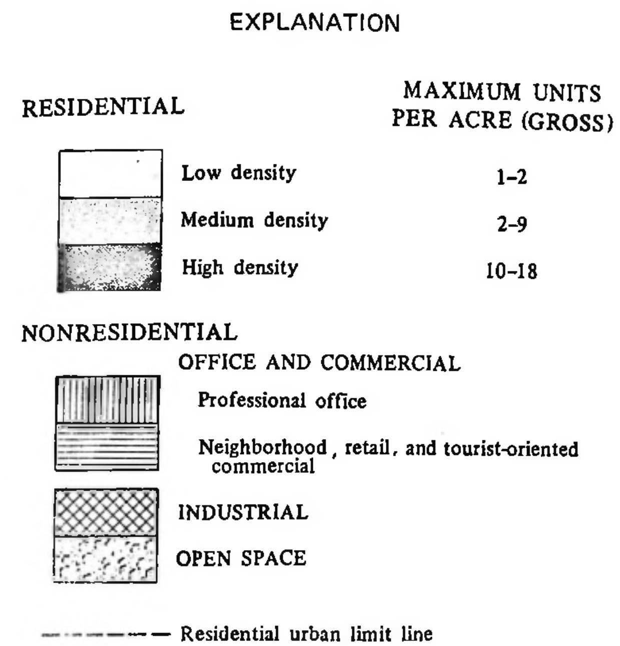


FIGURE 24.—Proposed land-use plan for city of Napa. (Generalized from Napa City Planning Department, 1975.)



local share of Federal flood-control projects. The local share for purchasing the right-of-way required for the multipurpose project is larger than for the single-purpose flood-control project. Thus, it became important that the State agree to assume the additional costs.

The Department of Housing and Urban Development, under Title I of the Housing Act of 1949, as amended (U.S. Congress, 1949), would provide funds for acquiring and clearing the land in central Napa for a redevelopment project to include a county government complex, a commercial area, and open space along the river. Planning of the various aspects of the project was to be partly financed with a HUD planning grant.

The State Division of Highways (now Department of Transportation) was to construct a north-south freeway through Napa which would cross the river twice. Both the county and city of Napa at that time favored the freeway as an important stimulant to economic and population growth of the county.

The Soil Conservation Service, under U.S. Public Law 83-566 (U.S. Congress, 1954), was to construct a reservoir on Redwood Creek west of the city of Napa to control flood waters on Napa Creek.

The project, as originally conceived, required an unusual degree of cooperation among government agencies to coordinate and resolve a number of interrelated problems. The Napa River Technical Committee, composed of city and county elected representatives and staff members, functioned as the main coordinating group for the various aspects of the plan. The plan was viewed as a model for intergovernmental relations and comprehensive planning. However, 10 years after the original concept was put together, problems of coordination and changing Federal and State regulations and priorities and new local preferences are strongly affecting the prospects for successfully completing the project.

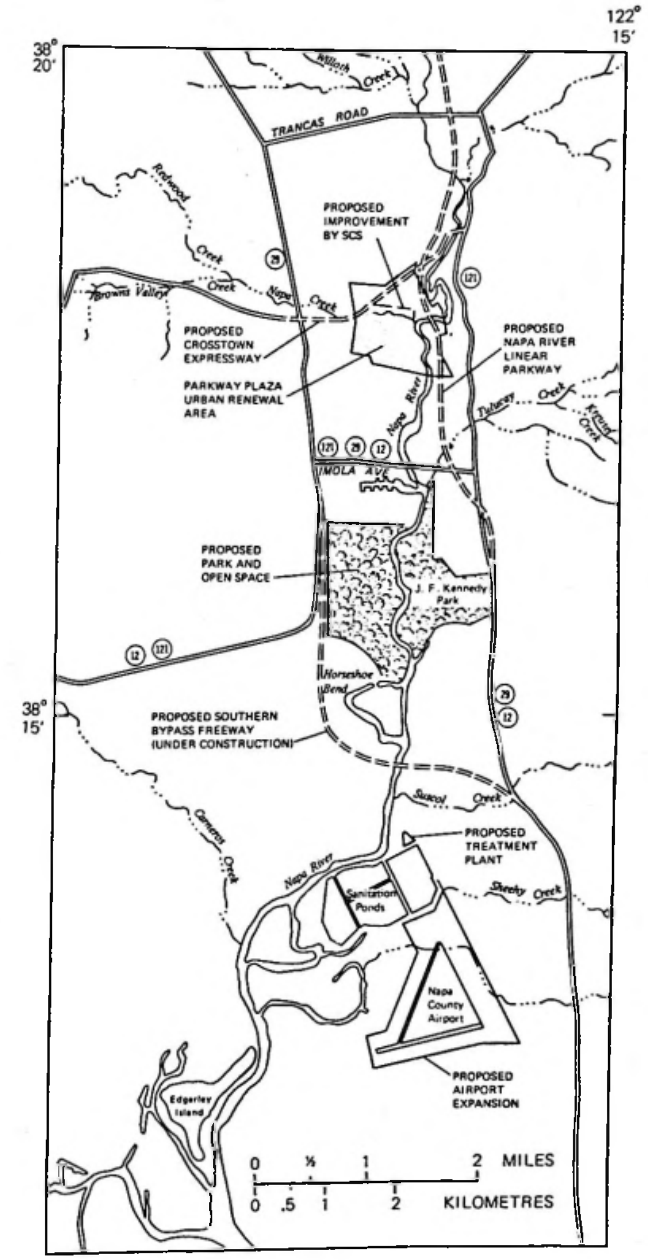


FIGURE 25.—U.S. Army Corps of Engineers flood-control project and related projects in the city of Napa. (From U.S. Army Corps of Engineers, 1975c.)

