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FOR

F L O O D C O N T R O L

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

GILA RIVER BASIN, ARIZ. AND N. MEX.

DECEMBER 31, 1957

BY

C. T. NEWTON
COLONEL, CORPS OF ENGINEERS
DISTRICT ENGINEER

REPORT OF THE DISTRICT ENGINEER

ON

SURVEY FOR FLOOD CONTROL, GILA RIVER,

CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

SYLLABUS

The district engineer finds that a flood problem exists in Arizona along the Gila River from the upper end of Safford Valley to the mouth of the Salt River, and that the water supply available for utilization is not adequate to satisfy the irrigation needs of the area. He also finds that river-bottom growth along the Gila River creates a major flood menace and transpires large amounts of water annually.

The district engineer finds that optimum development of the water resources of the area could be accomplished by a comprehensive improvement providing for (a) a flood-control reservoir at the Earven site, (b) channel improvements consisting of channel clearing along the Gila River from the upper end of Safford Valley to the Buttes Reservoir site, and (c) a multiple-purpose reservoir at the Buttes site. However, in this report, detailed consideration is limited to channel improvements only because (a) construction of the channel improvements is not dependent upon the other units considered, (b) completed studies on these channel improvements indicate that the improvements are well justified, and (c) studies of the other units of the comprehensive plan are not complete.

The district engineer finds that a cleared floodway along the Gila River from the upper end of Safford Valley to San Carlos Reservoir and from the mouth of the San Pedro River to the Buttes Reservoir site would provide partial protection to areas in Safford Valley that are primarily agricultural and would also result in a net increase to the farmer of 19,800 acre-feet of water annually.

The district engineer estimates the total Federal first cost of the channel improvements at $1,570,000 (December 1957), and the total non-Federal first cost at $200,000 (December 1957). He estimates the total average annual charges at $112,000, including an average of $50,000 annually for maintenance and operation. He estimates the average annual primary benefits that would accrue from flood control and water conservation at $324,000. He finds that the ratio of average annual primary benefits to average annual charges would be 2.9 to 1. He concludes that the project would be justified on the basis of the tangible primary benefits alone. Use of secondary and intangible benefits would further increase the justification.

The district engineer is of the opinion that, because of the water-conservation benefits that would result from construction of the recommended project, local interests should be required to reimburse the United States for that part of the project construction cost that is allocated to water conservation, and such reimbursement should be made in 40 equal annual payments without interest. On the basis of December 1957 prices, the estimated amount of $862,000 would be repaid in 40 equal annual payments of $21,550.

The district engineer recommends that the construction of channel improvements, consisting of a cleared floodway along the Gila River from the upper end of Safford Valley to San Carlos Reservoir and from the mouth of the San Pedro River to the Buttes Reservoir site, be authorized, subject to the condition that local interests furnish assurances satisfactory to the Secretary of the Army that they will (a) provide necessary lands, easements, and rights-of-way; (b) maintain and operate the channel improvements in accordance with regulations to be prescribed by the Secretary of the Army at an average annual cost estimated at $50,000; (c) keep the flood channel of the Gila River from the upper end of Safford Valley to San Carlos Reservoir and from the mouth of the San Pedro River to the Buttes Reservoir site free from encroachment; (d) repay to the United States 54.9 percent of the total construction cost in 40 equal annual payments without interest (the exact amount of the annual payments, presently estimated at $21,550, to be adjusted on the basis of actual costs of constructing the project - annual payments to be made to the Secretary of the Interior, who, in turn, shall deposit such funds in the Treasury of the United States as miscellaneous receipts); (e) hold and save the United States free from all damages arising from construction and operation of the work; and (f) adjust all water-rights claims resulting from construction, operation, and maintenance of the improvements.

REPORT ON SURVEY FOR FLOOD CONTROL

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

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U. S. ARMY ENGINEER DISTRICT, LOS ANGELES,
CORPS OF ENGINEERS,
OFFICE OF THE DISTRICT ENGINEER,
Los Angeles, Calif., December 31, 1957.

Subject: Report on survey, flood control, Gila River, Camelsback Reservoir site to Salt River, Ariz.

Through: The Division Engineer, U. S. Army Engineer Division, South Pacific, San Francisco, Calif.

To: The Chief of Engineers, Department of the Army, Washington, D. C.

SECTION I - INTRODUCTION

1. AUTHORITY

This report is submitted pursuant to resolution, dated August 7, 1956, by the Committee on Public Works, United States Senate, which reads in part as follows:

> * * * That the Board of Engineers for Rivers and Harbors, * * * be, and is hereby, requested to review the reports of the Chief of Engineers on the Gila River and tributaries, Arizona and New Mexico, published as House Document numbered 331, Eighty-first Congress, 1st session, and other reports, with a view to determining whether further improvements for flood control and allied purposes are advisable in the Gila River Watershed at this time, with particular reference to (1) Construction of a flood control dam on the Gila River at or in the vicinity of the Camelback site in eastern Arizona; (2) Construction of a flood control dam at or near the Buttes site or at a site above the mouth of the San Pedro River; (3) Rectification of the Gila River channel downstream from the location of that dam to the San Carlos Reservoir and from the Coolidge Dam downstream to the Hayden-Ashurst Dam.

* * * * * * *

2. SCOPE

a. General. The survey described in this report was made to (1) indicate a comprehensive plan of flood control and optimum water use in the Gila River Basin between the Camelsback Reservoir site and the Salt River and (2) develop in detail that part of the comprehensive plan that shows promise of providing, at this time, an economically feasible unit that would provide flood protection for the Safford Valley and water conservation for the Safford Valley and for the San Carlos project.

Under a memorandum of understanding formulated at a meeting on August 20-21, 1956, between representatives of the United States Army Engineer District, Los Angeles, and the United States Bureau of Reclamation, Region 3, arrangements were made for (1) cooperative and concurrent investigations of the area under consideration and (2) division of work on those investigations. The Corps was made responsible for (1) the design of the channel improvements, the comprehensive-plan unit considered in detail in this report; (2) the design of Earven Dam, one of the comprehensive-plan units to be studied further; and (3) the evaluation of flood-control benefits accruing from all units. The Bureau was made responsible for (1) the design of Buttes Reservoir and appurtenances, the other comprehensive-plan unit still under study, and (2) the evaluation of water-conservation benefits accruing from all units. In this report, detailed development of flood problems was limited to the Safford Valley and detailed development of water-conservation features was limited to those that would result from the construction of the recommended plan. No detailed consideration was given to other comprehensive-plan units, including Earven and Buttes Dams. The Bureau of Reclamation, with the cooperation of the Corps of Engineers, is studying Buttes Reservoir and is scheduled to complete a feasibility report on that reservoir in about 1 year. The Corps will give detailed consideration to Earven Reservoir under the outstanding authority for a comprehensive study of the Gila River Basin.

Consideration was given by both agencies to the preservation and protection of established and potential uses of water and to the development of comprehensive and coordinated projects for improvements.

b. Topographic surveys and mosaics. Aerial surveys of the area under consideration were made in October and November 1956. Aerial mosaics based on those surveys were used in conjunction with other data in economic studies and in preparation of maps. Check cross sections at selected points on the Gila River in the area were made in 1956. These check sections and the aerial mosaics were used to adjust data developed prior to 1945.

c. Economic and other investigations. Crop reports of the San Carlos project and of adjoining areas were analyzed to develop up-to-date estimates of crop distribution, yields, and values. Information

obtained during a field reconnaissance made in March 1957 was used to adjust available data on type and value of property in the overflow areas. A field inspection of the area was made by the district engineer.

3. PRIOR REPORTS

No prior survey report on flood control in the Gila River Basin from Camelsback Reservoir site to the Salt River, Ariz., has been submitted to Congress by the Corps of Engineers, United States Army.

SECTION II - DESCRIPTION

4. LOCATION AND EXTENT

The Gila River Basin, the largest drainage area tributary to the lower Colorado River, includes most of the southern half of Arizona and part of southwestern New Mexico. (See index map, pl. 1, at the back of this report.) The drainage area of the basin comprises about 58,200 square miles, 51,500 of which are in Arizona, 5,600 in New Mexico, and 1,100 in Sonora, Mexico. The Gila River Basin upstream from the Salt River comprises about 29,300 square miles.

5. STREAMS

The Gila River, the main stream in the drainage area, rises on the west slope of the Continental Divide in southwestern New Mexico and flows generally westward for 456 miles to the mouth of the Salt River and thence for 198 miles to the Colorado River. The principal tributaries that join the main stream upstream from the Salt River include the following streams, in downstream order: The San Francisco River (drainage area, 2,800 square miles), which enters the main stream from the north, upstream from Camelsback Dam site; San Simon River (drainage area, 2,200 square miles), which enters the main stream from the south; San Carlos River (drainage area, 1,100 square miles), which enters the main stream from the north; and San Pedro River (drainage area, 4,500 square miles) and Santa Cruz River (drainage area, 8,600 square miles), which enter the main stream from the south.

The headwaters of the Gila and San Francisco Rivers are perennial. Surface flow in other parts of the Gila River Basin upstream from the Salt River is mostly intermittent.

6. TOPOGRAPHY

The upper Gila River Basin (upstream from Coolidge Dam) is a complex area of mountains, plateaus, and valleys. Elevations range from about 2,300 feet in the vicinity of Coolidge Dam to about 11,000 feet along the Continental Divide. About 85 percent of this area is mountainous. Stream valleys, which range in width from a few thousand feet to several miles and in length from about 2 to 45 miles, constitute the remaining 15 percent. Toward the headwaters of the streams, the valleys become progressively shorter and narrower, and the intervening canyons become longer and steeper - in places narrowing to rock-walled box canyons less than 100 feet in width. Canyons of this type along the upper Gila River separate the Safford, Duncan-Virden, Red Rock, and Cliff Valleys.

The drainage area between Coolidge Dam and the Salt River comprises the large drainage areas of the San Pedro and Santa Cruz Rivers and those areas directly tributary to the main stream.

Elevations range from about 1,000 feet at the mouth of the Salt River to more than 9,000 feet at the crests of the mountains. The Gila River flows in a canyon from Coolidge Dam to a point near Florence, Ariz., where the river enters a wide plain of about 700,000 acres extending to the Salt River. Except for scattered low mountains, the surface of this plain is generally unbroken.

7. GEOLOGY AND SOILS

In general, the mountains in the Gila River Basin are of igneous rock - mostly granitic, schistose, or volcanic. The valleys along the main stream and its tributaries are alluvial fills of varying depths. The soil in the valleys is generally fertile; and, where water without a high saline content is available for irrigation, the crop yields are high.

8. STREAM CHARACTERISTICS

In general, stream slopes in the Gila River Basin are not excessive. The gradients of most streams are steep near the headwaters but decrease progressively downstream. In the area under consideration in this report, the average slope of the Gila River is about 9.5 feet per mile through the Safford Valley, 11 feet per mile between Coolidge Dam and Ashurst-Hayden diversion dam, and 7.5 feet per mile between Ashurst-Hayden diversion dam and the Salt River.

In most of the high mountain areas, the streams have carved narrow, deep channels of sufficient capacity to carry floods with very little local damage. In the narrow agricultural valleys lower in the basin, normal flows meander over the bottoms of wide channels of varying depths, and major flows overtop the banks and cause extensive inundation. Streams issue from these valleys and follow courses across the desert plains in wide, shallow channels that are usually inadequate to accommodate even moderate floodflows.

Safford Valley, the main agricultural area above Coolidge Dam, has an average width of about 1.5 miles and a maximum width of almost 4 miles. The river channel is 47 miles long. Flows in excess of about 12,000 cubic feet per second cause appreciable damage to agricultural land. The channel, which is unstable, meanders in a flood plain, which has a width ranging from 1/4 to 1-1/2 miles. The channel has become overgrown with phreatophytes, principally saltcedar and mesquite, which have choked the channel to such an extent that small floods overtop the banks and cause damage to adjoining land. Downstream from Safford Valley, the Gila River flows through the San Carlos Indian Reservation and empties into San Carlos Reservoir at Coolidge Dam. The river flows in a deep, winding gorge more than 60 miles between Coolidge Dam and Ashurst-Hayden diversion dam and thence meanders over a wide flood plain for about 85 miles to the mouth of the Salt River. Downstream from Ashurst-Hayden diversion dam, flows up to 20,000 cubic feet per second are confined to a wide, shallow channel, but major floods spread over an area ranging in width from 1 to 5 miles.

9. VEGETATION

The type, density, and distribution of native vegetation in the Gila River Basin upstream from the Salt River reflect the difference in altitude, temperature, and precipitation. In general, the desert vegetation is sparse. Cactus, creosotebush, and desert sage are the dominant plants in most of the desert area. Mesquite, saltcedar, and arrowweed grow in dense thickets in river bottoms and similar areas where the water table is close to the surface.

Native grasses, interspersed with desert and semidesert shrubs, grow at altitudes between 3,000 and 8,000 feet above sea level. However, the density of cover is low at altitudes below 4,500 feet and only fair at higher altitudes. Overgrazing has destroyed much of the natural grass, resulting in sparse vegetation or the replacement of grass by rabbitbrush and snakeweed. Woodlands of chaparral, oak, pinon, and juniper grow at altitudes between 4,000 and 7,000 feet above sea level. Aspen and such conifers as fir, spruce, and pine grow where elevations exceed 6,000 feet, but only the high mountain areas receive sufficient moisture to support dense stands of these forest types.

10. MAPS

An index map showing the drainage area and the location of the improvements considered is attached at the end of this report, together with nine aerial mosaics showing the areas subject to overflow and the location of the recommended improvements.

SECTION III - ECONOMIC DEVELOPMENT

11. POPULATION

The areas affected by improvements considered in this report lie principally in Graham and Pinal Counties, Ariz. According to the United States Census, the populations of those counties were 12,985 and 43,191, respectively, in 1950. The 1950 population estimates for the principal cities and towns that would be affected are as follows: Safford, 3,756; Thatcher, 1,284; Florence, 1,776; Pima, 824; Winkelman, 548; and Coolidge, 4,306.

12. OCCUPATIONS AND INDUSTRIES

The principal occupations in the area along the Gila River from Camelsback Reservoir site to the Salt River are agriculture, stock raising, and mining. About 90,000 acres were irrigated in 1956, providing crops with an annual gross value of about $16,000,000. Dairying and fattening of range livestock are important enterprises.

13. AGRICULTURE

Modern agricultural development in Safford Valley began about 1870. In 1899, about 20,000 acres were under cultivation. By 1935, the area under irrigation had increased to 32,000 acres and since that date there has been very little increase in the agricultural area. There are no storage reservoirs above San Carlos Reservoir, the reservoir created by Coolidge Dam. Diversions from the Gila River and pumping from underground storage are the sources of irrigation-water supply. Since 1940, the quantity of water pumped has increased. In 1940, about 120 wells were in use; by the fall of 1944, about 215 wells were being pumped; and 581 wells were in use in 1952. The following table summarizes data on amount of water diverted and pumped in Safford Valley from 1940 to 1956:

Data on water diverted and pumped in Safford Valley

Calendar year	Surface water	Pumped water	Total
	Acre-feet	Acre-feet	Acre-feet
1940	99,693	24,600	124,293
1945	148,675	35,000	183,675
1950	68,504	90,000	158,504
1953	39,342	120,000	159,342
1956	42,779	90,000	132,779

Along the Gila River between Coolidge Dam and the mouth of the Salt River, nearly all of the agricultural development is included

in the 100,000-acre San Carlos project. Lands within the project were inhabited by an ancient agricultural people who tilled the fertile soil of the valley and attained considerable skill in the art of irrigation. These lands were later cultivated by the Pima Indians and by non-Indian settlers. The Gila River Indian Reservation, including 50,000 acres of project lands, was established on February 28, 1859. Development of the agricultural lands continued to a point at which the normal flow of the river had been overappropriated, so that during low-flow periods water in the river was insufficient to irrigate all lands with water rights. Federal funds were made available for construction of irrigation works on the Indian reservation and for the construction of two diversion dams to serve both Indian and non-Indian lands. Ashurst-Hayden Dam, located on the Gila River about 10 river miles east of the city of Florence, Ariz., was completed in 1922. The dam is 11.5 feet high above the downstream apron and has a crest length of 375 feet. Diversion gates have a normal capacity of 1,200 cubic feet per second. Sacaton Dam, located on Gila River about 22 river miles west of the city of Florence, Ariz., was completed in 1925. The dam is 3 feet high above low-water surface elevation and has a crest length of about 2,000 feet. Two canals, with a combined capacity of 600 cubic feet per second divert flow from Gila River at this point. In 1924, construction of Coolidge Dam was authorized to provide storage on the Gila River for the control and regulation of floodflow. The dam was completed in 1928. That year, the Indian and the non-Indian lands were merged, and the combined development became known as the San Carlos project. The project area was expanded to include 100,000 acres, and provision was made for the development of hydroelectric power at Coolidge Dam.

Facilitated by the mild winters and the long growing season, the areas are well adapted climatically to the growing of highly profitable crops. At present, cotton is grown on about 50 percent of the cropped acreage. Yields of cotton in Arizona are among the highest in the nation; in recent years, average yields often exceed 2 bales to the acre and yields as high as 4 bales per acre have been obtained by some growers. Alfalfa and feed grains are grown on most of the remaining acreage. Crop values in the Salt River project (near Phoenix, Ariz.) are considered representative of the values obtained when an adequate supply of water is available. Average gross crop values per acre in the Salt River project for the years 1952 to 1956 for those crops grown along the Gila River were: Cotton, $450; alfalfa, $160; barley, $110; and grain sorghum, $80.

14. WATER RIGHTS

Water rights along the Gila River from the Virden Valley in New Mexico to the confluence of the Gila and Salt Rivers in Arizona are adjudicated by a decree entered in the United States District Court on June 29, 1935 (Globe Equity No. 59), locally known as the Gila River Decree. The decree is administered by the Gila Water Commissioner, an officer appointed by the court to distribute the available water supply according to prior rights or apportionments.

Under the decree, the San Carlos project has the right, with priority as of 1924, to store the waters of the Gila River in San Carlos Reservoir to the extent of its full capacity whenever water is available for storage. The decree provides that the commissioner, on January 1 of each year, or as soon thereafter as water is stored in San Carlos Reservoir, shall apportion to the upper valleys from the natural flow of the river a quantity equal to the available stored water, less losses, subject to a limitation in the amount and rate of diversion. Such water is known as "apportioned" water and is diverted in the upper valleys in disregard of the priorities of the San Carlos project. Although water rights in the area were settled by the Gila Decree, a serious controversy has persisted between certain interests over the diversion and use of waters of the Gila River. Safford Valley interests have objected to the construction of Buttes Reservoir on the basis that the reservoir could be operated, in conjunction with Coolidge Dam, to the detriment of their interests. They point out that water could be maintained in storage in Buttes Reservoir rather than in San Carlos Reservoir and thereby their apportionment might be adversely affected. They, therefore, object to construction of Buttes Reservoir unless a reservoir upstream from Safford Valley is constructed to compensate for this interference with the present operation of the Gila Decree.

On the other hand, San Carlos project interests would object to any construction of improvements upstream from Coolidge Dam that might tend to decrease the inflow to San Carlos Reservoir. They indicate that a reservoir upstream from Safford Valley might be operated to increase the diversions in Safford Valley or to increase the percolation to the ground water. Therefore, before any plan of improvement involving storage along the Gila River from Camelsback Reservoir site to Salt River could be recommended, agreement regarding water rights between upstream and downstream interests would have to be obtained.

15. TRANSPORTATION FACILITIES

Arterial highways and railroads connect the Gila River Basin with centers of manufacturing and commerce throughout the nation. United States Highway No. 70 traverses the entire length of Safford Valley. United States Highway No. 666 extends from the Mexican border to the State of Colorado and crosses Safford Valley at Safford, Ariz. United States Highways Nos. 80 and 89 cross the San Carlos project at Florence, Ariz. State and county highways and roads supply connecting links, and many local roads complete a network that adequately serves present needs. The main line of the Southern Pacific railroad crosses the San Carlos project at Coolidge, Ariz. Branch lines of the Southern Pacific railroad extend the length of most of Safford Valley and connect the mining communities along the Gila River below Coolidge Dam with the main line.

SECTION IV - CLIMATOLOGY

16. GENERAL

The climate of the area along the Gila River from Safford to the Salt River is subtropical and arid. Short, mild winters and long, hot summers are characteristic of the area. Relative humidity is low and evaporation is high. The average frost-free period is as high as 250 days and the growing season extends throughout the entire year for some crops. The mean daily temperatures at Safford and at Casa Grande are about 66° and 71° above zero Fahrenheit.

