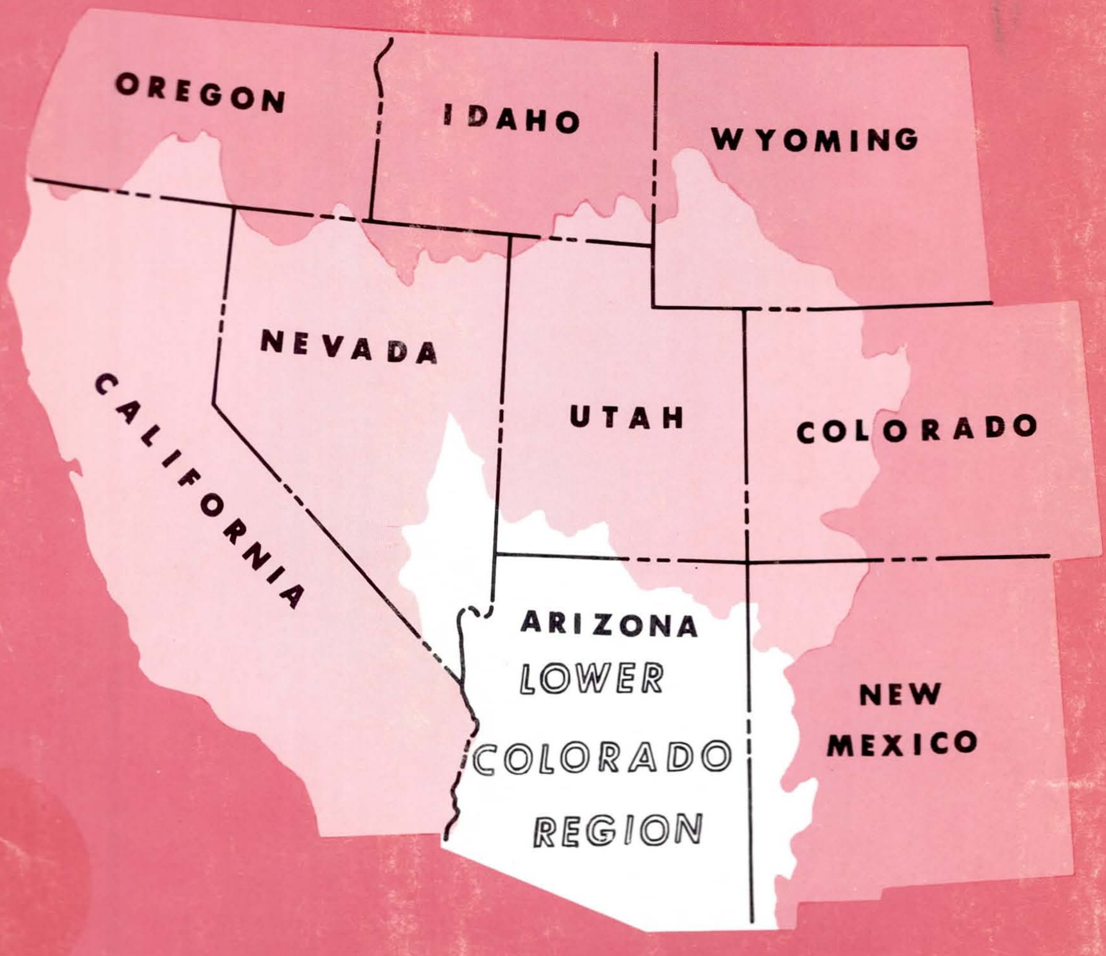
LOWER COLORADO REGION
Comprehensive Framework Study

APPENDIX IX
FLOOD CONTROL
JUNE 1971



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LOWER COLORADO REGION STATE – FEDERAL
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PACIFIC SOUTHWEST INTERAGENCY COMMITTEE

LOWER COLORADO REGION – Appendix IX Flood Control – June 19

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LOWER COLORADO REGION

COMPREHENSIVE FRAMEWORK STUDY

APPENDIX IX

FLOOD CONTROL

This report of the Lower Colorado Region Framework Study State-Federal Interagency Group was prepared at field level and presents a framework program for the development and management of the water and related land resources of the Lower Colorado Region. This report is subject to review by the interested Federal agencies at the departmental level, by the Governors of the affected States and by the Water Resources Council prior to its transmittal to the Congress for its consideration.

June 1971

The appendix was prepared by the
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of the
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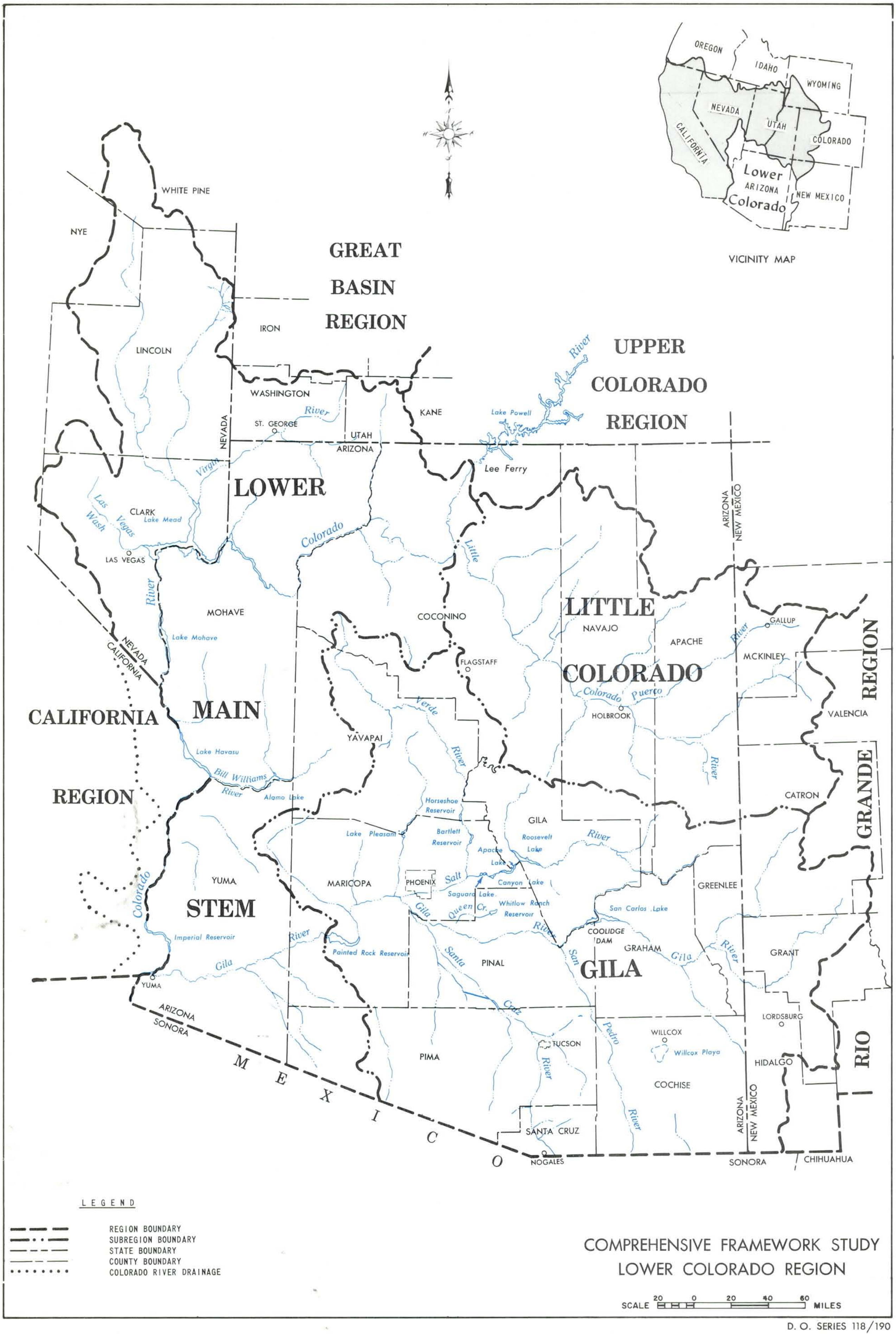

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SUMMARY

Major flood problems exist in urban and in highly developed agricultural areas throughout the Lower Colorado Region. Floods along the major streams cause recurrent damage of major proportions by cutting streambanks, changing the shape and location of channels, and eroding farmlands; inundating farmlands and urban areas; and damaging and destroying irrigation, communication, utility, and transportation facilities.

Initially, flood plain lands in the Region were developed for agriculture because they were near a source of water that was required for irrigation. However, low rainfall and infrequent flood occurrence have encouraged the expansion of urban growth into the flood plains of major streams, which are dry most of the time, and onto alluvial fans where stream channels are inadequate to accommodate even minor flows and where floodflows may take any one of a number of paths.

Estimated average annual flood damages for the Lower Colorado Region were about $41 million in 1965. The population and economic projections (MODIFIED OBERS) for the Region indicate that without any further flood control measures damages would increase to $310 million by 2020. Future damages were determined by projecting 1965 damages by using growth factors. Projections used in this appendix were based on the Department of Commerce Office of Business Economics and the Department of Agriculture Economic Research Service projections, which were modified in the Region. Detailed information on the population and economic growth projections is contained in Appendix IV, Economic Base and Projections.

Flood plain management is a comprehensive term that embraces the range of alternatives, including flood control structures, that can be employed to realize an appropriate use of flood plains. Proper flood plain management combines appropriate use with reduced risk, giving at the same time consideration to environmental, social, and economic aspects. Flood damage reduction may be accomplished by controlling the flow of water or by placing controls on the use and development of the flood plains. Although it is unrealistic to expect prevention of all flood damages, the projects in the flood control program should provide a minimum standard of protection. In agricultural areas, protection from the 10-year flood should be provided, and in urban areas, protection from the 100-year flood should be provided.

Implementation of the flood control program of structural and non-structural measures would effect damage prevention so that remaining damages of $68 million are estimated by the year 2020. The 1966-2020 flood control program would cost about $944 million. Incremental costs are estimated at about $359 million, $337 million, and $248 million, in the time frames of 1966-1980, 1981-2000, and 2001-2020, respectively.

All plans considered for the development of the water and associated land resources of the Lower Colorado Region will be based upon the desire to satisfy the needs of the people in a timely fashion. The flood control program will be flexible to permit adjustment to meet changing conditions and still be in consonance with the general plan for the Region. All possible means and approaches considered as solutions to flood related problems will strive to maintain or enhance the environmental quality of the Region.

APPENDIX IX

FLOOD CONTROL

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GLOSSARY

ACRE-FOOT--A term used in measuring the volume of water, equal to the quantity of water required to cover 1 acre 1 foot in depth or 43,560 cubic feet.

AVERAGE ANNUAL DAMAGES--The weighted average of all damages that would be expected to occur yearly under specified economic conditions and development. Such damages are computed on the basis of the expectancy in any one year of the amounts of damage that would result from events throughout the full range of potential magnitude.

EROSION CONTROL--The application of necessary measures to minimize soil erosion by artificial structures or vegetative manipulation.

FLOOD--A great flow along a watercourse or a flow causing inundation of lands not normally covered by water.

FLOOD CONTROL PROGRAM--Includes future Federal and non-Federal (structural and nonstructural) flood control and prevention measures from existing (1965) project conditions to the year 2020.

FLOOD CONTROL RESERVOIR--Wherein storage capacity is specifically allocated to storing flood waters. Water is stored for a relatively brief period of time, part of it being retained until the stream can safely carry the ordinary flow plus the released water. Such reservoirs may or may not have outlet control gates for flood regulation.

FLOOD CONTROL STORAGE CAPACITY--That part of the gross reservoir capacity which, at the time under consideration, is reserved for the temporary storage of floodwaters. It can vary from zero to the entire capacity (exclusive of dead storage) according to a predetermined schedule based upon such parameters as antecedent precipitation, reservoir inflow, potential snowmelt, or downstream channel capacities.

FLOOD DAMAGES--All economic losses resulting from a flood.

FLOOD FORECASTING--Forecasting the river stage and discharge.

FLOOD PLAIN--Land bordering a stream and which receives overbank flow. Also see FLOOD.

FLOOD PLAIN, PRIMARY--The streambed and that portion of the adjacent flood plain through which the main flow of water is channelized during flood conditions.

FLOOD PLAIN, SECONDARY--The fringe area of the flood plain within the boundaries of the selected flood which is subject to a less severe and less frequent inundation than found in the primary flood plain.

FLOOD PLAIN INFORMATION REPORTS--Reports prepared to provide local governmental agencies with basic technical data to properly plan for wise use and development of the flood plains.

FLOOD PLAIN MANAGEMENT--Comprehensive flood damage prevention program which requires integration of all alternative measures (structural and nonstructural) in investigation of flood problems and planning for wise use of the flood plain.

FLOOD PLAIN REGULATION--A general term applied to the full range of codes, ordinances, and other regulations relating to the use of land, water, and construction within a channel or flood plain area.

FLOOD PROOFING--A combination of structural changes and adjustments to properties subject to flooding primarily for the reduction of flood damages.

INSTALLATION COSTS--The value of goods and services necessary for the establishment of the project, including initial project construction; land, easements, rights-of-way, and water rights; capital outlays to relocate facilities or prevent damages; and all other expenditures for investigation and surveys, designing, planning, and constructing a project after its authorization (excludes interest during construction).

LAND TREATMENT AND MANAGEMENT MEASURES--A tillage practice, a pattern of tillage or land use, or land management facility improvements to alter runoff, reduce sediment production, improve use of drainage and irrigation facilities, or improve plant or animal production.

100-YEAR FLOOD--Represents a flood whose chance of occurrence, based upon past history, is once-in-100 years. It may, however, occur at any time and even more than once in a year.

OPERATION, MAINTENANCE, AND REPLACEMENT COSTS (OM&R)--The value of goods and services needed to operate a constructed project and make repairs and replacements necessary to maintain the project in a sound operating condition during its economic life.

RESIDUAL AVERAGE ANNUAL FLOOD DAMAGES--Those flood damages which are not prevented by the flood control program.

STANDARD PROJECT FLOOD (S.P.F.)--A hypothetical flood representing the critical volume and peak discharge that may be expected from the most severe combination of meteorologic and hydrologic condition reasonably characteristic of the geographical region excluding extraordinarily rare combinations.

INTRODUCTION

INTRODUCTION

PURPOSE AND SCOPE

The purpose of this appendix is to provide -

a. General history of the floodwater and sediment problem as it affected the Lower Colorado Region before 1965.

b. Data (including dollar losses) concerning the existing (1965) floodwater and sediment problem and the present status of remedial measures.

c. Broad-scope analysis of the magnitude and extent of potential flood problems in the Region. (The anticipated needs and demands for flood plain use are based on MODIFIED OBERS 1/ projections - population and economic growth.)

d. General appraisal of the alternatives, including costs, that would be available to provide the necessary floodwater and sediment protection to satisfy (c) above.

The study was preliminary or reconnaissance in nature. Existing reports and studies were used to determine current flood damages. For areas where little or no data existed, estimates of flood damages were made by comparing generalized hydrologic, hydraulic, land-use, and economic characteristics of the study areas with similar available data in other areas. All data were adjusted to reflect base year (1965) prices and conditions of development. Future needs and measures required to satisfy these needs were determined by evaluating existing problems concerning anticipated land use and increased development, and by using other indices which reflect an expanding population.

RELATIONSHIP TO OTHER PARTS OF REPORT

The objectives of the Lower Colorado Region study are to formulate a framework plan to provide a broad guide to the best use, or combination of uses, of water and related land resources to meet short- and long-term

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1/ Regional projections, OBERS, were prepared by the Office of Business Economics, U.S. Department of Commerce, and the Economic Research Service, U.S. Department of Agriculture. MODIFIED OBERS projections are modifications of the OBERS projections to more closely reflect regional trends.

needs. The regional study is composed of the Main Report and 16 appendixes. The Flood Control Appendix will indicate the flood problems that may impair the best uses of a resource, and will suggest measures to mitigate these problems.

The data concerning population, urban and agricultural growth, change in land use, and related land resources that affect the flood damages were obtained from the appropriate appendixes.

This appendix includes the total floodwater and sediment damages that generally is associated with flood control. Data concerning that part of the floodwater and sediment damages that can be attributed to upstream watersheds and the alternatives to mitigate these damages are also presented in Appendix VIII, Watershed Management.

DESCRIPTION OF THE REGION

The Lower Colorado Region comprises 141,137 square miles in the Pacific Southwest area of the United States. The Region includes the Colorado River drainage area in the United States below Lee Ferry, Arizona, except for that part that is in California. In addition, it includes several closed basins in Arizona, Nevada, and New Mexico and some areas in southern Arizona and New Mexico that drain into Mexico.

The Region has been divided into three hydrologic subregions: Lower Main Stem, Little Colorado, and Gila. (See map 1.) The Lower Main Stem Subregion includes 56,554 square miles in Arizona, Nevada, and Utah. The Little Colorado Subregion includes 26,977 square miles of the Little Colorado River Basin in Arizona and New Mexico. The Gila Subregion includes 57,606 square miles in southeastern Arizona and southwestern New Mexico.

The climate in the Lower Colorado Region varies widely as a result of the large differences in elevation, the considerable range in latitude, and the distribution of mountain ranges and highlands. The mean annual temperature ranges from 43.7 degrees in the mountainous area of eastern Arizona to 72.4 degrees in the desert area of Gila Bend, Arizona. In the desert sections, temperatures in excess of 100 degrees are common during much of the summer. In the mountains, temperatures sometimes drop as low as 30 degrees below zero. There are two distinct moisture sources. Winter precipitation is associated with moisture moving into the area from the Pacific Ocean, while the Gulf of Mexico is the source of much of the summer rainfall. About half of the Region receives an average of less than 10 inches of precipitation per year, and a large part of the remainder receives less than 20 inches per year. In a few small areas, the average annual precipitation is more than 25 inches. Some areas near Yuma, Arizona, receive less than 5 inches of precipitation per year, and a few mountain peaks receive more than 30 inches of precipitation per year.

The Lower Colorado Region is a complex of plateaus, mountains, deserts, and plains, with elevations ranging from 100 feet above sea level near Yuma to 12,611 feet in the mountains north of Flagstaff. The Region lies within the Basin and Range and the Colorado Plateau physiographic provinces. The Basin and Range province occupies the southern and western parts of the Region and is characterized by fault block mountains and valleys. In the mountains, streams have cut deep gorges. The valleys consist of a series of interlocking basins partially filled by alluvium. The basin rims are formed by the mountain ranges, which consist of all types of rock - sedimentary, igneous, and metamorphic. The Colorado Plateau province occupies the northeastern part of the Region and is characterized by alternating cliffs and slopes formed as a result of variations in resistance to erosion. Ledges, cliffs, or rock benches formed of resistant beds of sandstone and limestone are separated by slopes, valleys, and badlands carved on the weaker intervening shaly strata.

Population of the Lower Colorado Region was 1,847,280 in 1965. The following tabulation shows the 1965 population and projected population for the Region and Subregions.

Population (MODIFIED OBERS) 1/

Subregion	1965	1980	2000	2020
Lower Main Stem	312,780	762,300	1,429,300	1,874,700
Little Colorado	151,300	223,900	293,100	389,400
Gila	1,383,200	1,880,600	3,000,000	4,612,700
Region, total	1,847,280	2,866,800	4,722,400	6,876,800

1/ Based on hydrologic subregions.

The economy is based on manufacturing, mining, tourism, timber industries, irrigated farming, and livestock. The Region's rate of growth is currently one of the highest in the Nation. Some communities and cities and areas of intensive agricultural development have occupied the level areas along both sides of streams to be near the limited sources of water supply. These locations are subject to severe flooding. The Region's economic development is further discussed in Appendix IV, Economic Base and Projections.

In the Lower Main Stem Subregion, the major streams include the Colorado, Virgin, Muddy, and Bill Williams Rivers, and Las Vegas Wash and the Gila River downstream from Painted Rock Dam. The flow in the Colorado River is controlled by Lake Mead and by Lake Powell, which is just upstream from the Lower Colorado Region boundary. In the Little Colorado Subregion, the major streams, other than the Little Colorado River, include the Puerco and Zuni Rivers, Silver and Chevelon Creeks, Canyon Diablo, and Leroux, Dinnebito, and Moenkopi Washes. In the Gila Subregion, the major streams, in addition to the Gila River above Painted Rock Reservoir, include the San Francisco, San Pedro, Santa Cruz, Salt, Verde, and Agua Fria Rivers.

For the purpose of gathering data on floods and flood damages, the hydrologic subregions were divided into study areas which, generally, were based on hydrologic boundaries, except where divisions were at State boundaries. (See map 1.)

HISTORY OF FLOODING

HISTORY OF FLOODING

The Lower Colorado Region is one of the most arid areas in the United States. Streamflow is extremely variable both in time and location. Few of the tributaries of the lower Colorado River are perennial, except where base flow is provided by springs. The historical floods before 1900 and in this century caused severe property damage and loss of life. Recent development of flood plain land for agricultural and urban use has greatly increased the flood-damage potential in the region.

Floods in the area may be caused by snowmelt or by rainfall. However, since completion of Hoover Dam (1935) and of Colorado River storage reservoirs in the Upper Colorado Region, snowmelt floods on the lower Colorado River are no longer a problem. Major flooding is caused by rainfall and is the result of three types of storms: (a) general winter storms with low-intensity rainfall over wide areas, often continuing for several days; (b) general summer storms with heavy precipitation over large areas; and (c) local thunderstorms which cover a small area and are of high intensity but usually of short duration. Thunderstorms produce many of the destructive flash floods that are well known in the southwest. They can occur at any time in the year, but are most common during the late summer and fall. The amount of runoff that occurs during these storms depends not only upon the amount, type and intensity of the precipitation but also upon the features and conditions of the watershed.

In general, stream slopes in the mountains are steep. Thus, flows have high velocities and cut deep well-defined channels that have sufficient capacity to carry most flows. In the upstream mountainous areas the rate of runoff is high. During major storms the water concentrates quickly with relatively high peak discharges in comparison to the total volume of floodwater. This water debouches on the broad, level valleys causing violent and destructive floods. As the valleys widen and the gradients decrease, the channels increase in width and become more absorptive. Many of the stream channels have been encroached upon by urban and agricultural development; others are choked with phreatophytic growth such as salt cedar, willows, cottonwood, and mesquite.

During the summer months, the mainstreams are not usually in flood. Although summer storms do occur in tributary areas, the force of the peak flows from the side streams is dissipated rapidly in the main channels. Much of the sediment load is deposited, which creates divided channels and results in meandering flow in the mainstreams.

Historically, the largest flood known to have occurred in the Colorado River Basin was the spring flood of 1884. Since 1900, major floods occurred in 1905, 1909, 1916, 1917, 1923, 1926, 1937, 1939, 1941, 1952, 1957, 1962, 1964, 1965, and 1967.

In the Lower Main Stem Subregion, the earliest flood on the Colorado River for which information is considered adequate for use in making a reasonable estimate of flood discharge occurred in 1884. The total volume of this flood is estimated at 30.1 million acre-feet, with a maximum discharge of 300,000 cubic feet per second near Grand Canyon, Arizona. The greatest flood for which reliable data is available was produced by the heavy snowpack deposited during the winter of 1916-1917 combined with the accelerated snow-melting pattern of warm rains and higher-than-normal temperatures. The volume of this flood was 16.9 million acre-feet, with a peak discharge of 160,000 cubic feet per second near Grand Canyon, Arizona. This flood destroyed agricultural and transportation facilities throughout the length of the Colorado River in the Lower Main Stem Subregion.

