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Department of
Water Resources

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California
Flood Management:
An Evaluation of Flood Damage Prevention Programs

Bulletin 199
September 1980

Cover Photographs (left to right)

Upper: *Discovery Park Recreation Area in Sacramento at the confluence of the American and Sacramento rivers.*

Lake Oroville, key water supply feature of the State Water Project, also provides flood storage protection.

Lower: *Fullerton Golf Course, constructed around a creek in Orange County, demonstrates recreational use in a flood-prone area.*

Disaster in Los Angeles County caused by the devastating floods of January 1969.

Curved channel on Tamalpais Creek in Marin County was constructed to preserve the environment in its near-natural state.

Reclaimed salt water marsh along Alameda Creek in Coyote Hills Regional Park, Alameda County.

NOTE:

This is the fourth and last in a series of basic bulletins on major subject areas of California Water Management. Other volumes include:

- Ground Water in California, Bulletin 118 (Sept. 1975)*

- Water Conservation in California, Bulletin 198 (May 1976)

- Delta Water Facilities - Program for: Delta Protection and Water Transfer, Water Conservation, Water Recycling, Surface and Ground Water Storage, Bulletin 76 (July 1978)**

* This has been supplemented by Ground Water Basins in California, Bulletin 118-80 (Jan. 1980).

** Will be supplemented by Bulletin 76-80.

Department of
Water Resources

Bulletin 199

California
Flood Management:
An Evaluation of Flood Damage Prevention Programs

September 1980

Huey D. Johnson
Secretary for Resources

The Resources Agency

Edmund G. Brown Jr.
Governor

State of California

Ronald B. Robie
Director

Department of Water Resources

FORESIGHT IN FLOOD PLAIN MANAGEMENT is shown at Discovery Park in Sacramento, inside the confluence of the Sacramento and American Rivers. The left photo shows the area during flooding on January 14, 1980. The right photo shows the same area, including the implanted picnic benches, none-the-worse-for-wear on June 21, 1980.

Courtesy of Sacramento County Department of Parks and Recreation

FOREWORD

Floods are a fact of life in California. Human culture is part of a system where natural forces rule and our ability to control natural events is limited. Flood damage occurs when people and their activities encroach on a flood plain.

Destruction of property and loss of life from floods is not being prevented despite substantial expenditures for preventative efforts at all levels of government. In many instances, the technical and financial capability to build flood "control" works has been negated by the lack of political will to locate people away from flood plains or to make structures flood-resistant. Thus, in many areas extensive structural works provide considerable protection, but such protection has failed to keep pace with continued development in the flood plains.

Various methods of flood-damage prevention or reduction exist. Some of them have been employed for many years, some have evolved with time, and some are relatively new. The flood management policy of the California Department of Water Resources includes these principles:

- The preferred method of flood damage reduction is to adjust use and occupancy of the flood plain through management or regulation of uses, rather than solely by structural works in the stream.

- Structural flood damage reduction projects should usually be limited to those already developed areas in which flood-proofing or relocation of development is not economically or socially feasible.

- The social values of essentially natural streams will be recognized, and flexibility in degree of protection will be considered where a community so desires since the traditional solution of channelization or elimination of a stream is often seen as a bigger problem by a community.

- The structural integrity of existing flood protection works must be assured through effective maintenance and surveillance programs, accompanied by programs to deal with residual risks.

- Flood management efforts will be carried out in a way that incorporates ground water recharge, wetland, fish and wildlife protection and enhancement, and recreational development as integral parts of the flood management program. This includes recognition of the values of wetland and riparian habitat and native vegetation and maximum efforts to preserve these values and resources.

To achieve flood damage prevention or reduction, the Department recommends action that can be taken under present authority, some changes that could be made by new laws, and some actions by others.

The report focuses on flooding from inland streams and does not include flooding from ocean tsunamis or tidal waves and seiches on lakes and landlocked seas. The flood hazard from such other events has been and will continue to be severe and costly and must be taken into account but are of an entirely different nature. Information on these hazards may be obtained from the U. S. Army Corps of Engineers, the U. S. Geological Survey, the State Department of Boating and Waterways, the California Coastal Commission, and the Federal Emergency Management Agency.

This report provides the first summary and analysis of flood management projects and programs in the history of the State. In addition to its recommendations, we hope it will provide a useful reference document to the people of California.

Ronald B. Robie

Ronald B. Robie, Director
Department of Water Resources
Resources Agency
State of California

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The California Water Commission serves as a policy advisory body to the Director of Water Resources on all California water resources matters. The nine-member citizen Commission provides a water resources forum for the people of the State, acts as a liaison between the legislative and executive branches of State Government and coordinates Federal, State, and local water resources efforts.

The Reclamation Board is the State agency primarily responsible for flood damage reduction along the Sacramento and San Joaquin Rivers. The Board, created by the Legislature in 1911, has statutory flood management obligations and also provides an open forum where all interests may express their views on flood protection issues within the Central Valley.

CONVERSION FACTORS

Metric to Customary System of Measurement

Quantity	Metric Unit	Multiply by	To get customary equivalent
Length	millimetres (mm)	0.03937	inches (in)
	centimetres (cm) for snow depth	0.3937	inches (in)
	metres (m)	3.2808	feet (ft)
	kilometres (km)	0.62139	miles (m)
Area	square millimetres (mm^2)	0.00155	square inches (in^2)
	square metres (m^2)	10.764	square feet (ft^2)
	hectares (ha)	2.4710	acres (ac)
	square kilometres (km^2)	0.3861	square miles (mi^2)
Volume	litres (l)	0.26417	gallons (gal)
	megalitres	0.26417	million gallons (10^6 gal)
	cubic metres (m^3)	35.315	cubic feet (ft^3)
	cubic metres (m^3)	1.308	cubic yards (yd^3)
	cubic metres (m^3)	0.0008107	acre-feet (ac-ft)
	cubic dekametres (dam^3)	0.8107	acre-feet (ac-ft)
	cubic hectometres (hm^3)	0.8107	thousands of acre-feet
	cubic kilometres (km^3)	0.8107	millions of acre-feet
Flow	cubic metres per second (m^3/s)	35.315	cubic feet per second (ft^3/s)
	litres per minute (l/min)	0.26417	gallons per minute (gal/min)
	litres per day (l/day)	0.26417	gallons per day)(gal/day)
	megalitres per day (Ml/day)	0.26417	million gallons per day (mgd)
	cubic metres per day (m^3/day)	0.0008107	acre-feet per day
Mass	kilograms (kg)	2.2046	pounds (lb)
	tonne (t)	1.1023	tons (short, 2,000 lb)
Velocity	metres per second (m/s)	3.2808	feet per second (ft/s)
Power	kilowatts (kW)	1.3405	horsepower (hp)
Pressure	kilopascals (kPa)	0.145054	pounds per square inch (psi)
	kilopascals (kPa)	0.33456	feet head of water
Specific capacity	litres per minute per metre drawdown	0.08052	gallons per minute per foot drawdown
Concentration	milligrams per litre (mg/l)	1.0	parts per million
Electrical conductivity	microsiemens per centimetre (μS/cm)	1.0	micromho per centimetre
Temperature	degrees Celsius (°C)	(1.8 × °C) + 32	degree Fahrenheit (°F)

Photographs

CHAPTER I. SUMMARY

Lands alongside rivers have typically attracted occupancy by people because water was readily available and provided a mode of transportation, the lands were fertile and flat and easy to farm and build on, and the surroundings were aesthetically pleasing. In time, water transportation was largely supplanted by roads and railroads, which often were also built on those low-lying river flatlands. The result has been the large scale placement of people, their structures, and agriculture in the path of floods.

The settlement of flood-prone areas generally has proceeded on the premise that occasional floods are inevitable. Even when a major flood occurred with significant loss of life and property, communities have usually rebuilt at the same location, presumably willing to take the obvious risk of subsequent floods. Federal disaster assistance has frequently subsidized rebuilding in these hazard areas.

Protection of developed communities has required the construction of dams, levees, channel modifications, and bypasses. Today in California there are many adequately protected areas, some underprotected or unprotected highly developed areas, and a very few undeveloped or lightly developed major flood plains.

Despite general knowledge of the threat of damage by recurring floods, development continues on California's flood plains. While millions of dollars of potential damage is prevented each year, the level of actual and potential damage is still uncomfortably high. The general taxpayer, through disaster relief and after-the-fact structural works, subsidizes the unwise use of flood plains.

A recent study by the Federal Emergency Management Agency concludes that flood damages will continue to rise unless relocation effects are greatly increased. Continued emphasis on the use of structural methods to prevent flood damage is not enough. Appropriate management of the flood plain has the potential for cost effectiveness as well as protection of environmental and social values. If flood damage is to be reduced, flood hazard must be avoided through emphasis on nonstructural flood management measures, relocation must occur in some flood-prone areas, new protective facilities must be constructed for a few large, already developed areas that are flood prone, and existing protective works must be maintained.

Recognizing that future floods are inevitable but that flood damage is avoidable, the Department of Water Resources has surveyed and evaluated flood damage prevention programs throughout the State. It has defined the extent of known flood-hazard areas and protected areas by mapping them for the entire State. These areas are shown on 14 maps contained in this report. Structural flood protection projects and nonstructural flood management plans in each hydrologic area of the State are also described in tabular form.

The flood information and data were collected from Federal, State, and local agencies. Emphasis was placed on developing an inventory to determine the variety of flood problems characteristic of the various regions in California and the methods being employed to prevent or reduce flood damage. Flood damage prevention programs, at all levels of government, are described and evaluated as to their effectiveness. Also, the types of storms which cause floods, types of flooding, and methods available to mitigate flood damage are explained in this report for general background. The obvious need is for local government to improve its processes for approval of building construction and subdivision by integrating flood hazard identification, avoidance, and mitigation in the early planning phases. While zoning and regulation are important tools, they must be complemented by the requirement for local decision makers to seek the advice of local flood control districts regarding flood hazard and to make written findings on the hazard and disposition of advice or recommendations.

A program for future flood damage prevention and flood plain and wetland preservation in California has been developed from the study of on-going programs and their effectiveness. It does not include flood damage prevention programs along California's shoreline caused by ocean flooding from tsunamis, excessive high tides caused by storms in the Pacific, or seiches in ocean bays and inland lakes.

The Flood Situation

Types of flooding experienced in California include rainfloods, caused by moderate to heavy rain over long periods of time; snowmelt floods, caused by either a high rate of melt or a large volume of melt; and flash floods, caused by thunderstorms and tropical storms, including hurricanes, which originate in tropical latitudes and move into California. These storms produce high-intensity rainfall over short periods of time.

There have been numerous damaging rainfloods since intensive settlement of California, with the most serious flooding occurring in 1862, 1907, 1909, 1916, 1937-38, 1940, 1955, 1958, 1964, 1969, 1970, 1974, 1978, and 1980. In Southern California, other major rainfloods occurred in 1884, 1914, 1927, and 1943; the most serious flash floods occurred in 1939; and a hurricane caused widespread flooding in 1976. The State's most serious snowmelt floods occurred in 1967 and 1969 in the Southern San Joaquin Valley.

Whatever type of flood threatens, there are two basic ways of preventing or reducing major flood damage: by keeping the water away from people (with structural facilities) or by keeping the people away from the water and related hazards (with nonstructural flood management). Damage can also be reduced by flood warning and resultant evacuation and, in some areas, by reducing flood magnitudes with watershed treatment.

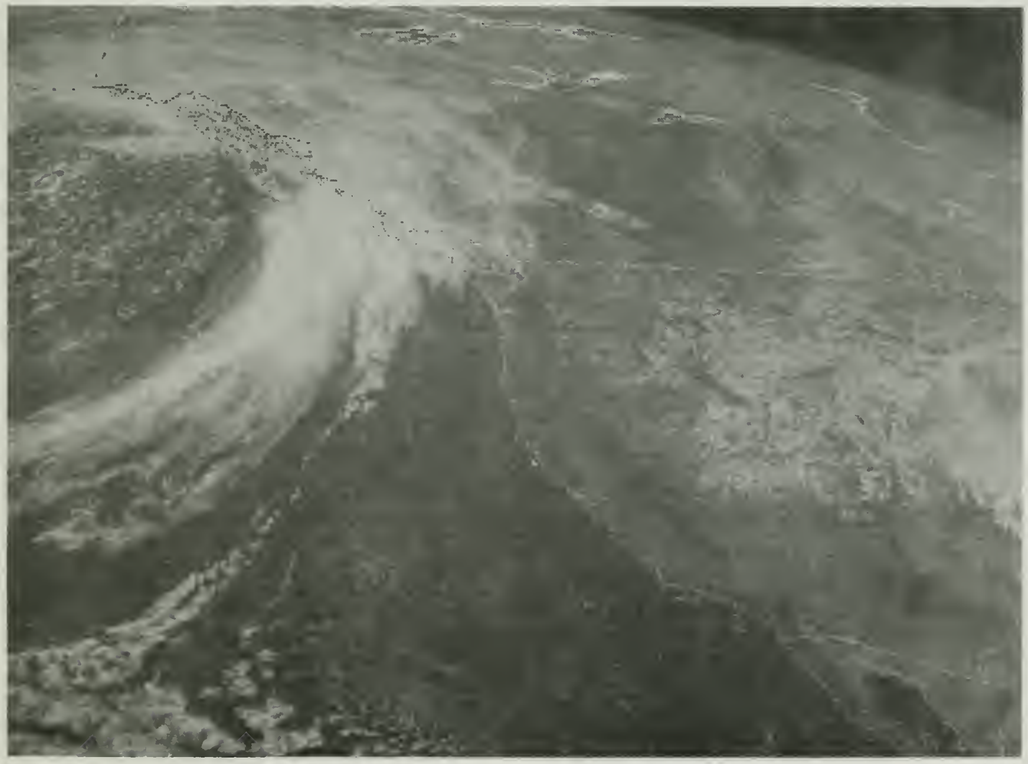
The extent of flood damage to public and private property has been related directly to level of development. Flood events of 1980, for example, demonstrated that the heavily populated area along the south face of the mountains extending from Santa Barbara on the west to San Bernardino on the east is still vulnerable to flood damage. Many effective flood protection structures have been constructed in this area, but continued population growth in the flood plains has exceeded their protective capacity. Many communities in Southern California are located directly in the path of known and demonstrated flood, debris, and mudflow hazard, as though the laws of nature had been suspended. In the Sacramento-San Joaquin Delta, levees protecting agricultural land are subject to damage caused by peak floodflows, high ocean tides, and strong winds occurring simultaneously in the Delta area. In January and February 1980, levees were breached on several Delta islands, with subsequent inundation.

Structural Facilities

Structural facilities used to prevent or reduce flooding include: (a) reservoir storage which can reduce peak floodflows by storing storm water for later release; (b) levees which contain storm flows within a defined area, thus keeping water away from developed areas; (c) bypasses which carry floodwater in excess of the capacity of stream channels which have often been reduced by development; and (d) channel modifications which increase the flow capacity of a stream channel. All structures provide protection up to some selected level of flooding and have a residual risk associated with them. Today, there is much concern for the environmental and aesthetic effects of structural works and their high cost.

Federal and local agencies are primarily responsible for flood protection in California. Federal and State programs are designed to provide assistance to local agencies. Federal flood protection projects are requested by the local agency, with the State assuming part of the local financial responsibility. The Reclamation Board, a State agency, participates with Federal agencies in the Central Valley and assumes some of the roles typical of local agencies.

County and local agency flood protection projects have been built extensively in California. The time span from the initiation of a study to construction of such projects is much shorter than on Federal projects, but the level of protection is seldom as high. The time required for major Federal projects, such as those constructed by the U. S. Army Corps of Engineers, typically ranges from 15 to 30 years. The level of protection provided is usually for a 1-in-100-year flood or greater. The Corps' small projects authorized by Section 205 of the Flood Control Act of 1948, as amended, take considerably less time to study and to complete.



SATELLITE PHOTO OF PACIFIC STORM SYSTEM moving toward the west coast of the United States. (NOAA National Weather Service photo.) Most California flooding is triggered by storms that start over the Pacific Ocean.

Nonfederal entities must assume responsibility for rights of way and road, highway, and utility relocation costs, and for Corps of Engineers channel projects and local protection reservoirs, and must share the recreation costs above a minimum level in reservoir projects. In addition, the nonfederal agencies must maintain and operate local protection projects and future reservoir recreation areas.

The Soil Conservation Service under Public Law 83-566 assists local agencies in the design, and provides funds for construction, of locally owned and operated projects which typically provide protection for a 1-in-50- to 1-in-100-year flood event for surburban areas and a lower level of protection for agricultural lands.

The State, through its flood subventions program, provides State funds for a major portion of local agency costs of rights of way and relocations for Corps of Engineers and Soil Conservation Service levee and channel projects. The reimbursement is limited to the part of these costs apportioned to flood damage reduction benefits. No State expenditures are allowed for land enhancement benefits.

Maintenance of major Federal flood storage projects is conducted by the U. S. Army Corps of Engineers or the U. S. Water and Power Resources Service (formerly Bureau of Reclamation) at Federal expense. Federal levee, bypass, and channel projects and local projects constructed by the Corps of Engineers and the Soil Conservation Service are maintained and operated by a local agency in accordance with agreements with the Federal construction agency. The local agency can be a city, county, district, the State Department of Water Resources, or State Reclamation Board. In areas where local maintenance is under the supervision of the State because of Reclamation Board participation in projects, the work is inspected twice annually by the Department of Water Resources, as are flood protection projects authorized by the Corps of Engineers.

Where maintenance in the Sacramento-San Joaquin Drainage Area is found to be inadequate and is not brought up to standards, a maintenance area is formed by the Reclamation Board on the recommendation of the Department. Maintenance areas outside the Sacramento-San Joaquin Drainage Area are formed by the Department of Water Resources. Maintenance areas can also be formed at the request of the local maintaining agency. In the latter cases, the State provides the maintenance with costs paid by the areas benefited.

In its maintenance efforts, the Department has a program for minimizing environmental and aesthetic effects including vegetative management and the use of Integrated Pest Management (IPM). This approach is described in Chapter 4 and emphasizes the entire relationship of pests (such as squirrels) with their environment in a control program.

Nonstructural Flood Management

Floods are not necessarily harmful. Under certain circumstances, when development has not encroached significantly, periodic flooding contributes aesthetic, ecological, environmental, and economic benefits to natural flood plains. Wetland and riparian vegetation adjacent to a stream also contributes water quality and erosion protection benefits.

Nonstructural flood management limits flood-prone lands to those uses that are compatible with periodic inundation. These uses may include agriculture, recreation fish and wildlife preservation areas, golf courses, and other open space activities. In flood-prone areas where predicted depths and velocities are not great, floodproofing of structures can be an integral part of comprehensive nonstructural flood management.

The Corps of Engineers has had an active flood plain management program since 1966. Under this program, the Corps has produced a number of flood plain information reports for 22 California counties. The reports provide flood risk information to local agencies for zoning and planning purposes. This report program is virtually ended, as it is being superseded by the studies and reports required by the Federal Emergency Management Agency (FEMA). The Corps has also published several guides for floodproofing structures and their contents.

The National Flood Insurance Program under FEMA makes technical information available locally, provides subsidized flood insurance, and provides sanctions against any direct federal financial assistance, including federally insured loans in flood plains, unless flood insurance is purchased. When detailed technical information is given to local communities, a strong flood plain management program is required of them to prevent development of the floodway which would cause a rise in water surface elevation. In addition, development within the flood plain fringe must be built above the water surface of the 100-year flood.

The National Flood Insurance Program has an emergency phase under which communities can obtain limited coverage at subsidized rates. Following the development of technical flood data and delineation of risk areas, the community enters the program's regular phase. Under this phase, full coverage is available. New construction is insured only at actuarial rates. Buildings in existence when the community shifts from the emergency to the regular phase may continue to obtain the limited coverage at the subsidized rate if it is less than the actuarial rate. Any insurance over the limited amount is at the actuarial rate; however there is a cap or ceiling of $.50 per $100 on this actuarial rate where it is applied to existing structures. Almost all flood-prone California communities have entered the emergency phase and are in the process of preparing for their conversion to the regular phase.

The State role in flood plain management involves: (a) flood-hazard studies conducted cooperatively with local agencies to provide information for use in zoning and planning, (b) participation in and promotion of the National Flood Insurance Program (including flood-hazard area mapping and frequency analysis), (c) the Designated Floodway Program of the State Reclamation Board, (d) the Cobey-Alquist Flood Plain Management Act, (e) State comments on project and environmental reports, and (f) California's Wild and Scenic River System.

The Designated Floodway Program typically defines the stream channel section required to carry safely the floodwaters of the 1-in-100-year flood or a designated flow. The Reclamation Board encourages compatible uses of the floodway area, and obstructions, dwellings, and bridges must be approved by the Board. This program is limited to Central Valley streams.

California's Cobey-Alquist Flood Plain Management Act provides that the State "...encourage local levels of government to accomplish flood plain management and to provide State assistance and guidance therefore," but specifically requires only that the local agency restrict development within the area required for authorized Federal flood protection if it is to receive State financial assistance for the nonfederal costs of lands, easements, and rights of way.

California's Wild and Scenic Rivers Act of 1972 provides for designation of certain rivers that shall be retained in their free-flowing state for the use of the people of the State. Specific reaches of the Smith, Klamath, Scott, Salmon, Trinity, Eel, Van Duzen, and American River systems have been so designated. The Act further provides that the Secretary for Resources shall develop a management plan in cooperation with the counties through which the rivers flow, and shall be responsible for its administration.

River Forecasting and Flood Warning

River forecasting and flood warning systems help reduce flood damage by providing time to evacuate people, livestock, and portable property from areas which will be inundated. River flow forecasting helps project operators achieve maximum efficiency in operating reservoirs and weirs.

River forecasting and flood warning for most large watersheds (518 square kilometres or 200 square miles or more) north of the Tehachapi Mountains are presently available from the Federal-State River Forecast Center and the State-Federal Flood Operations Center, both located in Sacramento. Some local agencies have forecast systems for individual streams. Flood warnings are distributed to emergency and law enforcement agencies for evacuation of people and portable property.

Watershed Treatment

Watershed treatment consists of crop rotation, terracing, contour stripping, and selective seeding and reforestation. It reduces erosion which could clog downstream channels and holds water in the soil to reduce peak storm flows. This is especially important after fires, which result in much larger flood peaks and an increase in debris production.

Under Public Law 83-566, the U. S. Department of Agriculture enters into cost-sharing arrangements with local sponsors (usually agricultural) of watershed treatment programs. In many cases, watershed treatment is applied in conjunction with other methods of flood damage prevention. The U. S. Forest Service and the State Department of Forestry have programs for seeding burned watersheds.

Comprehensive Flood Plain Management

A flooding problem, either existing or potential, needs to be properly defined so that opportunities for creative solutions are readily apparent. To accomplish this, the extent of various magnitude floods could be sketched and inundated structures, if any, noted for each event. The carrying capacity of distinct reaches of the flood plain should be calculated, natural and social resources delineated, and any drainage constraints (such as inadequate bridges and culverts) identified. An effective public participation program would identify legal and political constraints, various agency requirements, and concerns of the community and general public. The flood management agency could then propose various mixes of alternatives for the distinct segments of the flood plain, after balancing economic, environmental, social, and political factors. Some exemplary flood management projects and an educational brochure are depicted in Chapter 4.

The comprehensive approach recognizes that each distinct stream segment is amenable to different solutions or treatment and that structural and nonstructural measures can be combined to produce better projects. A comprehensive program includes educational brochures for developers and other agencies involved in the planning and approval process, so they can become aware of the many creative ways there are to avoid flood hazard. The local government with a comprehensive program has required decision makers to seek the advice and recommendations of the local flood control district regarding flood hazard during subdivision and building approval processes. Further, decision makers are required to make written findings regarding flood hazard and disposition of the advice and recommendations of the flood control district or other party with expertise.

Findings and Recommendations

Finding (1): Over the past 60 years, flood protection projects have been built on many of the major rivers of the State. No project can provide absolute protection; projects are designed to mitigate damage from floods of a specific magnitude. Some projects were built prior to intensive urbanization and are designed to provide a level of flood protection which is now less than adequate. Because some projects already protect against all but the larger, infrequent floods for which protection would be very costly, a higher level of protection sometimes is not [redacted] This situation can give people a false sense of security, because these projects do provide some protection. Too often people fail to realize that flood mitigation projects cannot provide absolute protection. A large flood can do severe, unexpected damage. What could we do about this problem in the Sac. River? warrant

Recommendation (1): Flood management agencies should strive for more imaginative analyses in devising solutions to these potential disasters. In some instances, additional physical works should be constructed and complemented by programs to deal with the residual flood risk. In other cases, extensive flood plain management programs should provide an appropriate mix of structural and nonstructural measures. These would include floodproofing, flood warning, watershed treatment, and removal of existing development from the flood plains as supplements to existing physical works.

The Santa Ana River Basin requires immediate attention. To a lesser degree, other areas in need of attention are: The Sacramento-San Joaquin Delta, the Sacramento River between the Butte County line and Chico Landing, the Colusa Drain, portions of the San Joaquin Valley, and northern Santa Clara County.

Finding (2): Since its modification by the Flood Disaster Protection Act of 1973, the 1968 National Flood Insurance Program has been the dominant force in flood plain management efforts. A community's participation makes flood insurance available to the citizens and requires the community to adopt a flood plain regulation plan.

The Federal Emergency Management Agency's (FEMA) Disaster Response and Recovery Regulations were expanded to include the evaluation and mitigation of natural hazards, the stimulation and encouragement of comprehensive hazard identification, the evaluation and mitigation of hazards by all levels of government, and the enforcement of current requirements for mitigation of natural hazards as a condition for Federal disaster assistance.

Recommendation (2): Action should be taken at the national level to ensure strengthening of the National Flood Insurance Program. All flood-prone California communities should enter the program and implement the flood plain regulations called for by the program. The State should continue supplementing the federal effort. Both FEMA and State agencies should ensure that natural hazard mitigation measures are effectively implemented as a condition for Federal disaster assistance.

Finding (3): Prior to the National Flood Insurance Program and the Reclamation Board's Designated Floodways Program, there was little incentive to adopt meaningful nonstructural flood management programs. Nonstructural flood management has not been widely practiced in California primarily because of opposition to regulation by landowners and real estate development interests, local pressure for growth and increased tax bases without regard to hazard and subsequent subsidy by the general taxpayer, and the reluctance of local government to resist this pressure. A secondary reason has been the lack of an adequate technical information base.

Local governments which are responsible for planning and zoning are often sensitive to interests proposing to develop in flood-prone areas. This is especially true when the flood risks are not well defined. Basically, there is no economic incentive to the landowners or real estate developers to encourage or support flood plain regulation. These special interests benefit from diffusion of the costs for disaster relief and structural works to the general taxpayer, who indirectly subsidizes their developments long after the developer has made an investment and is often no longer involved in the area. This has led to the building of homes, businesses, and related infrastructures that are incompatible with the flood hazard.

Recommendation (3): Completion of technical studies of flood risk, as a basis for flood plain regulation and flood insurance, needs to be accelerated by FEMA and supplemental State funding appropriated. All planning, zoning, and public works agencies should implement nonstructural flood management in partially developed areas before future development renders it impractical. Planning for future development must incorporate a positive effort to permit only nondamageable, compatible uses in high flood risk areas. Local government must require consultation with local flood control districts regarding flood hazard identification, avoidance or mitigation as a formal part of the process for subdivision and building approval, and must require local decision makers to make written findings of fact regarding flood hazard and disposition of flood control district recommendations.

Local government needs to explore the question of its liability in permitting development in a known flood-prone area. In addition, local governments should develop incentives to encourage compatible uses of the flood plain consistent with the degree of flooding.

The Department and FEMA should explore and implement possible actions or sanctions against local governments which allow unsuitable development in flood plains, including noncompliance with federal flood insurance regulations. FEMA should enforce effective hazard mitigation measures as a condition for Federal disaster assistance. The Department will recommend that all future State appropriations for flood disaster relief have requirements for hazard mitigation. As an example, Senate Bill 366 (Chapter 254, Statutes of 1979) for relief of Los Angeles and Riverside Counties required that adequate land use controls be exercised to assure that new construction or rebuilding of damaged buildings in flood or debris hazard areas be allowed only where adequate protection is to be provided.

Finding (4): Local communities with a serious flood problem that exceeds local funding capability generally turn to the Federal Government, particularly to the Corps of Engineers, for assistance. Previously, Corps procedures tended to favor the construction of an economically justified structural flood protection project as a vehicle for Federal financial participation. State financial assistance is also tied to project construction.

Recommendation (4): Nonstructural alternatives which could include floodproofing, flood plain acquisition, evacuation and relocation or replacement of existing structures or utilities should be considered on the same basis, and receive the same Federal and State financial assistance and encouragement, as structural alternatives. The Corps of Engineers has developed procedures to implement the provisions of Section 73 of the Water Resources Development Act of 1974 (PL 93-251), which requires consideration of nonstructual alternatives, and should recommend these measures as part of a comprehensive flood plain management project. The California Legislature should consider amending Water Code Sections 12573 and 12583, which provide State financial assistance for nonfederal costs, to include costs for those nonstructural measures required by Section 73.

Finding (5): Federal funds for flood investigation and project construction are limited. Local agencies compete for these funds. Success in the competition for funds is not necessarily related to the respective merits of a particular project. An objective evaluation of the investigations and projects, based on their relative contribution to reducing flood damage in the State, needs to be made.

Recommendation (5): In order to give priority to the more critical flood problems, the Department will recommend to Congress priorities for studies and projects being considered for Federal authorization or funding.

Finding (6): The maintenance of channels and levees has come under considerable public criticism in the last several years, to some extent due to a lack of environmental consideration by maintaining agencies. Past and present maintenance activities have had adverse impacts on environmental and aesthetic values. Maintenance activities need to be modified to a considerable degree to reflect environmental values without unduly sacrificing flood protection objectives. Lack of maintenance, particularly on the private levees of the Delta, has resulted in failure and subsequent flooding in some cases. Federal and State disaster funds, paid for by the general taxpayer, then subsidize restoration and rebuilding. Public payment for such improvidence is questionable.

Recommendation (6): All future levee project proposals should include construction of "set back" levees to enable more riparian growth and less intensive maintenance practices. The Department will continue efforts at persuading flood project maintenance agencies to limit vegetative control at rock revetment sites to that growth which substantially threatens to endanger the integrity of the revetment or carrying capacity of the project. Efforts will continue to employ mowing more often in lieu of burning levee slopes, and to time mowing and burning of levee slopes so as to not disturb nesting birds. There should be continued research to find feasible revegetation programs for rock revetments and levees. The Department will continue to strive for more use of an Integrated Pest Management (IPM) approach to maintenance, utilizing the natural enemies and physical needs to control unwanted pests on levees.

In order to avoid rewarding improvident maintenance, all State recommendations for disaster assistance will require a hazard mitigation program that brings a project up to some reasonable standard which is maintained.

Finding (7): Greater recognition is being given to the value of wetlands and riparian vegetation, not only for ecological, recreational, and aesthetic considerations but also for flood mitigation and water quality benefits. Some counties have passed ordinances to protect riparian vegetation, and State agencies are encouraging the concept. Decision 1460 of the Water Resoruces Control Board found that the elimination of a stream segment serving instream beneficial uses (for vegetative habitat) by removing non-floodflows is both a waste and an unreasonable method of diversion. Numerous other State laws and rules described in Chapter 2 also encourage preservation of vegetative habitat.

Recommendation (7): All planning, zoning, and public works agencies need to emphasize protection of wetlands and riparian vegetation as a technique of nonstructural flood management and to enhance water quality. Additional data should be generated, through studies similar to the Corps of Engineers' Pilot Levee Program on Steamboat Slough, to measure the cost effectiveness of various methods of riparian vegetation protection. Using this data, appropriate government agencies should continue their vigorous efforts to enact regulations to protect riparian vegetation and wetlands. This is particularly true in the aftermath of Proposition 13 wherein operation and maintenance funds are greatly reduced.

Finding (8): Emergency flood damage reduction measures by their nature are seldom subject to an evaluation of environmental impact, consistency with State policy, and cost effectiveness before they are undertaken.

Recommendation (8): Flood fighting measures should be submitted to a post-project analysis of environmental impact, consistency with State policy such as protection of wetland and riparian habitat, and cost effectiveness. Results of these analyses should be used to guide future emergency action and long-term action needed to prevent future damage. Senate Bill 366 (Chapter 254, Statutes of 1979) provided funds for the Department to make analyses of cost effectiveness of emergency funds allocated therein to the Los Angeles County Flood Control District, City of Los Angeles, and Riverside County Flood Control and Water Conservation District. The findings of these analyses will be used as guidelines in declaring future emergencies under the provisions of Section 128 of the Water Code.

Finding (9): There is a reluctance by government agencies in rural California counties to implement prudent nonstructural flood management practices. Paradoxically, rural areas are the very locations where flood plain regulation has the greatest potential for effectively preventing increases in flood damage and preserving environmental values.

Recommendation (9): FEMA should accelerate its effort to complete studies in rural areas and institute a program for informing residents of the rare opportunity they have to prevent the flood disasters and unnecessary expenses experienced by some developed areas. Rural administrators and the public could benefit from graphic illustrations of the flood damage suffered by more populated sections of the State which failed to adopt nonstructural flood management practices early in their development.

Finding (10): Planning, public works, and flood management agencies that have aggressively encouraged public involvement in the formulation and planning of flood programs and projects tend to experience fewer delays and less public objection and to achieve greater public acceptance and satisfaction. The public is made aware of the flood hazard, is educated about agency concerns and constraints, and can assist the agency in designing a project acceptable to those directly affected and to the general public.

Recommendation (10): All levels of government should encourage an active and effective role by the public early in the flood management planning process. They should recognize that public involvement is required in the local approval, EIR and right-of-way acquisition processes, and can produce more acceptable projects, as well as avoiding delays, litigation, and rejection by decision-making bodies. Public involvement is basically a process which combines the needs and wishes of various publics with the professional expertise of an agency to produce a result that will maximize the efforts of both.*

* "Public Participation," Proceedings of Flood Management Conference, Sacramento, California, October 24, 25, 1978, p. 82; other papers in this volume would be useful to flood management agencies.

Finding (11): There is increasing flood damage to high value crops in the Central Valley and Southern California resulting from more intensive agricultural uses in flood-prone areas. If flood damage reduction is to be accomplished, this trend must be halted.

Recommendation (11): The State Reclamation Board and other regulatory agencies should examine their rules and regulations for allowing prudent uses in flood plains with the objective of preventing rising agricultural flood damage. Long-term capital intensive crops such as orchards should be regulated so as to be excluded from areas where they will suffer frequent serious damage.

The goal of flood management programs is to prevent loss of life and damage to property and to preserve as much as possible the amenities of flood plains. It is unrealistic to aim for complete elimination of damage from floods. Over the years, economic analyses and policy determinations for projects have resulted in acceptance of specified levels of protection which are considered appropriate. Typical flood protection objectives of the U. S. Army Corps of Engineers are: (1) highly developed urbanized areas -- Standard Project Flood (usually 1-in-200-year flood or greater), (2) rural areas -- 1-in-100-year flood, and (3) agricultural areas -- 1-in-100-year flood. Most flood-prone areas of California do not have these high levels of protection.

Effects on the environment have been given added, and long overdue, consideration in recent years. The quality of life is enhanced by open spaces which can accommodate floodwaters, sediment, and debris on occasion, but which serve as recreation or agricultural areas most of the time. Because of the pursuit of recreation on streams, rivers, and lakes, environmental protection laws supported by a significant segment of the public require preservation of natural values. Concrete or rock-lined stream channels have generated extensive public protest as have flood storage reservoirs which inundate rivers and wildlife habitat and prevent the flow of sediment to ocean beaches. Such factors must be considered in developing policy.

Cost has a substantial bearing on the degree of protection which can logically be provided. Where existing development is sparse, structural works may not be economically justifiable, and nonstructural flood management methods should be used. Where urban development has already taken place, some sort of structural protection can usually be justified. In such cases, nonstructural measures can usually be combined with a structural approach to provide a higher and more acceptable level of protection.

California has approximately 40 million hectares (100 million acres) of land; 1 million hectares (2.6 million acres) are now covered by urban development, and 9 million hectares (22 million acres) are irrigable, of which 3.6 million hectares (9 million acres) are presently irrigated. Most of the State's flood plains are included in the irrigable land category. Use of the flood plains for agriculture is often compatible with occasional flooding of these lands. Wise land use which recognizes the value of prime agricultural lands could limit urban encroachment on such lands, thereby reducing the extent of flood damage.

Flood Management Policies of the State of California

The Department will cooperate with all levels of government to assist people in avoiding flood-related hazards (water, debris, mudflows, and erosion), and in reducing flood damages, in preventing incompatible developments in flood plains, and in protecting environmental values. In accomplishing this, the policies of the Department stem from various sections of the California Water Code, Fish and Game Code, Public Resources Code, Resources Agency policy, decisions of the State Water Resources Control Board, and Executive Order from the Governor. These policies are:

- To place emphasis upon nonstructural solutions, recognizing that sound flood plain management practices hold great future promise for providing economically and environmentally feasible flood protection. However, the Department also recognizes that there are developed areas where relocation or structural solutions are needed and necessary. Here, too, care must be taken to prevent encroachment on a floodway below projects which can negate the benefits gained by the project.

- To recognize the close relationship among flood management and wetlands, fish, wildlife, and recreation that has been stated by the California Legislature in the California Water Code (Chapter 3.5, Part 6, Division 6), the Fish and Game Code (Sections 1600, 1800, et seq.), and Decision 1460 of the State Water Resources Control Board. (Decision 1460 found that the elimination of a stream segment serving instream beneficial uses by diversion of non-floodflows is both a waste and an unreasonable method of diversion of water.) It is Department policy to carry out its programs in a way that incorporates wetlands, fish and wildlife protection and enhancement, recreational development, and ground water recharge as integral parts of its flood management efforts. The Department will seek the advice of the Department of Fish and Game in implementing this policy.

- To carry out its maintenance responsibilities in a way that will provide and restore as much protection as practicable to streamside riparian wildlife habitat and to fish habitats in streams.

- To recognize the social values of streams in that essentially natural streams frequently give focus or identity to a community, provide opportunities for education and natural history studies, and enhance property values and aesthetics. To recognize that the traditional "solution" of channel modifications or elimination of a stream is often seen as a bigger "problem" by a community, and to consider flexibility in degree of protection where a community so desires.

- To recognize the value of flood forecasting and flood warning as a complement to or an integral part of a flood plain management program, allowing maximum efficiency of operation of flood protection projects.

Flood Management Criteria of the Department of Water Resources

The following criteria have been developed to aid the Department in carrying out its flood management policy.

In striving to reduce flood damage, the Department will attempt to:

1. Support protection from at least a 1-in-100-year flood event for moderately developed areas unless there are overriding environmental or social considerations and relocation is not feasible. Flexibility in degree of protection is appropriate where there are overriding considerations of environmental and social values in maintaining an essentially natural stream system.

2. Support greater than 1-in-100-year flood protection for highly developed areas, if economically, environmentally, and socially feasible.

3. Where structural works are required, assure the design of projects with the best mix of structural and nonstructural approaches.

4. Give full recognition to the preservation of environmental and recreational values and ground water recharge areas.

In striving to control development within the State's flood plains, the Department:

1. Will not support development of structures within a stream channel section needed to contain a 1-in-100-year flood.

2. Will not support uses in a 1-in-100-year flood plain which would cause the 1-in-100-year flood to have a water level more than 1 foot higher than that which would occur without such development.

3. Will promote compatible uses of flood plains which emphasize environmental and recreational opportunities.

4. Will promote programs and legislation which are designed to emphasize non-structural solutions and guide compatible development within the State's flood plains, protecting their environmental values and maximizing beneficial uses in the public interest.

5. Will assist State agencies in carrying out the Governor's Executive Order which admonishes State agencies not to build State facilities in flood-prone areas.

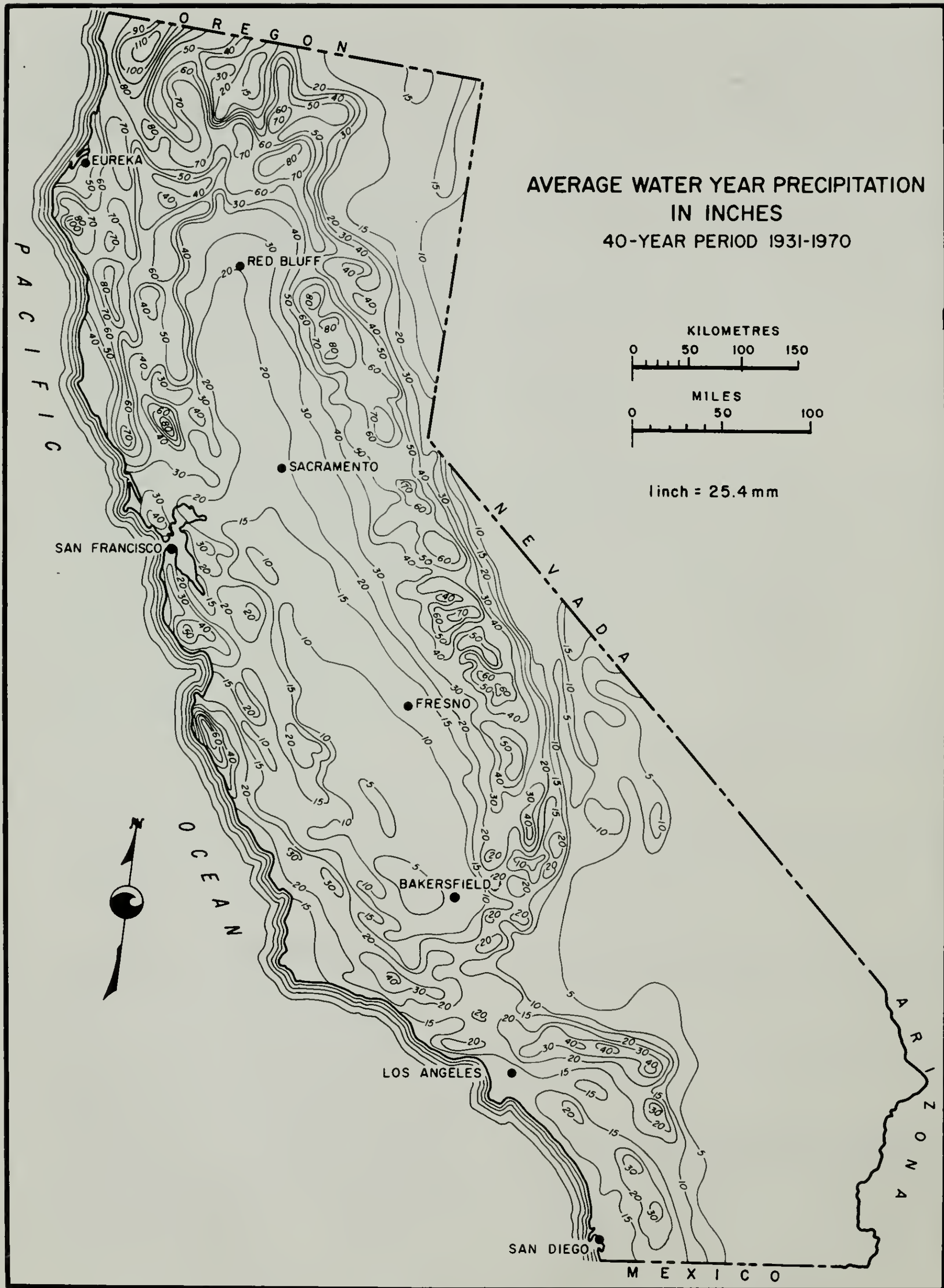


Figure 1. AVERAGE WATER YEAR PRECIPITATION IN CALIFORNIA

Floods in California generally result from storms, and occasionally from failures of constructed works. These types of floods, their history, and an explanation of flood magnitude are discussed below.

Storm Types Causing Floods

The amount of precipitation varies widely throughout California due principally to topography and Pacific storm patterns. Figure 1 illustrates the variability of precipitation over the State.

During the wet season, generally extending from October through April, California's weather is controlled by two semipermanent atmospheric systems -- the Pacific high-pressure and the Aleutian low-pressure centers. The specific location and strength of these pressure areas support, generally, three storm types which bring precipitation to California. The cold-type storm system comes from the Gulf of Alaska, the warm-type storm system comes from the Pacific Ocean, and the tropical storm (which may hit any time of the year) forms over the Pacific Ocean west of Central America and Mexico.

The Pacific high-pressure center occupies the area northeast of Hawaii during the dry season. During the wetter winter months, the Pacific high is usually weaker and located farther south allowing storm centers forming off the coast of Asia to move toward the semipermanent Aleutian low-pressure area. These cold-type storm systems are frequently rejuvenated, or new storms are formed. They continue their eastward flow into the Gulf of Alaska and approach the west coast. This storm system pattern is shown schematically in Figure 2. Storm systems moving out of the Gulf of Alaska southeastward toward California usually produce snow at low elevations.

The second type of storm arises in the Pacific Ocean, north of the Hawaiian Islands. The warm storms of this type, illustrated in Figure 3, involve air masses of tropical nature which are steered inland by westerly or southwesterly upper air winds bearing warm, moist air over California. These warm air masses produce both snow and rain. The elevation where the rain changes to snow is known as the snow level. In warm storms the snow level is higher than in the cold-type storms. The warm-type storm is the most critical for California, since it occasionally involves prolonged flood-producing rains.

At times, the persistence of the Pacific high at a higher latitude than normal keeps the Pacific storm track farther to the north. This results in either no precipitation for California or, at most, only light amounts. When the Pacific high acts as a block to the storm track, the high-pressure cell is referred to as a "blocking high". This storm pattern is illustrated in Figure 4.

The desert areas in the southeastern portion of California experience an entirely different type of flood-producing storm. A flow of moist, tropical air from either the Gulf of Mexico, the Caribbean Sea, or the Pacific Ocean west of the coast of Central America and Mexico brings masses of moisture-laden clouds to the desert areas. Occasionally the flow may involve a tropical storm or a hurricane (the latter has winds exceeding 120 kilometres [75 miles] per hour). When the moist air masses are carried to great heights by strong updrafts, thunderstorms develop. Accumulated water in the updrafts becomes so heavy that it cannot be supported and falls through the clouds. The frictional drag created by the falling water turns the updraft into a downdraft, and a heavy

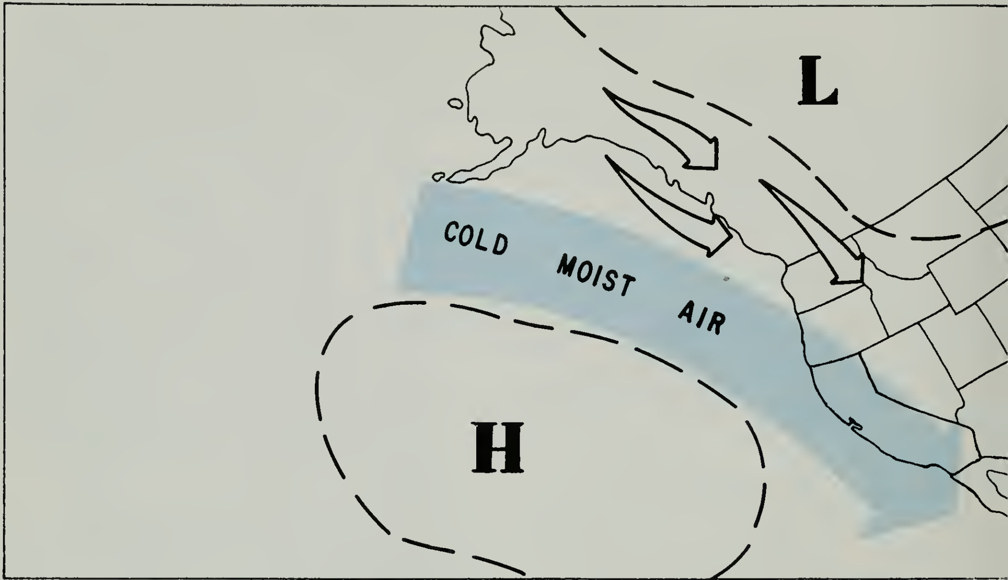


Figure 2. COLD STORM SYSTEM

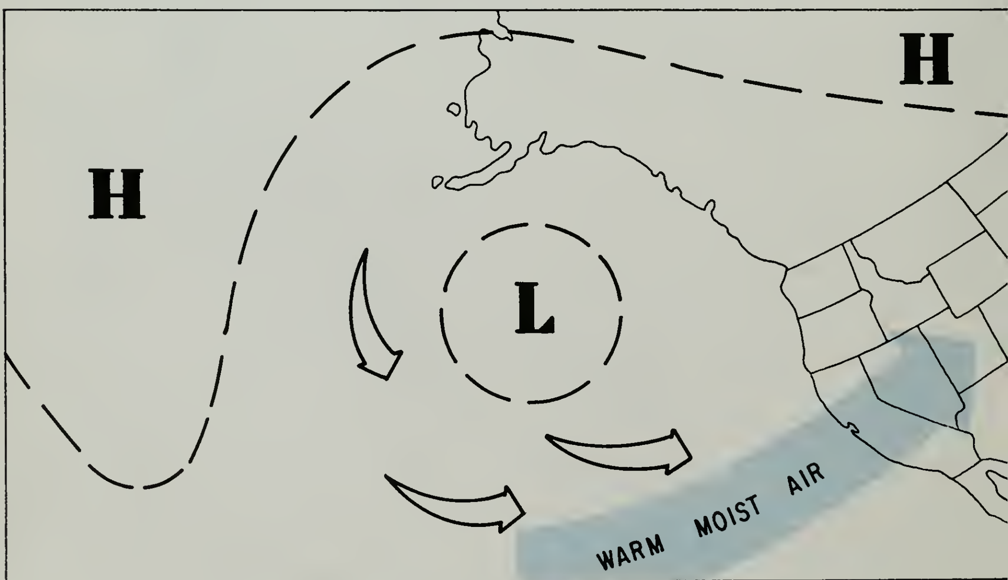


Figure 3. WARM STORM SYSTEM

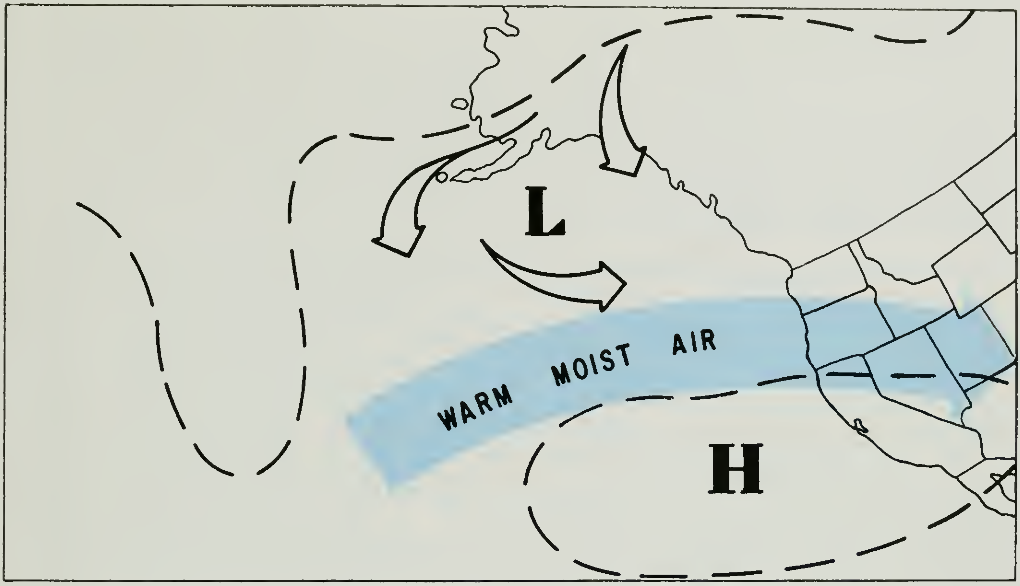


Figure 4. BLOCKING HIGH PRESSURE SYSTEM

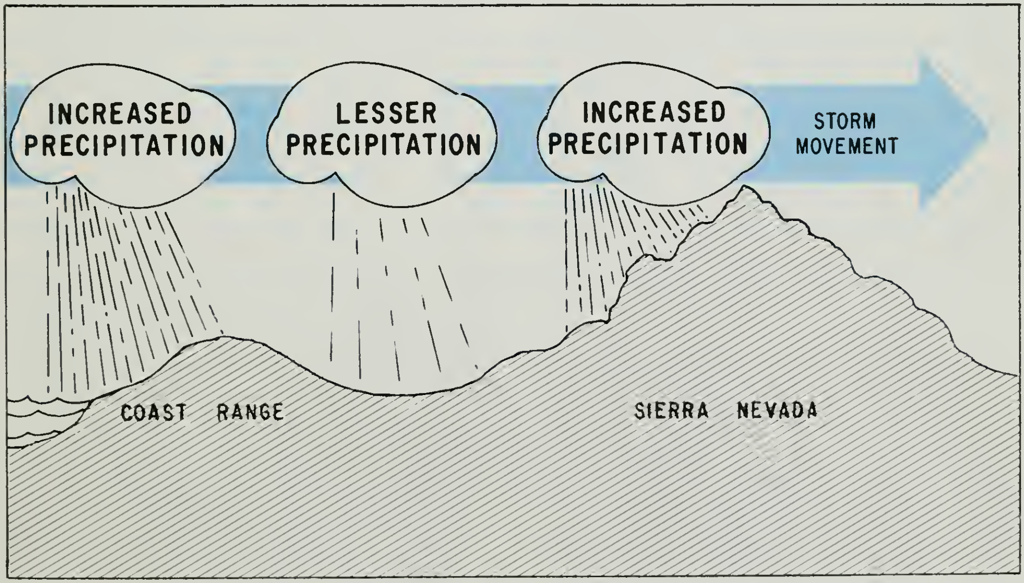
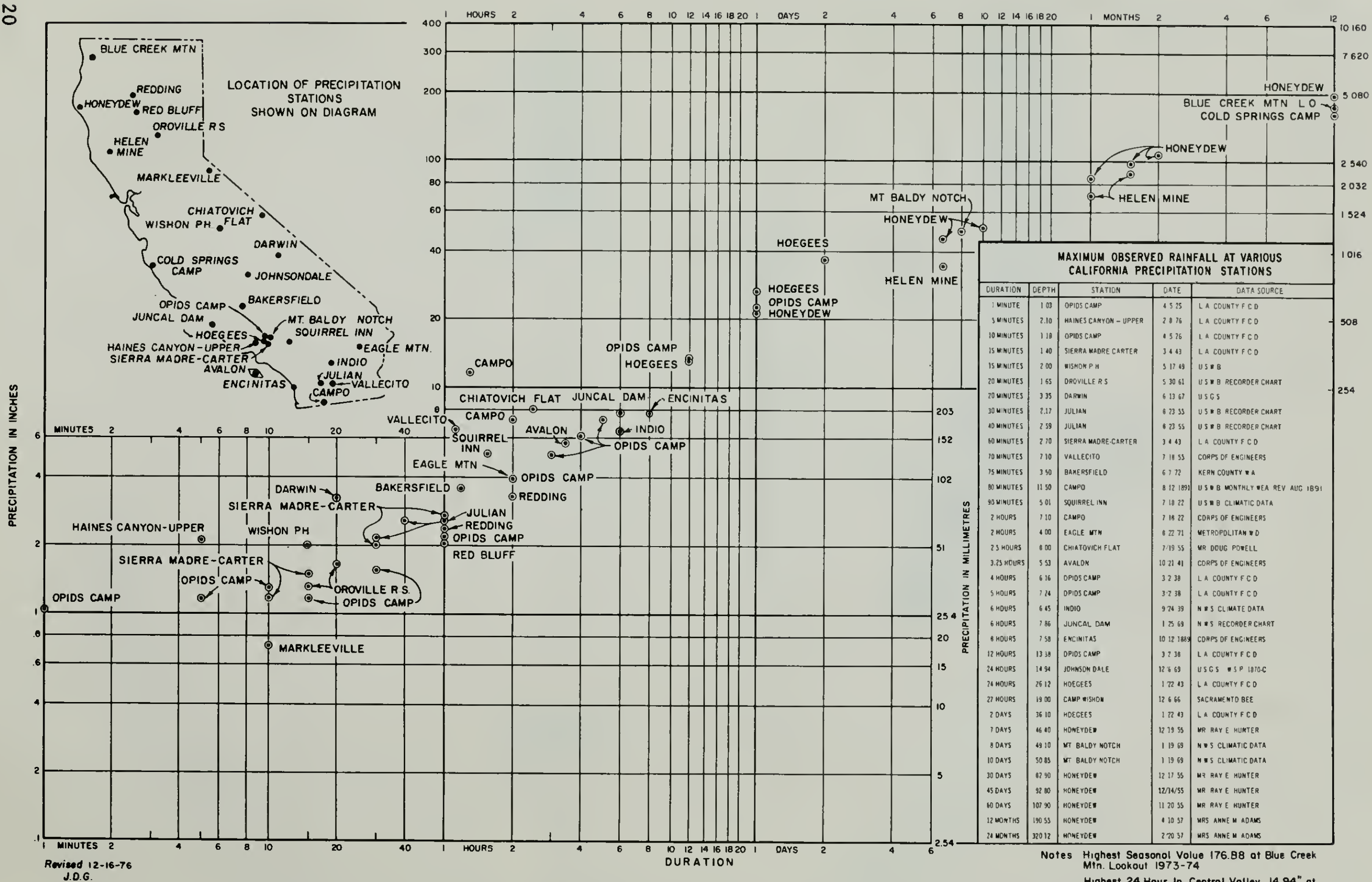


Figure 5. OROGRAPHIC PRECIPITATION



MAXIMUM OBSERVED RAINFALL AT VARIOUS CALIFORNIA PRECIPITATION STATIONS

DURATION	DEPTH	STATION	DATE	DATA SOURCE
1 MINUTE	1 03	OPIDS CAMP	4 5 25	L A COUNTY F C D
5 MINUTES	2.10	HAINES CANYON – UPPER	2 8 76	L A COUNTY F C D
10 MINUTES	1 18	OPIDS CAMP	4 5 76	L A COUNTY F C D
15 MINUTES	1 40	SIERRA MADRE CARTER	3 4 43	L A COUNTY F C D
15 MINUTES	2 00	WISHON P H	5 17 49	U S W B
20 MINUTES	1 65	OROVILLE R S	5 30 61	U S W B RECORDER CHART
20 MINUTES	3 35	DARWIN	6 13 67	U S G S
30 MINUTES	2.17	JULIAN	6 23 55	U S W B RECORDER CHART
40 MINUTES	2 59	JULIAN	6 23 55	U S W B RECORDER CHART
60 MINUTES	2 70	SIERRA MADRE-CARTER	3 4 43	L A COUNTY F C D
70 MINUTES	7 10	VALLECITO	7 18 55	CORPS OF ENGINEERS
75 MINUTES	3 50	BAKERSFIELD	6 7 72	KERN COUNTY W A
80 MINUTES	11 50	CAMPO	8 12 1891	U S W B MONTHLY WEA REV AUG 1891
90 MINUTES	5 01	SQUIRREL INN	7 18 22	U S W B CLIMATIC DATA
2 HOURS	7 10	CAMPO	7 18 22	CORPS OF ENGINEERS
2 HOURS	4 00	EAGLE MTN	8 22 71	METROPOLITAN W D
2.5 HOURS	8 00	CHIATOVICH FLAT	7/19 55	MR DOUG POWELL
3.25 HOURS	5 53	AVALON	10 21 41	CORPS OF ENGINEERS
4 HOURS	6 16	OPIDS CAMP	3 2 38	L A COUNTY F C D
5 HOURS	7 24	OPIDS CAMP	3 2 38	L A COUNTY F C D
6 HOURS	6 45	INDIO	9 24 39	N W S CLIMATE DATA
6 HOURS	7 86	JUNCAL DAM	1 25 69	N W S RECORDER CHART
8 HOURS	7 58	ENCINITAS	10 12 1889	CORPS OF ENGINEERS
12 HOURS	13 38	OPIDS CAMP	3 2 38	L A COUNTY F C D
24 HOURS	14 94	JOHNSON DALE	12 6 69	U S G S W S P 1870-C
24 HOURS	26 12	HOEGEES	1 22 43	L A COUNTY F C D
27 HOURS	19 00	CAMP WISHON	12 6 66	SACRAMENTO BEE
2 DAYS	36 10	HOEGEES	1 22 43	L A COUNTY F C D
7 DAYS	46 40	HONEYDEW	12 19 55	MR RAY E HUNTER
8 DAYS	49 10	MT BALDY NOTCH	1 19 69	N W S CLIMATIC DATA
10 DAYS	50 85	MT BALDY NOTCH	1 19 69	N W S CLIMATIC DATA
30 DAYS	82 90	HONEYDEW	12 17 55	MR RAY E HUNTER
45 DAYS	92 80	HONEYDEW	12/14/55	MR RAY E HUNTER
60 DAYS	107 90	HONEYDEW	11 20 55	MR RAY E HUNTER
12 MONTHS	190 55	HONEYDEW	4 10 57	MRS ANNE M ADAMS
24 MONTHS	320 12	HONEYDEW	2 20 57	MRS ANNE M ADAMS

Notes Highest Seasonal Value 176.88 at Blue Creek Mtn. Lookout 1973-74

Highest 24 Hour In Central Valley 14.94" at Johnsondale 12-6-69

Figure 6. DEPTH–DURATION RELATION OF CALIFORNIA'S GREATEST OBSERVED RAINFALLS

downpour results. Within several hours, the desert thunderstorms can produce disastrous flash floods of short duration, usually over a relatively small area or watershed.

As storms of all types sweep easterly in from the ocean, they encounter California's mountains. Air is forced upward along the mountain slopes, lifting and consequently expanding the moisture-laden air, which causes cooling of the air mass. As the air is cooled, the moisture-holding capacity is reduced and rainfall results. Thus, heavy rainfall occurs on the western or windward slopes of the mountain ranges. As the air mass passes the mountain crest, it begins to sink, compress, and warm up, with resultant light rainfall or no rainfall at all on eastern slopes. This mechanism, called orographic lifting, produces precipitation patterns as illustrated in Figure 5.

The rainfall extremes which produce floods have been observed statewide. A depth duration relationship showing some of California's greatest observed rainfall intensities is seen in Figure 6. These amounts vary from an intensity of 26 millimetres (1.03 inches) in one minute at Opids Camp to 663 millimetres (26.12 inches) in 24 hours at Hoegees.

Types of Flooding

Essentially Natural Causes

Almost every year, flooding occurs along some stream or river in California, and frequently whole regions, such as the North Coast, experience flooding to varying degrees. Three causes of flooding are generally recognized in California: the rainfloods during the winter from October through early April (moderate to heavy rainfall over hours or days); snowmelt through June (standing snowpack melting over days and weeks); and thunderstorms and tropical storms, including hurricanes, which originate in tropical latitudes and move into California. These storms produce high-intensity rainfall over short periods of time, especially in small watersheds.

Typically, precipitation at the higher mountain ranges of the coast and Sierra Nevada produces a winter snowpack which at times extends to lower elevations following cold-type storms. It is commonly thought that when heavy rains fall from a warm-type storm it is inevitable that the precipitation will melt the snowpack and cause flooding. The fact is that most of the time the result is just the opposite; the snowpack acts much like a sponge to retain most of the rainfall and delays runoff so that it does not contribute to peak flows. Every so often, however, periods of prolonged or heavy rainfall can cause snowmelt that will contribute significantly to flooding. This is particularly true when the snowpack is not deep.

Extended periods of heavy rainfall from storms originating over the Pacific Ocean produce floods in California which may be characterized by a rapid rise in streamflow and almost as rapid a recession from a single storm. Streams may be out of their banks for only a few hours or for several days. During the winter months, a series of storms or a single storm front which stalls over California is capable of producing large catastrophic floods, which can damage property by erosion, flotation, and inundation, and by depositing debris against bridges and on downstream properties.

One of the most catastrophic of these rainfloods occurring in California took place in Northern and Central California during the period December 18 through December 25, 1964. The rainfall began on the 18th and continued for over a week, with the heaviest amounts falling on the 21st and 22nd. Typical three-day precipitation totals exceeded 380 to 500 millimetres (10 to 20 inches). Communities along the North Coast rivers, especially the Klamath and Eel Rivers, were

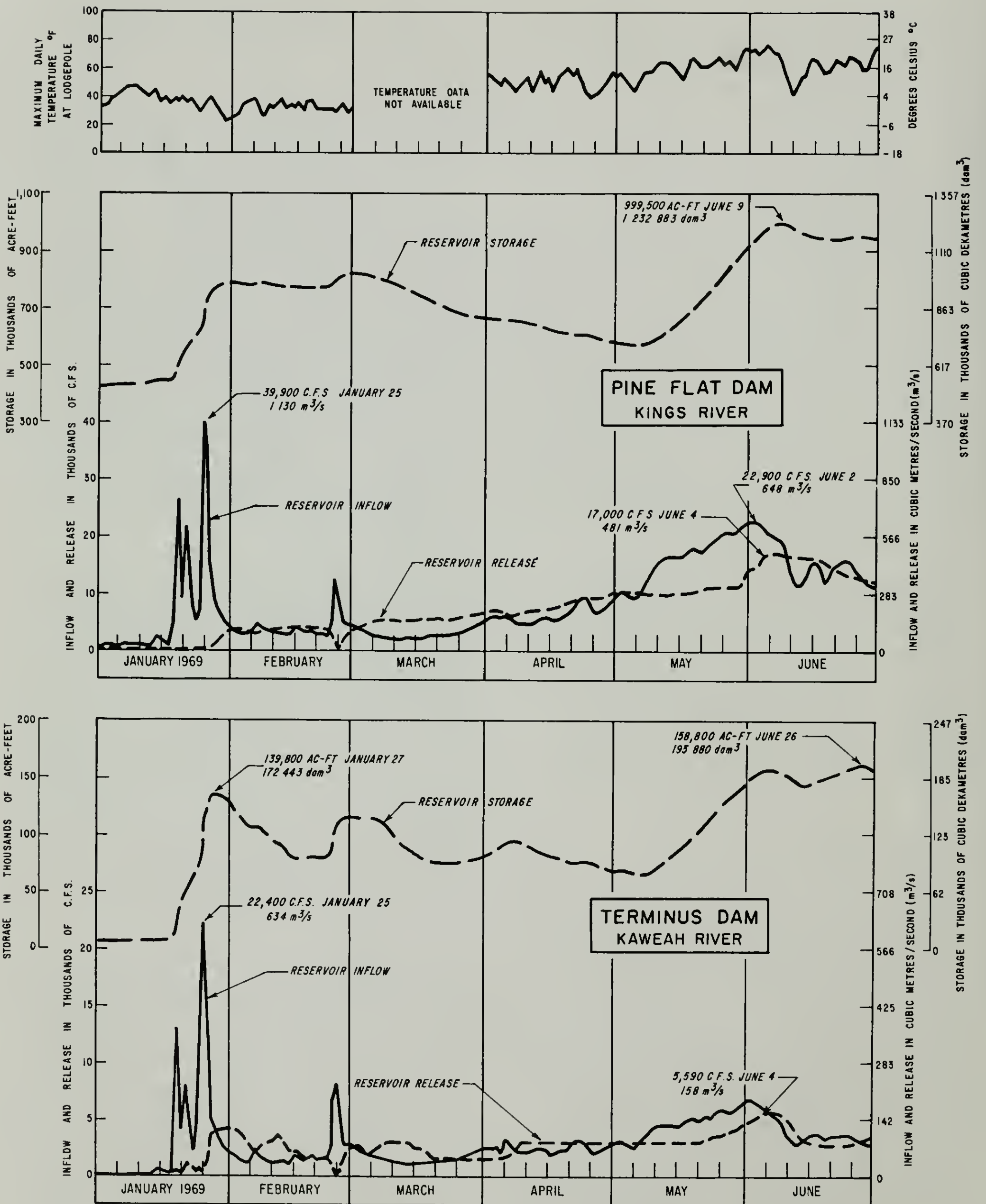


Figure 7. OPERATION OF PINE FLAT AND TERMINUS DAMS

particularly devastated. The towns of Klamath, Orleans, Myers Flat, Weott, South Fork, Shively, Pepperwood, Stafford, and Ti-Bar were completely destroyed. In the North Coastal area, there were 23 deaths and 1,700 injuries. Private and public damage was over $183 million. In the Central Valley, although damage was nearly $30 million, none was due to failure of the system of reservoirs, bypasses, and levees. Without them, damage would have been astronomically higher.

The same storms which cause rainfloods generally deposit snow at higher elevations. The frozen snow reservoir builds during the winter months and begins to melt in the spring. During this period rapid and sustained temperature rises, combined with an unusually large snowpack, can cause melt at such a high rate that flooding takes place along streams. Snowmelt floods are primarily a problem along the streams in the southern Sierra Nevada watersheds, where channel capacities are relatively small downstream from the large reservoirs. If the reservoirs become filled and a rapid snowmelt continues, the necessary spill or flood storage releases in excess of downstream channel capacities cause flooding. Damage from snowmelt flows may also be caused by seepage and raised water tables near leveed reaches of the larger rivers resulting from sustained high flows for several days or weeks during the early growing season.

Snowmelt in the spring of 1969 was of record-breaking proportions. Storms during December, January, and February, which caused flooding around the State at lower elevations, deposited all-time record snow depths at 78 out of the 109 snow courses from the Stanislaus River basin south to the Kern River basin. Typical reservoir operations of Pine Flat Dam and Terminus Dam are shown in Figure 7. Heavy precipitation in January and February nearly filled the reservoirs. Restricted downstream channel capacities prevented emptying the reservoir space quickly so that record snowmelt inflows in May and June almost exceeded the reservoir storage. In fact, Terminus and Success Reservoirs on the Kaweah and Tule Rivers had temporary restraining walls constructed on their spillways to increase storage and minimize damage downstream.

Thunderstorms or tropical storms can produce disastrous flash floods. These floods are of short duration but high in peak flow. They may strike only a small area but can destroy property and life miles from the storm center. A dramatic example of this was tropical Cyclone Kathleen which occurred ironically enough during the middle of one of California's most severe droughts. Tropical Cyclone Kathleen began as a tropical storm on September 6, 1976, about 480 kilometres (300 miles) southwest of Acapulco, Mexico. Kathleen moved northward and crossed into Southern California and was centered near Imperial at about 6 p.m. on the 10th. The storm lasted two more days, moving on through Nevada, Idaho, Utah, and Montana. On the average more than 75 millimetres (3 inches) of rain fell in Southern California. However, heavier amounts of 200 to 250 millimetres (8 to 10 inches) fell in the Southern California mountains, with 368 millimetres (14.50 inches) reported at San Gorgonio Mountain, northwest of Palm Springs.

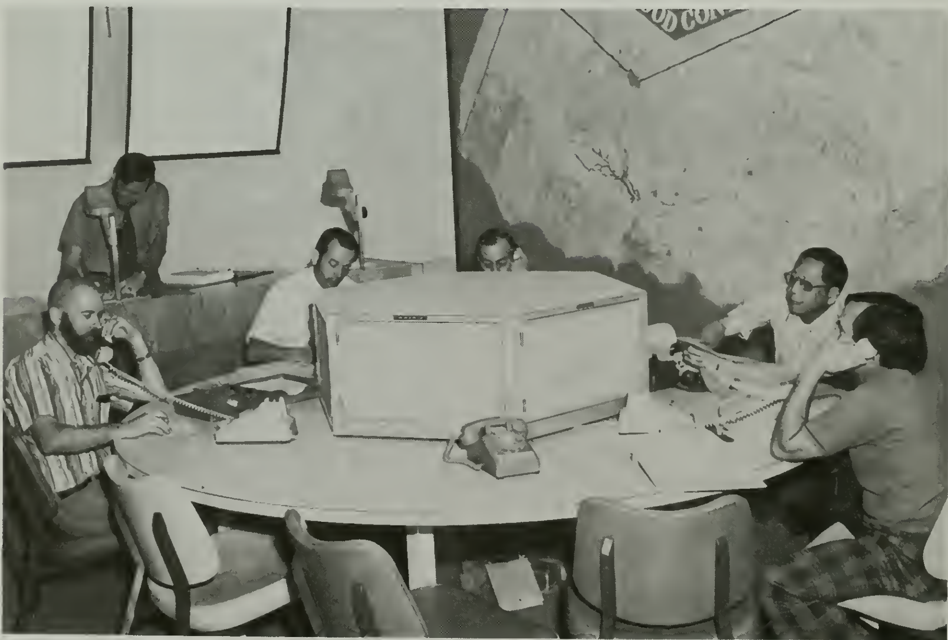
Watershed areas burned by wildfires create a potential threat to downstream areas. Should above-normal rainfall occur over burned watersheds, extensive damage to property from water, mud, and water-carried debris could take place in the burned and downstream areas. To minimize this threat, immediate action must be taken to reseed burned areas, clear a relatively unobstructed path of flow, and provide warning, advice, and sandbags to those in the path of inundation.

Fires occur naturally in the chaparral and forested areas of California, in each area on the average of about once every 50 years, and are not extraordinary events. During the summer and fall months, wildfires may burn entire watersheds and, in some cases, completely destroy all ground cover, homes, and overhead utilities. Examples include the Corona fire in San Bernardino County, the Ventana Wilderness fire in the Big Sur area of Monterey County, and the Santa Barbara fire in Santa Barbara County, all of which occurred during 1977.

Essentially Cultural Causes

In addition to natural flood disasters, occasionally reservoirs or levees have failed structurally, resulting in catastrophic flooding. During the flood of 1916, peak flow into Sweetwater reservoir in San Diego County overtopped the spillway and eroded the earthfill at the right abutment to a depth of 9.14 metres (30 feet) below the parapet level. The total damage to development below the dam was $400,000.

In March 1928, the St. Francis Dam, about 32 kilometres (20 miles) north of Los Angeles, failed due to defective foundations, causing over 400 deaths and claims of nearly $5 million in damages to communities along San Francisquito Creek and the Santa Clara River. On December 14, 1963, the Baldwin Hills Reservoir, in a strip surrounded by the City of Los Angeles, failed due to land subsidence, leaving five people dead and damage estimated at $15 million. During the December 1964 floods in Northern California, the partially constructed Hell Hole Dam on the Rubicon River was overtopped and destroyed by erosion. However, damage was relatively small, since Folsom Dam, located downstream on the American River, was able to contain the record inflows.



WHEN FLOODS THREATEN or are in progress, the State-Federal Flood Operations Center in the Resources Building in Sacramento is staffed 24 hours a day

On June 21, 1972, a levee failed in the Sacramento-San Joaquin Delta, inundating the low-lying Brannan-Andrus Islands. Damage claims of $50 million to the agricultural community and the town of Isleton were subsequently filed. In January and February 1980, several Delta islands were inundated as levees were breached. The public cost of restoration (by FEMA) was approximately $20 million. The Department of Water Resources prepared levee maintenance standards to be accomplished by the local people to prevent a recurrence of inundation that had occurred in part because of poor local maintenance. A program to accomplish this had not been initiated at the time this bulletin was printed.

Human influence on flooding is not limited to activities that always decrease potential flood risks or reduce flood damage. On the contrary, in the 1880s, hydraulic mining for gold caused stream and river channels to become sediment-laden and decreased channel capacities, thereby causing more frequent flooding during the winter flood season. Logging as well as fire-burn areas, especially on steep slopes, leads to accelerated runoff and increased sediment and debris discharge to streams and rivers. Urbanization causes increased runoff which at times exceeds the capacity of local storm drainage facilities. The elimination of the natural flood- and debris-carrying capacity of watercourses by converting them into storm drains and channels produces flooding which otherwise might not have occurred. And, finally, building near and dumping debris into watercourses, and the lack of maintenance of flood-carrying capacities in the flood channels may increase areas of flood inundation.

History of Flooding

For over 150 years, written records have been kept of California's floods and their devastation. Historians tell of severe floods in the 1800s, but in those days without dams, levees, or modified channels, floods took place nearly every winter. The legendary Great Flood occurred in the winter of 1861-62. Three heavy storms between December 9, 1861, and and January 10, 1862, extending from Canada to Mexico, provided some of the greatest discharges of water ever experienced in California.

Since the 1861-62 flood, there have been numerous floods in California. The floods that occurred in the rivers of the Sacramento Valley during March of 1907 caused inundation of more than 121 000 hectares (300,000 acres) of cropland. In addition, many miles of costly levees had to be rebuilt. Two years later, in 1909, a series of floods in the Central Valley, from January 14 to January 25 inclusive, equaled in intensity the flood of 1907.

The floods of March 1907 and January 1909 demonstrated the inadequacy of the then-proposed plan of carrying all the floodwaters of the Sacramento River and its tributaries in an enlarged leveed river channel. This led to the development of the present Sacramento River Flood Control Project which uses the three classic methods of managing floods -- leveed channels, leveed bypasses, and foothill reservoirs, as depicted at the end of this Chapter and as described in Chapter 4.

The flood of 1916 was the most destructive flood in San Diego County. It caused damage to all important highway and railroad bridges and washed out many miles of tracks and roadbeds. For nearly a month, all supplies had to be brought into San Diego by ship. All communication with areas outside the county was by wireless after all telephone and telegraph lines failed. Almost all water supply systems were damaged, including dams, water mains, pipelines, irrigation ditches, wells, and pumps. Most of the agricultural lands were severely damaged.

The flood of December 1937 was confined to the northern portion of the State. The outstanding characteristic of the flood was the suddenness with which all streams rose simultaneously to excessive heights.

During the period February 27 to March 4, 1938, Southern California was hit by a series of heavy rainstorms that produced flood discharge far in excess of any previously measured. The flood resulted in the loss of 87 lives and over $78 million in damage to homes and public utilities.

Since 1950 California has experienced several floods. Each resulted in extensive loss of human life, livestock, and property. Floods occurred in November-December 1950, December 1955, February-April 1958, October 1962, December 1964, January-February 1969, January 1970, the spring of 1974, September 1976, January-March 1978, and January-February 1980.

The flood of December 1955 was caused by the movement of warm, moist tropical air over the State north of a line drawn from Santa Barbara through Bakersfield to Independence up to the Oregon border. Nearly a million acres were inundated. This included highly developed areas in and near Yuba City, Stockton, Fresno, Visalia, Santa Cruz, Watsonville, Eureka, Klamath, Santa Rosa, Guerneville, and some tracts in the Sacramento-San Joaquin Delta.

