SUMMARY REPORT FOR FLOOD CONTROL
GILA FLOODWAY
MARICOPA AND PINAL COUNTIES, ARIZONA

PUBLISHED BY
U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT
SEPTEMBER 1977

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Summary Report for Flood Control

GILA FLOODWAY

Maricopa and Pinal Counties, Arizona

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September 1977

GILA FLOODWAY

MAIN REPORT

SYLLABUS

The study for flood control along the Gila Floodway was authorized under Section 6 of the Flood Control Act of 1938, which authorized and directed the Secretary of the Army to cause surveys for flood control of the Gila River and tributaries, Arizona and New Mexico. In October 1973, the Congress funded an interim study for the Gila Floodway portion of the drainage basin.

Historical accounts indicate that many large floods have occurred in the Gila River Basin. Recent recorded storms within the study area indicate a potential exists for a sizeable flood. A major flood, such as a standard project flood, would inundate a substantial portion of the study area and cause ponding behind manmade obstructions, such as canal levees, freeway embankments, and railroad embankments. A 100-year flood would inundate a much smaller area because of programs initiated ky the Soil Conservation Service (SCS) and also by local interests.

The Soil Conservation Service is constructing a watershed protection project in the eastern portion of the basin that provides facilities that would control runoff up to 100-year frequency flood magnitude for the drainage area east of the Roosevelt Water Conservation District Canal. In addition, local interests have instituted measures to provide local flood protection in the area west of the Roosevelt Water Conservation District Canal. The above two programs will significantly reduce flooding conditions that were experienced in the past. This study was made to determine the feasibility of constructing additional measures to convey floodflows away from populated areas.

Although the aggregate damages resulting from floods greater than a 100-year flood are large, the damages resulting from smaller floods are estimated to be small; thus, the average annual flood damages are not large enough to justify structural solutions. It is, therefore, recommended that no Federal improvements be utdertaken in the Gila Floodway study area at this time.

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SUMMARY REPORT FOR FLOOD CONTROL, GILA FLOODWAY

MARICOPA AND PINAL COUNTIES, ARIZONA

PURPOSE

This report summarizes the results of studies for flood control in the Gila floodway study area as shown on the attached maps (pls. 1, 2, and 3).

AUTHORIZATION

The study for flood control along the Gila floodway was authorized under Section 6 of the Flood Control Act of June 28, 1938, which authorized and directed the Secretary of the Army to cause surveys for flood control of the Gila River and tributaries, Arizona and New Mexico. In October 1973, the Congress funded an interim study for the Gila floodway portion of the drainage basin.

INVESTIGATION

PROBLEMS AND NEEDS

Early in the studies, coordination was instituted with an advisory committee of local citizens from the Mesa, Gilbert, Tempe, and Chandler area. This committee, which was composed of members representing diverse interests, was instrumental in identifying the problems and needs of the area and in developing alternative solutions to the problems. The committee recognized such secondary needs as conservation of water, water quality, recreation, open space, and esthetics, but concluded that flood control along the present stream alinement was a paramount need. The study area is shown on plate 1.

Although there is no long recorded history of floods in the Gila floodway study area, historical accounts indicated that many large floods have occurred in the Gila River Basin. Sizeable floods, whose magnitudes cannot be ascertained, occurred in 1833, 1862, 1869, and 1880. Major floods occurred in 1884, 1891, 1916, and 1938, but specific information for the Gila floodway basin is not available. General winter storms can cause flooding in the study area, but the most severe floods generally occur during the summer months as a result of localized thunderstorms often embedded in general summer storms.

Severe local storms occurred in and around the Gila floodway basin in 1921, 1926, 1929, 1930, 1933, 1935, 1936, 1939, 1943, 1946, 1952, 1954, 1955, 1957, 1959, 1963, 1964, 1966, 1967, 1969, 1970, 1971, and 1972. Information on storms and floods specific to the study area is sketchy, especially for earlier events. It is known that the town of Gilbert was hit by floods in 1926 and 1933, and again in the 1930's and 1940's. More recent events, such as the storm and flood of August 19, 1954, the storm and flood of October 31, 1957, and hydrologic studies make the potential for a sizeable flood evident.

The proposed Soil Conservation Service flood control structures that would protect the study area from floods originating upstream (east) from the Roosevelt Water Conservation District Canal were assumed to be in place in determining the hydrologic synthesis of floods and the corresponding overflow areas. Those facilities would provide protection from a 100-year flood. In addition, the proposed Superstition Freeway with its attendant drainage facilities were assumed to be in place. The drainage facilities, designed to convey a 50 year flood, would extend from the Roosevelt Canal westward to the Tempe Canal. Field surveys and analysis of aerial photographs and orthophoto quads determined the present development in the study area. The extent of future development in the study area was based on Office of Business Economics-Economics Research Service (OBERS) population projections and the Composite Land Use Plan for Maricopa County, Arizona, prepared by the Maricopa Association of Governments. Projections for future development were made in conformance with the National Flood Disaster Protection Act of 1973.

The overflow areas as delineated in this report were based on improvements and development projected to take place in the area as of 1980 and should not be used for flood insurance purposes. Flood insurance regulations require that the overflow area be delineated based on conditions existing at the time of the study.

PROBLEMS AREAS

The following subparagraphs summarize the results of the hydrologic studies, the overflow analysis, and the economic studies. The problem areas were divided as follows: (l) the City of Mesa along the north protection levee of the Superstition Freeway; (2) the City of Tempe; (3) the town of Gilbert; (4) the ponding area at the intersection of Baseline Road and Southern Pacific Railroad; (5) the Dobson Ranch development; (6) the City of Chandler; and (7) the main floodway in the vicinity of Interstate Highway 10. Damage estimates and property values are based on 1975 prices.

City of Mesa

Flooding in the City of Mesa is based on the assumption that the proposed Superstition Freeway with its attendant drainage facilities is assumed to be in place. The freeway and the drainage facilities designed to convey a 50-year flood, would extend from the Roosevelt Water Conservation District Canal to the Tempe Canal. Flooding would occur when major floods exceed the capacity of the drainage facilities and result in ponding along the north side of the freeway.

The standard project flood with a frequency of 500 years and a peak discharge of 6,700 cubic feet per second (cfs) would inundate about 1,835 acres along the north side of the freeway. The depth of inundation from ponding would average about 1.5 feet with a maximum depth of 3 feet, which would occur at the junction of Center Street and the Superstition Freeway. This flood would cause damages estimated at $3.0 million to property valued at $39.2 million.

The 100-year-frequency flood with a peak discharge of 3,500 cfs would cause ponding at the junction of Center Street and the Superstition Freeway to a maximum depth of 1.5 feet. This flood would cause damages estimated at $230,000 to property valued at $4.4 million.

Floods smaller than a 100-year flood would cause minimum damage. The resultant average annual flood damages are estimated at $56,000.

City of Tempe

Flooding in the City of Tempe results when major floods overtop the Tempe Canal and proceed northwestward through the city. The standard project flood would inundate about 2,200 acres to an average depth of about 3/4 foot. Property values subject to damage are presently estimated at $196.5 million. The flood would cause damages estimated at $8.2 million.

The Tempe Canal will contain floodflows up to a magnitude of about a 150-year flood. The resultant average annual flood damages in the City of Tempe are estimated at $32,000.

Town of Gilbert

Floodwaters from the southeast would be conveyed through the town of Gilbert along the embankment of the Southern Pacific Railroad. The standard project flood with a peak discharge of 4,000 cfs and a frequency of about 500 years would cause flooding to about 3,750 acres along the railroad embankment to an average depth of 2 feet. Damages to property valued at $7.9 million are estimated at $1.1 million.

The 100-year-frequency flood with a peak discharge of 600 cfs would inundate the Gilbert area to an average depth of 1 foot resulting in damages of $350,000 to property valued at $5.5 million. No appreciable damages would result from lesser floods. The average annual flood damages in Gilbert are estimated at $15,000.

Ponding at the junction of Baseline Road and Southern Pacific Railroad

Floodwaters from the east and from the town of Gilbert would pond at the junction of the Southern Pacific Railroad and Baseline Road 1/2 mile south of the proposed Superstition Freeway. The standard project flood with a peak discharge of 4,500 cfs and a frequency of 500 years would inundate approximately 920 acres to a depth of approximately 2 feet. The 100-year flood of 600 cfs would pond to a depth of approximately 1 foot.

Property values subject to damages from the standard project flood and the 100-year flood are estimated to be about $1.4 and $1.1 million, respectively. Damages from the standard project flood and the 100-year flood are estimated at $310,000 and $89,000, respectively. Minimal damage would occur from lesser floods. Average annual flood damages are estimated at $15,000.

Dobson Ranch

Floodwater from a standard project flood would overtop the Southern Pacific Railroad embankment near Baseline Road and flow westward into the Dobson Ranch residential development area where it would combine with flows in the Tempe channel and cause ponding to an average depth of 1.5 feet with a maximum of 3 feet to the residential development. The floodwaters would then breach the Western Canal and flow southwestward, flooding the Pima-Chandler Industrial Park. The standard project flood would inundate about1,760 acres. Damages are estimated at $5.4 million to property valued at $111.2 million.

No appreciable damage would occur from floods with a frequency of 120 years or less. The average annual flood damages are estimated at $24,000.

City of Chandler

Floodwaters from the east would pond in the City of Chandler along the Southern Pacific Railroad embankment. The standard project flood with a peak discharge of 5,000 cfs and a frequency of 500 years would pond to an average depth of 3 feet; would then overtop the railroad embankment to inundate the urban area west of the railroad tracks; and would then flow westward and inundate the Pima-Chandler Industrial Park. About 1,030 acres would be inundated by the standard project flood.

The 100-year flood with a peak discharge of 800 cfs would cause an average ponding depth of 1.5 feet on the east side of the railroad track embankment. No overtopping of the railroad embankment would occur from the 100-year flood.

Damages caused by the standard project flood are estimated at $8 million to property valued at $105.6 million. Damages caused by the 100-year flood would total $805,000 to property valued at $17.2 million. The average annual flood damages are estimated at $42,000.

Main floodway in the vicinity of Interstate Highway 10

Floodwaters from the standard project flood and the 100-year flood from the east and northeast would pond behind the Interstate Route 10 embankment. The standard project flood with a frequency of 500 years and a peak discharge of 19,000 cfs would pond to an average depth of 2 feet before overtopping the freeway; flows would then proceed west toward the Gila River. The 100-year-frequency flood with a peak discharge 2,500 cfs would pond to an average depth of 0.5 foot before overtopping the freeway and proceed west.