Prior to completion of Hoover Dam in 1935, disastrous snowmelt floods caused damage along the lower Colorado River each year. In addition to these floods, destructive summer rainfall floods often occurred. Levees had to be built and continually maintained to protect lowlands from flooding. Due to a demand for more water by newly arrived settlers, an additional opening was cut in the west bank of the Colorado River 4 miles downstream from the California-Mexico border to divert water into the Imperial Canal. The headgate that would regulate the flow into the canal had not yet been built when the floods of 1905 came. Uncontrolled floodwaters flowed towards the west through the ungated opening, caused the river to change its course, and created the Salton Sea. For about 16 months the river created havoc in the Imperial Valley; railroad tracks and highways were washed away and homes and farms were destroyed. In 1909, the Colorado River again broke through the levees and changed its course. However, at that time it ran into Bee (Abejas) River, and then into Volcano Lake in Mexico rather than into the Imperial Valley of California. From 1906 to 1924, a total of $10,250,000 was spent on levee work along the lower Colorado River. Most of the damage that occurred and levee work that was done in the United States was in California, which is outside the Lower Colorado Region study area.

Other streams in the Lower Main Stem Subregion that have experienced damaging floods include: Las Vegas Wash with 6,000 cubic feet per second in June 1955; Meadow Valley Wash with 15,000 cubic feet per second in March 1938; Virgin River with 32,500 cubic feet per second in December 1966; and Bill Williams River with 175,000 cubic feet per second in January 1916.

In the Little Colorado Subregion, the September 1923 flood on the Little Colorado River had the largest peak flow of record. The peak was estimated at 120,000 cubic feet per second at Grand Falls, near the mouth, and 60,000 cubic feet per second at Holbrook. Numerous floods dating back to the early 1900's have occurred in the basin, but in most instances no discharge records are available. Some of the larger floods for which discharges were estimated were the September 1928 flood on Ruby Wash at Winslow, Arizona, with an 8,000 cubic feet per second discharge; the August 1959 flood on Puerco River at Gallup, New Mexico, with a 9,400 cubic feet per second discharge; and the 1963 flood on the Zuni River at Zuni, New Mexico, with a 13,000 cubic feet per second discharge.

In the Gila Subregion, the February 1891 flood on the Salt River had an estimated peak floodflow of 300,000 cubic feet per second at Arizona Dam (approximately the same location as Granite Reef Dam). The storms of January 1916 produced the greatest magnitude of any flood involving the entire Gila River Basin since records have been kept. During that month, two Pacific storms, 10 days apart, brought warm rain to melt unusually heavy snow covers. The resulting flood, which ravaged the entire Gila River Basin had peak discharges of 230,000 cubic feet per second at the mouth of the Gila River; 130,000 cubic feet per second on the Gila River below San Pedro River; 90,000 cubic feet per second on the San Francisco River at Clifton; and 11,000 cubic feet per second on the Santa Cruz River near Greens Canal. Recent major floods along tributaries of the Gila River have produced lower peak discharges than the historical floods along the Colorado River or Gila River, but have caused more flood damage because of increased development. Notable examples are the 1962 flood on Santa Rosa Wash, which had a peak flow of 53,000 cubic feet per second near Vaiva Vo; the 1965-66 flood on the Salt River, which had a peak flow of 67,000 cubic feet per second below Verde River (photo 1); and the 1954 flood on Pinal Creek which had a peak flow of 6,500 cubic feet per second at Globe, Arizona (photos 2 and 3).

Damages from major past floods are shown in table 1 of this appendix. The early floods listed have few breakdowns in damage categories because the information is lacking or the development was minor. Some of the largest and earliest floods previously discussed are not included in the table because there is no record of the damages. Two columns in table 1, forest and range resources and facilities, have very few entries. This is probably due to the historical data being collected by not using these same headings, and by the reporting agency evaluating flood damages for only a particular area or reach of the stream where it had an interest. Table 2 shows the estimated damage for the maximum flood of record for several streams, with recurrence under 1965 economic, price, and project conditions. Table 3 shows the flood damages expected for selected areas upon the occurrence of the 100-year-frequency flood. Peak flows of maximum floods of record, standard project floods, and 100-year floods for selected stations are shown in table 11.

Loss of life occurred during the floods of 1890, 1891, 1906, 1914, 1935, 1938, 1940, and 1945. In 1890 a dam failure on the Upper Hassayampa River resulted in the loss of 70 lives. Ten persons drowned when one span of a bridge on Julian Wash at Tucson, Arizona washed out in a flash flood in August 1945. Twenty persons lost their lives due to floods in Arizona during the 1970 Labor Day week end. Loss of life from all floods probably is greater than that recorded.

Photo 1. The Salt River overflowed its banks at Tempe, Arizona, December 1965-January 1966. (Photo by Don Keller, Phoenix, Arizona)

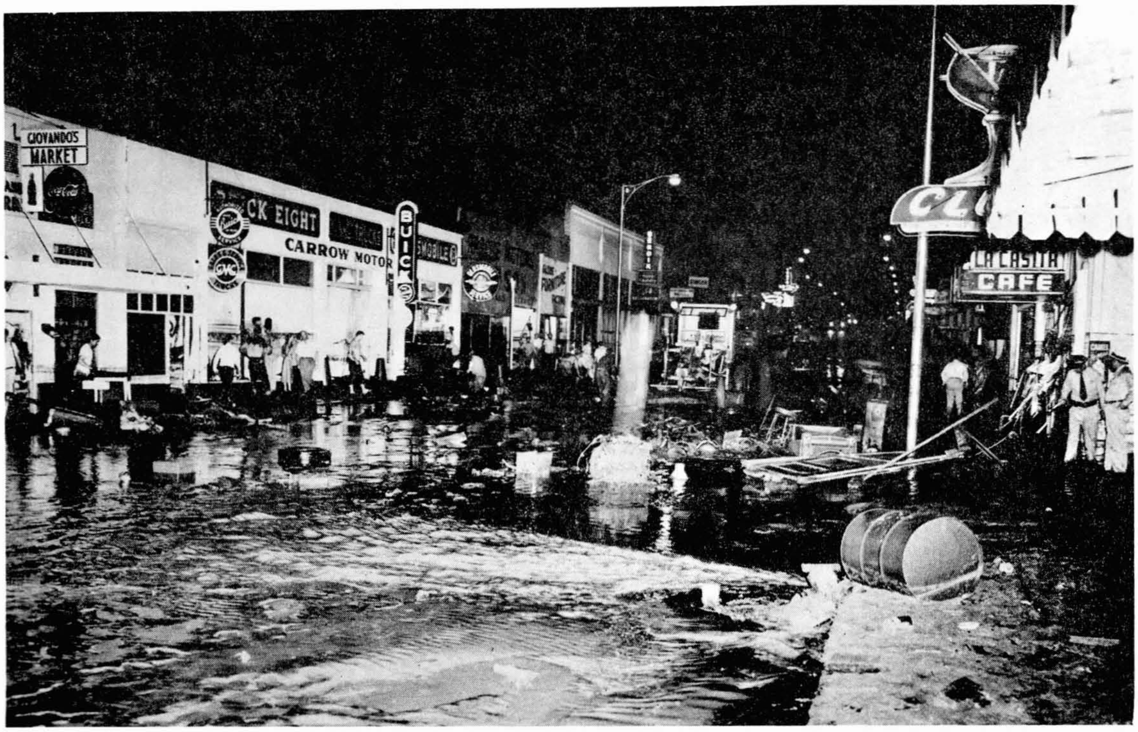

Photo 2. Damage to the business section of Globe, Arizona, from flood of July 1954. (Photo by Norman's Studio, Globe, Arizona)

Photo 3. Typical damage to stores along North Broad Street in Globe, Arizona, from flood of July 1954. (Photo by Norman's Studio, Globe, Arizona)

PRESENT STATUS

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Existing flood control measures consist of structural and nonstructural programs performed by Federal agencies, States, and local organizations. These measures include reservoirs, channel improvements, levees and dikes, channel stabilization, sediment control, flood forecasting, watershed management and land treatment practices, flood proofing, and flood plain regulations. The existing flood control program is conducted under statutory authorizations discussed in Appendix III, "Legal and Institutional Environments." The principal flood-damage-reduction measures are described in the following paragraphs.

FLOOD FORECASTING

The National Weather Service currently provides forecasts for 14 river gage locations in the Lower Colorado Region. (See map 2.) The National Weather Service's River Forecast Center and River District Offices issue riverflow and water-level forecasts daily or as required. The flood warnings developed and issued by the National Weather Service alert affected urban and agricultural areas of impending flood situations and provide them with an opportunity to institute emergency measures to minimize damages. These measures may include the evacuation of persons, livestock, and movable property and the construction of temporary protective structures.

The "Water Supply Forecasts" by the National Weather Service and "Water Supply Outlook" by the Soil Conservation Service are basic sources of information for long-range forecasts. These papers are issued on the 1st of January and are updated on the 1st day of each succeeding month through May. Additional river and flood forecasts issued by the National Weather Service, as necessary, include forecasts concerning snowmelt from above normal snowpack in early spring, heavy rains on melting snowpack (usually in midwinter), early winter rains, and summer cloudbursts.

Snowmelt volume runoff forecasts are developed from snow surveys and precipitation records. The basic data in the Region are collected by utilizing a system of 78 snow courses, 20 precipitation storage gages, seven soil moisture units, and 10 aerial snow depth markers. The depth and water content of snow are evaluated on the basis of previous measurements that have been correlated with the resultant flows. Agencies with operational responsibilities for dams and reservoirs use runoff and flood forecasts, together with information developed in their respective agencies, to determine flood routings through their reservoirs so that downstream damages are held to a minimum.

FLOOD CONTROL STORAGE

Flood control storage structures are designed to provide downstream protection by temporarily storing floodwaters, thereby reducing their peak flow, and subsequently releasing water in nondamaging amounts. These structures are often referred to as flood control reservoirs, floodwater retarding structures, or detention dams. The more significant existing flood storage structures are shown on map 3. Many other local structures provide varying degrees of flood protection, although they are not shown on the map. Their effect has been recognized in estimating the magnitude of floods and related damages. Most of them provide protection from relatively small floods and may be temporary in effect. Information on the major existing flood storage structures is given below.

Existing Flood Control Storage (1965)

Name	Number of Structures	Drainage area above structures (square miles)	Stream or basin	Flood control storage (acre-feet)
Lake Mead	1	167,800	Colorado River 1/	8,300,000
Flat Top	1	370	Virgin River	1,700
Iverson	1	84	Virgin River	1,300
Mathews Canyon	1	34	Virgin River	5,300
Pine Canyon	1	45	Virgin River	6,400
Arroyos No. 1	12	29	Gila River	1,400
Railroad Wash	15	203	San Simon Creek	2,700
Creighton	1	106	San Simon Creek	1,500
H-X	1	41	San Simon Creek	1,100
San Simon	1	1,310	San Simon Creek	9,500
Frye-Stockton	5	203	Gila River	7,500
Magma	1	62	Gila River	4,800
Whitlow Ranch	1	143	Queen Creek	28,900
Cave Creek	1	162	Salt River	11,000
McMicken	1	247	Agua Fria River	16,800
White Tanks	2	34	Gila River	3,500
Upper Centennial	1	448	Centennial Wash	3,200
Lower Centennial	1	785	Centennial Wash	2,400
Painted Rock	1	50,910	Gila River	2,292,000
Total				10,701,000

1/ Flood control storage, exclusive of 1,200,000 acre-feet of surcharge storage, in reservoir as completed in 1935. Flood control space previously required in Lake Mead is now distributed between Lake Mead and the reservoirs formed by four major upstream dams (Glen Canyon, Navajo, Blue Mesa, and Flaming Gorge) in accordance with published regulations and flood forecasting.

Other major reservoirs in the Region, such as Mojave, Havasu, San Carlos, Roosevelt, Bartlett, and Pleasant, do not have designated storage for flood control, but operation of reservoir storage on an inflow forecast basis provides floodflow reductions downstream. Glen Canyon, Navajo, Blue Mesa, and Flaming Gorge Dams have been constructed in the Upper Colorado Region upstream from Hoover Dam under the authority of the Colorado River Storage Project. These four dams control practically all inflow into Lake Mead, except for the side inflow entering the Colorado River between Lake Powell and Lake Mead.

Alamo Lake, a major multiple-purpose structure on the Bill Williams River, and four watershed projects were constructed between December 31, 1965, and December 31, 1970. These structures are discussed in a subsequent section titled "Measures Required to Satisfy Future Needs."

LEVEES AND CHANNELS

Local areas are often protected from the effects of floods by the construction of levee and channel improvements. Levees provide for channel capacity above the surrounding ground. Channel improvements provide for enlargement of natural channel capacity by straightening, clearing, widening, or deepening or by lining the channel, thereby decreasing overbank flooding. The existing (1965) levees and channels are summarized as follows:

Name	Levee (mile)	Channel (mile)
LOWER MAIN STEM		
Colorado River	78	55
Yuma Valley	17	-
Lower Gila River	44	24
Subregion total	139	79
LITTLE COLORADO		
Holbrook	1	-
Subregion total	1	-
GILA		
Arroyos No. 1	-	1
Frye-Stockton	-	14
Magma	-	4
Tucson Diversion Channel	2	5
Greene Wash	1	-
McMicken (outlet)	-	6
White Tanks	-	11
Subregion total	3	41
REGION TOTAL	143	120

Emergency flood control work under general congressional authorization includes emergency bank protection, snagging and clearing, flood emergency preparation, flood fighting and rescue operations, and repair and restoration of flood control works. Emergency work accomplished in the Region includes revetting and channel clearing at Jerome, Arizona; snagging and clearing on the San Francisco River at Clifton, Arizona; and repairing and revetting levees and removing sediment on Greens Canal, Arizona.

Under Public Law 875, the Office of Emergency Preparedness coordinates the disaster-relief functions of all Federal agencies. Rehabilitation of certain flood-damaged public facilities is accomplished under this authority.

LAND TREATMENT AND MANAGEMENT

The watershed areas of the Lower Colorado Region are radically different in appearance, vegetation, annual precipitation, and land use from those of most regions in the United States. However, these areas are similar to other regions in that they are the source of sediment-laden floodwaters that damage valuable land, crops, canals, roads, equipment, residences, and industry. The management of watershed lands and their resources has a beneficial effect by reducing damage from downstream floods. Land treatment and management practices and measures are effective in slowing runoff, thus permitting more precipitation to be absorbed where it falls. Land treatment programs supplement flood control structures by reducing the sediment load of floodwaters entering these structures, thereby prolonging their useful lives.

Land treatment and management includes the development and use as well as the conservation and protection of all watershed resources. These resources include land and water and the elements of each - forest, grass, crops, fish and wildlife, and scenic and wild areas. Modern land management affects the most efficient use of land for sustained production of crops, grass, and trees, and improves the quality of runoff water that is used for beneficial purposes. The program not only protects and restores the land and water resources of the immediate area for the benefit of onsite users, but also generally has beneficial offsite effects by reducing sedimentations, controlling runoff, and improving water quality and the environment. In addition, the program usually provides recreation and fish and wildlife benefits.

Land treatment and management programs include diversions, levees and dikes, channel improvement, floodways, streambank protection, controlled burning, fire prevention, grass seeding, reforestation of denuded forest land, contour trenching, furrowing, and terracing. (See photo 4.) Existing measures include 1,172 miles of dikes and levees, 508 miles of floodwater diversions, 19 miles of floodways, and 187 miles of channel improvements. Additional information on watershed flood prevention measures and land treatment and management is contained in Appendix VIII, "Watershed Management."

Photo 4. Contour trenches installed for flood prevention. (U.S. Forest Service photo.)

NONSTRUCTURAL FLOOD PLAIN MANAGEMENT

Throughout the Lower Colorado Region, major flood problems exist at unprotected cities and in highly developed agricultural areas on the flood plain. Progressive encroachment of the flood plain by urbanization, despite the potential hazards of floods, indicates a need for flood plain regulations to insure wise use and development. Flood plain regulations are effected by communities to control the extent and type of development on lands subject to flooding. Some counties and municipalities in the Lower Colorado Region have provided a degree of control through regulation of the flood plain by establishing health regulations and subdivision regulations and by revising building codes. Regulation of land use through zoning is not widely established in the Region. However, in February 1968, Scottsdale, Arizona, enacted flood plain zoning regulations and in February 1970, the State of New Mexico enacted legislation providing for county and municipal flood plain planning and zoning.

At the Federal level, steps have been taken to provide local governmental agencies with basic technical data that would enable them properly to plan for wise use and development of their flood plain areas. Flood plain management services include flood plain information studies and related technical services. Flood plain information reports are prepared upon the request of State and local agencies to delineate flood plains which may identify problem areas in communities throughout the country. States and their subdivisions use the data in these reports in considering legislation, ordinances, flood plain regulations, and proper management of the flood plains. Four flood plain information reports have been completed. The Federal agencies that manage lands in the flood plains have developed land-management programs. For example, developments on Federal lands in the flood plain along the Colorado River from Lake Mohave to the Mexican border are limited to those that have a low development cost and that have benefits (usually to recreation or agriculture) that clearly justify the assumption of a flood risk. Also, human occupancy is generally limited to areas where advance warning of floods would be adequate, and is further limited to short-term use of campers and trailers whose mobility would permit evacuation.

ACCOMPLISHMENTS OF EXISTING FLOOD CONTROL PROGRAM

State and local authorities are provided with water-supply forecasts and river-stage forecasts as general warnings of the flood potential. These data are evaluated to determine whether flood-emergency activities should be implemented. Flood forecasting has enabled local agencies to prepare for flood fighting and evacuation, thus preventing flood damage and possible loss of life. Reservoir operating agencies supplement flood forecast data with data of their own to determine flood routings through specific reservoirs so that downstream damages are held to the minimum. It is possible to reduce the reserved flood control space in Lake Mead when equivalent vacant space is available in Lake Powell and the other upstream Colorado River Storage Project reservoirs, thus permitting a higher operating head for power generation and increased water storage for irrigation.

Flood control reservoirs are generally designed so that flows released into the channel will cause a minimum amount of damage. Necessary discharges during large storms, which occur infrequently, cause the most downstream damage. During small floods the release of small amounts over a longer period is possible, thus permitting recharge of the ground-water system. Reservoirs with ungated dams have outlets that are designed to pass flows commensurate with the capacity of downstream channel and rate of channel percolation. For example, the ungated outlet for Whitlow Ranch Dam has been used very effectively in reducing the downstream flow in Queen Creek, thereby permitting more percolation into the ground-water basin. Controlled releases from Painted Rock Reservoir of flood waters in the Gila River have provided more time for percolation into the downstream ground-water basin.

When forecasts indicate that projected inflow will refill the reservoir for power generation and irrigation purposes, water can be released from reservoirs with no designated flood control storage earlier than would be the normal procedure during flood periods. This early release in controlled amounts reduces or eliminates the flood peaks that would otherwise pass unregulated through the reservoir.

When Hoover Dam was completed in 1935, control of releases of inflow from most floods on the Colorado River to an outflow of 40,000 cubic feet per second became possible. If a flood equal in magnitude to that of the 1884 flood should again occur, the peak inflow of about 300,000 cubic feet per second would be reduced to a peak outflow of 77,000 cubic feet per second. Inflow records show that the floods of 1941, 1952, and 1957 were the largest floods that have occurred since construction of Hoover Dam. It was necessary to make flood control releases during the 1941 and 1952 floods. During 1941, a maximum inflow of 119,200 cubic feet per second and a maximum outflow of 38,200 cubic feet per second occurred. In 1952, a maximum inflow of 122,000 cubic feet per second and a maximum outflow of 38,800 cubic feet per second occurred. In 1957, a maximum inflow of 124,000 cubic feet per second and a maximum outflow of 29,600 cubic feet per second occurred. With the completion of Blue Mesa Dam in 1966, Lake Powell and the other upstream Colorado River Storage Project reservoirs would probably have reduced releases from Hoover Dam in 1941, 1952, and 1957 to flows no greater than the irrigation demands and power releases.

Painted Rock Dam on the Gila River, which was completed in 1959, is designed to reduce the reservoir design flood inflow of 300,000 cubic feet per second to an outflow of 22,500 cubic feet per second. In 1966 Painted Rock Reservoir was operated to reduce an inflow of 48,900 cubic feet per second to an outflow of 2,850 cubic feet per second. (See photo 5.)

San Carlos Lake behind Coolidge Dam has no designated flood control storage, but since November 1928, the flow in the Gila River has been controlled at Coolidge Dam with the maximum release from San Carlos being 1,270 cubic feet per second. No estimate has been made of flood damages prevented by this reduction of flow.

Since 1965, a plan of operation was prepared by the owner (Salt River Project) for Lake Roosevelt and Bartlett Reservoir. The plan provided for the reservoirs to be operated for joint use, including flood control. Substantial floodflow reduction downstream from these reservoirs would result from operation of reservoir storage on an inflow forecast basis.

The existing flood control program of floodwater storage, levees, channel improvements, land treatment and management, flood forecasting, and nonstructural flood plain management has prevented flood damages estimated at $110,400,000 through 1965. Table 2 lists some maximum floods of record indicating the damages that would be prevented with existing (1965) structures if the record flood should reoccur. Protection has been provided for about 238 miles of rivers and streams and 734,000 acres of land.

Photo 5. View of Painted Rock Reservoir. Water impounded in January 1966 formed a lake 7 miles long, 3 to 4 miles wide, and 54 feet deep at the dam. (Corps of Engineers photo)

REMAINING FLOOD PROBLEMS

General

Major flood problems exist at unprotected cities and in highly developed agricultural areas through the Lower Colorado Region. Floods along the main streams cause recurrent damage of major proportions by cutting streambanks, changing the shape and location of channels, eroding farmlands, inundating farmlands and urban areas, depositing silt on crops, and destroying irrigation, communication, utility, and transportation facilities. The steep gradients of tributary streams cause debris-laden floods to debouch on the moderate slopes of alluvial cones where flood waters often spread out as overland flow. Downstream from the cones, the stream channels of the plains are generally poorly defined and are adequate to accommodate only minor flows.

In the Lower Main Stem Subregion, the Virgin River and many of its tributaries are cutting into banks and progressively widening the channels, which has resulted in high silt deposition in the streams during floods. The large quantity of silt contributes to the flood problem because of the cost of providing for sediment storage in flood control works. Bank erosion on the main stream of the Virgin River has increased the channel width, which has caused the destruction of irrigation diversion works, other riparian structures, and irrigated land. The channel of the largest tributary, Muddy River, has an insufficient capacity to carry peak flows. Consequently inundation of farmlands and urban areas has occurred.

High-intensity rainfall has caused floods in Las Vegas Wash and tributary channels, which have resulted in damage by inundation, by impact of high-velocity flow, and by debris deposition. (See photos 6 and 7.)

Prior to completion of Alamo Dam in 1968, a measure of control of floods originating on the Bill Williams River was provided by operation of Parker Dam and Reservoir and a flood warning system. Alamo Reservoir will reduce a design inflow of 300,000 cubic feet per second to 7,000 cubic feet per second, thereby appreciably reducing downstream damages.

The channel of the Gila River downstream from Painted Rock Dam is obstructed by the encroachment of phreatophytic growth and deposition of silt from tributary streams. The result is a constricted channel with reduced capacity where even small floods may overflow the bank before the streambed erodes enough to contain the flow. Channel improvements from Texas Hill (mile 66) to the Gila Siphon (mile 8.4), authorized for early construction, will correct the flood situation in the Wellton-Mohawk Irrigation District.