The pattern of the December 1964 storm was similar to that in December 1955. Damage from this storm occurred mostly in the North Coastal area where high water, heavy rain, and landslides created one disaster after another. Towns were wiped out; bridges, roads, communications were demolished; and thousands of people were left homeless. In the Central Valley a few bridges were washed out and Hell Hole Dam, which was then under construction on the Rubicon River, failed.

The floods of January-February 1969 resulted from statewide precipitation ranging from twice-normal in the north to almost six-times-normal in the South Coastal area. The South Coastal area experienced flooding almost as great as that of 1938. Property damage was extensive in Ventura, Los Angeles, Orange, San Benardino, and Riverside Counties. Damage resulted from erosion in canyons, mudslides in foothill communities, and inundation in low flatland areas.

The flood in the Sacramento River basin caused by the January 1970 storms was the third most destructive in recorded flood history for this area. Damage was estimated at $28,500,000, and approximately 223 000 hectares (550,000 acres) were inundated. Only the floods of 1955 and December 1964-January 1965 caused more damage.

The hurricane which drenched Southern California in September 1976 may have hit Imperial County the hardest of all. Catastrophic floods occurred in the desert town of Ocotillo, near the Mexican border. The community is located near the mouth of the In-Ko-Pa Gorge along Myer Creek. A flood crest of about 9 metres (30 feet) in the gorge swept down on the town. Witnesses reported that a wall of water about 0.8 kilometres (one-half-mile) wide and 1.2 to 1.8 metres (4 to 6 feet) high swept through Ocotillo, destroying scores of homes and property, and claiming three lives. Total damage in Imperial County was estimated at $25.9 million, while Riverside County suffered losses estimated at $18.9 million, and San Bernardino County and San Diego County suffered losses estimated at $4.37 million and $1.4 million, respectively.

The floods of January-February 1980 resulted from a series of warm, tropical storms that produced excessive amounts of rainfall statewide. In the South Coastal area property damage was extensive in Los Angeles, Orange, Riverside, San Bernardino, San Diego, Santa Barbara, and Ventura Counties. In the northern part of the State, a combination of high tides, high winds, and floodwaters caused the worst damage in the Sacramento-San Joaquin Delta in 25 years.

Flood Frequency and Magnitude

Flood events are usually described either with reference to their actual size and impact or by the frequency in which they can be expected to occur. Many of these definitions and approaches have been developed by the U. S. Army Corps of Engineers.

Probable Maximum Flood -- The flood discharge that may be expected from the most severe combination of critical meteorological and hydrological conditions that are possible in the region. As used by the Corps of Engineers, Probable Maximum Floods are used to design spillways and outlet facilities for dams, a case where it is desirable to provide virtually complete security of the structure from potential floods.

Standard Project Flood -- As used by the Corps of Engineers, a flood that may be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographic areas in which the drainage is located.

Capital Storm -- A four-day storm, with maximum rainfall quantities occurring on the fourth day of the storm. The Los Angeles County Flood Control District applies Capital Flood hydrology to determine design quantities for major channel systems and flood regulating or retention structures. The Capital Flood hydrology is based on a synthetic storm constructed from 50-year frequency rainfall values and patterned after rainfall events commonly observed during major extratropical storms in the Los Angeles region. While it is difficult to assign a recurrence interval, it is generally something like once in 250 years.

Intermediate Regional Flood -- A floodflow which, on the average, is equaled or exceeded once in 100 years, although the flood may occur in any year. A flood of this size is also referred to as a One-Percent Flood Event.

Two-Percent Flood Event -- A floodflow which, on the average, is equaled or exceeded once in 50 years.

Ten-Percent Flood Event -- A floodflow which, on the average, is equaled or exceeded once in 10 years.

Return Period -- Another way of describing flood frequency. A one-percent flood event is one that has 1 chance in 100 of being equaled or exceeded in any one year. Statistically, a one-percent flood is a 1-in-100 year flood, or has a return period of 100 years.

Design Flood -- The flood magnitude for which a specific project was designed.

The magnitude of a flood of a specific frequency is determined statistically where adequate streamflow records are available. Various analytical techniques are used. For example, the greatest floodflow of each year is selected and the flows are ranked in order of magnitude. The plotting of these values on probability graph paper produces a plot of magnitude of flood versus frequency. The one-percent flood event, or once-in-100-year event, can then be determined from the graph. A recommended procedure is described in "Guidelines for Determining Flood Flow Frequency" (Bulletin 17A, 1977, Corps of Engineers), U. S. Government.

Where streamflow records are not available, various techniques can be used to estimate flood frequencies. One method involves developing a magnitude versus frequency graph for a nearby similar watershed and "translating" the results to the watershed or stream where the information is needed.

The Standard Project Flood is determined by selecting an intense precipitation event which has occurred in a meteorologically similar area, and applying the resulting rainfall to a wet watershed. Soil water conditions are usually assumed to be in a state of

Folsom Reservoir - American River

Sacramento River
Sacramento-San Joaquin Delta

Sacramento Weir - Sacramento River

RESERVOIRS, LEVEES, AND BYPASSES, costing billions to construct and maintain, are the chief structures Californians have built to protect themselves from flooding. Over-reliance on these structures without sensible management of flood plains can result in a continuing flood danger of immense proportions.

saturation and reservoirs in the basin are assumed to be full. The water is then routed through the stream system mathematically, graphically, or by use of a watershed model to determine the streamflow magnitude and the area of inundation which would result.

The magnitude and frequency of floods from gaged and ungaged drainage areas for any recurrence interval from 2- to 100-year can be estimated by the method presented in the U. S. Geological Survey-Water Resources Investigation 77-21, entitled "Magnitude and Frequency of Floods in California".

Recent studies by the Federal Emergency Management Agency indicate that flood damage - loss of life and destruction of property - will continue to take place, unless relocation efforts are greatly increased.

There are two basic approaches to reducing flood damage: the nonstructural approach (keeping people away from the water) and the structural approach (keeping the water away from people). The most comprehensive nonstructural approach is the regulation of flood plains (nonstructural flood management), allowing storm water to use natural stream channels and adjoining flood plains without causing injury to people and damage to property. The structural approach attempts to manage the storm water through projects such as reservoirs, levees, and bypasses. Although both approaches have been used in California, to date the greater emphasis has been placed on structural solutions.

In addition to nonstructural flood management, there are other techniques for reducing flood damage that could be incorporated into a comprehensive flood plain management program. These include floodproofing and flood forecasting, which can be useful in mitigating damage, operating flood protection projects and evacuating people and property from flood plains.

Structural Methods and Programs

Structural facilities are used to reduce, retard, or prevent the flow of storm waters, mud, and other debris on natural flood plains and to convey storm and flood waters past areas to be protected. The principal types of structural facilities, which are generally combined to form a flood protection project, are reservoirs, levees, bypasses, and channel modifications. Structural features are designed to provide protection against a specific design flood. Often they can be incorporated at a relatively low cost as part of a multipurpose project, e.g., flood storage reservations in a major multipurpose reservoir. When the design flood is exceeded, there can be loss of life and damage to property, particularly with levees where structural failures can occur.

Reservoirs

A function of about 70 of the over 1,144 major reservoirs in California is flood storage. Flood storage may be the only purpose, or one of several purposes, for which reservoir space is set aside to store waters which, if unchecked, could contribute to downstream floodflows.

The principal benefit derived from the operation of large flood storage reservoirs is the substantial reduction in peak flow downstream. When a large storm occurs above the reservoir, the storm waters are captured in the flood storage space, and, at the same time, releases from the reservoir are increased to move the storm waters downstream without exceeding the downstream channel capacity. If the storm and resulting high water are at or below the design flood, this operation will result in maintaining downstream flows at or below channel capacity. Sustained relatively high flows must be released from the reservoir for some time after the peak inflow to evacuate water from the flood storage space to make room for the next storm flow.

The delay of the flood crest provided by the flood storage reservoir may range between 6 hours and 3-1/2 days and generally allows the reduced flood crest to pass through the downstream system after local peak inflow to the downstream channel has passed. Evacuation of storm waters from the reservoir may then be accomplished by releases which do not exceed the downstream channel capacity. The effectiveness of such an operation

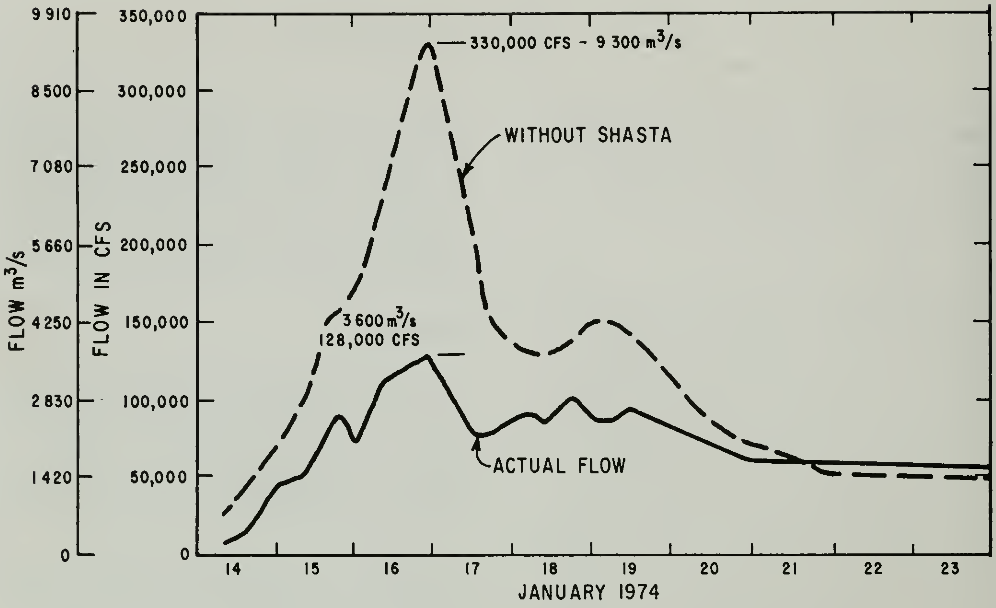


Figure 8. SACRAMENTO RIVER AT BEND BRIDGE

at Shasta Dam, for example, is illustrated (see Fig. 8) by the impact at Bend Bridge downstream from the reservoir on the Sacramento River during the January 1974 flood. Without Shasta the peak flow would have been 9 300 cubic metres per second (cms) or (330,000 cubic feet per second [cfs]). With Shasta in operation, the actual peak flow at Bend Bridge was 3 600 cms (128,000 cfs).

In the design of reservoirs, the flood storage space needed is determined by the available downstream channel capacity and the magnitude of the design flood which is to be mitigated. The flood storage space in most of California's existing large multipurpose reservoirs was paid for by the Federal Government even when constructed by State or local governments. For example, 22 percent of the cost of construction of Oroville Dam on the Feather River was paid through federal funding. As a result, the reservoir must be operated for flood storage in accordance with regulations prescribed by the U. S. Army Corps of Engineers.

The flood protection operation requirements and limitations on storage are specified by a storage (operation) diagram or "Rule Curve" as shown in Figure 9 for Folsom Reservoir on the American River. Consideration in specifying these requirements is given to the probability of various magnitude storm flows during each given month of the year.

Early in the fall there is little chance of a major flood in California because of dry conditions of the soil in the watershed and the low probability that a major storm will occur. Therefore, there is no flood reservation required until October 1, when the flood season starts. The reservation amount increases to maximum design reservation about the first of November.

Beginning April 1, when the chance of major rain-flood-producing storms in California becomes less, the flood reservation requirement is reduced gradually to become zero about the first of June. This allows the reservoir to store late spring snowmelt runoff. In areas where large snowpacks accumulate, it may be necessary to extend flood reservation later into the year. A nearly full or full reservoir is then available for water supply during the summer and fall.

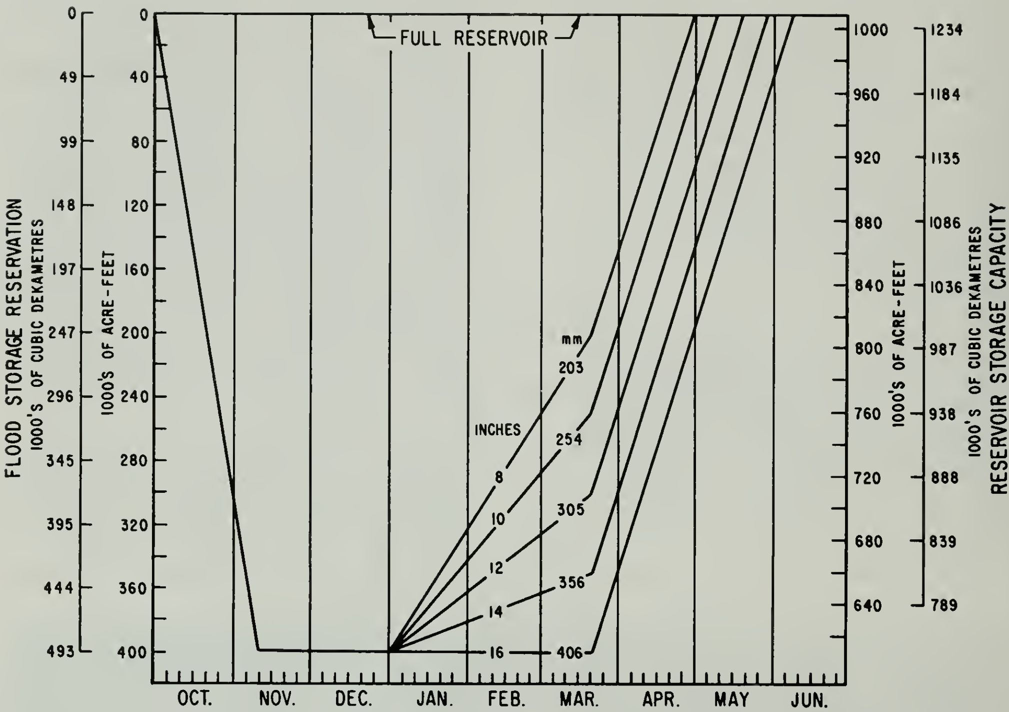
In addition to flood storage limitations, operational requirements are specified for a maximum size and a maximum rate of change for reservoir releases. The official regulations, however, are subject to temporary modification during emergencies by approval of the District Engineer, U. S. Army Corps of Engineers.

The operation of reservoirs for flood protection is not without problems, and occasionally the reservoirs are not operated according to the published rule curve requirements. The use of flood storage space for other purposes served by the reservoir, such as power generation or conservation storage, negates the benefits derived from flood protection. When heavy storm runoff fills the reservoir's flood storage space, it is tempting to release the water slowly through the power turbines rather than to quickly evacuate the space by additional controlled releases which may be called for by standard operating procedures. This practice could defeat the flood protection operation.

During the spring months of March through June, it is again tempting to store water above the level allowed by the flood storage parameter*. Unless

* A parameter is a constant value that determines the operation or characteristics of a system and is used as a fixed limit or guideline.

SHASTA DAM AND LAKE, with a capacity of 5.6 million cubic dekametres (4.5 million acre-feet) and a flood storage reservation of 1.6 million cubic dekametres (1.3 million acre-feet), is the largest reservoir in California and one of the largest ever built anywhere by the U. S. Water and Power Resources Service. Shasta is the keystone of the Central Valley Project.



NOTES

1. Rainflood parameters define the flood storage space reservation on any given day and are computed daily from the weighted accumulation of seasonal basin mean precipitation by adding the current day's precipitation in inches to 97% of the parameter computed the preceding day. Sample computation of required space is shown below.

SAMPLE COMPUTATION OF REQUIRED STORAGE

DATE	PRECIP. INCHES	PREVIOUS DAYS WEIGHTED PRECIP. x 0.97	WEIGHTED PRECIP. ACCUMULATION	REQUIRED FLOOD STORAGE, AF
7 Nov	0.0	0.0	0.00	370,000
8 Nov	1.0	0.0 x .97 = 0.0	1.00	380,000
9 Nov	1.5	1.0 x .97 = .97	2.47	390,000
10 Nov	3.0	2.47 x .97 = 2.396	5.40	400,000
11 Nov	0.0	5.40 x .97 = 5.238	5.24	400,000
12 Nov	0.0	5.24 x .97 = 5.081	5.08	400,000
			7.0	400,000
30 Dec	2.0	7.0 x .97 = 6.790	8.79	400,000
31 Dec	1.0	8.79 x .97 = 8.526	9.53	400,000
1 Jan	1.0	9.53 x .97 = 9.244	10.24	398,200
2 Jan	0.0	10.24 x .97 = 9.932	9.93	398.200
3 Jan	0.0	9.93 x .97 = 9.634	9.63	394,000
4 Jan	0.0	9.63 x .97 = 9.341	9.34	391,700

2. Except when larger releases are required by the emergency spillway release diagram currently in force (File No. AM-1-26-585), water stored within the flood storage reservation, defined hereon, shall be released as rapidly as possible subject to the following conditions:

   a. Outflows of the tailwater of Nimbus Dam in excess of power plant capacity may not exceed the lesser of 115,000 c.f.s. or the maximum rate of inflow to Folsom Lake experienced during the current flood event.

   b. Between 6 November and 1 December, the maximum release may be limited to the Folsom power plant capacity if less than 40,000 acre feet of water is stored in the flood storage space.

   c. Releases will not be increased more than 15,000 c.f.s. or decreased more than 10,000 c.f.s. during any 2-hour period.

Figure 9. FLOOD STORAGE CRITERIA, FOLSOM LAKE

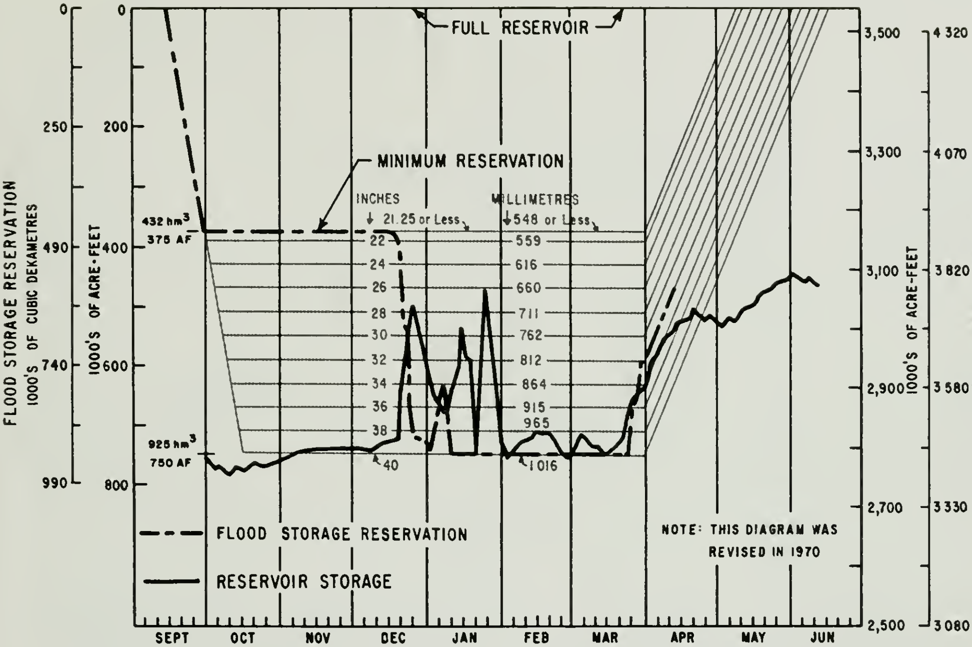


Figure 10. OROVILLE RESERVOIR FLOOD STORAGE OPERATION

the snowpack is large, there may not be enough spring inflow to fill the reservoir before the summer use season. This is exemplified by the 1970 operation depicted in Figure 10, wherein Oroville Reservoir received two very large inflows in December and January. The flood storage space was emptied each time, but then there was not enough precipitation in February and March to provide a snowpack to fill the reservoir for summer irrigation and increased hydropower production.

In trying to balance flood storage reservation and potential filling of the reservoir, a critical situation may occasionally develop when a major storm in late spring occurs. During 1974, the energy crisis prompted major emphasis on saving water to increase hydropower generation. Unusually large storms in late March nearly filled the available flood storage space in Shasta Reservoir, bringing the reservoir to its capacity of 5.6 million cubic dekametres (4.55 million acre-feet). As a result, the Water and Power Resources Service (formerly Bureau of Reclamation) released the full 1-in-100-year design flow of 2 200 cms (79,000 cfs) from the reservoir.

Another problem which has arisen with the operation of some reservoirs is encroachment along the streams below the reservoirs. This occurs when long periods elapse between high releases. Developments are constructed closer and closer to the stream until a condition is reached where design releases would cause significant damage. This generally results in pressure to reduce the design release. Furthermore, releases

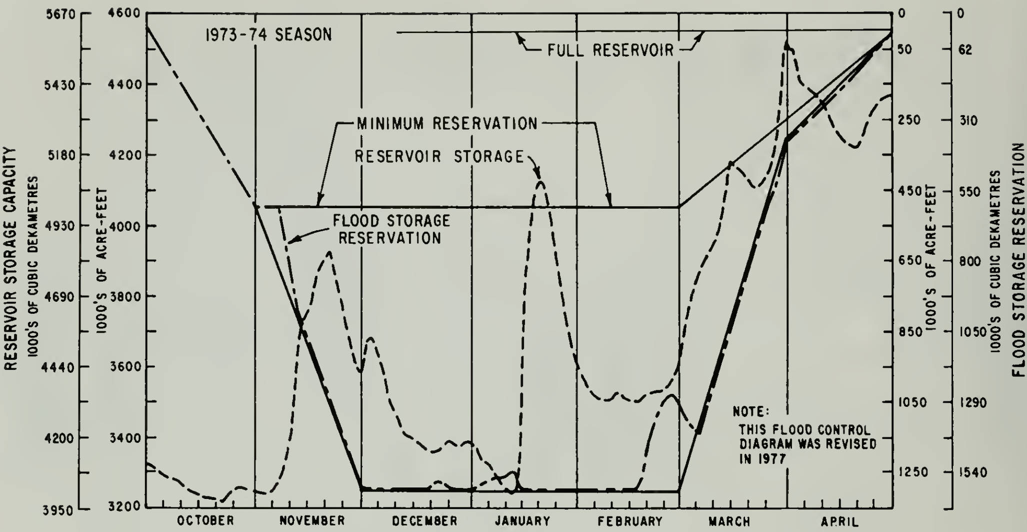


Figure 11. SHASTA LAKE FLOOD STORAGE OPERATION

may have to be delayed to give people time to evacuate.

This problem can be solved in future projects by making it a requirement to obtain control of the lands needed to pass design releases. For existing projects, warning markers should be placed on lands which would be inundated by design releases, and such locations should be recorded in county records. Diligence is required to keep the signs in place, and they are only effective if there are land use regulations. The design releases should be made when required.

Despite the many factors involved during a reservoir emergency, critical operations in recent years have often been excellent. The reservoir operation of Shasta and the downstream flow at Bend Bridge on the Sacramento River during January 1974, as shown in Figures 11 and 12, demonstrate this vividly. On January 16, when local inflow at Bend Bridge was peaking, the release to the river from the reservoir was brought to a minimum, so as to minimize peak downstream floodflows as much as possible. As soon as the downstream peak passed, releases were increased to evacuate reservoir space for future storms and snowmelt. This type of operation is assisted by the Federal-State River Forecast Center in Sacramento, which provides up-to-the-minute forecasts of reservoir inflow and downstream local flows from which emergency operational decisions can be based.

With experience and hindsight, there is usually some way in which a reservoir emergency operation might have been improved. As long as reservoirs are operated for multiple purposes (water supply, energy generation, flood protection, etc.), there will be conflicts. Decisions made during emergencies are based on information and probabilities determined at the time of the emergency.

Some reservoirs that are not specifically designed to provide flood protection can have an incidental role in reducing flood peaks. This occurs when

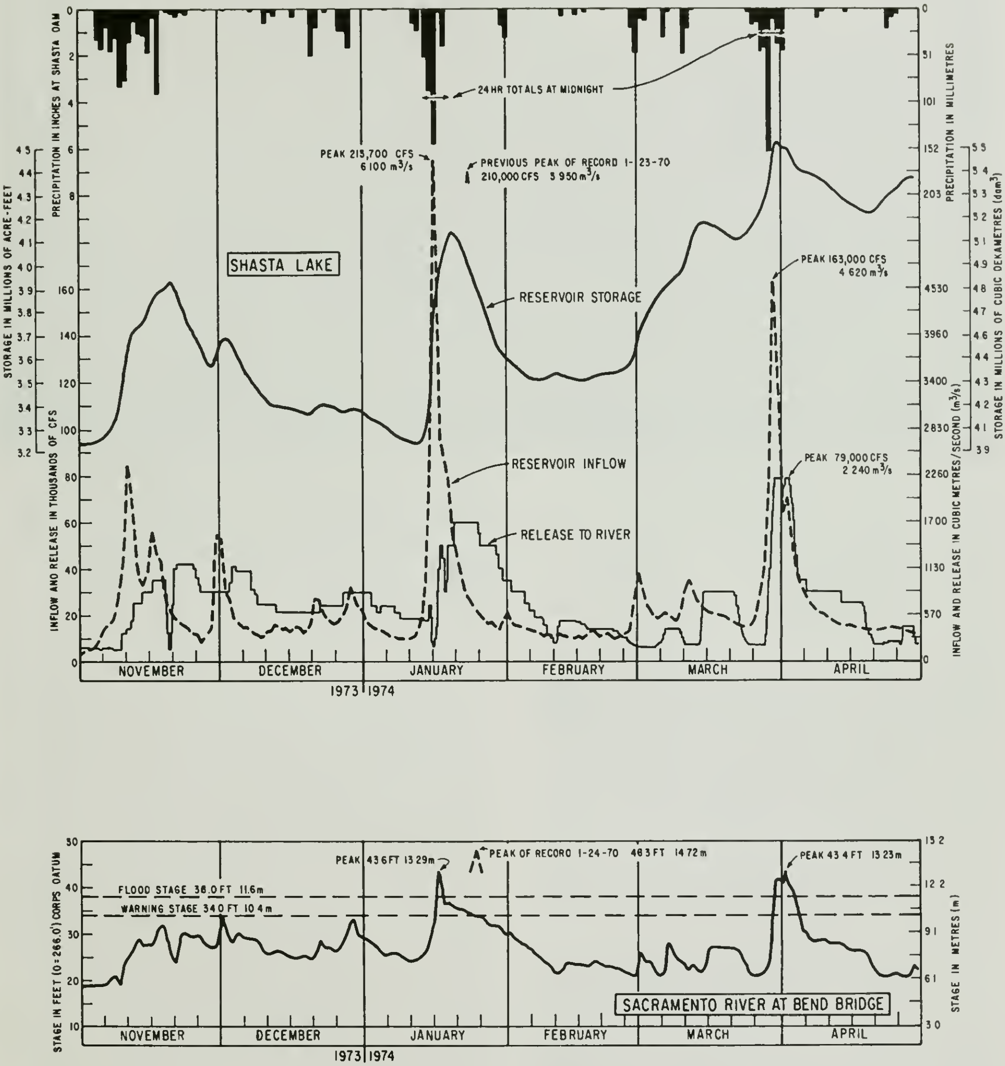


Figure 12. HYDROGRAPHS OF SHASTA LAKE AND SACRAMENTO RIVER

the reservoir is not full at the time of a storm or the water is stored temporarily. The outflow over the spillway is at all times less than the inflow until after the peak inflow has occurred. An example of such a reduction in peak flow by a reservoir without a flood storage reservation was at Lake Berryessa on Putah Creek in January 1970. The peak inflow was about 620 cms (22,000 cfs), the outflow was about 460 cms (16,300 cfs); this provided an incidental flood storage benefit and a reduction in peak flow.

Beneficial Uses of Reservoirs

Flood storage facilities can contribute to the recharge of ground water basins and should be designed to do so when feasible. The Santa Clara Valley Water District regulates the ground water by making releases from its reservoirs into gravelly streambeds and percolation ponds to recharge ground water. Stream channels are generally soft-bottomed with retarding structures added to increase percolation. The Santa Clara Valley Water District provides recreational areas around the percolation ponds, which are designed with rounded contours and islands in the center, both for aesthetics and for increased percolation capacity. In the Los Angeles area, flood storage reservoirs may release captured storm flows to percolate through spreading grounds and streambed sand and gravel into the ground water system. The Los Angeles County Flood Control District has installed special inflatable dams in gravelly sections of some of the area's stream channels to retard flows from storms and allow additional runoff to percolate into ground water storage to mitigate for the many concrete channels. Similarly, spreading grounds are used extensively in the San Joaquin and Tulare Lake basins. On the average, more than 407 000 cubic dekametres (330,000 acre-feet) of water, which includes some imported and reclaimed water, is added each year to the underground systems in Los Angeles County. This kind of percolation cannot be accomplished in the many concrete channels in Los Angeles County where, if the storm flow exceeds the capacity of perimeter reservoirs, it flows into the sea. This happens in many channels in the Los Angeles Area, most recently during the heavy rainstorms of 1978.

Reservoirs also serve many recreational needs for fishing, boating, swimming, water sports, hiking, camping, and related pursuits. They may also provide wildlife habitat for fish, waterfowl, and water for these forms of wildlife.

Local Protection Works

Major flood storage reservoirs can protect broad areas and produce benefits hundreds of kilometres from the damsite. Smaller reservoirs can protect a local area. In most situations, however, the benefits are achieved through a combination of reservoir storage and other local protection works. Local protection works include the smaller reservoirs, levees, bypass systems, and channel modifications.

Levees. Levees are the basic method of providing local flood protection in the United States. From the earliest French settlers along the Lower Mississippi to the forty-niners-turned-farmers in the Sacramento Valley, people have tried to protect themselves from floods by constructing levees. These earth embankments placed parallel to a stream along one or both sides contain storm waters and protect surrounding lands from inundation. A levee acts like a dam to hold back the weight of the water against it on the streamside and at the same time must withstand the erosive force of water flowing along its face.

Levees may be placed close to the edge of a stream channel or may enclose a portion of the flood plain by being set back away from the stream. The side slopes of a levee may be quite steep, 2 to 1, or quite flat, up to 8 to 1. Steeper levee side slopes and those close to the channel where velocities

WHERE BERMS REMAIN to afford protection to levees, trees and wild growth can be allowed to provide environmental and aesthetic values. Contrast the two levees in this photo. On the right the entire berm has been eroded away, leaving no opportunity for wild growth; on the left the remaining berm supports a good start of vegetation. Innovative approaches are needed not only to save berms but also to find ways to encourage growth when berms are gone.

are higher may require protection from erosion by placement of rock or other forms of bank protection. If space is limited, a special levee section called a floodwall may be used. A floodwall may be constructed of timber, stone, masonry, or reinforced concrete.

Levees are generally the least costly method of providing flood protection, except in highly developed urban areas. They are also the method with the greatest potential risk of failure. As long as the design flood is not exceeded and levees are properly maintained, levees effectively contain storm waters. But levee failures do occur. Such failures can be caused by high waters overtopping a levee or eroding a portion of a levee, or by excessive seepage through a levee. Also, very large trees can be uprooted, leaving excessive voids in a levee, which can accelerate levee destruction. An initial small breach can lead to great damage and loss. Problems such as these are anticipated during a storm, and the agency responsible for a levee patrols it and takes the necessary "flood fighting" actions. There can also be unanticipated failures. An example of unexpected levee failure was that of the Brannan-Andrus levee on June 21, 1972, when flow in the San Joaquin River was relatively low and tides in the Delta were moderate.

A special levee problem exists in California's Sacramento-San Joaquin Delta. Thousands of acres of the Delta lowlands, many of which are as much as 5 metres (15 feet) below sea level, are protected from floods and high tides by a vast network of levees totaling about 1 770 kilometres (1,100 miles) in length. Some of these levees are over 100 years old. Water is against the Delta levees at all times, in contrast with most levees that have water against them only a small fraction of the time. Much of the Delta is composed of organic peat material, which is ideal for agriculture purposes, but is poor foundation material for levees and structures. The peat has an average depth of about 6 metres (20 feet) with a maximum depth of over 15 metres (50 feet). The organic soil is constantly decomposing and subsiding, causing flood problems to be compounded.

Seventy-five percent of the levees in the Delta were privately constructed and are maintained either by the landowners or local agencies. The cost of maintenance is funded entirely, or in major part, by the landowners who many times have minimized maintenance work. This results in the maintenance rarely meeting any set of uniform standards. The other 25 percent were constructed or improved by the Federal Government and maintenance is provided to its standards.

Following the Sherman Island levee failure in 1969, the California Legislature, under Senate Concurrent Resolution No. 151, directed the Department of Water Resources to study the problems related to Delta levees and recommend a course of action to implement feasible solutions to the problems. Four alternatives were developed and presented in Bulletin 192, entitled "Plan for Improvement of the Delta Levees" (May 1975). These alternatives were: (1) no improvements, (2) extensive levee improvements, (3) moderate levee improvements, and (4) polders (master levee systems around groups of islands).

As an interim means to assist the local agencies, Senate Bill 541 (Way) was enacted as Chapter 717 of the Statutes of 1973. The bill provides for State reimbursement of a portion of the maintenance costs for nonproject levees.

Under any plan of improvement for the Delta levees, maintenance standards should be established and the improved levees should be maintained to these standards. The State Reclamation Board and the Department of Water Resources should develop proposed levee maintenance standards for multiple-purpose levees for adoption by the Corps of Engineers to supplement existing federal flood control maintenance standards. The Department of Water Resources should inspect the maintenance work performed on the improved levees to ensure compliance with the required standards. This would ensure that adequate levee maintenance would be performed on all improved levees.

In furtherance of this procedure Senate Bill 1390, enacted as Chapter 1302 of the Statutes of 1976, added Sections 12227 and 12228 to the Water Code. These sections cited as the "Nejedly-Mobley Act" provided State financial assistance to local agencies for the costs of maintaining local Delta levees. The Reclamation Board, in cooperation with the Department of Water Resources, administered this program which was in effect from fiscal year 1976/77 through fiscal year 1978/79. Each year, about $200,000 was disbursed to local agencies that participated on a voluntary basis for the rehabilitation and maintenance costs of critical levees. This program was terminated in 1979 when statewide economy moves were necessary.

The overall safety of Delta levees will continue to decline with failure of some island levees until an overall comprehensive rehabilitation project can be formulated and implemented. This is now under way.

Studies on ways to improve the Delta levees required by the Nejedly-Mobley Act are being conducted jointly by the Department of Water Resources and the Corps of Engineers. The Corps is providing design cost estimates for various levee rehabilitation alternatives, assessing the economics of these alternatives and their environmental effects. In addition, the Department is making a recreational use survey of the Delta, studying soil subsidence, and evaluating plant material in relation to levee erosion control. The Department findings were scheduled to be reported to the Legislature during early 1980.

The Corps has informed the Department that its portion of the study will not be completed on schedule. Therefore, it will be necessary to delay the completion of the Department's final report to May 1, 1982.

Bypass Systems. A bypass is an auxiliary channel used to pass floodwaters. Bypass systems are used in flood protection projects when the potential high flow is larger than the capacity of the existing river channel and a reasonable amount of leveed flood plain. This situation sometimes occurs when the natural river channel has built up its own levees through frequent overflows, leaving the natural channel relatively small. A comparable situation exists when development near the stream channel makes it economically prohibitive to set levees back from the stream channel to provide sufficient flowage area to pass the design flood.

The bypass is usually leveed in whole or in part. Its major purpose is to carry enough floodwater so that the normal stream channel capacity is not exceeded. Bypass systems may consist only of a basic diversion channel such as that in the Chico area of Butte County where water from Little Chico Creek above the city is carried to Butte Creek south of town, avoiding flooding of the city. This bypass is included in the system shown on Figure 13.

Figure 13. BYPASS SYSTEMS IN SACRAMENTO VALLEY

Larger bypass systems may be as complicated as that in the Sacramento River Flood Control Project, also shown on Figure 13. As the Sacramento River flows southward from Shasta Dam near Redding, natural overflow areas and two fixed weirs, Moulton and Colusa, permit floodwater to escape from the river into the Butte Basin. This basin is a natural flowage area that has not been drained and developed as have similar basins to the west and south. Waters in the Butte Basin move into the upstream end of the Sutter Bypass. At Tisdale Weir, additional water can be diverted from the Sacramento River directly into the Sutter Bypass. The Feather River system, which drains the east side of the Sacramento Valley, enters the Sutter Bypass directly. The Sutter Bypass and the Sacramento River join just above the Fremont Weir. This weir divides the joint flow of the river-bypass system, limiting flow into the Sacramento River channel to its capacity and permitting the excess flow to cross the river and enter the Yolo Bypass. Near Sacramento, the Sacramento Weir provides a final escape route from the river to the Yolo Bypass. It is the only weir in the system with gates which can be operated to vary the ratio of water leaving the river and the amount staying in the river. This enables management of water levels in the river at Sacramento, thereby giving added protection to the city and adjacent areas. The overflow area is used for agriculture during the summer and fall months and is valuable wetland during the flood season, supporting a significant waterfowl population.

While the Sacramento River Flood Control Project presents the best example of the use of bypass systems, this approach to handling floodflows has also been used successfully in the San Joaquin Valley.

Beneficial Uses of Bypass Systems

Bypass systems are needed only during major floods, and lands reserved for this purpose can be used for agriculture, wildlife management, recreation, or other compatible uses at other times. Bypass lands may be owned by the public and leased back to private users, or a flowage easement may be obtained for the project with the lands in private ownership. The more restrictive the easement is, the more it will cost. The experience of the Reclamation Board in the Central Valley bypass systems has been that, in order to obtain an easement adequate for desired management, costs can approach the full value of the land. Outright purchase of flood-prone areas and dedication of these lands to safe public uses can be used as a means of flood damage prevention.

On occasion, water transport facilities can be turned into virtual bypasses. For instance, during periods of excessive high flows, the Kern River Intertie can be used to divert excess water from the Kern River system into the California Aqueduct. This intertie enables the aqueduct to act as a bypass for the Kern River, relieving the Tulare Lake area of excessive volumes of water.

With almost 300 percent of normal runoff predicted for the Kern River in 1978, a great deal of attention was focused on the intertie. Early operation of it (through May) was very effective in removing 220 000 cubic dekametres (178,000 acre-feet) of excess snowmelt water.

In developed areas, high flow bypasses such as storm drains and open channels can divert storm flows from natural watercourses; such systems can provide a safe, scenic brook for low flows, which enhances property values and preserves natural and environmental amenities. High flow bypasses have been used by the Santa Clara Valley Water District for its Adobe Creek Project and are proposed by the Corps of Engineers for projects on Santa Paula Creek (Ventura County) and Novato Creek (Marin County). In Decision 1460 (1976) of the State Water Resources Control Board, the Los Angeles County Flood Control District was requested to construct a bypass from a storm drain so that low flows would remain in the natural channel of Dry Canyon Creek. This Decision found that elimination of a stream segment serving instream beneficial uses by diversion into a storm drain of non-floodflows was both a waste and an unreasonable method of diversion of water. This Decision has been helpful to many communities and the Department of Fish and Game in maintaining the amenities of natural streams.

Channel Modifications.

Channel modifications[1/] are designed to increase the flow-carrying capacity of a stream. They have traditionally included increases in the width and depth of the stream and the straightening of its alignment. Grouted riprap or concrete linings are generally part of channel modifications.

Although considerably more expensive than levees, channel modifications have been constructed extensively in California. In the last 40 years, government agencies have channelized nearly 1 600 kilometres (1,000 miles) of California streams.

Stream Miles Channelized in California	
1941-50	160 kilometres (100 miles)
1951-60	400 kilometres (250 miles)
1961-70	800 kilometres (500 miles)
1971-76	160 kilometres (100 miles)

Channelization has been particularly common in urban areas where the high value and limited availability of land have precluded other methods of flood protection. It has been very effective in preventing flood damage. During the 1969 floods, the Los Angeles County Drainage Area Project prevented

1/ Channel modifications, as used herein, is synonymous with the term Channel Improvements as used by federal agencies.

BEFORE AND AFTER photographs of Tamalpais Creek, in Marin County, demonstrate that channel modifications can be made without entirely destroying the beauty of the channel. In this stretch of creek, the channel was curved, first right, then left, to save oak trees. (U. S. Army Corps of Engineers, San Francisco District, Photos)

$1 billion in damage. The capital cost of the project was $400 million. When the capacity of a modified channel is exceeded, and there are no adjacent levees, there will be flood damage. This damage will not generally be of the catastrophic nature which can result from a levee failure.

Environmental Considerations

Channelization has become an increasingly controversial structural measure because of associated environmental and social costs. Channel modification projects sometimes require lining a river with concrete and nearly always involve some physical change to the river itself, having a disruptive impact on the natural characteristics of a stream. In developed areas, projects can still be designed to better fit into the environment, as does the Tamalpais Creek Project in Marin County (Corps of Engineers).

If all benefits and costs are recognized, other management options may turn out to be more beneficial. For example, floodway preservation provides many advantages, such as protecting wetlands and riparian vegetation and preserving open space which can support many land uses compatible with flooding.

Where channel modifications are necessary -- often in urban situations -- increased environmental awareness is leading to channel modification proposals which are more compatible with their surroundings and provide for some open space preservation. For example, the Corps' flood protection project along the coastal reach of Alameda Creek consists of levees, channel enlargement, bank protection works, marsh preservation, and a recreational trail system. To meet the social and environmental needs of the rapidly increasing population in the upper Alameda Creek basin, local planning agencies and the Corps have incorporated into the project protection of natural resources and provisions for recreation. Some examples of environmental considerations that have been given to channel modification projects are listed on page 46.

UPSTREAM VIEW of Los Angeles River with the Rio Hondo Channel entering from right. "Concrete river" protects vast industrial developments. (Is it too late to turn river into a greenbelt?) (Los Angeles County Flood Control District Photo)

UNATTRACTIVE is what some people call the concrete-lined Los Angeles River, seen above in its normal dry state. Besides being aesthetically displeasing to some, the all-concrete channelization results in loss of percolation and habitat. However, the section is efficient and provides the flood protection desired. (Los Angeles County Flood Control District Photo)

Projects	Environmental Considerations
<u>Orange County</u>	
Santiago Creek Channel	Park Area including golf courses and riding trails.
Trabuco Creek Channel	Greenbelt areas and structural treatment (stepped side slope).
Brea Creek Channel	Concrete channel with landscaping designed to screen it from roadway. Also has a greenbelt area golf course.
San Diego Creek Channel	San Joaquin Marsh Wildlife Refuge.
<u>Ventura County</u>	
Potrero Creek Channel	Converted into a public park in the community of Westlake.
Kadota Fig Drain	Grass planted in an unmodified channel through a subdivision of Simi Valley.
<u>Los Angeles County</u>	
Wilmington Drain Project near Harbor Lake	Bixby Slough Channel. Consists of marshland for nature preserve. Includes trails, landscaping, and observation decks.
<u>Santa Clara County</u>	
Alamitos Creek Calero Creek Santa Teresa Creek	The halting of quarry operations and the improvement of wildlife and recreational potential of ponded areas.
<u>Alameda County</u>	
Alameda Creek	Freshwater marshes and ponding areas at Coyote Hills Regional Park have been preserved.

Some of these projects are illustrated in the section on exemplary projects.

On the Sacramento River upstream from the levees of the Sacramento River Flood Control Project, the Corps of Engineers has a channel modification project which is designed to reduce or control erosion. This project, the Chico Landing to Red Bluff Bank Protection Project, provides for the placement of rock revetments to stop bank erosion. The State Reclamation Board has recognized the adverse environmental impacts of these rock revetments and has implemented a mitigation plan immediately landward from these revetments.

WALNUT CREEK CHANNEL in the San Francisco Bay Area demonstrates the integration of a high capacity concrete-lined channel into an urban environment. The transition to a trapezoidal section with riprap lining, shown here, demonstrates a less unpleasant type of channel which can be employed where more land is available. (U. S. Army Corps of Engineers, San Francisco District, photo)

The Board has mandated that landowners dedicate to the State a conservation easement to preserve riparian vegetation on the banks behind the rock revetments.

Federal Programs

The federal role in flood management evolved from the debate on "internal modifications" which began in the earliest years of the Republic. In 1824, Congress voted funds for navigation work on the Ohio River.

In California, the gold miners turned to hydraulic mining in the early 1850s. This method of mining was used extensively for some 25 years. Mining debris that was washed down from the foothills clogged the valley stream channels and caused runoff from even minor storms to overflow onto the newly developed farmland. From 1876 through 1880, suits were brought between miners and farmers, hearings were held by the U. S. Public Lands Commission, and charges and countercharges were made. Deposit of debris from hydraulic mining into a flowing stream was enjoined in 1884 in the historic case of Wooduff v. North Bloomfield Gravel Mining Co. (18F-753). In 1880, the Legislature passed an act to promote drainage (California Statute 1880, Chapter 117) and provided the establishment of drainage districts.

Within months, the U. S. Secretary of War asked the Corps of Engineers to examine the problem and design proposed public works. Establishment of the California Debris Commission in 1893 by the United States (Act of March 1, 1893, Chapter 183; 27 Stat. 507) put the Corps of Engineers in the flood management picture in California through its responsibility for stream navigation and debris management.

In 1917, the Federal Government directly assumed responsibility for flood protection work on the Sacramento River and, since 1936, for the general flood protection program throughout the United States. The 1936 Flood Control Act (Public Law 738, 74th Congress, 2nd Session; 49 Stats. 1570) established federal policy, which provides:

> "...that it is the sense of Congress that flood control on navigable waters or their tributaries is a proper activity of the Federal Government in cooperation with States, their political subdivision, and localities thereof...."

The federal role in flood protection is still governed by the policies established in this Act.

U. S. Army Corps of Engineers. The Corps of Engineers has the primary responsibility for carrying out federal flood protection policy. It has developed extensive procedures for evaluating flood problems and proposing projects to solve the problems. These procedures do, however, take a considerable amount of time. A major flood protection project, which requires authorization by Congress, usually takes about 15 years from the initial request for a study to the start of construction.

Flood protection projects are generally authorized to provide a specific degree of protection. The degree of protection afforded by a particular project represents the measure of flood severity for which essentially complete elimination of all detrimental flood effects is provided immediately downstream from a reservoir or within the confines of a local protection project. In the design of projects, allowances are made for

STARTING IN THE 1800s, hydraulic mining in California's gold fields swept thousands of tons of sediment into rivers, to clog or make channels more shallow. This increased the likelihood of floods in times of heavy rain or snowmelt. (National Archives Photo, courtesy of U. S. Army Corps of Engineers, Sacramento District) freeboard and channel aggradation. Additional flood protection provided by these allowances is not claimed as part of the degree of protection nor are the benefits claimed for this allowance. While the degree of protection is adequate for reasonable human activity, it is not absolute. There is a reasonable certainty that someday a flood will exceed the protective capacity of a project. If flood plains are to be used at all, this residual risk must be recognized, accepted, and anticipated.

In past years, projects were designed on the basis of economy and the effectiveness of the flood control function alone. Recently, however, the Corps of Engineers has incorporated environmental considerations into its proposals where local interests will support them.

A greatly improved type of flood protection project is now being proposed. Instead of planning single-purpose projects that solve only a given flood problem in the most efficient manner, the Corps of Engineers is also evaluating recreational needs and fish and wildlife preservation and enhancement opportunities. The projects resulting from this expanded approach are being integrated into the environmental setting. Concrete-lined channels are being limited to locations where the erosive force of high-velocity flows must be mitigated or where existing development limits the area of land available for construction of a channel. Projects with unlined bottoms and side slopes have been proposed, and recreational facilities, particularly riding and hiking trails, have been incorporated into the project works.

Major flood protection projects constructed by the Corps of Engineers can use the full range of structural methods described above. There are, however, different degrees of nonfederal participation required for reservoirs and local protection works. The President's Water Policy message of June 1978 recommended the equalization of cost sharing for both nonstructural and structural measures and additional financial participation by State and local governments.

Section 205 of the Flood Control Act of 1948 (Public Law 858, 80th Congress, 2nd Session) authorizes the Secretary of the Army to allot funds under certain conditions for the construction of small flood protection projects without specific authorization by Congress. These projects must be authorized by the Chief of Engineers and coordinated with concerned local interests. The federal cost of a small project is limited to \$2 million unless there has been a recent federally declared flood disaster in the area. In that case, the limit is \$3 million.

Soil Conservation Service. The Soil Conservation Service (SCS) of the U.S. Department of Agriculture administers the 1954 Watershed Protection and Flood Prevention Act (Public Law 566). Service policy originally provided flood damage prevention projects for primarily agricultural lands, but it has now been changed to include primarily urban lands.

Under the SCS's policy of multipurpose planning, local sponsoring organizations are encouraged to consider other water resource problems and needs in addition to flood protection. The act provides for cost sharing on other resource improvements, such as irrigation, drainage, recreation, and fish and wildlife enhancement. Watershed protection in upland areas is considered to be an important part of a Public Law 566 project.

While the act does not set a maximum cost limit, a practical limit is about \$10 million, which might be exceeded in special cases. Projects with federal construction costs under \$1 million can be authorized by the SCS State Conservationist, but those exceeding this amount must be authorized by congressional committees.

IN HILLY TERRAIN, the agriculture sector may apply watershed treatment techniques to minimize damage during heavy rainfall from sheet erosion and gully formation, which remove valuable soil from its natural location. The treatment, generally, consists of crop rotation, terracing (as seen here), contour stripping, seeding, and reforestation. (U. S. Soil Conservation Service Photo)

Recent amendments to the Public Law 566 Act provide cost sharing on nonstructural measures in flood plain areas. The cost sharing rate is 80 percent federal and 20 percent local for the following types of measures:

- Acquisition of land rights
- Floodproofing existing structures
- Flood warning systems
- Relocation of people and/or property

These types of measures must have a favorable benefit-cost ratio.

The SCS also administers the Flood Prevention Program (Public Law 534). Only two projects, the Los Angeles and Santa Ynez Flood Prevention Projects, were authorized in California under this program. The SCS is responsible for structural measures in the downstream flood plain areas, and the U. S. Forest Service is responsible for upstream watershed protection work, including fire management measures. No new projects will be approved and this program will be phased out as construction work on these two authorized projects is completed.

Water and Power Resources Service

The Water and Power Resources Service of the U. S. Department of the Interior does not have a direct flood management responsibility. It does, however, frequently include flood storage as a project purpose in its multiple-purpose reservoirs. Shasta is the outstanding example of this in California. When flood storage is included in a Service reservoir, the Corps of Engineers issues regulations for the operation of the flood storage space.

State Programs

The State Government became involved in flood matters with the enactment of an act to promote drainage in 1880. However, although independent flood protection efforts by State Government have had some success since the federal Debris Commission was created in 1883, California's role over the years has been largely in suport of federal efforts. This supportive relationship was emphasized in 1917 by the establishment of federal jurisdiction over flood protection of the Sacramento River, and in 1936 by the nationwide federal flood management authority. Since the State Constitution makes local agencies responsible for regulating flood-hazard areas in California and strong federal programs are initiated through local agencies, involvement by the State has usually been limited to special programs which complement federal activity and support local agency activity. Because of the federal policy which requires nonfederal payment of the costs or rights of way and relocations for local protection projects, the larger share of State financial assistance has gone into this area.

The Reclamation Board was created in 1911. Its powers and duties are described in Part 4 of Division 5 of the Water Code (commencing at Section 8520). It is empowered to participate with federal agencies in matters pertaining to flood management in the Central Valley. Under delegation of the Board's authority, the Department of Water Resources is responsible for administering State flood protection funds for all major State-authorized projects of the Corps of Engineers in the Central Valley. The Department acquires rights of way and makes relocations for these projects, just as a local agency does for its projects. Through the Reclamation Board, the Department also participates with the Corps in the Sacramento River Bank Protection Project, in which one-third of all costs are met by the State and two-thirds by the Federal Government.

The Department's Flood Subventions Program provides State financial assistance for the costs of rights of way and relocations to local agencies cooperating in the construction of federal local protection projects. Starting in 1946, the State paid all right-of-way and relocation costs on Corps of Engineers projects and, after 1955, paid similar costs on projects of the Soil Conservation Service. Between 1969 and 1973, when a new formula for cost sharing was adopted, there was a moratorium on new State authorizations. Appendix C presents a history of the program, including the activities which resulted in the 1973 adoption of a new cost-sharing formula.

The Reclamation Board funded the construction of bypass levees of the San Joaquin River Flood Control Bypass Project, in lieu of purchasing flowage easements for the federal project upstream from the Merced River.

Since 1973, the State has participated in projects authorized since 1969 by paying 75 percent of the right-of-way costs and 90 percent of the relocation costs apportioned to flood damage reduction benefits. The State also pays 50 percent of the nonfederal capital costs of the recreation and fish and wildlife enhancement features. No State funds are provided for the right-of-way and relocation costs allocated to land enhancement benefits.

This program is effective in helping local agencies achieve the flood management projects they want, and the formula gives maximum State support to projects which will protect already developed areas. Minimum support is given to projects providing protection so that flood plain lands can be developed.

The California Department of Transportation often builds quite extensive works to protect freeways or to pass floodwater around freeways so that freeway embankments will not cause floodwaters to back up.

Local Agency Programs

In California, the local level of government exercises the basic responsibility for regulating flood-hazard areas and for providing flood protection.

Flood control districts were formed under State law for the purpose of managing and conserving storm waters as a beneficial element. This is in contrast with drainage and irrigation districts which consider water a nuisance to be disposed of. The police, and health and welfare powers delegated to a local government give it the necessary authority to regulate any flood-hazard area. Possession of adequate authority has not resulted in prudent regulation of flood hazard areas. This has led the local governments to seek Federal projects and State financial assistance to provide protection when substantial amounts of unwise development were permitted on flood plains.

Many projects have been designed and constructed by local flood control districts without Federal or State financial contributions. Extensive projects have been built in the San Jose area in Santa Clara County, in Riverside and Orange Counties, and in many other areas of the State. The projects provide significant protection for large urban areas, some of which are now major metropolitan centers. Almost without exception, the degree of protection is less than the 1-in-100-year flood, usually for 1-in-50-year floods, but often even less. Los Angeles County projects that provide capital storm protection, which is generally higher than 1-in-100-year, are exceptions.

The above projects are well designed, constructed, and maintained locally, and they have functioned well in protecting against their design flood. However, many of these projects (with the Los Angeles' exceptions noted) do not provide the level of protection advisable for highly developed urban areas.

Maintenance of Completed Projects

The effectiveness of any method of structural flood protection depends on the maintenance of the completed projects. Maintenance is a continuing responsibility with the objective of retaining the functional capability of the structures to store or carry storm flows according to their design. In California, maintenance responsibilities are complicated by being widely distributed. Federal policy for local protection projects assigns maintenance to nonfederal interests. Except for certain specific works in the Central Valley, the State does not pay maintenance costs. Thus, local agencies of various kinds have the responsibility for maintaining both federal and local projects. The increase in environmental awareness has focused attention on the potentially adverse impacts of project construction and maintenance on environmental values. This has led to conflicts between maintaining agencies and environmental groups and the public in general concerning maintenance methods.

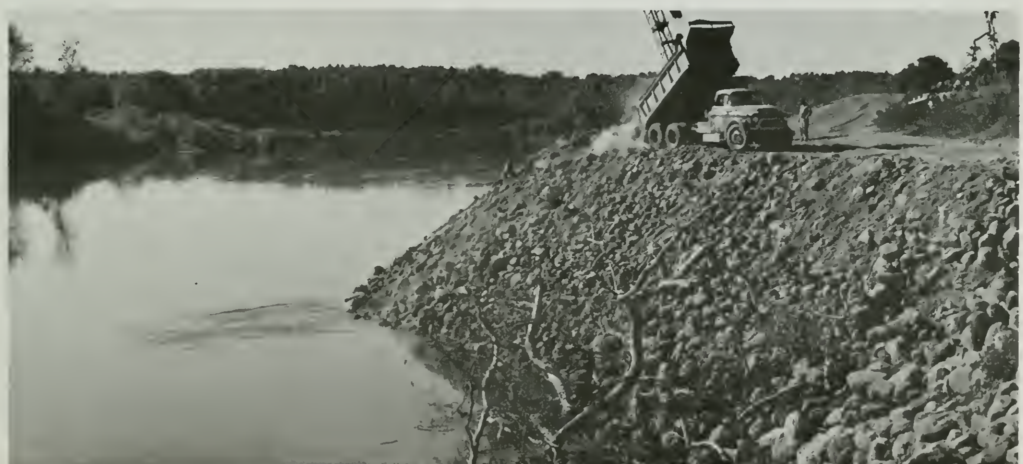
Reservoirs and Debris Basins. The dams which form reservoirs are major engineered structures. Because of the probability of catastrophic damage and extensive loss which would result from the failure of a major dam, the engineering profession has devoted great efforts to the design and maintenance of dams. Federal agencies maintain the dams they build and operate. Maintenance for safety of nonfederal dams is supervised by the Department's Division of Safety of Dams. Maintenance of flood storage dams in California is considered to be satisfactory.

Debris basins have been constructed near the base of mountains on streams that carry excessive debris loads during the above-normal flows. Their purpose is to provide relatively small reservoirs or stilling-type basins that reduce flow velocities sufficient to allow large rocks, sediment, and debris to be separated from the storm waters which are allowed to pass through the debris basins. The debris is removed from the flows to protect downstream facilities (not previously constructed to handle debris) from damage caused by the debris loads. They would not be needed if downstream facilities had been designed to handle sediment and debris.

After a series of storms, these basins become filled with rocks, gravel, mud, trees, branches, and other material, and they become ineffective unless the debris is removed. In addition to trapping large pieces of debris and rock, they retain finer sediments which could be transported downstream. Debris is removed by heavy earthmoving equipment, and it is deposited at a land fill site or some other area where it should not be picked up by floodwaters. These types of basins are prevalent in the arid regions of Southern California, particularly in Los Angeles County, where development has taken place along areas subject to flooding from streams that carry large debris loads. They are usually concrete; however some rail and timber debris-retarding structures have been constructed by the Los Angeles County Flood Control District and the City of Los Angeles below areas where all vegetative cover has been destroyed by wildfires.

The continual maintenance of debris basins has become prohibitively expensive, as do most interferences with natural processes. Further, the public objects to dust, noise, and traffic from debris trucks on residential streets, and to the ultimate disposal which fills scenic canyons. There is also a concern about providing sand to beaches as sediments once flowing there are now stored in debris basins. The Southern California Sediment Management Study is investigating this problem.

Levees. Levees are the most critical area in the maintenance of structural flood protection works. They are subject to the same forces that any earth dam must resist, and one additional force with which conventional dams seldom have to contend -- the erosive force of water flowing along the face of the levee. Historically, many methods of erosion control and levee repair have been used. These methods have included timber mattresses, bulkheads, vegetative plantings such as false bamboo, concrete paving, grouted riprap, and ungrouted rock. The most successful has been the use of ungrouted rock of sufficient size and density so as not to be moved by the force of the flowing water. The most



ROCK REVETMENT (RIPRAP) is a proven method for fortifying eroding river banks. This approach, while effective, causes significant environmental damage in terms of destruction of vegetation and reduced aesthetics. New approaches are needed to offset these damages.

common method of installation has consisted of resloping the bank or levee, i.e., cutting back the vertical or near vertical portion of the area to a slope sufficient to retain the rock, and then placing the rock on the raw slope from a trench below the channel bottom at the toe to, or near, the high water or design flood stage elevation. Maintenance of this rock work usually was accomplished by the use of a broad-base herbicide. Once a levee was restored to a safe condition, maintenance efforts were directed to keeping it clear of any growth.

After the major floods of 1955, maintenance efforts were increased. Levee inspection was intensified with emphasis placed on the clearing of brush and trees and other wild growth from the levee slopes, using chemicals and fire. This effort to clear the levee slopes, often resulted in "wholesale" removal of nearly all vegetation. It was this type of maintenance, along with clearing for bank protection works, that led to considerable criticism from environmentalists, the general public, and many public officials. Because of public concern, a number of studies were undertaken to find alternatives to complete clearing ("levee stripping"). The studies have led to some recent modifications in maintenance practices. The impact of these changes will be discussed following a description of the various levee maintenance arrangements throughout the State.

Outside the Central Valley, local agencies maintain the levees constructed as part of the Corps of Engineers and Soil Conservation Service local protection projects. The work is done in conformance with maintenance manuals prepared by the federal agencies. The federal agencies inspect the work and arrange

SELECTIVE CLEARING OF WILD GROWTH is a practice that has been adopted by the Department of Water Resources maintenance crews in recent years -- cutting swaths through vegetation choking a channel, but leaving strips of vegetation to preserve environmental and aesthetic values. When carefully done, this technique provides needed flood carrying capacity yet leaves a floodway both pleasing to look at, and valuable to wildlife.

for correction of any deficiencies found. In recent years, many local agencies responsible for Corps-built levees in urban areas have initiated planting and landscaping programs to improve the appearance of their levees and to integrate them into the community.

Within the Central Valley, the Reclamation Board has furnished the Federal Government with project assurances, including maintenance and operation of completed major Corps projects. In most instances, the maintenance responsibility is passed to a local flood control or maintenance district. The Department of Water Resources operates and maintains certain reaches of levees and channels, including the bypasses of the Sacramento River Flood Control Project. The Department also operates and maintains, at full cost to the benefited areas, certain levees where the local maintaining agency is unable or unwilling to do so. These are known as maintenance area levees.

Levees maintained by local agencies that are part of the Sacramento River Flood Control Project are inspected for adequacy of maintenance by the Department. Each spring and fall since 1947, the Department has rated the quality of maintenance on flood protection levees and channels operated under cooperative State and Federal agreements in the Sacramento-San Joaquin Valleys and in Lake and Placer Counties. The results of these inspections and descriptions of the various projects have been published in the Department's bulletins and the District Report series, "Flood Control Project Maintenance and Repair", and distributed to the local agencies responsible for maintenance, the Reclamation Board, and the Corps of Engineers. When an agency's levee maintenance receives a poor rating for several years, it is asked to meet with the Reclamation Board and propose a plan to improve its program. If a satisfactory agreement cannot be reached, a maintenance area can be established. Assembly Bill 549 has provided a mechanism for setting up a benefit assessment district for maintenance.

Vegetation along the levees and berms assist in binding the soil together, but the only effective method that has been found to be practical in protecting levees from erosion is the type of bank protection which consists of rock placed on an adequately prepared levee slope or berm. Rock revetment, being flexible, is not impaired by slight movement of the bank. Vegetation often grows through the rocks, eliminating much of its adverse aesthetic effects. Local damage or loss is easily repaired by placement of either recoverable or new rock. A bedding layer is required where the banks are subject to tidal action and severe wavewash. Bedding is not required on reaches where there are no significant tidal fluctuations, rapid drawdown is not expected, bank velocities are not high, and banks are not subject to excessive wave action.

Experience on the Sacramento River indicates that rock revetment should be extended into a toe trench below anticipated scour. Stone protection is especially adaptable to many rivers since it can readily be placed under water from both landside and waterside, depending on the site location. Prior to placement, the bank is graded to the desired slope and a riprap blanket is laid over the prepared slope. The equipment used for placement of the rock is of the crane type with rock tongs, slings, orange peel or clamshell attachments, depending on the size of the rock being placed. Placement by end dumping and spreading by bulldozer can be specified but is normally avoided. The cast stone approach is preferred since it avoids segregation of the riprap material that often accompanies the dumping process.

The Corps of Engineers has tried many different types of bank protection measures over the years and has kept records on effectiveness and costs. It has found rock revetment is the most effective and economical erosion protection.

The State is paying one-third of the cost of the Sacramento River Bank Protection Project. This project is a long-range effort aimed at preserving the levees on the Sacramento River and its tributaries. It was authorized by the federal Flood Control Act of 1960 (Public Law 86-645). This project is required so that the levees of the Sacramento River Flood Control Project can continue to furnish the degree of protection for which they were designed. It will also reduce the cost of emergency levee repairs and downstream dredging and will reduce land losses caused by bank erosion. The project has been very effective in maintaining the integrity of the levee system. However, the first phase of the project was not satisfactory from an environmental standpoint. Congress has authorized the expenditure of 10 percent of the overall project cost for environmental considerations in the second phase of the project.

In May 1972, in transmitting the State's comments to the Corps, Resources Secretary Livermore limited his endorsement to the extent of Phase II protective works 25 000 metres (82,000 linear feet) needed at that time. The State's position was that there was insufficient compensation for lost wildlife habitat provided in Phase I, Sacramento River Bank Protection Project. The position to provide mitigation was to be studied and resolved to mutual agreement in time for such mitigation to be incorporated as a project feature.

By December 1979, Secretary Huey Johnson was in a position to propose a resolution for the lost habitat along the Sacramento River. This position generally recognizes that, within the project area, 270 hectares (668 acres) of riparian land will be acquired, with the State and Federal Government sharing acquisition and maintenance costs, subject to the necessary authorizations and approvals. With resolution of the long-standing issue of replacing the riparian wildlife habitat lost through Phase I construction, bank protection work could proceed to maintain the integrity of the Sacramento River levee system and preserve the very important fish and wildlife resources.

Local agencies and private individuals are responsible for maintaining levees which are not part of federal flood protection projects. This includes 75 percent of the levees in the Sacramento-San Joaquin Delta. This work is not generally supervised by the State or Federal Governments. The quality of the maintenance work varies greatly and is basically dependent on the financial resources of the maintainers.

As noted above, levee maintenance efforts in the past were directed toward keeping the levee clear of all vegetation. Chemicals and burning were used to remove this vegetation for ease of visual inspection, for other maintenance work, and for economy. Unfavorable public reaction to the resultant bare levees and concern for chemicals led to using selective control sprays that destroy only certain plants, developing mowing equipment which can move around encroachments and operate on fairly steep slopes, trimming and topping some large trees instead of removing them, restricting burning to approved "burn days", improving fire control equipment and herbicide application, and controlling dust by oiling roads on levee crowns in urban areas. Several experimental maintenance programs under way or completed are being conducted to assess the costs of revising maintenance practices intended to improve the environment and reduce environmental damage, without affecting the integrity of levees. Methods which reduce the amount of clearing also have the potential of benefiting water quality.

For some years now, the Department of Water Resources has employed a form of Integrated Pest Management (IPM) in its flood project maintenance through biological control of the puncture vine along its levees and crown roadways. This has been accomplished through the introduc-

BURNING was once the accepted practice in foliage control. It enabled levee maintenance personnel to closely examine the ground for signs of weakness or burrows which could undermine the levees. Because of air pollution and the unsightliness of burnt areas, the amount of burning has been cut back in recent years. In certain areas, however, burning is still a viable maintenance tool.

GIANT ROTARY MOWERS AND SPRAYERS are now employed to control foliage. However, herbicide spraying often may indiscriminately destroy vegetation on levees and pose health and safety hazards to people. Herbicides which deal selectively with vegetation have been developed. And, for some years, the Department of Water Resources has engaged in a program called Integrated Pest Management, wherein insects and animals are used to maintain biological control of selected unwanted growths, such as puncture vine, Russian thistle, and tumbleweed.

A FLOOD CHANNEL need not be barren and ugly, as these before and after photographs of the San Lorenzo River at Santa Cruz show. Vegetation within riprap and on berms creates a pleasant vista.

tion of a particular species of weevil from India. To battle another critical pest, the Russian thistle or tumbleweed, the Department has introduced the larvae of a species of moth.

Recently, the Department has employed a research team from a nonprofit organization, the John Muir Institute, to study the potential for the development of a workable and cost-effective pest control program for the flood levee maintenance system. At this time, the team's direction is oriented toward reduction in the use of herbicides and the control of ground squirrels, the pests most threatening to the safety and stability of the project levee system. Five study areas have been set aside at the Sacramento Maintenance Yard. The experimental plantings here will test different shrubs and annual grasses for survival, compatibility with other maintenance practices, acceptability on levees, and ground squirrel resistance. Further IPM programs could be developed to control other pest problems, such as star thistle, algae, and aquatic plants.

A tentative conclusion resulting from the IPM study is that major concentrations of ground squirrel burrows in levees are associated with adjacent food supplies such as walnut orchards. It may be necessary to determine minimum desirable distances of such food sources from levees.

Integrated Pest Management is a process which recognizes the relationship of a pest to its environment. The following steps are used to arrive at an efficient solution that is environmentally and socially acceptable:

1. The target pests are identified, the extent of the actual damage caused by the pest is estimated, and acceptable damage levels are identified.

2. The process then determines when and where treatment of the pest is needed and the mix of control tactics to use, based on the environmental needs of the pest. The strategies used may include physical, cultural, biological, or chemical controls, with an emphasis on the use of the first three.

3. The use of pest control tactics is selected on the basis of:

   a. Selectivity in relation to the pest and potential harm to nontarget species;

   b. The potential the tactics have in creating other pest problems;

   c. The potential hazards to pest control personnel;

   d. Environmental impacts of the pest control techniques; and

   e. Economic analysis.

Most agencies are continuing to develop ways of making levees recreationally desirable, while still maintaining them as flood protection structures. Cost is one obstacle to performing the type of levee maintenance which would be completely acceptable to the public. Legal liability for maintenance of a functional project also causes agencies to exercise caution in changing methods. Making a levee "recreationally desirable" and providing public access has been a source of problems for many landowners. Before such plans are formulated, property acquisition details and public access should be worked out with the landowner.

Channel Modifications. As with levees, the maintenance of channel modifications is a local responsibility. The Corps of Engineers inspects the projects it has constructed. The Soil Conservation Service inspects its projects for the first three years after completion and makes periodic follow-up checks after that time to assure that adequate maintenance is being carried out. The local agencies are otherwise on their own. Maintenance of channels after their modification or incorporation into a project is not without problems. The work involves removal of vegetation to allow passage of design flows by creating open strips parallel to the direction of flow. The vegetation also tends to trap sediment and raise the channel bottom resulting in cross-section reductions. Removal of deposited sediment must also be accomplished from time to time by dredging in wet sections or by skiploader in dry sections. Riprap, other rock, or concrete protection is added where erosion begins to take place and where further erosion would lead to breaching of levees or pick up of high sediment loads which are later deposited in downstream channels.

This can be a particular problem in the tidal reach of streams. For example, the San Lorenzo River in Santa Cruz was modified to prevent a repeat of the extensive flood damage which occurred in 1955.

Since then, a lack of storm flows which would have flushed deposits into Monterey Bay and the failure of the local agency to perform maintenance have resulted in the buildup of deposits which have reduced the cross-sectional area of the channel by a third or more. The ability of the project to pass the design flood has been jeopardized and corrective action must be taken.

Effectiveness of Structural Methods and Programs

The topography of California is such that development naturally took place on the lands most subject to flooding. The history of the State is full of examples of the recognition of this problem and of efforts to prevent flood damage by structural works. For 125 years projects have been built which range from attempts to protect a specific local area to comprehensive plans to protect broad areas like the Sacramento Valley and the Los Angeles Coastal Plain. Billions of dollars have been spent on these efforts.

Adequacy of Structural Methods. The tools of flood damage prevention by structural methods -- reservoirs, levees, bypasses, and channel modifications -- are well defined. Modern flood protection projects, particularly those designed and constructed by federal agencies, will protect against their design floods. The selection of the design flood is of critical importance. It must be sufficiently large to give protection from floods which can reasonably be expected. It cannot be so large that a project to mitigate it would be beyond the capacity of the beneficiaries to pay for. Even if the design flood is not exceeded, human error can cause flood storage operation or releases in excess of the prescribed flood release. Because of human factors, flood storage reservoirs are not always capable of delivering 100 percent of their design capacity.

A real problem in California, particularly in the Central Valley but also in some areas outside the valley protected by locally constructed works, is the project which can mitigate only a comparatively small flood. Such projects create a false sense of security in the public mind. While no solution to this problem has yet been found, it must always be kept in mind by those responsible for flood damage prevention.

Another problem can occur when people are overly reliant on an existing major flood storage reservoir. It can occur because hundred year floods, or other large floods greater than those against which reservoirs are designed, happen infrequently. In the interim, people forget why the facilities were built. As the specter of a flood fades from memory, people start to build on the flood plain. As the encroachment continues, large communities are developed that could face disaster not only from the design flood but from lesser floods that would require flood releases. This leads to the need for a still larger facility at increasing economic, environmental, and social costs.

KEY WATER SUPPLY FEATURE of the State Water Project is Lake Oroville. The largest reservoir in the State Water Project, Oroville has a capacity of 4 000 cubic dekametres (3½ million acre-feet), of which 925 000 cubic dekametres (750,000 acre-feet) are for flood storage.

Prado Reservoir in Orange County is an example. The project was designed in the late 1930s. Since that time, upstream* and downstream growth have widely exceeded initial projections. Technical reanalyses lead hydrologists to believe that a larger-than-design flood could easily occur, endangering Prado Reservoir. This type of flood could exceed the existing spillway capacity and overtop the dam. Flows over the dam could cause erosion of the earth-filled portion and, ultimately, could cause failure of the dam. If Prado were to fail, extensive loss of life and damage exceeding $5 billion could be expected.

The costs of constructing additional features of the Santa Ana Project to provide the additional necessary flood protection also will be substantial. Existing development on the Santa Ana River took place on the premise that Prado Reservoir would provide adequate flood protection. Hopefully, future plans will probably include a requirement that the local agency will regulate the flood plain to prevent further development that would be subject to flood damage. Measures such as this help to break a potentially dangerous cycle.

Adequacy of Maintenance Operations. Maintenance is an essential part of a structural flood protection program. The Department's efforts to protect the integrity of the Sacramento River Flood Control Project have been discussed previously. In California, particularly in the Central Valley and the Sacramento-

* Upstream growth accelerates storm flows to a reservoir due to gutter runoff, etc.

San Joaquin Delta, levee maintenance is an area of grave concern. There are also problems with the maintenance of levee projects outside the Central Valley.

In February 1977, the Department checked maintenance practices on 33 flood protection projects throughout the State. The Corps of Engineers had built 13 of them, the Soil Conservation Service, 3, and local agencies, 17. It was found that the Corps of Engineers' projects were being maintained at an 85 percent acceptable level, the Soil Conservation Service projects at a 67 percent acceptable level, and the local projects at only a 29 percent acceptable level.

A low level of acceptable maintenance is found in the Sacramento-San Joaquin Delta where maintenance of locally constructed levee is funded almost entirely by local landowners. In January 1980, Webb and Holland Tracts were inundated as the levees failed during a combination of high runoff, high tides, and strong winds. The Federal Emergency Management Agency anticipates spending $20 million of public funds to restore these two tracts. The required hazard mitigation plan, developed by the Department to bring the levees up to a reasonable standard so that inundation does not occur again at the next high water, has not yet been implemented by FEMA and the Office of Emergency Services.

In the San Joaquin Valley there has been a loss of channel capacity due to excessive growth of vegetation, deposition of sediments, and lack of flushing flows. Two studies made in response to legislative resolutions indicate work may have to be done to restore the lost channel capacity. The substantial cost of maintaining debris basins in Los Angeles County has been described previously.

In summary, maintenance is the weakest part of the structural flood protection program. This is because of the limited revenue available to the local agencies, particularly in rural areas, and public objections.

Funding

An unevaluated impact on local agency

THE THREAT OF EROSION is ever present in the thousands of miles of levees that line California's waterways. Erosion like that shown above can result in a levee break and the flooding of thousands of acres of land.

maintenance practices was the passage of Proposition 13 in June 1978. This measure severely limits the amounts of property taxes collected by local agencies. Since this is the basic source of most of their revenues, they can be expected to do less maintenance work in the future until substitute funds are made available.

AB 549 (Chapter 261, Statutes of 1979, effective July 16, 1979) authorizes the levy of benefit assessments in addition to ad valorem assessments in flood control districts and in maintenance areas formed pursuant to Chapter 4.5 (commencing with Section 12878) of Part 6 of Division 6 of the Water Code. It permits the levy of assessments on each parcel of real property within the district or area or any zone thereof on the basis of estimated benefit sufficient to cover the cost of providing flood protection services, which cost is not otherwise offset by other available revenue. Public notice, hearing, and voter approval by majority vote is required. This may improve the financial situation of maintaining agencies.

In November 1979, Proposition A was passed by the electorate of Los Angeles County, authorizing the county to levy benefit assessments to property owners for flood damage prevention purposes. The amount of assessment is based on the area and use of the property and is expected to add $20 million to the Los Angeles County Flood Control District's flood maintenance program. This is expected to offset the impact of Proposition 13 in Los Angeles County. A similar proposition was passed by the electorate in Alameda County in June 1980.

<u>Evaluation of Existing Structural Programs</u>. Structural flood protection projects in California have prevented billions of dollars in damage and could prevent billions more in the future. The damages from the January-February 1980 floods in Southern California were estimated at about $268 million. The damages prevented by existing Corps of Engineers' projects were estimated at more than $1.8 billion. During the January-February 1978-80 floods, the Los Angeles County Drainage Area Project prevented damages in excess of $1.5 billion. Since their completion, the Los Angeles Drainage Area and Prado Reservoir projects have prevented damages of $4.5 and $0.75 billion respectively. The construction cost of these two projects totaled $443 million. The maintenance costs of these and other projects have become enormous, and public objections have increased.

Even though no flood protection project can provide absolute protection, most of the projects constructed by the Corps of Engineers do provide a high degree of protection. Some projects, however, were built before intensive urbanization and provide an inadequate level of protection. Other projects were constructed to provide a relatively low level of protection, such as for agricultural areas, and continue to be relied on when changes to urban land use occur. These projects not only create a false sense of security, they make it difficult to economically justify adequate projects under present federal criteria. Resolution of this problem requires the attention of all levels of government, but especially the local and federal levels.

Some local projects have severely diminished the carrying and storage capacity of natural watercourses by channelizing them into narrow corridors or by eliminating them with storm drains. During severe storm and debris flows, they are inadequate to prevent flood damage. Local governments have typically accepted these projects as a condition for development and the resolution of this problem rests with local government. Also, some structural facilities increase flooding problems downstream as velocities and volumes of water are increased when diverted from impervious developed areas. Local government should require mitigation so as to not increase flood peaks downstream.

The following table shows expenditures for major flood protection projects built between 1937 and 1978 exceeded $1.7 billion, of which about $631 million was expended by local agencies. Even at this cost, the structural program cannot keep up with the continuing flood damage as people unwisely encroach on flood plains.