Flood control.—Construction of the Corps of Engineers flood-control project, authorized by Congress in 1965, has not yet begun. A major problem has been raising the local share of project funds used to acquire land for the right-of-way and to relocate roads, bridges, and utilities. The California Resources Agency originally agreed to provide only partial reimbursement of the local share of the project cost. The city of Napa was unable to finance the remainder. In addition, Federal requirements regarding environmental impact statements have delayed the start of the construction.

The problems over State funding seem to be resolved. The State has now agreed to provide 75 percent of the cost of land acquisition and 90 percent of the cost of necessary road, bridge, and utility relocations. No State funding is presently provided for recreation or fish and wildlife enhancement.

The Corps released a draft environmental impact statement in April 1975 (U.S. Army Corps of Engineers, 1975c). The major concern regarding the project was voiced by the California Department of Fish and Game. The Department objected to the plan to deposit spoils from the river dredging on former marshland south of the city which was diked many years ago for agricultural use. If the dikes were removed and the land subjected to tidal action, marshes could be restored on the land. The Corps is working out a mitigation plan with the Department of Fish and Game involving the provision of public marshland elsewhere to compensate for the loss of potential marshland resulting from the project.

The Corps of Engineers recently released a General Design Memorandum which updates the 1965 flood-control study—particularly with respect to the cost/benefit analysis. Changes in the concept and design of the project, as well as sharp changes in growth assumptions over the last decade, made such an update necessary. The estimate of future average annual damages from flooding in the 1965 report (U.S. Army Corps of Engineers, 1965b) was based on population projections which foresaw almost an eight-fold increase in population from 1960 to 2060 (table 8). According to the report, the population increase would be accompanied by a large shift from agricultural to residential and commercial land uses (table 8). Changes of lesser magnitude would occur in other land uses which account for approximately 40 percent of the basin area.

These projections are inconsistent with the desires of the valley residents as expressed in plans and regulations adopted or under consideration. The future average annual damages from flooding would presumably be lower on the basis of more realistic land use and population projections. However, the progress of redevelopment in downtown Napa has undoubtedly increased potential future flood losses. The General Design Memorandum indicates a current benefit/cost ratio of 1.1 to 1.0 as opposed to a ratio of 1.6 to 1.0 in the 1965 study. As the ratio is still favorable, although considerably reduced, construction of the project may begin in 1978, if environmental and funding problems are finally resolved.

The Soil Conservation Service, in cooperation with the Napa County Flood Control and Water Conservation District and the Napa County Resource Conservation District, intends to construct a flood-control project in the city of Napa to reduce damages from Napa Creek flooding. Under Public Law 83-566 (U.S. Congress, 1954), the Soil Conservation Service is authorized to construct and maintain multipurpose flood-control projects in small watersheds. In 1962 the Congress authorized a project to construct a dam and reservoir on Redwood Creek west of the city of Napa. Redwood Creek joins Browns Valley Creek just west of the city to form Napa Creek which then follows a course through the middle of the city, and joins Napa River near the downtown area of Napa (fig. 25). To prevent flooding in downtown Napa requires coordination between the creek and river projects. The Soil Conservation Service has officially dropped consideration of the dam project because of rising costs and negative environmental impact associated with constructing the dam and relocating a county highway through very steep terrain.

As an alternative, the SCS is studying the feasibility of constructing an underground channel to divert excess flow from the stream channel through the downtown area into the river. The Corps of Engineers may become directly involved with structural improvements on Napa Creek if the river project is constructed and there is no alternate solution to control Napa Creek flooding.

TABLE 8.—*Population and land-use projections for the Napa basin, 1960–2060*

[Data from U.S. Army Corps of Engineers, 1965b. Figures include city of Vallejo and the part of Solano County between the Napa County line and San Pablo Bay]

Year	Population	Land use			
		Agricultural		Residential and commercial	
		Area (acres)	Percentage of basin area	Area (acres)	Percentage of basin area
1960	132,000	141,780	52.0	21,250	7.8
1980	260,000	127,000	46.5	38,000	13.9
2000	390,000	113,000	41.4	53,000	19.4
2020	630,000	94,500	34.1	76,000	27.8
2040	840,000	74,000	27.1	92,000	33.7
2060	1,020,000	59,000	21.6	107,000	39.4

Transportation.—Changing priorities have influenced the evolution of the freeway project. At the request of local authorities, the State Department of Transportation has removed the proposed north-south freeway through Napa Valley from its plans. With local goals for economic and population growth revised downward, the freeway was rejected by local authorities because it was considered to be a possible stimulant to growth.

Redevelopment.—In 1969 the Napa Community Redevelopment Agency submitted an Urban Redevelopment Plan for the Parkway Plaza Redevelopment Project (Napa Community Redevelopment Agency, 1969). The boundaries and land-use plan of the project are shown in figure 26. More than one-half the area is subject to the 100-year flood. In 1970 funding was received from HUD to acquire and clear parcels in the first nine-block section of the project (fig. 26). This phase of the project has been completed. New buildings housing government offices and commercial enterprises have been constructed. New street paving, lighting, brick sidewalks, benches, planters, and trees have been added to the area. Figure 27 shows part of the area developed in the first phase during and after construction.