In the Little Colorado Subregion the streams are characterized by periods of little or no flow. Usually there are short periods in which the streams gradually rise because of spring thaws. Otherwise, the only

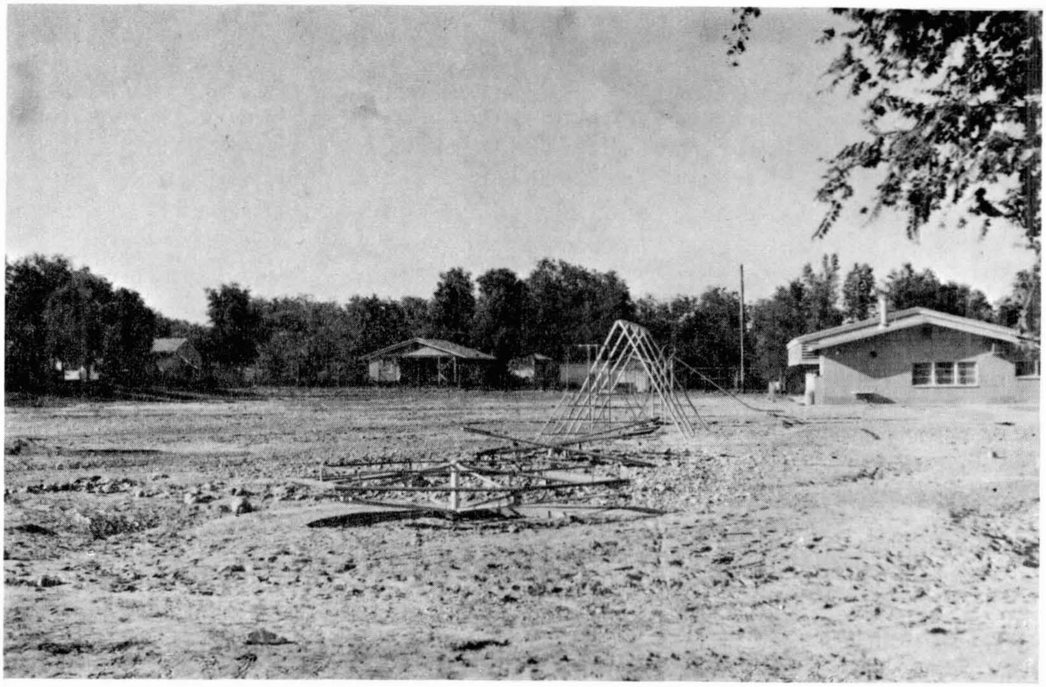


Photo 6. Sediment deposited during the flood of June 1955 on the playground of Mayfair School in the eastern section of Las Vegas, Nevada. (Corps of Engineers photo.)

Photo 7. A thunderstorm in September 1969 caused flashflooding in Las Vegas, Nevada. (Photo by Wide World Photos.)

Photo 8. Floodwaters from Ice House Wash during flood of August 1959 in Winslow, Arizona. (Photo by John P. Scott - Winslow, Arizona.)

period of appreciable flow is immediately following rainfall. In general, floods caused by rainfall are of the flash type, with relatively sharp peaks and short durations. (See photo 8.) Deposition of silt in some of the stream channels reduces their capacity so that even small flows may overflow the banks of those streams.

In the Gila Subregion, major floods cause extensive inundation of farmlands and city property in the overflow areas along Gila and Salt Rivers and their tributaries. Some reaches of channels of San Simon Creek, San Pedro River, and Santa Cruz River have degraded from shallow, meandering watercourses to deep gorges cut in erodible soils of the valleys. Major floods on the lower Santa Cruz River spread over a wide area below Red Rock, overflowing many acres of farmlands and sometimes reaching the towns.

Inundation

Floods on the main rivers and major tributaries usually differ materially from floods occurring on small creeks and headwater streams. Floods on the larger rivers usually rise and fall slowly and often inundate the flood plains for days. These floods are caused by long continuous storms, a series of general storms, or by a combination of snowmelt and general rainfall. Some of the most recent floods affecting the larger streams occurred in September 1962, September 1964, December 1965, and December 1967. Severe damages occurred to crops, agricultural improvements, urban developments, and public facilities. Almost every year, damaging floods occur in some small watersheds in the Region. These storms often attract little attention outside of the immediate area. This may lead to a conclusion that damages are local problems and are of minor importance. However, to the individuals involved, such damages represent severe economic losses. For the Lower Colorado Region as a whole, the sum of such damages represents a serious economic loss.

Some large historical floods were cited in the section titled "History of Flooding." Table 3 shows the estimated damages for the 100-year-frequency flood at selected locations. The average annual runoff with peak and minimum discharge is discussed in Appendix V, "Water Resources."

Bank Erosion

Streambank erosion occurs along most of the main streams and along tributary streams, except for protected and controlled reaches such as reaches of the Colorado River. Generally, streambank erosion is greater on the upper reaches of the streams, however, bank erosion occurs to the mouth of some streams, such as on San Simon Creek.

Land adjacent to the streams is usually fairly level and consists of either irrigated farmland or good range land. Bank erosion would therefore destroy some of the more productive land. Where high-value land is involved, protection of some type is frequently provided, but for range and low-value land, few measures have been installed. Photo 9 shows bank erosion along a developed reach of Rillito Creek at Tucson, Arizona.

On the Colorado River from Davis Dam to the international boundary, river stabilization work has been under construction since 1949. The river-management program is based on a multiple-purpose concept. The primary goals of the work are conservation, regulation and delivery of water, control of potential floods, improvement of navigation, stabilization of the river, and preservation of fish and wildlife and recreational resources. Spoil from channel dredging in certain areas is used to strengthen existing river banks or to construct relocated banklines. In other reaches, banks are being stabilized by providing river jetties, fill-training structures, or rock riprap. Information concerning bank erosion in the Region is given in the following tabulation.

Photo 9. Bank erosion on Rillito Creek (Santa Cruz River basin) at Tucson, Arizona, December 1965. (Pima County photo.)

Bank Erosion

Subregion	Length of channel (miles)	Length of erosion (bank miles)	Annual damages ($1000)
Lower Main Stem	59,425	5,135	158.5
Little Colorado	33,315	6,027	118.8
Gila	54,463	6,177	231.0
Region total	147,203	17,339	508.3

Sedimentation

Sedimentation and erosion are greatest in the Little Colorado Subregion where the soil and geologic materials are particularly sensitive to erosion, and the vegetal cover is too sparse to absorb and decrease runoff velocity. Other areas of the Region having high sedimentation rates are that part of the Region in Utah and the Safford-San Simon area, the San Pedro River area, the Santa Cruz River area, that part of the Verde River in the vicinity of Cottonwood, and the Big Sandy River south of Kingman in Arizona. (See photos 10 and 11.) More information on erosion and sedimentation may be found in Appendix VIII, "Watershed Management."

Flood Damages

Estimated average annual flood damages are $10,120,000 for the Lower Main Stem Subregion, $2,430,000 for the Little Colorado-Subregion, and $28,200,000 for the Gila Subregion. These damages reflect the effects of existing (1965) flood control structures and economic conditions. The evaluation is based on estimated tangible damages that can be expected from future flood occurrences. The amount of flood damage to be expected in a given area varies with the magnitude of the floods, frequency and season of flooding, and peculiar susceptibility of different properties to flood damage.

Flood damage data are shown in tables 4 and 9. The headings used in these tables are defined as follows:

a. Forest and range resources. Includes losses or reduced yields from timber, brush, range and creek-bottom meadow lands; reduced fish and wildlife harvest; and damage to fish and wildlife habitat.

b. Forest and range facilities. Includes damages to recreation facilities; fences and corrals; fish and wildlife facilities; roads, trails, and bridges; and public and private administration facilities.

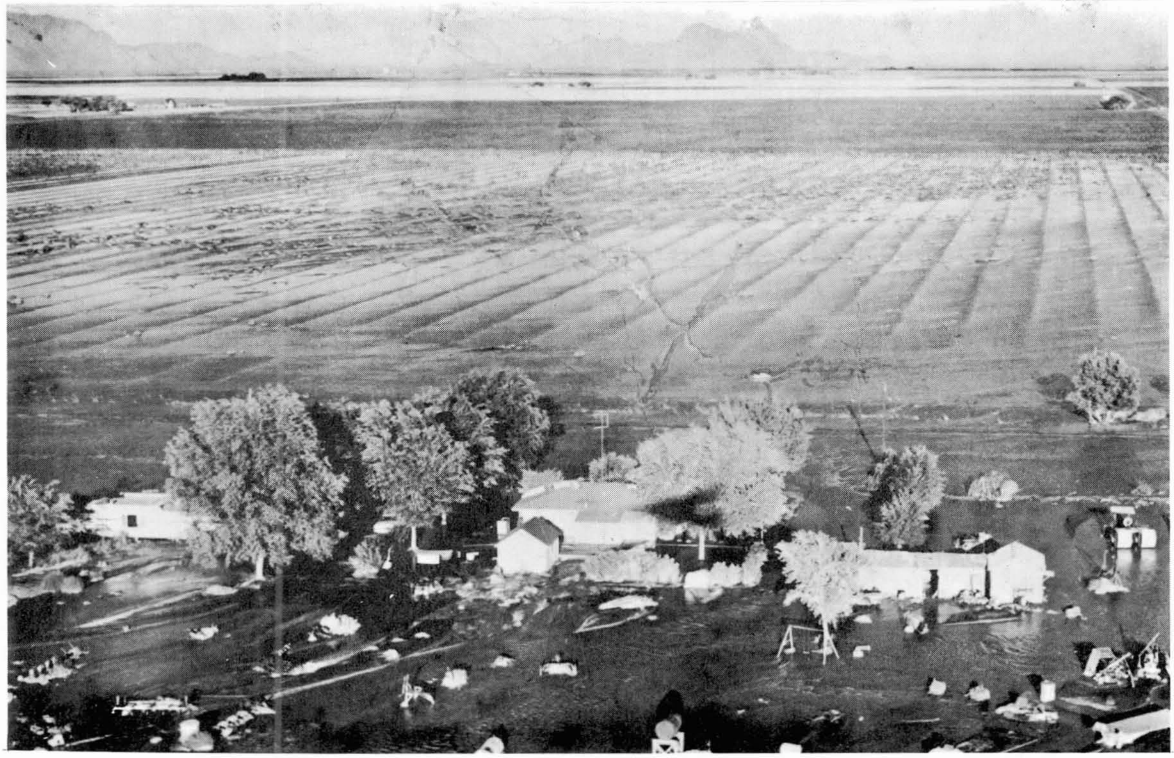


Photo 10. A cotton farm inundated during the flood of September 1962, Santa Cruz River basin. (Soil Conservation Service photo.)

Photo 11. Sediment deposition from floodwaters shown in the above photo. (Soil Conservation Service photo.)

c. Crop and pasture. Includes damages such as crop loss or reduced yield or quality; flooding; spreading of diseases and weed infestation; and the inability to grow crops best adapted to the area.

d. Other agricultural. Includes loss of livestock and stored crops, and damage to machinery, fences, farm buildings, bridges, roads, farm levees, and irrigation and drainage systems.

e. Land. Includes damages caused by erosion and sediment deposition, which may occur on forest land, range land, farm land, and urban land. Also includes land lost by gullying, streambank cutting, channel changes, and landslides caused by flooding and land rendered unproductive or less productive due to sediment deposition.

f. Residential. Includes damages to single and multiple residences, houses, and apartments, including structures, contents, and property improvements.

g. Commercial. Includes damages to businesses, hotels, motels, stores, and service establishments, including structures, furnishings, inventories, property improvements, and the resulting loss of business and wages.

h. Industrial and utility. Includes damages to manufacturing, processing, and fabricating plants and facilities; communication and utility lines and facilities; railroad lines, equipment, and facilities; and losses resulting from impact of these damages on the local and regional economy.

i. Public facilities. Includes damages to highways and bridges; levee systems, irrigation diversions and canals; wildlife; recreation; municipal facilities; and public schools, all of which property is owned or administered by public agencies or nonprofit political and semipolitical organizations. Included are expenditures for flood fighting, repairing flood control works, and caring for evacuated people; cost for adjudicating suits for flood damages; and losses to the traveling public resulting from damaged highways and bridges.

Other flood related damages, which are of an intangible nature and are not evaluated in this report, may include air pollution, loss of life, health hazards as to disease and epidemics, interruptions to normal ways of life, and objectionable changes in the environment.

FUTURE NEEDS

When floods strike developed areas, life and health are threatened, productive capacity is impaired, strategic transportation lines are cut, property and crops are destroyed, and soils are eroded. When large floods occur irrigation canals are broken or deposition of sediment reduces their capacity. Often, crops are lost or yields substantially reduced in areas not flooded because of the inability to irrigate.

In the Region, 45 percent of the developed urban area and 90 percent of the irrigated cropland are located on lands subject to flooding. Some of these valuable land areas are now protected to a degree by structural measures; however, most areas remain unprotected. Data on regional flood damages are incomplete, but economic losses are occurring on all flood plains despite the installation of dams, levees, channels, and land treatment measures.

A realistic appraisal of flood protection needs requires an evaluation of potential damages that might occur under future conditions to obtain a full perspective of the flood problems. Estimates of future damage levels were obtained through the use of MODIFIED OBERS projections, and were predicated on the fact that the flood problems in the Lower Colorado Region are such that almost all land having topography suitable for general development is subject to flood damage, whether it is near a defined stream or not. The estimate of projected damages, as tabulated in tables 5 and 9a, recog nizes the operational effects of the existing (1965) flood control projects, but assumes the absence of any future flood control programs to reduce or prevent flood damages. Figures 1 and 2 illustrate the magnitude and distribution, respectively, of annual flood damages. Present (1965) and future flood damages are summarized in the following tabulation.

Average Annual Flood Damages - in $1,000

State	1965	1980	2000	2020
Arizona	38,022	66,470	135,743	278,009
Nevada	1,591	4,303	12,116	25,438
New Mexico	806	1,320	2,143	3,560
Utah	331	757	1,648	2,993
Region total	40,750	72,850	151,650	310,000

In estimating probable future flood damages, composite growth factors were developed for each subregion. These factors were applied to the present estimated damages under present protection levels and conditions of economic development to obtain estimates of future damage levels. It was assumed future damages would increase if higher levels of development were attained

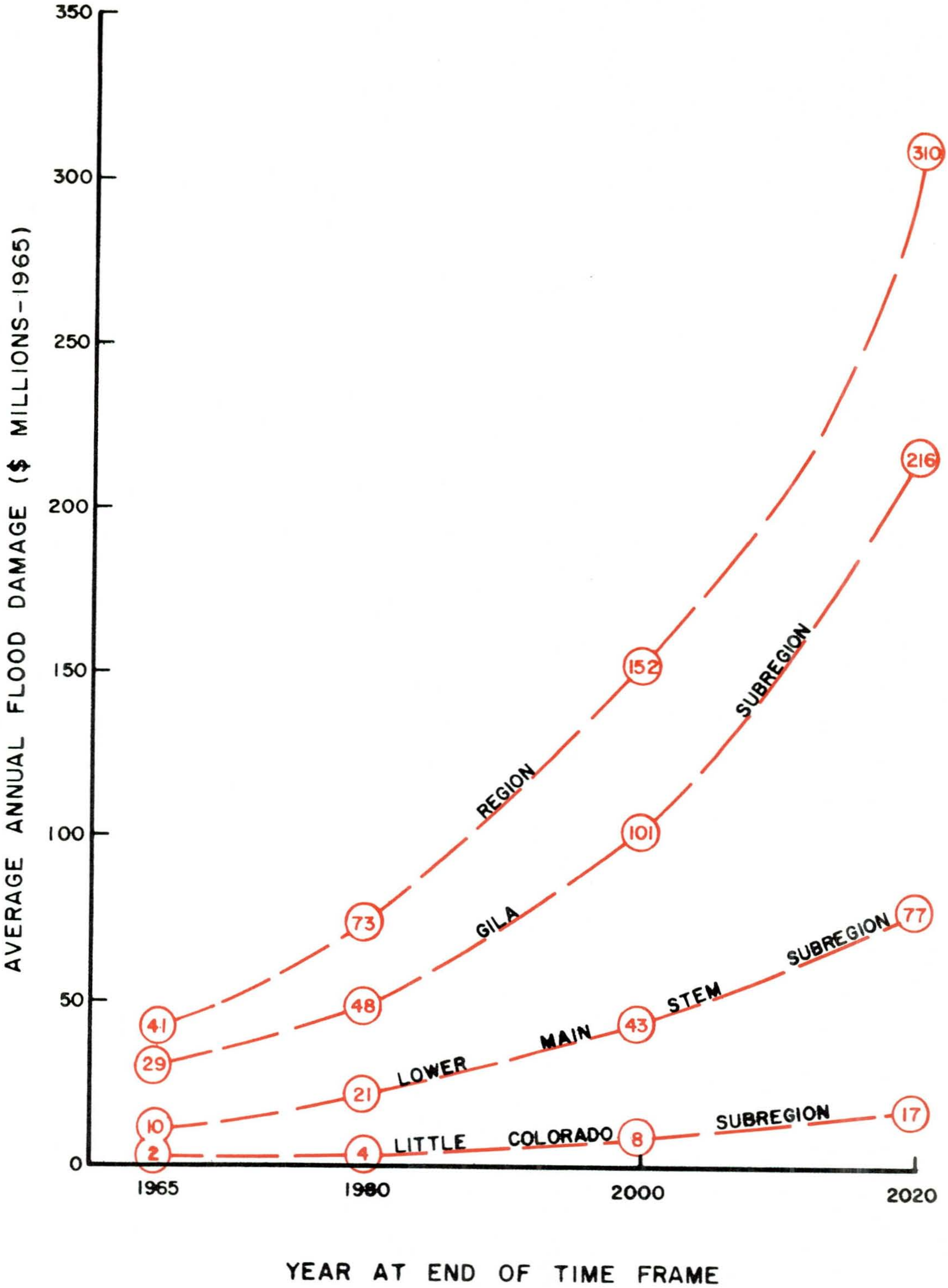


Figure 1. Annual damages with 1965 flood control installations.

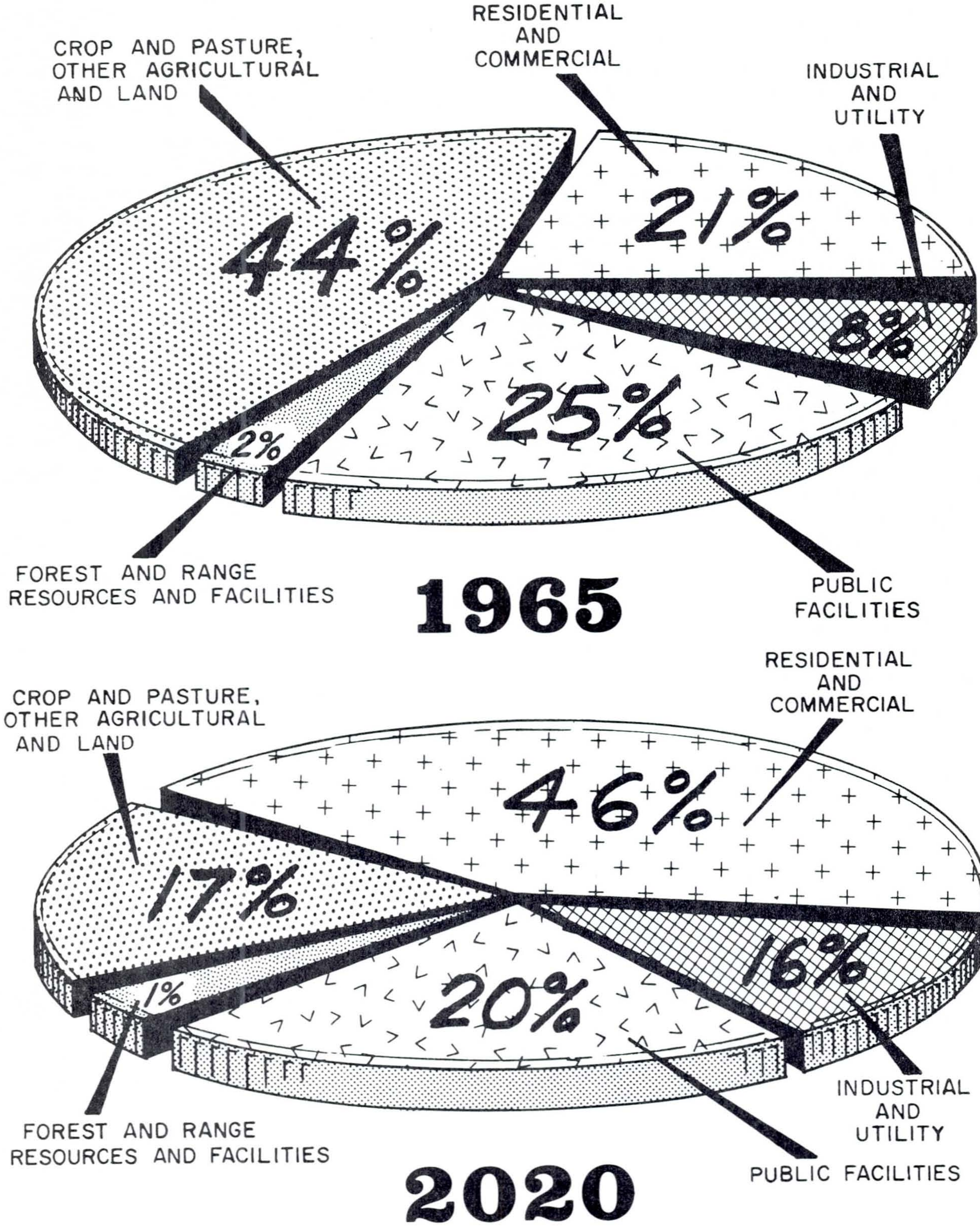


Figure 2. Distribution of annual flood damages.

in target years 1980, 2000, and 2020. Past trends have shown that damages generally increase when there is a rise in economic development.

Agricultural growth was based on total gross output of the various agricultural sectors in the Region. These sectors included food, feed, forage, fiber crops, livestock, dairy, and citrus. The total gross output for various sectors was calculated in the conventional way, as the product of production and price received for the commodity. Since commodity prices were held constant, changes in total gross output were a function of changes in the amount of product produced. In turn, changes in production resulted either from a change in the acreage of crops or number of livestock and from a change in rates of production. Basic data and projections are given in Appendix IV, "Economic Base and Projections."

Nonagricultural growth factors were developed from population, income, and productivity projections to estimate future damage on the basis that these factors would reflect the increase in production of goods and services, increase in consumption of goods and services, change in levels of capital development, and change in land uses. In all cases, growth factors were modified, as necessary, to permit the best use of data from detailed studies and to reflect the character of local areas. Various nonagricultural categories are discussed in the following paragraphs.

The residential and commercial growth trends were evolved as indicated by the projections of population and personal income. Projected rising real per capita income is good evidence that the value of residential property will increase. As real incomes rise, an increasing percentage of the income is spent on home improvements and recreational and educational items. A trend towards a higher percentage of multi-level buildings offsets somewhat the effect of rising real per capita income, but this is in turn counteracted by an increase in density. The residential and commercial rates of change were considered to be the same since they are closely interconnected and there is little information to suggest any difference.

Industrial and utilities values were assumed to follow the projected trends in industrial and utility employment. It was also assumed that damageable items would increase in proportion with the projected investment.

Public facilities growth was assumed to follow projected population and personal income. Public facilities growth would be at a slower rate than for residential and commercial values because of the expected more intensive use of the existing facilities.

Forest and range facilities growth was assumed to follow the projected growth of public facilities but at a slower rate. Damage to future facilities is expected to be less because of better site selection procedures.

The following tabulation illustrates the projection of present (1965) annual flood damages to future years for a Gila River study area.