Damages caused by the standard project flood are estimated to total $1.1 million to property valued at $8.7 million. The overflow area would cover about 2,100 acres. Damages caused by the 100-year-frequency flood would total $100,000 to property valued at $8.3 million. Minimal damages would occur from lesser floods. The average annual flood damages are estimated at $115,000.

Appendix 1 presents the hydrologic studies in detail, and Appendix 2 provides detailed economic studies. Appendix 3 includes an environmental inventory of the study area.

Local ordinances and storm-drain systems

The City of Mesa is developing a storm drainage system in conjunction with the proposed freeway drainage system to handle flooding north of the Superstition Freeway. The freeway drainage system consists of a series of retention basins designed for a 50-year-frequency flood according to Arizona Department of Transportation (ADOT) criteria. The Mesa system, which has been integrated into the freeway drainage system, consist of main laterals designed for a 10-year-frequency flood with sublaterals designed for a 2-year-frequency flood. In September 1972, the City of Mesa established a subdivision ordinance requiring that all precipitation from a 50-year, 24-hour storm falling within a proposed subdivision be retained within the subdivision boundaries. The City of Chandler has developed a local storm drain plan that would afford a minimum 2-year storm protection to the city. The city also adopted an ordinance in late 1975 requiring that 50-year, 24-hour rainfall be retained on site in all future developments.

The town of Gilbert has no local storm-drain plan but, in September 1975, adopted an onsite retention ordinance similar to the Chandler ordinance. In September 1975, the county of Maricopa adopted an ordinance requiring that flow from a 100-year, 2-hour rainfall leaving a

developed area be no greater than the predevelopment flow. These local ordinances should provide some localized flood protection in the three communities and, in addition, should effectively reduce the impact of future developments on the flood hazards in the area.

ALTERNATIVE PLANS

The alternative plans considered fall into two groups: major channels and retention basins. The major channels, Alternatives A through D, would convey floodflows away from populated areas to either the Salt River or the Gila River and would protect all or parts of the populated portions of the study area from flooding. The retention-basin alternative would give protection from a single 100-year flood, but would not provide storage for additional floods occurring in rapid sequence. The basins would have to be emptied in order to provide subsequent protection. The retention basins, which would be similar to the retention basins adjacent to the Superstition Freeway, would provide floodwater storage for the town of Gilbert and the City of Chandler. Table 1 lists the costs and benefits of the major channels and the retention basins alternatives.

The following paragraphs describe briefly the major alternatives studied as possible solutions. Design, cost, and economic data were developed for the alternatives considered to a degree sufficient to determine their economic feasibility. Plate 3 shows the location of Alternatives A through D.

ALTERNATIVE A—MAJOR CHANNEL (STANDARD PROJECT FLOOD RUNOFF) TO THE GILA RIVER

is alternative would provide standard project flood protection to populated areas in Mesa, Tempe, Gilbert, and Chandler; to the Dobson Ranch development and the Pima-Chandler Industrial Park; and to ponding areas at the junction of Baseline Road and the Southern Pacific Railroad and at the main floodway in the vicinity of Interstate Highway 10. In order for this plan to function properly, the elements would have to include (1) modification of the Superstition Freeway drainage facilities, (2) a trapezoidal earth outlet channel from the freeway facility to the Gila River, a distance of about 23 miles, (3) a collection facility at Gilbert and a connecting earth channel flowing westward to the outlet channel a distance of about 6 miles, and (4) a collection system at Chandler and a connecting earth channel flowing westward to the outlet channel, a distance of about 6 miles.

Detailed studies on this alternative did not consider the costs of modifying the freeway facilities nor the costs of providing collection facilities at Gilbert and Chandler. Even without these necessary elements of the plan, first costs were estimated to be $27 million and average annual charges were estimated at $1.79 million. The average annual benefits from flood damages prevented are estimated at $299,000, comprising benefits from the following areas: Mesa, $56,000; Tempe, $32,000; ponding at Baseline Road and Southern Pacific Railroad, $15,000; Dobson Ranch, $24,000; Gilbert, $15,000; Chandler, $42,000; and the main floodway, $115,000. The benefit-cost ratio would be less than 0.2.

ALTERNATIVE B—MAJOR CHANNEL (100-YEAR-FLOOD RUNOFF) TO THE GILA RIVER

This alternative would be similar to Alternative A except that this plan would provide flood protection from a 100-year flood. The first cost, even without including the costs of modifying the freeway facilities and providing collection facilities, is estimated at $8.75 million, with average annual charges of $580,000. The average annual benefits are estimated at $94,000. The benefit-cost ratio would be less than 0.2.

ALTERNATIVE C—MAJOR CHANNEL (SYSTEM 25 MILES LONG) TO THE SALT RIVER

As formulated, Alternative C would consist of (1) modification of the freeway drainage facilities to convey the standard project flood; (2) a concrete-lined trapezoidal outlet channel from the freeway facilities northward to the Salt River, a distance of about 4 miles; (3) a concrete-lined trapezoidal channel from the town of Gilbert northwestward to the freeway facilities, a distance of about 5 miles; and (4) a concrete-lined trapezoidal channel from the City of Chandler northward to the freeway facilities, a distance of about 6 miles. The concrete lining is necessary to prevent erosion caused by steep gradients. Detailed cost estimate did not consider the cost of modifying the freeway facilities. Even without the freeway facilities modification, the first cost of this plan was found to be $18.4 million and the average annual charges were estimated at $1.22 million. The average annual benefits are estimated at $241,000, comprising benefits from the following areas: Mesa, $56,000; Chandler, $42,000; Gilbert, $15,000; ponding area, $15,000; Dobson Ranch, $24,000; Tempe, $32,000; and Pima-Chandler Industrial Park, $57,000. The benefit-cost ratio would then be 0.2.

ALTERNATIVE D—MAJOR CHANNEL (SYSTEM 14.5 MILES LONG) TO THE SALT RIVER

This alternative, which would provide standard project flood protection only for the Cities of Mesa and Tempe, would consist of modification of the freeway facilities and providing a concrete-lined trapezoidal outlet channel from the freeway facilities northward to the Salt River, a distance of about 4 miles. The outlet channel alone is estimated to cost about $5.0 million, with average annual charges amounting to $335,000. The average annual benefits of the plan are estimated at $88,000, comprising benefits of $56,000 to City of Mesa and $32,000 to the City of Tempe. Even without including the cost of modifying the freeway facilities, the benefit-cost ratio woult be less than 0.3.

ALTERNATIVE E—RETENTION BASINS IN GILBERT AND CHANDLER

This alternative plan, which would protect the town of Gilbert and the City of Chandler, would consist of retention basins of sufficient volume to retain the runoff from a 100-year-frequency flood. The first cost for the Gilbert basin is estimated at $970,000, with the average annual charges amounting to $65,000. The average annual benefits are estimated at $8,000. The benefit-cost ratio for the Gilbert retention basin would be 0.1.

The first cost for the Chandler basin is estimated at $820,000, with the average annual charges amounting to $54,000. The average annual benefits of the plan would be $22,000; and the benefit-cost ratio would be 0.4.

NONSTRUCTURAL SOLUTIONS

Nonstructural solutions are defined in this report as those flood plain management measures that have not been traditionally implemented as part of Corps' solutions to flood problems. Nonstructural solutions include, but are not limited to flood plain regulations, onsite storage regulations, floodproofing individual or groups of structures, and evacuation. Following is a summary of these solutions.

Flood plain regulations

Currently, the following regulations are being implemented, primarily to reduce the magnitude of future damages.

(1) *National Flood Insurance Act of 1968.* The National Flood Insurance Act of 1968 (Public Law 90-448) and its amendments encourage State and local governments to regulate the development of land that is exposed to flood damage and to guide the development of future construction away from locations threatened by flood hazards. The Flood Disaster Protection Act of 1973 (Public Law 93-234) requires, in part, that State and local communities, as a condition of Federal financial assistance, participate in the flood insurance program and adopt adequate flood plain ordinances with effective enforcement provisions consistent with Federal standards to reduce or avoid future flood losses. The act imposed serious sanctions on communities having flood hazards for nonparticipation in the flood insurance program. The sanctions for nonparticipation are basically that no lending institution regulated by an instrumentality of the Federal Government (such as Federal Deposit Insurance Corporation member banks and all savings and loan associations) may make any loans for any structure in the areas identified as having flood hazards by the Federal Insurance Administration, Department of Housing and Urban Development. In addition, communities participating in the flood insurance program are required to adopt and enforce certain land-use regulations applicable to residential, commercial, and industrial construction in flood hazard areas.

(2) *State of Arizona Preventive Flood Control Law.* In compliance with these acts, the Governor of the State of Arizona approved an act on 3 May 1973 (House Bill 2010) providing for flood plain management within the State. The purpose of the act is to empower, encourage, and assist cities, towns, and counties of the State to establish appropriate regulations for a flood plain management program along watercourses, streams, and lakes, The act requires, in part, that local governments delineate flood plains within their jurisdiction and adopt flood plain regulations that (a) regulate construction and uses that may divert, retard, or obstruct floodwater; (b) establish minimum flood-protection elevations and flood-damage prevention requirements for uses vulnerable to flood damage; and (c) require that any dwelling built within a flood plain shall be constructed so as to place the minimum floor elevation above the highwater line of the 100-year flood. In part, the regulations are designed to minimize flood damages, reduce the height and violence of floods that are caused by obstructions restricting the capacity of the floodways, and prevent unwise encroachment and development within the flood plain areas.

(3) *Flood Plain Regulations for Maricopa County.* Flood plain regulations for the unincorporated areas of Maricopa County were initially adopted by the Board of Supervisors of Maricopa County, Arizona on 25 February 1974. On 14 July 1975, the Board adopted an improved regulation titled "Floodplain Regulations for the Unincorporated Area of Maricopa County." The purpose of this regulation is: "to promote and protect the public health, peace, safety, comfort, convenience, and general welfare of the citizens of the unincorporated area of Maricopa County; to minimize flood damages and reduce the height and violence of floods which are caused by obstructions restricting the capacity of floodways; to establish minimum flood protection elevations and flood damage prevention requirements for uses, structures and facilities which are vulnerable to flood damage; to prevent unwise encroachment and building development with floodplain areas; to protect the life and property of citizens who have settled in floodplain areas; to reduce the burden imposed on the community, its governmental units, and its citizens if such land is subject to flood; and to adopt and establish an official Floodplain Management Plan and Regulation for Maricopa County, Arizona." In accordance with the county's regulation, flood plain areas are divided into two districts, the Floodway District and Floodway Fringe District. The Floodway District, as defined in the act, is the area necessary to provide for the passage of the 100-year flood. The Floodway Fringe District is the land outside the Floodway District and lower than the 100-year flood elevation. Prior to occupancy or use of any structures or areas in the regulatory flood plain, a "Certificate of Compliance of Floodplain Use"

must be obtained. "No use is allowed which shall adversely affect the capacity of the channels or floodways. . ." Uses that do not obstruct flow and have a "low flood damage potential" are allowed in the Floodway District. Within the Floodway Fringe District, development is allowed provided it is elevated above the 100-year flood elevation and it will not unduly restrict flow capacities.