In 1972, the Urban Redevelopment Plan was amended (Napa Community Redevelopment Agency, 1973) to add 11 blocks to the project, and funds from HUD are now available to acquire three of these blocks. The 11 blocks (fig. 26) are also within the 100-year flood plain. The city of Napa received an open-space grant from HUD covering 50 percent of the cost of acquiring the first parcel for the linear park.

The redevelopment area remains subject to frequent flooding, and the potential cost of damages from a flood on either Napa Creek or Napa River has increased because of new construction in the redevelopment area. In addition, under the National Flood Insurance Program, the city faces a dilemma. Under present regulations the city will be required to enter the program or face the loss of all Federal funds. However, even if the city enters the program, HUD would be violating its own guidelines if it continued to fund the redevelopment project in the flood-prone area. The city seems to have little choice but to push for expeditious construction of flood-control structures on both Napa River and Napa Creek. If the downtown area is protected by flood-control works from the 100-year flood, HUD could, in accordance with its guidelines, continue to approve the use of Federal funds for the redevelopment project.

SIGNIFICANCE OF THE NAPA VALLEY EXPERIENCE

Flooding problems in the Napa Valley have been addressed in the plans and actions of numerous agencies with varying degrees of success. Many factors influence the success or failure of any particular action, or group of actions, in reducing flood losses. Experience in Napa Valley seems to indicate the following factors are particularly important.

Compatibility of flood-loss reduction with general community objectives.—A significant factor in reducing flood losses seems to be the compatibility of flood-loss reduction actions and techniques with general community objectives. The fact that the flood-prone areas of Napa Valley have other characteristics important for open space led ABAG to place high priority on preserving the flood-prone areas in open-space uses. Similarly, Napa County's goal to limit population growth and maintain agricultural uses has led to land-use plans and regulations consistent with reducing flood losses. In the city of Napa, however, the desire to redevelop flood-prone portions of the downtown area for intensive and economically valuable uses is inconsistent with reducing flood-loss potential. Even with a completed flood-control project, the redevelopment area would be subject to increased losses from floods exceeding the 100-year flood.

Compatibility of flood-loss reduction efforts with land-use economics.—Actions to reduce losses will be more widely accepted if economically viable land uses are permitted. A major reason for the success of Agricultural Preserve Zoning in Napa Valley has been the high market value of land for agricultural uses in relation to its value for urban uses.

Compatibility of flood-loss reduction efforts with objectives of other agencies.—The chances of reducing flood losses are enhanced if actions by a city of county are consistent with programs of other agencies with jurisdiction or responsibility in the drainage basin. For example, the plans and actions of Napa County, with respect to the unincorporated flood-prone areas, are reinforced by ABAG's policies and the requirements of the National Flood Insurance Program and the Disaster Relief Act. In turn, the potential for effective flood-loss reduction through proposed Corps of Engineers and Soil Conservation Service projects is enhanced by the planning and regulatory efforts of Napa County.

Intensity of existing development.—It is usually easier and less costly to maintain low flood-loss potential in undeveloped areas than to reduce loss potential in already urbanized areas. Napa County,

