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UNITED STATES ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

INTERIM REPORT

ON

SURVEY FOR FLOOD CONTROL

GILA AND SALT RIVERS

GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

(WITH APPENDIXES)

DECEMBER 4, 1957

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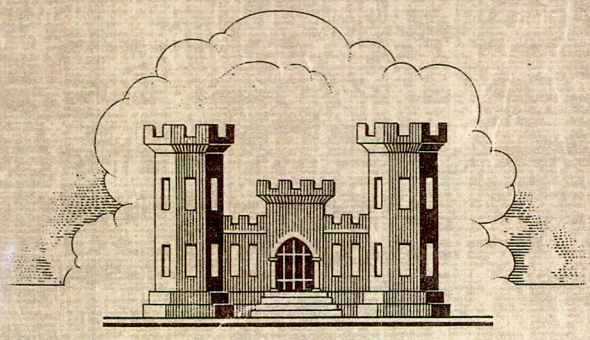

BY
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DISTRICT ENGINEER

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701 East Washington
Phoenix, Arizona

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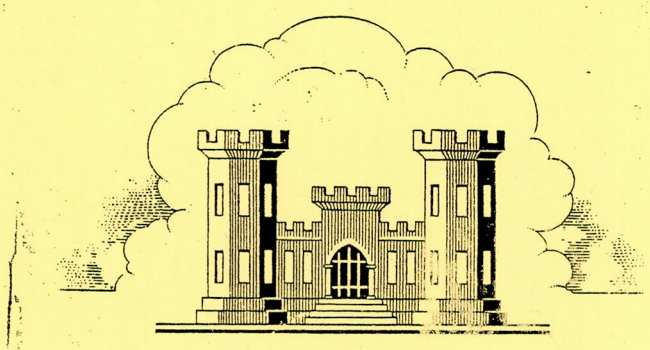

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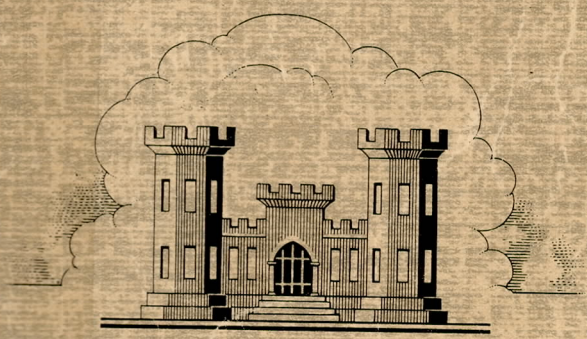

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December 4, 1957

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

REPORT OF THE DISTRICT ENGINEER

ON

INTERIM SURVEY FOR FLOOD CONTROL, GILA AND SALT RIVERS,

GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

SYLLABUS

The district engineer finds that a flood menace exists along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam. He also finds that the river-bottom growth within the channels of the Gila and Salt Rivers not only greatly adds to the flood hazard but also, by transpiring large volumes of water annually, greatly depletes the ground-water supply.

After investigation of the various prospective solutions to the above problems, the district engineer finds that the most suitable plan at this time would consist of levees and channel improvements to provide a reasonable degree of flood protection, and to conserve water by eradication of water-consuming vegetation as a part of the channel improvement work. The plan would include short levees along Salt River between 40th Street in Phoenix and Tempe Butte in Tempe, and improvement of the Gila and Salt River channels from Gillespie Dam upstream to Granite Reef Dam.

The district engineer estimates the total Federal first cost of the project at $3,360,000 (October 1957) comprising $3,300,000 to be spent for construction and $60,000 already spent for preauthorization studies; and the total non-Federal first cost at $210,000 (October 1957). He estimates the total average annual charges at $178,900, including an average of $53,000 annually for maintenance and operation of the levee and channel improvements. He estimates the average annual benefits that would accrue from flood control and incidental water conservation at $354,000. He states that the ratio of average annual benefits to average annual charges would be 1.98 to 1. He concludes that the project would be justified on the basis of the tangible benefits. Consideration of the intangible benefits would add weight to the justification.

The district engineer investigated the feasibility of the addition of flood-control storage to a terminal-storage reservoir at the McDowell site on Salt River. He concludes that the inclusion of sufficient flood-control space in a reservoir at the McDowell site to control the standard project flood would be justified in conjunction with development at that site of the terminal storage for the reclamation project proposed in House Document 136, 81st Congress, 1st session. Such flood-control space would be a

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REPORT OF THE DISTRICT ENGINEER

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GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

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desirable supplement to the above levee-and-channel improvement plan in order to insure an adequate degree of flood protection in the future for the rapidly growing urban area in the vicinity of Phoenix.

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 allocated to water conservation, and such reimbursement should be made in 40 equal annual payments without interest. On the basis of October 1957 prices, the estimated amount of $825,000 would be repaid in 40 equal annual payments of $20,625.

The district engineer recommends that a flood-control project comprising levee and channel improvements along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam, as outlined above, be authorized for construction by the Corps of Engineers, United States Army, subject to the condition that local interests furnish assurances satisfactory to the Secretary of the Army that they will pay for the cost of highway and utility relocation; provide necessary lands, easements, and rights-of-way; repay, to the United States, 25 percent of the total construction cost in 40 equal annual payments without interest (the exact amount of the annual payments, presently estimated at $20,625, 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, will deposit such funds in the Treasury of the United States as miscellaneous receipts); maintain and operate the levee and channel improvements in accordance with regulations to be prescribed by the Secretary of the Army; keep the flood channel of the Gila and Salt Rivers free from encroachment; hold and save the United States free from all damages arising from construction and operation of the work; and adjust all water-rights claims resulting from construction, operation, and maintenance of the improvements.

The district engineer also recommends that, because of the special circumstances wherein the water-conservation benefits would be realized, the 160-acre limitation in ownership of lands benefiting from the water-conservation features of the project should not be applied as a prerequisite for this project's qualifying for interest-free funds.

The district engineer further recommends that, in the event McDowell Reservoir, proposed in House Document 136, 81st Congress, 1st session, is adopted for construction, the design be modified to provide such additional flood-control storage as is determined to be needed and justified at that time.

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PLATES

No.	Title
1.	Index map
2.	Gila River Basin

LIST OF APPENDIXES MADE IN CONNECTION WITH REPORT

No.	Title
1.	Hydrology (18 plates)
2.	Geology and soils (4 plates)
3.	Bases for design (13 plates)
4.	Cost estimates
5.	Benefits from improvements (7 plates)
6.	Use of water by phreatophytes in 2,000-foot channel between Granite Reef and Gillespie Dams, Maricopa County, Ariz. (9 plates)
7.	Allocation of costs
8.	Resolution by local interests
9.	Comments of other agencies

UNITED STATES ARMY CORPS OF ENGINEERS,
OFFICE OF THE DISTRICT ENGINEER,
LOS ANGELES DISTRICT,
Los Angeles, Calif., December 4, 1957.

Subject: Interim report on survey for flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona.

Through: The Division Engineer, United States Army Engineer Division, South Pacific, San Francisco, Calif.

To: The Chief of Engineers, United States Army.

AUTHORITY

1. This report is submitted pursuant to act of Congress, Public Law 761, Seventy-fifth Congress, approved June 28, 1938, which reads in part as follows:

SEC. 6. The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control including floods aggravated by or due to tidal effect at the following-named localities, and the Secretary of Agriculture is authorized and directed to cause preliminary examinations and surveys for run-off and water-flow retardation and soil-erosion prevention on the watersheds of such localities; ***:

* * * * * * *

Gila River and tributaries, Arizona and New Mexico.

* * * * * * *

2. A preliminary examination report on Gila River and tributaries, Arizona and New Mexico, dated January 10, 1939, was submitted by the district engineer in accordance with the act mentioned in the preceding paragraph. The report, which was reviewed by the Board of Engineers for River and Harbors, is the basis of authorization, dated April 18, 1939, by the Chief of Engineers for a report on a flood-control survey of the entire Gila River Basin.

3. The survey for the entire basin is being covered in seven interim reports, two review reports, and a final comprehensive report. Interim reports have been submitted as follows: Tucson, Ariz., and vicinity, dated November 20, 1945; Queen Creek, Ariz., dated February 2, 1946; Gila River and tributaries below Gillespie Dam, Ariz., dated September 1, 1948; and lower Agua Fria River and vicinity, Arizona, dated December 10, 1952. Two additional interim reports covering (a) Pinal Creek and tributaries and (b) Gila River, Camelsback Reservoir site to Salt River, Ariz., have recently been started.

This interim report, the seventh, considers the area along Gila River from Gillespie Dam to the mouth of Salt River and the area along Salt River from its mouth to the McDowell Dam site. Review reports to consider the Gila River and tributaries, Arizona, downstream from Painted Rock Reservoir site, and Gila River and tributaries in the vicinity of Tucson, Ariz., were authorized in 1954 and 1955, respectively. Work on these review reports is under way. The final comprehensive report will include summaries of findings and conclusions in all interim and review reports, consideration of problems in area not covered in any interim report, and analysis of the interrelation of problems and plans of improvement in all parts of the Gila River Basin.

SCOPE OF SURVEY

4. General.--The survey described in this interim report was made to consider (a) the need for flood control and (b) the solution of the flood problems in that part of the Gila River Basin, Ariz., that is along Gila and Salt Rivers between Gillespie Dam and McDowell Dam site. Consideration was given to the preservation and protection of established and potential uses of water and to the development of comprehensive and coordinated projects for improvement.

5. Topographic surveys and mosaics.--Aerial surveys of Gila and Salt Rivers from Gillespie Dam to McDowell Dam site were made by the Corps of Engineers in 1949. Cross sections of the river channel were taken at intervals of approximately 1 mile. Reconnaissance surveys of McDowell Dam site were made; detailed topographic surveys of the dam site were made by the United States Bureau of Reclamation.

6. Site investigations and explorations.--Geological reconnaissance of the McDowell Dam site was made by the Corps of Engineers. Logs of holes drilled at the site were supplied by the United States Bureau of Reclamation. Power-auger borings along the alinement of the Salt River levees considered were made by the Corps of Engineers. Samples of existing gravel pits near the city of Phoenix were analyzed. Adjacent areas from which adequate quantities of suitable embankment material for the levees considered and of suitable soils and aggregates that might be feasibly transported to McDowell Dam site were explored. Details of the subsurface explorations are given in Appendix 2: Geology and Soils.

7. Economic and other investigations.--Newspaper accounts of past floods were analyzed to determine the extent of overflow and damage from past floods. Field investigations were conducted to determine the extent of overflow from future floods and the type and value of property in the overflow areas. Assessed valuations of properties in the overflow areas were obtained and true valuations were estimated. Economic studies included analyses of crop values and farming costs. Local interests were interviewed about property values, agriculture, use and availability of water, and flood damage. A field inspection of the area was made by the district engineer.

PRIOR REPORTS

8. No prior survey reports on flood control in the Gila River Basin between Gillespie Dam and McDowell Dam site have been submitted to Congress by the United States Army Corps of Engineers.

DESCRIPTION

9. Location and extent.--The Gila River Basin, the largest drainage area tributary to lower Colorado River, includes the southern half of Arizona and a part of southwestern New Mexico. (See pl. 2.) The drainage area of the basin comprises about 58,200 square miles, 5,600 of which are in New Mexico, 51,500 in Arizona, and 1,100 in Sonora, Mexico.

10. The part of the Gila River Basin under consideration in this report comprises the Salt River Valley between McDowell Dam site (river mile 46) and the mouth of Salt River, and the Gila River Valley from the mouth of Salt River (river mile 198) to Gillespie Dam (river mile 164). The drainage areas of Salt River at McDowell Dam site and at the mouth are 12,900 and 13,700 square miles, respectively. The drainage area of Gila River at Gillespie Dam is 49,600 square miles. The Gila River Valley between Gillespie Dam and the upper end of the authorized Painted Rock Reservoir (now under construction) was also considered in this report because of the effect of a dam at the McDowell site on this area. (See index map, pl. 1, and map of Gila River Basin, pl. 2.)

11. Streams.--Gila River, the main stream in the drainage area, rises on the west slope of the Continental Divide in southwest New Mexico and flows generally westward about 650 miles to a point on Colorado River about 11 miles upstream from the California-Mexico boundary. The principal tributaries that join the main stream upstream from Salt River include the following streams: San Francisco and San Carlos Rivers, which enter the main stream from the north; and San Simon Creek and San Pedro and Santa Cruz Rivers, which enter from the south. The principal tributaries that join the main stream in the area under consideration in this report include Salt, Agua Fria, and Hassayampa Rivers, and Centennial Wash, which enter Gila River from the north. The principal tributaries of Salt River upstream from McDowell Dam site include Tonto Creek and Verde River. No major streams enter Salt River downstream from McDowell Dam site. The headwaters of Salt and Gila Rivers are perennial. Surface flow in other parts of the drainage area is mostly intermittent.

12. Topography.--The area along Gila and Salt Rivers from Gillespie Dam to McDowell Dam site is part of an alluvial valley that is very favorable for agricultural development. In the drainage area above Gillespie Dam, the mountains, in the headwaters of Verde River, rise to a maximum elevation of 12,600 feet. The divide, in general, ranges in elevation from 3,000 to 9,000 feet along the south side of the basin, and from 7,000 to 9,000 feet along the north and

northeast sides. The mountains are rugged and precipitous, and the valleys are sufficiently level to be favorable for agriculture.

13. Geology and soils.--The area drained by Gila and Salt Rivers is part of the Basin and Range Province, which covers a large part of southwestern United States. The surface of the area is a series of broad, connected desert valleys and plains, from which rise numerous hills and short, isolated mountain ranges. South of the area, a highland with similar topography extends many miles into Mexico. On the north, rugged mountains separate the area from the upland province known as the Colorado Plateau.

14. The rocks that form the hills and mountains and underlie the valleys and plains are chiefly great masses of Pre-Cambrian, metamorphose granites and volcanics, with which occur minor amounts of sedimentary rocks. During the Tertiary period, much block faulting occurred in this region and structural valleys were formed between the upthrown mountain blocks.

15. The intermontane valleys and plains are deeply filled with alluvium consisting of poorly assorted, coarse sediments interbedded with silt and clay. The soil in the valleys is fertile; and, where water without a high saline content is available for irrigation, the crop yields are high. The areal extent of sediments in the Salt River Valley and adjacent parts of the Gila River Valley totals several thousand square miles and includes the broad plain extending southward from Mesa and Chandler to Gila River. The maximum thickness of these sediments has not been determined but is known to exceed 1,300 feet at one point. Additional information on geology and soils in the Gila River Basin and detailed information on geology and soils at the McDowell Dam site and at the site of recommended levee and channel improvements are given in Appendix 2: Geology and Soils.

16. Stream characteristics.--In general, stream slopes in the Gila River Basin are not excessive. The gradients of Gila River and of most of the secondary streams are steep near the headwaters and decrease progressively downstream. The average slopes of Gila and Salt Rivers from the headwaters to their mouths are 13 and 25 feet per mile, respectively. The average slope of Salt River from McDowell Dam site to its junction with Gila River is about 9 feet per mile; the average slope of Gila River from Salt River to Gillespie Dam is about 5.5 feet per mile.

17. The channel capacity of Salt River from McDowell Dam site to its mouth is about 50,000 cubic feet per second. Normal flows meander over the bottoms of wide channels of various depths; major floods overflow the banks and spread over an area from 1 to 3 miles wide. Large flows are infrequent and the channel is partially blocked by sandbars and river-bottom growth.

18. In the area along Gila River from the mouth of Salt River to Gillespie Dam, the flow meanders over the flat bottom of a trench

5 to 20 feet deep and 1/2 to 1 mile wide. However, most of the channel bottom is overgrown with phreatophytes, principally saltcedar. This river-bottom growth has increased the aggradation of the channel and has restricted the channel to such an extent that flows in excess of 20,000 cubic feet per second will overflow and inundate the adjoining cultivated area. The overflow area of the standard project flood would range from 1 to 2-1/2 miles in width.

19. The channel capacity of Gila River from Gillespie Dam to the upper end of the authorized Painted Rock Reservoir (now under construction) is about 50,000 cubic feet per second. Flows in excess of this amount will inundate adjoining land and spread over an area from 1/2 to 2 miles wide.

20. Vegetation.--The type, density, and distribution of vegetation in the Gila River Basin reflect the differences in elevation, temperature, and precipitation. In general, the desert vegetation is sparse. The principal desert vegetation is cacti, creosotebush, and sagebrush. Saltcedar, mesquite, and arrowweed grow in dense thickets in stream bottoms and other areas where the water table is near the surface of the ground. Grasses interspersed with desert and semidesert shrubs grow at elevations ranging from 3,000 to 8,000 feet, but the density of vegetal cover is low below 4,500 feet and only fair at higher elevations. Overgrazing has destroyed much grass, which has been replaced by rabbitbrush and snakeweed over large areas. Chaparral, oak, pinon, and juniper grow at elevations ranging from 4,000 to 7,000 feet. Aspen and conifers, such as fir, spruce, and pine, are common above elevations of 6,000 feet.

21. Maps.--Maps of the Gila River Basin that were prepared by agencies of the Federal Government, by the State of Arizona, and by local interests were used in the preparation of this report. Maps included as plates to this report are as follows: Plate 1, Index Map, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona; and plate 2, Gila River Basin. Additional maps prepared for special use in connection with this report accompany appendixes to this report.

ECONOMIC DEVELOPMENT

22. Population.--The area affected by improvements considered in this report lies entirely in and includes most of Maricopa County, Ariz. Population in this area has increased steadily from 1900 to 1950 and has continued to increase at a rapid rate since that date. According to the United States census, the Maricopa County population was about 20,000 in 1900, 90,000 in 1920, 186,000 in 1940, and 332,000 in 1950. A local agency estimates the 1957 population of the county at 550,000. A number of cities, including Phoenix, the capital and largest city in the State of Arizona, would be affected by the improvements considered. The following table gives the 1950 population for these cities, for the Phoenix urban area, and for Maricopa County. Population estimates for 1957, where available, are also given.

1950 and 1957 populations in area affected by the improvements considered in the interim report on survey, flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona

City or area	Population	
	1950	1957
Maricopa County	331,770	**550,000
Phoenix	*106,818	**172,000
Phoenix urban area	**230,000	**370,000
Mesa	16,790	(***)
Glendale	8,179	(***)
Tempe	7,684	(***)
Chandler	3,799	(***)
Tolleson	3,042	(***)

* A special census for the city of Phoenix made in March 1953 indicated a population of 128,840 in the city.
** Estimate made by Valley National Bank, Phoenix, Ariz.
*** Estimate not available.

23. Occupations and industries.--The principal activities in the Salt and Gila River Valleys from McDowell Dam site to Gillespie Dam are agriculture and stock raising. About 300,000 acres were irrigated in the area in 1956, providing an annual gross crop value of about $85,000,000. The gross value of livestock in December 1953 was about $15,000,000. The city of Phoenix is the trade and service center for most of the State of Arizona. The estimated value of retail sales in Maricopa County in 1956 was $705,000,000, which was over 50 percent of the State total. The estimated manufacturing production in Arizona in 1956 was $400,000,000, of which about 50 percent accrued in Maricopa County. Several large sand-and-gravel plants are located in the riverbed of Salt River.

24. Land use and development.--Irrigation of the Salt River Valley by white settlers began in 1867 soon after Arizona was given territorial status. Water was diverted to lands on the north bank of Salt River, near the site of the city of Phoenix. By 1871, staple crops were being produced on about 1,700 acres, and the new town of Phoenix had a population of about 300. The Santa Fe railroad was completed across northern Arizona to Colorado River in 1883, and in 1887 this line extended a branch to Phoenix. In 1900, Phoenix, with a population of 5,544, was the seat of the territorial government.

25. During the period 1890 to 1910, agriculture and associated industries expanded rapidly but spasmodically. Although the annual flows of the stream were more than adequate to supply the areas then irrigated, wide variations in flows occurred. Sudden rains would swell the streams to flood proportions, from which they would dwindle to

meager streamlets during the dry period. The agricultural economy was one of alternate prosperity and failure. Time after time, floods carried away the diversion dams, many of which had to be replaced every year. By the time these structures were repaired, the streamflow would in many cases be insufficient to irrigate crops in the area, or the crops had withered and died from the intensity of the desert sun. After the passage of the Reclamation Act of 1902, the Salt River project was constructed by the Bureau of Reclamation from 1903 to 1911. Granite Reef diversion dam was completed in 1908, and Roosevelt Dam was completed in 1911 with resultant impetus to agricultural development and stability for urban and industrial growth. Further developments by the Salt River Valley Water Users' Association from 1920 to 1930 provided relatively cheap electric power. As a result, irrigation of new lands by pumping from wells expanded rapidly. Development of the Salt River project, which comprises most of the irrigated lands along Salt River, is shown by the following table:

Area in cultivation, Salt River project (1910-56)

Year	Area in cultivation
	Acres
1910	106,000
1920	193,000
1930	217,000
1940	227,000
1950	225,000
1956	192,600

26. Development of lands along Gila River below the mouth of Salt River started at the same time as development of lands along Salt River. The first irrigation canal in this area was built in 1886, and the settlement of Buckeye was founded about the same time. In 1921, the Gillespie diversion dam was built to serve about 16,000 acres of land, mainly on the left bank in the vicinity of Gila Bend.

27. Agriculture.--The agricultural economy of the valleys along Salt and Gila Rivers is well stabilized, and the farmers are generally prosperous, although they experience serious losses because of floods and water shortages. The supply of irrigation water under present conditions is not sufficient to provide a full supply of good quality water to the entire acreage under cultivation. The excess acreage has been kept in production temporarily by overdrafts on ground-water storage and by failure to make adequate releases to maintain a suitable salt balance in the area. A reduction in use to fit the yield and salt-balance requirements would greatly reduce the production of agricultural crops.

28. Facilitated by the mild winters and a long growing season, the area is adapted to a wide range of agricultural crops. Principal crops include alfalfa, barley, cotton, flax, sugar beets, citrus crops, and truck crops, such as lettuce, cantaloupes, watermelons, and carrots. Many acres are double-cropped. During 1956, the gross value of crops in the Salt River project was about $55,300,000 for 192,600 acres, or about $287 per acre.

29. Irrigation.--Agriculture along the Salt and Gila Rivers from McDowell Dam site to Gillespie Dam is entirely dependent on irrigation. Most of the irrigated lands have gentle slopes; they are favorable for the distribution of water and for surface and underground drainage. The extensive irrigation works constructed by the prehistoric occupants of the basin and the existing development both emphasize the favorable conditions for growing crops by irrigation.

30. In the area under consideration, irrigation water is obtained by surface diversions supplemented by pumping from the underground supply. Along Salt River, water is diverted from the river to the two main canals at Granite Reef Dam, which is downstream from the confluence of Verde and Salt Rivers. The combined capacities of the Arizona canal, serving the north side, and the Southern canal, serving the south side, permit the diversion of all flows up to 4,000 cubic feet per second. The irrigation flow is regulated by Bartlett and Horseshoe Dams on Verde River, and Roosevelt, Horse Mesa, Mormon Flat, and Stewart Mountain Dams on Salt River. Lands in the Roosevelt Water Conservation District and the Roosevelt Irrigation District are also served by the diversion at Granite Reef Dam. Along Gila River, Buckeye and Arlington diversion structures and canals serve the Buckeye and Arlington Valleys, respectively. Gillespie Dam diverts the surface flow to lands of the Gillespie Land and Water Co. on the left bank and to lands supplied by the Enterprise canal on the right bank. Minor diversion structures, canals, and pumps serve the small irrigation districts along the Salt and Gila Rivers.

31. Use of ground water for the irrigation of lands in this area has increased rapidly since 1935. In 1956, about 45 percent of the total supply was obtained from wells. In the Salt River project in 1956, a total of 517,000 acre-feet were delivered from 264 wells.

32. The quantity of water applied annually to an acre of irrigated land varies with type of soil, kind of crops, efficiency of farm management, and amount of water available. The net duty of water varies from about 2.3 acre-feet per acre for truck crops to about 5.0 acre-feet per acre for alfalfa and grain. The average net duty of water is estimated at about 4.0 acre-feet per acre, measured at the farmer's headgate.

33. Water rights.--The water code of Arizona recognizes that both surface flow and underground waters flowing in definite channels belong to the public and are subject to appropriations governed by beneficial use. Percolating water in undefined channels is the property of the overlying land and is not subject to appropriation.

34. Water rights within the Salt River project are adjudicated under the Kent Decree, entered March 1, 1910. The Benson-Allison Decree of November 14, 1917, adjudicated water rights between the various users of water diverted by several ditches, including the Buckeye canal, from the Salt, Agua Fria, and Gila Rivers. Various arrangements have been made between the water users under these rights and the Salt River project for the delivery of their waters. A court decree effective January 1, 1944, fixed the amount of water that should be delivered to the Buckeye district by the Salt River project as 1.1 percent of the water actually diverted at Granite Reef Dam.

35. One of the most significant features in the use of irrigation water, and one that has grown in importance during the recent years of deficient water supply, is the increasing amount of pumping from underground storage to compensate for deficiencies in streamflow. Many pumping installations have been made indiscriminately according to individual requirements. Extension of this practice has led to overdevelopment and overdraft from ground-water sources of supply. In 1948, the Arizona Legislature passed an act authorizing the State Land Commissioner to designate critical ground-water areas for which adequate factual data indicate that the ground-water supply has been overdeveloped. After establishment of a critical area, no person is permitted to construct any irrigation well in that area without a permit, and no permit is to be issued for construction of any well that would tend to increase the acreage irrigated.

36. Power.--Most of the power used in the area under consideration is obtained from local sources. Power is obtained from the Salt River Project Agricultural Improvement and Power District and from the Arizona Public Service Company. To develop power, advantage is taken of the entire 723-foot fall on Salt River from high water level at Roosevelt Lake to tailwater below Stewart Mountain Dam. The combined generating capacity at the 4 structures is about 62,800 kilowatts. A standby diesel plant and modern steam plants are the other local sources of supply. In addition, the 2 local distributing agencies have contracts with the Arizona Power Authority and the United States Bureau of Reclamation, which obtain power from Parker and Davis Dams on Colorado River. A complete transmission and distribution system provides power for domestic use (including city and rural use) and for irrigation pumping. In general, the power supply (existing and contemplated) is adequate for the needs of the area.

37. Transportation facilities.--Arterial highways and railroads connect the areas along Gila and Salt Rivers with centers of manufacturing and commerce throughout the nation. United States

Highways Nos. 60, 70, and 80 cross the area on their routes from the Pacific coast to the Eastern States. United States Highway No. 89, which also crosses the area, extends from the Canadian to the Mexican border. Arizona State highways supply connecting links, and many local roads complete a network that adequately serves present needs. One of the main lines of the Southern Pacific railroad traverses much of the area under consideration. A branch line of the Atchison, Topeka and Santa Fe railway connects Phoenix with the main line to the north. The Sky Harbor Airport provides daily airmail, passenger, and freight service in and out of Phoenix. Many transcontinental bus routes pass through the area.

CLIMATOLOGY

38. General.--The climate of the area along Gila and Salt Rivers from Gillespie Dam to McDowell Dam site is subtropical and arid. Wind velocities are low to moderate. The average length of the season between frosts is about 300 days in Phoenix, Ariz. Recorded extremes of temperature for a 45-year period at Phoenix are 16° and 118° above zero Fahrenheit.

39. Precipitation records.--Precipitation records are available for more than 600 stations in and near the Gila River Basin. Many of these stations were established since 1935 in connection with projects of the United States Soil Conservation Service. The longest continuous record is for Yuma, Ariz., where precipitation was first measured in 1870; and the earliest records are for Fort McDowell, Ariz., and Prescott, Ariz., where precipitation was first measured in July 1866 and September 1866, respectively. Autographic records are available for more than 40 of the stations, most of which were established since 1939. The longest continuous autographic record is for Phoenix, where an automatic gage was installed in 1906.

40. For the 71-year period prior to about 1938, the average annual precipitation at stations in the Gila River Basin above Gillespie Dam ranged from about 33 inches at Carr's ranch (elev. 5,410 feet), about 14 miles northeast of Roosevelt Dam, to less than 7 inches at Saddle Mountain (elev. 1,125 feet), 20 miles northwest of Gillespie Dam. The mean annual precipitation in the Gila River Basin upstream from Gillespie Dam is about 15 inches. The largest annual precipitation recorded in the region was 58.45 inches, which occurred in 1905 at Pinal ranch (elev. 4,520 feet), about 6 miles east of Superior, Ariz. Precipitation data for the Gila River Basin are discussed in detail in Appendix 1: Hydrology. Pertinent data on representative stations in the Gila River Basin above Gillespie Dam are given in the following table:

Precipitation data, representative stations in the Gila River Basin above Gillespie Dam, Ariz. and N. Mex.

Station	Location		Elevation	Period of record	Complete years of record	Mean annual precipitation*
	Latitude	Longitude				
	Decrees-minutes	Degrees-minutes	Feet		Years	Inches
Luna ranger station, N. Mex...	33-50	108-56	7,050	1900-57	57	16.46
Red Rock, N. Mex.....	32-42	108-44	4,150	1905-57	50	11.99
Ashfork, Ariz.....	35-13	112-29	5,140	1902-57	55	12.92
Prescott, Ariz.....	34-33	112-28	5,354	1866-1957	81	18.75
Phoenix, Ariz.....	33-28	112-04	1,083	1876-1957	71	7.56
Gila Bend, Ariz.....	32-57	112-43	737	1889-1957	68	5.87
Roosevelt, Ariz.....	33-40	111-09	2,230	1905-57	52	16.50
Fort Apache, Ariz.....	33-48	109-59	5,300	1872-1934	62	18.42
Tucson, Ariz.....	32-15	110-58	2,423	1891-1957	66	11.46
Pinal Ranch, Ariz.....	33-20	111-00	4,520	1893-1957	64	25.04

* Computed for 71-year period (1868-1938) by index-of-wetness method. Data for period subsequent to 1938 were not considered necessary for adequate determination of mean annual precipitation.

41. Storms.--Most precipitation in the Gila River Basin occurs in two seasons: July through September, and December through March. Precipitation during the winter usually results from general winter storms associated with extratropical cyclones of North Pacific origin. During the months from December to March, such storms move south over the ocean and then inland to southern California, Arizona, and New Mexico and result in precipitation over areas of up to thousands of square miles. Precipitation during general winter storms may be more or less continuous for several days. Relatively localized showers near the end of such storms are common. In general, precipitation is small during spring and autumn. Most precipitation during the summer results from showers of short duration and small areal extent or from general summer storms. Storms of the thunderstorm type may occur separately or in conjunction with general storms. Detailed information on storms in the Gila River Basin is given in appendix 1.

42. Snow.--Many precipitation records since 1900 for stations in the area include information on snowfall. Snow-course observations have been made since about 1937 at several points in the drainage areas of Verde, Salt, and upper Gila Rivers. In winter, snow may accumulate to considerable depths at elevations above 4,000 feet but practically never falls at elevations below 2,000 feet. Heavy snowfalls in the drainage basin of Gila River are limited to areas tributary to Agua Fria, Verde, upper Salt, and San Francisco Rivers.

RUNOFF AND STREAMFLOW DATA

43. Streamflow records.--Streamflow records are available for 95 stations on Gila River and tributaries. Records of discharge at most stations during flood periods generally are inadequate. The earliest gagings for which records are available were on Salt River during 1888 near the site of Granite Reef Dam.

44. Records of stream discharge on Gila and Salt Rivers between Gillespie Dam and McDowell Reservoir site are available for four locations. Pertinent data for these locations are given in the following table:

Stream-gaging stations, Gila and Salt Rivers, Gillespie Dam to McDowell Reservoir site, Arizona

Location	Drainage area	Period of record	Maximum recorded flow	
			Peak	Date
	Square miles		Cubic feet per second	
Salt River near McDowell.	6,280	1895-99; 1901-10; 1934-57.	138,000	Nov. 27, 1905.
Verde River near McDowell.	6,620	1889; 1895-99; 1901-9; 1913-57.	96,000	Do.
Salt River near Granite Reef Dam.	12,900	1888-91; 1895; 1913-57.	300,000	Feb. 24, 1891.
Gila River below Gillespie Dam.	49,600	1921-57.	70,000	Dec. 28, 1923.

45. Adequacy of streamflow for multiple-purpose uses.--The daily surface runoff in Salt and Gila Rivers varies greatly during the year, and the annual surface runoff varies greatly from year to year. Flow in the river is erratic and out of phase with irrigation requirements. As a result, many large reservoirs have been constructed upstream from Gillespie Dam to store the runoff until needed. The effect of these structures has been to conserve nearly all flow of the Salt River upstream from McDowell Dam site except during some flood seasons. During the period 1923-57, if existing reservoirs had been in operation during the entire period, flow would have been available for conservation at McDowell Dam site for only 4 of the 35 years of record. Preliminary estimates made by the United States Bureau of Reclamation show the following flow as being available at McDowell Dam site:

Flow available for conservation at McDowell Dam site, Salt River, Ariz. (1923-57)

Year	Available flow
	Acre-feet
1927	80,600
1932	204,000
1937	188,800
1941	387,300
Total	860,700
Say	860,000

FLOODS

46. Floods of record.--Historical reference to floods on Salt and Gila Rivers from McDowell Dam site to Gillespie Dam extends back to 1833, but estimates of discharge measurements are for only the period 1888 to date. Large floods during this period occurred in 1891, 1905, 1916, 1920, and 1938.

47. The greatest flood of record occurred in February 1891. The peak discharge of this flood was estimated at 300,000 cubic feet per second on Salt River at Arizona Dam (approximately same location as the present Granite Reef Dam). Other major floods of record, for which adequate estimates of peak discharge along Salt River below Verde River are available, include: February 1920, 130,000 cubic feet per second; January 1916, 120,000 cubic feet per second; April 1905, 115,000 cubic feet per second; and March 1938, 95,000 cubic feet per second. Additional information on floods is given in Appendix 1: Hydrology; and in Appendix 5: Benefits from Improvements.

48. Flood characteristics.--Major floods along Salt and Gila Rivers from McDowell Dam site to Gillespie Dam result from general winter storms over the Gila River Basin. 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 and results in violent and destructive floods. The peak discharges of floods are relatively high in comparison with the total volume of floodwater. Channel storage and losses reduce the flood peaks when no additions are made by side drainage. Because Salt and Gila Rivers flow westward and winter storms usually move eastward over the basin, the probability of synchronization of peaks of winter floods from the different tributaries is small. Peaks from downstream (western) tributaries usually pass on before the runoff from the area farther east arrives. The base flow, made up of contributions from ground water, melting snow, and surface runoff from rain prior to rain of flood-producing intensities, is relatively small in comparison with the peak floodflows.

49. Flood frequencies.--The frequencies of floods considered in detail were determined under the assumption that all existing reservoirs in the Gila River Basin and the proposed Buttes and Charleston Reservoirs (see subsequent heading "Proposed Improvements Affecting the Problem") would be in operation. Records of peak flows and peak-flow estimates, based on data for the 69-year period 1889-1957, were used in preparing discharge-frequency curves. Detailed information on flood frequencies is given in Appendix 5: Benefits from Improvements. The estimated frequencies of floods of various magnitudes for Salt River at McDowell Dam site and Gila River at Painted Rock Dam site are listed in the following table:

Estimated frequencies of floods of various magnitudes, Salt River at McDowell Dam site and Gila River at Painted Rock Dam site, Arizona

Number of times that flood would be equaled or exceeded in 100 years	Peak discharge	
	Salt River at McDowell Dam site	Gila River at Painted Rock Dam site
	Cubic feet per second	Cubic feet per second
0.6	*290,000	*320,000
1	240,000	261,000
2	175,000	195,000
5	108,000	120,000
10	68,000	74,000
15	**50,000	52,000
20	(***)	38,000
32	(***)	**20,000

* Standard project flood.
** Minimum damaging flood.
*** Not determined.

50. Standard project flood.--A standard project flood may be defined as a large hypothetical flood that would be exceeded only on rare occasions. It could occur in the Gila River Basin if a storm equivalent in magnitude to the largest general storm or storms of record in the region were to center over the basin when ground and climatic 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 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.

51. Estimates of the magnitude of the standard project flood for points on Salt River from McDowell Dam site to the mouth are based on calculations of runoff that would have resulted if a storm having characteristics of both the January 1916 and March 1938 storms were centered over the area above the McDowell Dam site. Estimates of the magnitude of the standard project flood for points on Gila River are based on the assumed occurrence of the January 1916 storm, centered over the area above Gillespie Dam, and assuming that the proposed Buttes and Charleston Reservoirs were in operation. Detailed information on the determination of the standard project flood is given in Appendix 1: Hydrology. The peak discharges of the standard project flood are given in the following table:

Estimated peak discharges, standard project flood, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona

Stream	Location	River mile	Peak discharge
			Cubic feet per second
Salt River	McDowell Dam site	46	290,000
Do	Mouth	0	250,000
Gila River	Just below Salt River	198	370,000
Do	Gillespie Dam	164	350,000

52. Maximum probable flood.--The maximum probable flood is that flood that would result from the most severe combination of meteorological and ground conditions considered possible of attainment in the drainage area. The peak discharge of the maximum probable flood at McDowell Dam site is estimated at 600,000 cubic feet per second. This flood is used only for spillway-design purposes. Detailed information on the determination of the maximum probable flood is given in Appendix 1: Hydrology.

EXTENT AND CHARACTER OF OVERFLOW AREA

53. Location and extent.--The overflow areas considered in detail are as follows: (a) 44,000 acres along Salt River from McDowell Dam site to the mouth; (b) 41,000 acres along Gila River from Salt River to Gillespie Dam; and (c) 17,000 acres along Gila River from Gillespie Dam to the upper end of Painted Rock Reservoir site. The last area was considered because of the effect that McDowell Reservoir would have on floodflows of Gila River below Gillespie Dam. The overflow areas investigated in detail are described more fully in Appendix 5: Benefits from Improvements, and are shown on map, plate 1 of that appendix.

54. Type and value of improvements.--Developed areas subject to overflow by floods along Salt and Gila Rivers are mostly agricultural. However, the value of residential, business, industrial, and public properties in the cities of Phoenix and Tempe greatly exceeds the total value of other properties in these areas. Pertinent information on the type and value of improvements in overflow areas is given in the following subparagraphs.

(a) Overflow area along Salt River, McDowell Dam site to mouth.--The 1957 cultivated acreage in the overflow area of Salt River, McDowell Dam site to mouth, is estimated at 16,000 acres. In addition, about 4,000 acres of residential, commercial, and public property in Phoenix, Tempe, and South Phoenix are subject

to inundation. Other improvements subject to damage include highways, roads, two long highway bridges, one railroad bridge, irrigation works, and utilities including the Phoenix and Tempe sewage disposal plants.

(b) Overflow area along Gila River, Salt River to Gillespie Dam.--About 15,000 acres of the overflow area of Gila River, Salt River to Gillespie Dam, were cultivated in 1957. This acreage is mostly along the right bank of the river. The community of Liberty and many rural residences are subject to damage. The headings of the Buckeye and Arlington canals and the canals themselves are subject to overflow and repeated damage. Other property subject to damage includes short sections of highways and roads, the Buckeye sewer farm, and some utility crossings of Gila River.

(c) Overflow area along Gila River, Gillespie Dam to upper end of Painted Rock Reservoir site.--About 1,300 acres of irrigated land in the overflow area along Gila River, Gillespie Dam to the upper end of Painted Rock Reservoir site, are subject to inundation. Damage in this area will occur mainly to agricultural property, irrigation works including Gillespie Dam, and highways and roads.

(d) Summary.--A summary of information on the type and 1957 value of property in the overflow areas considered in detail is given in the following table:

Property subject to damage by the standard project flood in the overflow areas along Salt River from McDowell Dam site to the mouth and along Gila River from the mouth of Salt River to upper end of Painted Rock Reservoir site, Arizona

TRUE VALUE (1957)

Property	Overflow area		
	Salt River, McDowell Dam site to mouth	Gila River, mouth of Salt River to Gillespie Dam	Gila River, Gillespie Dam to upper end of Painted Rock Reservoir site
Residential	$46,930,000	$1,280,000	$5,000
Business and industrial	18,890,000	0	0
Public	22,200,000	0	8,000
Agricultural	14,580,000	13,470,000	670,000
Irrigation works	900,000	440,000	1,310,000
Highways and roads	2,000,000	290,000	500,000
Railroads	600,000	0	0
Utilities	4,940,000	80,000	0
Total	111,040,000	15,560,000	2,493,000
Grand total		129,093,000	
Say		129,000,000	

ACREAGE

	Acres	Acres	Acres
Cultivated	16,000	15,000	1,300
Urban	4,000	0	0
Other (stream channel and wasteland)	24,000	26,000	15,700
Total	44,000	41,000	17,000
Grand total		102,000	

FLOOD DAMAGES

55. Damages from past floods.--Floods on Salt and Gila Rivers from McDowell Dam site to the upper end of Painted Rock Reservoir site have caused severe damage to property and loss of at least 6 lives. Available data on damages from past floods are incomplete. Newspaper accounts supply incomplete flood-damage descriptions of those floods that have occurred since 1890, but monetary estimates are very limited. The flood of February 1920, the last large damaging flood of record, caused an estimated damage of $300,000 within the Salt River project. More complete information on damages from past floods is given in Appendix 5: Benefits from Improvements.

56. Damages from future floods--1957 conditions.--Damages from future floods under 1957 conditions 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 channels. 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. For each overflow area, the selected flood magnitudes range from the discharge that would cause a small amount of damage to the discharge of the standard project flood. Detailed data on damage from future floods are given in appendix 5. All damages evaluated in this report are classified as primary damages, which have been divided into direct and indirect damages. Such secondary damages as may exist are considered to be small and have not been included in the evaluation of the project. Direct damage to property is physical damage resulting from overflow or erosion. Indirect damage is the result of direct damage and includes (a) costs of flood fighting, rescue work, and similar emergency measures; (b) business and similar losses from decreased production, decreased profits and wages, and increased costs of normal operations and living; and (c) costs of rerouting traffic as a result of interruption of highway and railroad lines. Pertinent information on the direct and indirect damages in the overflow area along Salt River under 1957 conditions is given in the following tables:

Estimated damage from future floods of various magnitudes along Salt River from McDowell Dam site to mouth
(1957 conditions)

ESTIMATED DAMAGE FROM FUTURE FLOODS

Property subject to damage		Damage from future floods of various magnitudes*					
Type	Value (1957)	290,000 c.f.s.**		150,000 c.f.s.		100,000 c.f.s.	
		Direct	Indirect	Direct	Indirect	Direct	Indirect
Residential	$46,930,000	$3,140,000	$630,000	$650,000	$130,000	$43,000	$9,000
Business and industrial	18,890,000	1,990,000	690,000	580,000	210,000	70,000	14,000
Public	22,200,000	870,000	170,000	260,000	50,000	2,000	0
Agricultural	14,580,000	3,430,000	570,000	900,000	150,000	210,000	30,000
Irrigation works	900,000	190,000	440,000	90,000	110,000	5,000	1,000
Highways and roads	2,000,000	290,000	60,000	110,000	20,000	3,000	1,000
Railroads	600,000	90,000	90,000	35,000	35,000	2,000	0
Utilities	4,940,000	210,000	210,000	80,000	80,000	35,000	35,000
Total	111,040,000	10,210,000	2,860,000	2,705,000	785,000	370,000	90,000
Total direct and indirect damage		$13,070,000		$3,490,000		$460,000	

* Discharge on Salt River at McDowell Dam site.
** This is the standard project flood.

Estimated damage from future floods of various magnitudes in overflow area along Salt River (1957 conditions)

Flood magnitude*	Estimated damage		
	Direct	Indirect	Total
Cubic feet per second			
290,000	$10,210,000	$2,860,000	$13,070,000
150,000	2,705,000	785,000	3,490,000
100,000	370,000	90,000	460,000
50,000	0	0	0

* Discharge on Salt River at McDowell Dam site.

57. Estimates were made of the tangible damages under 1957 conditions from future floods of various magnitudes in the other overflow areas considered. These estimates are summarized in the following table:

Summary of estimated damage from future floods of various magnitudes in the overflow areas along Gila River (1957 conditions)

Overflow area	Flood magnitude*	Estimated damage		
		Direct	Indirect	Total
	Cubic feet per second			
Gila River, mouth of Salt River to Gillespie Dam.	**320,000	$3,590,000	$890,000	$4,480,000
	174,000	1,480,000	380,000	1,860,000
	115,000	704,000	156,000	860,000
	44,000	192,000	40,000	230,000
	20,000	0	0	0
Gila River, Gillespie Dam to upper end of Painted Rock Reservoir site.	**320,000	778,000	322,000	1,100,000
	193,000	346,000	131,000	477,000
	97,000	35,000	11,000	46,000
	50,000	0	0	0

* Discharge on Gila River at Painted Rock Dam site.
** Standard project flood.

58. Damages from future floods--average future conditions.--Damages from future floods under average future conditions were computed on the basis of (a) estimated average future economic development of the overflow area and (b) average future channel conditions. The populations and property values of the city of Phoenix, of the Phoenix urban area, and of Maricopa County have increased steadily from 1900 to 1950 and have continued to increase since that date. Between 1950 and 1957, the population of the Phoenix urban area is estimated to have increased from 216,000 to about 370,000. The population and property development in the overflow area along Salt River will continue to increase in the future. A study of future population growth in the city of Phoenix and in the Phoenix urban area was made in 1951 by a private consulting firm. Actual growth since 1951 exceeded the estimates made by the engineering firm. On the basis of past growth and the forecasts of future growth made by the consulting firm (which appear to be conservative), the average future development of residential, business, industrial, public, and utility properties in the overflow area along Salt River during the 50-year period, 1958-2007, is estimated at about 55 percent greater than the 1957 development. In the overflow areas along Gila River below the mouth of Salt River, present property development and average future property development are considered identical. More detailed information regarding the estimates of future growth is given in appendix 5.

59. Along Gila River, channel conditions during the next 50 years will vary from year to year depending on many factors, including (a) the occurrence of wet or dry cycles and (b) the importation of water. The surface flow and a relatively high ground-water table that now sustain the growth of water-loving plants (phreatophytes) will probably continue to sustain the growth. The average channel conditions during the next 50 years were therefore considered identical to the present channel conditions. Along Salt River, the stream channel is relatively clear at present. In 1941, local interests had burned much of the growth existing at the time. Since that time, the water table has lowered and no flows, except relatively minor flows in short stretches of the river, have occurred. On the occurrence of spills from Stewart Mountain or Bartlett Dams, phreatophytes will reoccur and will reduce the channel capacity to some extent. Estimates of damages along Salt River under average future conditions were made on the basis of average future development of the overflow area and on assumed average future conditions of the stream-channel area. Estimates of damage in the two overflow areas along Gila River are the same under average future conditions as under present conditions. The following table summarizes the damage under average future conditions in the overflow area along Salt River:

Summary of estimated damage from future floods of various magnitudes, along Salt River from McDowell Dam site to mouth (average future conditions)

Peak discharge*	Total direct and indirect flood damage
Cubic feet per second	
290,000	$19,400,000
150,000	5,600,000
100,000	1,000,000
50,000	0

* Discharge on Salt River at McDowell Dam site.

60. Average annual damages from future floods.--Curves were drawn showing the relationships between peak discharges and average future damages for the overflow areas. These curves were combined with the discharge-frequency curves previously described to obtain curves showing the estimated number of times in 100 years that damages from single floods would be equaled or exceeded. The areas under the damage-frequency curves represent the estimated total flood damages during a 100-year period, and the total for each overflow area divided by 100 is the estimated average annual flood damage for that area. A summary of the estimated annual damage from future floods is given in the following table:

Estimated average annual future flood damage in overflow areas, Salt and Gila Rivers, McDowell Dam site to upper end of Painted Rock Reservoir site, Arizona

Overflow area	Average annual damage
Along Salt River, McDowell Dam site to mouth.....	$460,000
Along Gila River, Salt River to Gillespie Dam.....	198,000
Along Gila River, Gillespie Dam to upper end of Painted Rock Reservoir site.....	33,000
Total.....	691,000

61. Intangible damages from future floods.--In addition to the tangible damages evaluated in this report, future floods along Salt and Gila Rivers would cause serious damages not calculable in terms of monetary value. Such intangible damages would result from loss of

life; delay in the 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; inconvenience caused by interruption of public utility services; lowering of property values because of fear of floods; and general lowering of community morale.

EXISTING CORPS OF ENGINEERS FLOOD-CONTROL PROJECTS

62. Existing Corps of Engineers flood-control projects in the Gila River Basin comprise one completed project, one project under construction, one project in the planning stage, and one project under review.

63. Public Law 209, 83rd Congress, 1st session, approved August 7, 1953, authorized the Secretary of the Air Force to construct a detention basin on Trilby Wash about 20 miles west of Phoenix, Ariz., and an outlet channel to convey flood releases from the Trilby Wash detention basin toward the Agua Fria River. This project was completed in July 1956. Flood problems along Trilby Wash and adjoining washes are local in character and do not affect the problem area under consideration.

64. The Flood Control Act of May 17, 1950, authorized construction of Painted Rock Dam for flood control at mile 126 on Gila River, Ariz. (See H. Doc. 331, 81st Cong., 1st sess.) The dam and reservoir (now under construction) would provide flood protection to lands along lower Gila River, along lower Colorado River, and in the Imperial Valley. The construction of Painted Rock Dam was assumed in the studies of this report and no benefits were considered to accrue to plans considered in this report below the upper end of the reservoir site.

65. The Flood Control Act of July 24, 1946, authorized construction of Whitlow Ranch Dam for flood control on Queen Creek, Ariz. (See H. Doc. 220, 80th Cong., 1st sess.) Definite design studies on this project were initiated in 1956. Floodwaters from Queen Creek very rarely reach Gila River, and problems of flood control and water utilization on the two streams are only slightly related.

66. The Flood Control Act of June 30, 1948, authorized construction of a diversion channel and levee system for flood control in the vicinity of Tucson, Ariz. Plans for the improvement provide for diverting floodflows from the upstream parts of the drainage areas of Tucson Arroyo and other minor adjacent streams to Santa Cruz River at a point upstream from Tucson. (See H. Doc. 274, 80th Cong., 1st sess.) In 1955, a review of the flood problems at Tucson was authorized, and work on this review report is under way. Flood problems in Tucson are local in character, and the authorized improvement would be unrelated to improvements in other parts of the Gila River Basin.

EXISTING IMPROVEMENTS BY OTHER FEDERAL AND NON-FEDERAL AGENCIES

67. Pertinent information on flood-control and water-utilization improvements constructed in the Gila River Basin above Gillespie Dam by other Federal and non-Federal agencies is given in the following subparagraphs:

(a) Flood-control improvements.--No adequate improvements for control of large floods are in the area under consideration. A small flood-control basin with a capacity of 14,000 acre-feet to spillway crest was constructed in 1923 on Cave Creek, a tributary of Salt River, to prevent overflow along that creek, and especially in the city of Phoenix. Minor channel improvements and emergency work have been constructed along Salt River to protect about one-quarter mile of stream banks.

(b) Other improvements.--Since 1936, the Soil Conservation Service of the United States Department of Agriculture has constructed some minor improvements along upper Gila River and tributaries, mostly for the control of erosion. Most water for irrigation of areas upstream from Gillespie Dam is supplied by storage reservoirs, diversion dams, and headgate structures on Gila River and tributaries. Many miles of canals serve these areas. Facilities for the production of hydroelectric power are provided at Coolidge, Roosevelt, Horse Mesa, Mormon Flat, and Stewart Mountain Dams. Pertinent information on existing dams constructed in the Gila River Basin by other Federal and non-Federal agencies is given in the following table:

Existing dams, Gila River Basin, Ariz. and N. Mex.

Dam	Stream	Drainage area	Operating agency	Purpose	Year completed	Reservoir capacity*
		Square miles				Acre-feet
San Jose-Montezuma	Gila River	7,960	Local	Diversion	1936	0
Coolidge	do	12,900	U.S.I.I.S.	Storage, power	1928	1,205,000
Ashurst-Hayden	do	18,300	do	Diversion	1922	0
Sacaton	do	18,800	do	do	1925	0
Gillespie	do	49,600	Local	do	1921	0
Roosevelt	Salt River	5,830	do	Storage, power	1911	1,382,000
Horse Mesa	do	5,940	do	do	1927	245,000
Mormon Flat	do	6,100	do	do	1925	58,000
Stewart Mountain	do	6,220	do	do	1930	70,000
Granite Reef	do	12,900	do	Diversion	1908	0
Horseshoe	Verde River	5,990	do	Storage	1945	**144,000
Bartlett	do	6,160	do	do	1939	180,000
Cave Creek	Cave Creek	161	do	Flood control	1923	14,000
Lake Pleasant	Agua Fria River	1,460	do	Storage	1927	178,000

* Top of spillway gates, if gated; otherwise, spillway crest.
** Enlarged in 1950 from 68,000 to 144,000 acre-feet.

Note.--U.S.I.I.S. refers to United States Indian Irrigation Service.

PROPOSED IMPROVEMENTS AFFECTING THE PROBLEM

68. Three reservoirs of significance to the problems discussed in this report have been recommended by the United States Bureau of Reclamation as part of the central Arizona project now pending for consideration in Congress (see H. D. 136, 81st Cong., 1st sess.). Action by Congress on the project is being held in abeyance pending settlement in the Supreme Court of the controversy between the States of Arizona and California regarding rights to Colorado River water. Those reservoir units of the proposed central Arizona project that affect the problems considered in this report are described according to location in the following subparagraphs:

(a) Gila River Basin above Salt River.--Two multiple-purpose reservoirs, providing flood-control storage, have been proposed for construction upstream from the area under consideration, as follows: Buttes Reservoir on Gila River at river mile 287 and Charleston Reservoir on San Pedro River at river mile 121 (see pl. 2). In general, although the overall effect of the two reservoirs on the flood problems in the area under consideration in this report is small, some significant effects in that part downstream from the mouth of Salt River would result from the reservoirs during large floods originating from the Gila River Basin above Salt River. In the studies for this report, these two reservoirs have been assumed to be in operation.

(b) Salt River Basin.--The Bureau of Reclamation's proposed central Arizona project provides for the importation of water from the Colorado River to the Gila River Basin. A portion of this imported water, in excess of immediate demands, would be stored in a proposed reservoir to be constructed at the McDowell site on Salt River (see pl. 1). A capacity of 188,000 acre-feet, designated in this report as "terminal" storage, would be required under the proposed project to store the imported water. In addition to such terminal storage, the proposed project would provide for flood-control storage of 390,000 acre-feet, making a total proposed capacity for the McDowell Reservoir of 578,000 acre-feet. The McDowell Dam proposed by the Bureau of Reclamation in House Document 136, 81st Congress, 1st session, would be 126 feet in height. The dam, which would be of concrete slab-and-buttress construction with earthfill wings, would contain a power plant as an integral part of the dam with a capacity of 4,100 kilowatts. The estimated construction cost for the dam and reservoir based on July 1947 prices as shown in the document is $16,326,000. The estimated construction cost of the power plant on the same basis is $1,012,000. Consideration is given in this report to the need and justification for including additional capacity for flood-control storage in the proposed reservoir.

IMPROVEMENTS DESIRED

69. Public hearing.--A joint public hearing on flood control in the entire Gila River Basin was held at Phoenix, Ariz., on October 20, 1938, by the Departments of Army and Agriculture with the district engineer, United States Army Engineer District, Los Angeles, Calif., presiding. The hearing was attended by 114 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.

70. Improvements desired by local interests.--Information obtained at the public hearing indicated that local interests desire clearing and straightening the channels of Gila and Salt Rivers to prevent flood damage along those streams. Since the public hearing, local interests have expressed grave concern about the deteriorated condition of the channels of Gila and Salt Rivers.

71. Reasons advanced in justification of improvements desired.--Representatives of local interests stressed the necessity of flood control on Gila and Salt Rivers between Gillespie Dam and McDowell Dam site to (a) prevent flooding and inundation of rural and urban properties in the cities of Phoenix and Tempe, in the communities of South Phoenix and Liberty, and in the project lands of the Salt River Valley Water Users' Association, the Buckeye Irrigation District, the Arlington Irrigation District, and on other lands; (b) prevent erosion of land; (c) prevent damage to cropland because of interruption of irrigation; and (d) prevent interruption of railroad and highway communication and of utility services. Representatives of local interests also stressed that control of floods by clearing the channel would result in reducing the evapotranspiration losses from the growth within the channel and thereby would increase the safe yield of the ground-water supplies.

FLOOD PROBLEMS AND RELATED PROBLEMS

72. Flood problems.--Salt River below Granite Reef Dam and Gila River below the mouth of Salt River and above Gillespie Dam flow through developed commercial and agricultural areas that have been subjected to flooding by these streams in the past. The cities of Phoenix and Tempe and the communities of Lehi, South Phoenix, and Liberty are subject to inundation. The most noteworthy of past floods occurred in 1891, 1905, 1916, 1920, and 1938.

73. During the 1891 flood, floodwaters eroded the right bank of Salt River near 40th Street, Phoenix, and then following a course along Henshaw Road (one-half mile south of the Southern Pacific railroad) inundated the developed area south of that road. Although extensive regrading of the area has taken place in

connection with construction of the Sky Harbor Airport, a recurrence of such an overflow probably would take place on the occurrence of a flood approaching the magnitude of the standard project flood.

74. Reservoirs on Salt and Verde Rivers have impounded much of the floodflows of recent years. The total storage space provided amounts to about 2,000,000 acre-feet. Since water-conservation storage has been provided, some flood control has been gained, especially in years of low flow or in years immediately following a depleted water supply. However, because of the great need for stored water for irrigation and for power, all reservoirs are filled to maximum capacity whenever possible, thus eliminating most of the flood-control features.

75. Since most floodflows were reduced by storage, the combination of a comparatively dry river channel and a high water table has resulted in an infestation of water-loving plants (phreatophytes) that have achieved in some places almost maximum density. With the channel thus choked, the occurrence of even a small flood on Salt and Gila Rivers could result in serious damage to highly improved rural and urban areas.

76. Water-conservation problems.--Flood problems in the Gila River Basin are related closely to the problems of water conservation and water utilization. The construction of the existing water-conservation reservoirs on Salt and Verde Rivers has conserved for use most of the flow of these streams. However, because of the nature of the streamflow, utilization of the runoff is incomplete. During the calendar years 1923-57, about 3,200,000 acre-feet have spilled over Granite Reef Dam. This amount is about 10 percent of the undepleted flow at Granite Reef Dam. During this period, Horse Mesa, Mormon Flat, Stewart Mountain, Bartlett, and Horseshoe Dams were constructed. Studies by the United States Bureau of Reclamation indicate that if these reservoirs had been in operation during the entire period they would have conserved all Salt River flow and most of Verde River flow. The amount of water that would have spilled under existing conditions of development is estimated at 860,000 acre-feet for the 35-year period, or an average of about 25,000 acre-feet per year. This water would have come during four flood seasons--1927, 1932, 1937, and 1941. In order to conserve the flow, large holdover storage would be required with attendant severe evaporation rates.

77. Phreatophytic growths within the channel area transpire and evaporate tremendous amounts of water annually. According to the United States Geological Survey, the annual use of water per acre by plants in the channel area, assuming 100 percent density, is estimated as follows: Saltcedar, 7.2 acre-feet; cottonwood and willow, 6.0 acre-feet; baccharis, arrowweed, and miscellaneous brush, 4.7 acre-feet; and mesquite and paloverde, 3.3 acre-feet. The minimum average annual transpiration by phreatophytes from a 2,000-foot-wide channel extending from Gillespie Dam on Gila River to Granite Reef

Dam on Salt River during a 50-year period under present conditions of water use (assuming no importation of water from outside the drainage area of Gila River) is estimated by the United States Geological Survey at 22,000 acre-feet. (See Appendix 6: Use of Water by Phreatophytes in 2,000-foot Channel between Granite Reef and Gillespie Dams, Maricopa County, Ariz.) Such use reduces the available safe yield of the ground-water reservoir and may reduce the surface flow farther downstream.

78. Methods of improvement considered.--Optimum utilization of the water resources of Gila and Salt Rivers is of utmost importance. In the investigations covered in this report, consideration was given not only to flood problems but also to the need for more adequate water supply for irrigation use. The control of floods by channel improvements, levees, flood-control reservoirs, reservoirs for multiple-purpose use including flood control, and various combinations of these improvements was considered.

PLANS OF IMPROVEMENT CONSIDERED

79. General.--Preliminary studies were made of plans for flood control by means of channel improvements, levees, reservoirs for flood control alone and for multiple-purpose use, and by combinations of these methods. Channel improvements comprising (a) removal of phreatophyte growth from an appropriate floodway and (b) pilot-channel excavation in some reaches were considered for Salt and Gila Rivers from Granite Reef Dam to Gillespie Dam. Levees were considered for the urban area along Salt River from Tempe to Phoenix. Preliminary analysis of costs and benefits eliminated the necessity for detailed consideration of levee improvements along the remaining reaches of the river. An enlarged excavated channel was considered along Salt River from Tempe to Phoenix, but, because of the wide stream channel, the cost of an enlarged channel would greatly exceed the cost of levees in the same area. Excavation in that reach, in addition to that required to obtain fill material for a levee, is not justified.

80. Consideration was given to control by means of reservoirs. Investigations revealed no reservoir sites where storage (a) solely for flood control or for flood control and conservation of local flows originating in the Gila River Basin and (b) providing an adequate solution for the flood problems in the area could be economically justified. However, as discussed under the previous heading "Proposed Improvements Affecting the Problem," the United States Bureau of Reclamation has proposed construction of a reservoir principally for terminal storage at the McDowell site on Salt River. Preliminary analysis indicated that flood-control storage alone, water-conservation storage alone (for conservation of flows originating in the Salt River Basin), or the combination of flood-control and water-conservation storage at this site is unjustified. Consideration was therefore given to the justification of providing

flood-control storage or flood-control and water-conservation storage in addition to the storage required for a terminal reservoir.

81. Detailed consideration was given to three plans of improvement, as follows: (a) The recommended plan, which would provide for short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam; (b) a plan for short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam; and flood-control storage added to the proposed terminal-storage reservoir at the McDowell site; and (c) a plan for levees along Salt River between 27th Avenue, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam.

82. Short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam (recommended plan).-- The recommended plan provides for 3½ miles of levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam. As discussed under the subsequent heading "Benefits from prevention of flood damage," improvements under this plan would provide complete protection against the standard project flood for most of the city of Tempe and a part of the city of Phoenix, but only partial protection for an additional area in the city of Phoenix, for the adjacent developed areas, and for other areas along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam. The average annual damages prevented would be 34 percent of the total average annual damages in the area under consideration. The short levees would consist of (a) a levee along the left bank of Salt River for about 2,000 feet from Tempe Butte to the Southern Pacific railroad bridge embankment and (b) a levee along the right bank of Salt River for about 16,700 feet from the Southern Pacific railroad bridge embankment to 40th Street, Phoenix. Construction of the major part of the right-bank levee would consist of enlarging the existing canal levee and of placing rock facing. The right-bank levee would incorporate the existing Joint Head Dam. The levees would be compacted earthfill structures that would range in height from 7 to 22 feet above the natural ground and from 23 to 28 feet above streambed. Slopes on both sides of the levee would be 1 on 2. The width of crown would be 18 feet. The levees were designed to accommodate the standard project flood of 270,000 cubic feet per second (290,000 cubic feet per second at McDowell Dam site) with a minimum freeboard allowance of 3 feet. Computed velocities would, in general, vary from 8 to 12 feet per second. The river side of the levees would be revetted with rock facing 1.25 feet thick on a gravel filter blanket 6 inches thick. The levee revetment would extend to a minimum depth of 5 feet below the existing streambed. Two ramps over the right-bank levee would be provided - one at Delano Avenue and the other at 40th Street.

83. Channel improvements would consist of a cleared floodway and of low-flow channels. Detailed studies were made to determine the width of cleared channel that would give optimum flood-control benefits (see appendix 5). Agricultural development and the natural topography limit the maximum width to about 2,000 feet. Channel widths of 500, 1,000, 1,500, and 2,000 feet were considered and evaluated. As indicated in appendix 5, incremental flood-control benefits exceed the incremental costs for all incremental widths considered. Additional clearing might be justified by the additional savings of water; however, such clearing, if determined to be desirable on the basis of actual experiences in savings of water, could be accomplished by local interests at a later date. Therefore, on the basis of this study, the 2,000-foot-wide cleared channel was determined as the most desirable at this time.

84. A floodway 2,000 feet in width would be created by clearing river-bottom growth along Gila River from Gillespie Dam to the mouth of Salt River and along Salt River from its mouth to Granite Reef Dam. Two reaches of low-flow or pilot channels located within the cleared floodway, the first along Gila River from Gillespie Dam to a point about 1 mile downstream from the mouth of Agua Fria River and the second along Salt River upstream from the highway bridge at Tempe, would be included in the improvement. The low-flow channels would tend to direct flows to within the cleared floodway, and would thereby accomplish desired river rectification; above the Tempe bridge, the low-flow channel would improve flow conditions on the approach to that bridge.

85. The removal of phreatophytic growth within a 2,000-foot channel along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam will greatly decrease the use of water by transpiration. The United States Geological Survey (see appendix 6) has estimated that the water saved and salvageable in Maricopa County by the removal of phreatophytic growth from the channel would amount to about 75 percent of the total water transpired by the river-bottom growth. The full savings could be obtained only by adequate maintenance of the channel area. Applying the factor of 75 percent to 22,000 acre-feet (the estimated average annual transpiration over the next 50 years), the amount of water saved by clearing the phreatophytes would be 16,000 acre-feet annually. This estimate is conservative, because the computed basic figures for use of water represent minimum amounts.

86. Short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam; and flood-control storage added to the proposed terminal-storage reservoir at the McDowell site.--Consideration was given to the justification of providing flood-control storage in addition to the storage required for a terminal reservoir at the McDowell site. The Bureau of Reclamation had proposed in its report on the central Arizona project that 390,000 acre-feet of flood-control storage be allocated in addition to the

188,000 acre-feet required for terminal and dead storage. The total storage capacity of the reservoir considered by the Bureau would be 578,000 acre-feet. Review of the Bureau design indicated that changes would have to be made to pass the spillway design flood as computed by the Corps of Engineers. A higher dam and an expensive spillway in the channel section of the dam would be required. Additional investigations indicated that, by further increasing the height of the dam, use could be made of a saddle about 1 mile southeast of the left abutment. A detached spillway in this saddle area would result in a relatively inexpensive structure. The resultant cost estimate for the larger structure (with the detached spillway) was determined to be appreciably less than the Corps' cost estimate for the 578,000-acre-foot reservoir with the spillway in the dam. Further details on the estimated costs for the various sizes of reservoirs considered for the McDowell site are given in appendix 4. Because construction of a reservoir at the McDowell site is dependent upon the outcome and settlement in the Supreme Court of the controversy between the States of Arizona and California regarding rights to Colorado River water and because predicting the outcome of the litigation is impracticable at this time, storage in a reservoir at the McDowell site was considered only as a supplement to the improvements under the recommended plan.

87. This plan provides for (a) short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; (b) channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam; and (c) 672,000 acre-feet of flood-control storage space added to the proposed terminal-storage reservoir at the McDowell site. Nearly all damages caused by the standard project flood along Salt River would be prevented by the construction of the improvements under this plan. Relatively minor damages along Salt River would still occur to property located in and immediately adjacent to the river channel. Downstream from the mouth of Salt River, partial flood protection would result. In addition to the flood control provided by the channel improvements, control of large floods originating in the Salt River Basin would be effected by reducing discharges to 82,000 cubic feet per second. Under average conditions, as a result of control effected by McDowell Reservoir, a flood of 320,000 cubic feet per second (at Painted Rock Dam site) would be reduced to a peak discharge of 170,000 cubic feet per second. Floods smaller than 82,000 cubic feet per second would not be affected by the operation of McDowell Reservoir. The average annual damages prevented by this plan would be 86 percent of the total average annual damages in the area under consideration.

88. The first two parts of the plan would be the same as under the recommended plan. The multiple-purpose dam would be an earthfill structure 169 feet high above streambed. The crest of the dam (elevation 1,494) would be about 5,180 feet long. A concrete overflow spillway structure 1,100 feet long would be located in a saddle about 1 mile southeast of the left abutment of the dam. At maximum water surface, elevation 1,486, the spillway would have a capacity of 288,000

cubic feet per second. The reservoir, at spillway crest elevation 1,470, would have an area of 15,200 acres and a capacity of 860,000 acre-feet. Allocation of storage space would be 46,000 acre-feet for sediment and dead storage, 142,000 acre-feet for terminal storage, and 672,000 acre-feet for flood control. The reservoir would be designed to reduce the standard project flood of 290,000 cubic feet per second to a maximum outflow of 82,000 cubic feet per second. Construction of the multiple-purpose reservoir with a capacity of 860,000 acre-feet would result in the flooding of the power plant at Stewart Mountain Dam. This power plant, operated by the Salt River Valley Water Users' Association, has a capacity of 10,400 kilowatts. Information obtained from the Bureau of Reclamation indicates that because of the diversion of Salt River flow from Sahuaro Lake, above Stewart Mountain Dam, to lands along Gila River, as proposed in the Bureau's report on the central Arizona project, it may be impractical to continue operating the Stewart Mountain power plant. Protection of the Stewart Mountain power plant therefore was not provided for in the design of the larger McDowell Reservoir described above.

89. Because available information indicates that water conservation cannot be justified at this time at McDowell Reservoir except as an addition to its use for terminal storage, detailed consideration was not given to the amount of conservation storage that might be provided under the plans considered. The Bureau of Reclamation in its report on the central Arizona project recommended the enlargement of Horseshoe Reservoir on Verde River from 68,000 acre-feet to 298,000 acre-feet. Since the preparation of that report, local interests have enlarged Horseshoe Reservoir to 144,000 acre-feet. Under these conditions, further enlargement of Horseshoe Reservoir might not be feasible. Therefore, consideration should be given to inclusion of water-conservation storage at McDowell terminal reservoir in the preparation of detailed plans prior to its construction.

90. Levees along Salt River between 27th Avenue, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam.--This plan provides for the construction of 20 miles of levees on Salt River, 10 miles on each bank. The improvements would provide complete flood protection against the standard project flood to developed areas in and adjacent to Phoenix and Tempe and partial flood protection similar to that under the recommended plan to other areas along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam. The annual damages prevented would be 60 percent of the total average annual damage in the area under consideration. The levees along Salt River would consist of (a) a levee on the left bank of Salt River for about 10 miles from Tempe Butte to 27th Avenue, Phoenix, and (b) a levee along the right bank of Salt River for about 10 miles from the Southern Pacific railroad bridge embankment at Tempe to 27th Avenue, Phoenix. The levees were designed to accommodate the standard project flood. The structural design of the levees would be similar to that under the recommended plan. The channel improvements would be the same as under the recommended plan.

RECREATIONAL DEVELOPMENT

91. Existing reservoirs behind Roosevelt, Horse Mesa, Mormon Flat, and Stewart Mountain Dams on Salt River are used extensively for boating, fishing, and picnicking. These reservoirs are operated for water conservation and water power and provide relatively stable pools. The proposed terminal-storage reservoir at the McDowell site would probably include some provision for recreational use. The extent of development would depend on the stability of the reservoir elevation.

92. Consideration was given to the possibilities of recreational development that might result from the addition of flood-control storage space at the McDowell Reservoir site. Although a large amount of storage would be allocated for flood-control use, the method of operation of the flood-control storage space precludes the use of that part of the reservoir for recreational purposes on an extensive scale. Any lake formed as a result of the flood-control storage at the reservoir would be temporary; the flood-control operation would provide for the emptying of the flood-control pool as fast as possible. The area of the flood-control pool normally would consist of mud flats that would become barren wastes during dry periods. Plans for flood-control storage at the McDowell Reservoir site therefore did not include any provision for recreational development. However, a favorable year-round climate and the scenic background of the dam and reservoir and its proximity to the centers of population in Arizona would contribute to the value of any recreational features that might be incorporated in the final plans for McDowell Reservoir.

ESTIMATES OF FIRST COST

93. The estimated first costs of the considered projects comprise expenditures for making preauthorization studies; for construction (including clearing river-bottom growth); and for relocating highways and utilities and purchasing rights-of-way. Estimates of cost are based on price levels for October 1957. Allowances are made for engineering, overhead, inspection, and contingencies.

94. Three methods of destroying phreatophytes, principally saltcedar, were considered: (a) Burning, (b) chemical treatment, and (c) mechanical means (see appendix 3). Numerous experiments are now being conducted by Federal, State, and local interests 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.

95. Details of the estimated first costs of the recommended plan are given in Appendix 4: Cost estimates. The following table summarizes the estimated first costs of the improvements considered:

Summary of estimated first costs, plans considered, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona (based on prices for October 1957)

Plan	Estimated first cost	
	Subtotal	Total
RECOMMENDED PLAN		
Short levees and channel improvements:		
Levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe		$1,240,000
Channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam		2,330,000
Total		3,570,000
OTHER PLANS CONSIDERED		
Short levees, channel improvements, and storage space in McDowell Reservoir:		
Levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe		1,240,000
Channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam		2,330,000
McDowell Reservoir:		
Multiple-purpose (terminal storage and flood control)	*$30,300,000	
Terminal storage	**-24,600,000	
Cost of flood-control storage		5,700,000
Total cost of flood control		9,270,000
Long levees and channel improvements:		
Levees along Salt River between 27th Avenue, Phoenix, and Tempe Butte, Tempe		8,660,000
Channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam		2,330,000
Total		10,990,000

* Estimated cost of reservoir with capacity of 860,000 acre-feet, based on earthfill dam and detached spillway.

** Estimated cost of reservoir with capacity of 188,000 acre-feet, based on earth dam with concrete spillway in the dam.

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ESTIMATES OF ANNUAL CHARGES

96. The estimate of annual charges for each plan of improvement comprises interest on the total investment, amortization of the total investment in 50 years, and average annual costs of maintenance and operation. The construction period of McDowell Reservoir for multiple-purpose storage or for terminal storage is estimated at 3 years; interest during construction was therefore computed. The construction period for the short levees would be less than 1 year; interest during construction would not be charged against that part of the plan. Because benefits from construction of the channel improvements and the levees between 27th Avenue, Phoenix, and Tempe Butte, Tempe, would accrue as the work proceeds, interest would not be charged. The entire first cost of the flood-control storage in the multiple-purpose reservoir would be borne by the United States. For the levees and for the channel improvements, the cost of construction and the cost of preauthorization studies would be borne by the United States, although local interests would repay that portion of the construction cost that is allocated to water conservation. The cost of highway and utility relocations, 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, recommended plan, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona (based on prices for October 1957)

(a)	Federal investment:	
	(1) Short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe.....	$1,170,000
	(2) Channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam.....	2,190,000
	(3) Total Federal first cost and total Federal investment.....	3,360,000
(b)	Federal annual charges:	
	(1) Interest, 2.5 percent on item (a) (3)..	84,000
	(2) Amortization of Federal investment in 50 years at 2.5 percent, 0.01026 times item (a) (3).....	34,500
	(3) Total Federal annual charges.....	118,500

Estimated first cost and annual charges, recommended plan, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona (based on prices for October 1957)--Continued

(c) Non-Federal investment:	
(1) Rights-of-way and highway and utility relocations for short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe	$70,000
(2) Rights-of-way and highway and utility relocations for channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam	140,000
(3) Total non-Federal first cost and total non-Federal investment	210,000
(d) Non-Federal annual charges:	
(1) Interest, 2.5 percent on item (c) (3)	5,200
(2) Amortization of non-Federal investment in 50 years at 2.5 percent, 0.01026 times item (c) (3)	2,200
(3) Maintenance and operation (average annual):	
Short levees	5,000
Channel improvements	48,000
(4) Total non-Federal annual charges	60,400
(e) Total annual charges:	
(1) Federal	118,500
(2) Non-Federal	60,400
Total annual charges	178,900

97. For the purpose of comparing the three plans of improvement considered in detail and of selecting the best plan, annual charges were computed. A summary of annual charges for each plan is given in the following table:

Summary of annual charges, plans considered, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona

Plan	Annual charges
RECOMMENDED PLAN	
Short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam..	$178,900
OTHER PLANS CONSIDERED	
Short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam; and flood-control storage added to the proposed terminal-storage reservoir at the McDowell site.....	382,400
Levee along Salt River between 27th Avenue, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam.....	477,500

ESTIMATES OF BENEFITS

98. Tangible benefits.--Tangible primary benefits from plans of improvement considered in detail would result from prevention of primary (direct and indirect) flood damage and from reduction of water losses resulting from transpiration of river-bottom growth. Such secondary benefits as may exist are small and have not been included in the evaluation of the project. Consideration of the benefits from construction of McDowell multiple-purpose reservoir was restricted to the benefits from the addition of flood-control storage to a terminal reservoir at the site. No evaluation was made of the benefits from construction of the terminal-storage feature. Although power facilities probably would be constructed at McDowell Reservoir in connection with the terminal storage, the addition of flood-control storage space would not appreciably increase the amount of power generated. The rapid drawdown of the flood-control storage would preclude the generation of power from this source.

99. No appreciable benefits would result from increased or higher property utilization made possible through provision of flood protection. The acute shortage of water in the area would preclude

any appreciable increased agricultural utilization of property. In addition, other development of the flood plain in the Phoenix and Tempe area is proceeding in spite of the existing flood hazard.

100. A detailed analysis of benefits from the plans of improvement under consideration is given in Appendix 5: Benefits from improvements. A brief description of benefits under the recommended plan is given in the following paragraphs. A summary of the estimated benefits that would accrue from the three plans of improvement considered in detail is given in a subsequent table.

101. Benefits from prevention of flood damage.--The levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe, and the channel improvement would provide complete protection against the standard project flood to most of the city of Tempe and a part of the city of Phoenix, but only partial protection for an additional area in the city of Phoenix and the adjacent commercial and agricultural area. Low-lying lands downstream from the levees would still be subject to inundation. However, a breakthrough similar to the one that occurred during the flood of 1891 would be prevented. In addition, damage to most of the Sky Harbor Airport, to the Grand canal, and to the cooling system of the Cross-Cut power plant would also be prevented.

102. Construction of channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam would provide partial flood control to additional property along Gila and Salt Rivers 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. The average water-surface elevation of the standard project flood along Gila River from Gillespie Dam to the mouth of Salt River would be reduced by about 3½ feet. Reductions would range, depending on location, from 1½ feet to 5½ feet. Nondamaging discharges in this reach would be increased from about 20,000 cubic feet per second (a discharge that would be equaled or exceeded about once in 3 years) to about 40,000 cubic feet per second (a discharge that would be equaled or exceeded about once in 5 years). As indicated in the previous paragraph, "Damages from future floods - average future conditions," the stream channel along the Salt River is relatively clear at present. However, on the occurrence of a wet cycle or of spills over Stewart Mountain or Bartlett Dams, phreatophytes will reoccur and would probably create a serious flood problem. The proposed clearing program would prevent the recurrence of this phreatophytic growth and would thereby prevent those damages that would occur under average future conditions as a result of the deteriorated channel condition. Analyses of the effect of clearing along the Salt River were based on detailed studies along the Gila River. It is not expected that phreatophytic growth along the Salt River would be as severe as along the Gila River. As a result of construction of the proposed channel improvements along the Salt River, the average water-surface elevation of the standard project flood along the Salt River from Granite Reef Dam to the mouth would be reduced under average future conditions by about ½ foot. Reductions would range, depending on location, from 0.2 foot to 2 feet. Nondamaging discharges in this reach would be increased

about 10 percent, from about 50,000 cubic feet per second to 55,000 cubic feet per second. The average annual flood-control benefits from construction of the recommended plan are estimated at $226,000.