(4) *Flood Plain Regulations for the City of Tempe.* On 24 October 1974 the City of Tempe passed two resolutions (Resolution Nos. 1272 and 1273). The purpose of the resolution 1272 is to "require the regulation and evaluation of flood hazards in all official actions relating to land use in the flood plain areas having special flood hazards" and to assure "the Federal Insurance Administration that it will enact as necessary, and maintain in force for those areas having flood hazards, adequate land use and control measures with effective enforcement provisions consistent with the criteria set forth in Section 1910 of the National Flood Insurance Program Regulations." As flood hazard boundary maps are not as yet available for the City of Tempe, the intent of Resolution 1273 is to conform to Section 1910.3a of the National Flood Insurance Regulations by enforcing certain building code regulations to minimize flood damage.

Onsite storage

Onsite storage requirements are ordinances requiring rainfall to be retained or detained in order to reduce runoff effects of future developments. Four ordinances in the area have been enacted to date.

(1) *City of Mesa.* The City of Mesa established as subdivision ordinance in September 1972 requiring that all precipitation from a 50-year, 24-hour storm falling within a proposed subdivision be retained within the subdivision boundaries.

(2) *City of Chandler.* The City of Chandler adopted an ordinance similar to Mesa's in late 1975.

(3) *Town of Gilbert.* The town of Gilbert adopted a similar ordinance to Mesa's in September 1975.

(4) *Maricopa County.* Maricopa County adopted an ordinance in September 1975 requiring that the flow from a 100-year 2-hour rainfall leaving a developed area be no greater than the predevelopment flow.

Floodproofing

This method of reducing flood damages would consist of the construction of floodwalls around existing structures to contain damages from a 100-year flood. As the only significant damage below 100-year events occurs in the Gilbert and Chandler areas, analysis of this method was confined to these areas. The floodwalls would have to be built to a sufficient elevation to keep floodwaters from entering and damaging structures and contents. Openings in the floodwalls to enter and exit the structures would have to be sealed shut with an impervious gate system (stop logs) following public warnings of approaching large storms. Because of the uncertainty of residents responding to warnings, this method was assumed to be 75 percent effective in reducing damages. This plan would also involve flood insurance and restriction on the use of the 100-year flood plain on future structures.

(1) *Town of Gilbert.* Flooding from the 100-year flood inundates about 196 residential structures within the town of Gilbert to an average depth inside structure of 1/2 foot. The average annual damage per existing structure for floods up to 100-year magnitudes equals $36. A 75

percent reduction ($27) of the damage justify expenditures per structure of $420. As the average structure is on a 6" foundation, a maximum floodwall of 1' would be required. A floodwall would be constructed immediately adjacent to residential structures, with openings for ingress and egress protected by removable flood sheets. Floodproofing costs are estimated at $2,100 per structure. Therefore, even assuming that adequate flood warning exists, the measures are 75 percent effective, and no O&M is required, the benefit-cost ratio for these measures is estimated at .2 to 1.

(2) *City of Chandler.* Flooding from the 100-year flood inundates about 212 residential structures within the City of Chandler to an average depth of approximately .5 foot. The average annual damage per existing structure is estimated at $61 of which $20 would be prevented by a 100-year floodwall. Again, as in Gilbert, a floodproofing cost of approximately $2,000 per unit is unjustifiable.

As flooding in these areas is primarily characterized by sheet flows, and inside depths of inundation for the 100-year flood averages .5 foot, the damaging floods are so infrequent as to make floodproofing measures unjustifiable.

Evacuation

Due to the high per unit costs of evacuation, and the relatively minimal per unit flood damages to be prevented, this alternative was deemed to be infeasible. This plan, involving the dislocation of families and businesses, would have significant social impacts.

Summary, nonstructural solutions

As current flooding can be primarily characterized by sheet flow, and damages to existing development below the 100-year flood are relatively small (50-year flood damage for the study area is $457,000), current flood plain regulations and onsite storage requirements were found to provide a high degree of flood damage control. Other advantages to these methods include water conservation due to percolation in onsite storage basins. This aspect is especially significant in an area characterized by a falling ground water table.

OTHER CONSIDERATIONS

At the request of local interests, a review was made of the impact that back-to-back floods would have on the storage capability of the Mesa-ADOT drainage system and the flood problems downstream of the system. Basically, there is a concern as to whether the system can be drained in an expeditious manner.

The Salt River Project (SRP) is responsible for the right-of-way of the Gila Drain (see pl. 1) from the Western Canal to the Gila River, a distance of approximately 17 miles. The existing Gila Drain (Floodway) facility is an unlined ditch ranging in dimension from 10 feet wide by 6 feet deep to 22 feet wide by 9 feet deep. The slope at the smallest cross-section is approximately .0003. The SRP has an irrigation canal with a rated capacity of 500 cfs, with a discharge structure into the Gila Drain with a capacity of 75 cfs, the contract capacity for the drain itself. Though the canal was constructed for irrigation requirements, storm water has been accepted in an effort to limit flooding as much as possible.

During and immediately following storm events, the SRP is expected to be using the 75 cfs capacity of the Gila Drain to relieve the Western Canal. However, since the SRP is concerned with water conservation, they are not expected to continue to dump water from the canal for long

periods. Though SRP has the contract to use the Gila Drain, it is feasible for the Mesa-ADOT system to begin emptying its water into the drain at a rate of 75 cfs when the SRP stops dumping. At this rate, it would take about 12 days to empty the system's maximum storage of 1,800 acre-feet (about a 100-year event). The likelihood of having back-to-back floods large enough to overtax the system and produce discharges causing significant damages is so rare as to have minimal effect on damage-frequency relationships. This consideration would not affect the feasibility of the alternatives considered.

SUMMARY

Table 1 summarizes the first costs, the average annual costs, the average annual benefits, and the benefit-to-cost ratios for most of the alternative plans. The benefit-to-cost ratios for the alternatives range between 0.1 and 0.4. Since these ratios are all significantly less than 1.0, there is no Federal interest in the construction of any of the alternatives.

TABLE 1

Costs and Benefits for Alternative Plans, Gila Floodway Study Area

Alternative plans	Level of protection	First cost	Interest and amortization	Operation and maintenance	Average annual costs: Total (6-1/8% 100 yrs)	Average annual Benefits (6-1/8% 100 yrs)	Benefit-cost ratio
A—Major channel to the Gila River	Standard project flood	$27,000,000	$1,660,000	$130,000	$1,790,000	$299,000	0.2
B—Major channel to the Gila River	100-year	8,750,000	540,000	40,000	580,000	94,000	0.2
C—Major channel to the Salt River	Standard project flood	18,400,000	1,130,000	90,000	1,220,000	241,000	0.2
D—Major channel to the Salt River	Do.	5,000,000	310,000	25,000	335,000	88,000	0.3
E—Retention basins:							
Gilbert	100-year	970,000	60,000	5,000	65,000	8,000	0.1
Chandler	Do.	820,000	50,000	4,000	54,000	22,000	0.4

EFFECTS OF SOIL CONSERVATION SERVICE PROJECT

Because local interests consider the flood problem to be severe in the developed portions of the study area, they have adopted ordinances for rainfall retention. In addition, local interests are in the process of developing local drainage systems, and are concerned with the need to convey the collected floodwaters away from the developed areas into the Salt River or the Gila River. However, the current construction of a watershed protection project by the Soil Conservation Service will significantly reduce flooding conditions in the study area. The watershed protection project, authorized under Public Law 566, provides for the construction of facilities to control flood runoff up to 100-year frequency for the drainage area east of the Roosevelt Water Conservation District Canal. Construction of the facilities, which is presently under way, is scheduled for completion in September 1981. Floods in excess of the 100-year frequency will continue to threaten development in the study area with some potential for injury and loss of property and life. Although the aggregate cost of damages is insufficient to justify structural improvements under current Federal regulations, personal losses in the event of large, infrequent floods could be extreme for some.

CONCLUSIONS

1. A flood problem exists in the Gila floodway study area. Damages will result from inundation, erosion, and siltation.

2. Future floods will endanger life and well-being of the people in the study area.

3. A structural solution to the flood problem is not economically justified.

4. To reduce and ameliorate future damages and hazards from floods, local interest should continue to implement flood plain management techniques and insurance programs to the maximum extent possible.

RECOMMENDATIONS

No Corps improvements are recommended in the Gila Floodway Study area at this time. However, as there is significant local desire for an increase in the capacity, either legally or structurally, of the Gila Floodway to sufficiently handle future drainage problems, and as federally funded improvements are not justifiable at this time, local interests should be made aware of other Corps programs available to assist them in their problems. The Corps' Flood Plain Management Services can provide assistance in defining flood limits and in assessing local solutions to flood problems. It is recommended that, at local request, the Corps of Engineers provide assistance to local communities through these programs.

GLOSSARY

Average annual benefits — The total amount of benefits that would accrue during the study period, amortized over the study period.

Average annual charges — The annual interest and amortization charges of first project costs, including annual operation and maintenance.

Average annual flood damages — The total amount of flood damages that would accrue during the study period, amortized over the study period.

Benefit-to-cost ratio — The ratio of estimated benefits to costs that represents the degree of economic justification of a project.

Benefits — Benefits include reduction of flood damages and flood related losses to homes, businesses, schools, streets, bridges, and utilities.

Cubic feet per second (CFS) — A unit expressing rates of discharge. One cubic foot per second is equal to the discharge of a stream of rectangular cross-section, 1 foot wide and 1 foot deep, at an average velocity of 1 foot per second.

Drainage area — A part of the surface of the earth that is occupied by a drainage system that consist of a surface stream of a body of impounded surface water, together with all tributary surface streams and bodies of impounded surface water.

Erosion — The wearing away of the land surface by floodwaters.

First cost — The total project construction costs, including costs of lands, relocations, engineering, design, administration, and supervision.

Flood — An overflow of water onto lands that are used or are usable by man and not normally covered by water. Floods have two essential characteristics: The inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river, stream, lake, or ocean. Adverse effects may include damages from overflow in land area, temporary backwater effects to sewers and local drainage channels, creation of unsanitary conditions or other unfavorable situations by deposition of materials in stream channels during flood recessions, use of ground water coincident with increased streamflow, and other problems.