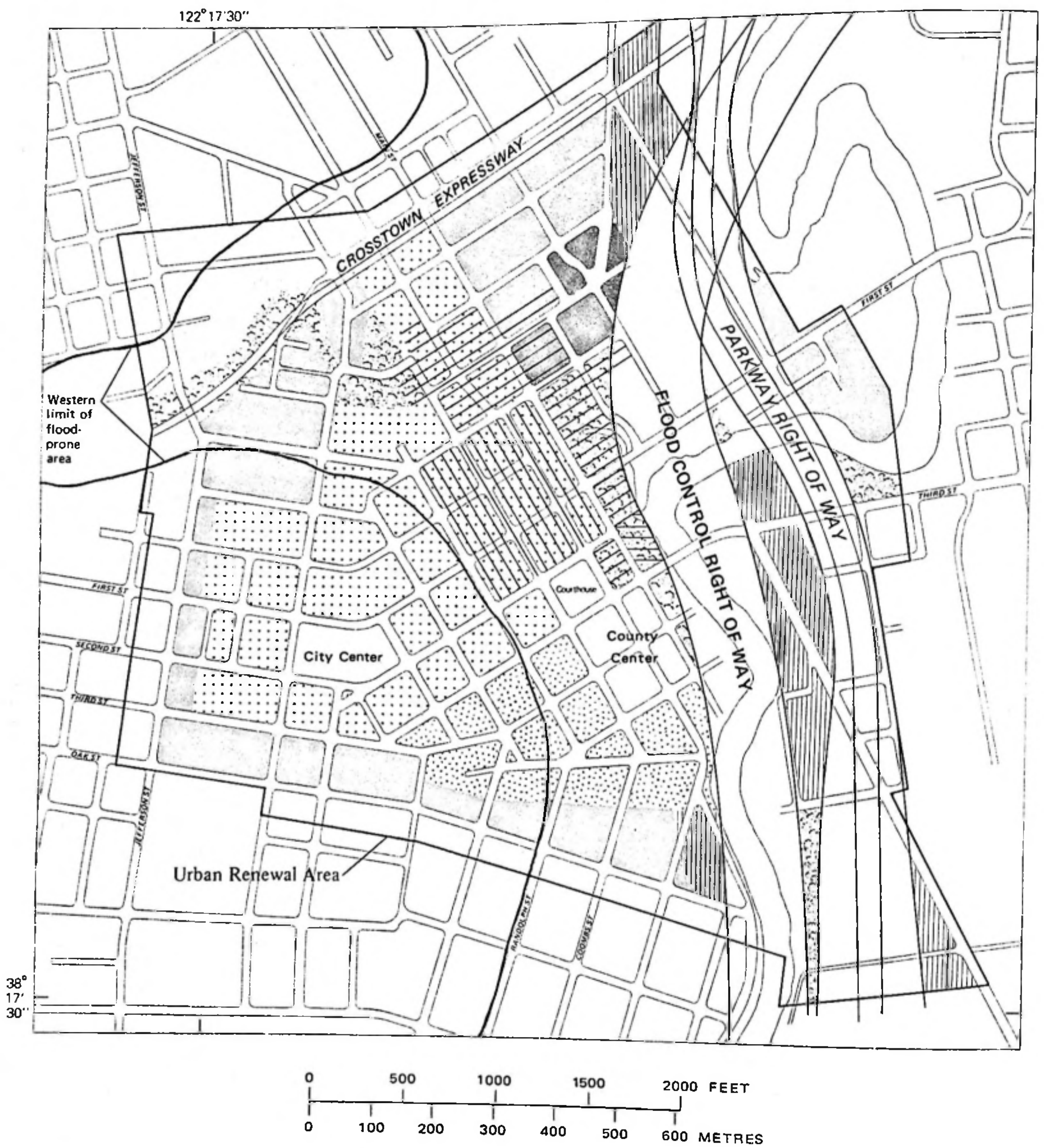
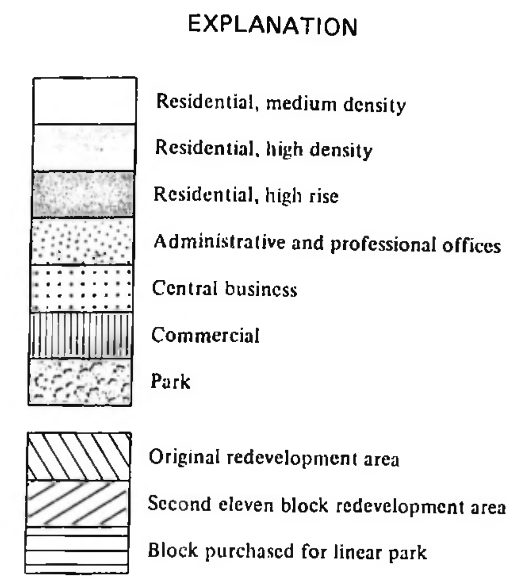


FIGURE 26.—Parkway Plaza Redevelopment Project in the city of Napa. (From Napa Community Redevelopment Agency, 1969.)



with largely undeveloped flood-prone areas, can prevent future increases in flood losses by regulating land uses in the flood plain; but, the city of Napa would have to convert existing developed areas to less intensive uses or provide flood-control works to significantly reduce flood-loss potential. These measures are costly and involve coordinating the efforts of various Federal, State, and local agencies.

Location of drainage basin with respect to jurisdictional boundaries.—Effective local efforts to reduce flood losses are easier to carry out if the major portions of a stream and its drainage area are located within a single jurisdiction. The Napa River and its drainage basin, with the exception of a small area of tidal flats along San Pablo Bay, are within Napa County. Thus the county can integrate drainage basin and flood-plain plans and regulations in a comprehensive program to reduce flood losses. If the drainage basin covered a multicounty area, the plans and programs of multiple local jurisdictions would have to be coordinated to achieve a comprehensive approach to flood-loss reduction.

Coordination of planning and implementation.—When flood-control works are planned to reduce flood-loss potential, related land-use decisions and public and private facility construction and(or) relocation should be appropriately phased to avert undue increases in flood-loss potential. Planning related to the Corps of Engineers project in the City of Napa dealt with flood control, urban redevelopment, highway construction, and relocation in a coordinated manner. Not completing the flood-control project prior to redevelopment has resulted in an increase (perhaps short term) in flood-loss potential in the city of Napa.

Availability of hydrologic information.—The specificity of plans and regulations dealing with flood-prone areas depends on the type, accuracy, and detail of information available to delineate the flood hazard. With more detailed data, particularly precise mapping of the floodway, the Napa County Flood Control and Water Conservation District could prepare and seek adoption of flood-plain zoning regulations covering the entire flood plain with restrictions reflecting varying degrees of flood risk within the flood plain. Such flood-plain zoning regulations could be overlain on, or combined with, the use and site restrictions of the basic or underlying zoning district.

The Napa Valley case study presents flood-loss reduction efforts in the context of land-use planning and decisionmaking proceeding from generalized regional policies and plans through county planning and regulation to detailed local planning and application of both structural and regulatory measures to reduce flood losses. In such a process the information requirements are graduated with the most specific information on flooding needed by cities with developed flood plains.