17. PRECIPITATION RECORDS

Records of precipitation are available for more than 400 stations in or near the area drained by the Gila River and its tributaries above the Salt River. However, the records for about 300 of these stations are of short duration and many of the records are fragmentary or incomplete. Fort Bayard, N. Mex., and Bowie, Ariz., have the earliest records. Monthly totals at these stations since 1867 are available except for a few short periods. The longest unbroken record of daily precipitation is for Tucson; it began in 1891. Recording rain gages have been maintained at Phoenix since 1906, at Tucson since 1927, and at Superior, Ariz., since 1939. Each of these stations is in or near the basin.

The computed average annual precipitation for the 71-year period 1869 to 1939, inclusive, ranges from about 7 inches at the mouth of the Salt River to about 30 inches on the crests of the mountains and averages about 16 inches.

Most of the precipitation occurs during two distinct rainy seasons. The winter season is from November to March, and the summer season from June until the early part of September. The average summer rainfall over the eastern and southern parts of the drainage basin is slightly greater than one-half the average annual precipitation; the ratio of summer to winter precipitation decreases from southeast to northwest.

18. STORMS

Three types of storms produce rain in the Gila River Basin: Pacific storms, Mexican storms, and local thunderstorms. Pacific storms, which occur during the winter rainy season, originate over the Pacific Ocean and are composed of polar Pacific and tropical Pacific air masses moving eastward. Such storms reflect an orographic influence and, though low in intensity, may last several days and cover the entire basin. Mexican storms result from an influx of moist tropical air from the Pacific Ocean or from the Gulf of Mexico. These storms approach the Gila River drainage area from the south or southeast and produce heavy precipitation on large areas. Such storms are subject to a small extent of orographic

influences. They usually occur during late summer or early fall, and occasionally as early as July or as late as February. Local thunderstorms, which are frequent summer phenomena, cover comparatively small areas and have high rainfall intensities of short duration.

Floods may result from any of the three types of storms. The most destructive floods on the Gila River have been produced by Pacific or Mexican winter storms of long duration, but in the San Pedro and Santa Cruz River Basins, the worst floods on record have been produced by Mexican storms in late summer or early autumn. In general, local summer storms, though higher in intensity than general storms, have not caused such severe flood conditions because they are of short duration and the areas covered are small.

19. SNOW

Many precipitation records since 1900 for stations in the area include information on snowfall. Snow-course observations have been made since 1937 at several points in the upper Gila River Basin. In winter, snow may accumulate to considerable depths at elevations above 4,000 feet but practically never falls at elevations below 2,000 feet.

20. STREAMFLOW RECORDS

Streamflow records are available for 67 stations on the Gila River and its tributaries above the Salt River. Records of discharge at most stations during flood periods generally are inadequate. The earliest recorded gagings are for 1889 on the Gila River at Buttes station, Arizona. The longest continuous record along the Gila River, in the area under consideration, began in January 1911 at Kelvin, Ariz. The records are published in the water-supply papers of the Geological Survey. The following table gives pertinent data for representative stream-gaging stations on the Gila River from Camelsback Reservoir site to the Salt River.

Pertinent data and estimates for representative stream-gaging stations, Gila River, Camelsback Reservoir site to Salt River, Ariz.

Location	Drainage area	Period of record	Maximum estimated flow	
			Peak	Date
	Square miles		Cubic feet per second	
Gila River at head of Safford Valley, near Solomon, Ariz.	7,900	1914-55	100,000	Jan. 19, 1916
Gila River at Calva, Ariz. (at head of San Carlos Reservoir).	11,470	1929-55	100,000	Jan. 20, 1916
Gila River at Kelvin, Ariz. (about 17 miles downstream from mouth of San Pedro River).	18,010	(1889-90 (1895-99 (1911-55	190,000	Nov. 28, 1905

21. FLOODS OF RECORD

The history of destructive floods on the Gila River has been compiled for the period 1833-1955, inclusive. Fragmentary historical records mention general floods in 1833, 1862,1869, 1880, and 1884. Quantitative data are available for floods since 1891.

The greatest floods of record in the areas under consideration occurred in 1891, 1905, and 1916, but descriptions and estimates of the floods of 1884 and 1906 indicate that they were of comparable magnitude. Although not larger than the great floods of earlier years, those of January 1916 were the most disastrous in the history of the basin because of the increased economic development. Two Pacific storms, about 10 days apart, brought warm rain to melt unusually heavy snow covers. The resulting floods were severe and

widespread. Other large floods occurred on the Gila River above Salt River in 1914, 1926, 1930, 1940, 1941, and 1949. The flood of September 1926 is especially notable in that it resulted from a tropical rainstorm of severe intensity over the southern part of the basin. The following table summarizes the larger floods of record for (a) the Gila River at the head of Safford Valley and (b) the Gila River at Kelvin:

Floods along the Gila River, Camelsback Reservoir site to the Salt River, Ariz.

Date	Estimated peak discharge*		
	Gila River at head of Safford Valley	Gila River at Kelvin, Ariz.	
		Historical	Average future conditions**
	Cubic feet per second	Cubic feet per second	Cubic feet per second
February 1891	(***)	102,000	65,000
March 1905	(***)	55,000	55,000
November 1905	(***)	190,000	123,000
October 1914	24,000	(#)	(#)
December 1914	50,000	67,300	67,300
July 1915	20,000	(#)	(#)
January 1916	100,000	132,000	70,000
October 1916	67,900	55,000	45,000
September 1926	(#)	82,000	82,000
August 1930	(#)	42,800	42,800
February 1932	24,000	(#)	(#)
August 1934	23,000	(#)	(#)
February 1937	23,700	(#)	(#)
August 1940	(#)	38,200	38,200
September 1941	31,900	(#)	(#)
January 1949	25,200	(#)	(#)

* Smaller floods occurring within a period of 60 days of a larger flood were not considered damaging and were therefore not included in this tabulation.

** Estimated peak discharges that would have occurred if San Carlos Reservoir had been in operation since 1888.

*** No estimate of peak discharge available.

\# No flood.

22. FLOOD CHARACTERISTICS

Many of the streams in the Gila River Basin rise in steep mountain areas where the rate of runoff is relatively high. During major storms, the water concentrates quickly in the channels,

producing violent and destructive floods. As the valleys widen and the gradients decrease, the channels increase in size and become more absorptive. Channel storage and losses diminish the flood peaks when no additions are made by side drainage. Winter floods resulting from general storms of several days' duration are prolonged and relatively large in total volume. Peak discharges increase gradually and progress steadily downstream with persistent force. Because winter storms usually move from west to east over the basin, the probability of synchronization of winter floods from the different tributaries is small. Peaks from downstream (western) tributaries pass on before the runoff from the area farther east arrives. Summer floods, because of the high rainfall intensities of the storms producing them, increase in discharge rapidly and generally cause severe damage when flowing through developed areas. Often, however, the summer storms are small in areal extent, and the severity exhibited by the floods in the upland areas of their origin is dissipated in the broader, flatter valleys downstream. Summer storms may be stationary or, on southern tributaries, may move in a general downstream direction; hence, summer floods from several tributaries are more likely to coincide in the main stream. The probability of coincidence of peak flows is somewhat reduced by the fact that summer storms usually are concentrated on one or two tributaries.

The base flow, made up of contributions from ground water, melting snow, and surface runoff from rain prior to the flood-producing intensities, is relatively small in the Gila River Basin streams in comparison with the size of peak floodflows although it was given consideration in the construction of hydrographs of floods. Some authorities believe that a decrease in the base flow and an increase in the frequency and magnitude of floods have occurred since the advent of the white man in the Gila River Basin. The change in conditions is attributed to the reduction of protective ground cover and to accelerated erosion caused by overgrazing of the rangelands in the areas producing runoff.

23. FLOOD FREQUENCIES

The probable future frequencies of floods of various magnitudes were determined for the purpose of estimating the economic value of flood-control improvements. Because of the relatively short period of recorded stream measurements, historical information about floods that occurred prior to those measured was used in the frequency studies. This historical information relates principally to the large floods. The assumption was made that smaller floods occurred during the period not covered by records of measurement with the same frequency as during the period of record.

Records of peak flows during the 41-year period, 1915-1955, and historical accounts of floods extending back to 1884 were used in preparing a discharge-frequency curve for the Gila River at the head of Safford Valley, near Solomon, Ariz. (See pl. 1, appendix 2.)

Additional information on frequency studies is given in Appendix 2: Benefits from flood control. The estimated frequencies of floods of various magnitudes for the Gila River near Solomon, Ariz., are summarized in the following table:

Estimated flood frequencies, Gila River at head of Safford Valley, near Solomon, Ariz.

Number of floods in 100 years	Peak discharge equaled or exceeded
	Cubic feet per second
0.5	*175,000
1.0	140,000
2.0	110,000
5.0	69,000
10.0	44,000
20.0	26,000
28.0	19,800
50.0	**12,000

* Standard project flood.
** Nondamaging discharge.

24. STANDARD PROJECT FLOOD

A standard project flood may be defined as a large hypothetical flood that would be exceeded only on rare occasions. Such a flood could occur in the area under consideration if a storm equivalent in magnitude to the largest general storm of record in the region were to center over the basin when ground and meteorological conditions were conducive to a high rate of runoff. Estimates of the magnitude of such a flood serve not only as a reasonable yardstick for determining the flood-producing potentialities of that part of the basin but also as a reasonable upper limit in determining the size of the flood that should be considered in designing flood-control improvements.

Upstream from the mouth of the San Pedro River, estimates of the magnitude of the standard project flood along the Gila River are based on calculations of runoff that would result if a storm having characteristics of the January 1916 storm were centered over the area. Details of the standard project flood at a point just upstream from Safford Valley are given in the following table:

Estimated peak discharges, standard project flood, Gila River at a point just upstream from Safford Valley

Item	Unit	Magnitude
River mile		439
Drainage area	Square miles	7,530
Peak discharge	Cubic feet per second	175,000
Volume	Acre-feet	665,000
Duration	Days	9

SECTION VI - EXTENT AND CHARACTER OF FLOODED AREA

25. LOCATION AND EXTENT

The overflow area affected by the improvements considered in detail in this report lies along the Gila River from the upper end of Safford Valley to San Carlos Reservoir and consists of broad strips of agricultural land roughly paralleling the main channel in the Safford Valley and in the San Carlos Indian Reservation. The total area in the flood plain amounts to 22,500 acres. Of the 12,800 cultivated acres subject to overflow, 12,500 acres are included in the Safford Valley and 300 acres are in the San Carlos Indian Reservation. The principal towns and communities are outside the flood plain. A small subdivision of very low-valued homes about 2 miles east of the city of Safford is, however, subject to overflow. The area subject to overflow upstream from San Carlos Reservoir is shown on aerial mosaics, plates 2 to 5. No appreciable flood-control benefits would accrue downstream from Coolidge Dam as a result of construction of the improvements considered in detail in this report.

26. TYPE AND VALUE OF IMPROVEMENTS

The present value of agricultural property and irrigation works is estimated at about 85 percent of the total value within the area. Agricultural improvements include farm buildings (exclusive of dwellings) and equipment, fences, farm roads, crops, and livestock. Irrigation works include diversion structures, canals and appurtenances, wells, and pumping equipment. Most of the diversion structures are of temporary character, subject to repeated damage or destruction by floods. Many low-lying canals are within the overflow area. Farm dwellings and residential properties are of medium to low value.

Three highway bridges, at Safford, Pima, and Calva, Ariz., are subject to damage. The highway bridge at Calva is now under construction to carry the transcontinental traffic of United States Highway No. 70. The Calva bridge of the Southern Pacific railroad is also subject to damage. Utilities subject to damage are electric transmission lines, telephone and telegraph lines, and gas pipelines.

As indicated under the previous heading "Agriculture," there has been very little increase in the agricultural area in Safford Valley since 1935. The agricultural economy has been generally stable. Therefore, no increase in agricultural development over the next 50 years was assumed under existing conditions. A summary of information on the type and average future value of property in the overflow area under detailed consideration is given in the following table:

Value of property subject to damage by standard project flood in the overflow areas along the Gila River from upper end of Safford Valley to San Carlos Reservoir, Ariz.

Property	Value (1957)
Residential	$510,000
Business and industrial	0
Public	0
Agricultural	11,760,000
Irrigation works	1,060,000
Highways and roads	1,240,000
Railroads	180,000
Utilities	60,000
Total	14,810,000

SECTION VII - FLOOD DAMAGES

27. DAMAGES FROM PAST FLOODS

Floods on the Gila River have cost many lives and have caused severe damage to property. Complete data on damages from past floods are not available. Newspaper accounts supply incomplete flood-damage descriptions of floods that have occurred since 1890. However, monetary estimates are very limited. Diversion dams and canal headings have been destroyed repeatedly. Bank erosion has robbed the agricultural valleys of much valuable land.

The greatest loss of land in any 1 year occurred in 1905, when the Gila River was in flood for 4 months and destroyed several thousand acres in Safford Valley. Compilation of incomplete data submitted by local interests on floods that occurred after 1879 on the Gila River and tributaries above Coolidge Dam shows that the reported damage was more than $3,500,000. Most of this damage occurred in Safford Valley.

28. DAMAGES FROM FUTURE FLOODS

Damages from future floods would be greater than from past floods because of increased development in the area subject to overflow and because of the deterioration of the flood channel. In estimating the damage from a single flood, consideration was given to the probable extent of its overflow area, the type and value of property subject to damage, and the extent of damage that would occur to each type of property from floodwaters of computed depth and velocity. The selected magnitudes range from the discharge that would cause a small amount of damage to the discharges of the standard project flood. Along the Gila River from the upper end of Safford Valley to San Carlos Reservoir, only a small amount of additional development is anticipated over the next 50 years and estimates of damages are the same under average future conditions as under present conditions.

Pertinent information on the direct and indirect damages under average future conditions in the overflow area along the Gila River from the upper end of Safford Valley to San Carlos Reservoir is given in the following two tables:

Estimated damages from a flood of 175,000 cubic feet per second* in the overflow area along the Gila River from the upper end of Safford Valley to San Carlos Reservoir

Type of property	Value (1957)	Estimated damage		
		Direct	Indirect	Total
Residential	$510,000	$260,000	$50,000	$310,000
Business and industrial	0	0	0	0
Public	0	0	0	0
Agricultural	11,760,000	1,340,000	220,000	1,560,000
Irrigation works	1,060,000	660,000	130,000	790,000
Highways and roads	1,240,000	950,000	190,000	1,140,000
Railroads	180,000	160,000	160,000	320,000
Utilities	60,000	10,000	10,000	20,000
Total	14,810,000	3,380,000	760,000	4,140,000

* Discharge at upper end of Safford Valley.

Estimated damage from future floods of various magnitudes in overflow area along the Gila River from the upper end of Safford Valley to San Carlos Reservoir

Flood magnitude*	Estimated damage		
	Direct	Indirect	Total
Cubic feet per second			
175,000	$3,380,000	$760,000	$4,140,000
72,000	1,520,000	310,000	1,830,000
35,000	640,000	110,000	750,000
17,000	150,000	30,000	180,000

* Discharge at upper end of Safford Valley.

29. AVERAGE ANNUAL DAMAGES FROM FUTURE FLOODS

A curve was drawn showing the relationship between peak discharges and average future damages for the overflow area between the upper end of Safford Valley and San Carlos Reservoir. This curve was combined with the discharge-frequency curve previously described to obtain a curve showing the estimated number of times in 100 years that damages from single floods would be equaled or exceeded. (See pl. 2, appendix 2.) The area under the damage-frequency curve

represents the estimated total flood damages during a 100-year period; and that total, divided by 100, is the estimated average annual flood damage. The average annual future flood damage in the overflow area along the Gila River between the upper end of Safford Valley and San Carlos Reservoir is estimated at $337,000. Additional information on flood damages is given in Appendix 2: Benefits from flood control.

30. INTANGIBLE DAMAGES FROM FUTURE FLOODS

Future floods along the Gila River would cause serious damages not calculable in terms of monetary value. The flood of 1891 caused the loss of eight lives in Safford Valley. Intangible damages from future floods would result from loss of life, delay in shipment of perishable products, interruption of passenger travel on railroads and highways, isolation of communities, interruption of home life and of school and other community activities, inconveniences caused by interruption of public-utility services, lowering of property values because of fear of floods, and general lowering of community morale.

SECTION VIII - EXISTING IMPROVEMENTS

31. EXISTING CORPS OF ENGINEERS FLOOD-CONTROL PROJECTS

Two flood-control projects have been authorized for construction by the Corps of Engineers in the Gila River Basin upstream from the mouth of the Salt River. Neither of these two projects, Whitlow Ranch Reservoir (on Queen Creek) or Tucson flood-control channel (in the vicinity of Tucson), affect the flood problem in the area under detailed consideration in this report.

32. IMPROVEMENTS BY OTHER FEDERAL AND NON-FEDERAL AGENCIES

Coolidge Dam on the Gila River at mile 349 was constructed by the United States Indian Irrigation Service at a cost of $5,250,000. The large capacity of San Carlos Reservoir, initially 1,195,000 acre-feet, is required for long holdover storage in the interest of water conservation. Although empty space in the reservoir frequently is sufficient to catch and store all floodwaters from the drainage area above the dam, the availability of such space cannot be depended upon for flood control because the method of operation is designed primarily to conserve water. San Carlos Reservoir is above the mouth of the San Pedro River and therefore has no effect on floods that originate on that stream.

SECTION IX - IMPROVEMENTS DESIRED

33. PUBLIC HEARING

Two public hearings were held jointly by the Department of the Army and the Department of Agriculture to determine the desires of local interests concerning flood control along the Gila River from Camelsback Reservoir site to the Salt River. They were attended by 270 persons, including representatives of various agencies of the Federal Government, officials of the State of Arizona and its political subdivisions, representatives of local civic organizations, and interested private citizens. The meetings were held at Safford, Ariz., and Phoenix, Ariz., on September 29, 1937, and October 20, 1938, respectively.

34. IMPROVEMENTS DESIRED BY LOCAL INTERESTS

The public hearings and subsequent contact with local interests disclosed that local interests desire construction of (a) a dam at or near the Camelsback site on the Gila River upstream from Coolidge Dam, (b) a dam downstream from Coolidge Dam either at the Buttes site on the Gila River or on the San Pedro River near its mouth, and (c) channel improvements extending from a dam at or near the Camelsback site to the Ashurst-Hayden diversion dam.

35. REASONS ADVANCED IN JUSTIFICATION OF IMPROVEMENTS DESIRED

The principal development above Coolidge Dam is in Safford Valley, where a total of about 32,500 acres of land has been reclaimed by irrigation. These lands, which are marginal to the Gila River, are to a great extent subject to flood damage due to bank erosion and overflow. Since the beginning of irrigation in this valley in 1872, progressive erosion of streambanks has destroyed more than 10,000 acres of arable land. Local interests also point out that large water losses occur as a result of the infestation of phreatophytes along the channel of the Gila River.

Floodwaters downstream from Coolidge Dam cause damage to agricultural lands, irrigation works, and other improvements in the San Carlos project area. The silt-laden floodwaters of the San Pedro River commingle with the waters of the Gila River. A part of this flow is later diverted into the irrigation canals leading to the San Carlos irrigation project and a part is wasted downstream. The silt causes great damage to crops. A severe shortage of water exists in the San Carlos project area. No storage exists to control and regulate summer floods occurring on the San Pedro River. Local interests in the San Carlos project area stress the necessity for optimum control and utilization of the flow in the San Pedro and Gila Rivers. They therefore desire a multiple-purpose reservoir either on the Gila River upstream from the Ashurst-Hayden diversion dam or on the San Pedro River.

SECTION X - FLOOD PROBLEMS AND RELATED PROBLEMS

36. FLOOD PROBLEMS

Floods along the Gila River cause recurrent damage of major proportions by eroding farmlands, cutting streambanks, and changing the shape and location of channels; overflowing stream channels and causing inundation of farmlands; and damaging and destroying irrigation, communication, and transportation facilities. In Safford Valley, about 12,800 acres of intensively developed irrigated farmland (about 40 percent of the total cultivated acreage in the valley) are subject to overflow and damage. Below Coolidge Dam and upstream from the Salt River, about 50 percent of the area cultivated in 1955 is subject to damage.

Floodwaters of the tributary streams are heavily laden with silt eroded from the land surface and scoured from the channels. During summer floods on the tributaries, when the Gila River is not usually in flood, the force of the peak flows from the side streams is dissipated rapidly in the main channel and much of the silt load is deposited, causing divided channels and meandering flow in the Gila River. Because depositing the silt load reduces the channel capacity - and because the subsequent growth of vegetation in the deposited material increases its resistance to scour, small flash floods may overflow the banks before degrading the streambed.

A combination of a comparatively dry river channel and a high water table in parts of Safford Valley has resulted in an infestation of water-loving plants (phreatophytes) that have achieved almost maximum density in many locations. With the channel thus choked, its capacity is seriously reduced and the occurrence of even a small flood along the Gila River could result in serious damage to the agricultural area in Safford Valley.