Flood damages — Flood damages may be classified as tangible and intangible. Tangible damages are those subject to monetary evaluation and include physical losses, flood emergency costs, and business or financial losses. Intangible damages are those not readily susceptible to identification in monetary terms and include loss of life, health, and scenic or historic values.

Flood plain — The areas adjoining a river, a stream, a watercourse, an ocean, a lake, or other body of standing water that may be covered by floodwater.

General winter storm — A widespread storm usually occurring in the months of December through March characterized by heavy and prolonged rainfall over a large area.

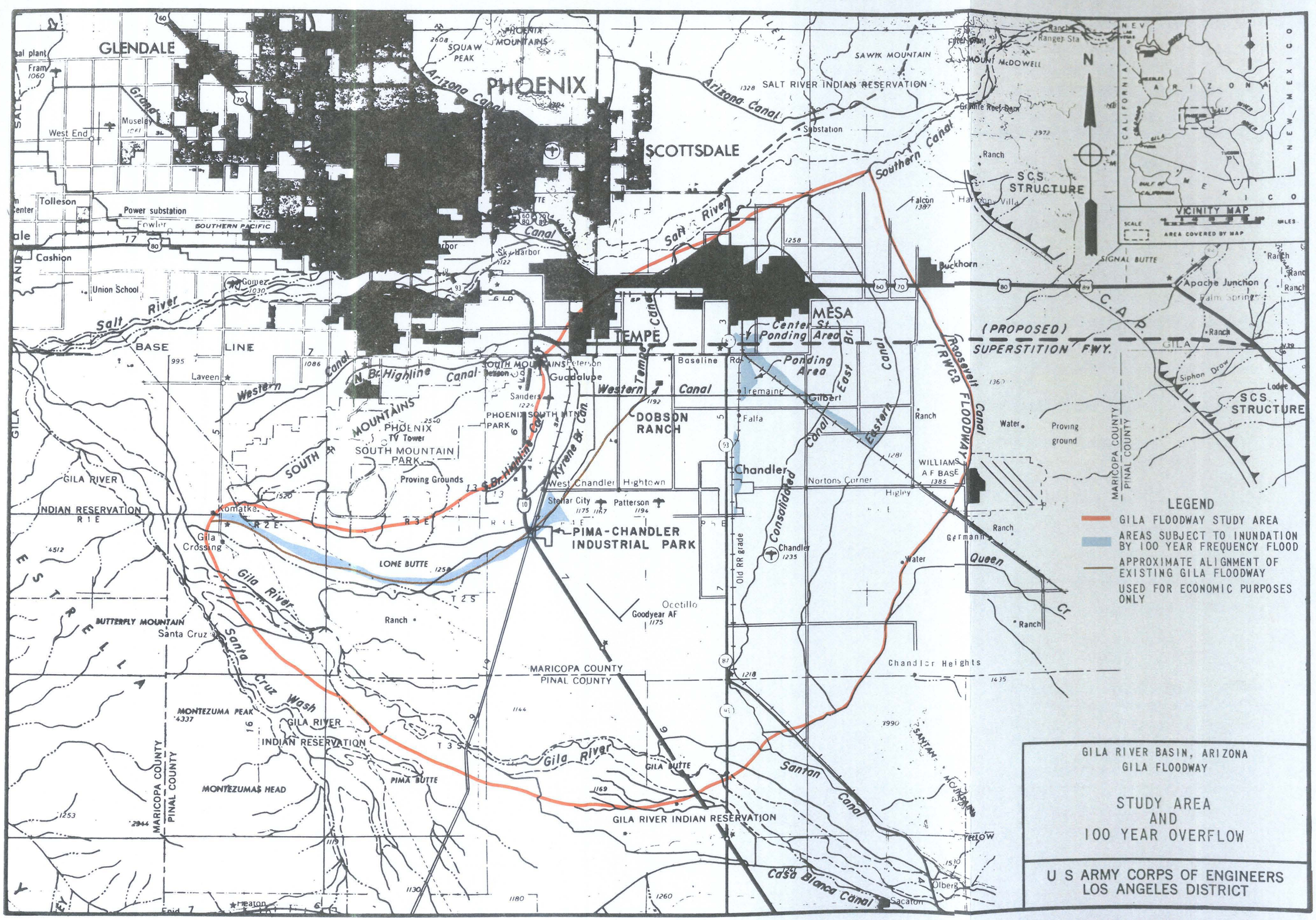
Intermediate regional flood — The intermediate regional flood is sometimes referred to as the 100-year flood, but which, over a long period of time (such as 500 years) would be equaled or exceeded an average of five times. It is conceivable that floods of this magnitude could occur during two consecutive years. Another way of referring to a 100-year flood would be to say that it is a flood that has a 1-percent chance of occurring during any year.

Peak discharge — The maximum instantaneous discharge of a flood at a given location. It usually occurs at or near the time of the flood crest, that is, the maximum stage or elevation reached by the floodflow.

Retention basin — A basin to hold storm runoff from a given area.

Standard project flood — The flood that may be expected from the most severe combination of meteorologic and hydrologic conditions that is considered reasonably characteristic of the geographic area in which the drainage basin is located, excluding rare combinations. As used by the Corps of Engineers standard project floods are intended as practicable expressions of the degree of protection that can be sought in the design of flood control works, the failure of which might be disastrous.

Thunderstorm — A high intensity, convective type rainstorm of short duration that is characterized by extremely heavy rainfall.



GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

STUDY AREA
AND
100 YEAR OVERFLOW

U S ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 1

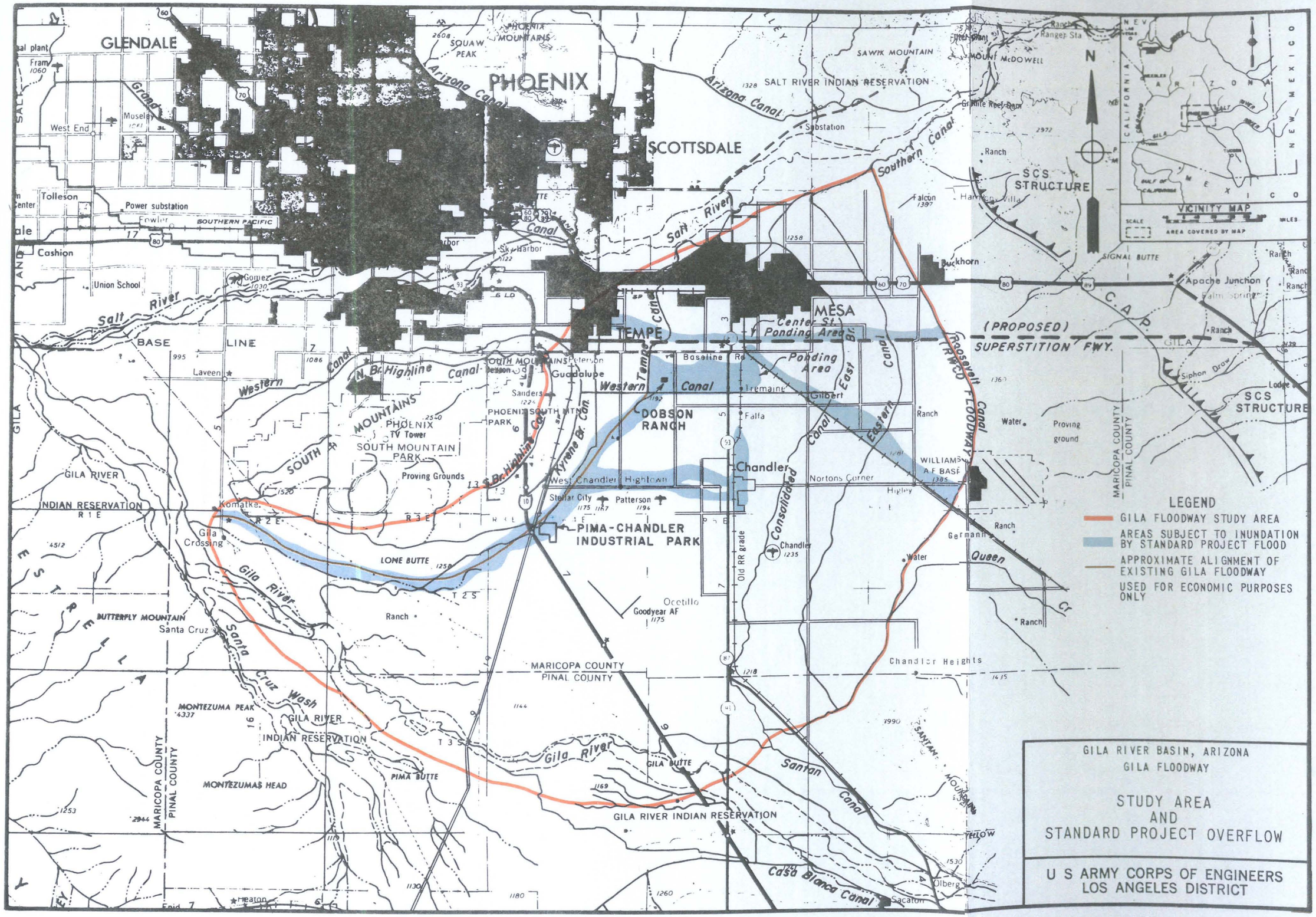

GLENDALE
PHOENIX
SCOTTSDALE
TEMPE
MESA
CHANDLER
DOBSON RANCH
PIMA-CHANDLER INDUSTRIAL PARK
SALT RIVER INDIAN RESERVATION
GILA RIVER INDIAN RESERVATION
SCS STRUCTURE
(PROPOSED) SUPERSTITION FWY.
C.A.P.
Salt River
Gila River
Arizona Canal
Southern Canal
Western Canal
Highline Canal
Roosevelt Canal
Consolidated Canal
Santan Canal
Casa Blanca Canal
Queen Cr
Santa Cruz Wash
SOUTH MOUNTAINS
PHOENIX MOUNTAINS
SAWIK MOUNTAIN
MOUNT McDOWELL
BUTTERFLY MOUNTAIN
MONTEZUMA PEAK
MONTEZUMAS HEAD
LONE BUTTE
PIMA BUTTE
GILA BUTTE
SIGNAL BUTTE
MARICOPA COUNTY
PINAL COUNTY
WILLIAMS A.F. BASE
Goodyear AF
Chandler Heights
Proving ground
Proving Grounds
PHOENIX TV Tower
SOUTH MOUNTAIN PARK
VICINITY MAP
AREA COVERED BY MAP
N
LEGEND
GILA FLOODWAY STUDY AREA
AREAS SUBJECT TO INUNDATION BY STANDARD PROJECT FLOOD
APPROXIMATE ALIGNMENT OF EXISTING GILA FLOODWAY
USED FOR ECONOMIC PURPOSES ONLY
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY
STUDY AREA AND STANDARD PROJECT OVERFLOW
U S ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 2