Although flood-prone areas and responses to flooding problems are highly variable, the Napa Valley study provides a reasonably typical view of the interplay among agencies, plans, and actions to reduce flood losses within the context of land-use planning. Many of the factors affecting success or failure of flood-loss reduction efforts in the Napa Valley can be important in other flood-prone areas.

SUMMARY

Flood plains historically have provided attractive and accessible sites for urban development. Use by man has been extensive, and growing urban pressures are causing still more intensive development. But use of the flood plain has exacted a price in losses from flooding or in costs of suitable protection.

Flood-loss reduction traditionally has been approached through installing structures such as dams, dikes, levees, channel improvements, and seawalls. These have provided only partial reduction of risk from flooding; flood losses have continued to rise as a result of continuing encroachment on flood plains.

In recent years Federal and State policies on flood-loss reduction have shifted from reliance on structural works to a balance between structural and nonstructural measures. For example, regulation of flood-plain development is a requirement for communities to qualify for subsidized flood insurance

FIGURE 27.—Part of Parkway Plaza during and after redevelopment.

and, under certain circumstances, flood-disaster relief. Information on the extent of the flood hazard, land use, and development is essential to develop a sound and effective flood-loss reduction program.

Flood-plain information reports, flood maps, and other information prepared by Federal, State, and local agencies provide pertinent information on flooding needed to evaluate flood risk. Flood-prone areas in the San Francisco Bay region are delineated on a series of topographic quadrangle maps (scale 1: 24,000) prepared by the Geological Survey. Regional maps of flood-prone areas (scale 1:125,000) provide an overview of the extent of potential flooding.

Many methods and devices are available to reduce flood losses. These include the protection, removal, discouragement, and regulation of certain types of development on flood plains. Programs for flood-loss reduction are most effective when based on adopted comprehensive plans that are firmly implemented. Effective flood-loss reduction programs achieve a balance between the use of flood plains and the hydraulic requirements of floods.

Protection of existing development often is necessary for economic or humanitarian reasons and can be provided by flood-control works, flood warning, evacuation, and floodproofing. Damage and hazards from flooding may be avoided through removal of existing structures or conversion of structures to less vulnerable uses. Structures within floodways may increase flood stage and velocity. Methods for removal or conversion include public acquisition, urban redevelopment, public-nuisance abatement, non-conforming-use provisions in zoning ordinances, conversion of use, and reconstruction of existing public facilities.

Discouraging development on flood plains may be achieved through public-information programs, warning signs, recordation of hazard, tax-assessment practices, financing policies, and public-utility extension policies. Flood insurance requirements and costs may constitute an additional deterrent.

The regulation of uses on flood plains provides a direct means for reducing flood losses through prohibition or regulation of uses vulnerable to flood damage. In most states the primary responsibility for planning, adopting, and enforcing land-use regulations rests with local government. Flood-plain development can be controlled through establishment of zoning districts and incorporation of flood-plain regulations in zoning, subdivision, sanitary, and building ordinances.

As the extent of damage from floods is a direct consequence of the use of the land, efforts to reduce losses from flooding logically occur within the context of land-use planning. Land-use planning considers the future development of an area in terms of the economic, political, social, and physical determinants of growth and change. The planning process involves identifying problems, defining goals and objectives, collecting and interpreting data, formulating plans, evaluating impacts, and adopting and implementing plans. Public participation is necessary throughout the planning process.

Many governmental agencies and programs influence planning for flood-loss reduction. Federal programs for flood insurance, disaster assistance, comprehensive planning grants, and community development grants all have impact on planning for flood-prone areas—primarily a local responsibility. A major portion of the cost of flood-control works is also borne by the Federal Government. State legislation defines the powers of local governments to plan, regulate, acquire land or development rights, or otherwise act to reduce flood losses. In addition, regional agencies may have specific authority derived from Federal or State legislation to make or influence decisions related to flood-loss reduction.

Improved coordination of governmental actions to reduce flood losses is needed. Flood-loss reduction efforts should be integrated into land-use planning for entire drainage basins. There is need also for coordination in providing data, notably among Federal agencies such as the Geological Survey, Corps of Engineers, and Soil Conservation Service, and the county flood control and water conservation districts, to assure comprehensive coverage and availability of pertinent data.

Study of the response to flooding problems in the Napa Valley outlines the complex intergovernmental responsibilities involved in developing plans and programs to reduce flood losses. In addition to the need for coordinating the actions of numerous agencies, the Napa Valley experience indicates that factors important in flood-damage reduction include compatibility of flood-damage reduction with general community objectives, land-use economics, and the objectives of other agencies; the intensity of existing development; the availability of hydrologic information; and the coordination of planning and implementation.

The Napa Valley study illustrates a graduated approach to flood-damage reduction proceeding from generalized regional policies and plans through county planning and regulation to detailed local planning and application of both structural and regulatory measures to reduce flood losses. In such a process the information requirements are also graduated with the most specific delineation of flood-prone areas needed for urban areas.

Although flood-prone areas and responses to flooding problems are highly variable, the Napa Valley study provides a typical view of interplay among agencies, plans, and actions in attempting to reduce flood losses within the context of land-use planning. Factors affecting the flood-loss reduction efforts in the Napa Valley can be important in other flood-prone areas.