37. WATER-CONSERVATION PROBLEMS

Flood problems along the Gila River are related closely to the problems of water conservation and water utilization. Because of the flashy nature of the streamflow and the high sediment content of floodwaters, utilization of the runoff is incomplete. That proportion of the water resources of the area that can be utilized effectively under present conditions closely governs values of lands and improvements and limits the area under cultivation. Because water is a vital factor in the economy of the area, maximum utilization of the available water supply is essential. Control of the Gila River to prevent flood damage should be accompanied by conservation for later beneficial use of as much as possible of the floodwaters.

The Gila River is a violently fluctuating stream whose flow is not by nature adapted to the seasonal demands of irrigation. Since 1914, the annual discharge at the head of Safford Valley

has ranged from about 73,000 acre-feet in 1951 to about 1,600,000 acre-feet in 1915, with monthly variations of proportional magnitude. The greater part of the annual flow occurs in winter, when the irrigation demand is least; in summer, when the demand is greatest, the flow is deficient.

Except for the year 1949, streamflow along the Gila River has been below average since 1941. Since September 1945, San Carlos Reservoir, which has a capacity of about 1,200,000 acre-feet, has been practically empty (below 50,000 acre-feet) except for brief periods in 1949, 1950, 1952, and 1954-57, inclusive. In December 1957, the water stored in the reservoir was about 70,000 acre-feet.

As discussed under the previous heading "Water Rights," diversions in Safford Valley are dependent to some extent upon the quantity of water stored in San Carlos Reservoir. Consequently, landowners both upstream and downstream from Coolidge Dam have an interest in having as much floodflow as possible reach San Carlos Reservoir.

Under present conditions, phreatophytic growth within the channel of the Gila River transpires tremendous amounts of water annually. Saltcedar, mesquite, arrowweed, and baccharis are the principal phreatophytes in the river-channel area. According to the Bureau of Reclamation, the net annual use of water per acre for saltcedar (which comprises over 80 percent of the growth to be cleared), assuming 100 percent density, amounts to 6.6 acre-feet - nearly twice the annual water use (about 3.5 acre-feet) for cultivated crops. The average annual transpiration by phreatophytes in the channel of the Gila River from the upper end of Safford Valley to San Carlos Reservoir and from the mouth of the San Pedro River to Buttes Reservoir site is estimated by the Bureau, after considering the areal and vertical densities of the various phreatophytes in the channel area, at about 48,000 acre-feet. (See Appendix 3: Water salvage and benefits, channel clearing - Gila River, Safford-San Carlos Coordinated Investigations.) Such consumptive water use reduces the amount of water available for diversion.

Safe-draft studies of San Carlos Reservoir indicate that the existing storage capacity is ample for maximum feasible conservation and regulation of the total inflow. However, the flow of the San Pedro River, which enters the Gila River downstream from Coolidge Dam and upstream from the Ashurst-Hayden diversion dam, is not regulated and much of the floodflow is wasted or inefficiently utilized. The irrigated and irrigable acreage in the San Carlos project is much greater than the area that can be irrigated by the controlled surface-water supply. The surface-water supply is supplemented by pumping from wells, but the combined surface and ground-water supply has never been sufficient to irrigate all project lands, and those lands that have been irrigated have seldom received a full supply of water. The maximum acreage ever irrigated was about 80 percent of the total project lands, and in recent years the irrigated acreage has averaged only 55 percent of the project area.

38. SEDIMENT PROBLEMS

Deposition of sediment in San Carlos Reservoir is decreasing the water-storage capacity. Because the reservoir was completed at the beginning of a long dry period and has never been filled, the decrease in net capacity has had no effect on the yield from the reservoir up to the present time. Over a long period, however, a reduction of the average annual yield of water for irrigation of the San Carlos project will result and, unless preventive measures are taken, sedimentation of the reservoir will shorten its useful life.

In many places upstream from the mouth of the Salt River, silt is deposited on agricultural lands directly by floodwaters or by water diverted from streams for irrigation. Generally, in the valleys above Coolidge Dam, surplus winter streamflow is used to flush the silt from the canals; but, in the San Carlos project, no surplus flow is available for that purpose. Silt from the San Pedro River is deposited in the irrigation canals and laterals throughout the San Carlos project. Silt deposited by irrigation water on the cultivated land causes the surface of the fields to be uneven, lowers the permeability of certain types of soil, reduces crop yield, increases irrigation costs, and thus reduces farm revenues. Removing the silt from the ditches, and releveling and reclaiming the land are expensive operations.

39. METHODS OF IMPROVEMENT CONSIDERED

Maximum utilization of the water resources of the Gila River above the Salt River requires coordinated development for flood control, water conservation, and sediment control. The control of floods by flood-control reservoirs, multiple-purpose reservoirs, and channel improvements was considered. Detailed consideration in this report is limited to channel improvements.

SECTION XI - PLANS OF IMPROVEMENT CONSIDERED

40. PLANS CONSIDERED

The plan of improvement presented in detail in this report was developed as part of a comprehensive plan (a) to control the floodwaters of the Gila and San Pedro Rivers, (b) to salvage as much of those floodwaters as practicable for utilization by irrigation interests, and (c) to reduce the sediment deposition in San Carlos Reservoir and on the lands of the San Carlos project. The plan of development is the result of a joint investigation by the Corps of Engineers and the Bureau of Reclamation. The Corps of Engineers is primarily responsible for the formulation of and the design of the channel improvements and Earven Reservoir. On the other hand, the Bureau of Reclamation is primarily responsible for the formulation of and design of Buttes Reservoir and appurtenances.

41. COMPREHENSIVE PLAN OF IMPROVEMENT

To provide optimum use of water resources in the drainage area of the Gila River between Camelsback Reservoir site and the mouth of the Salt River, consideration was given to a comprehensive plan of improvement providing for: (a) A flood-control reservoir at the Earven site on the Gila River at river mile 439; (b) channel improvements consisting of channel clearing along the Gila River between (1) the upper end of Safford Valley (river mile 435) and the San Carlos Reservoir (river mile 357) and (2) the mouth of the San Pedro River (river mile 319) to the upper end of Buttes Reservoir site (river mile 303); and (c) a multiple-purpose reservoir at the Buttes site (river mile 287). A reservoir at the Earven site with sufficient capacity to control a standard project flood would increase flood stages in the city of Clifton, Ariz. Therefore, consideration will be given to a reservoir providing partial control for Safford Valley. Clearing the channel from the upper end of Safford Valley to the Buttes Reservoir site would result in partial protection to lands and improvements in Safford Valley and in the San Carlos Indian Reservation upstream from Coolidge Dam and would reduce the nonbeneficial use of water by phreatophytes in the channel area. Buttes Reservoir would provide for the conservation of the floodflows originating downstream from Coolidge Dam. The reservoir would provide flood and sediment control and water conservation.

42. PLAN OF IMPROVEMENT CONSIDERED IN THIS REPORT

Studies on the comprehensive plan indicate that the channel improvements can be constructed, at this time, as an economically feasible unit under that plan. Construction of the channel improvements is not dependent upon the other units considered. As a result, detailed consideration is limited in this report to channel improvements only. The Bureau of Reclamation, with the cooperation of the Corps of Engineers, is studying Buttes Reservoir and is scheduled to

complete a feasibility report of that reservoir in about 1 year. The Corps will give further consideration to the Earven Reservoir under the outstanding authority for a comprehensive study of the Gila River Basin.

Channel improvements along the Gila River would consist of a cleared floodway for about 94 miles from the upper end of Safford Valley to San Carlos Reservoir and from the mouth of the San Pedro River to the Buttes Reservoir site. The Gila River channel from Coolidge Dam to the mouth of the San Pedro River is narrow and is limited by rock formations. Practically no phreatophytic vegetation is in this reach of the river. Saltcedar and other vegetative growth within the proposed cleared area (about 14,300 acres) would be cleared by mechanical means. The area to be cleared would have a maximum width of about 5,000 feet and an average width of about 2,500 feet. A fringe area, with a width of 50 feet adjacent to the bank, would be left untouched to prevent bank erosion. Aerial maps, plates 2 to 10, indicate the location and extent of the channel clearing under the recommended plan.

Consideration was given to an excavated and leveed channel that could convey flood releases of 5,000 cubic feet per second from Earven Dam site to Buttes Reservoir. Such a channel was estimated to cost about $4,000,000. However, studies indicate (a) that such a channel would be economically infeasible to maintain and (b) that no appreciable savings of water would result from this construction. Therefore, no further consideration was given to inclusion of an excavated or leveed channel in the area under consideration.

SECTION XII - ESTIMATES OF FIRST COST AND ANNUAL CHARGES

43. ESTIMATES OF FIRST COST

The estimated first cost for the improvements considered in detail in this report comprises expenditures for clearing the river-bottom growth and for rights-of-way. No appreciable costs are involved for relocation of roads, bridges, or utilities. Estimates of cost are based on price levels for December 1957. Allowances are made for engineering, overhead, inspection, and contingencies.

Three methods of destroying phreatophytes, principally saltcedar, were considered: (a) Burning, (b) chemical treatment, and (c) mechanical means. (See Appendix 1: Bases for design and cost estimates.) Numerous experiments are being conducted by Federal, state, and local groups on these means of eradication, but no final conclusions have been reached. Information to date indicates that burning and chemical treatment are not completely effective and would still require mechanical means of clearing the floodway. Therefore, for the purpose of preparing an adequate cost estimate, destruction of phreatophytes by mechanical means was assumed. Material would be removed from the area by burning or other adequate means of disposal.

The first cost of the proposed channel clearing, based on December 1957 prices, is estimated at $1,770,000, of which $1,570,000 is for construction and $200,000 is for rights-of-way. Details of the estimated first cost of the recommended plan are given in appendix 1.

44. ESTIMATES OF ANNUAL CHARGES

The estimate of annual charges for the plan of improvement considered in this report includes interest on the total investment, amortization of the total investment in 50 years, and average annual costs of maintenance and operation. Maintenance and operation charges for the above plan of improvement are estimated at $50,000 annually. (See appendix 1.) The construction period for the channel improvements is estimated at one calendar year; therefore, interest during construction would not be charged against that part of the plan.

The construction cost of the channel improvements would be borne by the United States, but repayments would be required from water-conservation interests for that part of the cost allocated to water conservation. The cost of lands, easements, and rights-of-way, and the cost of maintenance and operation would be borne by local interests. Estimates of the first cost and annual charges for the recommended plan are given in the following table:

Estimated first cost and annual charges, channel clearing, Gila River, upper end of Safford Valley to Buttes Reservoir site (based on prices for December 1957)

a.	Federal first cost and investment:	
	(1) Cost of clearing channel.....	$1,570,000
b.	Federal annual charges:	
	(1) Interest and amortization in 50 years at 2.5 percent, 0.03526 times item a.....	55,000
	(2) Total Federal annual charges....	55,000
c.	Non-Federal first cost and investment:	
	(1) Rights-of-way.....	200,000
d.	Non-Federal annual charges:	
	(1) Interest and amortization in 50 years at 2.5 percent, 0.03526 times item c.....	7,000
	(2) Maintenance and operation (average annual).....	50,000
	(3) Total non-Federal annual charges.....	57,000
e.	Total annual charges:	
	(1) Federal.....	55,000
	(2) Non-Federal.....	57,000
	(3) Total annual charges.....	112,000

SECTION XIII - ESTIMATES OF BENEFITS

45. TANGIBLE BENEFITS

Tangible benefits from plans of improvement considered in this report would result from (a) prevention of direct and indirect flood damages and (b) conservation of water for irrigation use. No appreciable tangible benefits from an increased utilization of land would result from the improvements considered. The shortage of water in the areas under consideration would prevent an appreciable increased utilization of property.

46. BENEFITS FROM FLOOD CONTROL

Clearing of the Gila River channel would effect partial flood control by increasing channel capacities with attendant lowering of the water-surface elevations of future floods and with resultant reduction in the extent of the flooded areas. Primary flood-control benefits from channel clearing were obtained by determining the difference between those primary flood damages (direct and indirect) that would occur if the considered improvements were not provided and those primary flood damages that would result even after construction of the improvements. Total average annual primary flood damages along the Gila River from the upper end of Safford Valley to San Carlos Reservoir would be reduced from $337,000 to $245,000. Average annual primary flood-control benefits from channel clearing would therefore amount to $92,000. More detailed information regarding the determination of flood-control benefits is given in appendix 2.

47. BENEFITS FROM WATER CONSERVATION

Eradication of the phreatophytes in the Gila River channel would result in the salvage of some of the water presently consumed by the river growth. The Bureau of Reclamation estimates that the net increase of water to the farmers resulting from clearing the Gila River channel from the upper end of Safford Valley to the Buttes Reservoir site would amount to 19,800 acre-feet annually. (See Appendix 3: Water salvage and benefits, channel clearing - Gila River, Safford-San Carlos Coordinated Investigations.)

The Bureau of Reclamation has estimated the irrigation benefits on the basis of those increases in net income that would result from project development. It was assumed, for purposes of this study, that the conserved water would be used to irrigate additional land within the confines of existing farms. The direct irrigation benefits as defined by the Bureau were measured by the increased net income to the project farmers. The indirect benefits from irrigation as defined by the Bureau represent the increase in net income to the off-farm handlers and processors of the increased production. Average annual water-conservation benefits were estimated by the Bureau at $232,000 direct (primary) benefits and $714,000 indirect (secondary) benefits, for a total of $946,000.

The conserved water would not be physically separable from the natural flow in the stream and would not be delivered to any individual, group, or irrigation district. The river growth upstream from Coolidge Dam reduces the inflow into San Carlos Reservoir and somewhat reduces the amount of water available for diversion in Safford Valley. Phreatophytes downstream from Coolidge Dam reduce the amount of water available for diversion at Ashurst-Hayden Dam. Under the Gila Decree (see previous paragraph on "Water Rights"), diversions upstream and downstream from Coolidge Dam are dependent to some extent upon the quantity of water stored in San Carlos Reservoir upstream from Coolidge Dam. The Gila Decree affects lands in Virden Valley in New Mexico and Duncan and Safford Valleys in Arizona. Downstream from Coolidge Dam, the decree affects lands in the vicinity of Winkelman, Ariz., and in the San Carlos project, which comprises both Indian and non-Indian lands.

48. INTANGIBLE BENEFITS

Many benefits not susceptible of monetary evaluation, but nevertheless of importance, would accrue from the improvements considered in this report. Partial control of the floods would lessen the interference by floods with normal home and social life and agricultural activities, and might effect a savings in life. Intangible benefits from water conservation would include partial stabilization of property values by reducing the water shortages in the area. The proposed improvement would help to reduce agricultural retrenchment due to depletion of the water resources.

49. SUMMARY OF BENEFITS

The estimated average annual benefits that would accrue from the construction of channel improvements along the Gila River from the upper end of Safford Valley to the Buttes Reservoir site are summarized in the following table:

Estimated average annual benefits from channel improvements along Gila River from the upper end of Safford Valley to Buttes Reservoir site, Arizona

Type of benefit	Amount
Flood-control benefits	$92,000
Water-conservation benefits:	
Primary benefits*	232,000
Total, including secondary**	(946,000)
Total benefits, considering primary benefits only***	324,000
Total benefits, including secondary benefits**	1,038,000

* Direct water-conservation benefits as defined by the Bureau of Reclamation are considered to be primary benefits.

** Indirect water-conservation benefits as defined by the Bureau of Reclamation are considered to be secondary benefits.

*** Primary benefits include primary benefits as defined by the Corps of Engineers and direct benefits as defined by the Bureau of Reclamation.

SECTION XIV - ECONOMIC JUSTIFICATION

50. COMPARISON OF BENEFITS AND COSTS

The recommended plan of improvement provides for channel clearing along the Gila River from the upper end of Safford Valley to the Buttes Reservoir site. The first cost of the improvement is estimated at $1,770,000 (December 1957), and the average annual charges $112,000. The total average annual primary benefits are estimated at $324,000, including $92,000 for flood control and $232,000 for water conservation. The ratio of average annual primary benefits to average annual costs would be 2.9 to 1. If consideration is given to the secondary water-conservation benefits, the total annual benefits would amount to $1,038,000, and the benefit-cost ratio would equal 9.3 to 1. Accordingly, the improvements are justified.

SECTION XV - ALLOCATION AND APPORTIONMENT OF COSTS

51. ALLOCATION OF COSTS

The separable costs-remaining benefits method was used in arriving at an equitable distribution of costs between flood control and water conservation. The following table summarizes the results of using the above method in the allocation of first costs for the recommended plan of improvement to flood control and water conservation. A more detailed development of the method of allocation of costs is given in Appendix 4: Allocation of costs.

Allocation of first costs, channel clearing along Gila River from the upper end of Safford Valley to Buttes Reservoir site

Item	Flood control	Water conservation	Total
First cost:			
Construction.....	$708,000	*$862,000	$1,570,000
Rights-of-way.....	90,000	110,000	200,000
Total.....	798,000	972,000	1,770,000

* Allocation of construction costs to water conservation amounts to 54.9 percent of total construction cost.

52. APPORTIONMENT OF COSTS

In accordance with the general policies expressed in acts of Congress, the cost of construction items allocated to flood control would be borne by the United States; and the cost of all lands, easements, and rights-of-way, and the cost of all maintenance and operation would be borne by local interests.

Reclamation law permits local interests to repay, in 40 years without interest, that part of the first cost of reclamation projects allocated to water conservation. Although this project would be authorized as a flood-control project, local interests should be permitted to avail themselves of interest-free repayments in reimbursing the United States for the portion of the cost allocated to water conservation.

The recommended channel improvement would be constructed by the United States at an estimated total first cost of $1,570,000 based on prices prevailing in December 1957, subject to reimbursement by local interests, in consideration of water-conservation benefits, of 54.9 percent of the total construction cost in 40 equal annual payments without interest. On the basis of

December 1957 prices, the estimated amount of $862,000 would be repaid in 40 equal annual payments of $21,550. The allocations and repayments would be adjusted on the basis of actual construction costs.

On the foregoing basis, local interests would (a) provide all lands, easements, and rights-of-way; (b) maintain and operate the entire project at local expense after completion; and (c) reimburse the United States in 40 equal annual payments, without interest, for that part of the project construction cost that is allocated to water conservation.

53. PROPOSED LOCAL COOPERATION

As a requisite to construction of the recommended plan by the United States, responsible local interests would be required to:

a. Provide necessary lands, easements, and rights-of-way at a cost estimated at $200,000 (December 1957);

b. Maintain and operate the channel improvements in accordance with regulations to be prescribed by the Secretary of the Army at an average annual cost estimated at $50,000;

c. Keep the flood channel of the Gila River from the upper end of Safford Valley to San Carlos Reservoir and from the mouth of the San Pedro River to Buttes Reservoir site free from encroachment;

d. In consideration of the water-conservation benefits, reimburse the United States an amount, allocated to water conservation, equal to 54.9 percent of the total construction cost in 40 equal annual payments, without interest. On the basis of present prices, the estimated amount of $862,000 would be repaid in 40 equal annual payments of $21,550. The allocations and repayments would be adjusted on the basis of actual construction costs;

e. Hold and save the United States free from any damages arising from construction and operation of the work; and

f. Adjust all water-rights claims resulting from construction, operation, and maintenance of the improvements.

SECTION XVI - COORDINATION WITH OTHER FEDERAL AGENCIES

54. ASSURANCES OF LOCAL COOPERATION

A public meeting was held in Phoenix, Ariz., on December 18, 1957, for the purpose of acquainting local interests with the findings of the investigation and survey and to indicate the requirements of local cooperation as a requisite to construction of the proposed project. Resolutions regarding local cooperation have been received from the San Carlos Irrigation and Drainage District, representing interests downstream from Coolidge Dam, and from Gila Valley Irrigation District, representing interests in Safford Valley upstream from Coolidge Dam. (See Appendix 5: Resolutions by local interests.) The San Carlos Irrigation and Drainage District agreed, in its resolution, to (a) assume joint sponsorship of the recommended project with other appropriate agencies and (b) attempt to arrive at an equitable distribution between the respective local agencies of those costs and items that are the obligation of local interests. The Gila Valley Irrigation District agreed in its resolution to the same items as indicated above, but made such agreement conditional, tentative, and dependent upon an overall project that would include the construction of a dam upstream from Safford Valley and in the vicinity of the Camelsback Dam site.

55. COORDINATION WITH OTHER FEDERAL AGENCIES

As indicated under a preceding heading, "Scope," this survey is the result of a coordinated investigation with the Bureau of Reclamation. Complete agreement was reached on all items that were the mutual concern of the two agencies. Division of work was accomplished to utilize the respective skills and backgrounds of the two agencies in the fields of water conservation and flood control. Plans for the recommended improvement do not conflict with plans of other Federal or non-Federal agencies.