103. Benefits from water conservation.--The clearing of phreatophytes from a 2,000-foot channel along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam would result in a savings of a minimum of 16,000 acre-feet of water annually. Conservation of the water resources of the area is essential in order to sustain land already under cultivation. In accordance with the recommendation of the Federal Inter-Agency River Basin Committee's report titled "Proposed Practices for Economic Analysis of River Basin Projects," dated May 1950, the net primary benefits from water conservation are evaluated in this report on the basis of such increase in production of irrigated crops as would result from construction of the project. This increase in production would result from construction of the project and also from the application of associated resources. Thus, the net benefit from water conservation would be the difference between the gross crop return to the farmer and the associated farm costs, which would include operating costs for production, interest on investment, maintenance and depreciation of equipment, property taxes, and management costs. After considering all the above factors, the value of water conserved by the elimination of transpiration losses from phreatophytes is estimated at $8 per acre-foot (see appendix 5). The average annual primary benefits from the conservation of a minimum of 16,000 acre-feet of water are estimated at $128,000.

104. Intangible benefits.--Many benefits not susceptible of monetary evaluation would accrue from the improvements considered in this report. Control of floods would save lives that might otherwise be lost by drowning and would reduce health hazards such as water-supply pollution resulting from overflow of sanitary facilities. Flood control would reduce the danger of temporary isolation of communities and would lessen the interference by floods with normal home and social life, public affairs, business transactions, and industrial activity. The safeguarding of the city of Tempe from all floods up to the standard project flood in magnitude and the prevention of a breakthrough into Phoenix similar to the one that flooded Phoenix in 1891 would result in large intangible benefits. The prevention of damage to the Grand canal of the Salt River project and the prevention of damage to the cooling system of the Cross-Cut power plant would result in large intangible benefits from prevention of interruption of irrigation to lands served by the Grand canal and the prevention of interruption of the power plant. Removal of the phreatophytes would improve flow conditions in the river channel and would thereby improve drainage conditions, especially in Buckeye and Arlington Valleys. Such benefits are considered intangible.

105. Intangible benefits from water conservation would include (a) stabilization of property values by partially alleviating the existing water shortage and (b) general improvement in the long-term social and economic welfare. The effect on the nation of the increased production of agricultural products is also considered an intangible benefit.

106. Summary of benefits.--The estimated annual benefits that would accrue from construction of improvements under the plans considered are summarized in the following table:

Estimated average annual benefits from plans considered, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona

Plan	Average annual tangible primary benefits			Intangible benefits
	Flood damages prevented	Water conservation	Total	
RECOMMENDED PLAN				
Short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam.	$226,000	$128,000	$354,000	Large.
OTHER PLANS CONSIDERED				
Short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam; and flood-control storage added to the proposed terminal-storage reservoir at the McDowell site.	595,000	128,000	723,000	Do.
Levees along Salt River between 27th Avenue, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam.	397,000	128,000	525,000	Do.

COMPARISON OF BENEFITS AND COSTS

107. Justification of improvements considered.--The recommended plan of improvement provides for short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam. The first cost of the improvements is estimated at $3,570,000 (October 1957), and the average annual charges, $178,900. The total average annual primary benefits are estimated at $354,000, including $226,000 for flood control and $128,000 for water conservation. The ratio of average annual primary benefits to average annual costs would be 1.98 to 1. Accordingly, the improvements are justified. The large intangible benefits previously discussed add support to this conclusion. A summary of the estimated costs, benefits, and economic ratios for all plans considered in detail is given in the following table:

Summary of economics of plans considered, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona

Plan	Total first cost (October 1957)	Average annual charges	Average annual tangible primary benefits	Benefit-cost ratio	Intangible benefits
RECOMMENDED PLAN					
Short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam.	$3,570,000	$178,900	$354,000	1.98	Large.
OTHER PLANS CONSIDERED					
Short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam; and flood-control storage added to the proposed terminal-storage reservoir at the McDowell site.					
Total amount	9,270,000	382,400	723,000		
Amount incremented to recommended plan	5,700,000	203,500	369,000	1.81	Do.
Levees along Salt River between 27th Avenue, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam.					
Total amount	10,990,000	477,500	525,000		
Amount incremented to recommended plan	7,420,000	298,600	171,000	0.57	Do.

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108. Comparison of plans.--The recommended plan providing for short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe, and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam is the best plan with a benefit-cost ratio of 1.98 to 1. Although the addition to the recommended plan of flood-control storage at a terminal reservoir at the McDowell site is justified as computed, the plan providing for this addition cannot be further considered until terminal storage is provided at the McDowell site. The report of the United States Bureau of Reclamation on the central Arizona project, which includes the recommendation for construction of the terminal-storage reservoir, was transmitted to Congress, but decision on the project has been held in abeyance pending settlement in the Supreme Court of the controversy between the States of Arizona and California regarding rights to Colorado River water. At the present time, no basis exists for determination of the outcome of the controversy. However, the plan for multiple-purpose utilization of the McDowell Reservoir site has value in future planning for the development of the water resources of the area. Levees along the Salt River between 27th Avenue, Phoenix, and Tempe Butte, Tempe, although providing nearly complete protection to Tempe, Phoenix, South Phoenix, and adjacent commercial areas, are not justified at the present time.

ALLOCATION OF COSTS

109. The separable costs-remaining benefits method was used in arriving at an equitable distribution of costs between flood control and water conservation. The recommended levees and low-flow channels would provide flood-control benefits only, whereas recommended channel clearing would provide flood-control and water-conservation benefits. The following table summarizes the results of using the separable costs-remaining benefits 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 7: Allocation of Costs.

Allocation of first costs, recommended plan of improvement, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona (based on October 1957 prices)

Item	Flood control	Water conservation	Total
First cost:			
Construction	$2,475,000	*$825,000	$3,300,000
Preauthorization studies	45,000	15,000	60,000
Rights-of-way and highway and utility relocations	157,000	53,000	210,000
Total	2,677,000	893,000	3,570,000

* On the basis of October 1957 prices, allocation of construction costs to water conservation amounts to 25 percent of the construction cost of $3,300,000, which includes all planning and design costs subsequent to authorization.

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110. In accordance with the general policies expressed in acts of Congress, the cost of the construction items allocated to flood control would be borne by the United States; and the cost of all highway and utility relocations, the cost of all lands, easements, and rights-of-way, and the cost of all maintenance and operation would be borne by local interests. The costs of all preauthorization studies are considered in this report to be nonreimbursable and thus would be borne by the United States.

111. 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. Local interests have agreed to enter into a contract with the United States for repayment of the construction costs allocated to water conservation, such costs to be repaid without interest, in 40 equal annual payments.

112. The recommended levee and channel-improvements works would be constructed by the United States at an estimated construction cost of $3,300,000, based on price levels prevailing in October 1957, subject to reimbursement by local interests, in consideration of water-conservation benefits, of 25 percent of the total construction cost in 40 equal annual payments without interest. On the basis of October 1957 prices, the estimated amount of $825,000 would be repaid in 40 equal annual payments of $20,625. The allocations and repayments would be adjusted on the basis of actual construction costs.

113. On the foregoing basis, local interests would (a) provide all rights-of-way and pay for the cost of all necessary highway and utility relocations; (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 portion of the project construction cost that is allocated to water conservation.

114. Federal laws that permit interest-free repayments of costs allocated to water conservation generally require that individual ownership of lands benefiting from irrigation projects constructed under these laws be limited to 160 acres. However, the project, as proposed, involves the salvage of water presently used nonbeneficially by river-bottom growth. The water conserved would not be delivered to any individual, group, or irrigation district - but would be made available to the ground-water basin to be used by all farmers who pump water from the underground. The ground-water basin benefited is not a closed basin, but underlies nearly all the irrigated land in Maricopa County. The Board of Supervisors of Maricopa County has recognized the general benefit to the county that would result from the salvage of water and has passed a resolution sponsoring the project, and has agreed to repay all costs allocated to irrigation. The district engineer is of the opinion that the 160-acre limitation should not be applied to the project because (a) the water salvaged

would accrue to the ground-water basin and could only be obtained by pumping and (b) the benefits of the salvaged water could not be limited to any individual group or irrigation district.

PROPOSED LOCAL COOPERATION

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

(a) Pay for the cost of highway and utility relocation and provide necessary lands, easements, and rights-of-way at a cost estimated at $210,000 (October 1957);

(b) Maintain and operate the levee and channel improvements in accordance with regulations to be prescribed by the Secretary of the Army at an average annual cost estimated at $53,000;

(c) Keep the flood channel of the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam free from encroachment;

(d) In consideration of water-conservation benefits, reimburse the United States an amount equal to 25 percent of the total construction cost in 40 equal annual payments without interest. On the basis of October 1957 prices, the estimated amount of $825,000 would be repaid in 40 equal annual payments of $20,625. The allocations and repayments would be adjusted on the basis of actual construction costs. Annual payments will be made to the Secretary of the Interior who, in turn, will 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.

116. The Board of Supervisors, Maricopa County, Ariz., has expressed willingness to participate in a flood-control project consisting of levees, channel rectification, and channel clearing along the Gila and Salt Rivers. The Board has agreed by resolution (see appendix 8) to cooperate with the Federal Government by paying the local interests' share of the costs of the project and by meeting other requirements of local cooperation.

COORDINATION WITH OTHER AGENCIES

117. Conferences on the related problems of flood control and water conservation along the Gila and Salt Rivers from Gillespie Dam to McDowell Dam site have been held with representatives of the United

States Bureau of Reclamation. In general, agreement was reached on the existing need for flood control and water conservation in the area. Both agencies agree that flood-control storage should be included in a reservoir at the McDowell site when a reservoir for terminal storage at the site is authorized and approved for construction by Congress. The evaluation of water-conservation benefits from construction of the recommended plan of improvement was worked out jointly between representatives of the Corps of Engineers and the Bureau of Reclamation. The proposed allocation of costs and the proposed repayment of those costs allocated to water conservation was discussed with representatives of the Bureau. Those representatives were in accord with the recommendations of the Corps of Engineers.

118. Conferences were held with representatives of the United States Department of Agriculture to correlate their plans with plans developed by the Corps of Engineers. A study of the use of water by phreatophytes in a 2,000-foot channel between Granite Reef and Gillespie Dams, Ariz., was made by the United States Geological Survey upon the request of the Corps of Engineers (see appendix 6).

119. In a letter dated April 13, 1951, the regional director, Region 2, of the Fish and Wildlife Service indicated that construction of the levee and channel improvements along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam would have little effect upon the fish and wildlife values in the project area (see Appendix 9: Comments of other agencies).

120. Conferences were also held with representatives of local agencies, including the Salt River Valley Water Users' Association and the Buckeye Water Conservation and Drainage District. Comments on this report were received from all other Federal agencies having an interest in water-resource development and from the States of Arizona and California (see appendix 9). Plans for the recommended improvement do not conflict with plans of other Federal and non-Federal agencies.

DISCUSSION

121. 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 Salt River Valley between McDowell Dam site and the mouth of Salt River and the Gila River Valley from the mouth of Salt River to Gillespie Dam. The drainage area of Salt River at the McDowell Dam site is 12,900 square miles and of Gila River at Gillespie Dam is 49,600 square miles. The Gila River rises on the west slope of the Continental Divide in southwest New Mexico and flows generally westward about 650 miles to the Colorado River.

122. The principal tributaries that join the main stream in the area under consideration in this report include, in downstream order, Salt, Agua Fria, and Hassayampa Rivers, and Centennial Wash. In general, stream slopes are not excessive. The average slope of the

Salt River from McDowell Dam site to its junction with the Gila River is about 9 feet per mile; the average slope of the Gila River from Salt River to Gillespie Dam is about 5.5 feet per mile.

123. The area affected by improvements considered in this report lies entirely in and includes most of Maricopa County, Ariz., one of the most rapidly growing areas in the United States. According to the United States census, the population of Maricopa County increased from 186,000 in 1940 to 332,000 in 1950. A local agency estimates the 1957 population of the county at 550,000. Several cities, including Phoenix, the capital and largest city of Arizona, are affected by the improvements considered. The 1950 populations of these cities are: Phoenix, 106,818; Mesa, 16,790; Glendale, 8,179; Tempe, 7,684; Chandler, 3,799; and Tolleson, 3,042.

124. The principal activities in the area under consideration are agriculture and stock raising. About 300,000 acres were irrigated in the area in 1956, providing an annual gross crop value of about $85,000,000. The city of Phoenix is the trade and service center for most of Arizona. The estimated value of retail sales in Maricopa County in 1956 was $705,000,000, which was over 50 percent of the State total. The agricultural economy of the valleys along the Salt and Gila Rivers is well stabilized. The area is adapted to a wide range of agricultural crops. Principal crops include alfalfa, barley, cotton, and truck crops. Many acres are double-cropped. Agriculture is entirely dependent on irrigation. Irrigation water is obtained by surface diversions and by pumping from the underground.

125. Measurement and estimates of floods of record are available for the period 1888 to date. Large floods during this period occurred in 1891, 1905, 1916, 1920, and 1938. The greatest flood of record occurred in February 1891; the peak discharge of Salt River downstream from the mouth of Verde River was estimated at 300,000 cubic feet per second. Major floods result from winter storms over the Gila River Basin. Available data on damages from past floods are incomplete. The flood of February 1920 caused an estimated damage of $300,000 to Salt River project lands. Since 1910, eight storage reservoirs for water conservation and power have been constructed on the Gila River and its tributaries upstream from Gillespie Dam. Their combined capacity is about 3,500,000 acre-feet. Since this water-conservation storage has been provided, some incidental flood control has been gained, especially immediately following a period of depleted water supply. However, because of the great need for water for irrigation and power, all reservoirs are filled to maximum capacity whenever possible, thus eliminating at that time most of the flood-control features.

126. Salt River downstream from Granite Reef Dam and Gila River downstream from the mouth of Salt River to Gillespie Dam flow through developed commercial and agricultural areas. The cities of Phoenix and Tempe and the communities of Lehi, South Phoenix, and Liberty are subject to inundation. Because most floodflows were curtailed

through storage, the combination of a comparatively dry river channel and a high water table has provided opportunity for an infestation of water-loving plants (phreatophytes) that in some places grow to almost maximum density. With the channel thus choked, the occurrence of even a small flood on the Salt and Gila Rivers could result in serious damage to highly improved rural and urban areas.

127. Flood problems in the Gila River Basin are related closely to the problems of water conservation and water utilization. The construction of the existing water-conservation reservoirs on the Salt and Verde Rivers has conserved for use most of the flow of these streams. However, because of the nature of the streamflow, utilization of the runoff is incomplete. The volume that would have spilled from existing reservoirs during the period 1923 to 1957 is estimated at 860,000 acre-feet; and all of it would have occurred during the four flood seasons 1927, 1932, 1937, and 1941. In order to conserve this flow, a large holdover storage capacity would need to be provided, with attendant severe evaporation losses. Phreatophyte growths within the channel area transpire tremendous amounts of water annually. The minimum average annual transpiration from a 2,000-foot-wide channel from Gillespie Dam on the Gila River to Granite Reef Dam on the Salt River during a 50-year period, under present conditions of water use (assuming no importation of water from outside the drainage area of the Gila River), is estimated by the United States Geological Survey at 22,000 acre-feet at least.

128. Preliminary studies were made of plans for flood control by channel improvements, levees, flood-control reservoirs, and multiple-purpose reservoirs. Construction of a terminal-storage reservoir at the McDowell site on the Salt River has been recommended by the United States Bureau of Reclamation as a part of the proposed central Arizona project. Preliminary analyses indicated that flood control alone, water conservation alone, or the combination of flood control and water conservation at this site is unjustified. Consideration was therefore given to the justification of providing flood-control storage or flood-control and water-conservation storage in addition to the storage required for a terminal reservoir.

129. Detailed consideration was given to three plans of improvement, as follows: (a) The recommended plan, which would provide for short levees along the Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; and channel improvements along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam; (b) a plan for short levees along the Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; channel improvements along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam; and flood-control storage added to the proposed terminal-storage reservoir at the McDowell site; and (c) a plan for levees along the Salt River between 27th Avenue, Phoenix, and Tempe Butte, Tempe; and channel improvements along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam.

130. Levees along the Salt River between 27th Avenue, Phoenix, and Tempe Butte, Tempe, would prevent nearly all damages to the city of Phoenix, the city of Tempe, the community of South Phoenix, the commercial area between the Phoenix city limits and the Salt River, and the agricultural area on both sides of the Salt River between Tempe and Phoenix. However, such levees were found to be unjustified at this time. Consideration was therefore given to a short levee system from 40th Street, Phoenix to Tempe. These levees would provide only partial protection to the city of Phoenix and adjacent commercial and agricultural areas by preventing a recurrence of a breakthrough similar to the one that occurred during the flood of 1891.

131. Consideration was also given to adding flood-control storage to the proposed terminal-storage reservoir at the McDowell site. The addition of flood-control storage to a terminal-storage reservoir at the McDowell site was found to be justified. However, the study was based on the assumption that provisions for terminal storage at the McDowell site would be required as a part of the central Arizona project recommended by the United States Bureau of Reclamation. The report on the central Arizona project was transmitted to Congress, but decision on the project has been held in abeyance pending settlement in the Supreme Court of the controversy between the States of Arizona and California regarding rights to Colorado River water. At the present time, no basis exists for determination of the outcome of the controversy. However, the plan for multiple-purpose utilization of the McDowell Reservoir site has value in future planning for the development of the water resources of the area.

132. Under the recommended plan of improvement, complete protection against the standard project flood would be provided to most of the city of Tempe and a part of the city of Phoenix, but only partial protection for (a) an additional area in the city of Phoenix and the adjacent commercial and agricultural area, and (b) additional property along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam. In addition, a minimum of about 16,000 acre-feet of water would be saved annually by the clearing of the phreatophytic growth.

133. The total first cost of the improvements under the recommended plan is estimated at $3,570,000 (October 1957), comprising $1,240,000 for the short levees and $2,330,000 for the channel improvements. Annual charges for maintenance and operation are estimated at $53,000. The total annual charges under the recommended plan would be $178,900.

134. For the recommended plan, the average annual tangible benefits from flood control are estimated at $226,000 and the average annual tangible benefits from water conservation, at $128,000. The total average annual tangible benefits therefore would be $354,000. The resultant benefit-cost ratio would be 1.98 to 1. In addition, the intangible benefits from flood control would include (a) prevention of loss of life; (b) prevention of interruption of

home life, public affairs, business transactions, and industrial activity; and (c) improvement of drainage conditions. Intangible benefits from water conservation would include a stabilization of property values by partially alleviating the existing water shortage and a general improvement in the long-term social and economic welfare. The project is justified.

135. 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 the general policies expressed in acts of Congress. Under this apportionment, local interests would repay, to the United States, 25 percent of the total construction cost in 40 equal annual payments without interest. Based on the present (October 1957) estimated construction cost for the project of $3,300,000, the total local reimbursement in consideration of water-conservation benefits would amount to $825,000 and the annual payments by local interests for the 40-year period would amount to $20,625. The actual 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) pay for the cost of highway and utility relocations and provide necessary lands, easements, and rights-of-way at a cost estimated at $210,000 (October 1957), and (b) maintain and operate the completed project at an average annual cost estimated at $53,000. Because of the special circumstances wherein the water-conservation benefits would be realized, the district engineer is of the opinion that the 160-acre limitation should not be applied as a prerequisite for this project's qualifying for interest-free funds.

136. The plans of improvement and the general requirements of cooperation were discussed with local interests. The Board of Supervisors of Maricopa County, Ariz., has expressed its willingness to participate in the costs of the project and in meeting other items of local cooperation.

CONCLUSIONS

137. The district engineer concludes that:

(a) A flood menace exists along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam.

(b) River-bottom growth within the channels of the Gila and Salt Rivers is a major flood hazard and transpires large amounts of water annually.

(c) Complete protection to most of Tempe against the standard project flood, partial protection to Phoenix and the adjacent commercial and agricultural areas, and partial protection to other

areas along the Gila and Salt Rivers between Gillespie Dam and Granite Reef Dam can be provided by construction of short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe, and channel improvements along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam.

(d) The proposed improvement would result in the salvage of at least 16,000 acre-feet of water annually, which would be available for beneficial use. To assure this saving, adequate maintenance would be required.

(e) 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.

(f) The total first cost of the proposed improvement would be $3,570,000 (October 1957), and the total annual charges would be $178,900. The average annual tangible benefits from this improvement would be $354,000.

(g) The ratio of tangible benefits to cost would be 1.98 to 1. The proposed project is feasible from an engineering standpoint and is well justified by the tangible and intangible benefits.

(h) The inclusion of sufficient flood-control space in a reservoir at the McDowell site to control the standard project flood would be justified in conjunction with development at that site of the terminal storage for the reclamation project proposed in House Document 136, 81st Congress, 1st session. Such flood-control space would be a desirable supplement to the above levee-and-channel improvement plan in order to insure an adequate degree of flood protection in the future for the rapidly growing urban area in the vicinity of Phoenix.

RECOMMENDATIONS

138. The district engineer recommends:

(a) That the United States adopt a flood-control and water-conservation project for the construction of short levees along the Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe, and channel improvements along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam at a total first cost estimated at $3,570,000 (October 1957), of which $60,000 have been expended on preauthorization studies, and an average annual maintenance and operation cost estimated at $53,000.

(b) That the Corps of Engineers, United States Army, construct the levee and channel improvements at a Federal construction cost estimated at $3,300,000 (October 1957) subject to the condition that local interests furnish assurances satisfactory to the Secretary of the Army that they will (1) pay for the cost of highway and utility

relocations and provide necessary lands, easements, and rights-of-way at a cost estimated at $210,000 (October 1957); (2) maintain and operate the levee and channel improvements in accordance with regulations to be prescribed by the Secretary of the Army at an average annual cost estimated at $53,000; (3) keep the flood channel of the Gila and Salt Rivers free from encroachment; (4) repay, to the United States, 25 percent of the total construction cost in 40 equal annual payments without interest (the exact amount of the annual payments, presently estimated at $20,625, 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, will deposit such funds in the Treasury of the United States as miscellaneous receipts); (5) hold and save the United States free from all damages arising from construction and operation of the work; and (6) adjust all water-rights claims resulting from construction, operation, and maintenance of the improvements.

(c) That, because of the special circumstances wherein the water-conservation benefits would be realized, the 160-acre limitation on ownership of lands benefiting from the water-conservation features of the project should not be applied as a prerequisite for this project's qualifying for interest-free funds.

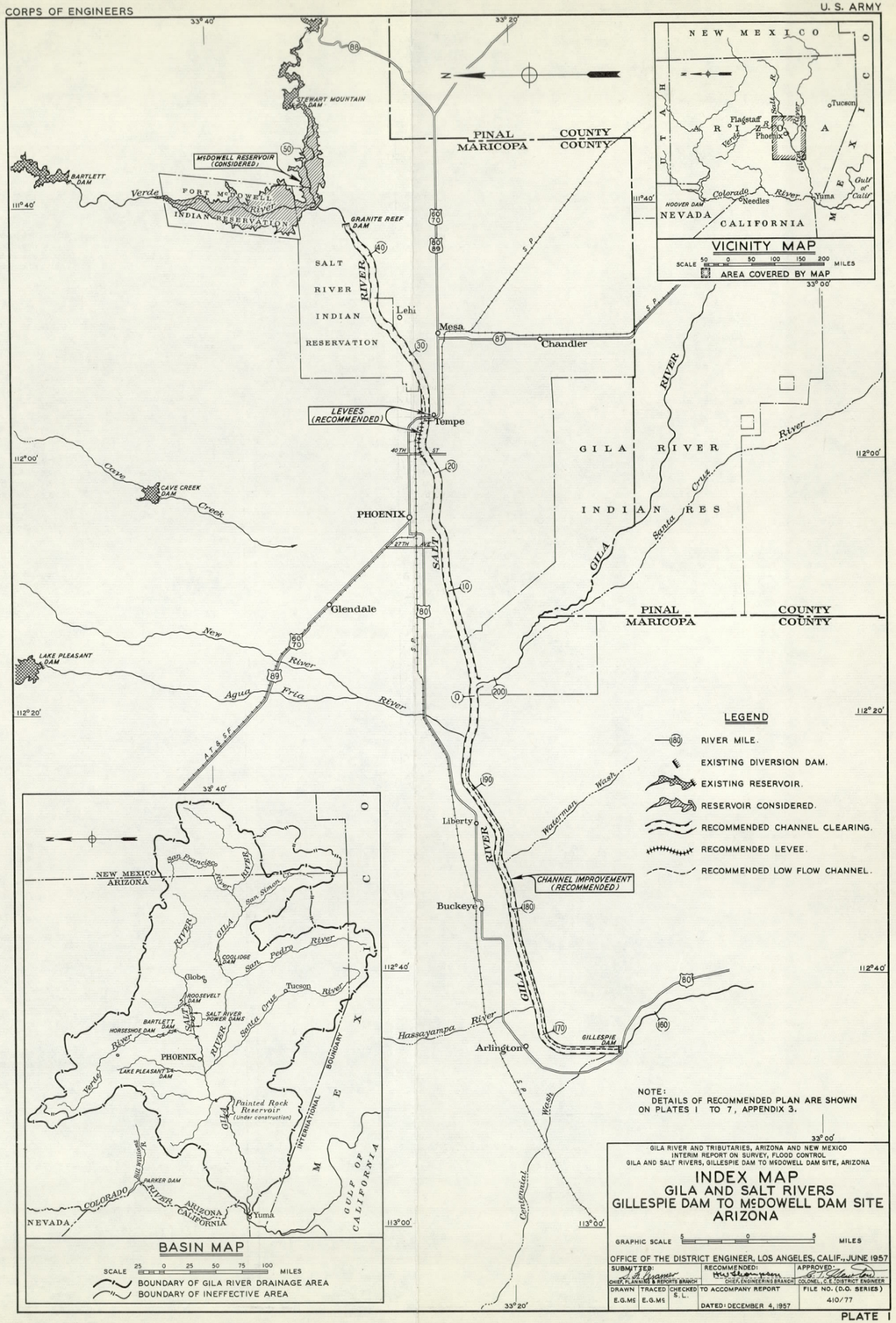
(d) That, in the event the McDowell Reservoir, proposed in House Document 136, 81st Congress, 1st session, is adopted for construction, the design be modified to provide such additional flood-control storage as is determined to be needed and justified at that time.

9 Appendixes
(See table of contents)

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

CORPS OF ENGINEERS

U. S. ARMY



GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

INDEX MAP
GILA AND SALT RIVERS
GILLESPIE DAM TO McDOWELL DAM SITE
ARIZONA

GRAPHIC SCALE 5 0 5 MILES

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

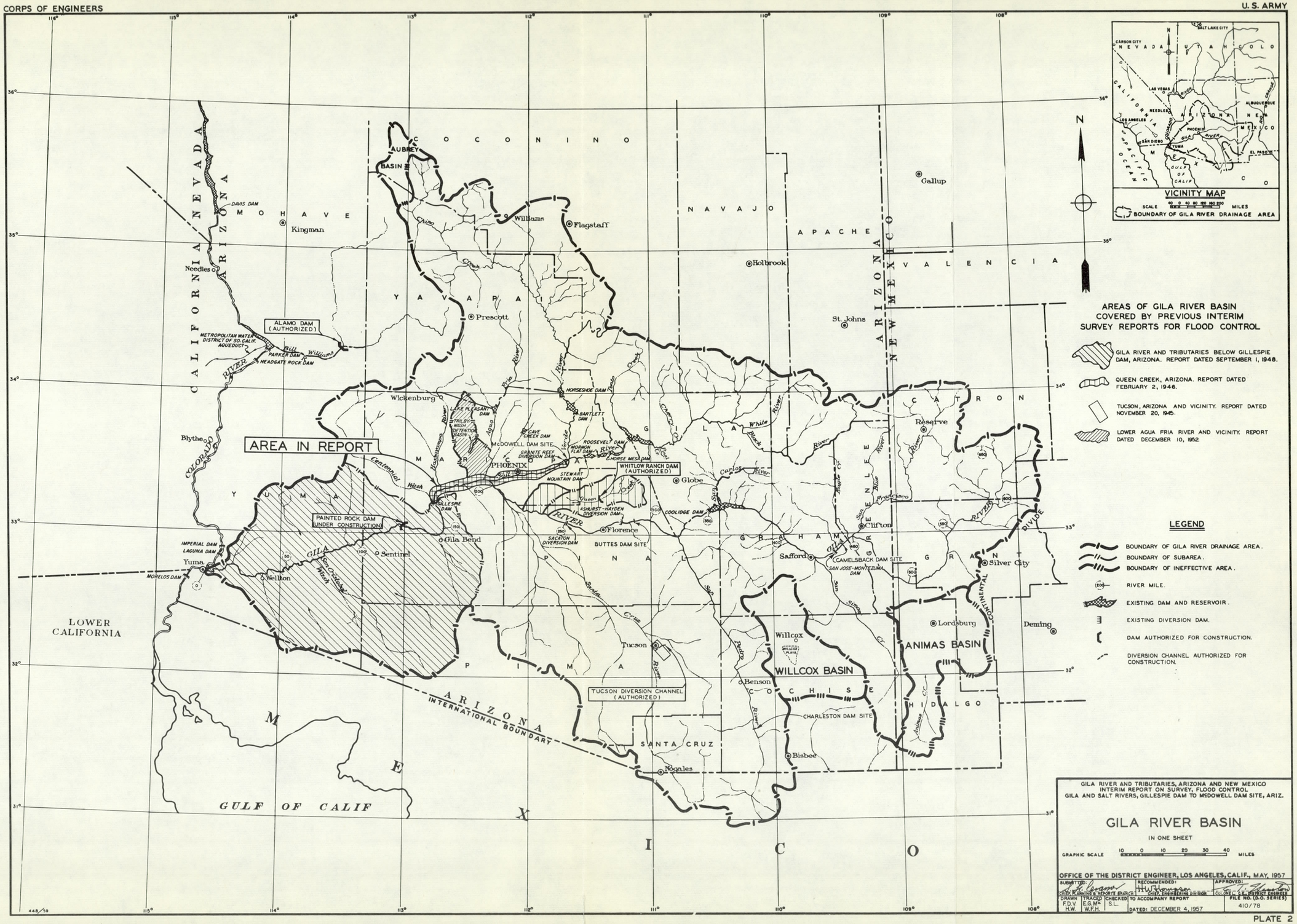
SUBMITTED:	RECOMMENDED:	APPROVED:
CHIEF, PLANNING & REPORTS BRANCH	CHIEF, ENGINEERING BRANCH	COLONEL, C.E. DISTRICT ENGINEER

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (D.O. SERIES)
E.G.MS	E.G.MS	E.L.	DATED: DECEMBER 4, 1957	410/77

PLATE 1

CORPS OF ENGINEERS

U. S. ARMY



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AREAS OF GILA RIVER BASIN COVERED BY PREVIOUS INTERIM SURVEY REPORTS FOR FLOOD CONTROL

- GILA RIVER AND TRIBUTARIES BELOW GILLESPIE DAM, ARIZONA. REPORT DATED SEPTEMBER 1, 1948.
- QUEEN CREEK, ARIZONA. REPORT DATED FEBRUARY 2, 1946.
- TUCSON, ARIZONA AND VICINITY. REPORT DATED NOVEMBER 20, 1945.
- LOWER AGUA FRIA RIVER AND VICINITY. REPORT DATED DECEMBER 10, 1952.

LEGEND

- BOUNDARY OF GILA RIVER DRAINAGE AREA.
- BOUNDARY OF SUBAREA.
- BOUNDARY OF INEFFECTIVE AREA.
- (200) RIVER MILE.
- EXISTING DAM AND RESERVOIR.
- EXISTING DIVERSION DAM.
- DAM AUTHORIZED FOR CONSTRUCTION.
- DIVERSION CHANNEL AUTHORIZED FOR CONSTRUCTION.

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

GILA RIVER BASIN

IN ONE SHEET

GRAPHIC SCALE 10 0 10 20 30 40 MILES

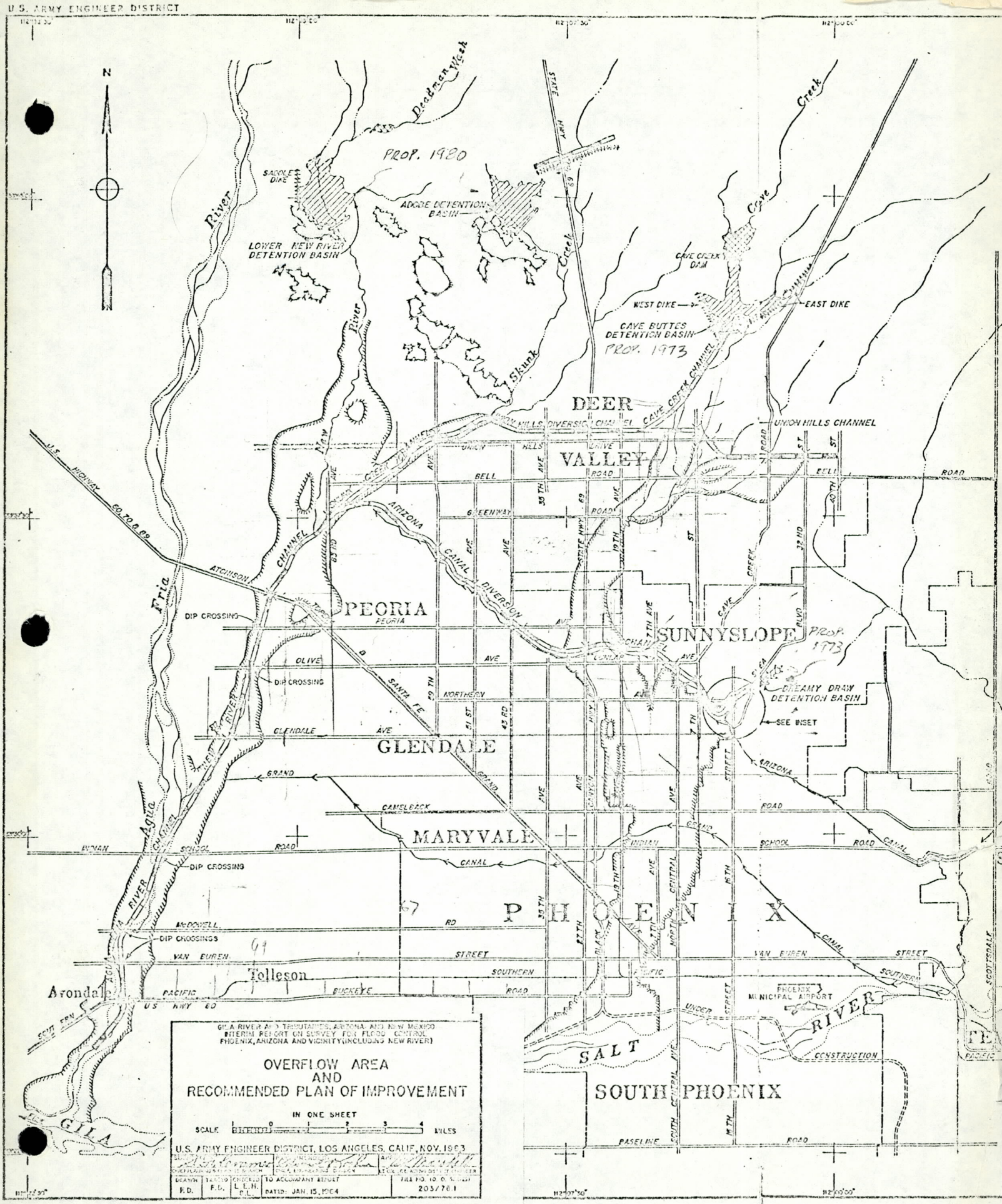
OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., MAY, 1957

SUBMITTED:	RECOMMENDED:	APPROVED:
COLO. PLANNING & REPORTS BRANCH	CHIEF, ENGINEERING DIVISION	COLONEL, U.S. ARMY, DISTRICT ENGINEER

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (D.O. SERIES)
F.D.V. H.W.	E.G.M. W.F.H.	S.L.	DATED: DECEMBER 4, 1957	410/78

PLATE 2

U.S. ARMY ENGINEER DISTRICT



GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY FOR FLOOD CONTROL
PHOENIX, ARIZONA AND VICINITY (INCLUDING NEW RIVER)

OVERFLOW AREA AND RECOMMENDED PLAN OF IMPROVEMENT

IN ONE SHEET

SCALE 0 1 2 3 4 MILES

U.S. ARMY ENGINEER DISTRICT, LOS ANGELES, CALIF., NOV. 1963

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO.
F.D.	F.D.	L.E.H. D.L.	DATED: JAN. 15, 1964	203/78.1

PLATE 3

UNITED STATES ARMY CORPS OF ENGINEERS

LOS ANGELES DISTRICT

A P P E N D I X E S

TO ACCOMPANY

INTERIM REPORT ON SURVEY FOR FLOOD CONTROL

G I L A A N D S A L T R I V E R S,

GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

DECEMBER 4, 1957

BY

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

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2.	Geology and soils (text and 4 plates)
3.	Bases for design (text and 13 plates)
4.	Cost estimates
5.	Benefits from improvements (text and 7 plates)
6.	Use of water by phreatophytes in 2,000-foot channel between Granite Reef and Gillespie Dams, Maricopa County, Ariz. (text and 9 plates)
7.	Allocation of costs
8.	Resolution by local interests
9.	Comments of other agencies

R. 3/20/58

UNITED STATES ARMY CORPS OF ENGINEERS

LOS ANGELES DISTRICT

HYDROLOGY

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

To accompany interim report on survey for flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated December 4, 1957.

APPENDIX 1

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FOREWORD

This inclosure contains the hydrology of the Gila and Salt Rivers between Gillespie Dam and McDowell Dam site.

The hydrologic analysis presented in this inclosure is not based entirely on the latest methods for developing the maximum probable flood discharges for the area adopted by this office and approved by the office, Chief of Engineers. Revised hydrologic procedures, which have been developed since the original analysis given in this appendix, are now being used for developing maximum probable discharges based on new methods of snow hydrology. In addition, loss rates for two subareas (below McDowell Dam site) have been revised for standard project flood discharges as the result of more detailed study of soil types indicating greater infiltration rates.

A comparative study of present hydrologic methods presented in the district engineer's report dated August 1, 1954, and titled "Design Memorandum No. 1, Hydrology for Painted Rock Reservoir, Gila River, Arizona," and the previous hydrologic methods presented in the district engineer's report dated September 1, 1948, and titled "Interim Report on Survey, Flood Control, Gila River and Tributaries below Gillespie Dam, Ariz.," indicates that the changes in peak discharges and flood volumes which would apply to this report would be relatively minor and unwarranted at this time.

The hydrologic analysis presented gives results believed to be adequate for use in developing the various plans of improvement considered. However, a review would be made of the hydrology for the drainage area upstream from any improvements that are adopted for construction.

HYDROLOGY

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

SCOPE

1. The studies described in this appendix were made to estimate the magnitudes of the maximum probable and standard project floods at each of five selected concentration points for which estimates were considered necessary in flood-control planning for Gila and Salt Rivers between Gilespie Dam and McDowell Dam site. The five concentration points are listed in table 1, and the locations are indicated on map, plate 1.

2. Detailed basic hydrologic data for the entire Gila River Basin, including the area under consideration in this report, were given in enclosure 2 of the district engineer's unpublished report dated December 1, 1945, and titled "Interim Report on Survey, Flood Control, Gila River and Tributaries above Salt River, Ariz. and N. Mex." Therefore, only such hydrologic data are given as are necessary to an understanding of the methods employed.

3. In order to show the relationship of this hydrology to that given in the district engineer's report titled "Interim Report on Survey, Flood Control, Gila River and Tributaries below Gillespie Dam, Arizona," dated September 1, 1948, the computations were carried downstream to Painted Rock Dam site, which is on Gila River, mile 126.

DRAINAGE AREA

4. Topographic and hydrometeorologic characteristics.--The Gila River Basin, which is an irregular area of 58,200 square miles (57,900 excluding all closed drainages) extending from the Continental Divide in southwestern New Mexico to Colorado River at Yuma, Ariz., includes practically all the southern half of the State of Arizona and constitutes a region of widely varying topographical and climatological characteristics. (For topographic map, see pl. 1.) The river, which is 654 miles long, rises in an area of high mountains and plateaus, and flows westward in a generally central course through the basin.

5. Much of the northern part of the basin is drained by Salt River, the largest tributary, which joins Gila River at mile 198, near Phoenix. The Salt River drainage area of 13,700 square miles (13,400 excluding all closed areas) is extremely irregular and rugged. Elevations rise commonly to more than 7,000 feet and, at San Francisco Mountain in the Verde River Basin, to more than 12,000 feet. Verde River is the main tributary to Salt River and comprises 6,620 square miles (6,320 excluding all closed areas) of the Salt River drainage area. The eastern portion of the southern part of the Gila River

Basin consists largely of long desert valleys lying between north-south ranges of rugged mountains; here the elevations, although rising in places to above 10,000 feet, are generally lower. The southwest portion of the basin consists essentially of broad, flat, low-lying desert valleys and isolated mountains of relatively low relief; comparatively few localities are more than 4,000 feet in elevation, and a large part is below 1,000 feet; the elevation of the river mouth near Yuma is about 130 feet. Gillespie Dam is in the upstream part of this basin, at river mile 164. Soils and vegetative types vary widely throughout the basin.

6. The climate of the Gila River Basin as a whole is semiarid but, depending principally upon elevation, ranges from hot and arid in some parts to cool and humid in others. The average annual precipitation ranges from less than 4 inches in the lower desert to 30 inches or more in the highest mountains. Most of the precipitation occurs in two distinct seasons, summer (July through September) and winter (December through March), and is about equally divided between them. Little rain falls during spring and autumn. During any season there may be many successive rainless days.

7. Summer precipitation may be placed in two general classifications. The first classification includes the sporadic showers and cloudbursts of small areal extent that occur, usually from insolational heating of tropical maritime air that frequently invades the region from the Gulf of Mexico or the Gulf of California and the South Pacific. The second classification includes the general rains that result from convergence, orographic lift, and frontal lift in situations where frontal systems with associated tropical maritime and polar continental or maritime air pass through the region; thunderstorms may or may not be associated with general rains in this classification.

8. In winter, most precipitation results from general storms that are associated with extratropical cyclones of North Pacific origin. Relatively localized showers commonly occur near the end of such storms. Both the general winter and the general summer storms may result in rain over the entire Gila River Basin. On the average, the general winter storms are longer in duration. They sometimes produce rain that is more or less continuous for several days. In winter, snow may accumulate to considerable depths at elevations above 4,000 feet but practically never falls at elevations below 2,000 feet. Isohyets of mean annual precipitation are shown on plate 2, and isohyets of mean precipitation for the months of October through May are shown on plate 3.

9. Flood causes.--The hydrologic records indicate that on lower Gila River the greatest floods have resulted from storms of the general winter type, and studies of rainfall and runoff relationships indicate that the most critical runoff quantities would probably result from such storms. In winter, the ground throughout the basin is most likely to be wet from other general rains; the upstream reservoirs are most likely to be full, or nearly full of water for conservation use; and the runoff due to snowmelt may be potentially great. In

major storms the duration of appreciable floodflows varies but seldom exceeds 8 days. The records show no large floods in lower Gila River in summer. There are indications that general summer storms approaching the winter storms in magnitude could occur over the entire river basin, but probably the attendant ground conditions would be less severe than those to be expected in winter. The size of the basin tends to preclude the probability of a great flood resulting from a series of thunderstorms.

10. Control at upstream reservoirs.--Within the Gila River Basin are numerous dams but, unless the quantity of water in storage is low, only a few of these will exert an appreciable influence on major floods. Pertinent data on the two existing reservoirs that would have a considerable effect in regulating a flood of standard project magnitude are tabulated below. The tabulation also includes data on two dams providing flood control that have been recommended for construction by the United States Bureau of Reclamation as part of the Central Arizona project now pending for consideration in Congress. (See H. Doc. 136, 81st Cong., 1st sess.)

Important reservoirs in Gila River Basin upstream from Gillespie Dam, Ariz.

Dam	Stream	Drainage area	Reservoir capacity		Purpose
			At spillway crest	At top of dam	
		Square miles	Acre-feet	Acre-feet	
Coolidge*.....	Gila River.	12,900	**1,205,000	1,460,000	Water conservation, power.
Roosevelt*.....	Salt River.	5,830	**1,382,000	1,622,000	Water conservation, power.
Buttes***.....	Gila River.	18,200	400,000	530,000	Flood control, water conservation, power.
Charleston***..	San Pedro River.	1,250	238,000	319,000	Flood control, water conservation.

* Existing.
** Top of spillway gates.
*** Recommended.

PRECIPITATION AND RUNOFF

11. General.--The following brief information on the extent of available hydrologic records, together with short summaries of the more noteworthy floods, is given to provide an indication of the quantity

and quality of data from which the standard project and maximum probable floods have been developed and to furnish a standard for judging the adequacy of those floods. Most of the information has been abstracted from the unpublished 1945 survey report previously mentioned.

12. Precipitation records.--Precipitation records are available for more than 600 rainfall stations in and near the Gila River Basin. Autographic records are available for 44 of the stations. The earliest record (Fort McDowell) begins in July 1866. The longest continuous record (Yuma) begins in 1870. The longest continuous autographic record (Phoenix) begins in 1906. Most of the autographic stations have been established since 1939. Many of the records since 1900 include information on snowfall, and snow-course observations have been made since about 1937 at several locations in drainage areas of Verde, Salt, and upper Gila Rivers.

13. Runoff records.--Runoff records are available for 95 stream-gaging stations on Gila River and tributaries. The longest record (Verde River near its mouth), which dates back to 1889, is nearly continuous since 1903. Records of discharges at most stations during flood periods are generally inadequate.

14. Floods.--Historical accounts indicate that general floods occurred in 1833, 1862, 1869, 1880, 1884, 1886, 1889, 1890, 1891, 1893, 1895, and 1903. Records since 1904 show that floods and/or storms occurred in March 1905, April 1905, November 1905, March 1906, December 1906, December 1914, January 1915, January 1916, October 1916, November 1919, February 1920, December 1923, September 1926, February 1927, February 1937, March 1938, March 1941, and September 1946. The flood of 1884 was the earliest for which a reasonable estimate of severity can be made. It probably was comparable to the greatest floods of record, those of February 1891 and January 1916. Major floods of record at or near McDowell Dam site are as follows:

Major floods of record at or near McDowell Dam site, Gila River Basin

Date	Flood peak	Volume
	Cubic feet per second	Acre-feet
February 1891	300,000	1,861,000
April 1905	115,000	656,000
January 19-20, 1916	120,000	700,000
January 29-30, 1916	105,000	660,000
February 1920	130,000	650,000
March 1938	*95,000	220,000

* U. S. Geological Survey estimate. Peak estimated by Raymond Hill equaled 66,500 cubic feet per second on basis of model study of Granite Reef Dam.

15. Storms and floods of February 1891.--Two storms occurred over the Gila River Basin in February 1891, one from the 15th to the 19th, and the other from the 22nd to the 25th. The storm, which originated over the Pacific Ocean, produced the maximum 24-hour rainfall of record of 17 inches on February 22 at Big Bear Valley in southern California, with a 2-day total at the Bear Valley Mutual Water Company of 32.2 inches. When the rain of the 22nd began, snow covered the mountains near San Bernardino and Riverside, Calif., down to the foothills. In the Gila River Basin there was no precipitation the first half of the month, and the records do not indicate the depth of snow cover over the area prior to the storms. Part of the precipitation during these storms apparently fell as snow, especially at higher elevations. Average rainfall depth over the area above Gillespie Dam is estimated to have been 4 inches, but the records are insufficient for preparation of an isohyetal map. Data on daily recorded precipitation for the period February 16-26 are given in table 2. In southern California, floods occurred on San Gabriel River, Santa Ana River and some of its tributaries, and the greatest flood of record (128,000 cubic feet per second) occurred on San Luis Rey River. Also, the maximum flood of record (200,000 cubic feet per second) occurred on the Bill Williams River at Planet, Ariz. The greatest floods of record occurred on the Gila and Salt Rivers. Estimated peak discharges for Gila River near Florence and at Gila Bend are 102,500 and 250,000 cubic feet per second, respectively, and on Salt River at Arizona Dam (approximately same location as the present Granite Reef Dam) 300,000 cubic feet per second. The flood on the Colorado River at Yuma was greater than any that had occurred prior to 1891 and may have exceeded the flood of 1916 (250,000 cubic feet per second).

16. Discharges for Salt River at Arizona Dam as prepared by Mr. Samuel A. Davidson, Engineer of the Arizona Canal Company, and published in the 12th Annual Report of the United States Geological Survey are given as follows:

> * * * First flood diminished rapidly averaging on the 20th about 69,100 and on the 22nd 14,800. This was followed by a second swell greater than the first, the flood increasing on the 24th a maximum of 300,000 second-feet was reached. This subsided almost as rapidly as it came so that by the second day after, the river was carrying less than 15,000 second-feet.* * *

Discharges for Salt River at Arizona Dam, Gila River Basin

Date	Average discharge	Date	Average discharge
	Cubic feet per second		Cubic feet per second
February 17, 1891..	835	February 22, 1891..	14,890
February 18, 1891..	154,000	February 24, 1891..	*300,000
February 19, 1891..	276,000	February 26, 1891..	15,000
February 20, 1891..	69,100		

* Given as a maximum discharge.

17. Information on the flood at Arizona Dam is given in the following data taken from the newspaper accounts of the flood:

ARIZONA REPUBLICAN

February 19. * * * At 2 o'clock this morning word was received from the Arizona Canal dam, by telephone, that the water of Salt river stood 16 feet upon the dam, the highest at any time during the great flood of last spring. * * *

February 20, Phoenix, Ariz. * * * Between five and six o'clock the height of the flood seemed to be reached and after remaining nearly stationary several hours the water began slowly to recede about 8 o'clock last night. * * *

* * * Contrary to the general opinion, but little of the flood water came from the Verde. That stream is said to have not reached its limit of last year and has fallen very rapidly since Thursday. Judging from the quickness with which the flood came and subsided it is thought that most of the water was delivered to Salt River by Tonto Creek, which draws the eastern slope of the Mazatzals and a large portion of the Mogollons. * * *

February 22 paper gave a review of events of the flood for the 19th. * * * The water at the Arizona canal dam had fallen 4 feet 6 inches by 6 P. M. yesterday, and the tendency was still downward. * * *

February 24. It was stated that on Saturday and Sunday bulkheads were being built in the consolidated Maricopa and Salt River Valley canals.

* * * The precaution was well taken as the steady rain began to tell and the water, which had fallen to but two feet

and eight inches over the Arizona dam at 4 o'clock Sunday afternoon, began to show an increase. At 8 P. M. it was up to four feet, and at 9 o'clock yesterday morning the register indicated eight feet. At 12 it had increased to ten and one-half feet, thus showing a rise of nearly one foot an hour. * * *

* * * Reports from the head of the Arizona canal showed the following stage of water over the dam at the hours named. At 12 o'clock noon, 10 feet 6 inches; 3:15 P. M., 12 feet 6 inches; 5:30 P. M., 13 feet 6 inches; 8:30 P. M., 14 feet 9 inches; 10:40 P. M., 15 feet 3 inches; 1:40 A. M., 17 feet; 2:40 A. M., 17 feet 1 inch. * * *

February 25. * * * Finally, at 2:40 yesterday morning, the faithful watchman at the dam reported 17 feet 1 inch of water, the height reached at the last flood, and the river still rising. * * * The river continued to rise until it reached the unprecedented height of 18 feet 2 inches over the dam. * * * About 10:30 news came from the dam that the river had begun falling and each succeeding message was but a repetition of the good news. * * *

February 26, Phoenix, Ariz. * * * After the water began to recede around the city, Tuesday night, it sank back towards the river almost as fast as it had risen. * * *

18. The United States Geological Survey in Water-Supply Paper No. 1049 gives the maximum daily discharge of 300,000 cubic feet per second occurring on February 24, 1891, computed from weir formula for Arizona Dam. Under remarks, the following statement is made:

* * * Records poor; they should be considered as estimates because of errors inherent in methods used and because discharge measurements are lacking both in sufficient number and in quality. * * *

19. From the above information and from a study of other floods that have occurred on Salt River below Verde River, a rating curve and a hydrograph (pls. 4 and 5) were developed to represent the discharges at Arizona Dam for the floods of February 1891.

20. Storms and floods of January 1916.--Two storms occurred over the Gila River Basin in January 1916, one from the 15th to the 21st, and the other from the 25th to the 30th. The first storm, which was of broader coverage than the second, produced the larger flood. Both storms were of the general winter type. The average

precipitation over the drainage area above Gillespie Dam and McDowell Dam site was about 3.5 and 4.9 inches for the first storm and 1.3 and 2.7 inches for the second, respectively; in each storm, approximately half of the precipitation occurred in a 24-hour period. Ground conditions were rather severe, owing to the occurrence of light rain on January 10-12 and to the presence of snow cover over much of the area. The estimated peak discharges of Gila River at the mouth were 230,000 and 155,000 cubic feet per second, respectively, for the two floods. Discharges on many of the tributaries were likewise severe, especially in the northern part of the drainage area. For example, on Salt River near Roosevelt (drainage area, 4,310 square miles) the peak discharge of the first flood was estimated at 100,000 cubic feet per second. Pertinent hydrologic data for the two storms and floods are given on plate 6.

21. Storm and flood of September 1926.--The storm of September 26-27, 1926, which occurred principally over the upper reaches of Santa Cruz River, San Pedro River, and San Simon Creek, is important because of its magnitude in that part of the basin. The storm apparently was associated with a tropical hurricane originating over the Pacific Ocean. The autographic record for Phoenix, which is the only such record available for this storm, showed that nearly all the rain at Phoenix fell during a 24-hour period, and that about 70 percent fell in less than 2 hours. The average depth of rain over the drainage area above Gillespie Dam and McDowell Dam site was about 1.5 and 1.4 inches, respectively. The maximum depth for a point was recorded as 8.15 inches. The storm produced the greatest flood of record on San Pedro River, at the mouth of which the peak discharge was 90,000 cubic feet per second. The peak discharge of Gila River at Gillespie Dam was 38,300 cubic feet per second.

22. Storm and flood of February 1937.--The storm of February 6-8, 1937, and the flood it produced are important because sufficient hydrologic observations were recorded to permit some analyses of rainfall and runoff relationships. The storm, which was of the general winter type, occurred at a time when the snow cover over much of the area was heavy and ground conditions generally were favorable for runoff. On the average, the rainfall intensities were low. The average depth of precipitation over the drainage area above Gillespie Dam and McDowell Dam site was 1.2 and 2.2 inches, respectively, most of which fell in 24 hours. Minor floods occurred on most streams in the drainage area. Flood inflows on Salt River at Roosevelt Reservoir were impounded. The peak discharge of Gila River at Gillespie Dam was 45,800 cubic feet per second. The discharge at the mouth of Gila River was about 6,000 cubic feet per second.

23. Storm and flood of February-March 1938.--The storm of February 27-March 5, 1938, and the resulting flood are also important because of the availability, throughout the southwest region, of hydrologic records for analysis, and for the intensity of the 6- and 12-hour rainfall amounts. The storm, which was of the general winter type, produced the greatest flood of record in the Los Angeles

area of southern California. However, except for some tributary flows, the flood was of relatively minor magnitude in the Gila River drainage area. Ground conditions were apparently only moderately conducive to runoff. The average depth of precipitation over the drainage area above Gillespie Dam and McDowell Dam site was 2.0 and 3.8 inches, respectively, about two-thirds of which fell in a 24-hour period near the end of the storm. The most important peak discharge in the flood was on Verde River, at the mouth of which a peak flow of 95,000 cubic feet per second occurred. The peak flow at Gillespie Dam was 60,000 cubic feet per second; the flow at the river mouth was 8,670 cubic feet per second. Pertinent hydrologic data for the storm and flood are given on plate 7.

24. Storm and flood of March 1941.--The storm of March 11-17, 1941, and the floods it produced, are important both because of the magnitude of runoff in some tributaries and because of the availability of hydrologic records. The storm, which originated over the Pacific Ocean, produced generally heavy precipitation accompanied by numerous heavy showers in southern California before reaching Arizona. In the Gila River Basin light rain began at many locations on the 11th. Practically all stations reported precipitation every day from the 12th to the 15th, and at some places the rain continued until the 17th. The average depth of rainfall over the drainage area above Gillespie Dam and McDowell Dam site was 2.0 and 3.0 inches, respectively, about half of which fell in a 24-hour period. Snow cover on the ground prior to the storm was negligible. Because the winter season of 1940-41 was wetter than normal, ground conditions were apparently conducive to runoff, especially in the Salt River drainage area. The peak flow on Salt River above Roosevelt Reservoir was 117,000 cubic feet per second, the greatest since January 1916. The peak on Gila River was 45,800 cubic feet per second below Gillespie Dam and about 10,000 cubic feet per second at the river mouth.

25. Storm and flood of September 1946.--The storm of September 17-19, 1946, is important because it illustrates the magnitude of rainfall that sometimes occurs in general summer storms. The storm consisted essentially of a cold front with associated tropical Pacific and polar continental air masses. Beginning as a series of thunderstorms about noon of the 17th, the storm produced practically continuous rain from the afternoon of the 17th until the morning of the 19th. The average depth of rain over the drainage area above Gillespie Dam and McDowell Dam site was 2.0 and 2.9 inches, respectively, more than three-fourths of which fell in a 24-hour period. Because the ground apparently was relatively dry when the storm began, only minor runoff resulted. The peak discharge on Salt River near Roosevelt was 15,100 cubic feet per second. On Gila River the maximum mean daily discharge below Gillespie Dam was only 2,530 cubic feet per second, and flow at the river mouth was zero.

26. Method of synthesis.--In Circular Letter No. 4262, Civil Works No. 65, issued by the Chief of Engineers under date of November 20, 1946, standard project floods are described as follows:

> * * * The "Standard Project Flood" is intended to represent a flood that would be exceeded in magnitude only on rare occasions, and thus to constitute a standard for design of structures that would provide a high degree of flood protection as determined by flood potentialities of the drainage system involved, without regard to localized economic or other practical limitations of individual projects. * * * In most cases, the Standard Project Flood should equal or approximate the flood that would result, under existing or specified conditions of basin development, if the most critical storm of record in the region should occur over the drainage area involved when hydrologic conditions were reasonably favorable for flood runoff. * * *

Studies of available hydrologic data for the Gila River Basin and adjacent southwest areas have shown that the storms of record with potentially the most critical flood-producing characteristics for the drainage areas above Gillespie Dam and McDowell Dam site were the first storm of January 1916 and the storm of February-March 1938. These storms, as actually oriented over the basin, produced rainfall amounts moderately less critical than those that would have resulted if the storms had been centered over the area. The standard project flood on Gila River between Gillespie Dam and Salt River has been synthesized on the basis of the assumed occurrence of a storm equivalent to the 1916 storm centered (approximately 50 miles northwest of actual occurrence) over the area above Gillespie Dam. The standard project flood on Salt River between the mouth and Verde River has been synthesized on the basis of the assumed occurrence of a storm equivalent to the 1938 storm and the 1916 storm centered (approximately 20 miles northeast and 80 miles northwest, respectively, of actual occurrence) over the area above the proposed McDowell Dam site. Ground conditions reasonably conducive to runoff were determined from approximate analyses of the relationships of runoff to rainfall in floods of record, and assumptions were made of reservoir storage conditions that might reasonably be expected to exist throughout the drainage area. The runoff quantities of the standard project floods were computed by dividing the drainage area above Gillespie Dam into 14 subareas (see pl. 1); developing a synthetic distribution graph for each; computing the rainfall amounts, losses, storage effects, and resulting runoff for each subarea; and combining the subarea runoff quantities by a routing process to determine the total flood hydrograph for the various concentration points as given in table 1. The various steps in the synthesis are outlined in the following paragraphs.

27. Subarea distribution graphs.--The method used in these studies for determination and application of unit hydrographs, which are used in computing time distribution of runoff from rainfall, is

similar to methods generally employed by the Corps of Engineers and other agencies throughout the United States. Detailed descriptions of the method may be found in recent hydrologic reports by this office. Synthetic distribution graphs for each of the 14 subareas were derived from data developed in unit-hydrograph studies previously made of several areas in the Gila River Basin and in southern California. A single basic S-graph representing an average of time-distribution characteristics of four comparable regional streams was assumed to be applicable for determining each of the required synthetic distribution graphs. The required lag values for the subareas (for use in converting the S-graph to distribution graphs) were taken from the lag curve applicable to the areas for which the original unit-graph studies were made. The S-graph and the lag curve are shown on plate 8. Lag data and distribution-graph percentages are given in tables 3 and 4. Corroborative studies of the applicability of the lag curve and the S-graph indicated that they would give the desired results within acceptable limits of accuracy.

28. Standard project storms.--Determination of the magnitude of the storms that would be equivalent to the 1916 and 1938 storms but would have a critical centering to the northwest and northeast, respectively, was accomplished by (a) expressing the actual rainfall amounts in the 1916 and 1938 storms as percentages of the mean rainfall amounts for the period of October through May, (b) constructing isopercentual maps based on those percentages, and (c) shifting the isopercentual lines to such a position over the basin as would result in more critical amounts of rainfall over the drainage area above the respective concentration points. Use of the mean precipitation for the months of October through May as a base for determining project-storm precipitation is considered warranted in view of the fact that most precipitation in those months in Arizona results from storms of the general winter type, and thus such mean seasonal precipitation is an indication of the effects of basin topography on precipitation in general storms. The project-storm rainfall amounts are shown by isohyetal lines on plates 9, 10, and 11.

29. Six hours was selected as the smallest time interval for which information on rainfall intensities would be required in developing the standard project floods. The time distribution of the rainfall intensities for the respective parts of the project storms over the different subareas was made equal (with 6-hour amounts expressed as percentages of total storm amounts) to the time distribution of rainfall in the same relative parts of the original 1916 and 1938 storms as computed from intensity patterns determined under assignments SP 1-20 and SP 2-8, respectively, of the cooperative storm-study program of the United States Weather Bureau and the Corps of Engineers. Four typical block diagrams of average 6-hour rainfall intensities are shown on plates 9, 10, and 11, and 6-hour intensity quantities for all storm centerings and subareas are shown in table 5.

30. Precipitation loss, snowmelt, base flow, and channel percolation.--In the absence of detailed analyses of relationships of runoff

to rainfall in recorded storms, the total amounts of precipitation that would appear in the streams as runoff (effective rain) during the standard project floods were computed on the basis of a study made of the volumes of runoff estimated to have occurred at various locations throughout the Gila River Basin as a result of the larger storms of record. The volumes of runoff were expressed as percentages of total precipitation for various storm periods. Such percentages reflect, in a general way, the amounts of rainfall lost by surface detention, infiltration, evaporation, and channel percolation losses in the various tributary areas. They also reflect the accretions to streamflow resulting from ground-water return flow and from melting snow. The percentages for the storms examined indicated that, in general, proportionately the greatest amounts of runoff were from the areas of higher elevation, where rainfall and snowmelt are usually greater. On the basis of this study, average percentages that would represent ground conditions reasonably conducive to runoff from each subarea were assumed. The assumed percentages, which ranged from 25 to 35 percent, are considered to include adequate allowances for snowmelt and base flow. Also, they collectively constitute an overall degree of severity slightly greater than that existing in the 1916 and 1938 storms.

31. To determine the amounts of effective rain (including base flow and snowmelt) by unit periods in the standard project flood, the results of unit-hydrograph studies for two areas in southern California for which relatively detailed hydrologic data are available (one area of high rainfall and one area of low) were utilized. For each study, a curve was plotted showing accumulative storm rainfall versus accumulated effective rainfall, both by unit periods throughout the storm. In each case the plotted points could be reasonably well fitted by a straight line. Using this method for estimating effective rainfall in the corroborative studies previously mentioned (i.e., in connection with the applicability of the adopted lag curve and S-graph) indicated that the straight-line relationship would give reasonably satisfactory hydrograph reproductions for the Gila River Basin floods studied, namely, the 1916, 1937, and 1941 floods on Salt River near Roosevelt Dam, and the 1937 flood on Verde River. Accordingly, such a straight-line relationship was adopted for the standard-project-flood computations. Its application to the subarea above Roosevelt Dam is illustrated on plate 12. As shown thereon, the indicated rainfall-loss rates for the 6-hour periods of heaviest rain range from 0.05 to 0.10 inch per hour. These rates appear reasonable.

32. Deviation from the straight-line relationship would tend to affect the shape of the computed flood hydrograph for each subarea and perhaps modify the peak discharge slightly, but would not affect the total volume of runoff.

33. Extensive investigations made by the United States Geological Survey concerning water resources of different parts of the Gila River Basin and brief studies made by this office concerning floodflows along Gila River indicate that percolation of floodwaters in overflow areas

along the river is of some consequence in reducing flood runoff. The percolation rates apparently are greater in the downstream parts of the basin. For the standard-project-flood computations, rates of 0.15 cubic foot per second per wetted acre were assumed for overflow areas along Salt River from the Verde River confluence to Gila River and the main stem of Gila River between the San Francisco River confluence and Coolidge Dam, and 0.30 cubic foot per second per wetted acre downstream from Coolidge Dam.

34. Channel- and reservoir-storage effects.--The reservoirs recommended for construction by the district engineer and the two largest existing reservoirs in the drainage area would have an appreciable regulatory effect on a flood of standard-project magnitude. The assumptions made concerning the operation of these reservoirs and the hydrographs showing their effect are shown on plate 13. The reservoir flood-routing studies were made by the Puls I.S.D. method. Channel-routing procedures were followed in combining floodflows from the different subareas.

35. Standard project flood.--The standard project flood for Gila River from Gillespie Dam to the mouth of Salt River was computed in accordance with the steps outlined in the preceding paragraphs. The hydrograph of the standard project flood at Gillespie Dam is shown on plate 13. A summary of hydrology is given in table 6. Computations for the standard project flood for Salt River from its mouth to McDowell Dam site, made in like manner, resulted in two alternative standard project floods. The 1938 storm transposed resulted in the highest peak discharge and the 1916 storm transposed resulted in the largest volume flood. In order to have only one standard project flood for Salt River to simplify investigations and planning, the rainfall pattern for the Verde River area, over which both the 1938 and 1916 storms were assumed centered, was adjusted to give higher intensities for the maximum 6- and 12-hour periods so that the resulting flood at McDowell Dam site would have the same peak as the one based on the 1938 storm transposed and the same volume as the one based on the 1916 storm transposed, and also McDowell Dam would provide the same degree of control as it would on a flood derived from the 1916 flood alone. In addition, when this flood was routed to the mouth of Salt River it would have a peak discharge equal to the one developed from the 1938 storm transposed. The hydrograph of the standard project flood at McDowell Dam site is shown on plate 14. The standard-project-flood peak discharges, at the various concentration points, with and without control at McDowell Dam, are shown on plates 15 and 16, respectively. A summary of hydrology is given in table 6.

MAXIMUM PROBABLE FLOOD

36. Method of synthesis.--As previously indicated, the maximum probable flood was synthesized by estimating the maximum-possible-storm rainfall for the basin and computing the runoff from that rainfall

on the basis of assumed basin ground conditions conducive to maximum runoff. In the absence of a determination by the United States Weather Bureau of maximum-possible-rainfall rates for the drainage area, analyses were made of possible critical air-mass characteristics and wind movements, and the maximum possible storm was developed essentially in the manner used by the Weather Bureau in determinations of this kind.

37. Maximum storm.--In determining maximum-possible-storm rainfall for other areas in southwestern United States, the Weather Bureau's method has consisted essentially of enveloping statistical hydrometeorological data, estimating the reasonable upper limits of severity for rain-producing factors, and organizing those factors into a maximum storm structure generally patterned after the greatest storm of record in the vicinity in question. Stated in another way, for areas where one storm of record considerably surpasses other storms in magnitude, the method constitutes an extrapolation of the rainfall rates in that storm to their upper limits. In order to obtain the maximum possible storm for the Gila River Basin, the most severe winter storm of record, which was the first storm of January 1916, was selected as the base storm to be increased. Assuming conditions in that storm, except for wind speed, to be at a maximum, it was necessary only to increase the moisture charge and wind speed. To compute the effective moisture charge, the average height of barrier to moist air entering the Gila River Basin was estimated as 3,600 feet, and the top of the moisture column was assumed as 30,000 feet. The maximum possible 12-hour dewpoint (converted to the 1,000-millibar value) was estimated from available data for December through March at Phoenix as 62°, which is 4° higher than the 12-hour dewpoint existing during the 1916 storm. Application of these factors would result in an increase of the 1916 storm rainfall by 30 percent. A reasonable increase in wind speed was assumed as 10 percent. The resultant increase in rainfall would likewise be 10 percent. Combining these factors results in a maximum storm that would be 140 percent of the base storm. In estimating the maximum-possible-storm rainfall for the drainage area above Gillespie Dam, the rainfall quantities of the standard project storm, which is equivalent to the 1916 storm centered above Gillespie Dam, were, therefore, increased by 40 percent.

38. A maximum possible storm was developed similarly for the Salt River Basin with the storm of 1938 being selected as the base storm. The combination of the factors for this storm resulted in a maximum storm that would be 180 percent of the base storm. In estimating the maximum-possible-storm rainfall for the Salt River drainage area, the rainfall quantities of the standard project storm, based on the 1938 storm transposed over the area above the proposed McDowell Dam, were, therefore, increased 80 percent.

39. Attendant conditions.--Conditions conducive to maximum runoff throughout the drainage area during the maximum storm were assumed as follows: (a) The standard-project-flood percentages of total rain that would run off were each increased 10 percent (for example, the percentage for subarea No. 4 was increased from 35

percent to 45 percent, which thus constitutes a 28-percent increase in effective rainfall for that subarea); (b) no channel percolation losses were subtracted; and (c) all reservoir storage space except for surcharge above spillways and crest gates was assumed filled at the start of the flood, with operation procedures as outlined on plate 17.

40. Maximum probable flood.--The hydrograph of the maximum probable flood at Gillespie Dam is shown on plate 17. A summary of hydrology is given in table 7. The hydrograph of the maximum probable flood at McDowell Dam site is shown on plate 18, with a peak discharge of 600,000 cubic feet per second. The maximum-probable-flood discharge, at various concentration points, with and without McDowell Dam, are shown on plates 15 and 16, respectively. A summary of hydrology is given in table 7.

ADEQUACY OF STANDARD PROJECT AND MAXIMUM PROBABLE FLOODS

41. The standard project and maximum probable floods for the Gila River between Gillespie Dam and Salt River were based on the same centering of the January 1916 storm for the standard project flood and the increasing of that storm to a maximum possible for the maximum probable flood as used for the Painted Rock hydrology given in enclosure 2 of the district engineer's report titled "Interim Report on Survey, Flood Control, Gila River and Tributaries below Gillespie Dam, Arizona," and dated September 1, 1948, and is, therefore, considered adequate for this report.

42. The adequacy of the standard project flood for Salt River can best be shown by comparison of the magnitudes of this flood with floods of record. The peak flow for the standard project flood, assuming no upstream dams, would be 350,000 cubic feet per second or 50,000 cubic feet per second larger than the uncontrolled peak of 300,000 cubic feet per second for the 1891 flood. The peak flow of the standard project flood modified by existing dams (290,000 cubic feet per second) is about equal to the peak estimated for the uncontrolled peak of the 1891 flood, which is probably the greatest flood of record, below confluence of Verde and Salt Rivers. The total volume stored at McDowell Dam (considered) with a controlled discharge of 82,000 cubic feet per second for standard project flood is 667,000 acre-feet, as compared to the corresponding volume for the floods of 1891 of 568,000 acre-feet. Therefore, the standard project flood would be more severe than the floods of 1891 for a controlled discharge of 82,000 cubic feet per second. It is considered that on the basis of hydrologic data now available the standard project flood as developed is adequate as a reservoir-design flood for McDowell Dam and for channel design on the Salt River from McDowell Dam site to the mouth of Salt River.

43. The maximum probable flood has been based on an estimate of the maximum possible precipitation and on ground conditions

conducive to maximum runoff. Although time was not available for a determination of maximum precipitation by the United States Weather Bureau, it is believed that the maximum precipitation determined herein would approximate such amounts. The assumed ground conditions, expressed as percentage runoff, are considerably more severe than those estimated for past floods. The occurrence of either the rainfall or the ground conditions assumed would be infrequent. A flood resulting from their combination, and at a time when upstream reservoirs would be full, would represent an extremely severe situation. The maximum-probable-flood peak at McDowell Dam site is more than twice as large as the standard-project-flood peak.

Table 1

Concentration points, Gila River Basin

Concentration point		Drainage area*
Designation	Description	
		Square miles
A	Salt River at McDowell Dam site	12,900
B	Salt River at mouth	13,700
C	Gila River below Salt River	43,000
D	Gila River below Agua Fria River	45,400
E	Gila River at Gillespie Dam	49,600

* Includes approximately 300 square miles noncontributing area.

Table 2

Recorded daily precipitation, February 16-26, 1891, in and near Gila River Basin

Station	Latitude	Longitude	Precipitation in inches recorded on dates shown											Total
			16	17	18	19	20	21	22	23	24	25	26	
	Degrees and minutes	Degrees and minutes												
Fort Whipple (Prescott)..	34-35	112-25	0.74	0.61	1.51	0	0	0	1.50	1.55	0	0	0	5.91
Tempe Date Orchard.....	33-24	111-57	(*)	(*)	(*)	2.26	0	0	(*)	1.34	0	0	0	3.60
Show Low.....	34-15	110-01	.50	.40	.50	.30	0		.60	.70	0	0	0	3.00
San Carlos....	33-22	110-27	0	.28	2.00	.47	0	0	(*)	2.50	0	0	0	5.25
Fort Lowell...	32-16	110-47	.11	.36	1.04	.35	.17	0	0	.15	.35	.40	.12	3.05
Fort Grant....	32-37	109-57	0	(*)	(*)	2.28	0	0	(*)	(*)	1.50	0	0	3.78
Fort Bowie....	32-20	109-27	0	.50	.70	0	0	0	.33	.65	T	0	0	2.18

* Included in next measurement.

Table 3

Subarea lags and pertinent elements, Gila River Basin

Subarea*	Area	L	L_{ca}	S	$\frac{L.L_{ca}}{S^{\frac{1}{2}}}$	Lag**
	Square miles	Miles	Miles	Feet per mile		Hours
1	4,200					
Hassayampa River	1,450	105	47	66	604	12.8
Centennial Wash	1,990	107	37	38	650	13.2
Waterman Wash	760	62	32	39	312	10.0
2	2,400	123	54	51	928	15.0
3	800	64	28	63	225	8.8
4	6,320	221	113	24	5,098	29.0
5	450	#13	#6	#310	#4	##14.0
6	5,830	174	50	41	1,359	17.7
7	8,990	241	104	23	5,226	29.0
8	2,110	116	68	28	1,491	18.3
9	4,050	162	69	25	2,236	21.3
10	1,250	60	33	68	240	9.1
11	3,730	146	34	45	740	13.9
12	2,280	120	45	55	730	13.9
13	4,060	203	98	21	4,344	27.2
14	2,830	160	92	34	2,525	22.2

* See pl. 1.

** See pl. 8 for lag curves.

\# Values given are for longest watercourse above dams.

Lag for subarea derived by adding travel time through dams (12 hours) and lag for longest watercourse above dams (2 hours).

Table 4

Subarea distribution-graph percentages, Gila River Basin

No. of 6-hour period	Percentage for indicated subarea*													
	**1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.7	1.4	3.9	0.5	1.3	0.9	0.5	1.0	0.9	4.1	1.5	1.5	0.6	0.7
2	15.9	9.1	44.6	2.0	11.7	6.4	2.0	5.5	4.0	42.6	12.2	12.2	2.3	3.6
3	40.2	37.6	38.4	4.1	42.4	23.5	4.1	21.5	12.7	39.6	42.0	42.0	5.0	9.2
4	25.1	29.8	9.4	10.4	26.4	35.0	10.4	35.7	33.0	9.9	26.9	26.9	13.6	29.0
5	10.1	11.6	3.1	23.0	9.9	17.1	23.0	16.7	22.5	3.1	9.0	9.0	26.7	25.8
6	4.2	5.5	.6	22.5	4.6	8.0	22.5	9.4	9.8	.7	4.7	4.7	19.9	13.3
7	1.9	2.8		13.3	2.3	4.1	13.3	4.7	6.8		2.4	2.4	11.7	7.3
8	.8	1.5		8.1	1.2	2.4	8.1	2.6	4.7		1.1	1.1	6.9	4.2
9	.1	.6		4.9	.2	1.5	4.9	1.6	2.3		.2	.2	4.3	2.7
10		.1		3.6		.9	3.6	.9	1.5				3.0	1.8
11				2.4		.2	2.4	.4	1.0				2.0	1.2
12				1.6			1.6		.6				1.5	.8
13				1.3			1.3		.2				1.0	.3
14				.9			.9						.8	.1
15				.7			.7						.5	
16				.5			.5						.2	
17				.2			.2							

* See pl. 1.