FLOOD CONTROL COSTS AND DAMAGES IN CALIFORNIA
IN MILLIONS OF DOLLARS
1937-1978
(Figures provided by Office of Emergency Services)

	EXPENDITURES			
	PROJECTS			
PERIOD	Federal 1/	Nonfederal 2/	EMERGENCY AND DISASTER RELIEF 3/	FLOOD DAMAGES 4/
1937-1940	$ 50	$ 0	$ 0	$ 100
1941-1950	68	14	2	40
1951-1960	338	112	16	230
1961-1970	387	257	75	750
1971-1978	840	248	20	221
TOTALS	$1,683	$ 631	$ 113	$1,341

1/ Federal expenditures for federal and nonfederal flood protection projects.
2/ Nonfederal expenditures for flood protection projects.
3/ Federal expenditures published in Chief of Engineers' annual reports.
4/ U. S. Weather Bureau and Corps of Engineers' Reports.

Nonstructural Methods and Programs

Destruction of property and loss of life from floods continue to take place in California despite efforts at all levels of government to prevent them. In many cases, extensive flood protection works have failed to keep pace with development on flood plains. All too frequently encroachments accelerate downstream from new flood storage reservoirs. Effective nonstructural methods of flood management practices are only now beginning to be implemented. Flood plain management is only one of a complex of issues and tradeoffs that should be considered and evaluated in comprehensive planning and management of water, land, air, and energy resources for the benefit of people in accordance with their objectives.

Nonstructural Flood Management

Flood damage is essentially a result of human carelessness or ignorance. High water ("flooding") results from the encroachment of human activities on to a flood plain, or from local high water caused by some upstream or downstream human activity. Watercourses and flood plains are generally obvious and known to flood control districts and planners. Problems arise when people and their activities encroach. While nonstructural management approaches do not usually allow for the maximum short- term economic use to the owner of a flood plain, they do provide many long-term advantages for a community.

Given the potential damage a flood can cause -- including property destruction,

WISE FLOOD PLAIN MANAGEMENT keeps structures out of floodways. This aerial view of the mouth of the Tijuana River shows that good management practices can be enforced even in a highly urbanized situation.

erosion, disruption of commerce and agriculture, and even loss of life -- what are the advantages of essentially natural flood plains with occasional high water? There are many benefits:

1. Flood plains can provide a pleasing and useful greenbelt and recreational area in an otherwise crowded urban environment, if urban development and capital-intensive agriculture are regulated. Parkways and open spaces (including low-intensity agriculture) are not only compatible with floodways, but provide a welcome relief and contrast to urban monotony. They provide focus and identity for a community, allowing wildlife and nature study and other active and passive recreation.

2. An essentially natural flood plain, if it results in stream channels being kept undeveloped and streams meandering freely, creates savings for a community. The enormous costs of levees, including their maintenance, can be avoided. Levee breach or failure is absent, and the high cost of flood fight-

ing is avoided. Expensive dams for flood storage are unnecessary. Disaster relief following the failure of flood avoidance structures becomes unnecessary. Property values are enhanced in a community with a safe, scenic brook.

3. Environmental benefits can be derived from occasional high water. High waters restore rich farmland with beneficial new topsoil. Sand transport to ocean beaches is primarily accomplished during high water periods. Conversely, flood storage and debris dams interrupt sand and gravel movement toward the ocean, resulting in depleted nourishment of beaches and river spawning gravels. Without occasional high water, expensive restoration and beach nourishment projects may become necessary.

4. Ecosystems are benefited by large freshwater flows as they have become adapted to occasional floods. Anadromous fish of some types rely heavily on the flows to find their way upstream to spawn. Dams and other measures to reduce floodflows make upstream migration more difficult and reduce the numbers of anadromous fish. The community is afforded an opportunity to observe and enjoy fish, birds, and other wildlife.

5. Natural flood plains have a large storage capacity for storm waters. As this capacity is reduced through encroachment or channelization, flood peaks are increased downstream, necessitating expenditures for protection works. Backwater effects could also necessitate protection works upstream of the constructed area. These investment costs are avoided by a natural flood plain.

Scientists are only now learning about the importance of large freshwater outflows into coastal estuaries. These estuaries provide nursing areas for a wide variety of animal life, including some of our most important fish and shellfish species. Artificial reduction of peak outflow may play a detrimental role in the health of the estuaries.

Because of these benefits, nonstructural flood management need not be viewed as a surrender to a rampaging aspect of nature but as a comfortable and cost-effective method for coexisting with natural processes. The large investment costs in structural measures can be avoided.

Nonstructural flood management includes a variety of activities which accommodate human activities with occasional high water. While it is basically concerned with the prudent regulation of land use, it includes measures to minimize damage to facilities located in flood-hazard areas. The goal is to prevent flood damage by limiting encroachment of damageable uses and developments into the path of floodwaters. Recreation, agriculture, fish and wildlife, and other uses of open space that are compatible with intermittent inundation need not be restricted.

A nonstructural flood management program also may have many other desirable benefits, including: open space and ground water recharge preservation; recreation development in urban areas; fish and wildlife preservation and enhancement; seepage damage reduction; and reduction of environmental, social, and economic impacts of flood prevention facilities such as dams, levees, and channels.

Land Use Regulation and Management. Local governments have the power to appropriately zone river basin lands within their jurisdiction. Local planning and zoning commissions and their staffs can obtain aid from State and Federal agencies for evaluating the likelihood of flooding and the potential damage from floods.

In those locations where inundation by floodwater is frequent, local residents are aware of the flood potential. However, where inundation occurs only infrequently, local residents may not even be aware of the risk because even a single flood in their personal memories may be considered to be very unusual.

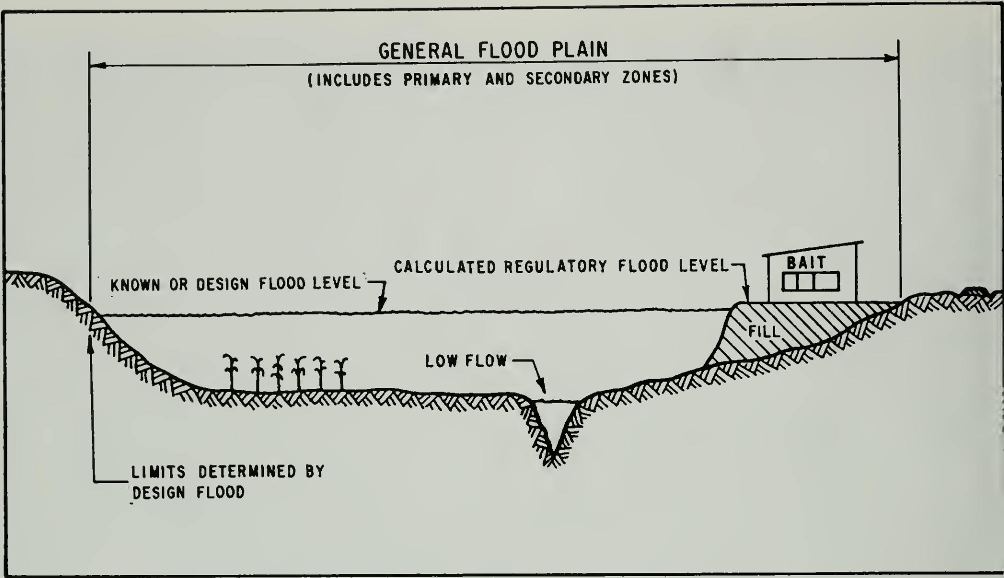


Figure 14. ONE-ZONE FLOODWAY

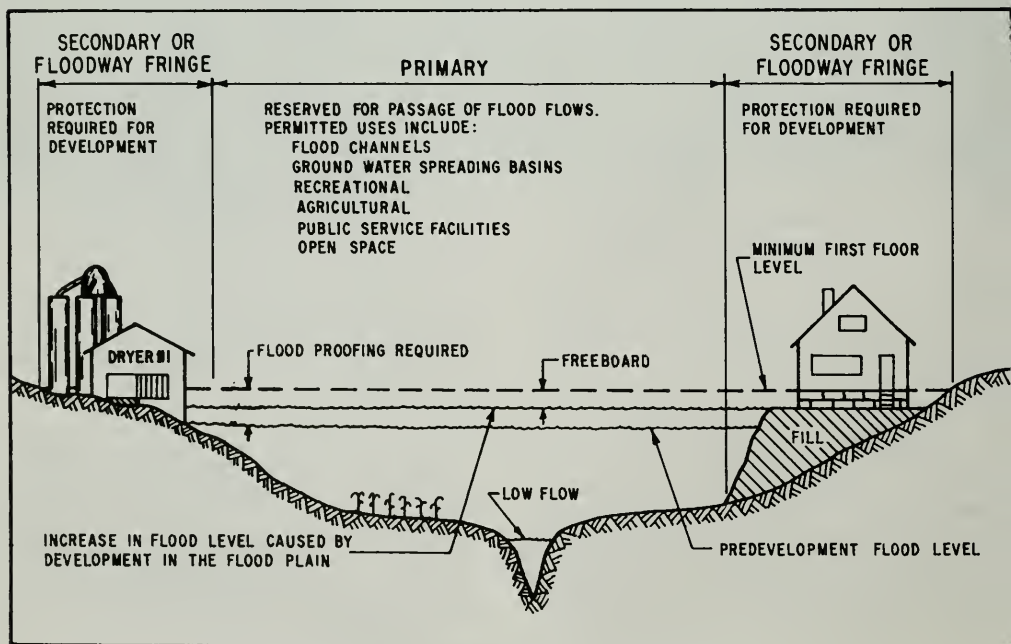


Figure 15. TWO-ZONE FLOODWAY

When inundation has not occurred for some years, the risk may be entirely forgotten. New residents, or nonresident developers, may be unaware of risks even in areas where fairly frequent flooding occurs. In addition, urban development in known flood-prone areas may subsequently be sold to unknowing buyers.

Development also has proceeded in areas which appear to be protected by levees and reservoirs, but in fact are protected only from small floods that occur frequently. A false sense of security has been created so that a flood event could have more serious consequences than if no protection existed.

Unrestricted growth in flood plains has occurred in part because information on flood risks for specific land areas has not been readily available. Flood plain management efforts need to be supported by technical studies defining the channel area required to carry an appropriate maximum flood, and indicating inundation lines for floods of selected magnitudes.

When detailed technical studies are not available, a one-zone floodway, as shown on Figure 14, may be used in guiding development. It may be defined as the area inundated by the largest flood of record. Each proposal for development is considered and a special permit is issued carrying specific restrictions. As long as development is sparse, there is little chance that the needed channel capacity will be blocked.

When an area is already urbanized, or where development is becoming dense, a two-zone floodway, as shown in Figure 15, should be used.

When technical information is available, a stream channel area can be kept free of damageable and obstructive development by regulations and ordinances enacted by and enforced by local government. Technical studies define the channel-carrying capacity, assuming no flow in the fringe areas. Therefore development in fringe areas must consider only potential inundation damage. Construction of buildings above the expected floodwater elevation can be accomplished by the use of fill or pilings.

Many types of agriculture can also be carried on economically in most flood plains, even with occasional flooding of the crops.

Another land use regulation technique revolves around protection of the riparian cover along watercourses. Riparian vegetation is a valuable natural resource which, in addition to being aesthetically pleasing, serves several useful functions. The vegetation supports a unique wildlife population, and dense tree growth provides shade which can keep water temperature cool, retarding algae blooms and enhancing fish habitat. In the right location, riparian vegetation can stabilize the river channel, protect levees from wind-driven wavewash, reduce bank erosion, and assist in maintaining hydraulic control for proper project operation. It also serves a valuable water quality function.

In 1974, the Napa County Board of Supervisors passed a comprehensive ordinance which, among other things, provides protection of the riparian cover within specified distances of certain watercourses within Napa County. Anyone wishing to plant or remove vegetation within the protected area must apply for a permit from the local planning commission. The commission may not issue a permit if the proposed work would destroy a significant amount of riparian cover.

In 1977, the Shasta County Board of Supervisors passed a similar measure which, in part, set limitations on the removal of natural riparian vegetation. Santa Cruz County has also adopted a riparian corridor protection ordinance. Other counties are considering measures presently in draft stages, and the State Resources Agency has developed a pro-

REMNANTS OF THE VAST RIPARIAN FORESTS that once lined the Sacramento River and its tributaries can be seen in a few areas on the middle reaches of the river. A recent report prepared for the State Reclamation Board attests to the value of these remaining trees in reducing flood damages.

posed "County General Plan Element for Wildlife and Fishery Habitat Areas" to ensure the preservation and enhancement of natural riparian vegetation.

In 1978, the State Reclamation Board adopted a resolution concerning "Retention of Riparian Vegetation, Sacramento River, Tisdale Weir to Hamilton City". The Board accepted a technical report delineating 38 sites containing significant riparian vegetation and directed that all activities carried out along that specific portion of the Sacramento River Flood Control Project be consistent with the report recommendations.

Other ways to regulate defined flood plains are local zoning ordinances, building code restrictions, severe financial sanctions, and purchase of land. Hopefully, communities will go beyond the restrictions and sanctions to assure nonstructural flood management. Land use planning can be used to direct compatible uses to flood plains while setting aside low flood-risk lands for intensive development.

Particularly in heavily populated Los Angeles County, there is much need for flood plain management.* Here, representatives of the Los Angeles County Flood Control District emphasize the need to implement flood plain management techniques (and do preventive planning) before opportunities for low-cost solutions are lost. Each new structure constructed at an inadequate elevation or in the wrong location presents a future problem for local government to solve through use of its most scarce commodity -- money to undo the mistake.

Regulation is especially important in foothill areas where natural processes will continue to wear the mountains down and throw down rock and mud without concern for homes that are in the way. There is abundant evidence to demonstrate to planners, elected officials, and developers that disregard for debris flows is far more costly in the long run than a flood plain management alternative. Local government is responsible for safe development, but has permitted the construction of many homes and businesses in extremely hazardous areas. From a hydrologic viewpoint, there is no question that major floods will occur.

The flood problems in Los Angeles County are but a microcosm of what faces the entire State of California, both in existing urban areas and in rural areas which can still avoid the current major problems of the urban areas.

Figures 16 through 21 (courtesy of John M. Tettemer) depict the typical flooding and debris problems encountered in Los Angeles County and the South Coastal Area and the need for land use regulation. In Santa Barbara County, natural streams and their flood-carrying capacity have been preserved through dedication of land by developers. In this way, expensive channel work is avoided and amenities are maintained. Channelization has been avoided in Santa Clara County by flood plain management alternatives which include purchase of flood insurance for some structures subject to flood hazard and by purchase of homes in a flood zone from willing sellers. In the City of Fresno, multipurpose storm water basins have been excavated to store runoff and serve as recreational areas. The Fresno Metropolitan Flood Control District has obtained a grant from the Environmental Protection Agency to study the quality of this storm runoff which eventually percolates into ground water basins. Other innovative programs are described in the Section on Exemplary Projects.

Floodproofing. A floodproofing program does not completely preclude flood damage. It consists of measures which render buildings and other contents less vulnerable to floods. Floodproofing is not a panacea for flood problems. It is, however, an important device available to reduce flood damage through structural changes to existing buildings and designed-in floodproofing for new buildings.

Measures can include structural features which offer protection with little dependence on any judgment, flood forecast, or action to put them into effect. For example, a building could be constructed with impervious walls without outer openings and with valves on sewer lines that automatically close from back pressure or, the "lower story" could consist of graceful open columns and patios. Concrete picnic tables in park areas would also constitute floodproofing.

* "Action Required Now to Manage Developing Flood Plains," and papers by John M. Tettemer, published in The Engineer of California in November 1979 and early 1980.

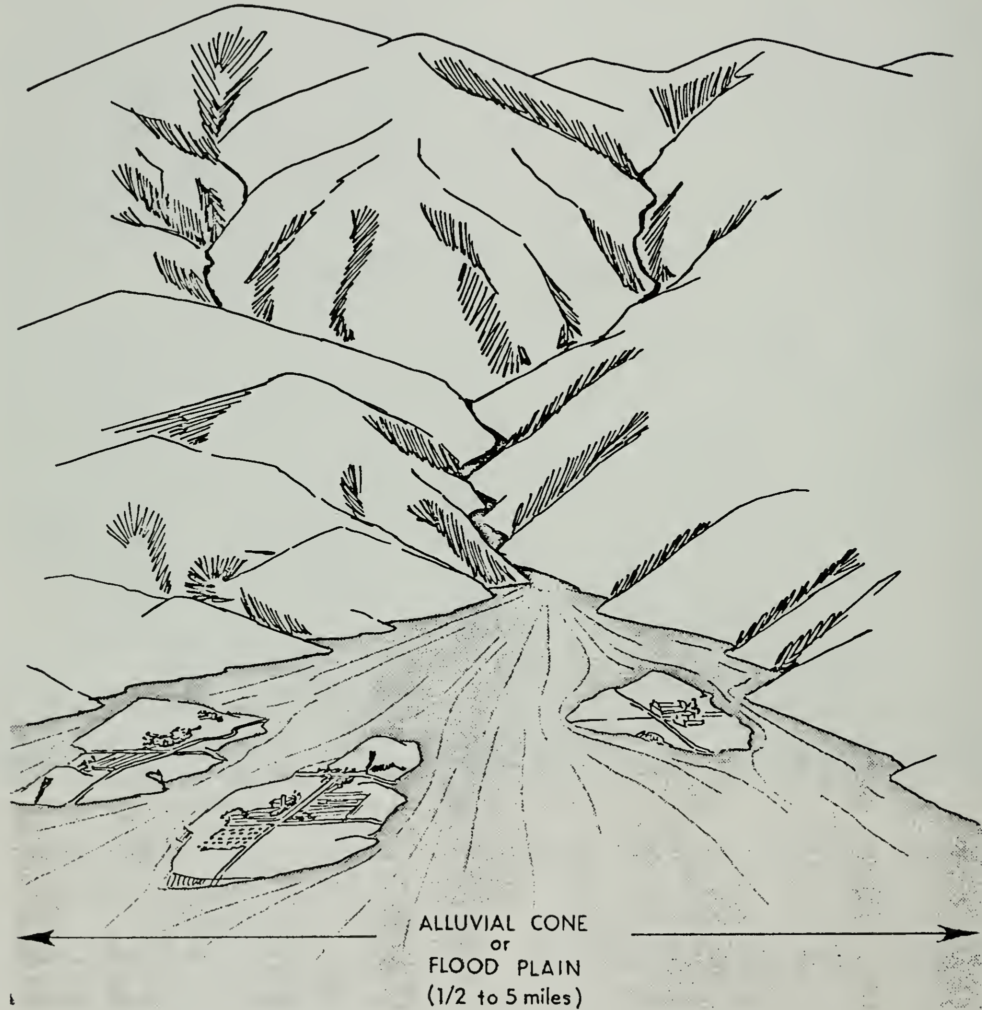


Figure 16 TYPICAL OF THE SOUTH COASTAL AREA

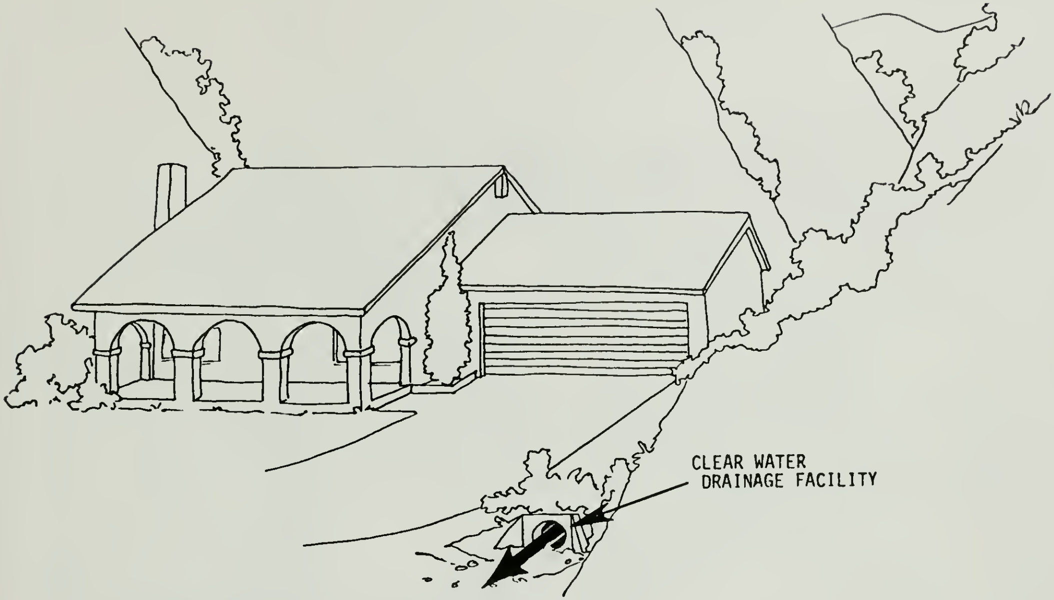


Figure 17. HOME CONSTRUCTED IN CANYON BOTTOM

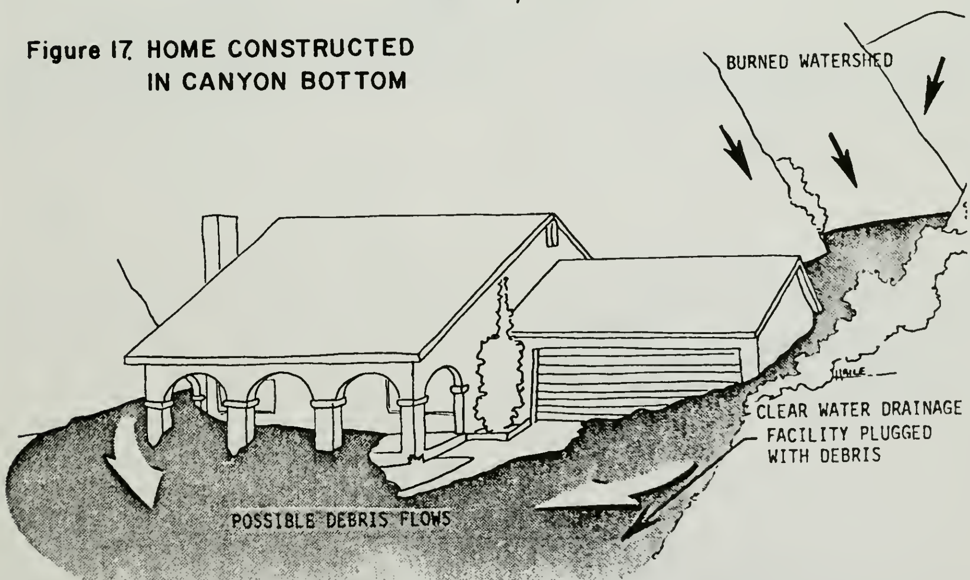


Figure 18. HOME CONSTRUCTED IN BOTTOM OF CANYON OVERRUN BY DEBRIS

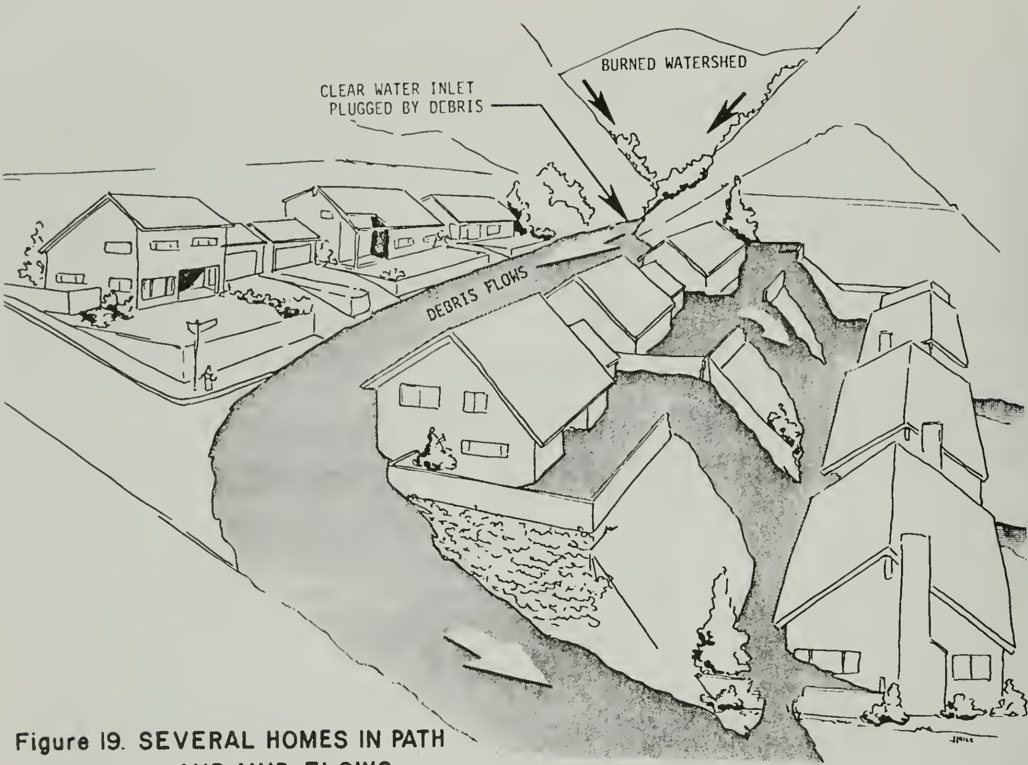


Figure 19. SEVERAL HOMES IN PATH OF ROCK AND MUD FLOWS

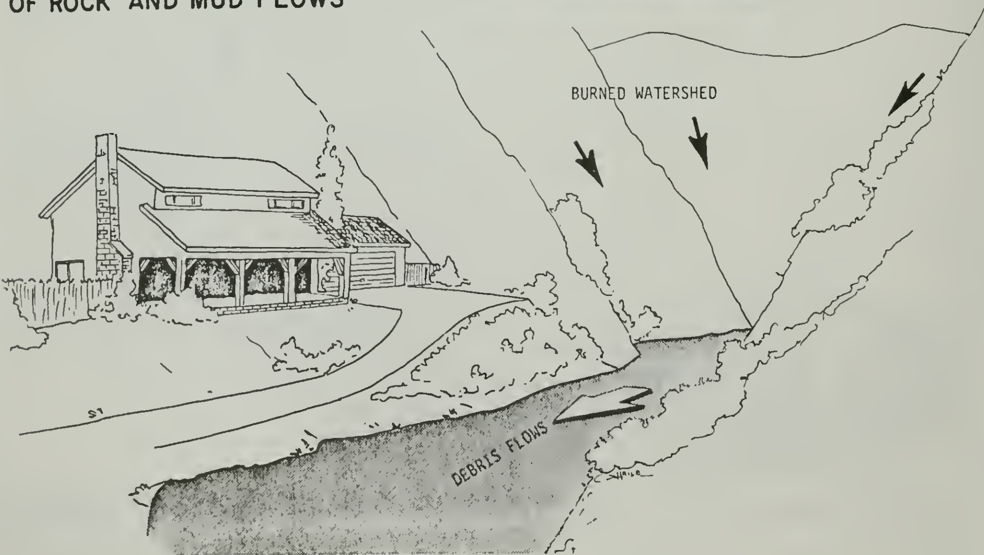


Figure 20 RAISED STRUCTURE ALLOWS ROCK AND MUD TO PASS SAFELY

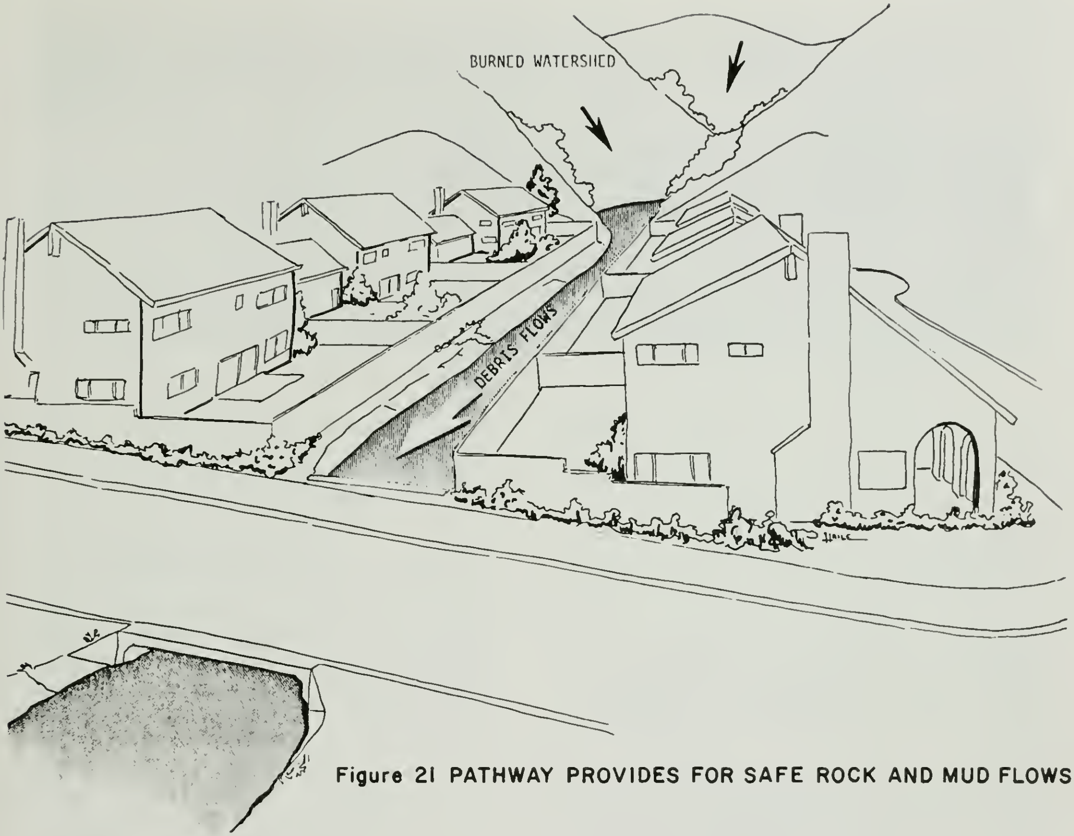


Figure 21 PATHWAY PROVIDES FOR SAFE ROCK AND MUD FLOWS

Flood Forecasting and Warning. Flood forecasting and warning involve the prediction of river stages and the timely notification of responsible authorities so that plans for the evacuation of people and property can be implemented. The technique is possible when there is sufficient time lapse between the occurrence of precipitation and the time when the ensuing runoff reaches the stream channel, causing water levels to rise. In addition, after the water reaches the stream channel, several hours or days may elapse before the flood crest reaches a flood-hazard area. This depends upon the length and configuration of the river system.

A forecasting and warning service can be used to provide: (1) river stage forecasts and flood warnings on unregulated streams, (2) downstream river stage forecasts on streams regulated by flood storage reservoirs, and (3) reservoir inflow predictions which may be used to provide more efficient reservoir regulation to minimize downstream peak flows. If the reservoir storage is low, much of the storm water will be retained for later power production, recreation, or water supply. However, as the flood reservation is filled, releases will be increased. Such increases are then routed to the next downstream forecast point. At each subsequent downstream

SNOWSURVEYORS working for private and public (Local, State, and Federal) agencies measure snowpack in many locations in the State. This data is provided to the Department of Water Resources Cooperative Snow Survey Program. Pack water volume along with weather predictions are used to calculate how much water to store in reservoirs to prevent or lessen the damage from floods.

forecast point, predicted incremental inflow from local runoff is added to the flow.

Factors which affect the actual benefits achieved by use of flood warnings include: reliability of forecast, length of forecast warning time, magnitude of reducible damage, and efficiency of response to warning.

The length of forecast warning time is the time from the first warning report until the time when flooding begins. This warning time is primarily determined by the size of the river basin. In an effort to gain more lead time for warnings, quantitative precipitation forecasts (QPF) can be used in preparing river stage forecasts. These QPFs are estimates of expected rainfall during a future time period, say the next 6 to 12 hours.

The forecasts generally provide more benefits to residential and commercial areas (without adequate flood protection projects) than to agricultural areas. People and portable property can be removed before a flood hits, while crops and sometimes livestock must bear the brunt of the flood.

Effective response to flood forecasting is almost entirely dependent upon the existence of a local agency which will act upon the warning information. Generally, it has been observed that action by occupants of frequently flooded areas is more efficient than that of occupants of infrequently flooded areas or areas which have not been flooded since occupancy. In areas of frequent flooding, such as the Eel River Delta, a local agency has emergency action plans and is prepared to carry them out. A local action agency may be the county office of emergency services, the sheriff's office or substation, or (in some cases) a highway patrol unit. Most local action agencies function well even during exceptionally large floods.

Where floods are infrequent, or a flood is greater than any recently experienced, a special problem exists; people may not believe the forecast, or individuals who should evacuate refuse to do so. Better methods of educating the public to the possibility of an extreme event are needed to assure prompt and effective action.

A flood forecasting and warning system requires large amounts of current data on precipitation and river stages. Elaborate data collection facilities are usually a part of the system. The information collected is quite often found to be useful for purposes other than flood management. A system can contribute needed information for river navigation and recreation use. Some of the data is also useful for water supply forecasts.

Federal Programs

While structural flood protection works have saved billions of dollars in flood damage in areas where they have been constructed, flood damage in the United States has continued to increase in absolute terms. This fact, together with the increasing cost of structural projects, has led the Federal Government to seek additional ways to prevent flood damage. A number of these programs is in the nonstructural area.

Presidential Executive Orders. In August 1966, the President issued Executive Order 11296, which dealt with the need for evaluation of the flood hazard in locating federally owned or federally financed buildings, roads, and other facilities. It ordered the heads of executive agencies to encourage a broad and unified effort to prevent the uneconomical uses and development of the nation's flood plains.

An updated version of this order was signed in May 1977. The new order, Executive Order 11988, requires the various federal agencies to develop programs and regulations to carry out the order. These programs and regulations must be approved by the U. S. Water Resources Council.

U. S. Army Corps of Engineers' Flood Plain Management Services Program. This program was authorized by the 1970 Flood Control Act (Public Law 86-645). Under it, the Corps of Engineers identifies areas subject to periodic inundation by floods of various magnitudes and frequencies, establishes general criteria for guidance in the use of these flood plains, disseminates these data to interested agencies and individuals, and provides engineering advice for use in planning local programs aimed at reducing flood hazards to life and property.

The results of the studies for a given stream or community are published in a Flood Plain Information Report. To date Flood Plain Information Reports have been prepared for portions of 39 counties in California. A list of the reports is presented in Appendix E.

With the advent of the National Flood Insurance Program, the need for, and use of, Flood Plain Information Reports diminished. Publication of this type of report has been halted. The Corps of Engineers continues to provide, upon the request of Federal, State, and local agencies, technical services needed for planning the best use of flood plain lands. These services include evaluation of flood hazard potential, guidance on nonstructural alternatives to flooding problems, and technical advice to all local governments in developing land use regulations.

Soil Conservation Service Flood Hazard Analysis. The Soil Conservation Service provides basic technical data about flood hazards in flood plain areas through cooperative flood hazard analyses. The purpose of the data is to help local units of government reduce potential flood losses. The information developed in the studies is published in a report, and it is also presented orally to the local cooperating government entity and other interested agencies. Two flood hazard analysis reports have been completed for the City of Winters (Yolo County) and Eastern Fresno (Clovis Area, Fresno County).

National Flood Insurance Program. Congress enacted the National Flood Insurance Act in 1968 (Public Law 90-448, Title XIII; 82 Stats. 572). This act recognizes the simultaneous difficulties and desirabilities of non-structural flood management. The program provides previously unavailable flood insurance to property owners in communities which have made a commitment to implement a flood plain management program. The Federal Emergency Management Agency administers the program. Local agencies operate on information furnished to the community by the Federal Insurance and Hazard Mitigation Office of the Federal Emergency Management Agency.

In the early years, the program met with limited acceptance by local legislative bodies, and property owners tended to ignore the opportunity to purchase insurance. When Hurricane Agnes struck the east coast in 1972, only two flood insurance policies were in force in the City of Wilkes-Barre, Pennsylvania, despite the fact that Wilkes-Barre is situated on a river with a long history of flooding, and the city's leaders long before had taken actions necessary to make the insurance available.

The financial shock (about $3 billion) and the human suffering wrought by Hurricane Agnes prompted Congress to pass the Flood Disaster Protection Act of 1973 (Public Law 93-234). The act virtually mandated a flood-prone community's participation in the program. If private individuals or public agencies wish to borrow money from a lending institution insured, regulated, or supervised by the Federal Government to purchase improved property located in an officially identified flood-prone area, they must also buy flood insurance. Federally insured lenders include banks, credit unions, and savings and loan associations. The insurance requirement also is mandated for direct aid from the Veterans Administration, the Farmers Home Administration, and other federal agencies. The impact of these possible sanctions, which are effective only within officially identified flood-prone areas, is demonstrated by a marked increase in the number of participating California communities.

A little over one hundred of the State's eligible jurisdictions were in the program when the 1973 act became effective. By late 1976 the number was nearly 400. Only about 20 of California's communities with officially identified flood-hazard areas have failed to enter the program. For the most part, these communities have either very small hazard areas or areas which are already appropriately developed, with such features as parks or farms.

Communities entering the National Flood Insurance Program usually do so in two phases. First, they become eligible for the purchase of flood insurance under the emergency program, which provides limited amounts of coverage. The insurance is sold at uniform, subsidized premium rates.

A community receives an official flood-hazard boundary map which depicts the areal extent of inundation due to the 1-in-100-year flood. Accuracy of the map can be challenged by property owners or community officials, but despite this, financial sanctions will become effective one year after the map is issued. During the year, the community must prepare a program application and enact an ordinance which provides for a minimum flood plain management program. This is primarily a building permit system and a commitment to institute a more complex and vigorous program when additional hydrologic and hydraulic data are furnished by the Federal Emergency Management Agency (FEMA). After acceptance of the community's application, property owners can buy flood insurance at subsidized rates. In the case of a residence, $35,000 worth of structural coverage is available at $0.25-per-year-per-$100 worth of coverage. This is the "emergency" phase of the program.

The FEMA provides a detailed hydrologic study to refine and supersede the flood-hazard boundary map, show elevations of the floodwater surface for the 1-in-100-year flood, establish the insurance rate zones, and, where appropriate, show the designated floodway. These are commonly called "rate studies". The FEMA defines a designated floodway as "...the channel of a river or other watercourse and adjacent land areas that must be reserved in order to discharge the 100-year flood without cumulatively increasing the water surface elevation more than one foot at any one point." The designated floodway corresponds to the "primary" zone as shown in Figure 15.

After flood insurance rate studies have been completed, the community then enters the second phase, called the regular program, under which an additional level of coverage up to full coverage is available. Under the regular program, buildings constructed on or before December 31, 1974, or the effective date of the Flood Insurance Rate Maps, if this is later, remain eligible for the first layer of available coverage at either the subsidized rates or actuarial rates, whichever are less. New buildings require actuarial rates for both levels of coverage. It should be remembered that land adjacent to these zones will be flooded if a flood larger than a 1-in-100-year flood event occurs.

The Flood Rate Insurance Studies define the federal designated floodway. These rate studies also define the areas where shallow flows can be obstructed by structures which are floodproofed so that there is no damage from a 1-in-100-year flood event.

After review by the community and FEMA, the rate study is officially presented to the community at a public meeting, where it may be contested on technical grounds. When review is complete and disputes resolved, the community has six months to develop a complete flood plain management program.

The most significant aspect of the resulting program is the requirement that all new residential construction have the first habitable floor at or above the water surface of the 1-in-100-year flood. Commercial buildings may be floodproofed or elevated. Where there is a floodway, the community must forbid virtually all new construction. As California's communities reach this phase of the insurance program, many adopt a two- zone flood area: a flood plain prime, which is the designated floodway or stream channel in which new construction is essentially forbidden, and a flood plain fringe in which development is elevated above the water level or in which floodproofed development is permitted.

After the community has implemented its complete flood plain management program, property owners can purchase additional insurance, another $150,000 in the case of a home, at actuarial rates. This is called the "regular" phase of the program. These rates vary with the location of the structure, with its type, and with the structure's elevation above or below the water surface elevation of the 1-in-100-year or base flood. For example, if the first floor of a home is 1.22 or more metres (4 feet or more) above the level of the base flood, the premium rate is only $0.01 per hundred dollars worth of coverage. Conversely, with a first floor which is 1.22 or 1.52 metres (4 or 5 feet) below the 1-in-100-year flood, the rate may be two or three dollars per hundred dollars worth of coverage.

A developer wishing to locate in a flood-prone area must elevate structures or pay a high mandatory insurance premium. If the structures are not elevated, a developer can ask for a variance from local building officials. Issuance of an unsuitable variance can result in suspension of the community from the program, thereby cutting off most mortgage sources.

Priorities have been set for flood insurance rate studies in California and most are already under way. Population, assessed valuation, and flooding history were the prominent criteria used in developing these priorities. These criteria led the Federal Emergency Management Agency to schedule its initial efforts in population centers of Southern California, and, to a lesser extent, the San Francisco Bay Area. By late 1979, almost 150 California communities had entered the regular phase of the program. Unfortunately, the number of individual policies purchased is quite small.

There seems to be a reluctance by government agencies in many rural California counties to impose land use restrictions in flood plains which may adversely affect investors and developers. This is so even though such rural areas provide the best conditions for controlling encroachments into the flood plains. Conversely, a number of heavily populated counties are now embracing nonstructural flood management when it is virtually too late -- too much construction has already taken place and nonstructural flood management can be applied only in a patchwork fashion.

If the program of flood insurance is to ultimately accomplish its purpose, city and county governing bodies will have to exercise sound, and at times painful, judgment in handling the many requests for variances from the ordinances adopted to restrict development in flood plains. These governing bodies must have access to competent technical advice so that patterns of incompatible uses of flood plains will not develop. These services could be provided by federal personnel or by State personnel under contract to the Federal Government or by local flood control districts. In any case, activity will expand as additional areas of the State enter the program.

This program shows the greatest promise of any of the current approaches to encourage sound flood plain management practices. However, the Housing and Community Development Act of 1977 (Public Law 95-128), which reauthorized the program, also modified the financial sanctions so that conventional mortgage loans may now be made without flood insurance in communities which are not participating in the program. Thus it is now possible for a community with heavy developmental pressures to drop out of the program, saturate its flood plains with new buildings, come back into the program and then insure those buildings.

Experience to date has not shown any significant use of this practice by communities. There is also an indication that major lending institutions would oppose such actions.

President's Water Policy Message. In June 1978, President Carter sent a Water Policy Message to Congress. He stated that his water policy initiatives were designed to improve planning and efficient management of federal water resources programs, provide a new national emphasis on water conservation, enhance Federal-State cooperation, and increase attention to environmental quality. With respect to flood damage prevention projects, the policy called for two significant changes: cost sharing would be equalized for both structural and nonstructural alternatives and an additional level of nonfederal financial participation would be required. There has been an avoidance of nonstructural alternatives in many communities because they have to be implemented at local expense. The Administration's policy reenforces Section 73 of the Water Resources Development Act of 1974 which permits federal participation in the costs of nonstructural projects. The Administration is also proposing that the states pay 5 percent of the costs allocated to flood protection purposes. This contribution, which is separate from, and in addition, to the present cost-sharing requirement, would have to be paid in cash for both structural and nonstructual plans as construction begins. The present nonfederal payment of project costs for nonstructural projects and 100 percent of right-of-way and relocation costs for structural projects would both be replaced with a uniform share of 20 percent of project costs. This share could be paid by cash or in-kind contributions (rights of way and/or relocations).

The major features of the policy changes will have to be enacted by Congress. The Administration's proposals have been included in three identical bills: HR 4127, HR 4135, and S 1599. The Corps of Engineers is, however, already incorporating the new cost-sharing provisions in individual project reports by making them requirements of local cooperation. In California there is presently no authorization for the State to pay the 5 percent share. New financial arrangements will have to be developed if the Administration's legislation is passed in its present form.

National Wild and Scenic Rivers System. In 1968, the Congress enacted Public Law 90-542, the Wild and Scenic Rivers Act. The purpose of this act is to

WILD AND SCENIC indeed is the Upper Trinity River in northwestern California. The Trinity is one of eight rivers designated for preservation in a near-natural state by the California Wild and Scenic Rivers Act which was enacted in 1972.

protect and preserve rivers and their immediate environments which possess "outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values for the benefit and enjoyment of future generations." For a river reach to be eligible for inclusion in the National Wild and Scenic Rivers System, it must be free-flowing and possess one or more of these values. Further, such values must be of national significance and the reach should have the following characteristics:

a. The reach must be long enough (generally, at least 40 kilometres or 25 miles) to provide a meaningful experience.

b. Streamflow should be sufficient for water-related recreation activities generally assoaeed with comparable rivers.

c. The river and adjacent lands should be outstandingly remarkable and generally pleasing to the eye; however some development would not necessarily preclude inclusion in the national system.

d. Water should be of high quality or restorable to that condition.

The three classes of river areas defined in the act are as follows:

a. Wild rivers - Those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted. These represent vestiges of primitive America.

b. Scenic rivers - Those rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely primitive and shorelines largely undeveloped, but accessible in places by roads.

c. Recreational rivers - Those rivers or sections of rivers that are readily accessible by road or railroad, that may have some development along their shorelines, and that may have undergone some impoundment or diversion in the past.

In California, only the Middle Fork Feather River and North Fork American River are included in the National Wild and Scenic Rivers System. Reaches of these rivers selected for the National and State Systems are shown on Figure 24 (page 86).

On September 11, 1970, the Secretaries of Interior and of Agriculture announced that segments of the Sacramento River, including the reach from Keswick Dam to Sacramento, had been identified as potential additions to the National Wild and Scenic Rivers System, in accordance with provisions of the Wild and Scenic Rivers Act of 1968, Public Law 90-542. Section 5(d) of this act, as amended, states in part that:

> "In all planning for the use and development of water and related land resources, consideration shall be given by all federal agencies involved to potential national wild, scenic and recreational river areas, and all river basin and project plan reports submitted to the Congress shall consider and discuss any such potential."

Based on Public Law 90-542 and considering various Corps of Engineers projects and studies affecting the Sacramento River, the Office of the Chief of Engineers approved preparation of a Section 5(d) study by the Sacramento District, Corps of Engineers. The results of this study were published by the Sacramento District, Corps of Engineers in an August 1975 report entitled "Wild, Scenic, and Recreational Characteristics--Sacramento River, California, Keswick Dam to Sacramento."

The purpose of this study was to inventory and describe characteristics of the Sacramento River between Keswick Dam and Sacramento and to provide a basis for future studies evaluating the effects of existing and proposed water resources projects on the wild, scenic, or recreational potential of the river. Supplements to this study, as required, will address the impacts of individual projects.

Other rivers designated for study for potential addition to the National Wild and Scenic Rivers System include: the North Fork American from the Cedars to the Auburn Reservoir; the main stem Tuolumne from its source on Mount Dana and Mount Lyell in Yosemite National Park to Don Pedro Reservoir; and the main stem of the North Fork Kern from its source to Isabella Reservoir, excluding its tributaries.

National Weather Service. Federal responsibilities for flood forecasting and warning are assigned to the National Weather Service. That organization and the Department jointly provide this activity for the northern and central portions of California.

After the disastrous floods of Christmas 1955 in the Sacramento Valley, the urgent need for advance warning of floods led to establishing the State-Federal Flood Operations Center. The Center was in operation in Sacramento by the end of 1956. The National Weather Service part of the operation is termed the River Forecast Center.

Another destructive flood, in 1964 in Northern California, impelled the Department, the National Weather Service, and other federal agencies to expand the system of telemetry for wider collection of hydrologic data. Continued development in this field has given California the largest network of this type in the United States.

Today the Center provides liaison among Federal, State, and local agencies during times of flooding or impending flooding. As a flood threat develops, the Center issues forecasts of expected river stages and reservoir inflows at 84 points in Northern and Central California, shown in Figure 22, and directs flood operations. The Center prepares and issues river forecast bulletins and coordinates flood fighting activities and technical and financial assistance for local agencies.

A satellite Flood Operations Center, set up in Eureka in 1965, provides information for the north coast region of the State and exchanges flood data with the Center in Sacramento.

An increase in the number and reliability of forecasts has been accompanied by improved equipment to obtain data in the field, to process the data, and to prepare forecasts in the Flood Operations Center.

Until recently, forecasts of flooding were confined to watersheds greater than about 500 square kilometres (roughly 200 square miles) and situated north of the Tehachapi Mountains. In certain highly urbanized areas of Southern California, the Corps of Engineers and the county governments do some flood forecasting. However, in these areas, in other well-developed areas along the coast south of San Francisco, and in endangered communities in smaller watersheds, California's flood warning efforts could be expanded or improved. Some service was provided in 1977 when flood advisory forecasts were initiated for three small watersheds in Monterey County, followed in 1978 with advisory forecasts for Sespe Creek watershed in Ventura County. Incorporating additional areas of the State into a flood forecasting system will require expenditures for additional telemetry data stations and participation by the communities themselves.

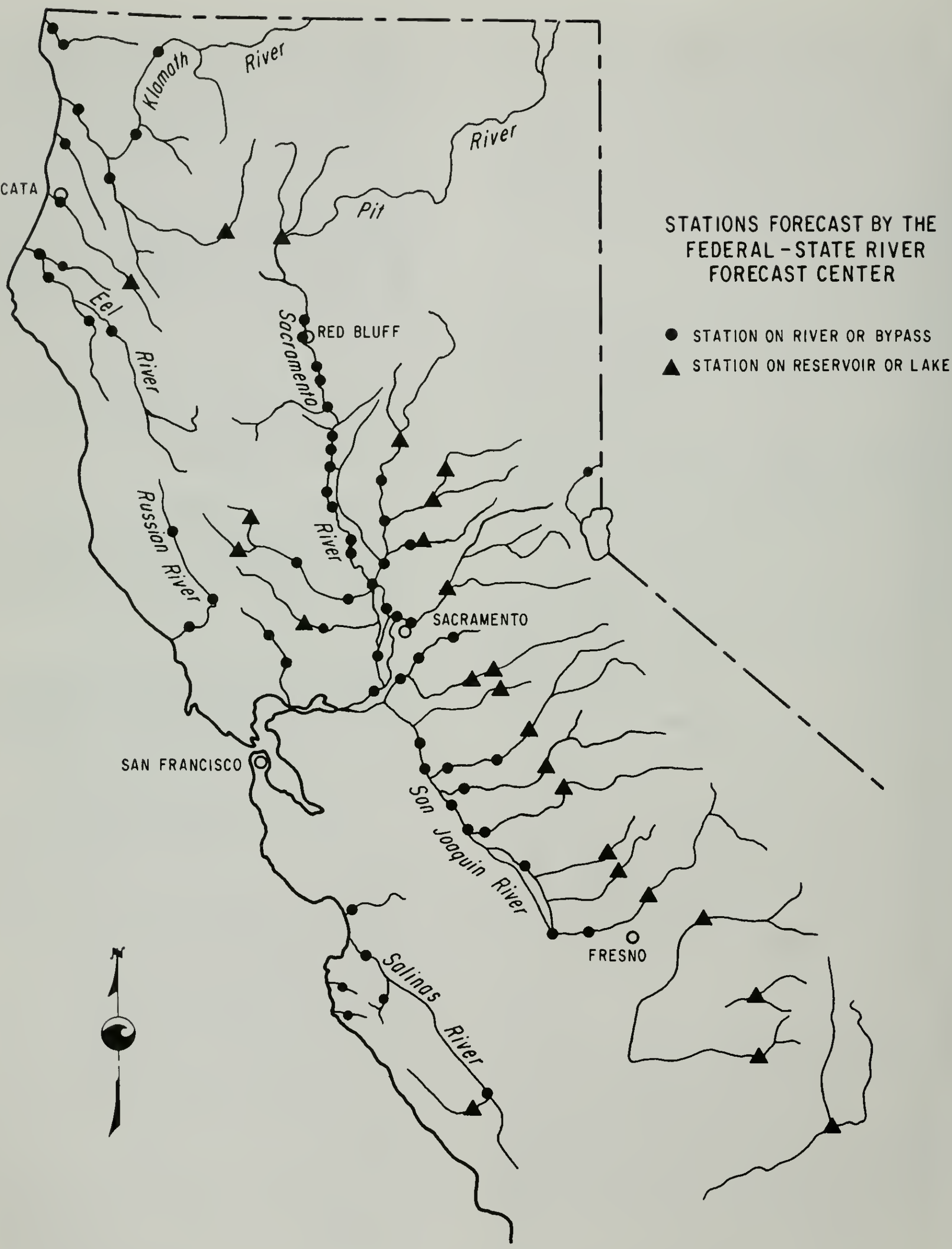


Figure 22. FLOOD FORECAST POINTS IN CALIFORNIA

The National Weather Service has recently begun a flash flood warning service. Flash flood alerts are issued when meteorologic conditions for an area indicate a strong possibility of heavy precipitation. These are followed by flash flood warnings, if necessary. This type of warning is provided by meteorologists, independent of the River Forecast Centers.

State Programs

The State of California has increased its activities in the area of nonstructural flood damage prevention. The State has several programs designed to reduce flood damage and to guide development away from flood-prone areas. These programs (1) encourage local governments to develop sound land-use practices consistent with existing potential for flooding (2) control encroachments within the primary floodways of the Central Valley (3) provide needed technical studies to define flooding potential (4) assist local governments in drafting land-use regulations in flood-prone areas, and (5) provide river stage and flood warning forecasts.

State leaders are dedicated to maintaining an awareness and promotion of sound nonstructural flood management. Distribution of information about the National Flood Insurance Program has been a major effort in recent years. The State Reclamation Board's Designated Floodway Program has spread knowledge concerning the potential for flooding and has reduced the rate of encroachment on flood plains of the Central Valley. Other specific State programs designed to promote sound flood plain management include the Cobey-Alquist Flood Plain Management Act, California's Wild and Scenic Rivers Act of 1972, State Executive Order B-39-77, comments on environmental documents and reports, and regulation of real estate activities, as well as participation in federal flood plain information surveys and flood insurance rate studies, and river stage forecasting and flood warning services.

Central Valley Designated Floodway Program. The primary function of the Designated Floodway Program is to restrict development in the area required for passage of a 1-in-100-year or designated floodflow on streams in the Central Valley.

The State Reclamation Board has adopted rules and regulations setting forth the criteria for establishing a designated floodway and for the uses that may be allowed in (and adjacent to) a designated floodway. The Reclamation Board must approve all proposed obstructions, dwellings, and bridges to be situated in a designated floodway. Authority of the Board is restricted to the Central Valley Region comprising the Sacramento River Basin and the San Joaquin River Basin.

In establishing the reach of a stream to be included in a Designated Floodway Program, the Board gives consideration to:

- Existing and proposed Federal, State, and local flood protection works and regulations affecting the flood plain.
- The degree of danger from flooding to life, property, and public health and welfare.
- The rate and type of development taking place on the flood plain.

Studies are made to define the stream channel area required to safely contain the design flood which, in general, is the 1-in-100-year flood. Earlier designated floodways were sometimes based on a design flood of lesser magnitude. Current practice is to determine the floodway by routing a theoretical 1-in-100-year floodflow down a stream and noting the area that would be inundated. Additional filling of the fringe areas is assumed until, by trial and error, the river stage is computed to be

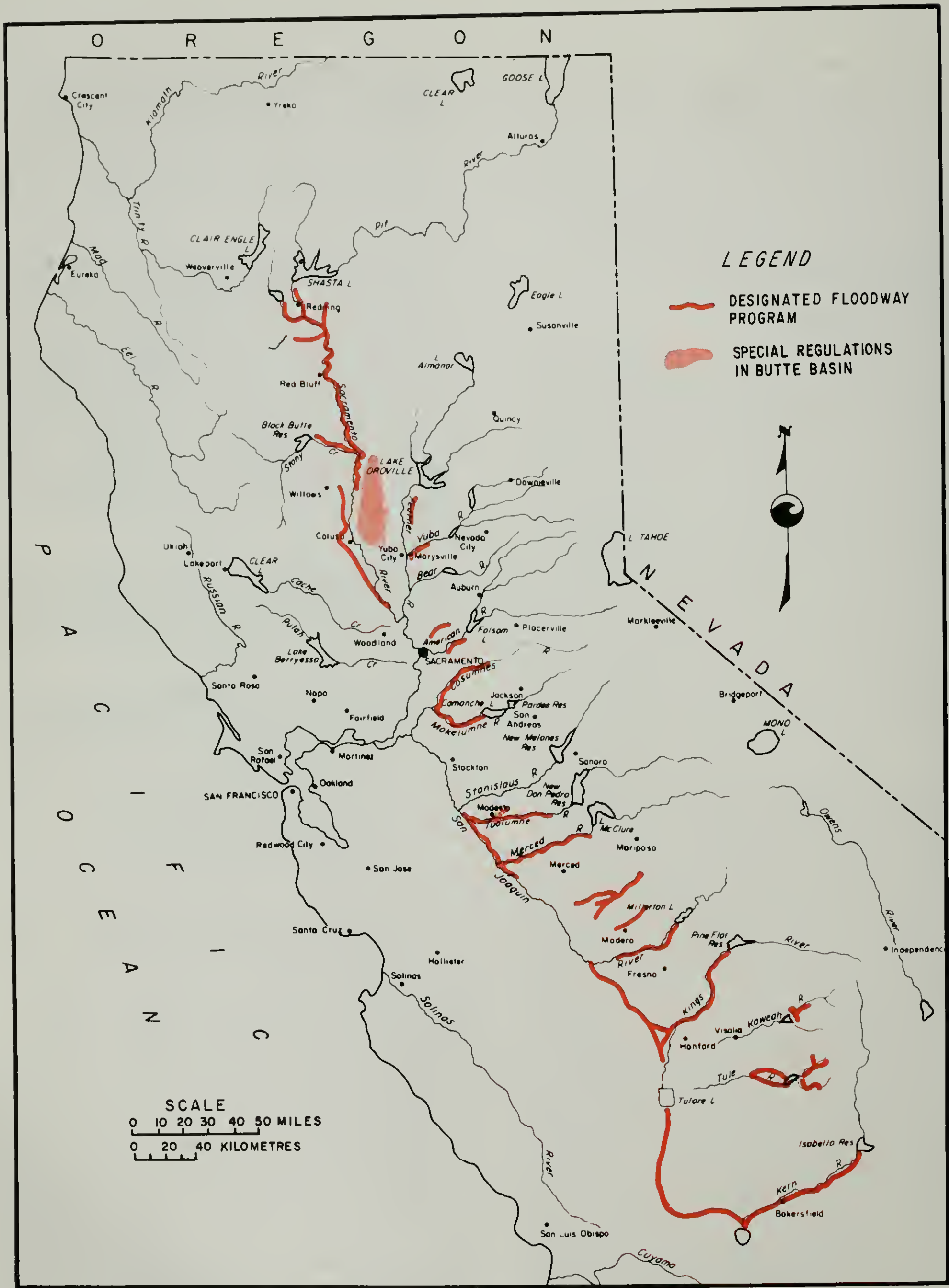


Figure 23. DESIGNATED FLOODWAYS ADOPTED by the RECLAMATION BOARD

0.3 metre (1 foot) higher than it would be without fill. The finally assumed fill line then defines the designated floodway. When the channel area to pass the designated flood has been selected, floodway encroachment lines are mapped on aerial photographs.

Before adopting a designated floodway, the Board holds public hearings to afford all interested parties an opportunity to present their views. After a designated floodway and the floodway encroachment lines have been adopted by the Board, the maps are recorded in each county in which a designated floodway has been adopted. Figure 23 shows the designated floodways which have been adopted to date.

The Board allows uses of designated floodways that are compatible with carrying storm flows, including:

A. Open-space uses of many lands such as:

   1. Golf courses
   2. Parks
   3. Roadways
   4. Parking lots

B. Most agricultural uses

C. Structures that are designed to have a minimum effect upon the passage of storm water and that do not involve human habitation.

The Designated Floodway Program is effective in controlling development in the stream channel space needed to carry the flow of a 1-in-100-year flood. However, it does not keep development out of the fringe areas which would be inundated by a greater than 1-in-100-year flood, should that flood occur.

The State Reclamation Board's Designated Floodway Program, where adopted, provides an effective tool for reducing flood damage throughout the Central Valley. However, failure to completely recognize the total contribution of agricultural damage to the overall flood problem results in this program attaining less than its full potential for reducing damage. Flood damage increases as additional flood-prone lands are converted to agricultural uses. Flood plain management as practiced by the State Reclamation Board allows almost all agricultural uses within the designated floodways. Structural flood protection facilities (dams and bypasses) reduce the magnitude of floods but permit, through "flood protection", the development of a newly "protected" area for agricultural uses. With these encroachments, it is difficult to prevent a continuing rise in flood damage, if and when flooding occurs. In fact, the economic losses to these newly developed areas are included in the economic justification for additional flood protection projects.

Take the Sacramento River from Shasta Dam to Colusa as an example. The 1955 flood inundated 40 700 hectares (100,600 acres) and caused $1.6 million (1977 dollars) in damage to agriculture. The 1974 flood inundated 46 300 hectares (114,500 acres) and caused $15.9 million (1977 dollars) in damage to agriculture. The damage to agriculture in 1955 was $17 per acre flooded, while in 1974 it was $139 per acre flooded. This increase can be explained by reviewing the DWR Northern District report that compares land use in 1952 to that in 1972. It shows that 53 percent of the high terrace land was converted from native climax vegetation to agriculture during the 20-year period. The reasons for the increased loss are more flood-prone land being planted to agriculture, several crops being planted each season, and more expensive crops being planted (e.g., walnuts).

Flood losses to residences, commercial buildings, public utilities, etc., are not increasing by the same magnitude because they are generally prohibited from flood-prone lands. In 1974, only 12 percent of the flood losses on the Sacramento River from Shasta to Colusa

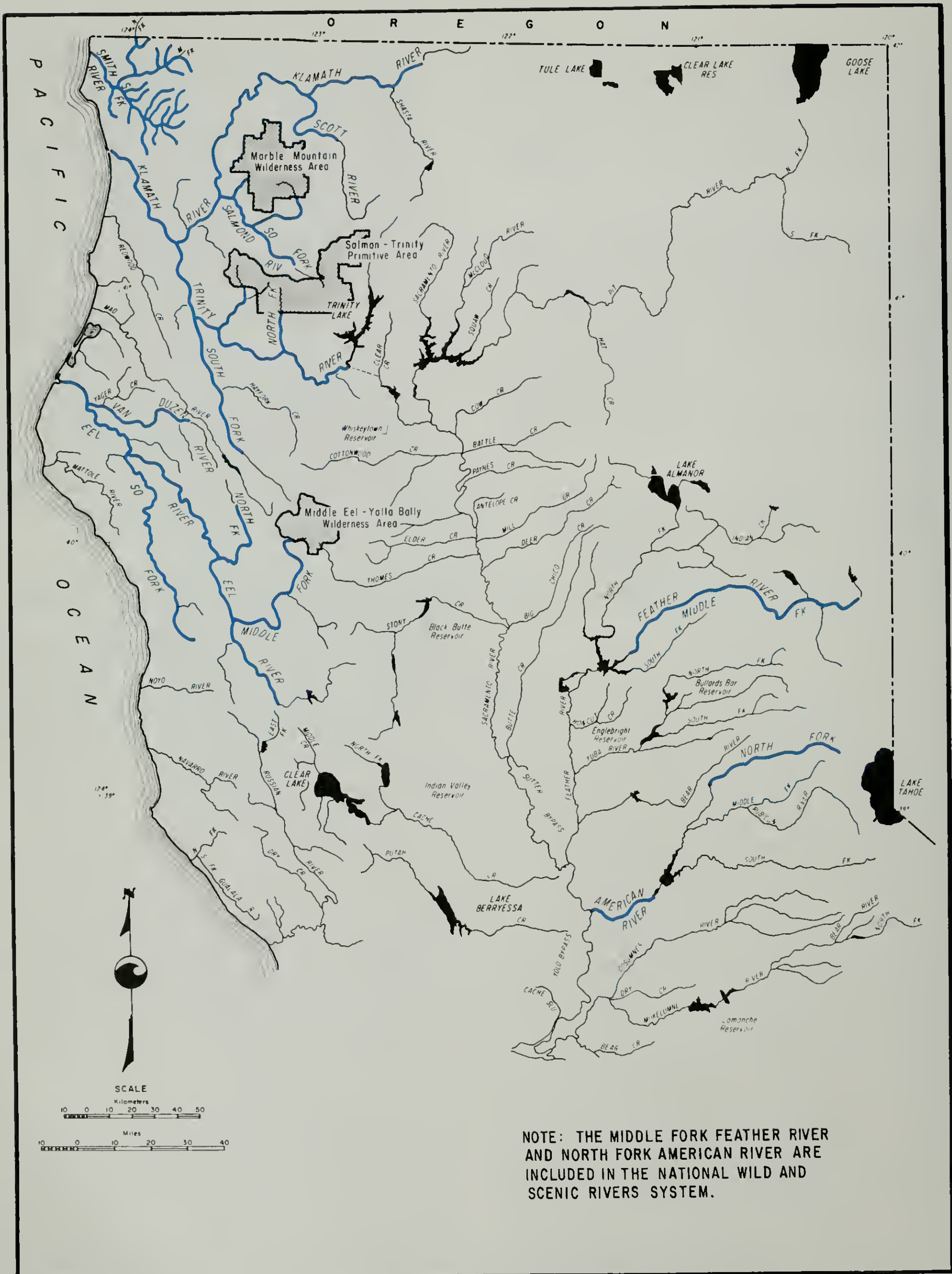


Figure 24. CALIFORNIA WILD AND SCENIC RIVER SYSTEM

were to nonagricultural developments. The total loss was $17.6 million--$15.9 million to agriculture and $1.7 million to everything else. Flood plain management works for structural encroachments such as residences, commercial buildings, etc., but it is not being used to reduce the losses to agriculture. The whole system is based upon using public funds to underwrite the unwise use of flood plains by farmers. They gamble that there will not be a flood. If the farmers guess wrong, they lose. However, because they lose, government steps in to protect them and uses their losses to justify new flood or erosion protection structures.

An effective approach to reducing flood losses in the Sacramento River Basin must consider management of agricultural uses. This would include restricting the types of crops grown in areas subject to high velocities and extreme hazard from bank erosion during flooding. Long term capital-intensive crops, such as orchard crops, should not be allowed in these critical areas, since their loss involves much more than one year's crop. The regulation of agricultural uses on flood plains has the potential for eliminating the repeated planting of permanent crops on lands subject to erosion and the necessity of costly structural works.

<u>Cobey-Alquist Flood Plain Management Act (Water Code Sections 8400-8415)</u>. This act, passed by the California Legislature in 1965, declares that it is the policy of the State to encourage local levels of government to institute nonstructural flood management, and State assistance and guidance is provided to this end. The law also has specific requirements regarding State financial assistance for costs connected with the right-of-way area of a federal project. Local agencies are required to adopt regulations to control development in the designated floodway of a project as a condition of receiving this aid. The designated floodway is defined as "...the channel of a stream and that portion of the adjoining flood plain required to reasonably provide for the construction of a project for the passage of the designed flood, including the lands necessary for construction of project levees...."

As soon as the Department of Water Resources or the Reclamation Board is informed that a federal agency has begun an initial study for flood protection, local agencies are notified in writing of the prospective requirements for regulation of development within the project-designated floodway.

The act effectively stops development in the project floodway. It may not have any effect on development of flood plains outside a project floodway since the act merely encourages regulation of the fringe area.

However, to implement the Klamath River Project, the Corps of Engineers required Del Norte County to zone a specified reach of the Klamath River. As a result of this zoning, Eugene L. Turner filed a claim in the courts alleging that the zoning by the county of his property in the designated floodway constituted inverse condemnation. The court rendered a judgment in favor of the county, finding that the enacted ordinance by Del Norte County is reasonable and that the county was acting within its policing powers.

<u>Wild and Scenic River Act of 1972 (Chapter 1.4 [commencing with Section 5093.50] of Division 5 of the Public Resources Code)</u>. In enacting this legislation, the California Legislature declared "...that certain rivers which possess extraordinary scenic, recreational, fishery or wildlife values, shall be preserved in their free-flowing state, together with their immediate environments, for the benefit and enjoyment of the people of the State." The rivers so designated are shown on Figure 24. The act requires the Secre-

tary of The Resources Agency to classify the rivers or segments of rivers into the following categories:

- Wild rivers that are free from impoundments and are generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted.

- Scenic rivers that are free from impoundments, with shorelines or watersheds still largely undeveloped but accessible in places by roads.

- Recreational rivers that are readily accessible by road or railroad that may have undergone some impoundment or diversion of water in the past.

Specific reaches of the American, Smith, Klamath, Scott, Salmon, Trinity, Eel, and Van Duzen River systems are designated as components of the system. The act further provides that the Secretary shall develop the management plan in cooperation with the counties through which the rivers flow and shall be responsible for administration of the system.

The act forbids the construction of dams, reservoirs, or other water impoundment facilities or any water diversion facility on any river in the system until the Secretary determines that such a facility is needed to supply domestic water to the residents of the county or counties through which the river flows, and it provides that any such approved facility must not adversely affect the river's free-flowing conditions.

The Legislature directed the Department of Water Resources to report to it by 1985 on the need for water supply and flood protection projects on the Eel River system.

<u>State Executive Order B-39-77</u>. The State order parallels Presidential Executive Order 11296 in that it requires officials to avoid use of flood plains, if possible. If such avoidance is not possible, then the proposed action must be modified to reduce or eliminate future flood damage. These orders apply when:

1. Selecting sites for governmental facilities

2. Acquiring or disposing of land

3. Granting financial assistance

4. Issuing permits for facilities

5. Developing land and water use plans

State agencies can obtain assistance in complying with this order from the Department of Water Resources.

<u>Regulation of Real Estate Activities in California</u>. The State Department of Real Estate has some measure of control of development on flood plains. Most residential subdivisions must be approved by the Department before lots or units can be offered for sale, and approval signifies that there are no known potential hazards such as flood hazard. Subdivisions under its jurisdiction include single-family residential subdivisions of five lots or more and condominium projects of two units or more. Subdivisions for commercial or industrial purposes are generally not subject to the Department of Real Estate's jurisdiction.

In its subdivision function, the Department of Real Estate relies on subdivision developers to supply complete and accurate flood hazard information under penalty of perjury.

The Department of Real Estate also licenses real estate brokers and real estate sales persons and regulates the activities of those agents for which a license is required. It may suspend or revoke a license for failure to disclose to a prospective purchaser of land information which the licensee has about so-called latent defects, including flood hazard information. An agent involved in a residential property sale must inform a prospective buyer that the property lies in a flood-prone area, if the licensee is aware of that fact and the buyer is not. The Department of Real Estate may take disciplinary action against the licensee who fails to do so.

Local Problems

As previously noted, while local governments have the basic responsibility for land use regulation, many have not been very receptive to nonstructural approaches to flood damage prevention. There are many reasons for this, but the primary ones are pressures for development regardless of location in a flood hazard area, and lack of technical information.

Land development increases the local tax base and creates jobs in the local economy. It also satisfies the continuing demand for new housing. Although the long-range service costs of this type of land development to the community may be very large, particularly in a flood hazard area, local officials often believe the short-range impact is beneficial.

While some counties already have ordinances on the books which are adequate to accomplish nonstructural flood management in high risk areas, many are not implemented because there is insufficient technical information to zone and enforce appropriate land uses. The "rate studies" being prepared by the Federal Emergency Management Agency will provide much of the data needed. When these studies are completed, "lack of information" will be less of a valid excuse for inaction.

Watershed Treatment. Among the types of damage caused by flood-producing rainfall are sheet erosion and gully formation. Watershed treatment is a method of preventing these.

Watershed treatment is, in general, applied to relatively small areas. It consists of crop rotation, terracing, contour stripping, and seeding and reforestation. These measures increase the capability of soils to absorb and retain rainfall. These efforts can reduce the rate of soil erosion and the rate of water runoff. While watershed treatment is effective in small flood events, it has little effect in reducing flows in extreme floods. However, it can effectively reduce soil erosion and erosion-caused damage, even in very large floods.

Effectiveness of Nonstructural Methods and Programs

Nonstructural methods of flood damage prevention have not been widely used in California. The programs which would advance these methods are in their early stages. As with most new programs, they suffer from insufficient funding and lack of acceptance, particularly by those who believe they would suffer financial losses from their implementation.

However, the perceived costs of keeping flood plains natural may be more than offset by the many environmental benefits, as well as by monetary savings which would stem from reduced flood damage and reduced expenditures incurred by constructing physical facilities, fighting floods, and providing disaster relief.

Adequacy of Nonstructural Flood Management. The general methods of nonstructural flood management have been developed and tested. A lack of precise technical data has been widely used as an excuse for not adopting such flood management practices.

Flood Plain Information Studies of the U. S. Army Corps of Engineers and Department of Water Resources and other agencies have been of help to a few governmental jurisdictions that aggressively employ zoning ordinances to protect people and property from floods. These accomplishments fall far short of comprehensive coverage of flood-prone areas. The State's Cobey-Alquist Program is likewise very limited in its accomplishment. The State Reclamation Board's Designated Floodway Program has had a significant impact. Floodways are now designated and managed on about 1 740 kilometres (1,080 miles) of Central Valley streams.

There are vast opportunities for applying nonstructural flood management methods in the rural areas of the State. The opportunities in the developed urban and suburban areas are more challenging. In much of the developed area, development has progressed to a degree that nonstructural methods alone will not solve existing problems. The most pressing problem for the nonstructural flood management program is obtaining the technical data base necessary to apply land use regulations.

Outlook for National Flood Insurance Program. The National Flood Insurance Program has the most potential for successful implementation of nonstructural methods of flood damage prevention. The "rate studies" will provide the technical base which has been missing in the past. Amendments to the program in 1977 have the potential to weaken it somewhat, and efforts should be made to restore the full strength of the mandatory regulation requirements.

If fully applied, the program would bring unwise development in flood-prone areas to a halt. This pause would give State and local officials the time needed to develop comprehensive land-use plans which fully recognize flood hazards.

Flood Forecasting and Warning. Residents along the larger rivers in Northern and Central California are now provided timely and accurate forecasts of floodflows. Timely flood warnings permit evacuation of people from threatened areas and removal of livestock and property ahead of the rising water. Forecasts of inflow to reservoirs, especially those with floodwater storage capacity, enable effective management of reservoir releases to complement available capacity in downstream channels. This minimizes the danger of flows that exceed the capacity of the flood systems.

The major population areas around San Francisco Bay and in Southern California receive little warning of impending flooding. However, the National Weather Service and the Department are working together to provide warnings to small watersheds throughout California by assisting local agencies to install systems similar to those in Monterey and Ventura Counties.

The program in Northern Central California should continue to be refined as additional equipment and forecasting techniques become available. Opportunities to establish the program in the urban areas of Southern California and the smaller coastal watersheds should be evaluated objectively when they are presented.

Combined Methods of Flood Damage Prevention

The solely structural flood protection project is not expected to be proposed very often in California in the future. While these projects have been technically and economically successful, they were often constructed at a high environmental cost and the builders frequently passed up opportunities to achieve other community values, such as recreation and fish and wildlife enhancement. Until recently nonstructural alternatives were seldom seriously considered as a solution or as a part of a solution to flood problems.

The formulation of flood management projects and programs is in a state of transition in California, and increased attention is being given to consideration of environmental and aesthetic values. Recreation plans are being incorporated into the proposals. Fish and wildlife enhancement plans are proposed where feasible. This trend away from the solely structural project includes the nonstructural approach as an adjunct to structural solutions. Nonstructural alternatives are being included in the Corps of Engineers' evaluation of flood protection projects. For example, the middle reach of the Calleguas Creek channel modification project will be left in its natural condition and the area needed for passage of the design flow will be maintained by land use controls. The Tijuana River Project has a natual flood plain. The reach of the main stem of the Santa Ana River between Mentone Dam and Prado Reservoir would have its flood-carrying capacity protected by land-use controls as part of the project proposed to increase the level of protection in the basin.

Section 73 of the Water Resources Development Act of 1974 (Public Law 93-251), requires consideration of nonstructural methods for federal participation in the cost of flood protection projects. Nonfederal interests would also have to participate, but their costs could not exceed 20 percent of the total project costs. The Legislature should accordingly modify The State Water Resources Law of 1945 to permit State participation in the nonfederal costs of nonstructural alternatives.

With financial assistance for nonstructural alternatives available equal to that of structural alternatives, a community could work toward a solution of its flood problems which would best meet its social and environmental objectives. It would no longer have to accept a structural solution because it was the only one available. On the other hand, a structural solution would not be precluded.

Freedom of choice at the local level, together with the requirements of the flood insurance program, should change the flood management practices of local government. This will be particularly true in rural areas and on smaller streams around the fringes of the highly developed urban areas. Where development is already far advanced, as it is in many areas of the State, the structural solution may still prevail, but with serious creative consideration being given to environmental and social amenities. A rational approach to flood management would require developers of new areas to plan and implement measures that would prevent or control increased runoff and sediment production in order to minimize downstream effects. For existing developments, the upstream areas should be required to bear part of the local costs for flood protection for the lower areas.

In the future, nonstructural flood management will be relied upon increasingly because of its many environmental, social, and economic benefits. In some instances, people will still need to look to structural solutions to flood problems, but not nearly so much as in the past. When proper adjustments are made in financial assistance programs, local communities will be able to consider a full range of flood damage prevention methods. The "best" solution to most flood problems usually involves an appropriate mix of structural and nonstructural measures.

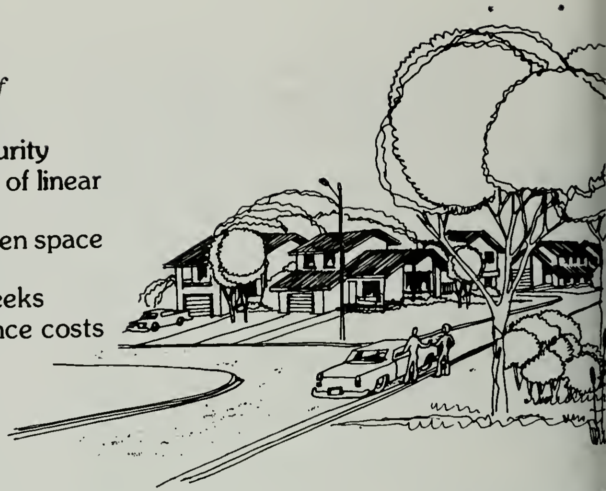
Exemplary Flood Protection

There are ways to safely convey storm water through urban areas without creating eyesores, as the pictured examples in this section will attest. The principal ingredient to accomplishing this lies not so much in engineering know-how as in a determination to create an environmentally and aesthetically sound waterway. Enlightened communities have already proven it can be done.