Average Annual Flood Damage, Gila River Study Area (State line to Coolidge Dam), Gila Subregion
(1965 project conditions and prices)
($1,000)

Conditions	Forest and range resources	Forest and range facilities	Crop and pasture	Other agricultural	Land	Residential and commercial	Industrial and utilities	Public facilities	Total
1965 economic conditions (base)	6	62	498	517	159	191	134	615	2,182
Development factor 1966-1980	1.59	1.8	1.59	1.59	1.59	1.65	1.84	1.5	1.59
1980 economic conditions	10	112	791	822	252	315	246	922	3,470
Development factor 1966-2000	2.16	3.2	2.16	2.16	2.1	5.0	5.0	3.0	2.84
2000 economic conditions	13	198	1,075	1,116	335	955	670	1,845	6,207
Development factor 1966-2020	2.81	5.5	2.81	2.81	2.4	12.1	11.8	5.8	5.05
2020 economic conditions	17	341	1,399	1,452	382	2,311	1,581	3,567	11,050

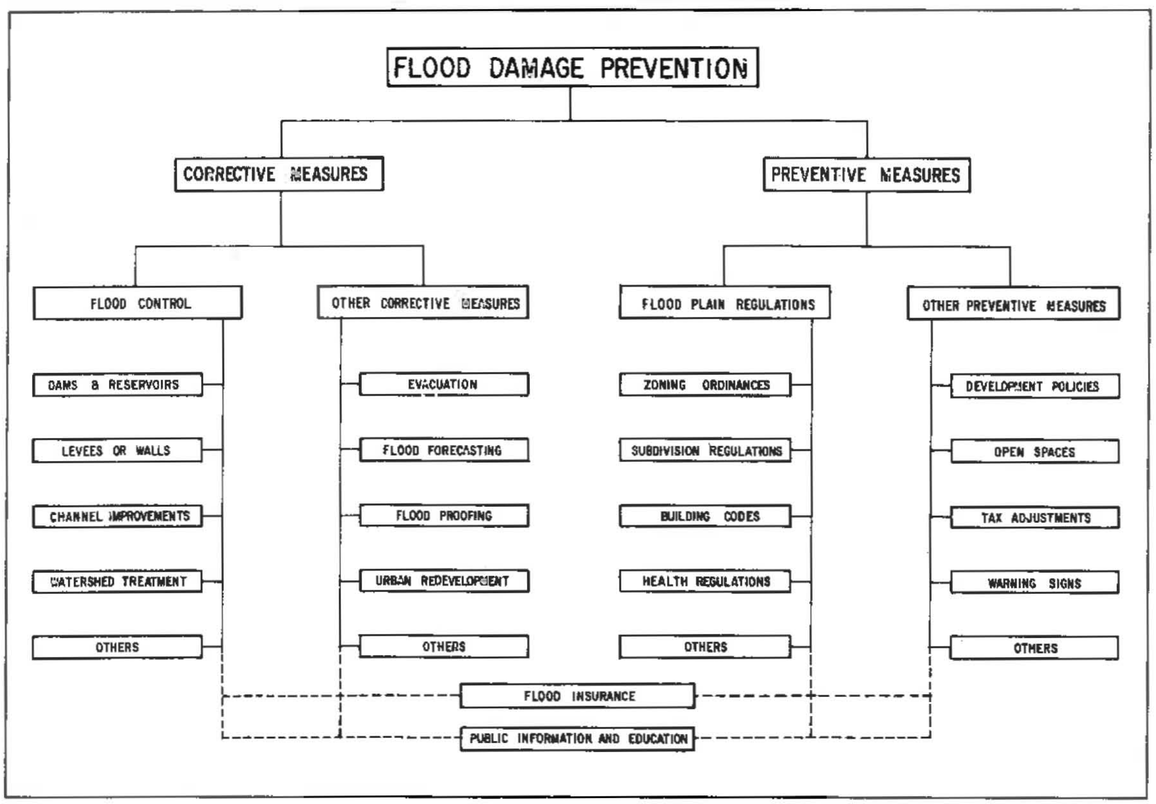
MEASURES REQUIRED TO SATISFY FUTURE NEEDS

MEASURES REQUIRED TO SATISFY FUTURE NEEDS

GENERAL

Flood plain management is a comprehensive term that embraces a range of alternatives, including flood control structures, that can be employed to realize a desired use of flood plains. The principal objective of flood plain management is to relate a desired use to an appropriate risk, while giving consideration to the improvement in quality of the environment, the betterment in the quality of life, and economic development.

Flood damage reduction may be accomplished by correction through control of water and by prevention through control of flood plain use. The principal function of corrective measures is to control floodwaters by reducing the flood stage so that the risk of flood damage to any part of the flood plain is compatible with its use. Preventive measures are directed to regulating flood plain development to minimize the damaging effects of floods. The principal features of corrective and preventive measures are shown in the following diagram.



An essential consideration during the early stages of the planning process for a flood control project is the full exchange of ideas, goals, and requirements of all interested groups and individuals. The flood control plan must also be fully coordinated with all future water and related land-resource development within the Region. Development of flood control programs normally go beyond the scope of reducing flood damages and include other elements such as recreation and fish and wildlife. For instance, the solution to flood problems must be correlated with measures that satisfy the present water quality, hydroelectric power, recreation, fish and wildlife, environmental quality, and urban development. Environmental quality should be one of the primary considerations. Other important factors that must be considered include health, safety, and loss of life. The 1966-2020 flood control program is shown on map 3.

FLOOD CONTROL STORAGE

Most flood control storage structures constructed today are designed to provide water-related benefits in addition to flood control. Demands for water in the future will encourage full development of potential floodwater storage in the Region. Large dams and other water control structures, possibly including underground cavities created by nuclear explosives, will be utilized to store floodwater. The flood control program includes 249 structures with storage for 4,389,000 acre-feet of floodwater and 1,240,000 acre-feet of sediment. Flood control storage by study areas is given in table 6 and a summary is given in the following tabulation.

Summary of Flood Control Storage (1,000 acre-feet)

Subregion and State	1966-1980 Storage capacity	1981-2000 Storage capacity	2001-2020 Storage capacity
LOWER MAIN STEM			
Arizona	1,043	26	29
Nevada	9	120	13
Utah	5	1	4
Subtotal	1,057	147	46
LITTLE COLORADO			
Arizona	83	45	26
New Mexico	26	0	0
Subtotal	109	45	26
GILA			
Arizona	1,898	404	559
New Mexico	81	0	17
Subtotal	1,979	404	576
REGION TOTAL	3,145	596	648

The flood control program for the 1966-1980 time frame is under way (1970). Twenty-three reservoirs, either completed or authorized, have a total storage capacity of about 2,518,400 acre-feet for flood control and 651,400 acre-feet for sediment. Information concerning completed and authorized projects (1966-1970) is summarized in the following tabulation.

Summary of Completed and Authorized Projects (1966-1970)

Subregion and stream	Reservoir or project	Status 1/	Number of reservoirs	Flood control storage (ac.ft.)	Levees (miles)	Channels (miles)
LOWER MAIN STEM						
Bill Williams River	Alamo	C 2/	1	838,000	0	0
Las Vegas Wash	Las Vegas Wash	A	1	1,600	2	2
Colorado River (tributaries)	Fredonia	A	1	400	1	2
LITTLE COLORADO						
Little Colorado River (tributaries)	Winslow	UC	0	0	5	3
GILA						
Gila River	Hooker	A 2/	1	71,000	0	0
Gila River	Camelsback	A	1	133,000	0	0
San Simon Creek	Barrier	A	1	13,500	0	0
San Simon Creek	Vanar Wash	C	0	0	5	1
Gila River	Middle Gila	UC	0	0	0	78
Gila River	Buttes	A 2/	1	133,000	0	0
San Pedro River	Charleston	A 2/	1	133,000	0	0
Gila River (tributaries)	Florence	C	1	4,000	0	1
Gila River (tributaries)	Apache Junction-Gilbert	C	1	4,000	0	9
Gila River (tributaries)	Williams-Chandler	C	2	8,000	0	1
Santa Rosa Wash	St. Clair	A 2/	1	141,000	0	0
Salt River	Orme	A 2/	1	950,000	0	0
Salt River (tributaries)	Buckhorn Mesa	A	1	4,500	0	8
Indian Bend Wash	Indian Bend Wash	A	0	0	0	9
Salt River (tributaries)	Cave Buttes	A	2	26,600	10	24
Agua Fria River (tributaries)	New River	A	1	29,500	10	8
Agua Fria River (tributaries)	Adobe	A	1	13,900	1	7
Agua Fria River (tributaries)	Buckeye	A	2	4,700	0	4
Agua Fria River (tributaries)	Harquahala Valley	A	2	8,700	2	17

1/ Status: C-Completed, A-authorized, UC-under construction
2/ Multiple-purpose project

Estimated costs for flood control storage structures are of reconnaissance quality and detail. Data from prior reports and previously built reservoirs in the region were updated. These costs are summarized in the following tabulation.

Cost of Flood Control Storage ($1,000)

Subregion	1966-1980	1981-2000	2001-2020
Lower Main Stem	41,409	26,914	7,558
Little Colorado	17,403	6,159	4,852
Gila	168,920	64,856	134,594
Region Total	227,732	97,929	147,004

LEVEES AND CHANNELS

A future flood control program would include 238 miles of levees and 1,121 miles of channel. (See table 7.) These levee and channel improvements would in some instances supplement the proposed storage structures, and in other instances would provide protection independently. Preliminary studies indicate that levee and channel improvements are desirable in the subregions as follows:

Summary of Levees and Channels (Miles)

Subregion and State	1966-1980		1981-2000		2001-2020	
	Levee	Channel	Levee	Channel	Levee	Channel
LOWER MAIN STEM						
Arizona	149	113	5	40	0	3
Nevada	2	11	12	42	0	8
Utah	0	10	0	2	0	0
Subtotal	151	134	17	84	0	11
LITTLE COLORADO						
Arizona	30	17	10	16	11	6
New Mexico	0	4	0	5	8	0
Subtotal	30	21	10	21	19	6
GILA						
Arizona	92	428	44	264	75	134
New Mexico	0	3	0	15	0	0
Subtotal	92	431	44	279	75	134
REGION TOTAL	273	586	71	384	94	151

Generally, except where sediment is causing extensive offsite damage, loss of high-value facilities is imminent or important recreation or wildlife resources are damaged, control of streambank erosion may not be economically feasible. Corrective measures may range from vegetative cover to graded rock revetment. In this region, most streambank erosion corrections require structural measures. On the lower Colorado River, streambank stabilization is part of the river-management plan. No evaluation of erosion control measures has been made to determine how much of the cost should be attributed to flood control.

Bank erosion on streams in the Region would be considered in the development of the flood control program. Potential reservoirs, levees, and channel improvement projects would protect those eroding streambanks that are in highly developed areas. However, eroding streambanks that are widely dispersed in undeveloped areas would not be protected.

Estimated costs for levees and channel improvement are of reconnaissance quality and detail. These costs were based on updated costs from prior studies and from construction of similar structures in the region. These costs are summarized in the following tabulation.

Cost of Levees and Channels ($1,000)

Subregion	1966-1980	1981-2000	2001-2020
Lower Main Stem	30,495	29,667	5,083
Little Colorado	4,203	5,680	3,392
Gila	75,583	169,819	47,419
Region Total	110,281	205,166	55,894

FLOOD FORECASTING

Flood forecasting and flood fighting provide opportunities for the implementation of emergency measures to minimize damages by evacuation of persons and movable objects from areas expected to be flooded and of other emergency flood fighting activities.

The flood forecasting system in the Lower Colorado Region should be improved by expansion of the data measuring and reporting networks. The location of the facilities would depend upon the construction program for dams, levees, and channel improvements. This expansion would include more extensive use of telemetered soil moisture and precipitation measuring devices in remote areas; the capability for satellite measuring of surface temperature fields, snow areas and depth, and atmosphere temperature-moisture profiles; and increased radar coverage. Efforts are being made to develop improved methods of evaluating radar echo data to take advantage of the rapid data processing method and expanded capacity of computer facilities to improve estimates of impending precipitation.

Increased research is needed to develop better hydrologic models. Communication of basic data collected and dissemination of forecasts among Federal, State and local governments should be expanded, and training in collection and use of the information should be intensified.

The cost of the flood forecasting portion of the flood control program was based on past records of expenditures for basic data collection and instrumentation and telemetry, plus the costs of the forecast service itself. Flood forecasting costs are summarized as follows:

Cost of Flood Forecasting Program ($1,000)

Subregion	1966-1980	1981-2000	2001-2020
Lower Main Stem	54	36	0
Little Colorado	49	44	0
Gila	228	162	0
Region Total	331	242	0

LAND TREATMENT AND MANAGEMENT

Land treatment and management practices and measures previously discussed ithe "Present Status" section would be installed to provide flood protection. The program includes 733,000 equivalent acres of land to be treated for flood prevention. The installation cost of the program is presented in the following tabulation.

Cost of Land Treatment and Management Measures ($1,000) 1/

Subregion	1966-1980	1981-2000	2001-2020
Lower Main Stem	486	1,595	1,855
Little Colorado	423	1,984	2,683
Gila	5,288	6,744	6,736
Region Total	6,197	10,323	11,274

1/ Includes only costs of those land treatment and management practices and measures which provide at least 10-year flood protection for agricultural areas, 10-year flood protection for resources and developments on forestland and rangeland, and 100-year flood protection for urban and industrial areas. The total land treatment and management program is reported in Appendix VIII, "Watershed Management."

NONSTRUCTURAL FLOOD PLAIN MANAGEMENT

Flood damage may be prevented by the application of control over the use of flood-prone lands through planned development and management. Wise use of the flood plain is illustrated in figure 3. Some nonstructural flood plain management measures are described in the following paragraphs.

Flood Plain Regulation

Flood damage prevention may be accomplished by controlling the use of the flood plain by adopting flood plain regulations, which include zoning ordinances, subdivision and building codes, health regulations, and development policies. The purpose of flood plain regulation is not to deny use of the flood plain. Rather, it is to prescribe uses that are compatible with nature's need to pass floodflows. Wise use of the flood plain is shown graphically in figure 3.

Flood plain regulation implies the use of the legal tools that are available to communities to control the extent and type of future development that will be permitted in flood-prone areas. It is essential that there be a good public understanding of the general flood problems, the degree of risk, and the legal tools that can be used to control the use of flood plain lands before successful flood plain management can be implemented.

Zoning is the legal tool that is used to implement and enforce the detailed plans resulting from the land-use planning programs. Zoning ordinances are promulgated by towns, cities, counties, and agencies of states to control and direct the use and development of land and property within their jurisdiction.

Subdivision regulations are utilized by local governments to specify the manner in which land may be divided into lots for the purposes of sale or development.

Building codes may be utilized effectively to prevent damages to developments in the flood plain by establishing minimum flood elevations, restricting building materials to be used, requiring construction that will withstand water pressure and high velocity, and requiring adequate foundation anchorage to prevent flotation.

Health regulations could restrict activities in the flood plain that would create a health hazard if facilities were inundated.

Development policies of local planning agencies should deter construction of streets and utility systems, schools, and other public facilities in flood-prone areas.

Flood Proofing

Flood proofing consists of a combination of structural changes and adjustments to facilities subject to flooding to reduce or eliminate flood damages. Flood proofing may be applied to existing or new structures, and accomplished by keeping the water out of buildings, internal flood proofing, raising buildings as on stilts, and by raising the site with land fill.

Other Measures

Open space is much in demand. Areas adjacent to streams have a natural environment that is readily adaptable to use as parks, playgrounds, picnic areas, and riding and hiking trails.

Tax concessions have been found to be effective in retaining the status of lands dedicated to agriculture, recreation, conservation, or other open-space uses, thereby preserving existing floodways along streams.

Urban renewal can be used in flood-blighted areas that are a drain on the economic life and welfare of the community and do not lend themselves to other methods of regulation and control.

A redevelopment program should include flood control works, where neces-sary and appropriate. The lower flood plain should be set aside for parks, open space, and other uses that would not be subject to substantial damages in the event of flooding. Areas above the elevation of the designated floodway should be utilized for new structures.

Lending institutions, both Federal and private, are in a position to exercise some control over flood plain development by denying mortgage guarantees or funds to developers if the lands are subject to flooding.

Permanent evacuation of developed areas subject to inundation involves acquisition by fee purchase, the removal of structures, and the relocation of the population from the area. Lands acquired in this manner may be used for parks or other purposes that would not interfere with floodflows or be subject to material damage from floods.

The National Flood Insurance Act of 1968 imposed requirements on community developments. These requirements are positive steps toward lessening flood damages. In order to participate in the flood insurance program, communities must show evidence of: (a) restricting development of land exposed to flood hazards; (b) guiding development of proposed construction away from flood prone areas; (c) assisting in reducing damage caused by floods; and (d) improving the long range land management and use of flood prone areas.

Utilization of flood plain information will be one of the major requirements in future community planning. Consideration of existing and anticipated flood problems will be essential, not only as they relate to present

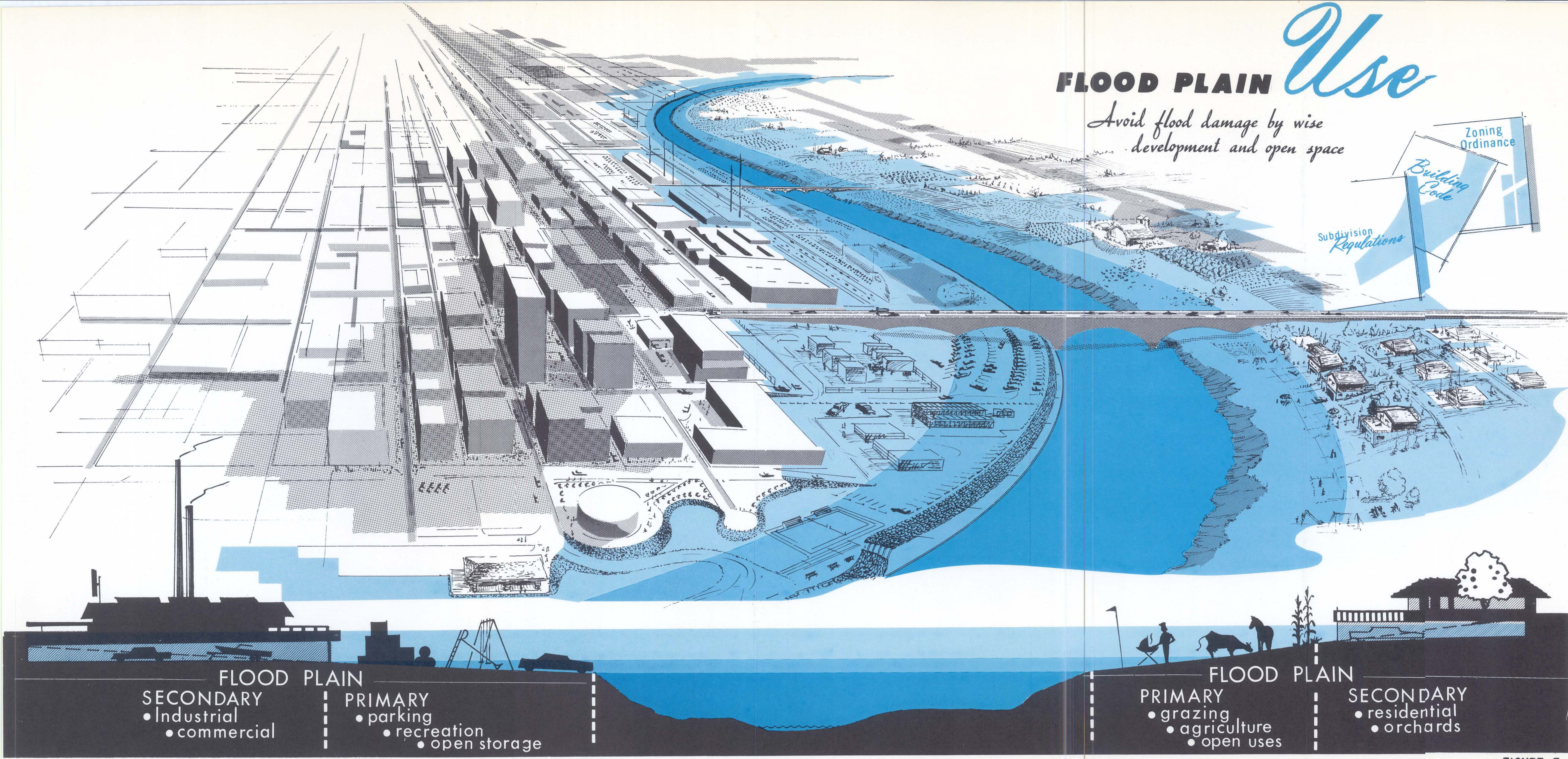

FLOOD PLAIN Use
Avoid flood damage by wise development and open space
Zoning Ordinance
Building Code
Subdivision Regulations
FLOOD PLAIN
SECONDARY
• Industrial
• commercial
PRIMARY
• parking
• recreation
• open storage
FLOOD PLAIN
PRIMARY
• grazing
• agriculture
• open uses
SECONDARY
• residential
• orchards

FIGURE 3

urban centers, but also to small communities, and to those unidentifiable areas that will be developed as urban centers in the future. Flood plain information reports for specific reaches of streams are prepared at the request of local interests. A typical report will in-clude maps or photo mosaics, flood profiles, charts, tables, photographs, and narrative material on the extent, depth, velocity, and duration of floods, and similar data on floods that may be reasonably expected in the future.

Technical services and guidance are provided to assist in the interpretation of flood data and the preparation of flood plain regulations. These services also include suggesting floodway areas, evaluating the effect of those floodways on flood heights, assisting in evaluating flood data concerning location of public buildings and subdivisions and other land uses, providing information on flood proofing, and collecting and disseminating data on flood loss, management, and resource development.

From 1965 to January 1970 three flood plain information reports were completed. Numerous flood hazard reports were also prepared for Federal and non-Federal agencies during this period. Many communities with expanding populations are expected to have flood problems in the future. It is anticipated that by 2020 flood plain information reports will be prepared for all communities with significant flood problems. In addition, hundreds of flood hazard reports will be prepared for specific areas that are now developed or where new development will be proposed.

Costs

Estimated costs for the nonstructural flood plain management program are based on limited data obtained from other regions and on prior studies of flood problems within the Lower Colorado Region. These data indicate the nature and extent of present development in the flood plains. These data, together with estimates of possible future growth, give some general indication of the probable cost of the program that would include flood plain information reports, land regulation and development, flood proofing, land fill, and land purchased for open space. Costs for nonstructural flood plain management are summarized as follows:

Costs for Nonstructural Flood Plain Management ($1,000)

Subregion	1966-1980	1981-2000	2001-2020
Lower Main Stem	3,290	5,194	6,607
Little Colorado	1,212	1,291	2,225
Gila	10,432	16,963	24,525
Region Total	14,934	23,448	33,357

SUMMARY OF COSTS

Costs for the 1966-2020 flood control program would be shared by the Federal government and non-Federal interests. The amount of participation by Federal and non-Federal interests would be based on the nature of benefits (national, regional, or local) derived from the proposed flood control improvements. Generally, the Federal government would be responsible for construction and for operation and maintenance if the benefits were general and widespread. If the project would provide local benefits primarily, the Federal government might be responsible for construction, and non-Federal interests would be responsible for the acquisition of rights-of-way and for operation and maintenance.

The cost of implementing flood plain regulations would be mainly a non-Federal responsibility. The Federal proportion of this cost would be the cost of preparing flood plain information reports and providing other technical services to States and local agencies. Operation and maintenance costs involved in the flood plain regulation program would be non-Federal costs.

The estimated total cost of the 1966-2020 flood control program would be about $944 million (1965 dollars). Federal and non-Federal costs for installation and operation, maintenance, and replacement are shown in tables 10, 10a and 10b by levees and channels, flood control reservoirs, and nonstructural measures which include flood forecasting, land treatment and management as it applies to flood control, and nonstructural flood plain management. The division of costs between Federal and non-Federal is based on their participation as described in the preceding paragraphs. A summary of costs is shown in the following tabulation.