** Distribution graph derived from combined unit graphs of 3 subareas shown in table 3.

Table 5

Average rainfall intensities by subareas in standard project storms, Gila River Basin

Time		Rainfall in inches per period for indicated subareas* and storm centering**																													
		Subarea 1		Subarea 2		Subarea 3			Subarea 4			Subarea 5			Subarea 6			Subarea 7		Subarea 8		Subarea 9		Subarea 10		Subarea 11		Subarea 12		Subarea 13		Subarea 14	
Day	Hour	A	B	A	B	A	B	C	A	B	C	A	B	C	A	B	C	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1st..	0000-0600	0	0.08	0.10	0.10	0	0.05	0	0.14	0.16	0.44	0	0.15	0.53	0.02	0.09	0.44	0	0	0	0	0	0.01	0	0	0.03	0	0	0	0	0	0	0
	0600-1200	0	.01	.13	.12	0	0	.78	.20	.21	.35	.10	.41	.26	.14	.12	.18	0	0	0	.16	.01	.04	0	0	.03	.03	0	0	0	0	0	0
	1200-1800	.35	.18	.05	.08	.09	.14	0	.11	.13	.12	.10	.16	0	.20	.13	.07	.01	.03	.09	.12	.05	.04	0	0	.05	.13	.02	.04	0	.05	.08	0
	1800-2400	0	0	.08	.16	0	0	0	.12	.09	.08	.11	.05	0	.15	.12	.04	.01	.04	.12	.08	.05	0	0	0	.03	.13	0	.04	0	.10	.16	.21
2d...	0000-0600	.05	.10	.18	.17	.62	.33	0	.22	.17	.08	.42	.36	.09	.20	.25	.08	.01	.07	.11	.24	.05	.04	0	0	.06	.12	0	.07	0	.13	.19	0
	0600-1200	.09	.05	.18	.11	.19	.09	0	.21	.21	.16	.31	.56	0	.20	.23	.14	.01	.04	.10	.16	.03	.05	0	0	.11	.08	0	.01	0	0	0	0
	1200-1800	.75	.34	.72	.38	.38	.56	0	.49	.35	.03	.31	.93	0	.71	.53	.04	.03	.14	.17	.39	.15	.19	0	0	.33	.25	.02	.03	0	0	0	0
	1800-2400	.11	.11	.31	.20	.05	.23	0	.24	.28	.10	.31	.30	.09	.24	.33	.04	.03	.08	.18	.20	.11	.11	0	0	.13	.19	.03	.03	0	.02	.04	.14
3d...	0000-0600	0	.03	.02	.05	0	0	0	.14	.28	.06	0	.05	0	.30	.13	.06	0	.04	0	0	.06	.01	0	0	0	.24	0	.07	.07	.03	.12	.14
	0600-1200	.24	.15	.62	.41	.43	.47	0	.52	.53	.06	.31	1.28	0	.61	.69	0	.01	.04	.12	.39	.03	.08	0	0	.08	.16	.02	.02	0	.05	.08	0
	1200-1800	.02	.07	0	.05	0	0	0	.05	.07	0	0	0	0	.32	.17	.03	.03	.02	0	0	0	.05	0	0	.22	.27	.02	.16	0	0	0	.21
	1800-2400	.02	.03	.05	.05	0	0	0	.10	.19	.04	0	.26	.09	.10	.12	.02	0	0	0	0	0	0	0	0	0	.11	0	.01	0	0	0	0
4th..	0000-0600	.24	.16	.47	.31	.09	.33	0	.54	.53	.06	.10	1.13	.09	.37	.68	.03	0	.02	.08	.07	.03	.05	0	0	.05	.15	0	0	0	0	0	0
	0600-1200	.04	.10	.05	.10	.24	.09	0	.24	.34	.02	.32	.37	0	.07	.38	.02	.06	.07	.18	.20	.04	.05	0	0	.11	.06	.02	.07	.05	.02	.04	.07
	1200-1800	.07	.04	0	0	0	0	0	.02	0	.04	.31	0	0	.27	.04	0	.13	.09	.37	.12	.03	.17	0	0	.41	.21	0	.11	0	0	0	.21
	1800-2400	.14	.07	.20	.16	0	.09	0	.26	.18	.14	.11	.25	0	.16	.44	0	.04	.05	.10	.12	.03	.07	0	0	.05	.13	.03	.04	0	.10	.15	0
5th..	0000-0600	.24	.12	.41	.48	.28	.23	0	.51	1.14	.32	.31	.62	.97	.45	.81	.36	.01	.04	.10	.27	.05	.04	.03	.02	.03	.16	0	.09	0	.08	.12	0
	0600-1200	.05	.03	.44	.43	.19	.37	.78	.39	.55	1.01	.83	.16	.79	.59	.54	.68	.04	.11	.35	.39	.19	.15	0	0	.19	.30	0	.14	0	.13	.19	0
	1200-1800	.02	.03	.13	.13	.14	.14	1.30	.27	.16	1.18	1.15	.41	.44	.81	.61	.79	.57	.65	1.09	.47	.18	.40	.04	0	.60	.51	.07	.12	.02	.18	.27	.35
	1800-2400	0	0	0	0	0	0	0	.03	.05	.24	.10	0	0	.44	.23	.47	.33	.33	.16	.04	.40	.55	.17	.24	.93	.57	.92	.40	.84	.23	.89	.85
6th..	0000-0600	0	0	0	0	0	0	0	.01	.02	.02	0	0	0	.13	.14	0	.47	.40	0	0	.75	.50	.55	.32	.35	.22	.83	.28	.72	.07	.54	.28
	0600-1200	.05	.01	0	0	0	0	0	0	0	0	0	0	0	.03	.01	0	.55	.30	0	0	.04	.40	.96	.82	.24	.03	.25	.10	.30	.08	.15	0
	1200-1800	.07	.03	.02	.03	.14	0	0	.09	.04	0	.83	.15	0	.47	.48	0	.85	.33	.39	.39	.55	.43	.34	.19	.66	.39	.37	.10	.18	.10	.15	.21
Total.....		2.55	1.74	4.16	3.52	2.84	3.12	2.86	4.90	5.68	4.55	6.03	7.60	3.35	6.96	7.27	3.49	3.19	2.89	3.71	3.81	3.93	3.43	2.09	1.59	4.69	4.44	2.60	1.93	2.18	1.37	3.17	2.67

* See pl. 1.

** A - Based on 1916 storm centered over Gila River Basin.
B - Based on 1916 storm centered over Salt River Basin.
C - Based on 1938 storm centered over Salt River Basin. (Storm was critical in subareas 3 to 6, inclusive, only.)

Table 6

Summary of hydrology, standard project flood, McDowell Dam site and Gillespie Dam

Item	Unit	Quantity	
		McDowell Dam site	Gillespie Dam
Drainage area	Sq. mi.	*12,900	#49,600
Peak flow	C.f.s.	290,000	350,000
Peak flow per square mile	C.f.s.	23.0	7.1
Rainfall (average over drainage area):			
Total storm	Inches	6.48	3.93
Effective, total storm	...do...	2.26	1.30
Runoff, total:			
Volume	Ac.-ft.	1,520,000	3,000,000
Depth over drainage area	Inches	2.26	1.14
Ratio to total storm rainfall	Percent	35	29
Runoff over 150,000 c.f.s.:			
Volume	Ac.-ft.	227,000	.....
Depth over drainage area	Inches	.34	.....

* 12,600 square miles, excluding all closed areas.
\# 49,300 square miles, excluding all closed areas.

Table 7

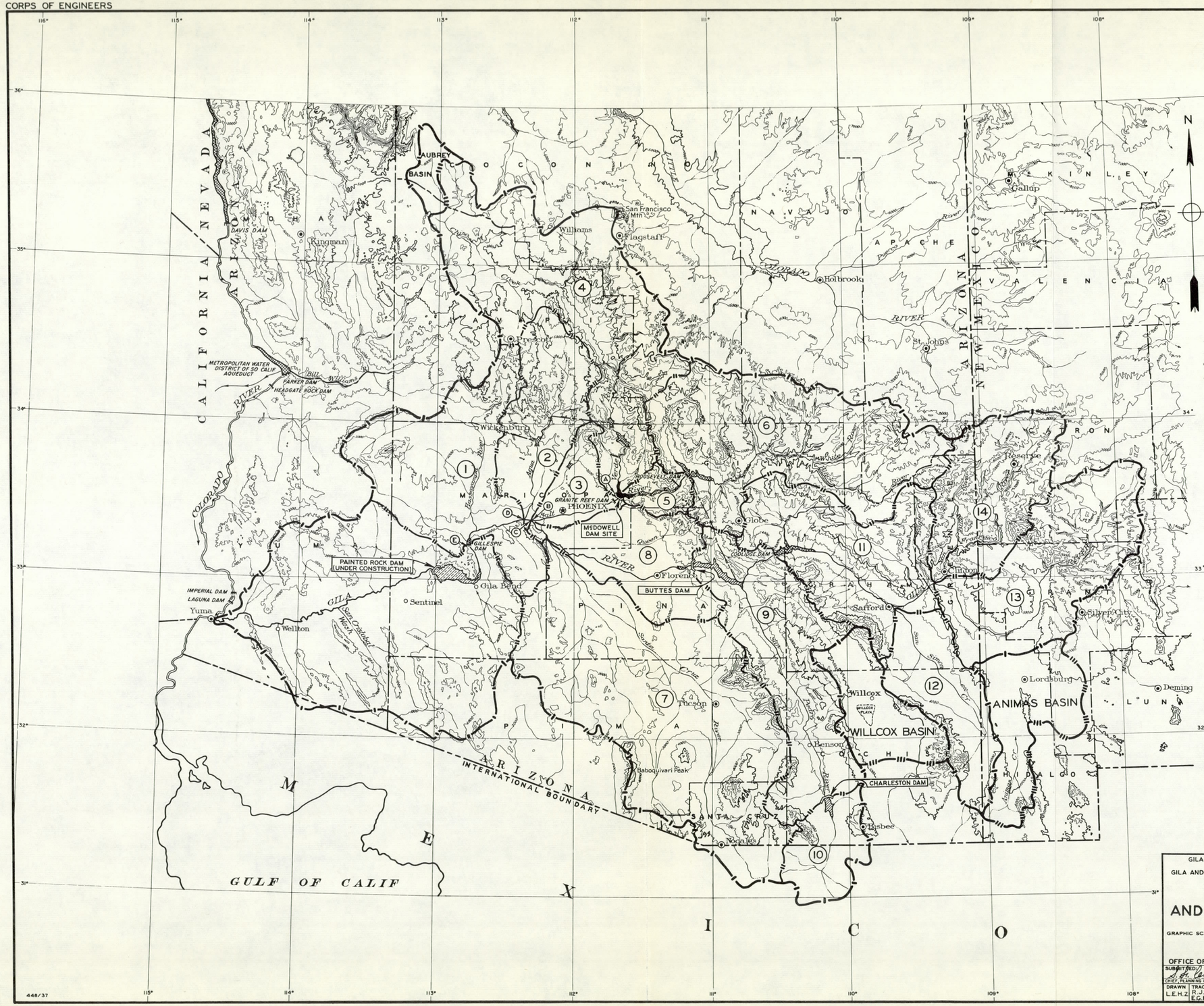
Summary of hydrology, maximum probable flood, McDowell Dam site and Gillespie Dam

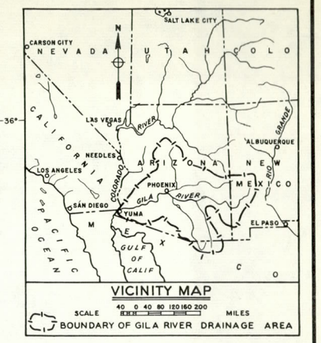
Item	Unit	Quantity	
		McDowell Dam site	Gillespie Dam
Drainage area	Sq. mi.	*12,900	#49,600
Peak flow	C.f.s.	600,000	730,000
Peak flow per square mile	C.f.s.	47.6	14.8
Rainfall (average over drainage area):			
Total storm	Inches	7.43	5.71
Effective, total storm	...do...	3.33	2.47
Runoff, total:			
Volume	Ac.-ft.	2,240,000	6,210,000
Depth over drainage area	Inches	3.33	2.36
Ratio to total storm rainfall	Percent	45	41

* 12,600 square miles, excluding all closed areas.
\# 49,300 square miles, excluding all closed areas.

CORPS OF ENGINEERS

U. S. ARMY





LEGEND

- BOUNDARY OF GILA RIVER DRAINAGE AREA
- BOUNDARY OF SUBAREA
- BOUNDARY OF INEFFECTIVE AREA
- EXISTING RESERVOIR
- MULTIPLE-PURPOSE RESERVOIR RECOMMENDED BY BUREAU OF RECLAMATION.
- FLOOD-CONTROL RESERVOIR AUTHORIZED BY FLOOD-CONTROL ACT APPROVED MAY 17, 1950
- MULTIPLE-PURPOSE RESERVOIR CONSIDERED
- (3) SUBAREA NUMBER
- (A) CONCENTRATION POINT (SEE TABLE 1)

NOTE:
CONTOUR INTERVAL 1000 FEET

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

TOPOGRAPHY DRAINAGE SUBAREAS AND CONCENTRATION POINTS

IN ONE SHEET

GRAPHIC SCALE 10 0 10 20 30 40 MILES

DATUM IS MEAN SEA LEVEL

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

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

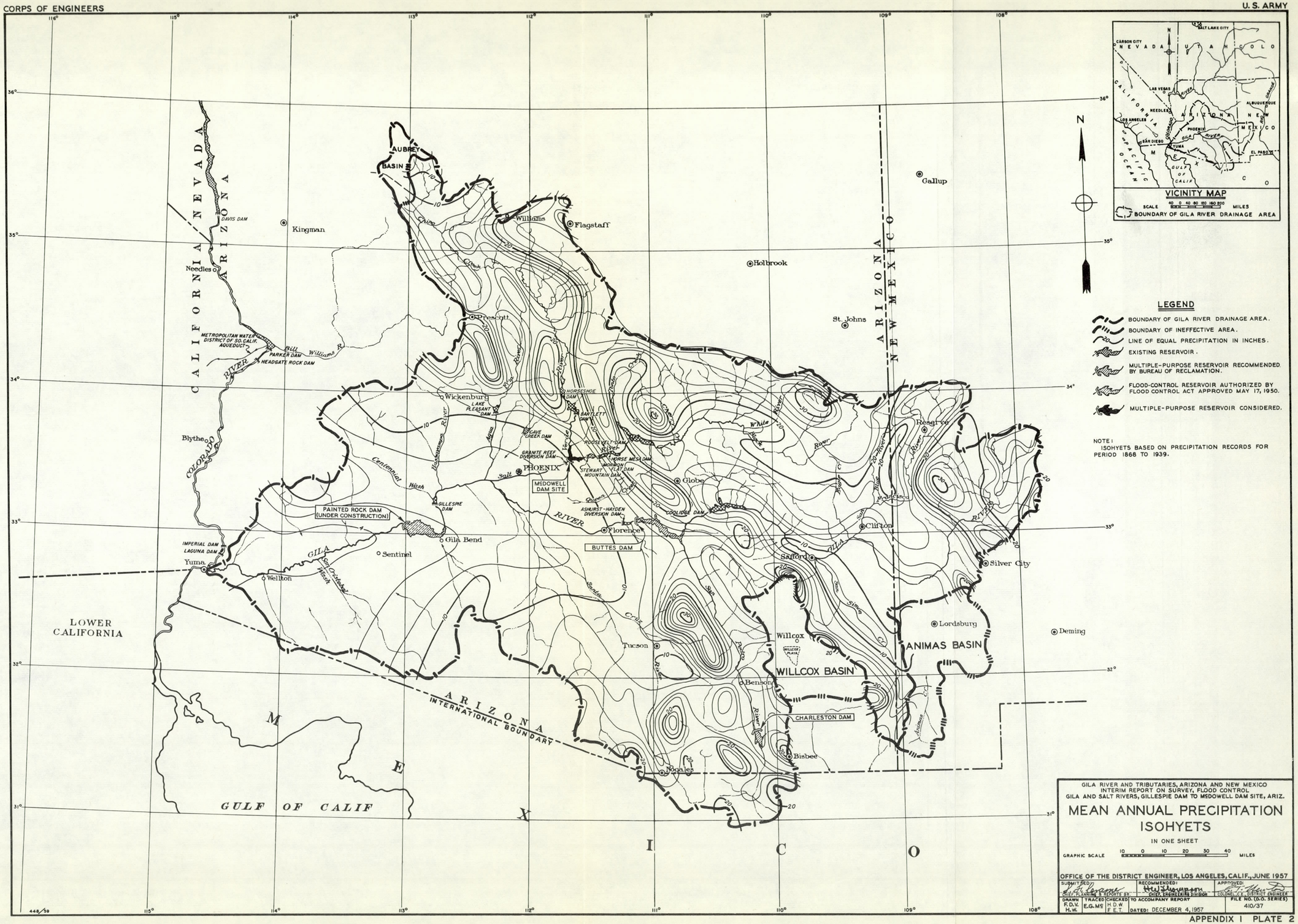
DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (D.O. SERIES)
L.E.H.Z	R.J.B. E.G.M.	H.D.W. F.E.T.	DATED: DECEMBER 4, 1957	410/36

448/37

APPENDIX I PLATE 1

CORPS OF ENGINEERS

U. S. ARMY



VICINITY MAP

SCALE 40 0 40 80 120 160 200 MILES

BOUNDARY OF GILA RIVER DRAINAGE AREA

LEGEND

- BOUNDARY OF GILA RIVER DRAINAGE AREA.
- BOUNDARY OF INEFFECTIVE AREA.
- LINE OF EQUAL PRECIPITATION IN INCHES.
- EXISTING RESERVOIR.
- MULTIPLE-PURPOSE RESERVOIR RECOMMENDED BY BUREAU OF RECLAMATION.
- FLOOD-CONTROL RESERVOIR AUTHORIZED BY FLOOD CONTROL ACT APPROVED MAY 17, 1950.
- MULTIPLE-PURPOSE RESERVOIR CONSIDERED.

NOTE:
ISOHYETS BASED ON PRECIPITATION RECORDS FOR PERIOD 1868 TO 1939.

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

MEAN ANNUAL PRECIPITATION ISOHYETS

IN ONE SHEET

GRAPHIC SCALE 10 0 10 20 30 40 MILES

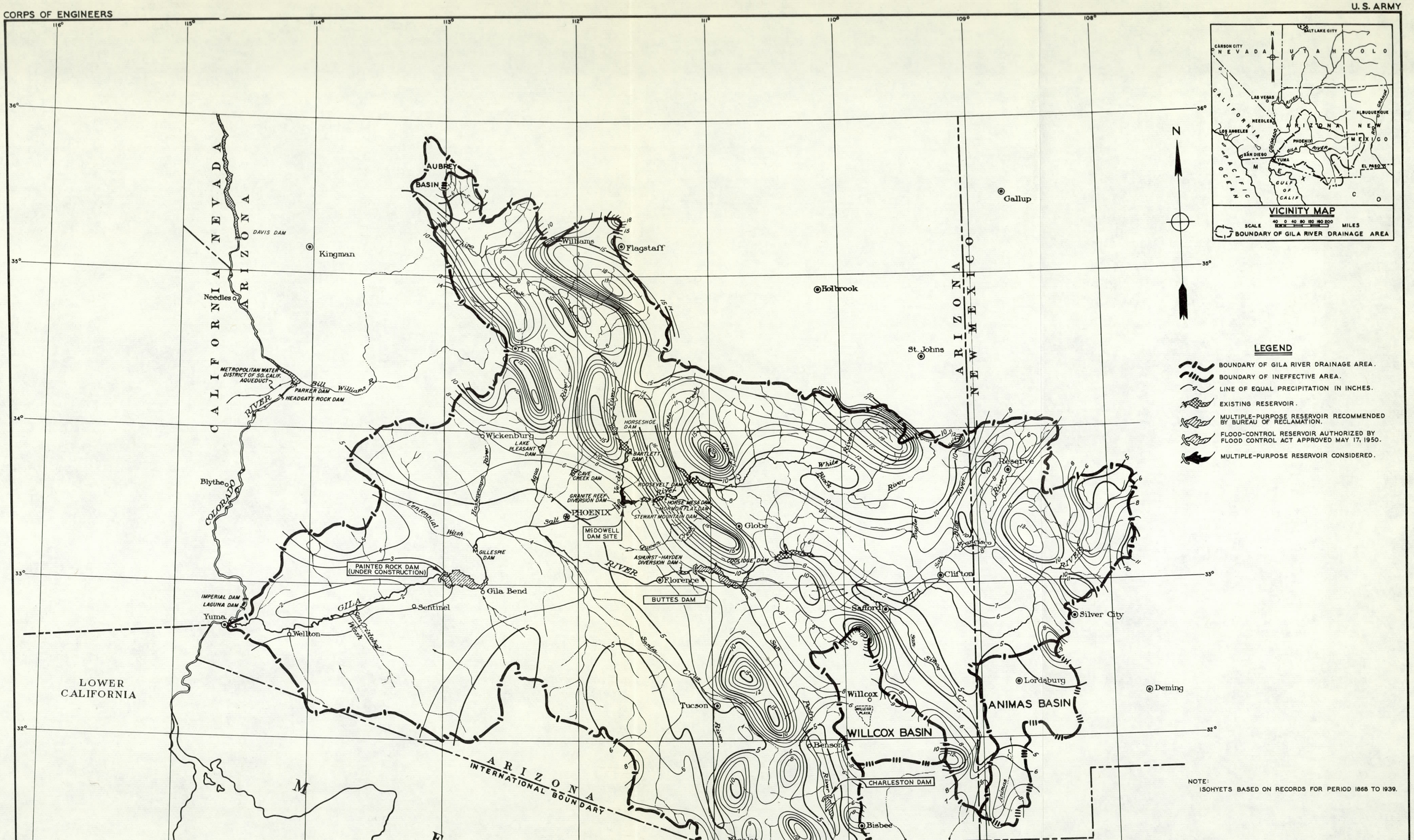
OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., JUNE 1957

SUBMITTED:	RECOMMENDED:	APPROVED:
CHIEF, PLANNING BRANCH	CHIEF, ENGINEERING DIVISION	COLONEL, CORPS OF ENGINEERS, DISTRICT ENGINEER

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (D.O. SERIES)
F.D.V. H.W.	E.G.M'S	H.D.W. F.E.T.	DATED: DECEMBER 4, 1957	410/37

448/39

APPENDIX I PLATE 2



NOTE:
ISOHYETS BASED ON RECORDS FOR PERIOD 1868 TO 1939.

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

MEAN WINTER PRECIPITATION ISOHYETS
(OCTOBER THROUGH MAY)

IN ONE SHEET

GRAPHIC SCALE 10 0 10 20 30 40 MILES

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

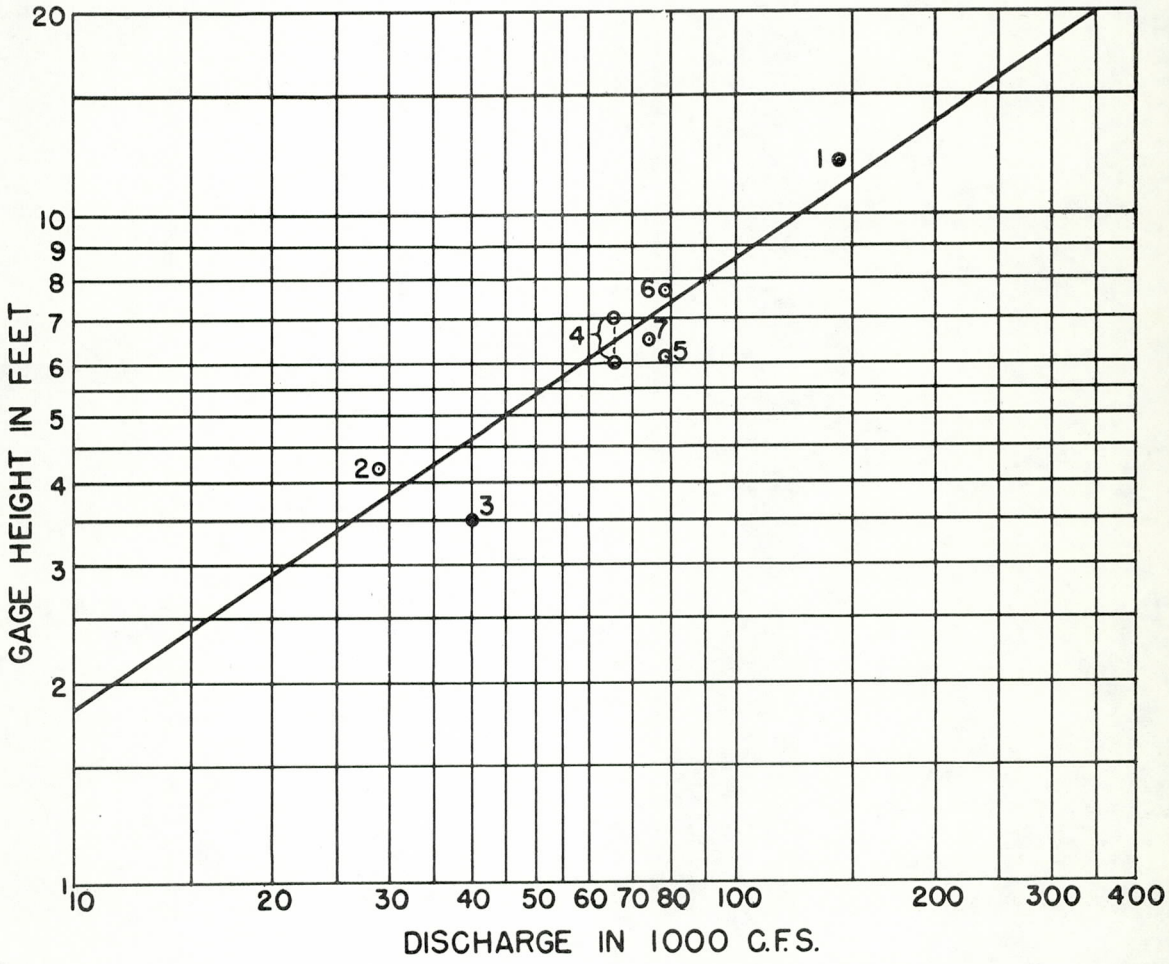
SUBMITTED:	RECOMMENDED:	APPROVED:
S. H. Cramer (signature) CHIEF, PLANNING & REPORTS BRANCH	H. W. Thompson (signature) CHIEF, ENGINEERING DIVISION	(signature) COLONEL, C.E., DISTRICT ENGINEER

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (D.O. SERIES)
F.D.V. H.W.	E.G.Mc	H.D.W F.E.T.	DATED: DECEMBER 4, 1957	410/38

NO.	YEAR	*GAGE HEIGHT FEET	DISCHARGE C.F.S.	SOURCE OF DISCHARGE DATA
1	1890	12.0	143,000	USGS - Salt River at Arizona Dam.
2	1905	4.2	29,000	USGS - Salt River plus Verde R. at McDowell, Ariz.
3	1905	3.5	40,000	Newspaper - Approx. in round numbers.
4	1905	6 to 7	65,300	USGS - Salt River plus Verde R. at McDowell, Ariz.
5	1908	6.1	# 77,900	USGS - Salt River plus Verde R. at McDowell, Ariz.
6	1916	7.7	# 78,000	Encl. 5 of Dist. Engrs. report "Interim Report on survey, Flood Control Gila River & Tributaries above Salt River Ariz. and N. Mex.," dated December 1, 1945.
7	1916	6.5	# 73,800	

* Data from newspaper accounts.

\# Discharge over 900 feet of Granite Reef spillway (total length 1,000 feet) to represent flow over Arizona Dam (spillway length 900 feet) for same gage height.



GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

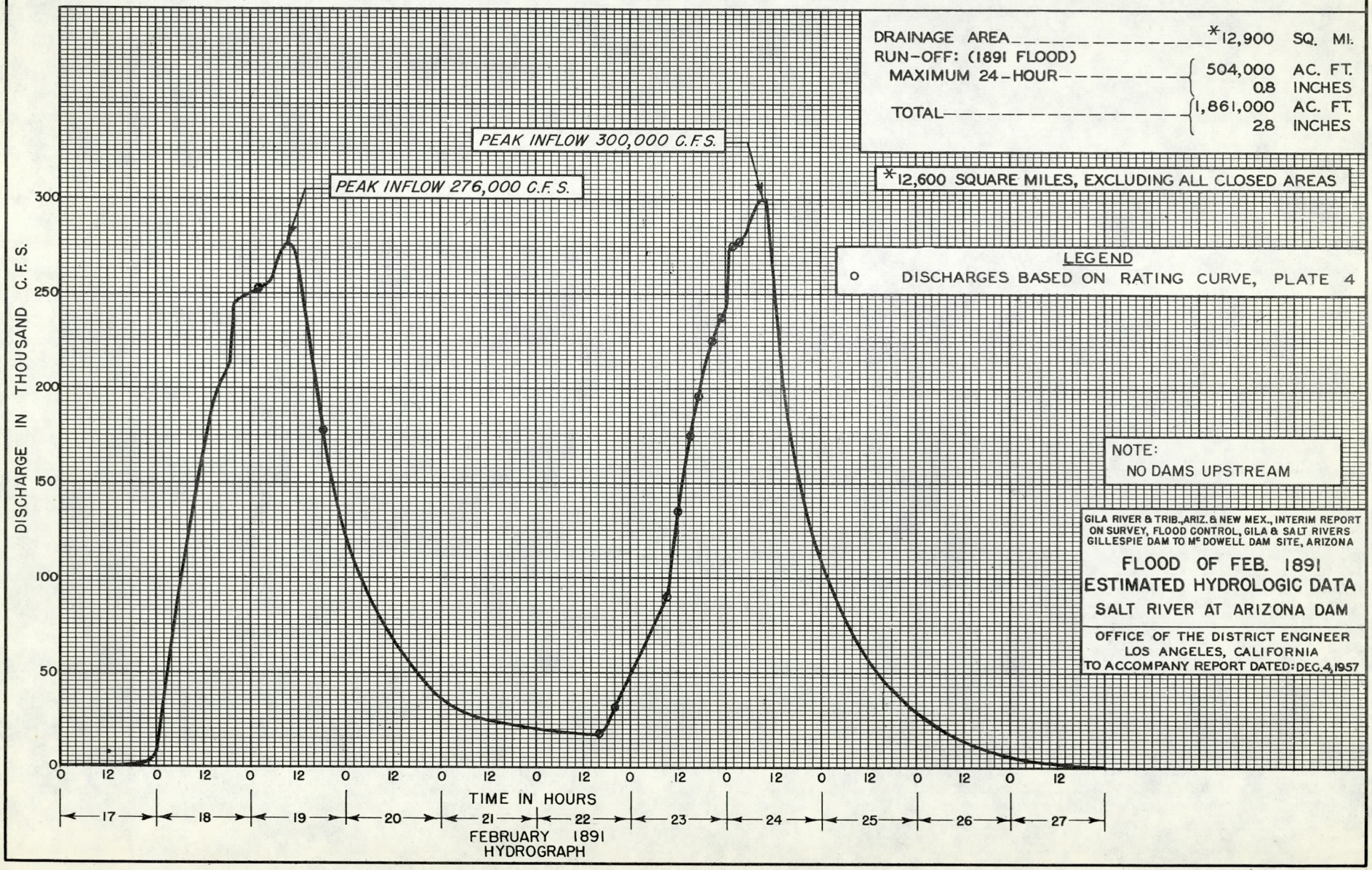
DISCHARGE CURVE

SALT RIVER AT ARIZONA DAM

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 4, 1957

CORPS OF ENGINEERS

U. S. ARMY



DRAINAGE AREA	*12,900	SQ. MI.
RUN-OFF: (1891 FLOOD)		
MAXIMUM 24-HOUR	504,000	AC. FT.
	0.8	INCHES
TOTAL	1,861,000	AC. FT.
	2.8	INCHES

*12,600 SQUARE MILES, EXCLUDING ALL CLOSED AREAS

LEGEND

o DISCHARGES BASED ON RATING CURVE, PLATE 4

NOTE:
NO DAMS UPSTREAM

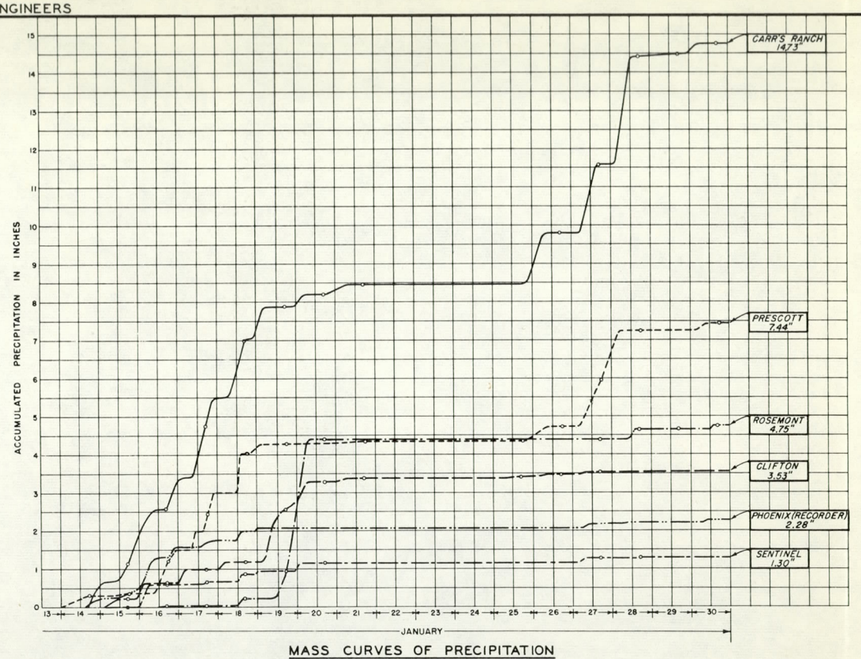
GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS GILLESPIE DAM TO Mc DOWELL DAM SITE, ARIZONA

FLOOD OF FEB. 1891
ESTIMATED HYDROLOGIC DATA
SALT RIVER AT ARIZONA DAM

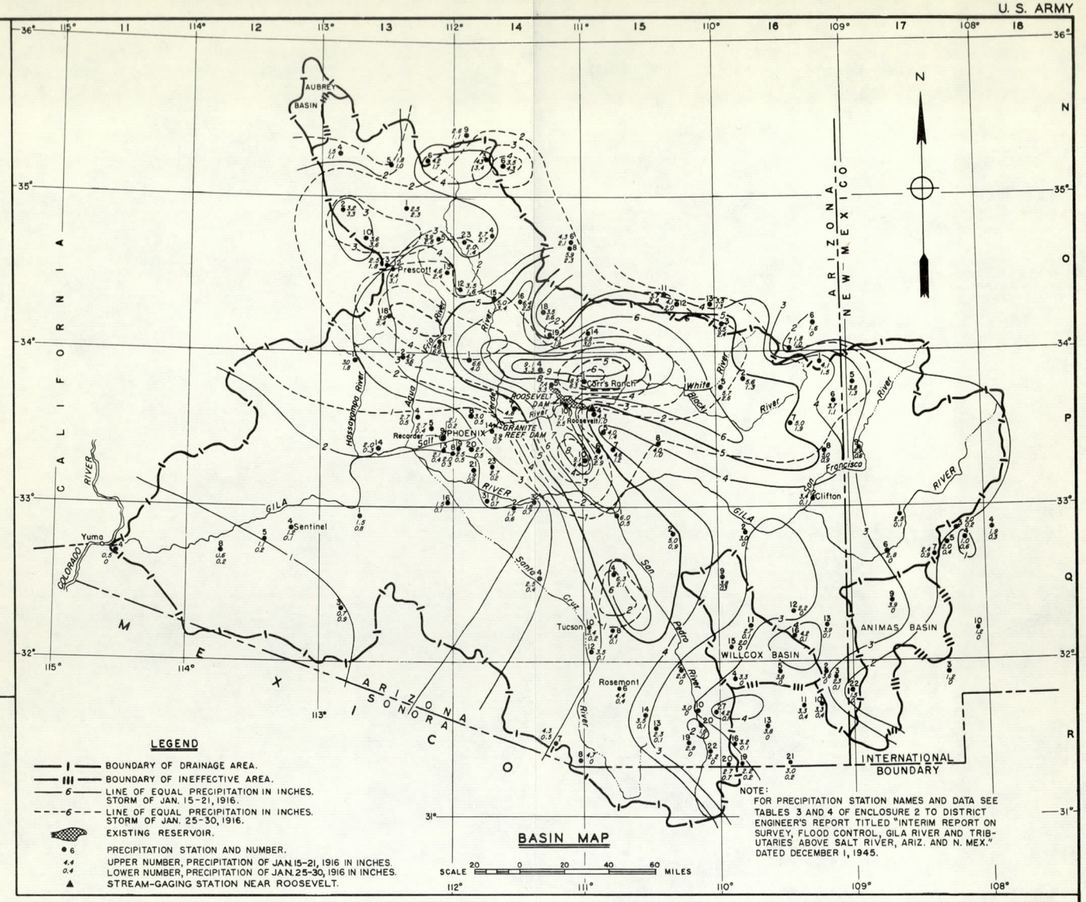
OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 4, 1957

APPENDIX I PLATE 5

FILE NO. 410/40



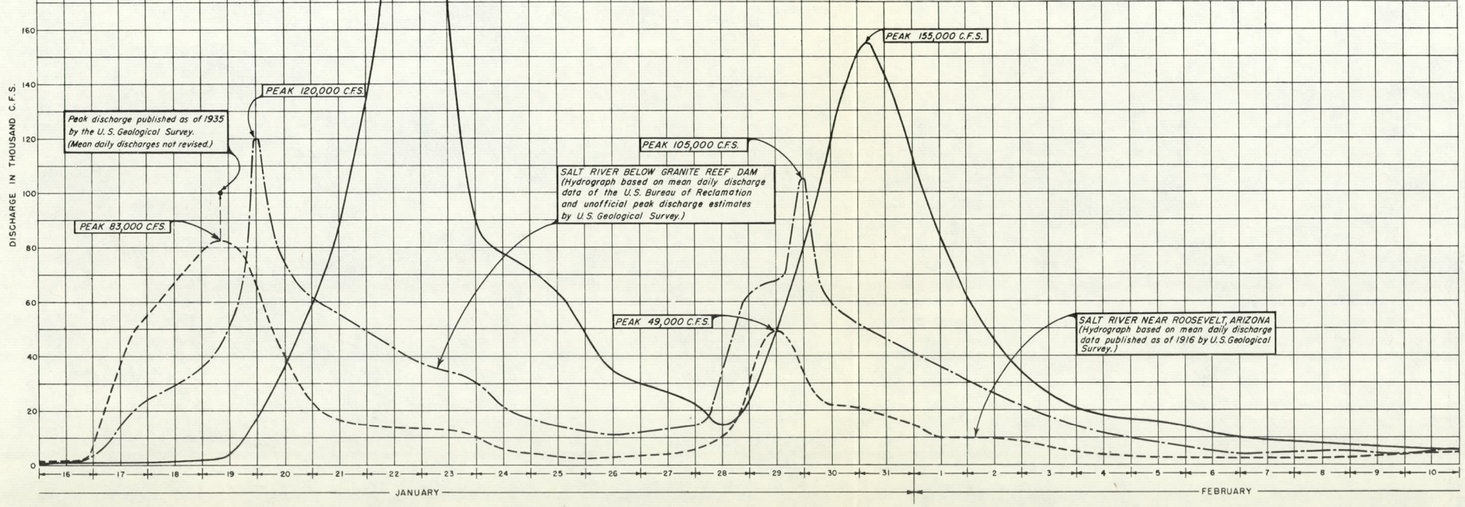
MASS CURVES OF PRECIPITATION
REPRESENTATIVE STATIONS
JANUARY 14-30, 1916



LEGEND

- I — BOUNDARY OF DRAINAGE AREA.
- III — BOUNDARY OF INEFFECTIVE AREA.
- 6 — LINE OF EQUAL PRECIPITATION IN INCHES. STORM OF JAN. 15-21, 1916.
- 6 — LINE OF EQUAL PRECIPITATION IN INCHES. STORM OF JAN. 25-30, 1916.
- EXISTING RESERVOIR.
- ● 6 PRECIPITATION STATION AND NUMBER.
- 4.4 UPPER NUMBER, PRECIPITATION OF JAN. 15-21, 1916 IN INCHES.
- 0.4 LOWER NUMBER, PRECIPITATION OF JAN. 25-30, 1916 IN INCHES.
- ▲ STREAM-GAGING STATION NEAR ROOSEVELT.

NOTE:
FOR PRECIPITATION STATION NAMES AND DATA SEE TABLES 3 AND 4 OF ENCLOSURE 2 TO DISTRICT ENGINEER'S REPORT TITLED "INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA RIVER AND TRIBUTARIES ABOVE SALT RIVER, ARIZ. AND N. MEX." DATED DECEMBER 1, 1945.



HYDROGRAPHS

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO MEDOWELL DAM SITE, ARIZ.

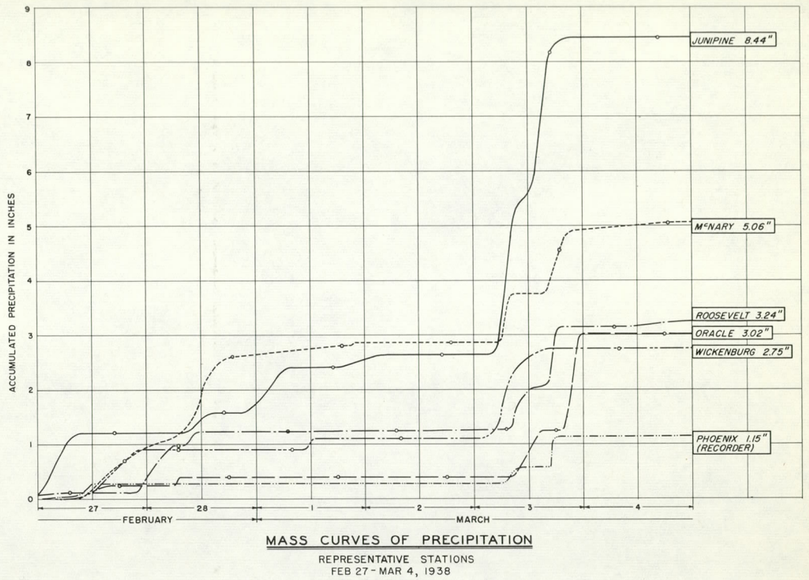
FLOOD OF JANUARY-FEBRUARY 1916
HYDROLOGIC DATA

SCALE: AS SHOWN IN ONE SHEET

OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., SEPT. 1950

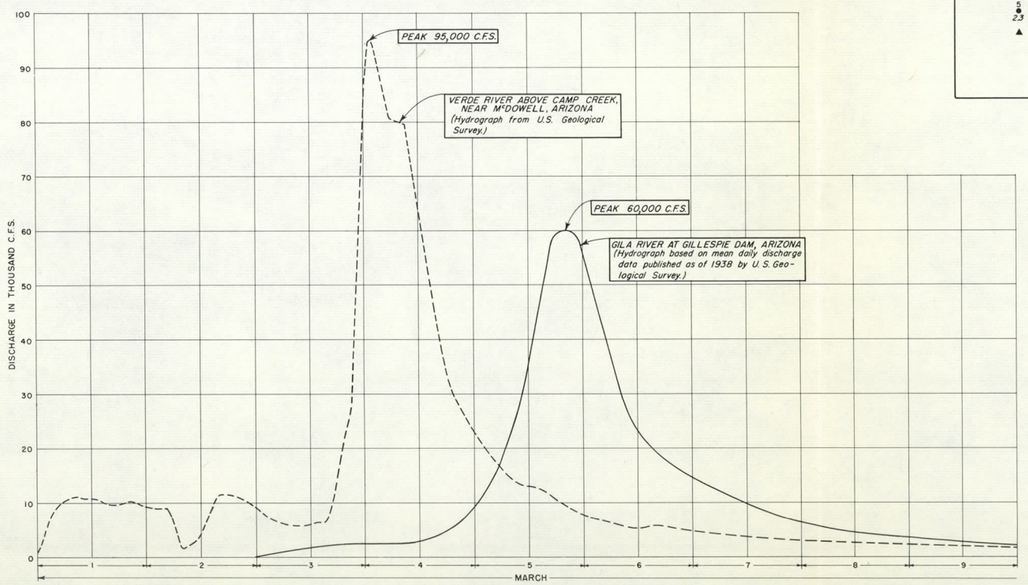
SUBMITTED:	RECOMMENDED:	APPROVED:
Chief, Planning & Reports Branch	Chief, Engineering Division	Colonel, C.E. District Engineer

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (D O SERIES)
R.L.	H.T.L. H.C.K.	H.D.W. F.E.T.	DATED: DECEMBER 4, 1957	410/41

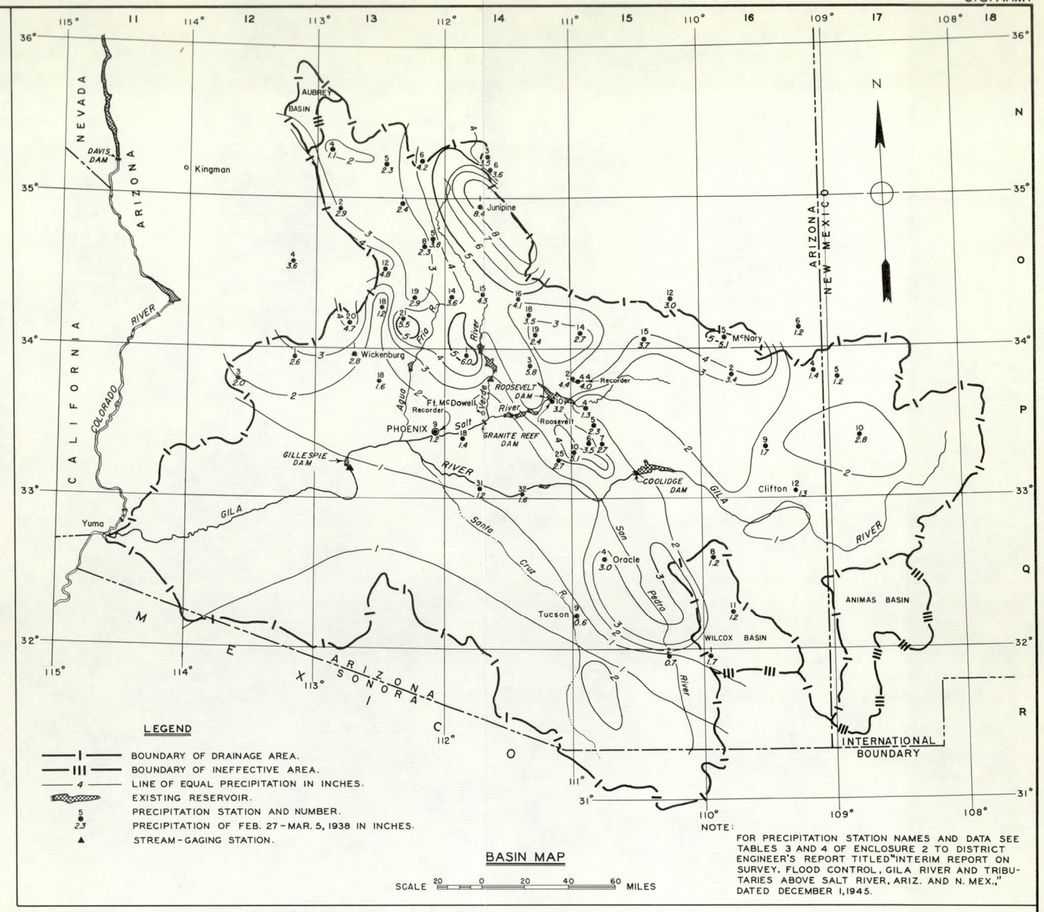


MASS CURVES OF PRECIPITATION

REPRESENTATIVE STATIONS
FEB 27 - MAR 4, 1938



HYDROGRAPHS



BASIN MAP

SCALE 20 0 20 40 60 MILES

NOTE:
FOR PRECIPITATION STATION NAMES AND DATA SEE TABLES 3 AND 4 OF ENCLOSURE 2 TO DISTRICT ENGINEER'S REPORT TITLED "INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA RIVER AND TRIBUTARIES ABOVE SALT RIVER, ARIZ. AND N. MEX.," DATED DECEMBER 1, 1945.

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

FLOOD OF FEBRUARY-MARCH 1938
HYDROLOGIC DATA

SCALE: AS SHOWN IN ONE SHEET

OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., SEPT. 1950

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

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (D.O. SERIES)
H.W.	H.C.K.	H.D.W. F.E.T.	DATED: DECEMBER 4, 1957	410/42

	DRAINAGE AREA SQ. MI.	L MILES	L_{CA} MILES	S FT/MI	LAG HOURS
1. SAN GABRIEL RIVER AT SAN GABRIEL DAM NO. 1, CALIF. *	182	23.2	11.6	350	3.3
2. WEST FORK SAN GABRIEL RIVER AT SAN GABRIEL DAM NO. 2, CALIF.	40.4	9.3	4.2	450	1.6
3. SAN DIMAS CREEK AT SAN DIMAS DAM, CALIF.	16.2	8.6	4.8	440	1.5
4. BILL WILLIAMS RIVER AT PLANET, ARIZ.	5,140	137.1	64.6	36	16.2
5. VERDE RIVER ABOVE CAMP CREEK, NEAR MCDOWELL, ARIZ.	6,230	201.0	90.0	25	19.7
6. MURRIETA CREEK AT TEMECULA, CALIF.	220	27.2	10.3	95	4.0
7. SANTA CLARA RIVER NEAR SAUGUS, CALIF.	355	36.0	15.8	140	5.6
8. TEMECULA CREEK AT PAUBA CANYON, CALIF. **	188	28.0	11.3	150	3.7
9. SANTA MARGARITA RIVER NEAR FALLBROOK, CALIF.	645	46.0	22.0	105	7.3
10. SAN VICENTE CREEK AT FOSTER, CALIF.	75	18.2	7.4	111	3.2
11. TUJUNGA CREEK AT BIG TUJUNGA DAM NO. 1, CALIF.	81.4	15.1	7.3	290	2.5
12. SANTA MARGARITA RIVER AT YSIDORA, CALIF.	740	61.2	34.3	85	9.5
13. LOS ANGELES RIVER AT SEPULVEDA DAM, CALIF.	152	19.0	9.0	145	3.5
14. PACOIMA WASH AT PACOIMA DAM, CALIF.	27.8	15.0	8.0	315	2.4
15. GILA RIVER AT CONNER NO. 4 DAM SITE, ARIZ.	2,840	131	71	29	21.5
16. SAN FRANCISCO RIVER AT JUNCTION WITH BLUE RIVER, ARIZ. ***	2,000	130	74	32	20.6
17. BLUE RIVER NEAR CLIFTON, ARIZ. ***	790	77	37	65	10.3
18. SAN DIEGO RIVER NEAR SANTEE, CALIF.	380	42.8	22.3	100	9.2
19. GILA RIVER NEAR CLIFTON, ARIZ.	4,040	197	97	24	35.8
20. SANTA ANA RIVER AT PRADO DAM, CALIF. *	1,466	68	26	115	13.0
21. SALT RIVER NEAR ROOSEVELT, ARIZ.	4,310	160	66	45	18.6

TERMINOLOGY

L = LENGTH OF LONGEST WATERCOURSE.

L_{CA} = LENGTH OF LONGEST WATERCOURSE, MEASURED UPSTREAM, TO POINT OPPOSITE CENTER OF AREA.

S = OVER-ALL SLOPE OF DRAINAGE AREA BETWEEN HEADWATERS AND COLLECTION POINT.

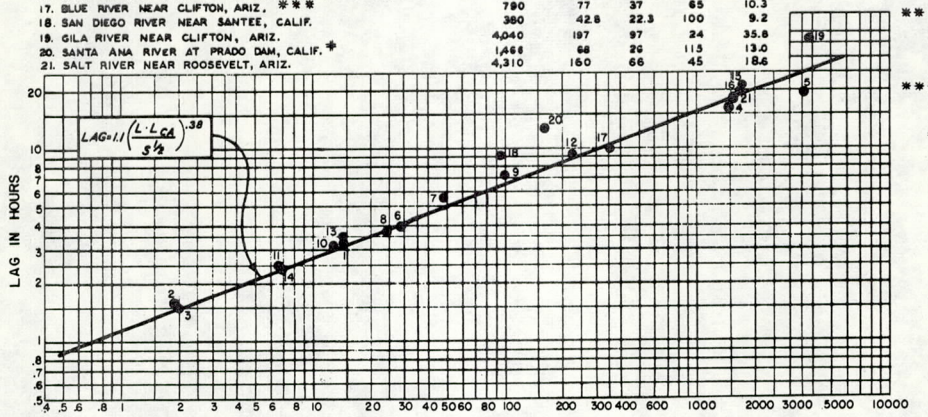
LAG = ELAPSED TIME FROM BEGINNING OF UNIT RAINFALL TO INSTANT THAT SUMMATION HYDROGRAPH REACHES 50% OF ULTIMATE DISCHARGE.

* EXCLUDES AREA ABOVE SAN GABRIEL DAM NO. 2.

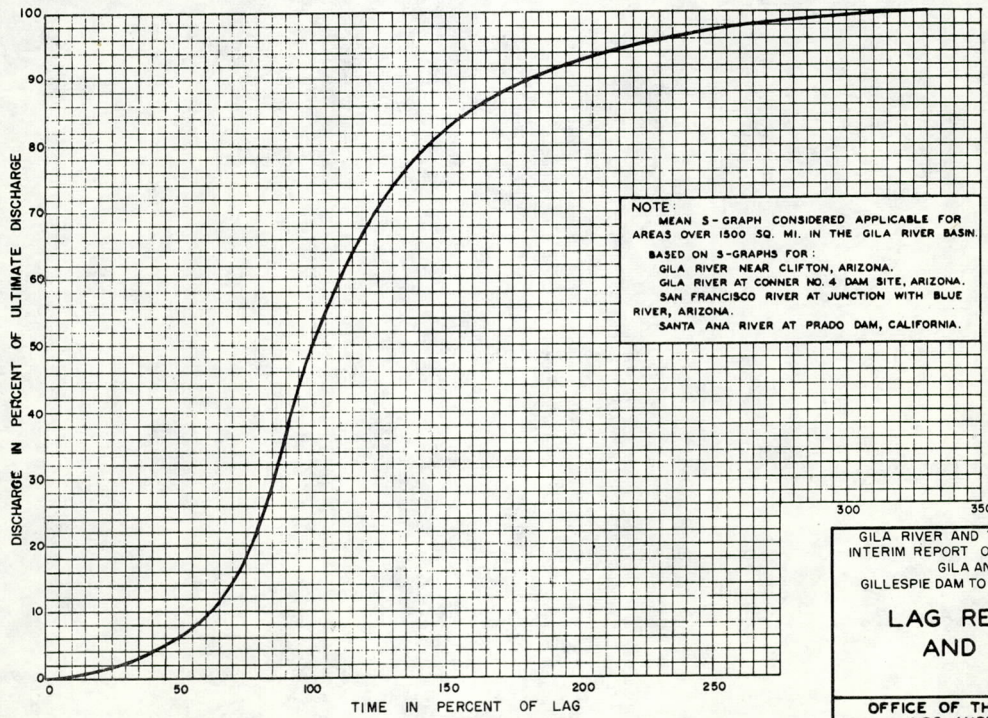
** PALOMAR MOUNTAIN PORTION. ENTIRE AREA IS 319 SQUARE MILES, OF WHICH 151 SQUARE MILES DID NOT CONTRIBUTE APPRECIABLE FLOOD FLOWS DURING THE FLOODS ANALYZED.

*** UNIT-GRAPH STUDY BASED ON RUN-OFF RECORDS FOR SAN FRANCISCO RIVER AT CLIFTON (DRAINAGE AREA = 2790 SQ. MI.)

EXCLUDES 25 SQUARE MILES TRIBUTARY TO BALDWIN LAKE AND 787 SQUARE MILES TRIBUTARY TO LAKE ELSINORE.



LAG RELATIONSHIPS



NOTE:
MEAN S-GRAPH CONSIDERED APPLICABLE FOR AREAS OVER 1500 SQ. MI. IN THE GILA RIVER BASIN.
BASED ON S-GRAPHS FOR:
GILA RIVER NEAR CLIFTON, ARIZONA.
GILA RIVER AT CONNER NO. 4 DAM SITE, ARIZONA.
SAN FRANCISCO RIVER AT JUNCTION WITH BLUE RIVER, ARIZONA.
SANTA ANA RIVER AT PRADO DAM, CALIFORNIA.

S-GRAPH

GILA RIVER AND TRIB., ARIZ. AND N. MEX.
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS,
GILLESPIE DAM TO MCDOWELL DAM SITE, ARIZ.

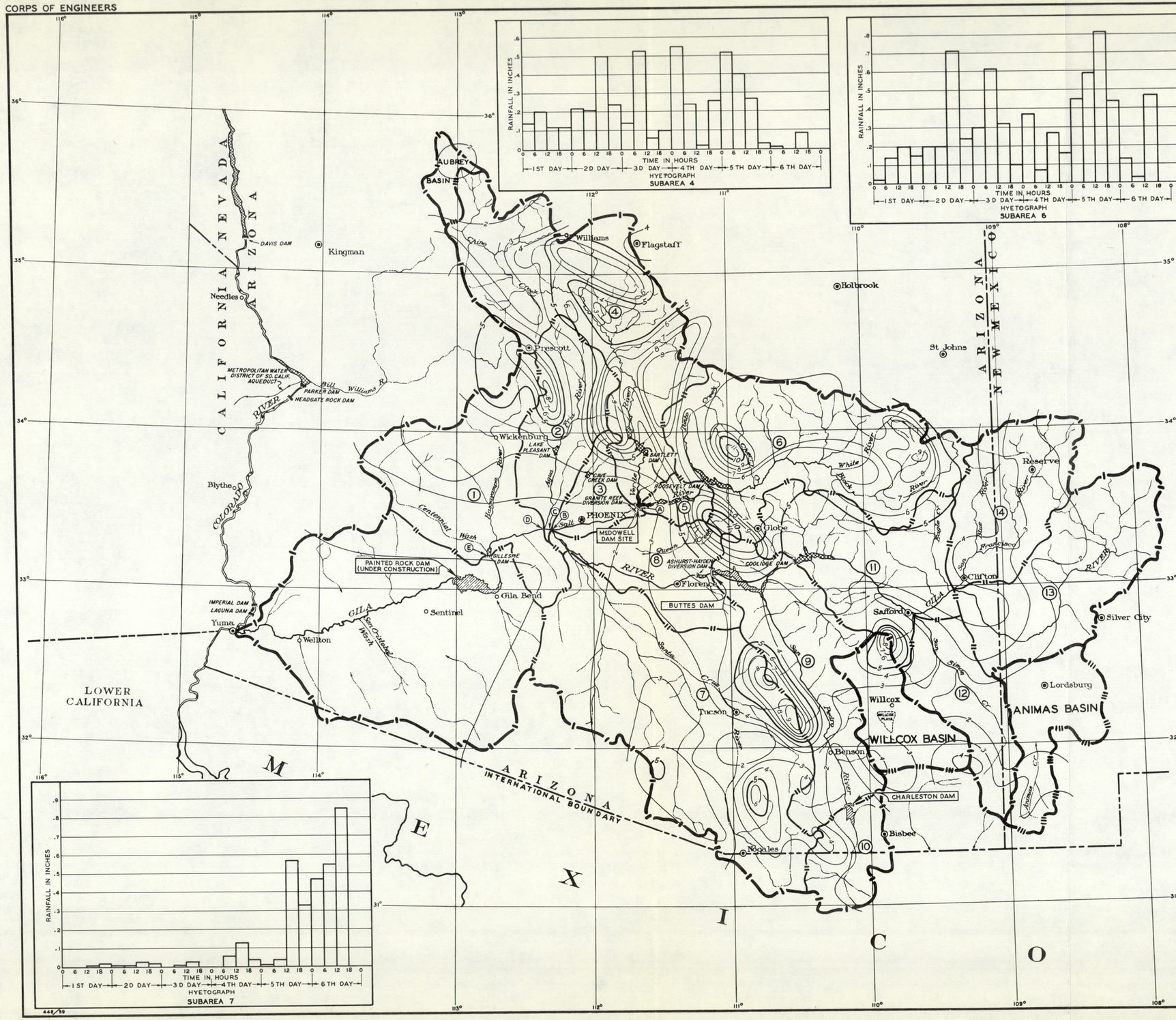
LAG RELATIONSHIPS AND S-GRAPH

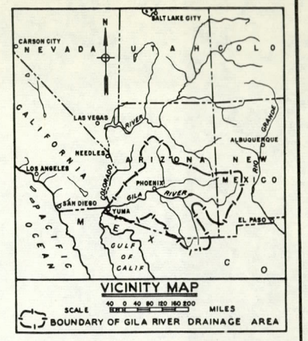
OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DECEMBER 4, 1957

FILE NO. 410/43 APPENDIX I PLATE 8

CORPS OF ENGINEERS

U. S. ARMY

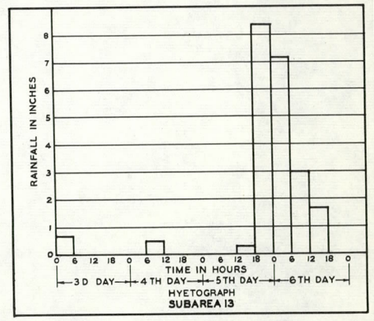




N

LEGEND

- BOUNDARY OF GILA RIVER DRAINAGE AREA.
- BOUNDARY OF SUBAREA.
- BOUNDARY OF INEFFECTIVE AREA.
- LINE OF EQUAL PRECIPITATION IN INCHES.
- EXISTING RESERVOIR.
- MULTIPLE-PURPOSE RESERVOIR RECOMMENDED BY BUREAU OF RECLAMATION.
- FLOOD-CONTROL RESERVOIR AUTHORIZED BY FLOOD CONTROL ACT APPROVED MAY 17, 1950.
- MULTIPLE-PURPOSE RESERVOIR CONSIDERED.
- (3) SUBAREA NUMBER.
- (A) → CONCENTRATION POINT (SEE TABLE 1).



NOTE:
ISOHYETS BASED ON JANUARY 15-21, 1916 STORM TRANSPOSED OVER AREA ABOVE GILLESPIE DAM AND INDICATE TOTAL PRECIPITATION FOR THIS PERIOD.

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO MSDOWELL DAM SITE, ARIZ.

STANDARD PROJECT STORM ISOHYETS

(FOR AREA ABOVE GILLESPIE DAM)

IN ONE SHEET

GRAPHIC SCALE 10 0 10 20 30 40 MILES

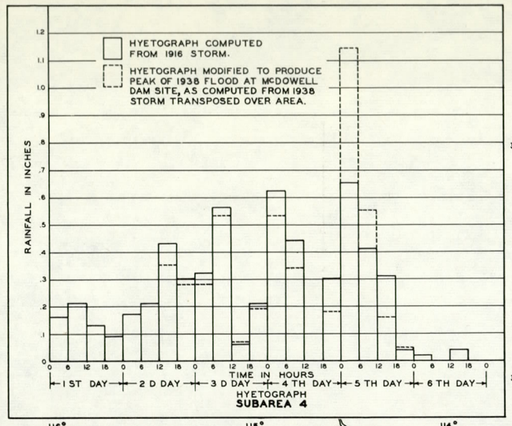
OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., JUNE 1957

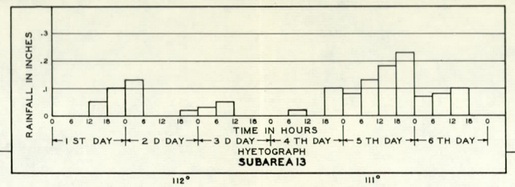
SUBMITTED:	RECOMMENDED:	APPROVED:
SHIRLEY M. HANNING, JR. REPORTS BRANCH	CHIEF, ENGINEERING DIVISION	COLONEL, C. E. DISTRICT ENGINEER

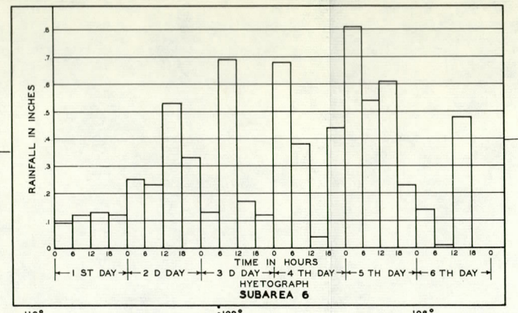
DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (D.O. SERIES)
F.D.V. H.W.	E.G.M.S	H.D.W. F.E.T.	DATED: DECEMBER 4, 1957	410/44

448/59

APPENDIX I PLATE 9







LEGEND

- BOUNDARY OF GILA RIVER DRAINAGE AREA.
- BOUNDARY OF SUBAREA.
- BOUNDARY OF INEFFECTIVE AREA.
- LINE OF EQUAL PRECIPITATION IN INCHES.
- EXISTING RESERVOIR.
- MULTIPLE-PURPOSE RESERVOIR RECOMMENDED BY BUREAU OF RECLAMATION.
- FLOOD-CONTROL RESERVOIR AUTHORIZED BY FLOOD CONTROL ACT APPROVED MAY 17, 1950.
- MULTIPLE-PURPOSE RESERVOIR CONSIDERED.
- (5) SUBAREA NUMBER.

NOTE:
ISOHYETS BASED ON JANUARY 15-21, 1916 STORM TRANSPOSED OVER AREA ABOVE McDOWELL DAM SITE AND INDICATE TOTAL PRECIPITATION FOR THIS PERIOD.

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO MSDOWELL DAM SITE, ARIZ.

STANDARD PROJECT STORM ISOHYETS

(FOR AREA ABOVE McDOWELL DAM SITE)

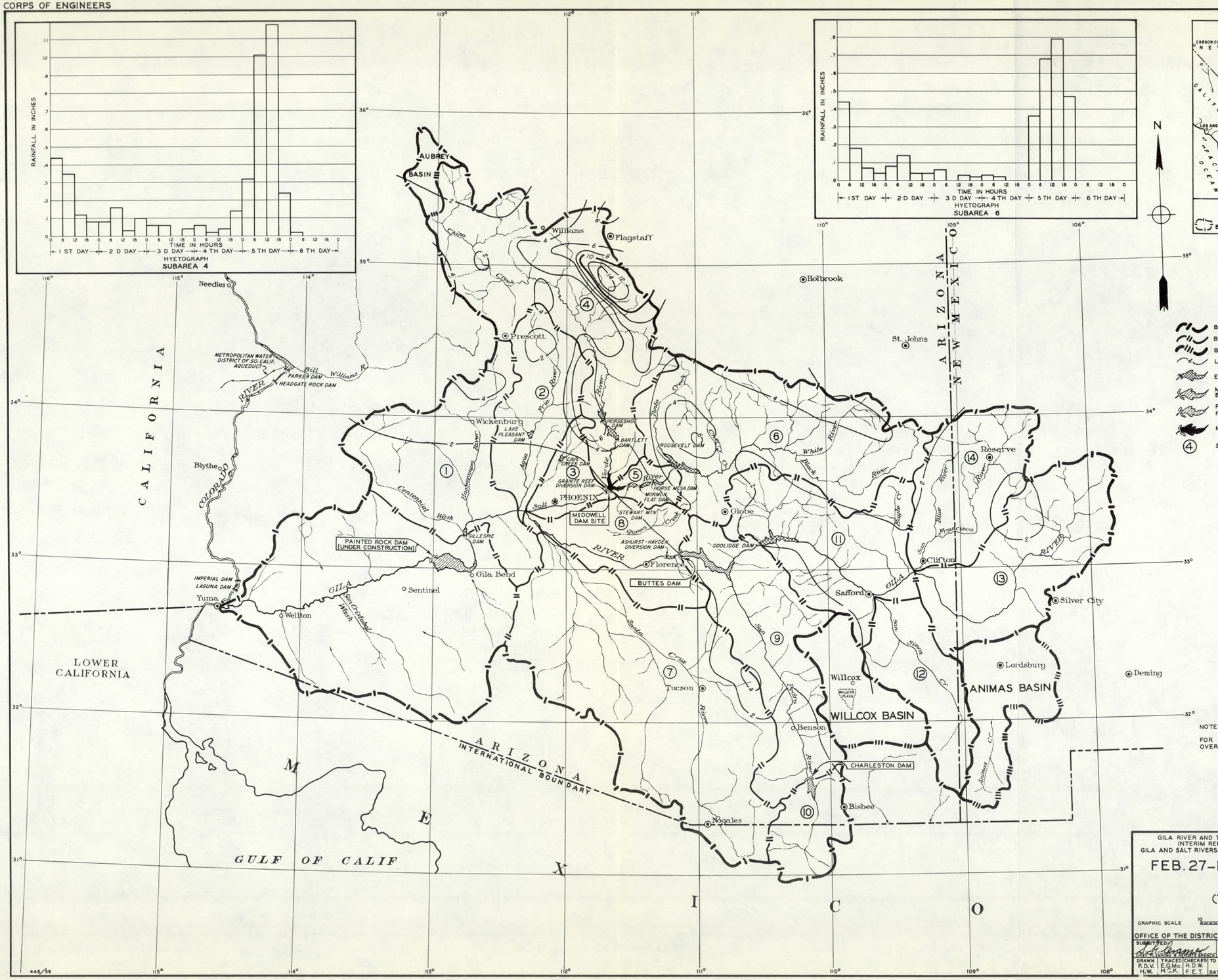
IN ONE SHEET

GRAPHIC SCALE 10 0 10 20 30 40 MILES

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

SUBMITTED:	RECOMMENDED:	APPROVED:
Chief, Planning & Reports Branch	Chief, Engineering Division	Colonel, C.E., District Engineer

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (O.D. SERIES)
F.D.V. H.W.	E.G.M.S	H.D.W. F.E.T.	DATED: DECEMBER 4, 1957	410/45



N

LEGEND

- BOUNDARY OF GILA RIVER DRAINAGE AREA.
- BOUNDARY OF SUBAREA.
- BOUNDARY OF INEFFECTIVE AREA.
- LINE OF EQUAL PRECIPITATION IN INCHES.
- EXISTING RESERVOIR.
- MULTIPLE-PURPOSE RESERVOIR RECOMMENDED BY BUREAU OF RECLAMATION.
- FLOOD-CONTROL RESERVOIR AUTHORIZED BY FLOOD CONTROL ACT APPROVED MAY 17, 1950.
- MULTIPLE-PURPOSE RESERVOIR CONSIDERED.
- (4) SUBAREA NUMBER.

NOTE:
ISOHYETS INDICATE TOTAL PRECIPITATION FOR STORM OF FEB. 27 - MAR. 4, 1938, TRANSPOSED OVER AREA ABOVE McDOWELL DAM SITE.

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

FEB. 27-MAR. 4, 1938 STORM ISOHYETS (TRANSPOSED)

IN ONE SHEET

GRAPHIC SCALE 10 0 10 20 30 40 MILES

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

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

DRAWN	TRACED	CHECKED
F.D.V. H.W.	E.G.Mc. H.C.K.	H.D.W. F.E.T.

TO ACCOMPANY REPORT DATED: DECEMBER 4, 1957

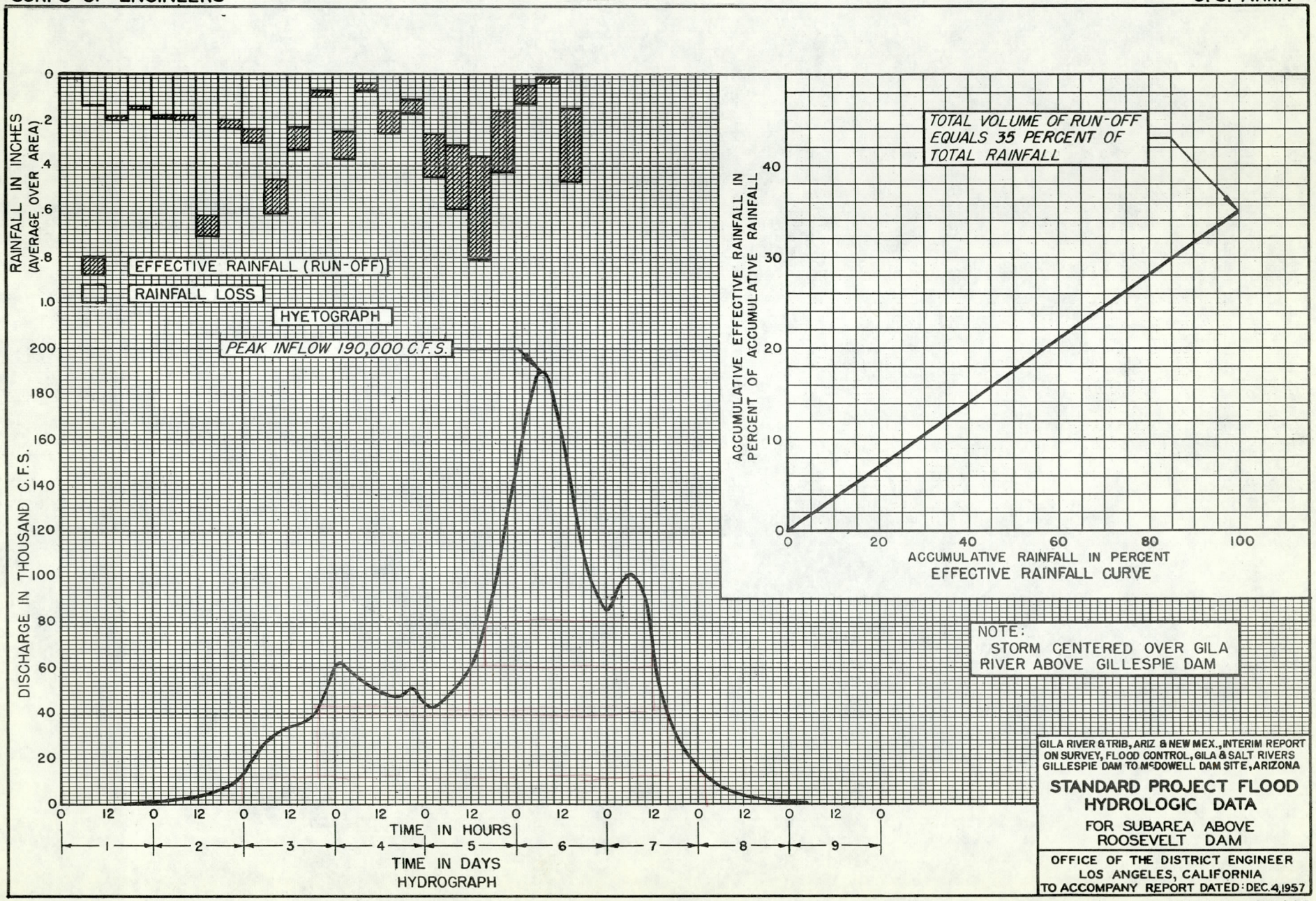
FILE NO. (D.O. SERIES) 410.46

448/59

APPENDIX I PLATE II

CORPS OF ENGINEERS

U. S. ARMY



GILA RIVER & TRIB., ARIZ & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

STANDARD PROJECT FLOOD HYDROLOGIC DATA

FOR SUBAREA ABOVE ROOSEVELT DAM

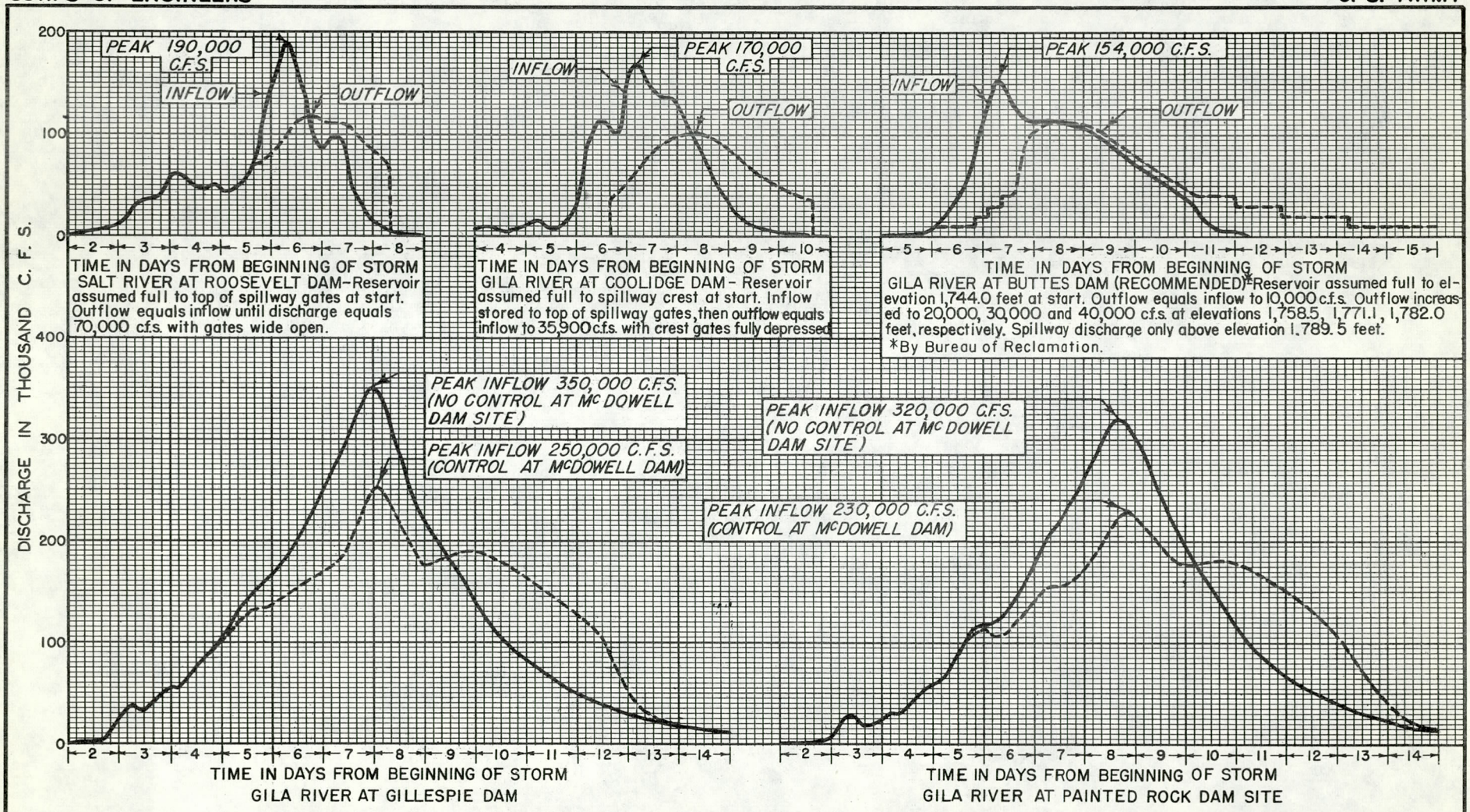
OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 4, 1957

APPENDIX I PLATE 12

FILE NO. 410/47

CORPS OF ENGINEERS

U. S. ARMY



AT GILLESPIE DAM	
DRAINAGE AREA	*49,600 SQ. MI.
AVERAGE RAINFALL DEPTH OVER AREA:	
TOTAL STORM	3.9 INCHES
EFFECTIVE, TOTAL STORM	1.3 INCHES
RUN-OFF:	
TOTAL FLOOD VOLUME	3,000,000 AC-FT. / 1.1 INCHES
RATIO OF RUN-OFF TO RAINFALL	28 PERCENT

*49,300 SQUARE MILES, EXCLUDING ALL CLOSED AREAS.

Note:

Storm centered over Gila River above Gillespie Dam.

Hydrographs for Charleston Dam (recommended by U.S.B.R.) on San Pedro River and Mc Dowell Dam (considered) on Salt River not shown.

Charleston reservoir assumed full to elevation 4,053.0 feet at start. Outflow equals inflow to 5,000 c.f.s. Inflow peak is 43,000 c.f.s., outflow 5,000 c.f.s.

McDowell reservoir assumed full to elevation 1,405.0 feet at start. Outflow equals inflow to 82,000 c.f.s. Inflow peak is 210,000 c.f.s., outflow, 82,000 c.f.s.