SECTION XVII - SUMMARY

56. DISCUSSION

The Gila River Basin, the largest drainage area tributary to lower Colorado River, comprises about 58,200 square miles, mostly in Arizona and New Mexico. That part of the Gila River Basin that is under consideration in this report comprises the Gila River Valley from the upper end of Safford Valley to the mouth of Salt River. The drainage area of the Gila River near the upper end of the Safford Valley amounts to 7,900 square miles and the drainage area of the Gila River above the mouth of the Salt River amounts to 29,300 square miles.

Floods along the Gila River in the area under consideration cause recurrent damage of major proportions. Upstream from San Carlos Reservoir, about 12,800 acres of intensively developed irrigated farmland (about 40 percent of the total cultivated acreage in the area) are subject to overflow and damage. A combination of a comparatively dry river channel and a high water table in parts of Safford Valley has resulted in an infestation of water-loving plants (phreatophytes) that have achieved almost maximum density in many locations. With the channel thus choked, its capacity is seriously reduced and the occurrence of even a small flood along the Gila River could result in serious damage to the agricultural area.

Flood problems along the Gila River are related closely to the problems of water conservation and utilization. Under present conditions, phreatophytic growth within the channel area of the Gila River transpires tremendous amounts of water annually. The net annual use of water per acre for saltcedar (one of the principal phreatophytes), assuming 100 percent density, amounts to 6.6 acre-feet - nearly twice the annual water use of cultivated crops. The average annual transpiration by phreatophytes in the channel of the Gila River from the upper end of Safford Valley to San Carlos Reservoir and from the mouth of the San Pedro River to Buttes Reservoir site is estimated at about 48,000 acre-feet. Such use reduces the amount of water available for diversion.

The plan of improvement presented in detail in this report was developed as part of a comprehensive plan to provide optimum use of water resources in the area. The comprehensive plan considered provides for (a) a flood-control reservoir at the Earven site, (b) channel improvements consisting of channel clearing along the Gila River from the upper end of Safford Valley to the Buttes Reservoir site, and (c) a multiple-purpose reservoir at the Buttes site. Detailed consideration is limited in this report to channel improvements only because (a) construction of the channel improvements are not dependent upon the other units considered, (b) completed studies on these channel improvements indicate that the improvements are well justified, and (c) studies of the other units of the comprehensive plan are not complete.

The recommended plan provides for a cleared floodway for about 94 miles along the Gila River from the upper end of Safford Valley to San Carlos Reservoir and from the mouth of the San Pedro River to the Buttes Reservoir site. Saltcedar and other vegetative growth within the proposed cleared area (about 14,300 acres), would be cleared by mechanical means.

The total first cost of the recommended plan is estimated at $1,770,000 (December 1957). Annual charges for maintenance and operation are estimated at $50,000. The total annual charges under the recommended plan would be $112,000.

Clearing the Gila River channel would effect partial flood control by increasing channel capacities with attendant lowering of the water-surface elevations of future floods and with resultant reduction in the extent of the flooded areas. In addition, eradication of the phreatophytes would result in the salvage of some of the water presently consumed by the river growth. The Bureau of Reclamation estimates that the net increase of water to the farmers resulting from the proposed clearing would amount to 19,800 acre-feet annually.

For the recommended plan, the average annual primary benefits from flood control are estimated at $92,000 and the average annual primary benefits from water conservation at $232,000. The total average annual primary benefits, therefore, would be $324,000. The resultant benefit-cost ratio, considering primary benefits only, would be 2.9 to 1. If consideration is given to secondary water-conservation benefits, the total annual benefits would amount to $1,038,000, and the benefit-cost ratio would equal 9.3 to 1. The project is justified by a substantial margin.

Allocation of costs between flood control and water conservation was arrived at by use of the separable costs-remaining benefits method. Costs of the recommended plan allocated to flood control and water conservation were further apportioned in accordance with existing policy. Under this apportionment, local interests would repay to the United States 54.9 percent of the total construction cost in 40 equal annual payments without interest. Based on the present (December 1957) estimated construction cost for the project of $1,570,000, the total local reimbursement, in consideration of water-conservation benefits, would amount to $862,000, and the annual payments by local interests for the 40-year period would amount to $21,550. The amount of local reimbursement would be adjusted on the basis of actual construction costs. In addition to such annual payments, local interests, at their own expense, would (a) provide all lands, easements, and rights-of-way at a cost estimated at $200,000 (December 1957); and (b) maintain and operate the completed project at an average annual cost estimated at $50,000.

57. CONCLUSIONS

The district engineer concludes that:

a. A flood problem exists along the Gila River from the upper end of Safford Valley to the mouth of Salt River.

b. The water supply available for utilization is not adequate to satisfy the irrigation needs of the area.

c. River-bottom growth along the Gila River is a major flood menace and transpires large amounts of water annually.

d. Investigations to date indicate that the plan for the development of water resources of the area would include (1) a flood-control reservoir at the Earven site, (2) channel improvements consisting of channel clearing along the Gila River from the upper end of Safford Valley to San Carlos Reservoir and from the mouth of the San Pedro River to the Buttes Reservoir site, and (3) a multiple-purpose reservoir at the Buttes site.

e. The channel improvements are not dependent upon construction of the other units of the comprehensive plan.

f. Partial protection to mostly agricultural areas along the Gila River from the upper end of Safford Valley to San Carlos Reservoir can be provided by a cleared floodway.

g. The proposed channel clearing would result in a net increase to the farmer of 19,800 acre-feet annually. To assure this saving, adequate maintenance would be required.

h. In consideration of the water-conservation benefits that would result from construction of the recommended project, local interests should be required to reimburse the United States for that part of the project construction cost allocated to water conservation, and such reimbursement should be made in 40 equal annual payments without interest.

i. The total first cost of the proposed improvement would be $1,770,000 (December 1957), and the total annual charges would be $112,000. The average annual tangible benefits, considering only primary benefits, from construction of the improvement would be $324,000.

j. The ratio of tangible primary benefits to cost would be 2.9 to 1. The recommended project is feasible from an engineering standpoint and is well justified by the tangible benefits alone.

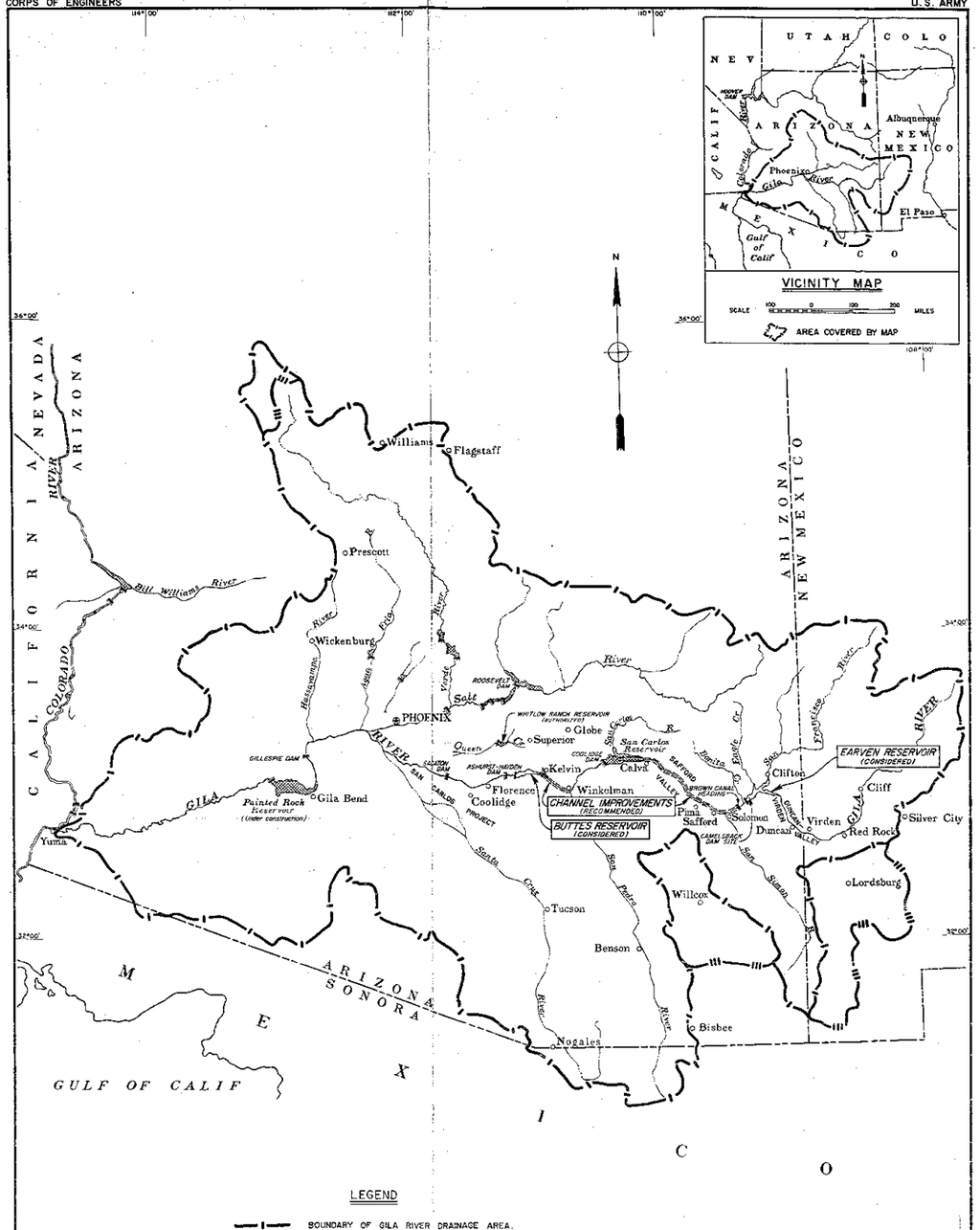
58. RECOMMENDATIONS

The district engineer recommends that construction of channel improvements, consisting of a cleared floodway along the Gila River from the upper end of Safford Valley to San Carlos Reservoir and from the mouth of the San Pedro River to the Buttes Reservoir site, be authorized at a Federal first cost estimated at $1,570,000 (December 1957), subject to the condition that local interests furnish assurances satisfactory to the Secretary of the Army that they will (a) provide necessary lands, easements, and rights-of-way; (b) maintain and operate the channel improvements in accordance with regulations to be prescribed by the Secretary of the Army at an average annual cost estimated at $50,000; (c) keep the flood channel of the Gila River from the upper end of Safford Valley to San Carlos Reservoir and from the mouth of the San Pedro River to Buttes Reservoir site free from encroachment; (d) repay to the United States 54.9 percent of the total construction cost in 40 equal annual payments without interest (the exact amount of the annual payments, presently estimated at $21,550, to be adjusted on the basis of actual costs of constructing the project - annual payments to be made to the Secretary of the Interior, who, in turn, shall deposit such funds in the Treasury of the United States as miscellaneous receipts); (e) hold and save the United States free from all damages arising from construction and operation of the work; and (f) adjust all water-rights claims resulting from construction, operation, and maintenance of the improvements.

C. T. Newton

5 Appendixes
(See table of contents)

C. T. NEWTON
Colonel, Corps of Engineers
District Engineer



GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
REPORT ON SURVEY FOR FLOOD CONTROL
GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZONA

INDEX MAP
GILA RIVER
CAMELSBACK RESERVOIR SITE TO SALT RIVER
ARIZONA

GRAPHIC SCALE 10 0 10 20 30 40 50 MILES

OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., DEC. 1957

SUBMITTED:	RECOMMENDED:	APPROVED:
CHIEF, PLANNING & REPORTS BR.	CHIEF, ENGINEERING DIVISION	COLONEL, C.E. DISTRICT ENGINEER

DRAWN:	TRACED:	CHECKED, TO ACCOMPANY REPORT:		FILE NO. (D.O. SERIES)
T.M.B.	T.M.B.	S.L.	DATED: DECEMBER 31, 1957	410/152

PLATE I

U. S. ARMY ENGINEER DISTRICT, LOS ANGELES

CORPS OF ENGINEERS

A P P E N D I X E S

TO ACCOMPANY

REPORT ON SURVEY FOR FLOOD CONTROL

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

GILA RIVER BASIN, ARIZ. AND N. MEX.

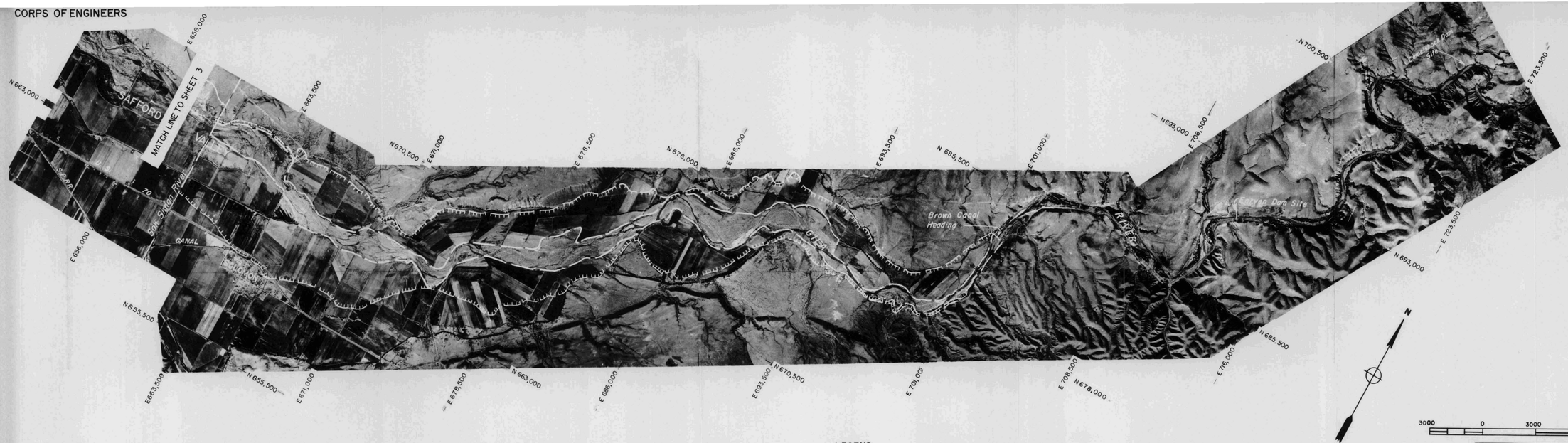
DECEMBER 31, 1957

BY

C. T. NEWTON
COLONEL, CORPS OF ENGINEERS
DISTRICT ENGINEER

CORPS OF ENGINEERS

U.S. ARMY



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LEGEND

LIMITS OF CLEARING OF PHREATOPHYTES

LIMITS OF OVERFLOW AREA

GILA RIVER & TRIB., ARIZ., & NEW MEX., REPORT ON SURVEY, FLOOD CONTROL, GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

PROPOSED CHANNEL CLEARING

ALONG GILA RIVER FROM EARVEN DAM SITE TO BUTTES RESERVOIR SITE, ARIZ. AND

OVERFLOW AREA IN SAFFORD VALLEY

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
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CORPS OF ENGINEERS

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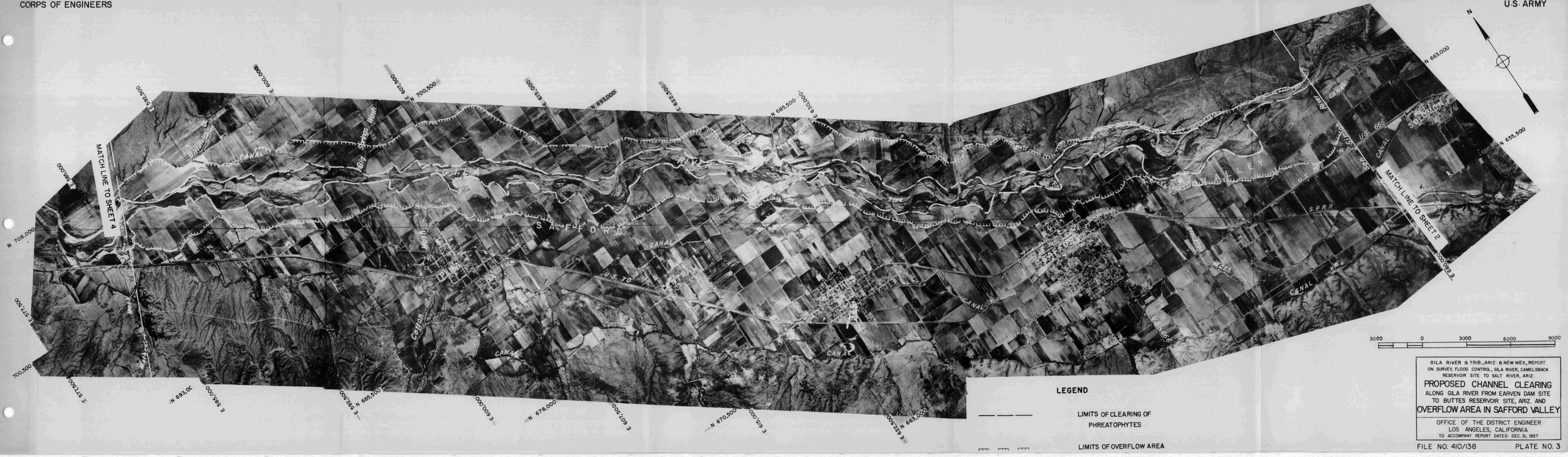

LEGEND

LIMITS OF CLEARING OF PHREATOPHYTES

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GILA RIVER & TRIB., ARIZ. & NEW MEX., REPORT ON SURVEY, FLOOD CONTROL, GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

PROPOSED CHANNEL CLEARING ALONG GILA RIVER FROM EARVEN DAM SITE TO BUTTES RESERVOIR SITE, ARIZ. AND OVERFLOW AREA IN SAFFORD VALLEY

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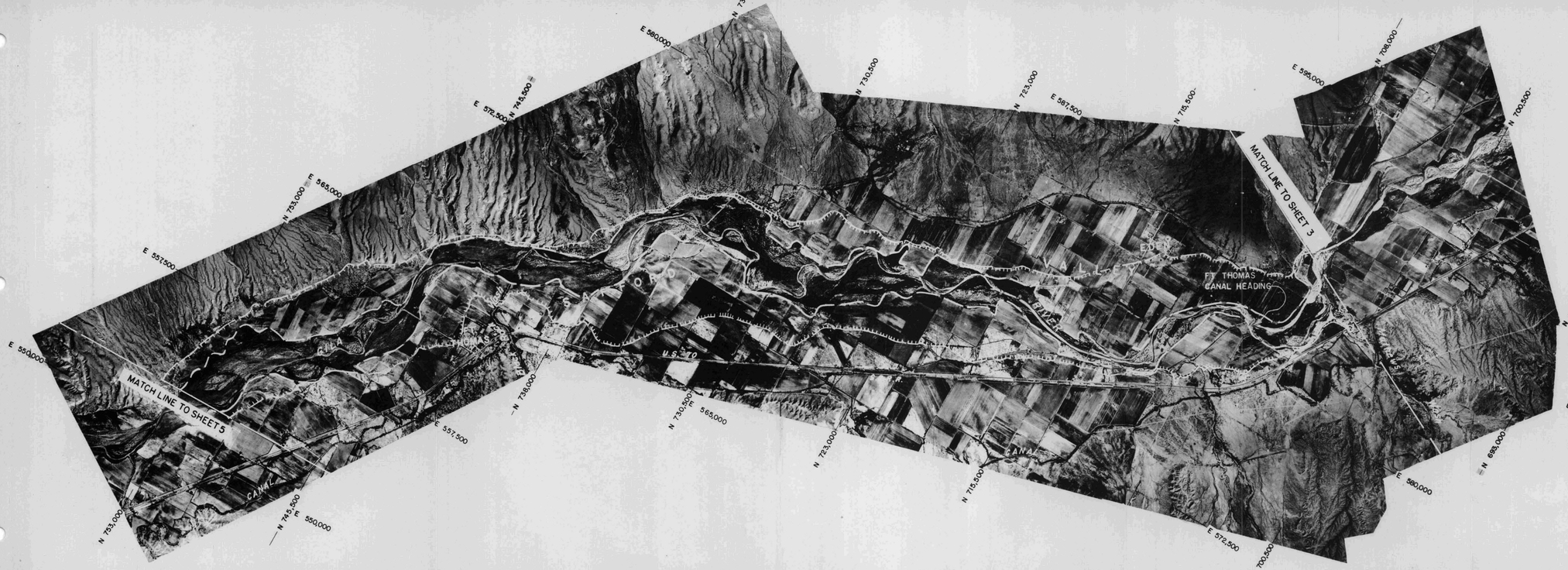

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GILA RIVER & TRIB., ARIZ. & NEW MEX., REPORT ON SURVEY, FLOOD CONTROL, GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