A number of California communities and water districts have recently begun to adopt creative yet practical approaches to streamside development in urban areas. An example of this is the Santa Clara Valley Water District (SCVWD).

STREAMSIDE DEVELOPMENT in urban areas of Santa Clara County

Maximum homeowner privacy and security
Passing motorists can enjoy the beauty of linear open space
Motorists have more access to linear open space when it is a public park
No backyards or sidewalks fronting creeks
May reduce flood protection maintenance costs



Minimize number of homes exposed directly to creeks
Liberal access to open space by neighborhood residents and motorists
Staggered loops give more visual open space than cul-de-sacs
Pedestrian oriented
Minimum fencing along linear open space compared to old "back yard facing creek" plan
Maximum lot yield with curving loops

- Homeowners prefer over other street types
- Pedestrian oriented
- Maximum use of linear open space by residents
- Allows good physical and visual access to linear open space

Courtesy of Santa Clara Valley Water District

The district has prepared educational material for residential developers urging them not to sandwich creeks with residential backyards, as has been the practice until now.

An SCVWD brochure describes the disadvantages of such sandwiching:

> Look around. There are many examples of creeks which have been sandwiched by residential backyards. Stripped of vegetation, straightened, smoothed off and made more efficient for flood protection, these sterile water ways have often been hidden from view.
>
> Talk to the people who live behind the creek access road fences, and they will tell you plenty about their loss of privacy and security. Motorcycles, vandals and other intruders often find the hidden channels to be perfect corridors for illegal and disruptive activities.

The SCVWD urges, in creekside developments, the use of parallel streets, loops, and cul-de-sacs as a means to providing greater privacy and security.

The brochure referred to above points out that these changes in approach to creekside building generally will allow maximum site lot yield or maximum lot investment return for the developer. It makes this statement: "Planners, designers, engineers, developers, political jurisdictions---we need help from all of you to succeed. We can show how the use of alternative street designs, floodplain zoning, modified floodplains, realigned channel or other methods can preserve our natural creeks and enhance creekside developments." The Santa Barbara Flood Control District uses a similar approach.

The County of Sacramento is taking a new approach to drainage problems caused by urbanization, noting that urbanization is increasing peak flows from rainfall runoff. Precipitation and irrigation runoff are no longer absorbed by the ground surface, which is covered with buildings and impervious roadways and parking lots. This kind of development requires efficient drainage and flood protection measures.

The traditional measures employed for resolving local flooding and stream erosion in highly urbanized areas have been to replace natural streams with concrete-lined channels and pipes. This costly process shifts drainage problems to areas further downstream and comes under fire from downstream property owners who experience increased streamflows and rates of erosion. Further, the carrying capacity of the natural streambed for storm water and debris is reduced, usually resulting in flood and mud damage that might not have occurred if the natural capacity had been preserved.

The process also has been criticized for eliminating riparian open spaces for wildlife habitat, scenic corridors, linear recreation and study trails. Moreover, studies have shown that retaining natural stream channels is less expensive than either stream piping or concrete lining. Only in the smallest tributaries with peak flows less than 0.4 cubic metres per second (15 cubic feet per second) can piping be justified from a fiscal point of view.

The County of Sacramento is in the process of adopting a Natural Streams Combining Zone for all properties within the 100-year flood plain. This will require permits for all uses within the flood plain except for single family houses, which require the approval of the Planning Department. Hearings on this proposal were held early in 1980 and adoption of this zoning action is expected.

Exemplary projects are depicted in photographs and others are described in the section on "Land Use Regulation and Management".

STREAMSIDE DEVELOPMENT in Santa Barbara County

The Santa Barbara County Flood Control District has a progressive program for maintaining streams in a natural state, with adjacent open space and streets parallel to the creeks. At Goleta Slough, the district restored tidal circulation and improved vegetative habitat while increasing the drainage capacity for upstream runoff.

GRASSED WATERWAY with concrete low flow.

OPEN SPACE FOR RECREATION at Goleta.

MARIA YGNACIA CREEK open space. Set-back adjacent streets parallel both banks of the creek.

ROCKED WALLS at Paulin Creek, Sonoma County, combine utility with grace in guarding against flood and erosion.

FIFTEENTH HOLE of the Riverview Golf Course in the Santiago River Channel demonstrates how a flood channel can be maintained and still be available for human use most of the time.

FLOOD PLAIN LEVEE is played down and creek and natural surroundings are preserved in this Santa Clara County housing tract alongside Alamitos Creek.

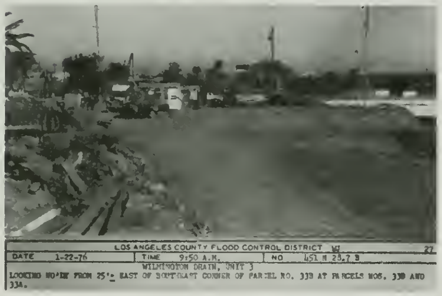
FLEXIBILITY OF GROUTED SANDBAGS allows majestic tree to be retained in channel of San Tomas Creek at Westmont in Santa Clara County. (Santa Clara Valley Water District photo)

FLOOD PLAIN RESIDENCE on Sacramento River in Tehama is prepared to meet flood threat half way. Note boat for evacuation when water rises.

EXEMPLARY FLOOD MANAGEMENT PROJECTS (cont'd)

A PROGRAM for remedying unsightly conditions caused by past flood protection efforts is being conducted in Los Angeles County. These before and after photos of the Wilmington Drain Waterway and Wildlife Area indicate how much can be done. Active involvement by environmentalists in project concept development and acceptance illustrate the benefits of public participation.

WHEN A RETURN TO NATURE is impractical, a cleanup job is a desirable alternative. On this parcel, a virtual dump was turned into a lecture area. (Below) One area of unauthorized fill on wetlands still requires attention by the Flood Control District. (Los Angeles County Flood Control District Photos)



A MARSH OBSERVATION DECK is located approximately where the little white shed appears in the photo. (Right) The Wilmington Drain Project was a joint effort by the Los Angeles County Flood Control District and the Los Angeles County Sanitation District, with cooperation of the City of Los Angeles Department of Parks and Recreation, California Department of Fish and Game, and others.

ALAMEDA CREEK FRESHWATER MARSH in Coyote Hills Regional Park, Alameda County, has been maintained in a near-natural state, providing refuge for wildlife, beauty to the beholder, and a nature study area for young people. (Alameda County Flood Control and Water Conservation District Photos)

RECREATIONAL USE of high terrace lands is commercially feasible, as in the case here of Sacramento's Campus Commons Golf Course alongside the American River. Such use creates a pleasant vista with little flood damage potential.

SACRAMENTO VALLEY TOWNS in many instances have done a praiseworthy job of preserving natural vegetation along their waterways. This setting along the American River in Sacramento is a favorite of rafters, horseback riders.

FROM A DISTANCE, rock encased in wire netting, with vegetation allowed to grow, provides a better appearance than would ordinary riprap on this stretch of the Guadalupe River in Santa Clara County. (Santa Clara Valley Water District Photo)

OLD FASHIONED retaining wall on San Francisquito Creek in Palo Alto is used to convey storm flows. It does not imitate nature but interferes as little as possible with natural vegetation. (Santa Clara Valley Water District Photo)

GOLF COURSE AROUND CREEK is compatible with short-season flood threat in Southern California, posing little danger of flood damage and almost no damage to human life. This photograph was taken at Fullerton Golf Course in Orange County.

Safety and Emergency Programs

Dam Safety

Following the catastrophic failure of the St. Francis Dam in Southern California in 1928, dam safety legislation was enacted the following year, and it became effective on August 14, 1929. Additional statutes were prompted in 1965 by the failure of the Baldwin Hills Reservoir at Los Angeles in 1963. Jurisdiction for dam safety is given to the Department of Water Resources and is administered by the Department's Division of Safety of Dams. Jurisdiction pertains to dams 7.6 or more metres (25 feet) high which impound more than 18.5 cubic dekametres (15 acre-feet) of water and dams more than 1.8 metres (6 feet) high which impound 61.7 or more cubic dekametres (50 acre-feet). Although dams owned by the U. S. Government are exempt from State supervision, copies of design reports, plans and specifications, and other construction data are provided to the State. However, separate cooperative dam safety programs were instituted in 1978 between the Corps of Engineers and the Department, and between the Water and Power Resources Service and the Department for an annual meeting and ongoing exchange of information on dams under the Corps' and the Service's jurisdiction. In addition, whenever the State finds a possible safety problem on a jurisdictional dam upstream from a federal facility, it shall inform the Corps or Service as promptly as possible. The Department also receives some information on dams owned by other federal agencies such as the U. S. Forest Service and Soil Conservation Service.

The Division's engineers and geologists review plans and specifications for construction of new dams and for enlargement, alteration, repair or removal of existing dams. Inspections are made before, during, and after construction to assure that hazardous conditions do not exist and also to assure compliance with plans and specifications and proper operation. On November 1, 1979, there were 1,144 dams and reservoirs subject to State jurisdiction.

In 1972, Section 8589.5 was added to the Government Code concerning seismic safety of dams. The act requires the establishment of procedures for the emergency evacuation and control of populated areas below dams. Under the act, the owner of each dam was required to prepare and file inundation maps which show the areas of potential flooding in the event of sudden or total failure of the dam. The program is administered by the Office of Emergency Services with assistance from the Department of Water Resources.

Federal Programs

The Corps of Engineers is frequently called upon to perform emergency work, principally flood-fighting activity and repair of publicly owned structures and public and private levees damaged by floods.

Continuing congressional authorizations permit the Corps to immediately undertake this work as needed to prevent emergency situations from arising. Emergency flood control work may also be undertaken under special, one-time congressional authorization. The Corps, additionally, repairs and restores flood-damaged facilities at the request of the Federal Emergency Management Agency.

Under Section 216 of the 1950 Flood Control Act (Public Law 516), the Soil Conservation Service administers funds to do restoration work in watersheds that have been suddenly impaired by a natural disaster. Emergency restoration work is limited to rivers, stream channels, and upper watershed areas. Proposed restoration work must be approved prior to starting the installation and some local cost sharing is required.

The Federal Emergency Management Agency's (FEMA's) Disaster Response and

Recovery Regulations have been amended to expand those portions which deal with the evaluation and mitigation of natural hazards. Field implementation of Section 406, Public Law 93-288, as amended, supplements FEMA's current efforts to stimulate and encourage comprehensive hazard identification, evaluation, and mitigation at all levels of government, and enforces the current requirement for mitigation of natural hazards as a condition for federal disaster assistance.

State Programs

The Natural Disaster Assistance Act (Government Code Sections 8680-8692), provides for State financial assistance for the repair, restoration, or replacement of public real property of cities, counties, and districts that has been damaged or destroyed by a natural disaster. This program is administered by the Office of Emergency Services (OES).

The Office of Emergency Services also performs the following functions during periods of flood emergency:

- Coordinates the extraordinary activities of all State agencies.
- Receives and disseminates emergency alerts and warnings.
- Receives, evaluates, and disseminates emergency intelligence.
- Prepares emergency proclamations and orders for the Governor and disseminates them to all concerned.
- Receives, processes, evaluates, and acts on requests for mutual aid.
- Coordinates application of State mutual aid resources and services.
- Receives, processes, prepares, and transmits requests for federal assistance.
- Maintains liaison with federal and local emergency response agencies.
- Sends out teams to survey disaster-caused damage.

When it is apparent that an extraordinary disaster is occurring from severe flooding or where watershed lands damaged by forest fires produce conditions that would cause excessive damage by floodwaters, mud, and debris, Section 128 of the Water Code provides that any person or political subdivision of the State may request the Director of Water Resources to declare the existence of an emergency. The request must (1) set forth the extraordinary conditions that create an imminent threat of damage by floodwaters, mud, or debris upon the occurrence of storms, and (2) describe the areas where extensive damage is expected to occur, the nature and causes of expected damage, and the extent of minimum temporary work required to relieve the emergency. The remedial action to cope with the problem must be beyond the financial and resource capability of the requesting interest and federal funds must not be available.

The general purpose of Section 128 is to participate in local flood fighting efforts for emergency work and temporary remedial measures required during times of extraordinary stress to avert damage or destruction to property having a general public and State interest and to protect the health, safety, convenience, end welfare of the general public of the State. Legislative appropriation is usually required. It is State policy that no emergency funds will be available to areas that have not enacted adequate land use controls for flood protection.

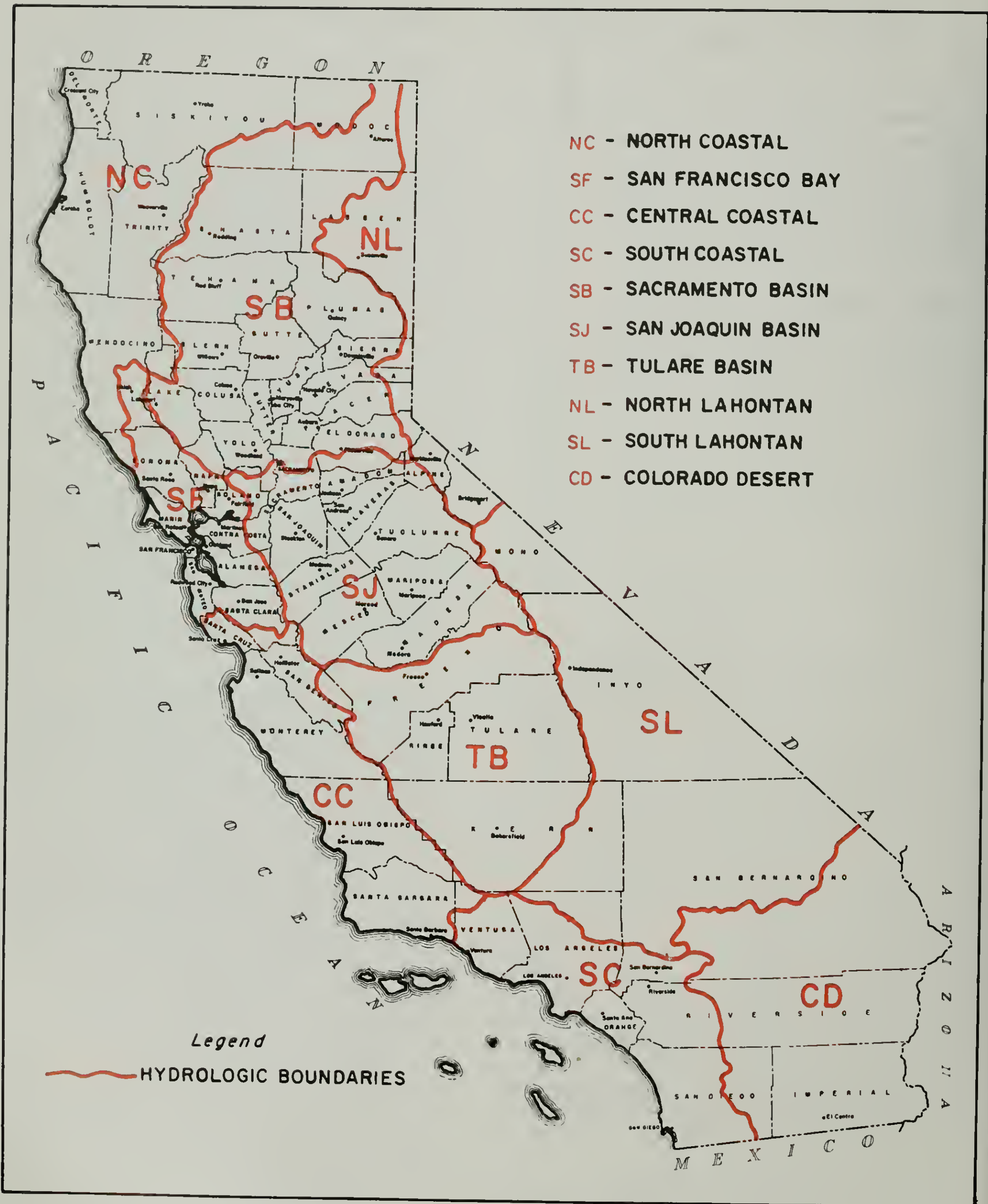


Figure 25. HYDROLOGIC AREAS

CHAPTER 5. AREAL ASSESSMENT OF FLOOD DAMAGE PREVENTION IN CALIFORNIA

During the last 60 years, large flood protection projects have been built on all the major rivers of the State, except in the north coastal area. Flood warnings are provided for large watersheds north of the Tehachapi Mountains.

This chapter represents an assessment of the ten hydrologic study areas into which the State of California is divided. Figure 25 defines the areas used in the presentation of material in the chapter.

The information for each area includes a history of flooding, flood protection facilities within the area, flood plain management history and current practices. The discussion of each study area concludes with an evaluation of the present flood damage situation and problems which need attention. The evaluation relates to policy presented in Chapter 2.

State Flood Information

Flood damage prevention facilities in each hydrologic study area are inventoried. Tables 1 through 20 list the details of projects and regulated floodways in each area. Every city and county having flood management responsibility is named and the extent of present flood plain management activities is indicated.

Figures 26 through 39 depict flood protection projects that provide urban areas with at least 1-in-100-year flood protection and agricultural areas with 1-in-50-year protection. The figures show the areas protected by each project and reservoirs that have a specific reservation for flood storage. Many other reservoirs provide incidental flood storage benefits. Not all of these appear on the figures.

Areas that are known to be subject to flooding are shown in red. They include areas that have been historically flooded or areas defined by hydrologic studies such as the Corps of Engineers' Flood Plain Information Reports listed in Appendix E. This information has been abstracted from the files of Federal, State, and local agencies and incorporated on one set of maps. These maps are retained in the local Department of Water Resources district office and are available for inspection. The absence of a flood-hazard area does not mean a flood hazard is nonexistent. It does indicate that flood information may not be available. The areas subject to flooding on Figures 26 through 30 and 32 through 39 range from historical floods to estimated Standard Project Floods. Flooding from ocean tsunamis or tidal waves and seiches on lakes are not included.

North Coastal Hydrologic Study Area

The North Coastal Hydrologic Study Area extends along the Pacific Ocean from the mouth of the Russian River to the California-Oregon border. Major river systems include the Smith River, Klamath River, Redwood Creek, Mad River, Eel River, and Mattole River, Noyo River, Navarro River, Garcia River, and Gualala River. Principal tributaries to the Klamath are the Trinity, Salmon, Scott, Shasta, and Lost Rivers. Flood information for the area is shown in Figures 26 and 27.

The area is sparsely populated, with about 4 persons per square kilometre (10 per square mile) in 1972. Average State population is about 50 persons per square kilometre (129 per square mile). Most of the population in this area is

O R E
Iron Gate Res.
N. Fk
Middle Fk
SMITH R.
CRESCENT CITY
South Fk
DEL NORTE
Indian Cr.
Happy Camp
KLAMATH
RIVER
YREKA
Shasta
Montague
Little Shasta
Scott
Fort Jones
S I S K
L. Shasta
Wooley Cr.
Etna
River
Weed
OCEAN
PACIFIC
KLAMATH
Orick
Redwood
RIVER
Salmon
Orleans
R.
H U M B O L D T
Hoopa
TRINITY
Arcata
Blue Lake
EUREKA
Jacoby Cr.
Creek
Mad
Clair Engle Lake
T R I N I T Y
WEAVERVILLE
RIVER
SOUTH
Salmon Cr.
MATCH
TO
FOLLOWING
PAGE
Hayfork Cr.
Hayfork
FORK
River
Robert W. Mathews Res.
TRINITY

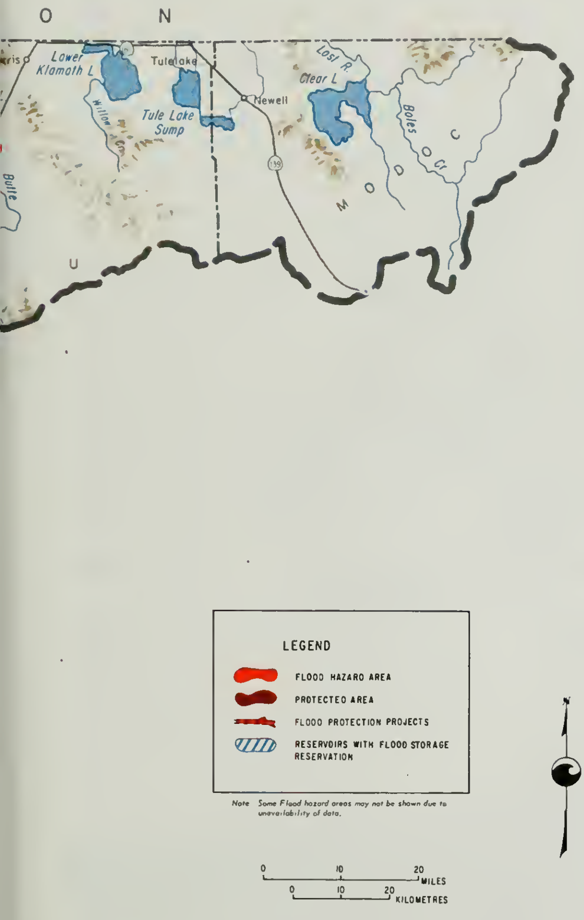


Figure 26

FLOOD INFORMATION

NORTH COASTAL HYDROLOGIC STUDY AREA
NORTHERN PORTION

Figure 27
FLOOD INFORMATION
NORTH COASTAL HYDROLOGIC STUDY AREA
SOUTHERN PORTION

concentrated around Humboldt Bay. The area currently has about 0.9 percent of the State's population. Projected rates of growth are less than that projected for the State. Population in Del Norte, Humboldt, Modoc, and Trinity Counties declined between 1960 and 1970.

Transportation development in the area has been hampered by its mountainous terrain. Highways serving the area include U.S. 97, 99, 101, 199, and Interstate 5 and several California routes, principally Highways 1, 20, 36, 96, 128, 136, and 299. Rail transportation is provided by the Northwestern Pacific Railroad, serving the north central and northeastern areas. Commercial air service is available at Eureka and Crescent City. Humboldt Bay at Eureka is a deep-water port serving coastal and foreign shipping.

The economy of the area depends heavily on local natural resources, primarily timber, fish, wildlife, irrigable land, minerals, and recreational lands. Principal commerce is in lumber, agriculture, fisheries, and trades and services catering to recreation.

History of Flooding

More rain falls annually in the North Coastal Area than in any other region of California, and, as a result, floods are typically severe. The average yearly rainfall varies between 1 000 and 2 800 millimetres (40 and 110 inches). Intense, short-duration rain follows prolonged moderate-to-heavy rain. Because of the steep, rugged terrain, and historic poor land use practices, flows in stream channels rise and fall with great rapidity. Floods are brief; the water seldom leaves the channels for longer than a few days. Snowmelt does not often contribute to flood runoff.

Floods of varying magnitudes frequently occur, causing extensive damage to homes, businesses, schools, utilities, transportation facilities, and, in certain instances, destroying entire communities. The floods of December 1955, January 1956, and December 1964 were the most severe. The damage resulting from the 1955-56 floods in the North Coastal Area was estimated by the U. S. Army Corps of Engineers at $36 million. In December 1964, 34 counties in Northern California were proclaimed flood disaster areas. Total damage was $175 million. The Klamath River rose rapidly and swept away the entire business section and many homes in the town of Klamath. Nearby towns of Camp Klamath, Requa, and Klamath Glen were also literally wiped out. Willow Creek, Orleans, and Happy Camp were severely damaged.

Flood Damage Prevention Facilities

In the North Coastal Area, there are five Corps of Engineers' channel and levee projects and one federal multipurpose reservoir, namely Clair Engle, that provide flood storage. Information on the projects and reservoir is presented in Table 1.

DOWN TO THE SEA IN CHIPS. Crescent City Harbor, on the northwest coast of California, woke up on December 29, 1964, to find itself logjammed as a result of flooding. (U. S. Army Corps of Engineers Photo)

Table 1: FLOOD DAMAGE PREVENTION PROJECTS IN NORTH COASTAL HYDROLOGIC STUDY AREA

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Klamath River	Klamath River (U.S. Army Corps of Engineers)	Del Norte County	Project consists of 1 510 metres (4,950 feet) of levee downstream and 2 225 metres (7,300 feet) of levee upstream of U. S. Highway 101	Relocated town of Klamath and the community of Klamath Glen.	Provides protection against floods up to a standard project flood.
Redwood Creek	Redwood Creek (U.S. Army Corps of Engineers)	Humboldt County	Channel rectification on the lower 6.4 kilometres (4 miles) of Redwood Creek, including levees on one or both banks over most of the 6.4 kilometre (4-mile) reach	Community at Orick	Standard project flood
Mad River	Blue Lake Levee (U.S. Army Corps of Engineers)	Humboldt County	Consists of 610 metres (2,000 feet) of new levee and 2 100 metres (7,000 feet) of improved levee	City of Blue Lake	Greater than a 1-in-100-year flood
Eel River	Sandy Prairie Levee (U.S. Army Corps of Engineers)	Humboldt County	Levee 6.4 kilometres (4 miles) along right bank of Eel and Van Duzen Rivers	City of Fortuna	Provides protection for a 1-in-75-year flood event
East Weaver Creek	East Weaver Creek (U.S. Army Corps Engineers)	Trinity County	Consists of 670 metres (2,200 feet) of trapezoidal earth channel and 910 metres (3,000 feet) of riprapped levee	Town of Weaverville	Standard project flood

Major reservoirs that provide incidental flood storage include:

Reservoir	Stream	Operating Agency
Clear Lake	Lost River	Water and Power Resources Service
Upper Klamath Lake	Klamath River	Pacific Power and Light Co.
Lake Shastina	Shasta River	Montague Water Conservation District
Tule Lake Sump	Lost River	Water and Power Resources Service
Ruth Lake	Mad River	Humboldt Bay Municipal Water District
Lake Pillsbury	Eel River	Pacific Gas and Electric Co.
Clair Engle Lake Trinity (Reservoir)	Trinity River	Water and Power Resources Service

In addition, numerous private levees offer degrees of flood protection to agricultural properties and small population centers.

With the exception of the levee protecting the City of Fortuna (in the Sandy Prairie area on the Eel River) from 1-in-75-year floods, the Corps of Engineers' projects described in Table 1 have provided 1-in-100-year or better flood protection. During the December 1964 flood, the Sandy Prairie levee was breached by floodwater from the Van Duzen River, an Eel River tributary, in what was generally determined to be a 1-in-100-year event.

Some watershed treatment measures have been taken in tributary watershed areas, including critical-area planting, tree planting, range seeding, and fire prevention.

Nonstructural Flood Management

Limited flood plain mangement is being applied in the North Coastal Area through the use of flood plain ordinances and flood warnings. Table 2 presents the types of regulations and controls adopted by county and city governments and the extent to which they have been implemented.

Many communities have adopted flood plain ordinances but have not implemented them. Only five locations in the North Coastal Area have been zoned as flood-hazard areas. Fort Jones, Etna, and the Scott Valley area in Siskiyou are the only regulated floodways which have been adopted without an outside financial incentive. The regulated floodway areas on the Klamath River in Del Norte County and the Eel River in Humboldt County were zoned under the Cobey-Alquist Flood Plain Management Act as a prerequisite to their receiving State financial assistance.

The National Flood Insurance Program has brought the need for nonstructural flood management to the attention of all counties and cities; however, a number of cities have not yet entered the emergency phase of the program, despite high flood risk such as exists in the City of Fortuna.

The California Wild and Scenic River System includes many of the North Coastal Area rivers. Streams designated in the system are shown on Figure 24. Nonstructural flood management will be the only method of preventing flood damage along those streams.

Except in isolated instances, little consideration has been given to implementing floodway controls, primarily because boundaries of flood-hazard areas for which local governments might adopt floodway controls have not been determined.

Because it is difficult to show a favorable benefit-cost ratio in studies for federal flood protection projects, and because of the low tax base in the area, structural flood damage prevention projects are not financially feasible. The way to reduce flood damage is to identify flood-hazard areas and to place adequate controls on them. Such controls allow for certain land uses, which will reduce damage caused by flooding. This has been accomplished in the Eel River Delta, where lands have been zoned for agriculture and are used primarily for stock grazing. With sufficient advance flood warning, livestock can be removed from the endangered lands, thereby minimizing injury and loss of life. This type of zoning effectively meets the principal needs of a sound flood plain management program.

Open space uses such as agriculture, parks, and golf courses are allowed in the primary floodway in the Scott Valley area in Siskiyou County. Structures may be constructed if they are floodproofed or if they have a first-floor elevation above the maximum level of the 1964-65 flood.

The federal flood damage prevention project authorized in 1966 provided for the construction of a levee at Klamath Glen and a flood-free townsite at Klamath by filling 20 hectares (50 acres) behind the reconstructed freeway and required local interests to regulate about 890 hectares (2,200 acres) in the Klamath River flood plain.

The City of Yreka has adopted a two-zone type of regulation. It intends to apply it to Yreka Creek and other flood-hazard areas when technical information becomes available.

The Joint Federal-State River Forecast Center in Sacramento provides an early warning of expected flood conditions and future water levels for the Smith, Klamath, and Trinity Rivers; Redwood Creek; and the Mad and Eel River systems.

Table 2: REGULATED FLOODWAYS IN NORTH COASTAL HYDROLOGIC STUDY AREA

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Modoc County	Ordinance 236 two-zone floodway; subdivision ordinance; uniform building code	None	None	Precise delination of flood-hazard areas	Yes
Del Norte County	Three-zone flood plain ordinances	About 13 kilometres (8 miles) of lower Klamath River	Urban, Industrial	Flood plain management is needed for other flood-hazard areas of the county. The Corps of Engineers has delineated the 1-in-100-year flood-prone area in the Lower Smith River Basin. Also, the Corps of Engineers delineated the 1964-65 flood which equaled or exceeded the 1-in-100-year flood on some of North Coastal streams. This information should be utilized until flood insurance studies are prepared by the Federal Emergency Management Agency	Yes
Crescent City	None	None	None	Flood plain management is needed for the flood-hazard areas of the City. The stage of the 1964-65 flood could be used until studies are completed by the Federal Emergency Management Agency	Yes
Siskiyou County	Two-zone flood plain ordinance	Scott River	Urban, agricultural	An accurate delineation of the 1-in-100-year flood in Scott Valley and other flood-prone areas of the County is needed. Also, the unregulated areas need flood plain management	Yes
Dorris	None	None	None	None	No
Etna	General flood plain ordinance	Etna Creek	Urban, industrial	An accurate delineation of flood-hazard areas	Yes
Fort Jones	General flood plain ordinance	Moffett Creek	Urban, industrial	An accurate delineation of flood-hazard areas	Yes
Montague	None	None	None	Identification of flood-hazard areas and flood plain management of these areas	No
Mt. Shasta	None	None	None	None	No
Tulelake	None	None	None	None	No
Weed	None	None	None	Identification of flood-hazard areas and flood plain management of these areas	No
Yreka	City has adopted a two-zone type flood plain ordinance but has not applied it to any flood-prone areas	None	None	Identification of flood-hazard areas and flood plain management of these areas	Yes
Humboldt County	County has adopted a general flood plain ordinance but has not applied it to any flood-prone areas, except for the Sandy Prairie Levee Project (a requirement of the Cobey-Alquist Flood Plain Management Act)	Eel River	Urban	Flood plain management is needed for those flood-prone areas delineated in the Corps of Engineers' Flood Plain Information Reports on the Eel River, Van Duzen River, and Freshwater Creek, and in the Corps' report on the 1964-65 flood. Also, the County needs an accurate identification of the flood-hazard areas expected during a 1-in-100-year flood	Yes

Table 2: REGULATED FLOODWAYS IN NORTH COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Arcata	None	None	None	Flood plain management is needed for those flood-prone areas delineated in the Corps of Engineers' report on the 1964-65 floods. A better identification of the flood-prone areas during a 1-in-100-year flood is needed	Yes
Blue Lake	None	None	None	Identification of flood-hazard areas and regulation of flood-hazard areas	Yes
Eureka	City has adopted a general flood plain ordinance but has not applied it to any flood-prone areas	None	None	Flood plain management is needed for those flood-prone areas delineated in the Corps of Engineers' report on the 1964-65 floods. A better identification of the flood-prone areas during a 1-in-100-year flood is needed	Yes
Ferndale	None	None	None	Flood plsin management is needed for those flood-prone areas of the City delineated in the Corps of Engineers' report on the 1964-65 floods	No
Fortuna	None	None	None	Flood plain management is needed until the Corps of Engineers' Sandy Prairie Project is upgraded to provide protection from a 1-in-100-year flood	Yes
Rio Del	None	None	None	Flood plain management is needed for those flood-prone areas of the City delineated in the Corps of Engineers' report on the 1964-65 flood. Also, an accurate identification of the flood-prone areas during a 1-in-100-year flood is needed	Yes
Trinidad	None	None	None	None	No
Trinity County	None	None	None	Flood plain management is needed for those flood-prone areas delineated in the Corps of Engineers' Flood Plain Information Report on the Trinity River and in the Corps' report on the 1964-65 flood. Also, the County needs an accurate identification of the flood-hazard areas expected during a 1-in-100-year flood	No
Mendocino County	County has adopted a general flood plain ordinance but has not applied it to any flood-prone area	None	None	Flood plain management is needed for those flood-prone areas delineated in the Corps' report on the 1964-65 flood. Accurate identification of flood-hazard areas and flood plain management of these areas	Yes
Fort Bragg	City has adopted a general flood plain ordinance but has not applied it to any flood-prone area	None	None	Identification of flood-hazard areas and flood plain management of these areas	Yes
Point Arena	None	None	None	Identification of flood-hazard areas and flood plain management of these areas	Yes

Table 2: REGULATED FLOODWAYS IN NORTH COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Ukiah	City has adopted a general flood plain ordinance but has not applied it to any flood-prone area	None	None	Identification of flood-hazard areas and flood plain management of these areas	Yes
Willits	None	None	None	Identification of flood-hazard areas and flood plain management of these areas	Yes

Flood Protection Needs

Except for the principal residential-industrial communities in the Crescent City, Eureka-Arcata, and Fort Bragg areas, and seasonal recreational development along the scenic rivers, the North Coastal Area has little urban development. Most of the urban areas are either already adequately protected by flood protection projects or else are located above the hazard level. Fortuna, with its 1-in-75-year flood protection, is a notable exception. The federal first cost of this completed work was $680,000 and nonfederal cost was $300,000. There are also many smaller communities along North Coast streams which are flooded periodically. Flood insurance and floodproofing of structures are needed because structural flood measures are neither practical nor desirable.

Nonstructural flood management is ideally suited to the area. Some locations have adopted ordinances, and have started zoning wherever federal Flood Plain Information Reports provide the necessary technical information on flood risks. Such information is critically needed in all the hazard areas. Most cities and counties in the area have entered the emergency phase of the National Flood Insurance Program and will eventually receive information on flood risks from the Federal Emergency Management Agency. Those which have not entered the program are being urged to do so.

The flood forecasting hydrologic data telemetry system in this area was replaced and augmented in 1979. This system improvement will assure continuation of river forecast accuracy.

San Francisco Bay Hydrologic Study Area

The San Francisco Bay Hydrologic Study Area is located on the north central coast of California. The area comprises all, or a major portion of, the nine counties surrounding the San Francisco Bay, plus the Russian River, Dry Creek, Big Sulphur Creek, Petaluma River, Napa River, Walnut Creek, Alameda Creek, Guadalupe River, Coyote Creek, San Gregorio Creek, and Pescadero Creek. The area is delineated on Figure 28.

This area is characterized by the mountainous Coast Ranges, rolling hills, the valleys along the Russian River in Mendocino and Sonoma Counties, and marshlands that surround San Francisco Bay and extend along small streams and rivers. It contains 480 kilometres (300 miles) of bay shoreline and over 240 kilometres (150 miles) of ocean coast line. It includes the densely populated metropolitan areas around the Bay.

The area is served by a major network of freeways, county roads, air and rail lines, and by water-borne traffic from the Pacific Ocean and the Sacramento and San Joaquin Valleys. San Francisco Bay is the largest and one of the most important ports on the Pacific Coast, con-

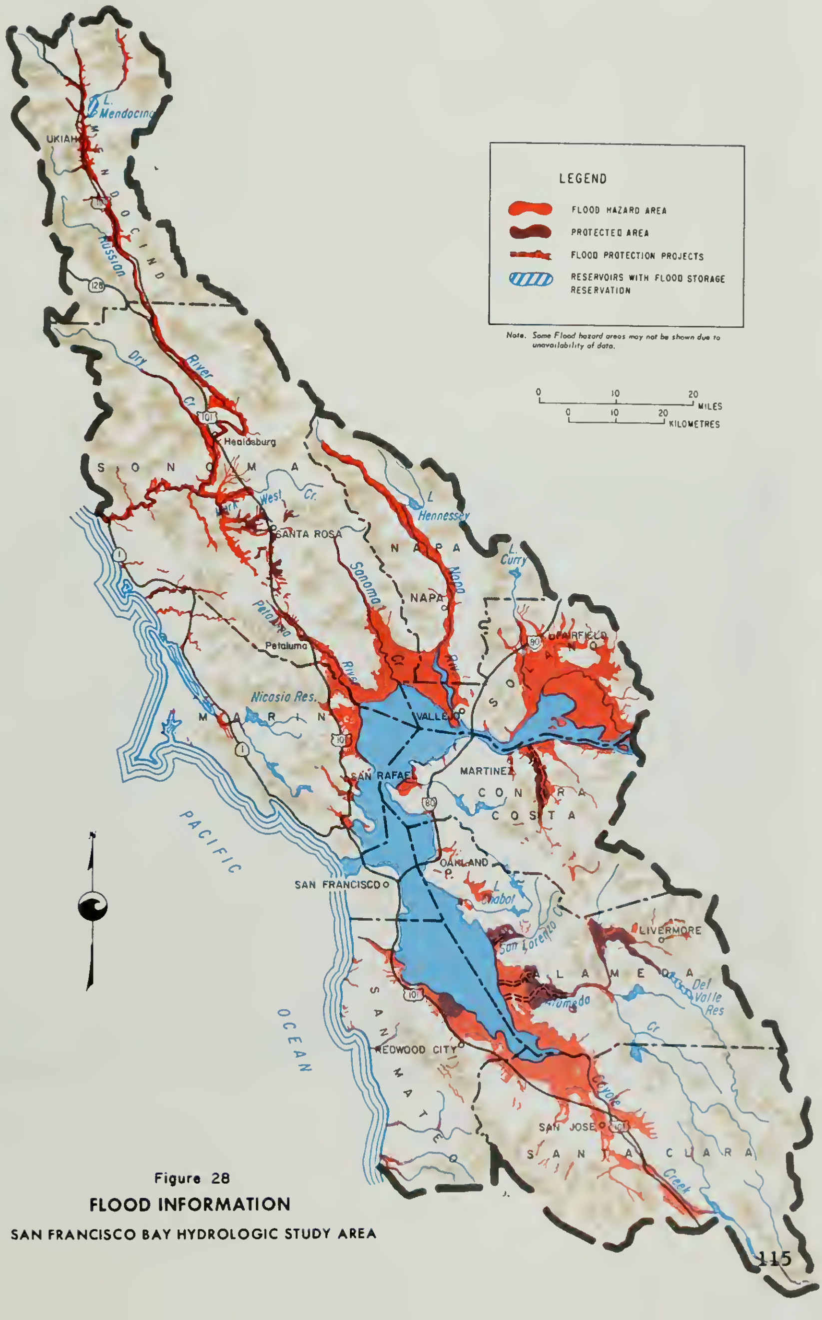


Figure 28
FLOOD INFORMATION
SAN FRANCISCO BAY HYDROLOGIC STUDY AREA

taining over 1 000 square kilometres (400 square miles) of inland waterways.

The San Francisco Bay Area has a highly complex and diversified economy. It is one of the nation's important centers for finance, international trade, and transportation. It has acquired international renown in the fields of space exploration, nuclear physics, and electronics, and is the center of a major agribusiness and manufacturing complex. The area forms a vast dynamic and prosperous market that is receiving attention from industries and investors from many parts of the world.

The growth in population and work force has created a large and rich market with a per capita income substantially above the national average. This makes the area an especially attractive market for the production and sale of a wide variety of goods and services. Population of the area was approximately 4.8 million in 1975 and is increasing at the rate of about 1.2 percent per year.

History of Flooding

Floods in the area are caused by intense rainstorms, generally preceded by rainfall that has saturated the watershed. Snowfall is rare and does not substantially contribute to runoff. A typical flood-producing storm consisting of a rapid succession of fronts may last from three to six days. Peak flows are generally of short duration; however, due to extensive overbuilding on the flood plain, the frequency of damaging floods on the Russian River, particularly near Guerneville, is among the highest in the State. Along much of the lower river channel, grape crops which are generally compatible with periodic

HIGHLY URBANIZED AREAS around the San Francisco Bay find some of their roadways turned into virtual rivers when rainfloods hit, as they did here on January 16, 1970. (U. S. Army Corps of Engineers, San Francisco District, Photo) inundation, are grown. The grapes and the land have become so valuable, however, that whenever flooding occurs, channel erosion frequently causes extensive economic loss.

Guerneville, which is close to San Francisco, and the surrounding community have developed as a resort area. The summertime peaceful climate and quiet river led to extensive development of summer homes in the flood-hazard area. In recent years, more and more of these summer homes are occupied all year long and the potential flood damage is increasing.

The most severe floods occurred in December 1955 and December 1964. The two floods claimed four lives; the 1955 flood inundated about 36 000 hectares (90,000 acres). During the 1964 flood, the Russian River Basin sustained unprecedented damage of about $17 million.

Peak discharge of 2 600 cubic metres per second (93,000 cubic feet per second) was recorded for the Russian River near Guerneville in 1964, a flood discharge frequency of approximately once in 30 years. Alameda Creek had a peak discharge of 820 m^3s (29,000 cfs) on December 23, 1955, a flood frequency of about once in 30 years. Lesser storms than those in 1955 and 1964 have produced maximum flooding in some of the smaller watersheds. A maximum discharge of 479 cubic metres per second (16,900 cubic feet per second) in the Napa River near Napa was recorded in January 1963. Walnut Creek produced its maximum recorded discharge of 227 m^3s (8,000 cfs) in April 1958. The maximum recorded discharge of the Guadalupe River at San Jose was 259 m^3s (9,150 cfs) during April 1958.

Flood Damage Prevention Facilities

Flood facilities in the hydrologic study area include flood storage reservoirs, channel modifications, levees, and watershed treatment. The degree of protection varies from the 1-in-100-year flood or greater in most urban areas to the 1-in-10- or 1-in-50-year flood in agricultural areas.

Large facilities in the area consist of seven Corps of Engineers' major flood protection projects and six small Corps' projects. The U. S. Soil Conservation Service has built three watershed protection projects. Two reservoirs, Lake Mendocino and Del Valle, constructed by the Corps of Engineers and Department of Water Resources, provide flood storage. These projects are operating as planned and are providing the intended flood protection. The Soil Conservation Service is currently designing the Lower Pine Creek Watershed Protection Project for which construction is scheduled to start in 1980. Information on these completed projects and reservoirs is presented in Table 3.

A number of project studies have been started by the Corps of Engineers, and they may lead to eventual construction. The Corps' proposed flood protection project for the Napa River was turned down in local elections in November 1976 and 1977. Under 1977 conditions, federal first cost is estimated at $38.6 million and local cost is $15.5 million.

The lower portion of the Corte Madera Creek Project in Marin County, extending from San Francisco Bay upstream to the community of Ross, is completed except for a levee gap that cannot be closed until upstream works are provided. An acceptable project for Unit 4, the upper portion of this channel modification project, has been developed by the Corps of Engineers. This alternative will preserve the aesthetic value of Corte Madera Creek. This unit is vital to the collection of floodwater into the completed project channels; without it, the project will not function as designed. The federal first cost is estimated at $2.4 million and local cost at $1.1 million.

Table 3: FLOOD DAMAGE PREVENTION PROJECTS IN SAN FRANCISCO BAY HYDROLOGIC STUDY AREA

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
East Fork Russian River	Lake Mendocino (Coyote Valley Dam) (U.S. Army Corps of Engineers)	U.S. Army Corps of Engineers	The project provides for total storage of 151 000 cubic dekametres (122,500 acre-feet) with a flood protection reservation of 59 000 cubic dekametres (48,000 acre-feet)	Agricultural lands in Ukiah and Hopland Valleys	
Russian River	Russian River Channel (U.S. Army Corps of Engineers)	Mendocino County River Flood Control and Water Conservation Improvement District, Sonoma County Water Agency	Channel modifications at various locations on lower 154 kilometres (96 miles) of the Russian River and on Dry Creek	Urban, agricultural and industrial lands along Russian River	
Santa Rosa Creek	Central Sonoma (U.S. Soil Conservation Service)	Sonoma County Water Agency	Five water retarding structures, and about 53.7 kilometres (33.4 miles) of channel modifications	Santa Rosa and vicinity	Protection provided for 100-year event floods in the major portion of the area. Minor damagea may occur along Matanzas, Spring, and upper Santa Rosa Creeks
Napa River	Napa River Watershed (U.S. Soil Conservation	Napa County Flood Control and Water Conservation District	Channel modification of Conn Creek and modification and realignment of Tulucay Creek	Agricultural and suburban areas adjacent to improved creeks	Approximately 1-in-10-year flood protection is provided by Conn Creek modification and 1-in-50-year flood protection by modification of Tulucay Creek
Walnut Creek	Walnut Creek Watershed (U.S. Soil Conservation Service)	Contra Costa County Flood Control and Water Conservation District	Flood atorage and detention reservoir on Pine Creek, 53 kilometres (33 miles) of channel modifications, and drop structures	Cities of Walnut Creek, Pleasant Hill, Concord	Project was deaigned to provide protection from a 1-in-50-year flood. However, all works of modification were not completed. Portions are now incorporated in the Walnut Creek Flood Control Project by the U.S. Army Corpa of Engineers
San Leandro Creek	San Leandro* (U.S. Army Corps of Engineers)	Alameda County Flood Conrol and Water Conservation District	Approximately 2.9 kilometres (1.8 miles) of channel improvements	Citiea of Oakland, San Leandro	The project is designed to contain floodflow of up to a 1-in-100 year flood
San Lorenzo Creek	San Lorenzo* (U.S. Army Corps of Engineers)	Alameda County Flood Control and Water Conservation District	Approximately 2.3 kilometres (1.4 miles) of leveed channel in the lower reach and a rectangular concrete channel extending upstream 6.3 kilometres (3.9 miles).	Communitiea of Hayward, San Lorenzo	The modifications are designed to contain floodflows up to the magnitude of a standard project flood.
Alameda Creek	Alameda Creek (U.S. Army Corps of Engineers)	Alameda County Flood Control and Water Conservation District	Approximately 21 kilometres (13 miles) of channel modification, including levees, channel enlargement, and bank protection	Communitiea of Niles and Union City and downstream areas	Project provides Standard Project Flood protection from Alameda Creek floodflows

* Small project

Table 3: FLOOD DAMAGE PREVENTION PROJECTS IN SAN FRANCISCO BAY HYDROLOGIC STUDY AREA (Cont'd)

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Arroyo Del Valle	Del Valle Reservoir (Department of Water Resources and U.S. Army Corps of Engineers)	State Department of Water Resources	Flood storage reservation consisting of 43 200 and 3 700 cubic dekametres (35,000 and 3,000 acre-feet) primary and secondary flood storage and 1 200 cubic dekametres (1,000 acre-feet) dual water supply and flood storage	Livermore Valley. Communities of Niles and Union City, and downstream areas	The project limits Standard Project Flood outflow to 198 m^3s (7,000 cfs) providing a reduction of approximately 467 m^3s (16,500 cfs) at the dam site
Green Valley Creek, Dan Wilson Creek	Green Valley Creek (U.S. Army Corps of Engineers)	Solano County Flood Control and Water Conservation District	Channel realignment and enlargement of 2.7 kilometres (1.7 miles) of Green Valley Creek and 4.2 kilometres (2.6 miles) of Dan Wilson Creek	Agricultural lands adjacent to Green Valley and Dan Wilson Creek	Project provides flood protection from a 1-in-40-year flood
Corte Madera Creek	Corte Madera Creek (U.S. Army Corps of Engineers)	Marin County Flood Control and Water Conservaton District	Approximately 17.7 kilometres (11 miles) of channel modification from San Francisco Bay to Sir Francis Drake Boulevard	Cities of Ross, Kentfield, Larkspur, Corte Madera, Greenbrae	The project is designed to provide Standard Project Flood protection. Modifications have been completed downstream of the town of Ross. Completion of the remainder of the project is uncertain
Coyote Creek	Coyote Creek* (U.S. Army Corps of Engineers)	Marin County Flood Control and Water Conservation District	Channel modification extending 2.1 kilometres (1.3 miles) from Richardson Bay.	Tamalpais Valley (residential)	Protects upper valley area from a 1-in-100-year flood
Rodeo Creek	Rodeo Creek* (U.S. Army Corps of Engineers)	Contra Costa County Flood Control and Water Conservation District	Channel modification extending about 1.6 kilometres (1 mile) from Interstate 80 to San Pablo Bay.	Community of Rodeo	Provides protection from a Standard Standard Project Flood
Pinole Creek	Pinole Creek* (U.S. Army Corps of Engineers)	Contra Costa County Flood and Water Conservation	Channel modification from East Shore Freeway to San Pablo Bay, a distance of approximately 2.4 kilometres (1.5 miles).	City of Pinole	Project provides protection from a 1-in-50-year flood
Rheem Creek	Rheem Creek* (U.S. Army Corps of Engineers)	Contra Costa County Flood Control and Water Conservation District	Channel modification of about 2 350 metres (7,700 feet) between San Pablo Avenue and San Pablo Bay	Cities of San Pablo and Richmond	Project provides protection from a 1-in-15-year flood
Walnut Creek (Grayson, Pacheco, Pine, Galindo and San Ramon Creeks)	Walnut Creek (U.S. Army Corps of Engineers)	Contra Costa County Flood Control and Water Conservation District	Channel modification and levees on Walnut and lower San Ramon Creeks and incidental work on Grayson and Pacheco Creeks	Cities of Walnut Creek, Pleasant Hill, Concord, and adjacent flood plains	Completion of the project will provide protection from 1-in-100-year floodflows. Modifications are complete on approximately 43 percent of the project channels
Pine Creek	Lower Pine Watershed (U.S. Soil Conservation Service)	Contra Costa County Flood Control and Water Conservation District	Flood storage and Detention Reservoir on Pine Creek	Cities of Walnut Creek and Concord	The dam is designed for 1-in-100-year flood protection. Downstream channel works as part of the Corps of Engineers' Walnut Creek Flood Control Project

* Small project

The Corps of Engineers is presently studying Guadalupe River and Coyote Creek in Santa Clara and Alameda Counties for possible projects. Previous studies have shown that there is definite need for a project in this area of Santa Clara County. However, over the years, the Santa Clara Valley Water District, which is charged with flood protection, has modified the channel in the most critical reaches along the Guadalupe River and has constructed Anderson Dam on Coyote Creek. Since the benefits derived from projects already completed by the Santa Clara Valley Water District cannot be included in a future project, additional work on these streams is difficult to justify economically.

In addition to the hazard of flooding from freshwater streams, there is the problem of saltwater flooding from San Francisco Bay. Subsidence is a contributing factor to these problems in the South Bay. In July 1971, the Santa Clara Valley Water District initiated a study of saltwater flooding along the Bay front and in the Bay lands of Santa Clara County. Congress has authorized and funded a San Francisco Bay Shoreline study, which began in fiscal year 1979. A survey report on the study is scheduled to be completed in October 1980.

The Lake Mendocino (Coyote Valley Dam) and Russian River Channel Projects have been authorized in three phases. They comprise the following multipurpose storage projects and channel work:

- Lake Mendocino on the East Fork Russian River (and bank stabilization work along the Russian River and its principal tributaries). \$15.4 million federal cost, \$5.8 million local cost (1959).

- Dry Creek (Warm Springs) Lake and Channel. Estimated first federal cost, \$220 million.

- Knights Valley Lake and the Franz-Maacama Creek drainage area. (Deauthorization August 5, 1977).

Land acquisition, road relocation, and construction of rock embankment and fish hatchery for the Warm Springs Project are in progress. This project will provide flood protection for about 8 300 hectares (20,600 acres) used for agricultural and recreational purposes, including 15 resort communities and numerous summer homes along the Russian River.

The Corps of Engineers is studying the flood problems in the City of Yountville and has an ongoing study for flood protection and allied purposes on Novato Creek in Marin County.

The Alhambra Creek Project in Contra Costa County, which consists of channel modifications and diversion works on Alhambra and Franklin Creeks in Martinez, has been reactivated by the Corps of Engineers. Federal first cost is estimated at \$17 million and local cooperation at \$1.9 million.

The Sonoma Creek Project along the lower 24 kilometres (15 miles) of Sonoma Creek has been placed in an inactive status by the Corps of Engineers because it was not possible to justify an economic project that would satisfy local environmental concerns.

Construction of the Fairfield Vicinity Streams Project has been stopped. This resulted from a conflict among local interest groups relating to the necessity of certain features of the project, and determination of project maintenance responsibility. Local opposition to the project resulted in the defeat of an initiative placed on the November 1976 ballot. Federal first cost would have been \$9.1 million and local cost would have been \$6.5 million.

Nonstructural Flood Management

Nonstructural flood management in the San Francisco Bay Area is currently being accomplished through flood plain ordinances, general plan building codes, and subdivision ordinances. The area is heavily populated, and some portions have a high rate of projected growth. Planners have given limited consideration to nonstructural flood management, and extensive development has taken place in flood-hazard areas. Types of regulations and regulated floodways in this area are presented in Table 4.

All streams and floodways in Sonoma County are covered by County Ordinance No. 230, as amended by subsequent ordinances. This rezones specific areas and establishes primary "F-1" and secondary "F-2" flood zones within specific flood plains. County Ordinance No. 2024 establishes flood zoning on the lower Petaluma River and on San Antonio Creek from below Petaluma to San Pablo Bay.

All Sonoma County cities have some form of regulation to control development in the flood plains, and they are now updating these regulations to conform with the National Flood Insurance Program.

The City of Sonoma, anticipating a federal flood protection project on Sonoma Creek, adopted flood plain ordinances for the designated floodway, as required under provisions of the Cobey-Alquist Flood Plain Management Act. Marin County has adopted a similar ordinance for regulation of Novato Creek, in anticipation of a federal flood protection project.

In the early development of the Santa Clara Valley, the county and cities approved development proposals that provided for dedication of rights of way, with the expectation that the Santa Clara Valley Water District would soon be able to enlarge the channels and remove flood hazards. As development soared, however, it soon became obvious that the district could not provide all the works needed, and that flood protection should be provided before further development took place. The Santa Clara Valley Water District has adopted an Ordinance (No. 74-1) that provides for nonstructural flood management by (1) defining flood management responsibility; (2) providing for establishment of designated floodways, maintenance of watercourses, and joint use of projects; and (3) prohibiting pollution of district water supplies, damage to district projects, and encroachment upon or interference with watercourses of the district. Santa Clara Valley Water District projects are generally designed to enhance ground water recharge and recreation, as described in Chapter 4 under "Beneficial Uses of Reservoirs".

In Santa Clara County some areas needing flood protection are San Tomas Creek, Calabasas Creek, Saratoga Creek, and Los Gatos Creek.

The City of Cupertino has adopted a general use plan with an area designated as flood plain. The area is being used as a golf course and has other recreational uses compatible with the hazard of potential flooding from Stevens Creek. The City of San Jose now requires that development within certain flood plains shall include rights of way and channel construction to protect the proposed development.

The extent of nonstructural flood management in Alameda County is fairly limited. A flood plain zone has been established on San Leandro Creek. This was done to satisfy requirements of the Cobey-Alquist Flood Plain Management Act. The county has proposed an ordinance which, if adopted, will preserve all watercourses within the unincorporated areas of Alameda County from obstruction, destruction, or interference by any material or waste deposited within the right of way and facilities of the district, or within the natural or unimproved watercourses of the county.

The Federal Emergency Management Agency is currently conducting flood insurance rate studies in several Bay Area counties. When these studies are completed, the cities and counties will be required to develop a comprehensive nonstructural flood management program that satisfies the Federal Emergency Management Agency's national criteria.

Table 4: REGULATED FLOODWAYS IN SAN FRANCISCO BAY HYDROLOGIC STUDY AREA

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Alameda County Flood Control and Water Conservation District	Building areas frozen by county ordinance	Cull Creek, Crow Canyon Creek, Alameda Creek, Arroyo De La Laguna	Urban, industrial, agricultural	Identification and regulation of remainder of flood-hazard areas in its jurisdiction	Yes
Alameda	City resolution establishing review and enforcement for flood plain management, uniform building code	Citywide - floodways not specified	Urban, industrial	Identification of flood-hazard areas	Yes
Albany	None			Identification of flood-hazard areas, codification of regulations	Yes
Berkeley	Building code, minimum elevation regulation	Tide plain	Urban, industrial	Identification and regulation of flood-hazard areas of streams and drains	Yes
Emeryville	None			Identification of flood-hazard areas, codification of regulations	Yes
Fremont	Municipal code, zoning ordinance	As shown on FEMA flood-hazard maps	Urban, industrial		Yes
Hayward	Municipal code, minimum elevation regulation, zoning ordinance	Tide plain	Industrial	Identification and regulation of flood-hazard areas of streams and drains	Yes
Livermore	None	None		Identification of flood-hazard areas, codification of regulations	Yes
Newark	City resolution, building permit system	Citywide - floodways not specified	Urban, industrial	Identification of flood-hazard areas	Yes
Oakland	City ordinance, building permit and review to minimize flood damage. City ordinance designating floodway and regulating structures to comply with Cobey-Alquist Flood Plain Management Act	Citywide - floodways not specified San Leandro Creek	Urban, industrial	Identification of flood-hazard areas	Yes
Piedmont	None			Identification of flood-hazard areas, codification of regulations	Yes
Pleasanton	General plan, building and land use controls	None		Identification of flood-hazard areas, codification of regulations	Yes
San Leandro	Municipal code, standards for constructing in flood-hazard zones. City ordinance designating floodway and regulating structures to comply with Cobey-Alquist Flood Plain Management Act	As shown on FEMA flood-hazard maps San Leandro Creek	Urban, industrial		Yes

Table 4: REGULATED FLOODWAYS IN SAN FRANCISCO BAY HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Union City	None			Identification of flood-hazard areas, codification of regulations	Yes
San Mateo County	None			Identification of flood-hazard areas, codification of regulations	Yes
Atherton	None			Identification of flood-hazard areas, codification of regulations	Yes
Belmont	City ordinance - land use and management of flood-prone areas	As shown on FEMA flood-hazard maps	Urban, Industrial		Yes
Brisbane	City ordinance. Control measures for flood-prone areas	As shown on FEMA flood-hazard maps	Industrial		Yes
Burlingame	Municipal code. Flood-hazard protection for subdivision and drainage requirement	Citywide - floodway not specified	Urban, industrial	Identification of flood-hazard areas, codification of additional regulations	Yes
Colma	Flood plain zoning ordinance	Citywide - floodway not specified	Urban, industrial	Identification of flood-hazard areas, application of zoning	Yes
Daly City	None	None		Identification of flood-hazard areas, codification of regulations	Yes
Foster City	Uniform building code, city resolution. Building permit and review to minimize flood damage	Citywide - floodway not specified	Urban, industrial	Identification of flood-hazard areas	Yes
Half Moon Bay	None	None		Identification of flood-hazard areas, codification of regulations	Yes
Hillsborough	City resolution. Permit and review to minimize flood damage	Citywide - floodway not specified	Urban, industrial	Identification of flood-hazard areas	Yes
Menlo Park	City flood plain district ordinance	Tide Plain	Industrial, agricultural	Identification and regulation of remaining flood-hazard areas in city	Yes
Millbrae	City resolution. Permit and review to minimize flood damage	Citywide - floodway not specified	Urban, industrial	Identification of flood-hazard areas	Yes
Pacifica	Uniform building code, city resolution. Building permit and review to minimize flood damage	Citywide - floodway not specified	Urban, industrial	Identification of flood-hazard areas	Yes
Portola Valley	None	None	Urban	Identification of flood-hazard areas, codification of regulations	Yes

Table 4: REGULATED FLOODWAYS IN SAN FRANCISCO BAY HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Redwood City	Municipal building codes, city resolution. Building permit and review to minimize flood damage	Citywide - floodway not specified	Urban, industrial	Identification of flood-hazard areas	Yes
San Bruno	Building regulations, ordinance regulating flood-hazard areas	As shown on FEMA flood-hazard maps	Urban, industrial		Yes
San Carlos	None			Identification of flood-hazard areas, codification of regulations	Yes
San Mateo	City ordinance. Site plan and architectural review, minimum floor elevation	Citywide - floodway not specified, minimum flood elevation for the North Shoreview area	Urban, industrial		Yes
South San Francisco	None	None		Identification of flood-hazard areas, codification of regulations	Yes
Woodside	Setback ordinance regulating activities within 6.1 metres (20 feet) of top of bank of any creek draining 20.2 hectares (50 acres) or more	Citywide - floodway not specified	Urban, industrial	Identification of flood-hazard areas, codification of regulations	Yes
Santa Clara County Santa Clara Valley Water District	Water district ordinance for establishment of a flood plain management program	Countywide - floodways not specified	Urban, industrial, agricultural	Adoption of ordinances designating floodways with the aid of District's flood data and U.S. Corps of Engineers' Flood Plain Information Reports on Guadalupe River, Alamitos Creek, Coyote Creek, and Fisher Creek	Yes
Campbell	Uniform building code, building permit system to minimize flood damage	Citywide - floodway not specified	Urban, industrial	Identification of flood-hazard areas	Yes
Cupertino	General plan - land use	Stevens Creek	Recreational, commercial, agricultural	Identification and regulation of remainder of flood-hazard areas in city	Yes
Los Altos	None	FEMA floodways		Identification of flood-hazard areas, codification of regulations	Yes
Los Altos Hills	Uniform building code. Minimum FEMA ordinance	Citywide FEMA floodways	Urban, agricultural	Identification of flood-hazard areas, codification of regulations	Yes
Los Gatos	Minimum FEMA ordinance	FEMA floodways		Identification of flood-hazard areas, codification of regulations	Yes
Milpitas	None	None		Identification of flood-hazard areas, codification of regulations	Yes
Monte Sereno	Uniform building code	None	Urban	Identification of flood-hazard areas, codification of regulations	Yes
Mountain View	City flood plain district zoning	None	Industrial, agricultural, recreational	Identification of flood-hazard areas, codification of regulations	Yes

Table 4: REGULATED FLOODWAYS IN SAN FRANCISCO BAY HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Palo Alto	City ordinance. Permit and review to minimize flood damage	None	Urban, industrial	Identification of flood-hazard areas for areas recently annexed to the city	Yes
San Jose	Municipal code. Special flood-hazard area regulations	As shown on FEMA flood-hazard map	Urban, industrial		Yes
Santa Clara	City resolution. Permit and review to minimize flood damage	Citywide - floodway not specified	Urban, industrial	Identification of flood-hazard areas	Yes
Saratoga	General plan. Restricted flood plain use recommendation, subdivision ordinance, investigate hazards, minimum FEMA ordinances	See FEMA flood-hazard maps for official identification for flood plain	Urban, industrial	Codification of additional regulations	Yes
Sunnyvale	Minimum FEMA ordinances	None		Codification of regulations	Yes
Marin County Flood Control and Water Conservation District	County floodway zoning ordinance to comply with Cobey-Alquist Flood Plain Management Act	Lower Novato Creek	Agricultural, native lands	Identification and regulation of remainder of flood-hazard areas in its jurisdiction	Yes
Belvedere	None			Identification of flood-hazard areas, codification of regulations	Yes
Corte Madera	Town ordinance regulating flood-hazard areas	As shown on FEMA flood-hazard maps	Urban, industrial		Yes
Fairfax	Town ordinances: (1) Building setback (2) Watercourse obstructions	(1) Fairfax and San Anselmo Creeks (2) All defined watercourses	Urban, industrial	Identification of flood-hazard areas, codification of	Yes
Larkspur	Uniform building code, city ordinance regulating flood-hazard areas	As shown on FEMA flood-hazard maps	Urban, industrial		Yes
Mill Valley	None			Identification of flood-hazard areas, codification of regulations	Yes
Novato	Flood zoning ordinance to comply with Cobey-Alquist Flood Plain Management Act	Novato Creek	Urban, industrial, agricultural	Identification and regulation of flood-hazard areas for remainder of city	Yes
Ross	None			Identification of flood-hazard areas, codification of regulations	Yes
San Anselmo	None			Identification of flood-hazard areas, codification of regulations	Yes
San Rafael	Municipal code regulating flood-hazard areas	As shown on FEMA flood-hazard maps	Urban, industrial		Yes
Sausalito	General plan - minimum elevation requirement	Bayshore waterfront	Urban, industrial	Codification of regulations	Yes

Table 4: REGULATED FLOODWAYS IN SAN FRANCISCO BAY HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Tiburon	None	None		Identification of flood-hazard areas, codification of regulations	Yes
Mendocino County	General flood plain ordinance	None		Identification of flood-hazard areas	Yes
Ukiah	General flood plain ordinance	None		Identification of flood-hazard areas	Yes
Napa County Flood Control and Water Conservation District	County flood zoning ordinance to comply with Cobey-Alquist Flood Plain Management Act	Napa River	Urban, industrial, agricultural	Identification and regulation of remainder of flood-hazard areas in its jurisdiction	Yes
Calistoga	Building permit and review to minimize flood damage	Citywide - floodway not specified	Urban, industrial, agricultural	Identification of flood-hazard areas	Yes
Napa	Building permit and review to minimize flood damage. City flood zoning ordinance to comply with Cobey-Alquist Flood Plain Management Act	Citywide - floodway not specified Napa River	Urban, industrial	Identification of flood-hazard areas	Yes
St. Helena	Special flood plain district ordinance, building permit and review to minimize flood damage	Flood plain district not specified	Urban, industrial, agricultural	Identification of flood-hazard areas	Yes
Yountville	Special flood plain combining district ordinances, review procedure for flood plain management	As shown on FEMA flood-hazard maps	Urban, agricultural		Yes
San Francisco City and County	All natural hazards covered under community master plan. Review by Planning Department approved by Engineering and Building Departments	None		No known flood-hazard areas	No
Contra Costa County Flood Control and Water Conservation District	County Ordinances, subdivision code and public works and flood control code for drainage	Countywide - floodways not specified	Urban, industrial, agricultural	Identification of flood-hazard areas	Yes
Clayton	None	None		Identification of flood-hazard areas, codification of regulations	Yes
Concord	General plan, municipal code regulating flood-hazard areas	As shown on FEMA flood-hazard areas	Urban, industrial, open space		Yes
El Cerrito	Uniform building code, city ordinance regulating flood-hazard areas	City - 1-in-100 year floodways	Urban, industrial		Yes
Hercules	City resolution, building permit system and review	City - floodway not specified	Urban, industrial	Identification of flood-hazard areas, codification of regulations	Yes
Lafayette	None	None		Identification of flood-hazard area, codification of regulations	Yes

Table 4: REGULATED FLOODWAYS IN SAN FRANCISCO BAY HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Martinez	Municipal code regulating flood-hazard areas	As shown on FEMA flood-hazard map; specifically, Alhambra Creek	Urban, industrial		Yes
Moraga	Town resolution, building permit system and review	Citywide - floodway not specified	Urban	Identification of flood-hazard areas	Yes
Pinole	Uniform building code, permit and review to minimize flood damage	Citywide - floodway not specified	Urban, industrial	Identification of flood-hazard areas	Yes
Pleasant Hill	None	None		Identification of flood-hazard areas, codification of regulations	Yes
Richmond	None	None		Identification of flood-hazard areas, codification of regulations	Yes
San Pablo	None	None		Identification of flood-hazard areas, codification of regulations	Yes
Walnut Creek	Municipal code for land management of flood-prone areas	As shown on FEMA flood-hazard map	Urban, industrial		Yes
Solano County Flood Control and Water Conservation District	County flood plain regulation ordinance. Zoning to comply with Cobey-Alquist Flood Plain Management Act	Project rights of way for Fairfield vicinity streams: Ledgewood, Pennsylvania Avenue, Union Avenue, Laurel, and McCoy Creeks	Agricultural	Identification of flood-hazard areas, appropriate zoning utilizing Flood Plain Regulation Ordinance	Yes
Benicia	City resolution. Building permit and review to minimize flood damage	Citywide - floodway not specified	Urban, industrial	Identification of flood-hazard areas	Yes
Fairfield	City flood plain regulation ordinance. Zoning to comply with Cobey-Alquist Flood Plain Management Act	Designated floodway for Fairfield Streams Groups in city limits. See Solano County regulated floodways.	Urban, industrial, agricultural	Identification of flood-hazard areas, appropriate zoning utilizing Flood Plain Regulation Ordinance	Yes
Suisun	City flood plain regulation ordinance. Zoning to comply with Cobey-Alquist Flood Plain Management Act	Designated floodway for Fairfield Streams Group in city limits. See Solano County regulated floodways	Urban, industrial, agricultural	Identification of flood-hazard areas, appropriate zoning utilizing Flood Plain Regulation Ordinance	Yes
Vallejo	None			Identification of flood-hazard areas, codification of regulations	Yes
Sonoma County	Countywide ordinance regulating flood zones, flood plain zoning ordinances	Sonoma Creek, Mark West Creek, Laguna de Santa Rosa drainage basin, Lower Petaluma River, and San Antonio Creek	Urban, industrial, agricultural	Identification and regulation of remainder of flood-hazard areas in its jurisdiction	Yes
Sonoma County Water Agency	Channel encroachment by exclusive control of easements and conditional building permits	Russian River	Agricultural, industrial, open space	Incentive to apply proposed countywide flood zoning ordinance to Russian River	

Table 4: REGULATED FLOODWAYS IN SAN FRANCISCO BAY HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Cloverdale	Watercourse ordinance, building permit system	Citywide - floodways not specified	Urban, industrial	Identification of flood-hazard areas, codification of regulations	Yes
Cotati	Setback ordinance for waterways and review by Sonoma County Water Agency	Citywide - regulates areas within 30 feet of top of bank	Urban, industrial	Identification of flood-hazard areas, codification of regulations	Yes
Healdsburg	Uniform building code, city resolution. Building permit and review to minimize flood damage and review by Sonoma County Water Agency	Citywide - floodways not specified	Urban, industrial	Identification of flood-hazard areas	Yes
Petaluma	City zoning ordinance - floodway and flood plain districts	Petaluma River	Urban, industrial agricultural		Yes
Rohnert Park	City resolutions. Permit and review to minimize flood damage, and review by Sonoma County Water Agency for District flood control and drainage facilities	Citywide - floodways not specified	Urban, industrial	Identification of flood-hazard areas	Yes
Santa Rosa	City resolution. Permit and review to minimize flood damage and review by Sonoma County Water Agency	Citywide - floodways not specified	Urban, industrial, agricultural	Identification of flood-hazard areas	Yes
Sebastopol	Subdivision ordinance. Drainage and minimum height requirements and review by Sonoma County Water Agency	Citywide - floodways not specified	Urban, industrial	Identification of flood-hazard areas, codification of regulations	Yes
Sonoma	Flood plain zoning ordinance to comply with Cobey-Alquist Flood Plain Management Act and review by Sonoma County Water Agency	Sonoma Creek	Urban, commercial	Identification of flood-hazard areas	Yes

Because federal flood-related disaster assistance would be denied to noncompliant communities, local governments are expected to develop and enforce an acceptable nonstructural flood management program.

Flood Protection Needs

The intense, rapid urban development in the San Francisco Bay Hydrologic Study Area and the high flood potential of the many small streams have presented local agencies with a multitude of flood problems. Many existing project facilities provide adequate protection to urban and agricultural areas.

Studies are under way for additional structural projects, some of which are difficult to justify economically and some of which are being questioned on the basis of environmental considerations.

Within the area, small streams are still subject to flooding. In some highly developed reaches, environmentally satisfactory structural solutions may be required. Nonstructural flood management and National Flood Insurance can be the solution in other reaches.

Coyote Creek in Marin County is partially provided with channel modifications built by the Corps of Engineers (federal cost $700,000), but portions of the lowland areas of the City of San Rafael along San Rafael Creek and Gallinas Creek will have flooding problems. Streams on the eastern slope of Marin County such as the Santa Venetia area east of the Marin Civic Center, the Rafael Manor area west of the Marin Civic Center, the Miller Creek area, portions of Hamilton Air Force Base along the Arroyo San Jose, Rush Creek, and San Antonio Creek also suffer from flooding.

The Walker Creek area along the western slope of Marin County has not been developed as yet and should be protected from development by regulation of the flood plain. The lower reaches of Lagunitas Creek, near Point Reyes Station, have flood problems where development has occurred. This area is not in a county flood zone, and more information is needed to determine the extent of flooding so that recommendations can be made.

Most areas in Alameda County are protected only from minor floods which occur at a frequency of 1-in-10-years. Flood problems also exist on a number of small streams, including Temescal Creek, Sausal Creek, Tressel Glen, Peralta Creek, Cortland Creek, Arroyo Viejo Creek, Elmhurst Creek, Durant Street Drain, Ashland Wash, Bachman Canal, Sulfur Creek, Arroyo De Laguna, Alamo Creek, Arroyo Del Valle, and Tassajara Creek.

Almost without exception, cities and counties in the study area have entered the emergency phase of the National Flood Insurance Program. The greatest need in implementing flood plain management is technical information identifying the high-risk lands. Some agencies are presently directing compatible recreational development to those lands which are already known to be flood prone. The Santa Clara Valley Water District provides educational pamphlets to developers along streamside property, as described in Chapter 4 under "Exemplary Projects".

With the high degree of urbanization, there undoubtedly will be some areas that need structural works. Examination of flood problem areas must be continued with the Corps of Engineers, the Soil Conservation Service, and local flood control districts.

Particular attention should be given to the Corps of Engineers' San Francisco Bay Shoreline Study authorized by Congress in 1976, which includes the six counties of San Mateo, Santa Clara, Alameda, Solano, Sonoma, and Napa. The study, which received initial funding in fiscal year 1979, will look at tidal and fluvial flooding in the area below mean higher high water in the six counties.

A number of agencies, in addition to the cities fronting the bay, have been vested with planning and regulatory controls over areas subject to saltwater flooding. Among the most important is the San Francisco Bay Conservation and Development Commission, which has adopted a San Francisco Bay Plan. Several alternative plans have been considered. They include a "Do-Nothing Plan", "Inboard Levee Plan", and "Outboard Levee Plan". The Bay Conservation and Development Commission has adopted a policy that, if salt production is terminated, future uses of the ponded areas should be water oriented. The Corps of Engineers also has regulatory authority under Section 10 of the 1899 Rivers and

Harbors Act, and Section 404 of the Clean Water Act.

The Corps of Engineers currently estimates it will cost $1,415,000 to accomplish a survey study to determine the feasibility of, and the federal interest in, constructing a project to protect bay lands in the six counties against tidal and stream flooding. The California Water Commission originally opposed funding for the San Francisco Bay Shoreline Study but later supported it, provided the study gives priority to the flooding problems of the three South Bay Counties of San Mateo, Santa Clara, and Alameda.

As in the North Coastal Area, the flood forecasting hydrologic data telemetry system is being replaced and augmented to assure continuation of river forecast accuracy.

Central Coastal Hydrologic Study Area

The Central Coastal Hydrologic Study Area extends along the Pacific Ocean from Ano Nuevo Point in San Mateo County nearly to the crest of the Coast Range. It comprises drainage areas of streams discharging into the Pacific Ocean, and includes a closed basin in the southeastern part of the Salinas River Basin.

Major urban centers include Salinas, Monterey, Carmel, Santa Cruz, Watsonville, San Luis Obispo, Santa Maria, Lompoc, and Santa Barbara. The population estimate for 1972 was 842,000, with a density in urban areas of 19 persons per square kilometre (49 persons per square mile). The population has been increasing faster than that of the State as a whole, and by 1990 is projected to be 1,300,000. Major urban centers such as Salinas, Santa Cruz, San Luis Obispo, Santa Maria, and Santa Barbara are expected to lead in growth.

The economy of the Central Coastal Area is supported primarily by agriculture and related industry. Manufacturing, petroleum, mineral production, military, space facilities, government, tourism, and recreation also contribute to the basic economy.

The area is served by Federal, State, and county roads which afford ready access to all parts. It is also served by railways and several airlines.

Important streams include San Lorenzo, Pajaro, Salinas, Carmel, Santa Maria, Big Sur, and Santa Ynez Rivers. The Salinas River is the largest stream in the area, draining over 40 percent of the total land. Major tributaries of the Salinas include the Nacimiento River, San Antonio River, and Arroyo Seco, which originate west of the main stem in the Santa Lucia Range, and Estrella Creek and San Lorenzo Creek, which originate east of the main stream in the Diablo Range. Lesser streams include the Morro-San Simeon and the San Luis Obispo-Arroyo Grande coastal groups in San Luis Obispo County, and another group in Santa Barbara County.

Except for the major river valleys, there is little or no coastal plain. Mountainous terrain and rolling hills extend to the shoreline throughout most of the area, and the rugged coast is considered one of the most scenic in the United States. Important mountain chains paralleling the coast are the Santa Lucia, Diablo, La Panza, and Gabilan Ranges; and the Sierra Madre, San Rafael, and Santa Ynez Mountains.

Figure 29 depicts the area.

History of Flooding

Because of the steep gradients involved, floodflows on streams draining the mountains of the Coast Range are characterized by extremely rapid rises and almost as rapid drops in water level. This has subjected agricultural and urban areas

AGRICULTURAL LANDS WERE HARD HIT in the Blanco area of the Salinas River Basin by Salinas River overflows in January-February 1969.

to frequent flood damage. The steep slopes in the upper watersheds undergo severe erosion during storm runoff, depositing large amounts of sediment in the flood plains. Erosion is further intensified following wildfires, which destroy vegetation in the upper watersheds, such as occurred in the Marble Cone area in Monterey County during 1977. Flood-producing storms vary in duration from three to six days.

Major floods occurred in 1907, 1914, February-March 1938, January 1952, December 1955, April 1958, December 1966, January 1967, January-February 1969, January 1970, January 1974, January-February 1978, and January-February 1980. The 1938, 1955, 1969, and 1978 floods were the most significant and widespread; the 1969 flood was the most severe.

The 1969 floods were caused by a series of Pacific storms which brought severe, widespread damage to large areas in Central and Southern California, including nearly all the Central Coastal Area. Damage was most severe in the Salinas River Basin, in the Santa Ynez River Group, and in the Carpenteria-Montecito area. Flooding on the Salinas River and its tributaries was estimated to equal a 1-in-100-year flood. Farms and cities both sustained heavy damage.