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SOURCES OF FLOOD-PLAIN MAPS AND INFORMATION

Flood-plain inundation maps have been prepared and other flood studies made by the Geological Survey and other Federal, county, local, and private agencies for many areas in the San Francisco Bay region. Information on flooding and flood hazards has been presented in pertinent maps and reports. The principal sources of the maps and flood information are summarized in table 9; the maps and reports available are listed in table 10. Figure 28 shows the quadrangle maps available in the Bay region.

TABLE 9.—*Sources of maps and flood information*

	Types of maps and reports					
	Flood-prone area maps		Flood-hazard maps	Flood-plain information reports	Flood-insurance studies	[illegible]
	Regional	Quadrangle				
U.S. Geological Survey	x	(1)	x			
U.S. Army Corps of Engineers				(2)		
U.S. Soil Conservation Service				(3)		
Federal Insurance Administration, U.S. Department of Housing and Urban Development					x	
County and municipal agencies						(4)

[1]Quadrangle maps available are shown in figure 28.
[2]In flood-plain information, flood, and flood-control project reports.
[3]Generally in watershed work plan or watershed investigation reports.
[4]Generally unpublished.

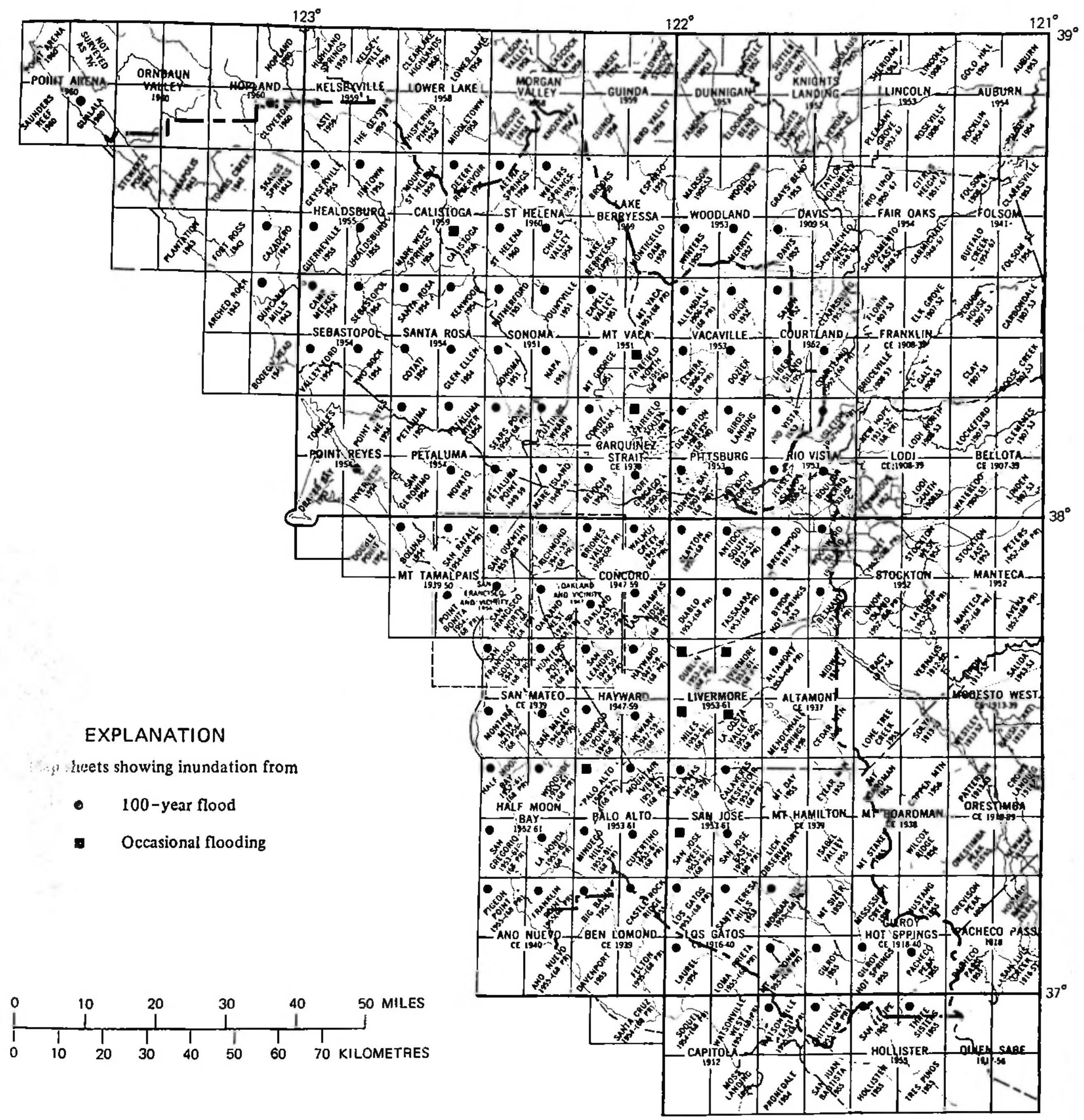

FIGURE 28.—Topographic map sheets and the flood-prone area maps available in the San Francisco Bay region.