PROPOSED CHANNEL CLEARING

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CORPS OF ENGINEERS

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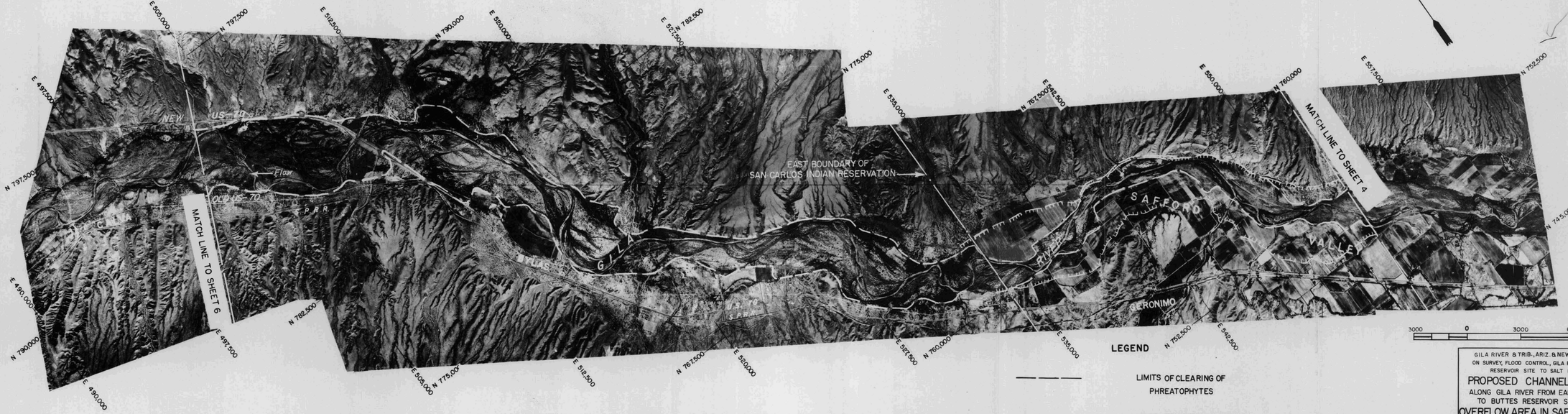

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LEGEND

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GILA RIVER & TRIB., ARIZ. & NEW MEXICO REPORT
ON SURVEY, FLOOD CONTROL, GILA RIVER, CAMELBACK
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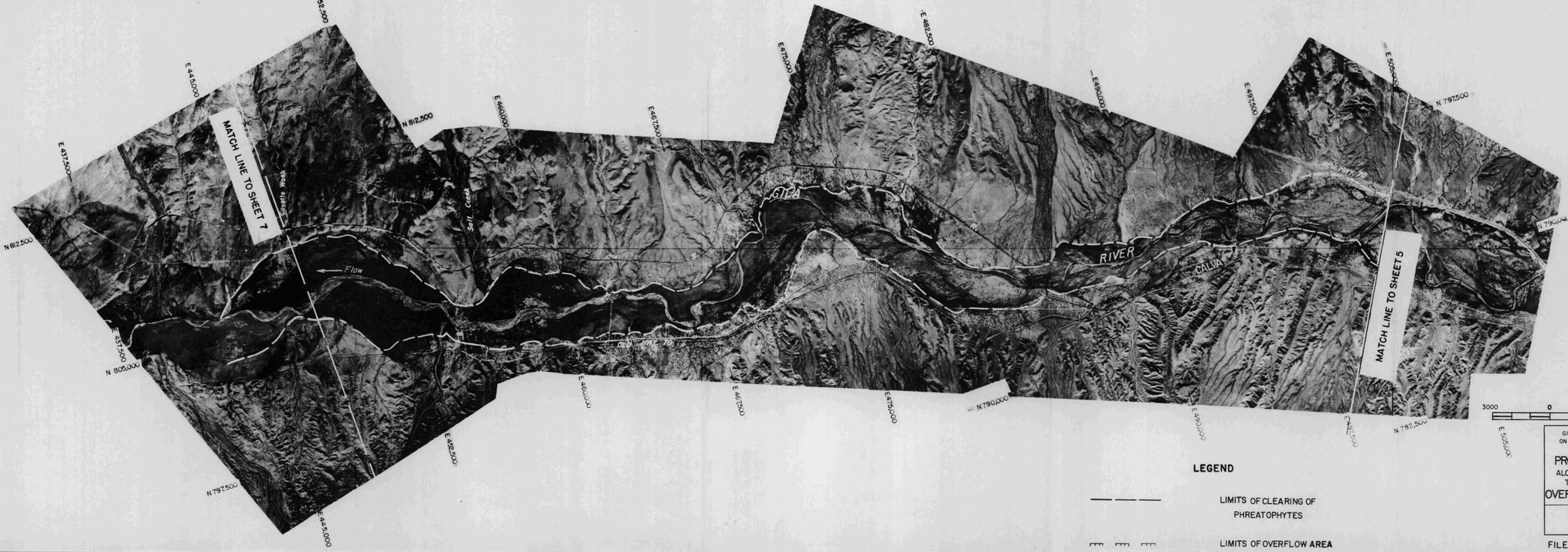

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GILA RIVER & TRIB., ARIZ. & NEW MEX., REPORT ON SURVEY, FLOOD CONTROL, GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

PROPOSED CHANNEL CLEARING ALONG GILA RIVER FROM EARVEN DAM SITE TO BUTTES RESERVOIR SITE, ARIZ. AND OVERFLOW AREA IN SAFFORD VALLEY

OFFICE OF THE DISTRICT ENGINEER
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CORPS OF ENGINEERS

U.S. ARMY

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LIMITS OF CLEARING OF PHREATOPHYTES

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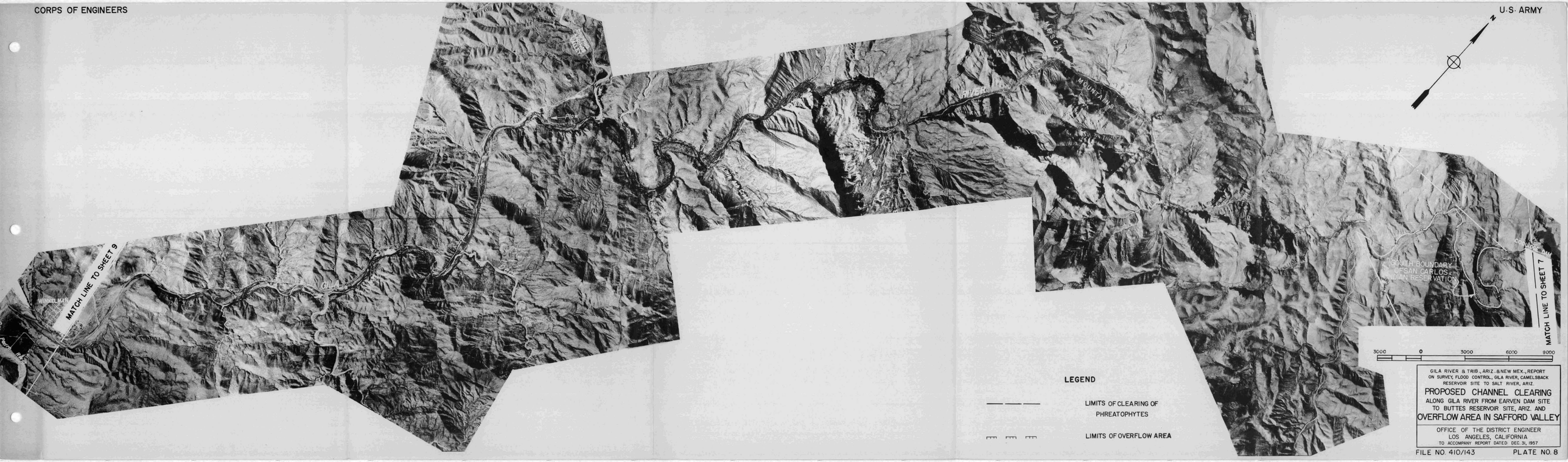

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PROPOSED CHANNEL CLEARING ALONG GILA RIVER FROM EARVEN DAM SITE TO BUTTES RESERVOIR SITE, ARIZ. AND OVERFLOW AREA IN SAFFORD VALLEY

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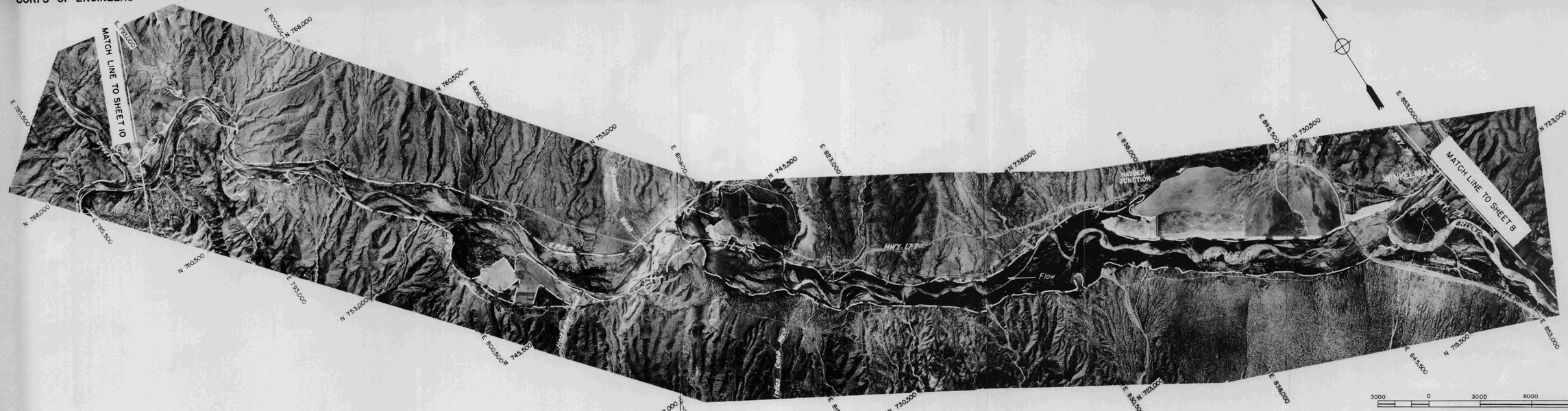

LEGEND

LIMITS OF CLEARING OF PHREATOPHYTES

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GILA RIVER & TRIB., ARIZ. & NEW MEX., REPORT ON SURVEY FLOOD CONTROL, GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

PROPOSED CHANNEL CLEARING

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OVERFLOW AREA IN SAFFORD VALLEY

OFFICE OF THE DISTRICT ENGINEER
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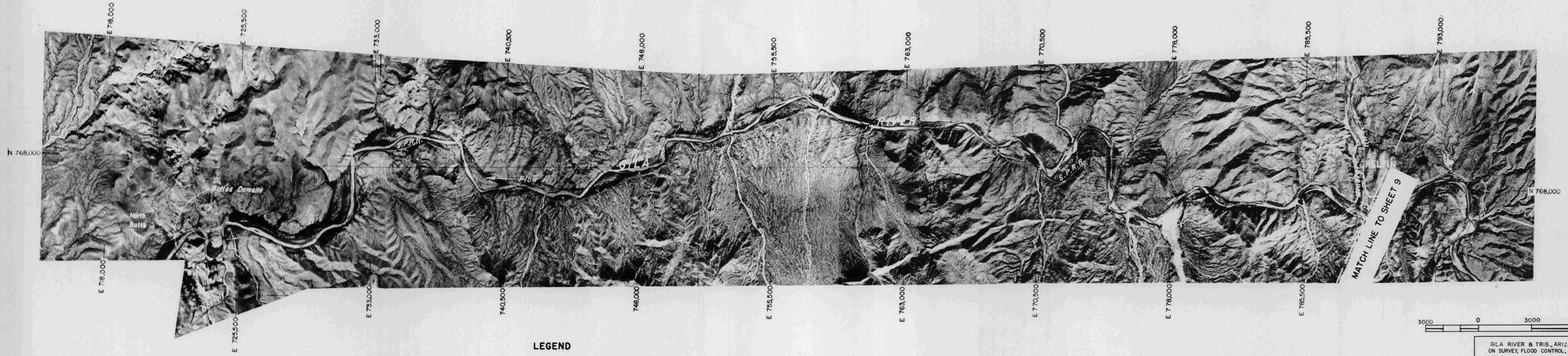

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LEGEND

LIMITS OF CLEARING OF PHREATOPHYTES

LIMITS OF OVERFLOW AREA

GILA RIVER & TRIB., ARIZ. & NEW MEX., REPORT ON SURVEY, FLOOD CONTROL, GILA RIVER, CAMELBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

PROPOSED CHANNEL CLEARING

ALONG GILA RIVER FROM EARVEN DAM SITE TO BUTTES RESERVOIR SITE, ARIZ. AND

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OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
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1	Bases for design and cost estimates
2	Benefits from flood control (text and 2 plates)
3	Water salvage and benefits, channel clearing - Gila River, Safford-San Carlos Coordinated Investigations
4	Allocation of costs
5	Resolutions by local interests

U. S. ARMY ENGINEER DISTRICT, LOS ANGELES

CORPS OF ENGINEERS

BASES FOR DESIGN AND COST ESTIMATES

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

GILA RIVER BASIN, ARIZ. AND N. MEX.

To accompany report on survey for flood control, Gila River, Camelsback Reservoir site to Salt River, Ariz., dated December 31, 1957.

APPENDIX 1

BASES FOR DESIGN AND COST ESTIMATES

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

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BASES FOR DESIGN AND COST ESTIMATES

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

SECTION I - INTRODUCTION

1. SCOPE

This appendix was prepared to present the engineering aspects and the estimated construction and maintenance costs of channel clearing along the Gila River from the upper end of Safford Valley to the Buttes Reservoir site, Arizona.

2. LOCATION AND DESCRIPTION

The location of the improvements is along the Gila River channel in the vicinity of Safford and Kelvin, Ariz. (see pls. 1 to 10, inclusive, of the main report). The improvements, which would be easily accessible via county roads and highways, would comprise channel clearing in two reaches of the river. The first reach, about 78 miles long, would extend downstream from the upstream end of Safford Valley to the mouth of the San Carlos River, in the San Carlos Reservoir. The second reach, about 16 miles long, would extend downstream from the mouth of the San Pedro River to Kelvin, at the upper end of the Buttes Reservoir site. The width of the channel clearing would be very irregular.

SECTION II - BASES FOR DESIGN

3. GENERAL

The work would be limited to clearing debris, phreatophytes, and other brush from the channel floodway and from adjacent phreatophyte-infested lowlands. A fringe about 50 feet wide of brush and saltcedar would be left standing on each side of the clearing to retard riverbank erosion. A minimum amount of grading would be done within the cleared area so that annual maintenance could be accomplished with tractor-drawn equipment. Important features of the proposed improvement are discussed in the following paragraphs.

4. PHREATOPHYTE PROBLEM

Phreatophytes, including saltcedar, grow profusely in and along the Gila River channel between the Brown canal heading (see pl. 2) and the mouth of the San Carlos River (see pl. 7) and between the mouth of the San Pedro River near Winkelman (see pl. 9) and the upstream end of the Buttes Reservoir site near Kelvin (see pl. 9). The saltcedar produces an enormous number of seeds that germinate readily and grow rapidly whenever sufficient moisture is available. Phreatophytes, especially

saltcedar, thrive whenever the water table is within about 10 feet of the ground surface.

During the analysis of densities of growth within the proposed clearing, as observed on the aerial mosaics, the work was divided into areas of dense growth (80 to 100 percent of maximum density) and areas of sparse growth (under 80 percent of maximum density). The number of acres in these categories is estimated at 7,665 acres of dense growth and 6,620 acres of sparse growth. The total of 14,285 acres differs somewhat from the total (13,840 acres) given in Appendix 3: Water Salvage and benefits, channel clearing - Gila River, Safford-San Carlos Coordinated Investigations. Additional small areas not considered in the United States Bureau of Reclamation water-salvage study would be cleared for purposes of flood control.

5. METHODS OF ERADICATING PHREATOPHYTES

In general, three methods of eradicating phreatophytes are now in use: (a) Burning, (b) chemical treatment, and (c) mechanical treatment. Numerous experiments are now being conducted by Federal, state, and local agencies dealing with this problem, but no satisfactory solutions have been determined thus far. Burning has been unsuccessful whenever tried. Experiments using 2,4-D and 2,4,5-T and combinations of these compounds have been the most promising in the chemical treatment. However, all experience to date indicates that (a) the percentage of kill by a single treatment may be as low as 40 percent and is seldom 100 percent, (b) the treatment must be repeated, (c) the treated area is reinfested by seeding from other areas, (d) considerable painstaking care must be practiced to protect crops when spraying close to farm areas, and (e) chemical treatment is more expensive than mechanical treatment. Based on information available to date, mechanical treatment appears to be the most effective and the least expensive both for initial clearing and for annual control.

6. INITIAL CLEARING

Mechanical treatment to destroy the phreatophytic growth and to clear the floodway was assumed for the purpose of preparing an adequate cost estimate. In order to destroy the existing growth, it must be removed below the root crown to a depth of 12 to 15 inches below the ground surface. A considerable amount of phreatophyte clearing has been accomplished along the Rio Grande by the Bureau of Reclamation and the International Boundary and Water Commission. Initial clearing by mechanical treatment is being effected by both agencies. Available information indicates that the equipment used by the International Boundary and Water Commission would be satisfactory for use along the Gila River. That agency has used two Towner stubble diskplows drawn in series by a D-8 Caterpillar. This type of equipment has been used to cut down and deroot saltcedar from 2 to 8 inches in diameter and from 10 to 15 feet in height.

7. MAINTENANCE OF CLEARING

The factors affecting the selection of the treatment for initial clearing are the same as those that apply to selecting the treatment for maintenance. A cleared channel can be maintained by continual destruction (mechanical or chemical) or by cutting of new growth. In addition, consideration was given to maintenance of clearing by planting selected grasses in all areas where moisture conditions are favorable. The International Boundary and Water Commission has demonstrated that a good cover of grass will discourage reinfestation by saltcedar. The land thus planted could be leased for pasture, and the lease could contain a proviso for maintenance of clearing free from reinfestation. However, definite information on the costs and benefits involved in such maintenance is not available.

Maintenance of a cleared floodway is being accomplished along the Rio Grande by the Bureau of Reclamation and the International Boundary and Water Commission. The Bureau of Reclamation is applying chemicals by aerial and ground spray rigs, but supplemental mechanical work is required to clear dead growth and to grub or remove the top portion of the root system. The International Boundary and Water Commission is using an 84-inch brush cutter drawn by a 40-hp. rubber-tired tractor. For the purpose of preparing an adequate cost estimate for maintenance, mechanical treatment similar to that being used by the International Boundary and Water Commission was assumed. The areas now classified as covered with dense growth (7,665 acres) would be cut about one and one-half times a year with power equipment. The areas now classified as covered with sparse growth (6,620 acres) would be cut about once a year. However, the frequency of cutting would vary from year to year according to surface-water conditions and water-table levels.

8. UTILITIES AND OTHER OBSTRUCTIONS

No utility relocations are contemplated.

SECTION III - COST ESTIMATES

9. GENERAL

Estimated costs for the work performed and for the use of equipment in initial clearing of the recommended project are based on prices prevailing in 1957. The estimates reflect the cost of labor, the cost of using equipment and supplies incidental to the performance of the work, and the cost of required rights-of-way and easements. No appreciable costs are involved for relocation of roads, bridges,or utilities.

10. APPLYING ANALYSIS OF PAST ESTIMATES

Information obtained from engineering periodicals and from various technical papers on phreatophyte clearing and control was studied, and the results were used as a check on the cost estimates given in this appendix.

11. OTHER COST FACTORS CONSIDERED

The field conditions, the geographical location of the proposed project, and the cost and availability of local labor and materials were considered in preparing the cost estimates.

12. CONSTRUCTION PERIOD

The time required to clear the entire project is estimated at one calendar year.

13. MAINTENANCE

Annual maintenance costs were based on the assumption that the responsible local interests would purchase two 40-horsepower rubber-tired tractors and two 84-inch brush cutters, and that this equipment would be used the year around in the maintenance of the cleared channel. Annual costs were based on equipment ownership expense, fuel, operator's wages, insurance, overhead, and contingencies. Considering these factors, and on the basis of December 1957 prices, annual maintenance costs for the recommended project are estimated at $50,000. This amount was checked for reasonableness by comparison with actual costs given in published and unpublished papers on phreatophyte clearing.