The 1955 flood inundated 5 830 hectares (14,400 acres) in the northern portion of the Central Coastal Area and caused $16 million in damage, 80 percent of which was agricultural, residential, and commercial. The 1938 flood extended throughout the area. Damage was only $1.2 million because of the small scale of development at that time.

Flood Damage Prevention Facilities

There is a moderate degree of flood protection on streams within the area. The existing flood-damage reduction facilities include flood storage and levee and channel modifications. These facilities protect against the 1-in-100-year or greater flood in urban areas, and the 1-in-10- to 1-in-50-year floods in agricultural areas. The flood damage prevention projects are shown on Table 5.


SANTA CRUZ
San Lorenzo R.
Soquel
Corralitos Cr.
SANTA CRUZ
Pajaro R.
CLARA
Hollister
SAN BENITO
Tres
Pinos Cr.
SAN BENITO RIVER
SALINAS
Monterey
Carmel R.
SALINAS
MONTEREY
Seco
Arroyo
Big Sur R.
San Lorenzo Creek
King City
RIVER
Pancho Rico Creek
San Antonio River
Nacimiento R.
San Antonio Res.
Nacimiento Res.
PACIFIC
OCEAN
Paso Robles
Estrella R.
Santa Rosa Creek
SAN LUIS OBISPO
Salinas
Chorro Creek
San Luis Obispo
Santa Margarita L.
Pismo Cr.
Arroyo Grande
Lopez Res.
Tar Springs Cr.
MATCH

Figure 29
FLOOD INFORMATION
CENTRAL COASTAL HYDROLOGIC STUDY AREA

Table 5: FLOOD DAMAGE PREVENTION PROJECTS IN CENTRAL COASTAL HYDROLOGIC STUDY AREA

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Pajaro River	Pajaro River Basin Project (U.S. Army Corps of Engineers)	Monterey County Flood Control and Water Conservation District and County of Santa Cruz	Project consists of levees on both sides of lower 19 kilometres (12 miles) of Pajaro River and lower 4 kilometres (2.5 miles) of of Salsipuedes Creek; safe maximum channel capacity of project about 623 cubic metres per second (22,000 cfs)	City of Watsonville and agricultural lands in downstream flood plain	Provides protection against floods up to about the 25-year flood
San Lorenzo River and Branciforte Creek	San Lorenzo River, Santa Cruz County (U.S. Army Corps of Engineers)	City of Santa Cruz	The project consists of 5 180 metres (17,000 feet) of levee, a floodwall, 2.6 kilometres (1.6 miles) of channel work and other modifications	City of Santa Cruz	Standard project flood
San Antonio River (tributary to Salinas River)	San Antonio Dam and Reservoir	Monterey County Flood Control and Water Conservation District	Multipurpose 429 000 cubic dekametres (348,000 acre-foot) reservoir with 62 000 cubic dekametres (50,000 acre-foot) flood protection reservation	Salinas River flood plain	Provides significant protection, but the level is unknown
Nacimiento River (tributary to Salinas River)	Nacimiento Dam and Reservoir	Monterey County Flood Control and Water Conservation District	Multipurpose 432 000 cubic dekametres (350,000 acre-foot) reservoir with 185 000 cubic dekametres (150,000 acre-foot) flood protection reservation	Salinas River flood plain	Provides significant protection, but the level is unknown
Santa Maria River	Santa Maria River Basin (U.S. Army Corps of Engineers)	Santa Barbara County Flood Control and Water Conservation District	The project consists of 35 kilometres (22 miles) of levee along the Santa Maria River and 3.2 kilometres (2 miles) of leveed channel along Bradley Creek	City of Santa Maria and 8 100 hectares (20,000 acres) of agricultural lands	1-in-100 year flood protection
Santa Maria River	Santa Maria River Levees (U.S. Army Corps of Engineers)	Santa Barbara County Flood Control and Water Conservaton District	43 kilometres (27 miles) of rock revetted levees	Santa Maria Valley and Oso Flaco area of San Luis Obispo County	Standard project flood
Rodeo-San Pasqual Creeks	Rodeo-San Pasqual Channel (Soil Conservation Service)	Santa Barbara County Flood Control and Water Conservation District	Rectangular and trapezoidal concrete channel with a debris basin	Lompoc Valley	1-in-100-year flood protection
Miguelito Creek	Miguelito Creek Channel Improvements (Soil Conservation Service - under construction)	Santa Barbara County Flood Control and Water Conservation District	Rectangular and trapezoidal concrete channel with a debris basin	City of Lompoc	1-in-100-year flood protection
Santa Ynez River	Santa Ynez River Flood Forecast and Warning System (SBCFC&WCD)	Santa Barbara County Flood Control and Water Conservation District	Nonstructural. Hydrologic telemeter and computer flow forecasting to enable evacuation of flood plain	Santa Ynez River flood plain	None
Arroyo Grande Creek	Arroyo Grande Creek Watershed (U.S. Soil Conservation Service)	San Luis Obispo County Flood Control and Water Conservation District	Project consists of 4.5 kilometres (2.84 miles) of channel modifications and diversion of Los Berros Creek to Arroyo Grande Creek	Agricultural lands adjacent to Los Berros and Arroyo Grande Creeks	1-in-100-year flood protection
Cuyama River	Twitchell Dam and Reservoir (U.S. Water and Power Resources Service)	U.S. Water and Power Resources Service	Multipurpose 296 000 cubic dekametres (240,000 acre-foot) reservoir with 106 000 cubic hectometre (86,000 acre-foot) flood protection reservation	Santa Maria Valley	Standard project flood
Santa Barbara Streams	Santa Barbara Streams Project (U.S. Army Corps of Engineers)	Santa Barbara County Flood Control and Water Conservation District	Emergency debris basins and and channelization	Cities of Santa Barbara and Carpinteria and Montecito area	1-in-25-year flood protection

Table 5: FLOOD DAMAGE PREVENTION PROJECTS IN CENTRAL COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Carpinteria Valley Streams	Carpinteria Valley Watershed Project (U.S. Soil Conservation Service)	Santa Barbara County Flood Control and Water Conservation District	Rectangular concrete-lined channels, earth levees with rock revetment and debris basins	Carpinteria Valley	1-in-100-year flood protection
Upper Llagas Creek, including Little Llagas Creek and its tributaries	Upper Llagas Creek Watershed Project (U.S. Soil Conservation Service)	Santa Clara Valley Water District	Modification of Chesbro Reservoir to provide for 4 400 cubic dekametres (3,570 acre-feet) of floodwater detention capacity and 24 kilometres (15 miles) of stream channel modifications: the works of modification are interdependent with those of the Lower Llagas Creek Watershed Project	Flood plains of Upper Llagas Creek in Santa Clara Valley; Cities of Morgan Hill and San Martin	1-in-100-year flood protection
Lower Llagas Creek, including West Branch Llagas Creek and Miller Slough Drainage	Lower Llagas Creek Watershed Project (U.S. Soil Conservation Service)	Santa Clara Valley Water District	About 27.7 kilometres (17.2 miles) of modified or realigned channels: works of modification are interdependent with those of Upper Llagas Creek Watershed Project	Flood plain of Lower Llagas Creek in Santa Clara Valley; City of Gilroy	1-in-100-year flood protection except in Soap Lake area at lower end of project at Pajaro River
Tributary Streams	Santa Ynez River Flood Prevention Project (U.S. Soil Conservation Service and U.S. Forest Service)	Santa Barbara Flood Control and Water Conservation District	36 kilometres (22 miles) of stream channel stabilization structures and fire control measures	City of Lompoc and agricultural areas in Lompoc Valley	1-in-100-year protection to the City Lompoc and 1-in-25-year protection to agriculture areas

Lake Cachuma on the Santa Ynez River and Santa Margarita Lake on the upper Salinas River, both of which are water supply reservoirs, also contribute to incidental flood-damage reduction at times, especially when the reservoir levels are below maximum when runoff begins.

Existing works which include a system of reservoirs, levees, and channel improvements, augmented by flood forecasting for the Salinas and Santa Ynez Rivers, are helping to prevent flood losses.

These structures reduced damage during the 1966, 1969, and 1979 floods. Nacimiento and San Antonio Reservoirs provided effective control of runoff on the Salinas River in 1966 and 1969. Twitchell Reservoir on the Cuyama River, together with the levee project on the Santa Maria River and the Arroyo Grande Watershed Project, also prevented \$2.2 million in damage in 1969. Flood losses were also prevented by the levee project in the Pajaro River Basin during the 1955 and 1958 floods.

The Corps of Engineers is processing a survey report on a study of the upper Pajaro River Basin which indicates that there are several water resources problems existing in the study area, most of which can best be solved through other authorities and ongoing projects. Flood protection in the lower Pajaro Valley at Watsonville has been considered under a separate authorization, flood problems on Llagas Creek are being addressed by the Soil Conservation Service under Public Law 83-566, and sources of water supply would best be provided by the San Felipe Project under construction by the Water and Power Resources Service. The Corps recommended that flood protection works on Uvas-Carnadero Creek should be constructed under authority of the Flood Control Act of 1944 (Public Law 78-534) and it received funds to begin Advanced Engineering and Design on the project in 1979. A Citizens Advisory Committee coordinates this study.

Most of the agricultural lands along the San Benito River are protected by levees constructed and maintained by county and private interests. Agricultural lands in the Santa Clara Valley are subject to flooding from Pacheco Creek and Tequisquita Slough.

The Corps of Engineers is studying the Carmel River with a view to providing supplemental water supplies and flood protection. In addition, private interests have constructed short lengths of levee along certain reaches of the river. While these private modifications may provide a measure of protection to individual properties, their existence may aggravate flood conditions along other reaches.

The Santa Barbara Streams Project consists of two emergency projects which provide for the construction of debris basins and for channel clearing and shaping downstream from burned-over areas. They were constructed on the south slope of the Santa Ynez Mountains above the cities of Santa Barbara and Carpinteria and adjoining communities in Santa Barbara County. The County of Santa Barbara and the Santa Barbara County Flood Control and Water Conservation District were the local agencies sponsoring these projects. Estimated Federal and State costs are about $2.3 million and $1 million, respectively.

The Goleta and Vicinity Project would provide flood protection to about 919 hectares (2,270 acres) in the rapidly developing Goleta Valley within the greater Santa Barbara area. The project would include 18 kilometres (11.2 miles) of channel construction on parts of Atascadero, Maria Ygnacio, San Jose, Las Vegas, San Pedro, and Carneros Creeks, and 2.1 kilometres (1.3 miles) of channel clearing on parts of Maria Ygnacio, San Jose, Las Vegas, San Pedro, and Carneros Creeks. The first cost of this work is estimated at $26.4 million in federal costs, and $8 million in nonfederal costs. Funds were received in fiscal year 1980 to initiate the review of the project, authorized in 1970, to determine if it satisfies the current needs of the project area or if modifications will be needed.

The Corps of Engineers and the U. S. Soil Conservation Service have sponsored other flood protection and watershed protection projects in the Central Coastal Area. San Antonio and Nacimiento Reservoirs have been built by the Monterey County Flood Control and Water Conservation District on San Antonio and Nacimiento Rivers to protect the Salinas River Basin.

Nonstructural Flood Management

Monterey County has adopted a countywide flood plain zoning ordinance to qualify for State financial assistance under the Cobey-Alquist Flood Plain Management Act, but has applied it only to a few areas in the Carmel Valley and to a narrow strip outside the proposed levee of the federally authorized Lower Pajaro River Levee Project. Throughout the county, development on flood-prone land is restricted through a subdivision review process. The county has established a Minor Subdivision Committee, which rules on developments of four lots or less, and a Major Subdivision Committee, which is concerned with larger developments. The Planning Commmission and the County Board of Supervisors consider recommendations of the committees concerning individual applications. The basis for restricting development on flood plains, when data are available, is the 1-in-100-year flood. Although proposals for incompatible development of flood plains have often been denied in the past, there are many examples where development was allowed to proceed over the objections of local residents, notably along the lower Carmel River. Effective nonstructural flood management, as encouraged by the National Flood Insurance Program, is being implemented by those communities whose flood-hazard areas have been identified.

In San Benito County, the concept of flood plain zoning apparently is generally accepted by local officials. The county controls noncompatible development on flood plains through the building permit process. Flood-hazard areas are identified through information developed by the Corps of Engineers in recent flood plain studies.

For many years, San Benito County has been a nearly stable agricultural area with little pressure for urban development. Recently, however, 1-to-2-hectare (2.5-to-5-acre) parcels in the north county area have become popular as homesites. This popularity apparently stems from relatively low land prices, the rural atmosphere, and the fact that the northern part of the county is within commuting distance of the Bay Area.

A somewhat informal master flood protection plan has been adopted by the San Benito Water Conservation and Flood Control District. Essentially, the plan is aimed, first, toward providing local drainage for the City of Hollister and, second, for the City of San Juan Bautista.

Santa Clara County and the cities of Gilroy and Morgan Hill have adopted ordinances to set aside designated floodways under the Cobey-Alquist Flood Plain Management Act for the Upper and Lower Llagas Creek Watershed Project.

In 1974, San Luis Obispo County adopted flood plain management regulations in the form of zoning ordinances. The ordinances define the types of flood-hazard areas that will be regulated and the development that will be allowed. However, the lack of adequate delineation of flood-hazard areas, except along San Luis Obispo Creek, has been a deterrent to their enforcement.

Santa Barbara County has adopted a Flood Hazard Zoning Ordinance to comply with the requirements of the Cobey-Alquist Flood Plain Management Act. This ordinance has only been applied to Carpenteria and Goleta. The county has effectively used building permits and subdivision restrictions to control development in flood-hazard areas. It is in the process of enacting a Flood Hazard Area Ordinance to comply with the requirements of the regular flood insurance program.

The regulated floodways in the Central Coastal Hydrologic Study Area are presented in Table 6.

Flood Protection Needs

Significant flood problems still exist, particularly in the Pajaro River Basin, the Salinas River Basin, the Carmel River Basin, the Santa Barbara streams area, and the populated downstream sections of various coastal streams, such as the Santa Ynez River. Some of these areas may require structural works.

Flood plain management and improved flood forecasting are also recognized as appropriate methods in flood damage prevention. Almost without exception, the counties and cities have entered the emergency phase of the National Flood Insurance Program. The completion of technical studies on which to base a flood plain management plan, coupled with the implementation of existing or new ordinances, are expected to reduce future flood damage.

Accuracy of river stage forecasts are lower than in other forecast areas. However, the State Legislature appropriated $120,000 in July 1978 for a hydrologic data network of telemetry of precipitation and stream levels on the Salinas and Pajaro Rivers. Some of the data stations are new, located in portions of the watershed where no data are now available. Once the new telemetry is in use, the accuracy of forecasts on the Pajaro and Salinas Rivers should improve.

The lack of maintenance by the City of Santa Cruz on the San Lorenzo River Flood Control Project has resulted in the deposition of large volumes of material in the flood channel. This has resulted in a significant loss of flood-carrying capacity that may cause storm water to overtop the project levees. The Department of Water Resources, Corps of Engineers, and City of Santa Cruz are working toward a solution to this problem.

Table 6: REGULATED FLOODWAYS IN CENTRAL COASTAL HYDROLOGIC STUDY AREA

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Santa Clara County	Water district ordinance for establishment of a flood plain management program	Countywide floodway not specified	Urban, industrial, agricultural	Adopting of ordinances designating floodways with the aid of District's flood data and U.S. Corps of Engineers' Flood Plain Information Reports Guadalupe River, Alamitos Creek, Coyote Creek, and Fisher Creek	Yes
Gilroy	City municipal code	Designated floodways of channels of Llagas Creek and tributaries of Lower Llagas Creek Watershed Project in Gilroy; floodway of Uvas Creek within city limits	Urban, industrial	Unknown	Yes
Morgan Hill	City municipal code	Designated floodway of channel of Little Llagas Creek of Upper Llagas Creek Watershed Project; adjacent overflow areas	Urban	Definitive delineation of flood-hazard outside designated floodway with depth of inundation information	Yes
Santa Cruz County	County building codes, resolution; building permit system regulating development in flood-hazard areas	"Areas Subject to Flooding," map dated Nov. 1, 1974, in Planning Department	Agricultural, urban, industrial	U.S. Corps of Engineer's Flood Plain Information Reports on San Lorenzo River, Boulder Creek, and City of Aptos could be used to establish zoning	Yes
Capitola	City resolution; building permit review system to minimize flood damage; uniform building code	Citywide - floodways not specified	Urban, industrial	City ordinance designating flood plain combining districts are used for information only. If adequate information is available, zoning controls could be used	Yes
Santa Cruz	City ordinance regulating development in a flood plain district	Citywide - floodways not specified	Urban, industrial	Designate flood plain districts	Yes
Scotts Valley	None			Identification of flood-hazard areas	Yes
Watsonville	Watsonville city ordinance; for interim use in overflow areas, requirement for owner's contingency plans for floodproofing and U.S. Corps of Engineers Flood Proofing Manual	A 7.6-metre (25-foot) wide strip of land adjacent to Pajaro River levee right-of-way boundary along Salsipuedes Creek and Pajaro River within City of Watsonville; area in city subject to inundation from 1-in-100-year flood on Pajaro River	Urban, industrial, agricultural	Realistic determination of extent of hazard to city from 1-in-100-year flood on Pajaro River	Yes
San Benito County	Flood plain regulations of County zoning ordinance and the building permit process	100-year flood plains of San Benito River from Pajaro River to Tres Pinos Creek and Tequisquita Slough and tributaries as delineated in U.S. Corps of Engineers Flood Plain Information Reports	Agricultural	Unknown	No

Table 6: REGULATED FLOODWAYS IN CENTRAL COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Hollister	Building permit system	Areas subject to local ponding	Urban	Unknown	Yes
San Juan Bautista	Floodway zoning ordinance	San Juan Canyon drainage within city limits	Agricultural	None	Yes
Monterey County	Flood plain zoning ordinance; subdivision review process	Narrow strip of land along Pajaro River needed for easements for enlarged levee project; two small secondary flood plains along Carmel River at kilometre 2.4 and kilometre 19 (mile 1.5 and mile 12). Subdivision review process is utilized to regulate development in other flood-prone areas	Urban, agricultural	Unknown	Yes
Carmel-by-the-Sea	No significant flooding problem				No
Del Rey Oaks	Permit review	None	Urban	Implementation	Yes
Gonzales	No significant flooding problem				Yes
Greenfield	Flood plain regulation of City zoning ordinance	Areas subject to local ponding	Urban	None	Yes
King City	City municipal code; code is in process of being amended to specifically define areas where its flood plain zoning regulation will be applied	Floodway of San Lorenzo Creek within city limits	Urban	Unknown	Yes
Monterey	Building permit system	Perimeter of El Estero and Del Monte Lake	Urban industrial	Unknown	Yes
Pacific Grove	No significant flooding problem				No
Salinas	Adopted land use policy; agricultural zoning; environmental review process	Mill Lake, Markley Swamp, and Carr Lakebed, all of which are subject to flooding from Gabilan and Santa Rita	Urban, agricultural	Detailed determination of extent of flood-hazard	Yes
Sand City	No significant flooding problems				No
Seaside	Building permit system; subdivision proposal review	Area at perimeter of Roberts and Laguna Grande Lakes	Urban	Water surface elevation of lakes resulting from 1-in-100-year storm	Yes
Soledad	Building permit system; land use zoning ordinance	Floodways of Salinas River and Bryant Canyon within city limits	Urban	Reappraisal of flood-hazard to city, taking into consideration construction completed to reduce flood-hazard	Yes
San Luis Obispo County	Ordinances defining zones of flood-hazards and imposing building regulations on such zones	San Luis Obispo Creek	Urban	Identification of flood-hazard areas	Yes
Arroyo Grande	Uniform building code	Arroyo Grande Creek, Corbit and Carpenter Canyon	Urban, agricultural	Identification of flood-hazard areas through FEMA Study	Yes
Grover City	Administered through building and planning review	Meadow Creek	Urban and agricultural	Identification of flood-hazard areas	Yes
Morro Bay	Ordinance	Morro Creek and Little Morro Creek	Urban	Identification of flood-hazard areas	Yes

Table 6: REGULATED FLOODWAYS IN CENTRAL COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Paso Robles	Ordinance	Salinas River, Three Canyons	Urban	Identification of flood-hazard areas and revision to ordinance	Yes
Pismo Beach	Ordinance	Pismo Creek, Meadow Creek	Urban	Identification of flood-hazard areas	Yes
San Luis Obispo	Ordinances defining building and drainage regulations on flood-hazard areas	San Luis Obispo Creek, Pertoma Creek, Stenner Creek, and Old Garden Creek	Urban	Identification of flood-hazard areas	Yes
Santa Barbara County	Building permits and subdivision restrictions and ordinance	Santa Ynez River, Santa Barbara Streams, Santa Maria River	Urban, agricultural, industrial	Identification of flood-hazard areas	Yes
Carpinteria	Ordinance	Santa Monica and Franklin Creeks	Urban	None, under regular insurance program	Yes
Guadalupe	None	None	None	Guadalupe has no floodways to be regulated	Yes
Lompoc	Building permits and subdivision restrictions	Santa Ynez River	Urban, industrial	Identification of flood-hazard areas and rezoning	Yes
Santa Barbara (City)	Building permits, subdivision restrictions, and Flood Plain Management ordinances	Sycamore and Mission Canyon Creeks	Urban, industrial	Identification of flood-hazard areas	Yes
Santa Maria	Building permits and subdivision restrictions	Santa Maria River	Urban, industrial, agricultural	Identification of flood-hazard areas	Yes

South Coastal Hydrologic Study Area

The South Coastal Hydrologic Study Area is bounded on the north and east by the watershed divides of the Tehachapi, San Gabriel, San Bernardino, and San Jacinto Mountains, on the south by the border with Mexico, and on the west by the Pacific Ocean. About one-third of the area is coastal plain (Figure 30).

Principal stream systems and minor coastal streams in this area are Calleguas Creek Basin, Malibu and Santa Monica Bay Coastal streams, the Orange County Streams, and the Ventura, Santa Clara, Los Angeles, San Gabriel, Santa Ana, Santa Margarita, San Luis Rey, San Dieguito, San Diego, Sweetwater, and Otay-Tijuana Rivers. In the coastal plain, contiguous drainage areas are separated by low, poorly defined divides.

Principal urban centers are the metropolitan complexes of Ventura-Oxnard, Los Angeles-Long Beach, Orange County, San Bernardino-Riverside, and San Diego. All of these have grown phenomenally during the past 30 years. The Department of Finance estimated areawide population in January 1976 was 11,954,000. Burgeoning urban development has taken place on flood plains, canyon bottoms, and adjacent to flood channels, greatly increasing the flood and debris damage potential in most of the area.

The highly developed transportation facilities include an extensive freeway-highway complex, transcontinental and local rail service, international and domestic air service, and deep-draft harbors for foreign and coastal trade.

The area's economy is based on a number of industries, and includes iron and steel production, automobile assembly, television and motion picture production, petroleum production and processing, aircraft production, and the manufacture of tires, furniture, and wearing apparel. Agriculture is also significant, and includes production of citrus and subtropical fruits and numerous truck crops. A large number of military installations forms an important segment of the economic base of the area.

History of Flooding

The area is subject to sudden and severe floods, with some flood damage occurring almost every year. Most floods are produced by winter storms, usually from December through March. Snow is seldom a factor in flooding. Thunderstorms occur very infrequently along the coast, and usually only during winter months, but are not uncommon in the higher mountains at any time. They affect comparatively small areas and may bring the high-intensity, short-duration precipitation that frequently results in flooding.

Information about floods in the south coastal streams was first recorded by the Spanish mission fathers who traveled between San Diego and San Francisco in 1769-70. These early records are too sketchy to determine the magnitude of the early floods.

Major floods have occurred in 1810, 1825, 1862, 1884, 1889, 1891, 1916, 1927, 1938, 1969, 1978, and 1980. The

FLOOD UNLEASHED MUDSLIDES are a too-common occurrence in Southern California. This mishap occurred in Glendora at the foot of the San Gabriel Mountains in the January storm of 1969. (Los Angeles County Flood Control District Photo)

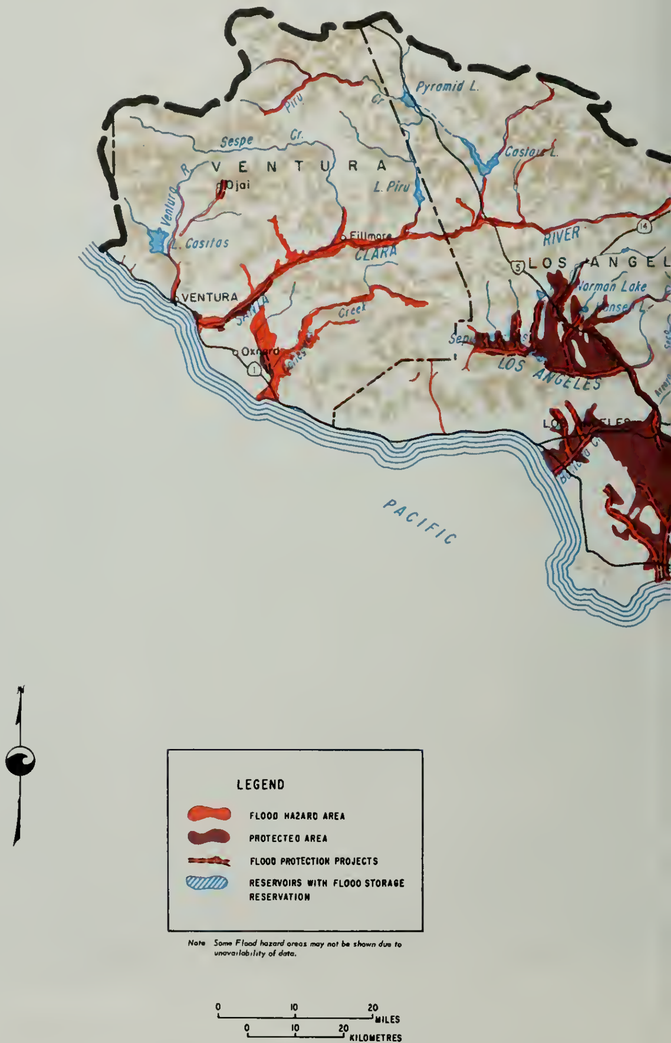


Figure 30

FLOOD INFORMATION

SOUTH COASTAL HYDROLOGIC STUDY AREA


SAN BERNARDINO
SAN BERNARDINO
Big Bear L.
San Gabriel
San Antonio Res.
Lytle Creek
RIVER
Cucamonga
RIVERSIDE
Prado Res
Corona
San Timoteo Canyon
San Jacinto Riv.
RIVERSIDE
SANTA ANA
Railroad Canyon Res.
L. Elsinore
L. Hemet
Bautista Cr.
Aliso
San Juan Cr.
San Onofre Canyon
OCEAN
Santa Margarita
SAN LUIS REY RIV.
L. Henshaw
Oceanside
Escondido
L. Wohlford
SAN DIEGO
San Vicente Res
El Capitan Res
River
Rose Cr.
Diego
San
Sweetwater
Barrett L.
SAN DIEGO
Sweetwater Res
Morena Res
Lower Otay Res

largest flood was probably that of 1862, although the most damaging flood was in 1969.

A storm occurred in 1810 which caused floods in the Santa Ana River that washed away adobes in the Santa Ana-Anaheim area. It is also known that damaging floods occurred in most of Southern California during the winter of 1824-1825. The flood of 1825 was severe enough to change the course of both the Santa Ana and Los Angeles Rivers.

The flood of January 1862 has been called the "Noachian deluge of California floods" by J. M. Guinn in "A History of California Floods and Droughts". This storm and flood were unusual in two ways. First, they occurred during the very severe drought of 1856-1864; second, the duration of flooding was extremely long, lasting for 20 days. Normally, major floods last no longer than a few days. Early diaries indicate that "it rained both day and night for three weeks". The Santa Ana for a time rivaled the "Father of Waters in magnitude". A feature article in the Los Angeles Times of February 11, 1973, stated that "in 1862 much of Orange County became an inland sea".

There was a long drawn-out wet period during the winter and spring of 1884, with short intervals between storms, and the rainy season continuing into June. More than double the normal amount of rain fell during the season. According to U. S. Geological Survey Water Supply Paper No. 844, one flood occurred in the latter part of February and did little damage. A second flood occurred a week later and did a great deal of damage. The Santa Ana River cut a new channel to the sea, beginning at a point below where Santiago Creek enters the Santa Ana River, inundating the towns of Santa Ana and Orange. A flood in Los Angeles County in 1914 caused more than $10 million in property damage and took many lives.

In January 1916, there were two heavy rainfalls in Southern California that occurred within a week of each other. During the second storm, the ground was already saturated and large volumes of runoff resulted.

The peak discharge in 1916 is considered to be less than that of 1884. However, far more damage was done in 1916 because the flood plain was more intensively developed and the bridges tended to act as plugs.

The widespread flood of 1938 was the first for which detailed damage and discharge records are available. It caused the loss of 87 lives and damage estimated at $78.5 million. Approximately 100 000 hectares (250,000 acres) were inundated in overflow areas from the Tijuana River north to the Ventura River.

Heavy flooding in January and February 1969 resulted in the loss of 103 lives and extensive damage, particularly in the north. The damage amounted to $157.4 million in the northern part of the area and $2.7 million in the southern part (San Diego County). This flood was the most severe of record in parts of Ventura, Orange, San Bernardino, and Riverside Counties. All of the counties in the South Coastal Area, except San Diego, were declared national disaster areas in 1969. While past floods may have equaled or surpassed them in magnitude of flow, the 1969 floods were the most damaging, largely because the earlier floods occurred when Southern California was less intensively developed.

During the 1978 floods, several streams overflowed, prompting the evacuation of homes and businesses in low-lying urban and rural areas. Widespread street flooding occurred where drainage systems failed or were not adequate to handle the excessive amounts of runoff. The total damage in the South Coastal Area from February-March floods, not including wind damage, coastal wave action, mudslides or flooding in undeveloped

IN FEBRUARY 1980, Lake Elsinore overflowed for the first time since 1916. (U. S. Army Corps of Engineers Photo)

canyon areas and isolated agricultural areas, is estimated to be $86 million.

The intense storms of January-February 1980 caused flooding and left a trail of damaged and destroyed homes, washed out bridges and roads, eroded beaches, disrupted transportation, and closed schools and recreation facilities. Thousands of people were evacuated from their homes, and some communities were without water or natural gas for extended periods of time. Twenty-nine people lost their lives during these storms. President Carter declared Los Angeles, Orange, Riverside, San Bernardino, San Diego, Santa Barbara, and Ventura Counties disaster areas. Preliminary estimates of damage in the South Coastal Area are approximately $200 million.

During the storms of January-February 1980, Lake Elsinore in Riverside County

DURING THE 1980 FLOODS in San Diego County, the San Luis Rey River overflowed near Oceanside. (U. S. Army Corps of Engineers Photo)

overflowed for the first time since 1916. The flood fight at the lake consisted of three measures: (1) moving people and property out of flooded areas, (2) building levees to protect homes and other development from flooding, and (3) creating an outlet channel to provide some relief from the inflow to the lake. Even a relatively small inflow to the lake during the next three years will be a significant threat because of the high residual lake stage.

Historical records of the U. S. Geological Survey indicate that the 1-in-100-year floodflow was exceeded in the following streams: San Luis Rey River near Bonsal in February 1891, and at Oceanside in January 1916; in the Santa Ana River Basin, Cajon, and San Antonio in March 1938; and Cucamonga Creek in January 1969; in the San Gabriel River Basin (the East Fork San Gabriel River near Camp Bonita in March 1938, and February 1969); in the Los Angeles River Basin (Tujunga Canyon in March 1938, and Topanga and Malibu Creeks in January 1969); in the Santa Clara River Basin (the Santa Clara River in January 1969); and in the Ventura River Basin (the Ventura River in January 1969).

Flood Damage Prevention Facilities

An extensive and effective flood damage prevention system has been developed in the South Coastal Area, principally in the Los Angeles and San Gabriel River Basins. Although a project was built to protect the Santa Ana River Basin area in Orange County, extensive development along the lower reaches of the river, coupled with the reevaluation of the flood potential, indicates a necessity for enlarging the existing flood-protection facilities. Existing flood-reduction measures provide some degree of protection to about 75 percent of the flood-hazard areas in the South Coastal Area.

Table 7 presents the projects in the area which are described in this section.

Table 7: FLOOD DAMAGE PREVENTION PROJECTS IN SOUTH COASTAL HYDROLOGIC STUDY AREA

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Los Angeles County	Los Angeles County Drainage Area Projects				
Los Angeles River	Channel (U.S. Army Corps of Engineers)	Los Angeles County Flood Control District	77 kilometres (48 miles) of concrete channel	Many cities of the Los Angeles-Long Beach metropolitan area	1-in-100-year flood
San Gabriel River	Channel (U.S. Army Corps of Engineers)	Los Angeles County Flood Control District	47 kilometres (29 miles) of concrete channel	Many cities of Los Angeles metropolitan area and Anaheim	Standard project flood
Rio Hondo	Channel (U.S. Army Corps of Engineers)	Los Angeles County Flood Control District	20 kilometres (13 miles) of concrete channel	Many cities of Los Angeles metropolitan area and Anaheim	Standard project flood
Ballona Creek	Channel (U.S. Army Corps of Engineers and Los Angeles County Flood Control District)	Los Angeles County Flood Control District	16 kilometres (10 miles) of concrete channel	Many cities of Los Angeles metropolitan area	1-in-100-year flood
Laguna Dominguez System	Channel (Los Angeles County Flood Control District)	Los Angeles County Flood Control District	27 kilometres (17 miles) of concrete channel	Many cities of Los Angeles-Long Beach metropolitan area	Capital flood
Tributary Channels	Channel (U.S. Army Corps of Engineers and Los Angeles County Flood District)	Los Angeles County Flood Control District	549 kilometres (341 miles) of tributary channels	Many cities of the Los Angeles-Long Beach metropolitan area	1-in-100-year flood
Big Dalton Creek	Big Dalton Dam and Reservoir (Los Angeles County Flood Control District - 1929)	Los Angeles County Flood Control District	Flood storage and water conservation dam and reservoir. Capacity 1 200 cubic dekametres (963 acre-feet)	Cities in eastern Los Angeles County	Capital flood
Trib. Rio Hondo	Santa Anita Dam and Reservoir (Los Angeles County Flood Control District - 1927)	Los Angeles County Flood Control District	Flood storage and water conservation dam and reservoir. Capacity 1 000 cubic dekametres (836 acre-feet)	Cities in eastern Los Angeles County	Capital flood
Big Tujunga Creek	Big Tujunga Dam and Reservoir (Los Angeles County Flood Control District - 1931)	Los Angeles County Flood Control District	Flood storage and water conservation dam and reservoir. Capacity 7 400 cubic dekametres (6,000 acre-feet)	Urban areas in Tujunga Canyon	Capital flood
West Fork San Gabriel River	Cogswell Dam (Los Angeles County Flood Control District - 1935)	Los Angeles County Flood Control District	Flood storage and water conservation dam and reservoir. Capacity 11 500 cubic dekametres (9,340 acre-feet)	Urban areas in West Fork of San Gabriel River	Capital flood
Arroyo Seco	Devils Gate Dam and Reservoir (Los Angeles County Flood Control District - 1920)	Los Angeles County Flood Control District	Flood storage and conservation dam and reservoir. Capacity 2 400 cubic dekametres (1,930 acre-feet)	Cities of Pasadena, Alhambra and East Los Angeles	Capital flood
Live Oak Creek	Live Oak Dam and Reservoir (Los Angeles County Flood Control District - 1922)	Los Angeles County Flood Control District	Flood storage and water conservation. Capacity 300 cubic dekametres (240 acre-feet)	Cities of eastern Los Angeles County	Capital flood
Eaton Wash	Eaton Wash Dam and Reservoir (Los Angeles County Flood Control District - 1936)	Los Angeles County Flood Control District	Debris storage and conservation. Capacity 1 000 cubic dekametres (880 acre-feet)	Pasadena and other cities of metropolitan Los Angeles	Capital flood

Table 7: FLOOD DAMAGE PREVENTION PROJECTS IN SOUTH COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Pacoima Creek	Pacoima Dam and Reservoir (Los Angeles County Flood Control District - 1929)	Los Angeles County Flood Control District	Flood storage and water conservation. Capacity 4 800 cubic dekametres (3,930 acre-feet)	Cities of San Fernando Valley	Capital flood
Walnut Creek	Puddingstone Dam and Reservoir (Los Angeles County Flood Control District - 1928)	Los Angeles County Flood Control District	Flood storage dam and reservoir, recreational area. Capacity 2 000 cubic dekametres (16,900 acre-feet)	Cities of eastern Los Angeles County	Capital flood
San Dimas Creek	Puddingstone Diversion Dam and Reservoir (Los Angeles County Flood Control District - 1928)	Los Angeles County Flood Control District	Flood storage dam diversion of flow and conservation. Capacity 200 cubic dekametres (150 acre-feet)	Cities of eastern Los Angeles County	Capital flood
San Gabriel River	San Gabriel Dam and Reservoir (Los Angeles County Flood Control District - 1938)	Los Angeles County Flood Control District	Flood storage and water conservation. Capacity 51 200 cubic dekametres (41,500 acre-feet)	Cities of eastern Los Angeles County	Capital flood
Sawpit Creek	Sawpit Dam and Reservoir (Los Angeles County Flood Control District - 1927)	Los Angeles County Flood Control District	Flood storage and water conservation. Capacity 500 cubic dekametres (390 acre-feet)	Cities of eastern Los Angeles County	Capital flood
Thompson Creek	Thompson Creek Dam and Reservoir (Los Angelea County Flood Control District - 1928)	Los Angeles County Flood Control District	Flood storage and water conservation. Capacity 600 cubic dekametres (450 acre-feet)	Cities of eastern Los Angeles County	Capital flood
Tujunga Wash	Hansen Dam (U.S. Army Corps of Engineers - 1940)	U.S. Army Corps of Engineers	Flood storage dam with recreational facilities. Capacity 36 600 cubic dekametres (29,700 acre-feet)	Burbank and cities in San Fernando Valley	Standard project flood
Upper Los Angeles River	Sepulveda Dam (U.S. Army Corps of Engineers - 1941)	U.S. Army Corps of Engineers	Flood storage dam with recreational facilities. Capacity 21 300 cubic dekametres (17,300 acre-feet)	Many cities in western Los Angeles County	Standard project flood
Pacoima Wash	Lopez Dam (U.S. Army Corps of Engineers - 1954)	U.S. Army Corps of Engineers	Flood storage dam and reservoir. Capacity 300 cubic dekametres (230 acre-feet)	Cities in the San Fernando Valley area	Standard project flood
San Gabriel River	Santa Fe Dam (U.S. Army Corps of Engineers - 1949)	U.S. Army Corps of Engineers	Flood storage dam and reservoir. Capacity 40 200 cubic dekametres (32,600 acre-feet)	Cities in eastern Los Angeles County	Standard project flood
Rio Hondo and San Gabriel River	Whittier Narrows Dam (U.S. Army Corps of Engineers - 1957)	U.S. Army Corps of Engineers	Flood storage dam and reservoir with recreational facilities. Capacity 44 700 cubic dekametres (36,200 acre-feet)	Cities in central portion of Los Angeles metropolitan area	Standard project flood
San Antonio River	San Antonio Dam (U.S. Army Corps of Engineers - 1956)	U.S. Army Corps of Engineers	Flood storage dam. Capacity 9 400 cubic dekametres (7,600 acre-feet)	Urban and industrial property in cities of Pomona and Claremont, Chino, Ontario, and Upland	Standard project flood

Table 7: FLOOD DAMAGE PREVENTION PROJECTS IN SOUTH COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Tributary Streams	Los Angeles River Flood Prevention Project (U.S. Soil Conservation Service and U.S. Forest Service)	Los Angeles County Flood Control District	62.6 kilometres (38.9 miles) of stream channel modifications, many debris basins, channel stabilization structures, and fire control measures	Urban areas in western San Fernando Valley	From 1-in-25-year to 1-in-100-year protection
Orange County					
Carbon Canyon Creek	Santa Ana River Basin Orange County Project - Carbon Canyon Dam and Channel (U.S. Army Corps of Engineers - 1961)	U.S. Army Corps of Engineers	Flood storage dam and incidental water conservation. Capacity 8 100 cubic dekametres (6,600 acre-feet) 1.3 kilometres (0.8 mile) of channel	Developed metropolitan and rural areas, including portions of the Cities of Anaheim, Los Alamitos, Placentia, and nearby Naval Air Station	Standard project flood
Brea Creek	Santa Ana River Basin and Orange County Project - Brea Dam (U.S. Army Corps of Engineers - 1942)	U.S. Army Corps of Engineers	Flood storage dam with recreational area. Capacity 5 000 cubic dekametres (4,000 acre-feet)	Cities of Fullerton and Buena Park	Standard project flood
Fullerton Creek	Santa Ana River Basin and Orange County Project - Fullerton Dam (U.S. Army Corps of Engineers - 1941)	U.S. Army Corps of Engineers	Flood storage dam. Capacity 900 cubic dekametres (764 acre-feet)	Cities of Fullerton and Santa Ana	Standad project flood
Santa Ana River	Santa Ana River Basin and Orange County Project - Prado Dam (U.S. Army Corps of Engineers - 1941)	U.S. Army Corps of Engineers	Flood storage dam. Capacity 244 000 cubic dekametres (198,000 acre-feet)	Developed metropolitan and urban areas in lower Orange County	1-in-70-year flood*
Santiago Creek	Santa Ana River Basin and Orange County Project - Villa Park Dam (Orange County Flood Control District - 1962)	Orange County Flood Control District	Flood storage reservoir. Capacity 19 000 cubic dekametres (15,600 acre-feet)	Cities of Orange, Santa Ana, and other urbanized areas of Orange County	1-in-100-year flood
San Bernardino County					
Lytle and Cajon Creeks	Santa Ana River Basin Orange County Project - Lytle and Cajon Creek Channel Improvements (U.S. Army Corps of Engineers - 1948)	San Bernardino County Flood Control District	16.7 kilometres (10.4 miles) of collecting levees and groins. 4.8 kilometres (3.0 miles) of channel modifications	Cities of San Bernardino, Colton, adjacent suburban areas, and parts of transcontinental transportation system	Standard project flood
Devil, Badger, East Twin, Warm, Lytle and Cajon Creeks	Santa Ana River Basin Project - Devil Creek Diversion - 1958, East Twin, and Warm Creeks Channel Improvements - 1961, and Lytle Creek Levee - 1956, (U.S. Army Corps of Engineers - Devil Creek Diversion - 1958 East Twin and Warm Creek Channel Improvement - 1961 Lytle Creek Levee - 1956)	San Bernardino County Flood Control District	Devil Creek Diversion consists of 2.1 kilometres (1.3 mile) of levee, 3.2 kilometres (2 miles) of channel. East Twin and Warm Creeks Channel modifications include 5.6 kilometres (3.5 miles) of levee revetment, 7.2 kilometres (4.5 miles) of concrete channel and 2.3 kilometres (1.4 mile) of revetted channel; Lytle Creek levee consists of 1.9 kilometres (1.2 mile) of levee	The unit provides protection to parts of City of San Bernardino and nearby suburban areas from floods on Devil, Cable, Badger, Waterman, East Twin, and Warm Creeks, and to water supply wells for Rialto, Bloomington and nearby irrigated acres	Standard project flood

* Existing level of protection

Table 7: FLOOD DAMAGE PREVENTION PROJECTS IN SOUTH COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Mill Creek	Santa Ana River Basin Project - Mill Creek Levees, (U.S. Army Corps of Engineers - 1960)	San Bernardino County Flood Control District	3.9 kilometres (2.4 miles) of levee	Cities of Redlands, Mentone and valuable citrus groves	Standard project flood
San Antonio and Chino Creeks	San Antonio and Chino Creeks Channel (U.S. Army Corps of Engineers - 1960)	U.S. Army Corps of Engineers	16.9 kilometres (10.5 miles) of rectangular concrete channel along San Antonio Creek and 8.4 kilometres (5.2 miles) of trapezodial concrete channel along Chino Creek	Cities of Pomona, Claremont, Chino, Ontario, and Upland	Standard project flood
Lytle and Warm Creeks Project	Lytle and Warm Creeks Project (U.S. Army Corps of Engineers - Being constructed)	San Bernardino County Flood Control District	5.6 kilometres (3.5 miles) channel along the East Branch of Lytle Creek, 2.4 kilometres (1.5 mile) channel on Warm Creek, levees and a 2.9-kilometre (1.8-mile) reach of channel and levees along the Santa Ana River	City of San Bernardino	Standard project flood
Cypress Creek	Cypress Creek Channel (San Bernardino Flood Control District - 1975)	San Bernardino County Flood Control District	6.4 kilometres (4.0 miles) channelization	City of Chino	1-in-100-year flood
City Creek	City Creek Levee* (U.S. Army Corps of Engineers - 1960)	San Bernardino County Flood Control District	0.8 kilometre (0.5 mile) of new levee and 1.0 kilometres (0.6 mile) of old revetted levee	City of San Bernardino	Standard project flood
<u>Riverside County</u>					
Alessandro Creek	Alessandro Dam (Riverside County Flood Control and Water Conservation District - 1956)	Riverside County Flood Control and Water Conservation District	Flood storage dam. Capacity 460 cubic dekametres (370 acre-feet)	City of Riverside	1-in-100-year flood
Box Springs Creek	Box Springs Dam (Riverside County Flood Control and Water Conservation District - 1960)	Riverside County Flood Control and Water Conservation District	Flood storage dam. Capacity 480 cubic dekametres (390 acre-feet)	City of Riverside	1-in-100-year flood
Harrison Creek	Harrison Street Dam (Riverside County Flood Control and Water Conservation District - 1954)	Riverside County Flood Control and Water Conservation District	Flood storage dam. Capacity 260 cubic dekametres (210 acre-feet)	City of Riverside	1-in-100-year flood
Pigeon Pass Creek	Pigeon Pass Dam (Riverside County Flood Control and Water Conservation District - 1958)	Riverside County Flood Control and Water Conservation District	Flood storage dam. Capacity 1 100 cubic dekametres (910 acre-feet)	City of Edgemont	1-in-100-year flood
Prenda Creek	Prenda Dam (Riverside County Flood Control and Water Conservation District - 1958)	Riverside County Flood County and Water Conservation District	Flood storage dam. Capacity 173 cubic dekametres (140 acre-feet)	City of Riverside	1-in-100-year flood

* Small project

Table 7: FLOOD DAMAGE PREVENTION PROJECTS IN SOUTH COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Sycamore Canyon	Sycamore Dam (Riverside County Flood Control and Water Conservation District - 1956)	Riverside County Flood Control and Water Conservation District	Flood storage dam. Capacity 1 400 cubic dekametres (1,150 acre-feet)	City of Riverside	1-in-100-year flood
Woodcrest Creek	Woodcrest Dam (Riverside County Flood Control and Water Conservation District - 1954)	Riverside County Flood Control and Water Conservation District	Flood storage dam. Capacity 520 cubic dekametres (420 acre-feet)	City of Riverside	1-in-100-year flood
Mockingbird Canyon	Mockingbird Dam (City of Riverside - 1914)	City of Riverside	Flood storage dam. Capacity 1 200 cubic dekametres (1,000 acre-feet)	City of Riverside	1-in-100-year flood
San Jacinto River and Bautista Creek	Santa Ana River Basin Project - San Jacinto River Levee and Bautista Creek (U.S. Army Corps of Engineers - 1961)	Riverside County Flood Control and Water Conservation District	6.3 kilometres (3.9 miles) of levee along San Jacinto River and 4.8 kilometres (3.0 miles) of concrete-lined channel on Bautista Creek upstream from State Highway 147	Cities of San Jacinto, Hemet, and Valle Vista and nearby agricultural areas	Standard project flood
Santa Ana River	Santa Ana River Basin Project - Riverside Levee (U.S. Army Corps of Engineers - 1958)	Riverside County Flood Control and Water Conservation District	8.9 kilometres (5.5 miles) of levee along both sides of the Santa Ana River near the City of Riverside	City of Riverside and Rubidoux	1-in-150-year flood
Main Street Wash	Main Street Wash Watershed Project (SCS - 1976)	City of Corona	5.3 kilometres (3.3 miles) concrete channel with inlet structured and energy dissipator outlet	City of Corona	1-in-50-year flood
Ventura County					
Stewart Canyon	Stewart Canyon Debris Basin and Channel (U.S. Army Corps of Engineers - 1963)	Ventura County Flood Control District	A debris basin with a capacity of 200 cubic dekametres (186 acre-feet) at the mouth of Stewart Canyon and a paved channel 1.4 kilometres (0.9 mile) long extending from the debris basin, through the City of Ojai, to a natural channel south of the City	City of Ojai	Standard project flood
Ventura River	Ventura River Levee (U.S. Army Corps of Engineers - 1963)	Ventura County Flood Control District	A rock-revetted earth-fill levee 4.2 kilometres (2.6 miles) long along west bank of Ventura River	Part of an oil field, agricultural, residential, and commercial property in and near City of Ventura	Standard project flood
Santa Clara River	Santa Clara River Basin Project - Santa Clara River Levee (U.S. Army Corps of Engineers - 1961)	Ventura County Flood Control District	A levee 7.6 kilometres (4.7 miles) long existing along the lower Santa Clara River from the western end of South Mountain to the bridge on U.S. Highway 101	City of Oxnard and U.S. Navy Base at Port Hueneme	Standard project flood
Calleguas Creek	Calleguas Creek Watershed Project (U.S. Soil Conservation Service - 1964)	Ventura County Flood Control District	Two units of channelization. One from Highway 101 Bridge to about 8.4 kilometres (5.2 miles) upstream. About 1.6 kilometres (1 mile) of channelization. The second unit includes the Walnut and Gobbert Canyons Watersheds west of Moorpark. About 1.6 kilometres (1 mile) of channelization in each		1-in-50-year flood

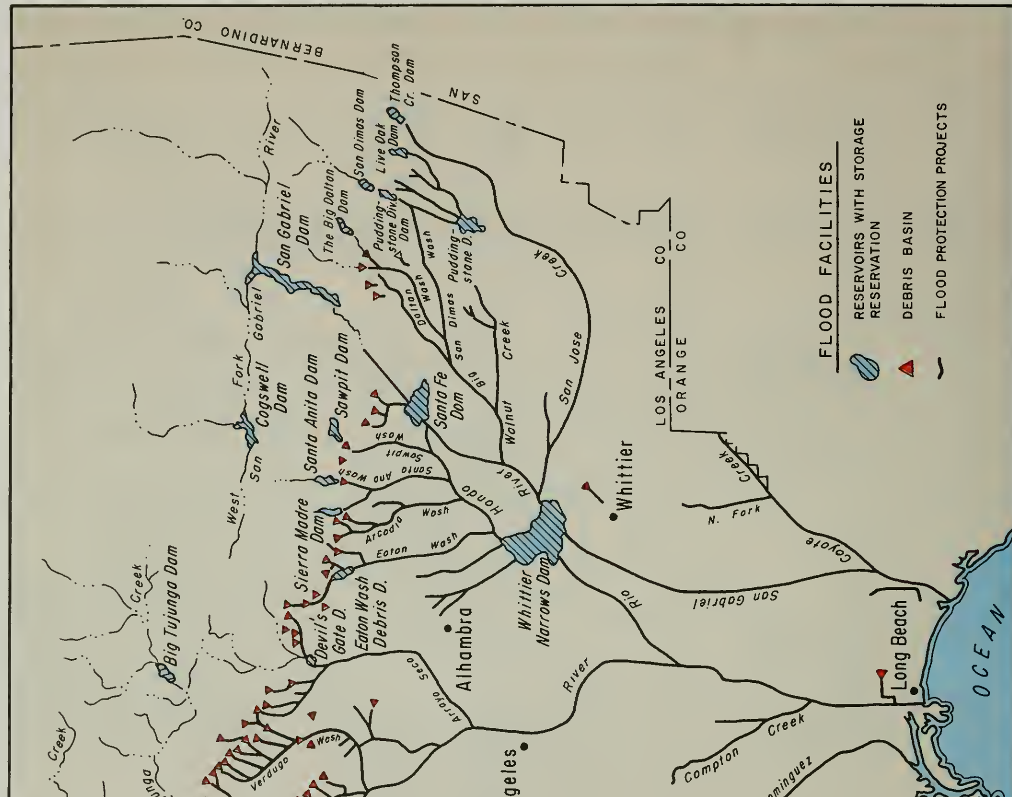
Table 7: FLOOD DAMAGE PREVENTION PROJECTS IN SOUTH COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Revolon Slough	Revolon Slough Watershed Project (U.S. Soil Conservation Service - Under Construction)	Ventura County Flood Control District	Project being constructed. Improving 10.9 kilometres (6.8 miles) of existing channel and adding 1.1 kilometres (0.7 mile) of channel to outlet channel from Beardsley Wash		1-in-50-year flood design, but project 17% completed
Beardsley Wash and others	Beardsley Wash (U.S. Soil Conservation Service)	Ventura County Flood Control District	10.5 kilometres (6.5 miles) of stream channel modifications, enlarge three debris basins, and four channel stabilization structures	Agricultural and urban areas in western Ventura County	1-in-50-year flood
San Diego County					
San Diego River	San Diego River Levee and Channel Improvements (U.S. Army Corps of Engineers - 1953)	City of San Diego	5.3 kilometres (3.3 miles) of a leveed flood channel and alteration of a railroad bridge over the channel	City of San Diego	Standard project flood
Rose Creek	Rose Creek Channel* (U.S. Army Corps of Engineers - 1970)	City of San Diego	Channel modifications from U.S. Highway 101 bridge southwestward to the Grand Avenue Bridge at Mission Bay. 317 metres (1,040 feet) of concrete rectangular channel in upstream reach and 768 metres (2,520 feet) of earth bottom trapezoidal channel with stone-revetted side slopes in the downstream reach	City of San Diego	Standard project flood
Buena Vista Creek	Buena Vista Creek Watershed Project (U.S. Soil Conservation Service - 1967)	City of Vista	6.4 kilometres (4.0 miles) of earth and concrete-lined channel in City of Vista	City of Vista	1-in-100-year flood
Escondido Creek	Escondido Creek Watershed Project (SCS - being constructed)	County of San Diego	Dixon Reservoir has been constructed and provides flood storage and water conservation. Capacity 2 800 cubic dekametres (2,300 acre-feet). Plans call for realigning, enlarging, and lining approximately 6.4 kilometres (4.0 miles) in City of Escondido	City of Escondido	1-in-100-year flood

* Small project

Los Angeles County Drainage Area Project. This is one of the most extensive flood protection projects ever built for a metropolitan area. After the 1914 flood, the State Legislature passed an act creating the Los Angeles County Flood Control District to control floods and conserve water. Early bond issues financed construction of 14 dams in the San Gabriel Mountains. In addition, debris basins were constructed to trap sediment which had caused major damage, and flood channel modification was undertaken.

The County Flood Control District's Comprehensive Plan, prepared in the early 1930s and modified over the years, serves as the basic blueprint for flood protection and water conservation. In 1936, federal legislation made the Corps of Engineers a participant in Los Angeles County's comprehensive flood protection program. The Corps' Los Angeles and San Gabriel Rivers and Ballona Creek Project, now nearing completion, calls for the construction of 5 flood storage reservoirs or basins, 24 debris basins, 153 km (95 mi) of main channel, 307 km (191 mi) of tributary


FLOOD FACILITIES
RESERVOIRS WITH STORAGE RESERVATION
DEBRIS BASIN
FLOOD PROTECTION PROJECTS
PACIFIC
OCEAN
MILES
KILOMETRES
0
10
20
VENTURA CO.
SAN BERNARDINO CO.
LOS ANGELES CO.
ORANGE CO.
Long Beach
Whittier
Alhambra
Los Angeles
Burbank
Chatsworth Res.
San Fernando Res.
Sepulveda Dam
Lopez Dam
Pacoima Dam
Hansen Dam
Big Tujunga Dam
Devil's Gate D.
Eaton Wash Debris D.
Sierra Madre Dam
Santa Anita Dam
Sawpit Dam
Cogswell Dam
San Gabriel Dam
Santa Fe Dam
Whittier Narrows Dam
The Big Dalton Dam
San Dimas Dam
Live Oak Dam
Thompson Cr. Dam
Puddingstone Dike Dam
Puddingstone D.
Arroyo Calabasas
Bull Creek
Pacoima Wash
Tujunga Wash
Big Tujunga Creek
Verdugo Wash
Burbank Western
Los Angeles River
Arroyo Seco
Eaton Wash
Arcadia Wash
Santa Anita Wash
Sawpit Wash
Rio Hondo
West Fork San Gabriel River
San Gabriel River
Dalton Wash
Big Dalton Wash
San Dimas Wash
Walnut Creek
San Jose Creek
Coyote Creek
N. Fork
Compton Creek
Dominguez
Laguna
Ballona
Benedict Cyn. Sys.
Sawtelle-Westwood Sys.
Santa Monica Cr.
Rustic Cr.
Pacoima
Creek

channels, and 2 jetties. Under the project the Corps has constructed 5 dams and reservoirs, 22 debris basins, and almost 480 km (300 mi) of channel modifications. In addition, the Corps constructed San Antonio Dam, which protects the cities of Pomona and Claremont in Los Angeles County, as well as cities in San Bernardino County.

The county's part of the overall system, the Los Angeles County Drainage Area Project, is a comprehensive flood protection program for which 20 dams, 737 km (458 mi) of permanent flood channels, 90 debris basins, and 1,424 separate storm drains, totalling 2 818 km (1,751 mi) have been completed. Figure 31 shows these projects.

In addition to flood protection, these projects also create extensive recreational opportunities at reservoir facilities developed primarily by the Corps in partnership with the cities and the County of Los Angeles. There are facilities for camping, picnicking, riding, hiking, bicycling, golf, archery, and tennis, as well as such water-oriented activities as fishing, swimming, boating, and waterskiing.

These projects also contribute to ground water recharge through spreading grounds. Here, storm runoff retained in debris basins and reservoirs is released to percolate through sand and gravel into the ground water system. The flood control district has also installed special inflatable dams in soft-bottom sections of streamways to trap the receding flows from storms, thus allowing additional runoff to percolate to the ground water. The inflatable dams are used in lined channels to divert water to offstream percolation basins. The Corps of Engineers reports that more than 407 000 cubic dekametres (330,000 acre-feet) of water is added to the underground systems annually by the water conservation part of the Los Angeles County Drainage Area Project, thereby providing mitigation for the extensive concrete channel system in which ground water recharge has been eliminated.

Excluding expenditures of the flood control district for existing and planned supplemental flood protection modifications ($1.14 billion and $1 billion, respectively), the cost of the project was about $433 million, of which $78.7 million was nonfederal. Project facilities prevented more than $2.7 billion in damage from the 1969 and 1978 floods. However, about $10 million in damage from mudflows in unprotected, rapidly developing foothill and canyon areas occurred in those years. In addition, about $2 million in damage from landslides occurred in the Pacific Palisades area. Also, there are many inadequate storm drains built by developers and accepted by Los Angeles County for maintenance.

The Corps' flood projects are sized to protect against Standard Project Floods to assure a reasonable degree of flood protection at the time of their construction. However, the tremendous population growth that has taken place within the vicinity of the projects could increase runoff to such a degree that these works may not provide the level of protection for which they were designed.

Dams built, maintained, and operated by the Corps as part of the Los Angeles County comprehensive plan are Hansen, Lopez, Santa Fe, Sepulveda, and Whittier Narrows Dams.

Hansen Dam was built on the Tujunga Wash in 1940 at a federal cost of $11.3 million. Recreation facilities have been built in the reservoir area by the City of Los Angeles at a cost of about $4 million. In addition, about $400,000 in federal funds have been expended for recreational development. The city plans to spend about $3.8 million for additional recreational facilities.

Lopez Dam was built on Pacoima Wash in 1954 at a federal cost of $700,000.

Santa Fe Dam was built on the San Gabriel River in 1949 at a federal cost of $12.6 million. Recreational facilities were built in the reservoir area at a cost of about $5.5 million in federal funds and $1.5 million in local funds.

Sepulveda Dam was built on the Upper Los Angeles River in 1941 at a federal cost of $6.7 million. The area behind this dam has been developed by the City of Los Angeles into a popular recreational area, including golf courses, riding, and hiking trails, model plane landing field and competition areas, archery ranges, tennis and basketball courts, a bicycle race track, a baseball park, and picnic areas. About $400,000 in federal funds were also expended on the area for recreation development.

Whittier Narrows Dam was built on the main channels of the Rio Hondo and San Gabriel Rivers in 1957 at a federal cost of $32.3 million. Existing recreation facilities were built by local interests at a cost of $5.25 million. The Los Angeles County Department of Parks and Recreation is developing a 470-hectare (1,160-acre) park and is planning to spend an additional $15 million. The City of Pico Rivera plans to spend $712,000 for future recreational facilities. More than 1.4 million people visited the area in 1975. About $6.5 million in federal funds have been spent for recreational development at Whittier Narrows.

An extensive network of channels and levees was constructed throughout the basin. Under the Code 710 Program, recreation trails for bicyclists and equestrians have been constructed along the lower Los Angeles and San Gabriel Rivers and along the upper and lower Rio Hondo channel. About $1 million in federal funds have been spent thus far and about $2.5 million in federal funds are expected to be spent in fiscal year 1980 to provide more recreation trails along the rivers and channels.

Additional Corps' studies of the Los Angeles County Drainage area and the San Gabriel River Basin authorized by Congress are under way. To determine the feasibility of adding landscaping, environmental, and recreational facilities, the studies include consideration of the adequacy of seven existing modified channels; the need for modifying about 105 km (65 mi) of channels along 44 unmodified streams; review of four existing Corps' reservoirs to determine the desirability of incorporating additional water conservation and recreational features; and review of 22 existing debris basins and 475 km (295 mi) of existing channel modifications. Completion of the studies is scheduled for 1984.

Santa Ana River Basin Project. The Corps has developed a single plan for flood protection and allied purposes for the Santa Ana River Basin. These modifications are divided into two projects in accordance with congressional authorization, the "Santa Ana River Basin and Orange County Project" and the "Santa Ana River Basin Project".

The federal first cost of the two projects was about $55.4 million. Local cooperation was required for only the following five units in San Bernardino and Riverside Counties: Lytle and Cajon Creeks channel modifications; Devil, East Twin, Lytle, and Warm Creeks channel modifications and Lytle Creek levee; Mill Creek levees, Riverside levees; and San Jacinto River Levee and Bautista Creek Channel.

The completed units of the two projects have prevented flood damage estimated at $510 million.

Although a highly effective system of flood protection projects has been developed under the plan, burgeoning development on the flood plains and in the foothills throughout the Santa Ana River Basin and adjacent basins in Orange County has left highly valuable urban property unprotected. Damage to property in the area during the 1969 floods totaled $85.8 million. If a Standard Project Flood should occur, it is now estimated that $3.3 billion in flood damage would occur in Orange County.

Santa Ana River Basin and Orange County Project. This project includes five dams (Brea, Carbon Canyon and related channel modifications, Fullerton, Prado, and San Antonio), two completed channel modifications (Lytle and Cajon Creeks and San Antonio and Chino Creeks), and three proposed dams in an inactive status (Aliso Creek, San Juan, and Trabuco Creek are authorized, but not started). One dam, Villa Park, was deauthorized on November 6, 1977, under Section 12, Public Law 93-251.

Brea Dam, on Brea Creek about 13 km (8 mi) upstream of the junction of Brea and Coyote Creeks, was completed in 1942 at a federal first cost of $1.2 million. Brea Dam has prevented about $3.3 million in damage, of which about $460,000 would have resulted from the 1969 flood. The reservoir is being developed as a recreational area by the City of Fullerton.

Carbon Canyon Dam and Channel are on Carbon Canyon Creek, near the mouth of Carbon Canyon and about 26 km (16 mi) northeast of Santa Ana and 6.4 km (4 mi) east of Brea. It was completed in 1961 at a federal first cost of $5.3 million. During the 1969 floods, the project unit prevented $192,000 in damage. The project unit also provides incidental water conservation benefits, regulating the release of storm water to allow percolation and ground water recharge in the downstream spreading grounds. Orange County is considering the development of a recreational area. Recreational facilities were built at the reservoir at a cost of $1.1 million in federal funds and $1.4 million in local funds.

Fullerton Dam, about 3 km (2 mi) northeast of the City of Fullerton and about 6.4 km (4 mi) from the junction of Fullerton and Brea Creeks, was completed in 1941 at a federal first cost of $411,000. It has prevented $1.6 million in flood damage, $66,000 of which would have resulted from the 1969 floods. Recreational facilities were built at a cost of $2.4 million, the cost shared equally by the Federal Government and local interests.

The Lytle and Cajon Creeks channel modification extends from 16 km (10 mi) northwest to 3 km (2 mi) south of the City of San Bernardino. It was completed in 1948 at a federal first cost of $7.6 million, plus a nonfederal first cost of $602,000. It has prevented flood damage of about $15.3 million, of which about $13.2 million would have occurred from the 1969 floods.

Prado Dam, on the Santa Ana River about 48 km (30 mi) upstream from the mouth of the river, was completed in 1941 at a federal first cost of $9.5 million. It has prevented flood damage of about $446.5 million, of which $440 million would have occurred in 1969. Although the dam was very effective during the 1969 floods, urban developments, both upstream and downstream of it, now face flood hazards. Based on the great urbanization that has taken place both upstream and downstream since project construction, together with new knowledge of basin hydrology, it can be estimated that the water in the reservoir would rise above the spillway elevation on an average of once in 70 years. Large parts of the area around the reservoir are being developed for recreational purposes by the counties of Riverside and San Bernardino, the City of Corona, and the Boy Scouts. Recreational facilities were built in the reservoir at a cost of $3.9 million, the cost shared equally by the Federal Government and local interests.

San Antonio Dam on San Antonio Creek about 26 km (16 mi) upstream of Prado Dam was completed in 1956 at a federal first cost of $7 million. The San Antonio and Chino Creek channels, completed in 1960 at a federal first cost of $10.9 million, extend from San

Antonio Dam downstream to Prado Dam, a distance of approximately 26 km (16 mi). The dam, in combination with the channels, has prevented about $27.5 million in flood damage, with an estimated $27.1 million of that a result of the 1969 floods.

Villa Park Dam on Santiago Creek, about 14 km (9 mi) upstream from its mouth at the Santa Ana River, was constructed by the Orange County Flood Control District in 1962 at an estimated cost of $2 million.

Santa Ana River Basin Project. This project consists of the following completed units: Devil, East Twin, Lytle, and Warm Creeks channel modifications and Lytle Creek levee; Lytle and Warm Creeks channels; Mill Creek levees; Riverside levees on the Santa Ana River; and San Jacinto River Levee and Bautista Creek Channel.

The Devil, East Twin, and Warm Creeks channel modifications and Lytle Creek levee were constructed in three parts. The Devil Creek diversion, which was completed in 1958, carries floodflows from Devil and Badger Creeks to the contiguous drainage area of Cajon Creek by an intercepting levee, an intake structure, and a concrete channel extending to Cajon Creek. The East Twin and Warm Creek channel modifications completed in 1961 include the revetment of a levee built by the San Bernardino County Flood Control District along Waterman and East Twin Creeks, and the construction of a continuous concrete channel along East Twin Creek and Warm Creek, and the revetment of side slopes. The Lytle Creek levee, completed in 1956, is an addition to the Lytle and Cajon Creeks channel modifications, extending along the east side of Lytle Creek near Cajon Creek. The total first cost of the project unit was $11.1 million, $7.8 million federal funds and $3.3 million in nonfederal funds.

The Lytle and Warm Creeks project provides for a channel along the east branch of Lytle Creek, a channel along Warm Creek to the Santa Ana River, and a levee and channel along the Santa Ana River from the East Twin and Warm Creeks channel to Mount Vernon Avenue Crossing. The project was completed in 1977 at a total first cost of $37.5 million, of which $32 million was federal and $5.5 million was nonfederal.

The Mill Creek levees are along Mill Creek near the base of the San Bernardino Mountains and about 8 km (5 mi) northeast of the City of Redlands. These three levees extend from the mouth of the canyon to a point near the confluence of Mill Creek and the Santa Ana River. They were completed in 1960 at a total first cost of $813,000, of which $618,000 was federal and $195,000 was nonfederal. During the 1969 floods, the levees prevented $11.4 million in flood damage.

The Riverside levees are along both sides of the Santa Ana River near the City of Riverside. They were completed in 1958 at a total first cost of $4 million, of which $2.1 million was federal and $1.9 million was nonfederal. During the 1969 floods, the unit prevented flood damage of about $710,000.

The San Jacinto River Levee and Bautista Creek Channel modifications were completed in 1961. They consist of a levee on the San Jacinto River and a concrete-lined channel on Bautista Creek upstream of State Highway 74. The first cost was $3,955,000, of which $3,027,000 was federal and $928,000 was nonfederal. During the 1969 flood, they prevented flood damage estimated at $1.3 million.

Other Projects. The Santa Ana River Main Stem Project has received authorization for preparation of the Phase I Design Memorandum. It will correct the problems with Prado Dam discussed above, and it will provide a much higher degree of flood protection for the Orange County portion of the flood plain and other areas. This alternative, supported by the State and local interests, has six major elements: construction of Mentone Dam on the Santa Ana River where it leaves the mountains, regulation of the flood plain between Mentone Dam and Prado Reservoir, channelization of Oak Street Drain upstream from Prado Reservoir, enlargement of Prado Dam and Reservoir, reconstruction and enlargement of the Santa Ana River channel downstream from Prado Dam to the ocean, and channelization of Santiago Creek. The State supports construction for enlargement of Prado Dam, the Santa Ana River Channel, and Mentone Dam, in that order.

The estimated capital cost of the recommended alternative, based on 1975 price levels, is $740 million. The nonfederal share of this is $85 million. Under current federal procedures, the project will again be submitted to Congress for a construction authorization when the Phase I Design Memorandum is completed.

The City Creek Levee Project in San Bernardino County is a small project constructed by the Corps in 1960 along City Creek, about 8.8 km (5.5 mi) east of San Bernardino. It consists of the revetment of the existing levee, the construction of a new levee, and the excavation of a channel. The total first cost was $885,000, of which $400,000 was federal and $485,000 was nonfederal.

Riverside County Flood Control and Water Conservation District has constructed six earth dams which protect parts of the City of Riverside and one earth dam which protects the City of Edgemont. In addition, the district has constructed a total of approximately 31.4 km (19.5 mi) of unlined channel and 8.8 km (5.5 mi) of lined channel throughout Riverside County, and approximately 250 metres (800 feet) of levee along Oak Street Drain in the City of Corona. These projects are all designed for 100-year flood protection.

Mockingbird Dam in Mockingbird Canyon is a hydraulic fill dam constructed by the City of Riverside to protect a part of that city from floods.

The Soil Conservation Service has completed approximately 5.3 km (3.3 mi) of concrete channel along Main Street Wash in the City of Corona, with an inlet structure and an energy-dissipating outlet structure. Structures were completed in 1976 at a total cost of $4.9 million, of which $3.4 million was federal funds.

The Stewart Canyon Debris Basin Channel Project in Ventura County was completed by the Corps in 1963 at a total first cost of $1,292,000, of which $950,000 was federal funds. The project consists of a debris basin at the mouth of Stewart Canyon and a paved channel extending from the debris basin, through the City of Ojai, to a natural channel south of the City. The project has prevented an estimated $2.1 million in flood damage, of which $2 million would have occurred as a result of the 1969 floods.

The Ventura River Levee Project, completed by the Corps in 1948, consists of a rock-revetted earthfill levee along the east bank of the Ventura River. Its first cost of $1,480,000 included $1,340,000 in federal funds. Total flood damage prevented by the project is estimated at $3.7 million, of which $3.1 million would have occurred in 1969.

The Corps' Santa Clara River Basin Project consists of two units: the Santa Clara River Levee, and the Santa Paula Creek Channel and Debris Basin (including Mud Creek). The Santa Clara River Levee, completed in 1961 at a first cost of $3 million (including $2.1 million in federal funds), consists of a levee along the lower Santa Clara River near Montalvo. Although it prevented flood damage estimated at $55 million during the 1969 flood, the levee suffered severe erosion problems. Around-the-clock work by the Corps prevented even more serious damage. This unit has prevented total flood damage estimated at $68 million. The other unit of this project, the Santa Paula Creek Channel and Debris Basin has not been completed. The original plan called for the construction of a channel along Santa Paula Creek. However, the 1969 flood-flows poured mud into homes and businesses in Santa Paula and carried boulders weighing up to one-third ton into Santa Paula Creek. Because it was apparent that the originally authorized plan would not fully solve the problem, the plan was revised to include the following: construction of a debris basin, with a channel extending 5.6 km (3.5 mi) downstream from the basin to the Santa Clara River; construction of the Mud Creek Debris Basin and the Mud Creek Channel extending 1.1 km (0.7 mi) downstream from the basin to its confluence with Santa Paula Creek. Costs are estimated to be $23 million, of which $20.9 million will be federal funds. The construction of the downstream 518 m (1,700 ft) of the Santa Paula Creek channel has been completed. However, all work on the rest of the channel has been halted, pending a ruling on a complaint filed with the U. S. District Court by the Sierra Club, four local organizations concerned with environmental protection, and several individuals who oppose the structural works.

The Calleguas Creek Watershed Project has been completed by the Soil Conservation Service at a first cost of $4,050,000, of which $3,753,000 was federal funds. It consists of two independent portions. One includes channelization of approximately 1.6 km (1 mi) of Calleguas Creek from the Highway 101A Bridge to a point 262 m (860 ft) upstream of the State Hospital Bridge. The second portion includes about 1.6 km (1 mi) of channelization in both Walnut and Gabbert Canyons west of Moorpark.

The Revolon Slough Watershed and Beardsley Wash Watershed Projects are two interdependent Soil Conservation Service (SCS) projects. The Beardsley Wash Project will consist of drop spillway structures, modified debris basin structures, and about 10.4 km (6.5 mi) of rectangular concrete-lined channel. The downstream end of this channel will connect to the Revolon Slough Watershed Project, which will consist of about 11 km (7 mi) of modified channel and 1.1 km (0.7 mi) of newly constructed channel to drain to Calleguas Creek. Construction of the Beardsley Wash Project would begin when the Revolon Slough Watershed Project is complete; it is now approximately 17 percent complete. Estimated costs of the Revolon Slough Watershed Project and the Beardsley Slough Watershed Project are $17.5 and $13.0 million, respectively.

In 1953, the Corps completed the San Diego River Levee and Channel modifications. Serving the dual purpose of flood protection and navigation, it consisted of a leveed channel on the San Diego River to conduct flows from near Morenga Boulevard directly to the ocean, and the alteration of a railroad bridge over the floodway. Since construction was completed, the south jetty of the floodway has been extended and the middle jetty restored at a federal cost of $412,000.

Rose Creek Channel was constructed by the Corps in 1970 as a small project for a total cost of $1.25 million, including $1.0 million in federal funds. The construction consisted of about 1 070 m (3,500 feet) of channel modifications within the City of San Diego. Careful planning to enhance the beauty of the area was considered in the project. The park-like setting within the project area consists of an arboretum with a variety of Australian and California plants which have been selected for their tolerance to the climate characteristic of the area.

The SCS completed the Buena Vista Creek Channel modifications through the City of Vista in 1965 at a cost of $2.8 million, including $1.9 million in federal funds.

Dixon Dam and Reservoir on Escondido Creek were completed by the SCS in 1970. These are part of the Escondido Creek Watershed Project, which also includes realigning, enlarging, and lining of existing channels of Escondido Creek. The total cost of the project is estimated to be $15.4 million, including $8.9 million in federal funds. The project is 95 percent complete.

A Corps' flood protection project has been started on Cucamonga Creek. It will consist of 10 debris basins, about 2.7 km (1.7 mi) of diversion, collection, and separation levees, and 42 km (26 mi) of channel. The project will protect the cities of Upland, Ontario, Alta Loma, Cucamonga, and San Antonio Heights. The cost of the project is estimated at $75 million, of which $62.1 million would be the federal share. About $12.8 million in damage occurred in the project area during the 1969 floods. More than 95 percent of the damage would have been prevented had the project been completed. Spreading grounds are being provided for ground water recharge to mitigate the effects of channel lining.

The Tijuana River International Flood Control Project planned by the Corps of Engineers for the U. S. State Department consists of a short segment of concrete channel from the International Border to an energy dissipator which drains into the natural channel of the Tijuana River. Estimated Federal and State costs are $12.6 and $1.4 million, respectively. The United State's portion is completed.

Authorized Projects

The University Wash and Spring Brook project by the U. S. Army Corps of Engineers has been authorized, but has been placed in an "inactive" status because it is not economically feasible. It would consist of about 8 km (5 mi) of channel modifications in the City of Riverside. The project would protect a portion of the City of Riverside.

The San Luis Rey River Project by the Corps has been authorized and Phase I General Design Memorandum studies are now under way. This project would consist of channel modifications along the San Luis Rey River, mostly in the City of Oceanside. Consideration would be given to maintaining in-channel vegetation and protection of wildlife habitat. The project is estimated at $25 million, of which $18 million would be federal funds. Preconstruction plans will be made when funds become available.

The Corps' San Diego River (Mission Valley) Project as authorized would consist of a leveed channel along the San Diego River with three short channels along three tributaries, Alvarado, Murphy, and Murray Canyons. Reformulation studies have shown that the authorized plan as well as other alternative plans are not justified, and the project has been placed in an inactive status.

The Sweetwater River Project by the Corps is now in the preconstruction planning stage. It will be part of a highway project consisting of a channel along State Highway 54. The estimated cost is $21.2 million, with a federal cost of $10 million. It will protect rapidly developing areas in Chula Vista and National City. The project has been delayed pending the resolution of environmental issues. The project as presently formulated would include a purchase of 76 hectares (188 acres) of marshland for mitigation and preservation of wildlife habitat.

The Calleguas Creek, Simi Valley to Moorpark project was authorized by Congress for a Phase I General Design Memorandum study in 1976. This study is presently under way. The study of the remaining area of the Calleguas Creek basin indicated that flood protection measures could not be economically justified. Therefore, that study has been placed in an inactive status.