All other reservoirs assumed full to spillway crest at start of flood and negligible in their effect on run-off.

GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS, GILLESPIE DAM TO Mc DOWELL DAM SITE, ARIZONA

STANDARD PROJECT FLOOD HYDROGRAPHS

GILLESPIE DAM

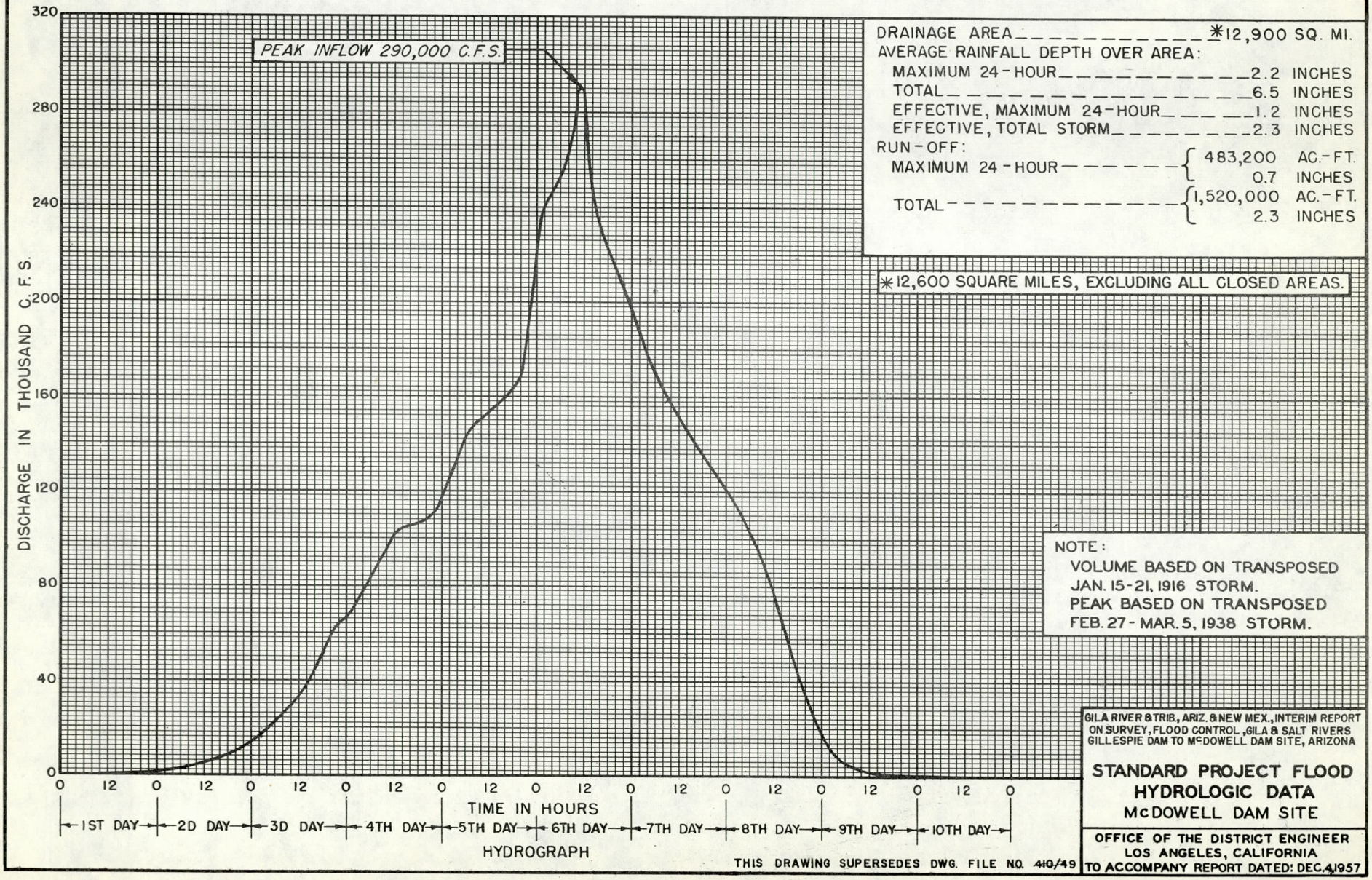
OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 4, 1957

APPENDEX I PLATE 13

FILE NO. 410/48

CORPS OF ENGINEERS

U. S. ARMY



DRAINAGE AREA	*12,900 SQ. MI.
AVERAGE RAINFALL DEPTH OVER AREA:	
MAXIMUM 24-HOUR	2.2 INCHES
TOTAL	6.5 INCHES
EFFECTIVE, MAXIMUM 24-HOUR	1.2 INCHES
EFFECTIVE, TOTAL STORM	2.3 INCHES
RUN-OFF:	
MAXIMUM 24-HOUR	483,200 AC.-FT. / 0.7 INCHES
TOTAL	1,520,000 AC.-FT. / 2.3 INCHES

*12,600 SQUARE MILES, EXCLUDING ALL CLOSED AREAS.

NOTE:
VOLUME BASED ON TRANSPOSED JAN. 15-21, 1916 STORM.
PEAK BASED ON TRANSPOSED FEB. 27 - MAR. 5, 1938 STORM.

GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

STANDARD PROJECT FLOOD HYDROLOGIC DATA

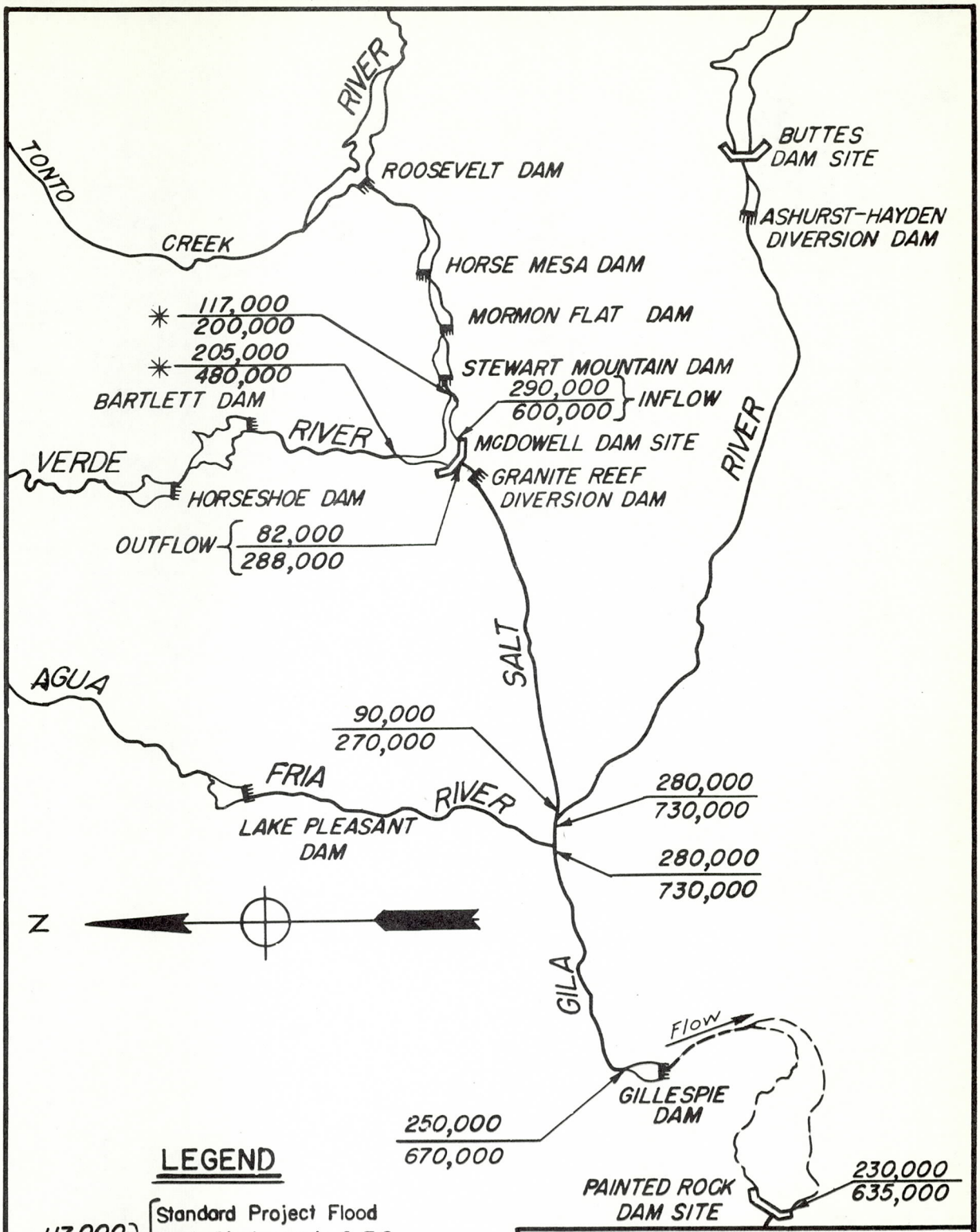
McDOWELL DAM SITE

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 4 1957

THIS DRAWING SUPERSEDES DWG. FILE NO. 410/49

APPENDEX I PLATE 14

FILE NO. 410/49



LEGEND

117,000 / 200,000 — Standard Project Flood Peak Discharge in C.F.S. / Maximum Probable Flood Peak Discharge in C.F.S.

✳ Components only of inflow to McDowell Reservoir.

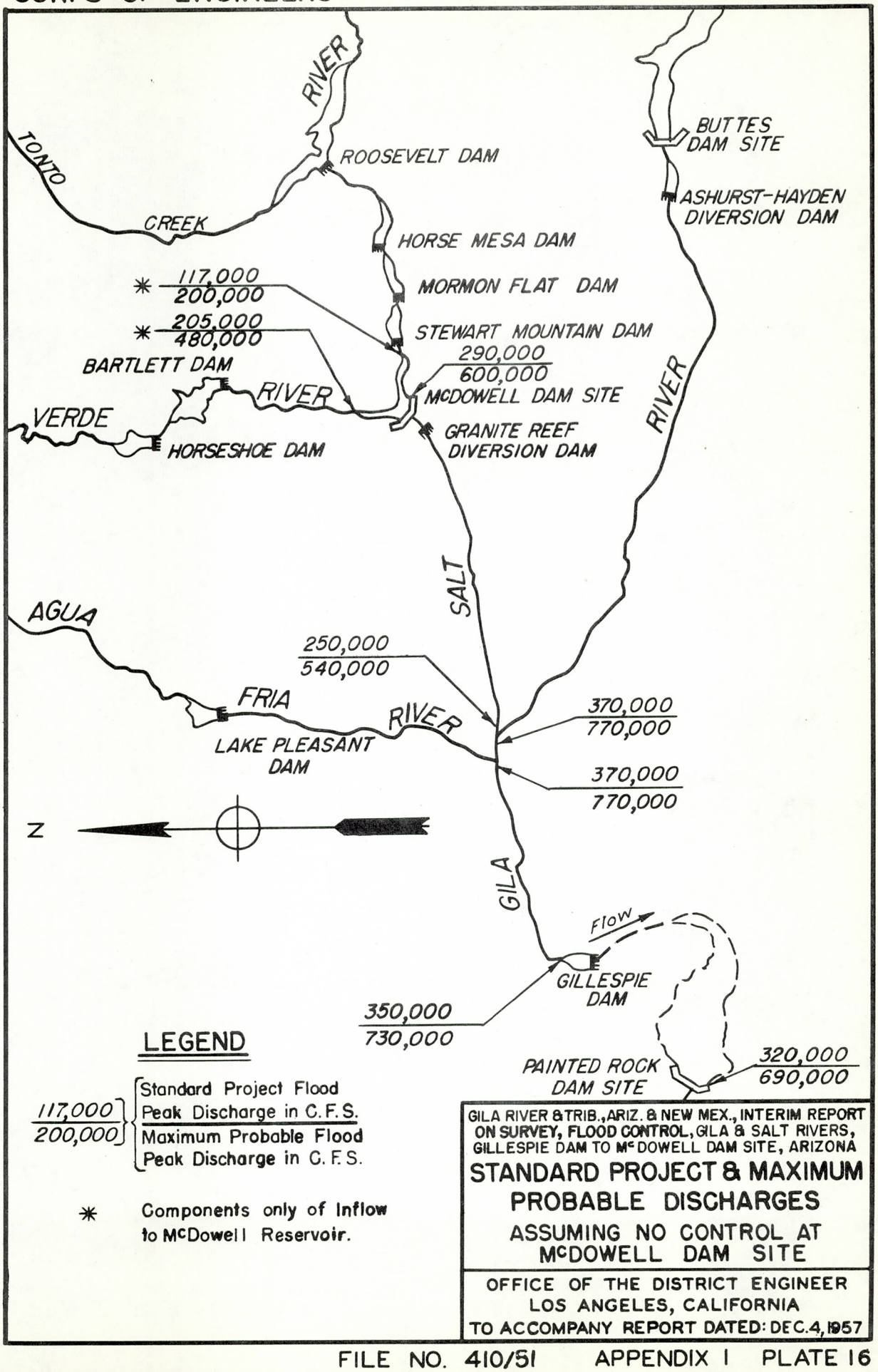
GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS, GILLESPIE DAM TO Mc DOWELL DAM SITE, ARIZONA

STANDARD PROJECT & MAXIMUM PROBABLE DISCHARGES

ASSUMING CONTROL AT McDOWELL DAM SITE

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC 4, 1957

CORPS OF ENGINEERS U.S. ARMY



LEGEND

117,000 / 200,000 — Standard Project Flood Peak Discharge in C.F.S. / Maximum Probable Flood Peak Discharge in C.F.S.

* Components only of Inflow to McDowell Reservoir.

GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

STANDARD PROJECT & MAXIMUM PROBABLE DISCHARGES

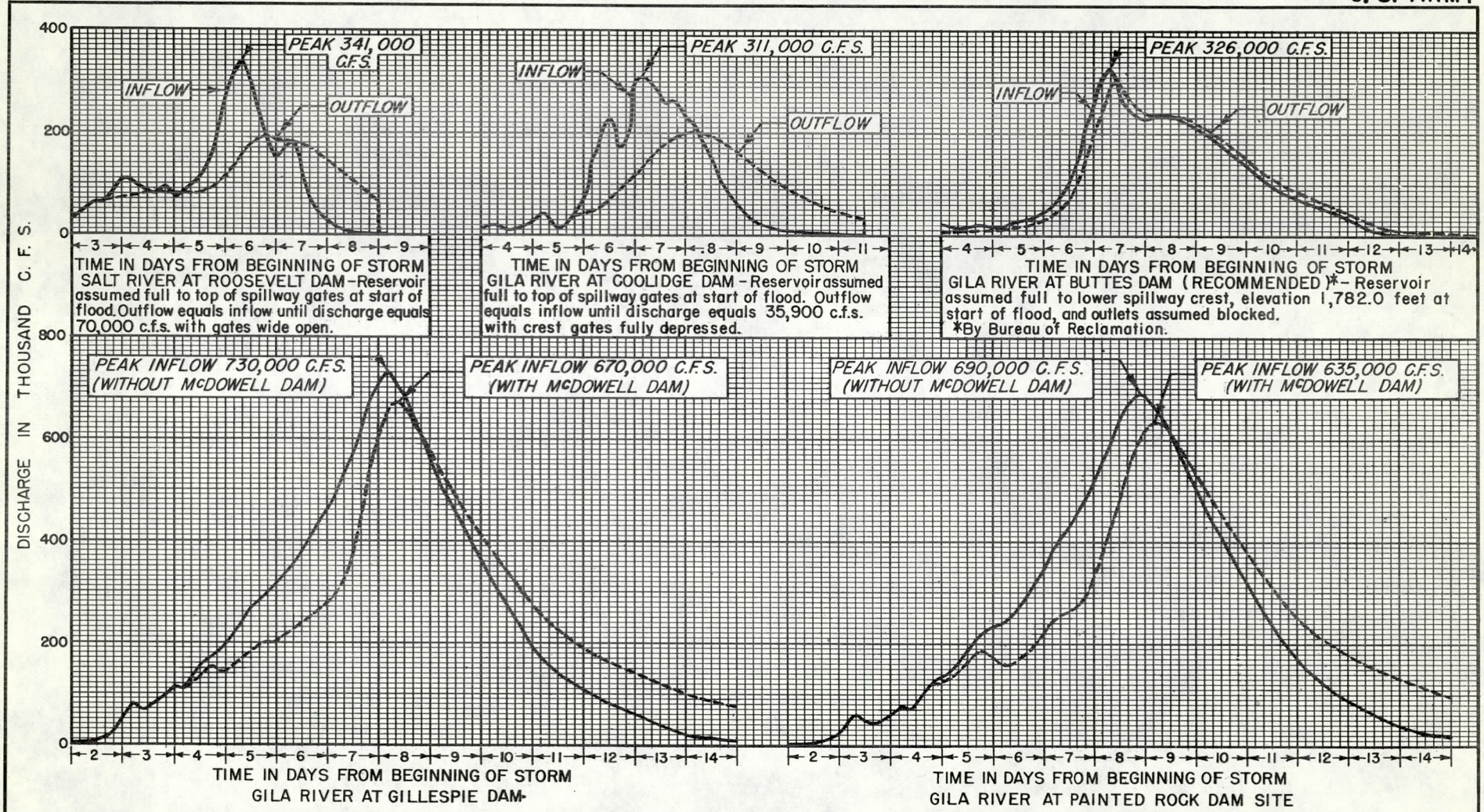
ASSUMING NO CONTROL AT McDOWELL DAM SITE

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 4, 1957

FILE NO. 410/51 APPENDIX I PLATE 16

CORPS OF ENGINEERS

U. S. ARMY



AT GILLESPIE DAM	
DRAINAGE AREA	*49,600 SQ. MI.
AVERAGE RAINFALL DEPTH OVER AREA:	
TOTAL STORM	5.7 INCHES
EFFECTIVE, TOTAL STORM	2.5 INCHES
RUN-OFF:	
TOTAL FLOOD VOLUME	6,210,000 AC-FT. / 2.4 INCHES
RATIO OF RUN-OFF TO RAINFALL	42 PERCENT

*49,300 SQUARE MILES, EXCLUDING ALL CLOSED AREAS

Note:

Storm centered over Gila River above Gillespie Dam.

Hydrographs for Charleston Dam (recommended by U.S.B.R.) on San Pedro River and McDowell Dam (considered) on Salt River not shown.

Charleston reservoir assumed full to notch crest elevation 4070.0 feet with outlets blocked. Inflow peak is 68,000 c.f.s., outflow 27,200 c.f.s.

McDowell reservoir assumed full to elevation 1405.0 feet at start. Outflow equals inflow to 82,000 c.f.s. Inflow peak is 350,000 c.f.s., outflow, 245,000 c.f.s.

All other reservoirs assumed full to spillway crest at start of flood and negligible in their effect on run-off.

GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

MAXIMUM PROBABLE FLOOD HYDROGRAPHS

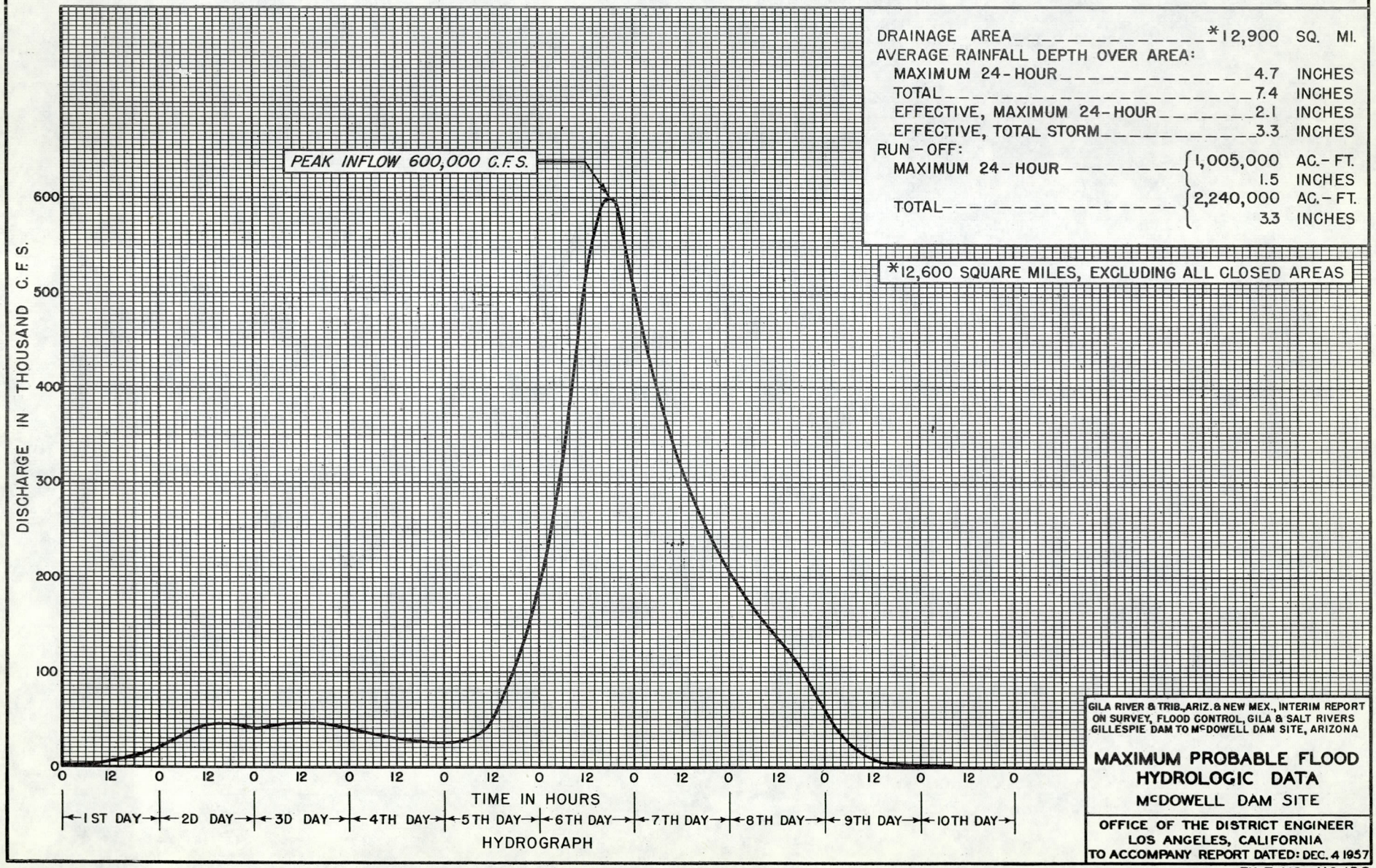
GILLESPIE DAM

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 4, 1957

APPENDIX I PLATE 17

FILE NO. 410/52

CORPS OF ENGINEERS U. S. ARMY



DRAINAGE AREA	*12,900	SQ. MI.
AVERAGE RAINFALL DEPTH OVER AREA:		
MAXIMUM 24-HOUR	4.7	INCHES
TOTAL	7.4	INCHES
EFFECTIVE, MAXIMUM 24-HOUR	2.1	INCHES
EFFECTIVE, TOTAL STORM	3.3	INCHES
RUN-OFF:		
MAXIMUM 24-HOUR	1,005,000	AC.-FT.
	1.5	INCHES
TOTAL	2,240,000	AC.-FT.
	3.3	INCHES

*12,600 SQUARE MILES, EXCLUDING ALL CLOSED AREAS

GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

MAXIMUM PROBABLE FLOOD HYDROLOGIC DATA

McDOWELL DAM SITE

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 4 1957

FILE NO. 410/53

APPENDIX I PLATE 18

UNITED STATES ARMY CORPS OF ENGINEERS

LOS ANGELES DISTRICT

GEOLOGY AND SOILS

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

To accompany interim report on survey for flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated December 4, 1957.

APPENDIX 2

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PLATES

No.	Title
1.	Gila and Salt Rivers, foundation exploration, plan and soil logs.
2.	McDowell Dam site, foundation explorations, geologic plan and profile.
3.	McDowell Dam site, foundation exploration, geologic sections.
4.	McDowell Dam site, foundation exploration, geologic logs.

GEOLOGY AND SOILS

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

SCOPE

1. This appendix deals with soils and geologic conditions along an 80-mile reach of the Gila and Salt Rivers in Maricopa County, Ariz., extending from Gillespie Dam on Gila River to McDowell Dam site on Salt River. Regional geology, the absence of destructive earthquakes, and the occurrence of ground water within this area are briefly mentioned. Particular attention is paid to the reach of Salt River between Tempe and Phoenix (where levee improvements are being considered) and to the McDowell Dam site on Salt River just below its junction with Verde River. Consideration is given to soil characteristics of the foundation and embankment materials, and to geologic features, ground-water conditions, and availability of construction materials.

REGIONAL GEOLOGY

2. The area drained by Gila River and its major tributary, Salt River, is part of the Basin and Range province, which covers a large part of southwestern United States. The surface of the area is a series of broad, connected desert valleys and plains from which rise numerous hills and short, isolated mountain ranges. South of the area, a highland with similar topography extends many miles into Mexico. On the north, rugged mountains separate the area from the upland province known as the Colorado Plateau.

3. The rocks that form the hills and mountains and underlie the valleys and plains are chiefly great masses of pre-Cambrian metamorphosed granites and volcanics, with which occur minor amounts of sedimentary rocks. During the Tertiary period, much block faulting occurred in this region and structural valleys were formed between the upthrown mountain blocks.

4. The intermontane valleys and plains are deeply filled with alluvium consisting of poorly assorted, coarse sediments interbedded with silt and clay. The valley-fill materials in the Salt River Valley were derived from the broken, mountainous country to the north and east and from the isolated ranges within the valley borders. These materials were deposited in such an irregular manner that tongues and lenses of boulders, gravel, sand, silt, and clay are indiscriminately mixed. The areal extent of sediments in the Salt River Valley and adjacent portions of the Gila River Valley totals several thousand square miles. The area includes a broad plain extending southward from Mesa and Chandler to Gila River. This plain is an ancient flood plain of Salt River. The maximum thickness of these sediments has not been determined but is known to exceed 1,300 feet in Section 34, T. 1 N., R. 5 E., about 2 miles south of Mesa.

EARTHQUAKES

5. No destructive earthquakes are known to have occurred within 100 miles of the McDowell Dam site during the period of earthquake record in this region (approximately 180 years). Earthquakes of record nearest the site occurred in 1906, 1910, and 1912, and had their epicenters in the San Francisco Mountain range of northern Arizona, about 130 miles north of the dam site. Their intensities were VII and VIII, Rossi-Forel scale. Other centers of recent seismic disturbances are found in the border areas of the State, at distances of 150 to 200 miles or more from the site. None of these epicenters are near enough to this site to cause much damage.

GROUND WATER

6. In the Salt River Valley and adjoining parts of the Gila River Valley, ground water occurs as a single ground-water body, which saturates all but the uppermost layers of the valley fill. The aquifers in this region are discontinuous tongues and lenses of sand and gravel, which represent parts of former stream channels that now are buried and are intermingled with beds of silt and clay. The comparatively uniform plane formed by the water table in any given locality within the area shows that there is effective hydraulic continuity between the aquifers.

7. Within the Salt River channel opposite Tempe, the water table has been close to streambed elevation for more than 40 years prior to 1947. Between 1947 and 1949, the water levels declined approximately 20 feet below the land surface (see appendix 6). Along most of the 20-mile reach of Salt River between Tempe and a point approximately 5 miles above the confluence with Gila River, the water table in the spring of 1949 was from 15 to 30 feet below streambed. In 1905, the water table along that reach was 10 to 20 feet higher than in 1949. Along most of the upstream half of that reach, between Phoenix and Tempe, the water table is from 20 to 30 feet below streambed.

SALT RIVER LEVEES

8. Location.--Levee improvements under consideration would be on Salt River between Tempe and Phoenix, Maricopa County, Ariz., in T. 1 N., Rs. 3 and 4 E., Gila and Salt River meridian. The project reach is accessible via numerous roads that lead to the bottom lands on both sides of the river.

9. Field investigation.--The field investigation began in September 1949 with a preliminary examination of the 80-mile reach between Gillespie Dam on Gila River and McDowell Dam site on Salt River. In October 1949, exploratory drilling was done along this reach and several commercial sand and gravel pits were examined, logged, and sampled.

10. The preliminary investigation consisted of examining the river-channel deposits and the adjacent bottom lands and noting the locations of commercial sand and gravel pits and several rocky buttes in the vicinity as possible sources of construction materials.

11. The exploratory drilling consisted of 10 power-auger holes (18-inch diameters) ranging from 15.0 to 21.0 feet in depth, with a total depth of 179.5 feet. The holes were located in the present flood plain of Gila and Salt Rivers. In general, each hole was drilled to a depth equal to the height of the levee. Samples were taken from each test hole at observed changes in formation. No undisturbed samples were taken during the exploration as the materials which were encountered were predominantly granular.

12. The sand and gravel layers exposed in several commercial pits in 4 separate areas along a 6-mile reach of Salt River near Phoenix were examined and logged. The vertical sections logged in these areas have been designated Sections A, B, C, and D. The thickness of these sections ranged from 13.5 to 45.0 feet, and totaled 114.5 feet. Disturbed samples of materials were taken in each of the 4 areas. The locations of the test holes and sections are shown on plate 1.

13. Laboratory tests.--Soils that would be excavated under the plans considered were tested to determine their suitability as material for levee fill. Soils on which the levees would be constructed were tested for competency as foundation materials. These tests, which were made at the Los Angeles District laboratory, included mechanical analyses, plasticity tests, and moisture-content determinations. Logs of the test holes and such pertinent data as soil classification, moisture content, and maximum grain size are shown on plate 1.

14. Foundation conditions.--The foundation materials for the levees under consideration would be Recent alluvium consisting of irregular lenses of sand, gravel, and boulders and occasional lenses of silt and clay. These materials, which are of medium density, would be competent to support the anticipated loads. Because these materials are predominantly granular, most of the expected settlement would occur during construction. Differential settlement may occur locally because of occasional lenses of silt and clay, but the degree and extent of such settlement probably would not be great enough to materially affect the overall stability of the structure. The occurrence of underseepage, which would be detrimental to the stability of the levees, is not considered likely except where the levees would cross old stream channels. This conclusion is based on the following factors:

(a) The net excess hydraulic head available between the riverside water surface and the landside toe of the levee would be less than 10 feet.

(b) The maximum period of submergence of the levee of approximately 4 days would be insufficient to permit the development of steady seepage under the structure except at points where the foundation consists of highly pervious materials.

(c) The ground water in the reach in most places is from 20 to 30 feet below streambed.

At points where the levee foundation is composed of highly pervious material, landside berms could be provided as protection against excessive seepage pressure.

15. Levee design.--The levee would range in height from 7 to 22 feet above the natural ground and from 23 to 28 feet above the streambed. The top width of the levee would be 18 feet and the slopes would be 1 vertical on 2 horizontal. The riverside slope would be protected by rock. The embankment material, which would consist of river fill, would be predominantly granular. Placement of the material should be accomplished by wetting and compaction with sheep's-foot or rubber-tired rollers.

16. Analysis of the levee slopes by the infinite-slope method indicates adequate factors of safety under conditions of rapid drawdown and steady seepage. The assumed soil values shown in the following table have been adopted for design and are considered conservative.

Design values, Salt River levees

Material	Angle of internal friction	Cohesion	Dry weight
	Degrees	Pounds per square foot	Pounds per cubic foot
Foundation	32	0	110
Embankment	34	0	120

17. Because the duration of flood stages is short, no special drainage provisions for the control of seepage through the levee are required. Drainage under the revetted levee slopes would not be necessary because the levee would be composed of free-draining sand and gravel.

18. Construction materials.--An ample supply of suitable embankment materials, chiefly sand, silty sand, and gravel, would be available at the site. Rock for facing the embankment would be available from local sources from 3 to 6 miles from the project. No other construction materials would be needed in appreciable quantities.

19. Conclusions.--The results of the preliminary investigation of the foundation conditions and of the availability of suitable construction materials show that construction of levees along Salt River is feasible.

20. The Recent alluvium would be fully competent to support the proposed load. The alluvium is predominantly granular and settlement within it would occur, principally during construction of the levees.

21. Recommendations.--Compaction of the levee material with sheep's-foot rollers, rubber-tired rollers, or other compaction equipment would be required.

22. In general, no special provisions for the control of seepage under or through the levee would be required in view of the short duration of the flood stages and the low height of levees. At those sections where the levee alinement crosses old stream channels, consideration should be given to the use of landside berms as a protection against excessive uplift pressures.

23. Prior to construction, additional soil and foundation investigations should be made.

McDOWELL DAM SITE

24. Location and description.--The dam site, which is in Sections 5 and 6, T. 2 N., R. 7 E., Gila and Salt River meridian, is at river mile 46, approximately, on Salt River immediately downstream from its confluence with Verde River. Granite Reef Dam and Stewart Mountain Dam are approximately 3 river miles downstream and 10 river miles upstream, respectively, on Salt River; and Bartlett Dam is about 23 river miles upstream on Verde River. Access to the right abutment is by 15 miles of paved road and 14 miles of graded service road extending from Phoenix to that city's water-treatment plant near the site. The distance by road from Phoenix to the left abutment is 35 miles, of which 24 miles are paved, 9 miles graded and improved, and 2 miles unimproved. The nearest railhead is at Mesa on the Southern Pacific lines, 19 miles by road southwest of the dam site.

25. The dam would be approximately 5,200 feet long, extending southeastward from a mountain lying west of the confluence of the Salt and Verde Rivers, to a group of low hills lying south of the confluence. The reservoir would extend about 10 miles northward within the broad, flat Verde River Valley and about 8 miles eastward along Salt River. The outlet works would be cut through a rock knob approximately 1/4 mile in front (southeast) of the toe of the right abutment. The spillway would be in a broad sag in the Salt River Valley wall, about 1 mile south of the left abutment.

26. Field investigations.--In 1901, the United States Geological Survey explored the original McDowell Dam site, which is on Verde River, approximately 1 mile upstream from the present McDowell site on Salt River. Ten test holes, drilled by the Geological Survey in the streambed area at the Verde River site, ranged from 22 to 99 feet in depth and totaled 587 feet, of which 529 feet were in overburden and 58 feet were core-drilled into bedrock. The greatest depth at which bedrock was found in this early drilling was 90 feet. (For other details see U.S.G.S. Water-Supply Paper 73, 1903, and U.S.G.S. Bulletin 573, 1915.)

27. During the summer of 1949, the Bureau of Reclamation explored the present McDowell site on Salt River. The results of this investigation were made available to the Corps of Engineers in "Preliminary report on the geology of the McDowell Damsite," Bureau of Reclamation, Phoenix Office of Project Planning, March 1950. The surface geology at the dam site was mapped on a scale of 1 inch to 100 feet. The subsurface work comprised explorations for foundation, excavation, and borrow materials.

28. The foundation materials and those to be excavated were jointly explored by drilling 23 test holes and excavating 3 shallow test pits. The test holes ranged from 40 to 222 feet deep and totaled 2,380 feet, of which 1,508 feet were in overburden and 872 feet were core-drilled into bedrock. The locations of the test holes are shown on plate 2. The 3 test pits at the left abutment--only 3 feet deep--are not designated by specific number and are not shown on the plan of foundation explorations.

29. The search for suitable embankment materials included an evaluation of materials from required excavation areas as well as explorations for impervious and pervious materials from borrow areas. The borrow exploratory work consisted of excavating 4 test pits and 1 open cut and drilling 5 hand-auger holes, each 4 inches in diameter. The test pits and auger holes ranged in depth from 4.5 to 32.0 feet, and had a combined total depth of 107 feet. Test pits 1 and 2 and all 5 of the auger holes are on the gently sloping flood-plain terrace that extends eastward from the river channel and approximately 1 mile downstream from the axis of the dam under consideration. Test pits 3 and 4 and the open cut are on the opposite (northwest) side of Salt River, test pit 3 being near the river bank and about 0.3 mile below the axis of the dam, and test pit 4 and the open cut being between the river and the red conglomerate knob, a short distance below the axis of the dam.

30. Laboratory tests.--Pertinent information on laboratory tests of rock and soils at the site is given in the following subparagraphs.

(a) Rock.--Selected core samples of rock were tested for compressive strength by the Bureau of Reclamation laboratory in Denver, Colo. The results of these tests are tabulated below:

Laboratory tests on rock samples

Rock type	Hole No.	Compressive strength
		Pounds per square inch
Red conglomerate	4 and 18	4,430
Basalt	15	3,970
Tuff	9	2,270

The preliminary indications of these results are that the foundations and abutments are competent to support the structures considered for this site. It was considered unnecessary at this time to test the granite, which, as a foundation rock, is superior to the three types of rock that were tested.

(b) Soils.--The testing of soils was conducted by the Los Angeles District, U. S. Army Corps of Engineers. Laboratory tests were limited to tests for classification of borrow material. The classification of foundation soils was made visually. Soil tests for engineering properties, such as shear strength, compressibility, and permeability, were not considered necessary at the present stage of investigation because a visual inspection of the material was considered sufficient to determine the suitability of these materials for embankment fill and to evaluate soil characteristics for embankment design. The classification tests on borrow material were conducted on continuous samples from 3 of the 4 test pits and included tests for plasticity characteristics and grain-size determination. The results of these tests are presented in the following table. The percentages of gravel, sand, and fines indicated in the table represent the averages of tests on a number of samples.

Laboratory tests on borrow materials

Test pit	Depth interval of sample	Soil type	Percent of--			Maximum size in inches or screen size
			Gravel	Sand	Fines*	
	Feet					
No. 1	0-4.5	Silty sandy gravel	64	11	25	3 inches.
No. 2	0-5.0	Silty gravelly sand	37	37	26	1/2 inch.
	5.0-12.0	...do	32	39	29	Do.
No. 3	0-4.0	Silty sand	0	74	26	No. 30.
	4.0-9.0	...do	0	89	11	No. 10.
	9.0-13.0	...do	0	78	22	Do.

* Materials smaller than .074 mm.

31. Field tests.--The water-pressure tests made in each of the holes drilled at the site by the Bureau of Reclamation were the only field tests made during this investigation. Because the water losses measured in these tests were generally negligible, a retabulation of the results is not essential here. (See logs of test holes included in the Bureau's "Preliminary report on the geology of the McDowell Damsite," Phoenix Office of Project Planning, March 1950.)

32. Geology of site.--Erosion has reduced a once continuous granite range to 3 principal remnants and associated pediments: McDowell Mountains, Mount McDowell, and Usery Mountains. The latter 2 mountains became isolated from each other when an ancient Salt or Verde River carved a notch or gap between them by cutting through the once continuous range. The dam site is at the upstream end of this notch.

33. Mount McDowell is a twin peak, the north peak being granite and the south peak being a butte of pre-Pleistocene conglomerate (probably in part fanglomerate), which dips gently westward. The same conglomerate is exposed dipping steeply southeastward in a small knob just west of the river junction. The north granite peak of Mount McDowell forms the right abutment of the proposed dam, and the small, red conglomerate knob is the site of the proposed outlet works.

34. The Usery Mountains, forming the east wall of the gap, consist of the main granite mass with a group of low hills of pre-Pleistocene conglomerate lying opposite the river junction. These hills would form the left abutment of the dam. The spillway would occupy a broad saddle in granite which lies at the south edge of the conglomerate hills, about 1 mile southeast of the left abutment.

35. Exploratory drill holes and a few small outcrops show the presence of a thick section of pre-Pleistocene conglomerates and associated volcanic rocks under the Salt River flood plain. This formation appears to be continuous from a point about 600 feet out from the toe of the right abutment to the toe of the left abutment, a total distance of about 3,200 feet. The formation dips southeastward at approximately 25°. The same formation probably underlies Verde River alluvium near its junction with Salt River.

36. Across Verde River from the north peak of Mount McDowell, a range of low hills strikes eastward as far as Stewart Mountain, forming a barrier between the Verde and Salt River Basins. These hills are composed of semiconsolidated Pleistocene sediments which are continuous with the deposits found in the broad basin to the north.

37. The youngest deposits at the dam site consist of Recent alluvium, talus debris, and soil, of which the alluvium is the most widespread. Along the axis of the dam, the alluvium occurs in 3

zones which differ considerably in thickness. Between the left abutment and the present channel of Salt River, the alluvium is less than 25 feet thick. From the river channel to the red conglomerate knob in front of the right abutment, the alluvium thickens progressively from almost nothing to more than 50 feet. A 1,200-foot-wide terrace between the red knob and the granite of the right abutment stands 50 feet higher than the present flood plain. The granite mass that forms the right abutment apparently extends beneath the adjacent (northwest) half of the terrace, where the greater part of the granite-bedrock surface is thinly covered with alluvium. Test holes in the southeast half of the terrace show a large channel buried beneath 120 feet of alluvium (see profile, pl. 2). The deepest part of this channel, which has been cut into the pre-Pleistocene basal conglomerate, is at least 20 feet deeper than the deepest point thus far known in the present Salt River channel near the axis of the dam. However, test holes in the bed of Verde River at the old dam site (about 1 mile upstream from the present site) show the top of bedrock to be more than 90 feet below streambed elevation.

38. The structural relationship of the rocks at the site is imperfectly known. The conglomerate in Mount McDowell dips about 10° eastward. The conglomerate in the red knob dips about 35° westward and, from test-hole information, it is inferred that this westward dip continues beneath the flood plain to approximately 400 feet from the toe of the left abutment. The conglomerate forming the left abutment dips from 20° to 37° northeastward. This marked reversal of dip indicates the presence of either a buried fold or a fault.

39. Two faults appear on the surface at the site, one at the base of the right abutment and the other in a ravine south of the left abutment. The right-abutment fault occurs with a vertical crushed zone, about 100 feet wide, in the granite. It strikes southwestward and is traceable downstream for a distance of more than 1 mile. This fault zone is characterized by shattered rock, innumerable parallel minor slip planes, and veins of calcite, quartz, and barite. The left-abutment fault strikes north 80° west and dips 75° southwestward. It has a reverse displacement of nearly 1,000 feet. This fault also outcrops 2/3 mile east of the left abutment, where barite, which occurs in veins in the fault, is being mined. Where exposed to view, the conglomerate adjacent to the fault is not disturbed.

40. Other faults may be concealed under the alluvium, particularly in the buried side channel near the right abutment. The poor core recovery from the 6 holes drilled here, the numerous minor fractures in the granite shelf that forms the southeast part of the terrace, and the narrow, gorge-like aspect of the channel suggest the presence of a fault striking north-south, with the upthrown side on the west.

41. Ground water occurs in nearly all of the formations encountered in drilling at the site. The main exception is the granite at the right abutment, where hole 1 was drilled 101.7 feet without finding water. In the buried-channel fill in front (southeast) of the right abutment, the water table was found in holes 2, 3, 19, 22, 23, and 24 (May 1949) at depths ranging from 32 to 55 feet, or at elevations of 1,327 to 1,329 feet. In hole 4, the water table was found in the red conglomerate of the small rocky knob at a depth of 75 feet, or at elevation 1,329 feet, approximately. In the greater part of the flood-plain area (from the red conglomerate knob to the southeast bank of Salt River), the water table was found in holes 5, 6, 7, 9, 13, 14, 15, 16, 17, 18, and 20 at depths ranging from 4 to 11.5 feet, or at elevations of 1,327 to 1,328 feet. In holes 10 and 11*, which are within 600 feet of the toe of the left abutment, the water level was at depths of 24 and 22 feet, or at elevations 1,328 and 1,336 feet, respectively. In hole 12*, on the left abutment, the water level was found within the gray conglomerate at a depth of 120 feet, or at elevation 1,341 feet. It is noteworthy that, within the greater part of the embankment area, the water table (May 1949) was within 1 foot of elevation 1,327 feet. The geologic plan and profile, sections, and logs are shown on plates 2, 3, and 4.

42. Foundation conditions.--The axis of the dam considered by the Corps of Engineers is from 60 to 200 feet or more upstream from the axis proposed by the Bureau of Reclamation. The width of the valley along the new axis is approximately 3,800 feet from toe to toe of the abutments, and approximately 5,200 feet at elevation 1,494 (m.s.l.), the elevation of the top of the dam considered. Streambed elevation of this alinement is about 1,324 feet.

43. The foundation materials comprise unconsolidated alluvium, partially cemented buried-channel fill, and several types of bedrock. The unconsolidated alluvium consists of sand, gravel, boulders, and occasional lenses of silt. The buried-channel fill consists of older river alluvium with various admixtures of slope wash and talus, unconsolidated in greater part but containing cemented zones. The bedrock components of the foundation materials consist of 5 separate rock units which, in stratiographic sequence, are: Granite, red conglomerate, basalt, rhyolite tuff, and gray conglomerate (also probably fanglomerate).

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* Water-table elevations obtained in holes 11 and 12 are considered by the Bureau of Reclamation as being "too high because of the influence of drill water remaining in these holes." See the Bureau's report, March 1950, pages 27 and 28.

44. At the right abutment, the ground slopes at the rate of 1 (vertical) on 2 (horizontal) for a horizontal distance of 200 feet. The abutment rock consists mainly of granite with small, widely separated inclusions of altered rock and with intrusions of hard, felsitic dikes. The granite is weathered near the surface and contains open joints to a depth of about 10 feet. The surface of the granite in this abutment is thinly covered locally with soil, slope wash, or residual debris. The average thickness of material to be removed from this abutment is estimated at not more than 2 feet. A grout curtain extending into bedrock would be provided to eliminate a harmful amount of underseepage. No core trench would be required at this abutment.

45. At the left abutment, the ground slopes at the rate of 1 on 4.5 for a horizontal distance of 400 feet from the toe of the abutment and 1 on 20 for the next 800 feet to the top of dam. The abutment rock consists of poorly cemented, gray conglomerate containing interbeds of sandstone. The rock in the lower, steeper part of the abutment is covered with talus and slope wash to an estimated average depth of 5 feet, and the rock on the upper slope, with partially cemented, terrace gravel to an estimated depth of 10 feet. The average depth of stripping is estimated at 7 feet or less. A core trench with a concrete cutoff extending into bedrock should be provided against harmful underseepage.

46. In addition to the 200 feet of embankment at the right abutment and the 1,200 feet at the left abutment, there would be approximately 3,800 feet of embankment extending between abutments. This 3,800 feet of embankment would comprise 1,200 feet of embankment founded on bedrock and 2,600 feet on alluvium. The average depth of stripping and scaling along the entire 3,800 feet is estimated at about 1 foot (pl. 2).

47. The first 500 feet of embankment out from the toe of the right abutment would be founded on granite. A nearly vertical zone of red-stained, shattered granite about 100 feet wide trends south 40° west and is crossed by the axis of dam about 100 feet out from the toe of the abutment. Elsewhere in this reach, the granite bedrock is believed to be similar to that in the right abutment. A grout curtain would be provided within this reach, but no core trench would be required.

48. The next 600 feet of embankment would cross the buried channel previously described and would be founded on the buried channel fill (see a preceding heading, "Geology of site"). The impervious section of the dam should extend within a core trench to bedrock (red conglomerate), where a grout cap would be provided and rock would be grouted.

49. The next 500 feet of embankment would cross the present site of the red conglomerate knob that stands between the old buried channel and the present flood plain of Salt River. This reach of embankment would be founded on red conglomerate except for that part to be occupied by the outlet works (pl. 2). No core trench would be required in this reach, but a grout cap would be provided and the rock would be grouted.

50. The next 1,200 feet of embankment would extend from the red conglomerate knob almost to the present Salt River streambed. This reach of embankment would be founded on the alluvium of the present flood plain. The impervious section of the dam should extend within a core trench to bedrock (red conglomerate and basalt), where a grout curtain would be provided.

51. The next 200 feet of embankment would occupy the present site of an exposure of rhyolite tuff at the confluence of Verde and Salt Rivers. This reach of embankment would be founded on a bedrock of rhyolite tuff, where a grout curtain would be provided. No core trench would be required.

52. The final reach of 800 feet, which would meet the 1,200-foot embankment of the left abutment, would be founded on alluvium of the present flood plain. The impervious section of dam should extend in a core trench to bedrock (chiefly gray conglomerate), where a grout curtain would be provided.

53. The outlet works would be founded on the red conglomerate that forms the knob between the flood plain and the buried channel. Concrete collars would be provided around the structure to prevent seepage along the structure. Grout pipes would be installed in the collar at the axis of the dam, and the rock would be grouted.

54. The detached spillway would be chiefly on granite. The spillway crest would be formed by a concrete weir extending into bedrock. The spillway walls would be of cut-and-fill construction. The channels would not require stripping or paving.

55. Borrow materials.--The greater part of the materials needed for the earthfill embankment would be obtained from borrow areas. The required excavation at the dam site would provide only a small fraction of the total amount needed. The methods and extent of the borrow exploration are described under a previous heading, "Field investigations." The principal source of borrow material for the random pervious zones of the embankment would be the streambed areas both upstream and downstream from the dam site. The random pervious material would consist principally of silty and sandy gravels. Material for the narrow impervious core and core trench would be obtainable from the terrace areas immediately downstream from the site. The impervious material would consist mostly of silty sand. Excavation for both random pervious and

impervious borrow would be conducted in the dry (i. e., above the water table). The depths of cut in the borrow areas would be sufficient to permit the efficient use of heavy power equipment.

56. Embankment section.--The dam at the McDowell site would be approximately 170 feet high above streambed. At the top of the dam (elev. 1,494), the embankment would be 5,180 feet long and 30 feet wide. The earth embankment would have an upstream slope of 1 on 3 and a downstream slope of 1 on 2.5. A 10-foot berm would be provided on the downstream slope at elevation 1,400. The upstream slope would be protected by a 2-foot blanket of quarrystone obtained from nearby sources and placed on a 12-inch layer of graded local gravel. The downstream slope would be protected from erosion by a 12-inch blanket of graded local gravel from the dam crest (elev. 1,494) to elevation 1,350, which is 5 feet above maximum tailwater. A layer of stone ranging in thickness from 4 feet at the top to 6 feet at the toe would be obtained from nearby sources and would be placed on the downstream face from elevation 1,350 to a depth of at least 15 feet below streambed for protection against tailwater. This layer of stone would overlie a 2-foot layer of spalls.

57. The material for the rolled-earth fill would be placed by wetting and compaction as follows: (1) Random pervious in zone II, adjacent to the upstream and downstream faces; (2) impervious in zone I, in the central part of the dam and continuing down to bedrock in the streambed part of the dam; and (3) select pervious under the downstream side of zone II. Protection against underseepage would be obtained by an impervious core trench extending to bedrock and a suitable cutoff extending several feet into bedrock. The core trench would be excavated to an average depth of 10 feet to bedrock along the terrace slope of the left abutment, to an average depth of 25 feet for the reach within the flood-plain area to the east of the tuff outcrop, to an average depth of 40 feet in the flood-plain area between the tuff outcrop and the red conglomerate knob, and to a maximum depth of 120 feet in the buried-channel area immediately northwest of the red conglomerate knob. A grout cap would be provided at the bottom of the core trench. Plates showing the plan, profile, and sections for the dam under consideration are inclosed in Appendix 3: Bases for Design.

58. Design of embankment slopes.--The stability of the embankment slopes with respect to sliding was investigated by the critical-circle method. The downstream slope was analyzed for conditions of earthquake and steady seepage, under the assumption that the water surface would remain at the reservoir design-flood level of elevation 1,470 for a sufficient length of time to develop a phreatic line through the embankment. The upstream slope was analyzed for the condition of rapid drawdown of the reservoir. Analysis of the upstream and downstream slopes indicates adequate factors of safety. Considering the range of shear-strength values presented in the following table, the downstream slope would have minimum factors of safety varying from 1.0 to 1.25 when acted upon by an earthquake

force equal to one-tenth the force of gravity. The upstream slope would have minimum factors of safety varying from 1.0 to 1.5 for the condition of a rapid drawdown from the spillway crest to the terminal-storage level. For the upstream slope, earthquake forces were not considered because the occurrence of earthquake and drawdown simultaneously is unlikely. Soil constants for the pervious and impervious embankment materials have been assumed and are considered conservative values. The values adopted for design are shown in the following table:

Soil constants used in design of McDowell Dam, Salt River, Ariz.

Material	Angle of internal friction	Cohesion	Dry weight
		Pounds per square foot	Pounds per cubic foot
	Degrees		
Foundation	30	0	100
Embankment (pervious)	30-36	0	120
Embankment (impervious)	25-30	0	110

59. Embankment seepage and drainage provisions.--Because the proposed design includes provisions for terminal storage in the reservoir with maximum water surface at elevation 1,405, which is approximately 80 feet above streambed elevation, the embankment section has been designed with a central impervious zone above streambed level and an impervious core trench extending below streambed elevation to bedrock. A grout cap would be placed at the bottom of the core trench and rock would be grouted. These provisions would tend to reduce the seepage through and under the embankment to a safe minimum. Control of detrimental uplift pressures in the vicinity of the downstream toe would be effected by use of a horizontal drainage layer 10 feet thick extending from the central impervious zone to the derrickstone backfill at the downstream toe. Discharge for the seepage collected by this drainage layer would be provided at the downstream toe by the derrickstone backfill, except during periods when high tailwater would exist. Such conditions should be extremely limited because the elevation of the maximum probable tailwater is 1,345 feet, which corresponds to the top elevation of the horizontal drainage layers.

60. Construction materials.--The availability of construction materials at or near the dam site was reconnoitered by the Bureau of Reclamation, but no effort was made to ascertain quantities. It is probable that the necessary materials can be found within a few miles of the site. Cement in quantity can be procured from a plant near Tucson. As stated in the 1950 report by the Bureau of Reclamation: "Concrete aggregate can probably all be obtained

from the alluvial material between the red conglomerate knob and Salt River at the dam site. Samples of this material were sent to the Denver laboratories for preliminary testing. In a letter to the Regional Director from Head, Research and Geology Division, dated August 25, 1949, it states that this material can be used for concrete aggregate provided that proper gradings are obtained, and low-alkali cement and air-entraining agents are used." A potential source of earth embankment material is the broad flat extending along the left side of Salt River for about 1 to 2 miles downstream from the site. This material consists of silt, sand, gravel, and boulders similar to the alluvium on the left side of the river at the dam site but overlain by lean clay to an average depth of 16 feet. Riprap and other quarryrock can be obtained from the granite of Mount McDowell, probably within a few hundred yards of the right abutment.

61. Leakage conditions in reservoir area.--The reservoir area would consist of an 8-mile reach of the Salt River Valley and a 10-mile reach on the Verde River Valley. These 2 branches of the reservoir area meet at right angles immediately upstream from the dam site.

62. The Salt River branch is rimmed by partially cemented Pleistocene alluvium, older conglomerates, pre-Cambrian granite, and Tertiary volcanics. Similar rocks probably underlie the reservoir area. In view of the results of pressure testing (at the dam site) in the same types of rocks, these rocks are considered as essentially impermeable and it is assumed that no major leakage would occur from this branch of the reservoir area.

63. Nearly all the Verde River branch of the reservoir area is in Pheistocene sediments underlain by granite. From a study by the United States Geological Survey in 1945 in the Verde Valley near Fort McDowell, it is evident that ground water has no path of escape from this part of the valley except downstream in the direction of the river channel. Under these conditions, no appreciable seepage would be expected from the Verde River branch of the reservoir area.

64. Conclusions.--The results of this preliminary investigation of the foundation conditions and of the availability of suitable construction materials show that the construction of a rolled-earthfill dam at McDowell Dam site is feasible.

65. Both the alluvial members and the rock members of the foundation would be fully competent to withstand the proposed load. The alluvial members are granular and settlement withim them would occur, principally, during construction of the embankment. Some degree of differential settlement may occur because of occasional silt layers in the streambed alluvium, but this settlement would not produce a detrimental effect on the overall stability of the structure.

66. The rock members of the foundation would be made sufficiently impermeable by grouting to keep the rate of percolation at a desirable minimum.

67. Overburden is not excessively thick, except in the abandoned channel between the toe of the right abutment and the rock knob, where the depth is about 120 feet. An impervious core trench to bedrock under the greater part of the embankment and a suitable cutoff extending several feet into bedrock under the entire embankment would provide protection against underseepage. Construction of the core trench is feasible although excavation in the deep channel on the terrace to the northwest of the red conglomerate knob would be as much as 120 feet below the ground surface. Dewatering of the excavation would be required for the greater part of the core-trench construction. The saddle selected for a broad-crested spillway would be an excellent site for the detached spillway because the bedrock is granite that outcrops at the surface or close to it and little grading would be required.

68. Because the faults at the dam site are believed to be inactive, they would require no other treatment than necessary dental work.

69. An adequate supply of pervious and impervious materials for the embankment would be available within reasonable distances of the dam site.

70. Recommendations.--To prevent excessive underseepage and detrimental underseepage pressures, an impervious core extending to bedrock should be provided under each part of the embankment that is founded on alluvium. A grout curtain cutoff in the bottom of the trench should be provided under the entire embankment.

71. An impervious central zone should be provided in the embankment section to control seepage through the dam. A horizontal drainage layer extending from the impervious zone to the derrick-stone backfill at the downstream toe should be provided to effect reduction in detrimental uplift pressures in the vicinity of the downstream toe.

72. Compaction of the embankment material with sheep's-foot rollers, rubber-tired rollers, or other compaction equipment to a density of at least 90 percent of that obtained by the Modified A.A.S.H.O. Method is required.

73. Prior to preparation of contract plans for the dam, additional soil and foundation investigations would be required.

CORPS OF ENGINEERS

U. S. ARMY

PLAN

GRAPHIC SCALE 5 0 5 MILES

Morristown

LAKE PLEASANT DAM

CAVE CREEK DAM

BARTLETT DAM

STEWART MTN. DAM

MORMON FLAT DAM

McDOWELL DAM SITE

GRANITE REEF DAM

JOINT HEAD DAM (ABANDONED)

BUCKEYE DIVERSION DAM

GILLESPIE DAM

PAINTED ROCK DAM (UNDER CONSTRUCTION)

Glendale

PHOENIX

SKY HARBOR AIRPORT

Tempe

Mesa

South Phoenix

Buckeye

Arlington

Centennial

Gila Bend

GILA BEND INDIAN RES.

SALT RIVER INDIAN RESERVATION

FORT McDOWELL INDIAN RESERVATION

T.H. 1 T.H. 2 T.H. 3 T.H. 4 T.H. 5 T.H. 6 T.H. 7 T.H. 8 T.H. 9 T.P. SEC. D T.P. SEC. C T.P. SEC. B T.P. SEC. A T.H. 10

T.H. 1 EL. 780 · T.H. 2 EL. 796 · T.H. 3 EL. 828 · T.H. 4 EL. 850 · T.H. 5 EL. 875 · T.H. 6 EL. 890 · T.H. 7 EL. 941 · T.H. 8 EL. 955 · T.H. 9 EL. 1000 · T.P. SEC. D EL. 1050 · T.P. SEC. C EL. 1075 · T.P. SEC. B EL. 1100 · T.P. SEC. A EL. 1128 · T.H. 10 EL. 1165

SOIL LOGS

VERTICAL SCALE 5 0 5 10 FEET

LEGEND

SOIL TYPE	SYMBOL	BASIS OF CLASSIFICATION
CLAY		Grain size: below No. 200 (.074 mm) sieve. Classification as silt or clay is determined by plasticity of minus 40 mesh material. Clay: LL over 28 or PI over 6. Silt: LL 28 or less, and PI 6 or less.
SILT		
SAND		Grain size: No. 200 (.074 mm) to No. 10 (2.0mm).
GRAVEL		Grain size: No. 10 (2.0mm) to 3 inches.

NOTE:
FOR COMBINATIONS OF THESE SOIL TYPES, THE PREDOMINANT SOIL TYPE IS INDICATED WITH THE HEAVIER SYMBOL, i.e.

SANDY CLAY CLAYEY SAND

● T.H. 10 TEST HOLE.
■ T.P. SEC. A TEST PIT.
W/70 DEPTH TO GROUND WATER IN FEET.
W.C. WATER CONTENT.

NOTE:
1. MAXIMUM SIZE OF SAMPLE EXPRESSED AS SIEVE NUMBER OR IN INCHES.
2. GROUND LEVEL ELEVATIONS ARE APPROXIMATE.

VICINITY MAP

SCALE 40 0 40 80 120 160 200 MILES

AREA COVERED BY MAP

BOUNDARY OF GILA RIVER DRAINAGE AREA

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

GILA AND SALT RIVERS
FOUNDATION EXPLORATION
PLAN AND SOIL LOGS

SCALE: AS SHOWN — IN ONE SHEET

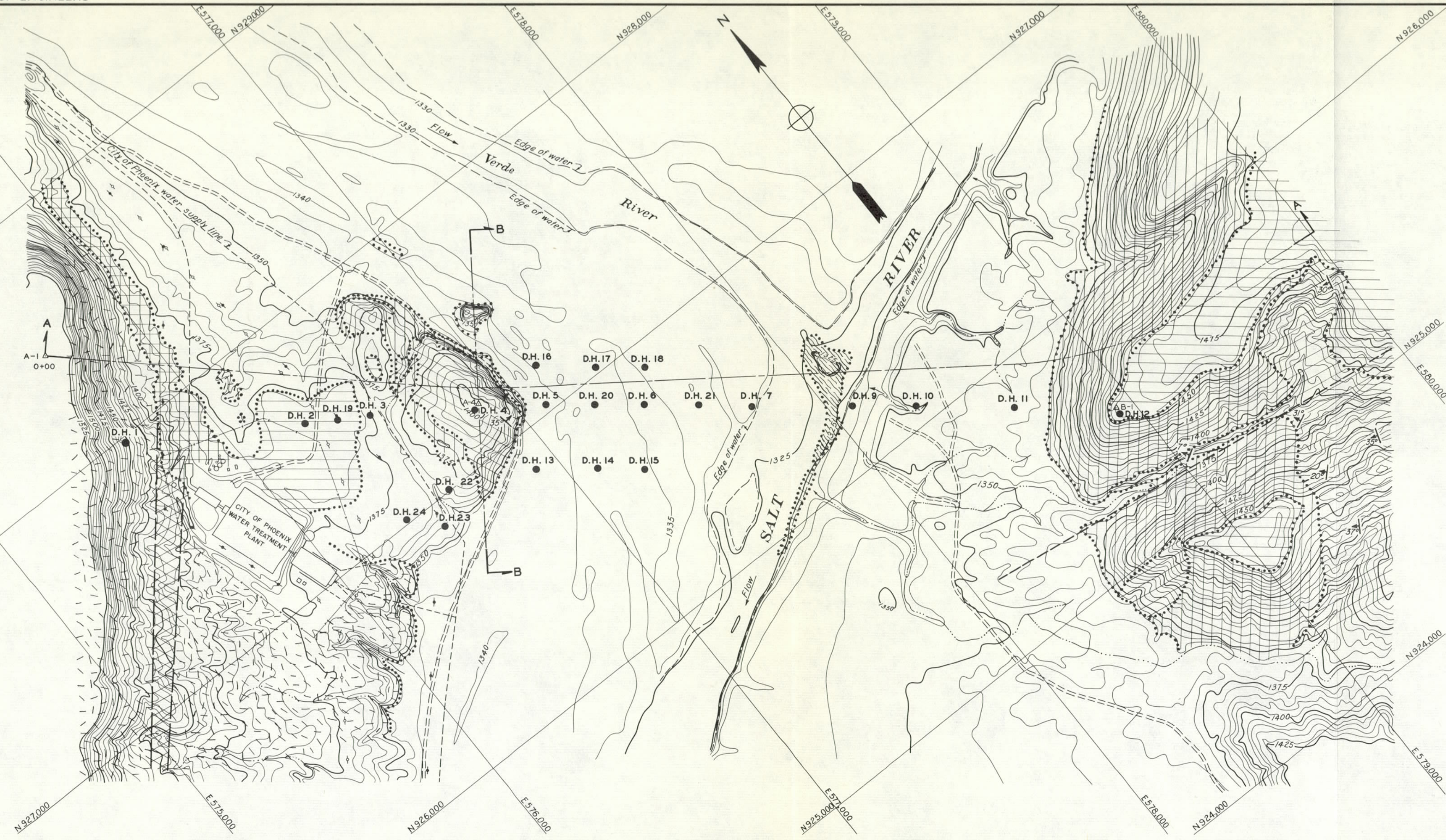
OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., DEC. 1957

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

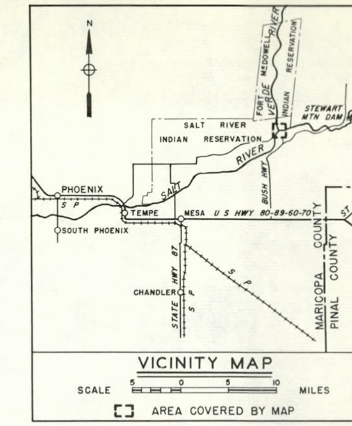
DRAWN E.G.M.S. | TRACED E.L.D. | CHECKED E.L.D. | V.V.P. | TO ACCOMPANY REPORT DATED: DECEMBER 4, 1957

FILE NO. (D.O. SERIES) 410/61

APPENDIX 2 PLATE 1



PLAN



LEGEND

QUATERNARY (PLEISTOCENE AND RECENT)

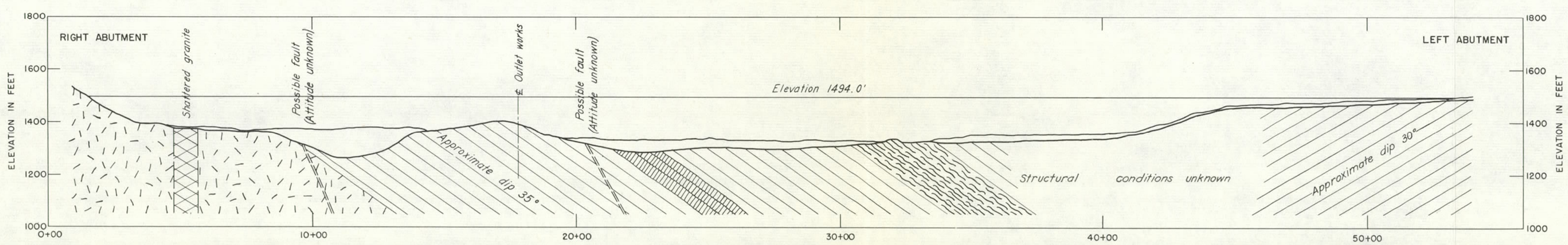
- SLOPE WASH, TALUS AND RESIDUAL SOIL.
- RIVER ALLUVIUM (UNCONSOLIDATED SILT, SAND, GRAVEL AND BOULDERS UNDIFFERENTIATED OVERBURDEN IN PROFILE).
- TALUS, SLOPE WASH AND ALLUVIUM WITH CEMENTED ZONES.
- TERRACE DEPOSITS (CEMENTED GRAVELS).

PRE-PLEISTOCENE (CRETACEOUS OR TERTIARY)

- UPPER GRAY CONGLOMERATE.
- RHYOLITE TUFF.
- BASALT SILL.
- LOWER RED CONGLOMERATE.

PRE-CAMBRIAN

- GRANITE WITH INCLUSIONS OF OTHER ROCKS.
- FAULT ZONE.
- FAULT.
- 35° STRIKE AND DIP.
- D.H. 17 DIAMOND DRILL HOLE.
- BOUNDARY BETWEEN ROCK TYPES.



SECTION A-A

PROFILE ALONG AXIS OF PROPOSED DAM

NOTE:
THIS CROSS SECTION IS AN EXTRAPOLATION OF DATA FROM NEARBY DRILL HOLES. FOR LOCATIONS OF HOLES, SEE PLAN ABOVE; FOR DETAILED LOGS, SEE PLATE 4. FOR SECTION B-B SEE PLATE 3.

NOTE:
TOPOGRAPHY FROM BUREAU OF RECLAMATION DRAWINGS, FILE NOS. 8b-4-281C TO 8b-4-284C.
CENTRAL ZONE-ARIZONA, TRANSVERSE MERCATOR PROJECTION, 1927 NORTH AMERICAN DATUM.
CONTOUR INTERVAL 5 FEET.
DATUM IS MEAN SEA LEVEL.

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

McDOWELL DAM SITE
FOUNDATION EXPLORATION
GEOLOGIC PLAN AND PROFILE

IN ONE SHEET

GRAPHIC SCALE 100 0 100 200 300 400 500 FEET

DATUM IS MEAN SEA LEVEL

OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., JULY 1950

SUBMITTED:	RECOMMENDED:	APPROVED:
CHIEF, PLANNING & REPORTS BRANCH	H.W. Thompson, CHIEF, ENGINEERING DIVISION	COLONEL, C.E., DISTRICT ENGINEER

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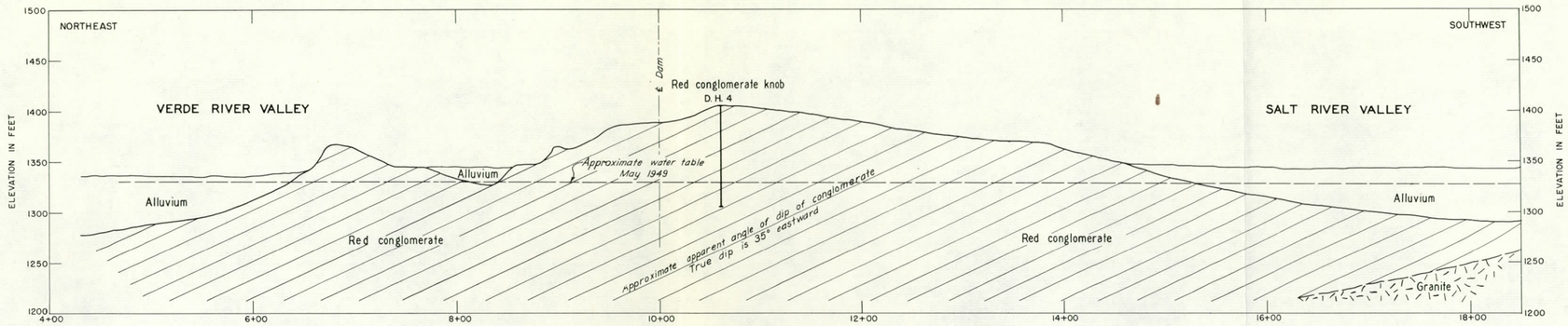
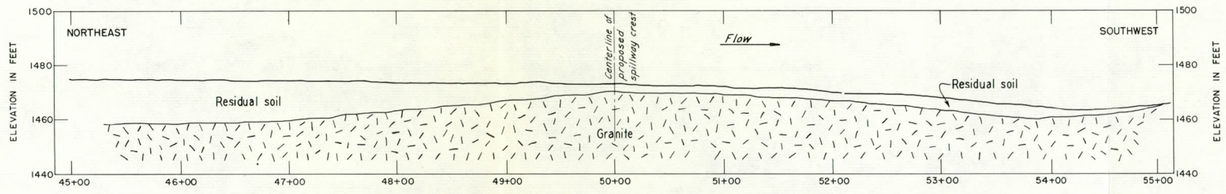


SECTION B-B'

PROFILE ALONG CENTERLINE OF PROPOSED OUTLET WORKS

HOR. SCALE 50 0 50 100 FEET

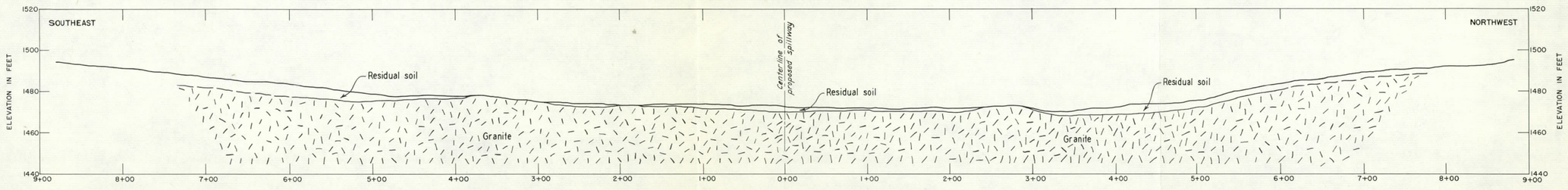
VERT. SCALE 50 0 50 100 FEET



PROFILE ALONG CENTERLINE OF PROPOSED SPILLWAY

HOR. SCALE 50 0 50 100 FEET

VERT. SCALE 10 0 10 20 30 40 50 FEET



CROSS SECTION OF PROPOSED SPILLWAY AT CREST

HOR. SCALE 50 0 50 100 FEET

VERT. SCALE 10 0 10 20 30 40 50 FEET

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

McDOWELL DAM SITE
FOUNDATION EXPLORATION
GEOLOGIC SECTIONS

SCALE: AS SHOWN IN ONE SHEET

DATUM IS MEAN SEA LEVEL

OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., JULY 1950

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

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APPENDIX 2 PLATE 3

CORPS OF ENGINEERS

U. S. ARMY

9 — El. 1336.2

0 — Sand and silt, unconsolidated.

7.0

9.0 — Watertable

Volcanic Tuff. Pinkish buff, fine-grained, vesicular. Most of the visible fragments are quartz and mica, but small fragments of granite and basalt ranging in size from a pea to an egg are scattered through the formation. In general this rock is hard.

75.0

Same as above except that color becomes predominantly red, and granite and basalt fragments are larger and more numerous, particularly at base.

Small slightly weathered joints at 97.0' and 115.0'.

120.0

122.0 — 122.' to 122.5' conglomerate altered to hard quartzite - like rock.

Conglomerate. Predominantly granite with subordinate amounts of basalt, quartzite, and sandstone. These fragments vary from rounded to angular in shape and range in size from sand grains to boulders two feet in diameter. The cementing material varies from a hard red siliceous substance to a red, shaly material. The hardness of the conglomerate varies with the type of cement. In general this conglomerate is fairly competent.

From 174.5 to 175.5 the cementing material is impregnated with a black soft manganese mineral.

222.0 — El. 1114.2

69 % recovery

19 — El. 1382.0

0 — Cemented by calcareous material 0' to 10'.

Generally unconsolidated silt, sand, gravel, and boulders.

53.8 — Watertable

Small, tight unweathered joints occur at 10.5', 13.5', and 36.0'. Somewhat larger, slightly weathered joints occur at 53.0' and from 58' to 59'.

There are numerous zones of cementation commonly called "caliche" in the alluvium. The thickest such bed is at the top, and is about 6' thick.

Conglomerate. Poorly cemented alternating with medium to coarse red sandstone. A finer-grained phase of the conglomerate probably predominates in the upper part of the hole. The coarser variety of red conglomerate probably predominates near the bottom.

175.5 — El. 1206.5

No core

20 — El. 1333.7

0

6.5 — Watertable

Silt, sand, gravel, and boulders, unconsolidated.

53.6

54.7 — Basalt, weathered.

Basalt, hard, fine-grained, dark grey. Numerous small calcite-filled slips and joints with some slickensides occur between 54.7' and 68'.

68.3

68.0 — El. 1265.7

95 % recovery

24 — El. 1379.5

0 — Silt, sand, gravel, and boulders, unconsolidated and containing thin zones of cemented material resembling caliche.

51.7 — Watertable

115.0

Conglomerate, red, poorly cemented. Samples were sludge, pebbles, and a few small broken pieces of core. Poor drill water return suggests that rock is badly weathered from 115' to 125'.

The core recovered between 165' and 170' is all badly shattered granite. It was impossible to determine if this represents the granite underlying the conglomerate or a large granite boulder in the conglomerate.

170.0 — El. 1209.5

3 % recovery

14 — El. 1331.2

0

3.9 — Watertable

Silt, sand, and gravel unconsolidated.

42.5

48.6 — Basalt, amygdaloidal. Same as encountered in Hole No. 15. Contains a few small joints filled with calcite.

Red conglomerate. In general harder and better consolidated than the average encountered in other holes. Top 0.5' baked and metamorphased into a harder rock than the lower portion.

68.3 — El. 1262.9

89 % recovery

12 — El. 1461.4

0 — Terrace gravel cemented with calcareous material, numerous boulders.

10.0

Conglomerate. No core recovered. From fragments of core and cuttings the rock was identified as conglomerate. Granite pebbles and boulders predominate but pieces of basalt and quartzite were also found. The grain size ranges from sand to boulders three feet in diameter. The cement is a brown shaly substance similar to the cement in the conglomerate found in Drill Holes 10 and 11, but probably less resistant.

120.0 — Watertable

150.3 — El. 1311.1

No core

21 — El. 1334.0

0

6.5 — Watertable

Silt, sand, gravel and small boulders, unconsolidated.

44.0

92.0 — Probably conglomerate. Lack of core made identification difficult. Probably poorly cemented and less indurated than the average conglomerate.

El. 1242.0

No core

2 — El. 1384.0

0 — Cemented alluvium

6.0

Silt, sand, and gravel generally unconsolidated but containing cemented zones at various depths.

55.0 — Watertable

80.0

Conglomerate. Upper 15' badly weathered. Meager core recovery made identification difficult but it is probably a conglomerate made up largely of granite boulders. From 95' to 100' the conglomerate was harder and distinctly red. 85.3

100.0

Granite. Somewhat weathered predominantly gray in color.

108.5

109.0 — Igneous rock dike, fine-grained, hard.

Granite. Same as above with numerous veinlets of calcite.

130.0

Granite. Fractured, the presence of gouge and slickensides indicate movement. Iron stain shows alteration.

136.0

Granite. Few small joints and slips present. One foot of brecciated granite at 143' - 149'.

150.0 — El. 1234.0

49 % recovery

22 — El. 1371.7

0

Silt, sand, gravel, and small boulders, generally unconsolidated but containing cemented zones.

43.7 — Watertable

51.0

Conglomerate, red, very soft and weathered. Identified from sludge samples resulting from wash boring operations.

61.0

Conglomerate, red. More poorly cemented than the average encountered in the other holes. Most of the core from this hole is from the granite boulders. Very little of the cement cored.

85.8 — El. 1265.9

22 % recovery

3 — El. 1375.7

0 — Silt, sand, gravel, and boulders generally unconsolidated but containing cemented zones at varying depths.

47.0 — Watertable

Conglomerate. No core recovered, but red material washed from the hole indicates a weathered conglomerate between 85' and 100'. No difficulty wash boring.

100.0

Conglomerate. Fragments are mainly granite with subordinate amounts of quartzite, moderately well cemented with a red shaly material. From 100' to 101' soft and weathered.

107.0

Small veinlets and seams filled with calcareous material occur between 118' and 141'.

141.0

El. 1234.7

38 % recovery

7 — El. 1330.6

0

4.0 — Watertable

Sand, gravel, and boulders, unconsolidated.

22.0

22.0' to 35.0' soft and badly weathered.

Conglomerate. Boulders of granite with some basalt, basalt porphyry and possibly andesite, cemented by a red shaly sandy substance that is considerably more competent than that encountered in Holes Nos. 10, 11, 12 and is comparable to that of Hole No. 9.

Many small joints from 22' to 81'. Larger joints filled with calcareous material from 41' to 45' and 60' to 72'.