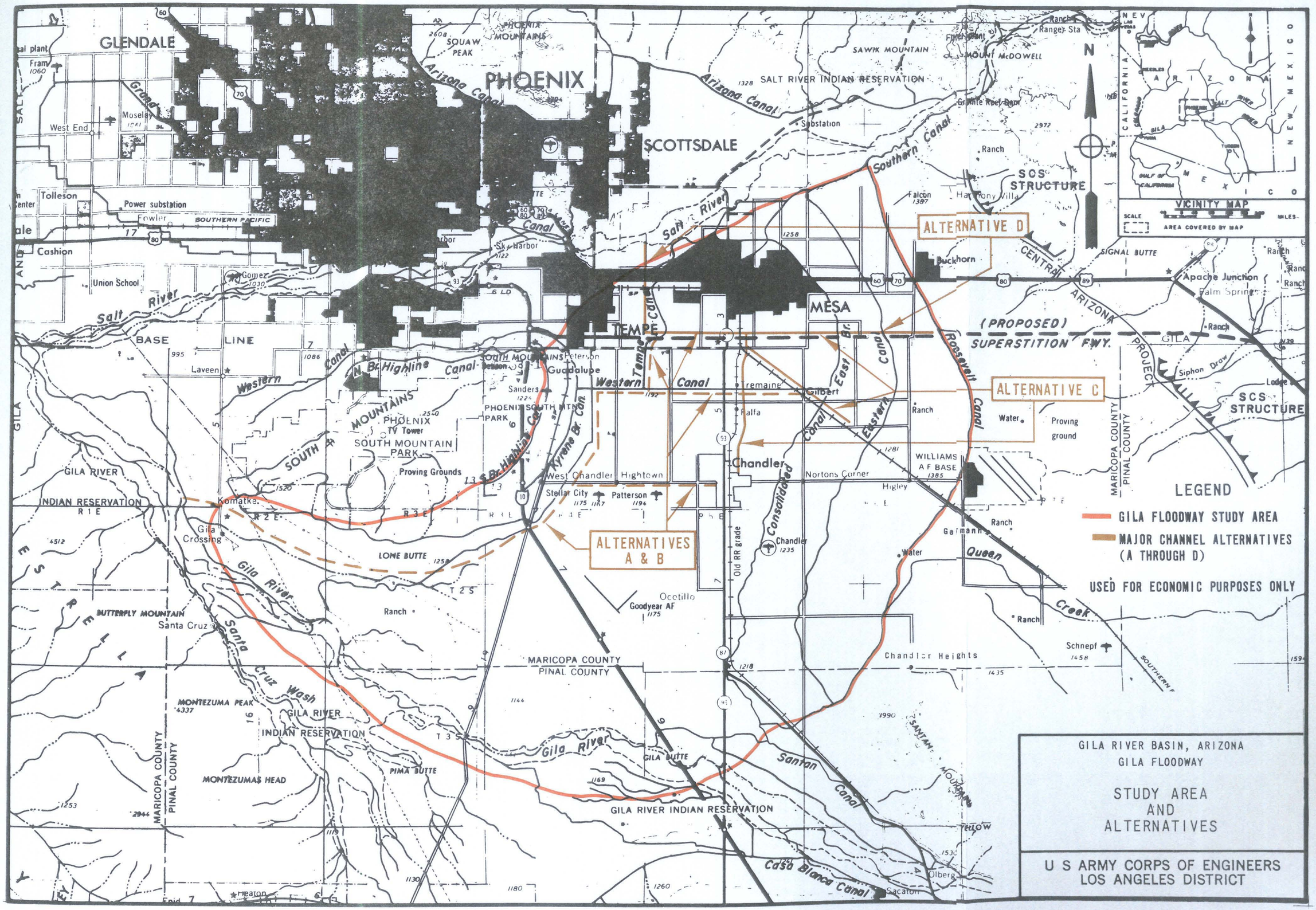

GLENDALE
PHOENIX
SCOTTSDALE
TEMPE
MESA
Chandler
SALT RIVER INDIAN RESERVATION
GILA RIVER INDIAN RESERVATION
MARICOPA COUNTY
PINAL COUNTY
Salt River
Arizona Canal
Grand Canal
Western Canal
Highline Canal
Consolidated Canal
Eastern Canal
Roosevelt Canal
Southern Canal
Santan Canal
Cañal Blanca Canal
Queen Creek
Gila River
Santa Cruz Wash
SOS STRUCTURE
SCS STRUCTURE
(PROPOSED) SUPERSTITION FWY.
CENTRAL ARIZONA PROJECT
ALTERNATIVE D
ALTERNATIVE C
ALTERNATIVES A & B
VICINITY MAP
AREA COVERED BY MAP
LEGEND
GILA FLOODWAY STUDY AREA
MAJOR CHANNEL ALTERNATIVES (A THROUGH D)
USED FOR ECONOMIC PURPOSES ONLY
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY
STUDY AREA AND ALTERNATIVES
U S ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 3

Appendix 1

HYDROLOGY
GILA FLOODWAY
MARICOPA AND PINAL COUNTIES, ARIZONA

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HYDROLOGY

GILA FLOODWAY
MARICOPA AND PINAL COUNTIES, ARIZONA

I. INTRODUCTION

1.01 PURPOSE AND SCOPE. This report presents hydrology studies for the Gila Floodway, Maricopa and Pinal Counties, Arizona. The general location of the study region is shown on plate 1. Plates 3 through 8 show subbasin boundaries. Schematic flow diagrams are presented on plates 9 through 12. The hydrologic study began with four major objectives: (a) to define the basic meteorologic and hydrologic characteristics of the study region; (b) to develop methods and techniques with which to model the runoff process; (c) to compute standard project flood peak discharges and total storm volumes at selected locations for present and future basin development under pre-project conditions; and (d) to determine discharge frequency values at selected locations for present and future development under pre-project conditions. In the course of the study, it became apparent that manmade diversions and barriers to flow store runoff from portions of the basin and thereby reduce the effective drainage area tributary to the Gila Floodway. Hence, discharge values for floods more frequent than a 100-year flood were not determined for some locations shown in tables 1 and 2. Tables 1 and 2 give standard project flood and n-year flood peak discharge and total storm volume values. Throughout this report, the term ''base year conditions'' refers to basin conditions existing in project year 1 (1980); likewise, ''future conditions'' pertains to project year 50 (2030).

1.02 PREVIOUS REPORTS. Recent Corps of Engineers reports containing hydrologic information pertinent to the study region are: (a) ''Hydrology Report for Type 15 Flood Insurance Study, Mesa, Arizona,'' dated 30 April 1975 (reference 1) and subsequent revisions; and (b) ''Gila River Basin, New River and Phoenix City Streams, Arizona, Design Memorandum No. 2, Hydrology, Part 1,'' dated October 1974 (reference 2). Appendix 1 lists these and other references with material of hydrologic importance for the study area.

II. GENERAL DESCRIPTION OF DRAINAGE AREA

2.01 PHYSIOGRAPHY AND TOPOGRAPHY.

a. The Gila Floodway drainage basin is located in southeast Maricopa County and northwest Pinal County, Arizona. All of the Pinal County portion of the study area is within the Gila River Indian Reservation. The drainage area, approximately 1,000 square miles in size, extends from the Usery, Goldfield, and Superstition Mountains on the east to the South Mountains on the west, and from the Salt River drainage boundary on the north to the Santan Mountains and the Gila River drainage boundary on the south. Approximately 20 percent of the basin is mountainous. The mountain areas are characterized by fairly rugged terrain and steep gradients. The remaining 80 percent of the area consists of very flat, valley land with alluvial slopes at the base of the mountains. Gradients in the valley are typically 10-20 feet per mile.

b. There are no large streams in the study area with the exception of Queen Creek, which is controlled by Whitlow Ranch Dam. Flash floods from the small creeks and rivulets originating in the mountainous areas do, however, cause serious damage to the valuable agricultural land on the valley floor, but by about 1981, approximately 750 square miles of the 1,000 square miles total area is expected to be controlled by authorized Soil Conservation Service (SCS) projects. These projects are designed to control all runoff from the area above them up to and including a 100-year flood (see references 3, 4, 5, and 6).

2.02 AVAILABLE MAPPING. The best general contour coverage of the study area available for this study was the 1:24,000 scale series of topographic maps published by the U.S. Geological Survey. These maps have contour intervals of 10-20 feet. In the vicinity of the City of Mesa, however, more recent, detailed contour information, supplemented with extensive new field information, was assembled for a stormwater drainage study of Mesa which is described in reference 7. This new information was also utilized in this study. An additional survey was performed to better define the relative difference in elevation between certain manmade barriers and the surrounding ground. The extent of the survey is shown on plate 13. Other available physiographic mapping includes USGS 1:24,000 orthophoto quads of most of the study area published in 1971, aerial photographs of the City of Mesa and vicinity dated October 1973, and SCS soil survey maps (references 8 and 9).

2.03 GEOLOGY AND SOILS.

a. The geology of the study area ranges from recent alluvium of the valley floors to Precambrian igneous and metamorphic rocks of the mountains. The present topography reflects the results of extensive mountain building and erosion. No activity, either volcanic or seismic, has been recorded in the written history of the area.

b. Soils in the basin are strongly influenced by the parent material and the attitude of the land. The mountains and lower buttes form shallow soils that are mostly gravel and coarse sand with very little clay. In a few flat areas, a small subsoil horizon can form and will support vegetation. Extending from the mountain fronts to the lower valley, the old alluvial fans have deep soils consisting of clay loams and sandy clay loams, often 4-5 feet deep. Soil on the lower, newer alluvial fans and flood plains are the result of erosion of the older fans and the rocks of the mountains. They tend to be very deep, 5 feet or greater, and consist of loams, fine sandy loams, and clay loams. Almost all of the soils in the study area are moderately alkaline and strongly calcareous, tending to form large areas of impervious caliche below the surface.

2.04 VEGETATION. Natural vegetation is sparse at best. Cacti grow throughout the area along with other desert shrubs. Native trees such as juniper, paloverde, mesquite, ironwood, and scrub oak are scattered among the shrubs. The vegetation tends to be thicker along and adjacent to streams and irrigation canals. Perennial grasses form a very small portion of the natural vegetation, but annual grasses occur after winter rains. Cultivated crops include alfalfa, barley, cotton, sugar beets, potatoes, lettuce, sorghum, small feed grains, and citrus and deciduous fruits.