Nonstructural Flood Management

Flood plain ordinances have been adopted by most counties and many cities in the South Coastal Area. These ordinances have been implemented on specific streams in the unincorporated areas. In most cases, cities apply controls to the principal floodways within their jurisdiction.

Ventura County. An ordinance has been adopted to control developments within the existing beds or banks of watercourses or channels owned or under the jurisdiction of the Ventura County Flood Control District. These designated areas are along the Santa Clara River and Tributaries drains, Revolon Slough, and Beardsley Wash, Las Posas Estates Drain, and Ferro, Las Posas, and Ramona Place Debris Basins.

Flood insurance rate maps are being prepared for Ventura County by Toups Engineers. When completed, the maps will be used to implement flood plain management.

Los Angeles County. Flood insurance rate maps are being prepared for Los Angeles County and its incorporated cities by the Los Angeles County Flood Control District. Land developments within flood plains have been regulated primarily under the authority of the local building and subdivision codes. Efforts are being made to implement a new comprehensive nonstructural flood management program. The new program involves mapping of flood plains, prohibiting building of structures with a flood protection set back or primary floodway, and elevating new structures within the secondary floodway above the designated flood level. Authority to enforce these new policies will be accomplished by amendments to the County Zoning Ordinances and the County Building Code.

Implementation of this new program has been applied to Sand Canyon, located in the Santa Clarita Valley, which is subject to a substantial flood hazard and which received damage during 1969.

The first proposal was presented at a community meeting but was rejected because of the direct cost to individuals and the land areas to be reserved for flood damage reduction purposes. Thus, the adopted plan provided for a reservation of a smaller flood protection setback than originally proposd. As a result of many meetings, the community reasserted its desire to be a rural neighborhood and accepted the residual flood hazard.

Orange County. In keeping with the National Flood Insurance Program, flood plain zoning ordinances have been applied to several flood plain areas in Orange County. The flood plain areas so zoned are those that have been determined in Corps of Engineers' Flood Plain Information Reports and as provided by the Flood Insurance Rate Maps that have been essentially completed for the unincorporated Orange County Area. These areas include Laguna Canyon; San Juan Creek, including a portion of Oso Creek; Trabuco Creek; Santa Ana River Channel upstream of Imperial Highway; San Diego Creek and certain tributaries; Peters Canyon Wash; Aliso Creek; Santiago Creek; Silverado Canyon; Modjeska Canyon; Handy Creek; Hicky Canyon; Sulphur Creek; Aliso Hills Creek; Salt Creek; Arroyo Salada; and La Paz Channel.

San Diego County. Zoning ordinances, subdivision regulations, and the building code are used to control developments within the flood plains. The San Diego County Board of Supervisors established a Flood Plain Mapping Program in 1962 to develop maps of the 1-in-100-year frequency flood plain. In 1972, the program was slightly modified to conform to the National Flood Insurance Program. Flood maps depicting flooding of seven streams have been completed: upper San Diego River, San Dieguito River, San Luis Rey River, Sweetwater River, Otay River, Lower Moosa Canyon Creek, and Escondido Creek. The Otay and San Diego Rivers have floodways defined.

The Department's Southern District office is working on a two-year Flood Insurance Rate Study of San Diego County. This work, which is being done under a $777,000 contract with the Federal Emergency Management Agency, will provide the technical data needed to develop a more comprehensive and complete flood plain management program throughout the county.

In addition, the county is developing the Sweetwater River Regional Park in a 9.6-kilometre (6-mile) reach of the river. Much of the land is in public ownership dedicated to open space uses. On the San Luis Rey River Flood Control Project, riparian vegetation would be allowed in the channel area and would be maintained at optimum density through the narrows near its mouth. To protect riparian vegetation and provide a wildlife refuge, no channalization would be allowed.

San Bernardino County. Flood plain zoning ordinances were adopted in 1966 with zoning along Lytle and Cajon Creeks, San Jacinto and Santa Ana Rivers, and Cucamonga Creek.

Riverside County. An ordinance adopted in 1955 requires all subdivisions to be protected from a 1-in-100-year flood. Flood insurance rate maps are being prepared by Toups Engineers and, when completed, they will be used to implement further zoning.

To comply with the provisions of the Cobey-Alquist Flood Plain Management Act, the Los Angeles County Flood Control District has regulated the western area of the San Gabriel Flood Control Project. San Diego County has regulated portions of the San Luis Rey River, Sweetwater River, San Diego River (Mission Valley), and Tijuana River; San Bernardino County has regulated portions of Cucamonga Creek, Oro Grande Wash, and Lytle and Warm Creeks; and Riverside County has regulated portions of University Wash, Main Street Canyon, Chino Canyon, and Tahquitz Creek. These regulations are applied only to those reaches of the stream on which federal flood protection projects are authorized.

Figure 30 shows these and other regulated areas in the South Coastal Area. Table 8 presents the methods adopted by local governments to implement floodway regulations.

Flood Protection Needs

In much of the South Coastal Area, extensive development within the flood plains has outpaced the construction of effective flood protection modifications. An example of this is in the Santa Ana River Basin, where development, reevaluation of the flood potential shows, has left much of the area subject to very serious flood hazards. Several Corps of Engineers studies are under way for the Santa Ana River tributaries in San Bernardino and Riverside Counties. Studies are considering mostly local protection projects. Studies to consider flood problems in Orange County were resumed in the summer of 1979. These studies are for streams not tributary to the Santa Ana River.

Flood protection modifications along the Santa Clara River in Santa Clarita Valley in Los Angeles County are being considered by the Los Angeles County Flood Control District; environmental impacts are a concern here. The Corps of Engineers is presently investigating, under the Small Project Authority, the flood problem along the South Fork of the Santa Clara River and along Newhall Creek in the Santa Clarita Valley. No other flood protection measures can be economically justified in other parts of the valley.

A comprehensive flood protection plan for San Diego County was completed in 1976. Channel modifications will be needed in Rainbow Valley, along the San Luis Rey River in Oceanside, in Poway Valley on Los Penasquitos Creek, San Diego and Sweetwater Rivers, Telegraph Canyon, Poggi and Los Chollas Creeks, and the Tijuana River. In San Diego County the Corps of Engineers is presently investigating the flood problems along Telegraph Canyon, Las Chollas,

Table 8: REGULATED FLOODWAYS IN SOUTH COASTAL HYDROLOGIC STUDY AREA

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Ventura County (Unincorporated Area)	Subdivision, Ordinance Water Course Ordinance, Building Codes	Santa Clara and Ventura River, Calleguas and Santa Paula Creek, Beardsley Wash, Revolon Slough, Happy Valley Drain, Cozy Dell Canyon, McDonald Canyon, San Antonio, Dron, McNell, Thatcher, and Reeves Creeks; Lion Canyon; Sisar, Sespe, Rincon, and Live Oak Creeks, Bear Canyon; Skyline, Mirror Lake, and Oakview Drains; Pole and Coyote Creeks, Canada Larga; Orcutt and Timber Canyons; South Grimes and Grimes Canyon Wash, Brown Barranca; Happy Camp and Strathearn Canyons; Canejo Creek, Arroyo Santa Rosa, Tierra Rajada, Cajegas Creek, Bell Canyon, Oxnard Industrial Drain	Urban, industrial, agricultural, watercourses and flood storage facilities	Additional identification of flood-hazard areas	Yes
Camarillo	County ordinance	Beardsley Wash, Somis drain and its east tributary; Calleguas and Conejo Creeks; Revolon Slough, Pleasant Valley and Camarillo hills drain	Urban, industrial, agricultural	None, no additional flood problems evident	Yes
Fillmore	County ordinance	Sespe Creek and Santa Clara River	Urban, industrial, commercial	None, no additional flood problems evident	Yes
Ojai	County ordinance building code, city resolution	San Antonio Creek, Stewart and Fox Canyon, Barranca and Thatcher Creeks	Urban, industrial, agricultural	Implementation of Land Use Plan to enforce regulations	Yes
Oxnard	County ordinance, city ordinance	El Rio drain, Santa Clara River, Revolon Slough West Wooley drain, Oxnard west drain, Doris drain, Oxnard industrial drain, Rice Road drain	Urban, industrial, commercial, agricultural	None, no additional flood problems evident	Yes
Port Hueneme	County ordinance	Bubbling Springs Channel, Hueneme drain	Urban	None, no additional flood problems evident	Yes
Ventura	County ordinance	Ventura and Santa Clara River	Urban and industrial	None, no additional flood problems evident	Yes
Santa Paula	Ordinance	Santa Clara River, Santa Paula Creek	Industrial	None, no additional flood problems evident	Yes
Simi Valley	County ordinance	North Simi drain, White Oak Creek, Sycamore Canyon Arroyo Las Llejas, Arroyo Simi Tapa Canyon Creek, Alamo Canyon, Bus Canyon	Urban, commercial	None, no additional flood problems evident	Yes

Table 8: REGULATED FLOODWAYS IN SOUTH COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Thousand Oaks	Ordinance, county ordinance	Arroyo Conejo, Lang Creek and other minor creeks, Tierra Rejada Creek, South Branch and North Fork Arroyo Conejo	Urban	Identification of flood-hazard areas through FEMA study	Yes
Los Angeles County (Unincorporated Area)	Subdivision ordinance, building code	Malibu coastal streams	Urban, industrial, agricultural	Identification of flood-hazard areas through FEMA study	Yes
Alhambra	County flood control	Alhambra Wash	Urban	None, no additional flood problems evident	Yes
Arcadia	Ordinance	Santa Anita	Urban	None, no additional flood problems evident	Yes
Artesia	*	**	None	None	Yes
Avalon	*	Avalon Channel	Urban	Identification of flood-hazard areas	Yes
Azusa	*	Isolated flood-prone areas	Urban	Identification of flood-hazard study through FEMA Study	Yes
Baldwin Park	None	None	None	None, no flood problems evident	Yes
Bell	None	None	None	None, no flood problems evident	Yes
Bellflower	*	None	None	None, no flood problems evident	Yes
Bell Garden	*	None	None	Identification of flood-hazard areas	No
Beverly Hills	None	None	None	None, no flood problems evident	Yes
Bradbury	*	Sawpit Wash, Bradbury and Spink Channel	Urban	None, no additional flood problems evident	Yes
Burbank	Building code	Country Club Drive	Urban	Identification of flood-hazard areas	Yes
Carson	*	Dominguez Wash	Urban, industrial	Identification of flood-hazard areas through FEMA Study	Yes
Cerritos	*	**		None, no flood problems evident	Yes
Claremont	None	None		None, no flood problems evident	Yes
Commerce	*	**		None, no flood problems evident	Yes
Compton	Ordinance	Compton Creek	Urban, industrial, commercial	Identification of flood-hazard areas through FEMA Study	Yes
Covina	Building code	None	None	None, no flood problems evident	Yes
Cudahy	None	None	None	None, no flood problems evident	No
Culver City	None	None	None	None, no flood problems evident	Yes

* Los Angeles County Building Code and Subdivision Regulations
** Minor or no significant flood-prone areas

Table 8: REGULATED FLOODWAYS IN SOUTH COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Downey	None	None	None	None, no flood problems evident	No
Duarte	*	Van Tassel, Maddock, and Bradbury Channels, Spinks Canyon, Duarte Drain	Urban	Identification of flood-hazard areas through FEMA Study	Yes
El Monte	None	**		Identification of flood-hazard areas	No
El Segundo	Ordinance, uniform building code	None	None	Identification of flood-hazard areas through FEMA Study	Yes
Gardena	None	None	None	None, no flood problems evident	Yes
Glendale	Ordinance	Various mudflow areas		None, under regular flood insurance program	Yes
Glendora	None	None	None	None, under regular flood insurance program	Yes
Hawaiian Gardens	*	**		None, no flood problems evident	Yes
Hawthorne	None	None		None, no flood problems evident	Yes
Hermosa Beach	None	None		Identification of flood-hazard areas and adoption of flood plain regulations	Yes
Hidden Hills	*	Long Valley Channel	Suburban	Identification of flood-hazard areas through FEMA and adoption of flood plain regulations	Yes
Huntington Park	None	None	None	None, no flood problems evident	No
Industry	County building code	Portion of Old Santa Fe Creek, Bixby Channel, portion of Nogales Channel, channel between Nogales Street and Jeloick Ave., channel upstream of San Jose Creek	Urban, industrial	Identification of flood-hazard areas through FEMA Study	Yes
Inglewood	Ordinance building permit	None	None	Identification of flood-hazard areas through FEMA Study	Yes
Irwindale	None	None	None	None, no flood problems evident	Yes
Lakewood	County ordinance, zoning regulations, open space	Coyote Creek, San Gabriel Channel	Urban	None, no additional flood problems evident	Yes
La Mirada	*	La Mirada Creek	Urban	Identification of flood-hazard areas through FEMA Study	Yes
La Puente	*	**		None, no flood problems evident	Yes
La Verne	Ordinance	San Dimas Wash, Marshall Canyon Streams, Emerald and Live Oak Wash	Urban	Identification of flood-hazard areas through FEMA Study	Yes
Lawndale	*	**		None, no flood problems evident	Yes
Lomita	*	**		None, no flood problems evident	Yes

* Los Angeles County Building Code and Subdivision Regulations
** Minor or no significant flood-prone areas

Table 8: REGULATED FLOODWAYS IN SOUTH COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Long Beach	Uniform building code	Project 130 Channel Hamilton Bowl retention basin, and several smaller areas	Urban, industrial	Identification of flood-hazard areas through FEMA Study and adoption of flood plain ordinances	Yes
Los Angeles	Municipal code, building and safety requirements	Various portions of cities	Urban, industrial, agricultural	Identification of flood-hazard areas through FEMA Study	Yes
Lynwood	Uniform building code	Portions of Louise Avenue	Urban	Identification of flood-hazard areas through FEMA Study	Yes
Manhattan Beach	Ordinance	Coastal areas	Urban	None, no additional flood problems evident	Yes
Maywood	None	None	None	None, no flood problems evident	No
Monrovia	Ordinance	Several small areas	Urban, Industrial	Identification of flood-hazard areas through FEMA Study	Yes
Montebello	Ordinance	Rio Hondo Channel	Industrial	Identification of flood-hazard areas through FEMA Study	Yes
Monterey Park	None	None	None	None, no flood problems evident	Yes
Norwalk	*	**		None, no flood problems evident	Yes
Palos Verdes Estates	None	None	None	None, no flood problems evident	Yes
Paramount	*	**		None, under regular flood insurance program	Yes
Pasadena	Ordinance, uniform building code	Devils Gate Canyon Eaton Canyon, Canyon off Glenoaks Boulevard	Urban	Identification of flood-hazard areas through FEMA Study	Yes
Pico Rivera	*	**		None, no flood problems evident	Yes
Pomona	None	None		None, no flood problems evident	Yes
Rancho Palos Verdes	*	**		None, no flood problems evident	Yes
Redondo Beach	Resolution	Intersection of Vincent and Irena Streets	Urban	None, no additional flood problems evident	Yes
Rolling Hills	*	**		None, no flood problems evident	Yes
Rolling Hills Estate	*	**		None, no flood problems evident	Yes
Rosemead	None	None		None, no flood problems evident	Yes
San Dimas	Uniform building code	Walnut Creek, San Dimas Wash	Recreational	None, under regular flood insurance program	Yes
San Fernando	None	None		None, under regular flood insurance program	Yes
San Gabriel	None	None		None, under regular flood insurance program	Yes
San Marino	None	None		None, no flood problems evident	Yes

* Los Angeles Building Code and Subdivision Regulations
** Minor or no significant flood-prone areas

Table 8: REGULATED FLOODWAYS IN SOUTH COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Santa Fe Springs	*	**		None, no flood problems evident	Yes
Santa Monica	None	None		None, no flood problems evident	Yes
Sierra Madre	None	None		None, no flood problems evident	Yes
Signal Hill	None	None		None, no flood problems evident	Yes
South El Monte	*	**		None, under regular flood insurance program	Yes
South Gate	Resolution	Portion of Blumont Road	Urban	Identification of flood-hazard areas through FEMA Study	Yes
South Pasadena	None	None	None	None, under regular flood insurance program	Yes
Temple City	None	None	None	None, no flood problems evident	No
Torrance	Uniform building code	Isolated flood-prone areas	Urban	Identification of flood-hazard areas through FEMA Study	Yes
Vernon	None	None	None	None, no flood problems evident	No
Walnut	None	None	None	None, no flood problems evident	Yes
West Covina	None	None	None	None, no flood problems evident	No
Whittier	Ordinance	Isolated flood-prone areas	Urban	No additional flood-hazard areas evident	Yes
San Bernardino County	Ordinance, flood plain zoning	Cucamonga, Lytle and Cajon Creeks, Santa Ana River and Silver Lake area	Urban, industrial, agricultural	Identification of flood-hazard areas through FEMA Study	Yes
Chino	Building code	Between Chino and Shafer on Magnolia Avenue; 6th and Buena Vista	Urban	Identification of flood-hazard areas	Yes
Colton	Ordinance	Lytle and Warm Creek	Urban, industrial, agricultural	None, no additional flood-hazard areas evident	Yes
Fontana	Ordinance	San Sevaine Channel, Etiwanda Wash	Urban, industrial	None, no additional flood-hazard areas evident	Yes
Loma Linda	Ordinance	San Timoteo Creek	Urban	Identification of flood-hazard areas through FEMA Study	Yes
Montclair	None	None	None	Identification of flood-hazard areas	Yes
Ontario	None	None	None	None, no flood problems evident	Yes
Redlands	Ordinance	Lytle and Warm Creeks	Urban, industrial, agricultural	None, no additional flood-hazard areas evident	Yes
Rialto	None	None	Urban	None, no flood problems evident	Yes

* Los Angeles Building Code and Subdivision Regulations
** Minor or no significant flood-prone areas

Table 8: REGULATED FLOODWAYS IN SOUTH COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
San Bernardino	Ordinance	Lytle and Warm Creeks	Urban, industrial	Identification of flood-hazard areas	Yes
Upland	None	None	Urban	None, no flood problems evident	Yes
Riverside County	Subdivision ordinance building code	Santa Ana River, University and Springfield Wash	Urban, industrial, agricultural	Identification of flood-hazard areas	Yes
Beaumont	Ordinance	Main Street Watershed	Urban, industrial	Identification of flood-hazard areas	Yes
Corona	Ordinance	Main Street Watershed	Urban, industrial	Identification of flood-hazard areas	Yes
Elsinore	Ordinance	Portions of City	Urban	Identification of flood-hazard areas	Yes
Hemet	None	None	Urban	Identification of flood-hazard areas	Yes
Norco	Ordinance	North and South Norco Channels and tributaries, Santa Ana River	Urban,	Identification of flood-hazard areas	Yes
Perris	Building permit	None	Urban, agricultural	Identification of flood-hazard areas through FEMA Study and adoption of ordinance	Yes
Riverside	Ordinance	Portion of Spring Brook and University Wash	Urban, industrial	Identification of flood-hazard areas	Yes
San Jacinto	Ordinance	San Jacinto River	Urban	None, under regular flood insurance program	Yes
Orange County	Flood plain zoning ordinances	Laguna Canyon, San Juan Creek, Trabuco and Oso Creeks, Santa Ana and San Diego Rivers and Peters Canyon, Lower Santiago and Aliso Creeks	Urban, industrial, agricultural	Identification of flood-hazard areas	Yes
Anaheim	Permit through Flood Control District	Santa Ana River, Carbin Creek and La Palma Avenue	Urban	None, no flood problem evident	Yes
Brea	Flood plain zoning	Brea and Carbon Canyon Creeks, Memory Garden and Loftus Diversion Channels	Urban, industrial, recreational	Identification of flood-hazard areas through FEMA Study	Yes
Buena Park	Ordinance	None	Urban	None, no flood-hazard areas evident	Yes
Costa Mesa	Subdivision ordinance	Santa Ana River	Urban	Modify subdivisions ordinance and building code	Yes
Cypress	Subdivision ordinance, uniform building code	San Gabriel River	Urban	None, no additional flood problems	Yes
Fountain Valley	None	None	None	Identification of flood-hazard areas, adoption of regulations	Yes
Fullerton	None	Brea, Fullerton, Carbon Creek, Santa Ana River Imperial Channel	Urban, industrial	None, under regular flood insurance program	Yes

Table 8: REGULATED FLOODWAYS IN SOUTH COASTAL HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Garden Grove	Ordinance, subdivision regulation, uniform building code	Santa Ana River	Urban	None, no additional flood problems	Yes
Huntington Beach	None	None	None	Identification of flood-hazard areas through FEMA Study and adoption of flood regulations	Yes
Laguna Beach	Resolution to Municipal Code, General Plan	Laguna Canyon	Urban, industrial	Identification of flood-hazard areas	Yes
La Habra	Uniform building code as part of city ordinance	Coyote Creek, Imperial, and La Mira Channel	Urban	Identification of flood-hazard areas through FEMA Study	Yes
La Palma	Ordinance	Moody, Los Coyotes, Fullerton Creeks and Santa Ana River	Urban	None, no additional problems evident	Yes
Los Alamitos	Ordinance	Santa Ana River	Urban	Identification of flood-hazard areas	Yes
Newport Beach	Resolution building code	Upper Newport Bay	Urban, industrial	Identification of flood-hazard areas	Yes
Orange	None	None	Urban	Identifying flood-hazard areas adopting and enforcing regulations	No
Placentia	Uniform building code as part of city ordinance	Atwood, Richfield, and Carbon Canyon Channel	Urban, industrial	None, no additional flood-hazard areas	Yes
San Clemente	Building code as part of city ordinance	Prima Deshecha Canada, Segunda Deshecha Canada	Urban, industrial	None, no additional flood-hazard areas	Yes
San Juan Capistrano	None	None	Urban	Implementation	Yes
Santa Ana	Ordinance	Santa Ana River, Santiago Creek	Urban, industrial	None, no additional flood-hazard areas	Yes
Seal Beach	None	None		Identification of flood-hazard areas. Adoption of regulations	Yes
Stanton	Orange County Flood Control jurisdiction	Anaheim, Harbor City, and Stanton Channel	Urban	None, no additional flood problems evident	Yes
Tustin	Ordinance	Peters Canyon Wash	Industrial	None, no additional flood problems evident	Yes
Villa Park	None	None	Urban	None, no flood problems evident	Yes
Westminster	Flood plain zoning	Santa Ana River	Urban	Identification of flood-hazard areas through FEMA Study	Yes
Yorba Linda	Ordinance, uniform building code	Several small streams	Urban	Identification of flood-hazard areas through FEMA Study	Yes
Irvine	Resolution	None	Urban, industrial	Identification of flood-hazard areas	Yes
San Diego County	Ordinance, land use regulations	All streams by County ordinances and land use regulations	Urban, industrial, agricultural	Identification of flood-hazard areas through FEMA Study	Yes
Carlsbad	Ordinance	Buena Vista and Agua Hedionda	Urban	Identification of flood-hazard areas through FEMA Study	Yes

resulted during the 1970 floods in the Sacramento Basin, according to the Corps of Engineers' estimate.

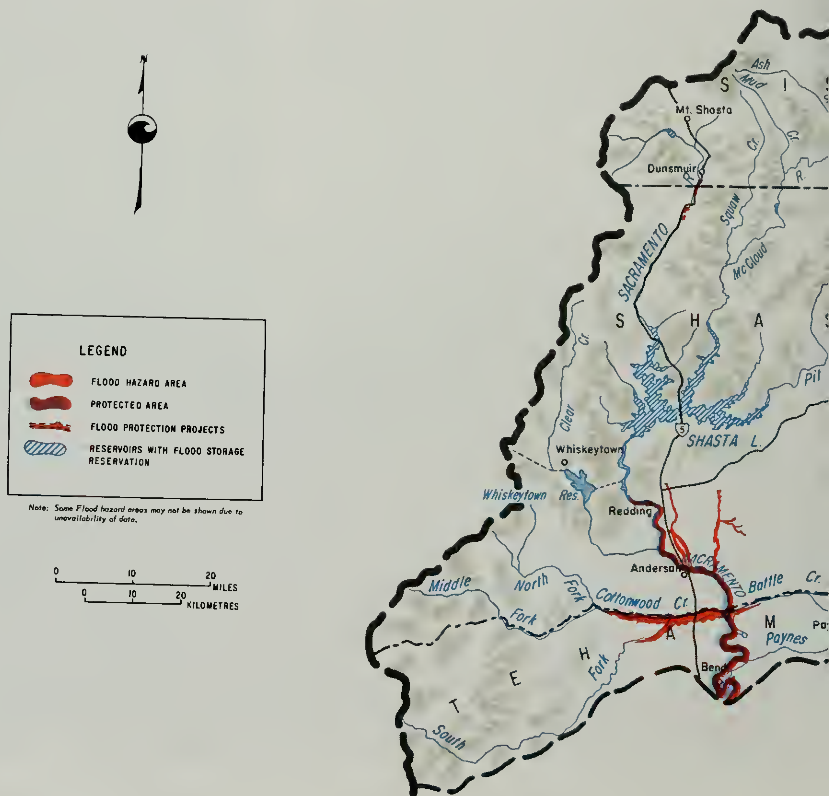
Precipitation in January 1974 resulted in record peak flows on the Sacramento and McCloud Rivers above Shasta Lake and on Cottonwood Creek, a tributary to the Sacramento River below Shasta Lake. As a result of flooding, seven counties sustained substantial flood damage. Four of the counties were declared disaster areas. Together, the January and March-April 1974 floods inundated about 85 000 hectares (210,000 acres) of land and caused an estimated $39.2 million in damage.

In 1974, projects operated specifically for flood and bank protection functioned effectively and prevented a total of about $146.0 million in flood damage that otherwise would have occurred.

In 1980, the highest streamflows in nearly a decade occurred on the Sacramento River system during mid-January and the last week of February.

The warm storms that brought rain to elevations as high as 2 750 metres (9,000 feet) in the Central Sierra instigated high volumes of runoff and prompted unscheduled releases from major flood storage reservoirs. Releases as high as 1 400 cubic metres per second (50,000 cubic feet per second) at Shasta Dam through Keswick, 2 400 cms (85,000 cfs) at the Oroville complex, and 2 100 cms (75,000 cfs) at Folsom Dam through Nimbus activated the Sacramento-San Joaquin Flood Control Project, resulting in overflow at all fixed weirs into the Sutter and Yolo Bypasses. In mid-January, 26 of the 48 gates of the Sacramento weir were opened, releasing 710 cms (25,000 cfs) into the Sacramento Bypass, thus reducing the threat of danger to levees in the vicinity of the City of Sacramento. Subsequent storms in February reactivated the weir system, and inundation of the three flood project bypasses was repeated. Overflow of the Tisdale Weir into the Sutter Bypass

DROWNED COWS bear mute witness to the helplessness of all creatures before an unexpected levee break. Dairy herd was trapped in floodwaters after Nicolaus levee break of January 1956. (U. S. Army Corps of Engineers, Sacramento District, Photo)


LEGEND
FLOOD HAZARD AREA
PROTECTED AREA
FLOOD PROTECTION PROJECTS
RESERVOIRS WITH FLOOD STORAGE RESERVATION
Note: Some Flood hazard areas may not be shown due to unavailability of data.
0 10 20 MILES
0 10 20 KILOMETRES
Mt. Shasta
Dunsmuir
Ash
Mud
Cr.
R.
Squaw
McCloud
SACRAMENTO
S H A
Pit
SHASTA L.
Clear
Cr.
Whiskeytown
Whiskeytown Res.
Redding
Anderson
SACRAMENTO
Battle Cr.
Cottonwood Cr.
Middle
North
Fork
Fork
Paynes
Bend
T E H A M
South
Fork

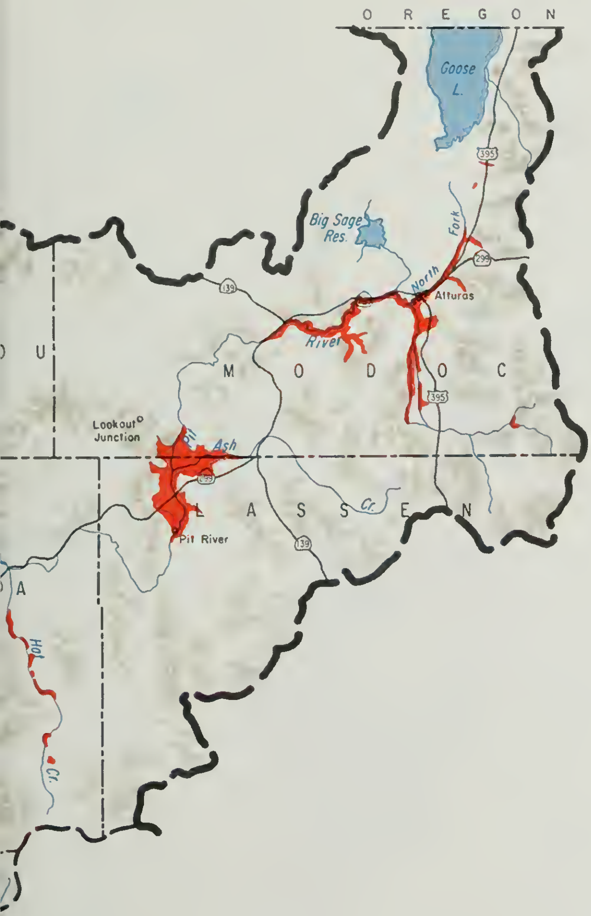
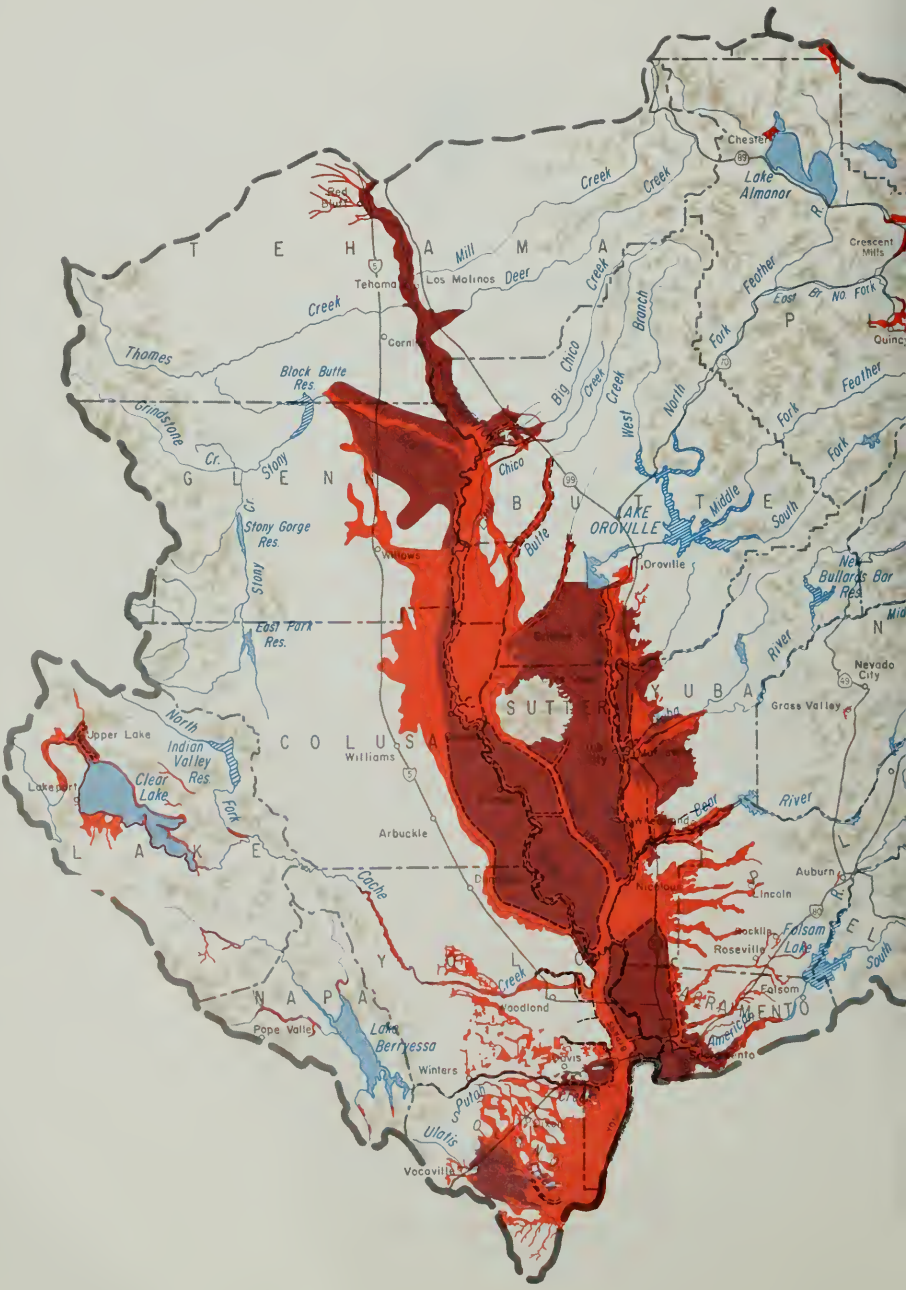


Figure 32
FLOOD INFORMATION
SACRAMENTO BASIN HYDROLOGIC STUDY AREA
NORTHERN PORTION



T E H A M A
G L E N N
B U T T E
C O L U S A
S U T T E R
Y U B A
L A K E
N A P A
Y O L O
SACRAMENTO
Red Bluff
Tehama
Los Molinos
Corning
Chico
Willows
Oroville
Williams
Arbuckle
Woodland
Davis
Winters
Vacaville
Dixon
Nicolaus
Lincoln
Rocklin
Roseville
Folsom
Auburn
Grass Valley
Nevada City
Chester
Crescent Mills
Quincy
Upper Lake
Lakeport
Pope Valley
Lake Almanor
LAKE OROVILLE
Clear Lake
Lake Berryessa
Folsom Lake
New Bullards Bar Res.
Block Butte Res.
Stony Gorge Res.
East Park Res.
Indian Valley Res.
Mill Creek
Deer Creek
Thomes Creek
Grindstone Cr.
Stony Cr.
Big Chico Creek
West Branch
North Fork
Middle Fork
South Fork
East Br. No. Fork
Feather R.
Butte Creek
Yuba River
Bear River
American River
Cache Creek
Putah Creek
Ulatis Creek
North Fork

Figure 33

FLOOD INFORMATION

SACRAMENTO BASIN HYDROLOGIC STUDY AREA
SOUTHERN PORTION

continued through March 19. Prolonged flooding occurred in areas near Tehama Bridge and Vina Woodson Bridge on unleveed portions of the Sacramento River. Damage was primarily limited to trailer and recreational parks at low-lying areas and within the flood plain. Similar conditions occurred on the lower reaches of the Feather and Yuba River area and within the confines of levees on the American River.

Stages at Clear Lake in Lake County reached the flood stage of 2.3 m (7.6 ft) on February 17, and on February 24, a stage of 3 m (9.7 ft) was recorded. The high stages coupled with strong winds battered lake shore resort facilities, including some older residences and eroded public and private thoroughfares.

Flood Damage Prevention Facilities

Toward the end of the 19th Century, the conversion of Sacramento Valley lands to agricultural, industrial, and urban uses brought flood problems to the forefront. The natural flood danger was further aggravated by deposits of hydraulic mining debris in the channels of the Yuba, Feather, American, and Sacramento Rivers. Individual flood protection facilities were constructed without adequate consideration of overall basin needs. Private levees were constructed haphazardly, compounding the flood problems by changing natural flow characteristics.

This lack of planning stimulated the involvement of the Federal and State Governments in flood protection activities and resulted in the Sacramento River Flood Control Project. The initial phase for flood protection for the Sacramento River and Tributaries was authorized by the 1917 Flood Control Act.

This initial project, generally referred to as the "Old Project", consisted of a comprehensive system of levees, overflow weirs, pumping plants, bypass channels, and channel enlargements. The active portion of the overall project was completed in 1968.

The Sacramento River and Major and Minor Tributaries Project supplements the initial Sacramento River Flood Control Project. The project descriptions are included in Table 9.

During the December 1964-January 1965 floods, the project prevented damage to all major cities along the river system and to 356 000 hectares (880,000 acres) of agricultural lands.

The Sacramento River Bank Protection Project provides for phased modifications of the Sacramento River Flood Control Project.

Recreation facilities are provided at bank protection sites on Steamboat Slough, at Garcia Bend on the Sacramento River near Sacramento, and at a site on the Feather River floodway near the town of Live Oak. Other sites such as Elkhorn Park on the Sacramento River, where recreation and mitigation potential exists, will be considered in the future. Studies are under way by the Corps of Engineers to develop aesthetic bank protection to replace the quarry riprap that has been used to protect eroding levees and berms.

The Sacramento River, Chico Landing to Red Bluff Project, is stated by the Corps of Engineers to be an extension of the Sacramento River Flood Control Project. It provides for the construction of bank protection works and minor channel modifications, in conjunction with flood plain regulation by local communities.

These regulations are planned to prevent development in the flood plains, and to provide areas that will accommodate maximum flood releases from Shasta Lake. Local interests are required to provide assurance that adequate flood plain regulations will be implemented. Tehama County has adopted flood plain ordinances. Butte and Glenn County regulations have been satisfied by the State

Reclamation Board's Designated Floodway Program and by county building ordinances to control uses within the designated floodway.

A study is being conducted jointly by the Department of Water Resources and the Corps of Engineers in response to Senate Bill 1390 (Chapter 1302, Statutes of 1976). The purpose of the study is to complete plans for the improvement and rehabilitation of the nonproject levees of the Sacramento-San Joaquin Delta.

Portions of the study being conducted by the Department include subsidence, vegetation, levee maintenance standards, present recreation use, economics, water quality, maintenance, and profile and cross section surveys.

The Corps of Engineers is providing design and cost estimates for various alternatives of levee rehabilitation, is assessing the economics of these alternatives, the environmental effects, recreational demand, and is studying the water quality and hydrologic factors.

The Corps informed the Department that its portion of the joint studies and report would not be completed by January 15, 1980, which was the date for completion of the Department's report as called for in Senate Bill 1390. Under these circumstances, it was necessary to reschedule the completion of the Department's final report to May 1981. This will allow additional time for related studies originally proposed to be conducted by other agencies but which have been necessarily reduced or eliminated by the reduction in funding for this program.

The U. S. Soil Conservation Service, under Public Law 83-556, has sponsored two watershed protection projects in the Sacramento Basin, one of which provides 1-in-10-year protection to agricultural lands. These projects, as well as the Corps of Engineers' projects, are described in Table 9.

Table 9: FLOOD DAMAGE PREVENTION PROJECTS IN THE SACRAMENTO BASIN HYDROLOGIC STUDY AREA

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
North Fork Pit River	North Fork Pit River* at Alturas (U.S. Army Corps of Engineers)	Modoc County	The project consists of two diversion inlet levees and 3.2 kilometres (2 miles) of channel modification including rock-filled gabion bank protection	City of Alturas	The project has a design flow of 225 m^3s (8,000 cfs), a flood expected once in 60 years
Sacramento River	Shasta Lake (U.S. Water and Power Resources Service)	U.S. Water and Power Resources Service	The project provides a total storage of 5.6 million cubic dekametres (4.5 million acre-feet) of which 1.6 million cubic dekametres (1.3 million acre-feet) is flood storage	Redding and Sacramento River Basin	During a 1-in-100-year flood event a maximum release of 2 265 m^3s (80,000 cfs) is expected under the new operations criteria for Shasta Lake
Stony Creek	Black Butte Lake	U.S. Army Corps of Engineers	The project provides a maximum storage capacity of 190 000 cubic dekametres (160,000 acre-feet) with a flood protection reservation of 185 000 cubic dekametres (150,000 acre-feet)	Agricultural lands along Stony Creek, Sacramento River and Butte Basin, Hamilton City, and Orland	Provides flood protection from a 1-in-100-year flood
Feather River	Oroville Lake	State Department of Water Resources	The project provides a maximum storage capacity of 4.3 million cubic dekametres (3.5 million acre-feet) with a flood protection reservation of 925 000 cubic dekametres (750,000 acre-feet)	Cities of Oroville, Marysville, and Yuba City-Urban and agricultural lands in Feather River Basin	During a standard project flood, the flow in the Feather River at Yuba City would not exceed 5 097 m^3s (180,000 cfs) the channel capacity

* Small project

Table 9: FLOOD DAMAGE PREVENTION PROJECTS IN THE SACRAMENTO BASIN HYDROLOGIC STUDY AREA (Cont'd)

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
North Yuba River	New Bullards Bar Reservoir	Yuba County Water Agency	The project provides a maximum storage capacity of 1.2 million cubic dekametres (966,000 acre-feet) with a flood protection reservation of 209 000 cubic dekametres (170,000 acre-feet)	Cities of Marysville and Yuba City - Urban and agricultural lands in Yuba and Feather River Basins	During a 1-in-80-year flood reservoir release is 1 416 m^3s (50,000 cfs) which along with local inflow is contained by downstream levees
American River	Folsom Lake	U.S. Water and Power Resources Service	The project provides a maximum storage capacity of 1.25 million cubic dekametres (1.01 million acre-feet) with a flood protection reservation of 493 000 cubic dekametres (400,000 acre-feet)	Cities of Folsom and Sacramento - Urban and agricultural lands in American and Sacramento River Basins	1-in-120-year flood regulated release of Folsom Reservoir is 3 256 m^3s (115,000 cfs), the downstream channel capacity
North Fork Cache Creek	Indian Valley Reservoir	Yolo County Flood Control District	The project provides a maximum storage capacity of 370 000 cubic dekametres (300,000 acre-feet) with a flood protection reservation of 49 000 cubic dekametres (40,000 acre-feet)	Agricultural lands along Cache Creek	Flood storage releases are controlled to maintain a maximum flow of 566 m^3s (20,000 cfs) at Capay
Sacramento, Feather, and American Rivers	Sacramento River FCP "Old Project" (U.S. Army Corps of Engineers)	The Reclamation Board, Department of Water Resources, and levee and maintenance districts	The principal project facilities include levees and channel modifications along the Sacramento River from its mouth to the vicinity of Chico Landing, and along the lower reaches of the American, Bear, Yuba, and Feather Rivers; the Moulton, Colusa, Tisdale, Fremont, and Sacramento overflow weirs; and the Sacramento, Tisdale, Colusa, Sutter, and Yolo bypasses.	Urban and agricultural lands in Sacramento River Basin downstream from Chico Landing and along the project reaches of the Feather, Yuba, and American Rivers	The levees provide flood protection from a 1-in-50-year event on the right bank from Ord Bend to South Parrot Grant Line (Butte County southerly boundary) a 50-year event on the right bank from South Parrot Grant Line to Colusa, and a 1-in-100-year event on both banks from Colusa to Knights Landing. In addition, Sutter Bypass, Yolo Bypass, Tisdale Bypass, and the left levee bank of the Colusa Basin Drainage Canal below Colusa are designed to provide for a 1-in-100-year flood event. The project levees of the Feather, Yuba, and American Rivers will contain the 1-in-100-year flood. High flood stages on the Feather River, however, can cause backwater flooding in the Jack and Simmerly Sloughs. A lower degree of protection is afforded by the levee system in the Bear River Basin where frequency of flooding is once in 10 years.
Sacramento River	Sacramento River Flood Control Project "Major and Minor Tribs." (U.S. Army Corps of Engineers)	The Reclamation Board, Department of Water Resources, and levee and maintenance districts	The completed units provide for levee construction and/or channel enlargement on Chico Creek, Mud Creek, Sandy Gulch, Butte Creek, Little Chico Creek, Cherokee Canal, Elder Creek, and Deer Creek	Urban and agricultural adjacent to Sacramento River and tributaries from Chico Landing to to Moulton Weir	Chico Creek 100-year Mud Creek 100-year Sandy Gulch 100-year Butte Creek 50-year Little Chico Creek 50-year Cherokee Canal 50-year Elder Creek 50-year Deer Creek 50-year

Table 9: FLOOD DAMAGE PREVENTION PROJECTS IN THE SACRAMENTO BASIN HYDROLOGIC STUDY AREA (Cont'd)

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Sacramento River	Sacramento River Flood Control Project "Chico Landing to Red Bluff" (U.S. Army Corps of Engineers)	The Reclamation Board, Department of Water Resources, and levee and maintenance districts	The project provides for construction of bank protection works and minor channel modifications. Local interests are reqoired to provide assurances that adequate flood plain regulations will be implemented	Urban and agricultural lands adjacent to Sacramento River	Reduces bank erosion upstream of the levees of the Sacramento River Flood Control Project
Sacramento River	Sacramento River Bank Protection Project (U.S. Army Corps of Engineers)	The Reclamation Board, Department of Water Resources, and levee and maintenance districts	The first phase of the completed project consists of approximately 131 000 metres (430,000 linear feet) of bank protection at critical locations	Areas protected by Sacramento River Flood Control Project	The project is designed to help maintain the integrity of the levee system of the Sacramento River Flood Control Project
American River	American River Levees (U.S. Army Corps of Engineers)	The Reclamation Board and American River Flood Control District	Rock revetment on levees - two pumping plants	City of Sacramento and urban and agricultural lands adjacent to American River	Provides 1-in-120-year flood protection in conjunction with controlled releases from Folsom Reservoir
Middle Creek	Middle Creek improvement (U.S. Army Corps of Engineers)	Lake County and Department of Water Resources	The project provides for enlargement of existing levees and construction of additional levees, incidental channel modification along the lower 11.3 kilometres (7 miles) of Middle Creek and along tributary streams pumping plant, and 1 200 metres (4,000 feet) of channel to divert Clover Creek floods around the town of Upper Lake	Town of Upper Lake and agricultural lands	The project provides flood protection from a 1-in-100-year event except the lower reach where settlement of the left levee has reduced the protection to agricultural areas to floods not exceeding a 1-in-50-year event
North Fork Feather River	Chester Project (U.S. Army Corps of Engineers)	Plumas County and Department of Water Resources	Partially leveed floodway bypass channel and diversion dam	Town of Chester and adjacent area	Standard Project Flood protection for 230 hectares (570 acres)
Adobe Creek	Adobe Creek Watershed Project (U.S. Soil Conservation Service)	Lake County Flood Control and Water Conservation District	Two water detention reservoirs and 3.62 kilometres (2.25 miles) channel improvement	Watershed area of 8 700 hectares (21,500 acres) along Adobe Creek near Lakeport	Provides for only 1-in-10-year protection
Ulatis Creek	Ulatis Creek Watershed Project (U.S. Soil Conservation Service)	Solano County Flood Control and Water Conservation District	Improvement and realignment of 83.5 kilometres (51.9 miles) of channel, drop structures, grade stabilization, and inlet structures	Watershed area of 39 000 hectares (96,000 acres) along Ulatis Creek in Solano County	Provides for 1-in-10-year flood for agricultural lands and 1-in-25-year flood for urban lands

Major reservoirs in the Sacramento River Basin not providing flood storage as a designated function but providing incidental flood protection benefits include:

Reservoir	Stream	Operating Agency
Lake Siskiyou	Sacramento River	Siskiyou County Flood Control and Water Conservation District
Bowman	Canyon Creek	Nevada Irrigation District
Camp Far West	Bear River	South Sutter Water District
Clear Lake	Cache Creek	Yolo County Flood Control and Water Conservation District
Jackson Meadows	Middle Yuba River	Nevada Irrigation District
L. L. Anderson	Middle Fork American River	Placer County Water Agency
Lake Almanor	North Fork Feather River	Pacific Gas & Electric Co.
Lake Spaulding	South Fork Feather River	Pacific Gas & Electric Co.
Little Grass Valley	South Fork Feather River	Oroville-Wyandotte Irrigation District
Loon Lake	Gerle Creek	Sacramento Municipal Utility District
Lower Hell Hole	Rubicon River	Placer County Water Agency
Rollins	Bear River	Nevada Irrigation District
Sly Creek	Lost Creek	Oroville-Wyandotte Irrigation District
Union Valley	Silver Creek	Sacramento Municipal Utility District
Virginia Ranch	Dry Creek	Browns Valley Irrigation District
East Park	Little Stony Creek	Water and Power Resources Service
Stony Gorge	Stony Creek	Water and Power Resources Service
Lake Berryessa	Putah Creek	Water and Power Resources Service
Whiskeytown	Clear Creek	Water and Power Resources Service

Nonstructural Flood Management

Consistent with its varying topographical configuration, the Sacramento Basin has been divided into three study areas: the mountainous area above Shasta Lake, the mountainous areas adjacent to the valley floor below Shasta Lake, and the valley floor.

Two areas in the Sacramento Basin above Lake Shasta have adopted effective flood plain zoning. These are the North Fork Pit River in the vicinity of Alturas, and Burney Creek near Burney.

Zoning on the North Fork Pit River in Modoc County was carried out, as required by the Cobey-Alquist Flood Plain Management Act, to obtain State financial assistance for the cost of the lands, easements, and rights of way for the North Fork Pit River Flood Control Project. The zoning on Burney Creek was adopted by Shasta County as a result of a comprehensive townsite study used to guide the orderly development of Burney.

The only implementation of flood plain management in the mountain streams tributary to the Sacramento River below Shasta Lake was adopted by the County of Plumas to qualify the Chester Flood Control Project for aid under the Cobey-Alquist Act. Little, if any, other consideration has been given to adopting or implementing flood plain management because of the limited amount of land that might be developed in flood-hazard areas.

Where the Sacramento River Basin widens below Lake Shasta, incompatible agriculture, industrial, and urban uses have intensified and have encroached into the floodways of the Feather and American River systems, as well as on other streams tributary to the Sacramento River system.

As a condition for provision of bank protection by the Corps of Engineers along the Sacramento River, local interests were required to adopt regulations to control the primary and secondary floodways along the river. The City of Red Bluff and the counties of Tehama, Glenn, and Butte have adopted such regulations, but they have done little to enforce them.

Until the inception of the Reclamation Board's Designated Floodway Program and the National Flood Insurance Program, little, if any, effort had been made by local interests to effectively regulate construction in flood-hazard areas.

Uncontrolled construction has been allowed over the past decade in the

CALIFORNIA'S history is replete with floods which reached awesome proportions. Perhaps the most costly were the floods that struck northern and central California during the week preceding Christmas 1955, killing 64 persons and causing over $200 million in direct losses. This picture was taken at Yuba City on Christmas day 1955.

flood-hazard areas along the Sacramento River between Lake Shasta and the Upper Butte Basin. This flood plain development has been accompanied by demands from developers and residents for lower flood releases from Lake Shasta during high water periods on the Sacramento River and its downstream tributaries. To satisfy this demand, the Corps of Engineers and the Water and Power Resources Service have been urged to delay flood storage releases from Lake Shasta until peak flows from downstream tributaries to the Sacramento River have receded. Records indicate that no delay in flood storage releases were ever effected to satisfy the demands from developers and residents in the flood plain between Lake Shasta and Butte Basin.

In Butte Basin, land leveling for farming has been allowed to such an extent that stream channels have been obliterated. Floods that exceed the capacity of the Sacramento River Flood Control Project enter Butte Basin along the reach of the Sacramento River between Chico Landing and the project levees. Because of the extensive land leveling, there are now floodwater sheet-flows over lands in the upper Butte Basin that were not previously inundated. To protect development, levee systems within the basin have been built around certain areas. In addition, the Reclamation Board has enacted land leveling regulations for areas in Butte Basin.

Historically, the Butte Basin and other overflow lands in the Sacramento Valley have provided winter living space for large flights of waterfowl using the Pacific Flyway. Today, the remaining overflow areas, coupled with State and Federal waterfowl management areas, support the remnant population of the flyway.

Colusa Basin lies on the west side of the Sacramento River from about Willows south to Knights Landing. It is protected from flooding from the Sacramento River, and most of the area also receives protection afforded by levees lying east of the Colusa Drain. However, some parts of the basin still are flooded from local runoff of westside streams and at times from drainage of rice fields. There is continuing local interest in devising an economical solution to these flooding problems.

Most of the areas adjacent to the Feather and American Rivers are protected combined levee systems and flood storage reservations in Oroville and Folsom Lakes. These projects are required to protect agricultural use of the flood plains along the Feather River and urban development along the American River.

Expensive homes have been built on the riverside berms of the levees in the reach of the Sacramento River along the Garden Highway northwest of the City of Sacramento. When the river is at or below normal flow stages, homeowners enjoy the aesthetics of the Sacramento River. However, during those occasional, brief periods when river flows rise excessively, these residents become interested in the routing of floodflows through the flood protection system.

Throughout the Sacramento Basin Hydrologic Study Area, the increased development in flood-hazard areas and the lack of regulated floodways demonstrate that community development is continuing without adequate consideration of the potential flood threat. Instead, developers and residents of flood plains continue to demand that government agencies increase the flood storage reservations in reservoirs and other flood protection facilities to prevent damage in flood-prone areas.

Those flood-hazard areas that have been regulated are shown in Figures 23 and 24; the methods adopted by the Reclamation Board and local governments to implement flood plain regulations are presented in Table 10. Most cities in the area have adopted a general plan

Table 10: REGULATED FLOODWAYS IN THE SACRAMENTO BASIN HYDROLOGIC STUDY AREA

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
State Reclamation Board	Designated floodway	Sacramento River - Keswick Dam to South Parrott Grant Line	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Stony Creek - Sacramento River to Black Butte Dam	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Clear Creek - Whiskeytown Dam to Sacramento River	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Cow Creek - from mouth including tributaries Little Cow, Dry, Oak Run, and Clover Creeks	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Cottonwood Creek - proposed Dutch Gulch damsite to mouth plus 11.3 kilometres (7 miles) on South Fork	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Willow Creek - Colusa Basin Drain - Glenn Colusa Irrigation District Canal to Knights Landing	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Feather River - Honcut Creek to Oroville Fish Hatchery Dam	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Yuba River - Highway 70 to Daguerre Point Dam	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Dry Creek - Natomas East Drain to easterly Roseville City limits	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	American River - Mayhew Road to Nimbus Dam	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Butte Basin - East of Sacramento River between mouth of Little Chico Creek and head of Sutter Bypass	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
Modoc County	Ordinance 236; two-zone flood plain; subdivision ordinance; uniform building code	North Fork Pit River	Urban, industrial	Precise delineation of flood flood-hazard areas upstream and downstream of regulated area and other flood-prone areas in the county	Yes

Table 10: REGULATED FLOODWAYS IN THE SACRAMENTO BASIN HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Alturas	Two-zone flood flood plain ordinance	North Fork Pit River	Urban, industrial	City needs to regulate the 100-year flood-prone area along the North Fork Pit River until the federal flood control project is upgraded to provide for a 1-in-100-year flood	Yes
Lassen County	None	None	None	Identification of flood-hazard areas	No
Siskiyou County	None	None	None	Identification of flood-hazard areas and flood plain management	Yes
Dunsmuir	None	None	None	Identification of flood-hazard areas and flood plain management	Yes
Shasta County	Two-zone flood plain ordinance	Churn Creek from Sacramento River to Rancho Road about 9.7 kilometres (6 miles) upstream and to Burney Creek at the community of Burney	Urban	Flood plain management is needed for flood-prone areas shown in the Corps Flood Plain Information Report on Cow Creek at Palo Cedro, and Sacramento River at Redding and Anderson. Identification of flood-hazard areas and flood plain management is needed in other areas of the county	Yes
Anderson	None	None	None	City has adopted a two-district flood plain ordinance and the Corps of Engineers has completed a Flood Plain Information report for the City. Flood plain management is needed	Yes
Redding	None	None	None	Flood plain management is needed for flood-hazard areas identified in Corps Flood Plain Information Report on Sacramento River at Redding	Yes
Tehama County	None	None	None	Flood plain management is needed for flood-prone areas shown in flood insurance study of unincorporated areas of Tehama County until the new study is completed. Identification of flood-hazard areas and flood plain management is needed for other areas of the county	Yes
Corning	None	None	None	Identification of flood-hazard areas and flood plain management	Yes
Red Bluff	None	None	None	Flood plain management is needed for flood-prone areas shown in flood insurance study of Red Bluff until the new study is completed	Yes
Tehama	None	None	None	Flood plain management is needed until the Cottonwood Creek Project or a new levee is constructed to protect the City of Tehama	Yes
Glenn County	None	None	None	Identification of flood-hazard areas and flood plain management	Yes
Orland	None	None	None	Identification of flood-hazard areas and flood plain management	No
Willows	None	None	None	Identification of flood-hazard areas and flood plain management	Yes

Table 10: REGULATED FLOODWAYS IN THE SACRAMENTO BASIN HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Butte County	None	None	None	Identification of flood-hazard areas and flood plain management	No
Biggs	None	None	None	None	No
Chico	None	None	None	Identification of flood-hazard areas along Little Chico Creek and flood plain management	No
Gridley	None	None	None	Identification of flood-hazard areas and flood plain management	No
Oroville	Oroville general uniform building code, building permit system	Feather River flood plain and open space, all flood hazard areas	Open space, urban, industrial	Identification of flood-hazard areas and flood plain management	Yes
Colusa County	None	None	None	Identification of flood-hazard areas and flood plain management	Yes
Colusa	None	None	None	None	Yes
Williams	None	None	None	Identification of flood-hazard areas and flood plain management	Yes
Lake County	Flood plain management ordinance and building permit system	All flood plains identified by flood insurance studies	Urban/ suburban, industrial, recreational	Flood plain management is fully implemented countywide under Flood Insurance Program	Yes
Lakeport	Building code which establishes minimum first flood elevation above the 1-in-100-year flood stage	Shore of Clear Lake	Urban	Flood plain management is fully implemented under flood insurance program	Yes
Sutter County	County zoning code and general plan, county ordinance	Feather and Sacramento Rivers, floodways and tributaries	Agricultural, urban, industrial, open space	Unknown	Yes
Live Oak	Uniform building code. Building permit system	Feather River and drainage	Urban, industrial	Codification and enforcement of regulations	Yes
Yuba City	Municipal Code (flood district zoning)	Feather River and drainage	Agricultural, urban, industrial	Unknown	Yes
Yuba County	County general plan, building code	None	None	Codification and enforcement of regulations	Yes
Marysville	General plan, flood plain zoning	Feather and Yuba Rivers	Agricultural, urban, industrial, open space	Unknown	Yes
Placer County	Placer County general plan, uniform building code, Loomis basin zoning ordinance	All flood-hazard and problem drainage areas	Agricultural, urban, industrial, recreational, open space	Incentive to adopt and enforce floodway regulations countywide	No
Auburn	Building and subdivision ordinances	Problem drainage areas	Agricultural, urban, industrial	Unknown	Yes
Colfax	None	None	None	None	No
Lincoln	Land use control zoning, building and subdivision ordinances, uniform building code and building permit system	Auburn Ravine and Markham Ravine flood plains	Urban, industrial	Unknown	Yes

Table 10: REGULATED FLOODWAYS IN THE SACRAMENTO BASIN HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Rocklin	None	None	None	Adoption of regulations based on Corps of Engineers' Flood Plain Information - "Antelope Creek, Secret Ravine and Tributaries, Rocklin, California", 1976	Yes
Roseville	Two-zone floodway zoning, ordinance, general plan, subdivision ordinance, building code	Dry Creek, Antelope, Cirby, and Linda Creeks. Secret, Miners, and Strap Ravines	Agricultural, urban, industrial, recreational	Floodway zoning drainage based on Corps of Engineers' Flood Plain Information - "Dry Creek and Tributaries, Roseville, California", 1973. Enforcement of regulations	Yes
Wheatland	Uniform building code, subdivision ordinance and building permit system	Dry Creek	Agricultural, urban, industrial	Codification and enforcement of regulations	Yes
Sacramento County	General flood control zoning plan; grading, drainage and specific floodway ordinances; uniform building code and county improvement standards. Metropolitan storm drainage district, Sacramento Water Agency, Maintenance Areas Nos. 9, 10, 11. Sacramento River Flood Control District	American and Sacramento Rivers and all streams on which historical flood data is known	Agricultural, urban, industrial, recreational, open space	Adequate regulation and enforcement	Yes
Folsom	None	None	None	None	Yes
Sacramento	Comprehensive zoning plan, includes general plan and American River Parkway Plan	Sacramento and American Rivers and adjacent flood plains	Urban, industrial, agricultural, open space	Adequate regulation and enforcement	Yes
Yolo County	County Code. Special flood plain combining zone	Countywide. Floodways not specified	Agricultural, urban, industrial, open space	Incentive to enforce regulations	Yes
Davis	None	None	None	Unknown	Yes
Winters	Zoning ordinance, uniform building code, building permit system	Putah Creek	Urban, industrial	Codification and enforcement of regulations	Yes
Woodland	None	None	None	Codification and enforcement of regulations	Yes
Solano County	County flood plain regulation ordinance (three-district)	All natural watercourses, sloughs, and constructed water channels	Agricultural, urban, industrial	Codification and enforcement of regulations	Yes
Plumas County	Two-zone master zoning ordinance, uniform building code	Feather River and tributaries	Agricultural, urban, industrial, open space	Incentive to adopt and enforce flood zoning regulations countywide	Yes
Portola	Uniform building code, building permit system	Middle Fork Feather River and flood plains	Urban, industrial	Codification and enforcement of flood plain regulations	Yes

Table 10: REGULATED FLOODWAYS IN THE SACRAMENTO BASIN HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Sierra County	Building code	None	Agricultural, urban, industrial	Codification and enforcement of regulations	No
Loyalton	None	None	None	Incentive to adopt and enforce floodway regulations	No
Nevada County	Building code, subdivision ordinance	None	Agricultural, urban, industrial	Codification and enforcement of regulations	Yes
Grass Valley	Uniform building code, building permit system	All flood-hazard areas	Urban, industrial	Identification of flood-hazard areas	Yes
Nevada City	None	None	None	None	No
El Dorado County	Building code, subdivision ordinance	None	Agricultural, urban, industrial	Codification and enforcement of regulations	No
Placerville	None	None	Urban, industrial	Identification of flood-hazard areas; codification and enforcement of regulations	Yes

SNAGGING OPERATION on Sacramento River. (U. S. Army Corps of Engineers Photo) and have established a building code, and counties have adopted subdivision ordinances. Some of the regulations are inadequate for flood plain management, or they are not enforced. Therefore, they are not listed in the table.

Flood Protection Needs

The primary need in the Sacramento Basin Hydrologic Study Area is an effective flood plain management program. Many of the flood-hazard areas have been identified in the Flood Insurance Studies, Corps of Engineers' Flood Plain Information Reports, Flood-Prone Area Maps, Federal Emergency Management Agency (FEMA) Flood Boundary Maps, Federal and State project reports, and reports on historical floods. Much of this information will be revised in future studies; however, it is the best information available at present, and it could be used by local communities in the initial phase of regulating the flood-hazard areas.

There is also an urgent need to more precisely identify the flood-hazard areas, especially those in urban-industrial areas where encroachments could result in extensive flood damage. FEMA and other Federal and State agencies should allocate additional resources toward a more rapid identification of these flood-hazard areas.

Local communities should be persuaded to implement an effective flood plain management program as soon as possible to help reduce flood damage. The National Flood Insurance Program is very effective in this regard, but it may require a number of years for its full implementation.

The adoption of designated floodways by the Reclamation Board is the most positive approach to controlling encroachments into flood-hazard areas along the Sacramento River system. By seeking the cooperation of local planning commissions and requiring Board approval before development proceeds in designated floodways, a form of nonstructural flood management has been implemented. Designated floodways have been adopted along the Sacramento, Feather, Yuba, and American Rivers; Clear, Cow, Stony, and Cottonwood Creeks; Dry Creek (Natomas East Drain to Roseville City Limits), Dry Creek system (Roseville); and the Colusa Drainage Canal. The Reclamation Board is continuing to study other streams and is contemplating designating other floodways. The adopted designated floodways are shown on Figure 23.

Agriculture incurs major flood damage in the upper Sacramento River Basin. For example, agricultural damage from the 1974 flood was about $15.9 million, while other damage totaled about $1.7 million. Since this represents over 90 percent of the 1974 flood damage, and since agricultural development has never been regulated, flood plain management of this land use is clearly needed. The regulations should not restrict all agricultural endeavors, but only those that are most susceptible to flood damage.

Although flood plain regulations are the key element in the reduction of flood damage in the area, there are several areas in Modoc, Shasta, Tehama, Butte, and Glenn Counties where flood damage prevention projects might be constructed. These projects would protect existing urban development within flood-prone areas where nonstructural flood management would not be as effective. These include the following:

Location	Stream	Description of Projects' Needs
Cottonwood	Cottonwood Creek	Corps of Engineers' Cottonwood Creek Project
Burney	Burney Creek	Enlargement of existing channels through Burney to pass 1-in-100-year flood.
Redding Basin (Lower Churn Creek)	Churn Creek	Flood channel project.
City of Tehama	Sacramento River	Cottonwood Creek Project or/and modification of existing levee system.
Red Bluff	Sacramento River	Cottonwood Creek Project and improvement and maintenance of the three existing bypass channels through the Antelope Area.
Hamilton City	Sacramento River	Cottonwood Creek Project and improvement of existing levees.
Chico	Little Chico	Enlargement of existing modified channel to provide for a 1-in-100-year flood event.
Chico	Chico and Mud Creeks and Sandy Gulch	Downstream extension of Chico and Mud Creeks and Sandy Gulch levees to provide greater than 1-in-100-year flood protection to existing urban development.
Chico	Mud and Sycamore Creeks	Enlargement of levees to provide greater than 1-in-100-year flood protection to existing urban development.
Linda and Olivehurst	Reeds Creek and other local streams	Levees and channel works needed to protect the communities of Linda and Olivehurst against a Standard Project Flood.
Roseville	Linda Creek	Channel enlargement to provide 1-in-100-year protection.
Clear Lake Area	Clear Lake	Combination structural-nonstructural flood protection plan.

Additional flood protection would be provided to the lower Sacramento River Basin should Marysville Reservoir be constructed on the Yuba River and when Auburn Reservoir is completed on the North Fork American River.

Construction of future flood protection projects in this basin will have an effect on peak Delta outflow. For example, the peak flow past the latitude of Sacramento for the January 1970 high water period was 12 700 cubic metres per second (450,000 cubic feet per second). Had the proposed Auburn, Marysville, and Cottonwood Creek projects been in existence, the peak flow would have been reduced to 11 300 cms (400,000 cfs) -- a reduction of 11 percent. Special attention needs to be paid to the environmental and other impacts on the Bay and Delta of this reduction of peak Delta outflow.

San Joaquin Basin Hydrologic Study Area

The San Joaquin Basin Hydrologic Study Area is located in the central portion of the Central Valley of California. It is bounded on the north by the American-Cosumnes River watershed divide, the crest of the Sierra Nevada on the east, the San Joaquin-Kings River watershed divide on the south, and the crest of the Coast Range on the west. This service area, which includes the Sacramento-San Joaquin Delta, is shown on Figure 34.

The principal stream in the San Joaquin Basin is the San Joaquin River, with its major tributaries: Cosumnes River, Dry Creek, Mokelumne and Calaveras Rivers, Littlejohn Creek; Stanislaus, Tuolumne, and Merced Rivers; Bear, Owens, and Mariposa Creeks; Chowchilla and Fresno Rivers; and Los Banos, San Luis Orestimba, and Marsh Creeks. All these streams eventually drain into the Sacramento-San Joaquin Delta, and to a common mouth at the upper end of Suisun Bay.

The population estimate for the area in 1972 was 911,000, with a density within urban areas of 1,130 persons per square kilometre (2,940 persons per square mile). The population has been increasing faster than for the State as a whole, and by 1990 it is projected to increase by 41 percent from 1972. The areas of population concentrations, such as Stockton and Modesto, are expected to witness increased urbanization.

The economy of the area is dominated by highly diversified agricultural and related manufacturing and industrial activities, such as food processing and fabrication of agricultural machinery. The production of natural gas, clay and clay products, limestone, sand and gravel, and lumber and forest products are also significant economic activities. The area is served by air and rail lines and the Stockton and Sacramento Deep Water Ship Channels and by primary and secondary highway systems.

For a number of years, the Central Valley Area has made progress in broadening its economic base. In addition to a growing manufacturing sector, gains have come in government, retail trade, services, and home building. It is anticipated that the agricultural interests will continue to be the dominant force in the area's economic picture, the area maintaining its position as one of the nation's leading agricultural areas.

History of Flooding

Three types of floods are characteristic of the San Joaquin Basin Hydrologic Study Area: (1) those that occur during the late fall and winter months, primarily as a result of prolonged rain in the mountain and valley areas; (2) those that occur during the spring and early summer months, primarily from melting of the winter snowpack in the high Sierra Nevada; and (3) those that occur in the Sacramento-San Joaquin Delta as a result of a combination of high tides, high winds, and flood inflows. Of the three, the most frequent type is the late fall and winter floods caused by rainstorms.

In the northern portion of the area, the 1962-63 flood was considered the most severe that has ever occurred on the westside tributary streams; the December 1955-January 1956 flood was considered the most severe ever to strike the eastside tributary streams. The January 1969 flood was considered the most severe flood ever to occur in the southern part of the area. The January-February

1980 flooding caused some of the most severe damage in the Sacramento-San Joaquin Delta in 25 years. While these floods are considered the most severe on a regional basis, other floods may have caused higher flows on individual streams.

Preceding the December 1955 flood, heavy rainfall and snowmelt occurred in the upper watersheds of the eastside tributaries to the San Joaquin River. This caused extensive flooding along the San Joaquin River and all its major eastside tributaries and flooding on the larger westside tributaries. This flood caused extensive damage to agriculture, homes, and public facilities. Thousands of people were evacuated from their homes during the Christmas holiday season, and several people died of heart attacks during the flood. Unusually high tides aggravated the situation by impeding the passage of floodwater through the Sacramento-San Joaquin Delta.

Flood damage to agricultural and public facilities during the 1962-63 flood was particularly serious along the streams flowing from the westside tributaries.

Severe rain-caused floods struck the northern part of the area during the 1968-69 season, and in the southern part of the area both rain and snowmelt floods occurred. Heavy rains fell during January 1969 and substantial but lesser amounts in February. As the heavy rains continued in the valley, a snowpack of unprecedented depth and water content accumulated in the watershed above 2 400 metres (8,000 feet) along the crest of the Sierra Nevada. The flood season was climaxed by near-record snowmelt floods during April through July. The total volume of snowmelt was estimated to be 11 100 000 cubic dekametres (9 million acre-feet), which approached the record established in 1906. During the January-February 1980 storms, a combination of high tides and flood level flows, which were aggravated by 50-65 kilometre-per-hour (30-40 mile-per-hour) northerly winds caused breaches in and rapid deterioration of private levees in the Sacramento-San Joaquin Delta. Approximately 4 570 hectares (11,300 acres) of agricultural land were inundated on Webb and Holland Tracts and Prospect and Dead Horse Islands.

HIGHWAY 99 through Chowchilla on December 23, 1955. Many towns as well as farms were devastated by the holiday season floods.

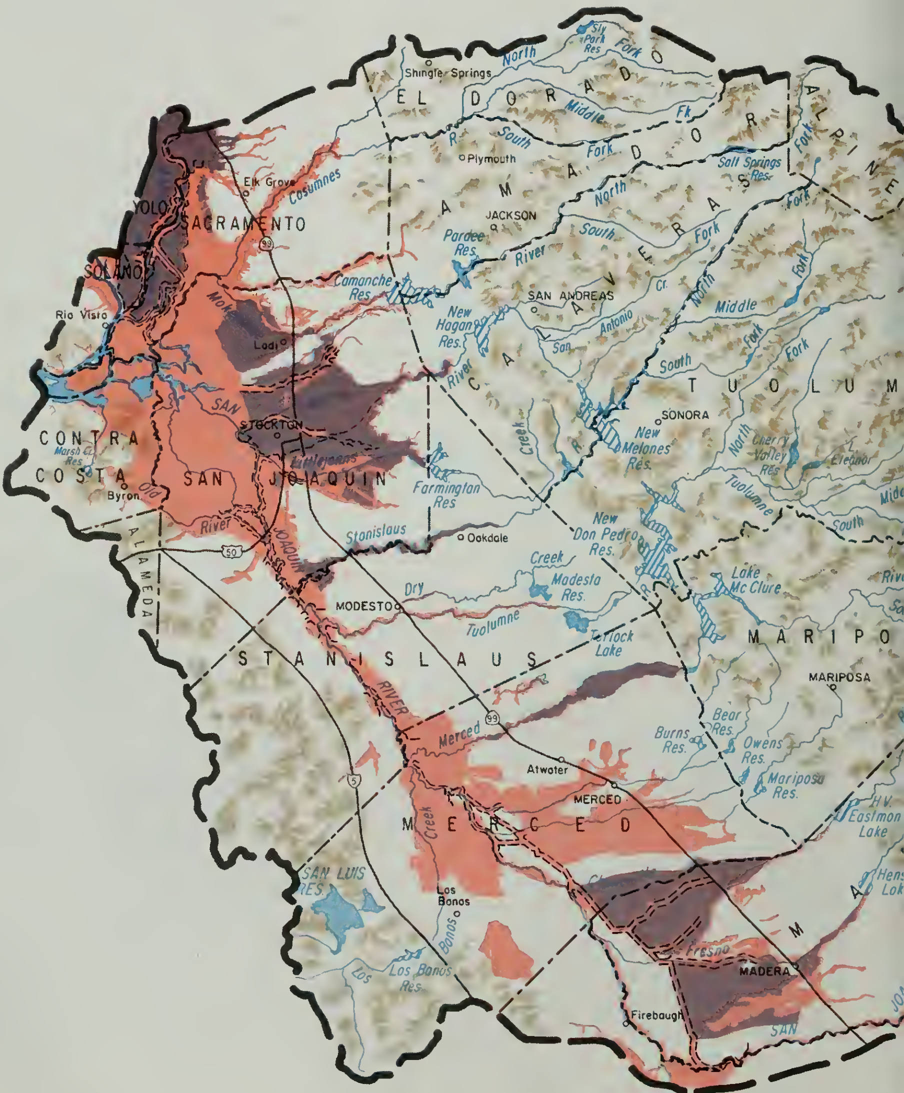

EL DORADO
AMADOR
CALAVERAS
TUOLUMNE
ALPINE
MARIPOSA
MADERA
MERCED
STANISLAUS
SAN JOAQUIN
SACRAMENTO
YOLO
SOLANO
CONTRA COSTA
ALAMEDA
Shingle Springs
Sly Park Res
North Fork
Middle Fk.
South Fork
Plymouth
Elk Grove
Cosumnes
JACKSON
Pardee Res.
River
Salt Springs Res.
Camanche Res.
New Hogan Res.
SAN ANDREAS
San Antonio Cr.
Middle Fork
South Fork
North Fork
Lodi
Rio Vista
STOCKTON
SAN
SONORA
New Melones Res.
Cherry Valley Res.
Eleanor
Littlejohns
Farmington Res
Marsh Cr. Res.
Byron
Old River
Creek
Stanislaus
Oakdale
New Don Pedro Res.
Tuolumne
South
Creek
Modesto Res.
Dry
MODESTO
Tuolumne
Turlock Lake
Lake Mc Clure
MARIPOSA
RIVER
Merced
Burns Res.
Bear Res.
Owens Res.
Mariposa Res.
Atwater
MERCED
H.V. Eastman Lake
Creek
SAN LUIS RES.
Los Banos
Bonos
Los Banos Res.
Los
Fresno
MADERA
Firebaugh
SAN
JOAQUIN
50
99
5

Figure 34
FLOOD INFORMATION
SAN JOAQUIN BASIN HYDROLOGIC STUDY AREA

Flood Damage Prevention Facilities

Flood protection is provided by a variety of facilities, including flood protection reservoirs, floodwater retardation structures, levees and channels, bypass systems, and tributary watershed treatment. Structural facilities in the San Joaquin Basin provide flood protection to only a portion of the flood-prone areas. With few exceptions, the degree of protection varies from 1-in-100-year or greater in urban areas to 1-in-10-year to 1-in-50-year protection in agricultural areas.

Flood forecast procedures are an integral part of existing flood protection developments. The Federal-State River Forecast Center in Sacramento maintains continuous surveillance of flood situations, issuing forecasts for reservoir inflows; expected flows and stages on the San Joaquin River and its tributaries, and on the Cosumnes and Mokelumne Rivers; and stages in the Sacramento-San Joaquin Delta. Islands below sea level in the Delta are subject to flooding during periods of high inflow from the Sacramento and San Joaquin basins, and particularly when high inflow occurs concurrently with high tides and strong southerly or southwesterly winds. The key flood forecast point in the Delta is Rio Vista, to which other forecast points throughout the Delta are referenced.

An extensive system of levees, channels, and bypasses is an important element in the overall flood protection program for the San Joaquin Basin and the lower Sacramento River System. In addition to the principal levee and channel systems, local interests have constructed numerous secondary levees and improved channels. These secondary improvements provide flood protection of varying degrees, primarily to agricultural areas. In general, the protection afforded ranges from a 1-in-2-year flood to a 1-in-25-year flood.

Planning activities primarily related to flood protection under way at this time include a preauthorization study by the Corps of Engineers for a project on the San Joaquin River from the Merced River to Stockton, and a number of small watershed investigations by the Soil Conservation Service.

In recognition of the need for additional flood protection for rapidly growing urban areas, the Corps of Engineers has been studying feasible projects within the San Joaquin River Basin under the authority of its San Joaquin River Basin Study.

The flood problems of the Merced area are an example of this activity. The Merced County Stream Group Project authorized by the 1944 Flood Control Act provided some flood protection to the City of Merced. It provided no protection to Castle Air Force Base nor did it provide any recreational benefits. However, a new Merced County Streams Project authorized by Congress in 1970 and authorized by the State in 1974 provides a higher degree of flood protection to the City of Merced, the surrounding agricultural areas, and to Castle Air Force Base.

The U. S. Soil Conservation Service, under Public Law 566, has sponsored three watershed protection projects in the San Joaquin Basin. These projects, as well as the Corps of Engineers' projects, are described in Table 11.