81.0 — El. 1249.6

28 % recovery

23 — El. 1359.6

0

32.0 — Watertable

Silt, sand, gravel, and boulders, unconsolidated and containing thin zones of cemented material resembling caliche.

76.0

Conglomerate, red, soft, poorly cemented, similar to rock in upper part of D.H.3. Samples were sludge and a few broken pieces of core.

Same as above, but better cemented.

132.0 — El. 1227.6

No core

11 — El. 1358.5

0

Silt, sand, gravel and boulders, unconsolidated.

22.2

24.7 — Watertable

Conglomerate. Fragments are nearly all granite boulders which vary considerably in size and shape. Cement is mostly a grey-brown shaly, siliceous substance which is less competent than that found in either drill Holes No. 9 or No. 10.

80.8 — El. 1277.7

39 % recovery

5 — El. 1336.2

0 — Silt, sand, and gravel, unconsolidated.

6.0 — Watertable

21.0

As indicated from core recovery and water loss the top 45.0' of rock appears to be badly weathered and broken.

Conglomerate. Fragments of granite with subordinate amounts of basalt and quartzite. Moderately well cemented with a red shaly sandy mixture. Better consolidated than the gray-brown conglomerate on the left side of the river.

56.0

Loss of drilling water at 47.0' and 62.0' plus caving, suggest structural weaknesses in the rock at those depths. Nature of these weaknesses could not be determined.

74.0

Seams and joints showing some slickensides and filled with calcareous material occur between 85' and 95'.

120.0 — El. 1216.2

42 % recovery

15 — El. 1333.8

0

6.0 — Watertable

Silt, sand, gravel, and small boulders, unconsolidated.

45.0

Conglomerate? Sludge samples indicate the first foot of bedrock is conglomerate.

Basalt, amygdaloidal. The cavities are filled with calcite and other minerals. The rock is very hard and competent, cut only by few small joints filled with calcite.

46.5

48.2 — A thin 3" inclusion of conglomerate occurs near the top of the basalt.

58.7 — El. 1275.1

91 % recovery

17 — El. 1334.8

0

7.3 — Watertable

Silt, sand, gravel and boulders, unconsolidated.

Conglomerate, red. In general harder, less weathered, and better cemented than the average encountered directly under the overburden.

58.0 — El. 1276.6

90 % recovery

1 — El. 1455.6

0 — Granite. Weathered, containing cracks filled with thin layers of gouge and red iron oxide.

28.0

Granite. Because of poor core recovery between 28' and 56', a fully accurate determination of the rock was impossible. A study of the short pieces of core and the larger cuttings washed out of the hole indicates that the rock is granite with inclusions of a more basic rock containing quartz and probably chlorite.

56.0

Granite. Same as from 0' to 28', but less weathered near the base.

74.0

Granite. Coarse-grained, hard, sound, gray color. Thin fractures containing gouge and red iron oxide occur at 78', 84', 86-88', 92' and 99'-100'.

101.7 — El. 1353.9

43 % recovery

6 — El. 1336.1

0

8.0 — Watertable

Unconsolidated sand, gravel and boulders with 2.0' of fine sand and silt at top.

45.0

Conglomerate. Fragments of granite, basalt, basalt porphyry, and andesite; granite predominating. Cement consists of a red, shaly, sandy substance that is better consolidated than the average encountered in the grey-brown conglomerate on the left side of river. Thin layers of coarse-grained sandstone interbedded with the conglomerate at various depths. Small faults occur, filled with calcareous material at 80' to 85' and some without calcareous material at 86' and 95' to 100'.

Joints filled with calcareous material occur at 75' and 76'.

100.0 — El. 1236.1

58 % recovery

4 — El. 1404.5

0 — Conglomerate. Fragments of granite with subordinate amounts of gneiss and quartzite. Cement consists of a red, shaly, sandy substance. Zones occurring between 52' and 75' and between 78' and 95' contain layers of larger rocks and are not so well cemented as the average conglomerate.

Small tight joints occur between 25.5' to 32.0'.

75.0 — Watertable

100.0 — El. 1304.5

51 % recovery

10 — El. 1352.2

0

Silt, sand, gravel, and boulders unconsolidated.

24.0

24.3 — Watertable

Conglomerate. Granite fragments that vary considerably in shape and size. Cement is mostly a greyish-brown shaly, siliceous material that is somewhat less competent than the red cement found in the conglomerate of Hole No. 9. A thin layer of brown medium-grained, poorly cemented sandstone was found between 41.0' and 41.8'.

41.0

41.8

There is a weathered joint at 42.7 lined with a calcareous material.

65.6

95.6 — Volcanic Tuff. Very similar to that found between 20' and 75.0' in hole No. 9 except that this rock is less vesicular and there are fewer inclusions of other rock.

El. 1256.6

53 % recovery

18 — El. 1331.5

0

4.0 — Watertable

Silt, sand, gravel, and boulders unconsolidated.

36.0

Conglomerate, red. 36' to 39.5' weathered, 39.5' to 48' unweathered and moderately hard.

48.0 — El. 1283.5

62 % recovery

16 — El. 1331.8

0

4.5 — Watertable

Silt, sand, gravel, and boulders, unconsolidated.

24.0

Basalt, hard, fine-grained, dark grey. Same as encountered in D.H. 20. Badly weathered between 24' and 28'. Numerous small slips and joints between 28' and 39.5' filled with calcite. Slickensides show in fractures

39.5 — El. 1292.3

83 % recovery

13 — El. 1339.3

0

11.8 — Watertable

Silt and sand, unconsolidated.

24.5

Conglomerate, red. Contains large granite boulders at top which decrease in size towards base. In comparison to conglomerate encountered in the other holes, this is average hardness and cementation.

42.5 — El. 1296.8

64 % recovery

SCALE 10 0 10 20 FEET

Note:
Log data based on records furnished by Bureau of Reclamation. Numbers refer to B.R. drill hole (D.H.) designations.

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

McDOWELL DAM SITE
FOUNDATION EXPLORATION
GEOLOGIC LOGS

SCALE: AS SHOWN — IN ONE SHEET

DATUM IS MEAN SEA LEVEL

OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., JULY 1950

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

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (D.O. SERIES)
F.E.B.	V.F.W.	V.V.P.	DATED: DECEMBER 4, 1957	410/64

UNITED STATES ARMY CORPS OF ENGINEERS

LOS ANGELES DISTRICT

BASES FOR DESIGN

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

To accompany interim report on survey for flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated December 4, 1957.

APPENDIX 3

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No.	Title
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BASES FOR DESIGN

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

SCOPE

1. This appendix covers the engineering aspects of (1) the levee and channel improvements recommended for construction along Gila and Salt Rivers, Gillespie Dam to McDowell Dam site; and (2) the McDowell multiple-purpose reservoir, which was considered in detail. The area along Gila and Salt Rivers from Gillespie Dam to McDowell Dam site and the locations of improvements considered are shown on map, plate 1, at the end of the text of report; and details of improvements considered are shown on plates 1 to 9, inclusive, of this appendix.

LEVEE AND CHANNEL IMPROVEMENTS ALONG GILA AND SALT RIVERS

2. Location.--The levee and channel improvements recommended for construction along Gila and Salt Rivers from Gillespie Dam to McDowell Dam site consist of the following: (1) A levee system along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; and (2) channel improvements along Gila River from Gillespie Dam to the mouth of Salt River--a distance of 34 miles--and along Salt River from its mouth to Granite Reef Dam--a distance of 43 miles.

3. Levee system along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe.--The levees would consist of (1) a levee along the left bank of Salt River for about 2,000 feet from Tempe Butte to the Southern Pacific railroad bridge embankment and (2) a levee along the right bank of Salt River for about 16,700 feet from the Southern Pacific railroad bridge embankment to 40th Street, Phoenix. Construction of the major part of the right-bank levee would consist of enlarging the existing canal levee and of placing rock facing. The right-bank levee would incorporate the existing Joint-Head Dam.

(a) Structural design.--The earthfill part of the levees would be alluvium compacted in place. The levee would range in height from 7 to 22 feet above the natural ground and from 23 to 28 feet above the streambed. The top width of the levee would be 18 feet and the slopes would be 1 vertical on 2 horizontal. The river side of the levees would be revetted with rock facing 1.25 feet thick on a gravel filter blanket 6 inches thick. The levee revetment would extend to a minimum depth of 5 feet below the existing streambed. Details of the levee design are shown on plate 6. For information on construction material see Appendix 2: Geology and Soils.

(b) Hydraulic design.--The levee system would be designed to accommodate the standard project flood of 270,000 cubic feet per second (290,000 at McDowell Dam site) with a minimum freeboard

allowance of 3 feet. Water-surface elevations were computed by using the reach method. A roughness coefficient of n equals 0.035 was used in Manning's formula for determining the effect of friction. The backwater effect of bridge piers was computed by using Yarnell's formula for Class A flow. Allowance was made for the accumulation of debris on the bridge piers. Velocities, including those through the United States Highway Nos. 60, 70, 80, and 89 bridge and the Southern Pacific railroad bridge, would range from 8 to 12 feet per second.

4. Channel improvements along Gila and Salt Rivers, Gillespie Dam to Granite Reef Dam.--Channel improvements would consist of a cleared floodway and of 2 low-flow channels. The floodway, 2,000 feet in width, would be created by clearing river-bottom growth along Gila River from Gillespie Dam to the mouth of Salt River and along Salt River from its mouth to Granite Reef Dam. The 2 low-flow or pilot channels would be within the cleared floodway; the first, along Gila River from Gillespie Dam to a point about 1 mile downstream from the mouth of Agua Fria River; and the second, along Salt River upstream from the highway bridge at Tempe. Important features of the proposed improvement are discussed in the following subparagraphs.

(a) Phreatophyte problem.--Phreatophytes, including saltcedars, grow profusely in and along the streambeds of Gila and Salt Rivers between Gillespie Dam and Granite Reef Dam. These plants produce enormous quantities of seed that germinate and grow rapidly when the water table is not more than 10 feet below the ground surface. Three general methods of eradicating the phreatophytes have been proposed: (1) Burning, (2) chemical treatment, and (3) mechanical means. Numerous experiments are now being conducted by Federal, State, and local interests on these means of eradication, but no final conclusions have been reached. Experience with burning indicates that, within 2 years after infested areas within the flood plain had been burned, many saplings have sprung up from the root crowns of burned trees and have grown to heights of 5 to 7 feet, depending on the location within the floodway and on the availability of surface or ground water. Studies of chemical treatment have considered chemicals like 2,4-D and 2,4,5-T. Results of current studies by other agencies indicate that chemical treatment of saltcedars by spraying would be only partially effective and that complete removal would require subsequent cutting, raking, and burning to provide a cleared floodway. In addition, adequate care must be exercised to prevent spray from drifting to adjacent crops. Mechanical means of eradicating phreatophytes would be effective.

(b) Initial clearing of river channels.--Because information to date indicates that burning and chemical treatment would still require mechanical means of clearing the floodway, initial destruction of growth and clearing of floodway by mechanical means 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, at 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 means is being utilized by both agencies. Available information indicates that the equipment utilized by the International Boundary and Water Commission would be satisfactory for use along the Gila and Salt Rivers. That agency has used two Towner disc stubble ploughs in series drawn 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 10 to 15 feet tall. During the analysis of densities of growth within the proposed 2,000-foot floodway, 3 categories of density were assumed: dense growth, sparse growth, and very sparse growth. The number of acres in these categories is estimated at 4,323, 6,743, and 6,119, respectively.

(c) Maintenance of floodway.--The same factors affecting the selection of the method of initial clearing apply to the problem of maintenance. A cleared floodway can be sustained by continual destruction (mechanical or chemical) or by cutting of new growth. In addition, consideration was given to maintenance of the floodway by means of revegetation by selective planting of grasses and to partial utilization of the cleared channel as pasture. Studies are being conducted by other agencies to determine the efficacy of such a method. However, no conclusions have yet been formulated on the costs or the results of such a means of maintenance. 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 methods, but supplemental mechanical work is required to clear dead growth and grub or remove the top portion of the root system. The International Boundary and Water Commission is utilizing an 84-inch brush cutter drawn by a 40 horsepower rubber-tired tractor. For the purpose of preparing an adequate cost estimate, mechanical means, similar to the method being used by the International Boundary and Water Commission, was assumed. The areas now classified as covered with dense growth (4,323 acres) would be cut twice a year with power equipment. The areas now classified as covered with sparse and very sparse growth would be cut once every year. However, more frequent cutting might be necessary in areas where growth is now sparse if ground- and surface-water conditions become more favorable for saltcedar growth.

(d) Design of low-flow channels.--The low-flow channel along Gila River would have a bottom width of 50 feet, side slopes of 1 on 1.5, an average depth of about 5 to 6 feet, and a capacity of approximately 1,000 cubic feet per second. Creation of the low-flow or pilot channel along Gila River would tend to direct flows to within the cleared floodway, and would thereby accomplish desired river rectification. The low-flow channel along Salt River would have a bottom width of 200 feet, side slopes of 1 on 1.5, an average depth of 6.5 feet, and a capacity of about 6,500 cubic feet per second. Creation of the low-flow or pilot channel along Salt River would direct flows to within the cleared floodway and would thereby improve flow conditions at the approach to the existing highway bridge near Tempe. The plan and profile of the low-flow channel

along Gila River is shown on plates 1 to 3, and the plan and profile of the low-flow channel along Salt River is shown on plate 6.

5. Utility and road relocations.--Two ramps over the right-bank levee along Salt River would be provided: one at Delano Avenue and the other at 40th Street. Culvert or road crossings would be provided to replace all existing crossings along Gila River in the vicinity of the low-flow channel. No other road relocations and no utility relocations would be required.

McDOWELL RESERVOIR

6. Location.--The McDowell Dam site is on Salt River at river mile 46, just downstream from the mouth of Verde River and about 25 miles northeast of the city of Phoenix. The site is in a relatively broad section between rolling hills on the left bank and a high mountain on the right. The streambed at the site is about 1,500 feet wide.

7. Area and capacity.--The latest available topographic maps of the United States Geological Survey were utilized in the preparation of data for plotting the area-capacity curves. The reservoir areas were determined by planimeter, and the reservoir capacities were computed by cumulative addition of increments of volume between adjacent contours. The estimates of volume between adjacent contours were based on the arithmetic average of the areas inclosed by the contours. The area-capacity curves are shown on plate 10.

8. Sediment.--The problem of sediment at the McDowell Reservoir site would not be serious. Reservoirs to store sediment from the upstream part of the drainage area are on both Salt and Verde Rivers upstream from the McDowell site. Comparison of sedimentation studies for similar reservoir areas in southwestern United States indicates that an allocation of 25,000 acre-feet for sedimentation during a 50-year period would be adequate.

9. Dam.--An analysis of topographic, geologic, and hydrologic data for the dam site indicates that an earthfill dam with an ungated detached spillway would be the most economical. The dam would be 169 feet high above streambed. The top of the dam (elevation 1,494) would be 5,180 feet long and 30 feet wide. The earth embankment would have an upstream slope of 1 on 3 and a downstream slope of 1 on 2.5. A 10-foot berm would be provided on the downstream slope at elevation 1,400.

10. The upstream slope would be protected by a 2-foot blanket of quarrystone, obtained from nearby sources and placed on a 12-inch layer of graded local gravel. The downstream slope between top of dam and elevation 1,350 (5 feet above maximum tailwater elevation) would be protected by a 12-inch blanket of graded local gravel. A layer of stone from nearby sources, varying in thickness from 4 feet at the top to 6 feet at the toe, would be placed on the downstream face from elevation

1,350 to a depth of at least 15 feet below streambed for protection against tailwater. This layer of stone would be underlain by a 2-foot layer of spalls.

11. The material for the rolled earthfill would be placed by wetting and compaction as follows: (1) Random pervious in zone II, adjacent to the upstream and downstream faces, (2) impervious in zone I, central part of the dam and continuing down to bedrock in the streambed part of the dam, and (3) select pervious under the downstream side of zone II. Protection against underseepage would be obtained by an impervious core trench extending to bedrock and a grout curtain extending into bedrock. The core trench would be excavated to an average depth of 10 feet to bedrock along the terrace slope of the left abutment, to an average depth of 25 feet for the reach within the flood-plain area to the east of the tuff outcrop, to an average depth of 40 feet in the flood-plain area between the tuff outcrop and the red conglomerate knob, and to a maximum depth of 120 feet in the reach immediately west of the red conglomerate--where an old stream channel exists. A grout cap would be provided at the bottom of the core trench. Plan, profile, and sections for the dam are shown on plates 8 and 9, and details of geology and soils at the site are given in Appendix 2: Geology and Soils.

12. Outlet works.--The outlet works consist principally of 4 rectangular conduits, a water-supply outlet, a power penstock, a control tower, an access bridge to tower, and a stilling basin. The 4 outlets, which would be 22- by 19-foot reinforced concrete conduits, would be founded on bedrock in an open cut through an existing rock knoll adjacent to the right bank of the river and would terminate in a stilling basin at the downstream end. A channel about 1,200 feet long would be constructed between the downstream end of the stilling basin and the existing channel of Salt River downstream from the dam site. The 4 conduits would be used for diversion during construction. Later, the intake for the conduits would be controlled by mechanically operated 22- by 19-foot service gates (radial type). Emergency closure of the conduits would be provided by stop logs upstream from the service gates.

13. The power penstock and the intake for the water-supply system would be on the right side of the control tower and adjacent to it. Three selective takeoffs on water supply would be provided, each of which would be controlled by a hydraulically operated valve. Takeoffs at different elevations would be required for selection of the best quality of water for domestic use. The takeoffs would be placed at 15-foot intervals--the lowest intake about 40 feet above streambed (elevation 1,365) and the highest intake (elevation 1,395) about 10 feet below the maximum water-surface elevation of the terminal storage pool. Access to the control tower would be by bridge; and access to the service gates, the hoists, and the valve chamber for domestic supply would be by ladders within the tower. A trash-rack structure would be provided at the intake for the power penstock

and the water supply. Stoplogs can be provided for the power penstock intake. Details of the outlet works are shown on plates 8 and 9, and an outlet-discharge curve is shown on plate 11.

14. Spillway.--Estimates of the maximum probable flood were used in the design of the spillway. Topographic and geologic conditions at the site indicate that the most feasible location for the spillway would be in the saddle 1 mile southeast of the left abutment of the dam. A detached spillway in this saddle area was considered most feasible because (a) use would be made of a natural site for an inexpensive structure and (b) a detached spillway at this site would eliminate excessively high tailwater on the main embankment.

15. The spillway channel would be approximately 8,000 feet long; the approach channel, 3,600 feet; the crest section, 20 feet; and the downstream channel 4,400 feet. The spillway structure, which would be founded on rock, would be a broad-crested weir 1,100 feet in length and have an upstream and downstream concrete cutoff wall extending to a depth of 10 feet and 15 feet, respectively, into bedrock. The crest would be reinforced concrete slab, amply anchored into the cutoff walls. The approach channel at the entrance will be approximately 1,800 feet in width with a transition to 1,100 feet at the weir. The downstream channel would have a minimum width of 1,100 feet, and at a distance of 300 feet below the spillway crest the major portion of the channel will be daylighted and flow will follow a broad natural drain of uniform slope to the Salt River approximately one-half mile below the proposed dam. Details of the spillway are shown on plates 8 and 9, and a spillway-discharge curve is shown on plate 11.

16. Reservoir operation.--Storage in McDowell Reservoir would be allocated as follows: 46,000 acre-feet for sediment and dead storage, 142,000 acre-feet for terminal storage, and 672,000 acre-feet for flood control.

17. The standard project flood was selected for use in the design of the flood-control features of McDowell Reservoir. Along Salt River downstream from the McDowell Dam site, a discharge of 100,000 cubic feet per second will cause a small amount of damage and a flow of 82,000 cubic feet per second will cause only minor damages. Under the operation of the reservoir, the standard project flood (290,000 cubic feet per second) would be reduced to a peak outflow of 82,000 cubic feet per second as indicated on plate 12, and the maximum probable flood (600,000 cubic feet per second) would be reduced to a peak outflow of 288,000 cubic feet per second as indicated on plate 13. The assumption was made that the reservoir would be full to maximum terminal-pool level (elevation 1,405) at the start of the reservoir design flood or spillway design flood.

18. The following operation procedure was assumed--

(a) Below elevation 1,405, inflow would be stored.

(b) At elevation 1,405, outflow would equal inflow until a discharge of 82,000 cubic feet per second is reached.

(c) Between elevation 1,405 and elevation 1,470 (spillway crest), the conduit gates would be operated to maintain a constant outflow of 82,000 cubic feet per second.

(d) Above elevation 1,470, uncontrolled flow would pass over the spillway and a constant flow of 82,000 cubic feet per second would pass through the conduit system.

19. Freeboard.--In the design of an earth dam or earth dike, the elevation of the top of the dam or dike is determined by adding to the elevation of the spillway-design surcharge an allowance for wave height and rideup and for wind setup. The Stevenson formula as modified by Molitor was used in determining the freeboard. The elevation of the top of the dam was set at 1,494.

20. Control of stream during construction of dam.--During the first phases of the dam construction, stream diversion for protection of the work area from flooding would not be required. The first phases of construction would probably consist of excavating and constructing the outlet works, clearing and grubbing the site of the dam base within the streambed, excavating at the site of the spillway, and completion of concrete work for the spillway. Upon near completion of the outlet works, an earth cofferdam at the upstream limits of the work area would divert low surface flows into the outlet works. If several wet seasons precede construction of McDowell Dam, and all upstream reservoir storage has been occupied, a portion of the streambed should be left for additional facilities for diversion during the period of construction. An extensive well-point system in the streambed work area would be used to divert subsurface flow and seepage into pipes and open flumes.

21. Utility and road relocations.--Because most of the McDowell Reservoir site is in a relatively undeveloped area, only minor utility relocations would be required, with the exception of the abandonment of the infiltration galleries and wells for the city of Phoenix water supply on the Verde River. The power line and highway in the vicinity of the spillway will have to be relocated. The now existing road to the dam site and the city of Phoenix water-filtration plant will have to be relocated to give access to the dam and water plant during periods of extreme flood stages. Protection of the Stewart Mountain power plant, which would be inundated at high reservoir stages, is not provided for in the design. The power plant would probably be abandoned when McDowell Reservoir is constructed.

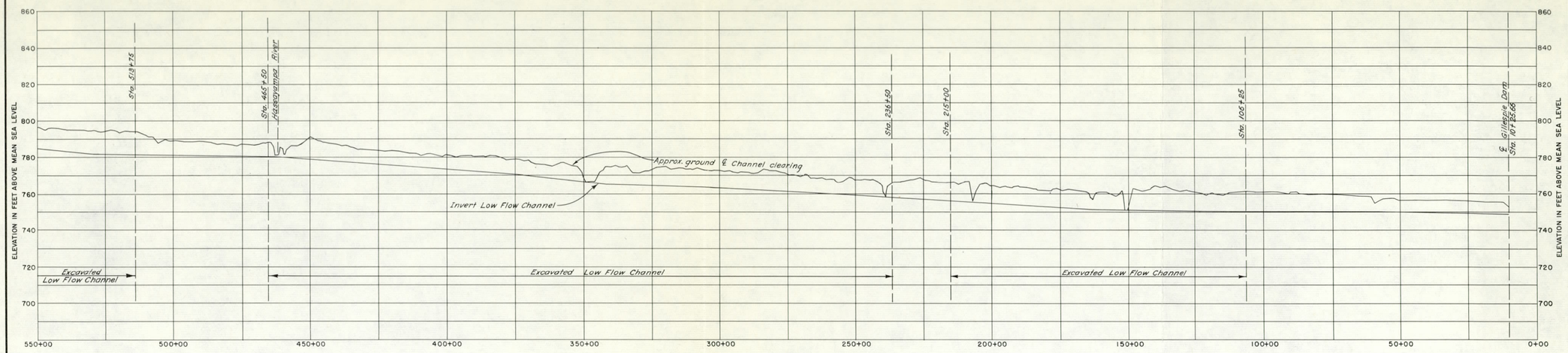
22. Summary of pertinent data on McDowell Reservoir.--A summary of pertinent data on the McDowell multiple-purpose reservoir is given in the following table:

Summary of pertinent data, McDowell Reservoir

Item	Unit	Quantity
GENERAL		
Drainage area	Square miles	12,900
STRUCTURAL		
Dam (earthfill):		
Height above foundation	Feet	234
Height above streambed	do	169
Streambed elevation	Feet, m.s.l.	1,325
Top elevation	do	1,494
Length at crest	Feet	5,180
Freeboard	do	8.0
Spillway (broad-crested weir, left of dam):		
Crest length (net)	do	1,100
Crest elevation	Feet, m.s.l.	1,470
Height of design surcharge above crest	Feet	16
Outlet works (flood control):		
Invert elevation at entrance	Feet, m.s.l.	1,325
Service gate (radial, 22' x 19')	Each	4
Emergency gate (stoplogs)	do	14
Conduit (rectangular concrete, 22' x 19')	do	4
Length of conduit	Feet	600
Outlet elevation at stilling basin	Feet, m.s.l.	1,324.4
Stilling basin:		
Length	Feet	365
Width	do	179
Elevation	Feet, m.s.l.	1,286
Sill elevation	do	1,295
Outlet works (water supply):		
Conduit size	Inches	48
Intakes:		
Number	Each	3
Size	Inches	48
Invert elevation at entrance	Feet, m.s.l.	(1,365 (1,380 (1,395
Outlet works (power):		
Conduit size	Feet	10
Invert elevation at entrance	Feet, m.s.l.	1,365

Summary of pertinent data, McDowell Reservoir--Continued

Item	Unit	Quantity
HYDRAULIC		
Standard project flood (reservoir design flood):		
Peak inflow	C.f.s	290,000
Volume (10 days)	Acre-feet	1,520,000
Peak outflow	C.f.s	82,000
Maximum probable flood:		
Peak inflow	C.f.s	600,000
Volume (10 days)	Acre-feet	2,240,000
Peak outflow	C.f.s	288,000
RESERVOIR		
Length (spillway-crest elevation)	Miles	10
Storage allocation:		
Terminal storage	Acre-feet	142,000
Flood control	...do	672,000
Sediment and dead storage	...do	46,000
Total	...do	860,000
Terminal storage pool:		
Elevation	Feet, m.s.l.	1,405
Area	Acres	5,800
Capacity (including sedimentation storage)	Acre-feet	188,000
Maximum water surface:		
Elevation	Feet, m.s.l.	1,486
Area	Acres	18,000
Capacity	Acre-feet	1,130,000
Spillway:		
Elevation	Feet, m.s.l.	1,470
Area	Acres	15,200



PROFILE

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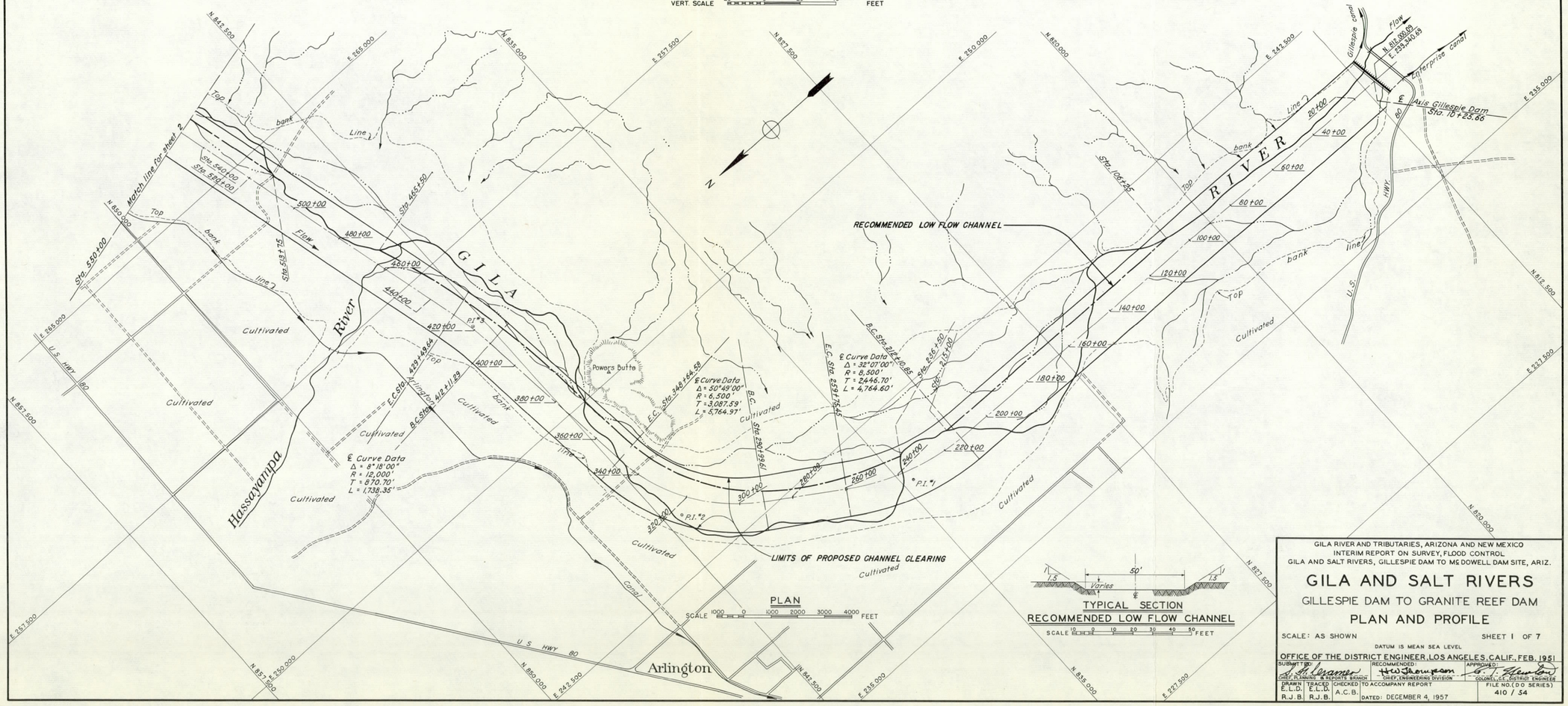
VERT. SCALE 20 0 20 40 FEET



PLAN

SCALE 1000 0 1000 2000 3000 4000 FEET

TYPICAL SECTION
RECOMMENDED LOW FLOW CHANNEL

SCALE 10 0 10 20 30 40 50 FEET

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

GILA AND SALT RIVERS

GILLESPIE DAM TO GRANITE REEF DAM

PLAN AND PROFILE

SCALE: AS SHOWN SHEET 1 OF 7

DATUM IS MEAN SEA LEVEL

OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., FEB. 1951

SUBMITTED:	RECOMMENDED:	APPROVED:
CHIEF, PLANNING & REPORTS BRANCH	CHIEF, ENGINEERING DIVISION	COLONEL, CE, DISTRICT ENGINEER

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (DO SERIES)
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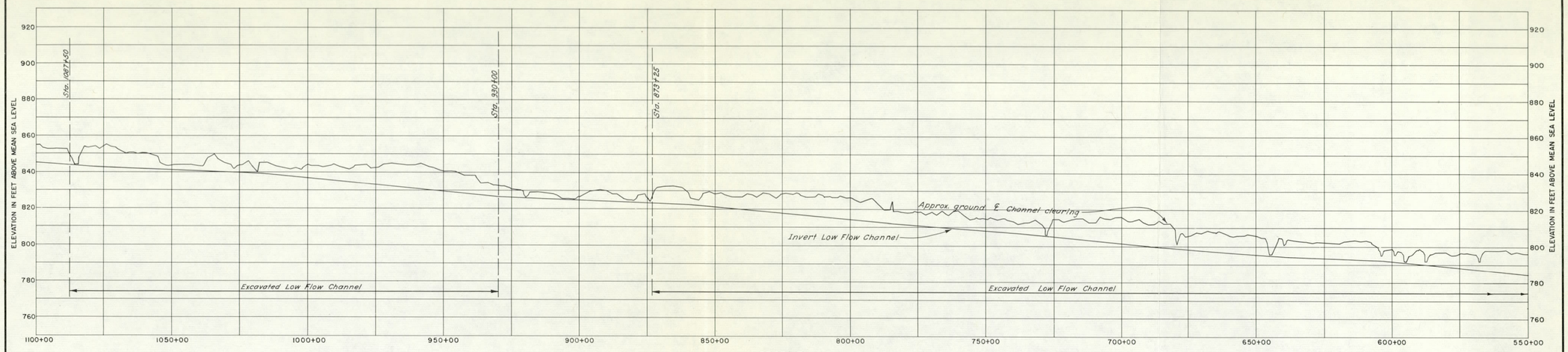
U.S. ARMY



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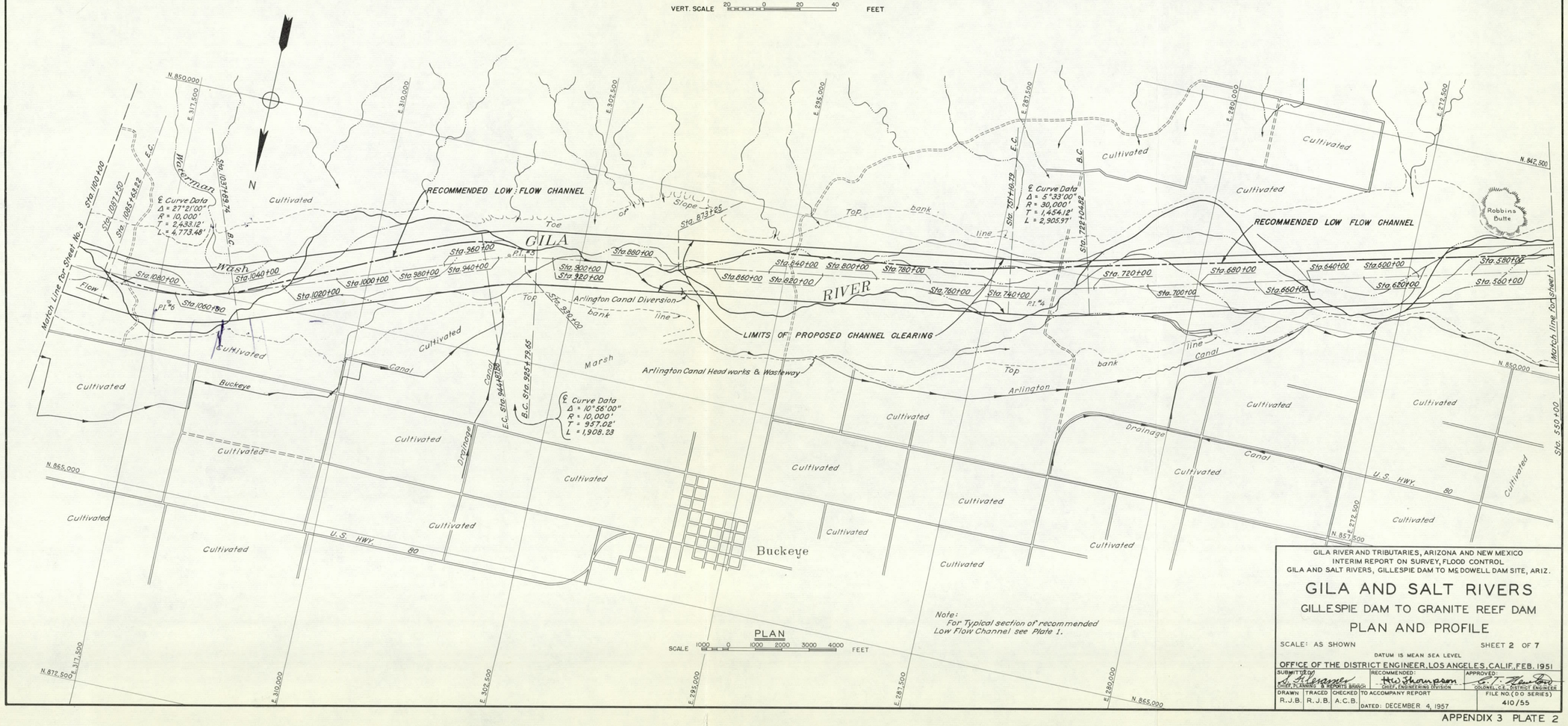

PLAN

SCALE 1000 0 1000 2000 3000 4000 FEET

Note:
For Typical section of recommended Low Flow Channel see Plate 1.

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

GILA AND SALT RIVERS

GILLESPIE DAM TO GRANITE REEF DAM

PLAN AND PROFILE

SCALE: AS SHOWN SHEET 2 OF 7

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OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., FEB. 1951

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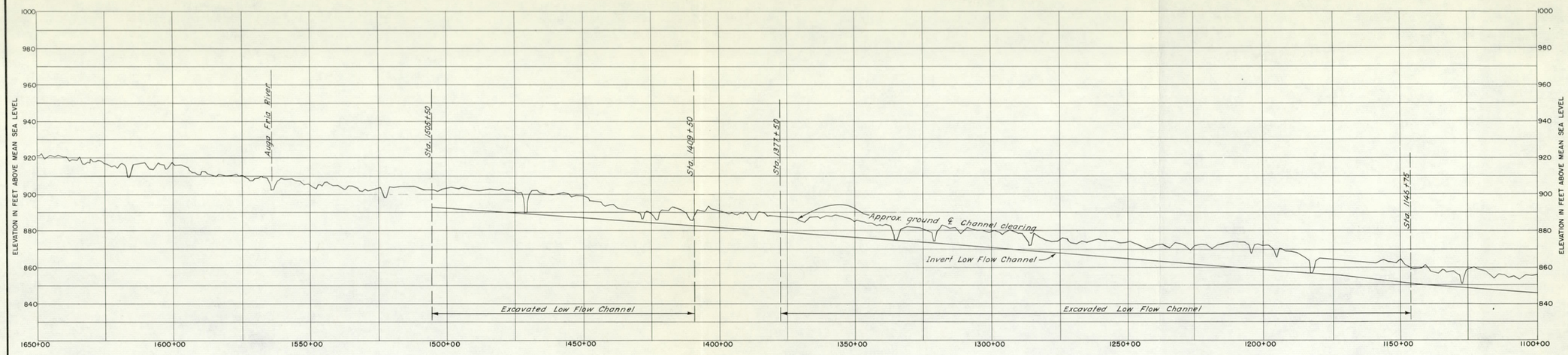

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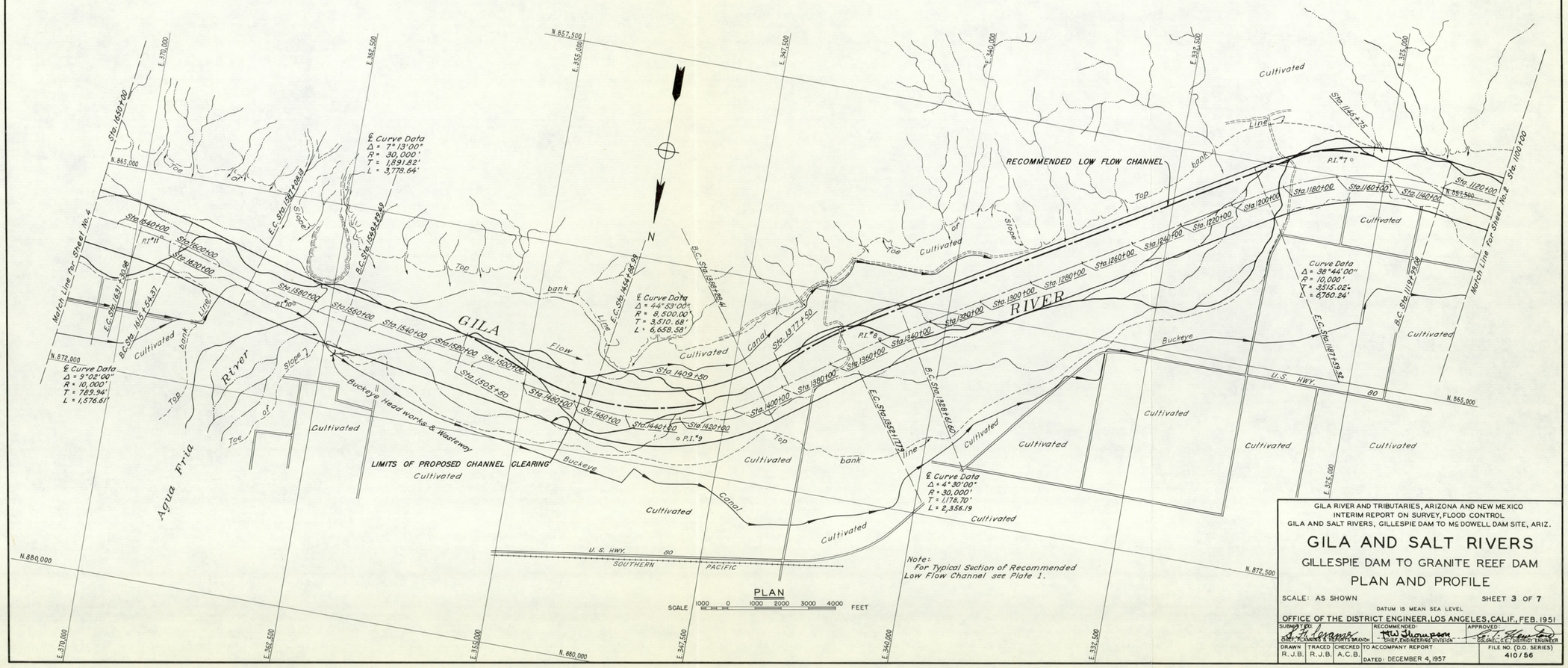

Note:
For Typical Section of Recommended Low Flow Channel see Plate 1.

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO MC DOWELL DAM SITE, ARIZ.

GILA AND SALT RIVERS
GILLESPIE DAM TO GRANITE REEF DAM
PLAN AND PROFILE

SCALE: AS SHOWN SHEET 3 OF 7

DATUM IS MEAN SEA LEVEL

OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., FEB. 1951

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R. J.B.	R. J.B.	A.C.B.	DATED: DECEMBER 4, 1957	410/56

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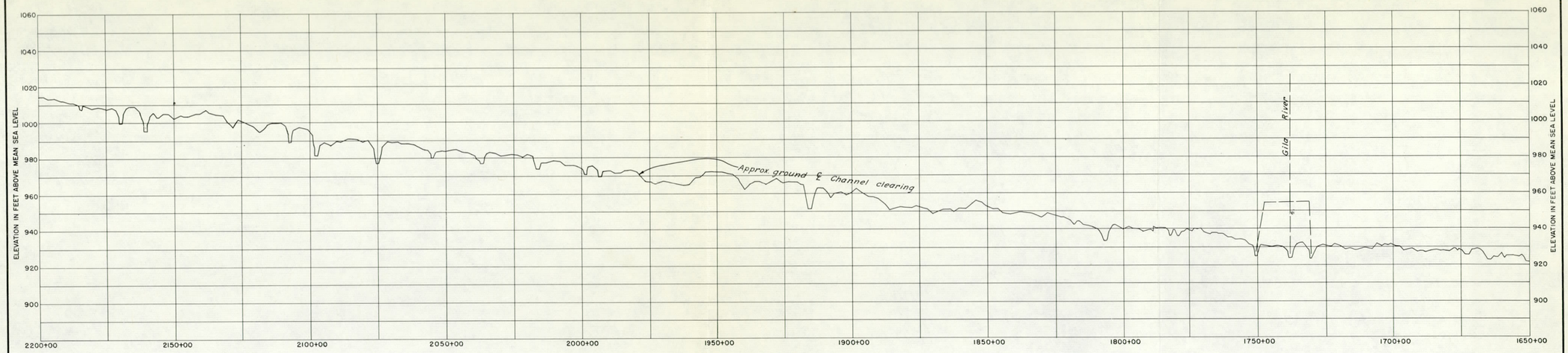

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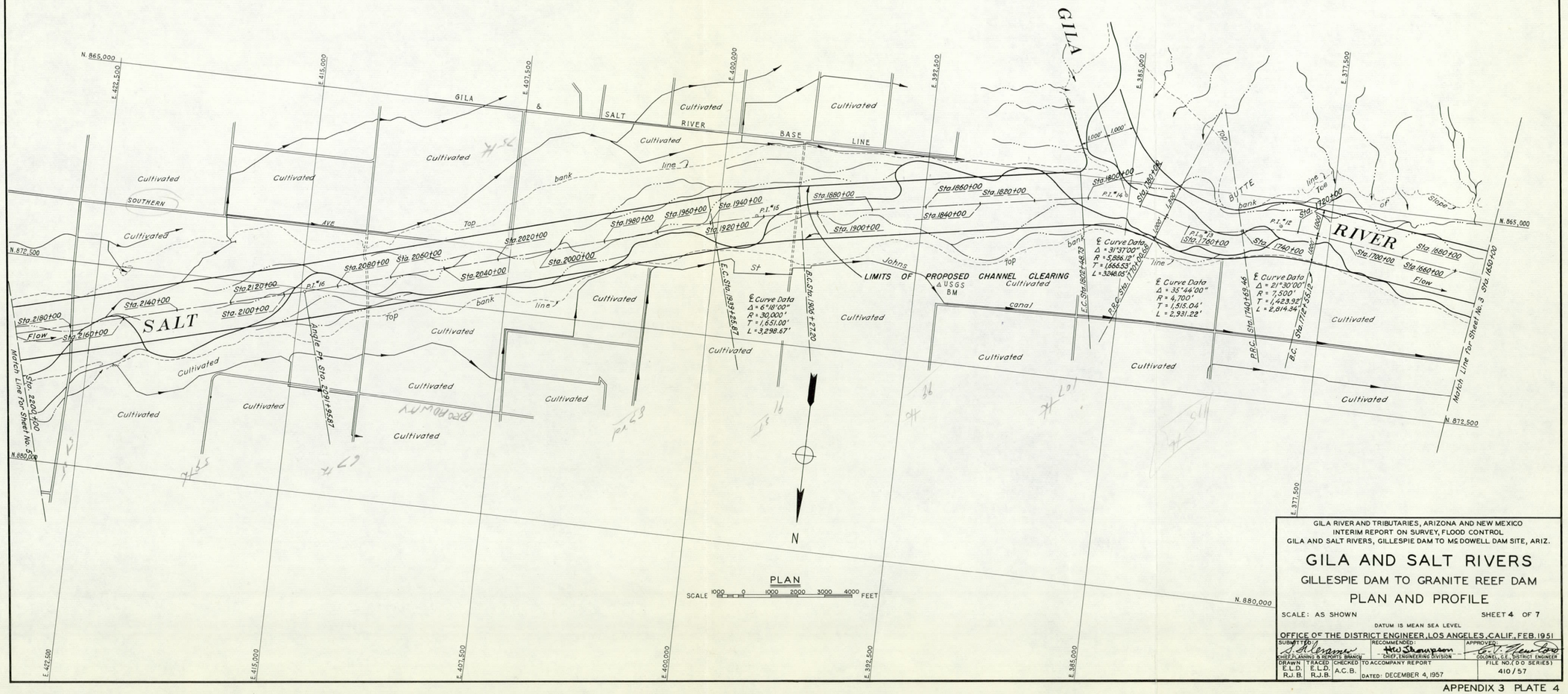

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

GILA AND SALT RIVERS

GILLESPIE DAM TO GRANITE REEF DAM

PLAN AND PROFILE

SCALE: AS SHOWN

SHEET 4 OF 7

DATUM IS MEAN SEA LEVEL

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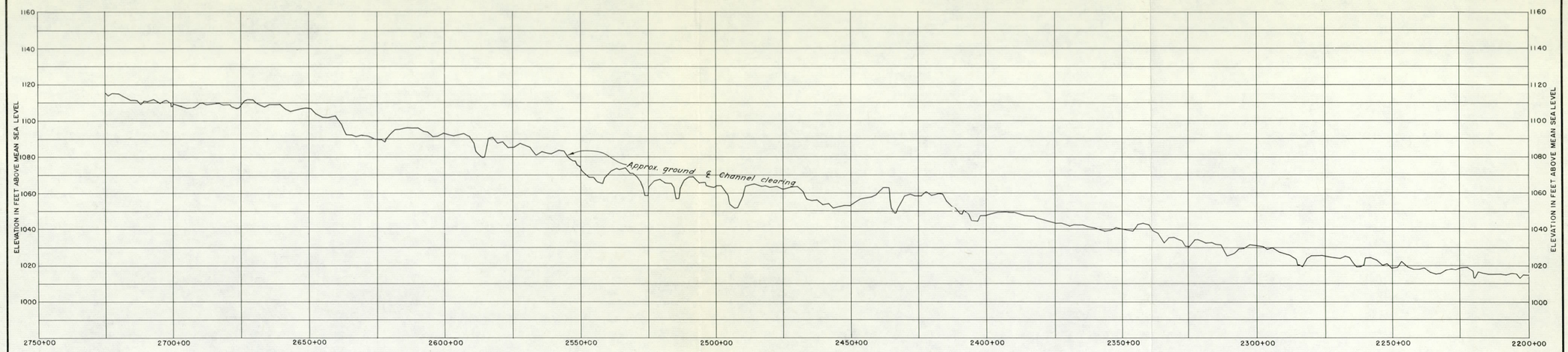
APPENDIX 3 PLATE 4

CORPS OF ENGINEERS

U.S. ARMY



PROFILE

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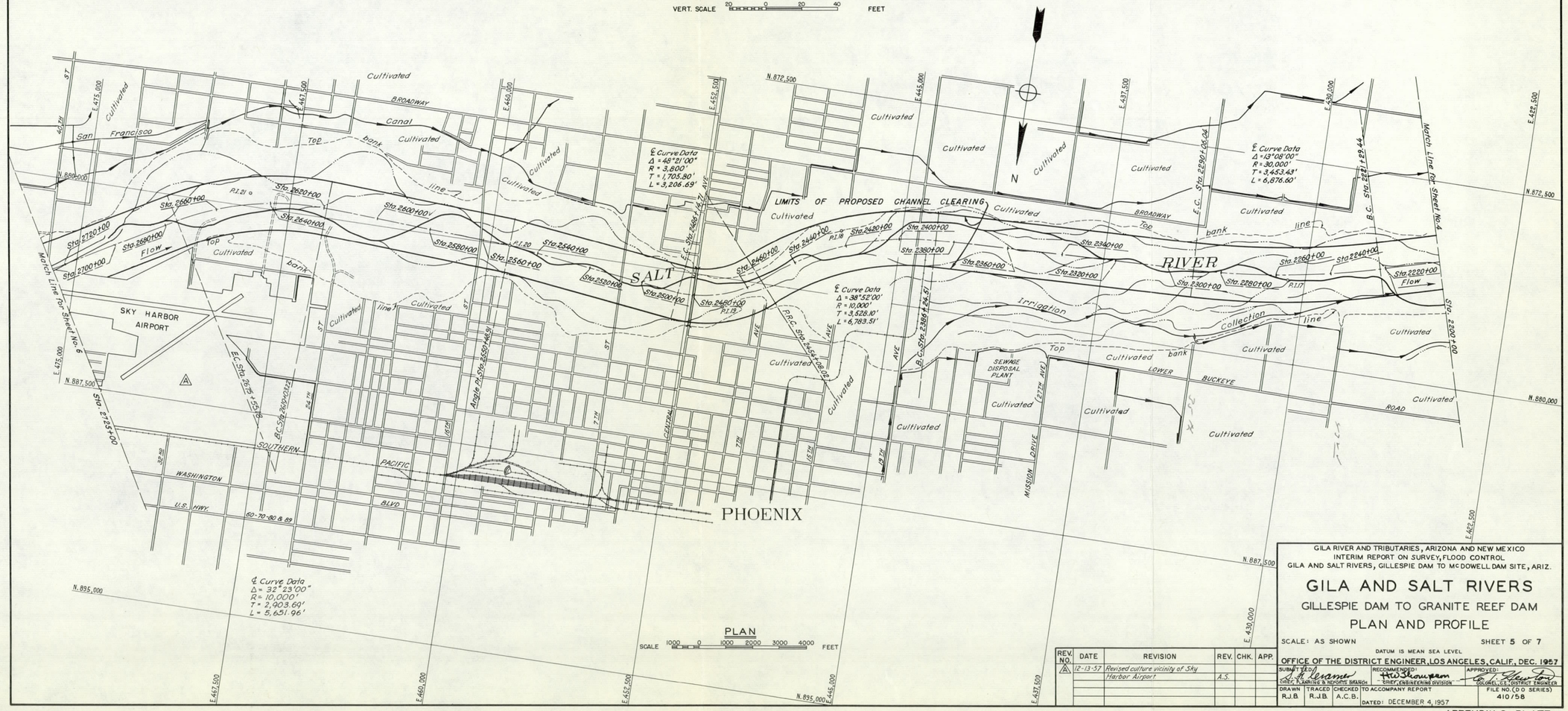

PLAN

SCALE 1000 0 1000 2000 3000 4000 FEET

REV. NO.	DATE	REVISION	REV.	CHK.	APP.
1	12-13-57	Revised culture vicinity of Sky Harbor Airport	A.S.		

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

GILA AND SALT RIVERS

GILLESPIE DAM TO GRANITE REEF DAM

PLAN AND PROFILE

SCALE: AS SHOWN

SHEET 5 OF 7

DATUM IS MEAN SEA LEVEL

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

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APPENDIX 3 PLATE 5

CORPS OF ENGINEERS

U. S. ARMY

PROFILE

HOR. SCALE 1000 0 1000 2000 3000 4000 FEET

VERT. SCALE 20 0 20 40 FEET

ELEVATION IN FEET ABOVE MEAN SEA LEVEL

Approx. ground & channel clearing

End Low Flow Channel Sta. 2987+00

Invert Low Flow Channel

Approx ground & left bank levee

Left bank levee Sta. 3167+50

U.S. Hwy. 60 Bridge Sta. 2902+20

Atchison, Topa & Santa Fe R.R. Bridge Sta. 2894+50

Sta. 2875+00

Sta. 2844+00

Sta. 2779+00

Sta. 2721+00

El. 1170.8

El. 1169.1

El. 1167.7

El. 1167.5

El. 1165.8

El. 1167.0 Base of rail-North abutment

El. 1166.0 Base of rail-South abutment

El. 1165.1

El. 1159.7

El. 1152.8

El. 1143.0

El. 1139.5

El. 1136.5

El. 1135.7

El. 1135.0

El. 1131.0

El. 1124.7

El. 1114.4

El. 1132.7

El. 1104.0

S=.0021

S=.0020

S=.0020

S=.0016

S=.0020

Excavated Low Flow Channel (Recommended)

Left bank levee

Right bank levee

Top of Levee

Approx. ground & right bank levee

Water surface

Toe of stone facing

Orange Ave. Ramp Sta. 2769+50

40 th Street Ramp Sta. 2734+60

Begin right bank levee Sta. 2721+00

3250+00 3200+00 3150+00 3100+00 3050+00 3000+00 2950+00 2900+00 2850+00 2800+00 2750+00

E 512 500

N. 880 000

Hayden

Canal

E 491 500

E 490 000

N. 881 500

E 527 500

E 520 000

Cultivated

LIMITS OF PROPOSED CHANNEL CLEARING line

bank

Top

Ditch

Waste

Flow

RECOMMENDED LOW FLOW CHANNEL

Excavated low flow channel

Tempe

Tempe Butte

Mill

Rocker

Road

Hunter

Drive

Sta. 3080+00

Sta. 3040+00

Sta. 3120+00

Sta. 3060+00

Sta. 3140+00

Sta. 3100+00

Sta. 3160+00

Sta. 3180+00

Sta. 3200+00

Sta. 3220+00

Sta. 3240+00

Sta. 3260+00

Sta. 3080+00

Sta. 3000+00

Sta. 2960+00

Sta. 2920+00

Sta. 2940+00

Sta. 2900+00

Sta. 2880+00

Sta. 2860+00

Sta. 2840+00

Sta. 2820+00

Sta. 2800+00

Sta. 2780+00

Sta. 2760+00

Sta. 2740+00

Sta. 2725+00

P.I. 24°

P.I. 25

P.I. 27

P.I. 26

P.I. 28

P.I. 22

Sta. 2898+00 ℄ Low Flow Channel

Sta. 2987+00 ℄ Low Flow Channel

℄ Curve Data
Δ = 21°12'00"
R = 5,000'
T = 935.72'
L = 1850.05'

℄ Curve Data
Δ = 18°43'00"
R = 5,000'
T = 690.10'
L = 1,371.54'

℄ Curve Data
Δ = 31°05'20"
R = 8,000'
T = 2,224.86'
L = 4,340.05'

℄ Curve Data
Δ = 19°03'00"
R = 10,000'
T = 1,677.91'
L = 3324.85'

℄ Curve Data
Δ = 20°03'00"
R = 15,000'
T = 2,651.65'
L = 5,249.08'

℄ Curve Data
Δ = 43°05'20"
R = 8,000'
T = 3,158.01'
L = 6,015.57'

B.C. Sta. 3247+78.83
E.C. Sta. 3260+50.83

B.C. Sta. 3264+58.65
E.C. Sta. 3277+80.18

B.C. Sta. 3292+04.60
E.C. Sta. 3305+48.65

B.C. Sta. 3307+55.91
E.C. Sta. 3321+79.47

B.C. Sta. 2985+37.89
E.C. Sta. 2987+00

B.C. Sta. 2829+08.05
E.C. Sta. 2798+86.46

SALT RIVER

INDIAN RESERVATION

Cultivated

Match Line for sheet No. 7 Sta. 3275+00

Match Line for Sheet No. 5

N 902 500

N 895 000

N 887 500

E 482 500

E 505 000

E 497 500

E 490 000

E 512 500

E 520 000

E 415 500

Canal

Fish Hatchery

Angle Point Sta. 2884+40.04

Cross Cut Power Plant

Southern Pacific

Jointhead Dam

Levee

Ramp Required

Ramp Required

Pacific Grand

Washington Ave

Van Buren U.S. Hwy 60-70 80 & 89

Blvd

Canal

De Amo St

TYPICAL SECTION
RECOMMENDED LOW FLOW CHANNEL

℄

200.0'

Varies

1:5

1:5

SCALE 50 0 50 100 FEET

N

TYPICAL LEVEE SECTION

18.0'

Existing low flow channel

Quarry-stone

Backfill

Compacted earth fill

12" min. stripping

1:5

SCALE 10 0 10 20 30 40 50 FEET

PLAN

SCALE 1000 0 1000 2000 3000 4000 FEET

REV. NO.	DATE	REVISION	REV.	CHK.	APP.
1	6-20-53	Revised depth of quarry stone and gravel blankets in section.			
2	12-13-57	Revised culture vicinity of Sky Harbor Airport	A.S.		

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO MC DOWELL DAM SITE, ARIZ.

GILA AND SALT RIVERS

GILLESPIE DAM TO GRANITE REEF DAM

PLAN AND PROFILE

SCALE: AS SHOWN

SHEET 6 OF 7

DATUM IS MEAN SEA LEVEL

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

SUBMITTED: Chief, Planning & Reports Branch

RECOMMENDED: H.J. Thompson, Asst. Engineering Division

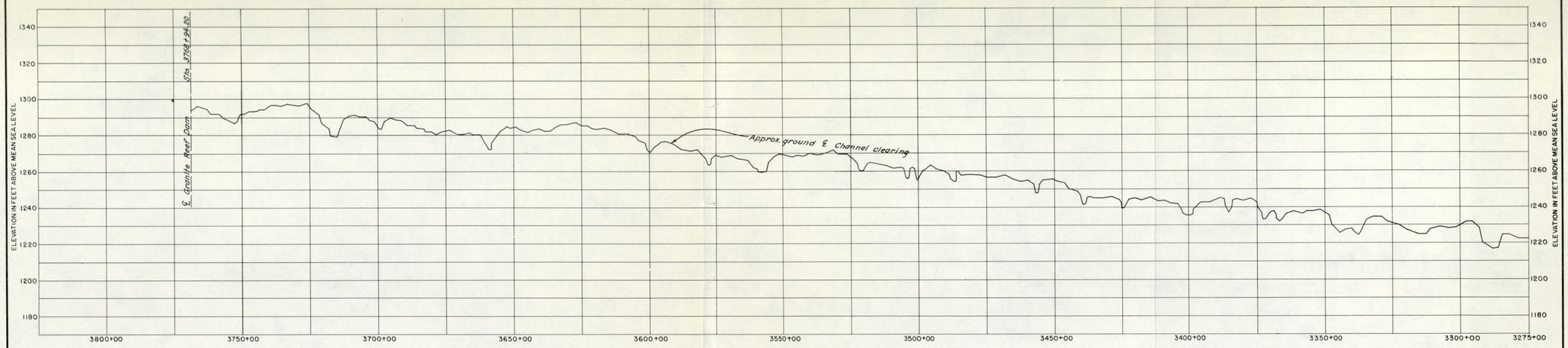
APPROVED: Colonel, C.E. District Engineer

DRAWN E.L.D. R.J.B. | TRACED E.L.D. | CHECKED R.J.B. A.C.B.

TO ACCOMPANY REPORT DATED: DECEMBER 4, 1957

FILE NO. (DO SERIES) 410/59 REV."A"

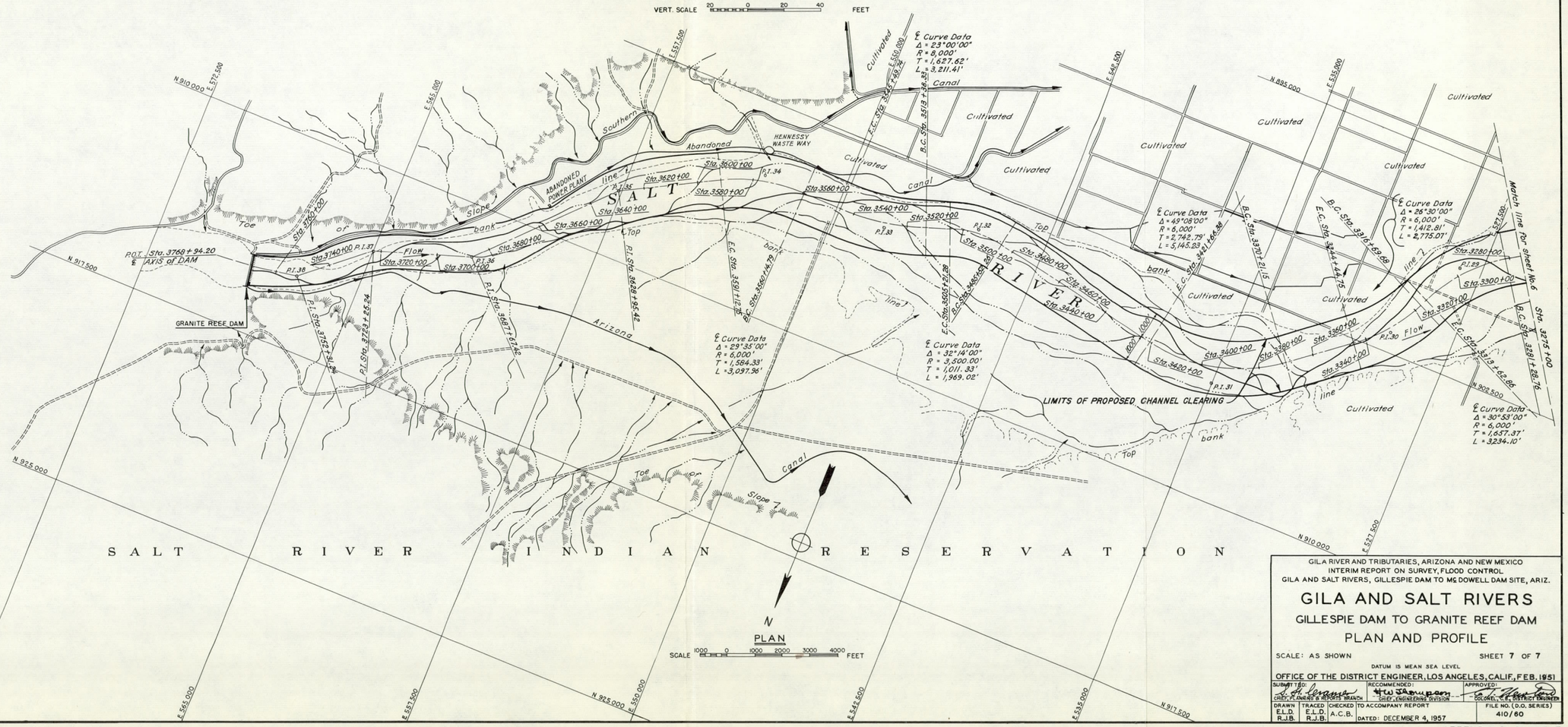
APPENDIX 3 PLATE 6



PROFILE

HOR. SCALE 1000 0 1000 2000 3000 4000 FEET

VERT. SCALE 20 0 20 40 FEET



GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

GILA AND SALT RIVERS
GILLESPIE DAM TO GRANITE REEF DAM
PLAN AND PROFILE

SCALE: AS SHOWN SHEET 7 OF 7

DATUM IS MEAN SEA LEVEL

OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., FEB. 1951

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

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (D.O. SERIES)
E.L.D. R.J.B.	E.L.D. R.J.B.	A.C.B.	DATED: DECEMBER 4, 1957	410/60

CORPS OF ENGINEERS

U.S. ARMY

NOTE:

TOPOGRAPHY FROM BUREAU OF RECLAMATION DWGS., FILE NOS. 88-4-281C, 282C, 283C, 284C, AND 292C.

DASHED LINES ARE FORM LINES FROM AERIAL PHOTOGRAPHY UTILIZING STEREOSCOPIC PLOTTING METHODS.

CENTRAL ZONE - ARIZONA, TRANSVERSE MERCATOR PROJECTION, 1927 NORTH AMERICAN DATUM.

CONTOUR INTERVAL 5 FEET.

DATUM IS MEAN SEA LEVEL.

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO Mc DOWELL DAM SITE, ARIZ.

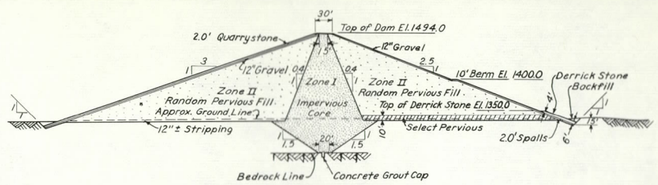
McDOWELL DAM
GENERAL PLAN

GRAPHIC SCALE 500 0 500 1000 FEET

OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., FEB. 1951

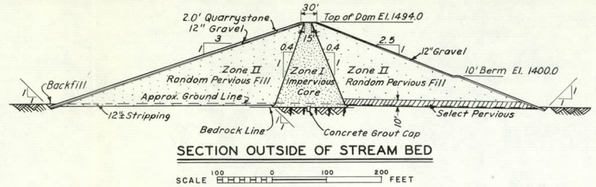
SUBMITTED:	RECOMMENDED:	APPROVED:
CHIEF, PLANNING & REPORTS BRANCH	CHIEF, ENGINEERING DIVISION	COLONEL, C.E., DISTRICT ENGINEER

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (DO SERIES)
H.T.L.	H.T.L.	A.C.B.	DATED: DECEMBER 4, 1957	410/69
	H.C.K.			



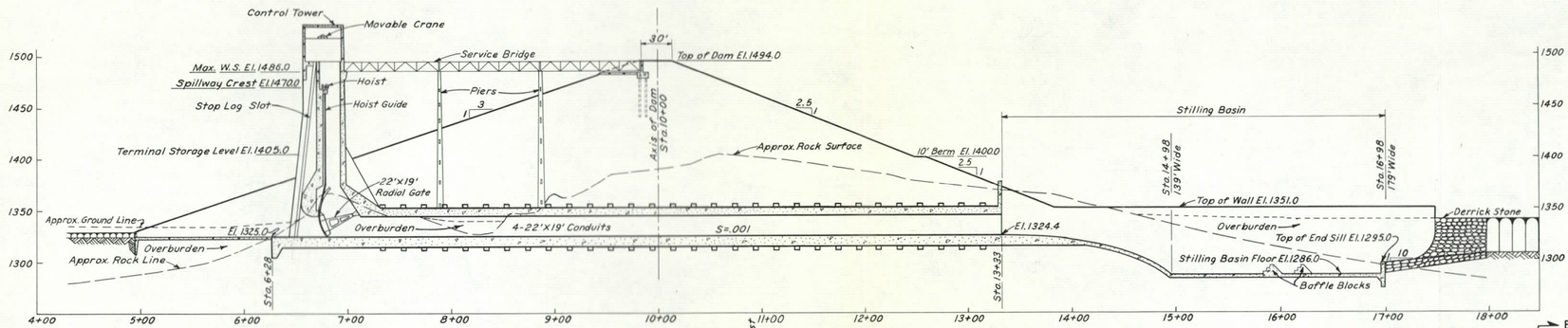
SECTION IN STREAM BED

SCALE 100 0 100 200 FEET



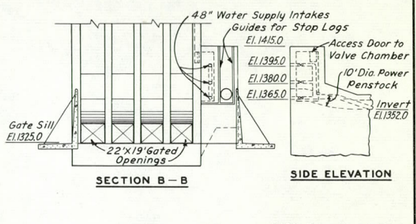
SECTION OUTSIDE OF STREAM BED

SCALE 100 0 100 200 FEET



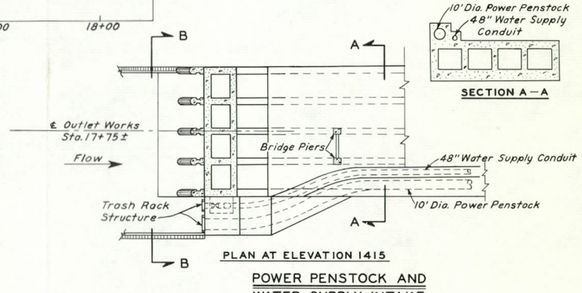
SECTION THRU OUTLET WORKS

SCALE: 50 0 50 100 FEET



SECTION B—B

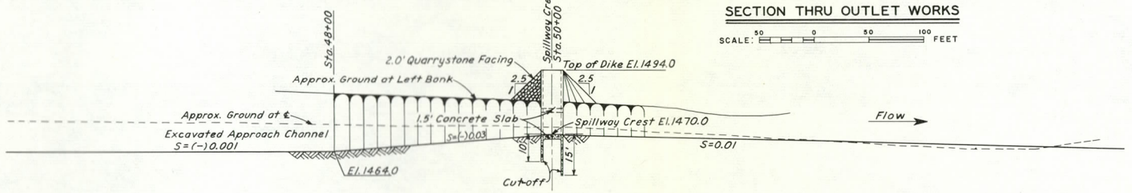
SIDE ELEVATION



PLAN AT ELEVATION 1415

POWER PENSTOCK AND WATER SUPPLY INTAKE

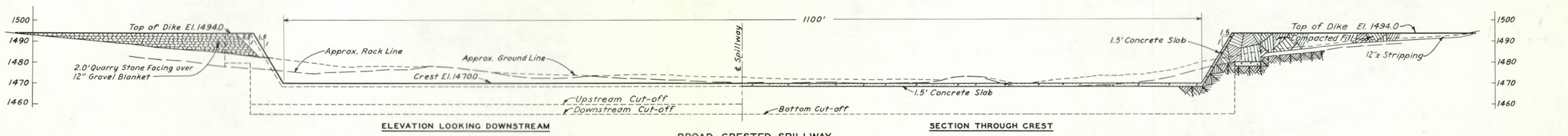
SCALE 50 0 50 100 FEET



PROFILE ALONG € SPILLWAY

HOR. SCALE 50 0 50 100 FEET

VERT. SCALE 10 0 10 20 30 40 50 FEET



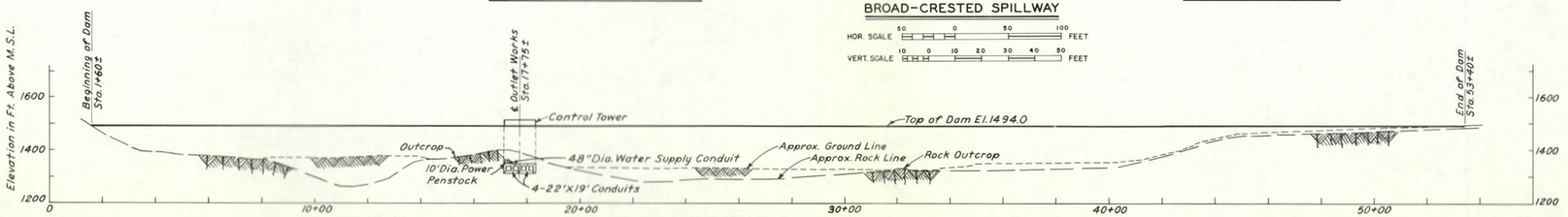
ELEVATION LOOKING DOWNSTREAM

SECTION THROUGH CREST

BROAD-CRESTED SPILLWAY

HOR. SCALE 50 0 50 100 FEET

VERT. SCALE 10 0 10 20 30 40 50 FEET



PROFILE ON AXIS OF DAM

SCALE 100 0 100 200 300 400 500 FEET

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO Mc DOWELL DAM SITE, ARIZ.

McDOWELL DAM
PROFILES & SECTIONS

SCALE: AS SHOWN IN ONE SHEET

DATUM IS MEAN SEA LEVEL

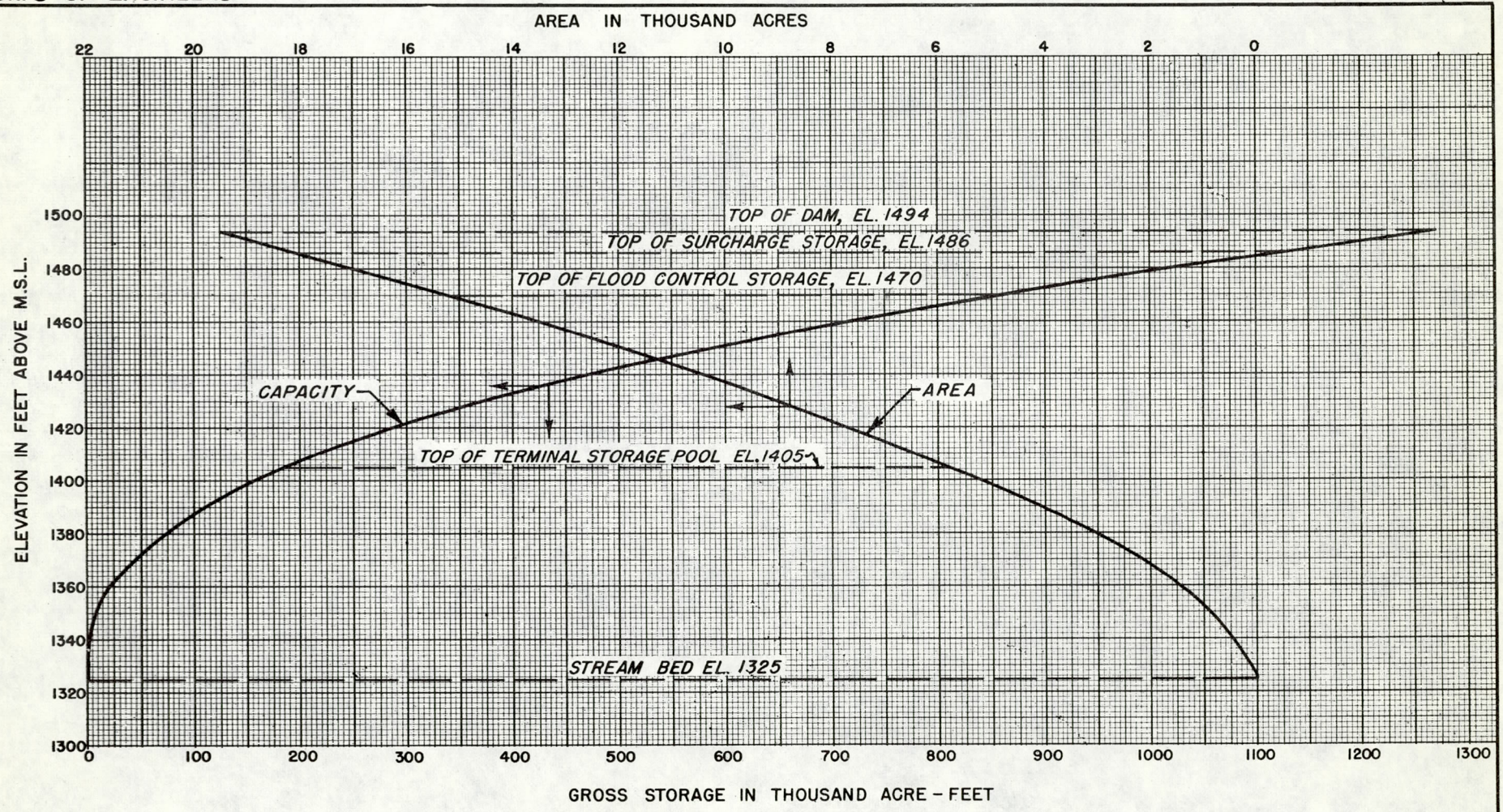
OFFICE OF THE DISTRICT ENGINEER, LOS ANGELES, CALIF., FEB. 1951

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

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (DO SERIES)
E.L.B.	F.A.K.	A.C.B.	DATED: DECEMBER 4, 1957	410/70

CORPS OF ENGINEERS

U. S. ARMY



GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

AREA AND CAPACITY CURVES

McDOWELL RESERVOIR

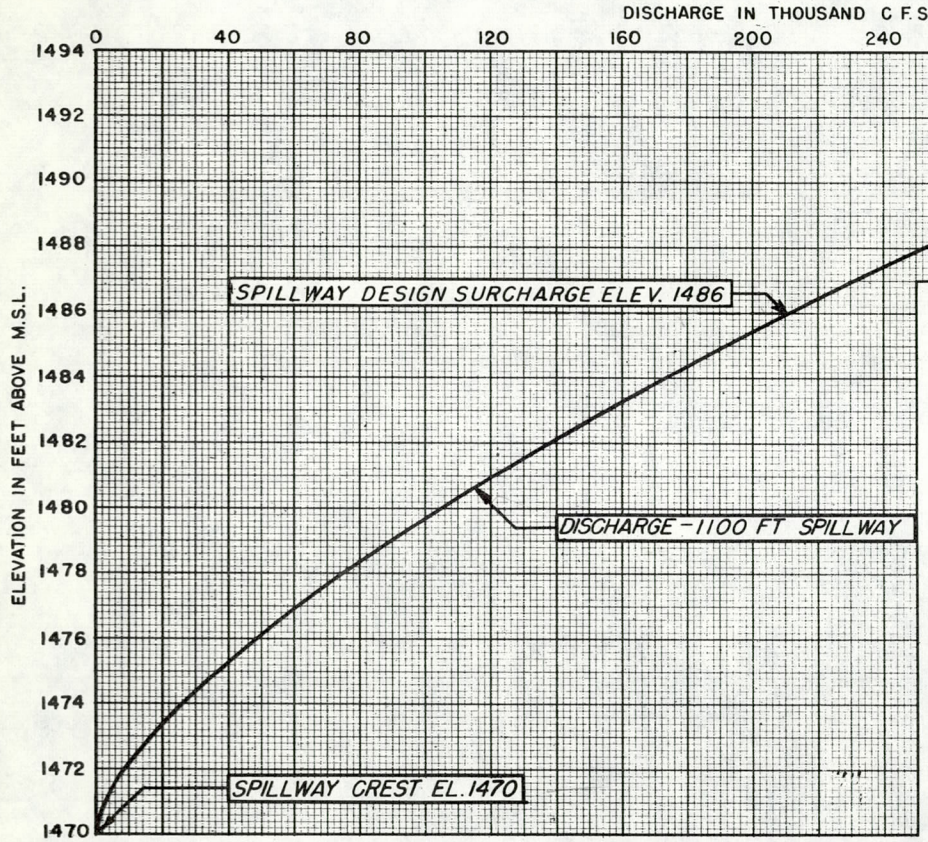
OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 4, 1957

FILE NO. 410/67

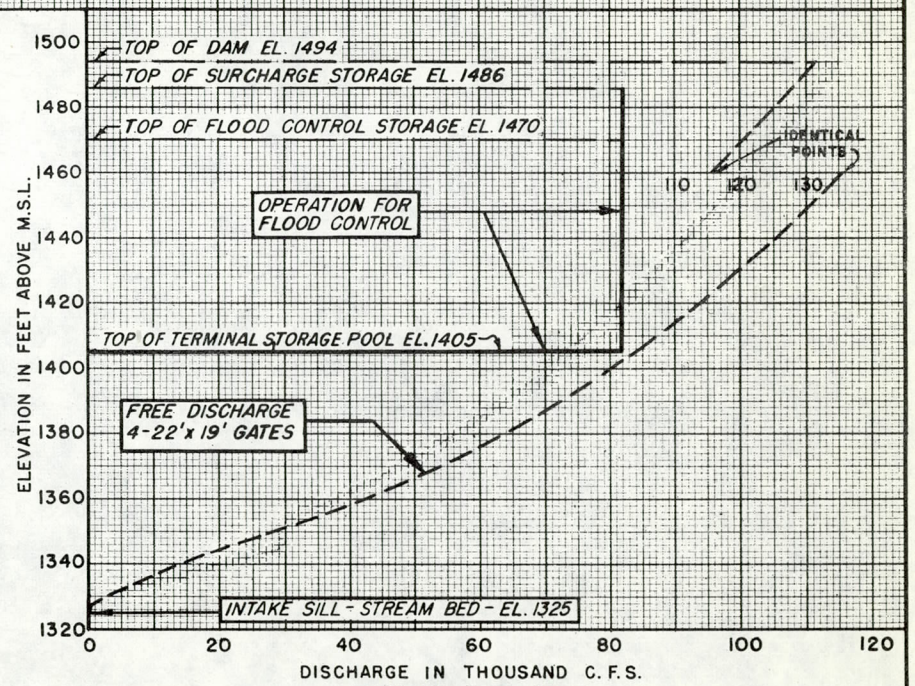
APPENDIX 3 PLATE 10

CORPS OF ENGINEERS

U. S. ARMY



SPILLWAY DISCHARGE



OUTLET DISCHARGE

RESERVOIR OPERATION PLAN

RESERVOIR WOULD BE ASSUMED FULL TO MAXIMUM TERMINAL STORAGE LEVEL ELEVATION 1405, AT START OF FLOOD. OUTFLOW WOULD EQUAL INFLOW UNTIL OUTFLOW EQUALLED 82,000 C.F.S. THEN THE GATES WOULD BE SET TO MAINTAIN 82,000 C.F.S. OUTFLOW. WHEN RESERVOIR WATER SURFACE REACHED ELEVATION 1470 THE OUTFLOW WOULD BE 82,000 C.F.S. THROUGH THE OUTLETS AND UNCONTROLLED OVER SPILLWAY.

GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

DISCHARGE CURVES

McDOWELL DAM

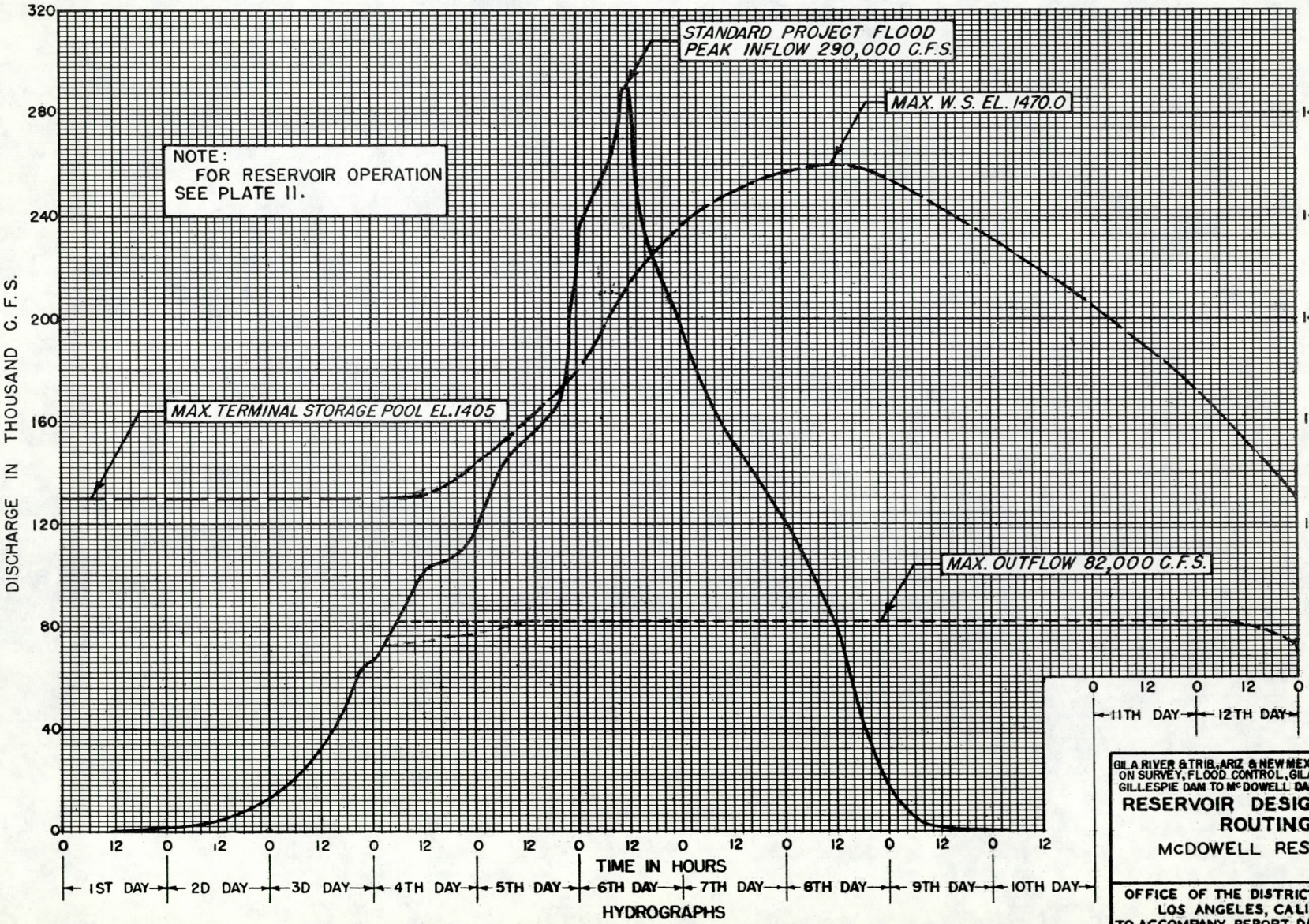
OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 1957

FILE NO. 410/65

APPENDIX 3 PLATE 11

CORPS OF ENGINEERS

U. S. ARMY



GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

RESERVOIR DESIGN FLOOD ROUTING

McDOWELL RESERVOIR

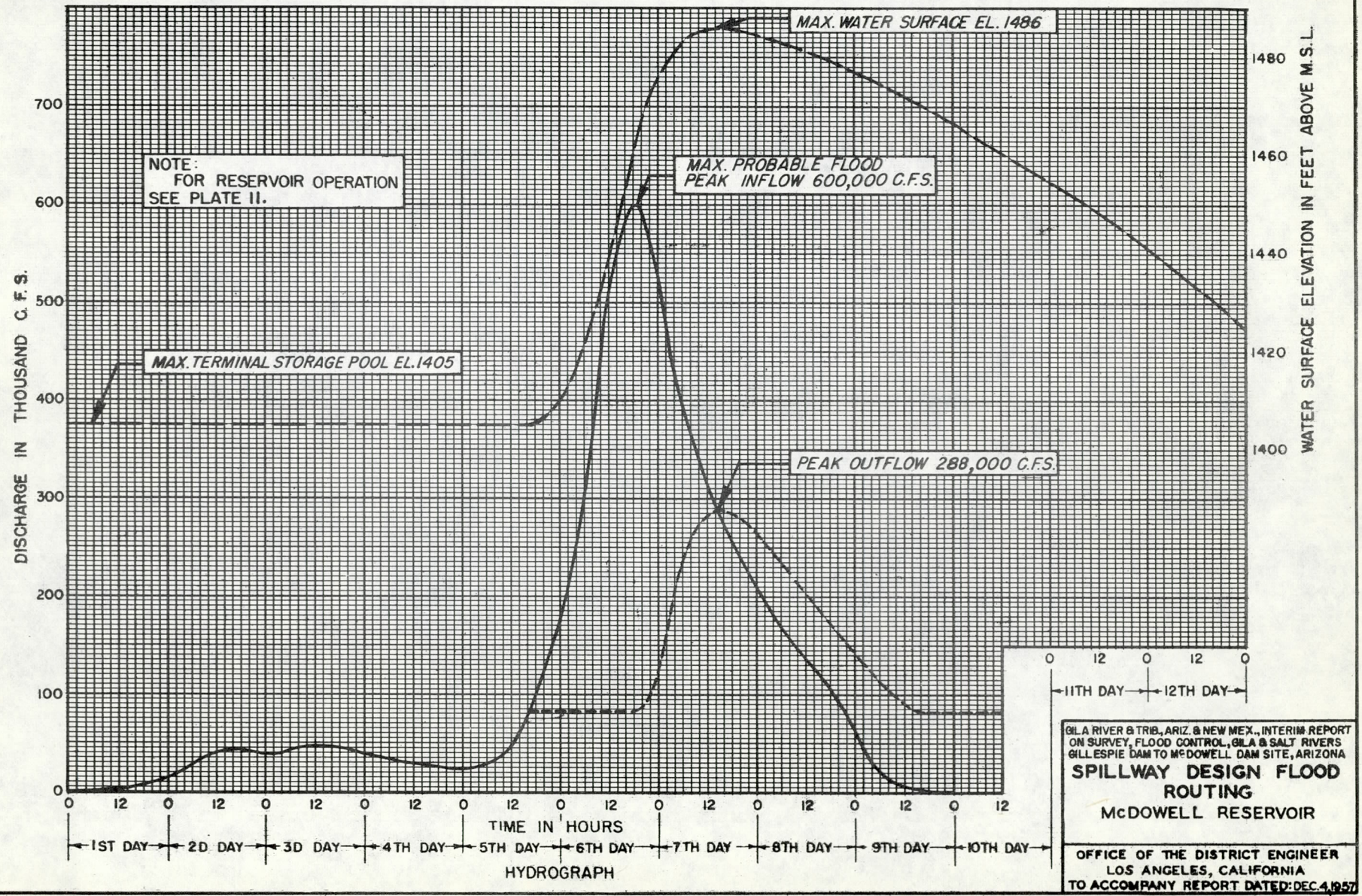
OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 4, 1957

FILE NO 410/66

APPENDIX 3 PLATE 12

CORPS OF ENGINEERS

U. S. ARMY



GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

SPILLWAY DESIGN FLOOD ROUTING

McDOWELL RESERVOIR

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 4, 1957

FILE NO. 410/68

APPENDIX 3 PLATE 13

UNITED STATES ARMY CORPS OF ENGINEERS

LOS ANGELES DISTRICT

COST ESTIMATES

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

To accompany interim report on survey for flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated December 4, 1957.

APPENDIX 4

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Applying analysis of past estimates by Corps of Engineers	4-1
Applying analysis of past estimates by other agencies	4-1
Other cost factors considered	4-1
Comparative studies for McDowell Reservoir	4-2
Construction periods	4-2
Maintenance and operation	4-2

TABLES

Title	
Short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe	4-4
Channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam	4-5
McDowell Reservoir, multiple-purpose	4-7

COST ESTIMATES

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

1. General.--Estimated construction and maintenance and operation costs of improvements considered in detail for Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, are based on prices prevailing in October 1957. The estimates of first cost reflect the cost of levees, channel improvements, and McDowell Dam and appurtenant works and the cost of rights-of-way and of road and utility relocations. Detailed cost estimates are given in this appendix for the levees and channel improvements under the recommended plan and for the McDowell multiple-purpose reservoir considered in detail by the United States Army Corps of Engineers. All estimates include allowances for contingencies, engineering and design, and supervision and administration. The total first costs for the considered projects comprise (a) costs for preauthorization studies, (b) construction costs, and (c) costs for lands and damages and relocations. Construction costs include all engineering and design and supervision and administration costs necessary for the completion of the project and accrued subsequent to the authorization.

2. Applying analysis of past estimates by Corps of Engineers.--Estimates of costs for levees and dams constructed by the United States Army Corps of Engineers, Los Angeles District, were analyzed; and weighted averages of bid prices for individual items of construction on earthfill dams and levees in the Los Angeles area were prepared. These weighted averages, which reflect bids from several bidders, were adjusted to prevailing prices in computing the cost of improvements in the Phoenix, Ariz., area.

3. Applying analysis of past estimates by other agencies.--Construction bids for many construction jobs by other agencies were analyzed from information obtained from engineering periodicals. Actual cost experiences along the Rio Grande by the Bureau of Reclamation and the International Boundary and Water Commission were analyzed and considered in determining the cost estimates given in this appendix.

4. Other cost factors considered.--Field conditions, geographical location of the project, and cost and availability of local labor and materials were considered in determining the cost estimates. Available existing transportation facilities were considered important in determining cost estimates because existing access roads to the dam site are unsurfaced for several miles and nearest access to railhead is at Tempe and Mesa. Minimum costs for derrickstone and quarrystone facing at McDowell Dam were estimated because quarrying operations would be within a short-haul distance from the dam site. Quarrystone facing for levees would be obtained from Tempe Butte. A shrinkage factor of 20 percent was used to account for loss, compaction, and shrinkage of excavated materials used for embankments. Local aggregate would be used for blanketing of slopes, and local aggregates with addition of pozzuolanic cement would be used for the dam structures. The unit price used for determining the cost of excavating the low-flow channel along Gila River was based on casting and distributing waste on each side of the low-flow channel.

5. Comparative studies for McDowell Reservoir.--The Bureau of Reclamation has proposed in its report on the Central Arizona Project that 390,000 acre-feet of flood-control storage be added in addition to the 188,000 acre-feet required for terminal and dead storage at the McDowell Reservoir site. The total storage capacity considered by the Bureau would be 578,000 acre-feet. Review of the Bureau design indicated that changes would have to be made to pass the spillway design flood. A higher dam and an expensive spillway in the channel section of the dam would be required. Further investigation indicated that, by further increasing the height of the dam, use could be made of a saddle about 1 mile southeast of the left abutment. A detached spillway in this saddle area would result in a relatively inexpensive structure. Cost studies also showed that the cheapest type structure for a terminal reservoir (188,000-acre-foot capacity) would be an earth dam with a gated concrete spillway in the dam. The following table summarizes the Corps of Engineers' estimates of cost for the three sizes of reservoir considered at the McDowell site.

Estimates of cost of reservoirs of various sizes at the McDowell site (estimates prepared by Corps of Engineers based on October 1957 prices)

Capacity of reservoir	Height of dam	Description	Cost
Acre-feet	Feet		
188,000	123	Concrete spillway in earth dam. 6 - 50' x 22' gates	$24,600,000
578,000	131	Concrete spillway in earth dam. 9 - 31' x 50' gates. Auxiliary spillway (fuse plug) in left abutment	31,000,000
860,000	169	Earth dam with detached spillway, ungated	30,300,000

6. Construction periods.--The construction periods for the improvements considered are as follows: Short levees, less than 1 year; channel improvements, 2 years; and McDowell Reservoir, 3 years.

7. Maintenance and operation.--Average annual maintenance and operation charges for McDowell Reservoir are estimated at $41,000. In estimating the maintenance and operation charges, consideration was given to (a) total estimated construction cost of the dam and appurtenances; (b) construction cost of outlet gates, valves, and piping and mechanical and electrical equipment; and (3) fixed sum for operating labor and supplies.

8. Average annual maintenance charges for the recommended 2,000-foot-wide cleared floodway from Gillespie Dam to Granite Reef Dam are estimated at $48,000. For purposes of obtaining the cost estimate, the floodway areas now infested with dense growths of saltcedar were assumed to be cut twice annually and the remaining areas were assumed to be cut once a year. Until a more economical method for control of new growth either by chemical means or by reseeding with grass is proven, mechanical means appears to be the most desirable and definite method for controlling the prolific growth of the young seedlings.

9. Average annual maintenance and operation charges of the short levees were estimated at $5,000.

Short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe
(based on prices for October 1957)

Cost acct. No.	Description	Unit	Quantity	Unit price	Amount Subtotal	Amount Total
	FEDERAL COSTS					
11.	Levees:					
	Clearing and grubbing	Lump sum			$7,500	
	Stripping for levee	Cu. yd.	46,700	$0.30	14,000	
	Stripping for borrow	do.	68,200	.30	20,500	
	Excavation, toe	do.	304,500	.40	121,800	
	Excavation, borrow	do.	408,600	.40	163,400	
	Embankment, levee	do.	417,400	.20	83,500	
	Backfill, toe	do.	212,200	.15	31,800	
	Quarrystone facing	do.	56,100	6.00	336,600	
	Gravel blanket		23,600	2.75	64,900	
	Road ramps	Lump sum			22,000	
	Contingencies				174,000	
	Total, levees					$1,040,000
29.	Preauthorization studies					10,000
30.	Engineering and design					59,000
31.	Supervision and administration					61,000
	Total project cost to United States.					1,170,000
	NON-FEDERAL COSTS					
	Lands and damages					70,000
	Total project cost to local interests.					70,000
	Total project cost					1,240,000

Channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam
(based on prices for October 1957)

Cost acct. No.	Description	Unit	Quantity	Unit price	Amount	
					Subtotal	Total
	FEDERAL COSTS					
09.	Channels:					
	Clearing 2,000-foot-wide floodway along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam:					
	Dense growth	Acre	4,323	$87.00	$376,100	
	Sparse growth	do	6,743	40.00	269,700	
	Very sparse growth	do	6,119	20.00	122,400	
	Contingencies				156,800	
	Total, clearing					$925,000
	Low-flow channel along Salt River near Tempe:					
	Excavation	Cu. yd	510,000	.35	178,500	
	Contingencies				36,500	
	Total, low-flow channel along Salt River.					215,000
	Low-flow channel along Gila River, Gillespie Dam to point near the Buckeye irrigation heading:					
	Excavation, common	Cu. yd	2,163,000	.30	648,900	
	Contingencies				131,100	
	Total, low-flow channel along Gila River.					780,000

Channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam
(based on prices for October 1957)--Continued

Cost acct. No.	Description	Unit	Quantity	Unit price	Amount	
					Subtotal	Total
29.	Preauthorization studies					$50,000
30.	Engineering and design					107,000
31.	Supervision and administration					113,000
	Total project cost to United States.					2,190,000
	NON-FEDERAL COSTS					
	Lands and damages					120,000
	Relocations:					
	Roads:					
	Culvert and road crossings					20,000
	Total project cost to local interests.					140,000
	Total project cost					2,330,000

McDowell Reservoir, multiple-purpose (based on prices for October 1957)

Cost acct. No.	Description	Unit	Quantity	Unit price	Amount	
					Subtotal	Total
01.	Lands and damages					$300,000
02.	Relocations:					
.1	Roads and utilities				$300,000	
.3	Water-supply replacement				2,640,000	
	Total, relocations					2,940,000
03.	Reservoir:					
	Clearing reservoir area	Acre	16,000	$20.00	320,000	
	Contingencies				60,000	
	Total, reservoir					380,000
04.	Dam:					
	General:					
	Diversion and care of water	Lump sum			100,000	
	Construction facilities	do			150,000	
	Contingencies				50,000	
	Subtotal, general				300,000	
.1	Main dam:					
	Clearing and grubbing	Acre	85	100.00	8,500	
	Stripping	Cu. yd	173,000	.40	69,200	
	Excavation, common	do	76,000	.40	30,400	
	Excavation, rock trench	do	9,400	6.00	56,400	
	Excavation, cutoff	do	557,000	1.00	557,000	
	Excavation, borrow	do	10,800,000	.50	5,400,000	
	Embankment, zone I	do	2,046,000	.16	327,400	
	Embankment, zone II	do	7,540,000	.11	829,400	
	Backfill, toe	do	37,000	.14	5,200	
	Concrete grout cap	do	10,300	20.00	206,000	
	Graded gravel blanket	do	142,000	2.75	390,500	

McDowell Reservoir, multiple-purpose (based on prices for October 1957)--Continued

Cost acct. No.	Description	Unit	Quantity	Unit price	Amount	
					Subtotal	Total
.1	Main dam--Continued:					
	Quarrystone facing	Cu. yd.	162,000	$3.50	$567,000	
	Derrickstone toe protection	do.	31,000	6.00	186,000	
	Spalls	do.	12,000	1.00	12,000	
	Drainage relief	Lump sum			50,000	
	Grouting foundation	do.			180,000	
	Contingencies				1,775,000	
	Subtotal, main dam				10,650,000	
.1	Spillway:					
	Clearing and grubbing	Acre	100	100.00	10,000	
	Excavation, channel	Cu. yd.	1,360,000	.38	516,800	
	Excavation, trench	do.	4,400	5.00	22,000	
	Concrete, slab and cutoff	do.	4,600	35.00	161,000	
	Reinforcement, steel	Lb.	460,000	.14	64,400	
	Filters and drains	Lump sum			5,000	
	Embankment for dike	Cu. yd.	4,700	.25	1,200	
	Gravel blanket	do.	850	3.00	2,550	
	Quarrystone facing	do.	850	3.50	3,000	
	Contingencies				161,050	
	Subtotal, spillway				947,000	
.3	Outlet structure:					
	Excavation, rock	Cu. yd.	328,000	3.00	984,000	
	Excavation, common	do.	105,000	.50	52,500	
	Backfill	do.	57,000	.75	42,750	
	Concrete, conduit	do.	62,500	45.00	2,812,500	
	Concrete, walls	do.	3,100	40.00	124,000	
	Concrete, slab	do.	6,900	20.00	138,000	
	Concrete, mass	do.	60,700	20.00	1,214,000	

McDowell Reservoir, multiple-purpose (based on prices for October 1957)--Continued

Cost acct. No.	Description	Unit	Quantity	Unit price	Amount	
					Subtotal	Total
.3	Outlet structure--Continued:					
	Reinforcement steel	Lb	12,730,000	$0.13	$1,654,900	
	Access bridge	Lump sum			100,000	
	Mechanical and electrical	do			90,000	
	Gates	Each	4	129,000.00	516,000	
	Stop logs	Lump sum			75,000	
	Miscellaneous steel	do			25,000	
	Filters and drains	do			85,000	
	Grouting	do			30,000	
	Tower and control house	do			1,212,000	
	Derrickstone protection	Cu. yd.	14,500	6.00	87,000	
	Contingencies				1,857,350	
	Subtotal, outlet structure				11,100,000	
.4	Power penstock and water-supply intake.				590,000	
	Total, dam					23,587,000
08.	Roads:					
	Construction and access roads				50,000	
	Contingencies				10,000	
	Total, roads					60,000
29.	Preauthorization studies					40,000
30.	Engineering and design					943,000
31.	Supervision and administration					2,050,000
	Total first cost of McDowell Reservoir.					30,300,000

UNITED STATES ARMY CORPS OF ENGINEERS

LOS ANGELES DISTRICT

BENEFITS FROM IMPROVEMENTS

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

To accompany interim report on survey for flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated December 4, 1957.

APPENDIX 5

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B E N E F I T S F R O M I M P R O V E M E N T S

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

SCOPE

1. The studies described in this appendix were made to evaluate the flood-control and incidental water-conservation benefits that would accrue from flood-control and multiple-purpose improvements considered in detail for protection of the areas along Gila River from Gillespie Dam to the mouth of Salt River and of the areas along Salt River from its mouth to the McDowell Dam site. Detailed field and office investigations were made to determine the extent, character, and value of the overflow areas. Estimates were made of (a) the frequency and magnitudes of future floods, (b) the damages from past floods, and (c) the probable damages from future floods. Because of the effect of a reservoir on Salt River on floodflows on Gila River above Painted Rock Reservoir (under construction), consideration was given also to the area along Gila River from Gillespie Dam to the upper end of Painted Rock Reservoir. Crop returns and associated farm costs were analyzed to determine the net water-conservation benefits.

HISTORY OF FLOODS

2. The principal sources of information concerning past floods on Gila River and tributaries are records of the United States Geological Survey, newspaper accounts, data from irrigation districts, and testimony of local residents. A history of destructive floods in the entire Gila River Basin for the period 1833-1947, inclusive, is tabulated in appendix 6 to the district engineer's report on survey, flood control, Gila River and tributaries below Gillespie Dam, Ariz., dated September 1, 1948. The tabulation shows available estimates of peak discharges of historical floods, as well as estimates of peak discharges that would have occurred if the existing reservoirs had been in operation since August 1, 1888.

3. Since submission of that survey report, discharge estimates of two floods have been revised. Water-Supply Paper 1049 (p. 401) indicates that--on the basis of weather records, statements of men conversant with conditions on Salt River in 1893, and records of flow on nearby streams--the estimate of historical maximum average daily discharge of Salt River below Verde River in 1893 should be revised to 37,000 cubic feet per second. Historical discharge estimates for Salt River above Verde River and for Verde River near McDowell should be adjusted accordingly. Discharges under average future conditions would have been negligible. Also revised were the peak discharges during the floods of January 20 and 29, 1916. Additional information indicates that the historical peak discharges during these floods for Salt River below Verde River were 120,000 and 105,000 cubic feet per second, respectively.

EXTENT AND CHARACTER OF OVERFLOW AREA

4. Location and extent.--The overflow areas that were considered in detail are as follows: (a) Along Salt River from McDowell Dam site to the mouth, (b) along Gila River from Salt River to Gillespie Dam, and (c) along Gila River from Gillespie Dam to Painted Rock Reservoir. These overflow areas, which are described in subsequent paragraphs, are shown on plate 1.

5. Overflow area along Salt River, McDowell Dam site to mouth.--Newspaper accounts of the flood of February 1891 (estimated peak discharge at McDowell Dam site of 300,000 cubic feet per second) and of subsequent floods were reviewed in order to delineate the overflow area of the standard project flood in the vicinity of Phoenix and Tempe, Ariz. Consideration was also given to changes in and relocations of the canal distribution system of the Salt River project since the flood of 1891. That area along Salt River that is subject to overflow by the standard project flood (290,000 cubic feet per second at McDowell Dam site) comprises 44,000 acres, consisting of 16,000 acres of cultivated land, 4,000 acres of residential and commercial areas, and 24,000 acres of land including river bottom and wasteland. All cultivated land is irrigated. Principal irrigated crops include alfalfa, barley, cotton, flax, sugar beets and truck crops such as lettuce, cantaloupe, watermelons, and carrots.

6. Parts of the cities of Phoenix and Tempe, parts of their suburbs, and parts of the community of South Phoenix are in the overflow area. The following list includes types of property subject to overflow and damage:

(a) About 7,500 residences.

(b) Business and industrial properties (about 650 in number) such as retail and service outlets, wholesale and manufacturing establishments, warehouses, and industrial plants including sand-and-gravel works.

(c) Public properties, such as schools, churches, parks, the Santa Monica Hospital, and the Sky Harbor Airport.

(d) Agricultural property, such as land, crops, farm equipment, and livestock.

(e) Irrigation works, such as canals, canal levees, laterals, wells, and pumps.

(f) Highways and roads and highway bridges at Tempe and at Central Avenue south of Phoenix.

(g) The main-line railroad bridge of the Southern Pacific Co. near Tempe.

(h) Utilities such as the Phoenix sewage disposal plant, the Tempe sewage disposal plant, and miscellaneous telephone, telegraph, power transmission, and natural gas lines crossing Salt River.

7. Overflow area along Gila River, mouth of Salt River to Gillespie Dam.--The area subject to overflow in this reach by the standard project flood comprises 41,000 acres including 15,000 acres of irrigated land, mostly along the right bank of the river. Most of the cultivated land is planted to field crops. The community of Liberty and many rural residences are subject to damage. The headings of the Buckeye and Arlington canals and the canals themselves are subject to overflow and damage. Other property subject to damage includes short sections of highways and roads, the Buckeye sewer farm, and some utility crossings of Gila River.

8. Overflow area along Gila River, Gillespie Dam to upper end of Painted Rock Reservoir.--About 17,000 acres, including 1,300 acres of irrigated land, are subject to inundation by the standard project flood. Damage in this area will occur mainly to agricultural property, irrigation works including Gillespie Dam, and highways and roads.

9. Valuation data by overflow areas.--The 1957 true value of property subject to damage along Salt River and along Gila River from the mouth of Salt River to the upper end of Painted Rock Reservoir is estimated at $129,000,000. A summary of information on the type and 1957 value of property in the overflow areas considered in detail is given in the following table:

Property subject to damage by the standard project flood in the overflow areas along Salt River from McDowell Dam site to the mouth and along Gila River from the mouth of Salt River to upper end of Painted Rock Reservoir site, Arizona

TRUE VALUE (1957)

Property	Overflow area		
	Salt River, McDowell Dam site to mouth	Gila River, mouth of Salt River to Gillespie Dam	Gila River, Gillespie Dam to upper end of Painted Rock Reservoir site
Residential	$46,930,000	$1,280,000	$5,000
Business and industrial	18,890,000	0	0
Public	22,200,000	0	8,000
Agricultural	14,580,000	13,470,000	670,000
Irrigation works	900,000	440,000	1,310,000
Highways and roads	2,000,000	290,000	500,000
Railroads	600,000	0	0
Utilities	4,940,000	80,000	0
Total	111,040,000	15,560,000	2,493,000
Grand total		129,093,000	
Say		129,000,000	

ACREAGE

	Acres	Acres	Acres
Cultivated	16,000	15,000	1,300
Urban	4,000	0	0
Other (stream channel and wasteland)	24,000	26,000	15,700
Total	44,000	41,000	17,000
Grand total		102,000	

DAMAGES FROM PAST FLOODS

10. Floods on Salt and Gila Rivers from McDowell Dam site to the upper end of Painted Rock Reservoir have caused severe damage to property and loss of some lives. Available data on damages from past floods are incomplete. Newspaper accounts supply incomplete flood-damage descriptions of those floods that have occurred since 1890. During this time, the entire area has increased in development, and man-made improvements have encroached upon the flood channel. In addition, in recent years the channel areas of Salt and Gila Rivers, especially Gila River, have been overgrown with phreatophytes. Monetary estimates are very limited and incomplete for all past floods. However, the type and severity of past flood damage give an indication of the widespread character of the overflow and of the type of damage that may occur in the future. No flood-damage surveys have been made by this office on floods in the area under consideration. The following is a summary of the flood damages as reported in newspaper accounts and as estimated by local interests.

(a) February 1891.--Damage of $70,000 to residential and business property was reported. All diversion structures and canal headings, with the exception of Arizona diversion dam, and many miles of canal were washed out. The railroad bridge and trestle at Tempe were destroyed; rail traffic was interrupted for 3 months. All telegraph communication from Phoenix to the East was interrupted for a period of 9 days. One hundred families out of a total population of 11,000 in Maricopa County lost their homes. Five lives were reported lost.

(b) March-April 1905.--Two spans of the Phoenix and Eastern Railroad bridge at Tempe were washed out; damage was estimated at $40,000. The Arizona diversion dam was breached.

(c) November 1905.--All three railroad bridges at Tempe were damaged. Three spans of the old Maricopa and Phoenix Railroad bridge were destroyed. This bridge was never repaired. The north approaches of both the new steel Maricopa and Phoenix bridge and the Phoenix and Eastern bridge at Tempe were washed away. Traffic was cut off for an entire week. Several farms were eroded by bank cutting. The Arizona diversion dam was completely destroyed; Arizona diversion dam was replaced in 1907 by Granite Reef Dam at a cost of $627,000.

(d) December 1908.--Fourteen canal breaks occurred, and irrigation was interrupted for 4 days.

(e) January 1915.--The north abutment of Joint Head Dam was washed out. The San Francisco Canal and headworks were severely damaged.

(f) January 1916.--Large areas of agricultural land were flooded. Canals and headworks were damaged. The south approach of the Central Avenue bridge south of Phoenix was washed away. The rock-and-gravel plants in the Salt River channel, the Phoenix

sewage disposal plant, and Riverside Park at the north end of Central Avenue bridge were severely damaged.

(g) February 1920.--The south abutments of both the Central Avenue bridge and the highway bridge at Tempe were damaged. Large damage occurred to residential and agricultural properties and irrigation works. Damage was estimated by local interests at $300,000.

(h) February 1937.--The natural gasline crossing at Tempe, which was buried 3 feet deep, was broken. Service was interrupted for about 24 hours. It was necessary to reroute the gasline over the Central Avenue bridge; the length of relocated line was about 8 miles.

(i) March 1938.--Nearly all land in Arlington Valley was inundated. Buckeye Canal was washed out in several places. Two county bridges over Gila River were washed out. About 20 acres of land along Salt River north of Mesa, Ariz., were eroded. One boy was drowned. Riverside Park, south of Phoenix, was inundated.

DAMAGE FROM FUTURE FLOODS

11. Procedure in evaluating primary flood damages.--All damages evaluated in this appendix are classified as primary damages, which have been divided into direct and indirect damages. Such secondary damages as may exist are considered to be small and have not been included in the evaluation of the project. Direct damage to property is physical damage resulting from overflow or erosion. Indirect damage is the result of direct damage and includes (a) costs of flood fighting, rescue work, and similar emergency measures; (b) business and similar losses from decreased production, profits and wages, and increased costs of normal operations and living; and (c) costs of rerouting traffic as a result of interruption of highway and railroad lines.

12. The record of damages from past floods is inadequate as a measure of damage from future floods because of (a) the incompleteness of the record of damages from past floods, (b) the growth of the valleys since the occurrence of large floods, and (c) the deterioration of the stream channel.

13. The overflow areas of floods of various magnitudes were delineated on maps and aerial mosaics to facilitate identification of properties subject to damage. Properties were inspected in the field and were classified according to type and use. Assessed valuations were obtained of properties in the overflow areas; true values were estimated after comparing assessed values with selling prices and after interviewing local residents. Crop and livestock reports were obtained from local agencies. Production costs of the important crops were analyzed to obtain the crop value subject to damage during any month in the year. The time of occurrence of

floods during the year, being a factor in amount of flood damage, was taken into account by estimating the percent probability of the floods occurring in any one month. Cross sections and values of highways and railroad bridges were obtained from the State Highway Department and the Southern Pacific Co., respectively.

14. Estimates of damages were made under 1957 conditions and under assumptions of average future conditions. Damages from future floods under average future conditions were computed on the basis of (a) estimated average future economic development of the overflow area and (b) average future channel conditions.

15. Flood frequencies and magnitudes.--The estimates of frequencies and magnitudes of future floods were obtained for two points: Salt River at McDowell Dam site and Gila River at Painted Rock Dam site. These estimates were based on records or estimates of peak discharges of past floods that occurred during the 69-year period 1889-1957, modified to provide for the effect of existing reservoirs in the Gila River Basin (see "History of Floods") and for the effect of proposed reservoirs at the Buttes and Charleston sites. Since the "History of Floods" was compiled in the report on survey, flood control, Gila River and tributaries below Gillespie Dam, Ariz., dated September 1, 1948, ten additional years of record have been made available. No flood occurred at the two points under consideration during the period 1948-57. The California modified method, as described in United States 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.

16. 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:

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

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.

17. Discharge-frequency relations are shown on plate 2. The calculations of plotting points to determine probable flood frequencies for Salt River at the McDowell Dam site and for Gila River at the Painted Rock Dam site, considering the 69-year period 1889-1957, are summarized in the following two tables:

Table 2

Estimated flood frequencies and magnitudes, Salt River at McDowell Dam site

Date	Peak discharge that would have occurred under existing conditions*	n	f** (Plotting point)
	Cubic feet per second		
February 1891	250,000	1	0.72
January 1916	150,000	2	2.17
February 1920	130,000	3	3.62
March 1906	73,000	4	5.07
February 1890	70,000	5	6.52
March 1907	57,500	6	7.97
April 1903	55,000	7	9.42
April 1917	50,000	8	10.87
November 1919	50,000	9	12.32
December 1923	50,000	10	13.77
March 1941	46,000	11	15.22
February 1927	45,000	12	16.67
March 1889	40,000	13	18.12
January 1895	40,000	14	19.57
April 1905	40,000	15	21.01
March 1908	40,000	16	22.46
February 1937	40,000	17	23.91
February 1911	39,000	18	25.36
January 1922	27,000	19	26.81
March 1918	25,000	20	28.26
January 1910	15,000	21	29.71

* Control at all existing reservoirs.

** 69 years of record, 1889-1957, inclusive.

Table 3

Estimated flood frequencies and magnitudes, Gila River at Painted Rock Dam site

Date	Peak discharge that would have occurred under-- Existing conditions*	Existing conditions plus control at Buttes and Charleston Reservoirs	n	f** (Plotting point)
	Cubic feet per second	Cubic feet per second		
February 1891...	300,000	290,000	1	0.72
January 1916....	180,000	170,000	2	2.17
February 1920...	150,000	150,000	3	3.62
March 1906.....	100,000	100,000	4	5.07
November 1919...	90,000	90,000	5	6.52
March 1907.....	85,000	85,000	6	7.97
March 1905.....	100,000	75,000	7	9.42
February 1890...	75,000	75,000	8	10.87
April 1917.....	55,000	55,000	9	12.32
March 1889.....	50,000	50,000	10	13.77
November 1905...	80,000	45,000	11	15.22
February 1927...	40,000	40,000	12	16.67
March 1941.....	40,000	40,000	13	18.12
April 1903.....	35,000	35,000	14	19.57
December 1923...	35,000	35,000	15	21.01
January 1895....	30,000	30,000	16	22.46
March 1908.....	30,000	30,000	17	23.91
February 1911...	30,000	30,000	18	25.36
December 1914...	50,000	30,000	19	26.81

* Control at all existing reservoirs.
** 69 years of record, 1889-1957, inclusive.

18. Discharge-damage relationships.--The damage caused by floods on Gila and Salt Rivers depends upon three important factors: The reduction of flow that may be caused by existing reservoirs, the character of the flood, and the condition of the stream channel at the time of the flood.

19. Existing upstream reservoirs in the Gila River Basin retain large parts of the flood discharges above the reservoirs, and the floods that would otherwise be expected on Salt and lower Gila Rivers are thereby reduced. Because of this factor, many floods of the past would have been reduced considerably with the present storage facilities. Many floods caused by similar flood-producing conditions, therefore, may be expected to be smaller in the future, even with no further flood-control construction. This factor is taken into account in the preceding tabulation of past floods, by routing all recorded flows above each existing dam into the reservoirs and by assuming releases from the reservoirs in accordance with present requirements of water use in order to determine how much water would have been in each reservoir at the time of each particular flood. In this manner, it is determined which floods would have been controlled by the existing reservoirs and approximately how much flow reduction would have been effected. Dams proposed for the Buttes Dam site on Gila River and at Charleston Dam site on San Pedro River were assumed to be constructed. The effect provided by the reservoirs of each of these dams on floodflows in Gila River between the mouth of Salt River and the Painted Rock Dam site was considered.

20. In the past, floods of fairly uniform flow or of uniformly increasing and decreasing flow over a period of several days have eroded the streambed, and the resultant increase in channel capacity has caused large parts of the flow to be confined within the channel limits. Many flash floods of equal magnitude, however, arrive so suddenly that there is insufficient time for streambed erosion to take place and, therefore, large parts of the flows exceed the channel limits and cause considerable damage to lands, crops, and improvements by overflow and surface erosion.

21. The condition of the Gila and Salt River channels at the time of a flood also has considerable effect upon the amount of damage caused by the floods. On Salt River, large floods in general erode and enlarge the stream-channel area. Subsequent floods occurring within a short period are more easily confined within the enlarged channel and therefore cause only nominal damage. When, however, there are no large floods for a period of several years, the streambed is filled with sediment and overgrown with brush and small trees. At such times, because of the lack of a clear channel, small floods often cause as much damage as a much larger flood with clear-channel conditions.

22. Along Gila River from the mouth of Salt River to a point about 2 miles below Gillespie Dam, and at a few points on Salt River,

the stream channel in recent years has been overgrown with phreatophytes, especially saltcedar. These phreatophytes, which range from shrubs of less than a foot in height to trees of 30 feet in height and average about 12 feet, in some cases have completely filled the channel area with a dense brush. Even a small flood occurring under these conditions will overflow adjoining land and a large flood may cut an entirely new channel through the adjoining cultivated land.

23. Estimates of flood damage were based upon consideration of the magnitude of the floods, the sequence in which floods of different magnitudes occur, and the channel condition at the time of flood. Estimates were made under present channel conditions and estimated average future channel conditions. Discharge-damage relationships were established for floods of various magnitudes by delineating the overflow areas of each flood considered and estimating the flood damage to property within these areas.

24. The channel capacity of Salt River from McDowell Dam site to its mouth is about 50,000 cubic feet per second. Some river-bottom land, especially south of Phoenix, has been encroached upon and would be subject to damage by even smaller flows. A flood of 100,000 cubic feet per second would inundate about 600 acres of cultivated area. Overflow would be restricted to areas where the banks are low. A very small portion of the community of South Phoenix would be flooded. A flood of 150,000 cubic feet per second would inundate about 11,200 acres of cultivated land. A large part of the community of South Phoenix and the residential and commercial area on the north bank of Salt River adjacent to the city of Phoenix would be flooded. Damages would occur also to irrigation works, highways, railroads, and utilities. A flood of 290,000 cubic feet per second at McDowell Dam site, equivalent in size to a standard project flood, would inundate about 16,000 cultivated acres and 4,000 acres devoted to residential and commercial use. Most of the business district of the city of Tempe, parts of the city of Phoenix and the community of South Phoenix, and the urban and suburban areas adjacent to the cities would be flooded.

25. The channel capacity of Gila River from Salt River to Gillespie Dam is estimated at 20,000 cubic feet per second. A flood of 115,000 cubic feet per second (measured at Painted Rock Dam site) would inundate about 3,500 cultivated acres, mainly on the north bank of Gila River, in the Buckeye and Arlington Valleys. Damage would be mainly to land and crops; minor damage would occur to residential property, irrigation works, and highways and roads. A flood of 174,000 cubic feet per second would inundate about 9,000 acres. The Buckeye and Arlington Canal headings would be damaged, causing an interruption in the supply of irrigation water. A flood of 320,000 cubic feet per second would inundate about 15,000 acres of cultivated land. The community of Liberty would be flooded. Severe damage would occur to land, crops, irrigation works, and residential property; small damage would occur to highways and utilities.

26. The channel capacity of Gila River from Gillespie Dam to the upper end of Painted Rock Reservoir is estimated at 50,000 cubic feet per second. A flood of 97,000 cubic feet per second (measured at Painted Rock Dam site) would inundate about 400 cultivated acres. Damage would be mainly to agricultural property. A flood of 193,000 cubic feet per second would inundate about 800 cultivated acres. Large damage would occur to agricultural property, to Gillespie Dam, and to the highway bridge just below Gillespie Dam. Interruption of irrigation and transportation would occur. A flood of 320,000 cubic feet per second would inundate 1,300 cultivated acres and would cause severe damage to the same types of properties as damaged by a flood of 193,000 cubic feet per second.

27. Damage from single floods--1957 conditions.--A summary of estimates of the cultivated area subject to overflow and the 1957 property values in the overflow areas considered and a summary of estimates of primary (direct and indirect) damage that would result from future floods of various magnitudes in these areas are given in the following tables:

Table 4

Estimated overflow areas and damage from future floods of various magnitudes along Salt River from McDowell Dam site to mouth (1957 conditions)

ESTIMATED DAMAGE FROM FUTURE FLOODS

Property subject to damage		Damage from future floods of various magnitudes*					
		290,000 c.f.s.		150,000 c.f.s.		100,000 c.f.s.	
Type	Value (1957)	Direct	Indirect	Direct	Indirect	Direct	Indirect
Residential	$46,930,000	$3,140,000	$630,000	$650,000	$130,000	$43,000	$9,000
Business and industrial	18,890,000	1,990,000	690,000	580,000	210,000	70,000	14,000
Public	22,200,000	870,000	170,000	260,000	50,000	2,000	0
Agricultural	14,580,000	3,430,000	570,000	900,000	150,000	210,000	30,000
Irrigation works	900,000	190,000	440,000	90,000	110,000	5,000	1,000
Highways and roads	2,000,000	290,000	60,000	110,000	20,000	3,000	1,000
Railroads	600,000	90,000	90,000	35,000	35,000	2,000	0
Utilities	4,940,000	210,000	210,000	80,000	80,000	35,000	35,000
Total	111,040,000	10,210,000	2,860,000	2,705,000	785,000	370,000	90,000
Total direct and indirect damage		$13,070,000		$3,490,000		$460,000	

CULTIVATED AREA SUBJECT TO OVERFLOW

Acres	16,000	11,200	600

* Peak discharge at McDowell Dam site.

Table 5

Estimated overflow areas and damage from future floods of various magnitudes along Gila River from mouth of Salt River to Gillespie Dam (1957 conditions)

ESTIMATED DAMAGE FROM FUTURE FLOODS

Property subject to damage		Damage from future floods of various magnitudes*							
Type	Value (1957)	320,000 c.f.s.		174,000 c.f.s.		115,000 c.f.s.		44,000 c.f.s.	
		Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
Residential	$1,280,000	$280,000	$50,000	$80,000	$10,000	$30,000	$6,000	$1,000	0
Agricultural	13,470,000	3,190,000	680,000	1,380,000	280,000	670,000	150,000	190,000	$40,000
Irrigation works	440,000	70,000	150,000	10,000	90,000	1,000	0	0	0
Highways and roads	290,000	40,000	10,000	10,000	0	3,000	0	1,000	0
Utilities	80,000	10,000	0	0	0	0	0	0	0
Total	15,560,000	3,590,000	890,000	1,480,000	380,000	704,000	156,000	192,000	40,000
Total direct and indirect damage		$4,480,000		$1,860,000		$860,000		$232,000	

CULTIVATED AREA SUBJECT TO OVERFLOW

Acres	15,000	9,000	3,500	1,200

* Peak discharge at Painted Rock Dam site.

Table 6

Estimated overflow areas and damage from future floods of various magnitudes along Gila River from Gillespie Dam to upper end of Painted Rock Reservoir (1957 conditions)

ESTIMATED DAMAGE FROM FUTURE FLOODS

Property subject to damage		Damage from future floods of various magnitudes*					
		320,000 c.f.s.		193,000 c.f.s.		97,000 c.f.s.	
Type	Values (1957)	Direct	Indirect	Direct	Indirect	Direct	Indirect
Residential	$5,000	$3,000	$1,000	$2,000	0	$1,000	0
Public	8,000	5,000	1,000	4,000	$1,000	3,000	$1,000
Agricultural	670,000	140,000	50,000	80,000	30,000	30,000	10,000
Irrigation works	1,310,000	290,000	180,000	60,000	40,000	0	0
Highways and roads	500,000	340,000	90,000	200,000	60,000	1,000	0
Total	2,493,000	778,000	322,000	346,000	131,000	35,000	11,000
Total direct and indirect damage		$1,100,000		$477,000		$46,000	

CULTIVATED AREA SUBJECT TO OVERFLOW

Acres	1,300	800	400

* Peak discharge at Painted Rock Dam site.

28. Damage from single floods--average future conditions.--The populations of the city of Phoenix and Maricopa County have increased steadily since 1900. The following table summarizes the estimates of population for the period 1900-57:

Table 7

Population (1900-57), Maricopa County and Phoenix, Ariz.

Year	Population estimate*		
	Phoenix	Greater Phoenix	Maricopa County
1900	5,540	15,000	20,460
1910	11,130	35,000	34,490
1920	29,050	60,000	89,580
1930	48,120	93,000	150,970
1940	65,410	140,000	186,190
1950	106,818	216,000	331,770
1953	128,840	275,000	420,000
1955	155,000	310,000	490,000
1957 (September)	172,000	370,000	550,000

* Bases of population estimates are as follows:

City of Phoenix	
1900 - 1950	U. S. Census
1953	Special Census made in March 1953
1955 and 1957	Valley National Bank, Phoenix, Ariz.
Greater Phoenix	
1900 - 1950	Engineering Consultant Firm, Phoenix, Ariz.
1953 - 1957	Valley National Bank, Phoenix, Ariz.
Maricopa County	
1900 - 1950	U. S. Census
1953, 1955, and 1957	Valley National Bank, Phoenix, Ariz.

29. The populations and property values of the city of Phoenix, of the Greater Phoenix area, and of Maricopa County increased steadily from 1900 to 1950 and have continued to increase since that date. Between 1950 and 1957, the population of the city of Phoenix is estimated to have increased from 106,818 to 172,000. Although Phoenix and Tempe are dependent to some extent on the economy of the Salt River project, the growth of these cities is affected by many other factors. The Salt River project increased in acreage by only 17 percent from 1920 to 1950, but

at the same time the population of the city of Phoenix increased by about 270 percent. The Phoenix urban area and Maricopa County have experienced a similar increase in population. The many factors affecting the growth in and near Phoenix include the trend of migration from the East to the West, the tourist and climatic conditions, the location of industrial plants in the locality, and the growth of the entire State. A comparison based on detailed appraisals of population growth in the Phoenix urban area, valuation of property in the overflow area near Phoenix, and damage from single floods, was made for the years 1955 and 1957. This comparison indicated that population, values of property in the overflow area, and resultant damages, all increased about 10 percent during the period 1955 to 1957. Another comparison made for the years 1950 to 1955 showed similar results. It was therefore concluded that increases in values of property in the overflow area and in estimated future damages would be generally proportional to increases in population in the urban area. A study of future population growth in the city of Phoenix and in the Phoenix urban area was made in 1951 by a private engineering consulting firm. Actual growth since 1951 exceeded the estimates made by the engineering firm. On the basis of (a) past growth and forecasts, which appear to be conservative, of future growth made by the consulting firm, and (b) the conclusion that increases in values of property would be generally proportional to increases in population, the average future values of residential, business, industrial, public, and utility properties in the overflow area along Salt River during the 50-year period 1958-2007 is estimated at about 55 percent greater than the 1957 values. Curves showing actual population growth in the Phoenix urban area from 1900 to 1957 and forecasts of future growth during the next 50 years are shown on plate 3. In the overflow areas along Gila River below the mouth of Salt River, average future property development is estimated at the same as present development.

30. Channel conditions along Gila River over the next 50 years will vary from year to year, depending on many factors, including (a) the occurrence of wet or dry cycles and (b) the importation of water. The surface flow and a relatively high ground-water table that now sustains the growth of phreatophytes will probably continue to sustain the growth. The average channel conditions over the next 50 years were therefore considered identical to the present channel conditions. Along Salt River, the stream channel is relatively clear at present. In 1941, local interests had burned much of the growth existing at the time. Since that time, the water table has lowered and no flows, excepting relatively minor flows in short stretches of the river have occurred. On the occurrence of spills from Stewart Mountain or Bartlett Dam, phreatophytes will reoccur and will reduce the channel capacity to some extent. Estimates of damages along Salt River under average future conditions were made on the basis of average future development of the overflow area and on assumed average future conditions of the stream-channel area. Estimates of damage in the two overflow areas along Gila River are the same under

average future conditions as under present conditions. The following table summarizes the damages under average future conditions in the overflow area along Salt River. Curves showing the relation between peak discharges in cubic feet per second and total damage in dollars under average future conditions for the three overflow areas are shown on plate 4.

Table 8

Summary of estimated damage from future floods of various magnitudes along Salt River from McDowell Dam site to mouth (average future conditions)

Peak discharge*	Total direct and indirect flood damage
Cubic feet per second	
290,000	$19,400,000
150,000	5,600,000
100,000	1,000,000
50,000	0

* Discharge on Salt River at McDowell Dam site.

31. Average annual flood damage.--The discharge-damage curve for each overflow area considered (pl. 4) was combined with the corresponding discharge-frequency curve (pl. 2) to obtain the damage-frequency relationship. Damage-frequency curves for the various overflow areas under average future conditions are shown on plates 5 to 7, inclusive. The curves show the relation of total damage to the number of times in 100 years the damages would be equaled or exceeded. The areas under the damage-frequency curves represent the estimated total flood damages during a 100-year period; the total for each overflow area divided by 100 is the estimated average annual damage for that area. The estimated average annual damages from future floods in each overflow area under present and average future conditions of development are given in the following table. Average future channel conditions were assumed in each case.

Table 9

Estimated average annual flood damage in overflow areas, Gila and Salt Rivers, McDowell Dam site to upper end of Painted Rock Reservoir

Overflow area	Average annual damage	
	Present conditions of development	Average future conditions of development
Along Salt River, McDowell Dam site to mouth	$344,000	$460,000
Along Gila River, Salt River to Gillespie Dam	198,000	198,000
Along Gila River, Gillespie Dam to upper end of Painted Rock Reservoir	33,000	33,000
Total	575,000	691,000

BENEFITS FROM IMPROVEMENTS

32. Plans of improvement.--Detailed consideration was given to three plans of improvement on Gila and Salt Rivers from Gillespie Dam to McDowell Dam site, as follows:

(a) The recommended plan comprising short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe, and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam;

(b) A plan for short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam; and a multiple-purpose reservoir at the McDowell site for terminal storage and flood control; and

(c) A plan for levees between 27th Avenue, Phoenix, and Tempe Butte, Tempe, and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam.

33. Selection of optimum width of cleared channel.--Studies were made to determine the width of cleared channel that would give optimum flood-control benefits. Detailed investigations were made of the most heavily infested area along Gila River from Gillespie Dam to the mouth of Salt River. Agricultural development and the natural topography limit the maximum width to about 2,000 feet at numerous points along the Gila River (see pls. 1 to 4, appendix 3). A floodway of greater width would impinge on cultivated land and

might result in increased bank erosion and flood damage to these agricultural areas. In addition, Gillespie Dam and low hills along the river act as control sections and limit the effective width of the floodway to a maximum of 2,000 feet. Channel widths smaller than 2,000 feet were therefore considered in detail to determine the optimum width of clearing. Channel widths of 500, 1,000, 1,500, and 2,000 feet were considered and evaluated. Table 10 summarizes the cost, flood-control benefits, and the incremental benefit-cost ratios for clearing the various widths of channel. As indicated in the table, incremental flood-control benefits exceed the incremental costs for all incremental widths considered. Actual experience may show that additional clearing might be justified by the additional savings of water; however, such clearing, if determined to be desirable at a later date, could be accomplished by local interests at that time. Therefore, on the basis of this study, the 2,000-foot-wide cleared channel was determined as the most desirable at this time.

Table 10

Summary of study to determine width of cleared channel that would result in optimum flood-control benefits, Gila River from Gillespie Dam to mouth of Salt River

Width of clearing	First cost*	Maintenance and operation	Total annual charges*	Incremental cost	Flood damages prevented	Incremental benefits	Benefit-cost ratio**
Feet							
500	$165,000	$7,800	$13,600	$13,600	$63,000	$63,000	4.63
1,000	330,000	15,600	27,200	13,600	91,000	28,000	2.06
1,500	495,000	23,400	40,800	13,600	109,000	18,000	1.32
2,000	665,000	31,200	54,600	13,800	126,000	17,000	1.23

* Cost of channel clearing only. Does not include cost of low-flow or pilot channel. Because the cost of the pilot channel would be constant for all widths of clearing, incremental costs would not be affected.

** Ratio of incremental benefits to incremental costs.

34. Benefits from flood damage prevented.--Channel improvements along Gila River from Gillespie Dam to the mouth of Salt River and along Salt River from its mouth to Granite Reef Dam are a part of all plans considered in detail. This part of each plan would provide partial flood control to adjoining property by lowering the water-surface elevations of future floods and thereby reducing the extent of the flooded areas. The average water-surface elevation of the standard project flood along Gila River from Gillespie Dam to the mouth of Salt River would be reduced by about 3-1/2 feet. Reductions would vary, depending on location, from 1-1/2 feet to 5-1/2 feet.

35. The construction of short levees along Salt River, as a part of the recommended plan, would prevent the overflow of nearly all of Tempe, and provide partial protection to Phoenix and to the commercial and agricultural area adjacent to Phoenix from floods on Salt River. Damage to the Sky Harbor Airport, to the Grand Canal, and to the cooling system of the Cross-Cut power plant would also be prevented.

36. McDowell multiple-purpose reservoir would reduce the inflow peak of the standard project flood from 290,000 cubic feet per second to a maximum outflow of 82,000 cubic feet per second. As a result, the overflow area along Salt River downstream from the dam site would be protected from all but minor damage caused by Salt River floods, and the overflow area along Gila River between the mouth of Salt River and the upper end of the Painted Rock Reservoir site would be protected from most damage.

37. Levees along Salt River between 27th Avenue, Phoenix, and Tempe Butte, Tempe, would protect the developed area of South Phoenix, the commercial area in the southern part of the city of Phoenix, the commercial and agricultural area between the Phoenix city limits and Salt River, and the agricultural area on both sides of Salt River between Tempe and Phoenix from floods along Salt River.

38. Damage-frequency curves were drawn indicating the damages that would not be prevented under the operation of the three plans of improvement. Damage-frequency curves representing average future conditions are shown on plates 5, 6, and 7. Table 11 summarizes the estimated average annual tangible primary benefits that would result from damage prevented under each of the plans considered under present (1957) conditions of development. Table 12 summarizes the same information for conditions that are expected during the next 50 years, 1958-2007. On each of the tables, the areas that would be affected are listed; and for each area the total average annual damage, the damage that would not be prevented, and the damage that would be prevented are given.

Table 11

Estimated average annual tangible benefits from flood damages prevented by improvements considered, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site
(present conditions of development)

Plan	Areas affected	Average annual damages		
		Total	Non-preventable	Prevented
Short levees and channel improvements.	Salt River, McDowell Dam site to mouth...	$344,000	$270,000	$74,000
	Gila River, Salt River to Gillespie Dam..	198,000	72,000	126,000
	Total.....	542,000	342,000	200,000
Short levees, channel improvements, and McDowell Reservoir.	Salt River, McDowell Dam site to mouth...	344,000	33,000	311,000
	Gila River, Salt River to Gillespie Dam..	198,000	41,000	157,000
	Gila River, Gillespie Dam to upper end of Painted Rock Reservoir site.	33,000	14,000	19,000
	Total.....	575,000	88,000	487,000
Levees between 27th Avenue, Phoenix, and Tempe Butte, and channel improvements.	Salt River, McDowell Dam site to mouth...	344,000	149,000	195,000
	Gila River, Salt River to Gillespie Dam..	198,000	72,000	126,000
	Total.....	542,000	221,000	321,000

Table 12

Estimated average annual tangible benefits from flood damages prevented by improvements considered, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site
(average future conditions of development)

Plan	Areas affected	Average annual damages		
		Total	Non-preventable	Prevented
Short levees and channel improvements.	Salt River, McDowell Dam site to mouth...	$460,000	$360,000	$100,000
	Gila River, Salt River to Gillespie Dam..	198,000	72,000	126,000
	Total.....	658,000	432,000	226,000
Short levees, channel improvements, and McDowell Reservoir.	Salt River, McDowell Dam site to mouth...	460,000	41,000	419,000
	Gila River, Salt River to Gillespie Dam..	198,000	41,000	157,000
	Gila River, Gillespie Dam to upper end of Painted Rock Reservoir site.	33,000	14,000	19,000
	Total.....	691,000	96,000	595,000
Levees between 27th Avenue, Phoenix, and Tempe Butte, and channel improvements.	Salt River, McDowell Dam site to mouth...	460,000	189,000	271,000
	Gila River, Salt River to Gillespie Dam..	198,000	72,000	126,000
	Total.....	658,000	261,000	397,000

39. Benefits from water conservation.--The clearing of phreatophytes from a 2,000-foot channel along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam would result in a savings of a minimum of 16,000 acre-feet annually. In accordance with the recommendations of the Federal Inter-Agency River Basin Committee's report titled "Proposed Practices for Economic analysis of River Basin Projects" and dated May 1950, the primary benefits from water conservation are evaluated in this report on the basis of the net increase in production of irrigated crops that would result from construction of the project. This increase in production would result from construction of the project and also from the application of associated resources. As considered in this report, the net primary benefit from water conservation was calculated to be the difference between the gross crop return to the farmer and the associated farm costs, which would include operating costs for production, interest on investment, maintenance and depreciation of equipment, property taxes, and management costs.

40. The quality of water has an important bearing on the type of crops grown in an area and in the yield to be obtained from these crops. Chemical analyses of water samples of the surface water in the Gila River upstream from Gillespie Dam are not adequate to develop an average figure for the water quality in the river. Numerous spot samples have been taken, but these samples are not correlated with the volume of flow. However, the United States Geological Survey took continuous samples of the flow of the Gila River below Gillespie Dam from December 1950 to September 1951 and the results of analyses of this water are given in Geological Survey Water-Supply Paper 1264. These samples indicate that 87 percent of the time the water carried over 5,000 parts per million of dissolved solids. Only during high flows following rains was the quality of water below 5,000 parts per million. It is therefore estimated that most surface or near surface water in the channel area between the mouth of Salt River and Gillespie Dam (the area where the major water savings will occur) will have a quality similar to that indicated at Gillespie Dam. In recent years, the flow at Gillespie Dam plus that diverted from the river by the Buckeye Irrigation District and the Arlington Ditch Company has averaged about 175,000 acre-feet annually. This represents the volume of water remaining after consumptive use by the phreatophytes in the river channel. This water is estimated to have a concentration of 5,000 parts per million under present conditions. The removal of phreatophytes would save 16,000 acre-feet annually and the addition of this water to the supply would reduce the average concentration of salts in the entire area to about 4,600 parts per million.

41. Not all crops are suitable for cultivation with water of this quality. Only the more salt-tolerant crops can be grown. Crops such as cotton, alfalfa, and small grains are tolerant to water with such a high salt content, but such crops do not reach their optimum yields. Based upon comparisons of yields experienced in the area under consideration and the yields obtained in the Salt River project, it is estimated that the crop yields in the area benefited by the conservation of water through the removal of phreatophytes will be equal to 75 percent of the crop yields experienced in the Salt River project.

42. Crop reports of the Salt River project for the years 1951 to 1956 were analyzed to determine the gross income per acre for representative crops (see table 13). The crop returns were then reduced by 25 percent to reflect the use of poor quality water. The years considered are indicative of the current value of crops. Because (a) cotton, alfalfa, grain sorghum, and other small grains comprise the bulk of the irrigated acreage, and (b) these crops are tolerant to water with a high salt content, these representative crops were analyzed in detail. Production costs of these crops for the same years were determined, based on information contained in bulletins prepared by the Arizona Experiment Station, University of Arizona. A summary of production costs for representative crops is given in table 14. On the basis of (a) the gross income per acre for representative crops, (b) the production costs for these crops, (c) the distribution of crops in the area, and (d) the duty of water, the value of water conserved by the elimination of phreatophytes is estimated at $8 per acre-foot (see table 15). The average annual primary benefits from the conservation of 16,000 acre-feet of water are estimated at $128,000.

Table 13

Gross income per acre for representative crops, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona

Crop	Gross income per acre*							
	1951	1952	1953	1954	1955	1956	Average	Adjusted average**
Cotton	$487.50	$421.00	$361.25	$453,50	$411.40	$463.30	$432.99	$324.74
Alfalfa and pasture	163.78	180.20	150.08	152.86	175.53	148.36	161.80	121.35
Grain sorghum	81.00	99.00	91.00	79.20	69.30	64.96	80.74	60.56
Other small grains***	83.75	108.00	119.20	102.00	118.80	118.95	108.45	81.34

* Based on crop reports of Salt River project.

** A reduction in yield of 25 percent was estimated because of high salt content of water. Values were rounded to nearest dollar.

*** Mostly barley. Pasture value added because of practice of pasturing livestock on barley lands after cutting.

Table 14

Production costs for representative crops, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site

Crop and item	Production costs per acre							
	1951	1952	1953	1954	1955	1956	Average	Say
Cotton								
Interest and taxes (land)*	$18.50	$18.50	$18.50	$18.50	$18.50	$18.50		
Water**	10.40	10.40	10.40	10.40	10.40	10.40		
Cultural costs***	75.00	89.00	72.00	77.00	78.00	83.00		
Harvesting costs#	95.63	96.75	98.03	95.78	97.13	97.13		
Interest on operating costs##	4.53	4.90	4.51	4.58	4.64	5.27		
Management	10.00	10.00	10.00	10.00	10.00	10.00		
Total	214.06	229.55	213.44	216.26	218.67	224.30	$219.38	$219.00
Alfalfa and pasture								
Interest and taxes (land)*	18.50	18.50	18.50	18.50	18.50	18.50		
Water**	13.00	13.00	13.00	13.00	13.00	13.00		
Cultural costs***	15.45	15.85	22.00	34.00	39.00	47.00		
Harvesting costs#	24.00	30.00	25.10	21.00	21.00	22.50		
Interest on operating costs##	1.31	1.47	1.50	1.70	1.82	2.06		
Management	10.00	10.00	10.00	10.00	10.00	10.00		
Total	82.26	88.82	90.10	98.20	103.32	113.06	95.96	96.00

See footnotes at end of table.

Production costs for representative crops, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site--Continued

Crop and item	Production costs per acre							
	1951	1952	1953	1954	1955	1956	Average	Say
Grain sorghum								
Interest and taxes (land)*	$18.50	$18.50	$18.50	$18.50	$18.50	$18.50		
Water**	7.80	7.80	7.80	7.80	7.80	7.80		
Cultural costs***	30.65	34.85	38.00	37.00	41.00	43.00		
Harvesting costs#	8.25	8.63	8.25	8.25	8.25	7.50		
Interest on operating costs##	1.17	1.28	1.35	1.33	1.43	1.46		
Management	7.50	7.50	7.50	7.50	7.50	7.50		
Total	73.87	78.56	81.40	80.38	84.48	85.76	$80.74	$81.00
Other small grains###								
Interest and taxes (land)*	18.50	18.50	18.50	18.50	18.50	18.50		
Water**	7.15	7.15	7.15	7.15	7.15	7.15		
Cultural costs***	31.85	35.00	28.00	34.00	32.00	34.00		
Harvesting costs#	6.25	8.25	7.50	7.50	7.50	7.50		
Interest on operating costs##	1.13	1.26	1.07	1.21	1.17	1.22		
Management	7.50	7.50	7.50	7.50	7.50	7.50		
Total	72.38	77.66	69.72	75.86	73.82	75.87	74.22	74.00

* Includes interest of 5 percent on estimated value of $300 for land. Taxes estimated at $3.50.

** Cost of pumping water based on estimated pump lift of 65 feet. Cost is estimated at $0.04 per acre-foot per foot of lift.

*** Based on bulletins of Agricultural Experiment Station, University of Arizona.

Harvesting costs taken at 75 percent of costs shown in bulletins of Agricultural Experiment Station. Factor applied to reflect reduction in yield assumed because of high salt content. Cotton yield assumed at 1.5 bales per acre.

Interest of 5 percent applied for 1/2 year on water, cultural, and harvesting costs.

Mostly barley.

Table 15

Value of water per acre-foot, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona

a. Value of water per acre-foot for representative crops.

Crop	Gross income per acre	Production cost per acre	Net income per acre	Water use acre-feet per acre	Value of water per acre-foot
Cotton	$325	$219	$106	4	$26.50
Alfalfa and pasture	121	96	25	5	5.00
Grain sorghum	61	81	*-20	3	-6.67
Other small grains**	81	74	7	2-3/4	2.55

b. Average value of water per acre-foot.

1	2	3	4	5	6	7
Crop	Percent of land cropped***	Water use acre-feet per acre	Column 2x3	Percent of total water used	Value of water per acre-foot	Average value of water per acre-foot column 5x6
Cotton	20	4.0	0.80	19.8	$26.50	$5.25
Alfalfa and pasture	45	5.0	2.25	55.5	5.00	2.78
Grain sorghum	15	3.0	0.45	11.1	-6.67	-0.74
Other small grains**	20	2.75	0.55	13.6	2.55	0.35
Total			4.05	100.0		7.64
Say						8.00

* This indicates a loss of $20 per acre in growing of grain sorghum. This means that return of land investment, interest on operating costs, and return for management will be reduced from an average of $24 per acre to an average of about $4 per acre. Ordinarily this is too low for profitable farming, but because of the practice of farming more than one crop and crop rotation, such small returns are offset by larger gains from other crops.

** Mostly barley.

*** Crop distribution based on analysis of crop distribution in Salt River project, in Buckeye Irrigation District, and in Arlington Irrigation District for the years 1948 to 1955.

43. Summary of average annual benefits.--The estimated average annual primary benefits that would accrue from construction of the plans considered are summarized in the following table:

Table 16

Estimated average annual benefits from plans considered, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona

Plan	Average annual tangible benefits		
	Flood damages prevented	Water conservation	Total
Short levees and channel improvements	$226,000	$128,000	$354,000
Short levees, channel improvements, and McDowell Reservoir	595,000	128,000	723,000
Levees between 27th Avenue, Phoenix, and Tempe Butte, and channel improvements	397,000	128,000	525,000

CORPS OF ENGINEERS

U. S. ARMY

Morristown

LAKE PLEASANT DAM

CAVE CREEK DAM

BARTLETT DAM

Hassayampa River

New River

Cave Creek

Agua Fria River

ATSF

ARIZONA

Glendale

PHOENIX

SALT RIVER INDIAN RESERVATION

FORT McDOWELL INDIAN RESERVATION

Verde River

STEWART MTN DAM

McDOWELL DAM SITE

NORMON FLAT DAM

GRANITE REEF DAM

SOUTHERN CANAL

SALT RIVER

JOINT HEAD DAM (ABANDONED)

Tempe

Mesa

Scottsdale

Buckeye

BUCKEYE DIVERSION DAM

ROOSEVELT IRRIGATION DISTRICT CANAL

BUCKEYE CANAL

ARLINGTON CANAL

GILA RIVER

Centennial Wash

Arlington

Waterman Wash

Chandler

GILLESPIE DAM

GILLESPIE CANAL

GILA CANAL

PAINTED ROCK DAM (UNDER CONSTRUCTION)

GILA BEND INDIAN RES

Gila Bend

GILA RIVER INDIAN RES

Santa Cruz River

MARICOPA COUNTY

PINAL COUNTY

CONSOLIDATED CANAL

EASTERN CANAL

AUXILIARY CANAL

SKY HARBOR AIRPORT

VAN BUREN

BROADWAY

WESTERN CANAL

112°40'

112°20'

112°00'

111°40'

33°40'

33°20'

33°00'

113°00'

VICINITY MAP

SCALE 40 0 40 80 120 160 200 MILES

AREA COVERED BY MAP

BOUNDARY OF GILA RIVER DRAINAGE AREA

LEGEND

AREA SUBJECT TO OVERFLOW BY STANDARD PROJECT FLOOD.

(160) RIVER MILE (ABOVE MOUTH).

EXISTING RESERVOIR.

AUTHORIZED RESERVOIR (UNDER CONSTRUCTION).

GILA RIVER AND TRIBUTARIES, ARIZONA AND NEW MEXICO
INTERIM REPORT ON SURVEY, FLOOD CONTROL
GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZ.