Channel clearing along Gila River from upper end of Safford Valley to Buttes Reservoir site (based on prices for December 1957)

Cost acct. no.	Description	Unit	Quantity	Unit price	Amount
	FEDERAL COSTS				
09.	Channels:				
	Clearing floodway of dense growth.	Acres..	7,665	$100	$766,500
	Clearing floodway of sparse growth.	...do...	6,620	60	397,200
	Contingencies.....	.....	.....	.....	236,300
	Total, clearing....	.....	.....	.....	1,400,000
30.	Engineering and design....	.....	.....	.....	85,400
31.	Supervision and administration.	.....	.....	.....	84,600
	Total Federal cost.	.....	.....	.....	1,570,000
	NON-FEDERAL COSTS				
	Rights-of-way and easements.	.....	.....	.....	200,000
	Total first cost of project.	.....	.....	.....	1,770,000

U. S. ARMY ENGINEER DISTRICT, LOS ANGELES

CORPS OF ENGINEERS

BENEFITS FROM FLOOD CONTROL

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

GILA RIVER BASIN, ARIZ. AND N. MEX.

To accompany report on survey for flood control, Gila River, Camelsback Reservoir site to Salt River, Ariz., dated December 31, 1957.

APPENDIX 2

BENEFITS FROM FLOOD CONTROL

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

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BENEFITS FROM FLOOD CONTROL

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

1. SCOPE

This appendix presents supplemental material covering the evaluation of flood-control benefits from channel clearing along the Gila River from the upper end of Safford Valley to the San Carlos Reservoir.

Field investigations were made to determine the extent, character, and value of the overflow area. Topographic maps, to a scale of 1" = 600' and with a contour interval of 2 feet, originally developed by the United States Soil Conservation Service in 1935, were extended in 1939 by the Corps of Engineers. Cross sections were taken in 1939 at about 2-mile intervals throughout the length of the valley. Check cross sections were taken in December 1956 to determine the changes that have taken place since the previous survey. Aerial surveys of the area were made in October and November 1956. Crop reports of the University of Arizona, the San Carlos project, and the Salt River project were analyzed to obtain up-to-date estimates of crop distribution, yields, and values. A field reconnaissance was made in March 1957 to determine the change in development that has taken place since previous detailed surveys made in the early 1940's. Office studies were made to determine the frequency of floods, the estimated damage from future floods, and the estimated benefits from the proposed improvement.

2. FLOOD FREQUENCIES

The principal sources of information concerning past floods on the Gila River in Safford Valley are records of the United States Geological Survey, reports of the Reclamation Service, congressional documents, newspaper accounts, and testimony of local residents. Historical references to destructive floods along Gila River in and near the area under consideration extended back to 1884, but records of peak flows are available only for the period 1915 to 1955, inclusive. The greatest floods of record occurred in January and October 1916, but descriptions and estimates of the floods of November 1905, February 1891, December 1906, February 1905, and February 1884 indicate that they were of comparable magnitude. The California modified method, as described in Geological Survey Water-Supply Paper 771, was used to determine plotting points for the discharge-frequency curve. In general, the peak discharges of all recorded floods during the period considered were used. However, if two or more floods occurred within a 4-month period, only the maximum crest flow was considered.

The peak discharges, thus selected, were tabulated in order of decreasing magnitude, and a discharge-frequency curve was prepared on logarithmic probability paper from the tabulated data by using the equation:

$$f = \frac{100\ (n - 0.5)}{t},$$ in which

f = number of times in 100 years that discharge is equaled or exceeded,

n = series number of flood in order of decreasing magnitude, and

t = number of years of record.

Discharge-frequency relations are shown on plate 1. The calculations of plotting points to determine probable flood frequencies for the Gila River at the head of Safford Valley near Solomon, Ariz., are summarized in the following table.

Estimated flood frequencies and magnitudes, Gila River at head of Safford Valley, near Solomon, Ariz.

Date	Peak discharge	Number of floods in 72 years* (1884-1955)	n	f
	Cubic feet per second			
November 1905	.....	1	1	0.69
January 19, 1916	100,000	1	2	2.08
February 1891	.....	1	3	3.47
December 1906	.....	1	4	4.86
October 14, 1916	67,900	1	5	6.25
February 1905	.....	1	6	7.64
February 1884	.....	1	7	9.03
December 20, 1914	50,000	1	8	10.4
September 30, 1941	31,900	1.76	9.38	12.3
January 14, 1949	25,200	1.76	11.14	14.8
October 4, 1914	24,000	1.76	12.90	17.2
February 10, 1932	24,000	1.76	14.66	19.7
February 8, 1937	23,700	1.76	16.42	22.1
August 27, 1934	23,000	1.76	18.18	24.6
July 26, 1915	20,000	1.76	19.94	27.0
January 19, 1952	19,700	1.76	21.70	29.5
December 31, 1940	17,600	1.76	23.46	31.9
September 3, 1925	15,900	1.76	25.22	34.4
September 25, 1944	15,800	1.76	26.98	36.8
August 21, 1921	15,700	1.76	28.74	39.3
August 3, 1919	15,000	1.76	30.50	41.7
July 30, 1929	12,700	1.76	32.26	44.1
August 12, 1923	12,600	1.76	34.02	46.6
March 15, 1941	12,300	1.76	35.78	49.0
July 24, 1955	11,700	1.76	37.54	51.5
December 28, 1923	10,600	1.76	39.30	53.9
February 15, 1931	10,500	1.76	41.06	56.4
February 21, 1915	10,500	1.76	42.82	58.8
August 11, 1930	10,100	1.76	44.58	61.2
March 24, 1953	9,850	1.76	46.34	63.7
September 6, 1940	9,840	1.76	48.10	66.1
September 9, 1933	9,600	1.76	49.86	68.6
September 13, 1927	9,320	1.76	51.62	71.0
August 30, 1947	9,250	1.76	53.38	73.5

* Peak discharges available for 41 years of record, 1915-1955; historical accounts relate only to those floods exceeding 50,000 c.f.s. and are for entire 72-year period.

3. DAMAGE FROM FUTURE FLOODS

A summary of estimates of primary (direct and indirect) damage that would result from future floods of various magnitudes along the Gila River from the upper end of Safford Valley to San Carlos Reservoir is given in the main report. A curve showing the relationship between peak discharges in cubic feet per second and total damage in dollars under average future conditions is shown on plate 2. The discharge-damage curve was combined with the discharge-frequency curve (pl. 1) to obtain a damage-frequency curve (see pl. 2). The area under the damage-frequency curve represents the estimated total flood damages during a 100-year period; the total for the overflow area divided by 100 is the estimated average annual damage for the area.

Clearing of the Gila River channel from the upper end of Safford Valley to San Carlos Reservoir would provide partial flood control by increasing channel capacities with attendant lowering of the water-surface elevations of future floods and with resultant reduction in extent of the flooded areas. The following table shows a comparison of resultant damage under existing channel conditions and under improved channel conditions.

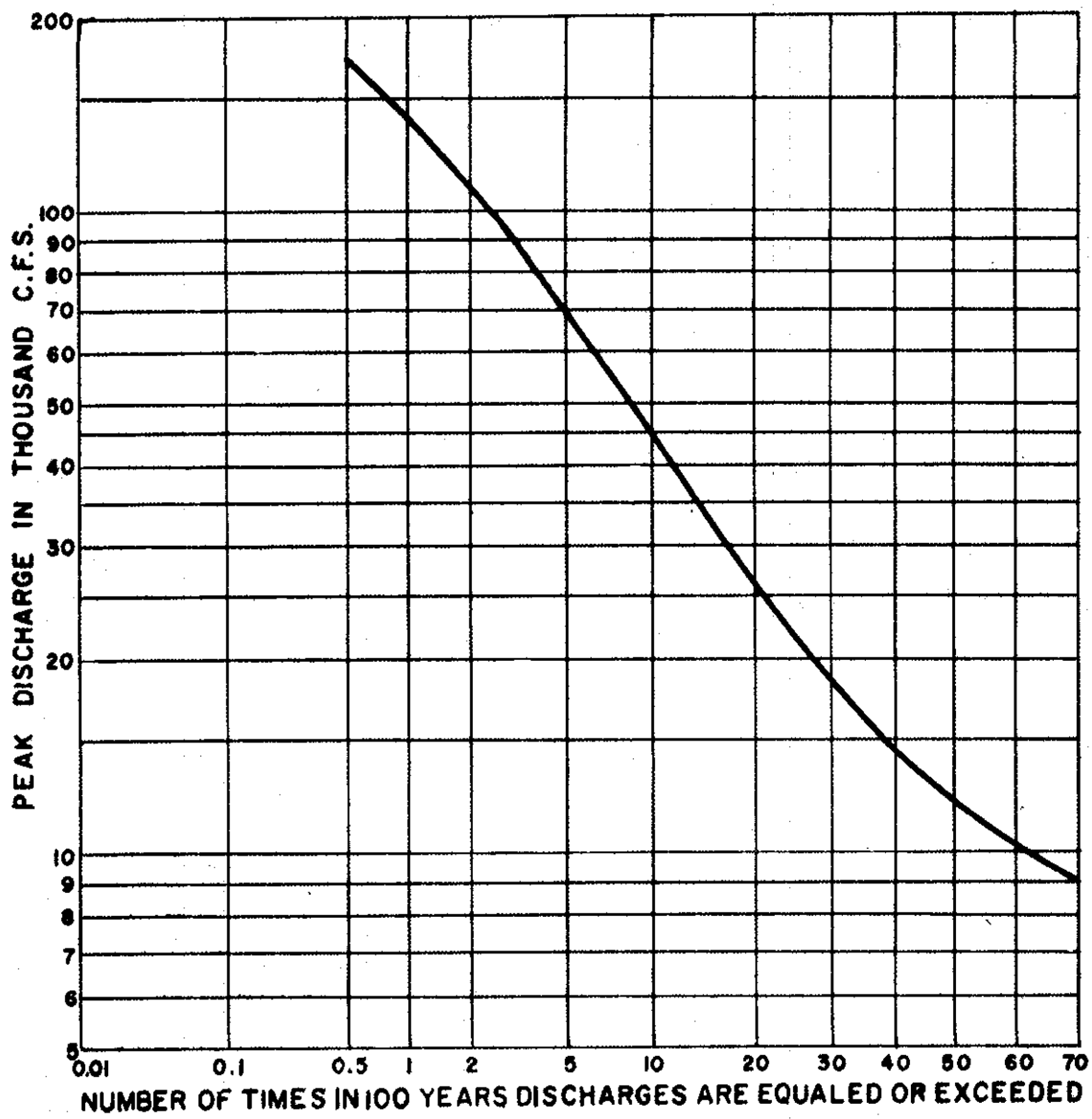
Comparison of estimated damages under cleared conditions with damages under existing conditions, Gila River, upper end of Safford Valley to San Carlos Reservoir, Ariz.

Discharge	Estimated damage from single floods	
	Present (1957) conditions	Assumed cleared conditions
Cubic feet per second		
175,000	$4,140,000	$3,760,000
72,000	1,830,000	1,430,000
35,000	750,000	510,000
17,000	180,000	60,000

A damage-frequency curve was drawn indicating the damage that would not be prevented if the channel were cleared (see pl. 2). The following table summarizes the estimated average annual tangible primary benefits that would result from damages prevented under the proposed plan of improvement.

Estimated benefits from prevention of flood damage from channel clearing along the Gila River, upper end of Safford Valley to San Carlos Reservoir, Ariz.

Item	Average annual damage
Total damages	$337,000
Nonpreventable damages	245,000
Damages prevented	92,000



NOTE:

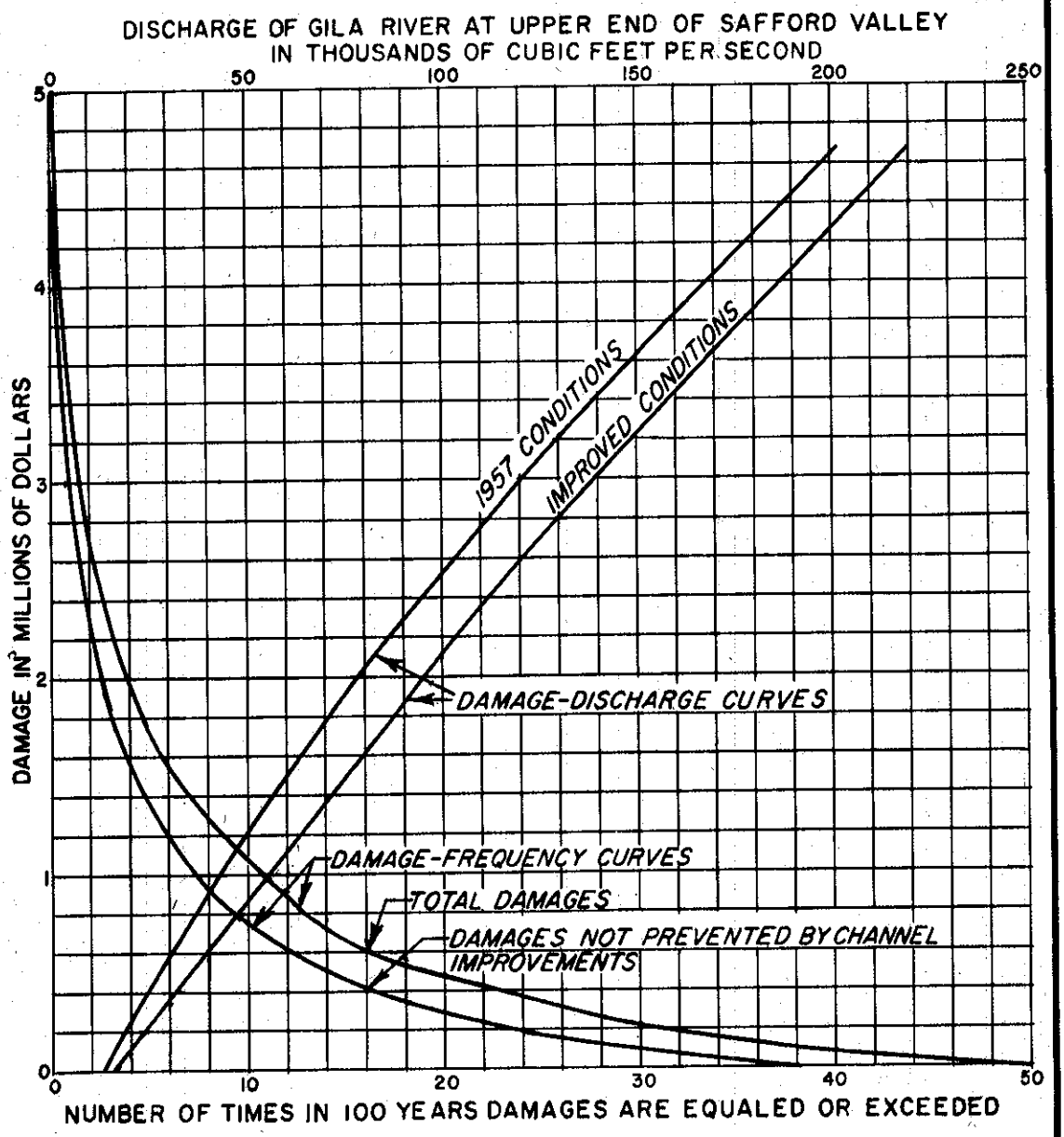
BASED ON PERIOD
1884-1955 (72 YEARS)

GILA RIVER & TRIB., ARIZ., & NEW MEX., REPORT ON SURVEY FOR FLOOD CONTROL, GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

DISCHARGE-FREQUENCY CURVE

GILA RIVER AT UPPER END OF SAFFORD VALLEY, ARIZONA

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 31, 1957



GILA RIVER & TRIB., ARIZ., & NEW MEX., REPORT ON SURVEY FOR FLOOD CONTROL, GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

DAMAGE-DISCHARGE AND DAMAGE-FREQUENCY CURVES

SAFFORD VALLEY, ARIZONA

THIS DRAWING SUPPERSEDES DWG. FILE NO. 410/154

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 31, 1957

U. S. ARMY ENGINEER DISTRICT, LOS ANGELES

CORPS OF ENGINEERS

WATER SALVAGE AND BENEFITS

CHANNEL CLEARING - GILA RIVER

SAFFORD-SAN CARLOS COORDINATED INVESTIGATIONS

REPORT OF THE
U. S. BUREAU OF RECLAMATION

To accompany report on survey for flood control, Gila River, Camelsback Reservoir site to Salt River, Ariz., dated December 31, 1957.

APPENDIX 3

WATER SALVAGE AND BENEFITS
CHANNEL CLEARING - GILA RIVER
SAFFORD-SAN CARLOS COORDINATED INVESTIGATIONS

Clearing of the river bottom vegetation in the flood plains of the Gila River in the two reaches from the head of Safford Valley to the San Carlos Reservoir and from the mouth of San Pedro River to Kelvin at the head of the potential Buttes Reservoir would result in salvage of water which could be put to beneficial agricultural use. The total amount of water which could be salvaged from clearing an estimated 13,840 acres of river bottom land is estimated at 34,000 acre-feet. Of this amount it is estimated that 19,800 acre-feet would be available at points of farm delivery. The estimated economic value of the salvaged water delivered to the farm is approximately $9.00 per acre-foot. Estimated annual direct and indirect benefits total $945,660.

A discussion of the procedures used in estimating the amount of water salvaged, the value of the water, and the benefits, together with the results, is contained in the following paragraphs.

Bottom Land Vegetation Survey

A survey was conducted to estimate the density and type of native vegetation in the flood plain of the Gila River from the Brown Canal heading to the storage pool above Coolidge Dam and from the confluence of the San Pedro River near Winkelman to the head of the Buttes Reservoir site near Kelvin. The line transect method was used to estimate the areal densities of each type of native vegetation in each of the selected classes. The line transect method is a procedure for sampling vegetation designed to lessen the effect of personal judgment and bias by the observer in determining densities. The principal density or type classes were delineated by examination of the shading on aerial photographs. River channel and barren areas were outlined. Differences in species were discernible from the shading and apparent variances in cover density provided a breakdown of types. A field examination was then made to determine if the classes as selected were appropriate. Accessible transect locations were selected and marked on the aerial photographs. The transects selected were then surveyed in the field. The vegetation in the river reaches was classified into four density classes with a fifth classification used to designate bare ground or grassy areas. The classified areas were outlined on appropriate maps. Transects were 100 feet each in length and 109 transects were surveyed in the reach upstream from Coolidge Dam and 46 transects were run in the downstream reach. Heights of vegetation were noted as the transects were surveyed to provide the basis for estimating vertical densities. Average areal and vertical densities as determined from the transects selected for each of the four classes of vegetation were applied to all areas of similar

classification in each of the two river reaches. The volume densities were computed as the product of the areal and vertical densities for each type of vegetation in each class in each river reach. The areas of the various classes outlined on the maps were determined by planimetering and the equivalent areas of 100 percent volume density were estimated for each type of vegetation in each class in each river reach. The acreage and density data for the reach from the Brown Canal heading to San Carlos Reservoir are summarized in Table 1, and Table 2 presents a summary for the reach from the mouth of the San Pedro River to the Buttes Reservoir site.

Under the plan of development for the Middle Gila River area, the Gila River channel would be improved by clearing river bottom vegetation. A 50-foot vegetative fringe would be left along both banks of the flood plain to help protect the banks from erosion. The acreages of the various classes of vegetation in the 50-foot fringe were determined as shown in Table 3.

Consumptive Use by Bottom Land Vegetation on Area to be Cleared

The consumptive use minus precipitation (U-R) rates were estimated by the Blaney-Criddle Formula (U = KF) for salt cedar, mesquite, and arrowweed or baccharis for 100 percent volume density from the data presented in Appendix B of the Bureau of Reclamation's November 1952 "Report on Water Supply of the Lower Colorado River Basin." Appendix B had been prepared by Messrs. Harry F. Blaney and Karl Harris of the United States Department of Agriculture to present consumptive use of water rates in the various areas of the Lower Colorado River Basin. The rates were applied to the acreages of each type of vegetation to estimate the consumptive use by native vegetation in the areas to be cleared in the two river reaches as presented in Table 4.

Water Salvage

Water salvage would be realized from the removal of the native vegetation. However, continuous maintenance or the establishment of a beneficial vegetative cover such as native grasses in the place of the present phreatophytic growth would be required to realize the water salvage estimated to result from clearing the river bottom vegetation. The consumptive use, minus effective precipitation, by regrowth of vegetation under normal maintenance or by native grasses is estimated to average one acre-foot an acre for the entire cleared area.

The area to be cleared amounts to 11,200 acres between the heading of the Brown Canal and the San Carlos Reservoir and about 2,640 acres for the reach from the mouth of the San Pedro River to the Buttes Reservoir site or a total of 13,840 acres with an estimated total consumptive use of 47,840 acre-feet (Table 4).