Summary of Costs of Flood Control Program ($1,000)

Subregion, State Federal, and Non-Federal	1966-1980 Install-ation	1966-1980 Annual OM&R	1981-2000 Install-ation	1981-2000 Annual OM&R	2001-2020 Install-ation	2001-2020 Annual OM&R
SUBREGION						
Lower Main Stem						
Federal	69,226	149	49,259	33	12,727	108
Non-Federal	6,508	220	14,147	219	8,376	97
Subtotal	75,734	369	63,406	252	21,103	205
Little Colorado						
Federal	21,477	48	12,675	39	8,930	104
Non-Federal	1,813	107	2,483	76	4,222	69
Subtotal	23,290	155	15,158	115	13,152	173
Gila						
Federal	228,899	418	211,406	193	166,592	606
Non-Federal	31,552	895	47,138	865	46,682	720
Subtotal	260,451	1,313	258,544	1,058	213,274	1,326
Region Total	359,475	1,837	337,108	1,425	247,529	1,704
STATE						
Arizona						
Federal	285,520	531	225,358	236	176,072	758
Non-Federal	36,270	1,130	51,023	954	55,513	801
Subtotal	321,790	1,661	276,381	1,190	231,585	1,559
Nevada						
Federal	3,609	23	38,642	9	6,404	25
Non-Federal	2,334	26	10,912	143	2,814	31
Subtotal	5,943	49	49,554	152	9,218	56
New Mexico						
Federal	26,658	51	5,848	16	3,638	33
Non-Federal	881	49	1,719	47	760	45
Subtotal	27,539	100	7,567	63	4,398	78
Utah						
Federal	3,815	10	3,492	4	2,135	2
Non-Federal	388	17	114	16	193	9
Subtotal	4,203	27	3,606	20	2,328	11
Region Total	359,475	1,837	337,108	1,425	247,529	1,704

LAND REQUIREMENTS

Land requirements for the 1966-2020 flood control program for levees, channels, dams, outlet works, and reservoir areas total about 259,300 acres. A summary of the land requirements by States is given in the following tabulation:

Land Requirements

Subregion	State	Acres		
		1966-1980	1981-2000	2001-2020
Lower Main Stem	Arizona	29,700	5,800	4,000
	Nevada	2,000	12,400	1,600
	Utah	1,000	200	1,100
Little Colorado	Arizona	9,100	4,500	3,500
	New Mexico	3,200	100	200
Gila	Arizona	103,200	36,600	34,600
	New Mexico	4,100	0	2,400
Region Total		152,300	59,600	47,400

Much of the land required for flood control would be available for other purposes most of the time. These purposes would include but not be limited to recreation, wildlife, agricultural crops, grazing, and open space.

POTENTIAL TO SATISFY FUTURE NEEDS

POTENTIAL TO SATISFY FUTURE NEEDS

DISCUSSION

Potential measures considered for use in meeting the future needs for flood control are analyzed in this chapter. Past experience points to an increase in flood damage as river valleys are more fully developed. The increase in the amount of protection provided by engineering works has not kept pace with the rapidly increasing amount of flood damage that is occurring in these developing areas. However, it is recognized that it would not be physically or economically feasible to eliminate all flood damages. National goals of economic efficiency are realized in flood damage prevention planning when net monetary benefits expressed in terms of reduction in average annual flood damages are maximized. However, efficiency is not the only objective. Other major objectives include well-being of people, environmental quality, and regional development.

A single-purpose plan for flood control and damage prevention was prepared for the MODIFIED OBERS projections of population and economic level of development, except for those areas where multiple-purpose projects have been authorized (1970).

The potential flood control and damage prevention program consists of a combination of structural and nonstructural measures and public policy decisions that would appear to present the best solution to flood problems in the Region. The proposed program would provide for flood control storage, levees, channel improvements, flood forecasting, land treatment and management, and nonstructural flood plain management. Implementation of the program would reduce the estimated present (1965) flood damages and prevent some of the projected future flood damages. With no additional flood control measures after 1965, annual flood damages of $310,000,000 are estimated by the year 2020. However, with implementation of the flood control program, remaining damages of only $68,050,000 are estimated by the year 2020. (See tables 8 and 9b and figure 4.) A summary of the remaining annual damages is given in the following tabulation.

Remaining Damages ($1,000)

Subregion	1980	2000	2020
Lower Main Stem	11,397	13,795	19,600
Little Colorado	3,076	3,729	5,730
Gila	25,870	32,149	42,720
Region Total	40,343	49,673	68,050

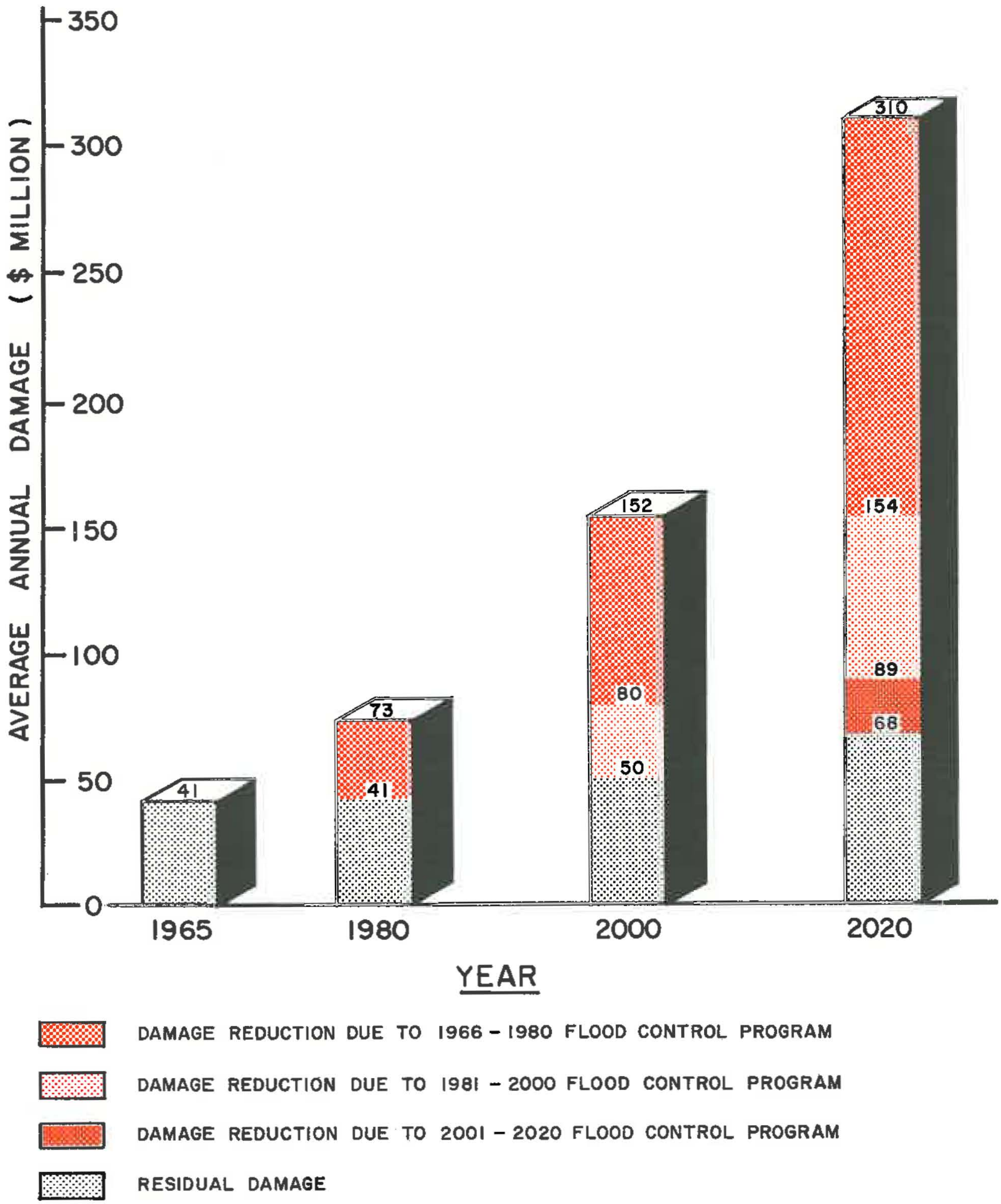


Figure 4. Effects of the flood control program.

Flood control reservoirs can increase the water supply in the Region by storing floodwater. A single purpose flood control reservoir detains most of the runoff resulting from a storm in the drainage basin upstream of the dam. The reservoir is allowed to drain over a period of time which permits more time for water percolation into the groundwater basin. The multiple reservoir with storage space designated for water conservation would retain the floodwater until it was requested. Two projects in the Lower Colorado Region, the Alamo Reservoir (completed in 1968) and the authorized Santa Rosa Wash Project (St. Clair Reservoir), have water conservation storage. It is estimated that about 9,000 acre-feet of water per year would be added to the Region water supply. From the two authorized channel improvement projects on the Gila and Salt Rivers, it is estimated that the downstream waterflow would be increased by about 36,000 acre-feet per year by clearing salt cedar and other vegetative growth from the channels. The clearing would affect other resources, such as the environment and the habitat of some species of wildlife.

The flood control program should not overlook a potential flood threat that may be caused from dam failure. During the past half century or more, many dams were built using hydrologic and design data that may be inadequate when considered under present-day criteria. Each State should initiate an inspection program in the 1966-1980 time frame. This should be followed by a rehabilitation program to bring all dams up to an acceptable standard of safety.

ENVIRONMENTAL CONSIDERATIONS

The development of plans for future flood control projects involved in the comprehensive program for the Lower Colorado Region would include detailed consideration of the environmental quality. Every effort would be made to meet in a timely manner the ecological needs of the people in the affected project areas in the Region. Environmental planning in connection with such project planning would consider, but not be limited to, recreation, fish and wildlife, and esthetic aspects of the area, and the preservation of unique or historic sites. Such planning would also consider the preservation and enhancement of existing open space, or the creation of open space, to be used in consonance with zoning and development plans of local and regional planning agencies. An additional consideration in environmental planning would involve the preservation of streams, or certain reaches thereof, in accordance with the Wild and Scenic Rivers Act of 1968.

Recreational development would provide for water-oriented activities such as boating, swimming, water skiing, and fishing; and land-based activities such as horseback riding, hiking, bicycling, and picnicking. The provision of rest areas would also be considered.

Environmental planning would include beautification measures by the preservation or addition of landscaping features and of vegetative plantings, such as trees, shrubs, and ground cover; the provision of properly designed access and maintenance roads with native plantings alongside; and the use of architectural concrete, all to be employed in an effort to enhance the natural scene. Some of these measures would benefit wildlife. If not, mitigation programs through cooperative efforts among agencies would seek to minimize the loss of fish and wildlife habitat.

CONSTRAINTS

Constraints that may delay the implementation of the flood control program include Federal agencies policies, local agencies financial capability, availability of funds, State and local agencies authorities, changing social conditions, and environmental considerations.

Federal agencies policies of cost sharing by local agencies in the construction of flood control projects are directly related to the financial capability constraint of local agencies. Competition for funds by other programs and the lack of local incentives to implement measures to reduce flood damages may preclude implementation of the total flood control program.

Local agencies should have the authority to regulate the use and development of the flood plains and to enter into contracts with other agencies for these purposes. Constraints on such authority could be removed by each state passing enabling legislation. The State of New Mexico, for example, enacted legislation in February 1970 providing for county and municipal planning and zoning for flood control purposes.

A statewide water resource agency that would coordinate the various water resources plans and assist local agencies is desirable. In addition, this State agency could be helpful in evaluating changing social conditions and environmental considerations involved in water resource development.

FUTURE STUDIES

The magnitude of the flood problem indicates the need for a research program for flood damage reduction. Specific suggestions for more detailed studies include:

a. Urban hydrology and related problems concerning greater runoff resulting from urbanization should be studied.

b. Desert hydrology should be studied because a large part of the Region is in an arid area.

c. Research should be conducted to determine the potential for floodwater storage in underground reservoirs created by nuclear devices and the feasibility of fracturing rocks to create greater rates of percolation.

d. Research should be conducted to develop better hydrologic models that can be used in studies to improve flood forecasting services.

e. Research should be conducted to improve flood warning systems by studying radar sounding and other methods used in precipitation forecasts.

f. Further studies should be made concerning the evaluation of alternative methods to provide flood protection in specific areas. These studies should include, but not be limited to, environmental considerations, nonstructural flood plain management measures and open space.

g. A continuous review should be made of the purpose and operation of existing projects to insure that each project continues to fulfill the public needs.

CONCLUSIONS

The flood control program considered for the Lower Colorado Region is designed to provide a framework plan to meet projected needs to the year 2020. This program, which includes structural and nonstructural measures, considers not only the most desirable and effective methods of preventing flood damage and of reducing the future damage potential, but also considers all possible uses of land and water resources.

The magnitude of annual flood damages in the Lower Colorado Region presents a major problem. The per-capita share of existing (1965) annual flood damages is estimated at $22 based on a population of 1.8 million. This amount is projected to increase to $45 per capita based on a population of 6.8 million in the year 2020. Although flood damages would not be completely eliminated because of physical and economical feasibility factors, maximum flood control protection should be one of the major objectives to be considered in the development of a water and land resources plan.

Any conflict in use or specific impact on the environment would be thoroughly analyzed during subsequent studies. Public hearings would be held, at which time interested persons would be given an opportunity to express their needs and views.

To be effectual, the framework plan must be implemented as a joint local, State, and Federal effort. The plan is based on long-range projections. Consequently, periodic review and revision will be necessary to insure that it is properly responsive to changing times and conditions.

POTENTIAL FLOOD CONTROL PROGRAM

The potential flood control program, based on MODIFIED OBERS projections, consists of a combination of various structural and nonstructural measures. These appear to be the most practicable, considering present social goals, economic development, and the achieving of a better environment.

The potential program would include 4,389,000 acre-feet of storage, 238 miles of levees, 1121 miles of channel, an improved and expanded flood forecasting service, the application of land treatment and management practices to 733,000 acres of land for flood prevention, and the application of nonstructural flood plain management measures along 168 miles of stream channel. The total costs of the program would be about $944 million.

ALTERNATIVE LEVELS OF DEVELOPMENT

ALTERNATIVE LEVELS OF DEVELOPMENT

The preceding material in this appendix has dealt exclusively with MODIFIED OBERS projected levels of development. These projections were developed on the basis of regional review and modifications of the March 1968 OBERS projections. Revised population projections were prepared by the Office of Business Economics in March 1969.

The difference between the OBERS projections for the Region and the MODIFIED OBERS projections used in developing the flood control program are nominal. However, the differences between the projections for the Lower Main Stem and Little Colorado Subregions are more significant than the difference in the projections for the Gila Subregion.

The OBERS projections showed less of an overall increase in flood damages at the end of the last time frame (2020) than the increase shown by the MODIFIED OBERS projections. Projected flood damages were analyzed by using two general categories, agricultural and nonagricultural. In addition, the damages were separated by time frames and subregions. Agricultural damages included those occurring to forest and range resources, crop and pasture, other agricultural, land, and part of the public facilities (see headings in table 4). Nonagricultural damages included those occurring to forest and range facilities, residential, commercial, industrial, utilities, and remaining public facilities that are not considered agricultural.

Agricultural damages for the Region were higher for the 1966-1980 and 1981-2000 time frames with the OBERS projections, but the MODIFIED OBERS projections resulted in the larger damages in the 2001-2020 time frame. The MODIFIED OBERS projected damages were 1.05 times the OBERS damages. In the Lower Main Stem Subregion, the agricultural damages were higher for the MODIFIED OBERS in all three time frames. In the Little Colorado Subregion, the damages were the same for both projections in the first two time frames and the highest for MODIFIED OBERS in the last time frame. In the Gila Subregion, the first two time frames had more damages using the OBERS projections, but in the last time frame, the MODIFIED OBERS projection had the most damages.

Nonagricultural projected damages followed the higher trend of the MODIFIED OBERS projections. The largest increase in these damages, which was $9.4 million or 48 percent of the 1965 damages, was in the 1981-2000 time frame. For the subregions, the Lower Main Stem had the largest percentage of change in damages. These amounts were 45 percent, 37 percent, and 8 percent for the three time frames. These increases followed the general trend of the projected population differences. A summary of the present and projected MODIFIED OBERS and OBERS flood damages is shown in the following tabulation:

Annual Flood Damages ($1,000)

Subregion	1965 Agricultural	1965 Nonagricultural	1980 Agricultural	1980 Nonagricultural	2000 Agricultural	2000 Nonagricultural	2020 Agricultural	2020 Nonagricultural
Lower Main Stem								
MODIFIED	6.3	3.8	9.8	10.7	13.6	29.3	18.8	58.2
OBERS	6.3	3.8	9.5	7.4	13.1	21.4	16.8	53.7
Little Colorado								
MODIFIED	0.4	2.0	0.5	3.8	0.7	7.6	0.9	16.2
OBERS	0.4	2.0	0.5	3.7	0.7	6.9	0.8	12.9
Gila								
MODIFIED	14.6	13.6	23.2	24.8	31.5	68.8	41.0	174.9
OBERS	14.6	13.6	25.8	24.4	32.5	68.0	40.4	173.6
Region								
MODIFIED	21.3	19.4	33.5	39.3	45.8	105.7	60.7	249.3
OBERS	21.3	19.4	35.8	35.5	46.3	96.3	58.0	240.2

Flood forecasting, watershed land treatment and management, and structural measures consisting of reservoirs, levees, and channels would be the same for both OBERS and MODIFIED OBERS projections of growth. In the Lower Main Stem Subregion, the nonstructural flood plain management program would be larger for the MODIFIED OBERS projections because of the appreciable increase in projected flood damages. In the Little Colorado Subregion, the nonstructural flood plain management program would be larger only in the last time frame, which had the largest increase in projected damages. In the Gila Subregion, no increase in the program was proposed because there were only minor changes in the projected damages.

The 1966-2020 nonstructural flood plain management program is estimated to cost about $3 million more for the MODIFIED OBERS projections than for the OBERS projections. These costs are divided approximately equally between time frames.

The March 1969 projections from the Office of Business Economics gave the population of the Lower Colorado Region as 77 percent of the 1968 projections. Assuming the same relationship between all three projections, the projected average annual flood damages for the March 1969 projections would be less than for either of the other two projections in the year 2020.

For the 1969 projections level of development, the proposed structural measures consisting of reservoirs, levees, and channels for the 1966-1980 time frame would remain the same as for MODIFIED OBERS and 1968 OBERS projection levels, because these structures consisted mostly of those already authorized (1970) but not constructed. For the last two time frames, the structural measures would be reduced by about 20 percent, and some of those in the second time frame may be shifted to the last time frame. The flood forecasting and watershed land treatment and management programs are assumed to remain the same. The nonstructural flood plain management program for the 1966-1980 time frame would be the same as for the 1968 OBERS projections. The program in the last two time frames would be less than the 1968 OBERS program.

TABLES

EXPLANATION OF TABLES

The tables in this appendix present data concerning past, present (1965), and projected future flood problems in the Lower Colorado Region. A brief explanation of the tables is as follows:

Table 1 - A tabulation of peak flows and flood damages for selected historical floods.

Table 2 - A tabulation of data on the effect (damage reduction) 1965 project conditions would have had on the historical flood damage shown in table 1.

Table 3 - A tabulation of estimated damages that would be expected to be caused by a large flood (one occurrence in 100 years on the average) on selected streams if the economic development were the same as in 1965.

Table 4 - A tabulation of average annual flood damage to selected classifications of property.

Table 5 - A tabulation of average annual flood damage in 1965 and at future target dates. Future damage figures were obtained by multiplying the 1965 damage by an appropriate development factor.

Table 6 - A tabulation of the flood control capacity of reservoirs existing in 1965 and of those proposed for the target years.

Table 7 - A tabulation of data concerning levee and channel improvements existing in 1965 and those improvements proposed for the target years.

Table 8 - This table indicates the following for the region:

- Col. 2 - Flood damage under 1965 economic and project conditions as reflected in table 4.
- Col. 3 - Flood damage in col. 2 projected to 1980 economic conditions.
- Col. 4 - Reduction in flood damages in col. 3 credited to the 1966-1980 flood control program.
- Col. 5 - Damages remaining in 1980 with the 1966-1980 flood control program in operation.
- Col. 6 - Flood damages under 2000 economic conditions with the 1966-1980 program in operation. Values were obtained by multiplying col. 5 by a development factor based on projected economic growth.
- Col. 7 - Reduction in flood damages in col. 6 credited to the 1981-2000 flood control program.

EXPLANATION OF TABLES (Cont'd.)

Table 8 - Continued.

Col. 8 - Flood damages remaining in 2000 with the 1981-2000 flood control program in operation.

Col. 9 - Flood damages in year 2020 with 1981-2000 flood control program in operation. Values were obtained by multiplying col. 8 by a development factor based on projected economic growth.

Col. 10 - Reduction in flood damages in col. 9 credited to the 2001-2020 flood control program.

Col. 11 - Flood damages remaining in 2020 with the 2001-2020 flood control program in operation.

Table 9 - A tabulation of flood damage at urban areas in the region and an indication of the type of program proposed for solution of the problems.

Table 9a - A tabulation of urban area damage projected to target years.

Table 9b - This table concerns flood damage in urban areas and is similar to Table 8. The discussions of Table 8 apply to Table 9b.

Tables 10, 10a & 10b - A tabulation of estimated costs of the flood control programs, proposed for the period 1966-1980, 1981-2000, and 2001-2020, respectively.

Table 11 - A tabulation of data concerning the maximum floods of record, standard project floods, and 100-year floods on selected streams, including estimates of the reductions in the flow of these floods credited to the proposed flood control program.

LOWER COLORADO REGION

Table 1 - Historical Flood Data

Subregion, study area, and stream	Flood	Location and flow (cfs)	Area inun-dated (1,000 acres)	Flood damage 1/ - ($1,000): Forest and range resources	Forest and range facil-ities	Crop and pasture	Other agricul-tural	Land	Residen-tial and commer-cial	Indus-trial and utility	Public facil-ities	Total
LOWER MAIN STEM												
Colorado River												
Bill Williams	1939	Alamo Lake 86,000	-	0	0	2	16	22	0	0	10	50
Colorado River	1939	Lake Havasu 75,000	-	0	0	350	440	0	70	3,200	260	4,320
Kanab Creek	1963	Fredonia -	.1	0	0	3	12	1	58	0	6	80
Snake Creek	1965	Near Fredonia -	-	0	0	2	15	0	1	0	27	45
Bouse Wash	1967	Bouse Wash -	-	0	0	10	0	0	0	0	0	10
Virgin River												
Meadow Valley Wash	1910	Near Caliente 11,000	-	0	0	20	67	0	0	714	30	831
Meadow Valley Wash	1938	Near Caliente 15,000	-	0	0	20	47	0	25	188	38	318
Gould Wash	1954	Near St. George 2,200	.35	0	0	10	7	5	8	0	20	50
Warner Valley	1955	St. George 5,000	1.2	0	0	40	4	18	0	0	5	67
Virgin River	1966	Littlefield 32,500	.7	0	0	128	420	80	5	0	335	968
Las Vegas Wash												
Las Vegas Wash	1955	Las Vegas 6,000	-	0	0	0	0	0	681	300	519	1,500
Las Vegas Wash	1957	Las Vegas 700	35.2	0	0	0	0	0	85	0	280	365

LOWER COLORADO REGION

Table 1 - Historical Flood Data (Cont'd.)

Sheet 2 of 7

Subregion, study area, and stream	Flood	Location and flow (cfs)	Area inundated (1,000 acres)	Flood damage 1/ - ($1,000): Forest and range resources	Forest and range facilities	Crop and pasture	Other agricultural	Land	Residential and commercial	Industrial and utility	Public facilities	Total
LOWER MAIN STEM (Cont'd.)												
Lower Gila River												
Lower Gila River	1891	Near Gila Bend 250,000	-	0	0	3	1	110	400	0	0	514
Lower Gila River	1916	Near Yuma 200,000	-	0	0	0	3	5	300	0	0	308
Lower Gila River	1955	Fortuna Wash 20,000	32.0	0	0	60	122	0	0	100	107	389
LITTLE COLORADO												
Little Colorado River, N. Mex.												
Puerco River	1959	Gallup 9,380	.1	0	0	0	0	0	43	0	20	63
Puerco River	1964	Gallup 1,400	1.7	0	0	0	0	0	20	10	7	37
Zuni River	1963	Zuni 13,000	.5	0	0	1	2	1	0	0	50	54
Oak Creek Wash	1928	Ojo Caliente -	.4	0	0	6	2	0	1	0	1	10
Little Colorado River, Ariz. (Incl. Puerco River)												
Unnamed Wash	1965	St. Johns 3,860	-	0	0	0	0	0	12	0	3	15
Silver Creek	1965	Snowflake -	-	0	0	0	0	0	11	0	0	11
Jadito Wash	1967	Near Corn Creek -	18.7	0	0	0	0	0	2	0	4	6

Table 1 - Historical Flood Data (Cont'd.)