OVERFLOW AREA GILA AND SALT RIVERS

IN ONE SHEET

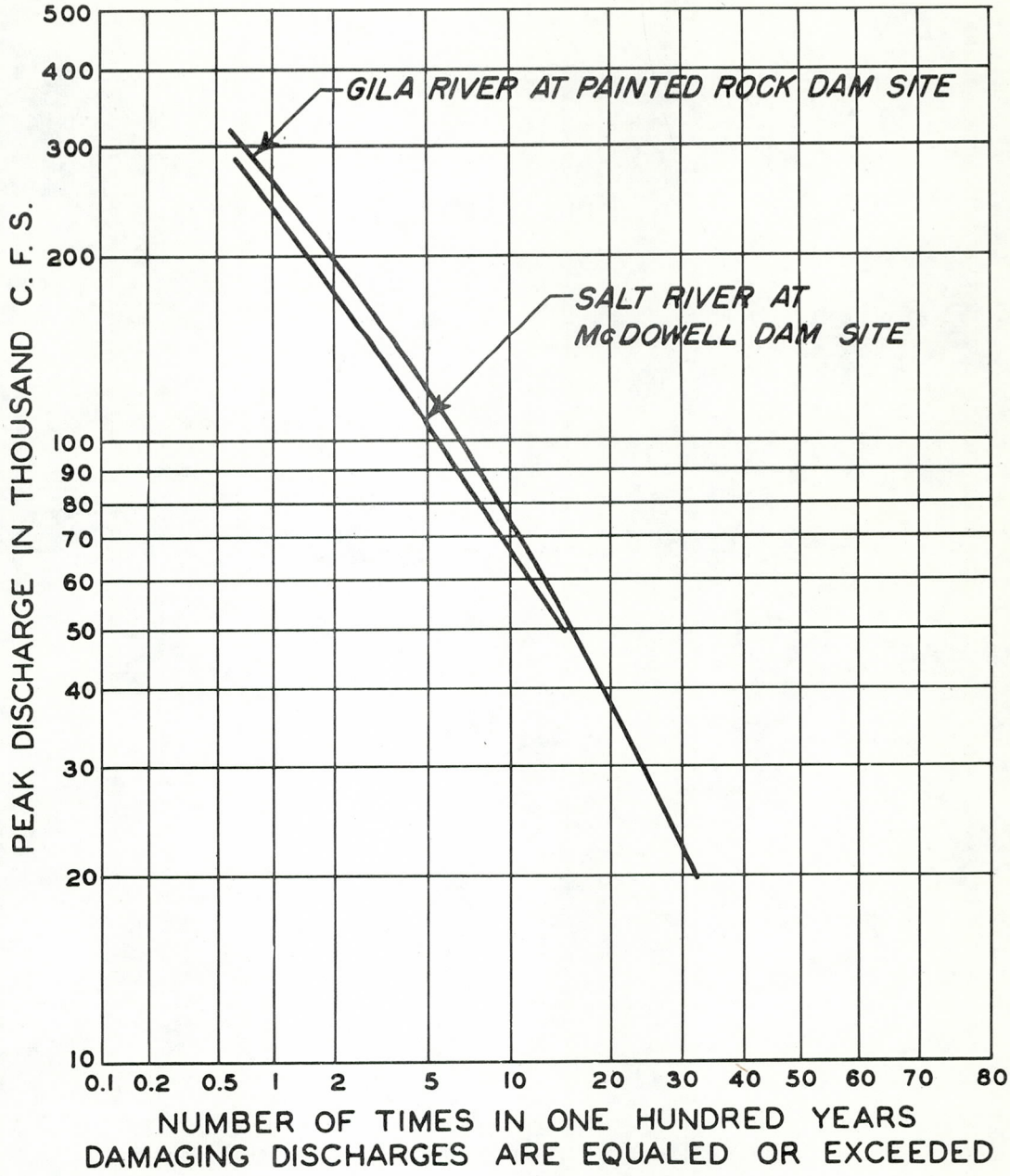
GRAPHIC SCALE 0 2 MILES

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

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

DRAWN	TRACED	CHECKED	TO ACCOMPANY REPORT	FILE NO. (DO SERIES)
C.G.M. E.L.D.	E.L.D. W.F.H.	S.L.	DATED: DECEMBER 4, 1957	410/71

APPENDIX 5 PLATE 1



GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

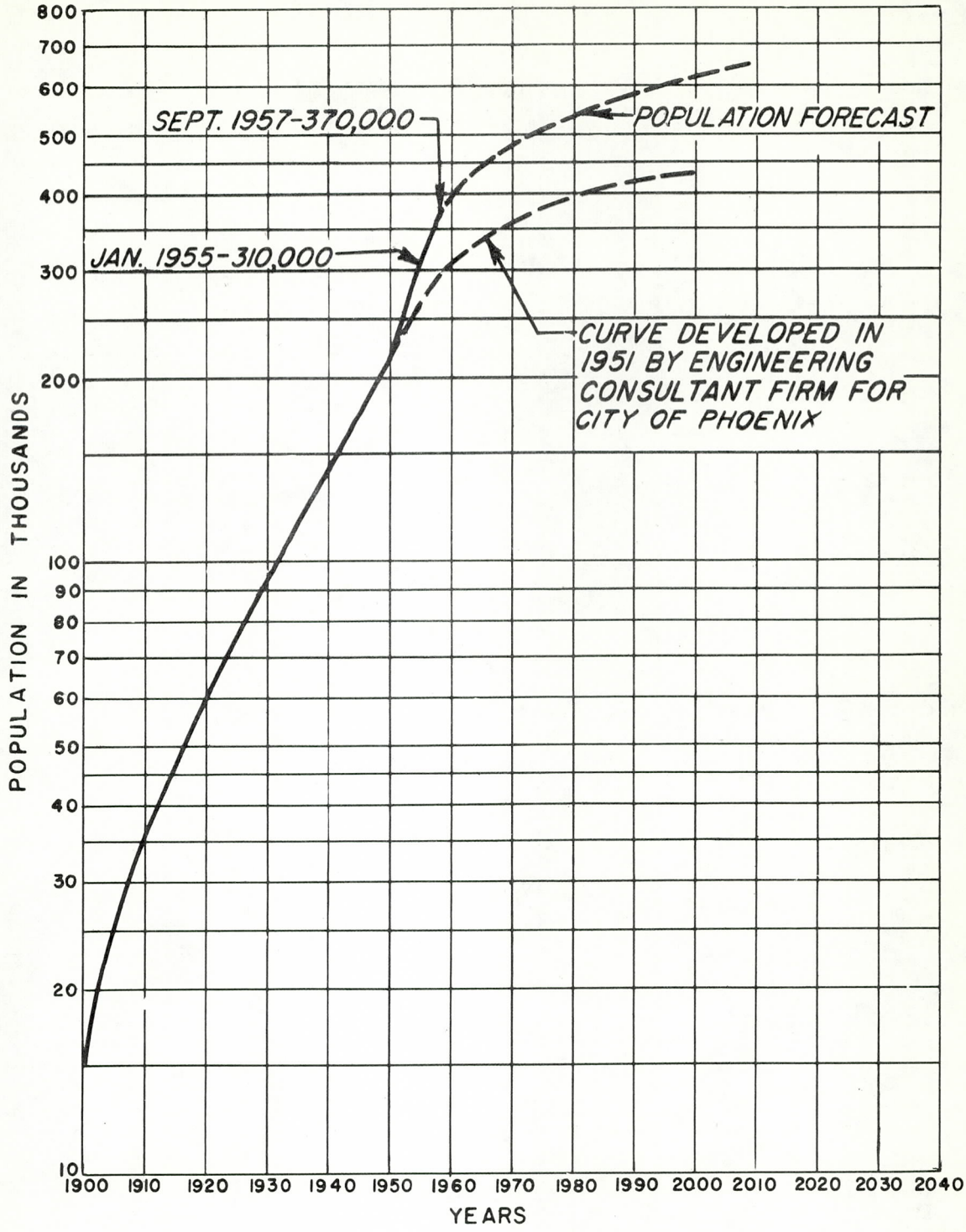
DISCHARGE-FREQUENCY CURVES

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 4, 1957

THIS DRAWING SUPERSEDES DWG. FILE NO. 410/73

FILE NO. 410/73.1 APPENDIX 5 PLATE 2

CORPS OF ENGINEERS U. S. ARMY



LEGEND

ACTUAL

ESTIMATED

GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

POPULATON CURVES

GREATER PHOENIX AREA

1900 TO 2007

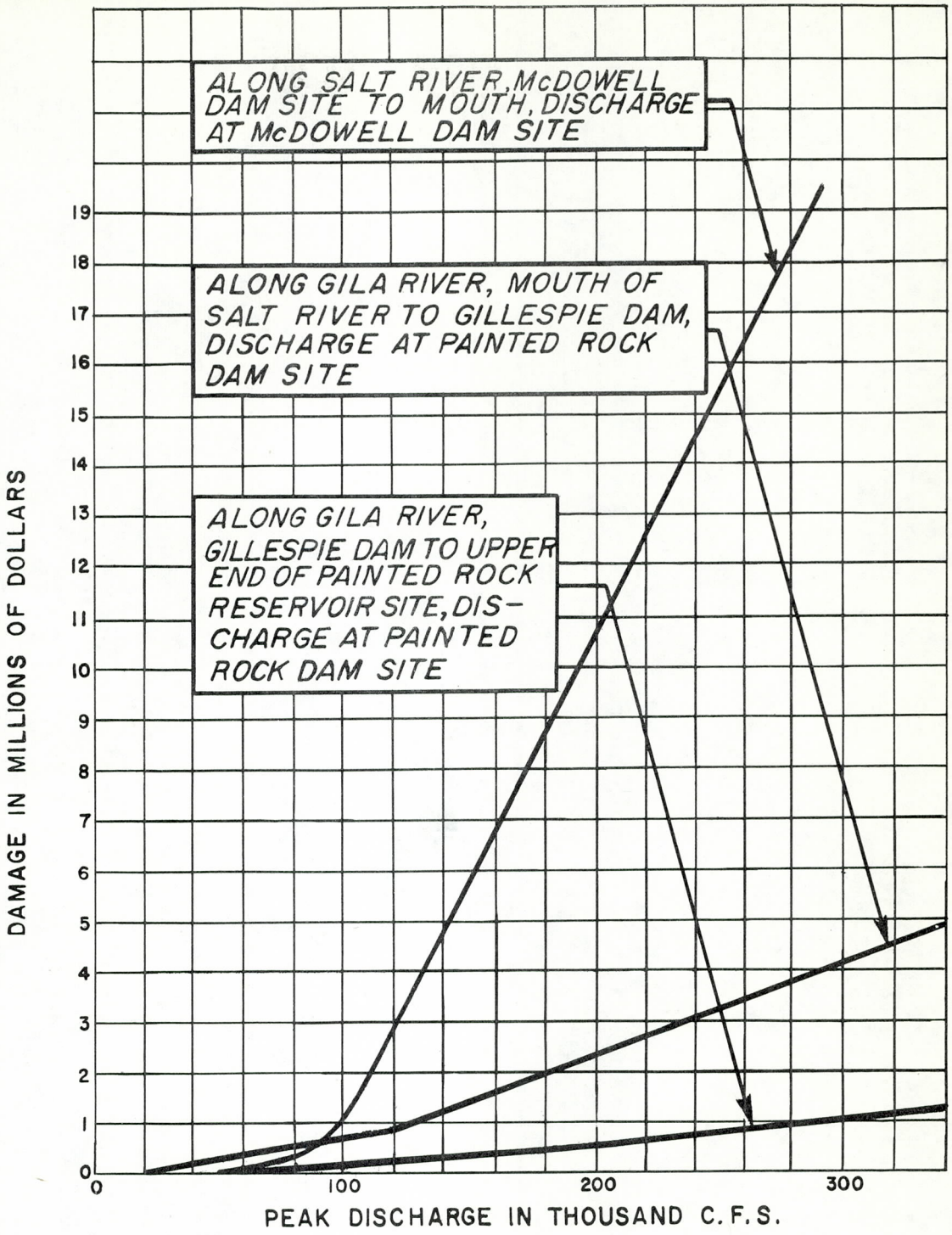
ACTUAL AND PROJECTED

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA

TO ACCOMPANY REPORT DATED: DEC. 4, 1957

FILE NO. 410/136 APPENDIX 5 PLATE 3

CORPS OF ENGINEERS U.S. ARMY



GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS, GILLESPIE DAM TO Mc DOWELL DAM SITE, ARIZONA

DISCHARGE – DAMAGE CURVES

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA

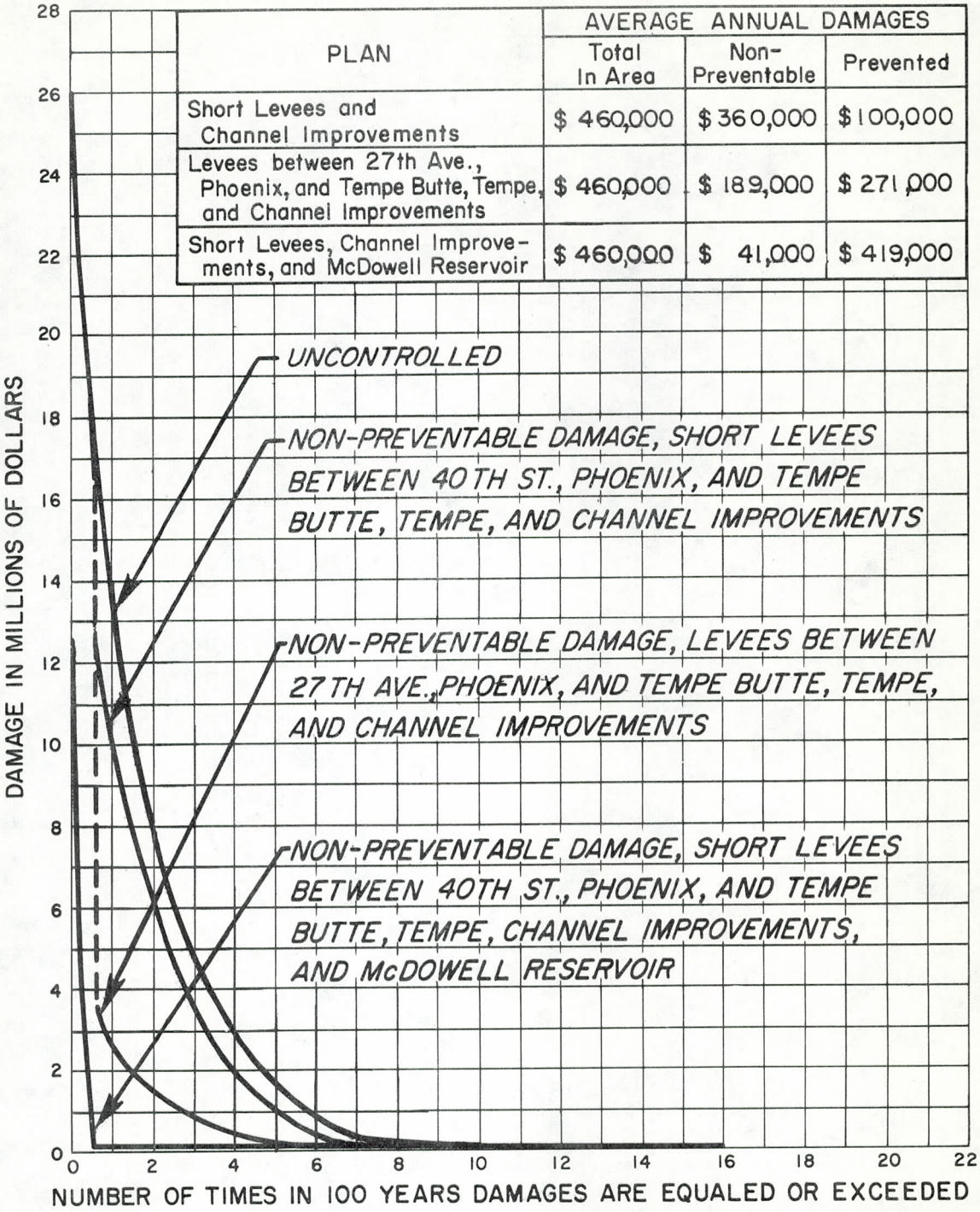
TO ACCOMPANY REPORT DATED: DEC. 4, 1957

THIS DRAWING SUPERSEDES DWG. FILE NO. 410/72

FILE NO. 410/72.1 APPENDIX 5 PLATE 4

CORPS OF ENGINEERS U. S. ARMY

PLAN	AVERAGE ANNUAL DAMAGES		
	Total In Area	Non-Preventable	Prevented
Short Levees and Channel Improvements	$ 460,000	$ 360,000	$ 100,000
Levees between 27th Ave., Phoenix, and Tempe Butte, Tempe, and Channel Improvements	$ 460,000	$ 189,000	$ 271,000
Short Levees, Channel Improvements, and McDowell Reservoir	$ 460,000	$ 41,000	$ 419,000



GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

DAMAGE – FREQUENCY CURVES

SALT RIVER

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA
TO ACCOMPANY REPORT DATED: DEC. 4 1957

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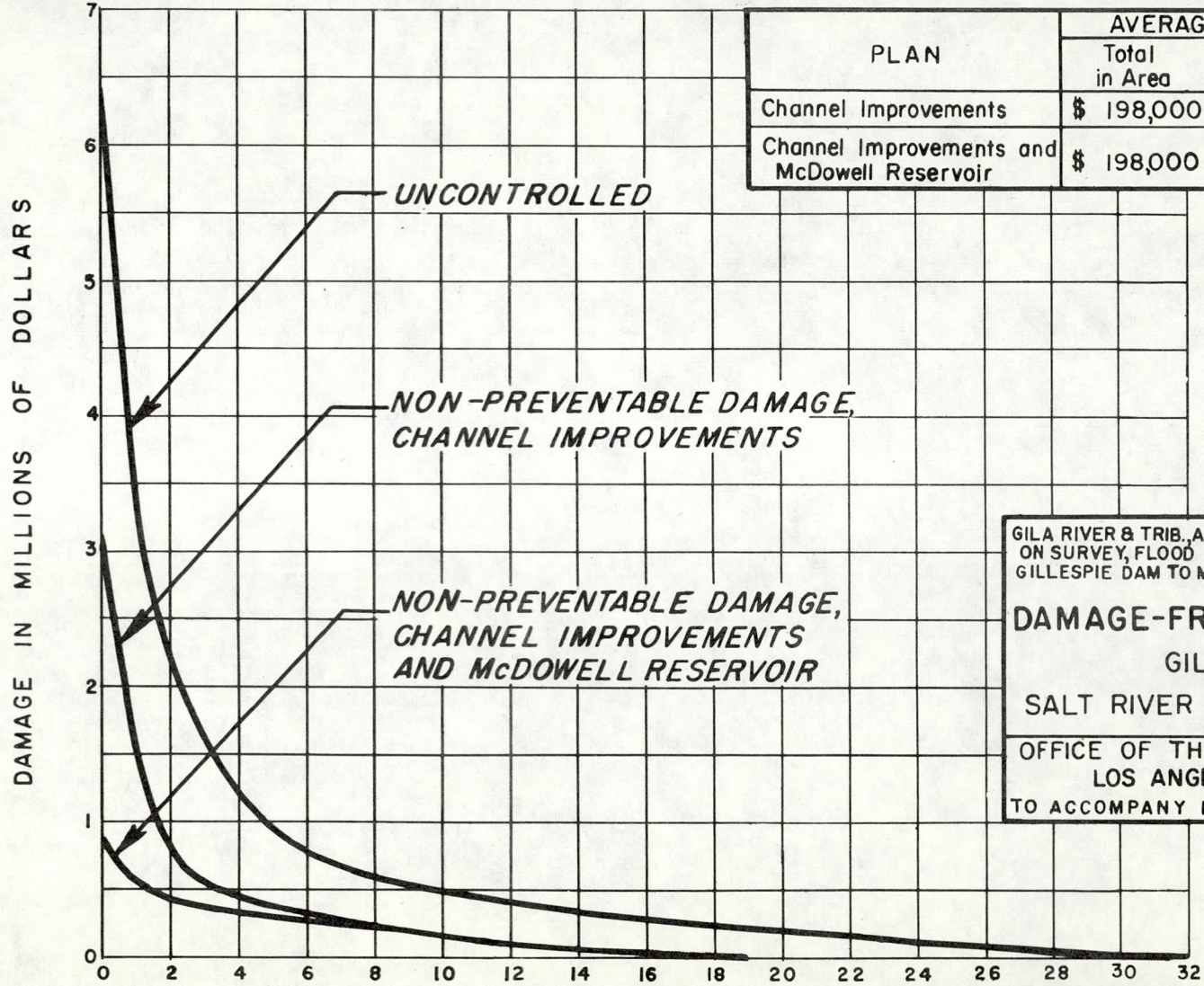
FILE NO. 410/74.1 APPENDIX 5 PLATE 5

CORPS OF ENGINEERS

U.S. ARMY

PLAN	AVERAGE ANNUAL DAMAGES		
	Total in Area	Non-Preventable	Prevented
Channel Improvements	$ 198,000	$ 72,000	$ 126,000
Channel Improvements and McDowell Reservoir	$ 198,000	$ 41,000	$ 157,000



GILA RIVER & TRIB., ARIZ & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

DAMAGE-FREQUENCY CURVES

GILA RIVER

SALT RIVER TO GILLESPIE DAM

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA

TO ACCOMPANY REPORT DATED: DEC. 4, 1957

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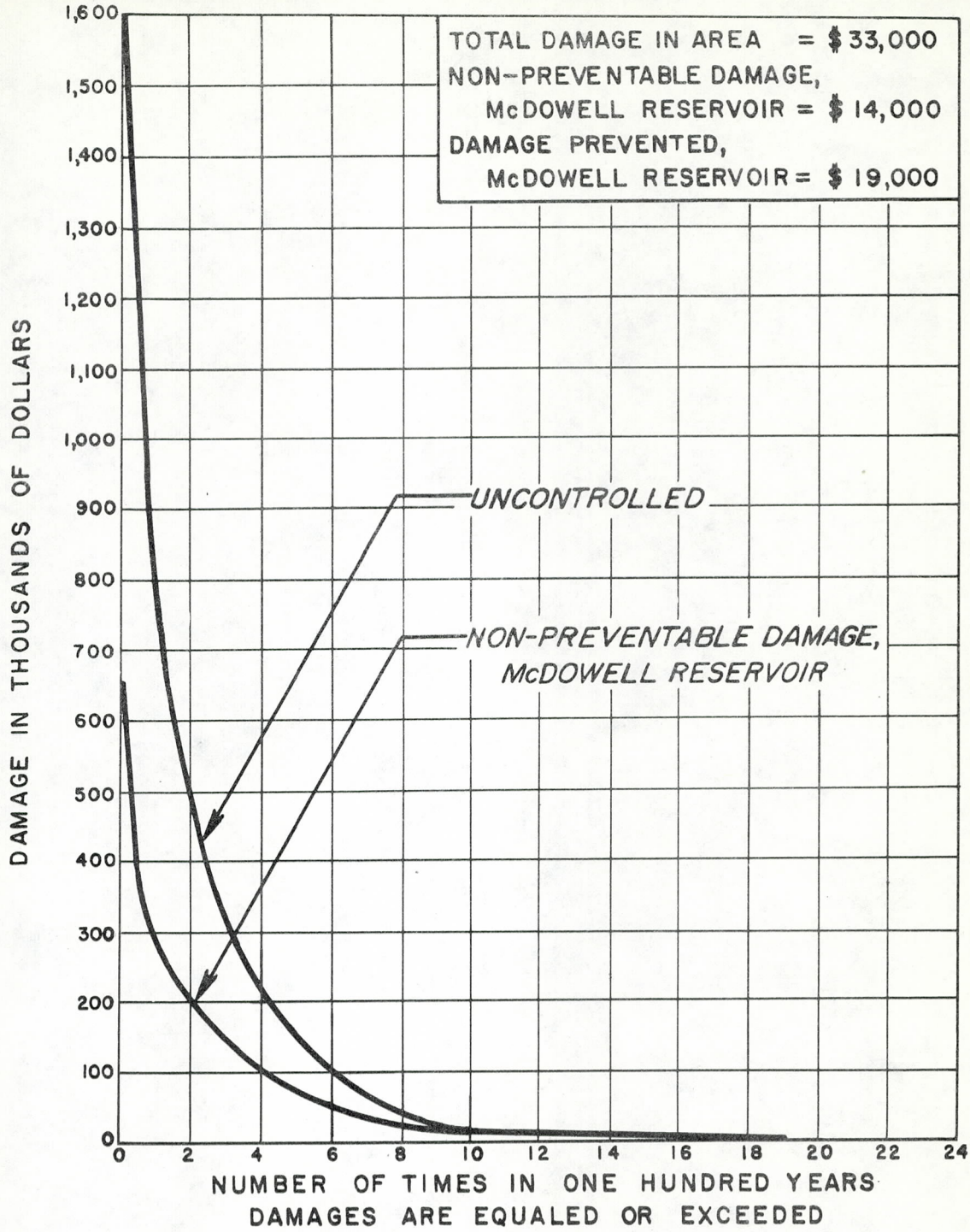
APPENDIX 5 PLATE 6

FILE NO. 410/75.1

CORPS OF ENGINEERS U. S. ARMY



GILA RIVER & TRIB., ARIZ. & NEW MEX., INTERIM REPORT ON SURVEY, FLOOD CONTROL, GILA & SALT RIVERS GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

DAMAGE-FREQUENCY CURVES

GILA RIVER

GILLESPIE DAM TO UPPER END OF PAINTED ROCK RESERVOIR SITE

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA

TO ACCOMPANY REPORT DATED: DEC. 4, 1957

THIS DRAWING SUPERSEDES DWG. FILE NO. 410/76

FILE NO. 410/76.1 APPENDIX 5 PLATE 7

UNITED STATES ARMY CORPS OF ENGINEERS

LOS ANGELES DISTRICT

USE OF WATER BY PHREATOPHYTES IN 2,000-FOOT CHANNEL BETWEEN GRANITE REEF AND GILLESPIE DAMS, MARICOPA COUNTY, ARIZONA

REPORT OF THE
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

To accompany interim report on survey for flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated December 4, 1957.

APPENDIX 6

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ILLUSTRATIONS

Figure 1. Section of proposed Gila River flood-control channel showing plant types and densities, March 1950.

2. Profile of land surface and ground-water levels along Salt River from about 3 miles north of Mesa downstream to junction with Gila River.

3. Graph showing fluctuation of ground-water level in Gila River channel, north of Mesa, Maricopa County, Ariz.

4. Graph showing fluctuation of ground-water level in Gila River channel, about 1 mile east of Tempe, Maricopa County, Ariz.

5. Graph showing fluctuation of ground-water level in Gila River channel, about 3 miles east of Phoenix, Maricopa County, Ariz.

6. Graph showing fluctuation of ground-water level in Gila River channel, about 6 miles west of Phoenix, Maricopa County, Ariz.

7. Graph showing fluctuation of ground-water level in Gila River channel, about 2 miles above junction of Salt and Gila Rivers, Maricopa County, Ariz.

8. Graph showing fluctuation of ground-water level in Gila River channel, south of Liberty, Maricopa County, Ariz.

9. Graph showing estimated future annual transpiration from ground water by phreatophytes in proposed flood-control channel between Granite Reef and Gillespie Dams, Maricopa County, Ariz.

USE OF WATER BY PHREATOPHYTES IN 2,000-FOOT CHANNEL BETWEEN GRANITE REEF AND GILLESPIE DAMS, MARICOPA COUNTY, ARIZONA

By
S. F. Turner and H. E. Skibitzke

ABSTRACT

The following is a summary of data obtained in a study of transpiration by phreatophytes in the channels of the Salt and Gila Rivers, between Granite Reef and Gillespie Dams, Maricopa County, Ariz. The study was made in the spring of 1950 by the Geological Survey, United States Department of the Interior, in cooperation with the Corps of Engineers of the United States Army. The kind and amount of phreatophyte growth was mapped in the area covered by a proposed flood-control channel, 2,000 feet wide, extending between the two dams. Most of the mapping was done from the air, using recent aerial photos. Transpiration by the phreatophytes was computed by using the results of the mapping combined with water-use factors developed by experimental work of the Geological Survey in Safford Valley, Ariz., during 1943 and 1944. Estimates of future phreatophyte use and of the amount of water that might be saved by clearing and maintaining the channel area were based on extensions of water-level graphs to include the next 50 years and on the experimental work at Safford. The estimates were as follows:

(1) Total estimated transpiration within the channel area, from ground water, at time of investigation - 29,000 acre-feet per year.

(2) Estimated average transpiration from ground water during period 1950-1999.

(a) Without Colorado River water - 22,000 acre-feet per year.

(b) With Colorado River water in 1960 - 30,000 acre-feet per year.

(3) Estimated average water saving effected by channel clearing, 1950-1999.

(a) Without Colorado River water - 16,000 acre-feet per year.

(b) With Colorado River water in 1960 - 22,000 acre-feet per year.

(4) Estimated amount of salvaged water available for irrigation in Maricopa County - same as (3).

INTRODUCTION

An investigation of the use of water by phreatophytes along the Salt River and Gila River channels between Granite Reef Dam and Gillespie Dam in Maricopa County, Ariz., has been made by the Geological Survey, United States Department of the Interior, in cooperation with the Corps of Engineers of the United States Army. The purpose of the investigation was to determine various effects that would result from clearing the phreatophytes (bottom-land vegetation) from a proposed 2,000-foot-wide flood-control channel between the two dams, a distance of approximately 70 miles. Field work and computations were carried on during February and March 1950, under the direction of S. F. Turner, district engineer (Ground Water) of the Geological Survey.

In a letter dated December 30, 1949, the Corps of Engineers requested answers to the following questions:

(1) Estimated total present transpiration by phreatophytes within the limits of the proposed channel, in acre-feet per year.

(2) Estimated average future (over 50-year period) transpiration by phreatophytes within the area, in acre-feet per year.

(3) Estimated amount of water that will be saved if the area is maintained in a reasonably clear condition, in acre-feet per year.

(4) Estimated average amount of salvaged water that might be made available for irrigation in Maricopa County, in acre-feet per year.

Aerial Photographs and Maps

The Corps of Engineers furnished two complete set of contact prints of aerial photographs on a scale of approximately 1,500 feet to the inch, and a set of aerial mosaics on the same scale. The aerial photographs were made during October 1948 and May 1949. The mosaics were used to delineate the areas of different density in phreatophyte growth, and the contact prints were used in the field for the purpose of recording phreatophyte types, heights, and areal densities. The Corps of Engineers also furnished prints of base maps showing the natural river channel and the proposed 2,000-foot flood-control channel. These maps were drawn to the same scale as the aerial mosaics, and were used to show the outlines of the various phreatophyte areas.

METHODS USED IN INVESTIGATION

In obtaining the data desired by the Corps of Engineers, the following steps were taken: The areas of different apparent phreatophyte densities were outlined on the aerial mosaics and on the contact

prints. The areas were measured by planimeter and numbered consecutively, beginning at Gillespie Dam. The contact prints were then taken into the field, and notes were made as to the types, heights, and areal densities of the phreatophytes, in each numbered area. Most of the observation was made from a light plane at altitudes of 50 to 100 feet above the ground. Checks were made on foot along numerous type cross sections (see fig. 1) throughout the length of the channel and these ground checks were compared with the aerial observations. The comparison between results obtained by air and ground mapping led to the conclusion that the former offers a much faster and more accurate method, particularly in areas of dense growth.

The data obtained from the field work were tabulated and evaluated as to total water use by phreatophytes in each individual area, on the basis of acreage, growth types, use factors (amounts of water used by different species), and densities. Use factors for different types of phreatophytes were taken from the results of experimental work done by the Geological Survey at Safford in 1943 and 1944.* It was recognized that, because of higher temperatures and a longer growing season, water use in Maricopa County would be somewhat greater than at Safford. However, as the actual amount of difference in water use is not known, the Safford figures were used, except for miscellaneous brush, and therefore the results are conservative. Water use according to plant types and on the basis of 100-percent areal and vertical frondage density was taken as follows: by saltcedar, 7.2 acre-feet per acre per year; cottonwood and willow, 6.0 acre-feet; baccharis, 4.7 acre-feet; arrowweed and miscellaneous brush assumed the same as baccharis; mesquite, 3.3 acre-feet; and palo verde assumed the same as mesquite. From each of the above figures was deducted 0.65 acre-foot of rainfall, leaving only the factor applicable to the use from ground water. The amounts of ground water used in the individual areas were combined to give the total amount of water used within the 2,000-foot channel.

In estimating the future average annual transpiration from ground water by phreatophytes within the proposed channel area, the following steps were taken. Profiles (fig. 2) were drawn to show water levels along the line of the channel for the years 1923, 1939, and 1949. The profiles extended from a point in the channel approximately 3 miles north of Mesa downstream to a point 1½ miles below the junction of the Salt and Gila Rivers. Graphs (figs. 3-8) were then drawn to show water-level fluctuations between 1905 and 1949 at six selected places along the channel. Estimated trends during

* Gatewood, J. S., Robinson, T. W., Colby, B. R., Hem, J. D., and Halpenny, L. C., Use of water by bottom-land vegetation in lower Safford Valley, Ariz.: U. S. Geol. Survey Water-Supply Paper 1103, 1950.

the period 1950-1999 are shown on the same graphs. These estimated trends are based both upon the continuation of present conditions and upon the possible introduction of Colorado River water in 1960. The graphs and the following factors were used in estimating future phreatophyte growth and ground-water use along the channel.

Factors Considered in Forecast of Water Use

In any attempt to forecast water-level fluctuations and the corresponding changes in water use by phreatophytes along the Salt and Gila River channels during the next 50 years, many factors must be taken into consideration. Some of these factors can be evaluated and used in the calculations. Others, of equal or even greater weight, are recognized but cannot be transposed into mathematical values with any degree of accuracy. All the factors listed below were given consideration.

Factors tending to raise water levels

(1) Increase in salt content of ground water.

A continuing increase in salt content of the ground water in the area west of Phoenix would cause land now developed to be taken out of cultivation and would decrease pumpage for irrigation purposes.

(2) Lower prices for agricultural products.

This is a factor that would have an important effect on future water use. However, no attempt was made to forecast economic trends, and current price levels were assumed in estimating water use during the period 1950-1999.

(3) Possible introduction of Colorado River water.

The forecast should not ignore the effects that would be caused by bringing Colorado River water into the area. There is uncertainty regarding this matter and also as to the actual date additional water might be brought in. For the purposes of this estimate, 1960 was arbitrarily chosen, and any change in that date would mean either a hastening or retarding of the effects that would be felt.

(4) A prolonged wet cycle similar to the period 1905-1920.

It is believed that the possibility of a wet cycle should be seriously considered in any water-use forecast. Rainfall and runoff records available for the 1905-1920 period were studied in order to determine the nature, sequence, magnitude, and duration of the effects of another such wet cycle. Taking into account the storage dams on the Salt and Verde Rivers, it was determined that the effects would be reflected quickly along the Salt and Gila River channels and that

continuous surface flow probably would occur between Granite Reef Dam and Gillespie Dam within 3 or 4 years. Recharge from the streams would build up a steep ground-water ridge under the channels and the slopes would gradually flatten as the water moved outward into depleted areas within the valley. It is estimated that the rise in water levels in the basin would average not less than 5 feet per year during a wet cycle of this sort. The phreatophyte problem would be greatly intensified by the rise of water levels, and an areal density approaching 100 percent might eventually be expected over the entire channel.

Although it appears reasonable to anticipate another protracted wet cycle at some time during the next 50 years, the date when such a cycle might begin is a matter of speculation. For that reason, the effects were not indicated on the graphs that show the estimated water levels during the period from 1950 to 1999 inclusive.

(5) Higher power rates.

Increased power costs would automatically curtail pumping and thus prevent further decline of the water table in some areas that are now near the borderline between profitable and unprofitable agricultural development.

Factors tending to lower water levels

(1) Additional agricultural development.

All available surface water is now being used and additional agricultural development would necessarily entail increased use of ground water.

(2) Lining of canals in the Salt River Valley.

This would greatly reduce recharge from the canals. As the time of installation and the amount of canal lining could not be predicted, the effect was considered only in a general way.

(3) Construction of a storage dam on the Gila River at the Buttes, east of Florence.

This would reduce the amount of water that now enters the channel area as surface flow and underflow at the junction of the Salt and Gila Rivers. This is another factor that cannot be predicted as to date and quantitative effects.

(4) Development and mining of the San Manuel ore body near Mammoth, on the San Pedro River.

The amount of water used may be considerable and will correspondingly reduce the flow of the San Pedro River, a tributary of the Gila River.

(5) Lowering of power rates.

This would allow pumping from deeper levels.

(6) Higher prices for agricultural products.

This, as in the case of lower prices, is an economic factor with an unknown time element. The forecast, therefore, was based upon the continuation of present price levels.

(7) Increased efficiency in application of irrigation water and use of fertilizers, and increased mechanization of crop harvesting.

This would lower over-all production costs and leave money available for deeper pumping.

Indeterminate factors

In addition to factors that would exert definite influences toward raising or lowering water levels in the basin, there are a few that would have effects in each direction, and the final net effect of their influence cannot be forecast. An example is the probable increased use of sprinkler systems to replace present methods of irrigation. Sprinkling would decrease the amount of water used per acre of crops, but it would also increase evaporation loss and would decrease recharge to the ground-water reservoir. Whether the widespread adoption of sprinkling systems in the area would eventually raise or lower the water table is debatable.

INTERPRETATION OF WATER-LEVEL GRAPHS

In constructing the graphs shown in figures 3-8, all available water-level records of a group of wells within the selected area were combined to show average fluctuations in the area. In some cases only partial records, particularly for the years preceding 1925, were available. Water levels as shown on the graphs may not be strictly accurate for any individual year, but the general trends are as shown.

Figure 3 shows the fluctuation of the water level in the part of the river channel between secs. 3 and 4, T. 1 N., R. 5 E., approximately 3 miles north of Mesa. Recharge from irrigation raised water levels in this area until 1925. At that time increased pumpage caused a sharp decline which continued through 1939. The abrupt rise after 1939 was caused by the wet winter of 1940-41. Increased development and pumpage during and after the war have lowered water levels at an accelerated rate.

Without the introduction of Colorado River water the decline in water levels will continue. If Colorado River water is brought in about 1960, water levels in this area will rise, probably to a level about 50 feet below the land surface.

Figure 4 shows the fluctuation of the water level in sec. 14, T. 1 N., R. 4 E., near Tempe Narrows. From 1902 to 1920, water levels in this area declined because of local pumping. This is one of the first areas in which extensive pumping was done. Between 1920 and 1930, recharge from irrigation overcame the effects of pumping and water levels rose until they were above the land surface in 1930. Surface flow continued until 1947, with the exception of a short period of drought that ended in the fall of 1940. Between 1947 and 1949 the water levels declined approximately 20 feet below the land surface. Several new wells of large capacity were drilled in the area in 1949.

Without Colorado River water the present rate of decline will probably continue for a few years and then will decrease as higher pumping lifts cause some wells to be taken out of use. If Colorado River water were brought in about 1960, the water levels in this area would recover very rapidly at first, then more gradually.

Figure 5 shows the fluctuation of the water level between secs. 13 and 14, T. 1 N., R. 3 E., approximately halfway between Phoenix and Tempe. From 1902 to 1925 the water levels in this area rose, because of recharge from irrigation. Drought and increased local pumping for drainage purposes caused a sharp decline between 1925 and 1927. After 1927 the rise in water levels was resumed and reached a peak during the wet winter of 1940-41. Then the water levels receded slowly until 1944, when increased pumping started the rapid decline.

Without Colorado River water, the present rapid rate of decline will probably continue and may increase, owing to lessened recharge after the main canals have been lined. The rate of decline will probably decrease at depths greater than 150 feet because of reduced pumping. If water from the Colorado River were brought into the area about 1960, the ground-water levels would rise continuously to within about 80 feet of the ground surface, where they probably would be stabilized. It is believed that, if the water table were stabilized at a much greater depth in this area, the movement of water out of the area would be reduced to such an extent as to have an adverse effect upon the salt balance in the basin.

Figure 6 shows the water-level fluctuation in sec. 29, T. 1 N., R. 2 E., approximately halfway between Phoenix and the junction of the Salt and Gila Rivers. In this area the water level was practically at the surface of the ground and water was flowing in the deeper channels of the river until 1941. Since that time the general trend of the water table has been downward.

Without Colorado River water, the rate of decline will probably increase for about 10 years and then will gradually decrease. It is probable that a water level at about 120 feet is the lowest that can be maintained without reversing the gradient and causing salt water encroachment. If Colorado River water were brought into the basin,

the water levels in this area probably would rise to about 35 feet below the ground surface. Such a level probably would be sufficient for maintenance of surface flow at the junction of the Salt and Gila Rivers and thus of the salt balance in the basin.

Figure 7 shows the water-level fluctuation in sec. 33, T. 1 N., R. 1 E., approximately 2½ miles east of the junction of the Salt and Gila Rivers. The water levels in this area were practically at the surface of the ground, with flow in the Salt River, until 1947. Then a gradual decline started, and it is expected that the rate of this decline will increase as the effect of pumping in the Maricopa area is transmitted along the Gila River to the junction with the Salt River. It is probable that the water table cannot be lowered more than 100 feet below ground surface without an increase in the salt content sufficient to make the water unfit for use. If Colorado River water is brought into the basin, the ground-water levels probably will rise to the surface of the ground in 10 to 20 years.

Figure 8 shows the water-level fluctuation between secs. 4 and 5, T. 1 N., R. 2 W., near Liberty and about 10 miles below the junction of the Salt and Gila Rivers. Water levels in the river-bottom portion of this area were practically at the surface of the ground and there was flow in the Gila River until 1947. The withdrawal of nearly all surface flow from the river, together with the expanding effect of upstream pumping, caused the water levels to start declining during 1947. This decline of the water table will continue until the increasing salt content compels a decrease in the water pumped and the abandonment of wells. Then the water table will rise until flow returns in the river. The only effect of the introduction of Colorado River water into the area would be to hasten the return of surface flow.

RESULTS OF INVESTIGATION

The river-bottom vegetation in parts of this area has deteriorated rapidly during the past few years. A part of this deterioration was caused by the rapidly declining water levels, and, in the lower portion of the area, a part may have been caused by a change in the kind of dissolved solids contained in the ground water. A part of the deterioration was caused by the burning of large areas during the past 2 years. Where the water level was shallow, the phreatophytes in the burned areas recovered rapidly, but in areas where the depth to water was more than 12 to 15 feet and the phreatophytes had to struggle for their existence, they made little or no recovery after burning.

The total transpiration within the channel limits was estimated as 29,000 acre-feet per year under present conditions. This is certainly a minimum amount because the rates of water use determined in Safford Valley were applied unchanged to the phreatophytes in this locality. No allowance was made for the fact that plants in Maricopa County must use more water than those at the higher

elevations in Safford Valley. The estimate must also be considered a minimum figure because the survey was made at a time of year when the phreatophytes were practically bare of foliage. It is likely that a survey made during the summer would indicate a higher density of growth and, consequently, a higher rate of water use.

Using the water-level profiles and graphs, and considering the factors previously described, another graph (fig. 9) was constructed to show the estimated annual transpiration of ground water by the phreatophytes during the next 50-year period. This estimate was made to cover two different conditions: (1) a continuation of the present conditions and (2) the possible introduction of Colorado River water in 1960. In neither case was any allowance made for the effects of wet cycles that will probably occur during the 50-year period. The estimate, therefore, represents minimum values. During the next 50 years there will probably be several short wet cycles and there may be a long wet cycle similar to the period 1905-20. The effect of a short wet period like the winter of 1940-41 is shown on figure 3.

The results of the foregoing work indicate that the minimum average annual transpiration by phreatophytes within the channel limits during the period 1950 to 1999, inclusive, would be: (1) Without the introduction of Colorado River water - 22,000 acre-feet; (2) with Colorado River water introduced in 1960 - 30,000 acre-feet.

The answer to the third question asked by the Corps of Engineers, the amount of water that will be saved if the channel area is cleared and maintained in a reasonably clear condition, was obtained by again using data from the experimental work in Safford Valley. Clearing the phreatophytes from the channel area will greatly decrease the use of water by transpiration, but will result in some increase in evaporation. No experimental data were available on the evaporation of water from wetted soil surfaces in the Maricopa County area. A careful study was made of the Safford data and, considering all the factors involved, it was estimated that the water saved in the Maricopa County area would amount to about 75 percent of the total water transpired by the river-bottom growth. The full saving could be obtained only by constant maintenance of the channel area. This maintenance would also be required to make the channel effective for flood control.

Applying the factor of 75 percent to the estimated present transpiration of 29,000 acre-feet, the amount of water saved by clearing the phreatophytes would be approximately 22,000 acre-feet annually. In like manner, the average annual water saving effected by keeping the channel cleared during the next 50 years would be: (1) Without the introduction of Colorado River water - approximately 16,000 acre-feet; (2) with Colorado River water introduced in 1960 - approximately 22,000 acre-feet. These amounts are minimum savings because the computed basic figures for present and future use of water represent minimum amounts.

Regarding the fourth inquiry by the Corps of Engineers, the amount of salvaged water that would be available for irrigation in Maricopa County, there is no apparent reason why the entire saving could not be so used, or the salvaged water could be used to carry more salt out of the area. It should be noted, however, that because most of the saving would be effected in the lower reaches of the channel where water levels are and will remain the highest, and phreatophyte growth the heaviest, probably not more than 20 percent of the salvaged water would be available to the Buckeye Canal and possibly another 20 percent would be available to the Arlington Canal. The remaining 60 percent would be available to canals and wells along the Gila River below the Arlington Canal intake, but within the limits of Maricopa County.

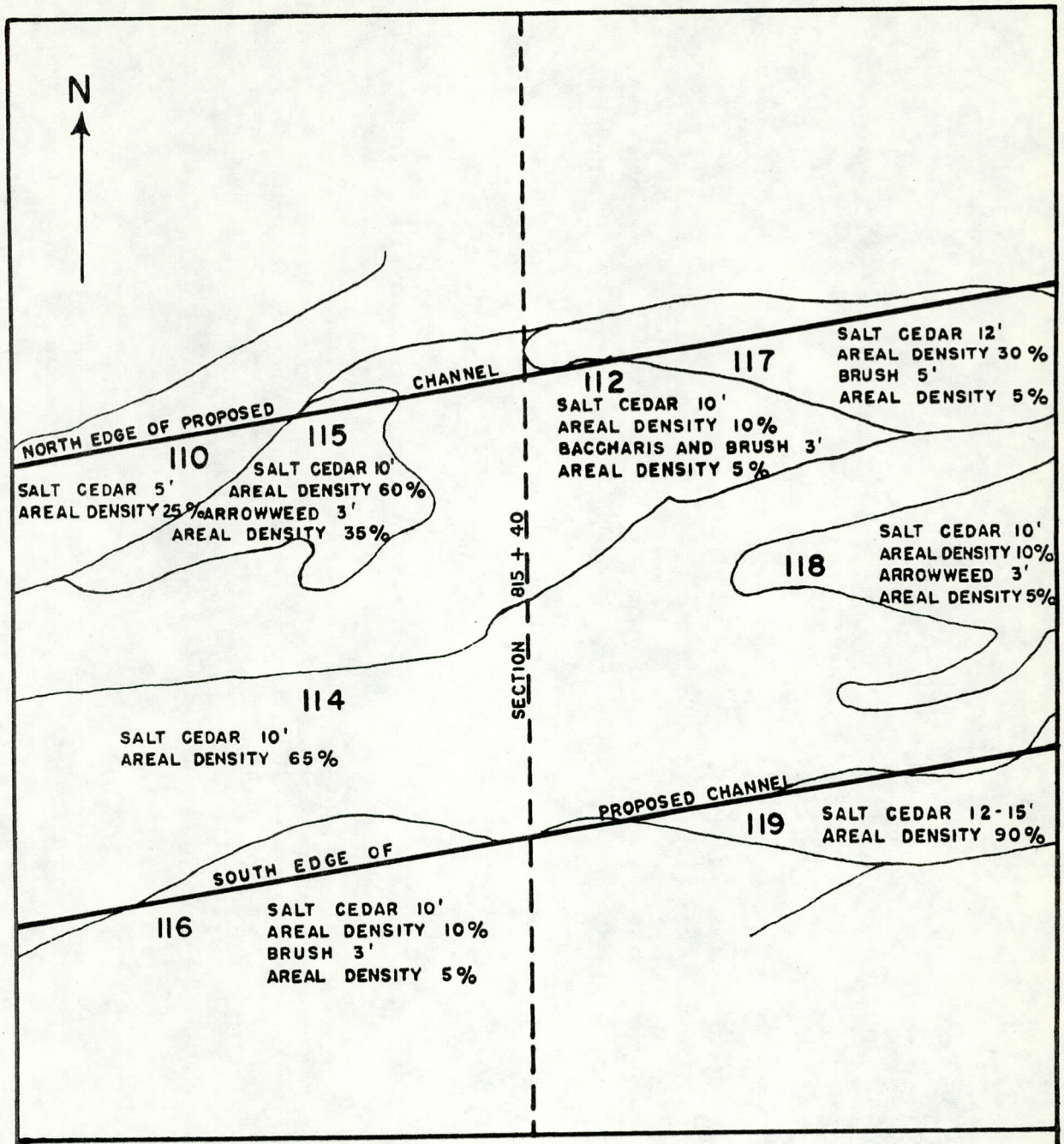

FIGURE 1. — SECTION OF PROPOSED GILA RIVER FLOOD-CONTROL CHANNEL SHOWING PLANT TYPES AND DENSITIES
MARCH 1950

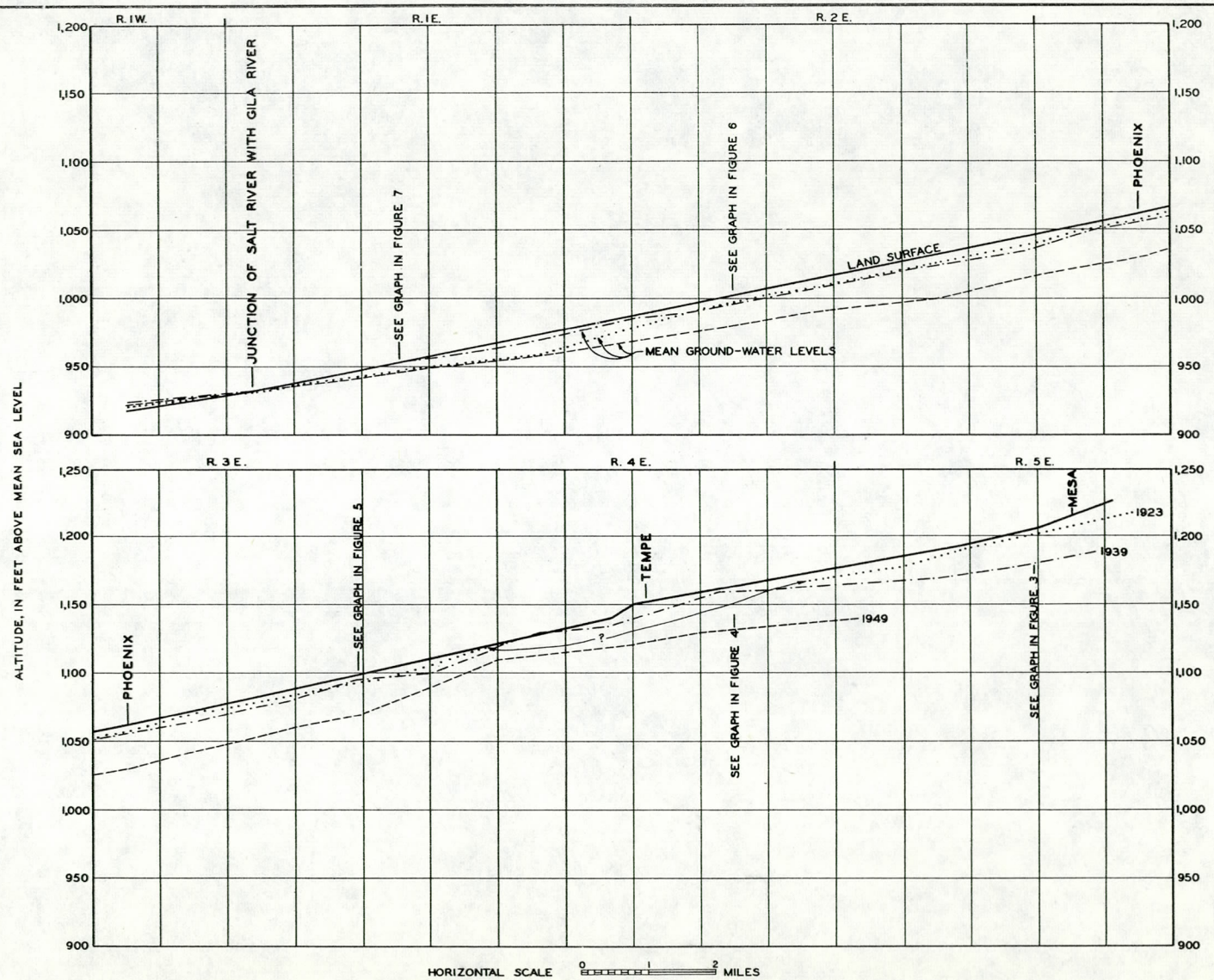

FIGURE 2.— PROFILE OF LAND SURFACE AND GROUND-WATER LEVELS ALONG SALT RIVER FROM ABOUT 3 MILES NORTH OF MESA DOWNSTREAM TO JUNCTION WITH GILA RIVER

RETRACED FROM U.S. G.S. SURVEY REPORT DATED SPRING OF 1950

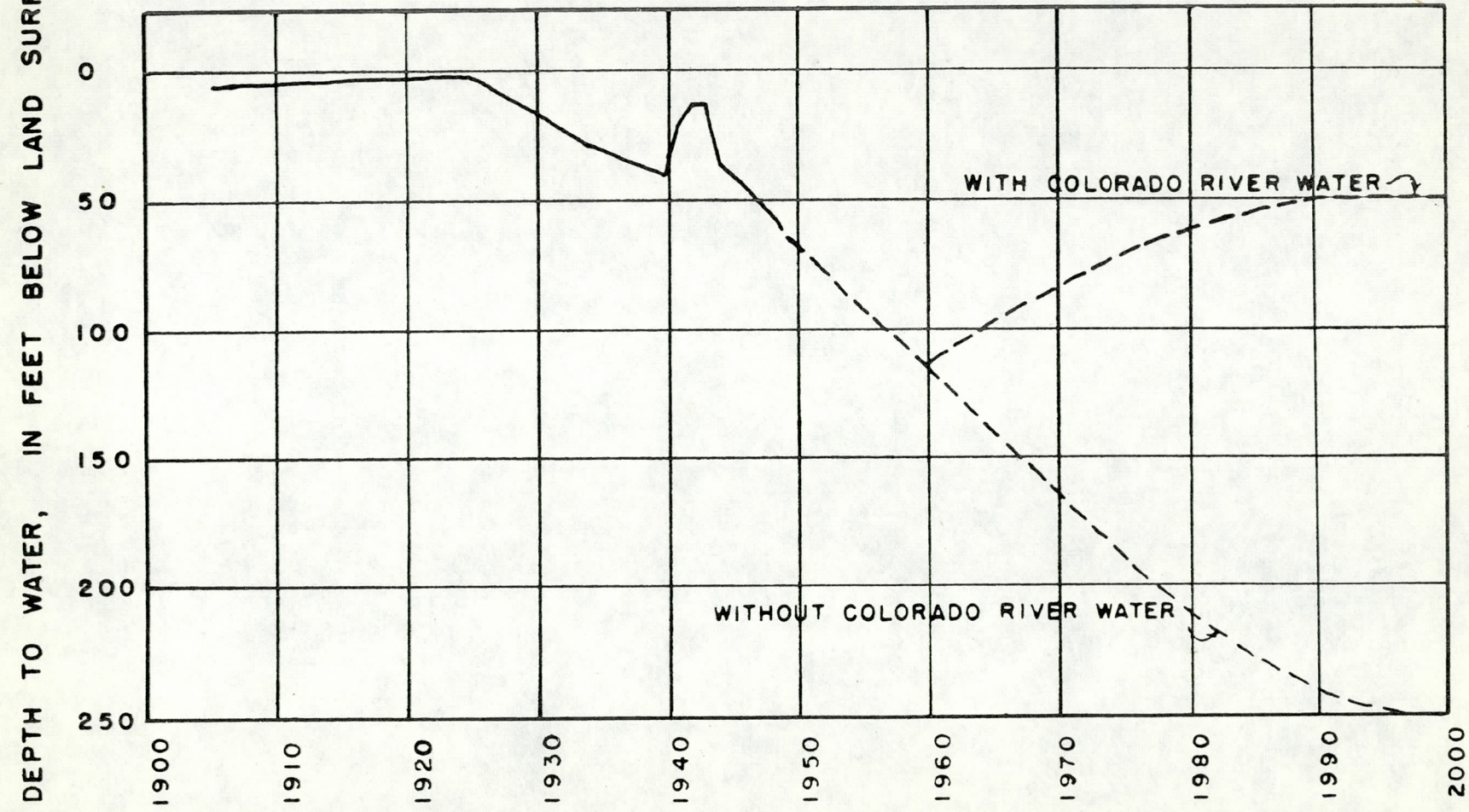

FIGURE 3.—GRAPH SHOWING FLUCTUATION OF GROUND-WATER LEVEL IN GILA RIVER CHANNEL, NORTH OF MESA, MARICOPA COUNTY, ARIZONA.

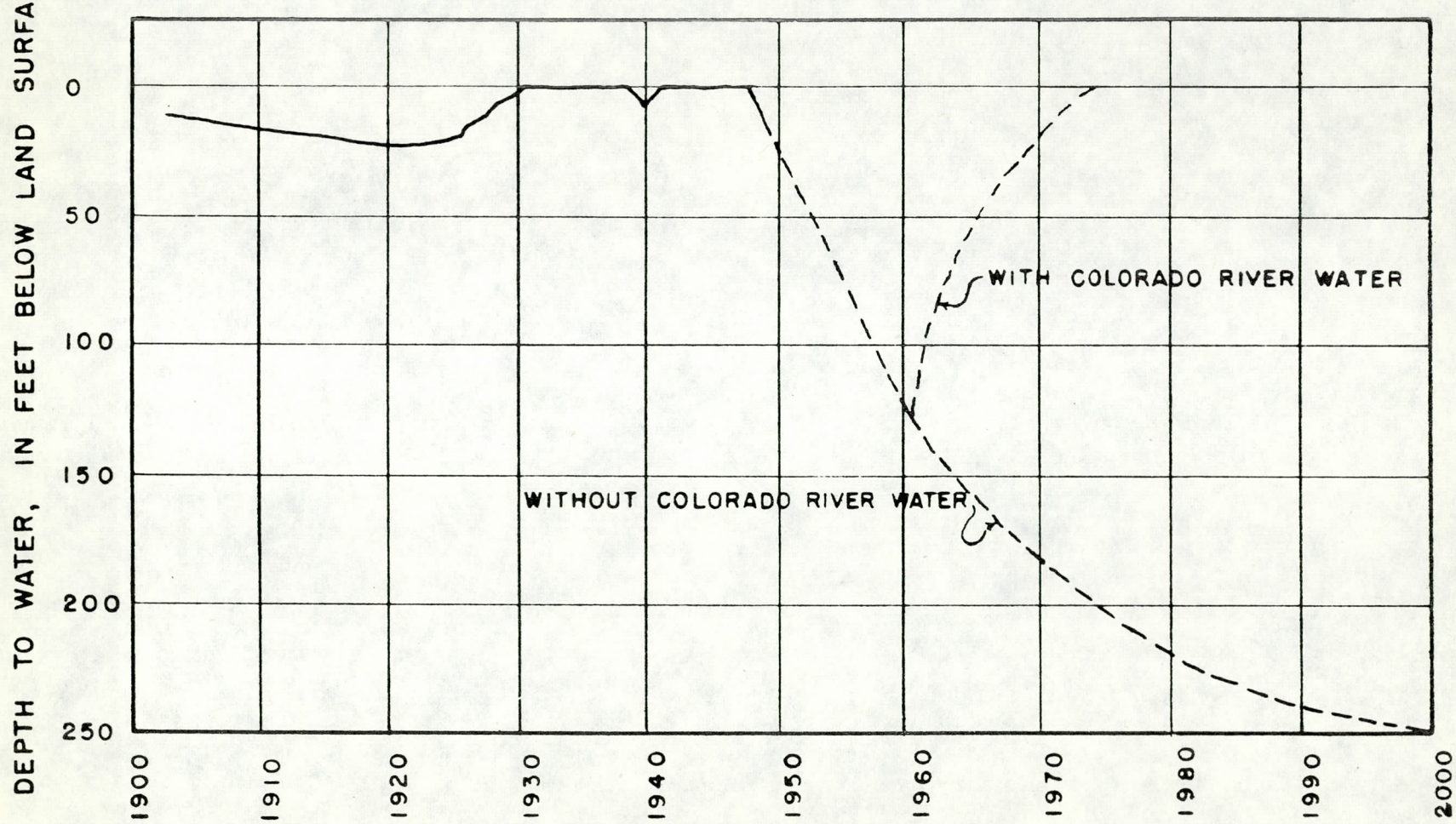

FIGURE 4.—GRAPH SHOWING FLUCTUATION OF GROUND-WATER LEVEL IN GILA RIVER CHANNEL, ABOUT 1 MILE EAST OF TEMPE, MARICOPA COUNTY, ARIZONA.

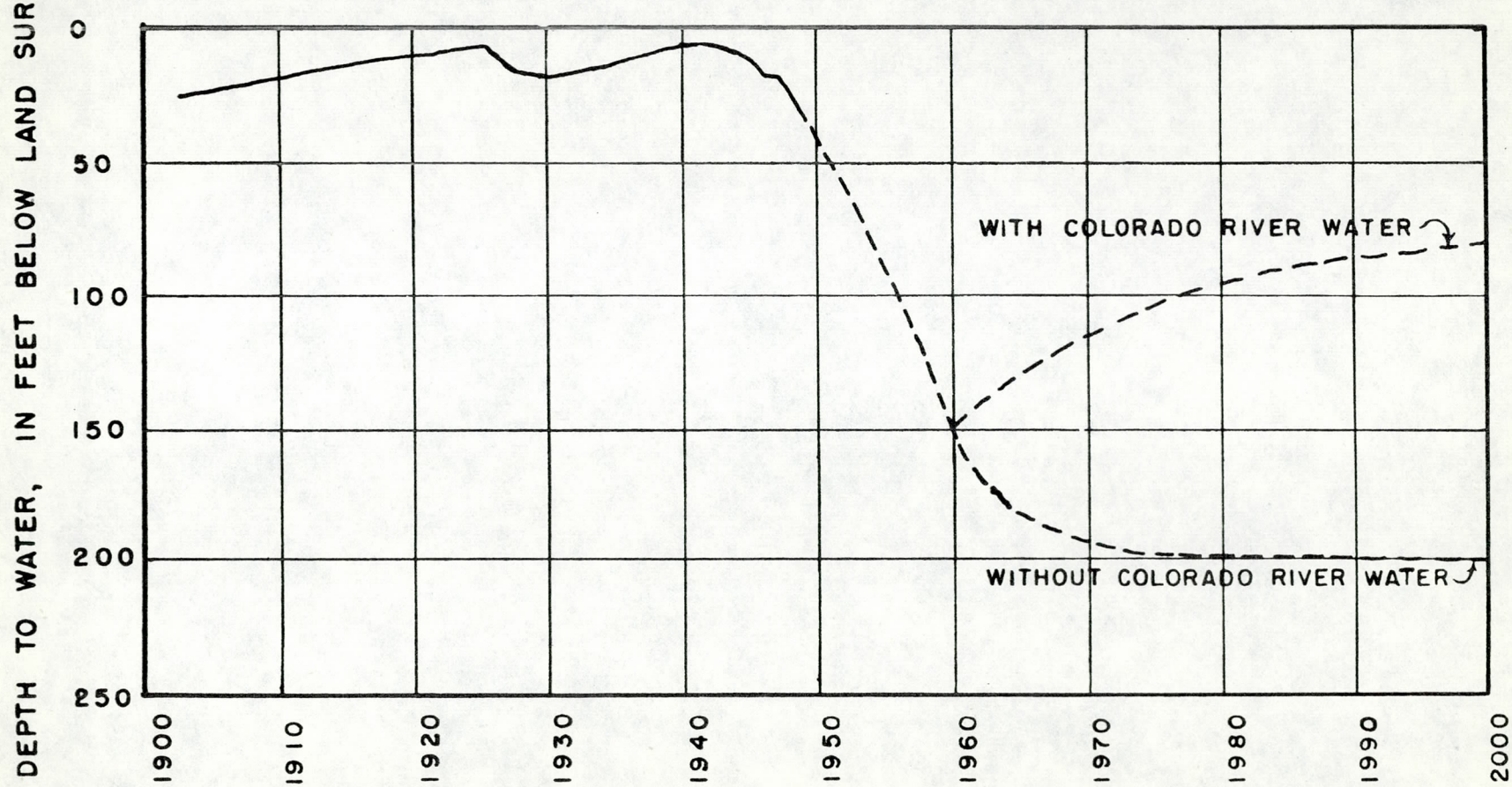

FIGURE 5.— GRAPH SHOWING FLUCTUATION OF GROUND-WATER LEVEL IN GILA RIVER CHANNEL, ABOUT 3 MILES EAST OF PHOENIX, MARICOPA COUNTY, ARIZONA.

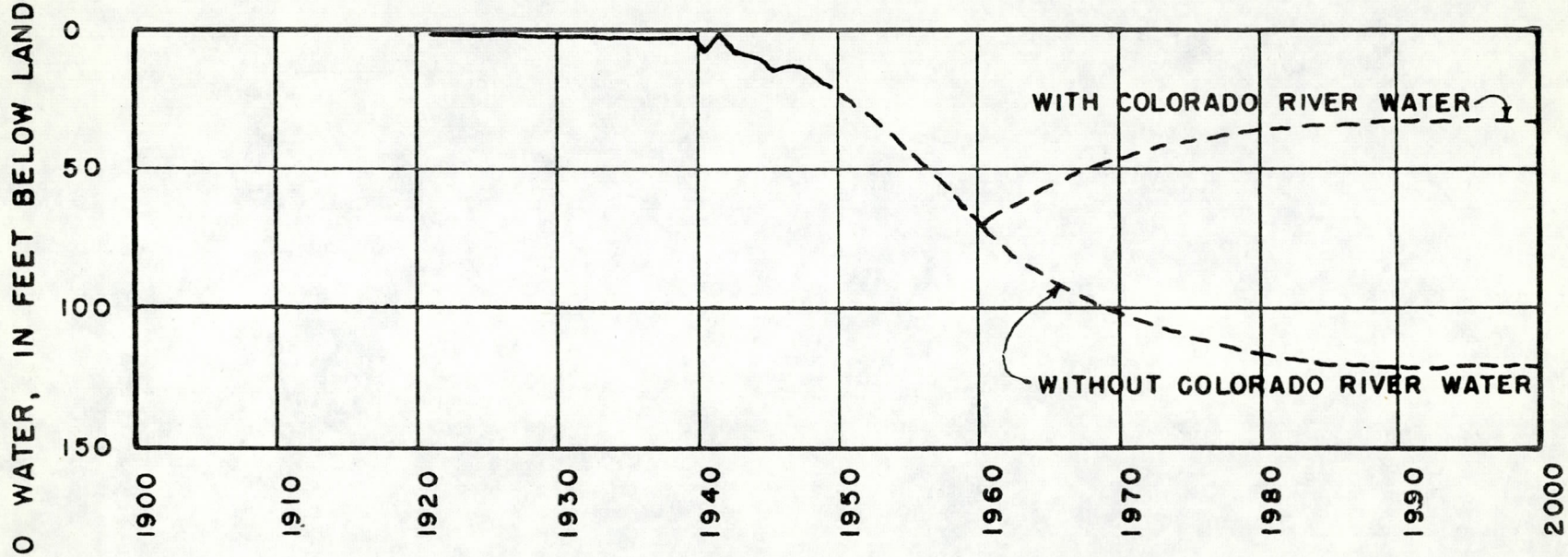

FIGURE 6.—GRAPH SHOWING FLUCTUATION OF GROUND-WATER LEVEL IN GILA RIVER CHANNEL, ABOUT 6 MILES WEST OF PHOENIX, MARICOPA COUNTY, ARIZONA.

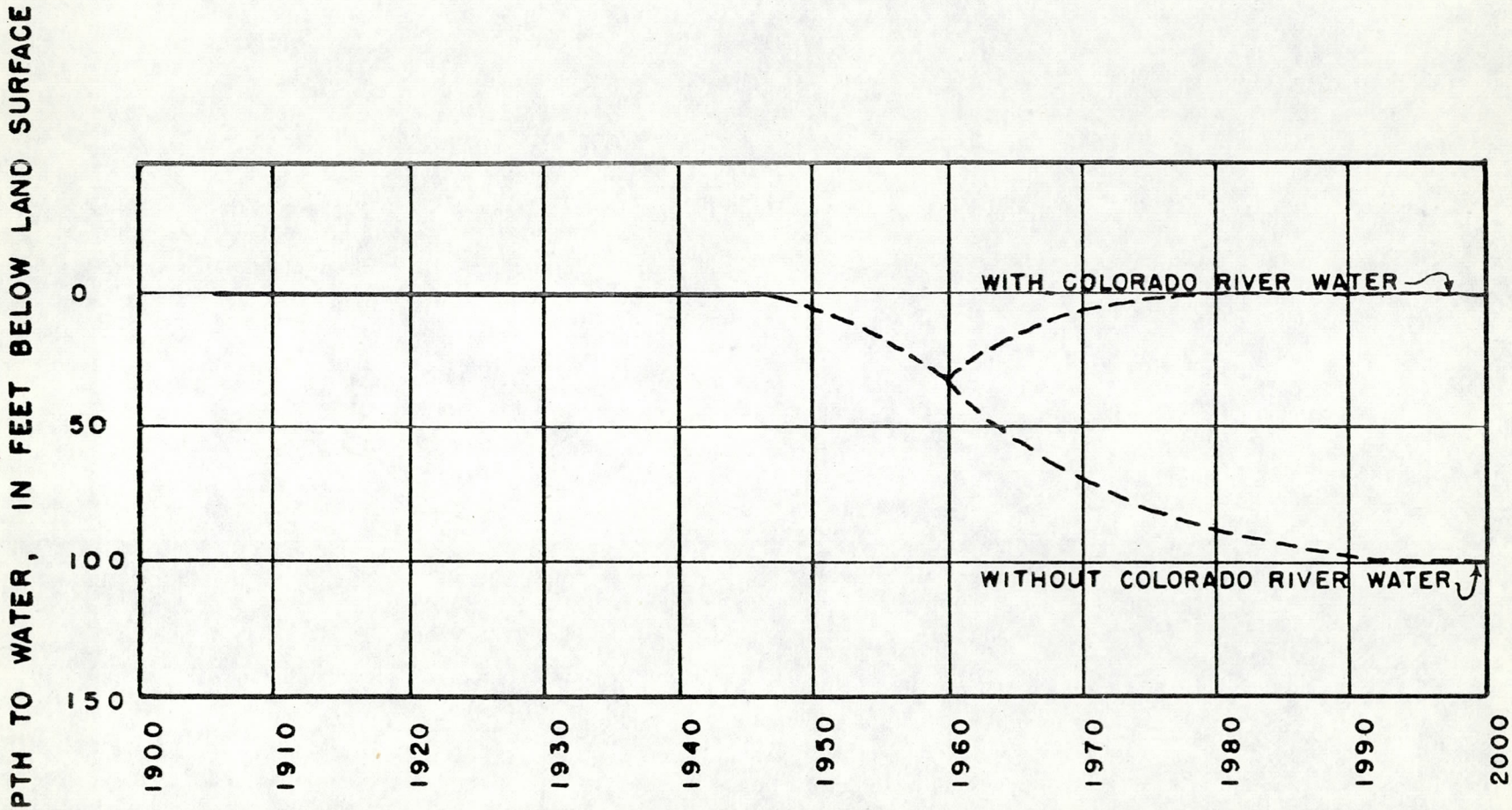

FIGURE 7 — GRAPH SHOWING FLUCTUATION OF GROUND-WATER LEVEL IN GILA RIVER CHANNEL, ABOUT 2 MILES ABOVE JUNCTION OF SALT AND GILA RIVERS, MARICOPA COUNTY, ARIZONA.

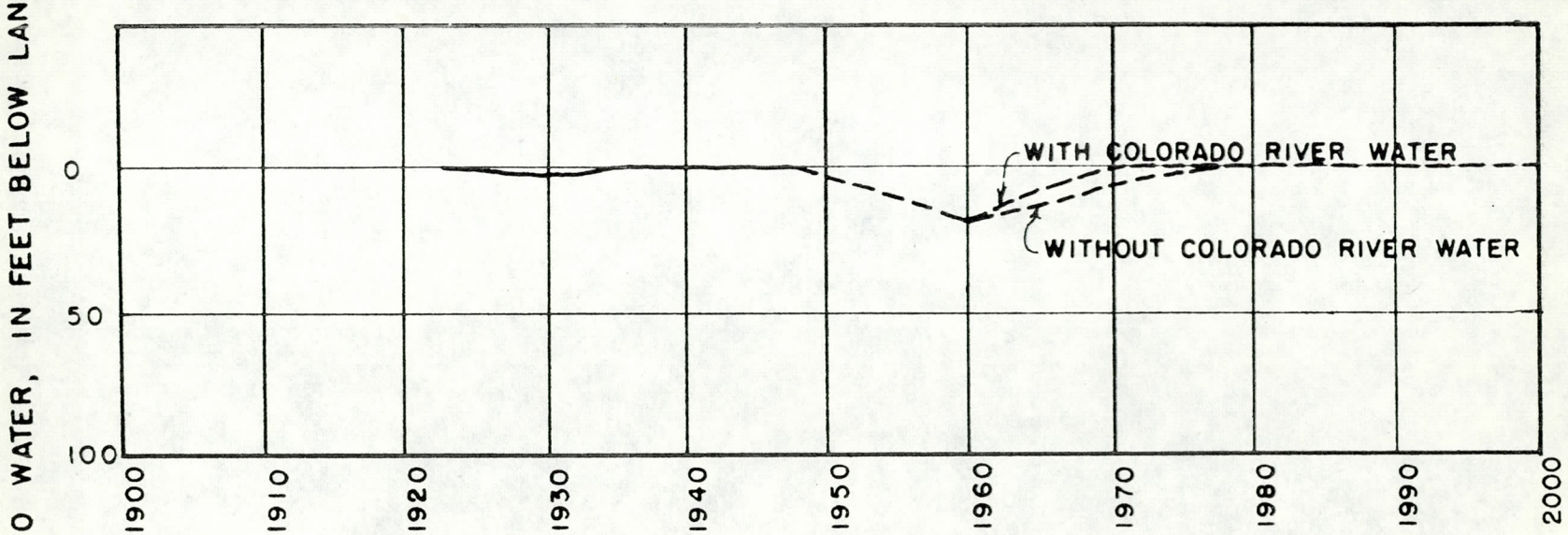

FIGURE 8.—GRAPH SHOWING FLUCTUATION OF GROUND-WATER LEVEL IN GILA RIVER CHANNEL, SOUTH OF LIBERTY, MARICOPA COUNTY, ARIZONA.

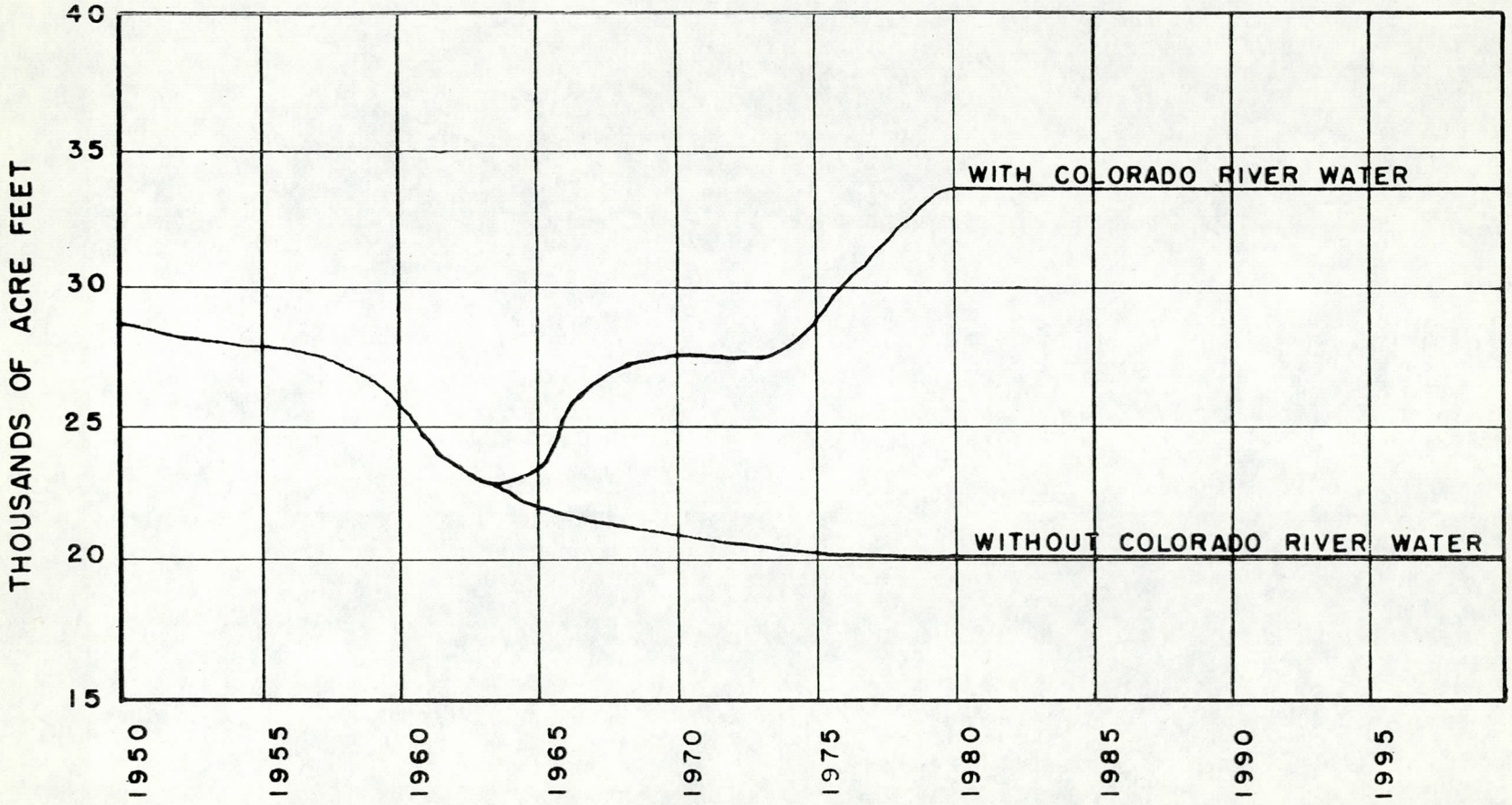

FIGURE 9 — GRAPH SHOWING ESTIMATED FUTURE ANNUAL TRANSPIRATION FROM GROUND WATER BY PHREATOPHYTES IN PROPOSED FLOOD-CONTROL CHANNEL BETWEEN GRANITE REEF AND GILLESPIE DAMS, MARICOPA COUNTY, ARIZONA.

UNITED STATES ARMY CORPS OF ENGINEERS

LOS ANGELES DISTRICT

ALLOCATION OF COSTS

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

To accompany interim report on survey for flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated December 4, 1957

APPENDIX 7

A L L O C A T I O N O F C O S T S

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

1. This appendix contains a discussion of the method of allocating the first costs and annual charges for the improvements recommended for construction along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam, Ariz.

2. The recommended plan of improvement provides for (a) short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe, and (b) channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam. The channel improvements would consist of a cleared floodway and two low-flow channels. Flood-control benefits would result from the construction of all features of the recommended plan. Water-conservation benefits would result only from the cleared floodway. The short levees and the low-flow channels would provide flood-control benefits only. The first cost of the recommended plan is estimated at $3,570,000 (October 1957) and the average annual cost of maintenance and operation at $53,000 (October 1957). The first cost of the cleared floodway, not including the cost of the low-flow channels, is estimated at $1,150,000 (October 1957) and the average annual cost of maintenance and operation at $48,000 (October 1957).

3. 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 multiple-purpose development." The amount of benefits used as a basis for the allocation is limited by the costs of available single-purpose alternative projects.

4. The method consists of (a) determining the separable cost of including each function in the multiple-purpose project and (b) determining an equitable distribution of joint costs incurred for several purposes in common. The separable cost for any purpose is defined as the difference between the cost of the multiple-purpose project as a whole and the cost of the project with that purpose omitted.

5. The following table summarizes the calculations in the determination of allocation of costs for the recommended plan:

Allocation of costs, recommended plan of improvement, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona (based on October 1957 prices)

Item	Flood control	Water conservation	Total
ALLOCATION OF ANNUAL COSTS			
1. Benefits (average annual)	$226,000	$128,000	$354,000
2. Alternative costs (annual charges)	$178,900	$89,500	$268,400
3. Benefits limited by alternative costs	$178,900	$89,500	$268,400
4. Separable costs	$89,400	0	$89,400
5. Remaining benefits (item 3 minus item 4)	$89,500	$89,500	$179,000
6. Allocated joint costs	$44,800	$44,700	$89,500
7. Total allocation, project costs (item 4 and item 6)	$134,200	$44,700	$178,900
8. Allocation in percent	75	25	100
ALLOCATION OF FIRST COSTS			
9. Allocated construction costs	$2,475,000	$825,000	$3,300,000
10. Allocated costs of preauthorization studies	$45,000	$15,000	$60,000
11. Allocated costs of rights-of-way and highway and utility relocations	$157,000	$53,000	$210,000
ALLOCATION OF MAINTENANCE AND OPERATION COSTS			
12. Allocated annual maintenance and operation costs	$40,000	$13,000	$53,000

NOTE: Given below is pertinent information on determining alternative costs (item 2), separable costs (item 4), allocated joint costs (item 6), and allocated construction costs (item 9).

R. 8/13/58

Item 2 - Alternative cost

Flood control

Average annual charges for recommended plan of improvement.....	$178,900

Water conservation

First cost and total investment of cleared floodway.....	1,175,000
Average annual charges:	
Interest and amortization of investment in 50 years at 2½ percent (.03526 times investment).....	41,500
Maintenance and operation.....	48,000
Total average annual charges.....	89,500

Item 4 - Separable costs (separable cost is difference between cost of multiple-purpose project and the cost with purpose omitted)

Average annual charges for multiple-purpose project (recommended plan of improvement).....	178,900
Separable cost of flood control: $178,900 minus $89,500 =	89,400
Separable cost of water conservation: $178,900 minus $178,900 =	0

(No cost is involved in including water-conservation features in recommended plan of improvement.)

Item 6 - Allocated joint costs

Total of joint costs (total charges for project, $178,900 minus total of separable costs, $89,400) =	89,500

Joint costs are then allocated in same proportion as remaining benefits.

Item 9 - Allocated construction costs

Total construction cost =	3,300,000

Allocation of construction costs is in same proportion as item 8 (allocation in percent).

Allocation of items 10 through 12 are in the same proportion as item 8.

R. 8/13/58

6. Costs of the recommended plan allocated to flood control were further allocated in accordance with the general policies expressed in acts of Congress. The cost of the construction items allocated to flood control would be borne by the United States. The cost of the highway and utility relocation, the costs of lands, easements, and rights-of-way, and the cost of maintenance and operation would be borne by local interests. The costs of all preauthorization studies are considered in this report to be nonreimbursable and thus would be borne by the United States.

7. On the basis of present (October 1957) costs, that part of the construction cost that is allocated to the United States for flood control would therefore amount to $2,475,000, which constitutes 75 percent of the estimated construction cost. The allocated first cost to local interests for flood control for rights-of-way and for highway and utility relocations would be $157,000. The first cost to local interests for water conservation would be $878,000, of which $825,000 (25 percent of the estimated total construction cost) would be for construction and $53,000 would be for rights-of-way and for highway and utility relocations.

8. It is proposed that local interests (a) provide all rights-of-way and pay for the cost of highway and utility relocations and (b) be permitted to repay that part (25 percent) of the total cost of construction allocated to water conservation, in 40 years without interest.

9. Under the proposed allocation of costs, the United States would construct the levee and channel improvements at an estimated Federal construction cost of $3,300,000 (October 1957). Local interests would (a) provide necessary rights-of-way and pay for the cost of highway and utility relocations at a cost estimated at $210,000 (October 1957); (b) maintain and operate the improvements at an average annual cost estimated at $53,000; and (c) repay 25 percent of the total construction cost in 40 equal annual payments without interest. On the basis of October 1957 prices, the estimated amount of $825,000 would be repaid in 40 equal annual payments of $20,625. The allocations and repayments would be adjusted on the basis of actual construction costs.

UNITED STATES ARMY CORPS OF ENGINEERS

LOS ANGELES DISTRICT

RESOLUTION BY LOCAL INTERESTS

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

To accompany interim report on survey for flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated December 4, 1957.