Table 1
BOTTOM LAND VEGETATION SURVEY
Gila River Channel
Brown Canal Heading to San Carlos Reservoir
Middle Gila River Area, Arizona

Density Classification and Type of Vegetation	Total Area Surveyed 1/ (Acres)	Total Length of Transects (Feet)	Transect Length Covered by Phreatophytes (Feet)	Areal Density 2/ (Percent)	Vertical Density 3/ (Percent)	Volume Density 4/ (Percent)	Equivalent Area of 100% Volume Density 5/ (Acres)
Class A	460	900					
Mesquite	--	--	612	68	95.6	65	300
Class B	7,032	5,500					
Salt Cedar	--	--	4,272	78	88.5	69	4,852
Mesquite	--	--	58	1	100.0	1	70
Class C	2,799	2,600					
Salt Cedar	--	--	1,285	49	79.6	39	1,092
Mesquite	--	--	90	3	66.7	2	56
Class D	1,839	1,900					
Salt Cedar	--	--	149	8	87.5	7	129
Mesquite	--	--	343	18	83.3	15	276
Arrowweed or baccharis	--	--	105	6	83.3	5	92
All Classes - Totals	12,130	10,900					
Salt Cedar	--	--	5,706	--	--	--	6,073
Mesquite	--	--	1,103	--	--	--	702
Arrowweed or baccharis	--	--	105	--	--	--	92

1/ Determined by planimetering.
2/ Computed as the ratio of the length of transects covered by each species of vegetation to the total length of transects surveyed in each density class.
3/ Based on optimum height of 13.0 feet for salt cedar and mesquite and 5.5 feet for arrowweed and baccharis.
4/ Product of areal density and vertical density.
5/ Product of volume density and total area surveyed.

Table 2
BOTTOM LAND VEGETATION SURVEY
Gila River Channel
Confluence of San Pedro River to Buttes Reservoir Site
Middle Gila River Area, Arizona

Density Classification and Type of Vegetation	Total Area Surveyed 1/ (Acres)	Total Length of Transects (Feet)	Transect Length Covered By Phreatophytes (Feet)	Areal Density 2/ (Percent)	Vertical Density 3/ (Percent)	Volume Density 4/ (Percent)	Equivalent Area of 100% Volume Density 5/ (Acres)
Class A	441	1,100					
Mesquite	--	--	944	86	97	83	366
Class B	1,286	1,900					
Salt Cedar	--	--	1,603	84	94	79	1,016
Mesquite	--	--	156	8	96	8	103
Arrowweed or baccharis	--	--	17	1	100	1	13
Class C	451	1,100					
Salt Cedar	--	--	249	23	75	17	77
Mesquite	--	--	405	37	78	29	131
Class D	674	500					
Mesquite	--	--	175	35	86	30	202
Arrowweed or baccharis	--	--	14	3	71	2	13
All Classes - Totals	2,852	4,600					
Salt Cedar	--	--	1,852	--	--	--	1,093
Mesquite	--	--	1,680	--	--	--	802
Arrowweed or baccharis	--	--	31	--	--	--	26

1/ Determined by planimetering.
2/ Computed as the ratio of the length of transects covered by each species of vegetation to the total length of transects surveyed in each density class.
3/ Based on optimum height of 13.0 feet for salt cedar and mesquite and 5.5 feet for arrowweed or baccharis.
4/ Product of areal density and vertical density.
5/ Product of volume density and total area surveyed.

Table 3

BOTTOM LAND VEGETATION SURVEY
Gila River Channel
50-Foot Vegetative Fringe Along Both Banks of Flood Plain
Middle Gila River Area, Arizona

Density Classification and Type of Vegetation	Total Area of Fringe (Acres)	Volume Density From Tables 1 and 2 (Percent)	Equivalent Area of 100% Volume Density 1/ (Acres)
BROWN CANAL HEADING TO SAN CARLOS RESERVOIR			
Class A	101		
Mesquite		65	66
Class B	549		
Salt Cedar		69	379
Mesquite		1	6
Class C	165		
Salt Cedar		39	64
Mesquite		2	3
Class D	112		
Salt Cedar		7	8
Mesquite		15	17
Arrowweed or baccharis		5	6
All Classes - Totals	927		549
Salt Cedar	--		451
Mesquite	--		92
Arrowweed or baccharis	--		6
CONFLUENCE OF SAN PEDRO RIVER TO BUTTES RESERVOIR SITE			
Class A	40		
Mesquite		83	33
Class B	100		
Salt Cedar		79	79
Mesquite		8	8
Arrowweed or baccharis		1	1
Class C	45		
Salt Cedar		17	8
Mesquite		29	13
Class D	31		
Mesquite		30	9
Arrowweed or baccharis		2	1
All Classes - Totals	216		152
Salt Cedar			87
Mesquite			63
Arrowweed or baccharis			2

1/ Product of volume density and total area of fringe.

Table 4
CONSUMPTIVE USE BY NATIVE VEGETATION ON AREA TO BE CLEARED
Gila River Channel
Middle Gila River Area, Arizona

Type of Native Vegetation	Consumptive Use Coefficient 100% Volume Density K	Consumptive Use Factor F	Consumptive Use U (Inches)	Effective Precipitation R (Inches)	Consumptive Use Rate 100% Volume Density U-R (Inches)	(Feet)	Area 100% Volume Density 1/ (Acres)	Consumptive Use (Acre-Feet)
BROWN CANAL HEADING TO SAN CARLOS RESERVOIR								
Salt Cedar	1.50	58.16	87.24	8.01	79.23	6.60	5,622	37,105
Mesquite	.75	58.16	43.62	8.01	35.61	2.97	610	1,812
Arrowweed or baccharis	1.00	58.16	58.16	8.01	50.15	4.18	86	360
Total							6,318	39,277
CONFLUENCE OF SAN PEDRO RIVER TO BUTTES RESERVOIR SITE								
Salt Cedar	1.50	58.13	87.19	10.49	76.70	6.39	1,006	6,428
Mesquite	.75	58.13	43.60	10.49	33.11	2.76	739	2,040
Arrowweed or baccharis	1.00	58.13	58.13	10.49	47.64	3.97	24	95
Total							1,769	8,563

1/ Computed by subtracting totals listed for each species in Table 3 from those listed in Tables 1 and 2.

K = Empirical coefficient developed for the Lower Colorado River Basin.
F = Sum of monthly consumptive use factors for the growing season of a specific area. The monthly consumptive use factor is the product of mean monthly temperature and monthly percent of daytime hours for a specific area
U = KF = Consumptive use in inches.
R = Effective precipitation for the growing season of a specific area in inches. Only monthly rainfall exceeding 0.55 inches has been considered effective. Months with precipitation of 0.55 inches or less are omitted from the computations and the entire precipitation for months with precipitation greater than 0.55 inches is included.

The consumptive use required to support a beneficial vegetative cover such as native grasses, or to support the regrowth of the native vegetation under normal maintenance is estimated at the rate of one acre-foot an acre or 11,200 acre-feet a year for the acreage to be cleared between the heading of the Brown Canal and the San Carlos Reservoir. With present consumptive use by native vegetation of 39,280 acre-feet a year in this area and consumptive use of 11,200 acre-feet a year subsequent to clearing, the estimated water salvage to be realized by clearing would average 28,100 acre-feet a year for this section of the Gila River.

The present consumptive use of the 2,640 acres of native vegetation to be cleared in the river reach between the mouth of the San Pedro River and the Buttes Reservoir site would average 8,560 acre-feet a year. Allowing for an annual consumptive use of one acre-foot an acre for the 2,640 acres subsequent to clearing, the estimated water salvage resulting from the improvement would average 5,920 (rounded 5,900) acre-feet a year for this reach of the Gila River.

The water salvaged by the removal of phreatophytes would decrease the present valley depletions upstream and downstream from Coolidge Dam. It cannot be stated definitely how and where the salvaged water would be used as part of the water would be salvaged downstream from the points of upper valley diversions. For the purpose of estimating the net amount of salvaged water available for farm use, it was necessary to make certain assumptions as to where the water would be used. Of the 28,100 acre-feet salvaged upstream from Coolidge Dam, it is estimated that 4,600 acre-feet would be salvaged upstream from the heading of the Ft. Thomas Consolidated Canal and 23,500 acre-feet downstream. It was assumed that the 4,600 acre-feet salvaged upstream from the heading of Ft. Thomas Consolidated Canal would be used in the Safford Valley by either pumping from the ground-water reservoir or gravity diversion and that 15 percent of the salvaged water would be lost in delivering the water to the farms. The 23,500 acre-feet salvaged between the heading of the Ft. Thomas Consolidated Canal and the San Carlos Reservoir and the 5,900 acre-feet salvaged between the mouth of the San Pedro River and the Buttes Reservoir site were considered as being routed to Ashurst-Hayden Dam. In routing the water to the farms, it was estimated that 20 percent of the water salvaged between the heading of the Ft. Thomas Consolidated Canal and San Carlos Reservoir and 10 percent of the water salvaged between the mouth of the San Pedro River and the Buttes Reservoir would be lost en route to Ashurst-Hayden Dam. On the basis of past diversions, it is estimated that 34 percent of the water diverted at Ashurst-Hayden Dam would be lost en route to the farms.

Table 5 presents a summary of the water salvaged and delivered to farms resulting from the proposed clearing of native vegetation in the Gila River flood plain.

Table 5
WATER SUPPLY SUMMARY
Middle Gila River Area, Arizona

Location of Channel Clearing	Acreage Cleared	Present Consumptive Use on Land to be Cleared	Subsequent Consumptive Use on Land Cleared	Water Salvaged (Rounded) (2)-(3)	Salvaged Water Delivered to Farm
Brown Canal to Ft. Thomas Canal	2,000	6,590	2,000	4,600	3,900
Ft. Thomas Canal to Coolidge Dam	9,200	32,690	9,200	23,500	12,400
Mouth of San Pedro River to Buttes Reservoir Site	2,640	8,560	2,640	5,900	3,500
Total	13,840	47,840	13,840	34,000	19,800

Areas of Water Conservation Benefit

The agricultural areas in the Safford Valley and in the San Carlos Project area in Pinal County would be the principal areas benefiting directly from the water that would be salvaged from the eradication and control of phreatophytes along the Gila River. The water would be available for irrigation of agricultural crops and would therefore constitute a direct beneficial addition to the existing agricultural economy. The comparatively small amount of incremental water and the manner in which it would become available would, however, prohibit any substantial increase in the irrigated areas. Although this supplemental water could be used to more completely provide an adequate supply to the crop acreage presently irrigated, in this study it is assumed that the water will be used to irrigate additional land within the confines of existing farms.

Project Lands

The irrigated areas of the Safford Valley and San Carlos Project areas have developed on the alluvial filled valley soils of the Gila River. The Safford Valley has some 32,500 acres of irrigated land while the San Carlos Project, although containing 100,000 acres of land entitled to water, has only been able to irrigate about 60,000 acres annually during the past several years. The soil material consists primarily of old, water-laid unconsolidated deposits which originally had their source in a variety of formations in which granite and related rocks predominate. The soil body is quite heterogeneous, both in texture and depth, and consists generally of various sizes of quartzitic sands. Most of the soil bodies are composed of coarse

textured loamy sands and sandy loams although there are finer textured silt loams and clay deposits in local areas. Surface drainage is generally good over most of the irrigated area but internal drainage is restricted in places by compact subsoil material. The land areas are usually smooth and comparatively flat or gently sloping but near the present channel of the river the land areas are occasionally dissected by old meanders of the stream. Excess quantities of soluble salts restrict crop growth in local areas of small extent; however, this adverse condition is often a result of having inadequate water to keep the salts leached out of the soil body. Shallow soil cover over coarse sand and gravel, or lime cemented "caliche" areas cause crop production trouble in places but generally this condition is not extensive. Much of the land has been irrigated for many years with no serious soil or drainage problems developing.

Agricultural Economy

The agriculture in both the Safford Valley and the San Carlos Project area is quite similar. Both areas experience water shortages and the farmers' adjustments to these shortages are much the same. The typical adjustment to the highly variable water shortage is to reduce the irrigated area and use the available water for irrigation of higher value annual crops having lower water requirements. Cotton is by far the most important crop in both areas with alfalfa, barley, and sorghum accounting for most of the remaining irrigated land. The lands in the Indian owned and operated section of the San Carlos Project have not been farmed as intensively in the past as those in the other areas. The quality of the land and the water supply available to them, however, are comparable to other areas. In this study no distinction has been made between the agricultural value of water in the areas. The mild almost frost-free winter climate of the farm areas result in crops being grown all year long. It is a common practice, when sufficient irrigation water is available, to double crop a part of the irrigated land. Likewise, barley and alfalfa are often pastured for short periods before being harvested. Although much of the harvested produce is sold the feeding of beef for the market is increasing in importance. Pasture feeding of lambs is also a common practice in places.

The analysis of agricultural value and benefit of the salvaged water was made on a reconnaissance level. As it was not possible to collect complete basic information of the agricultural practices and costs under the time allowed for the study it became necessary to rely on information already available in the Bureau of Reclamation files. Previously furnished data on the San Carlos Project operations and published bulletins of the University of Arizona were the principal sources of information.

Land Use and Crop Yields

As most of the available information dealt with the agricultural practices of the San Carlos Irrigation and Drainage District, the non-Indian portion of the San Carlos Project, and since the farming practices and the crop yields were similar to other areas that would be benefited, the non-Indian farmed portion of this project was used as the basis for developing the agricultural value and benefits of the program.

The period 1950-1954 was used to determine the average crop yields and the acres irrigated. In this period an average of about 30,000 acres or about 60 percent of the 50,000 acres in the District were cropped. Cotton occupied about 68 percent of the net area cropped with alfalfa hay and pasture, barley, and sorghum comprising the rest of the acreage. Only 2 percent of the total area cropped was occupied by crops other than those listed.

The yields obtained by these crops for the period 1950-1954 were adopted as representative of future long time yields for the study. The increased water supplies available through phreatophyte removal are expected to result in a corresponding increase in the cropped acreage rather than in increased yields. Hence, the same level of yields was assumed to prevail in the future.

Representative Farm and Farm Prices

After study of the ownership records of San Carlos Irrigation and Drainage District lands, a farm containing 200 acres was selected as a representative farm for use in determining the value of water salvaged from phreatophyte removal. During the 1950-1954 period approximately 60 percent of the acreage was cropped, thus on the representative farm 120 acres of the 200 acres was assumed to produce crops. The prices used in this analysis are long-term projections expected to prevail over an extended period in the future. These prices are based on a general level equal to 250 percent of the 1910-1914 level for prices received by farmers and a level of 265 percent of the 1910-1914 level for prices paid by farmers for items used in farm production.

This level and relationship of prices paid and received has been adopted by the Bureau of Reclamation for making agricultural studies as those which may be expected to prevail over an extended period of years under assumptions of relatively high employment.

Agricultural Value of Water

The agricultural value of the salvaged water was calculated by use of a farm budget method using the crops, crop yields, and prices, and the size of farm as discussed previously. A representative farm budget was prepared and the value derived represents the average value of one acre-foot of water delivered to the farm.

The results of the budget study are summarized in Table 6. Two values are developed, $11.75 and $8.94 (rounded to $9.00). The higher value is comparable to the maximum amount that might be available for water charges without allowing any profit to the owner for management of the farm. The lower figure recognizes a profit to the farmer for his management of the concern.

Agricultural Benefits of Salvaged Water

The annual irrigation benefits creditable to salvaged water are based on a net increased annual farm delivery of 19,800 acre-feet as shown in Table 5. At a farm delivery rate of 3.5 acre-feet per acre the 19,800 acre-feet would serve an equivalent acreage of about 5,650 acres. Crop distribution used in the representative farm budget summarized in Table 6 is about the same as that prevailing in the period 1950-1954 except the cotton acreage was reduced somewhat and the alfalfa acreage increased for the long-time projections of farm operations. This adjustment permits a more suitable crop rotation plan from the standpoint of productivity and crop diversification and fits in better with the development of a livestock enterprise. Crop distribution on the 5,650 acres was assumed to be the same as that used in the farm budget. This distribution is shown in Table 7. Likewise in the budget analysis and the benefit calculations, it was assumed that the farm would be operated as a cotton-livestock enterprise. The cotton was considered sold as a cash crop. Livestock was considered purchased and fattened for sale through feeding of the forage crops.

The agricultural benefits include direct and indirect benefits resulting from the increased production attributable to the added water supply. The direct benefits are measured as the increased net income to the project farmers. The indirect benefits represent the increase in net income to the off-farm handlers and processors of the increased production and are measured by applying appropriate factors to the farm value of the increased production. Derivations of the direct and indirect benefits are summarized in Tables 8 and 9.

The total benefits resulting from the salvaged water by this method are estimated to average $945,660 annually. The direct annual benefits would amount to $231,950 and the indirect annual benefits would be $713,710.

Table 6
FARM ORGANIZATION AND FINANCIAL ANALYSIS
Representative Farm
Middle Gila River Area, Arizona

Item	Amount (Acres)
Total land in farm	200
Area irrigated	120
Land use	
Alfalfa Hay	48
Barley	24
Sorghum, silage, double-cropped	(24)
Cotton, upland, short staple	48
Livestock, beef feeder calves	125 head
Farm income 1/	Dollars
Cotton lint - 859 lbs per acre at $0.266 per lb	10,970
Cotton seed - 1,397 lbs per acre at $71.00 ton	2,380
Livestock sales - 125 head weighing 750 lbs at $21.75 cwt	20,400
Gross farm income	33,750
Farm expenses 2/	
Alfalfa - 48 acres at $80	3,840
Barley - 24 acres at $53	1,270
Sorghum - 24 acres at $59	1,415
Cotton - 48 acres at $217	10,415
Livestock - 125 head at $95.00	11,875 3/
Total farm expenses	28,815
Net return above production costs, total farm	4,935
Net return per acre-foot 4/	11.75
Net return per acre-foot after allowance for operator management return 5/	8.94
Say	9.00

1/ Based upon projected prices received by farmers at the general level of 250 percent of the 1910-14 base period.

2/ Based upon projected prices paid by farmers equal to 265 percent of the 1910-14 base period. Estimates of production costs are based upon information published by the University of Arizona indexed to 265 price levels.

3/ Includes purchase cost of 125 head of feeder calves at total cost of $10,195 and production expense of $1,680 for raising them.

4/ Based on the use of 3.5 acre-feet of water per acre (farm delivery) on 120 acres.

5/ Management return was calculated at 5 percent of gross farm income after deducting purchase price of feeder livestock (purchase cost $10,195).

Table 7
IRRIGATED LAND EQUIVALENT OF
SALVAGE WATER FROM RIVER CHANNEL CLEARING
Middle Gila River Area, Arizona

Item	Amount
Estimated water savings, farm delivery 1/	19,800 Acre-Feet
Estimated per acre water use, farm delivery 2/	3.5 Acre-Feet
Irrigated land equivalent, total	5,650 Acres
Cotton (40 percent)	2,260
Alfalfa (40 percent)	2,260
Barley (20 percent)	1,130
Sorghum (20 percent) double-cropped	(1,130)

1/ As estimated in Table 5.

2/ Based on records of past measured deliveries and estimates of unmeasured deliveries.

Table 8
COMPUTATION OF DIRECT IRRIGATION BENEFITS
FROM RIVER CHANNEL CLEARING
Middle Gila River Area, Arizona

Item	Amount
Increased gross farm income	
Cotton lint - 2,260 acres at $228 1/	$515,280
Cotton seed - 2,260 acres at $50 1/	113,000
Livestock - 5,887 head at $163 1/	959,580
Total	1,587,860
Increased farm costs	
Livestock purchases 2/	480,160
All other farm costs 3/	875,750
Total	1,355,910
Increased net income (direct benefits)	231,950

1/ Derived for units shown from data developed in Table 6.

2/ 5,887 head at an average weight of 375 pounds and at an average price of $21.75 per cwt.

3/ Based upon estimated average farm costs of $240 per irrigated acre less $85 for livestock purchases at 1.042 head per irrigated acre ($155 per acre).

Table 9
COMPUTATION OF ANNUAL INDIRECT IRRIGATION BENEFITS
FROM RIVER CHANNEL CLEARING
Middle Gila River Area, Arizona

Commodity	Increased Sales 1/	Indirect Benefits Factor 5/	Indirect Benefits Dollars
Benefits from increased marketing			
Cotton lint	$515,280	.83	$427,680
Cotton seed	113,000	.30	33,900
Livestock	479,420 2/	.11	52,740
Subtotal	1,107,700 3/		514,320
Benefits from increased local expenditures 4/			199,390
Total indirect benefits (annual)			713,710

1/ As summarized in Table 8.

2/ Exclusive of purchase cost of feeder cattle ($959,580 - $480,160).

3/ Increased gross farm income less purchase price of feeder cattle.

4/ Estimated as 18 percent of increased gross farm income after correction for livestock purchases ($1,587,860 - $480,160 x .18).

5/ Factors contained in Bureau Manual that were developed by Bureau of Reclamation to measure value of indirect benefits accruing to off-farm enterprises through processing of farm products and sale of farm equipment.