2.05 LAND USE.

a. Urbanization Projections. Much of the land in the study area is now devoted to agriculture or is still in its natural state. Urbanization is taking place rapidly, however, and by 2030, a large portion of the basin is expected to have been developed. Plate 14 shows the extent of projected urban development for base year (1980) and future (2030) conditions in the study area. The projections were based on Office of Business Economics-Economics Research Service (OBERS) population projections; the Composite Land Use Plan for Maricopa County, Arizona, prepared by the Maricopa Association of Governments (MAG); and the City of Mesa 1990 General Land Use Plan. This information was supplemented by field surveys and analysis of aerial photographs and orthophoto quads. Projections were made in conformance with the National Flood Disaster Act of 1973. Projected city boundaries for the Cities of Mesa, Chandler, and Gilbert were obtained from the appropriate city agencies. It was assumed that no new extensive agricultural development would take place east of the proposed Central Arizona Project (CAP) canal.

b. Effective Impervious Cover.

(1) Effective impervious cover estimates used in this study are given in table 3. These percentages were based on the values given by Yost and Gardner Engineers for Mesa's storm drain study (reference 7). Since the values given for residential land use seemed low, an analysis of the percent impervious cover for two typical residential areas was performed, using 1973 aerial photographs having a scale of 1 inch equals 100 feet. The following items were determined:

(a) Area 1 - Tract bounded by Broadway Road, Gilbert Road, and Consolidated Canal.

1. Lot size is approximately 70 to 80 feet wide by 110 to 120 feet long equals 7,700 to 9,600 square feet.

2. There are about 5 units per acre.

3. Roof surface is approximately 2,000 square feet. (However, only a small portion is hydraulically connected to the street. Yost and Gardner, after field investigation, have estimated 20 percent effectiveness for roof surface contribution).

4. Driveways average about 500 square feet of pavement.

5. Streets average 10 to 15 feet to centerline by 70 to 80 feet long equals 700 to 1,200 square feet in front of each lot.

6. Total impervious area including streets (assuming 20 percent of roof surface effective) equals 1,600 to 2,100 square feet equals 19 percent impervious cover.

(b) Area 2 - Tract between Stapley Drive and Mesa Drive just north of Main Street.

1. Lot size is approximately 65 feet wide by 140 feet long equals 9,100 square feet.

2. There are approximately 3-1/2 units per acre.

3. Roof surface is approximately 1,600 square feet.

4. Driveways average about 500 square feet.

5. Total impervious area including streets (assuming 20 percent roof surface effective) equals 1,500 to 1,800 square feet or 15 to 18 percent impervious cover.

(2) An effort to confirm the measurements taken from the aerial photographs was made by contacting officials of the City of Mesa. The Assistant City Engineer* estimated that (a) the typical residential lot size is about 9,000 square feet; (b) the roof area of the average house is about 1,800 square feet; and (c) there are about 3 units per acre, although many lots are 1/2 acre in size.

*Telephone conversation on 17 June 1975 with Assistant City Engineer, Pete Peterson.

(3) In view of the foregoing, the assumption of 25 percent effective impervious cover for typical residential areas seems reasonable. Higher density residential use areas such as apartment complexes and condominiums, a relatively small portion of the city, would have a higher degree of impervious cover as reflected in the land-use table. However, the same concepts of hydraulic connectivity apply, tending to make the values lower than might be expected.

2.06 RUNOFF CHARACTERISTICS. None of the natural watercourses in the study area flow perennially. Generally runoff occurs only during and immediately following heavy precipitation because climatic and drainage area characteristics are not conducive to continuous flow. Significant runoff occurs mostly in the summer months (June through September) as a result of local storms and to a lesser degree general summer storms. Stream channels are fairly well defined in the mountain areas, but upon reaching the valley transition, lose definition, and flow proceeds downslope as sheetflow. The shallow depths encountered with sheetflow allow seemingly insignificant obstructions to radically alter the path of flow. Factors altering flow patterns are discussed in the following paragraphs.

2.07 FACTORS AFFECTING RUNOFF.

a. Whitlow Ranch Dam. The Whitlow Ranch Dam, an earthfill structure built by the Corps of Engineers in 1960, controls 143 square miles of Queen Creek. The reservoir was designed for SPF and has a gross capacity at spillway crest of about 36,000 acre-feet (reference 10).

b. SCS Flood Control Structures. Fourteen flood retarding structures, floodways, and diversions which have been built by the SCS or are authorized for construction are shown on plate 1. These structures are designed to control runoff from floods up to and including a 100-year flood (references 3, 4, 5, and 6). The design adequacy of the structures was found to be satisfactory, based on the computational procedures described in subsequent paragraphs. Thus, for floods with a return period of 100 years or less, the easternmost drainage boundary becomes the Roosevelt Water Conservation District (RWCD) Floodway, and the area potentially contributing runoff to the Gila Floodway is reduced from approximately 1,000 square miles to about 250 square miles. Routing SPF through the retarding structures showed that although emergency spillway flow would occur during a Standard Project Flood, the structures would not be overtopped. The RWCD Floodway and the floodways connecting the retarding structures would be overtopped, however, but the system as a whole would serve to significantly lessen the downslope flood hazard.

c. Superstition Freeway. A significant factor affecting the drainage pattern in the Mesa area is the proposed Superstition Freeway, with its attendant drainage facilities. Traversing the study area from east to west, the freeway will divert flow from its normal north-east to south-west flow path, forcing floodwaters to travel due west. The freeway drainage system,

designed for a ''50-year'' flood according to Arizona Highway Department criteria (reference 11), consists of cross-drainage structures east of RWCD Floodway and a system of detention basins, to be constructed as part of the City of Mesa storm drain system, and connecting channel west of RWCD Floodway. Plate 15 shows the presently conceived drainage system west of RWCD Floodway.

d. Irrigation Canals.

(1) The need for water for agricultural use has given rise to numerous irrigation canals which criss-cross the study area, altering the normal drainage pattern. Two of the major canals west of the RWCD Floodway, Eastern and Consolidated Canals, flow north to south through the City of Mesa and beyond on very shallow slopes cutting the drainage pattern with obstructions in the form of canal levees. The levees are normally 2-3 feet high, but in some places approach ground level. Runoff in the form of sheetflow is directed southward by the levees until the conveyance capacity is exceeded or another barrier such as a cross road is encountered. Roads crossing the canals are sometimes elevated above the surrounding ground for some distance, forming ponding areas at the intersection of the road and canal. Culverts through the roads are occasionally found, but they are usually small and plugging by debris and sediment is common. The canal levees are made from loose soil dredged from the canals at periodic intervals and are subject to failure when overtopped. When runoff volume exceeds the pond capacity, the levee breaches and flow proceeds downslope until the next barrier is encountered. Pond capacity is expected to be decreased in future years because of a flood plain management requirement that first floor level be above the 100-year flood level. Developers are complying by filling the area adjacent to the canals on the upstream side to approximately the elevation of the canal bank.* This was considered where future development was projected (see pl. 14).

(2) Western Canal, between Canal Drive and the Chandler branch of the Southern Pacific Railroad, is another obstruction to flow attempting to reach the Gila Floodway. Except in the immediate vicinity of the railroad, the canal is 2-5 feet higher than the surrounding ground. Floodwaters north of Western Canal and west of the railroad would be diverted westward until meeting the Tempe Canal channel. However, developers are filling the area between the railroad and Tempe Canal to approximately the elevation of the canal banks. When runoff volume is sufficient, flow will most likely overtop Western Canal near its junction with Tempe Canal, causing levee embankment failures. Floodwaters would then proceed in a southerly direction toward the Gila Floodway.

(3) Tempe Canal, just north of the Superstition Freeway would also obstruct the flow path of floodwaters. If flow rates exceed the capacity of the Tempe Canal channel, ponding would take place. Sufficiently large volumes of runoff, as would occur during SPF, would overtop the canal, causing it to fail, and flow would proceed in the direction of the City of Tempe.

*Letter dated 15 December 1975 from Assistant City Engineer, Pete Peterson.

e. Railroads. Three branches of the Southern Pacific Railroad run through the study area, effectively diverting or obstructing floodflows (see pl. 1). The railroad bed is generally 3-6 feet higher than the surrounding ground. Such cross-drainage structures as exist are small and often plugged with dirt and debris. Where two of the branches converge near Mesa, the potential ponding capacity is approximately 1,000 acre-feet.

f. Streets and Highways. Numerous high crowned or elevated streets and highways provide artificial drainage boundaries. In addition to the Superstition Freeway, portions of Apache Trail (Main Street), Southern Avenue, and Interstate 10, to name a few, serve to concentrate runoff from its normal path. At intersections of roads with other barriers such as railroads or canals, small ponding pockets are effective in retarding flow and decreasing total runoff volume.

g. On-Site Storage Policy.

(1) Since September 1972, the City of Mesa has had a subdivision ordinance which gave the City Engineer authority to establish on-site storage requirements for storm runoff. The policy applies to all new development and is enforced through the building permit granting process. The policy states that all precipitation from a 50-year, 24-hour storm (approximately 3 inches) which falls within a subdivision being developed must be retained within the subdivision boundaries. The method of retention is left to the developer. Two common methods are to depress individual lots to retain the rain falling on them, providing an additional storage area for street runoff, and to provide a large retention area designed to retain runoff from the entire subdivision.

(2) The City of Chandler adopted an on-site storage ordinance in late 1975 which applies to all new development and is enforced by inspection by city forces. The ordinance requires that the 50-year, 24-hour precipitation be retained on site.

(3) In August or September 1975, the town of Gilbert began enforcing an on-site storage requirement as part of its new subdivision ordinance. On-site retention of the 50-year, 24-hour rainfall is required. Compliance will be enforced through the development plans approval process.

(4) In September 1975, the county of Maricopa adopted amendments to its subdivision regulations which require on-site storage for all unincorporated areas of the county. The amendments call for sufficient on-site storage such that the peak discharge, computed from 100-year, 2-hour rainfall, leaving the developed subdivision does not exceed the predevelopment peak discharge, determined from the same storm. The method of on-site storage is not specified in the ordinance, but, according to Maricopa County Flood Control District personnel, up to 50 percent of the future developed area may possibly use a retention type storage. The remaining development would use a detention type storage. The two types of storage and their effects on a hydrograph are discussed in paragraph 6.02.

h. Land Treatment. With much of the study area devoted to farming, land treatment becomes an important factor affecting runoff. Where crops are being grown, it is standard procedure in this region to grade the fields for optimal irrigation water use before planting. The fields are graded nearly flat, and tailwater berms are often built. The SCS has estimated that this type of treatment effectively stores an average of 2 inches of the rain falling on the field before runoff occurs. In addition, where citrus groves are located, berms inclose the groves to facilitate ''flood'' irrigation, permitting little or no runoff. Normally, shallow sheetflow is directed around these structures, altering an otherwise direct flow path.