APPENDIX 8

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 and Salt Rivers between Gillespie Dam and McDowell Dam site; and

WHEREAS, an interim report on survey, flood control, Gila and Salt Rivers between Gillespie Dam and McDowell Dam site, 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 other responsible local agencies have given assurances satisfactory to the Secretary of the Army that they will assume certain enumerated obligations; and

WHEREAS, Section 3 of House Bill 254, 19th Legislature of the State of Arizona, authorizes Maricopa County to cooperate with the United States by assuming certain obligations in connection with flood-control projects built at the expense of the United States on Salt and Gila Rivers; and

WHEREAS, Protection against flood damages would be provided for property along Gila and Salt Rivers in the County of Maricopa, State of Arizona, by flood-control improvements considered for construction by the United States along Gila and Salt Rivers between Gillespie Dam and McDowell Dam site; and

NOW, THEREFORE, BE IT RESOLVED by the Board of Supervisors of Maricopa County, that, if a flood-control project consisting of levees, channel rectification, and channel clearing along Gila and Salt Rivers be found economically feasible and be authorized by act of Congress, the County of Maricopa will participate to the best of its ability by assuming the following obligations:

(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 and the cost of performing the work required under item "b" below is presently estimated at $194,000;

(b) Perform, without cost to the United States, all necessary utility and highway relocations and all necessary street modifications required in connection with the project;

(c) Hold and save the United States or any instrumentality, department, or agency thereof, free from any claim for damages arising from the construction, maintenance, and operation of the project;

(d) Maintain and operate, upon completion, all works in accordance with regulations prescribed by the Secretary of the Army;

(e) Establish and enforce flood-channel limits and regulations satisfactory to the Secretary of the Army for the protection of the flood-carrying capacity of the channel;

(f) Enter into a contract with the United States for repayment of the costs allocated to water conservation; such costs, estimated at $810,000, to be repaid, without interest, in 40 equal annual payments of $20,250; and

BE IT FURTHER RESOLVED, That this resolution be entered in the minutes of the Board of Supervisors of the County of Maricopa and that the Clerk of said county be, and he is hereby directed to forward a certified copy of this resolution to the District Engineer, Los Angeles District, Corps of Engineers, U. S. Army, P. O. Box 17277, Foy Station, Los Angeles 17, California.

Passed and approved by the Board of Supervisors of the County of Maricopa this 16th day of July, 1956.

Approved this 16th day of July, 1956.

/s/ James G. Harth
Chairman, Board of Supervisors

UNITED STATES ARMY CORPS OF ENGINEERS

LOS ANGELES DISTRICT

COMMENTS OF OTHER AGENCIES

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

To accompany interim report on survey for flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated December 4, 1957.

APPENDIX 9

R. 3/20/58

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COMMENTS OF OTHER AGENCIES

GILA AND SALT RIVERS, GILLESPIE DAM TO McDOWELL DAM SITE, ARIZONA

SCOPE

This appendix includes the comments of other Federal and State agencies on the interim report on survey for flood control along the Gila and Salt Rivers from Gillespie Dam to the McDowell Dam site in Arizona. The report was initially submitted for review and comment in June 1951, was subsequently revised in September 1953, and was resubmitted for review and comment in December 1957. Where pertinent, replies of the United States Army Engineer District, Los Angeles, are included.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

REGION III
BOULDER CITY, NEVADA

July 26, 1951

District Engineer
Corps of Engineers, U. S. Army
Los Angeles District
751 South Figueroa Street
Los Angeles 17, California

Dear Sir:

As requested in your letter of June 28, 1951, the "Interim Report on Survey, Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona", has been reviewed by this office.

The Bureau of Reclamation has been carrying on investigations for a number of years in this part of Arizona, in connection with the Salt River Project and the proposed Central Arizona Project. The construction of almost any type of flood control works in the reach of the Gila and Salt Rivers covered by your report would necessitate at least minor changes in our plans for irrigation development.

We agree with your statement that even a minor flood passing through this reach of river in its present condition would cause considerable damage to residential, industrial and agricultural developments located near the river channel.

The flood control improvements which would be provided under your recommended plan consisting of (1) short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe, and (2) channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Rock Dam, would benefit present irrigation developments in the area and could be coordinated with potential irrigation developments under consideration by this office.

We note that you conclude that the addition of flood control storage to the required terminal storage is justified in the potential McDowell Dam and Reservoir, which is a feature of the Bureau of Reclamation plan for development of the Central Arizona Project. Also, you recommend that flood control storage be included in the reservoir when the project is authorized for construction. The Bureau plan provides for flood storage capacity of 390,000 acre-feet.

Your plan of development for the multiple-purpose McDowell Dam and Reservoir differs somewhat from that of the Bureau of Reclamation, which introduces a number of problems related to design, allocation of storage, and allocation of costs which we believe should be resolved before the project is constructed. One problem in particular is the effect of the reservoir on Stewart Mountain Power Plant, to which effect we have been unable to find a reference in your report. This plant, having a capacity of 10,400 kw would be completely inundated at your maximum proposed water surface elevation of 1486. We feel that it would be impracticable to protect this plant against complete inundation and, therefore, abandonment of the plant would be necessary if the McDowell Dam were constructed to the height recommended. Abandonment of the power plant would necessarily require inclusion in the cost of the project of a sizeable amount to reimburse the Salt River Valley Water Users' Association for its loss. We question whether the construction of protective works for the Stewart Mountain Power Plant above elevation 1443 could be economically justified.

Very truly yours,

/s/ C. A. Bissell
C. A. Bissell
Acting Regional Director

SPLGD 6 August 1951

Mr. C. A. Bissell
Acting Regional Director
United States Bureau of Reclamation
Boulder City, Nevada

Dear Sir:

Thank you for your letter of 26 July 1951 commenting on the interim report on survey, flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona.

It is noted that you agree that the flood-control improvements which would be provided under the recommended plan would benefit present irrigation developments in the area and that you state that those improvements could be coordinated with potential irrigation developments under consideration by your office.

You state that our plan of improvement for the multiple-purpose McDowell Dam and Reservoir differs somewhat from the plan of the Bureau of Reclamation. Inasmuch as the Corps' report did not recommend construction of the multiple-purpose reservoir at McDowell site at the present time because of the imponderable political, legal, and economic considerations, it was not believed necessary to resolve all of the problems of design, allocation of storage, and allocation of costs. We agree that before the project is constructed, agreement must be reached on these points.

With regard to the effect of the reservoir on Stewart Mountain Power Plant, we had noted that your report on the Central Arizona Project, page R62, states that "it is considered the reduction in inflow to Stewart Mountain Power Plant might make it impractical to continue operating this unit, and consequently, the total output would be lost." On the basis of this statement in your report, and on other factors, this office did not believe it necessary to provide for the protection of the power plant. Here again is a matter to be resolved prior to the construction of the project.

A copy of your letter will be forwarded to the Chief of Engineers, Washington, D. C., for his consideration.

Your promptness in reviewing the report and submitting your comments is appreciated.

Very truly yours,

JOHN R. JANNARONE
Lt. Col., Corps of Engineers
Acting District Engineer

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION III
BOULDER CITY, NEVADA

December 11, 1951

District Engineer
Corps of Engineers
Los Angeles District
751 South Figueroa Street
Los Angeles 17, California

Refer to: SPLGD 800.92 (Gila & Salt Rivers - Gillespie Dam to McDowell Dam Site)

Dear Sir:

The revisions to your "Interim Report on Survey, Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona, dated June 8, 1951, have been received and reviewed by this office.

As stated in our letter of July 26, 1951, we believe that the flood control improvements which would be provided under your recommended plan consisting of short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe, and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam, would benefit present irrigation developments in the area and could be economically coordinated with potential irrigation developments under consideration by this office.

There is no doubt that the construction recommended in your report would alleviate damage to residential, industrial, and agricultural developments located near the river channel in case of a flood.

We agree that if the McDowell Dam is to be built for terminal storage as a unit of the Central Arizona Project consideration should be given to increasing the capacity to provide for flood control storage. Also, in view of the recent improvements made at Horseshoe Dam by local interests it might be desirable to include some water conservation storage in the McDowell Reservoir. However, we believe that there are a number of problems related to design, allocation of storage, and allocation of costs which cannot be firmly resolved at this time. A detailed comparison of cost estimates of the McDowell Dam as planned by the Bureau of Reclamation and the larger structure considered by your office has not been made. However, we do not feel that your

statement that the larger structure recommended in your report can be built for one percent more than the structures presently considered by the Bureau is based on entirely comparable hypotheses. It is realized that the river channel spillway in the Bureau of Reclamation plan is a relatively expensive structure, but it is believed that silting damage to the Granite Reef forebay and the canal system would be much less in case of high flood flows than with the detached type spillway proposed in your report. This office has not made subsurface investigation at the weir location but it is believed that the discharge channel would require substantial protection to prevent erosion.

The "Report on Central Arizona Project" recognizes the reduction of power output of the Stewart Mountain Powerplant due to diversion above this plant and provides for replacement of energy equal to the reduction. It is also recognized that the flow remaining after the upstream diversion is made might not be sufficient for economic operation of this plant, although that remains a question at this time. If it is determined that it would be economical to operate the Stewart Mountain Powerplant after the Salt-Gila diversion is made and McDowell Dam constructed as planned by the Bureau, and further, that increasing the capacity to that contemplated by the Corps of Engineers would force abandonment of the plant, then we believe that adjustment or compensation to the Salt River Valley Water Users' Association, in addition to that contemplated by the Bureau, would be necessary, and that the cost of such additional adjustment should be a charge against the increased flood control storage capacity.

We wish to call your attention to the fact that the name McDowell Dam and Reservoir has been changed to Maxwell Dam and Reservoir.

Sincerely yours,

/s/ E. G. Nielsen
E. G. Nielsen
Acting Regional Director

SPLGD 28 December 1951

Mr. E. A. Moritz
Regional Director, Region 3
U. S. Bureau of Reclamation
Boulder City, Nevada

Dear Sir:

Thank you for Mr. Nielsen's letter of 11 December 1951 commenting upon the interim report on flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona.

It is noted that you believe that the flood-control improvements that would be provided under the recommended plan would benefit present irrigation developments in the area and could be economically coordinated with potential irrigation developments under consideration by your office.

You agree that if the McDowell Dam is to be built for terminal storage as a unit of the Central Arizona Project, consideration should be given to increasing the capacity to provide for flood-control and water-conservation storage. You also state that there are a number of problems related to design, allocation of storage, and allocation of costs that cannot be firmly resolved at this time.

You state that the silting damage to the Granite Reef forebay and the canal system would be much less in case of high flood flows if a river channel spillway were constructed as contemplated in the Bureau of Reclamation plan than if the detached-type spillway were constructed as proposed by the Los Angeles District. McDowell Reservoir, as contemplated in the report of this office, would reduce the standard project flood of 290,000 cubic feet per second to a peak outflow of 82,000 cubic feet per second. The chance of occurrence of such a flood is very small. The entire discharge of such a flood and all lesser floods would be through the outlet structure in the river channel and no flow would be over the spillway. On the infrequent occurrence of floods larger than 290,000 cubic feet per second, only discharges in addition to those passing through the outlet structure would pass over the spillway. If a large flood resulting in flow over the spillway were to occur, such spillway discharge would probably erode the discharge channel above Granite Reef diversion dam. It is doubtful whether much water would be diverted into the canals during the period of high-water stages in the river. After the recession of the high water, the entire 672,000 acre-feet capacity of the reservoir reserved for flood control would be emptied at the rate of 82,000 cubic feet per second. This uniform flow would tend to sluice the river channel above

Granite Reef Dam and transport the sediment downstream from the canal intakes. Therefore, it was not considered economical or necessary to provide substantial protection to the discharge channel at the detached spillway location.

With regard to the effect of the reservoir on Stewart Mountain power plant, you agree that the flow remaining after the upstream diversion is made (under the Central Arizona project) might not be sufficient for economic operation of this plant. However, you indicate that the economy of operating the Stewart Mountain power plant with that remaining flow has not been finally determined. You further state (1) that increasing the capacity of McDowell Reservoir under the plan described in the interim report would force abandonment of the Stewart Mountain power plant, (2) that additional compensation or adjustment to the Salt River Valley Water Users' Association would be necessary as a result of such abandonment, and (3) that such additional compensation or adjustment should be a charge against flood control. As discussed at the conference held in Boulder City on 3 October 1951 between representatives of the Los Angeles District, Corps of Engineers, and Region 3, Bureau of Reclamation, the maximum annual loss to the Salt River Valley Water Users' Association because of the abandonment of the Stewart Mountain power plant would not exceed $20,000. This is a minor item in the justification of flood-control storage at the McDowell Reservoir.

It is noted that the name of McDowell Dam and Reservoir has been changed to Maxwell Dam and Reservoir. Because the report is dated 8 June 1951, prior to the change in name, the name was not changed in the report.

A copy of your letter will be forwarded with the report to the Chief of Engineers, Washington, D. C., for his consideration.

Your promptness in reviewing the report and submitting your comments is appreciated.

Very truly yours,

W. R. SHULER
Colonel, Corps of Engineers
District Engineer

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

REGION 3

3-700 BOULDER CITY, NEVADA

February 6, 1958

District Engineer
Los Angeles District
Corps of Engineers
P. O. Box 17277, Foy Station
Los Angeles 17, California

Re: SPLGP-F

Dear Sir:

This office is pleased to have the opportunity to review your "Interim Report on Survey for Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona", dated December 4, 1957, which was transmitted to this region by your letter of January 8, 1958.

Our review paid particular attention to Appendixes 4, 5, and 7, and it was concentrated for the most part on the recommended plan of improvement which provides for (a) short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe, and (b) channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam. Revision in your present report to bring costs up to date and to allocate costs between flood control and water conservation are straightforward, and are not, therefore, deemed to require comment.

Our letters of July 26 and December 11, 1951 commented on matters connected with the potential McDowell (Maxwell) Dam. No additional comments are made at this time because so many uncertainties seem to lie ahead of its being authorized.

We appreciate your courtesy in making your report available for our comment.

We would appreciate your furnishing us an extra copy of the report for use in our Phoenix Development Office.

Very truly yours,

/s/ W. H. Taylor
W. H. Taylor
Regional Director

FEDERAL POWER COMMISSION
REGIONAL OFFICE
100 McAllister Street
San Francisco, Calif.

85-Gila
WA#32

July 18, 1951

Lt. Colonel W. R. Shuler, District Engineer
Los Angeles District
Corps of Engineers, U. S. Army
P. O. Box 17277, Foy Station
Los Angeles 17, California

Dear Colonel Shuler:

In compliance with your request of June 28, 1951, your File No. SPLGD, we have reviewed your proposed Interim Survey Report on Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona, dated June 8, 1951. Enclosed are three copies of a memorandum by Mr. Robert H. Griffin of this office giving his conclusions on the proposed development.

Since the developments recommended in your report will consist of levees and channel improvements, the proposed project offers no possibility for the inclusion of hydroelectric power. However, your studies do include the consideration of the prospective multiple-purpose dam and reservoir at the McDowell site on the Salt River. This is a part of the Bureau of Reclamation's Central Arizona Diversion Project.

Your report suggests certain changes in the McDowell Project, namely, an increase in the reservoir capacity to provide for more flood control storage, and the possible addition of storage capacity for water conservation purposes, as distinguished from storage required for terminal use in connection with the Central Arizona Diversion Canal. Inasmuch as you do not recommend the McDowell Reservoir as part of your proposed plan, Mr. Griffin's only purpose in discussing the McDowell Project has been to consider the possible effect of the construction of this reservoir, as a part of the Central Arizona Diversion Project, on the economics of the levee and stream-channel improvements proposed in your report.

I concur in the conclusions presented in Mr. Griffin's memorandum. Apparently the McDowell Reservoir, if constructed at present as a terminal reservoir for the Central Arizona Diversion Project,

would offer an economical means of controlling the downstream floods. The construction of this reservoir depends, however, on so many imponderable political, legal, and economic considerations that I believe the project recommended in your report, providing immediate flood control and water conservation benefits, should be constructed.

Very truly yours,

Lesher S. Wing
Regional Engineer

By /s/ Daniel J. Fee
Acting

Enclosure:
Copy of memo 7/13/51
RHG to RE (in trip.)

FEDERAL POWER COMMISSION
SAN FRANCISCO REGIONAL OFFICE

85-Gila
WA#32

July 13, 1951

MEMORANDUM FOR THE REGIONAL ENGINEER:
(Through the Engineer-in-Charge)

Subject: Investigation - U. S. Engineer's Survey Report on Gila River Basin (W. A. No. 32)

Introduction

On June 29, 1951, this office received from the Corps of Engineers in Los Angeles an "Interim Report on Survey, Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona" dated June 8, 1951. Our informal comments on this report were requested.

This report by the Army is the fifth of a series of interim reports. Of the other four, three have been completed and one - concerning the Gila River and Tributaries above Salt River - is under consideration. The three completed reports cover Tucson, Arizona and vicinity; Queen Creek; and Gila River and Tributaries below Gillespie Dam. A final report covering the entire Gila Basin, and summarizing the several interim reports, is planned. The area covered by the present report and the other interim reports is shown on a map taken from the Army's report and reproduced as Plate 1 of this memorandum.

Basin Description

The Gila River Basin includes the southern half of New Mexico and part of southwestern New Mexico. The total drainage area is 58,200 square miles. The Gila heads in the high mountains and flows westerly across hot, dry, desert areas to its junction with the Colorado. Its principal tributaries are the Salt, Santa Cruz, and San Pedro Rivers. The largest tributary of the Salt River is the Verde. The drainage area of the Salt River at its junction with the Gila is 13,700 square miles; the area of the Gila at Gillespie Dam, below the Salt River, is 49,600 square miles.

The area considered in the report under review is the Salt River Valley from the McDowell dam site to the Gila River (38 miles) and the Gila River Valley from the Salt River to Gillespie Dam (28 miles). The Gila Valley from Gillespie Dam to the backwater of the proposed Painted Rock Reservoir is also considered as it would be affected by a dam at the McDowell site. (See map - Plate 1).

The Gila River and its tributaries are usually perennial streams at their origin in the higher mountains, but are intermittent in their lower reaches. Local summer thunder storms occur, but do not cover sufficient area to cause major floods. General storms occur in the winter and may cause large floods. The maximum recorded flood at the Gillespie dam site is 70,000 cfs, although much greater flows have occurred; and the Army estimates the "standard project flood" at the McDowell site on the Gila River as 290,000 cfs. The estimate for the Gila River at Gillespie Dam is 350,000 cfs.

Economic Development

The area affected by the proposed improvements lies entirely within Mariposa County, Arizona, and includes the cities of Phoenix, Mesa, Glendale, Tempe, Chandler, and Tolleson. Phoenix, the capital of Arizona, has with its surrounding urban area an estimated 1950 population of 235,000. Irrigated areas in the Salt and Gila Valleys from McDowell dam site to Gillespie Dam total 320,000 acres. Crop production is entirely dependent on irrigation, which is in turn dependent on a highly developed and complex system of irrigation works including dams, reservoirs, canals, power plants, and numerous deep-well pumps. A large overdraft of ground water is occurring in the area at present.

Prior Reports

Many prior reports on the Gila River Basin, or portions thereof, are available. Three interim reports by the Army have already been mentioned. These have been commented upon by this office. Other important reports are:

Survey Report, Queen Creek Watershed, Arizona, June 1950, U. S. Department of Agriculture

Power Market Survey, Colorado River - Lower Basin, Part 1 - Power Requirements, May 1950, Federal Power Commission, San Francisco Regional Office

Staff Report on the Colorado River Basin, October 1948, Federal Power Commission, San Francisco Regional Office

Staff Report on Central Arizona Project as presented by the Department of Interior in its report of December 1947 - March 1948, Federal Power Commission, San Francisco Regional Office

Report on Central Arizona Project, December 1947, U. S. Bureau of Reclamation

The Colorado River, March 1946, U. S. Bureau of Reclamation

Plans of the Army Department

The recommended plan of the Army Department consists of short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe; and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam. The levees along the left and right banks of the Salt River would have lengths of 2,000 feet and 16,700 feet, respectively. The height above streambed would be 23 to 28 feet. The leveed channel would accommodate the standard project flood for that location of 270,000 cfs.

The channel improvements would consist of a floodway 2,000 feet wide and low-flow channels to reduce stream meandering and assist in keeping floods in the intended area. The floodway would be constructed by clearing river-bottom growths, largely salt cedar, from the river channel. The floodway would be about 71 miles long. The original clearing would probably be done by mechanical means, although clearing by use of chemicals followed by burning is also under consideration. Maintenance of the cleared areas would be by cultivation of areas where regrowth occurs. Other means of maintenance such as planting grasses and pasturing are under study.

It is expected that the floodway clearing and maintenance program would reduce transpiration losses by about 16,000 acre-feet per year. In this area, where a serious and chronic water shortage exists, this water saving is of considerable importance.

The floodway and levees would not affect any present or future power development; and offer no opportunity for production of hydroelectric power.

The District Engineer also investigated the potential multiple-purpose dam and reservoir at the McDowell site on the Gila River. This structure is not economically feasible for flood control alone. However, it has been proposed by the Bureau of Reclamation as the terminal storage reservoir for the Granite Reef aqueduct of the Central Arizona Project. The Bureau's proposal provides for terminal storage of 142,000 acre-feet, dead storage of 16,000 acre-feet, and flood control storage of 300,000 acre-feet, giving a total storage of 578,000 acre-feet. The Army suggests a reservoir of 860,000 acre-feet total capacity, of which 672,000 would be flood control and the remainder allocated as proposed by the Bureau of Reclamation. The Army also recommends that if the McDowell Reservoir is constructed consideration be given to additional storage for water conservation purposes, as distinguished from that required for terminal use.

The Bureau of Reclamation proposed a power plant of 4,100 kilowatts at the McDowell site. Additional flood control storage would not affect the power installation. However, if conservation storage should be provided in addition to terminal storage the power installation would probably be changed. There are other uncertainties

in connection with this project, especially as to the available Colorado-River water supply, which is dependent on the final settlement of the Arizona-California controversy. Any change in water supply would affect the power installation. It is suggested that further studies of the power feature be made after (1) the amount of conservation storage is determined, (2) the available Colorado River water supply is definitely known.

Costs and Benefits

The capital cost of the Army's recommended plan is $3,583,000, of which $1,240,000 is for levees and $2,343,000 for channel improvements. If flood control storage is provided at the multiple-purpose McDowell site, as suggested by the Army, the incremental capital cost, for flood control storage, would be $4,864,000. The annual cost of the recommended program is estimated at $224,800, of which $133,100 is Federal and $91,700 is non-Federal. The non-Federal costs include $80,000 annually for floodway maintenance. The additional flood control storage at the McDowell site would increase the total annual costs to $417,400.

Estimated tangible benefits from the recommended plan are $262,000, of which flood control gives $166,000 and water conservation (at $6.00 per acre-foot) gives $96,000. The addition of flood control storage at the McDowell site would increase the flood control benefits to $437,000, giving a total annual benefits of $533,000.

The benefit-cost ratio of the recommended plan is 1.17, and of the recommended plan plus McDowell flood control storage is 1.28.

Alternative Plan Considered by FPC

The Army report does not include an estimate of benefits from the 672,000 acre-feet of flood control storage in the McDowell Reservoir without any downstream channel clearing or levees. However, according to the Army's estimates the annual benefits of the McDowell Reservoir, considered as an increment to the recommended plan, amount to $271,000. The corresponding annual costs are $192,600, giving an incremental benefit-cost ratio of 1.41.

The benefit-cost ratio of McDowell Reservoir considered as an increment to the recommended plan is higher than the benefit-cost ratio for either the recommended plan of channel improvements alone or the recommended plan plus McDowell Reservoir. This indicates that flood control storage at McDowell Reservoir, assuming this reservoir constructed as a part of the Central Arizona Project, might be the most economical means of controlling floods in the stretch of river under consideration. This conclusion cannot be checked without detailed studies of the benefits which would be produced by flood control storage at McDowell Reservoir operating without downstream improvements. These studies cannot be made in this office because the necessary data are not available.

Cost estimates in the Army report show conclusively that the McDowell Reservoir is not feasible as a single-purpose flood control project. If this reservoir were constructed as a part of the Central Arizona Project, and if detail studies show that the addition of flood control storage would be the most economical means of preventing flood damages, the most desirable project would depend primarily upon the relative timing of the Central Arizona Project and the proposed flood control measures. If the Central Arizona Project were to be constructed immediately, it is possible that flood control could be obtained in connection with the McDowell Reservoir and that the remaining benefits available for the channel improvement would not be sufficient to make this work feasible. However, if the Central Arizona Project is to be indefinitely delayed, it would be desirable to proceed with the channel improvements as recommended by the Army. This would allow immediate realization of the water-conservation and flood-control benefits.

A bill authorizing the Central Arizona Project has passed the United States Senate. However, the House Interior Committee has voted 16 to 8 not to consider the project further until the Arizona-California dispute over water rights in the Colorado River has been settled. It is evident that authorization of the Central Arizona Project (including McDowell Reservoir) depends on many imponderable political, economical, and legal factors; and may be indefinitely delayed. It is, therefore, believed that the Army's recommended plan is the most appropriate for existing conditions.

Summary

The Los Angeles District Office of the Corps of Engineers has submitted to us for informal comments its "Interim Report on Survey, Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona" June 8, 1951. This report is the fifth of a series of interim reports which will be followed by a final report covering the entire Gila River Basin.

The report under review recommends construction of a cleared floodway 71 miles in length between Granite Reef Dam on the Salt River and Gillespie Dam on the Gila River. Also recommended is construction of short levees on the right and left banks of the river near Phoenix, with lengths of 16,700 and 2,000 feet, respectively. The estimated capital cost of the recommended project is $3,583,000; the annual cost is $224,800; annual benefits are $262,000; and the benefit-cost ratio is 1.17. The recommended plan would have no effect on present or future power developments, but offers no opportunity for power generation.

The Army also investigated the proposed McDowell Reservoir on the Salt River. This reservoir is not economically feasible for flood control purposes alone. However, if it should be constructed as the terminal reservoir for the Bureau of Reclamation's Central Arizona Project, the provision of flood control storage on an incremental basis would be feasible. The addition of this flood control storage to the Army's recommended project would give an overall benefit-cost ratio of 1.28.

The McDowell Reservoir, if constructed at present as a terminal reservoir for the Central Arizona Project, with the suggested flood-control capacity would apparently provide an economical means of controlling floods in the stretch of river considered. Since construction of the reservoir depends on many imponderable political, legal, and economic factors it is believed that the Army's recommended plan, providing immediate flood control and water conservation benefits, is preferable under present conditions to the Bureau of Reclamation's plan for McDowell Reservoir.

A power development of 4,100 kilowatts has been proposed by the Bureau of Reclamation at the McDowell dam site. Further investigation of this proposed installation should be made if conservation storage is to be provided at the McDowell Project, or if the amount of Colorado River water available for the Central Arizona Project is definitely determined.

Robert H. Griffin
Senior Hydraulic Engineer

FEDERAL SECURITY AGENCY
PUBLIC HEALTH SERVICE
Norman Building
Dallas, Texas

July 10, 1951

W. R. Shuler
District Engineer
Los Angeles District
Corps of Engineers
P. O. Box 17277, Foy Station
Los Angeles 17, California

Dear Sir:

We are pleased to acknowledge the receipt of the proposed Interim Survey Report on Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated June 8, 1951.

Your courtesy in supplying this report is greatly appreciated and we find it a valuable reference work.

Very truly yours,

/s/ R. F. Poston
R. F. Poston
Senior Sanitary Engineer
Officer in Charge

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
Region Three
Santa Fe, New Mexico

July 25, 1951

Lt. Col. W. R. Shuler
District Engineer, Los Angeles
District
Corps of Engineers, U. S. Army
P. O. Box 17277, Foy Station
Los Angeles 17, California

My dear Colonel Shuler:

Reference is made to your letter of June 28 (your file reference No. SPLGD) addressed to our Regional Director, Region 4, in San Francisco. As explained in Mr. E. M. Hilton's letter of July 3 to you, your Interim Survey Report and Appendices on Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, June 6, 1951, transmitted with your above letter, was forwarded to this office for review and informal comment.

No National Park Service area or direct interest will be affected by the flood control features proposed. However, the entire Salt River Valley, from above the proposed McDowell Dam to the confluence with the Gila River, is an area very rich in significant archeological remains. Along the Gila River also, many archeological sites are known above the mouth of the Salt River and below Gila Bend; presumably, archeological remains of importance may be expected to occur between the mouth of the Salt River and the Gillespie Dam. In the Gila-Salt channelization work and levee construction from Granite Reef Dam to Gillespie Dam, provision should be made for archeological survey and recovery work before and during construction operations. A crew of an Archeologist GS-7 or GS-9, and a junior professional assistant or archeological aid, GS-5, plus occasional use of unskilled labor as required, for a period of three to six months, should be sufficient for this, including preparation of a final report. Archeological investigation of the McDowell Reservoir, as of other proposed reservoirs of the Central Arizona Project, will have to be made upon authorization of construction or before; a survey can be done by an Archeologist and his assistant in two weeks to a month, but it is not possible to predict how much salvage excavation of archeological sites will be found to be essential.

The opportunity to review your report has been very much appreciated.

Sincerely yours,

Hugh M. Miller
Assistant Regional Director

9-19

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

Region Three
Santa Fe, New Mexico

January 22, 1958

District Engineer
U. S. Army Engineer District, Los Angeles
P. O. Box 17277, Foy Station
Los Angeles 17, California

Dear Sir:

This refers to Chief, Engineering Division, H. W. Thompson's letter of January 8, concerning your Interim Report on Survey for Flood Control, Gila and Salt Rivers - Gillespie Dam to McDowell Dam Site, Arizona.

We have reviewed the report and find no reason to change our comment as was submitted by our letter of July 25, 1951. You may, therefore, consider those comments as currently applicable.

Sincerely yours,

/s/ John J. Moseley
John J. Moseley
Acting Regional Chief
Division of Recreation Resource
Planning

UNITED STATES
DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Albuquerque, New Mexico
July 16, 1951

Lt. Col. W. R. Shuler
Corps of Engineers
District Engineer
Los Angeles District
751 South Figueroa Street
Los Angeles 17, California

Dear Col. Shuler:

We have reviewed your "Interim Report on Flood Control for the Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site". We are particularly interested in this area because of our cooperative work with several soil conservation districts in improving the use of land and water resources. We are also quite interested in the control of salt cedars and other useless river-bottom vegetation because it is a serious problem in many soil conservation districts here and elsewhere. We have made no attempt to check the engineering or economic phases of this report but the program which you recommend appears to be sound and should contribute materially to the stabilization and future welfare of this area.

Before long this Service expects to be called on by increasing numbers of land owners who need technical assistance in clearing their lands of these phreatophytes so they can be restored to production of crops or forage for livestock. Irrigation and other water-using interests are becoming increasingly concerned about the inroads these useless growths make on their water supplies. The program which you propose for this reach of the Gila and Salt Rivers is a much larger test of phreatophytes so they can be restored to production of crops or forage for livestock. Irrigation and other water-using interests are becoming increasingly concerned about the inroads these useless growths make on their water supplies. The program which you propose for this reach of the Gila and Salt Rivers is a much larger test of phreatophyte control than has been carried out so far. We hope that during this operation a few different methods of control can be tested, for the information that will be useful in other areas.

If this floodway develops into one like that constructed and maintained by the International Boundary and Water Commission on the Rio Grande between Caballo Dam and El Paso, there will be extensive areas of stream bank between the low-water channel and the levees on which a grass cover must be established. This Service maintains a nursery at Tucson and numerous observational plots throughout Arizona, for testing various grasses and methods of revegetation. We also intend to undertake field trials of various methods of revegetating cleared areas so

they will not be exposed to serious erosion during the conversion from phreatophytes to useful vegetation. Please feel free to consult this office about that phase of your project when you begin operations.

The only point we noticed in your report that seemed open to question is the value of water, $6 an acre-foot, that is used in evaluating the channel improvements. This appears to be low for the productive value of water, particularly since farmers in that area now pay from $5 to $9 an acre-foot for pumped water and the water saved by clearing this channel will largely recharge underground reservoirs. We have not yet made any calculations in this respect but expect to do so during our current watershed survey of the Gila Basin in aid of flood control. Our experience in the Pecos and Rio Grade Basins leads to the conclusion that the productive value of water in the Phoenix area is much higher than $6 an acre-foot. Since that value shows a favorable cost-benefit ratio there is no need to change it in this report. We mention this point chiefly because our forthcoming survey report for the Gila watershed may carry a higher value on water.

We appreciate the opportunity to review this report and hope that this project can get underway soon. Any improvement of this kind will help to stabilize the agriculture of this area and should fit in well with our programs of land and water conservation and watershed improvement.

Sincerely yours,

/s/ Cyril Luker
Cyril Luker
Regional Director

SPLGD 23 July 1951

Mr. Cyril Luker
Regional Director
Soil Conservation Service
U. S. Department of Agriculture
Albuquerque, New Mexico

Dear Sir:

Thank you for your letter of 16 July 1951 commenting on the interim report on survey, flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona.

It is noted that you state that the recommended program appears to be sound and should contribute materially to the stabilization and future welfare of this area.

Your invitation to consult with your office about methods of revegetation of the cleared floodway is appreciated. When that phase of the operation is considered, we shall be very glad to avail ourselves of your services and expert advice.

We note that you question the value of water at $6 per acre-foot. It is true that the $6 per acre-foot value is a conservative figure, but not unduly so. The unit value applies to the value of water in Buckeye and Arlington Valleys and in the areas below Gillespie Dam, all in Maricopa County. According to the United States Geological Survey (see page 13 of Appendix 6), "probably not more than 20 percent of the salvaged water would be available to the Buckeye Canal and possibly another 20 percent would be available to the Arlington Canal. The remaining 60 percent would be available to canals and wells along Gila River below the Arlington Canal intake, but within the limits of Maricopa County." The average value of crops is not so high in these areas as in the Phoenix area.

A copy of your letter will be forwarded to the Chief of Engineers, Washington, D.C., for his consideration.

Your promptness in reviewing the report and submitting your comments is appreciated.

Very truly yours,

W. R. SHULER
Colonel, Corps of Engineers
District Engineer

UNITED STATES
DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Albuquerque, New Mexico
Post Office Box 1348
December 5, 1951

Lt. Col. John R. Jannarone
District Engineer
Los Angeles District
Corps of Engineers
Post Office Box 17277 Foy Station
Los Angeles 17, California

Dear Colonel Jannarone:

Thank you for providing us with the revised pages for our copy of your interim report on survey, flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated June 8, 1951.

The initial draft of this report was reviewed in July, 1951, and our comments were sent to your office on July 16, 1951. Colonel Shuler's letter of July 23 cleared up the question we raised relative to the value of irrigation water used in the report.

We have no further comments on the report.

Very truly yours,

/s/ Cyril Luker
Cyril Luker
Regional Director

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Forest Service Building
Ogden, Utah

RIFC-INT
COOPERATION
Corps of Engineers
(Gila River)

July 13, 1951

Lt. Col. W. R. Shuler
District Engineer
Corps of Engineers
751 South Figueroa Street
Los Angeles 17, California

Dear Colonel Shuler:

The report "Interim Report on Survey, Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona" dated June 8, 1951 has been reviewed with interest since this office has been assigned primary responsibility for a Department of Agriculture flood control survey of the watershed lands comprising the Salt, Verde, Hassayampa, and Agua Fria watershed.

We have no comments to raise concerning either the report or supporting appendix material, except to raise a question concerning the evaluation of benefits anticipated from water conservation to be obtained through the control of phreatophytes.

We agree fully with the philosophy and reasons stated in paragraphs 101, 102, and 103 on pages 43 and 44. This approach is generally similar to procedure which we have followed in several surveys, primarily because of our conviction that evaluation of water conservation should at least partially reflect benefits to the dependent community. Our question, therefore, does not concern the procedure but rather the $6 per acre-foot value which seems to be quite conservative in view of the preponderance of specialized, high value crops produced in the Salt River area.

When funds become available, we expect to initiate a survey of watershed lands in this area and since your report contains much basic data which will be useful to us, we wish to retain your report in our files unless you prefer that it be returned.

Very truly yours,

/s/ Reed W. Bailey
REED W. BAILEY
Director

SPLGD 23 July 1951

Mr. Reed W. Bailey
Director, Intermountain Forest and
Range Experiment Station
Forest Service
U. S. Department of Agriculture
Forest Service Building
Ogden, Utah

Dear Sir:

Thank you for your letter of 13 July 1951 commenting upon the interim report on flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona.

It is noted that you have no comments to raise concerning either the report or supporting appendix material, except to raise a question concerning the evaluation of the water-conservation benefits.

It is true that the $6 per acre-foot value is a conservative figure, but not unduly so. The unit value applies to the value of water in Buckeye and Arlington Valleys and in the areas below Gillespie Dam, all in Maricopa County. According to the United States Geological Survey (see page 13 of Appendix 6), "probably not more than 20 percent of the salvaged water would be available to the Buckeye Canal and possibly another 20 percent would be available to the Arlington Canal. The remaining 60 percent would be available to canals and wells along the Gila River below the Arlington Canal intake, but within the limits of Maricopa County." The average value of crops is not so high in these areas as in the Phoenix area.

A copy of your letter will be forwarded to the Chief of Engineers, Washington, D. C., for his consideration.

Your promptness in reviewing the report and submitting your comments is appreciated.

Very truly yours,

W. R. SHULER
Colonel, Corps of Engineers
District Engineer

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
SOUTHWESTERN REGION
Post Office Building
Albuquerque, New Mexico

D
COOPERATION
FIARBC
Corps of Engineers-L.A. Dist.
Gila River Basin

August 9, 1951

District Engineer
Los Angeles District
P.O. Box 17277, Foy Station
Los Angeles 17, California

Dear Sir:

Reference is made to your letter of June 28, File SPLGD, and the "Interim Report on Survey, Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona", which was enclosed.

We are interested in your discussion of "Floods of Record" that listed the flood of 1891 as being the largest. It may be significant that this date coincides with the period of the great increase in livestock numbers in the southwest. The rather frequent recurrence of subsequent floods, the ultimate channel erosion and sedimentation problem of the present, might well be closely associated with overgrazing and abuse of watershed lands that started before the turn of the century.

In paragraph 20, "Vegetation", you state that "overgrazing has destroyed much grass, which has been replaced by rabbitbrush and snakeweed over large areas". This loss of grass has undoubtedly reduced the rate of infiltration which in turn would increase surface run-off and summer floods peaks. A program to restore the grass and herbaceous cover would reduce future flood peaks and aid in erosion control, and lengthen the effective life of downstream structures. We believe the report might include some such statement. This subject has been studied at the Southwestern Forest and Range Experiment Station at Tucson. These studies at Sierra Ancha are reported in their report "Watershed Research Aids Salt River Valley", a mimeographed publication dated 1947.

Many of the high water yielding areas of the watershed are within National Forests. The objective is to administer these lands in such a way that the watershed function is not impaired. In some places the vegetative cover is not sufficient to control erosion and provide for proper watershed functions. In these places we are taking corrective action as rapidly as possible under present limitation.

It is noted that as a result of the studies covered by the report the District Engineer recommends: The adoption of a project incorporating short levees along Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe, and channel improvements along Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam. He also recommends that flood-control storage be included in the planning and authorization for a terminal-storage reservoir at the McDowell site.

This office recognizes the need for channel clearing and levee work where proposed in the report. Improved watershed conditions would lengthen the life of major channel improvements by retaining sediment in place on the watershed. This improvement should be accomplished not later than concurrently with heavy channel works. The flood-control survey by the Department of Agriculture has been authorized for the area being considered but has not been accomplished. Early completion of this survey and the program to be proposed for the watershed is desirable.

This office has no suggestions to offer in regard to the report. Your kindness in making it available for review is appreciated.

The report (No. 32) is being sent to the Southwestern Forest and Range Experiment Station, Tucson, Arizona for review and information. In case that office of the Forest Service has important comments in regard to the report, these will be forwarded to you.

Sincerely yours,

O. OTTO LINDH, Regional Forester

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
SOUTHWESTERN REGION

P. O. Box 1310
Albuquerque, New Mexico

M
COOPERATION
CORPS OF ENGINEERS

January 15, 1958

Mr. H. W. Thompson
Chief, Engineering Division
Corps of Engineers
P. O. Box 17277, Foy Station
Los Angeles 17, California

Dear Mr. Thompson:

We appreciate receiving a revised copy of the Interim Report on the Gila and Salt Rivers which was transmitted by your letter of January 8.

These reports, even though the structures do not affect national forest land, complete our file on river basin work and are valuable to us for reference purposes. We have no comments to make other than those made in our letter of August 9, 1951.

Very truly yours,

FRED H. KENNEDY, Regional Forester

/s/ By W. L. Hansen

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
Washington 25, D. C.

FP
COOPERATION
ICWR, Department of Army
(Corps of Engineers - Gila River)

March 4, 1958

AIRMAIL

Mr. H. W. Thompson, Chief
Engineering Division
U. S. Army Engineer District
P. O. Box 17277
Foy Station
Los Angeles, California

Dear Mr. Thompson:

Several weeks ago you forwarded a draft copy of your interim report on flood control improvements, Gila and Salt Rivers - Gillespie Dam to McDowell Dam site, Arizona.

This report and your request for review and comment was delayed considerably in reaching me since I have been absent from my Ogden office on an extended detail.

I have no additional comments to make on your report at this time. However, I am forwarding the copy which I received to the Regional Forester, U. S. Forest Service, Albuquerque, New Mexico, with a request that he write you directly concerning any comments which he may desire to make.

Very truly yours,

/s/ Henry L. Lobenstein
HENRY L. LOBENSTEIN
Forest Service Liaison Representative
Pacific Southwest Interagency Committee

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Office of the Regional Director
Albuquerque, New Mexico
P. O. Box 1306

April 13, 1951

Lt. Col. W. R. Shuler
District Engineer
Corps of Engineers, U. S. Army
Post Office Box 17277, Foy Station
Los Angeles 17, California

Dear Colonel Shuler:

Reference is made to your letter dated 26 February 1951, File PSLGD 800.92, in which you request our comments on the plan for flood control to be recommended in your forthcoming report on survey, flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona.

It is our understanding that the features to be recommended in the plan would consist of short levees along the Salt River from 40th Street in the City of Phoenix to the City of Tempe, and channel improvements along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam. The short levees would consist of (1) a levee along the left bank of Salt River for about 2,000 feet from Tempe Butte to the Southern Pacific Railroad bridge embankment, and (2) a levee along the right bank of Salt River for about 16,700 feet from the Southern Pacific Railroad embankment to 40th Street, Phoenix. The channel improvements would consist of a cleared floodway and low-flow channels. A floodway 2,000 feet in width would be created by clearing river bottom vegetation along the Gila River from Gillespie Dam to the mouth of Salt River and along Salt River from its mouth to Granite Reef Dam. Two low-flow channels within the cleared floodway, the first along Gila River from Gillespie Dam to a point about one mile downstream from the mouth of Agua Fria River, and the second along Salt River upstream from the highway bridge at Tempe, would be included in the plan. The report will also point out that the addition of flood control storage at the McDowell Reservoir site (proposed by the Bureau of Reclamation in a report on the Central Arizona Project) is justified when a reservoir at the site is authorized and approved for construction.

The projects briefly outlined above would affect the fish and wildlife which now exist in the approximately 70 miles of river bottom lands between Granite Reef Dam and Gillespie Dam. Generally, stream flows in this reach are low--the river consisting of a shallow, narrow

ribbon of water bordered by thick and extensive stands of saltcedar with some willow, cottonwood, mesquite, and arrowweed. Except during flash floods along the lower reaches of the Salt River, the water from the river is all diverted at the Granite Reef Dam for irrigation of the area north of the Salt and Gila Rivers.

Fisheries - The fishery resources of the project site are of little importance. A few channel catfish, bluegills, and large-mouth black bass are taken from the pools from below the mouth of Salt River. Construction of a low flow channel would probably eliminate this meager fishery.

Wildlife - Wildlife resources are of considerable importance, especially on that part of the project area below the mouth of Salt River. Game animals found on the area consist of mourning doves, white-winged doves, Gambel's quails, cottontails, jack rabbits, and waterfowl. The upper portion of the project, lying within, and adjacent to, the Salt River Indian Reservation, contains some quail habitat and is used for nesting by both mourning doves and white-winged doves. The entire project area is used to some extent by the white-winged doves which are found in great numbers along the Gila River just above the mouth of Salt River.

Below the mouth of Salt River water is found in the river channel at all times. The presence of water, cultivated crops north of the river, and suitable nesting cover south of the river makes this a good habitat for quails. There are a few areas of brushland south of the river which are being cleared for irrigated cropland, but this is still so limited and scattered that it tends to improve the quail habitat. The presence of water along this section of the Gila River attracts a considerable number of waterfowl during the fall and spring migrations and some teals and shovellers winter here. The area is grazed heavily and this results in limiting the desirable wildlife food and cover plants as, for the most part, these are taken first by the cattle. Desert mule deer are found on the higher ground south of the Gila River, but they do not use the proposed project area.

The proposed channel improvements would have little effect upon the wildlife resources of the project site. It would greatly reduce, but not eliminate, the saltcedar growth along the improved sections of the Salt and Gila Rivers. Saltcedar has little value to wildlife except for protection in stormy weather. It provides little, if any food. It is used to a considerable extent by nesting doves, but mesquite serves this purpose at least as well. It is assumed that the recommended low flow channel would result in the loss of the present waterfowl habitat along the Gila section of the project.

The Arizona Game Department is planning the development of two waterfowl areas adjacent to the Gila River, between the town of Buckeye and Gillespie Dam. It does not appear that the proposed floodway would seriously affect these plans; however, future investigations would clarify this point.

Recommendations - Provided some other form of vegetation is planned to help prevent the reestablishment of the saltcedar, consideration should be given to those species which would have some value to wildlife as well as serving their primary purpose of retarding the growth of saltcedar. Continued grazing on the floodway would encourage the regrowth of saltcedar and limit the wildlife value of the project area.

The proposed plan of improvement would probably necessitate the use of heavy equipment in clearing the floodway and constructing the low flow channel. If, in connection with this work, shallow depressions of about one-tenth acre could be excavated to below the normal water table in the floodway area, there would result a considerable waterfowl value. Such excavation, if they could be made without reducing the effectiveness of the floodway, would compensate for the destruction of the existing waterfowl habitat and create new waterfowl habitat of a value more than commensurate with their cost of construction.

Your consideration of fish and wildlife interests in this project is sincerely appreciated. We would like to have an opportunity to participate in the future planning for this project at such time as the project may be authorized.

Yours very truly,

/s/ John C. Gatlin
John C. Gatlin
Regional Director

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
Post Office Box 1695
Albuquerque, New Mexico

July 26, 1951

Lt. Col. W. R. Shuler
District Engineer
Los Angeles District
Corps of Engineers
P. O. Box 17277, Foy Station
Los Angeles 17, California

Dear Sir:

Reference is made to your letter of June 28, 1951 (File SPLGD), in which you request our comments on the proposed interim survey report on flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated 8 June 1951.

We have reviewed the interim report and appendixes (No. 36) and have no comment to offer. Based upon a review of the report, very little land under the jurisdiction of the Bureau of Land Management will affect or be affected by the contemplated flood control projects described.

We thank you for the opportunity of reviewing this report and are retaining the copies for our files and future reference.

Very truly yours,

/s/ Harold T. Tysk
Harold T. Tysk
Acting Regional Administrator

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF INDIAN AFFAIRS
FIELD SERVICE
Phoenix Area Office
P. O. Box 7007
Phoenix, Arizona

July 10, 1951

Colonel W. R. Schuler
District Engineer
Corps of Engineers
P. O. Box 17277
Los Angeles 17, California

Dear Sir:

This is to acknowledge receipt of your letter of 28 June 1951 (File SPLGD) and the transmitted copy of the proposed interim survey report on flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated 8 June 1951.

Your sending of the copy of the proposed report is appreciated.

It is noted that practically all of the irrigated lands and about half of the grazing lands of the Fort McDowell Indian Reservation would be flooded if the flood-control storage in a multiple-purpose reservoir at the McDowell site is provided.

Also there may be a possibility that improved channel conditions on Salt River above its mouth will deliver more water into the Gila River than the channel of the Gila will carry away without backing water up the Gila above the mouth of the Salt and thus flooding Indian lands. This would be most likely if maintenance on the Gila River portion of the proposed channel improvement is neglected.

The above comments are offered, although your letter did not specifically ask for comments.

When the time is appropriate for making formal comments regarding the report, please advise.

Very truly yours

/s/ L. L. Nelson
for Ralph M. Gelvin
Director, Phoenix Area Office

SPLGD 23 July 1951

Mr. Ralph M. Gelvin
Director, Phoenix Area Office
Office of Indian Affairs
P. O. Box 7007
Phoenix, Arizona

Dear Sir:

Thank you for your letter of 10 July 1951 commenting on the interim survey report on flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site.

The flooding of practically all of the irrigated lands and about half of the grazing lands of the Fort McDowell Indian Reservation was given full consideration in the report. Agreement to maintain the entire cleared channel on Salt and Gila Rivers between Granite Reef and Gillespie Dams is one of the conditions that is required of a responsible organization of local interests prior to initiation of construction. Therefore, the probability of Salt River flows' flooding Indian lands along Gila River above the mouth of Salt River as a result of inadequate maintenance of the Gila River cleared channel is considered unlikely.

A copy of your letter will be forwarded to the Chief of Engineers, Washington, D. C., for his consideration. Formal submission to the Secretary of the Interior will be made by the Chief of Engineers in accordance with the Flood Control Act approved 22 December 1944.

Your promptness in submitting your comments is appreciated.

Very truly yours,

W. R. SHULER
Colonel, Corps of Engineers
District Engineer

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF INDIAN AFFAIRS
Phoenix Area Office
P.O. Box 7007
Phoenix, Arizona

December 11, 1951

John R. Jannarone
Lt. Col., Corps of Engineers
Acting District Engineer
751 South Figueroa Street
Los Angeles 17, California

Dear Sir:

This is to acknowledge receipt of your letter of 27 November 1951 (file SPLGD) and the transmitted material covering minor changes in the proposed interim report on survey, flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona, dated 8 June 1951.

An inspection of the changes indicates that they do not affect the general conclusions which have been made, nor do they warrant any changes in the comments which this office submitted to you in our letter of 10 July 1951. However, we take this opportunity to emphasize the fact that practically all of the irrigated lands and about half of the grazing lands of the Fort McDowell Indian Reservation would be flooded if the flood control storage in a multiple purpose reservoir at the Fort McDowell site is provided. We realize that flood control storage is part of an alternate plan which is not recommended at this time in your interim survey report, but is proposed for construction if and when the Central Arizona Project's terminal reservoir is constructed. The flooding of the Fort McDowell Reservation would necessitate moving the tribe of Indians occupying this reservation, and we doubt that the $300,000 set up in the cost estimate for Lands, Easements and Rights of Way would be sufficient.

We also desire to call attention again to the possibility that improved channel conditions and levees along Salt River above its mouth, as provided in the recommended plan, will deliver a greater flood peak into Gila River than possible under present conditions and unless the channel of Gila River downstream is maintained with adequate capacity there may be flooding of Indian lands at the lower end of Gila River, caused by back water from Salt River floods.

Articles 109 and 112 mention coordination with other agencies. Statements concerning comments of the Phoenix Area Office of the

Bureau of Indian Affairs pointing out the situation mentioned above have not been included. Possibly you have omitted mention of our comments because you desire that the Chief of Engineers decide whether or not these comments should be included in the interim report.

Very truly yours,

/s/ Ralph M. Gelvin
Ralph M. Gelvin
Area Director

SPLGD 28 December 1951

Mr. Ralph M. Gelvin
Area Director
Office of Indian Affairs
P. O. Box 7007
Phoenix, Arizona

Dear Sir:

Thank you for your letter of 11 December 1951 commenting on the interim survey report on flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site.

You state that an inspection of the changes indicates that they do not affect the general conclusions that have been made and do not warrant any changes in the comments that your office submitted in the letter dated 10 July 1951.

You express a fear that improved channel conditions and levees along Salt River above its mouth, as provided in the recommended plan, may result in a greater flood peak on Gila River than possible under present conditions; and that unless the channel of Gila River downstream is maintained with adequate capacity, backwater from Salt River floods might flood Indian lands along Gila River above the mouth of Salt River. At present about 90 percent of the dense vegetative growth that will be cleared is in the bed of Gila River. The remaining 10 percent is in the bed of Salt River mostly near the mouth of the river and near Tempe.

The recommended clearing along Gila River will provide an escape channel for flood flows and thereby reduce such flooding of Indian lands as would result from direct flow or from backwater conditions created by the present channel growth. Agreement to maintain the entire cleared channel on Salt and Gila Rivers between Granite Reef and Gillespie Dams is one of the conditions that is required of a responsible organization of local interests prior to initiation of construction. Therefore, the probability of Salt River flows' flooding Indian lands along Gila River above the mouth of Salt River as a result of inadequate maintenance of the Gila River cleared channel is considered unlikely.

The flooding of practically all of the irrigated lands and about half of the grazing lands of the Fort McDowell Indian Reservation was given consideration in the report. However, because the report could not recommend construction of McDowell Reservoir for multiple purposes, including flood control, at this time, the cost of lands, easements, and rights-of-way were not investigated in detail. It is also pointed out that this office considered only the justification of adding

flood-control storage to the proposed terminal storage reservoir at the McDowell site. Therefore, we were concerned mostly with the difference in cost of construction of a multiple-purpose reservoir and a reservoir for terminal storage alone. Furthermore, rights-of-way are only a relatively minor item in the total cost of the project.

A copy of your letter will be forwarded with the report to the Chief of Engineers, Washington, D. C., for his consideration.

Your promptness in submitting your comments is appreciated.

Very truly yours,

W. R. SHULER
Colonel, Corps of Engineers
District Engineer

STATE LAND DEPARTMENT
STATE OF ARIZONA
PHOENIX, ARIZONA

December 4, 1951

Colonel W. R. Shuler
District Engineer
Corps of Engineers, U. S. Army
751 South Figueroa Street
Los Angeles 17, California

Dear Sir:

Reference is made to your letter of November 23d with respect to your report on flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, and forwarding to me the changes that have been made since the original interim report was made June 8, 1951.

In connection with this report I wish to advise that I have reviewed the interim report together with the changes recently forwarded to me, and I have no suggestions to make with respect to it. I think the work as outlined in the report, when completed, will afford protection to the area with the possible exception of extreme conditions. Even under such extreme conditions the protection afforded will be of material advantage.

Thanking you for sending me copies of the report, I am

Very truly yours,

/s/ W. W. Lane
W. W. Lane
State Land Commissioner

ARIZONA HIGHWAY DEPARTMENT

PHOENIX, ARIZONA

February 17th, 1958

Mr. H. W. Thompson
Chief, Engineering Division
U. S. Army Engineer District,
Los Angeles
Corps of Engineers
751 South Figueroa Street
Los Angeles 17, California

RE: SPLGP-F

Dear Mr. Thompson:

Reference is made to your letter of January 8th, with a copy of the interim survey report for flood control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam site, Arizona.

Subject to further study, I had no specific comment at this time except that I concur with the report in general.

Thank you for a copy of this report and for keeping me informed on this project.

Very truly yours,

WM. E. WILLEY
State Highway Engineer

/s/ Martin Toney
MARTIN TONEY
Engineer of Bridges & Dams

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SACRAMENTO

February 4, 1958

Colonel Carroll T. Newton, District Engineer
Los Angeles District
U. S. Army Corps of Engineers
P. O. Box 17277, Foy Station
Los Angeles 17, California

Attention: Mr. H. W. Thompson, Chief
Engineering Division

Dear Colonel Newton:

Reference is made to your letter of January 8, 1958, transmitting for our information a copy of your "Interim Report on Survey for Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona," dated December 4, 1957.

The report which proposes construction of short levees along the Salt River between 40th Street, Phoenix, and Tempe Butte, Tempe, and removal of phreatophytes along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam was inspected with great interest. The proposed channel improvement would undoubtedly increase flood peaks downstream, but would not appear to affect flows in the Colorado River bordering California, especially after completion of Painted Rock Dam. It is noted the report states that removal of native vegetation along the Gila and Salt Rivers would increase the safe yield from the ground water reservoir in the project area.

This Department greatly appreciates receipt of this report and being kept informed of flood control and water conservation projects proposed in California and adjoining states.

Very truly yours,

/s/ Harvey O. Banks
HARVEY O. BANKS
Director

UNITED STATES
DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE
Bureau of Sport Fisheries and Wildlife

OFFICE OF THE REGIONAL DIRECTOR
Albuquerque, New Mexico
P. O. Box 1306

2-RB

AIR MAIL
SPECIAL DELIVERY

December 2, 1958

Colonel C. T. Newton
District Engineer
Los Angeles District
Corps of Engineers, U. S. Army
751 South Figueroa Street
Los Angeles 17, California

Dear Colonel Newton:

The following comments constitute our report on the "Interim Report on Survey for Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona," dated December 4, 1957, corrected to August 27, 1958.

The plan proposes short levees along the Salt River between 40th Street, Phoenix, and Tempe Butte; clearing of a 2,000-foot channel along the Gila and Salt Rivers from Gillespie Dam to Granite Reef Dam (McDowell Dam Site); and channelization at two sites--one within the cleared floodway from Gillespie Dam to a point 1 mile downstream from the mouth of the Agua Fria River and the other, a 2-mile stretch, just upstream from the highway bridge at Tempe.

Since the reach of Salt River extending from Granite Reef Dam downstream through Tempe and Phoenix is only sparsely vegetated, usually dewatered, and largely within what is rapidly becoming an urbanized area, its fish and wildlife values are considered insignificant.

As a decided contrast, the reach of the Salt and Gila Rivers downstream from Phoenix is an important wildlife area.

This report is accordingly concerned with the effects of the proposed project upon fish and on wildlife in the 45-mile reach of the Gila and Salt Rivers, extending upstream from Gillespie Dam to a point about 5 miles above their confluence. (See map) It is our understanding that channel rectification and clearing in this 45-mile reach is proposed for flood control in the immediate agricultural area and is not essential for flood prevention for the city of Phoenix.

Due to dewatering there is no fishery in the Salt River from Granite Reef Dam downstream through the City of Phoenix. Below Phoenix, the Salt and Gila Rivers retain permanent pools. Water quality and habitat, however, are not generally satisfactory for the survival of significant numbers of game fishes, and the proposed project is not likely to cause a significant change in fishing opportunities for the people of the area.

Without the project, the 45-mile reach of the Salt and Gila Rivers will continue to offer some of the finest dove hunting in the Nation. In addition, the area will provide the only permanent source of waterfowl hunting for a future Central Arizona population that is expected to approximate 2 million people within the next 50 years. Substantial quail and rabbit hunting opportunities will also be afforded by this portion of the project area.

Originally, small-game populations in the broad valley of the Gila were unconfined and well distributed along the many large washes and tributaries emptying into the Gila River. As agriculture advanced and more land was cleared and leveled to grow crops, these washes gradually disappeared until at present the only small-game habitat remaining in this valley is restricted to the bottom-land thickets of the Gila River and to a few of the major washes.

The extensive desert areas bordering the Gila River Valley also provide small-game hunting. However, if we were to weigh desert hunting against river-bottom hunting, the river-bottom hunting would be far superior in terms of hunter success and the variety of small-game species available.

Dove hunting in Arizona is unsurpassed. There is no other State in which a hunter is permitted to take more than 10 white-winged doves. Yet, in Arizona, a bag of 25 white-winged doves is permitted in addition to the 10-bird limit of mourning doves. Moreover, no other State can match the Arizona dove hunter's success, which in 1957 was 16.4 doves per hunter on the opening day and 13.0 per hunter-day for the entire season. Doves are hunted during the entire month of September, and the long season and high hunter success attracts sportsmen from all over the United States.

In recent years there has been a rapid increase in the number of dove hunters. This increase has been due to the generous bag limit, an abundance of white-winged and mourning doves, increased prosperity, a rapid population expansion, and an overall demand for more recreation. In view of the anticipated population growth of Maricopa County, to 1,000,000 within the next 17 years, the local hunting pressure is certain to increase tremendously. Arizona, with a 93.7 percent 19-year gain in population, is the Nation's second most rapidly growing State and the greatest part of this growth is occurring in the Phoenix area. Another factor contributing to increased future dove use will be the necessity for the Arizona Game and Fish Department to direct more hunting pressure on doves as hunting pressure on big game and other species exceeds the possible supply.

Regarding dove hunting, most of the above-mentioned pressure is and will continue to be centered in one locality. This locality is the Gila and Salt River bottoms beginning north of Phoenix and continuing along the Gila River to Gillespie Dam. White-winged doves nest in large colonies in the bottom-land thickets and many winter in this same area. Large numbers of mourning doves also nest and winter here. Moreover, both white-winged and mourning doves make extensive use of the area during migration. There is no other place in Central Arizona which can offer as much hunting opportunity for small game. In 1957, the Arizona Game and Fish Department calculated 12,597 man-days of dove hunting in the area, and this use represented only a part of the potential.

For one basic reason, desert dove hunting can never be considered an alternative or substitute for river-bottom hunting. The unsurpassed bottom-land hunting is due to the large flights of white-winged doves which nest in the thickets along the river in concentrated colonies. In the fall of the year, their feeding flights from roosts in these thickets to the nearby grain fields provide hunters with the chance to bag a limit from one stand. These thickets are an absolute necessity to the maintenance of high-quality dove hunting for the people of Arizona and for many nonresidents. In fact, this area is one of the few remaining places in the entire nation where white-winged doves can be seen in such concentrations.

In view of the foregoing facts, the average annual use of the 11,500 acres of river-bottom thickets to be cleared in the 45-mile reach above Gillespie Dam is estimated to be 30,000 dove-hunter-days during a 50-year period of analysis without the project.

Quail hunting is another popular sport in Arizona for which there is a continual demand for more and better hunting. At present, quail hunting occurs primarily in the desert areas, not because the desert provides more quail to hunt, but because the hunting conditions are more favorable. The mesquite and salt cedar thickets along the Gila River provide excellent cover and will support very high populations of Gambel's quail whenever food is available. This bottom-land habitat will provide a vast reserve of huntable birds for the not distant future when it will become necessary to manage these thickets more intensively. The thick growth is presently the primary deterrent to hunters. With some selective thinning of coppice and other management measures, the river bottom will provide a more productive area to manage for quail than the desert areas. The day when such management will be necessary is very near.

Average annual hunter use of the river-bottom thickets along the 45-mile reach above Gillespie Dam is estimated to be 2,000 quail hunter-days during a 50-year period of analysis without the project.

Cottontail rabbit hunting, like quail hunting, is also more popular on the desert simply because hunting conditions are more favorable. The bottom-land thickets, however, provide suitable habitat for the cottontail, and a future management plan for quail will also benefit rabbit hunting. Although rabbit hunting has not been the popular sport

in Arizona that it has been in many of the eastern states, it is anticipated that with a future increase in hunting demand of future years this sport will increase in popularity. Average annual use is estimated at 2,000 rabbit-hunter-days without the project.

The Arizona Game and Fish Department has had many requests from local sportsmen to establish more small-game species. At present, the Department is attempting to establish the chukar partridge in the wild. If, however, the need arises for public hunting areas where exotics such as the pheasant must be released on a put-and-take basis in order to meet public demands, it is likely that the Gila River bottom would provide the best areas for such practices.

The vast areas and washes in Central Arizona which were formerly inhabited by large populations of quail, rabbits, and nesting doves have been reduced gradually by agricultural practices, until at present the Gila River bottom lands offer the only remaining habitat that will support large populations of small game. Most of these thickets must be preserved, if the people of Arizona and neighboring states are to have the benefit of the few remaining large colonies of nesting white-winged doves as well as other small-game animals.

As might be expected in the desert of Central Arizona, waterfowl hunting is concentrated in the few areas of permanent water. The larger reservoirs, generally because of their lack of waterfowl food and location at the edge of the mountains a long distance from agricultural lands, offer only resting areas. As a result, both migrating and wintering waterfowl concentrate in any small pools which they can find near the food supplies offered by irrigated lands.

The 45 miles of the Gila and Salt Rivers upstream from Gillespie Dam comprise the one major area where a significant amount of water is available for waterfowl use adjacent to irrigated lands. The river meanders through dense, ofer impenetrable thickets of salt cedar and mesquite which protect the birds from outside disturbances and create ideal refuge. This situation exists despite the fact that the permanent pools usually do not exceed 60 feet in width. Hunters penetrate the thickets at road crossings and game trails from which they usually can hunt short distances up and downstream. Close spacing of hunters in the natural growth of the streamside thickets is surprisingly effective. Ducks principally baldpates, mallards, and green-winged teal, decoy readily to closely spaced blinds.

Anticipated average annual use of the area without the project is estimated as 20,000 duck-hunter-days.

This reach of river possesses more than a duck hunting value. It has been in many years the most important waterfowl wintering area in Arizona for mallards, baldpates, green-winged teal, and pintails. These birds spend about 4 winter months in the area, and it is this wintering population which has been largely responsible for the annual harvest of about 20,000 birds. The interest of the Arizona Game and Fish Department in this area has been evidenced by their withdrawal and acquisition of 6,856 acres along the subject reach of the Gila River for a waterfowl project.

In summation, the Gila River bottoms extending upstream 45 miles from Gillespie Dam offer the richest small-game resource in Arizona and potentially the finest small-game management area in the State. In fact, this is the last major nearby area where the people of Phoenix and surrounding communities will be able to hunt white-winged doves, mourning doves, and waterfowl.

The proposed project through channelization and clearing of a 2,000-foot floodway through the heart of this area will largely destroy waterfowl values. Permanent pools will be drained and bank-side cover will be destroyed. The project also will deplete white-winged and mourning doves resources by about 50 percent as a direct result of the destruction of about 11,500 acres of natural nesting and roosting habitat and escape cover. Quail and rabbit management opportunities will be reduced by approximately 25 percent. Annual maintenance of the 11,000 acres of cleared area will result in the destruction of plants which otherwise would offer winter food for quail and rabbits.

The ensuing losses will be about 18,000 days of duck hunting, 15,000 days of dove hunting, 500 days of quail hunting, and 500 days of rabbit hunting. Such losses in an area which has no other way to turn for comparable hunting are so serious that the Bureau of Sport Fisheries and Wildlife must object to construction of the project as presently planned for the 45-mile reach of the Gila and Salt Rivers, extending upstream from Gillespie Dam to a point 5 miles above the confluence of the Salt and Gila Rivers.

In view of the above-mentioned project losses we request particular attention to table 10, appendix 5 of your December 4, 1957, report, wherein you have indicated incremental benefit-cost ratios of 4.63, 2.06, 1.32 and 1.26, respectively, for channel-clearing widths of 500, 1,000, 1,500 and 2,000 feet. Inasmuch as clearing and maintenance and operation costs at 500 feet offer an incremental benefit-cost ratio much more favorable than at greater widths, please note that wildlife losses also would be much less at 500 feet than at the 2,000-foot width proposed in your report.

Accordingly, our recommendations, which pertain only to the 45-mile reach of the Salt and Gila Rivers immediately upstream from Gillespie Dam, are:

1. That an alternate project plan which would involve channel clearing to a maximum width of 500 feet rather than 2,000 feet be adopted.

2. That the cleared area be meandered, where feasible, to minimize destruction of dove habitat, and provide waterfowl use of the area.

3. That the low-flow channel be widely meandered within the cleared area.

4. That the low-flow channel be excavated to an incremental depth of at least 3 feet at intervals of about one-fourth of a mile to form a series of permanent pools throughout the 45-mile reach of river, with each pool at least 400 feet in length.

5. That the construction agency and those individuals or organizations charged with maintenance cooperate with the appropriate fish and wildlife conservation agencies during all phases of construction and maintenance to devise and apply means and methods for mitigatin fish and wildlife losses, particularly through the planting of wildlife food plants in parts of the cleared area.

6. That no herbicides toxic to fish and wildlife be used in the subject area without the written approval of the Arizona Game and Fish Department.

If the project is modified as suggested in all of the six foregoing recommendations, fish and wildlife losses can be largely avoided, and the project will not jeopardize the important public benefits which this area holds for the people of Arizona.

In the event, however, that the project is undertaken as currently planned with a 2,000-foot channel clearing, recommendations Nos. 2 through 6 should be adopted as a means of partial mitigation of wildlife losses.

Adoption of recommendations Nos. 2, 3, 4, and 5 would result in a reduction of dove losses from 15,000 dove-hunter-days to a loss of about 8,000 hunter-days. Complete mitigation of the remaining 7,000 dove-hunter-days by means of a dove development project would involve replacement of about 3,500 acres of habitat similar to the cleared area. Irrigated land of this type is not available at reasonable cost. If an attempt were made to purchase irrigated lands with values often in the vicinity of $1,000 per acre, the replacement and development cost of 3,500 acres could exceed $3,500,000. Mitigation of dove losses on the basis of such costly development is not considered justifiable.

Adoption of recommendations Nos. 2, 3, 4, and 5 also would reduce the estimated annual loss of 18,000 waterfowl-hunter-days to a loss of about 8,000 hunter-days. This remaining 8,000 hunter-days could be mitigated through development projects for waterfowl costing about $240,000 initially with annual operation and maintenance costs of $12,000. If recommendations Nos. 2, 3, 4, and 5 are not adopted, mitigation will need to be made entirely through acquisition and development of waterfowl management areas in the Gila River bottoms. The cost of this type of mitigation, exclusive of land acquisition, will amount to about $540,000 capital investment plus $27,000 annual operation and maintenance costs, for 18,000 hunter-days, or about

$30,000 investment and $1,500 annually, per 1,000 hunter-days. The costs of land acquisition are not estimated at this time due to the fact that the use of presently withdrawn lands will offer possibilities for solving this problem.

Adoption of recommendation No. 5 with proper use of winter food plants in the cleared area could completely mitigate the loss of 500 quail-hunter-days and 500 rabbit-hunter-days.

Recommendation No. 6 has been made to prevent the possibility of increasing the assigned wildlife losses.

Any modification of the plans for the project as presently proposed should be brought to the attention of the Bureau of Sport Fisheries and Wildlife in order that this report may be revised to reflect the effects of proposed changes in project plans.

Sincerely yours,

/s/ William T. Krummes
Acting Regional Director

SPLGP-F 12 January 1959

Regional Director
Fish and Wildlife Service
Bureau of Sport Fisheries and Wildlife
P. O. Box 1306
Albuquerque, N. Mex.

Dear Sir:

Receipt is acknowledged of your letter dated 2 December 1958 containing your revised comments on this office's report entitled "Interim Report on Survey for Flood Control, Gila and Salt Rivers, Gillespie Dam to McDowell Dam Site, Arizona," dated 4 December 1957.
* * *

* *

Your comments regarding the effect of the proposed plan of improvement on wildlife in the area are noted. You indicate that clearing the 2,000-foot channel along the Gila and Salt Rivers from Gillespie Dam to a point about 5 miles above the mouth of the Salt River would result in the following annual losses during a 50-year period:

18,000 days of duck hunting out of 20,000
15,000 days of dove hunting out of 30,000
500 days of quail hunting out of 2,000
500 days of rabbit hunting out of 2,000

Such conclusions are surprising, if you consider that we are proposing to clear only 9,300 acres out of a total phreatophyte area of 19,000 acres along the Gila River from Gillespie Dam to a point on the Salt River 5 miles upstream from the mouth. An additional phreatophyte area of 13,000 acres located along the Gila River from the mouth of Salt River to a point about 32 miles upstream remains untouched. It should also be noted that the phreatophyte area in Arizona, which exists in all parts of the State, has increased greatly since 1940. Informed opinion is that the phreatophyte area will continue to occupy greater areas in the future unless checked.

For a long time, water experts have recognized that phreatophytes pose a severe flood-control and water-conservation problem. The phreatophytes obstruct and restrict channel capacities of streams with resultant overflow and severe damage to adjoining properties. In addition, the consumptive water use of saltcedar, the principal phreatophyte in the area, is about twice the consumptive water use of cultivated crops. In a water-shortage area such as Arizona every effort must be made to conserve the existing water supplies. Unless water is available to sustain the economy of Arizona and unless floods are controlled, the needs for recreation will not exist. Interested Federal and State agencies, recognizing the need for further investigation on means of control and eradication of phreatophytes, have

formed the Phreatophyte Subcommittee in the Pacific Southwest Inter-Agency Committee with the aim of determining the best methods of destroying these undesirable phreatophytes. Mr. George Barclay of your Albuquerque office represents the Fish and Wildlife Service on this subcommittee, but has never presented any agency views against eliminating phreatophytic growth along southwestern streams.

We have given consideration to the six proposals listed in your letter and have the following comments regarding your suggestions:

1. "That an alternate project plan which would involve channel clearing to a maximum width of 500 feet rather than 2,000 feet be adopted." You refer to table 10 of appendix 5 of our report wherein we have indicated incremental benefit-cost ratios of 4.63, 2.06, 1.32, and 1.26, respectively, for channel clearing widths of 500, 1,000, 1,500, and 2,000 feet. Reference is made to the report entitled "Proposed Practices for Economic Analysis of River Basin Projects" prepared by the Subcommittee on Benefits and Costs of the Federal Inter-Agency River Basin Committee. This report is commonly referred to as the "Green Book." On pages 11-13, the economic limitations on scale of project development are discussed. It is emphasized here that "The scope or scale of development of a project should be established at the point where the net benefits from use of resources for project purposes are at a maximum. Net benefits are at a maximum when the scale of development is established at the point where the benefits added to the last increment of extension of scope are equal to the cost necessary to add that increment of scope to the project. * * * At the point of maximized net benefits, the total project benefits will necessarily exceed the total project costs by the maximum." Table 10, appendix 5, proved that, considering flood-control benefits only, increasing the width to 2,000 feet was justified. In addition, water-conservation benefits would further increase the justification of the 2,000-foot-wide clearing. If the channel width were reduced to 500 feet, flood-control benefits in the area would be reduced 50 percent and water-conservation benefits by 75 percent. The total reduction in benefits would amount to about $150,000 annually, compared with incremental annual charges of about $41,000 annually. Such large benefits, meeting the needs of local interests, should not be foregone, when justified by such a large margin.

2. "That the cleared area be meandered, where feasible, to minimize destruction of dove habitat, and provide waterfowl use of the area." At present, the stream channel meanders widely over the relatively flat bottom of a trench one-half to one mile wide. In laying out a floodway to carry large floods, it was realized that the floodflows would tend to follow straight courses; the high velocities would not permit the large meanders. At the same time, if flood control were to be effected, the 2,000-foot floodway would require the removal of the restriction - the river-bottom growth. In general, the cleared area might be meandered more than recommended, but probably

such increase in meanders would result in greater removal of phreatophytic growth - not less as implied. Meandering the channel to miss the phreatophyte areas would reduce the effectiveness of the floodway for flood control and for water conservation. We would be happy to develop, with your assistance, the optimum meandering for a floodway during the preparation of detailed plans for the area.

3. "That the low-flow channel be widely meandered within the cleared area." In laying out the floodway, the existing low-flow channel was not always included within the floodway area. To ensure that the floodflow would follow the floodway rather than the existing channel, it was necessary to include a low-flow or pilot channel in the plan. We realize it would be impracticable to maintain the course of any low-flow channel. The varying streamflows (including the varying sediment loads) would cause changes in the low-flow channel. After a short time, unless the low-flow channel were leveed, the stream slope (which would be reflected in the length of the course of the channel) would be restored to the same stream slope that now exists. Thus, meanders, similar to those existing, would be reflected in the low-flow channel after a short period of operation of the project. This matter will be discussed with you more fully during the preparation of detailed plans.

4. "That the low-flow channel be excavated to an incremental depth of at least 3 feet at intervals of about one-fourth of a mile to form a series of permanent pools throughout the 45-mile reach of river, with each pool at least 400 feet in length." These pools could be accomplished during construction, but they would be impracticable to maintain. As for the previous item, no attempt will be made to maintain a low-flow channel, once constructed. Any attempt to maintain such a channel would be very costly and could not be justified. The first flows (they need not be floodflows) would tend to change the regimen of the stream, as it attempts to restore the previous gradient. In addition, any stagnant pools might tend to breed mosquitoes and measures would have to be taken for the control of such insects.

5. "That the construction agency and those individuals or organizations charged with maintenance cooperate with the appropriate fish and wildlife conservation agencies during all phases of construction and maintenance to devise and apply means and methods for mitigating fish and wildlife losses, particularly through the planting of wildlife food plants in parts of the cleared area." This office can assure you that it would cooperate in every way to devise and apply means and methods for mitigating fish and wildlife losses, within the limits of our authority. It should be pointed out that maintenance of the floodway would be the responsibility of Maricopa County. The only property rights to be acquired for the project in this area would be flowage-easement rights and rights to keep the channel clear of phreatophytes and other encroachments.

6. "That no herbicides toxic to fish and wildlife be used in the subject area without the written approval of the Arizona

Game and Fish Department." This office recognizes that herbicides may be harmful not only to the fish and wildlife, but also to the cultivated crops. Therefore, unless a herbicide could be developed that would not be harmful to the crops and wildlife and the cost of application of such herbicide would be less than the cost of mechanical means of control, mechanical means would be utilized.

You also suggest that 8,000 waterfowl hunter-days could be mitigated through development projects for waterfowl costing about $240,000 initially with annual operation and maintenance costs of $12,000. Because of the intangible nature of the waterfowl losses that may result from clearing of the phreatophytes, this office does not consider that such waterfowl development projects should be made a part of the recommended plan of improvement.

It is hoped that these comments on your proposals will meet with your approval. If you feel it desirable, we would be pleased to have personnel from this office discuss the matter with you further. We are forwarding copies of your letter and of our reply to our higher authority for their consideration. After authorization of the project by Congress and after the appropriation of funds for advance planning, we shall be pleased to work out with you, in detail, the optimum plan of improvement to provide the required flood control and water conservation and, at the same time, to minimize any adverse effects on the wildlife resources. It is believed that any required changes are details that would not affect the overall conclusions and recommendations and can be worked out within the framework of the recommended plan of improvement.

Your letter of 2 December 1958 was forwarded to the Board of Supervisors of Maricopa County, Phoenix, Arizona, for its comments inasmuch as that agency is the sponsoring agency for the proposed plan of improvement and because suggested revisions in the plan would have involved additional costs for the project, part of which would have to be borne by that agency. A copy of the reply from the Board of Supervisors is inclosed. (That letter informed the Corps of Engineers that Maricopa County expresses its complete confidence in the design proposed by the Corps and urges that nothing be done to delay approval of funds for the final design and construction. The County also suggests that in preparing the final detailed design, the Corps might consider the recommendations contained on page 6 of the 2 December 1958 letter of the Fish and Wildlife Service with a view towards adopting those portions of the recommendations which may be adopted without otherwise increasing the initial cost or the cost of maintenance of the project, and which would not adversely affect the principal objective of the project, namely, flood protection.)

It should be noted that Maricopa County, in recognizing the need for flood control and storm-drain construction in the County and especially in view of the large increases in population taking place in the area, has formed the Maricopa Flood Control Agency with authority to undertake studies and construct flood-control improvements. The County

recognizes that the Salt and Gila Rivers are the major outlets for any additional flood-control work that may be undertaken and considers our recommended plan the first step in an overall comprehensive plan of improvement for the area.

This office has been advised that as a result of a meeting held on 30 October 1958 between members of the Board of Directors of the Maricopa Flood Control Agency and representatives of the Arizona Game and Fish Department, Mr. R. J. Smith, Director of the Arizona Game and Fish Department, has verbally notified the Maricopa Flood Control Agency that the Arizona Game and Fish Department has no objection to the report as written.

Very truly yours,

JOHN R. OSWALT, JR.
Lt. Col., Corps of Engineers
Deputy District Engineer