Subregion, study area, and stream	Flood	Location and flow (cfs)	Area inun-dated (1,000 acres)	Flood damage 1/ - ($1,000): Forest and range resources	Forest and range facil-ities	Crop and pasture	Other agricul-tural	Land	Residen-tial and commer-cial	Indus-trial and utility	Public facil-ities	Total
LITTLE COLORADO (Cont'd.)												
Little Colorado River, Ariz. (below Puerco River)												
Little Colorado River	1923	Holbrook 60,000	-	0	0	0	0	10	13	0	25	48
Ruby and Ice House Washes	1957	Winslow 2,000	-	0	0	0	0	0	-	-	-	60
Ruby and Ice House Washes	1964	Winslow 2,400	1.0	0	0	0	0	0	224	54	29	307
Rio De Flag	1963	Flagstaff -	0	0	0	0	0	0	0	0	25	25
GILA												
Gila River (State Line to Coolidge Dam)												
Gila River	1905	Coolidge dam site 150,000	-	0	0	115	280	750	0	0	150	1,295
San Francisco	1916	Clifton 108,000	-	0	0	0	50	0	0	0	200	250
Gila River	1916	Solomon 100,000	-	0	0	65	280	200	0	0	150	695
San Simon Creek	1931	Solomon 27,500	2.0	0	0	36	19	0	5	0	1	61
Gila River	1941	Solomon 31,900	2.5	0	0	270	254	0	710	2	78	1,314
Frye Creek-Stockton Wash	1944	Safford -	5.6	0	0	490	805	0	928	149	328	2,700
Gila River	1949	Solomon 25,000	1.0	0	0	282	60	0	14	0	46	402

LOWER COLORADO REGION

Table 1 - Historical Flood Data (Cont'd.)

Sheet 4 of 7

Subregion, study area, and stream	Flood	Location and flow (cfs)	Area inundated (1,000 acres)	Flood damage 1/ - ($1,000): Forest and range resources	Forest and range facilities	Crop and pasture	Other agricultural	Land	Residential and commercial	Industrial and utility	Public facilities	Total
GILA												
Gila River (State Line to Coolidge Dam) (Cont'd.)												
Frye Creek - Stockton Wash	1957	Safford -	5.3	0	0	85	120	50	50	0	99	404
Vanar Wash	1961	Cochise -	1.7	0	0	71	6	0	0	0	0	77
San Carlos River	1965	Peridot 36,300	0.15	0	0	2	14	23	1	0	88	128
Blue River	1965	Greenlee Co. -	0.3	0	25	7	0	0	0	0	0	32
Gila River	1967	Solomon 34,800	-	0	4	634	18	0	0	66	155	877
Gila River (Coolidge Dam to Salt River)												
Queen Creek	1919	Whitlow Ranch Dam 10,000	15.0	0	0	-	-	-	-	-	-	300
San Pedro River	1926	Near Charleston 98,000	-	0	0	0	0	0	0	2,000	500	2,500
Queen Creek	1954	Williams-Chandler 43,000	30.0	0	0	1,527	56	82	97	38	279	2,079
Magma Watershed	1954	Magma -	10.5	0	0	274	41	25	9	0	49	398
Gila River	1955	Near Coolidge 4,200	30.0	0	0	190	35	0	68	0	148	441
Gila River	1955	Florence-Coolidge -	-	0	0	100	75	0	40	20	165	400

LOWER COLORADO REGION

Table 1 - Historical Flood Data (Cont'd.)

Subregion, study area, and stream	Flood	Location and flow (cfs)	Area inundated (1,000 acres)	Flood damage 1/ - ($1,000): Forest and range resources	Forest and range facilities	Crop and pasture	Other agricultural	Land	Residential and commercial	Industrial and utility	Public facilities	Total
GILA (Cont'd.)												
Gila River (Coolidge Dam to Salt River) (Cont'd.)												
Whitewater Draw	1957	Northeast of Douglas -	-	0	0	2	300	100	30	0	1,006	1,438
Whitewater Draw	1958	East of Willcox -	2.7	0	0	195	45	0	5	0	44	289
Gila River	1965	Below Coolidge Dam 26,300	15.0	0	0	200	47	0	8	0	28	283
Gila River	1965	Near Coolidge 10,900	16.0	0	0	1,100	43	12	0	0	58	1,213
Whitewater Draw	1966	South of Willcox -	-	0	0	40	0	0	0	0	0	40
Santa Cruz River												
Santa Cruz River	1940	Red Rock 17,000	6.14	0	0	100	20	14	75	5	83	297
Santa Cruz River	1946	Red Rock -	-	0	0	300	0	0	0	0	25	325
Tucson Arroyo	1953	Tucson 3,300	0.6	0	0	-	-	-	-	-	-	200
Santa Rosa Wash	1957	Vaiva Vo 10,000	16.0	0	0	285	22	134	15	30	139	625
Vekol Wash	1957	Pinal Co. -	2.8	0	0	2	2	3	0	0	4	11
Tucson Arroyo	1961	Tucson 5,100	0.5	0	0	-	-	-	-	-	-	200
Santa Cruz River-Santa Rosa Wash	1962	Vaivo Vo 53,000	9.0	0	0	4,644	2,995	1,622	748	334	1,027	11,370

Table 1 - Historical Flood Data (Cont'd.)

Subregion, study area, and stream	Flood	Location and flow (cfs)	Area inun- dated (1,000 acres)	Flood damage 1/ - ($1,000): Forest and range resources	Forest and range facil- ities	Crop and pasture	Other agricul- tural	Land	Residen- tial and commer- cial	Indus- trial and utility	Public facil- ities	Total
GILA (Cont'd.)												
Santa Cruz River (Cont'd.)												
Tortolita Mountains	1962	Near Red Rock -	-	0	0	225	48	153	0	0	107	533
Santa Cruz River	1964	Upper Santa Cruz River 16,200	-	0	0	940	547	553	121	56	268	2,485
Rillito Creek	1965	Tucson 12,400	-	0	0	0	0	50	0	600	510	1,160
Santa Cruz River	1967	Santa Cruz County 25,000	8.5	0	0	0	23	43	134	20	96	316
Greene Wash	1967	Above Santa Rosa Wash 9,000	3.6	0	0	46	41	9	28	4	120	248
Salt River												
Salt River	1905	Below Verde R. 115,000	-	0	0	-	-	-	-	-	-	627
Pinal Creek	1928	Globe -	-	0	0	0	0	0	-	-	-	300
Pinal Creek	1954	Globe 6,500	0.1	0	0	0	0	0	690	30	50	770
Bloody Tanks Wash	1954	Miami 7,500	-	0	0	0	0	0	377	0	0	377
Buckhorn Watershed	1954	Near Phoenix -	5.75	0	0	300	0	0	100	0	155	555
Granite Creek	1963	Prescott 8,510	0.17	0	0	0	0	0	221	280	45	546
Salt River	1963	Near Phoenix -	6.5	0	0	178	97	0	2,397	26	192	2,890

LOWER COLORADO REGION

Table 1 - Historical Flood Data (Cont'd.)

Subregion, study area, and stream	Flood	Location and flow (cfs)	Area inundated (1,000 acres)	Flood damage 1/ - ($1,000): Forest and range resources	Forest and range facilities	Crop and pasture	Other agricultural	Land	Residential and commercial	Industrial and utility	Public facilities	Total
GILA (Cont'd.)												
Salt River (Cont'd)												
Salt River	1965	Below Verde River 67,000	-	0	0	17	37	0	109	3,600	2,057	5,820
Salt River	1965	Near Roosevelt 68,800	-	0	0	6	25	75	0	2	30	138
Oak Creek	1965	Above mouth 17,000	-	0	0	0	0	0	180	0	5	185
New River-Cave Creek	1921	Phoenix 33,000	-	0	0	-	-	-	-	-	-	1,000
Gila River (Salt River to Painted Rock)												
Hassayampa River	1935	Wickenburg -	-	0	0	0	0	0	0	3	31	34
Agua Fria-New River	1951	Near Phoenix 24,000	-	0	0	995	317	0	264	0	2,052	3,628
Trilby Wash	1951	Near Phoenix 34,000	-	0	0	375	75	205	10	393	1,792	2,850
Buckeye Watershed	1951	Buckeye -	12.24	0	0	956	183	0	75	0	0	1,214
Centennial Wash	1964	Near mouth -	-	0	0	490	337	7	0	0	0	834

1/ Data based on prices and project and economic conditions at time of occurrence of flood. Other floods have occurred but no damage estimate has been made. Also, when damage estimates were made, all categories shown herein were not used by the estimators; therefore, many columns show zero damages. A dash (-) means there is no estimate available.

LOWER COLORADO RIVER

Table 2 - Flood Damage

Sheet 1 of 2

Subregion, study area, and stream	Date of flood	Location and flow (cfs)	Total damage - ($1,000) 1/ At time of flood 2/ Actual damage	Damage without flood control projects	Damage prevented by flood control projects	1965 economic conditions and prices 3/ Damage with 1965 project conditions	Damage without flood control projects	Damage prevented by 1965 projects
LOWER MAIN STEM								
Colorado River								
Bill Williams River	1939	Alamo Lake 86,000	50	50	0	100	100	0
Virgin River								
Virgin River	1966	Littlefield 32,500	968	968	0	950	950	0
Meadow Valley Wash	1938	Near Caliente 15,000	318	318	0	800	2,000	1,200
Las Vegas Wash								
Las Vegas Wash	1955	Las Vegas 6,000	1,500	1,500	0	2,900	2,900	0
Lower Gila River								
Gila River	1916	Near Yuma 200,000	308	308	0	6,300	63,800	57,500
LITTLE COLORADO								
Little Colorado River, N. Mex.								
Puerco River	1959	Gallup 9,400	63	63	0	110	110	0
Little Colorado River, Ariz. (below Puerco River)								
Ruby Wash	1928	Winslow 8,000	100	100	0	1,175	1,175	0
Ice House Wash	1945	Winslow 1,500	48	48	0	224	224	0
GILA								
Gila River (Stateline to Coolidge Dam)								
Gila River	1905	Coolidge damsite 150,000	1,295	1,295	0	3,700	3,700	0

LOWER COLORADO REGION

Table 2 - Flood Damage (Cont'd.)

Subregion, study area, and stream	Date of flood	Location and flow (cfs)	Total damage - ($1,000) 1/ At time of flood 2/ Actual damage	Damage without flood control projects	Damage prevented by flood control projects	1965 economic conditions and prices 3/ Damage with 1965 project conditions	Damage without flood control projects	Damage prevented by 1965 projects
GILA (Cont'd.)								
Gila River (Coolidge Dam to Salt River)								
San Pedro River	1926	Near Charleston 98,000	2,500	2,500	0	4,000	4,000	0
Queen Creek	1954	Near Florence 43,000	2,079	2,079	0	1,480	2,860	1,380
Santa Cruz River								
Tucson Arroyo	1961	Tucson 5,100	200	200	0	45	230	185
Santa Rosa Wash	1962	Vaivo Vo 53,000	11,370	11,370	0	15,300	15,300	0
Rillito Creek	1965	Tucson 12,400	1,160	1,160	0	1,160	1,160	0
Salt River								
Salt River	1905	Below Verde R. 115,000	627	627	0	3,440	3,440	0
Granite Creek	1963	Prescott 8,500	546	546	0	690	690	0
Salt River	1965	Roosevelt Lake 68,800	139	139	0	139	139	0
Gila River (Salt River to Painted Rock)								
Trilby Wash	1951	Near Phoenix 34,000	2,850	2,850	0	510	3,420	2,910
Agua Fria River	1951	Near Phoenix 20,800	3,628	3,628	0	4,350	4,350	0

1/ Maximum flood for which data are available
2/ Data based on prices and project and economic conditions at time of occurrence of flood
3/ Data based on recurrence of the historical flood

LOWER COLORADO REGION

Table 3 - Estimated Flood Damage for the 100-year Frequency Flood for Selected Streams

Subregion, study area, and stream	Area inundated (1000 acres)	Flood damage 1/ - ($1,000)						
		Crop & pasture	Other Agricul-tural	Land	Residen-tial & commercial	Indus-trial & utility	Public facili-ties	Total
LOWER MAIN STEM								
Colorado River								
Bill Williams River	111.0	2,450	1,010	370	1,960	330	2,480	8,600
Virgin River								
Virgin River	.6	140	170	20	0	5	95	430
Muddy River basin	15.7	100	130	70	70	1,530	260	2,160
Lower Gila River								
Gila River	42.8	8,400	16,670	0	2,050	300	8,300	35,720
LITTLE COLORADO								
Little Colorado River, N.Mex.								
Puerco River	-	0	0	0	349	2	159	510
Little Colorado River, Ariz. (below Puerco River)								
Ruby Wash	2.3	0	0	0	785	235	250	1,270
GILA								
Gila River, N. Mex.	2.7	307	240	133	0	0	220	900
Gila River (State line to Coolidge Dam)								
San Francisco River	-	0	0	0	924	342	354	1,620
Gila River, Safford Valley	19.7	504	2,060	0	326	370	1,170	4,430
Gila River (Coolidge Dam to Salt River)								
Gila River	48.8	2,430	2,130	870	600	480	1,450	7,960
San Pedro River	4.6	120	1,060	0	100	2,500	920	4,700
Santa Cruz River								
Rillito Creek	-	30	68	0	2,800	97	1,125	4,120
Santa Rosa Wash	54.8	810	2,100	0	1,560	1,110	1,120	6,700
Salt River								
Pinal Creek	.16	0	0	0	1,900	280	370	2,550
Salt River(below Verde River)	18.5	345	1,170	0	1,800	6,365	1,360	11,040
Gila River (Salt River to Painted Rock)								
New River	9.0	1,040	220	0	670	330	560	2,820
Gila River	55.0	1,033	2,476	0	270	153	200	4,132

1/ Based on July 1965 prices, economic conditions, and project conditions.

LOWER COLORADO REGION

Table 4 - Estimated Average Annual Flood Damage - 1965

Subregion and study area	Flood damage 1/ - ($1,000)								
	Forest & range resources	Forest & range facilities	Crop & pasture	Other agricultural	Land	Residential & commercial	Industrial & utility	Public facilities	Study area total
LOWER MAIN STEM									
Colorado River	10	135	656	411	197	394	99	1,268	3,170
Virgin River	2	35	84	104	32	78	104	251	690
Las Vegas Wash	1	20	0	0	7	740	198	209	1,175
Lower Gila River	0	5	1,609	1,864	181	245	44	1,137	5,085
Subregion total	13	195	2,349	2,379	417	1,457	445	2,865	10,120
LITTLE COLORADO									
Little Colorado River, N. Mex.	0	12	79	32	18	41	19	147	348
Little Colorado River, Ariz. (incl. Puerco River)	1	28	48	69	10	219	40	280	695
Little Colorado River, Ariz. (below Puerco River)	5	75	35	55	7	214	132	864	1,387
Subregion total	6	115	162	156	35	474	191	1,291	2,430
GILA									
Gila River, N. Mex.	4	48	163	73	49	7	2	112	458
Gila River, (State line to Coolidge Dam)	6	62	498	517	159	191	134	615	2,182
Gila River (Coolidge to Salt River)	0	2	1,185	933	323	621	272	1,014	4,350
Santa Cruz	5	50	2,940	1,207	597	1,355	688	1,588	8,430
Salt River	10	75	639	657	136	4,478	1,453	1,812	9,260
Gila River (Salt River to Painted Rock)	0	15	1,223	935	287	170	56	834	3,520
Subregion total	25	252	6,648	4,322	1,551	6,822	2,605	5,975	28,200
Region total	44	562	9,159	6,857	2,003	8,753	3,241	10,131	40,750

1/ Damages are based on July 1965 prices, economic conditions and project conditions.

LOWER COLORADO REGION

Table 5 - Estimated Average Annual Flood Damage for Present and Future Conditions of Economic Development with Existing Flood Control Measures

Subregion and study area	Average annual flood damage 1/ - ($1,000) 1965 economic conditions	1980 economic conditions	2000 economic conditions	2020 economic conditions
LOWER MAIN STEM				
Colorado River	3,170	6,700	14,440	24,820
Virgin River	690	1,420	3,000	5,100
Las Vegas Wash	1,175	3,960	10,600	23,500
Lower Gila River	5,085	8,450	14,940	23,580
Subregion total	10,120	20,530	42,980	77,000
LITTLE COLORADO				
Little Colorado River, N. Mex.	348	555	980	1,770
Little Colorado River, Ariz. (incl. Puerco River)	695	1,255	2,600	5,830
Little Colorado River, Ariz. (below Puerco River)	1,387	2,550	4,720	9,500
Subregion total	2,430	4,360	8,300	17,100
GILA				
Gila River, N. Mex.	458	765	1,163	1,790
Gila River (State line to Coolidge Dam)	2,182	3,470	6,207	11,050
Gila River (Coolidge Dam to Salt River)	4,350	7,085	12,947	23,960
Santa Cruz River	8,430	13,920	26,610	53,080
Salt River	9,260	17,090	44,760	113,140
Gila River (Salt River to Painted Rock)	3,520	5,630	8,683	12,880
Subregion total	28,200	47,960	100,370	215,900
Region total	40,750	72,850	151,650	310,000

1/ Damage based on July 1965 prices and project conditions, and estimated economic conditions for the year shown.

LOWER COLORADO REGION

Table 6 - Flood Control Capacity for Existing and Potential Reservoirs

Subregion and study area	Flood control capacity 1/ - (1,000 ac-ft)				
	Projects of 1965	Projects of 1966-1980 2/	Projects of 1981-2000 2/	Projects of 2001-2020 2/	Total
LOWER MAIN STEM					
Colorado River	8,300	1,043	23	29	9,395
Virgin River	15	6	47	17	85
Las Vegas Wash	0	8	70	0	78
Lower Gila River	0	0	7	0	7
Subregion total	8,315	1,057	147	46	9,565
LITTLE COLORADO					
Little Colorado River, N. Mex.	0	26	0	0	26
Little Colorado River, Ariz. (inc. Puerco River)	0	54	17	4	75
Little Colorado River, Ariz. (below Puerco River)	0	29	28	22	79
Subregion total	0	109	45	26	180
GILA					
Gila River, N. Mex.	1	81	0	17	99
Gila River (State line to Coolidge Dam)	22	173	52	35	282
Gila River (Coolidge Dam to Salt River)	34	388	201	14	637
Santa Cruz River	0	223	69	398	690
Salt River	11	1,053	47	26	1,137
Gila River (Salt River to Painted Rock)	2,318	61	35	86	2,500
Subregion total	2,386	1,979	404	576	5,345
Region total	10,701	3,145	596	648	15,090

1/ Maximum flood control capacity. Does not include surcharge or sediment storage.
2/ Includes only reservoirs controlling the 100-year flood, or better, at the damsite immediately above the urban areas and reservoirs controlling at least the 10-year flood at the damsite where only rural areas are to be protected.

LOWER COLORADO REGION

Table 7 - Levee and Channel Flood Protection Projects - Existing and Potential

Subregion and study area	Levee and channel projects 1/									
	Existing projects (1965)		Projects of 1966 - 1980		Projects of 1981 - 2000		Projects of 2001 - 2020		Total as of 2020	
	Levees (miles)	Channels (miles)	Levees (miles)	Channels (miles)	Levees (miles)	Channels (miles)	Levees (miles)	Channels (miles)	Levees (miles)	Channels (miles)
LOWER MAIN STEM										
Colorado River	95	55	42	48	5	28	0	3	142	134
Virgin River	0	0	0	8	4	10	0	0	4	18
Las Vegas Wash	0	0	2	11	8	35	0	8	10	54
Lower Gila River	44	24	107	67	0	11	0	0	151	102
Subregion total	139	79	151	134	17	84	0	11	307	308
LITTLE COLORADO										
Little Colorado River, N. Mex.	0	0	0	4	0	5	8	0	8	9
Little Colorado River, Ariz. (incl. Puerco River)	0	0	1	8	4	3	0	1	5	12
Little Colorado River, Ariz. (below Puerco River)	1	0	29	9	6	13	11	5	47	27
Subregion total	1	0	30	21	10	21	19	6	60	48
GILA										
Gila River, N. Mex.	0	1	0	3	0	15	0	0	0	19
Gila River, (State line to Coolidge Dam)	0	14	23	95	4	15	11	12	38	136
Gila River (Coolidge to Salt River)	0	4	8	173	0	12	0	14	8	203
Santa Cruz River	3	5	1	44	0	97	54	82	58	228
Salt River	0	0	20	88	14	73	0	11	34	172
Gila River (Salt River to Painted Rock)	0	17	40	28	26	67	10	15	76	127
Subregion total	3	41	92	431	44	279	75	134	214	885
Total Region	143	120	273	586	71	384	94	151	581	1,241

1/ Includes only projects giving 100-year flood protection, or better, to urban areas and at least 10-year flood protection to agricultural areas.

LOWER COLORADO REGION

Table 8 - Estimated Average Annual Flood Damage and Damage Reduction for Present and Future Economic Conditions

Subregion and Study Area	Total Damage - 1965 Prices ($1,000)									
	1965	1980 economic conditions			2000 economic conditions			2020 economic conditions		
	economic and project conditions	With 1965 project conditions	Reduction in damages due to 1980 flood-control program	Residual damage w/1980 potential program	With 1980 program	Reduction in damages due to 2000 flood-control program	Residual damage w/2000 potential program	With 2000 program	Reduction in damages due to 2020 flood-control program	Residual damage w/2020 potential program
1	2	3	4	5	6	7	8	9	10	11
LOWER MAIN STEM										
Colorado River	3,170	6,700	2,563	4,137	8,596	2,502	6,094	9,577	693	8,884
Virgin River	690	1,420	430	990	1,916	560	1,356	2,129	189	1,940
Las Vegas Wash	1,175	3,960	880	3,080	8,470	6,930	1,540	3,200	1,224	1,976
Lower Gila River	5,085	8,450	5,260	3,190	5,310	505	4,805	7,170	370	6,800
Subregion total	10,120	20,530	9,133	11,397	24,292	10,497	13,795	22,076	2,476	19,600
LITTLE COLORADO										
Little Colorado River, N.Mex.	348	555	75	480	816	243	573	907	104	803
Little Colorado River, Ariz. (incl. Puerco River)	695	1,255	581	674	1,246	338	908	1,781	257	1,524
Little Colorado River, Ariz. (below Puerco River)	1,387	2,550	628	1,922	3,375	1,127	2,248	3,842	439	3,403
Subregion total	2,430	4,360	1,284	3,076	5,437	1,708	3,729	6,530	800	5,730
GILA										
Gila River, N. Mex.	458	765	143	622	926	235	691	1,030	98	932
Gila River (State line to Coolidge Dam)	2,182	3,470	1,302	2,168	3,505	952	2,553	3,994	465	3,529
Gila River (Coolidge Dam to Salt River)	4,350	7,085	4,685	2,400	4,329	928	3,401	6,033	1,183	4,850
Santa Cruz River	8,430	13,920	3,386	10,534	20,390	8,578	11,812	21,975	13,395	8,580
Salt River	9,260	17,090	10,535	6,555	15,494	5,936	9,558	21,562	1,900	19,662
Gila River (Salt River to Painted Rock)	3,520	5,630	2,039	3,591	5,379	1,245	4,134	6,100	933	5,167
Subregion total	28,200	47,960	22,090	25,870	50,023	17,874	32,149	60,694	17,974	42,720
Region total	40,750	72,850	32,507	40,343	79,752	30,079	49,673	89,300	21,250	68,050

LOWER COLORADO REGION

Table 9 - Estimated Average Annual Flood Damage for Urban Areas with Significant Flood Problems

Subregion, study area and stream	Damage center	Average Annual Flood Damage ($1,000) 1/				
		Resi-dential	Com-mercial	Indus-trial and utility	Public facili-ties	Total
LOWER MAIN STEM						
Colorado River						
Colorado River	Lake Havasu City	44	10	3	3	60
Colorado River	Bull Head City	36	6	4	2	48
Colorado River	Kingman	55	10	10	5	80
Virgin River						
Tributaries	St. George	36	29	0	13	78
Las Vegas Wash						
Las Vegas Wash	Las Vegas	500	240	74	86	900
LITTLE COLORADO						
Little Colorado River, N.Mex.						
Puerco River	Gallup	15	23	1	16	55
Little Colorado River, Ariz. (incl. Puerco River)						
Silver Creek	Snowflake	53	24	9	10	96
Silver Creek	Showlow	21	12	6	1	40
Silver Creek	Shumway-Taylor	39	19	3	3	64
Little Colorado River (below Puerco River)						
Little Colorado River	Winslow	59	64	30	29	182
Canyon Diablo tributary	Flagstaff	29	28	11	12	80
GILA						
Gila River (State line to Coolidge Dam)						
San Francisco River	Clifton	22	26	18	19	85
Gila River	Safford	30	0	34	103	167
Gila River	Pima	27	12	7	2	48
Gila River (Coolidge Dam to Salt River)						
Side washes	Florence	40	17	0	8	65
Side washes	Coolidge	40	11	12	9	72
Queen Creek	Chandler	68	5	13	12	98
Side washes	Douglas	150	50	25	25	250
Side washes	Benson	40	25	8	7	80
Unnamed washes	Willcox	17	40	13	15	85
Santa Cruz River						
Tributaries	Nogales	40	20	7	9	76
Santa Cruz River and tributaries	Tucson	323	385	94	246	1,048
Side washes	Eloy	40	5	10	5	60
Side washes	Casa Grande	60	20	15	5	100
Salt River						
Pinal Creek	Globe	29	60	11	22	122
Pinal Creek	Miami	10	53	10	5	78
Granite Creek	Prescott	33	2	51	14	100
Salt River and tributaries	Phoenix Metro	3,330	638	728	424	5,120
Gila River (Salt River to Painted Rock)						
White Tank Mountains	Buckeye	25	15	1	9	50

1/ Damage based on July 1965 prices, economic conditions, and project conditions.