U. S. ARMY ENGINEER DISTRICT, LOS ANGELES

CORPS OF ENGINEERS

ALLOCATION OF COSTS

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

GILA RIVER BASIN, ARIZ. AND N. MEX.

To accompany report on survey for flood control, Gila River, Camelsback Reservoir site to Salt River, Ariz., dated December 31, 1957.

APPENDIX 4

ALLOCATION OF COSTS

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

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ALLOCATION OF COSTS

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZONA

1. GENERAL

This appendix presents the details of the allocation of first costs and annual charges for the improvements recommended for construction at this time along the Gila River from the Camelsback Reservoir site to the Salt River, Ariz.

The recommended plan of improvement provides for clearing of the river channel growth along the Gila River from the upper end of Safford Valley to the Buttes Reservoir site. Both flood-control and water-conservation benefits would be provided under the recommended plan. The first cost of improvements under the plan is estimated at $1,770,000 (December 1957); and the average annual cost of maintenance and operation, $50,000 (December 1957).

Various methods of allocation of costs between flood control and water conservation were considered, as follows: (a) Separable costs-remaining benefits method, (b) use of facilities method, (c) benefit method, and (d) incremental method. Consideration of all these methods indicates that, in this particular case, the separable costs-remaining benefits method is the preferable method.

2. SEPARABLE COSTS-REMAINING BENEFITS METHOD (RECOMMENDED)

The report, "Proposed Practices for Economic Analysis of River Basin Projects," prepared by the Subcommittee on Benefits and Costs, Federal Inter-Agency River Basin Committee, under date of May 1950, recommends use of the separable costs-remaining benefits method of cost allocation. The report states that "equitable distribution may be obtained by preventing costs allocated to any purpose from exceeding corresponding benefits; by requiring each purpose to carry at least its separable cost; and, within these maximum and minimum limits, by providing for proportional sharing of the savings resulting from multipurpose development." The amount of benefits used as a basis for the allocation is limited by the cost of available single-purpose alternative projects.

In this specific case, the only alternative plan to develop similar flood-control or water-conservation benefits would be the same as the recommended plan. Thus, the annual charges for the alternative plans for flood control or water conservation are equal to the annual charges for the recommended plan and no separable costs would result from including the individual function in the multiple-purpose project.

The following table summarizes the calculations in the determination of allocation of costs for the recommended plan, using the separable costs-remaining benefits method.

Allocation of costs, recommended plan of improvement, Gila River, Camelsback Reservoir site to Salt River, Ariz. (based on December 1957 prices)

(Separable costs-remaining benefits method)

Item	Flood control	Water conservation	Total
1. Benefits - average annual	$92,000	$232,000	$324,000
2. Alternative cost (annual charges)	112,000	112,000	224,000
3. Benefits limited by alternative cost	92,000	112,000	204,000
4. Separable costs	0	0	0
5. Remaining benefits (item 3 minus item 4)	92,000	112,000	204,000
6. Allocated joint costs	50,500	61,500	112,000
7. Total allocation - average annual (item 4 plus item 6)	50,500	61,500	112,000
8. a. Allocated first cost of construction	708,000	862,000	1,570,000
b. Allocated first cost of rights-of-way	90,000	110,000	200,000
c. Allocated total first cost	798,000	972,000	1,770,000
d. Allocated maintenance and operation	22,500	27,500	50,000

The costs of the recommended plan allocated to flood control were further allotted, in accordance with the general policies expressed in acts of Congress. The cost of construction items allocated to flood control would be borne by the United States and the costs of lands, easements, and rights-of-way and of maintenance and operation would be borne by local interests.

On the basis of present (December 1957) costs, the allocated first cost to the United States for flood control would be $708,000, which is 45.1 percent of the estimated construction cost. The allocated first cost to local interests for flood control for rights-of-way would be $90,000. The first cost to local interests for water conservation would be $972,000, of which $862,000 (54.9 percent of the estimated total construction cost) would be for construction and $110,000 would be for rights-of-way.

It is proposed that local interests (a) provide all rights-of-way and (b) be permitted to repay that part (54.9 percent) of the total construction cost that is allocated to water conservation, in 40 years without interest.

Under the proposed allocation of costs, the United States would clear the channel at an estimated Federal first cost of $1,570,000 and local interests would (a) provide rights-of-way at a cost estimated at $200,000,

(b) maintain and operate the improvement at an average annual cost estimated to be $50,000, and (c) repay 54.9 percent of the total construction cost in 40 equal annual payments without interest. On the basis of December 1957 prices, the estimated amount of $862,000 would be repaid in 40 equal annual payments of $21,550. The allocations and repayments would be adjusted on the basis of actual construction costs.

3. USE OF FACILITIES METHOD

The use of facilities method is based on the premise that the joint costs should be proportioned among the various functions according to their amount of "use" of the joint facilities. Joint costs are determined by subtracting the sum of the separable costs from the total cost of the project. In this specific case, both flood control and water conservation would have equal use of the required facilities. The project would function for both purposes at all times. Therefore, joint costs would be divided equally between the two functions. As indicated in the previous paragraph, no separable costs are involved for either of the two purposes.

The following table summarizes the calculations in the determination of allocation of costs for the recommended plan, using the use of facilities method.

Allocation of costs, recommended plan of improvement, Gila River, Camelsback Reservoir site to Salt River, Ariz. (based on December 1957 prices)

(Use of facilities method)

Item	Flood control	Water conservation	Total
Separable costs	0	0	0
Allocated joint costs (average annual)	*$56,000	*$56,000	$112,000
Total allocation (average annual)	56,000	56,000	112,000
Allocated first cost of construction	785,000	785,000	1,570,000
Allocated first cost of rights-of-way	100,000	100,000	200,000
Allocated total first cost	885,000	885,000	1,770,000
Allocated maintenance and operation	25,000	25,000	50,000

* Both flood control and water conservation require 100 percent use of facilities.

The costs allocated to flood control would be further allocated in accordance with the general policies expressed in acts of Congress. On the basis of present (December 1957) costs, the allocated first cost to the United States for flood control would be $785,000, which is 50 percent of the estimated construction cost. The allocated first cost to local interests for flood control for rights-of-way would be $100,000. The first cost to local interests for water conservation would be $885,000, of which $785,000 (50 percent of the estimated construction cost) would be for construction and $100,000 would be for rights-of-way.

The use-of-facilities method is not considered as desirable as the separable costs-remaining benefits method. The former method does not consider the relative value or benefits received by each of the purposes. It is also difficult in this case to evaluate the degree of use of the project. Although the project is required at all times for both flood-control and water-conservation purposes, this does not necessarily mean that each should share equally in the cost of the project.

4. BENEFIT METHOD

The benefit method provides for the allocation of the total cost among the various functions in proportion to their estimated benefits. The following table summarizes the calculations in the determination of allocation of costs for the recommended plan, using the benefit method.

Allocation of costs, recommended plan of improvement, Gila River, Camelsback Reservoir site to Salt River, Ariz. (based on December 1957 prices)

(Benefit method)

Item	Flood control	Water conservation	Total
Benefits (average annual)	$92,000	$232,000	$324,000
Percent of total benefits	28.4	71.6	100.0
Allocation of costs:			
Construction costs	$446,000	$1,124,000	$1,570,000
Rights-of-way costs	57,000	143,000	200,000
Total first costs	503,000	1,267,000	1,770,000
Maintenance and operation costs	14,200	35,800	50,000

The costs allocated to flood control would be further allocated in accordance with the general policies expressed in acts of Congress on the basis of present (December 1957) costs. The allocated first cost to the United States for flood control would be $446,000, which is 28.4 percent of the estimated construction cost. The allocated first cost to local interests for flood control for rights-of-way would be $57,000. The first cost to local interests for water conservation would be $1,267,000, of which $1,124,000 (71.6 percent of the estimated construction cost) would be for construction and $143,000 would be for rights-of-way.

The benefit method is not considered to be as desirable a method as the separable costs-remaining benefits method. The method does not consider the alternative means of providing the same degree of flood control or the same measure of water conservation. These alternative measures should be limiting factors to be applied in the allocation of costs in order to provide for equitable sharing of the savings or economies resulting from joint use.

5. INCREMENTAL METHOD

The incremental method allocates the separable costs to their respective purposes and the total joint cost to the one basic purpose that is considered the principal or basic function of the project. This method is generally used where one purpose is clearly incidental to the overall purpose of the project. In this particular case, both flood control and water conservation are primary purposes - neither can be considered as secondary or incidental to the overall needs of the situation.

If flood control were considered the primary purpose of the recommended plan, flood-control benefits could not, by themselves, justify the project. Assuming a benefit-cost ratio of 1.2 to 1, the justifiable average annual expenditure for flood control would be $76,700. On the other hand, if water conservation were considered the primary purpose, the water-conservation benefits would justify the entire cost of the recommended plan. The following table summarizes the calculations in the determination of allocation of costs for the recommended plan, using the incremental method. No separable costs are involved for either of the two purposes. The costs allocated to flood control would be further allocated in accordance with the general policies expressed in acts of Congress.

Allocation of costs, recommended plan of improvement, Gila River, Camelsback Reservoir site to Salt River, Ariz. (based on December 1957 prices)

(Incremental method)

Primary purpose	Item	Flood control	Water conservation	Total
Flood control.	Separable cost of water conservation.	.....	0	.....
	Flood-control benefits (average annual).	$92,000	.....	.....
	Justifiable expenditure for flood control (average annual).*	76,700	.....	.....
	Allocated costs (average annual).	76,700	$35,300	$112,000
	Allocated first cost of construction.	1,075,000	495,000	1,570,000
	Allocated first cost of rights-of-way.	137,000	63,000	200,000
	Allocated total first cost.	1,212,000	558,000	1,770,000
	Allocated maintenance and operation.	34,000	16,000	50,000
Water conservation.	Separable cost of flood control.	0	.....	.....
	Water-conservation benefits (average annual).	.....	232,000	.....
	Justifiable expenditure for water conservation.*	.....	193,000	.....
	Allocated costs (average annual).	0	112,000	112,000
	Allocated total first cost.	0	1,770,000	1,770,000
	Allocated maintenance and operation.	0	50,000	50,000

* Assuming a benefit-cost ratio of 1.2 to 1.

On the assumption that flood control were the primary purpose of the recommended plan, the allocated first cost to the United States for flood control would be $1,075,000, which is 68.5 percent of the estimated construction cost. The allocated first cost to local interests for flood control for rights-of-way would be $137,000. The first cost to local interests for water conservation would be $558,000, of which $495,000 (31.5 percent of the estimated construction cost) would be for construction and $63,000 would be for rights-of-way.

On the assumption that water conservation were the primary purpose of the recommended plan, water-conservation features would pay the entire cost of the recommended plan.

The incremental method is not considered a suitable method of allocation of costs in this specific case. As indicated above, neither of the two purposes (water conservation or flood control) can be considered as secondary or incidental to the overall needs of the situation. In addition, this method violates one of the principles of allocation of costs - that joint costs be allocated in such a way that each purpose will share equitably in the savings or economies resulting from the joint use.

6. RECOMMENDATIONS

The separable costs-remaining benefits method of allocation of costs is recommended for use in this report.

U. S. ARMY ENGINEER DISTRICT, LOS ANGELES

CORPS OF ENGINEERS

RESOLUTIONS BY LOCAL INTERESTS

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

GILA RIVER BASIN, ARIZ. AND N. MEX.

To accompany report on survey for flood control, Gila River, Camelsback Reservoir site to Salt River, Ariz., dated December 31, 1957.

APPENDIX 5

RESOLUTIONS BY LOCAL INTERESTS

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

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RESOLUTIONS BY LOCAL INTERESTS

GILA RIVER, CAMELSBACK RESERVOIR SITE TO SALT RIVER, ARIZ.

RESOLUTION

WHEREAS, Section 6 of Public Law 761, 75th Congress, approved June 28, 1938, authorized the preliminary examination and survey for flood control on Gila River and Tributaries, Arizona and New Mexico; and

WHEREAS, a preliminary examination report on Gila River and tributaries, Arizona and New Mexico, indicated the advisability of a flood-control survey of the entire Gila River Basin, including the area along Gila River from Camelsback Reservoir site to Salt River; and

WHEREAS, the Senate Public Works Committee Resolution of August 27, 1956 requested the Board of Engineers for Rivers and Harbors to review the reports of the Chief of Engineers, with a view to determining what further improvements for flood control and allied purposes were advisable for Gila River Basin at this time, with particular reference to (a) construction of a flood-control dam on Gila River at or in the vicinity of Camelsback site in eastern Arizona; (b) construction of a flood-control dam at or near the Buttes site, or at a site above the mouth of San Pedro River; and (c) rectification of the Gila River channel downstream from the location of that dam to the San Carlos Reservoir and from the Coolidge Dam downstream to the Ashurst-Hayden Dam; and

WHEREAS an Interim Report on Survey for Flood Control, Gila River, Camelsback Reservoir site to Salt River, Arizona, has been authorized by the Chief of Engineers, United States Army; and

WHEREAS, Section 3 of Public Law 738, 74th Congress, provides that no money appropriated shall be expended on the construction of any project until States, political subdivision thereof, or any other responsible local agencies have given assurances satisfactory to the Secretary of the Army that they will assume certain enumerated obligations; and

WHEREAS, Article 13, Section 7 of the Constitution of Arizona provides that Irrigation Districts are vested with all rights, privileges and benefits granted Municipalities, and Sections 45-2321 and 45-2322 A.R.S. grant to Cities and Towns the right to cooperate with the United States for construction of flood-control projects; and

WHEREAS, protection against flood damages would be provided to property along the Gila River in the Counties of Graham and Pinal, State of Arizona, by channel clearing along the Gila River between the upper end of Safford Valley to the Buttes Reservoir site;

NOW, THEREFORE, BE IT RESOLVED by the Board of Directors of the San Carlos Irrigation and Drainage District that if a flood-control project comprising channel clearing along Gila River be found economically feasible and be authorized by Act of Congress, the San Carlos Irrigation and Drainage District will participate to the best of its ability by (1) assuming joint sponsorship of the proposed project with other appropriate agencies and (2) attempting to arrive at an equitable distribution between the respective agencies of those costs and items that are the obligation of local interests. We understand that the obligations of local interests, as their part of the proposed project, are as follows: (a) Acquire and provide, without cost to the United States, lands, easements and rights-of-way necessary for the construction of the project; the cost of such rights-of-way is presently estimated at $200,000; (b) hold and save the United States or any instrumentality, department, or agency thereof, free from any damages arising from construction, maintenance, and operation of the work; (c) maintain and operate, upon completion, all works in accordance with regulations to be prescribed by the Secretary of the Army; (d) establish and enforce flood-channel limits and regulations, satisfactory to the Secretary of the Army, for the preservation of the flood-carrying capacity of the channel; (e) in consideration of the water-conservation benefits, enter into a contract with the United States for repayment of the costs allocated to water conservation; such costs, now estimated to be 54.9 percent of the total construction cost, to be repaid in 40 equal annual payments without interest; on the basis of present prices, the estimated amount of $862,000 would be repaid in 40 equal annual payments of $21,550; the allocation of repayments to be adjusted on the basis of actual construction costs; and

BE IT FURTHER RESOLVED that in the event the Graham County interests are unwilling to approve or to participate in the project, then this District will participate to the best of its ability in assuming joint sponsorship of a project designed to eliminate such upper valley areas as are unwilling to participate and, if such altered project be found feasible, will lend its best efforts toward seeking sponsorship and approval of such altered or modified project by those other public agencies found to be benefited thereby; and

BE IT FURTHER RESOLVED, that this resolution be entered in the minutes of the Board of Directors, San Carlos Irrigation and Drainage District, and that the Secretary of said District be, and he is hereby directed to forward a certified copy of this resolution to the District Engineer, United States Army Engineer District, Los Angeles, Corps of Engineers, P. O. Box 17277 Foy Station, Los Angeles 17, California.

Passed and approved by the Board of Directors of the San Carlos Irrigation and Drainage District, Pinal County, Arizona, this 28th day of December, 1957.

/s/ O. W. Rugg
O. W. Rugg, President

ATTEST:

/s/ Ed. R. Wildermuth
Ed. R. Wildermuth, Secretary

CERTIFICATE

STATE OF ARIZONA)
) ss
COUNTY OF PINAL)

I, Ed. R. Wildermuth, Secretary of the Board of Directors of the San Carlos Irrigation and Drainage District, do hereby certify the foregoing to be a full, true and correct copy of a resolution passed by the Board of Directors at a special meeting held in the office of the District at Coolidge, Arizona, on December 28, 1957.

WITNESS my hand and seal of the San Carlos Irrigation and Drainage District this 28th day of December, 1957.

/s/ Ed. R. Wildermuth
Ed. R. Wildermuth, Secretary

RESOLUTION

WHEREAS, Section 6 of Public Law 761, 75th Congress, approved June 28, 1938, authorized the preliminary examination and survey for flood control on Gila River and tributaries, Arizona and New Mexico; and

WHEREAS, a preliminary examination report on Gila River and tributaries, Arizona and New Mexico, indicated the advisability of a flood-control survey of the entire Gila River Basin, including the area along Gila River from Camelsback Reservoir site to Salt River; and

WHEREAS, the Senate Public Works Committee Resolution of August 27, 1956, requested the Board of Engineers for Rivers and Harbors to review the reports of the Chief of Engineers, with a view to determining what further improvements for flood control and allied purposes were advisable for Gila River Basin at this time, with particular reference to (a) construction of a flood-control dam on Gila River at or in the vicinity of Camelsback site in eastern Arizona; (b) construction of a flood-control dam at or near the Buttes site, or at a site above the mouth of San Pedro River; and (c) rectification of the Gila River channel downstream from the location of that dam to the San Carlos Reservoir and from the Coolidge Dam downstream to the Ashurst-Hayden Dam; and

WHEREAS, an Interim Report on Survey for Flood Control, Gila River, Camelsback Reservoir site to Salt River, Arizona, has been authorized by the Chief of Engineers, United States Army; and

WHEREAS, Section 3 of Public Law 738, 74th Congress, provides that no money appropriated shall be expended on the construction of any project until States, political subdivisions thereof, or any other responsible local agencies have given assurances satisfactory to the Secretary of the Army that they will assume certain enumerated obligations; and

WHEREAS, the laws of the State of Arizona permit irrigation districts to cooperate with the United States in the construction of flood control projects and other purposes; and

WHEREAS, protection against flood damages would be provided to property along the Gila River in the Gila Valley Irrigation District by channel clearing along the Gila River between the upper end of Safford Valley to the Buttes Reservoir site; and

NOW, THEREFORE, BE IT RESOLVED by the Board of Directors of the Gila Valley Irrigation District that if a flood-control project comprising channel clearing along Gila River be found economically feasible and be authorized by Act of Congress, the Gila Valley

Irrigation district will participate to the best of its ability by (1) assuming joint sponsorship of the proposed project with the San Carlos Irrigation and Drainage District and other interested parties, and (2) attempting to arrive at an equitable distribution between the respective groups of those costs and items that are the obligation of local interests. We understand that the obligations of local interests, as their part of the proposed project, are as follows: (a) Acquire and provide, without cost to the United States, lands, easements, and rights-of-way necessary for the construction of the project; the cost of such rights-of-way is presently estimated at $200,000; (b) hold and save the United States or any instrumentality, department, or agency thereof, free from any damages arising from construction, maintenance, and operation of the work; (c) maintain and operate, upon completion, all works in accordance with regulations to be prescribed by the Secretary of the Army; (d) establish and enforce flood-channel limits and regulations, satisfactory to the Secretary of the Army, for the preservation of the flood-carrying capacity of the channel; (e) in consideration of the water-conservation benefits, enter into a contract with the United States for repayment of the costs allocated to water conservation; such costs, which amount to 54.9 percent of the total construction cost, to be repaid in 40 equal annual payments without interest; on the basis of present prices, the estimated amount of $862,000 would be repaid in 40 equal annual payments of $21,550; the allocation of repayments to be adjusted on the basis of actual construction costs; and

ON BEHALF of the Gila Valley Irrigation District this approval is conditional and tentative and is dependent upon an over-all project to include the building of a dam in the vicinity of Camelback, and that a proper agreement with respect to the use of the salvaged water and who pays for what and how much, between the two irrigation districts, and that the rights under the Gila Decree be not impaired or modified without an agreement; and

BE IT FURTHER RESOLVED, That this resolution be entered in the minutes of the Gila Valley Irrigation District, and that the Secretary of said District be and he is hereby directed to forward a certified copy of this resolution to the District Engineer, United States Army Engineer District, Los Angeles, Corps of Engineers, P. O. Box 17277, Foy Station, Los Angeles 17, California.

Passed and approved by the Board of Directors of the Gila Valley Irrigation District this 6th day of January, 1958.

GILA VALLEY IRRIGATION DISTRICT

/s/ M. J. Ferguson
President

/s/ Emil Crockett
Secretary

(SEAL)