2.08 CLIMATOLOGY.

a. The climate of the Gila Floodway basin ranges from warm and arid over the desert to relatively cool and moderately humid in the higher mountain portions of the basin. Mean maximum/minimum daily temperatures range from approximately 65/35 degrees Fahrenheit in January to about 105/75 degrees Fahrenhait in July over the lower valleys, and from around 50/25 in January to about 90/60 in July over the higher mountain peaks. At Mesa Experiment Farm, the National Weather Service normal temperatures range from a daily mean of 50.3 degrees in January to 89.2 degrees in July. The extreme temperatures experienced in the region range from 120 degrees in portions of the lower desert to near zero in some of the higher mountain canyons. Prevailing winds are generally rather light, but winds can become moderate during the winter and spring, especially during stormy periods. Summer thunderstorms often produce strong gusty winds over local areas.

b. Mean annual precipitation ranges from about 7 inches in the western portion of the basin to nearly 20 inches in the mountainous extreme eastern portion (see pl. 2). The heaviest rainfall of the year normally occurs during the summer months of June through September; much of the remainder falls during the period December through March. Some snow falls in the higher elevations during the winter months. There is considerable month-to-month and year-to-year variability in precipitation in the basin.

c. Three basic types of storms affect the Gila Floodway basin, although some individual storms may consist of a combination of types: general winter storms, general summer storms, and thunderstorms. Reference 2 describes each type in detail, and gives several examples of each.

III. STORMS AND FLOODS OF RECORD

3.01 GENERAL. Historical accounts indicate that many large floods have occurred in the general Gila River basin. Apparently, there were important general floods in 1833, 1862, 1869, and 1880, although magnitudes of the flood events cannot be ascertained. Sizeable floods were produced by the general storms of February-March 1884, February 1891, January 1916, and February-March 1938, but specific information for the Gila Floodway basin is not available. General winter storms can cause flooding in the study area, but the most severe floods generally occur during the summer months as a result of localized thunderstorms, often embedded in general summer storms. Severe local storms and floods occurred in and around the Gila Floodway basin in 1921, 1926, 1929, 1930, 1933, 1935, 1936, 1939, 1943, 1946, 1951, 1953, 1954, 1955, 1957, 1959, 1963, 1964, 1966, 1967, 1969, 1970, 1971, and 1972. Storm and flood information specific to the study area is sketchy, especially for the earlier events. It is known that the town of Gilbert was hit by floods in 1926, 1930, and 1933, with others following in the 1930's and 1940's. More recent events for which information is available are briefly described in the following paragraphs and in table 4.

3.02 STORM AND FLOOD OF 19 AUGUST 1954.

a. The storm and flood of 19 August 1954 is the most severe occurrence of record within the Queen Creek drainage area, located in the southeast corner of the Gila Floodway basin. Precipitation in the Superstition and Pinal Mountain areas occurred between 0100 and about 1000 hours. Rainfall intensities were very high during portions of the storm, especially between 0500 and 0900 hours. Boyce Thompson Southwestern Arboretum, about 4 miles west of Superior, recorded the highest measured precipitation amount, 5.3 inches, most of which fell within 3 hours, although greater amounts are believed to have fallen in the mountains to the south. An estimated 140 square miles of area received over 5 inches of precipitation. Another storm, more local in character and with lower rainfall intensities, occurred in the vicinity of Apache Junction, just east of Mesa, between 0200 and 0500 hours on 20 August.

b. The extent of the flooded area can be seen on plate 16. Within the outline of the flooded area, there were places, such as Williams Air Force Base, which were not completely inundated. To the north and east of the flooded region shown on plate 16, floodwaters traveled across the desert as sheetflow, with occasional islands of land not covered with water. To the south and east of the flooded area shown on the plate, severe damage occurred to the farmland along Queen Creek. Runoff from the Superstition Mountain area flooded agricultural land adjacent to and east of RWCD Canal, overtopped and breached the canal in many places, and flooded farmland from the RWCD Canal all the way to Gilbert, inundating much of the town itself. For a more detailed description of the storm and flood of 19 August 1954, see references 2 and 12.

3.03 STORM AND FLOOD OF 31 OCTOBER 1957. Precipitation began early on the morning of 31 October. Rainfall continued with moderate to high intensities for a period of 2-3 hours. In the Queen Creek-Superstition Mountain area, recorded rainfall amounts varied from 0.95 inch at Williams Air Force Base to 1.71 inches at Superior, but greater amounts were indicated in the Superstition Mountains. Available peak discharge estimates are as follows: (1) Queen Creek at Whitlow Ranch Reservoir Site - 2,000 cfs; (2) Queen Creek 500 feet upstream from SPRR bridge - 1,000 cfs; (3) Queen Creek half mile west of Powers Road - 800 cfs; (4) Weekes Wash at U.S. Highway 60-70-80-89 - 1,100 cfs; (5) Siphon Draw at U.S. Highway 60-70-80-89 - 1,500 cfs; and (6) Williams Air Force Base channel at bridge at west end of base - 1,300 cfs. For more details, see reference 13.

IV. SYNTHESIS OF STANDARD PROJECT FLOOD

4.01 GENERAL. The Standard Project Flood (SPF) represents the flood that would result from the most severe combination of meteorologic and hydrologic conditions considered reasonably characteristic of the region. It normally is larger than any past recorded flood in the area, and can be expected to be exceeded in magnitude only on rare occasions. It thus constitutes a standard for design that will provide a high degree of flood protection.

4.02 STANDARD PROJECT STORM. The 19 August 1954 thunderstorm that was centered generally in the Queen Creek drainage area was determined to be the most severe flood producing rainfall depth-area-duration relationship and isohyetal pattern that may reasonably be expected to occur over the study area. A detailed description of the storm, along with total rainfall amounts, intensity-duration relationships, and precipitation patterns, is given in reference 2.

4.03 RAINFALL-RUNOFF RELATIONSHIPS.

a. Runoff Models.

(1) Mountain areas. Reference 2 discusses rainfall-runoff relationships developed from reconstitutions of floods which have occurred in several mountain basins around Phoenix. These relationships were considered applicable to the mountainous portion of the study area.

(2) Valley areas.

(a) The valley watersheds in the Gila Floodway basin have very flat slopes. Urbanization together with agricultural development has obliterated most original watercourses, and runoff occurs basically as sheetflow. Flat valley areas are not conducive to good runoff measurement; hence, sufficient data with which to derive precipitation-runoff relationships from past runoff events does not exist. A theoretical procedure was needed which allowed computation of flood hydrographs using parameters that could be determined from topographic maps or had generally accepted values as opposed to empirically determined coefficients. A review of the literature revealed that several studies dealing with sheetflow have been conducted, and various models for determining hydrographs have been derived. For this study, some models were rejected due to the difficulty of accurately estimating rather sensitive input variables; purely graphical methods were not used because the large number of hydrograph computations necessitated computerization of the methodology.

(b) In this study, a linear storage system was used to determine the time distribution of runoff from an effective rainfall hyetograph. Although nonlinearity of the rainfall-runoff process has long been recognized, the sparsity of data makes the use of a simple procedure the most reasonable approach. The linear storage system is analogous to a reservoir in which storage is related to overflow by the equation

$$S = KO \qquad (1)$$

in which K is a proportionality factor and is a constant value for a true linear storage system. Basin storage S at any time is equal to a summation of rainfall excess minus the volume of outflow up to that point. When combined with the general storage equation

$$I - O = \frac{dS}{dt} \tag{2}$$

equation (1) can be expressed as

$$O_2 = C_1 (I_1 + I_2) + C_2 O_1 \tag{3}$$

where

$$C_1 = \frac{t}{2K + t} \tag{4}$$

and

$$C_2 = \frac{2K - t}{2K + t} \tag{5}$$

The following paragraphs address two important questions: (1) How can the coefficient K be determined from the physical characteristics of a watershed and storm characteristics of the rainfall hyetograph? and (2) Does a linear system adequately model the sheetflow runoff process?

(c) In studies of urban watersheds, Willeke (reference 14) utilized the linear storage system concept and found that the coefficient K could be approximated by what he called ''lag time'' (time between centers of mass of effective precipitation and runoff). Further review of the literature did not reveal a relationship between lag time as defined by Willeke and measurable physical parameters; however, relationships between sheetflow time of concentration and measurable physical characteristics did exist. Time of concentration is defined as the time from commencement of rainfall excess until flow from the uppermost edge of the basin arrives at the overflow point (analogous to time to equilibrium). Henderson and Wooding (reference 15) have shown that for a constant effective rainfall intensity, time of concentration, tc, using kinematic wave theory, can be expressed as

$$tc = \frac{Li^{1-m}}{} \; 1/m \tag{6}$$

where L = length
= coefficient
i = effective rainfall intensity
m = exponent

Ragan and Duru (reference 16) have demonstrated coefficient values for an altered form of equation (6) as follows:

$$tc = 0.93 \frac{(Ln)^{0.6}}{i^{0.4} s^{0.3}} \tag{7}$$

where tc = time of concentration in minutes
L = length in feet
i = effective rainfall intensity in inches per hour
n = Manning's roughness coefficient
s = slope in feet per foot

The hydrograph resulting from a constant effective rainfall intensity i of a duration t = tc is shown on plate 17. If the time to peak is used to approximate the time to the center of mass of the hydrograph, then K = tc/2. Equations (4) and (5) then become respectively,

$$C_1 = \frac{t}{tc + t} \tag{8}$$

and

$$C_2 = \frac{tc - t}{tc + t} \tag{9}$$

(d) The validity of any hydrologic model is best tested by the model's ability to reproduce observed flood hydrographs. The absence of runoff information in the study area required use of data from other sources. In the experimental program conducted by the Los Angeles District during the period 1948 to 1954 (reference 17), simulated rainfall produced runoff from surfaces of both concrete and simulated turf, set at various slopes. Different combinations of rainfall intensity, slope, length of plane, and surface roughness led to a variety of flow patterns. Plates 18 through 21 show some of the observed hydrographs together with reproduced hydrographs computed using equations (3), (8), and (9). Equation (7) was used to compute tc. For the reproduction on plate 21, the higher intensity was used in equation (7). Much of the discrepancy between the observed and reproduced hydrographs is probably due to the non-linearity of the rainfall-runoff process, although some is undoubtedly due to experimental error. For example, the observed steady-state discharge on plate 19 is about 2 percent greater than the theoretical steady-state discharge computed from rainfall. If K in the model was varied in an appropriate manner, less runoff would take place at the beginning of the hydrograph and more could be made to occur near the peak. However, the reproduced peak discharges correspond fairly well with the observed peaks.