Table 9a - Estimated Average Annual Flood Damage for Urban Areas with Significant Flood Problems - Present and Future Conditions of Economic Development with Existing Flood Control Measures

Subregion, study area and stream	Damage center	Average annual flood damage 1/ - ($1,000) 1965 Economic conditions	1980 Economic conditions	2000 Economic conditions	2020 Economic conditions
LOWER MAIN STEM					
Colorado River					
Colorado River	Lake Havasu City	60	160	540	1,160
Colorado River	Bull Head City	48	128	421	870
Colorado River	Kingman	80	214	720	1,640
Virgin River					
Tributaries	St. George	78	210	700	1,500
Las Vegas Wash					
Las Vegas Wash	Las Vegas	900	2,660	9,000	20,400
LITTLE COLORADO					
Little Colorado River, N.Mex.					
Puerco River	Gallup	55	119	310	840
Little Colorado River, Ariz. (incl. Puerco River)					
Silver Creek	Snowflake	96	220	600	1,600
Silver Creek	Showlow	40	92	250	680
Silver Creek	Shumway-Taylor	64	147	400	1,100
Little Colorado River (below Puerco River)					
Little Colorado River	Winslow	182	416	1,140	3,100
Canyon Diablo tributary	Flagstaff	80	183	500	1,360
GILA					
Gila River (State line to Coolidge Dam)					
San Francisco River	Clifton	85	141	428	1,035
Gila River	Safford	167	274	840	2,030
Gila River	Pima	48	79	242	585
Gila River (Coolidge Dam to Salt River)					
Gila River	Florence	65	113	347	845
Side Drains	Coolidge	72	125	384	935
Queen Creek	Chandler	98	190	580	1,590
Side washes	Douglas	250	436	1,333	3,255
Side washes	Benson	80	141	425	1,045
Unnamed washes	Willcox	85	148	425	1,105
Santa Cruz River					
Tributaries	Nogales	76	131	444	1,055
Santa Cruz River and tributaries	Tucson	1,048	2,030	6,210	16,980
Side washes	Eloy	60	105	320	830
Side washes	Casa Grande	100	175	535	1,380
Salt River					
Pinal Creek	Globe	122	212	652	1,690
Pinal Creek	Miami	78	136	416	1,085
Granite Creek	Prescott	100	174	533	1,380
Salt River and tributaries	Phoenix Metro	5,120	9,900	30,400	83,400
Gila River (Salt River to Painted Rock)					
White Tank Mountains	Buckeye	50	97	297	810

1/ Damage based on July 1965 prices and project conditions, and estimated economic conditions

Table 9b - Estimated Average Annual Flood Damage and Damage Reduction for Urban Areas with Significant Flood Problems

Sheet 1 of 2

Subregion, study area, and stream	Damage center	Total damages - 1965 prices ($1,000): 1965 economic & project conditions	1980 economic conditions: With 1965 program	1980 economic conditions: Reduction due to 1980 program: Nonstructural measure	1980 economic conditions: Reduction due to 1980 program: Structural measure	1980 economic conditions: Residual damage w/1980 program	2000 economic conditions: With 1980 program	2000 economic conditions: Reduction due to 2000 program: Nonstructural measure	2000 economic conditions: Reduction due to 2000 program: Structural measure	2000 economic conditions: Residual damage w/2000 program	2020 economic conditions: With 2000 program	2020 economic conditions: Reduction due to 2020 program: Nonstructural measure	2020 economic conditions: Reduction due to 2020 program: Structural measure	2020 economic conditions: Residual damage w/2020 program
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
LOWER MAIN STEM														
Colorado River														
Colorado River	Lake Havasu City	60	160	13	0	147	500	10	477	13	28	5	0	23
Colorado River	Bull Head City	48	128	5	110	13	44	5	0	39	88	8	0	80
Colorado River	Kingman	80	214	20	0	194	655	15	620	20	45	5	0	40
Virgin River														
Tributaries	St. George	78	210	16	175	19	64	5	0	59	130	10	0	120
Las Vegas Wash														
Las Vegas Wash	Las Vegas	900	2,660	130	340	2,190	7,400	200	6,400	800	1,800	120	990	690
LITTLE COLORADO														
Little Colorado River, N. Mex.														
Puerco River	Gallup	55	119	15	0	104	260	20	185	55	145	10	0	135
Little Colorado River, Ariz. (incl. Puerco River)														
Silver Creek	Snowflake	96	220	0	183	37	97	6	0	91	245	25	0	220
Silver Creek	Showlow	40	92	0	79	13	34	2	0	32	85	5	0	80
Silver Creek	Shumway-Taylor	64	147	0	124	23	58	5	0	53	150	15	0	135
Little Colorado River, Ariz. (below Puerco River)														
Little Colorado River	Winslow	182	416	24	238	154	460	6	300	154	435	65	135	235
Canyon Diablo tributary	Flagstaff	80	183	10	61	112	310	10	270	30	70	5	0	65

LOWER COLORADO REGION

Table 9b - Estimated Average Annual Flood Damage and Damage Reduction for Urban Areas with Significant Flood Problems (Cont'd.)

Sheet 2 of 2

Subregion, study area, and stream	Damage center	Total damages - 1965 prices ($1,000)												
		1965	1980 economic conditions:				2000 economic conditions:				2020 economic conditions			
		economic & project conditions	With 1965 program	Reduction due to 1980 program: Non-structural measure	Reduction due to 1980 program: Structural measure	Residual damage w/1980 program	With 1980 program	Reduction due to 2000 program: Non-structural measure	Reduction due to 2000 program: Structural measure	Residual damage w/2000 program	With 2000 program	Reduction due to 2020 program: Non-structural measure	Reduction due to 2020 program: Structural-measure	Residual damage w/2020 program
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
GILA														
Gila River (State line to Coolidge Dam)														
San Francisco River	Clifton	85	141	5	16	120	367	12	278	77	186	20	0	166
Gila River	Safford	167	274	10	237	27	63	0	0	63	153	15	0	138
Gila River	Pima	48	79	0	71	8	26	0	0	26	61	5	0	56
Gila River (Coolidge Dam to Salt River)														
Side washes	Florence	65	113	0	111	2	7	0	0	7	18	2	0	16
Side washes	Coolidge	72	125	0	112	13	40	0	0	40	90	6	45	39
Queen Creek	Chandler	98	190	0	168	22	67	0	0	67	185	12	130	43
Side washes	Douglas	250	436	20	330	86	266	25	195	46	102	6	0	96
Side washes	Benson	80	141	0	126	15	44	0	0	44	97	6	40	51
Unnamed washes	Willcox	85	148	0	75	73	224	22	0	204	510	50	0	460
Santa Cruz River														
Tributaries	Nogales	76	131	0	0	131	405	0	387	18	45	2	0	43
Santa Cruz River & tributaries	Tucson	1,048	2,030	175	0	1,855	6,140	600	4,570	970	2,770	300	1,320	1,150
Side washes	Eloy	60	105	15	0	90	275	13	245	17	46	3	0	43
Side washes	Casa Grande	100	175	0	163	12	37	3	0	34	90	5	0	85
Salt River														
Pinal Creek	Globe	122	212	0	130	82	252	25	0	227	590	10	0	580
Pinal Creek	Miami	78	136	10	0	126	385	0	330	55	150	10	0	140
Granite Creek	Prescott	100	174	0	135	39	119	11	60	48	124	12	0	112
Salt River and tributaries	Phoenix Metro	5,120	9,900	227	7,454	2,219	6,810	220	3,640	2,950	8,125	500	0	7,625
Gila River (Salt River to Painted Rock)														
White Tank Mountains	Buckeye	50	97	5	72	20	61	10	0	51	115	10	0	105

LOWER COLORADO REGION

Table 10 - Estimated Costs of Potential Flood Control Program (1966-1980)

(Costs in $1,000)

Subregion and study area	Levees and channels: Federal Instal-lation costs	Levees and channels: Federal Annual OM&R costs	Levees and channels: Non-Federal Instal-lation costs	Levees and channels: Non-Federal Annual OM&R costs	Flood control reservoirs: Federal Instal-lation costs	Flood control reservoirs: Federal Annual OM&R costs	Flood control reservoirs: Non-Federal Instal-lation costs	Flood control reservoirs: Non-Federal Annual OM&R costs	Nonstructural measures: Federal Instal-lation costs	Nonstructural measures: Federal Annual OM&R costs	Nonstructural measures: Non-Federal Instal-lation costs	Nonstructural measures: Non-Federal Annual OM&R costs
LOWER MAIN STEM												
Colorado River	4,347	0	291	20	33,955	75	1,590	85	217	23	692	9
Virgin River	555	0	11	2	3,107	0	72	13	95	18	307	3
Las Vegas Wash	1,046	0	125	4	2,429	0	256	11	100	16	1,950	10
Lower Gila River	23,320	12	800	50	0	0	0	0	55	5	414	13
Total Subregion	29,268	12	1,227	76	39,491	75	1,918	109	467	62	3,363	35
LITTLE COLORADO												
Little Colorado River, New Mex.	390	0	5	2	3,927	0	67	16	51	2	313	6
Little Colorado River, Ariz. (incl. Puerco River)	735	0	8	3	8,301	0	113	34	116	19	326	5
Little Colorado River (below Puerco River)	2,796	0	269	15	4,931	0	64	21	230	27	648	5
Total Subregion	3,921	0	282	20	17,159	0	244	71	397	48	1,287	16
GILA												
Gila River, New Mex.	20	0	3	1	18,000	15	358	15	414	34	135	9
Gila River, Ariz. (above Coolidge Dam)	3,327	0	706	50	4,800	10	357	17	552	58	719	23
Gila River (Coolidge Dam to Salt River)	11,257	0	2,633	30	55,474	40	2,900	73	67	31	661	40
Santa Cruz River	3,340	0	166	14	14,646	8	746	40	1,288	72	4,021	113
Salt River	17,453	0	3,587	63	57,458	50	861	83	728	65	6,365	57
Gila River (Salt River to Painted Rock)	28,304	0	4,605	131	11,281	0	2,039	94	308	35	690	42
Total Subregion	63,883	0	11,700	289	161,659	123	7,261	322	3,357	295	12,591	284
Total Region	97,072	12	13,209	385	218,309	198	9,423	502	4,221	405	17,241	335

Table 10a - Estimated Costs of Potential Flood Control Program (1981-2000)

(Costs in $1,000)

Subregion and study area	Levees and channels				Flood control reservoirs				Nonstructural measures			
	Federal		Non-Federal		Federal		Non-Federal		Federal		Non-Federal	
	Instal-lation costs	Annual OM&R costs	Instal-lation costs	Annual OM&R costs	Instal-lation costs	Annual OM&R costs	Instal-lation costs	Annual OM&R costs	Instal-lation costs	Annual OM&R costs	Instal-lation costs	Annual OM&R costs
LOWER MAIN STEM												
Colorado River	2,067	0	100	9	7,298	0	337	31	808	14	845	8
Virgin River	1,410	0	262	12	7,271	0	775	36	208	7	175	2
Las Vegas Wash	21,379	0	3,773	48	7,252	0	2,909	32	142	6	3,025	15
Lower Gila River	572	0	104	3	750	0	322	4	102	6	1,520	19
Total Subregion	25,428	0	4,239	72	22,571	0	4,343	103	1,260	33	5,565	44
LITTLE COLORADO												
Little Colorado River, New Mex.	2,400	0	500	20	0	0	0	0	206	4	395	7
Little Colorado River, Ariz. (incl. Puerco River)	299	0	5	1	2,235	0	30	9	435	20	712	6
Little Colorado River (below Puerco River)	2,226	0	250	11	3,842	0	52	16	1,032	15	539	6
Total Subregion	4,925	0	755	32	6,077	0	82	25	1,673	39	1,646	19
GILA												
Gila River, New Mex.	2,710	0	670	12	0	0	0	0	532	12	154	8
Gila River, Ariz. (above Coolidge Dam)	2,607	0	748	11	7,206	0	280	30	777	42	664	21
Gila River (Coolidge Dam to Salt River)	699	0	48	4	33,093	0	1,197	39	311	32	1,914	45
Santa Cruz River	38,436	0	8,031	156	7,261	0	488	31	1,106	59	11,265	145
Salt River	93,600	0	12,298	126	8,859	0	1,405	83	932	31	4,600	45
Gila River (Salt River to Painted Rock	9,053	0	919	44	3,852	0	1,215	20	372	17	1,242	45
Total Subregion	147,105	0	22,714	353	60,271	0	4,585	203	4,030	193	19,839	309
Total Region	177,458	0	27,708	457	88,919	0	9,010	331	6,963	265	27,050	371

LOWER COLORADO REGION

Table 10b - Estimated Costs of Potential Flood Control Program (2001-2020)

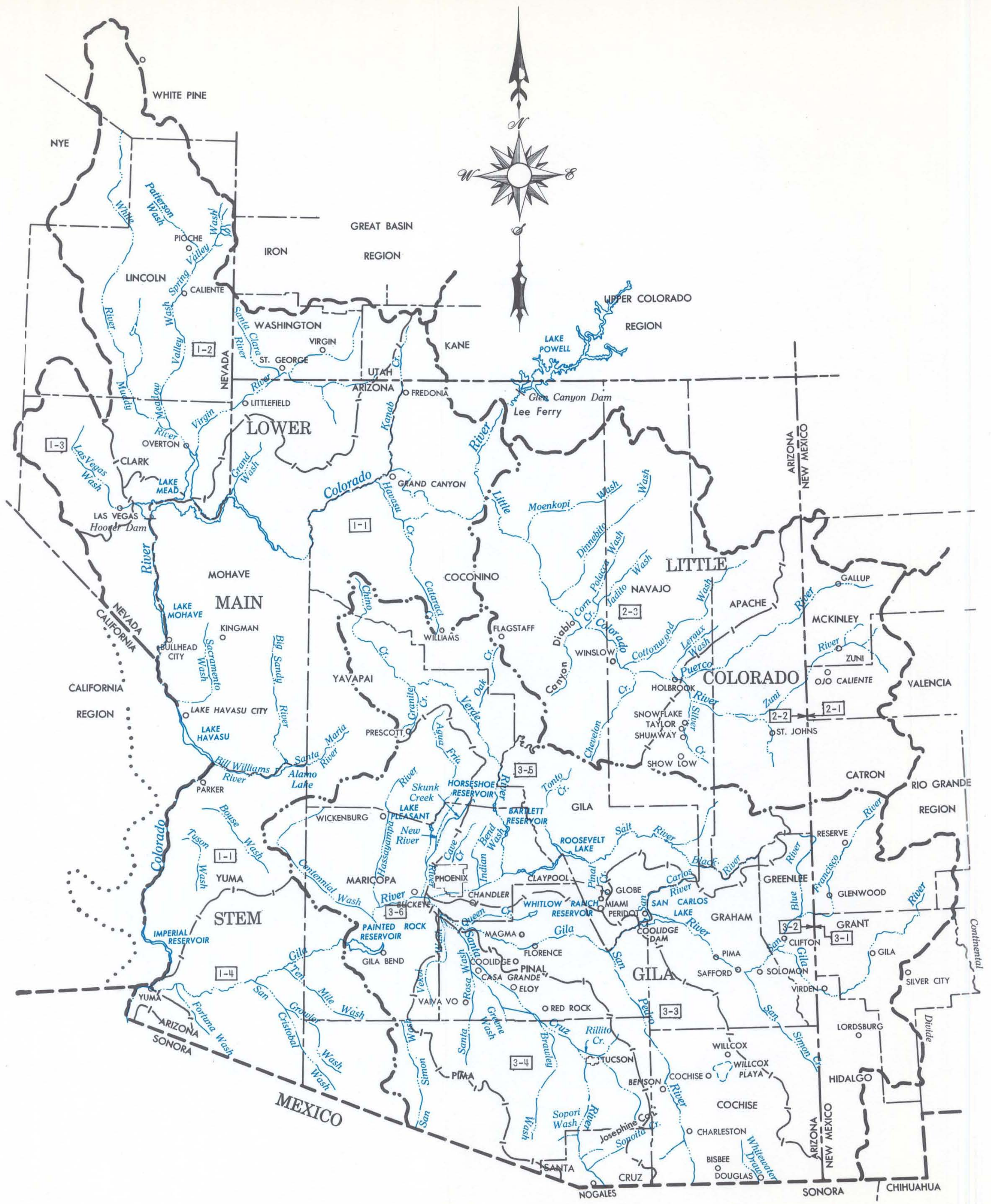
Subregion and study area	Levees and channels				Flood control reservoirs				Nonstructural measures			
	(Costs in $1,000)											
	Federal		Non-Federal		Federal		Non-Federal		Federal		Non-Federal	
	Instal-lation costs	Annual OM&R costs	Instal-lation costs	Annual OM&R costs	Instal-lation costs	Annual OM&R costs	Instal-lation costs	Annual OM&R costs	Instal-lation costs	Annual OM&R costs	Instal-lation costs	Annual OM&R costs
LOWER MAIN STEM												
Colorado River	195	0	8	1	3,104	0	322	14	735	72	1,096	9
Virgin River	0	0	0	0	3,923	0	209	16	188	19	415	3
Las Vegas Wash	4,335	0	545	13	0	0	0	0	118	10	1,850	9
Lower Gila River	0	0	0	0	0	0	0	0	129	7	3,931	32
Total Subregion	4,530	0	553	14	7,027	0	531	30	1,170	108	7,292	53
LITTLE COLORADO												
Little Colorado River New Mex.	1,250	0	0	6	0	0	0	0	128	12	440	6
Little Colorado River, Ariz. (incl. Puerco River)	52	0	1	1	1,359	0	57	6	27	25	1,289	7
Little Colorado River (below Puerco River)	1,776	0	313	22	3,390	0	46	14	948	67	2,076	7
Total Subregion	3,078	0	314	29	4,749	0	103	20	1,103	104	3,805	20
GILA												
Gila River, New Mex.	0	0	0	0	1,868	0	47	8	392	21	273	24
Gila River, Ariz. (above Coolidge Dam)	1,421	0	42	6	5,520	0	199	23	564	30	1,310	43
Gila River (Coolidge Dam to Salt River)	910	0	31	4	2,061	0	114	9	309	16	3,635	55
Santa Cruz River	41,195	0	2,435	177	98,157	420	14,626	10	989	60	11,870	162
Salt River	267	0	37	2	2,136	0	190	9	794	38	9,165	94
Gila River (Salt River to Painted Rock)	910	0	171	4	8,754	0	922	39	345	21	1,615	51
Total Subregion	44,703	0	2,716	193	118,496	420	16,098	98	3,393	186	27,868	429
Total Region	52,311	0	3,583	236	130,272	420	16,732	148	5,666	398	38,965	502

LOWER COLORADO REGION

Table 11 -- Flow Data at Selected Locations (flow in 1000 cfs)

Stream and location	Non damaging flow (cfs) 1/	Maximum flood of record: Date	Maximum flood of record Flow (cfs): At time of occurrence	Maximum flood of record Flow (cfs): Existing (1965) project conditions	Maximum flood of record Flow (cfs): Future project conditions 2/ 1980	2000	2020	Flow of standard project flood (cfs): Existing (1965) project conditions	Flow of standard project flood (cfs): Future project conditions 2/ 1980	2000	2020	Flow of 100-year frequency flood (cfs): Existing (1965) project conditions	Flow of 100-year frequency flood (cfs): Future project conditions 2/ 1980	2000	2020
Bill Williams River Near mouth	7	1891	200	200	7	7	7	317	7	7	7	260	7	7	7
Gila River Solomon 3/	16	1916	100	100	16	42	77	175	120	143	167	137	67	97	120
Santa Cruz River At Santa Rosa Wash	-	1929	24	24	24	24	5	145	145	145	5	55	55	55	5
Salt River Phoenix	20	1891	300	250	180	180	180	250	180	180	180	180	100	100	100
Santa Rosa Wash At Greene Wash	5	1962	53	53	4	4	4	78	5	5	5	42	4	4	4

1/ Under 1965 project conditions
2/ Flows as modified by future projects likely to be in a future flood control program by the years 1980, 2000 and 2020
3/ Only partial control would be effected by operation of the reservoir after 50 years of sediment cumulation



LEGEND

REGION BOUNDARY
SUBREGION BOUNDARY
STATE BOUNDARY
COUNTY BOUNDARY
COLORADO RIVER DRAINAGE
STUDY AREA BOUNDARY

LOWER MAIN STEM SUBREGION

1-1	COLORADO RIVER
1-2	VIRGIN RIVER
1-3	LAS VEGAS WASH
1-4	LOWER GILA RIVER

LITTLE COLORADO SUBREGION

2-1	LITTLE COLORADO RIVER, NEW MEXICO
2-2	LITTLE COLORADO RIVER, ARIZ. (INCL. PUERCO RIVER)
2-3	LITTLE COLORADO RIVER, ARIZ. (BELOW PUERCO RIVER)