TABLE 10.—*Flood-plain maps and information available for areas in the San Francisco Bay region*

A. Flood-prone area maps

Regional maps:

U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA, 94025

1. "Flood prone areas in the San Francisco Bay region, California," by J. T. Limerinos, K. W. Lee, and P. E. Lugo (1973), in three sheets, scale 1:125,000. Map shows areas in the region subject to inundation by the 100-year flood. Coastal areas subject to a potential hazard from high tides are delineated with respect to the 100-year tide. (SFBRS Interpretive Report 4).
2. "Map showing areas of potential inundation by tsunamis in the San Francisco Bay region, California," by J. R. Ritter and W. R. Dupre (1972), in two sheets, scale 1:125,000. Map shows estimated extent of potential inundation from a tsunami wave height of 20 feet at the Golden Gate (recurrence interval, about 200 years). Inundation hazard from tsunamis was not included in the delineation of flood-prone areas shown on the regional map. (SFBRS Basic Data Contribution 52).

Quadrangle maps (fig. 28):

U.S. Geological Survey, California District, Water Resources Division, 855 Oak Grove Avenue, Menlo Park, CA, 94025

1. Maps, on topographic map sheets, scale 1:24,000, showing areas prone to occasional flooding, prepared in 1969:

Calistoga
Dublin
La Costa Valley
Livermore
Niles
Palo Alto
San Jose West

2. Maps, on topographic map sheets, scale 1:24,000, showing areas prone to flooding from the 100-year flood, prepared 1971–75 (location shown in fig. 28):

Aetna Springs
Allendale
Altamont
Antioch North
Antioch South
Asti
Benicia
Bethany
Big Basin
Birds Landing
Bolinas
Bouldin Island
Brentwood
Briones Valley
Byron Hot Springs
Calaveras Reservoir
Camp Meeker
Capell Valley
Castle Rock Ridge
Cazadero
Chiles Valley
Chittenden
Clayton
Cloverdale
Cordelia
Cotati
Courtland
Cupertino
Cuttings Wharf
Davis
Denverton
Detert Reservoir
Diablo
Dixon
Dozier
Duncans Mills
Elmira
Fairfield North
Fairfield South
Franklin Point
Geyserville
Gilroy
Gilroy Hot Springs
Glen Ellen
Gualala
Guerneville
Half Moon Bay
Hayward
Healdsburg
Honker Bay
Hunters Point
Inverness
Isleton
Jersey Island
Jimtown
Kenwood
La Honda
Las Trampas Ridge
Laurel
Liberty Island
Los Gatos
Mare Island
Merritt
Milpitas
Mindego Hill
Montara Mountain
Morgan Hill
Mountain View
Mt. George
Mt. Madonna
Napa
Newark
Novato
Oakland East
Oakland West
Pacheco Peak
Petaluma
Petaluma Point
Petaluma River
Pigeon Point
Point Bonita
Port Chicago
Redwood Point
Richmond
Rio Vista
Rutherford
San Felipe
San Francisco North
San Francisco South
San Gregorio
San Jose East
San Leandro
San Mateo
San Quentin
San Rafael
Santa Rosa
Santa Teresa Hills
Saxon
Sears Point
Sebastopol
Sonoma
St. Helena
Tassajara
Three Sisters
Two Rock
Valley Ford
Walnut Creek
Walter Springs
Watsonville East
Winters
Woodside
Woodward Island
Yountville

These maps and flood-prone area maps available for other areas in California are listed in an "Index of Flood Maps for California Prepared by the U.S. Geological Survey through 1974," compiled by J. R. Crippen (1975) and supplements. The maps are listed alphabetically and by counties, with information on location, map scale, and year mapped. Copies of the index may be obtained from the California District, Water Resources Division, U.S. Geological Survey, 855 Oak Grove Avenue, Menlo Park, Calif. 94025.

B. Flood-hazard maps

U.S. Geological Survey, Denver Federal Center, Lakewood, CO, 80225

1. Hydrologic Investigations Atlas HA-54, "Floods at Fremont, California," by L. E. Young (1962).
2. Hydrologic Investigations Atlas HA-348, "Floods on Napa River at Napa, California," by J. T. Limerinos (1970).

TABLE 10.—*Flood-plain maps and information available for areas in the San Francisco Bay region—Continued*

C. Flood-plain information reports

U.S. Army Engineer District, San Francisco, 211 Main Street, San Francisco, CA, 94105. Copies of reports generally available from the flood control and water conservation districts and collaborating county agencies.

Flood-plain information for:

Rush Creek—Petaluma River to U.S. Highway 101, Marin County (1975).
Alamo and Ulatis Creeks, Vacaville, Solano County (1973).
Green Valley, Dan Wilson and Suisun Creeks, Cordelia, Solano County (1972).
Alamitos Creek, including Guadalupe Creek, Arroyo Calero, and Santa Teresa Creek, Santa Clara County (1973).
Coyote Creek, San Francisco Bay to Anderson Reservoir, Santa Clara County (1970).
Fisher Creek, Santa Clara County (1973).
Guadalupe River, Santa Clara County (1972).
Llagas Creek Unit 1, including Edmundson, Church, San Martin, New, Center, Corralitos, Tennant, Maple, and Foothill Creeks, Santa Clara County (1975).
San Felipe Lake and Pacheco Creek, San Benito County and part of Santa Clara County (1973).
Uvas-Carnadero Creek, Pajaro River to Uvas Reservoir, Santa Clara County (1973).