Table 11: FLOOD DAMAGE PREVENTION PROJECTS IN THE SAN JOAQUIN BASIN HYDROLOGIC STUDY AREA

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Sacramento River and tributaries	Sacramento River Flood Control Project	The Reclamation Board, Department of Water Resources, levee and maintenance districts	Project provides a levee system along the Sacramento River and sloughs in the northwestern Delta area	Urban and agricultural lands along the Sacramento River and the northwestern Delta islands	The project levees provide containment of the 1-in-100-year flood. Some of the Delta islands are not entirely protected. Frequency of flooding depends on the degree of protection provided by the nonproject levees
Mokelumne River	Camanche Reservoir	East Bay Municipal Utility District	Multipurpose 532 000 cubic dekametres (431,500 acre-foot) reservoir with 245 000 cubic dekametres (200,000 acre-foot) flood protection reservation	28 000 hectares (69,000 acres) of agricultural lands and 1 200 hectares (3,000 acres) of urban and suburban land, including the City of Lodi and the town of Woodbridge	Protection against 90 percent of the Standard Project Flood for City of Lodi. Agricultural area protection is 1-in-50-year flood
Calaveras River	New Hogan Lake (U.S. Army Corps of Engineers)	U.S. Army Corps of Engineers	Multipurpose 400 000 cubic dekametres (325,000 acre-foot) reservoir with 200 000 cubic dekametres (160,000 acre-foot) flood protection reservation	19 000 hectares (46,000 acres) of agricultural land and the City of Stockton and environs	In conjunction with the Mormon Slough Project, Standard Project Flood protection for City of Stockton; 1-in-60-year protection for agricultural area
Bear Creek	Bear Creek Channel (U.S. Army Corps of Engineers)	San Joaquin County Flood Control and Water Conservation District	Project includes 66 kilometres (41 miles) of low levees and 39 kilometres (24 miles) of channel modifications along Bear Creek	12 000 hectares (30,000 acres) of agricultural lands aod the City of Stockton and environs	
Duck Creek	Duck Creek* (U.S. Army Corps of Engineers)	San Joaquin County Flood Control and Water Conservation District	Modification of 23 kilometres (14 miles) of channel to provide a carrying capacity of 20 to 25 m^3s (700 to 900 cfs)	City of Stockton and environs	1-in-50-year flood protection
Littlejohns Creek	Farmington Dam (U.S. Army Corps of Engineers)	U.S. Army Corps of Engineers and San Joaquin County Flood Control and Water Conservation District	Flood storage reservoir with flood detention capacity of 64 000 cubic dekametres (52,000 acre-feet) and channel modification on Littlejohns and Duck Creeks diverting facilities	23 000 hectares (58,000 acres) of agricultural land, suburban areas, and industrial site southeast of Stockton	
Calaveras River	Mormon Slough (U.S. Army Corps of Engineers)	San Joaquin County Flood Control and Water Conservation District	Increased capacity of existing channels by enlarging Mormon Slough	City of Stockton and environs	City of Stockton has Standard Project Flood protection with the New Hogan Project; agricultural area has 1-in-60-year protection
San Joaquin River	Lower San Joaquin River and tributaries (U.S. Army Corps of Engineers)	Various Reclamation Districts	Modification of existing levees and construction of new levees along more than 160 kilometres (100 miles) of San Joaquin River and lower reaches of its principal tributaries from mouth of Merced River downstream to Stockton, capacity varies from 1 300 to 1 500 m^3s (45,000 to 52,000 cfs)	Suburban areas in vicinity of Stockton, and 56 000 hectares (140,000 acres) of highly-developed agricultural lands along San Joaquin River and in the upper Sacramento-San Joaquin Delta	In conjunction with flood coatrol projects on Stanislaus and Tuolumne Rivers, provides protection against floods up to about a 1-in-50-year flood

* Small project

Table 11: FLOOD DAMAGE PREVENTION PROJECTS IN THE SAN JOAQUIN BASIN HYDROLOGIC STUDY AREA (Cont'd)

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
San Joaquin River	Lower San Joaquin River Flood Control Project (State of California)	State Department of Water Resources and Lower San Joaquin Levee District	Bypass system consisting of a network of channels, about 306 kilometres (190 miles) of levees, and several major bridges and flow-control structures. Project was coordinated with Corps' Lower San Joaquin River and tributaries project. Capacity varies from 156 to 736 m^3s (5,500 to 26,000 cfs)	Flood plain areas along San Joaquin River from mouth of Merced River upstream to vicinity of Gravelly Ford	Provides protection against floods up to the 1-in-25-year project design flood
Stanislaus River	New Melones Lake constructed by U. S. Army Corps of Engineers	Upon completion project will be transferred to U.S. Water and Power Resources Service	A 3.0 million cubic dekametres (2.4 million acre-foot) multipurpose reservoir with a 550 000 cubic dekametre (450,000 acre-foot) flood protection reservation. Maximum flood control release of 200 m^3s (8,000 cfs)	14 000 hectares (35,000 acres) of highly-developed agricultual land along Stanislaus River. Also, aids in protection of 95 000 hectares (235,000 acres) of intensively developed agricultural land, military installations and industrial and suburban areas in vicinity of Stockton	Provides protection against floods up to the 1-in-100-year or greater flood to Stanislaus River flood plain
Tuolumne River	New Don Pedro Reservoir	Turlock and Modesto Irrigation Districts and City and County of San Francisco, with federal financial participation for flood control function	A 2.5 million cubic dekametre (2.0 million acre-foot) multipurpose reservoir with a 420 000 cubic dekametre (340,000 acre-foot) flood protection reservation. Design release for flood protection is 370 m^3s (13,000 cfs), the combined downstream capacity of the river channel and distributary irrigation canals	City of Modesto and several other communities along river and to 3 000 hectares (8,000 acres) of agricultural lands. Also, aids in protection of industrial and suburban areas in vicinity of Stockton, a number of military installations and 57 000 hectares (140,000 acres) of highly developed agricultural lands	Provides protection against at least the 1-in-30-year rainfall flood and 1-in-50-year snowmelt flood to lands in Tuolumne River flood plain
Merced River	New Exchequer Reservoir	Merced Irrigation District	A 1.3 million cubic dekametre (1.0 million acre-foot) multipurpose reservoir with a 500 000 cubic dekametre (400,000 acre-foot) flood protection reservation	Small downstream communities and 20 000 hectares (50,000 acres) of agricultural land in Merced River flood plain. Significantly reduces flood damage along lower San Joaquin River and in Sacramento-San Joaquin Delta	Project will control the 1-in-15-year rainflood and the 1-in-50-year snowmelt flood to nondamaging release of 170 m^3s (6,000 cfs)

Table 11: FLOOD DAMAGE PREVENTION PROJECTS IN THE SAN JOAQUIN BASIN HYDROLOGIC STUDY AREA (Cont'd)

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Merced County Stream Group	Burns Creek Flood Retention Dam	U.S. Army Corps of Engineers	A 8 000 cubic dekametre (6,800 acre-foot) flood retention capacity; 53 m^3s (1,860 cfs) outlet capacity	Development in down stream areas including City of Merced, towns of Planada and Le Grand, and other small communities, highway and transportation facilities, and about 55 000 hectares (136,000 acres) of agricultural lands. Reduces flood flow from stream group into San Joaquin River	Provides protection against floods up to the 1-in-25-year flood
	Bear Creek Flood Retention Dam		A 9 500 million cubic dekametre (7,700 acre-foot) flood retention capacity; 51 m^3s (1,800 cfs) outlet capacity		
	Owens Creek Flood Retention Dam		A 4 900 cubic dekametre (3,600 acre-foot) flood retention capacity; 5 m^3s (185 cfs) outlet capacity		
	Mariposa Creek Flood Retention Dam		A 19 000 cubic dekametre (15,000 acre-foot) flood retention capacity; 30 m^3s (1,000 cfs) outlet capacity		
	Associated diversion works		Black Rascal Diversion channel, capacity 85 m^3s (3,000 cfs); Owens Creek channel, capacity 11 m^3s (400 cfs)		
Los Banos Creek	Los Banos Reservoir (U.S. Water and Power Resources Service)	State Department of Water Resources	A 40 000 cubic dekametre (34,500 acre-foot) reservoir with a 17 000 cubic dekametre (14,000 acre-foot) flood protection reservation. Maximum flood protection release, 28 m^3 (1,000 cfs)	Downstream flood plain which includes the California Aqueduct and the City of Los Banos	Provides protection against floods up to the 1-in-50-year or greater flood
Chowchilla River	Buchanan Dam (H.V. Eastman Lake) (U.S. Army Corps of Engineers)	U.S. Army Corps of Engineers - except for channel improvements maintained by the County of Madera	A 185 000 cubic dekametre (150,000 acre-foot) multipurpose project with a 56 000 cubic dekametre (45,000 acre-foot) flood protection reservation, 32 kilometres (20 miles) of levee and channel modifications along Ash & Berenda Sloughs, distributary of Chowchilla River. Maximum flood protection release, a nondamaging 210 m^3s (7,400 cfs)	City of Chowchilla and about 45 000 hectares (110,000 acres) of suburban, industrial, and agricultural areas along the river and its tributaries and assists in controlling floods along the San Joaquin River	Provides protection against floods equal to 70 percent of standard project flood
Fresno River	Hidden Dam (Hensley Lake) (U.S. Army Corps of Engineers)	U.S. Army Corps of Engineers - except for channel improvements maintained by the County of Madera	A 111 000 cubic dekametre (90,000 acre-foot) multipurpose project with a 80 000 cubic dekametres (65,000 acre-foot) flood protection reservation and about 21.4 kilometres (13.3 miles) of levee and channel modifications. Maximum flood protection release, a nondamaging 150 m^3 (5,000 cfs)	About 59 000 hectares (145,000 acres) of urban and rural areas including City of Madera, and assists in controlling floods on San Joaquin River	Provides protection against floods up to the 1-in-200-year or greater flood

Table 11: FLOOD DAMAGE PREVENTION PROJECTS IN THE SAN JOAQUIN BASIN HYDROLOGIC STUDY AREA (Cont'd)

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
San Joaquin River	Lake Millerton (Friant Dam) (U.S. Water and Power Resources Service)	U.S. Water and Power Resources Service Service	A 640 000 cubic dekametre (520,000 acre-foot) multipurpose reservoir with flood protection reservation of 210 000 cubic dekametres (170,000 acre-feet) during winter rainflood season and 480 000 cubic dekametres (390,000 acre-feet) during the snowmelt season. Maximum flood release 230 m^3s (8,000 cfs)	Project is a major contributor to major flood control regulation for the San Joaquin River	Provides protection against floods up to the 1-in-20-year flood
Marsh and Kellogg Creeks	Marsh-Kellogg Watershed (U.S. Soil Conservation Service)	Contra Costa County Flood Control and Water Conservation District	Detention Reservoir on Marsh Creek, channel modifications on Sand Creek, detention reservoir on Kellogg Creek	46 900 hectares (116,000 acres) of agricultural lands near Brentwood	Designed to provide 1-in-50-year flood protection on Marsh and Kellogg Creeks
Mosher Creek	Mosher Creek Watershed (U.S. Soil Conservation Service)	San Joaquin County Flood Control and Water Conservation District	Mosher Creek to Bear Creek Diversion and 8.4 kilometres (5.2 miles) of channel modification on Mosher Creek below diversion	Agricultural land in San Joaquin County	1-in-50-year protection
Mustang Creek	Mustang Creek Watershed (U.S. Soil Conservation Service)	County of Merced	A 600 cubic dekametre (512 acre-foot) flood water retarding structure, 7.9 kilometres (4.9 miles) of modified or realigned channel, and a 120 cubic dekametre (95 acre-foot) off-stream sump. Maximum outlet capacity 9.2 m^3s (325 cfs)	1 000 hectares (2,500 acres) of prime agricultural land	Provides protection against floods up to the 1-in-17-year flood

Many reservoirs on streams tributary to the San Joaquin River provide incidental, but often significant, contributions to flood protection. For example, the development of the Tuolumne River involved a cooperative agreement among the Corps of Engineers, the City and County of San Francisco, and the Turlock and Modesto Irrigation Districts. Under the initial phase of the agreement, local interests built Cherry Valley Reservoir with financial assistance from the Federal Government and, in return for such assistance, operated the reservoir in conjunction with Lake Eleanor, Hetch Hetchy, and Don Pedro Reservoirs to provide interim flood protection before New Don Pedro Reservoir was built.

Under the final phase of the program, local interests constructed New Don Pedro Reservoir, with further financial assistance from the Federal Government, to provide 419 000 cubic dekametres (340,000 acre-feet) of flood storage reservation. Completed in 1971, New Don Pedro Reservoir is now an integral unit of the flood protection plan on the San Joaquin River.

Other reservoirs which provide incidental flood protection in the San Joaquin Basin are:

Reservoir	Stream	Operating Agency
Pardee	Mokelumne River	East Bay Municipal Utility District
Salt Springs	North Fork Mokelumne River	Pacific Gas and Electric Co.
Jenkinson Lake	Sly Park Creek	Water and Power Resources Service
San Luis	San Luis Creek	Water and Power Resources Service
Beardsley	Middle Fork Stanislaus River	Oakdale and South San Joaquin Irrigation District
Donnells	Middle Fork Stanislaus River	Oakdale and South San Joaquin Irrigation District
Florence Lake	South Fork San Joaquin River	Southern California Edison Co.
Huntington Lake	Big Creek	Southern California Edison Co.
Mammoth Pool	San Joaquin River	Southern California Edison Co.
Cherry Lake	Cherry Creek	City and County of San Francisco
Lake Eleanor	Eleanor Creek	City and County of San Francisco
Hetch Hetchy Reservoir	Tuolumne River	City and County of San Francisco
Bass Lake	Willow Creek	Pacific Gas and Electric Co.
Shaver Lake	Stevenson Creek	Southern California Edison Co.
Tulloch	Stanislaus River	Oakdale and South San Joaquin Irrigation District
Lake Thomas A. Edison	Mono Creek	Southern California Edison Co.

Nonstructural Flood Management

The topography of the San Joaquin Basin can be divided into the mountainous area of the Sierra Nevada, comprising the eastern half of the basin, and the valley area, comprising the western half.

The eastern portion is sparsely populated because the land is steep and its potential for growth is limited. As in most mountainous areas, stream channels required to carry storm flows are well defined, and these flows occur often enough to preclude extensive development. Therefore, nonstructural flood management appears to be the best method of flood protection. However, the limited growth potential and well-defined floodways have provided little, if any, incentive for local governments to adopt and implement flood plain regulations.

The major development and most intensive land uses have generally occurred on the valley floor. Sacramento and Merced Counties are the only counties in the area in which countywide flood plain zoning ordinances regulating development on flood plains have been adopted. Through ordinances, these counties have adopted comprehensive flood plain management programs, which guide development of the flood-prone areas depicted on Flood Insurance Rate Maps.

The grasslands of the San Joaquin Valley support large numbers of waterfowl using the Pacific Flyway. Flood plain regulation (nonstructural methods) will tend to protect some of the remaining waterfowl habitat.

The Reclamation Board has adopted designated floodways on the Cosumnes, Mokelumne, San Joaquin, Tuolumne, Merced, Chowchilla, and Fresno Rivers and on Dry Creek (tributary to the Tuolumne River near Modesto), and Ash and Berenda Sloughs. The locations of these floodways are shown on Figure 23.

All county and city participation in the National Flood Insurance Program is listed on Table 12. This program may have served to introduce flood plain management as a means of dealing with flood problems to supplement and replace traditional project-oriented means. The program has also provided an incentive for local governing bodies to restrict development on flood plains. The methods adopted by local governments to implement floodway regulations are presented in Table 12.

Flood Protection Needs

The most urgent problem is clearing and maintaining the San Joaquin River channel in the reach from below Friant Dam to the Sacramento-San Joaquin Delta, at the same time protecting and enhancing fish and wildlife values. With one exception, on a relatively short reach in the vicinity of Mendota, no local agency has volunteered to participate in either construction or maintenance costs.

Other long-range needs include (1) protection from a 1-in-100-year or greater flood for existing urban areas, (2) flood protection for existing agricultural land to the extent economically feasible, (3) assurance that future development on flood plains is compatible with flood risks, and (4) mapping showing a 1-in-100-year flood.

Throughout the valley, uncontrolled local runoff from minor watersheds and from certain urban and agricultural areas often causes significant flood damage. Flooding on the valley floor is compounded by land-leveling practices which obliterate channels and by farming practices which promote runoff. In certain instances, where floodwater enters irrigation canal systems,

WEBB TRACT in the Delta was flooded on January 18, 1980, when a portion of its weakened, peat-based levee failed, causing the flooding of 2 100 hectares (5,200 acres) of agricultural lowland. Restoration under the Corps of Engineers was scheduled to take at least six months. Owners of both the Webb and Holland tracts, in accepting federal aid, were required to take steps to strengthen the levees and improve maintenance practices.

THE PRIVATE LEVEE at Holland Tract, in the Sacramento-San Joaquin Delta, failed on January 18, 1980, as a result of high tides and floodflows aggravated by 50-65 kilometre (30-40 mph) northerly winds. The 1 660-hectare (4,100-acre) tract was completely flooded, with four or five hundred head of cattle drowning. The island has since been restored.

urban flooding may result when canal levees fail or are overtopped. The cities of Turlock, Farmersville, and Visalia have had notable examples of such situations. Additional flood protection is needed in many parts of the area such as along the reaches of Orestimba Creek north of Newman, and Salado Creek which passes through the City of Patterson.

The Delta is one of the most fertile agricultural areas in the United States. Its rich soil supports a wide variety of crops which significantly contribute to California's economy. The Delta channels, particularly the Sacramento and San Joaquin Rivers and two deep-water channels and ports, support important commercial shipping. Surplus water from Northern California is transferred through the Delta for use in Central and Southern California. The Mokelumne Aqueduct, which conveys water from the Sierra Nevada to the San Francisco Bay Area, crosses the Delta. The area also encompasses one of California's important high-quality natural gas producing areas.

Thousands of acres of the Delta lowlands are protected from floods and high tides by a vast network of privately constructed levees, some of which are over 100 years old. Many of the levees are in poor condition and need to be rehabilitated. The protection and enhancement of the Delta is of prime importance not only to the Delta residents but to California and others throughout the nation.

The Corps of Engineers is presently investigating the flood hazards, navigation, water quality, and recreation problems in the Delta. The purpose of this study is to determine the advisability of draining certain tracts which are continually subjected to inundation by tidal actions and floodflows, and to consider closing some channels to floodflows and navigational use in order to reduce maintenance costs.

Table 12: REGULATED FLOODWAYS IN THE SAN JOAQUIN BASIN HYDROLOGIC STUDY AREA

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
State Reclamation Board	Designated floodway	Cosumnes River - El Dorado County Line to mouth	Agricultural	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Mokelumne River - Cosumnes River to Camanche Dam	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Tuolumne River - La Grange Dam to mouth	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Dry Creek - A.T.&S.F.R.R. crossing to Tuolumne River	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Merced River - Merced Falls to mouth	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	San Joaquin River - Salt Slough to Airport Way	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Chowchilla River - Eastside Bypass to Buchanan Dam	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Ash Slough - Chowchilla to Chowchilla River	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Berenda Slough - Ash Slough to Avenue 21-1/2	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Fresno River - Road 22-1/2 to Hidden Dam site	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	San Joaquin River - Gravelly Ford area to Friant Dam	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Fresno Slough - Crescent Dam to Mendota Pool	Agricultural, urban, industrial	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities

Table 12: REGULATED FLOODWAYS IN THE SAN JOAQUIN BASIN HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Sacramento County Sacramento County Water Agency Sacramento River Flood Control District Maintenance Areas Nos. 9, 10, & 11 Metropolitan Storm Drainage District	General flood control zoning plan; grading, drainage, and specific floodway ordinances; uniform building code and county improvement standards	Sacramento, American, Cosumnes, Mokelumne, and San Joaquin Rivers and adjacent flood plains; Sacramento-San Joaquin Delta waterways	Agricultural, urban, industrial, recreational, open space	Adequate regulation and enforcement	Yes
Galt	None	None	None	Codification and enforcement of regulations	Yes
Isleton	Uniform building code, land use and subdivision ordinances, and building permit system	Sacramento River overflow	Agricultural, urban, industrial	Enforcement of regulations	Yes
Solano County	Three-zone flood plain regulation ordinance	All natural watercourses, sloughs and constructed water channels	Agricultural, urban, industrial, recreational	Unknown	Yes
Dixon	Zoning ordinance, uniform building code, building permit system	Dickson Creek and problem drainage areas	Urban, industrial	Codification and enforcement of regulations	Yes
Rio Vista	Land use zoning ordinance, uniform building code, building permit system	Sacramento River	Urban, industrial	Unknown	Yes
Vacaville	City code, uniform building code, building permit system	Alamo, Ulatis, and Gibson Canyon Creeks	Agricultural, urban, industrial	Adoption of flood plain regulations based on U.S. Army Corps of Engineers Flood Plain Information-"Alamo and Ulatis Creeks-Vacaville, 1973"	Yes
Contra Costa County Contra Costa County Flood Control and Water Conservation District	County code zoning, building and subdivision ordinances, flood control code for drainage	Countywide - floodways not specified Kellogg and Marsh Creeks	Urban, industrial, agricultural, recreational	Unknown	Yes
Antioch	Uniform building code, building permit system	Citywide - floodways not specified	Agriculture, urban, industrial	Identification of flood-hazard areas. Codification and enforcement of regulations	Yes
Brentwood	None	None	None	Identification of flood-hazard areas and codification and enforcement of regulations	Yes
Pittsburg	Uniform building code, building permit system	Citywide - floodways not specified	Urban	Identification of flood-hazard areas and codification and enforcement of regulations	Yes
San Joaquin County San Joaquin County Flood Control and Water Conservation District	Land leveling, land and subdivision regulations	All flood-hazard areas and problem areas - Bear, Duck, and Littlejohns Creeks, Mormon Slough and Calaveras River	Agricultural, urban, industrial, recreational, open space	Identification of flood-hazard areas and codification and enforcement of regulations	Yes
Escalon	None	None	None	No need for regulation	No
Lodi	Zoning ordinance, municipal code	Mokelumne River flood plain	Agricultural, urban, industrial	Unknown	Yes

Table 12: REGULATED FLOODWAYS IN THE SAN JOAQUIN BASIN HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Manteca	None	None	None	No need for regulation	No
Ripon	None	None	None	Codification and enforcement of regulations	Yes
Stockton	None	None	None	Floodways regulated by county code and reclamation districts	Yes
Tracy	Municipal code, uniform code. Zoning regulations	Citywide - floodways not specified	Urban, industrial	Unknown	Yes
El Dorado County	Building code, subdivision ordinance	Countywide - floodways not specified	Agricultural, urban, industrial	Identification of flood-hazard areas and codification and enforcement of regulations	No
Alpine County	None	None	None	Identification of flood-hazard areas and codification and enforcement of regulations	No
Amador County	General plan	None	None	Identification of flood-hazard areas and codification and enforcement of regulations	No
Amador City	None	None	None	Identification of flood-hazard areas	No
Ione	None	None	None	Identification of flood-hazard areas and codification and enforcement of regulations	Yes
Jackson	None	None	None	Identification of flood-hazard areas	Yes
Plymouth	None	None	None	Identification of flood-hazard areas	No
Sutter Creek	Municipal code, building permit system	Citywide - floodways not specified	Urban, industrial	Identification of flood-hazard areas and codification and enforcement of regulations	Yes
Calaveras County	None	None	None	Incentive to adopt and enforce regulations	No
Angels Camp	Building permit and subdivision proposal review	Angels Creek within city limits	Urban	Realistic delineation of flood-hazard from one-percent flood event	Yes
Stanislaus County	Flood plain zoning overlay-type ordinance; agricultural zoning, building permit process	Overlay ordinance is presently applied only to areas along designated floodways of Tuolumne River and Dry Creek in vicinity of Modesto, but will be expanded to cover all flood-hazard areas when Flood Insurance Rate Maps are adopted; other means listed are currently utilized to regulate development in other flood-prone areas of county	Urban, industrial, agricultural	Adoption of Flood Insurance Rate Maps, which are essentially completed	Yes
Ceres	No flood hazard				No
Hughson	No flood hazard				No

Table 12: REGULATED FLOODWAYS IN THE SAN JOAQUIN BASIN HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Modesto	Review by State Reclamation Board	State Reclamation Board designated floodway on Dry Creek and Tuolumne River within city limits	Urban, agricultural	Realistic delineation of flood-hazard from one-percent flood event	Yes
Newman	Building permit review	Floodway resulting from breach in Delta-Mendota Canal or California Aqueduct	Urban	None	Yes
Oakdale	Flood plain provisions of city zoning code	Small area adjacent to Stanislaus River within high water mark of 1955 flood	Urban	None	Yes
Patterson	Building permit review; flood plain provision of subdivision ordinance	Floodway of Salado Creek within city limits	Urban, industrial	None	Yes
Riverbank	City presently has no flood-hazard areas, but it is considering annexing areas along the Stanislaus River that are subject to floodway				No
Turlock	Building permit and subdivision proposal review	Overflow areas of local irrigation laterals	Urban, industrial	Realistic delineation of flood-hazard from irrigation lateral overflow	Yes
Waterford	Flood plain zoning ordinance	Floodway of Tuolumne River within city limits	Urban	None	Yes
<u>Tuolumne County</u>	None	None	None		No
Sonora	Building permit process	Flood plains of Woods and Sonora Creeks within city limits	Urban	None	Yes
<u>Mariposa County</u>	County subdivision ordinance, building permit process	Any known flood-hazard area	Urban	None	No
<u>Merced County</u>	Countywide flood damage prevention ordinance	All floodways depicted on countywide Flood Insurance Rate Map	Urban, industrial agricultural	Realistic countywide map of flood-hazard areas. Such a map is presently under preparation by local consultants	Yes
Atwater	Building permits	Overflow areas of local canals and drains	Urban		Yes
Dos Palos	Flood plain zoning ordinance	Small area designated as subject to flooding from breach in local irrigation lateral	Undeveloped urban areas	None	Yes
Gustine	No flood-hazard areas				No
Livingston	Building permit review	Two small areas subject to inundation from local ponding	Urban	None	Yes

Table 12: REGULATED FLOODWAYS IN THE SAN JOAQUIN BASIN HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Los Banos	Local drainage problem only				No
Merced	Floodway zoning ordinance	Floodways of Bear, Black Rascal, and Fahrens Creeks, and Hartley Slough within city limits	Urban, industrial	None	Yes
Madera County	Subdivision ordinance, building permit process, environmental impact report process	Flood-hazard areas as delineated on maps in U.S. Corps of Engineers Flood Plain Information Reports and flood-prone area maps prepared under Federal Flood Insurance Program	Urban, industrial, agricultural	Realistic countywide map of flood-hazard areas with floodwater surface elevations for 100-year flood	Yes
Chowchilla	Any flood-hazard eliminated with recent completion of major flood control project on Chowchilla River				No
Madera	The minor flood threat to this city from the Fresno River was eliminated for floods equal to the 100-year flood by the recent completion of a major flood control project on the River (Lake Hensley). However, the city was a participant in the Federal Flood Insurance Program prior to the completion of the project and has not asked to be exempted as a result of the project			Flood Plain Information Report available Fresno River, Cottonwood, Little Dry and Root Creeks, June 1973	Yes
Fresno County	Flood-prone areas provisions of ordinance code of Fresno County; open conservation district provision of county ordinance, subdivision ordinance building code	Flood-prone areas as delineated on maps of historical flooding; maps of U.S. Corps of Engineers. Flood plain information reports; and maps prepared under Federal Insurance Program	Urban, industrial, agricultural	Accurate maps of areas subject to flooding from 1-in-100-year flood with floodwater surface elevations	Yes
Firebaugh	Building permit process	Flood plain of San Joaquin River within city limits	Urban, public park	Unknown	Yes
Mendota	Building permit review	Floodway of Panoche Creek within city limits	Urban		Yes

With the exception of Bethel Island, which has been undergoing a high degree of urbanization, flood problems in the Delta generally involve agricultural lands. An urgent need exists on Bethel Island for greater flood protection than that which is now provided. Levees surrounding the island are low, are of inadequate cross section, and are situated on unstable foundation material. Emergency action by the State of California and the Corps of Engineers has saved Bethel Island from inundation several times.

Local jurisdictions presently in the emergency phase of the National Flood Insurance Program need detailed mapping of special flood-hazard areas, along with determinations of actuarial premium rates.

Tulare Basin Hydrologic Study Area

The Tulare Basin Hydrologic Study Area is located in the southern portion of the Central Valley. It is bounded by the divide between the San Joaquin and Kings Rivers on the north, the crest of the Sierra Nevada on the east, the Tehachapi Mountains on the south, and the crest of the Coast Range on the west.

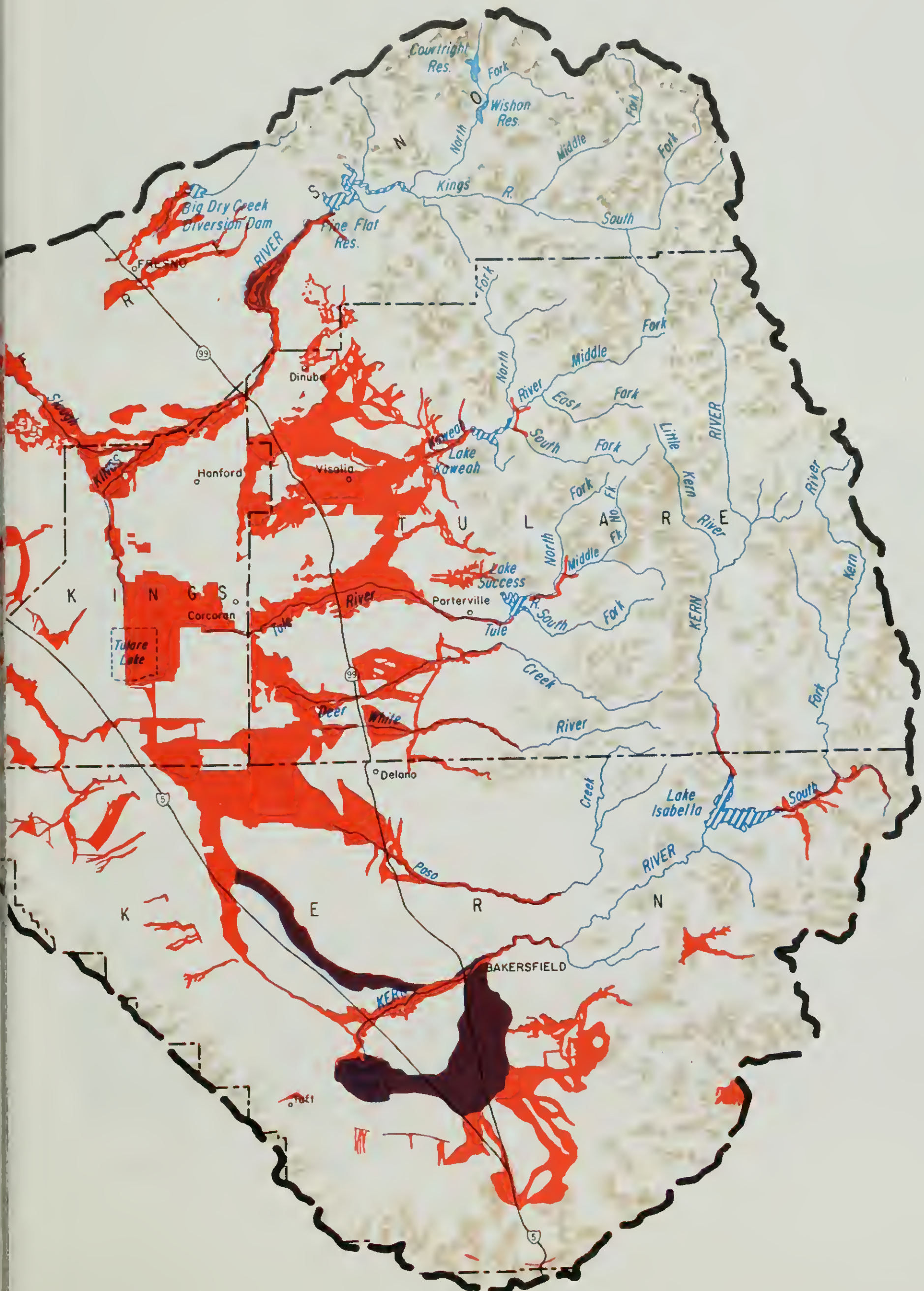
Major streams are the Kings, Kaweah, Tule, and Kern Rivers, which originate in the Sierra Nevada and, with the exception of the Kings River, terminate in the basin of Tulare Lake. Tulare Lake is dry during most of the year because of impoundments in upstream reservoirs and diversions for irrigation. The Kings River flows along the alluvial ridge between the Tulare and San Joaquin basins and divides to form the Kings River South, which flows into the Tulare Lake bed, and the Kings River North, which flows into the Fresno Slough and the San Joaquin River. The Kings River is controlled; excess floodflows are usually diverted into the San Joaquin River System near Mendota. Heavier flows are diverted into the Kings River South and the Tulare Lake bed. The area is depicted in Figure 35.

A number of minor, and mainly intermittent, streams and stream groups drain the regions between major streams along the Sierra Nevada, the northern slopes of the Techachapi Mountains, and the eastern slopes of the Coast Range. The Tulare Basin is separated from the San Joaquin Basin by a low ridge formed by the coalesced alluvial cones of the Kings and San Joaquin Rivers. Historically, floodwaters in the Tulare Lake area flowed across this ridge into the San Joaquin River, thus providing an outlet from this area to the sea. The last time such a discharge occurred was about 100 years ago.

In 1972 the population of the area was estimated at 980,000, with an urban density of 57 persons per square kilometre (147 persons per square mile). The population is projected to increase to 1,200,000 by 1990, with a corresponding increase in urban density to 63 persons per km^2 (163 persons per mi^2). Areas of population concentration such as Fresno and Bakersfield are expected to continue to grow.

The area is one of the nation's leading agricultural regions. Its economy is dominated by highly diversified farming and by related manufacturing and industrial activities, such as food and fiber processing and fabrication of agricultural machinery. The production of oil and forest products and manufacture of such products as plate glass and tires are also significant economic activities. Transportation facilities serving the area include modern highways and air and rail lines. For a number of years, the area has made progress in broadening its economic base. In addition to a growing manufacturing sector, gains have been made in government, retail trade services, and home building. Agricultural and oil production are

Figure 35
FLOOD INFORMATION
TULARE BASIN HYDROLOGIC STUDY AREA


Courtright Res.
Wishon Res.
Fork
North
Middle
Fork
Kings R.
South
Big Dry Creek Diversion Dam
Pine Flat Res.
FRESNO
RIVER
KINGS
Slough
Dinuba
Hanford
Visalia
Kaweah
Lake Kaweah
River
East
South
Fork
North
Middle
Little Kern River
RIVER
KERN
Lake Success
Porterville
Tule
River
South
Fork
K I N G S
Corcoran
Tulare Lake
T U L A R E
Creek
Deer
White
River
Delano
Creek
Lake Isabella
South
RIVER
Poso
K E R N
BAKERSFIELD
KERN
Taft
99
5

NIGHT SCENE IN VISALIA in 1955 flood. Tulare basin residents hope subsequent flood protection measures prevent recurrence of such events in the future.

expected to remain the dominant forces in the area's economic picture, with agriculture expected to maintain its position of national prominence.

History of Flooding

In general, two types of flooding occur in the area. One is the late fall and winter flood produced by prolonged rainstorms in the mountains and valley floor areas; the other is the spring and early summer runoff from the melting of a very large winter snowpack in the Sierra Nevada. Local floods can also result from thunderstorms. The most severe floods of the past two decades occurred in 1955-56, 1966-67, and 1968-69. Flood damage caused by these events was $17 million, $26 million, and $62 million, respectively.

In late December 1955, an intense rainstorm over the basin resulted in exceptionally high streamflows and subsequent flooding. Snowmelt from the Sierra Nevada added substantially to the flood-producing runoff. About 74 000 hectares (183,000 acres), mostly agricultural lands, were inundated. The 1966-67 floods claimed three lives and inundated about 57 500 hectares (142,000 acres).

Rain and snowmelt in the basin during the 1968-69 season were caused by heavy precipitation in January and substantial but lesser amounts in February, and a snowpack of unprecedented depth and water content in the Sierra Nevada. Over 36 000 hectares (89,000 acres) in the Tulare Lake bed were flooded by approximately 1 190 000 cubic dekametres (962,000 acre-feet) of water. Total inflow into Tulare Lake during the period January through July included 406 000 cubic dekametres (329,000 acre-feet) from the Kaweah River, 354 000 cubic dekametres (287,000 acre-feet) from the Kern River, 270 000 cubic dekametres (219,000 acre-feet) from the Tule River, 275 000 cubic dekametres (181,000 acre-feet) from the Kings River and 92 000 cubic dekametres (75,000 acre-feet) from other sources. In February and March 1978 severe flooding occurred in Kern County, especially from Caliente Creek.

Flood Damage Prevention Facilities

Existing flood protection facilities

within the Tulare Basin Hydrologic Study Area include flood storage reservoirs, floodwater retardation structures, locally owned levee systems, and tributary watershed treatment. The degree of flood protection provided by these facilities varies from 1-in-50-year or greater protection for urban areas to 1-in-10-year to 1-in-50-year protection for agricultural areas. These projects are described in Table 13.

River stage forecasts and flood warnings are issued by the Flood Operations Center in Sacramento. Inflow forecasts are made for major reservoirs such as Pine Flat, Terminus, Success, and Isabella. During periods of heavy winter rainfall, warnings are issued for the mountain stations, Springville on the Tule River, and Kernville on the Kern River. When flows below the reservoirs are expected to exceed channel capacities, warnings are issued for Bakersfield and Porterville.

In the watershed that is tributary to the Tulare Basin, flood protection facilities have been constructed by private initiative, and include channel work, stabilization structures, levees, and basic land treatment. Farmland in the Tulare Lake bed is protected by levees that form a system of cells designed to confine floodwater entering the lake bed to the smallest possible area.

An intertie channel project to regulate floods by diverting snowmelt flows from the Kern River into the California Aqueduct was constructed by the U. S. Army Corps of Engineers. This project, completed in 1977, greatly reduced floodflows into the Tulare Lake bed from the Kern River in 1978.

KERN RIVER FLOODWATER entering California Aqueduct through the Kern River Intertie near Tupman.

Table 13: FLOOD DAMAGE PREVENTION PROJECTS IN THE TULARE BASIN HYDROLOGIC STUDY AREA

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Little Panoche Creek	Little Panoche Reservoir (U.S. Water and Power Resources Service)	State Department of Water Resources	A 16.3 cubic dekametre (13,200 acre-foot) flood detention reservoir	The California Aqueduct, Interstate Highway 5, and agricultural lands along stream	Provides protection against floods up to the 1-in-100-year flood
Big Dry Creek	Big Dry Creek Dam and Diversion (U.S. Army Corps of Engineers)	County of Fresno	A 20 000 cubic dekametre (16,250 acre-foot) flood detention reservoir and appurtenant upstream and downstream diversion facilities	Cities of Fresno and Clovis and their suburban areas	Provides significant flood protection. Level not known
Kings River	Pine Flat Lake and Kings River	U.S. Corps of Engineers except for channel modification maintained by Kings River Conservation District	A 1.23 million cubic dekametre (1,000,000 acre-foot) multipurpose reservoir with the full capacity available for flood storage, and about 56 kilometres (35 miles) of levee rehabilitation and 88 kilometres (55 miles) of channel clearing. Maximum design flood storage release is 510 m^3s (18,000 cfs)	32 000 hectares (80,000 acres) of rich agricultural lands along the river; helps reduce flood damage to 105 000 hectares (260,000 acres) of cropland in Tulare Lake area and contributes to flood damage reduction along San Joaquin River	Provides protection against at least the 1-in-100-year rainflood and at least the 50-year snowmelt flood along the Kings River and about a 1-in-10-year flood in the Tulare Lake area
Stone Corral Creek	Stone Corral Watershed. Dual-purpose flood control and agricultural drainage project. (U.S. Soil Conservation Service)	Stone Corral Irrigation District	Modification of 6.4 kilometres (4 miles of channel) a 14.6 hectare (36-acre) off-stream sump, 10.3 kilometres (6.4 miles) of pipeline, and 4.2 kilometres (2.6 miles) of open joint pipe	4 450 hectares (11,000 acres) of agricultural lands in Tulare County	Provides protection against floods up to the 1-in-10-year flood
Kaweah River	Terminus Dam (Lake Kaweah)	U.S. Corps of Engineers	A 185 000 cubic dekametre (150,000 acre-foot) multipurpose reservoir with 175 000 cubic dekametres (142,000 acre-feet) available for flood storage	City of Visalia and about 51 000 hectares (126,000 acres) of agricultural lands along rivers; helps reduce flood damage to 105 000 hectares (260,000 acres) of cropland in Tulare Lake area	Provides protection against floods up to the 1-in-50-year flood along the Kaweah River and about a 1-in-10-year flood in Tulare Lake area
Tule River	Success Lake	U.S. Corps of Engineers	A 101 000 cubic dekametre (82,000 acre-foot) multipurpose reservoir with 94 000 cubic dekametres (76,000 acre-feet) available for flood protection reservation. Maximum permissible flood storage release about 90 m^3s (3,200 cfs)	City of Porterville 24 000 hectares (60,000 acres) of highly developed agricultural land in the Tule River area; helps reduce flood damage on 105 000 hectares (260,000 acres) of cropland in Tulare Lake area	Provides protection against floods up to the 1-in-50-year flood along the Tule River and about a 1-in-10-year flood in Tulare Lake area
Kern River	Isabella Lake	U.S. Corps of Engineers	A 700 000 cubic dekametre (570,000 acre-foot multipurpose reservoir with the total capacity available for flood protection reservation	142 000 hectares (350,000 acres) of agricultural land and oil fields in Kern River area; serves to reduce flood damage to 105 000 hectares (260,000 acres) of cropland in Tulare Lake area	Provides protection against floods up to the 1-in-100-year or greater flood to the City of Bakersfield and to the old inundation area south to Kern Lake and west to Buena Vista Lake. Provides protection against the 1-in-25-year flood to the Kern River flood plain west of Bakersfield
Kern River	Kern River - California Aqueduct Intertie* (U.S. Army Corps of Engineers)	Kern County Water Agency	Sedimentation basin and gated interconnection structure to divert Kern River floodwater into the California Aqueduct	Helps reduce flood damage to 105 000 hectares (260,000 acres) of cropland in Tulare Lake area	Provides protection against snowmelt floods up to the 1-in-100-year flood

* Small project

All these measures have provided a high degree of flood protection in the area. Coordinated systems of reservoirs and levees have been especially effective in preventing widespread flooding and flood damage.

Water is released from flood storage dams to maintain riparian flows and to eliminate scouring flows. Without channel maintenance, these low flow releases have led to substantial riparian vegetative growth and silting that has diminished channel capacity. The Tule River below Success Dam is a notable example of this situation. But the removal of the riparian vegetative growth to restore channel capacity would directly conflict with fish and wildlife interests and cause maintenance expense.

In recent years, operation of certain flood reservoirs has demonstrated a need for additional flood storage. Reservoirs on minor streams east of the Fresno-Clovis metroplitan area and on the Kaweah and Tule Rivers fall into this category. Throughout the area, uncontrolled local runoff from minor watersheds and from certain urban and agricultural areas causes significant flood damage. Flooding on the valley floor is compounded by land-leveling practices that obliterate channels and by downhill row irrigation practices that promote runoff. In some areas, where floodwaters enter irrigation canals, urban flooding may result from overtopping or failure of canal levees. This situation occurs in the City of Fresno during major flooding events.

Although the Tulare Basin is generally well protected against inundation, flood problems still exist in some areas. Flooding adjacent to certain rivers damages agricultural lands and urban properties. Such problems are encountered along the Kings, Kaweah, Tule, and Kern Rivers; Caliente and Poso Creeks; and the Westside Stream Groups. On the valley floor, streambank erosion is a serious problem in many places. Upstream sheet erosion constantly threatens steeper lands. To protect these areas, additional flood protection measures are needed.

Information on flood protection projects which have been constructed by federal agencies is presented in Table 13. Other reservoirs that provide incidental flood storage are:

Reservoir	Stream	Operating Agency
Courtright	Helms Creek	Pacific Gas & Electric Co.
Wishon	North Fork Kings River	Pacific Gas & Electric Co.

Nonstructural Flood Management

Countywide flood plain zoning ordinances have been adopted by Tulare and Kern Counties and have been applied to specific flood plains. However, the Reclamation Board has adopted designated floodways on the lower Kings River and portions of the Tule, Kaweah, and Kern Rivers, and Porter Slough. The Board, in cooperation with Fresno, Kings, Tulare, and Kern Counties, and the Kings River Conservation District, is effecting a form of flood plain management by requiring an approved application for conforming uses in a designated floodway.

Through the efforts of the National Flood Insurance Program, flood-hazard areas in the basin are being identified. All counties and all cities subject to flooding are in the emergency phase of the program. Under the emergency phase, incompatible developments on the flood plains are being restricted by open space, health, and subdivision ordinances, and selective issuance of building permits. Numerous local jurisdictions have appealed the flood-hazard areas shown on the Flood Hazard Boundary Maps on the basis that the flood-hazard areas are not realistic. The Federal Emergency Management Agency Office has withdrawn many of these maps for further study and revision. Other jurisdictions may likewise appeal their maps and some have reluctantly accepted what they consider to be unrealistic maps without appeal.

Problems with inaccurate maps will lessen as communities shift from the emergency to regular phase of the program. The rate maps which characterize the regular program are the products of comprehensive engineering studies which are reviewed by community officials prior to becoming effective.

There are only a few specific regulated flood-hazard areas in the Tulare Basin. The methods presently used by local governments to implement flood plain management are presented in Table 14.

Table 14: REGULATED FLOODWAYS IN THE TULARE BASIN HYDROLOGIC STUDY AREA

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
State Reclamation Board	Designated floodway	Kern River - Isabella Dam to Tulare Lake	Urban, industrial, agricultural	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Tule River - Success Dam to Road 192	Urban, industrial, agricultural	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Porter Slough - Tule River to Road 192	Urban, industrial, agricultural	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Kings River - Piedra to Tulare Lake	Urban, industrial, agricultural	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Kaweah River - Three River Area	Urban	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
State Reclamation Board	Designated floodway	Tule River Springville Area	Urban	Adequate regulation and enforcement	Information on eligibility for flood insurance - see data for counties and cities
Fresno County	Flood-prone areas provisions of ordinance code of Fresno County; open conservation district provisions of county zoning ordinance, subdivision ordinance, building code	Flood-prone areas as delineated on maps of historical flooding; maps in U.S. Corps of Engineers Flood Plain Information Reports; and maps prepared under Federal Flood Insurance Program	Urban, industrial, agricultural	Accurate maps of areas subject to flooding from 1-in-100-year flood with flood water surface elevations	Yes
Clovis	Building permit and subdivision proposal review	Floodways of Pup and Dry Creeks within city limits	Urban, industrial	Realistic delineations of flood-hazard from 1-in-100-year flood	Yes
Coalinga	Building permit review; open space zoning	Floodways of Warthan and Los Gatos Creeks within city limits	Urban, industrial		Yes
Fowler	Building permit review	Areas of local ponding	Urban	Realistic delineation of flood-hazard	Yes

Table 14: REGULATED FLOODWAYS IN THE TULARE BASIN HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Fresno	**Flood plain zoning ordinance**	Floodways of Herndon Canal and Fancher Creeks within city limits	Urban, industrial		Yes
Huron	**Building permit review**	Floodway of Los Gatos Creek within city limits	Urban		Yes
Kerman	**Local drainage problems only**				No
Kingsburg	**City has no flooding problems**				Yes
Orange Cove	**Building permit and subdivision proposal review**	Floodways of Wooten Creek and unnamed creek within city limits	Urban, agricultural	Realistic delineation of flood-hazard from 1-in-100-year flood	Yes
Parlier	Building permit and subdivision proposal review	Areas of local ponding	Urban		Yes
Reedley	Building permit and subdivision proposal review	Small, undeveloped area adjacent to Kings River	Agricultural		Yes
Sanger	Building permit review	Two small areas of local ponding	Urban		Yes
San Joaquin	Local drainage problems only				Yes
Selma	Local drainage problems only - in process of being remedied				No
<u>Tulare County</u>	Flood plain zoning regulations of county zoning ordinance, channel maintenance ordinance, subdivision ordinance, building permit process	Flood plain zoning regulations have to date been applied only to easements and right of way needed for Stone Corral watershed protection project; other means listed are utilized to regulate development in other flood-prone areas of county	Urban, industrial, agricultural	Adoption for zoning for specific flood-hazard areas	Yes
Dinuba	Building permit review	Floodways of Orange Cove Stream Group within city limits	Urban		Yes
Exeter	Building permit review	Floodways of Yokohl and Mehrten Creeks within city limits	Urban, industrial	Adequate information relating to flood-hazard, depth of inundation, etc.	Yes
Farmersville	Building permit review	Short reach of Deep Creek within city limits	Urban	Adequate information relating to flood-hazard, depth of inundation etc.	Yes
Lindsay	Building permit system and site plan review	Floodway of Lewis Creek within city limits	Urban	Adequate information relating to flood-hazard depth of inundation, etc.	Yes
Porterville	Building permit review	Floodways of small, unnamed foothill drainages	Urban	Realistic delineation of flood-hazard	Yes
Tulare	Public park and open space zoning	Public park area along Elk Bayou	Public recreation		Yes
Visalia	Flood plain zoning ordinance	Floodways of Mill and Packwood Creeks within city limits	Urban		Yes

Table 14: REGULATED FLOODWAYS IN THE TULARE BASIN HYDROLOGIC STUDY AREA (Cont'd)

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Woodlake	Building permit review. Exclusion of some flood areas to future development	Floodway of Antelope Creek within city limits	Urban	Realistic delineation of flood-hazard; information as to depth of inundation	Yes
Kings County	Building permit procedures and environmental review. County preparing a flood management plan as a basis for the adoption of a flood plain zoning ordinance	Flood-hazard areas identified on Flood-Hazard Boundary Maps	Urban, industrial, agricultural	Adoption and enforcement of flood plain zoning ordinance	Yes
Corcoran	No flood hazard; exempted from National Flood Insurance Program				Yes
Hanford	No flood hazard				
Lemoore	Building permit review	Small areas designated as subject to flooding from breaching of local irrigation lateral	Industrial park area	Realistic delineation of flood hazard	Yes
Kern County	Flood plain zoning ordinance, subdivision proposal review, and building permit process. Development proposals are often referred to Kern County Water Agency for determination of extent of flood hazard	Flood plain zoning ordinance has been applied to areas along Erskine Creek in Lake Isabella area and Cuddy Creek in Frazier Park area; the other means listed are used to regulate development in other flood-prone areas of the county	Urban, industrial, agricultural	Obtain local acceptance of the adoption of zoning for specific flood-hazard areas	Yes
Arvin	None	None			No
Bakersfield	Municipal Code	City area adjacent to Kern River	Urban, industrial	Endorsement of flood plain regulation of municipal code	Yes
Delano	Building permit system	Areas of local ponding	Urban	Realistic delineation of flood-hazard areas	Yes
Maricopa	Building permit system, subdivision proposal review	Floodway of Bitterwater Creek within city limits	Urban	Unknown	Yes
McFarland	Subdivision proposal review and building permit process	Floodway of Poso Creek within city limits	Urban	Definitive delineation of flood-hazard area with floodwater surface elevations	Yes
Shafter	Building permit system	Industrial areas subject to local ponding	Urban	None	Yes
Taft	Review by Kern County Water Agency	Floodway of Sandy Creek within city limits	Urban	Unknown	Yes
Tehachapi	Building permit system, subdivision proposal review	City areas subject to flooding from local foothill drainages	Urban	Realistic delineation of flood-hazard areas; information on depth of inundation	Yes
Wasco	Building permit system	City areas subject to local ponding	Urban	Unknown	Yes

Flood Protection Needs

Most major Sierra Nevada streams have flood storage which provides protection from the 1-in-100-year flood. Short-range needs include (1) flood protection measures on Redbank and Fancher Creeks, and (2) minimum maintenance of the Tule River channel to provide for design flood releases below Success Reservoir, while preserving riparian habitat to the greatest extent possible.

Long-range needs include provision for (1) at least 1-in-100-year protection for existing urban areas, (2) flood protection for existing agricultural land to the extent feasible, and (3) assurances that future development on flood plains is compatible with flood risks.

The National Flood Insurance Program implementation requires detailed mapping of flood-hazard areas.

North Lahontan Hydrologic Study Area

The North Lahontan Hydrologic Study Area is located in northeastern California. It extends from the California-Oregon border on the north to Bridgeport in Mono County on the south, and from the crest of the Sierra Nevada, Cascade Range, and the Warner Mountains on the west to the California-Nevada border on the east. The area is shown on Figure 36.

The area comprises the California portions of the Susan, Truckee, Carson, and Walker River Basins, and Surprise Valley. These streams have no outlets to the sea; they terminate in lakes or playas. The Susan River flows generally southeast and terminates in Honey Lake. The Carson and Walker Rivers originate in California but terminate in the Carson Sink and Walker Lake, respectively, in Nevada. The major portion of the Truckee River System also originates in California and flows into Pyramid Lake in Nevada. Most of the streams draining Surprise Valley originate along the steep slopes of the Warner Mountains and discharge into Upper, Middle, and Lower Alkali Lakes.

The North Lahontan Area is periodically subjected to widespread storms from November through March. Floods are of three types. The first are those that occur during late fall and winter, primarily as a result of prolonged general rainstorms. The second occurs during spring and early summer, primarily as a result of melting snowpack deposited by cold winter storms in high areas of the Sierra Nevada. The third occurs during late spring through fall as a result of intense local rainstoms. The most significant flood-producing types are rainstorms that occur during fall and winter.

History of Flooding

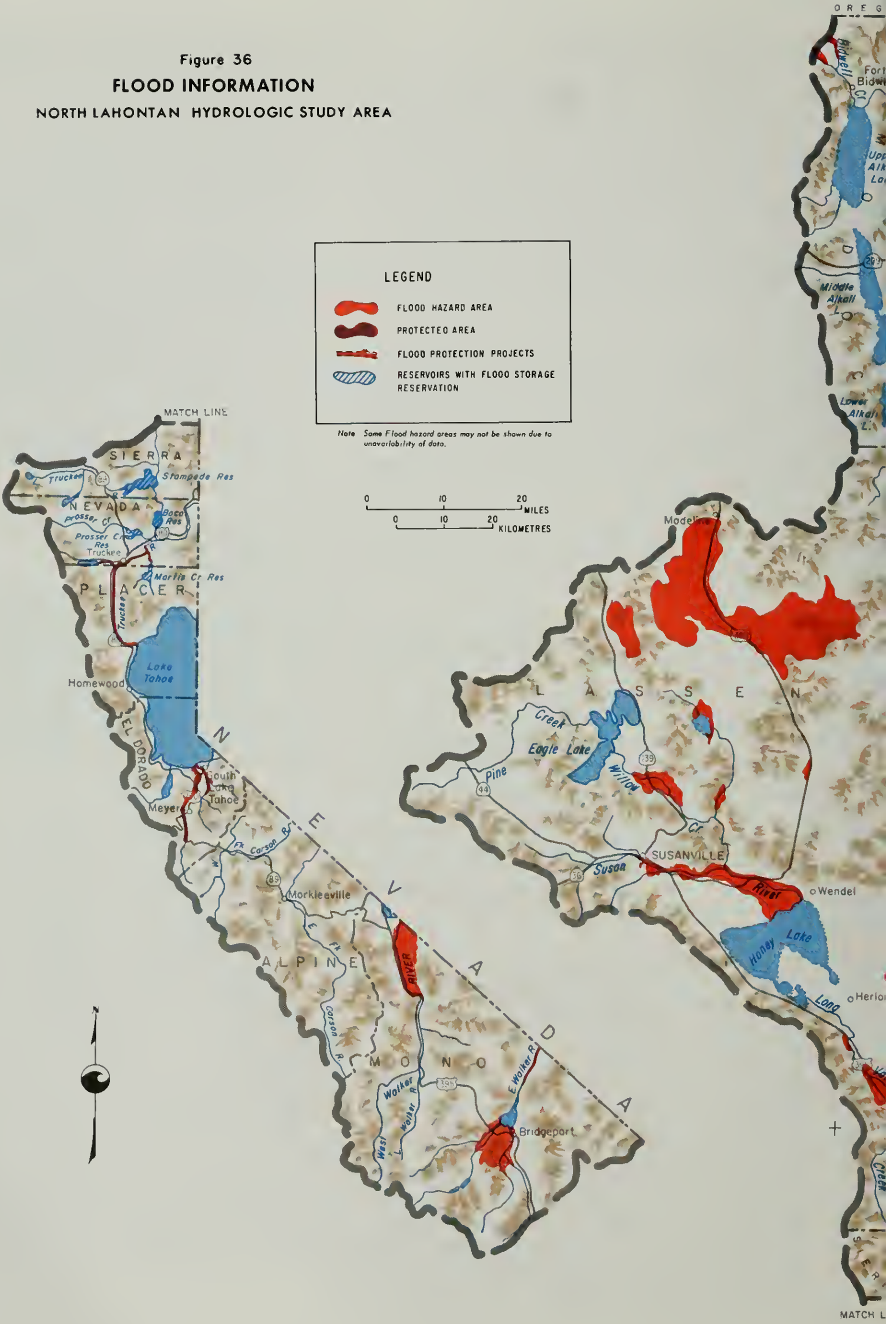
During 1950-51, intense winter rainstorms produced flooding on the Truckee, Carson, and Walker Rivers. The floods of 1962-63 caused extensive damage in the Carson River Basin. The most severe floods of record occurred in December 1964-January 1965, causing heavy damage in the Truckee River Basin.

Flood problems in the North Lahontan Area are evident. This area does not have a well-developed flood protection system; flooding often occurs along many streams, damaging agricultural and urban properties and causing channel and bank erosion. It is a serious problem along Bidwell Creek in Surprise Valley, and along the Susan, Truckee, Carson, and Walker Rivers. The Susan River watershed and the Surprise Valley streams are particularly critical areas of erosion. Erosion is also a serious problem in the Lake Tahoe area, where valuable creekside land is undergoing urban development. Projected population and economic growth will increase the potential for flood damage, particularly around Lake Tahoe, if adequate protection measures are not provided.

Figure 36

FLOOD INFORMATION

NORTH LAHONTAN HYDROLOGIC STUDY AREA



Flood Damage Prevention Facilities

Flood protection facilities in the North Lahontan Area include flood storage reservoirs, channel-modification projects, and watershed treatment. Forecasts of snowmelt inflows to Lake Tahoe are made by the California Cooperative Snow Surveys and are used to determine the amounts of water that must be released from the lake to prevent the water surface from exceeding the maximum elevation of 1 898.6 metres (6,229.1 feet) established by federal decree, and to minimize downstream damage.

During storm periods, inflow forecasts are made for Prosser and Boca Reservoirs, and river stage forecasts are made for the Truckee, Carson, and Walker Rivers by the Federal-State River Forecast Center.

Prosser Reservoir and Martis Creek Lake are the only reservoirs in this area operated primarily for flood storage. In addition, Stampede and Boca Reservoirs are operated for multipurpose uses with flood storage reservations. Information on these projects is presented in Table 15.

Table 15: FLOOD DAMAGE PREVENTION PROJECTS IN THE NORTH LAHONTAN HYDROLOGIC STUDY AREA

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Martis Creek	Martis Creek Lake (U.S. Army Corps of Engineers)	U.S. Corps of Engineers	The project provides a maximum storage capacity of 24 700 cubic dekametres (20,000 acre-feet) for flood protection	Martis Creek, Truckee River, and City of Reno	Contributes to protection for Reno, Nevada
Prosser Creek	Prosser Creek Reservoir (U.S. Water and Power Resources Service)	U.S. Water and Power Resources Service	The project provides a maximum storage capacity of 37 000 cubic dekametres (30,000 acre-feet) with a flood protection reservation of 25 000 dekametres (20,000 acre-feet)	Prosser Creek, Truckee River, and City of Reno	Contributes to protection for Reno, Nevada
Little Truckee River	Stampede Reservoir	U.S. Water and Power Resources Service	The project provides a maximum storage capacity of 27 000 cubic dekametres (22,000 acre-feet) for flood protection	Little Truckee River, Truckee River, and City of Reno	Contributes to protection for Reno, Nevada
Little Truckee River	Boca Reservoir	U.S. Water and Power Resources Service	The project provides a maximum storage capacity of 10 000 cubic dekametres (8,000 acre-feet) for flood protection	Little Truckee River, Truckee River, and City of Reno	Contributes to protection for Reno, Nevada

Other reservoirs providing incidental, but often significant, flood protection benefits are:

Reservoir	Stream	Constructing Agency or Operator
Bridgeport	East Walker River	Walker River Irrigation District
Lake Tahoe	Truckee River	Federal Court Watermaster

The projects described in Table 15 provide practical protection to the Truckee River Basin and the City of Reno. Channel project work in California includes the enlargement of the Truckee River channel downstream from the existing control structure at Lake Tahoe. This modification prevents the lake level from exceeding the 1 898.6-metre (6.229.1-foot) level. However, if excessively high releases are made, cabins along the Truckee River may be damaged.

Comprehensive studies have been undertaken by the Water and Power Resources Service to investigate the feasibility of multipurpose development plans that include flood storage features for the Carson and Walker River basins. Water resource developments in these basins are complex because the principal streamflows are generated in California and cause floods in both California and Nevada. Future flood protection would result if flood storage reservation is included in the following locations: Watasheamu Reservoir Project on the East Fork Carson River, Hope Valley Reservoir Project on the West Fork Carson River, and Pickle Meadow Reservoir Project on the West Walker River.

A comprehensive flood control investigation has been undertaken by the Corps of Engineers to develop a basinwide plan to reduce flood damage along the Truckee River, especially in the vicinity of Reno.

Nonstructural Flood Management

With the exception of the Lake Tahoe area, no nonstructural flood management measures are being implemented in the

EVEN HIGH IN THE MOUNTAINS floods may strike. Record-breaking floodflows of June 1969 eventually overtopped this homemade barrier on the Truckee River near Tahoe City. (Sacramento Bee Photo)

North Lahontan Area. Effective regulations are limited and the only consideration given to flood damage is remedial measures taken when flooding occurs. Therefore, development in flood-prone areas remains substantially unregulated, and local legislative bodies have placed a low priority in establishing meaningful floodway controls. Consideration of the National Flood Insurance Program has been minimal in the North Lahontan area, and most local jurisdictions have not attempted to participate in the program. Types of regulations and regulated floodways are presented in Table 16.

Table 16: REGULATED FLOODWAYS IN THE NORTH LAHONTAN HYDROLOGIC STUDY AREA

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Modoc County	Ordinance 236, two-zone floodway; uniform building code	None	None	Precise delineation of flood-hazard areas	Yes
Lassen County	None	None	None	Identification of flood-hazard areas	No
Susanville	None	None	None	Identification of flood-hazard areas	Yes
Sierra County	Building code	None	None	Codification and enforcement of regulations	No
Nevada County	Building code, subdivision ordinances	None	None	Codification and enforcement of regulations	Yes
Placer County	Placer County general plan, uniform building code, county setback and grading ordinance Truckee River zoning, Tahoe Regional Planning Agency land use ordinance	Truckee River, Martis Creek, and Tahoe Basin streams	Agricultural, urban, industrial, recreational, open space	Incentive to adopt and enforce regulations countywide	No
El Dorado County	Building code, subdivision ordinances	None	None	None	No
South Lake Tahoe	General plan, building code	None	None	None	Yes
Alpine County	None	None	None	None	No
Mono County	None	None	None	None, no flood problems evident	Yes

In general, building codes and subdivision ordinances have not been effective in controlling development in floodways. The California Environmental Quality Act of 1970 has some potential as a control device because of its provisions concerning the possible effects of future projects on the environment and the requirement to implement feasible mitigation measures.

The northern portion of the area, in Modoc, Lassen, and Sierra Counties, consists of several closed basins that contain numerous streams. The Susan River in the Honey Lake Basin is the largest. However, because agriculture is the dominant land use in the north, there is little need for nonstructural flood management, except in rural communities.

In the central portion of this study area, recreation is the major activity, particularly in the Lake Tahoe region, although agriculture is increasing in Mono County.

Placer County has made the only effective attempt to control development in flood-hazard areas along the Truckee River. It has passed ordinances to ban building in the Truckee River channel between Tahoe City and Squaw Creek, which are depicted as areas subjected to inundation in Flood Plain Information Reports prepared by the Corps of Engineers.

The only other attempt to control floodways is by the California Tahoe Regional Planning Agency. Its land use ordinance subdivision-and-grading restrictions prohibit the filling, grading, or construction requiring filling or grading of wetlands, stream environmental zones, or flood plains. The State Water Resources Control Board is developing a plan to control erosion at Lake Tahoe.

Flood Protection Needs

An effective nonstructural flood management program needs to be extended throughout the entire North Lahontan Area. Flood-hazard areas have been identified in the Lake Tahoe and Truckee River region in a Corps of Engineers' Flood Plain Information Report, and other flood-hazard areas are expected to be identified through the National Flood Insurance Program.

The Corps of Engineers has studied the feasibility of a multipurpose plan to reduce flood damage in the Carson River Basin. Water resources problems in the basin are complicated because California is the principal source of stream flow, and the major areas of use and flood damage are in Nevada.

The Corps of Engineers has studied the feasibility of a multipurpose plan to reduce flood damage along the West Walker River. In addition, the Water and Power Resources Service is preparing a feasibility report to develop the Walker River Basin. The plan includes a multipurpose reservoir at the Pickle Meadows site on the West Walker River which would substantially alleviate flood problems in the basin. However, channel modification work may also be required at selected locations along the river system.

South Lahontan Hydrologic Study Area

The South Lahontan Hydrologic Study Area is bounded by the Mono Lake Valley on the north, California-Nevada stateline on the east, the Northern Colorado Desert area on the south; and the ridges of the San Bernardino, San Gabriel, Tehachapi Mountains, and the Sierra Nevada on the west (Figures 37 and 38).

Principal streams in the area include the Mojave River, Big Rock Creek, Little Rock Wash, Amargosa River, Owens River, and Bishop Creek.

Major urban centers are Barstow, Bishop, Lancaster, Palmdale, California City, Ridgecrest, and Victorville. Estimated population in 1972 was 241,000. The economy of the area is based on agriculture. However, there are defense activities related to flight testing and research, as well as mining, manufacturing, and recreation, particularly in the Death Valley and the Mono Lake-Owens Valley areas. Flatwater recreational opportunities in the region are enhanced at Lake Silverwood and will be further enhanced with the development of facilities planned for Mojave River Dam.

Transportation facilities connecting cities and towns are well-developed Federal, State, and county roads and highways. Many desert and mountain areas have limited access by 4-wheel drive vehicles using dirt roads and trails, or no vehicular access at all. Two transcontinental railroads pass through the southern portion of the area. Feeder airline service is available.

History of Flooding

Because of its location on the east side of the Sierras, the South Lahontan Area has fewer storms than do most other parts of California. This rainshadow location, coupled with the presence of porous alluvial cones and streambeds typical of the area, lessens the chance of damaging floods. Those that do occur result from either of two types of storms: (1) an occasional winter storm lasting as long as four days and resulting in widespread precipitation, or (2) a convection storm (thunderstorm) with high-intensity, short-duration precipitation confined to a particular area, causing flash floods. Thunderstorms may occur any time from spring through fall.

Winter storms generally create the greatest flood damage and disruption of the area's economy. However, severe local damage may also be sustained when thunderstorms generate floods upstream of an urban development. No records of the magnitude of flow and damage exist for floods that occurred in the South Lahontan Area before 1938. Recent significant floods occurred in 1938, 1943, 1961, 1963, 1965, 1969, 1978, and 1980. Detailed flood-damage surveys have been made for some of these floods in the Mojave River Basin and vicinity. However, because of the sparse and scattered development, little data have been collected elsewhere.

Records of the U. S. Geological Survey indicate that during the March 1938 flood the 1-in-100-year frequency floodflow was exceeded in Deep Creek near Hesperia, in West Fork of the Mojave River, in Big Rock Creek near Valyermo, and in Little Rock Creek near Little Rock. Six persons died, and the inundation of approximately 24 000 hectares (60,000 acres) caused $2.5 million

THE NORMALLY DRY MOJAVE RIVER turns into a turbulent, swift-flowing stream following desert cloudbursts. These storms often seem to strike without warning, creating great peril to travelers on the desert. (Photo courtesy The Daily Press, Victorville)

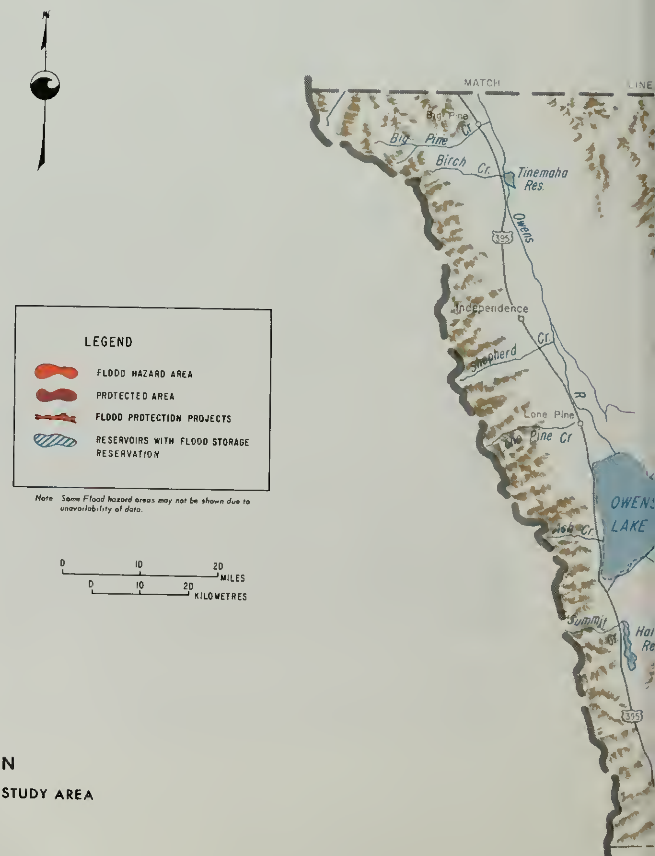
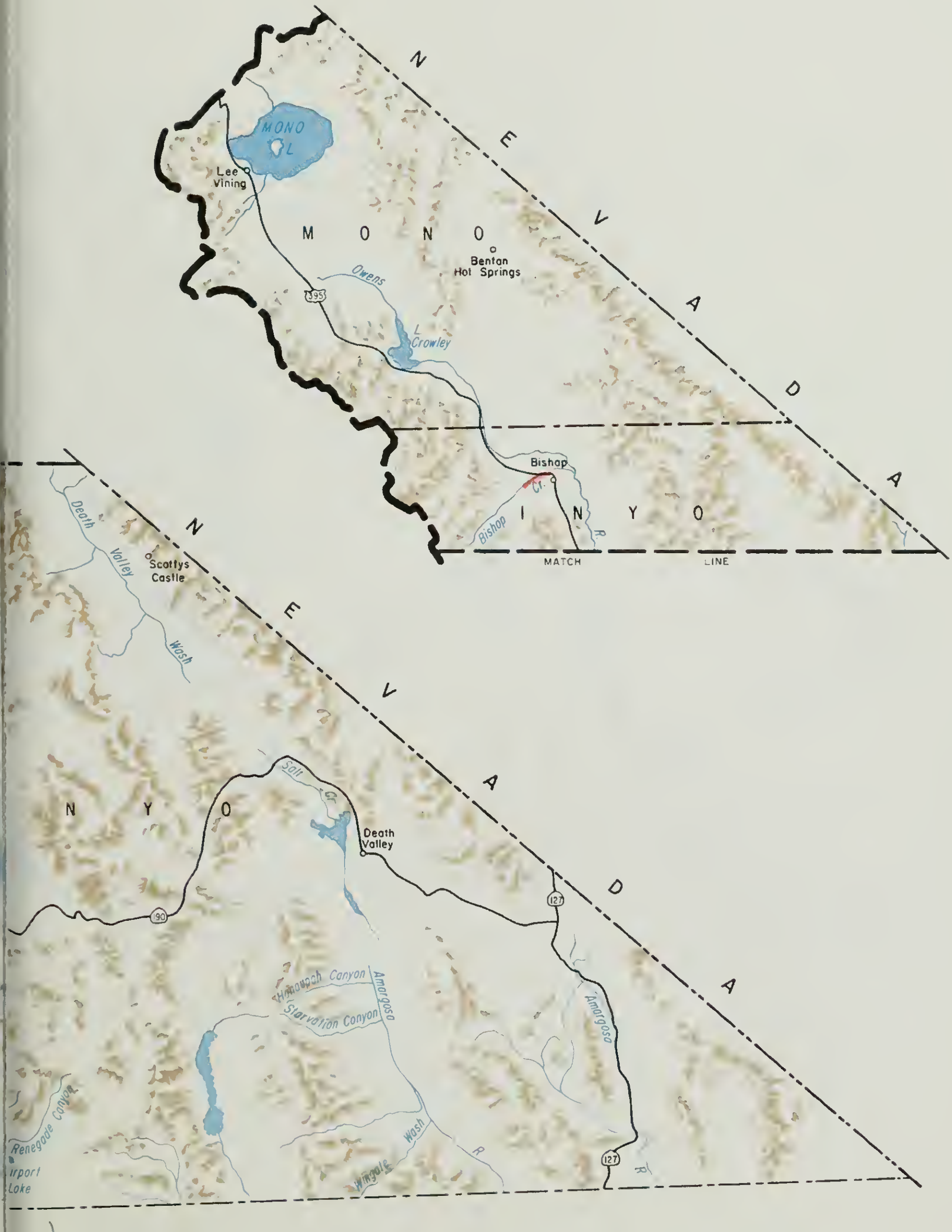


Figure 37
FLOOD INFORMATION
SOUTH LAHONTAN HYDROLOGIC STUDY AREA
NORTHERN PORTION


NEVADA
MONO L.
Lee Vining
MONO
Benton Hot Springs
Owens
395
L. Crowley
Bishop
Cr.
Bishop
INYO
R.
MATCH LINE
NEVADA
Death Valley
Scottys Castle
Wash
INYO
Salt Cr.
Death Valley
190
127
Hanaupah Canyon
Amargosa
Starvation Canyon
Amargosa
Renegade Canyon
Wingate Wash
R.
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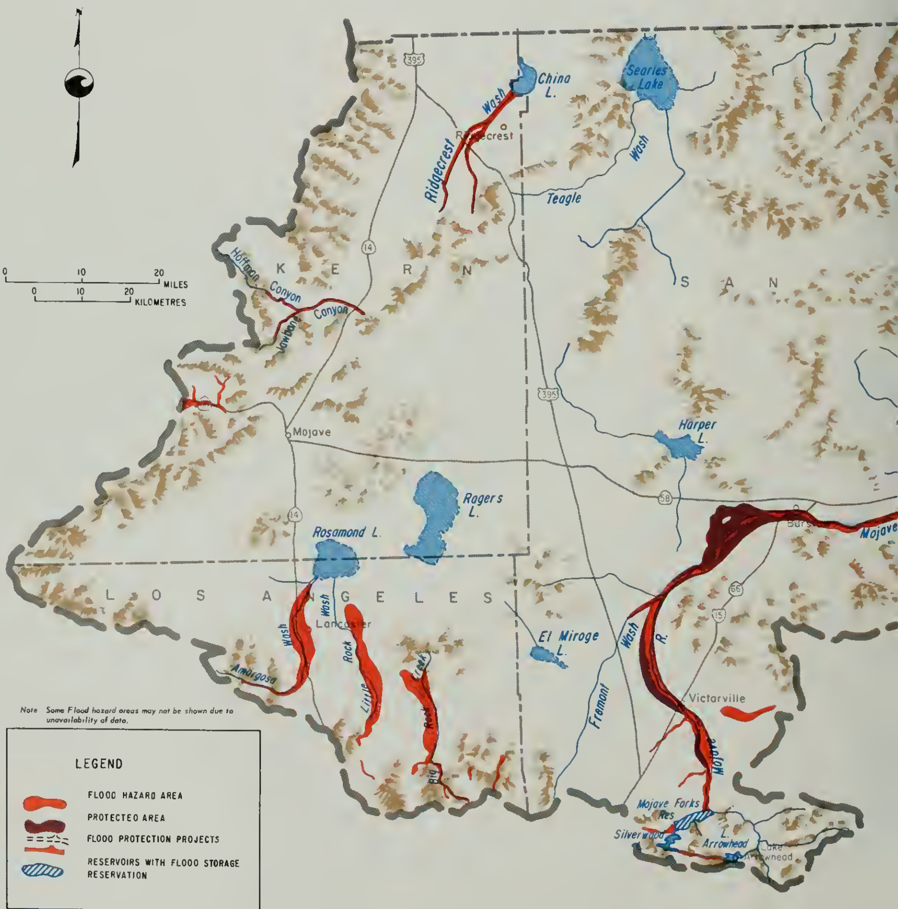
0 10 20 MILES
0 10 20 KILOMETRES
K E R N
S A N
L O S A N G E L E S
China L.
Searles Lake
Ridgecrest Wash
Ridgecrest
Teagle Wash
Hoffman Canyon
Jawbone Canyon
Mojave
Rogers L.
Rosamond L.
Harper L.
El Miroge L.
Lancaster
Amargosa Wash
Little Rock Wash
Big Rock Creek
Fremont Wash
Mojave R.
Victorville
Mojave Forks Res.
Silverwood
L. Arrowhead
Lake Arrowhead
395
14
58
66
15
Note Some Flood hazard areas may not be shown due to unavailability of data.
LEGEND
FLOOD HAZARD AREA
PROTECTED AREA
FLOOD PROTECTION PROJECTS
RESERVOIRS WITH FLOOD STORAGE RESERVATION

Figure 38

FLOOD INFORMATION

SOUTH LAHONTAN HYDROLOGIC STUDY-AREA
SOUTHERN PORTION

in damage. About 80 percent of the damage occurred in urban areas, and the remainder in agricultural areas. These percentages also hold true for the January 1943 flood, in which inundation of 14 000 hectares (35,000 acres) caused more than $200,000 in damage. Extensive flood damage estimated at $11.4 million in the Mojave River Basin and $2.2 million in Antelope Valley resulted from the January and February 1969 floods.

Erosion is a problem in the South Lahontan Area. Because of its arid climate and high-intensity rain, there is no protective vegetative cover and continuous wind erosion and intermittent water erosion take a heavy toll of the topsoil throughout the area. Some land treatment measures have been implemented in the Antelope Valley, where limited irrigation water is available.

Flood Damage Prevention Facilities

Until recently, development in this area has been so sparse that few major flood protection modifications have been warranted. However, there are now two flood protection projects: the Mojave River Dam and the Oro Grande Wash Channel in Victorville. Both were built by the Corps of Engineers.