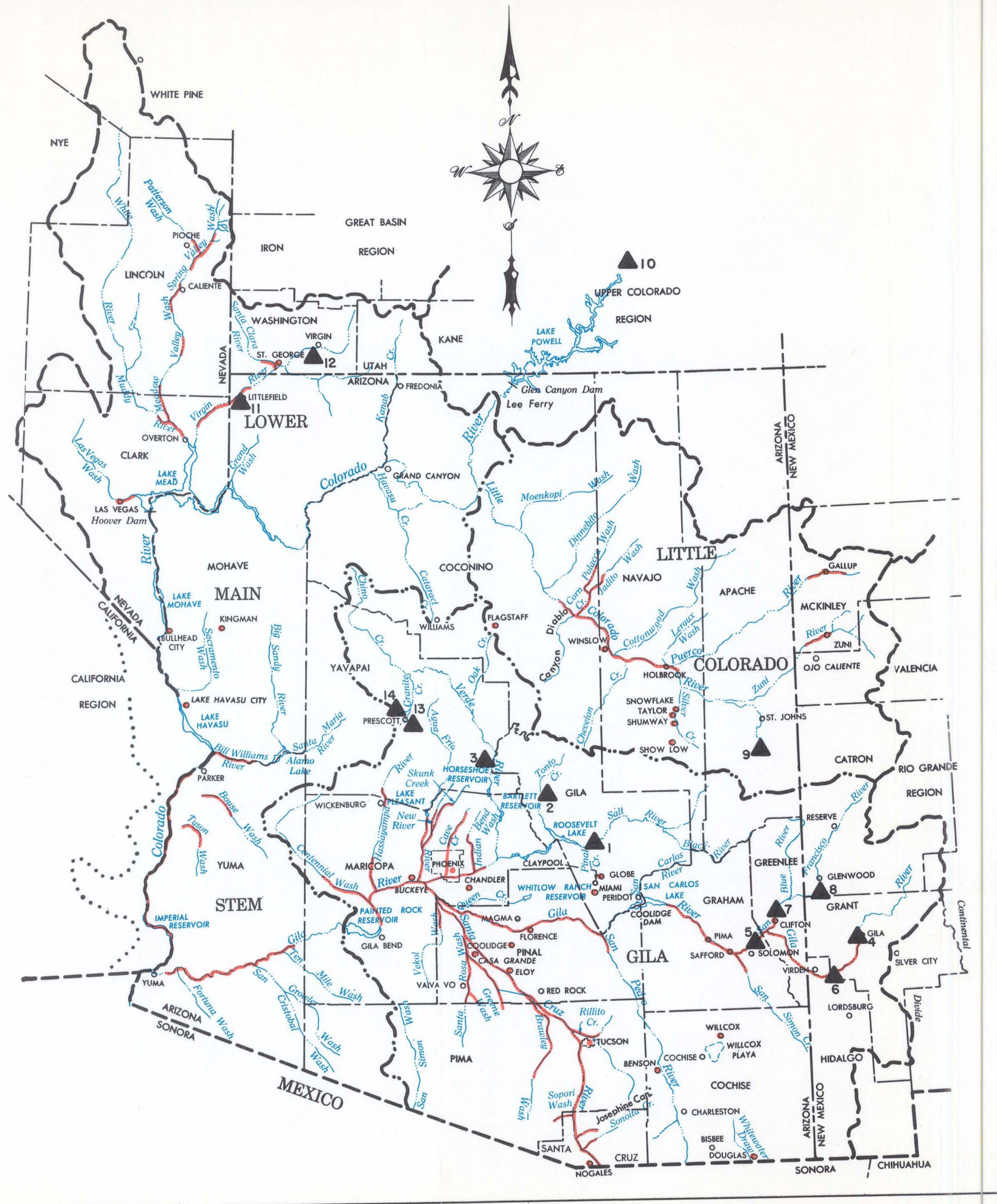
GILA SUBREGION

3-1	GILA RIVER , NEW MEXICO
3-2	GILA RIVER (STATE LINE TO COOLIDGE DAM)
3-3	GILA RIVER (COOLIDGE DAM TO SALT RIVER)
3-4	SANTA CRUZ RIVER
3-5	SALT RIVER
3-6	GILA RIVER (SALT RIVER TO PAINTED ROCK DAM)

COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION

STUDY AREAS

SCALE 20 0 20 40 60 MILES



LEGEND

- REGION BOUNDARY
- SUBREGION BOUNDARY
- STATE BOUNDARY
- COUNTY BOUNDARY
- COLORADO RIVER DRAINAGE
- STREAM FLOW FORECAST STATIONS
- AREAS SUBJECT TO FLOODING
- MAJOR URBAN DAMAGE CENTERS

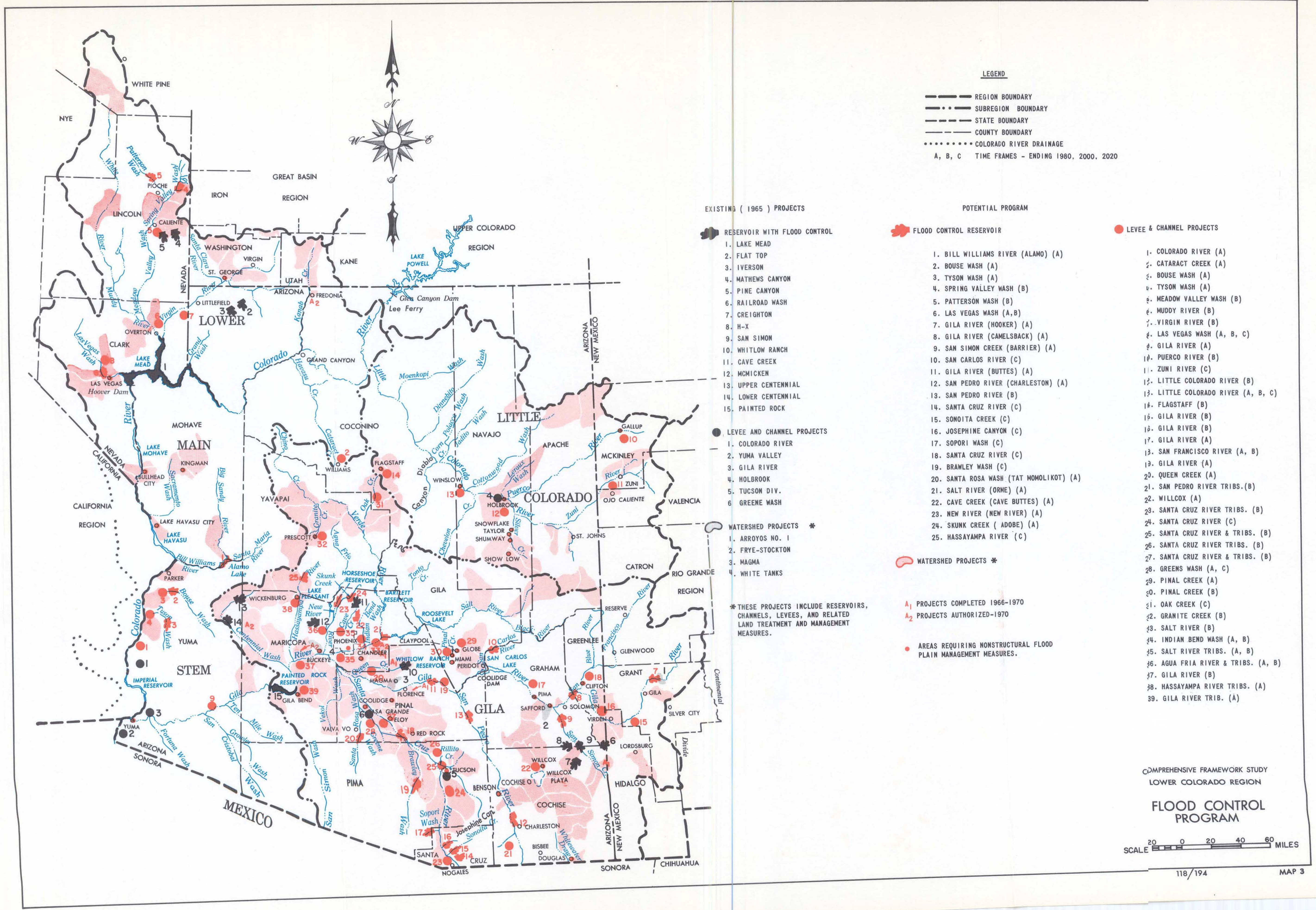
NO.	LOCATION
1	SALT RIVER NEAR ROOSEVELT RES.
2	TONTO CREEK NEAR ROOSEVELT RES.
3	VERDE RIVER ABOVE HORSESHOE RES.
4	GILA RIVER NEAR GILA
5	GILA RIVER NEAR SOLOMON
6	GILA RIVER NEAR VIRDEN
7	SAN FRANCISCO RIVER AT CLIFTON
8	SAN FRANCISCO RIVER AT GLENWOOD
9	LITTLE COLORADO RIVER ABOVE ST. JOHNS
10	COLORADO RIVER ABOVE LAKE POWELL
11	VIRGIN RIVER NEAR LITTLEFIELD
12	VIRGIN RIVER AT VIRGIN
13	GRANITE CREEK NEAR PRESCOTT
14	WILLOW CREEK NEAR PRESCOTT

COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION

FLOOD-DAMAGE AREAS AND STREAM FLOW FORECAST STATIONS

SCALE 20 0 20 40 60 MILES

MAP 2


LEGEND
REGION BOUNDARY
SUBREGION BOUNDARY
STATE BOUNDARY
COUNTY BOUNDARY
COLORADO RIVER DRAINAGE
A, B, C TIME FRAMES - ENDING 1980, 2000, 2020
EXISTING (1965) PROJECTS
RESERVOIR WITH FLOOD CONTROL
1. LAKE MEAD
2. FLAT TOP
3. IVERSON
4. MATHEWS CANYON
5. PINE CANYON
6. RAILROAD WASH
7. CREIGHTON
8. H-X
9. SAN SIMON
10. WHITLOW RANCH
11. CAVE CREEK
12. MCMICKEN
13. UPPER CENTENNIAL
14. LOWER CENTENNIAL
15. PAINTED ROCK
LEVEE AND CHANNEL PROJECTS
1. COLORADO RIVER
2. YUMA VALLEY
3. GILA RIVER
4. HOLBROOK
5. TUCSON DIV.
6 GREENE WASH
WATERSHED PROJECTS *
1. ARROYOS NO. 1
2. FRYE-STOCKTON
3. MAGMA
4. WHITE TANKS
* THESE PROJECTS INCLUDE RESERVOIRS, CHANNELS, LEVEES, AND RELATED LAND TREATMENT AND MANAGEMENT MEASURES.
POTENTIAL PROGRAM
FLOOD CONTROL RESERVOIR
1. BILL WILLIAMS RIVER (ALAMO) (A)
2. BOUSE WASH (A)
3. TYSON WASH (A)
4. SPRING VALLEY WASH (B)
5. PATTERSON WASH (B)
6. LAS VEGAS WASH (A,B)
7. GILA RIVER (HOOKER) (A)
8. GILA RIVER (CAMELSBACK) (A)
9. SAN SIMON CREEK (BARRIER) (A)
10. SAN CARLOS RIVER (C)
11. GILA RIVER (BUTTES) (A)
12. SAN PEDRO RIVER (CHARLESTON) (A)
13. SAN PEDRO RIVER (B)
14. SANTA CRUZ RIVER (C)
15. SONOITA CREEK (C)
16. JOSEPHINE CANYON (C)
17. SOPORI WASH (C)
18. SANTA CRUZ RIVER (C)
19. BRAWLEY WASH (C)
20. SANTA ROSA WASH (TAT MOMOLIKOT) (A)
21. SALT RIVER (ORME) (A)
22. CAVE CREEK (CAVE BUTTES) (A)
23. NEW RIVER (NEW RIVER) (A)
24. SKUNK CREEK (ADOBE) (A)
25. HASSAYAMPA RIVER (C)
WATERSHED PROJECTS *
A_1 PROJECTS COMPLETED 1966-1970
A_2 PROJECTS AUTHORIZED-1970
AREAS REQUIRING NONSTRUCTURAL FLOOD PLAIN MANAGEMENT MEASURES.
LEVEE & CHANNEL PROJECTS
1. COLORADO RIVER (A)
2. CATARACT CREEK (A)
3. BOUSE WASH (A)
4. TYSON WASH (A)
5. MEADOW VALLEY WASH (B)
6. MUDDY RIVER (B)
7. VIRGIN RIVER (B)
8. LAS VEGAS WASH (A, B, C)
9. GILA RIVER (A)
10. PUERCO RIVER (B)
11. ZUNI RIVER (C)
12. LITTLE COLORADO RIVER (B)
13. LITTLE COLORADO RIVER (A, B, C)
14. FLAGSTAFF (B)
15. GILA RIVER (B)
16. GILA RIVER (B)
17. GILA RIVER (A)
18. SAN FRANCISCO RIVER (A, B)
19. GILA RIVER (A)
20. QUEEN CREEK (A)
21. SAN PEDRO RIVER TRIBS.(B)
22. WILLCOX (A)
23. SANTA CRUZ RIVER TRIBS. (B)
24. SANTA CRUZ RIVER (C)
25. SANTA CRUZ RIVER & TRIBS. (B)
26. SANTA CRUZ RIVER TRIBS. (B)
27. SANTA CRUZ RIVER & TRIBS. (B)
28. GREENS WASH (A, C)
29. PINAL CREEK (A)
30. PINAL CREEK (B)
31. OAK CREEK (C)
32. GRANITE CREEK (B)
33. SALT RIVER (B)
34. INDIAN BEND WASH (A, B)
35. SALT RIVER TRIBS. (A, B)
36. AGUA FRIA RIVER & TRIBS. (A, B)
37. GILA RIVER (B)
38. HASSAYAMPA RIVER TRIBS. (A)
39. GILA RIVER TRIB. (A)
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
FLOOD CONTROL PROGRAM
SCALE 20 0 20 40 60 MILES
118/194
MAP 3

BIBLIOGRAPHY

BIBLIOGRAPHY

Arizona Crop and Livestock Reporting Service, "Arizona Agricultural Statistics."

Arizona Interstate Stream Commission, "Water Resources, State of Arizona, 1967."

Flood Control District of Maricopa County, Arizona, "Comprehensive Flood Control Program Report." 1963.

Maricopa County Planning and Zoning Department, "Planning Report for Gila Bend, Arizona." December 5, 1960.

New Mexico State Engineer Office. "Water Resources of New Mexico, 1967."

Pacific-Southwest Inter-Agency Committee, Report of the Water Management Subcommittee, "Framework Study Glossary." May 1968.

United States Senate, Select committee on National Water Resources. "Water Resources Activities in the United States. Floods and Flood Control." Pursuant to S. Res 48, 86th Congress. July 1960.

U. S. Army, Corps of Engineers

"Design Memorandum No. 3, General Design for Alamo Reservoir, Bill Williams River, Arizona." April 1964.

"Design Memorandum No. 1, Hydrology for Whitlow Ranch Reservoir, Queen Creek, Arizona." July 1957.

"Memorandum No. 3, General Design for Whitlow Ranch, Queen Creek, Arizona." June 1958.

"Flood Damage Report on Storm and Flood of 16-17 August 1963, Glendale-Maryvale Area, near Phoenix, Arizona." June 1964.

"Flood Damage Report on Storm and Flood of 9-11 September 1964, Upper Santa Cruz River, Southern Arizona." 10 March 1965.

"Flood Damage Report on Storm and Flood of 16-19 August 1963, Granite Creek and Tributaries, Prescott, Arizona." March 1964.

"Flood Damage Report, Storm and Flood of 12 August 1964, Church Rock School and Indian Village, New Mexico." December 1964.

"Flood Damage Report on Storm of 26-30 September 1962, Santa Cruz River and Santa Rosa Wash, Southern Arizona." November 1963.

U. S. Army Corps of Engineers (continued)

"Flood Damage Report on Flood of December 1965-January 1966, Salt and Gila Rivers, Granite Reef Dam to Gillespie Dam, Arizona." April 1966.

"Flood Hazard Information, Santa Cruz River, Vicinity of Sonoita Creek Confluence, Santa Cruz County, Arizona." November 1969.

"Flood Plain Information Study for Maricopa County, Arizona, Indian Bend Wash Report." June 1964.

"Flood Plain Information Study for Maricopa County, Arizona, Cave Creek Report." November 1964.

"Flood Plain Information Study for Maricopa County, Arizona, Skunk Creek Report." March 1965.

"Flood Plain Information Study for Maricopa County, Arizona, Wickenburg Report." December 1965.

"Flood Plain Information Study for Maricopa County, Arizona, New River Report." April 1967.

"Flood Plain Information, Lower Las Vegas Wash, Clark County, Nevada." December 1967.

"Flood Plain Information, Agua Fria River, Maricopa County, Arizona." March 1968.

"Guidelines for Reducing Flood Damages." May 1967.

"Interim Report on Survey for Flood Control, Phoenix, Arizona and Vicinity (Including New River), Gila River and Tributaries, Arizona and New Mexico." January 15, 1964.

"Interim Report on Survey for Flood Control, Indian Bend Wash, Arizona." April 15, 1962.

"Interim Report on Survey, Flood Control, Gila River and Tributaries Above Salt River, Arizona and New Mexico." December 1, 1945.

"Interim Report on Survey, Flood Control, Lower Agua Fria River and Vicinity, Gila River Basin, Arizona." December 10, 1952.

"Interim Report, Gila River and Tributaries Below Gillespie Dam, Arizona." September 1, 1948.

"Interim Report on Survey of Gila River and Tributaries in the Vicinity of Tucson, Arizona." November 20, 1945.

"Interim Report on Survey, Flood Control, Meadow Valley Wash and Lower Muddy River, Nevada." November 15, 1948.

U. S. Army, Corps of Engineers (continued)

"Interim Report on Survey for Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona." December 4, 1959.

"Interim Report on Survey for Flood Control, Santa Rosa Wash, Arizona." August 1, 1963.

"Interim Report on Survey for Flood Control, Pinal Creek and Tributaries, Arizona." September 15, 1961.

"Interim Report on Survey for Flood Control, Gila River, With Particular Reference to a Dam at or near the Camelsback Dam Site." May 1, 1960.

"Preliminary Examination Report, Flood Control, Hassayampa River, Arizona." January 20, 1938.

"Reconnaissance Report on Willcox, Arizona, and Vicinity." June 1964.

"Report on Flood of 21 August 1957, Las Vegas and Vicinity, Nevada." 16 September 1957.

"Report on Flood of 13 June 1955, Las Vegas and Vicinity, Nevada." July 6, 1955.

"Report on Floods of 31 October 1957. Santa Rosa Wash, Queen Creek, and Vicinity, Arizona." February 28, 1958.

"Report on Reservoir Regulation for Flood Control Storage at Hoover Dam and Lake Mead." September 1955, Revised November 1968.

"Report on Survey for Flood Control, Gila River, Camelsback Reservoir Site to Salt River, Arizona." December 31, 1957.

"Report on Survey for Flood Control, Las Vegas Wash and Tributaries, Las Vegas and Vicinity, Nevada." September 30, 1959.

"Report on Survey, Flood Control, Gila River and Tributaries Above Coolidge Dam, Arizona and New Mexico." December 1, 1941.

"Report on Survey, Flood Control, Virgin River and Tributaries in Nevada, Arizona, and Utah." June 20, 1942.

"Review Report for Flood Control, Winslow, Arizona and Vicinity." December 15, 1961.

"Review Report of Flood Control, Gila River and Tributaries, Downstream from Painted Rock Reservoir, Arizona." April 1, 1961.

"Review Report on Interim Report for Flood Control, Tucson and Vicinity, Gila River Basin, Arizona and New Mexico." January 26, 1959.

U. S. Army, Corps of Engineers (continued)

"Survey, Flood Control, Bill Williams and Tributaries, Arizona." January 15, 1941.

"Survey, Flood Control, Little Colorado River and Its Tributaries Upstream from the Boundary of the Navajo Indian Reservation in Arizona." December 5, 1940.

"Survey Report, Flood Control, Queen Creek, Arizona." February 2, 1946.

"Water Resources Development" in New Mexico, January 1965.

"Water Resources Development" in Utah, January 1965.

"Water Resources Development" in Arizona, January 1965.

"Water Resources Development" in Nevada, January 1965.

U. S. Bureau of Reclamation, Region 3, Boulder City, Nevada.

"Draft Report, Comprehensive River Management Plan, Lower Colorado River, Yuma Division." Colorado River Front Work and Levee System, Arizona - California. April 1966.

"Draft Report, Comprehensive Plan, Lower Colorado River Channelization, Parker Division." Colorado River Front Work and Levee System, Arizona - California. September 1965.

"Lower Colorado River Water Salvage Phreatophyte Control, Arizona - California - Nevada." Reconnaissance Report, June 1963.

"Report on Comprehensive River Management Plan, Lower Colorado River, Topcok George Division," Colorado River Front Work and Levee System, Arizona - California. August 1967.

"Report on Dixie Project, Utah." Project Development Report. October 1961.

U. S. Department of Agriculture, Soil Conservation Service.

"Economics Guide for Watershed Protection on Flood Prevention." March 1964.

"Inventory of Arizona Soil and Water Conservation Needs." A Multi-Agency Report. 1970.

"Various Storm Reports."

"Watershed Protection Handbook." August 1967.

U. S. Department of Agriculture, Soil Conservation Service (continued)

"Watershed Work Plan, Apache Junction - Gilbert Watershed." Maricopa and Pinal Counties, Arizona. January 1963.

"Watershed Work Plan, Buckeye Watershed." Maricopa County, Arizona. October 1963.

"Watershed Work Plan, Buckhorn-Mesa Watershed." Maricopa and Pinal Counties, Arizona. January 1963.

"Watershed Work Plan, Florence Area Watershed." Pinal County, Arizona. October 1961.

"Watershed Work Plan, Fredonia Watershed." Coconino County, Arizona. February 1968.

"Watershed Work Plan, Frye Creek-Stockton Wash Watershed." Graham County, Arizona. September 1958.

"Watershed Work Plan, Guadalupe Watershed." Maricopa County, Arizona. Review Draft, July 1970.

"Watershed Work Plan, Harquahala Valley Watershed." Maricopa and Yuma Counties, Arizona. January 1967.

"Watershed Work Plan, Magma Watershed." Pinal County, Arizona. August 1960.

"Watershed Work Plan, Parilla Mountain Watershed." Cochise County, Arizona. April 1970.

"Watershed Work Plan, Upper Frisco Watershed." Catron County, New Mexico, and Apache County, Arizona. May 1964.

"Watershed Work Plan, Upper Gila Valley Arroyos Watershed No. 1." Grant County, New Mexico. October 1959.

"Watershed Work Plan, Upper Meadow Valley Wash Watershed." Lincoln County, Nevada. August 1959.

"Watershed Work Plan, Vanar Wash Watershed." Cochise County, Arizona and Hidalgo County, New Mexico. September 1964.

"Watershed Work Plan, Virgin Valley Watershed." Clark and Lincoln Counties, Nevada, and Mojave County, Arizona. October 1962.

"Watershed Work Plan, Warner Draw Watershed." Washington County, Utah. Draft, January 1968.

U. S. Department of Agriculture, Soil Conservation Service (continued)

"Watershed Work Plan, Williams-Chandler Watershed." Maricopa and Pinal Counties, Arizona. January 1963.

"Work Plan, White Tanks Watershed." Maricopa County, Arizona. April 1954.

U. S. Department of Agriculture, Soil Conservation Service. Salt River Valley Water Users Association and Arizona Experiment Station, Phoenix, Arizona. "Water Supply Outlook for Arizona and Federal-State-Private Cooperative Snow Surveys." Report Prepared by Richard W. Enz.

U. S. Department of Commerce, Bureau of Census, "U.S. Census of Agriculture, 1964."

U. S. Department of Interior

"The Colorado River. A Comprehensive Report on the Development of Water Resources of the Colorado River Basin. . ." March 1946.

"The Lower Colorado River and Land Use Plan. A Report of the Lower Colorado River Land Use Advisory Committee. January 1964.

U. S. Geological Survey

Flood Information for Flood-Plain Planning." Circular 539.

"Water Resources Report No. 13, "Desert Floods, A Report on Southern Arizona Floods, September 1962."

Water Supply Paper 967-A, "Floods in Colorado River Basin Below Boulder Dam." September 1939.

Water Supply Paper 1049, "Summary of Records of Surface Waters at Stations on Tributaries in Lower Colorado River Basin, 1888-1938." Geological Survey and State of Arizona.

Water Supply Paper 1313, "Part 9. Colorado River Basin, Compilation of Records of Surface Waters of the United States through 1950."

Water Supply Paper 1455-B, "Summary of Floods in the United States During 1955."

Water Supply Paper 1683, "Part 9. Colorado River Basin Magnitude and Frequency of Floods."

Water Supply Paper 1810, "Summary of Floods in the United States During 1961," by J. O. Rostvedt.

U. S. Geological Survey (continued)

Water Supply Paper 1820, "Summary of Floods in the United States During 1962, by J. O. Rostvedt and Others.

Water Supply Paper 1838, "Reservoirs in the United States."

U. S. Geological Survey, State and Other Agencies

"Surface Water Records of Arizona." Yearly, 1961-1965.

"Surface Water Records of Nevada." 1961.

"Surface Water Records of New Mexico." 1961-1962.

"Surface Water Records of Utah." Yearly, 1961-1964.

"Water Resources Data for Arizona - Part 1, Water Surface Records." Yearly, 1965-1967.

"Water Resources Data for Nevada." 1966.

Water Resources Council, "Proposed Flood Hazard Evaluation Guidelines for Federal Executive Agencies." Washington, D.C., September 1969.