D. Flood-insurance studies

Communities participating in the National Flood Insurance Program as of October 31, 1975, that have special flood hazard areas identified, and wherein the sale of flood insurance is authorized, include the following:

County and community

Alameda County:
Unincorporated area
Alameda
Berkeley
Emeryville
Fremont
Hayward
Livermore[1]
Newark
Oakland
Piedmont
Pleasanton
San Leandro
Union City

Contra Costa County:
Unincorporated area
Antioch
Brentwood
Clayton
Concord
El Cerrito
Hercules
Lafayette
Martinez
Pinole
Pittsburg
Pleasant Hill
Richmond
San Pablo
Walnut Creek

Marin County:
Unincorporated area
Belvedere
Corte Madera
Fairfax
Larkspur[1]
Mill Valley

Marin County—Continued:
Novato
Ross
San Anselmo
San Rafael
Sausalito
Tiburon

Napa County:
Unincorporated area
Calistoga
Napa
St. Helena
Yountville

San Francisco County:
San Francisco City and County[2]

San Mateo County:
Unincorporated area
Atherton
Belmont
Brisbane
Burlingame
Colma
Daly City
Foster City
Half Moon Bay
Hillsborough
Menlo Park
Millbrae
Pacifica
Portola Valley
Redwood City
San Bruno
San Carlos
San Mateo
South San Francisco
Woodside

Santa Clara County:
Campbell
Cupertino
Gilroy
Los Altos
Los Altos Hills
Los Gatos
Milpitas
Monte Sereno
Morgan Hill
Mountain View
Palo Alto
San Jose
Santa Clara
Saratoga
Sunnyvale

Solano County:
Benicia
Dixon
Fairfield
Rio Vista
Suisun City
Vacaville
Vallejo

Sonoma County:
Unincorporated area
Cloverdale
Cotati
Healdsburg
Petaluma
Rohnert Park
Santa Rosa
Sebastopol
Sonoma

[1]Participating in program, but special flood hazard areas not yet delineated.
[2]Determined to have no special flood-hazard areas.

TABLE 10.—*Flood-plain maps and information available for areas in the San Francisco Bay region—Continued*

E. Other flood-control and watershed projects

U.S. Army Engineer District, San Francisco, Corps of Engineers, 211 Main Street, San Francisco, CA, 94105

Flood control projects:

Name	County	Nature of work	Status
San Lorenzo Creek.	Alameda	Levees and channel improvements.	Completed 1962.
Alhambra Creek	Contra Costa	Channel improvements, diversion.	Not started.
Walnut Creek	do	Channel enlargement and stabilization.	Under construction (1977).
Corte Madera Creek.	Marin	Channel improvements.	Under construction, in court.
Napa River basin.	Napa	Channel enlargement, realinement levees.	Planning completed.
Alameda	Santa Clara	Channel improvements.	Under construction.
Fairfield vicinity streams.	Solano	Channel improvements, diversion.	Planning completed 1973.
Sonoma Creek basin.	Sonoma	Channel improvements.	Planning and EIS completed 1973.
Warm Springs Dam, Lake Sonoma.	do	Dam and lake, channel improvements.	Planning, land acquisition, road relocation in progress.

Small flood-control projects:

Name	County	Nature of work	Status
San Leandro Creek.	Alameda	Channel improvements.	Near completion.
Pinole Creek	Contra Costa	do	Completed 1966.
Rheem Creek	do	do	Completed 1960.
Rodeo Creek	do	do	Completed 1966.
Coyote Creek	Marin	Channel lining.	Completed 1965.
Green Valley Creek.	Solano	Channel enlargement, realinement.	Completed 1962.

Flood control studies:

Name	County	Date authorized
Wildcat and San Pablo Creeks.	Contra Costa	1960
Novato Creek and tributaries.	Marin	1941
Pacific coastal streams.	San Mateo	1965
South San Francisco streams.	San Mateo	1958
Guadalupe River.	Santa Clara	1941
Russian River.	Sonoma	1958

TABLE 10.—*Flood-plain maps and information available for areas in the San Francisco Bay region—Continued*

E. Other flood-control and watershed projects—Continued.

U.S. Soil Conservation Service. Information pertaining to these and other studies in the region may be obtained from offices of the Soil Conservation Service (Concord, Dixon, Half Moon Bay, Livermore, Morgan Hill, Napa, Santa Rosa, Petaluma) or from offices of cooperating soil conservation districts and county flood control and water conservation districts.

Small watershed projects under Public Law 83-566 (U.S. Congress, 1954):

Project	Sponsoring agencies	Purpose	Year authorized	Status
Ulatis Creek			1961	Complete.
Central Sonoma	Sonoma County Water Agency. Santa Rosa Resource Conservation District.	Flood control.	1958	Nearing completion.
Lower Llagas Creek and Upper Llagas Creek.	Santa Clara Valley Water District. South Santa Clara County Water District. Loma Prieta Resource Conservation District.	do	1969	Not yet under construction.
Lower Pine Creek	Contra Costa County Flood Control and Water Conservation District. Contra Costa County Resource Conservation District. East Bay Regional Park District.	Flood control, water storage, recreation.	1970	do
Marsh-Kellogg Creek.	Contra Costa County Flood Control and Water Conservation District. Contra Costa County Resource Conservation District.	Flood control.	1959	Nearing completion.
Napa River	Napa County Flood Control and Water Conservation District. Napa County Resource Conservation District.	do	1962	Stalled.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1977 - 789-025/66

Waananen and others—FLOOD-PRONE AREAS AND LAND-USE PLANNING—Geological Survey Professional Paper 942