The Mojave River Dam, a multipurpose project, was completed in 1971. The dam and reservoir protect the cities of Barstow and Victorville from floods, conserve water by reducing large storm flows to sustained reservoir releases for recharging downstream ground water basins, and provide recreational facilities. The project cost $17.6 million, with local interests contributing $250,000

The Oro Grande Wash Channel Project was authorized in 1967 and completed in 1969. A small project, it consists of inlet levees and a concrete channel extending from the southeast limits of Victorville to the Mojave River. About 655 m (2,150 ft) is open channel and 1 300 m (4,290 ft) is reinforced concrete box culvert. Cost of the project was $1,500,000, of which $500,000 was provided by local interests.

Table 17 describes flood protection projects in the area.

Table 17: FLOOD DAMAGE PREVENTION PROJECTS IN THE SOUTH LAHONTAN HYDROLOGIC STUDY AREA

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Mojave River	Mojave River Dam (U.S. Army Corps of Engineers)	U.S. Army Corps of Engineers	The project consists of a 111 000 cubic dekametre (90,000 acre-foot) reservoir which provides flood protection and incidental water conservation	City of Victorville	Standard project flood at the damsite
Oro Grande Wash	*Oro Grande Wash (U.S. Army Corps of Engineers)	San Bernardino County Flood Control District	The project consists of inlet levees and 2.0 kilometres (1.25 miles) of concrete channel	City of Victorville	1-in-100-year flood

* Small project

Nonstructural Flood Management

In 1966, San Bernardino County adopted an ordinance to regulate development in areas considered to be prone to floods. These areas are portions of Swarthout Creek; Mojave River and Forks Reservoir; Silverwood, Green Valley, Big Bear, Baldwin, Erwin Lakes; and Rathbone Creek. The September 1976 report entitled "Wrightwood Debris and Mud Flow Investigation", by the Department of Water Resources, also indicates that zoning might be advisable for the Wrightwood area in San Bernardino County. In 1974, Kern County adopted general flood plain zoning ordinances, establishing a review system for building permits.

Table 18 presents the methods adopted and enforced by local governments to implement flood plain regulations.

Table 18: REGULATED FLOODWAYS IN THE SOUTH LAHONTAN HYDROLOGIC STUDY AREA

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
Los Angeles County	Building and sub-division codes	Antelope Valley Basin	Urban, industrial, agricultural	Identification of flood-hazard areas	Yes
Palmdale	City ordinance and county building codes	Anaverde and Little Rock Creeks	Urban, agricultural	Identification of flood-hazard areas and adoption of flood plain zoning	Yes
San Bernardino County	Ordinance	Mojave River, Mojave Forks Reservoir and Lake Arrowhead and fringe areas	Urban, industrial, agricultural	Identification of flood-hazard areas	Yes
Adelanto	None	None	None	None, no flood problems evident	Yes
Barstow	None	None	None	None	No
Victorville	Ordinance	Oro Grande Wash	Urban, industrial, agricultural	Identification of flood-hazard areas	Yes
Kern County	Ordinance, building permits	None	Urban, agricultural	Identification of flood-hazards	Yes
Ridgecrest	Ordinance	Vicinity of Ridgecrest	Urban	Identification of flood-hazard areas	Yes
Inyo County	Ordinance	None	Urban, agricultural	Identification of flood-hazard areas	Yes
Bishop	Ordinance	Bishop Creek	Urban	None, no additional flood problems evident	Yes
Mono County	None	None	None	None, no flood problems evident	Yes

Flood Protection Needs

The Corps has just completed a draft survey report for streams flowing through Antelope Valley in Los Angeles and Kern Counties. The Corps found that no structural measures can be economically justified at this time. Recognizing the lack of economic justification for structural works in the areas, the flood damage can be minimized by non-structural measures such as floodproofing and flood plain management. To reduce future flood damage and hazard, local interests should utilize to the maximum extent possible the flood plain management and the flood insurance programs.

Although flood problems in the area will be somewhat alleviated by existing flood protection projects, additional levee and channel projects and detention structures may be required to regulate storm flows and provide sufficient flow-carrying capacities in developed local areas. Flood plain management must also become an important part of community planning in the South Lahontan Area.

Plans for flood protection projects should provide for maximum possible conservation to replenish ground water basins currently being overdrawn to meet agricultural and urban needs in Antelope Valley and the Mojave River Basin. The water supply of these areas is being augmented by the State Water Project. The need to protect the fragile desert and mountain environments of the territory is of paramount concern to planners.

Flood problems are expected to increase if urban centers and agriculture continue to expand into unprotected flood plains or if development is not controlled by nonstructural flood management. For example, these problems would be expected along the desert slopes of the Sierra Nevada and the adjoining desert land along Highway 395. Damage is compounded by the deposition of sediment orginating upstream where the steeper gradient encourages erosion. Developments taking place in dry lake beds which are occasionally flooded also present problems.

Because the area is still sparsely developed, nonstructural flood management is the most practical method of dealing with flooding. However, land use in the areas is rapidly changing. Agricultural and open-space lands are being developed for residential, commercial, and industrial uses. More detailed flood mapping is needed to implement effective, nonstructural flood management practices. In addition, the public should be informed of flood hazards. If this information is not provided, the residents could react unfavorably to the cost of structural flood protection measures or the uncertainty of floodway regulations.

Routine flood forecasting is considered impractical in the South Lahontan Area because floods are generally produced by thunderstorms which cause almost instantaneous rainfall over isolated watersheds. Runoff from this type of storm can be devastating for a short period of time. However, the National Weather Service distributes flash flood warnings when areawide internal storm patterns or thunderstorm activity warrants. In addition, the counties, particularly San Bernardino County, have organized flood control districts and emergency operations programs. During a flood alert, these programs provide technical aid and advice on flood-fighting preparation.

Colorado Desert Hydrologic Study Area

The Colorado Desert Hydrologic Study Area is bounded on the north by the South Lahontan Hydrologic Study Area, on the east by the California-Nevada stateline and the Colorado River, on the south by the Mexican border, and on the west by the crest of the Coast Range in the eastern part of San Diego County and the San Bernardino and San Jacinto Mountains. Flood information for the areas is presented on Figure 39.

This areas includes a number of closed basins, as well as lands which drain into the Colorado River. Its principal streams are the Whitewater, Colorado, New, and Alamo Rivers. All except the Colorado River drain into the Salton Sea. The New and Alamo Rivers are old Colorado River overflow channels that once flowed north from Mexico to the Salton Sea. They now carry mostly waste and drainge water from irrigated lands in the Imperial Valley and the Mexicali Valley in Mexico. Streams which are tributary to the Colorado River are small; none has a perennial flow.

The largest urban centers are Banning, Blythe, Brawley, Calexico, Calipatria, Coachella, El Centro, Holtville, Imperial, Indio, Needles, and Palm Springs. The estimated population in 1972 was 231,300.

The economy of the Colorado Desert Area is based principally upon agricultural development in the Imperial, Coachella, and Palo Verde Valleys. Extensive areas have been developed into productive farmlands with surface water imported from the Colorado River and ground water pumped in the Coachella Valley. Irrigation has transformed this desert into one of the country's outstanding agricultural areas. The long growing season permits as many as three crops in two years in some localities. The mild, dry winter climate makes the desert an outstanding resort area. Palm Springs is one of the most popular desert winter resorts in the United States. Desert Hot Springs, Palm Desert, and Twentynine Palms are also popular.

Highly developed Federal and State highways and county roads provide ready access to the developing urban centers and the agricultural regions in the areas, although most of the desert has only limited highway access. The area is also served by railroad and feeder and commuter airlines.

History of Flooding

Very little streamflow occurs in the Colorado Desert Area, except at high elevations during winter and spring and in the desert valleys during and immediately following rainstorms. Flood damage results from two types of storms: (1) those originating in the north Pacific Ocean, which occasionally last as long as four days and produce rainfall over large areas, and (2) those accompanying tropical storms from the west coast of Mexico that move north of their usual path and bring intense rainfall into Southern California.

Thunderstorms may also cause short-duration, high-intensity rainfall over small areas, either independent of, or in conjunction with, general storms. This type of storm frequently results in a flash flood. As urban and commercial development continues in the desert, flood damage can be expected to increase.

AWESOME FLASH FLOODS hit barren country near Cabazon in Riverside County when heavy rains hit the area. Here, road traffic is halted by flood-flows from the usually dry Noble and San Gorgonio Creeks in January 1969. (U. S. Army Corps of Engineers, Los Angeles District, Photo)

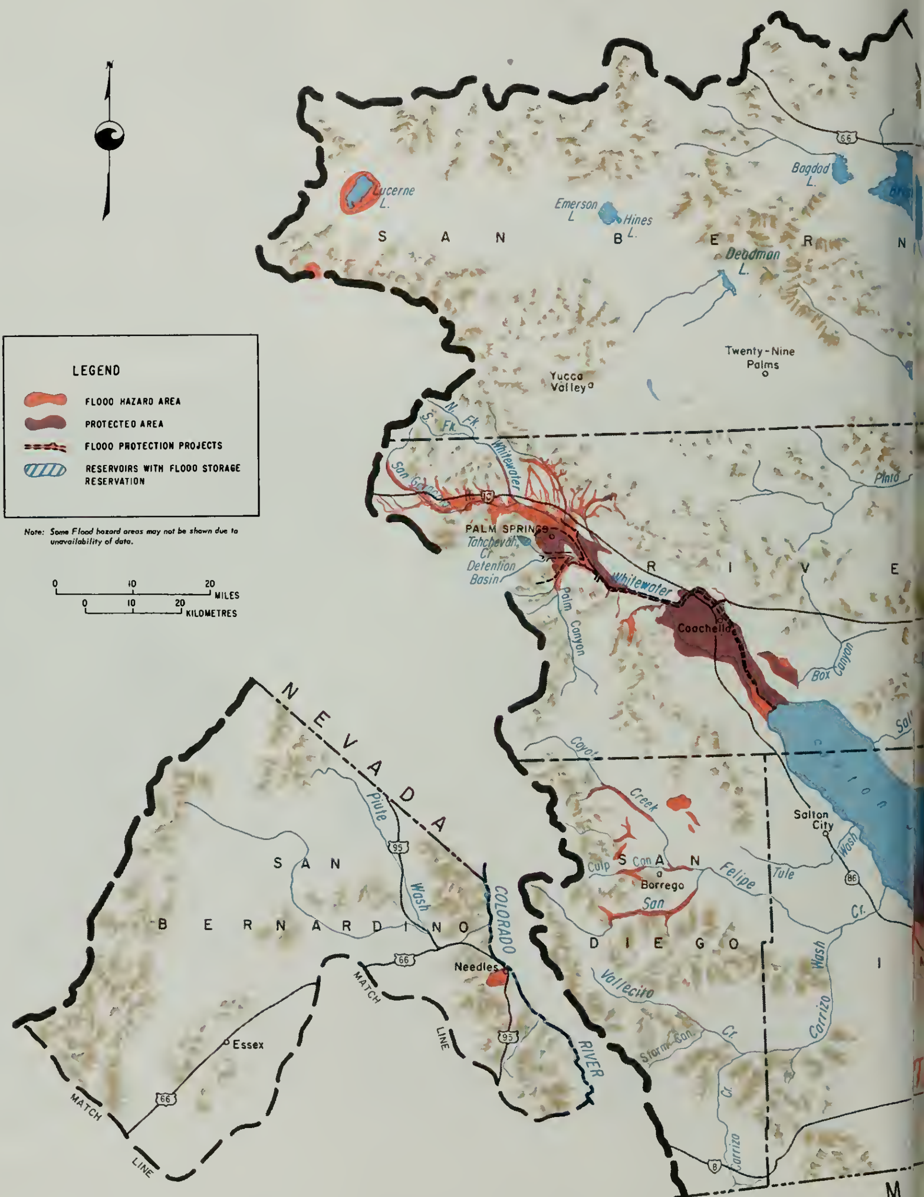
LEGEND
FLOOD HAZARD AREA
PROTECTED AREA
FLOOD PROTECTION PROJECTS
RESERVOIRS WITH FLOOD STORAGE RESERVATION
Note: Some Flood hazard areas may not be shown due to unavailability of data.
0 10 20 MILES
0 10 20 KILOMETRES
N
Lucerne L.
Emerson L.
Hines L.
Bagdad L.
Deadman L.
S A N B E R N
Twenty-Nine Palms
Yucca Valley
N. Fk.
S. Fk.
Whitewater
San Gorgonio
PALM SPRINGS
Tahchevah Cr Detention Basin
Palm Canyon
Whitewater
R I V E
Coachella
Box Canyon
Pinto
Salton City
Coyote
Creek
Culp Can.
S A N
Felipe
Borrego
San
D I E G O
Tule
Wash
Cr.
Vallecito
Storm Can.
Cr.
Carrizo
Wash
Carrizo
Cr.
N E V A D A
Piute
Wash
S A N
B E R N A R D I N O
COLORADO
RIVER
Needles
Essex
MATCH LINE
MATCH LINE
M

Figure 39

FLOOD INFORMATION

COLORADO DESERT HYDROLOGIC STUDY AREA

Damaging floods occurred in the Colorado Desert Area in 1916, 1927, 1938, 1961, 1965, 1966, 1969, 1976, 1977, 1979, and 1980. The November 1965 flood in the Whitewater River Basin resulted in the death of three persons and damage exceeding $3 million. the January-February flood of 1969 caused flood damage estimated at $11 million in the Whitewater River Basin. Flooding caused extensive damage in the Palm Desert, Rancho Mirage, Indian Wells, Imperial, Coachella, and Palo Verde Valleys in September 1976. Heavy rains accompanied by strong winds inflicted an estimated $62.6 million in damage to residential, commercial, and agricultural areas and closed several highways. Flow from McCoy Wash in Palo Verde Valley inundated agricultural land, causing an estimated $12 million crop loss.

Records of the U. S. Geological Survey indicate that the Whitewater River exceeded the estimated 1-in-100-year frequency flood at Whitewater in March 1938. The November 1965 flood approached the January-February floods of 1969 and was well below the 1-in-100-year frequency. The 1-in-100-year frequency was exceeded in Lone Creek near Desert Hot Springs in August 1963. Local residents in the Palo Verde Valley estimate that the September 1976 flood was the worst since 1938.

Flood Damage Prevention Facilities

Flood protection facilities in the Colorado Desert Area include flood storage reservoirs, floodwater percolation basins, and levees and channels, most of which protect against a 1-in-10-year to 1-in-50-year flood; few areas have 1-in-100-year protection. Major flood damage protection projects have been constructed by the Corps of Engineers, the Riverside County Flood Control and Water Conservation District, and the Coachella Valley County Water District. Table 19 presents information on projects in the area.

There are two flood storage reservoirs in the Colorado Desert Area. The Tahchevah Creek Detention Basin and Channel Modification Project, completed by the Corps of Engineers in 1965 at a cost of $2.8 million, consists of a detention reservoir and channel modifications on Tahchevah Creek in the City of Palm Springs. Operation of the detention reservoir reduces the peak flow which then is carried by the modified channel through Palm Springs and part of the Caliente Indian Reservation. The project has prevented $430,000 in damage. Wide Canyon Dam was constructed by the Riverside County Flood Control and Water Conservation District in West Wide Canyon in 1968. With a storage capacity of 1 264 cubic dekametres (1,025 acre-feet) it protects property near Cathedral City.

The Whitewater River Storm Channel and Levee System, constructed by the Coachella Valley County Water District, includes realignment and channelization of the river and construction of levees. It extends from Windy Point, just east of Palm Springs, approximately 80 kilometres (50 miles) to the Salton Sea. Due to the steepness of a reach of the channel, erosion has been a problem. Drop structures are being installed to decrease the flow velocity. Percolation basins are also a by-product of the project. The Whitewater River Storm Channel collects water from San Gorgonio Pass and Whitewater, Snow, Falls, Chino, Tahchevah, Tahquitz, Murray, Palm, Cathedral, Magnesia, and Deep Canyons. Flows from many smaller canyons in the southern portion of Coachella Valley also feed into the Whitewater River Storm Channel and Levee System.

Small projects of the Corps of Engineers in the region are:

The Banning Levee Project, completed in 1965 at a cost of $120,000, consisting of a revetted levee along the south side of San Gorgonio River at Banning. It has prevented flood damage estimated at $145,000.

Table 19: FLOOD DAMAGE PREVENTION PROJECTS IN THE COLORADO DESERT HYDROLOGIC STUDY AREA

Stream	Flood Project	Maintaining Agency	Project Description	Area Protected	Level of Protection
Tahchevah Creek	Tahchevah Creek Detention Basin and Channel Improvement (U.S. Army Corps Engineers)	Riverside County Flood Control and Water Conservation District	The project consists of a 1 170 cubic dekametres (945 acre-feet) detention reservoir, channel modifications underground conduit, and modified channel	City of Palm Springs and part of the Caliente Indian Reservation	Standard project flood
San Gorgonio River	*Banning Levee (U.S. Army Corps of Engineers)	Riverside County Flood Control and Water Conservation District	Improvement of about 0.48 kilometres (0.3 miles) of revetted levee along right bank of San Gorgonio River	City of Banning	Standard project flood
Chino Canyon	*Chino Canyon Improvements (U.S. Army Corps of Engineers)	Riverside County Flood Control and Water Conservation District	The project consists of 5.5 kilometres (3.4 miles) of levee, 2.6 kilometres (1.6 miles) of excavated channel and 11 directional groins	City of Palm Springs	Standard project flood
"S" Street and Sidewinder Wash	*Needles, San Bernardino County (U.S. Army Corps of Engineers)	San Bernardino County Flood Control District	The project includes two inlet levees, a rectangular concrete channel, an unlined trapezoidal diversion channel, a diversion levee, and two deflection levees	City of Needles	Standard project flood
Quail Wash	*Quail Wash Levee (U.S. Army Corps of Engineers)	San Bernardino County Flood Control District	The project includes 0.8 kilometres (0.5 miles) grouted stone revetment, an access road, and access ramps	Community of Joshua Tree	Standard project flood
West Wide Canyon	Wide Canyon Dam (Riverside County Flood Control and Water Conservation District)	Riverside County Flood Control and Water Conservation District	Provides 1 260 cubic dekametres (1,025 acre-feet) flood protection reservation	Property near Cathedral City	Standard project flood
Whitewater River	Whitewater River Storm Channel (Coachella Valley County Water District)	Coachella Valley County Water District	80 kilometres (50 miles) of realignment channelization and levees along Whitewater River	Agricultural land and cities of Palm Springs, Cathedral City, Rancho Mirage, Palm Desert, Indian Wells, La Quinta, Indio, Coachella, Thermal, and Mecca	Under investigation by U.S. Army Corps of Engineers

* Small project

The Chino Canyon Modifications, completed in 1972, consisting of a levee, an excavated channel, and 11 direction groins. These cost $1,130,000. These modifications are situated on the alluvial cone of the Chino Canyon and extend along the west bank of the Whitewater River, protecting Palm Springs.

The Needles, San Bernardino County, Project, completed in 1973, consisting of two inlet levees, a concrete channel, an unlined diversion channel, and levees. The project, which cost $1.7 million, protects property on the "S" Street and Sidewinder Washes.

The Quail Wash Levee, authorized and completed in 1961, which is designed to prevent Quail Wash floodwater from flowing west through the community of Joshua Tree. Cost of the project was $250,000.

The proposed Tahquitz Creek Project which has been authorized and for which preconstruction planning is completed. This project includes a debris basin and channel within the city limits of Palm Springs. The $12.7 million proposed project would protect an overflow area of approximately 486 hectares (1,200 acres), including valuable residential, business, and public property in Palm Springs. However, the project has been put on an inactive status by the Corps of Engineers because the debris basin is Tribal Council land containing archeological resources. The Riverside County Flood Control and Water Conservation District is working with the Tribal Council to develop a compromise solution to the flood problem.

Nonstructural Flood Management

Riverside County has attempted to adopt and enforce regulations on development in flood-hazard areas. In 1955, the county adopted an ordinance requiring that all subdivisions be protected from a 1-in-100-year flood. Also, the Riverside County Flood Control and Water Conservation District has proposed floodproofing guidelines to the County Planning Commission that would limit the density of development and elevations of building pads on floodhazard areas. Unfortunately, inadequate mapping has hindered the implementation of these guidelines.

San Bernardino County has similar regulations. It adopted an ordinance to prohibit development on flood plains and to keep developments on fringes above design flood elevations.

Table 20 presents information on the type of flood plain management adopted and areas regulated by county and city governments in the area.

Flood Protection Needs

The average annual cost of flood damage is estimated at $11 million (based on 1965 prices). This amount indicates that flood protection measures may be required in local urban areas. Additional measures are needed to provide at least 1-in-100-year flood protection in urban areas and 1-in-50-year flood protection in some agricultural areas.

To meet these needs, the Corps of Engineers will, when funds are available, begin to study streams in San Diego and Imperial Counties which flow into the Salton Sea to determine if it is advisable to provide flood storage, water conservation, and related modifications. Construction of detention and debris dams, diversion levees, and channel modifications will be considered, along with flood plain management.

An investigation of the Whitewater River by the Corps of Engineers, suspended several times since its authorization in 1937, was resumed in 1977. This investigation will report on the flood and associated problems and possible solutions for the reach of the main stem from the headworks to the Salton Sea and for the communities of Palm Desert, Indian Wells, Rancho Mirage, and La Quinta. The study of flood problems in the latter two areas is being pursued under the Corps' Small Projects Authority. Its completion date is scheduled for 1981. The purpose of the investigation is to consider justification of additional flood protection projects in the study area, with respect to current and expected future development. The study area comprises about 5 050 square kilometres (1,950 square miles) in San Bernardino and Riverside Counties, extending from the City of Banning about 110 kilometres (70 miles) to the Salton Sea. The investigation will examine justification of structural works to protect agricultural areas in the lower basin and the fast-growing desert communities. It will also consider the feasibility of ground water recharge and development of recreational facilities in conjunction with flood protection modifications. Single and multipurpose reservoirs, debris basins, and channel and levee modifications will also be considered.

Local government implementation and enforcement of land-use controls that adequately consider the potential flood threat is a practical approach. In areas of less intensive development, and in undeveloped areas, reserving adequate channel space could eliminate the need for structural facilities.

Flooding along the Salton Sea shoreline was not a major problem until early

Table 20: REGULATED FLOODWAYS IN THE COLORADO DESERT HYDROLOGIC STUDY AREA

Responsible Agency	Type of Floodway Regulation	Floodways Regulated	Type of Area Regulated	Information or Action Needed to Regulate Floodways	Eligible for Flood Insurance
San Diego County	Comprehensive flood management plan, flood control ordinance, building codes, subdivision ordinance	None	Urban, agricultural	Identification of flood-hazard areas	Yes
Imperial County	Building code. Subdivision regulations	New and Alamo Rivers and streams to Salton Sea and Colorado River	Urban, agricultural, industrial	Identification of flood-hazard areas	Yes
Brawley	None	New River	Recreational	None, no flood problems evident	Yes
Calexico	Resolution	New River	Urban	Identification of flood-hazard areas	Yes
Calipatria	None	None		Identification of flood-hazard areas	Yes
El Centro	Building code	None		None, no flood problems evident	Yes
Holtville	Ordinance	Alamo	Industrial, commercial	None, no additional flood problems evident	Yes
Imperial	County jurisdiction	El Centro drain	Urban	Identification of flood-hazard areas	Yes
Westmorland	None	None		None, no flood problems evident	Yes
Riverside County	Ordinance, subdivision regulations, building code	Whitewater River, Little Berdo and Lower Berdo Canyon areas below elevation 67 metres (220 feet)	Urban, industrial, agriculture	Identification of flood-hazard areas	Yes
Banning	Resolution	West Pershing Creek, lower reaches of Gilman Home and Indian Canyon Channel, San Gorgonio River	Urban	Identification of flood-hazard areas through FEMA Study	Yes
Blythe	None	None	None	None, no flood problems evident	Yes
Coachella	None	None	None	None, no flood problems evident	Yes
Desert Hot Springs	Ordinance	Morongo Wash Mission Creek Wash	Industrial	Identification of flood-hazard areas	Yes
Indian Wells	None	Deep Canyon Storm Water Channel	Residential, recreational	Identification of flood-hazard areas	Yes
Indio	None	None		None, no flood problems evident	No
Palm Desert	Building ordinance	Isolated flood-prone areas	Urban	Identification of flood-hazard areas through FEMA Study	Yes
Palm Springs	Ordinance	Tahquitz Creek and Tahchevah Creek	Urban, industrial	Identification of flood-hazard areas	Yes
Rancho Mirage					
San Bernardino County	Ordinance	Palm Pipes Wash, Lucerne Lake, Rabbit Lake, and Airport Wash	Urban, agriculture	Identification of flood-hazard areas	Yes
Needles	Ordinance	"S" Street and Sidewinder, Roadrunner and Fox Wash	Urban	Identification of flood-hazard areas	Yes

1976, when the water level rose from elevation -70 metres (-230 ft) in January to a level of -69.7 m (228.8 ft) in May. The Sea has continued to rise, reaching a level of -69.3 m (-227.5 ft) in May 1979 and -69.02 m (226.45 ft) in May 1980, the highest in more than 50 years.

Damage to shore installations and some dwellings and businesses has been occurring since the level reached -69.7 m (-228.8 ft) in 1976. Due to flooding of the southern portion of the community of Bombay Beach, 240 lots have been totally lost, being under 0.9 m to 1.2 m (3 to 4 ft) of water. The boat launching facility at the State park along the north shore of the Sea was inundated by the rising water caused by tropical storms.

Conservation of agriculture water to reduce the flow of agriculture drainage into the Sea and diversion of water from the New River for powerplant cooling are two measures that are being considered to keep the Sea level from rising.

A study group was named by the Secretary for Resources in January 1980 to investigate the issues and to develop alternative management plans for the Salton Sea. One of the objectives of the management plan is "Lowering the level of the Salton Sea to eliminate flooding of beach front developments, agricultural lands and wildlife areas...."

CHAPTER 6. FUTURE FLOOD DAMAGE PREVENTION IN CALIFORNIA

Actions under consideration by the Department of Water Resources to prevent flood damage fall into two categories: actions which can be taken by the State under existing authority and budget; and actions for which additional authority or means are required, i.e., funding, legislative direction, and participation of other levels of government, or are long-range and innovative requiring further analysis.

Actions Planned Under Existing Auhtority

The Department plans to:

1. Work with the Corps of Engineers on the Sacramento River Bank Protection Project to assure that maximum use is made of construction techniques and designs which protect existing berms and riparian vegetation.

2. Work with the Corps of Engineers to review and revise current maintenance standards to allow the preservation of more riparian vegetation along California floodways.

3. Modify and sensitize its flood protection project maintenance programs to make maximum use of integrated pest management (IPM). IPM involves taking an ecosystem approach to pest management. Programs are developed which encourage a natural systems approach to controlling undesirable plants and animals by encouraging desirable plants and animals including predators.

4. Explore the use of hand methods of maintenance on levees to enhance the environmental and aesthetic aspects of selected levees.

5. Study alternatives to riprap as a means of erosion protection.

6. Continue working with university and U. S. Soil Conservation Service experts in the field of horticulture to: (a) identify vegetation that will sustain growth without irrigation on levees, berms, and channels throughout California; and (b) select from the identified vegetation those plants which would cause minimum levee maintenance problems and would be unattractive to squirrels, be aesthetically pleasing to recreational users, and provide wildlife habitat for desirable species along the California floodways.

7. Continue its joint effort with the California Department of Fish and Game to develop replacement of annual grasses on levees with perennial grasses, including bunch grass. Perennial grasses could provide improved wildlife habitat and reduce maintenance costs.

8. Assist State agencies in implementing the Governor's executive order on the inclusion of flood plain management concepts in all State agency activities.

9. Comment with respect to flood hazard on all environmental impact reports, other reports and environmental documents referred to the State Clearinghouse. Explain all applicable laws, regulations, and executive orders and recommend mitigation measures as appropriate. Also comment on the beneficial uses of natural flood plains for wildlife habitat, ground water recharge and recreation as well as storm water storage and open space benefits. If stream segments are pro-

posed to be eliminated, comment strongly that CEQA requires mitigation, that the Department of Fish and Game must be notified under Sections 1601-1603 of the Fish and Game Code, and that the unmitigated elimination of instream beneficial uses could be a waste of water as determined in Decision 1460 of the State Water Resources Control Board.

10. Continue to work with the Federal Emergency Management Agency on the implementation and execution of the National Flood Insurance Program, particularly in encouraging local governments to adopt and enforce adequate flood plain regulations.

11. Work with the California Coastal Commission to incorporate nonstructural flood mangement in local coastal plans in accordance with Cobey-Alquist Flood Plain Management Act Policy and Executive Order, which encourage local levels of government to accomplish nonstructural flood management with State guidance in such activity.

12. When appropriate, recommend the purchase of lands for use as replacement townsites, and the removal of development from the flood plains as an alternative for all or part of proposed federal projects. This concept could include payment for losses and/or purchase of property rights within the flood plains. Selection of alternative sites will require consolidation of complex tradeoffs involving such things as transportation, utilities, energy, aesthetics, natural resources, costs, funding, and public preference.

13. In coordination with the Corps of Engineers and others, prepare an economic study of the pumping out and reclaiming of each of the Sacramento-San Joaquin Delta Islands, should they be inundated before protection is improved under the Delta Levees Improvement Program being developed by the Department and the Corps of Engineers. This information would provide guidance to the Department and other agencies at the time of an emergency.

14. Require that funds provided for flood emergency purposes under Section 128 of the Water Code be given only on the condition that local governments implement an adequate hazard mitigation program.

15. Assist the California Water Commission in establishing priorities for projects and investigations being considered for authorization or funding by Congress for the Corps of Engineers and other federal agencies, in order to emphasize the more critical flood problems in the state. Refuse to support solely structural projects. Through its comments, ensure that federal agencies give serious considerations to nonstructural alternatives.

16. Support construction of appropriate structural facilities for flood protection, when adequate nonstructural measures are incorporated in the proposals.

17. Work with the Corps of Engineers to shorten the process from initiation of a study proposal to implementation of its flood management proposals.

18. Continue work with federal and local agencies to extend flood forecasting and flood warning where appropriate. These efforts should include studying the need to develop flood forecasting and warning systems in the populated areas of Southern California, the smaller coastal watersheds, and areas subject to tidal flooding.

Long-Range and Innovative Actions Which May Require Authority or Funding

Over a period of time, if funds are made available, the Department plans to:

1. Advance a program for improvement of the Sacramento-San Joaquin Delta Levee System.

2. Attain broader authority for the State to regulate land uses to assure preservation of flood plain lands that are of intrinsic value for agricultural development or maintenance of fish and wildlife. Other states (Nebraska, Wisconsin, Minnesota) have adopted legislation enabling them to regulate flood plain use to protect environmental values. An analysis of their efforts should be the subject of a future Department report.

3. Expand the areal scope of the Department report on Flood Control Project Maintenance and Repair to include all levees and channels for which the State has provided or may in the future provide financial support.

4. Develop and propose stronger State sanctions which could be used to prevent imprudent land use in flood plains. (This would extend and emphasize the Governor's executive order requiring all State agencies to consider nonstructural flood management in their activities.)

5. Study the possibility of installing sensors in levees to react to changes in the line of saturation in order to provide early warning if the structural integrity of the levee is endangered.

6. Study the possibility of developing construction methods for low-cost installation of impervious cut-off walls in existing levees to improve structural integrity.

7. Support legislation that would require flood-hazard information to be provided for each property in the title package for that property, so that all home buyers are informed and not just buyers in new subdivisions, as is now the case.

8. Determine how costs can be distributed throughout a watershed when increased storm runoff or erosion caused by development taking place in the upper watershed requires enlarged flood protection measures in the lower watershed.

9. Study the economics of alternative land uses in planning flood damage prevention and mitigation programs and in relocating development away from flood-prone areas. Acceptable land uses should include wildlife habitat, native vegetation, ground water recharge, recreation needs, and other human activities that are compatible with the flood potential threat. This study should also consider acquisition of open spaces to preserve streams in their natural condition. If obstructions (structures) exist in the flood plain, compute and depict a design natural floodway assuming the obstructions have been removed. Provision of this information will enable planners to determine the cost-effectiveness of building structural protective works or relocating some existing development.

10. There are 40 million hectares; (100 million acres) of land in this State. Urban development occupies 1 million hectares (2.6 million

acres) and 9 million hectares (22 million acres) are irrigable (3.6 million hectares [9 million acres] are now irrigated). The remaining 30 million hectares (75 million acres) could be classified as to their suitability for urban and agricultural use. This type of information would enable city and county planners to point to suitable areas for urban expansion, as well as identify land unsuited for urban use or better suited for other uses. It would identify areas where certain types of agricultural uses could be incompatible with flood hazard. It would also allow State agencies to comment appropriately on project environmental impact reports and on master plan revisions and amendments.

California has two major land use challenges: protection of prime agricultural lands from urban encroachment and protection of flood plains and wetlands from incompatible uses. To date, the State's approach to both of these problems has been essentially passive. What is needed is a positive approach, perhaps patterned after the Office of Planning and Research's Urban Strategy for California.

APPENDIXES A THROUGH G

APPENDIX A

Procedure for Authorization of Corps of Engineers Flood Control Projects

Corps of Engineers projects may be initiated in a variety of ways. A Corps study may reveal the need for a project. A state or local agency study may suggest a possible Corps project. Once the need for a project or an investigation has been identified, Congress may direct that an investigation be initiated. Depending on whether there has been a previous Corps of Engineers investigation, a congressman can take one of two routes to arrange for an investigation of the flood problem. If there has been a previous investigation of the basin or locality, a request is made to either the House or Senate Committee on Public Works and Transportation to pass a resolution directing the Corps of Engineers to "review" its previous report and make recommendations for such additional modifications as it finds appropriate. If there was no previous investigation, a bill is introduced requesting the Corps of Engineers to prepare a "survey" report of the basin or locality and to make recommendations on its findings. These proposed projects are generally incorporated into the Omnibus River and Harbor and Flood Control Bill (sometimes referred to as Water Resources Development Act) or a separate bill.

After Congress authorizes the investigation, it must be funded. The funding process is separate from the authorization process and generally follows authorization by one or more years. Funds for investigations are included in the annual Public Works Appropriation Act. The California Water Commission makes a presentation to the appropriate congressional committees in support of these appropriations.

Upon funding, the appropriate Corps of Engineers' District conducts the investigation, inviting extensive public participation by all interests. A draft review, or draft survey report, is prepared which contains recommendations for a project or for no further federal action, as appropriate. The reports sometime conclude that a flood plain management program should be implemented by local government. Under present policy, a draft environmental impact statement must accompany this report if a federal project is recommended.

Interested federal, state, and local agencies and the public are invited to review and comment on the draft review or survey report and the accompanying environmental impact statement. The Department of Water Resources conducts an engineering and economic review of these reports for California and acts as coordinator in the preparation of comments by other departments and agencies of the State Resources Agency.

The Corps of Engineers' District Engineer considers all commments received, revises the report as appropriate, and forwards it and the revised draft environmental impact statement to the Division Engineer, who issues a public notice and transmits the report with his recommendations to the Board of Engineers for Rivers and Harbors for an independent review. The Board reviews the report and transmits its recommendations to the Chief of Engineers. The Chief of Engineers then transmits his proposed report to the governor of the affected state and to interested federal agencies for formal review and comment.

In California, the State Resources Agency has been delegated the responsibility for preparing the State's comments; the Department of Water Resources has been delegated the responsibility for coordinating the State's comments. Following receipt of the formal comments, the Chief of Engineers prepares his final report and final environmental impact statement and submits the reports to the Secretary of the Army. The Secretary of the Army submits a draft letter of transmittal to Congress and the report of the Chief of Engineers to the Office of Management and Budget for determination of the relationship of the report to the program of the President. The Secretary of the Army then transmits the report of the Chief of Engineers to Congress and the final environmental impact statement is filed with the Environmental Protection Agency. Less than half of the feasibility reports prepared by the Corps of Engineers recommend authorizations and construction of projects.

When the report of the Corps of Engineers is transmitted to Congress favorably recommending a project, the proposed project is considered by the Congressional Committee on Public Works and Transportation. The project may then be included in an Omnibus River and Harbor and Flood Control Bill for authorization for construction. Project authorization may also be by resolution by both Public Works Committees rather than by an act when a project has a federal cost of less than $15 million. In all cases, however, Congress must appropriate funds before advanced planning, design, and construction can be undertaken. Such funding is an entirely separate action. Also, Congress has delegated to the Chief of Engineers continuing authority to proceed with several types of small projects generally costing less than $2 million ($3 million where recent flood disasters have been declared). The planning and construction of these small projects are funded from an annual appropriation for this purpose. For the first time in 1975 and again in 1976, the Water Resources Development Act authorized only certain advanced engineering and design work (Phase I studies) on some of the projects contained in these Acts and review project recommendations, in view of current conditions and criteria. These projects will require further congressional authorization.

The Congress then appropriates funds to initiate the Phase I Design Memorandum stage of advanced engineering and design. Funds for this stage are individually authorized on a project-by-project basis in the Public Works Appropriations Act. There can be a delay of several years between authorization and funding of this stage. Upon completion of the Phase I Design Memorandum, a project must again be submitted to Congress for construction authorization if the project is authorized for Phase I studies only. The state will be given an opportunity to review a project before the Phase I report is submitted to Congress under the new procedures.

Federal appropriations for construction are made on an individual project-by-project basis in the Public Works Appropriations Act. When construction funds are appropriated by Congress, the District Engineer completes advance engineering and design and plans and specifications before he awards a construction contract to a private contractor. Local interests generally must acquire the necessary rights of way to provide for the relocations of highways and utilities and give the required formal assurances of local cooperation to the Federal Government, including assurance that the project will be operated and maintained in accordance with federal criteria, as outlined in the project maintenance manual, before the award of the construction contract.

The interval between the initial request for federal assistance and completion of a federally authorized project is usually from 20 to 30 years.

APPENDIX B

Application Procedure for PL 566 Projects

Soil Conservation Service

Under PL 566, projects are considered to be local projects under the local sponsoring organizations, with financial and technical assistance available from the Soil Conservation Service (SCS). The following are the major steps leading to the authorization of a project for installations:

1. A letter requesting assistance on a PL 566 project should be submitted to:

   Francis C. H. Lum
   State Conservationist
   Soil Conservation Service
   2828 Chiles Road
   Davis, California 95616

2. SCS personnel will make a preliminary field review of the project with the sponsors to see if it fits the program and appears to have economic feasibility.

3. The sponsors will notify State and local clearinghouses of their intent to apply for a PL 566 project. Notice of Intent forms are available from the State at:

   Office of the Governor
   Office of Planning and Research
   1400 Tenth Street
   Sacramento, California 95814

4. The sponsors will hold a public meeting or possibly several meetings to get local input and reaction to the project. SCS personnel can assist with the meeting, if requested.

5. The sponsors will prepare an application. Assistance in the preparation is available from the SCS field offices. A draft copy should be sent to the SCS State Conservationist for comments prior to finalizing it.

6. The sponsors will submit the application for review and approval to the:

   State Resources Conservation
   Commission
   1416 Ninth Street, Room 1354
   Sacramento, California 95814

7. After its approval, the Commission will submit the application to the SCS State Conservationist, who will acknowledge its receipt.

8. Priorities for planning assistance are assigned by the State Resources Conservation Commission, in cooperation with the SCS.

9. A planning authorization is requested from the SCS Administrator.

10. After planning is authorized, the SCS or the sponsors will obtain the necessary basic data and investigate several alternative solutions to the problem, along with appropriate costs for each alternative.

11. The alternatives will be presented to the sponsors and at public meetings for selection of an alternative.

12. A draft work plan and environmental impact statement will be prepared on the selected alternative.

13. The draft plan and EIS will undergo a series of reviews by the SCS, other agencies, interested organizations, and the public.

14. The final plan and EIS will be submitted to Congress for authorization to install.

15. Funds for installation are allotted each year by the SCS Administrator.

16. Design and construction contracts can be handled by either the SCS or the sponsors.

APPENDIX C

History of Flood Control Subventions Program

The program provides assistance to local agencies cooperating in the construction of federal flood control and watershed-protection projects. State assistance is limited to reimbursement of (1) all or a portion of the costs of rights of way and relocations which are necessary for construction of the flood control features of levee and channel improvement projects, and (2) 50 percent of the nonfederal costs of recreation and fish and wildlife enhancement features.

The major development in federal responsibility for flood control occurred in 1936, when a national flood control policy was adopted by the U. S. Congress. Under this policy, the Federal Government would pay for the construction of projects authorized by Congress. However, local interests would pay the costs of rights of way and relocations.

The federal flood control program was considered to be a key feature of the pre-war recovery, and Congress authorized a large number of flood control projects in 1944. Local agencies would have to pay for rights of way and relocations, financed primarily by local property taxes, for these federal flood control projects. The financial squeeze caused local agencies to look to the State as a source of the capital funds because the State treasury was bursting with revenues of the war years when there were restrictions on nonessential activities.

The passage of the State Water Resources Law of 1945 and the Flood Control Law of 1946 established the policy of State reimbursement of rights of way and relocation costs for Corps of Engineers' levee and channel projects. U. S. Soil Conservation Service Watershed Protection Projects were added in 1955.

The Flood Control Subventions Program is based on this leglislation. The 1973 cost-sharing law changed the amount paid by the State, but not the policy with respect to flood control features. The old and new levels of State financial assistance are as follows:

Pre 1973:

State Share = 100% R/W and Relocation Costs.

Post 1973:

State Share =

$$0.75 \left(\frac{FDRB}{TB}\right) \text{ R/W Costs}$$

$$+0.90 \left(\frac{FDRB}{TB}\right) \text{ Relocation Costs}$$

Where, FDRB = Flood Damage Reduction Benefits

LEB = Land Enhancement Benefits

TB = Total Benefits = FDRB + LEB

The scope of the program was expanded in 1973 to include 50 pecent state payment of the nonfederal capital costs of recreation and fish and wildlife enhancement features.

The 1973 cost-sharing formula was apparently based on the belief that local cost sharing would cause interests to make a more complete evaluation of their needs for a flood control project, rather than just uncritically accepting a project because the Federal and State levels of government were paying for it. Local financial participation is also expected to keep total costs associated with rights of way and relocation to a minimum.

The cost-sharing viewpoint came before the Legislature in 1965, with the adoption of Senate Resolution No. 249. It directed that a study be made of the State's subventions program and that a report recommending a program of cost sharing be submitted to the 1967 Regular Session. A report recommending 50-50 state-local cost sharing was submitted, but no action was taken until after a 1969 announcement by the Governor that he would sign no more project authorizaton bills until a cost-sharing program was adopted.

A total of 10 cost-sharing bills were introduced during the 1970, 1971, 1972, and 1973 Sessions of the Legislature. The impact on the amount of State financial assistance was computed for a sample of 14 authorized and proposed projects. The State share ranged from 45 to 85 percent of rights of way and relocation costs.

Several philosophies were reflected in the various bills. Some interests sought minimum local participation. Others sought basic significant local participation for all projects and increased local participation when land enhancement benefits were claimed for the project. Some believed that unjustified "wind-fall" profits would accrue to the owners of enhanced land as soon as a project was constructed.

The cost-sharing formula adopted in 1973 was based on the current economic evaluation procedures used by the Corps of Engineers. Two types of flood control benefits were generally claimed for a project: flood damage reduction and land enhancement. Flood damage reduction benefits were claimed for protecting both existing development and the development projected to take place in the absence of a project and in spite of the flood hazard. Land enhancement benefits resulted from the increased value of land that is made available for development by construction of the project. The State pays 75 percent of the rights of way costs and 90 percent of the relocation costs apportioned to flood damage reduction benefits. The local agency pays the remainder of the costs apportioned to flood damage reduction benefits and all of the costs apportioned to land enhancement benefits.

In August 1974, the Corps of Engineers changed its economic evaluation procedures. The most important change was the incorporation of the concept that the land-use regulation requirements of the Nationnal Flood Insurance Program would be in effect. This precludes projecting development of a flood plain in spite of the flood hazard. The Corps of Engineers now claims three types of flood control benefits: inundation reduction, location, and intensification.

Inundation reduction benefits are attained by the reduction of flood losses to those activities which would have used the flood plain without a project; they are fully comparable to flood damage reduction benefits. Location benefits are attained by making flood plain land available for new uses which can take place only with flood protection; they are fully comparable to land enhancement benefits. Intensification benefits are the value a project has for those activities which enables it to utilize land more intensively.

Interpreting intensification benefits is a problem in administering the cost-sharing formula. From the examples in the federal regulations, some types could be considered flood damage reduction benefits, some could be considered land enhancement benefits, and some don't fit either category. At the present time, the benefits for each federal project must be evaluated and divided into the two categories of the cost-sharing formula. Intensification benefits which don't fit either category are excluded from the formula.

The present cost-sharing formula gives maximum state financial assistance to already developed areas and minimum assistance to areas in the process of being developed on flood plains.

STATE FLOOD CONTROL SUBVENTIONS FUNDS
Reallocated to Projects under the Jurisdiction of the
DEPARTMENT OF WATER RESOURCES
(Amounts in $1,000)

COUNTY AND PROJECT	Total thru 1979-1980
ALAMEDA COUNTY	(14,527)
Alameda Creek MFCP[1/]	12,386
San Lorenzo Creek MFCP	1,096
San Leandro Creek SFCP[2/]	1,045
CONTRA COSTA COUNTY	(10,675)
Walnut Creek MFCP	6,697
Pinole Creek SFCP[2/]	379
Rheem Creek SFCP	172
Rodeo Creek SFCP	572
Marsh-Kellogg WPP[3/]	1,674
Walnut Creek WPP	1,181
DEL NORTE COUNTY	(821)
Klamath River MFCP	821
FRESNO COUNTY	(96)
Kings River MFCP	96
HUMBOLDT COUNTY	(637)
Eel River at Sandy Prairie MFCP	126
Redwood Creek at Orick MFCP	494
Mad River at Blue Lake SFCP	17
KERN COUNTY	(41)
Ridgecrest Wash SFCP	19
Kern River Intertie SFCP	22
LAKE COUNTY	(413)
Adobe Creek WPP	413
LOS ANGELES COUNTY	(78,338)
Los Angeles River MFCP	66,933
Los Angeles River Watershed MFCP	11,405

1/ MFCP = Major Flood Control Project (A project specifically authorized by Congress).
2/ SFCP = Small Flood Control Project (A project authorized by the Chief of Engineers, USA).
3/ WPP = Watershed Protection (A project authorized by the Administrator, SCS, USDA).

STATE FLOOD CONTROL SUBVENTIONS FUNDS
Reallocated to Projects under the Jurisdiction of the
DEPARTMENT OF WATER RESOURCES
(Amounts in $1,000)

COUNTY AND PROJECT	Total thru 1979-1980
MARIN COUNTY	(4,335)
Corte Madera Creek MFCP	3,445
Coyote Creek SFCP	890
MENDOCINO COUNTY	(14)
Russian River MFCP	14
MERCED COUNTY	(683)
Mustang Creek WPP	683
MODOC COUNTY	(330)
North Fork Pit River at Alturas SFCP	330
MONTEREY COUNTY	(276)
Pajaro River MFCP	276
NAPA COUNTY	(386)
Napa River WPP	326
Napa River MFCP	60
RIVERSIDE COUNTY	(5,576)
Santa Ana River Basin MFCP	3,056
Tahchevah Creek MFCP	1,101
Banning Levee SFCP	14
Chino Canyon SFCP	222
Main Street Canyon WPP	821
Oak Street Channel Watershed MFCP	315
SAN BERNARDINO COUNTY	(16,924)
Lytle & Warm Creeks MFCP	5,780
Santa Ana River Basin MFCP	3,175
City Creek SFCP	467
Oro Grande Wash SFCP	311
Quail Wash Levee SFCP	39
S Street Channel SFCP	75
Cucamonga Creek MFCP	7,077
SAN DIEGO COUNTY	(12,620)
San Diego River & Mission Bay MFCP	2,992
Sweetwater River MFCP	4,132
Rose Creek SFCP	472
Buena Vista Creek WPP	799
Escondido Creek WPP	3,029
Tijuana River MFCP	1,196

STATE FLOOD CONTROL SUBVENTIONS FUNDS
Reallocated to Projects under the Jurisdiction of the
DEPARTMENT OF WATER RESOURCES
(Amounts in $1,000)

COUNTY AND PROJECT	Total thru 1979-1980
SAN JOAQUIN COUNTY	(894)
Duck Creek SFCP	671
Mosher Creek WPP	223
SAN LUIS OBISPO COUNTY	(81)
Arroyo Grande Creek WPP	81
SANTA BARBARA COUNTY	(4,708)
Santa Barbara Streams MFCP	824
Santa Maria Levee MFCP	1,440
Santa Ynez River Watershed MFCP	1,253
Carpinteria Valley WPP	1,191
SANTA CLARA COUNTY	(2,627)
Lower Llagas Creek WPP	1,944
Upper Llagas Creek WPP	683
SANTA CRUZ COUNTY	(2,788)
Pajaro River MFCP	339
San Lorenzo River MFCP	2,449
SOLANO COUNTY	(2,661)
Green Valley Creek SFCP	115
Ulatis Creek WPP	2,546
SONOMA COUNTY	(3,667)
Russian River MFCP	56
Central Sonoma WPP	3,611
TRINITY COUNTY	(215)
East Weaver Creek SFCP	215
TULARE COUNTY	(188)
Stone Corral WPP	188
VENTURA COUNTY	(4,046)
Santa Clara River MFCP	1,682
Ventura River MFCP	359
Calleguas Creek WPP	297
Revolon Slough WPP	1,630
Beardsley Wash WPP	78
TOTALS	168,567

APPENDIX D

EXECUTIVE DEPARTMENT

STATE OF CALIFORNIA

EXECUTIVE ORDER B-39-77

WHEREAS, throughout the state the magnitude of annual flood caused property losses and threats to human safety is increasing, largely as the result of unwise use and continuing development of the state's flood plains and despite substantial efforts to control floods; and

WHEREAS, state government has programs for the construction of facilities and annually disposes of state lands in flood-hazard areas; and

WHEREAS, the purchase of flood insurance is a condition of any federal financial assistance for any state or local government in the location, construction, or acquisition of property in identified flood-hazard areas; and

WHEREAS, the availability of state financial assistance is often a determining factor in the use of land and the location and construction of public and private facilities; and

WHEREAS, state agencies need to be more cognizant of long and short term flood risk and losses associated with occupancy of flood plains and more consistent in the evaluation of flood hazards in implementing their programs; and

WHEREAS, significant new legislation has been enacted including at the state level the Cobey-Alquist Flood Plain Management Act of 1965, and at the federal level the Flood Disaster Protection Act of 1973, and others, and the state is supportive of the federal acts and desires to provide leadership in management of natural resources, including flood plains; and

WHEREAS, similar action has been taken at the national level affecting federal construction and at the state level by other states;

NOW, THEREFORE, I, Edmund G. Brown Jr., Governor of the State of California, by virtue of the power and authority vested in me by the Constitution and statutes of the State of California, do hereby issue this order to become effective immediately:

1. The heads of all state agencies shall provide leadership in efforts to minimize the risk of flood losses in connection with state lands and installations and state financed, insured, or assisted improvements. The heads of such agencies shall take particular care to avoid unwise or hazardous use of flood plains in connection with all activities under their authority. Specifically:

   a. All agencies responsible for the construction of state facilities shall, in writing, evaluate flood hazards when planning the location of new facilities. The evaluation shall consist of a determination of whether the proposed site lies in a flood-hazard area and, if so, what precautions have been taken to minimize the hazard. If the facility does not have to be in the flood plain to serve an essential purpose and the proposed site lies within an identified flood-hazard area, all feasible alternative locations for siting outside of the flood-prone area shall be given consideration. New structures proposed in flood plains must be constructed and maintained in accordance with the design and floodway standards set forth in the Code of Federal Regulations (24 CFR, Parts 1910.3, 1910.4 and 1910.5). Where the flood-hazard area has not been delineated by the federal government, the agency should contact the Department of Water Resources for assistance in evaluating the hazards in the area.

   b. With respect to existing state-owned buildings which have previously suffered flood damage or are in an identified flood-hazard area, the agencies shall require analysis of past and probable flood heights. In the case of the reconstruction, rehabilitation, or addition to existing publicly used state structures, such activities shall be carried out in accordance with the design and floodway standards set forth in the Code of Federal Regulations. Whenever practical and appropriate, floodproofing measures shall be applied to existing structures in identified flood-hazard areas.

c. All agencies responsible for the administration of any form of direct or indirect state assistance involving construction or acquisition of any state facilities shall assure that the evaluation and mitigation of flood hazards in connection with such facilities is carried out in the manner specified in this Executive Order.

d. All agencies responsible for the disposal of state lands or properties shall evaluate and mitigate flood hazards. When lands or properties proposed for disposal are found to be susceptible to specified flooding hazards, the state agency shall obtain assurances that proposed uses are appropriate under the provisions of the Cobey-Alquist Flood Plain Management Act.

e. All agencies responsible for programs which affect land use planning, including state permit programs, shall take flood hazards into account in accordance with recognized floodway and 100-year frequency flood design standards when evaluating plans and shall encourage land use appropriate to the degree of hazard involved.

2. Technical evaluations of flood hazard can be obtained from the U. S. Army Corps of Engineers and the U. S. Department of Housing and Urban Development. The California Department of Water Resources is hereby designated to coordinate requests for flood hazard information from the U. S. Army Corps of Engineers and other governmental agencies.

3. Assistance in compliance with this order is available through the Department of Water Resources.

IN WITNESS WHEREOF, I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 26th day of November, nineteen hundred and seventy-seven.

/s/ Edmund G. Brown Jr.
Governor of California

(Seal)

ATTEST:

/s/ March Fong Eu
Secretary of State

APPENDIX E

Flood Plain Information Reports in California

Prepared by Corps of Engineers

Butte County

Feather and Yuba River, Marysville-Yuba City (also in Sutter and Yuba Counties)	June 1968

Del Norte County

Lake Earl-Lake Talawa and Lower Smith River	June 1971

El Dorado County

Trout and Bijou Creeks, South Lake Tahoe	July 1969
Upper Truckee River, South Lake Tahoe	October 1969

Fresno County

Kings River, Sanger, California	June 1972

Humboldt County

South Fork Eel River, Weott to Myers Flat	June 1968
South Fork Eel River, Phillipsville to Garberville	June 1969
Eel River, Stafford to Holmes	December 1970
Van Duzen River, Humboldt County	July 1973
Freshwater Creek	October 1975

Imperial County

New River, Vicinity of Brawley	July 1976

Kern County

Kern River, Kernville	May 1968
Kern River, Bakersfield	October 1969
Sandy Creek, Taft and Ford City	October 1970
Ridgecrest and Vicinity	June 1976

Lake County

Big Valley Streams (Manning, Adobe, Kelsey and Cole Creeks)	June 1974

Madera County

Fresno River, Cottonwood, Little Dry, and Root Creeks	June 1973

Marin County

Rush Creek - Petaluma River to U.S. Highway 101	June 1975

Monterey County

Carmel River	May 1967

Orange County

Laguna Canyon	March 1969
San Juan Creek (including Arroyo Trabuco and Oso Creek)	November 1970
Santa Ana River (Imperial Highway to Prado Dam - also in Riverside County)	June 1971
San Diego Creek and Peters Canyon Wash	June 1972
Aliso Creek, Orange County	March 1973
Lower Santiago Creek	June 1973
Upper Peters Canyon Wash	June 1974
Tributaries of Upper San Diego Creek	December 1974

Placer County

Truckee River, Tahoe City	January 1971
Dry Creek and Tribs. vic. Roseville	May 1978
Truckee River and Martis Creek	June 1974
Antelope Creek, Secret Ravine and Tribs. - Rocklin	April 1976

Riverside County

San Jacinto River (San Jacinto to Railroad Canyon)	May 1970
Santa Ana River (Imperial Highway to Prado Dam) - Also in Orange County	June 1971
Salt Creek, Hemet to Railroad Canyon Reservoir	June 1971
San Gorgonio River and Smith Creek	June 1973
San Gorgonio River and Tribs.	October 1974

Sacramento County

American River Flood Plain	March 1963
Morrison Creek Basin	August 1963
Snodgrass Slough Flood Plain	August 1963
Northeastern Sacramento County	June 1965
Cosumnes River Basin	August 1965

San Benito County

San Felipe Lake and Pacheco Creek	July 1973
San Benito River, Pajaro River to Tres Pinos Creek	June 1974
San Felipe Lake Unit II	June 1975

San Diego County

Los Penasquitos Drainage Area	May 1967
Spring Valley Creek	September 1967
Los Chollas Creek	March 1968
Sweetwater River	February 1969
Rose Canyon and San Clemente Canyon (FHR)	July 1970
San Marcos Creek (Vicinity of San Marcos)	April 1971
Escondido Creek	May 1972
Aqua Hedionda Creek, Pacific Ocean to Buena Vista	July 1973
Buena Vista Creek, Pacific Ocean to Vista	July 1973
San Luis Rey River, Loretta Street to Eastern City Limits, vicinity of Oceanside	December 1974
Otay River	December 1974
Moose Canyon	October 1975
Keys Canyon	April 1976

San Bernardino County

Mojave River (vicinity of Barstow)	October 1968
Mojave River (vicinity of Victorville)	April 1969
Wilson and Wildwood Creeks	June 1972
San Timoteo Creek, vicinity of Loma Linda	June 1973

San Joaquin County

Northeast Stream Group, Stockton	January 1974
Southeast Stream Group, Stockton	June 1974
Southwest Stream Group, Stockton	December 1975
Northwest Stream Group, Stockton	July 1976

San Luis Obispo County

San Luis Obispo Creek and Tributaries	November 1974

Santa Barbara County

Santa Ynez River (including Alamo Pintado Creek) Cachuma Dam to Buellton	November 1968
Santa Ynez River (Lompac to Pacific Ocean)	January 1970
Santa Barbara Stream Group, vicinity Santa Barbara	April 1975
Montecito Streams, vicinity of Montecito	June 1974

Santa Clara County

Coyote Creek San Francisco Bay to Anderson Reservoir	February 1970
Guadalupe River	January 1972
Uvas-Carmadero Creek, Pajaro River to Uvas Reservoir, Santa Clara County	May 1973
Fisher Creek, Santa Clara County	July 1973
Alamitos Creek, including Guadalupe Creek - Arroyo Calero and Santa Teresa Creek, Santa Clara County	July 1973
Llagas Creek Unit I including Edmundson, (Little Llagas) Church, San Martin, New, Center, Corralitos, Tennent, Mapes and Foothill Creeks	July 1975
Upper Penitencia Creek, City of San Jose	August 1975

Santa Cruz County

Aptos, Trout and Valencia Creeks, City of Aptos	July 1973
San Lorenzo River, Boulder Creek, Felton	July 1973
Soquel Creek	July 1973
Corralitos Creek	July 1973

Shasta County

Cow Creek, Palo Cedro	June 1971
Churn Creek, Enterprise	June 1975
Sacramento River, Anderson and Olinda Creeks, and Spring Gulch	June 1975
Sacramento River, Redding	December 1975
Clover Creek, Stillwater Creek and Stillwater Tributaries, Loomis Corners	October 1977
Sacramento River and Cottonwood and Battle Creeks, Cottonwood-Bend Area	August 1978

Sierra County

North Yuba and Downey Rivers	January 1975

Solano County

Green Valley, Dan Wilson and Suisun Creeks, Cordelia	June 1972
Alamo and Ulatis Creeks, Vacaville	June 1973

Sutter County

Feather and Yuba Rivers, Marysville-Yuba City (also in Butte and Yuba Counties)	June 1968
Feather River, Nicolaus (also in Yuba County)	November 1968

Trinity County

Trinity Rivers, Lewiston Lake to Junction City	April 1976

Tulare County

Kaweah River, Three Rivers	October 1967
Tule River, Springville	July 1968
Deer Creek and White River, Earlimart	June 1971
Sand and Cottonwood Creeks and Lower Kaweah River, Visalia	May 1972

Yuba County

Feather and Yuba Rivers, Marysville-Yuba City (also in Butte and Sutter Counties)	June 1968
Feather River, Nicolaus (also in Sutter County)	November 1968

Ventura County

Santa Clara River (Saticoy to Pacific Ocean)	June 1968
Calleguas Creek (including Canejo Creek and Arroyo Santa Rosa), Somis To Pacific Ocean	September 1969
Santa Clara River (vicinity of Santa Paula)	March 1970
Calleguas Creek (vicinity of Moorpark)	July 1970
Ventura River (including Coyote Creek)	June 1971
Santa Clara River and Sespe Creek (vicinity of Fillmore)	June 1972
San Antonio Creek and Tributaries (vicinity of Ojai) County of Ventura	June 1973
Santa Clara River and Piru Creek	April 1973
Santa Clara River (Saticoy to Pacific Ocean)	Rev. January 1973
Calleguas Creek and Conejo Creek (vicinity of Camarillo)	January 1977

APPENDIX F

Glossary

ACTUARIAL RATES - Insurance rates based upon computed risk. Normal rates, without subsidy or special governmental purchase incentives.

ALLUVIAL CONE - Sediment deposit left by flowing water, spreading from the base of hills or mountains like a spread fan or a cone.

BERM - Land between the toe of a levee and a riverbank.

BULKHEAD - Wall or embankment constructed to protect against water.

BYPASS - A channel designed to divert water from a river, usually in times of high water, and channel that water to where it can do relatively little damage.

CALIFORNIA COOPERATIVE SNOW SURVEY - Program to measure snowpack in selected locations in the State to aid in predicting future water supply and estimate the snowpack's effect on streamflows.

CAPITAL FLOOD - Flood with recurrence interval of about 1 in 250 years.

CHANNEL IMPROVEMENTS - Works which reshape a stream channel so as to increase its flow carrying capacity.

CLIMAX VEGETATION - Relatively stable vegetation in equilibrium with its environment and with good reproduction of the dominant plants.

COMPUTER MODELING - Use of a digital computer in the development and application of a mathematical representation to simulate a physical process.

DESIGNATED FLOODWAY (under Federal Emergency Management Agency and Reclamation Board Designated Floodway Programs) - The channel of a river or other watercourse and adjacent land areas that must be reserved in order to discharge the 1-in-100-year flood without increasing water surface elevation more than one foot at any one point.

DESIGNATED FLOODWAY (under Cobey-Alquist Flood Plain Management Act) - The channel of a stream and that portion of the adjoining flood plain required to reasonably provide for the construction of a project for passage of the design flood including the lands necessary for construction of project levees.

DESIGN FLOOD - Selected maximum magnitude of flood for which protection is provided or will eventually be provided.

EASEMENT - Right afforded a party to make limited use of another's real property.

FLOOD PLAIN - Plain bordering a river that is subject to flooding.

FLOOD PLAIN MANAGEMENT - Regulation of use and occupancy of flood-prone lands to prevent or limit flood damage.

FLOODPROOFING - Physically altering or moving a structure to avoid or limit damage from inundation.

GEOMORPHIC CYCLE - Series of changes involved in the upheaval and complete reduction of a region to base level by any geologic process.

GROUTED RIPRAP - Stones or rocks with a thin mortar filling the crevices between them.

HERBICIDE - A substance used to kill plants.

LINEAR - In a straight line.

NATIONAL WATER RESOURCES COUNCIL - Federal agency responsible for implementing the Water Resources Planning Act (PL 89-80).

PARAMETER - Constant value used to determine the operation or characteristic of a system.

PERCOLATION - Drainage through a porous substance, such as sand or gravel.

REVETMENT - Slope of an embankment.

RIPARIAN RIGHT - A legal right to water use possessed by one who owns land on the bank of a river, a pond, or small lake.

RIPRAP - Rock used to strengthen a streambank or a levee embankment.

SANCTION - Penalty for noncompliance with a law or regulation.

SHEET EROSION - The carrying off of soil particles by water movement over a broad surface.

STANDARD PROJECT FLOOD - Flood caused by the most severe combination of meteorological and hydrological conditions that are reasonably characteristic of the geographic area in which the flood occurs.

TELEMETRY - The science and technology of automatic measurement and transmission of data by wire, radio, or other means from remote sources.

TOE OF LEVEE - Lower portion of the levee cross-section, where it intersects natural ground on either the water or landward side of the levee.

VARIANCE - License to build or otherwise act contrary to a usual rule.

WATERSHED - Region draining into a river, river system, or a body of water.

WATERSHED TREATMENT - Structuring and planting terrain in such a way as to make it resistant to erosion from precipitation or the flow of water.

WEIR - A dam placed across a river or canal to raise or divert water.

ZONING - Regulating the manner in which land may be used.

APPENDIX G

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ACTIONS TO PREVENT FUTURE DAMAGE

(Letters correspond to those under "Prevent With Action" under map)

A. Floodproof homes & buildings with permanent walls or removable wood planks & architecturally pleasing deflector walls to guide flow to channel.

B. Implement strict land use controls to prevent structures from being rebuilt in areas of heavy damage & to prevent encroachment on streambeds. (For homes damaged more than 50% of market value, local government enforce requirements of National Flood Insurance Program for adequate protection from future damage; if protection cannot be provided, deny building permits.)

C. City, County, State, & Federal land management agencies develop watershed management plan for mountain and hill areas to reduce amounts of mud and debris carried down to developed areas. Should prohibit new bare cut-&-fill slopes, require runoff to be discharged into channels at low velocities, plant unstable slopes, and, in extreme cases, use structures to stabilize slopes & trap debris.

D. Strengthen & enforce ordinances requiring geologists and engineers to analyze stability of hillsides & flood control districts to approve proposed drainage facilities before issuing building permits.

E. Install aesthetically pleasing deflecting and training walls at critical points along streams & at junctions to keep flows in channels & streets. Sandbags can be temporary measure.

F. Stabilize slopes next to buildings & critical sections of streets & channels. Example: homeowners use grouted riprap to transform channel into pleasing cascade. Terrace hillside slopes & install slope drains.

G. Check capacity of culverts, storm drains, & inlets, taking into account level of development in watershed.

H. Local government adopt & implement regulations restricting homes & development along shore within 100-year flood tide hazard boundary.

I. Develop & follow adequate maintenance program for drainage systems. Have crews available to clear debris basins between storms. Keep culvert & storm drains, particularly inlets, clear. Keep & analyze records to determine probable future problem areas.

J. Require in-depth study before issuing building and grading permits.

K. Reconstruct protective walls with deeper foundations to prevent failure by erosion.

L. Follow protective maintenance for private drains & sump pumps.

M. Use vegetative cover on slopes where control of mud-slides not otherwise cost-effective or practical. Covering slopes with plastic sheeting gives temporary protection.

N. Check adequacy of drains protecting cuts & fills.

O. Design outlets to prevent erosion with riprap or energy dissipators.

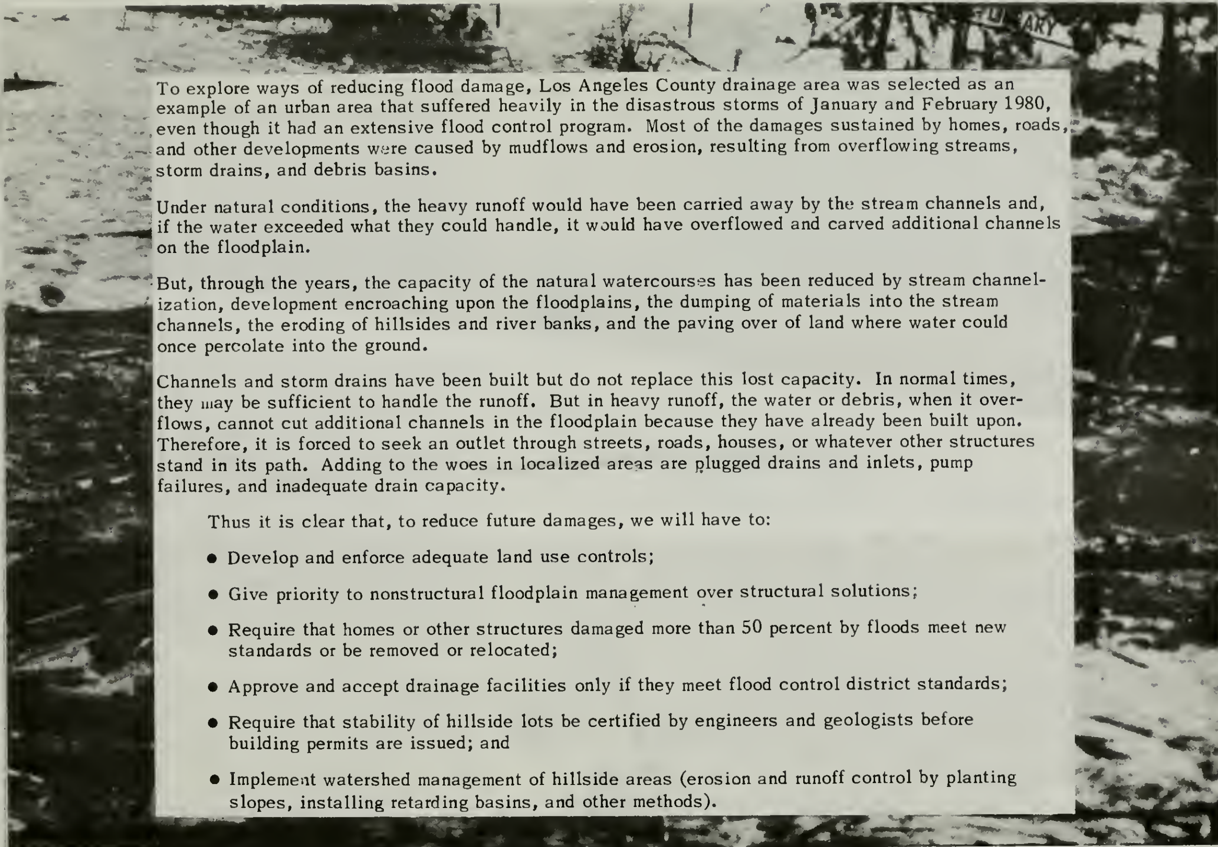
P. Exercise strict traffic control during storms.

Q. Install signs on roads subject to flooding & mud & debris flows.

R. Construct grade control structures to blend into environment & to reduce flow velocity in channel.

S. If increased capacity of drain or channel is only feasible solution, assign priority for construction funds.

T. Relocation.



To explore ways of reducing flood damage, Los Angeles County drainage area was selected as an example of an urban area that suffered heavily in the disastrous storms of January and February 1980, even though it had an extensive flood control program. Most of the damages sustained by homes, roads, and other developments were caused by mudflows and erosion, resulting from overflowing streams, storm drains, and debris basins.

Under natural conditions, the heavy runoff would have been carried away by the stream channels and, if the water exceeded what they could handle, it would have overflowed and carved additional channels on the floodplain.

But, through the years, the capacity of the natural watercourses has been reduced by stream channelization, development encroaching upon the floodplains, the dumping of materials into the stream channels, the eroding of hillsides and river banks, and the paving over of land where water could once percolate into the ground.

Channels and storm drains have been built but do not replace this lost capacity. In normal times, they may be sufficient to handle the runoff. But in heavy runoff, the water or debris, when it overflows, cannot cut additional channels in the floodplain because they have already been built upon. Therefore, it is forced to seek an outlet through streets, roads, houses, or whatever other structures stand in its path. Adding to the woes in localized areas are plugged drains and inlets, pump failures, and inadequate drain capacity.

Thus it is clear that, to reduce future damages, we will have to:

- Develop and enforce adequate land use controls;
- Give priority to nonstructural floodplain management over structural solutions;
- Require that homes or other structures damaged more than 50 percent by floods meet new standards or be removed or relocated;
- Approve and accept drainage facilities only if they meet flood control district standards;
- Require that stability of hillside lots be certified by engineers and geologists before building permits are issued; and
- Implement watershed management of hillside areas (erosion and runoff control by planting slopes, installing retarding basins, and other methods).

State of California
Edmund G. Brown Jr., Governor

The Resources Agency

Department of Water Resources
September 1980

Reducing Flood Damage

ACTIONS TO PREVENT FUTURE DAMAGE

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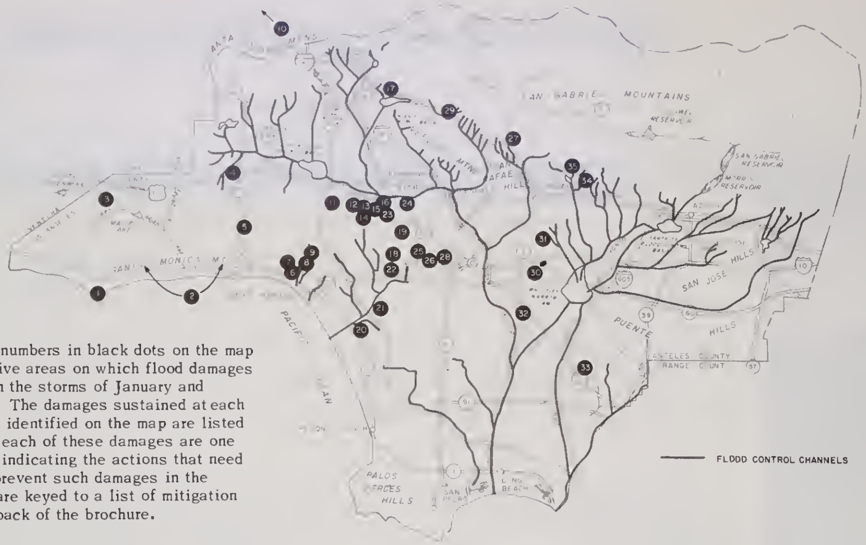
State of California
Edmund G. Brown Jr., Governor
The Resources Agency
Department of Water Resources
September 1980



Identified with numbers in black dots on the map are representative areas on which flood damages were suffered in the storms of January and February 1980. The damages sustained at each of the locations identified on the map are listed below. Beside each of these damages are one or more letters indicating the actions that need to be taken to prevent such damages in the future. These are keyed to a list of mitigation actions on the back of the brochure.

ON MAP SEE:	JANUARY-FEBRUARY 1980 DAMAGES	PREVENT WITH ACTION*:
1	Malibu. Debris washed to sea, plus heavy seas, battered pilings & bulkheads of homes on Pacific Coast Highway. Some invaded by mud & water from hillsides; sandbagging required.	B H J M T
2	Pacific Coast Highway. Closed from Santa Monica Freeway to Pt Dume by mudslides & flooding.	C G M
3	Malibu Canyon. Mulholland Dr closed from coast to Malibu Lake, because road flooded or washed out. In Monte Nido, woman killed when buried by mud.	F G
4	Woodland Hills. Home near Ventura Freeway and Ave San Luis inundated when Dry Canyon flood control channel overflowed.	G I
5	Topanga Canyon Rd. Washed out in places.	O
6	Bel Air Estates. Swift current through intersection of Sunset Blvd & Charring Rd; people rescued from cars. Water 1.2 metres (4 feet) deep at Sunset & Chautauqua.	G I P Q
7	Rivas Canyon. Yards of 3 homes eroded when double-wire revetment washed out. Owners sandbagged threatened homes.	B F K,R
8	Mandeville Canyon Rd. Flooding & mudflows for 4 kilometres (2.5 miles)	C,I P,Q
9	Mandeville Canyon. Mudflows through homes forced 200 persons to evacuate; 1 house lost; 1 person killed by wall of flowing mud; 20 homes damaged by mud.	A,B C,D E,J T
10	Saugus. Magic Mtn Parkway closed for 0.5 kilometre (0.3 mile) because washed out in places.	G P Q
11	Stone Canyon Rd. Mudslides closed at Valley Vista Blvd.	M Q
12	Hollywood Hills. Mudslides blocked 13200 block of Mulholland Dr.	M P,Q
13	Coldwater Canyon. Flooded on San Fernando Valley side.	G,I P,Q
14	Trousdale Estates. Water & mud broke open doors & damaged living rooms of homes.	A,D J,T
15	Laurel Canyon. 1 home demolished by mudslide; another collapsed when supporting ground became saturated & started creeping.	B,D F J T
16	Laurel Canyon. 40 homes near Mt Olympus evacuated, mainly because of mudflows, with erosion in yards.	A,B C,D E,J
17	Kagel Canyon. 4 homes flooded when debris clogged drain, causing overflow.	B G,I

ON MAP SEE:	JANUARY-FEBRUARY 1980 DAMAGES	PREVENT WITH ACTION*:
18	Beverly Hills & West Hollywood. Gravel & mud on streets in localized areas; underground garage & foyer of apartment house flooded.	G L
19	Hollywood. Residents on Genesee Ave alerted for possible evacuation if Nichols Canyon debris basin overflowed (Basin did not overflow.)	I
20	Culver City. Flooding closed Lincoln Blvd between Jefferson Blvd & W 83rd St.	G,I P,Q
21	Baldwin Hills. Mudslides closed La Cienega Blvd between Stocker St & Rodeo Dr.	M Q
22	Beverly Hills. Flooded at Olympic & La Cienega Blvds.	G I
23	West Los Angeles. Laurel Canyon Blvd flooded near Lookout Mountain Rd. One woman swept down to Hollywood Blvd.	G I P,S
24	Hollywood. Mudslides closed Cahuenga Blvd between Pilgrimage Theatre & Barham St.	M Q
25	West Los Angeles. Rossmore Ave flooded between Beverly Blvd & W 3rd St.	G I
26	Los Angeles. Underground garage on S Kenmore St flooded.	G L
27	Angeles Crest Highway. Mudslides & washouts closed 3 kilometres (2 miles) north of Foothill Blvd.	M N
28	Los Angeles. Elevator shaft in Queen of Angels Hospital flooded; also basement & 1st floor of St Vincent Medical Center & Midway Hospital.	G L
29	Verdugo Hills Cemetery. Coffins exposed by erosion.	J T
30	Monterey Park. 4 houses collapsed & 2 knocked off foundation when mud slammed into them. Mudslides overtopped mud barrier & destroyed house.	B,C D,F J,M N,T
31	Alhambra. Backyard of home eroded when concrete wall of San Pasqual Creek channel undermined & collapsed.	K R
32	City of Commerce. Santa Ana Freeway flooded between Garfield & Washington Aves. Also, intersection of Atlantic Ave & Telegraph Rd.	G I P,Q
33	Norwalk. Imperial Highway flooded near Bloomfield St; people rescued from tops of cars.	G,I P,Q
34	East Pasadena. Mud from hillsides closed several streets in Pasadena Glen. Man caught by mud & water swept 0.4 kilometre (0.25 mile) downstream.	C,G I M Q
35	Altadena. Rubio Diversion Channel became clogged & overflowed, carrying mud into 20 homes.	B E I

*See next page for list of mitigation actions corresponding to letters.

[redacted]

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