(e) Reconstitutions of observed flood events in urbanized basins outside of the study area are shown on plates 22, 23, and 24. Although not technically sheetflow areas because runoff is concentrated by streets or, in the case of El Modena-Irvine, conveyed in a channel, hydrograph reproduction using the linear reservoir model are generally good. Measurement of lag time (time between centers of mass of rainfall excess and runoff) compares favorably with $K = tc/2$ when the maximum 15 minute effective rainfall intensity is used as in equation (7).

(f) Further evidence of both the non-linearity of the runoff process and the appropriateness of the relationship for K in the model can be seen in the storage-outflow loops shown on plates 25 through 31. The coefficient K is equal to the ratio of the change in storage ΔS to the change in outflow $\Delta 0$. For a good portion of the various loops, $\Delta S/\Delta 0$ approximates the computed K very closely. In other parts of the loops, the non-linearity of the storage-outflow relationship is obvious.

b. Precipitation Loss Rates. In that the soil types in the Gila Floodway basin are fairly similar to soils in the Phoenix area, the loss rates used in this study were based on the loss function presented in reference 2, reproduced here as plate 32. Consideration of on-site storage, along with other necessary assumptions, suggested the use of an initial loss and an average constant loss rate. Using the ''SPF-Local Storm'' loss function on plate 32, the average loss rate during the fifth and sixth hours, the intense portion of the storm, were determined. This value, 0.35 inch per hour, was used as the constant loss rate for SPF calculations.

c. Depression Storage and Manning's N-Value.

(1) Summer storms in the study area often occur on relatively dry watersheds. Although the soil may have been wetted by antecedent rainfall, evaporation rates are high, and depression storage must be satisfied prior to runoff. The amount of this initial loss and the Manning's n-value for various types of surfaces used in this study are within the range recommended by Chow (reference 18). They are:

Surface Type	Depression Storage (inches)	Manning's N-Value
Impervious areas	0.0625	0.015
Residential lawns	0.200	0.100
Natural terrain	0.500	0.050
Developed farmland	2.000	0.070
Citrus groves	Total storm	No contribution*
Pasture land	2.000	0.200

*Citrus groves are considered non-contributing to runoff because of the dikes built around the groves to facilitate irrigation by flooding. These dikes are 6 inches or more in height.

Where a subarea contained more than one type of surface, some scheme had to be devised to compute average parameters for the composite catchment. In this study, depression storage was calculated as a weighted average based on the percent imperviousness of the catchment. For example, depression storage for a residential subarea with x fraction impervious was calculated by

$$\text{Average depression storage} = 0.0625(x) + 0.20\ (1-x) \qquad (10)$$

In the case of Manning's n, a harmonic mean was used, following reference 20:

$$\frac{1}{n} = \frac{x}{0.015} + \frac{(1-x)}{0.10} \qquad (11)$$

where 0.015 and 0.10 are the Manning's coefficients for impervious and residential lawn areas, respectively, taken from the above table.

(2) An extensive study of the sensitivity of the final results to various changes in Manning's n-value was not performed. Certain n-value changes made in the course of the study indicate, however, that the final solution is not extremely sensitive to changes in n. In one case, n was changed from 0.075 to 0.040, nearly 90 percent, with a resultant change in peak of about 25 percent and only a small change in timing of the peak. When n was increased from 0.030 to 0.050, about 70 percent change, the peak decreased about 15 percent. In this range of Manning's n, it appears that the ratio of change in n to change in the magnitude of the peak is about 4 or 5 to 1.

d. Baseflow and Snowmelt. Baseflow is considered negligible in the study area. Allowance for snowmelt is inappropriate in this region for storms occurring in the summer season.

4.04 FLOOD ROUTING.

a. Flood routing techniques in this study area must be general enough to handle a wide range of discharge and channel conditions. Of primary importance is the ability of a routing procedure to reasonably describe the attenuation of a flood wave when a large amount of channel storage or overland flow is encountered. For this reason, the Muskingum method was chosen for channel routing. Reservoir routing, where appropriate, was accomplished by the Modified Puls routing procedure.

b. Flood wave travel time in a reach is normally determined by dividing reach length by average peak flow velocity. Muskingum K value is approximated by the travel time. For overland flow over the flat topography typical of the study area, however, appropriate cross sections for velocity are difficult if not impossible to ascertain. For this study, a value of 1.5 feet per second was chosen as the flood wave velocity in overland flow areas. This value compares favorably with slope-velocity curves such as those used by the SCS and the City of Los Angeles. An overland flow velocity of 1.5 feet per second was in fact used by SCS in their design of RWCD Floodway. A Muskingum X value of zero was used to approximate the rather level water surface profile of overland flow.

4.05 CANAL LEVEE FAILURE ASSUMPTIONS. Storage behind canal levees was computed using a variable depth, sloping wedge as the model for ponding areas. Volumes were calculated by the average end area method with maximum depths equal to the levee heights as illustrated on plate 33. Average height of levees and surface areas of ponding were determined by field inspection and from 1:24,000 scale topographic maps with superimposed 2 feet contour intervals taken from reference 7. Canal levee failure hydrographs were determined based on the following assumptions: (1) the levee will fail rapidly, but not instantaneously; (3) the maximum water surface elevation will be approximately the original levee height; (4) the failure section will erode to accommodate inflow plus dead storage (wedge) release; (5) dead storage outflow is maximum when inflow is maximum; (6) dead storage release varies linearly; and (7) outflow equals inflow plus dead storage release. Plate 34 shows the effect of canal levee failure for a hypothetical situation.

4.06 COMPUTATION OF STANDARD PROJECT FLOOD.

a. Stream System Analysis.

(1) A stream system analysis approach to computation of design floods involves division of the study area into subbasins which are homogeneous with respect to hydrologic and meteorologic factors; and routing and combining the flood hydrographs generated from each subbasin are then routed and combined to determine the design flood at a desired location. Subdividing a watershed permits more accurate modeling of the runoff process, as variations in topography, urbanization, and rainfall, as well as consideration of on-site

storage requirements and manmade barriers may be incorporated into the hydrologic description of the basin. The required number of subbasins are governed by the size of the basins used to verify the model.

(2) Standard Project Flood is computed by centering the standard project storm over the basin in the most critical flood producing manner. Application of the rainfall loss function described previously to standard project precipitation enables determination of the rainfall excess hyetograph. The appropriate runoff model, unit hydrograph for mountain areas and linear reservoir for valley areas, is then used to transfer the effective rainfall hyetograph into a runoff hydrograph for the subbasin, considering any on-site storage requirement. Routing and combining of all subarea hydrographs to the desired location completes the computation of SPF.

b. SPF peak discharges and total storm volumes, computed as described in the foregoing paragraphs, are presented in tables 1 and 2 for present without project and future without project conditions, respectively.

V. DISCHARGE FREQUENCY ANALYSIS

5.01 STREAM GAGE RECORDS.

a. Only two stream gages in the Gila Floodway basin have records over 10 years in length, both in relatively mountainous areas. The gage on Queen Creek at Whitlow damsite, near Superior, has a fragmented record 16 years long (1915-1920, 1948-1959). Data from this gage, along with others in the mountains around Phoenix (see reference 2), were used to estimate 100-year floods for the design adequacy analysis of the SCS structures in the mountain portions of the study area. The Queen Creek tributary at Apache Junction gage has 14 years of record (1961-1974), but the data is affected by high channel percolation rates and is therefore somewhat unreliable.

b. An analysis of the records of stream gages in seven other basins in the general area with flat drainage slopes was attempted, but the results showed very little correlation on which to base runoff frequency. The gages used were Durham Wash, Silver Reef Wash, Agua Fria Tributary at Youngtown, Military Wash, Waterman Wash, Rainbow Wash, and Bender Wash.

5.02 DISCHARGE FREQUENCY DETERMINATION.

a. In the absence of runoff data from comparable basins, flood frequency in the Gila Floodway basin was based on rainfall frequency. The idea of determining flood frequency from rainfall frequency is not new. The intention is to estimate the flood of a selected frequency from rainfall of the same frequency. The actual relationship between frequency of rainfall and the derived flood is obscure as each part of the computational model introduced some joint probability. For this reason, frequency analysis of observed runoff data is the preferred procedure.

b. The basic premise adopted in this study was that if ''average'' values of other parameters such as Manning's n value and loss rate are used, the frequency of the derived flood should approximate the frequency of rainfall. The rainfall parameters chosen to preserve the consistency between rainfall and runoff frequency were the maximum 15 minute, 30 minute, and 1 hour precipitation amounts. Due to the nature of summer storms in the area, these parameters are good indicators of storm severity.

c. Summer storms generally last 12 hours or less, with most of the rain falling within 3 hours. The intense portion of the storm often lasts 1 hour or less. A comprehensive analysis of temporal patterns for summer storms in the area, described in reference 2, formed the basis for determining the average time distribution of rainfall employed in this study.

d. The maximum 15 minute, 30 minute, and 1 hour precipitation amounts were determined from n-year, 6-hour and n-year, 24-hour rainfall amounts and regression equations for finding n-year, t-hour amounts presented in reference 19. Depth-area relationships were based on the storm analysis presented in reference 2.

e. N-year flood peak discharge and total storm volumes were calculated in the same manner as SPF. Constant loss rates, estimated from the ''Dry Watershed'' loss function on plate 32, were adopted as follows:

Storm Frequency Years	Constant Loss Rate Inches per hour
100	0.40
50	0.45
25	0.50
10	0.55

Peak discharges and total storm volumes for selected locations are given in tables 1 and 2.

VI. ANALYSIS OF RESULTS

6.01 GENERAL. A quick glance at the discharge values presented in tables 1 and 2 may be disconcerting. It appears that the given discharges are low, in some cases extremely low. Plotting these values on an enveloping curve of peak discharges which have occurred in Arizona leads to the same conclusion. However, the following factors must be kept in mind: (1) the study area for the most part is very flat, and floodwaters do not concentrate, traveling instead as sheetflow: (2) as will be shown, on-site storage can drastically alter the quantity and timing of runoff from a subbasin; (3) manmade barriers have changed drainage patterns, caused substantial opportunity for ponding, and, in certain cases, caused areas to be non-contributing to flow at a particular location; and (4) land in agricultural use has the potential to store about 2 inches of rain before runoff occurs.

6.02 EFFECT OF ON-SITE STORAGE.

a. On-site storage can drastically change the expected quantity and timing of runoff from an area. Maricopa County's on-site storage ordinance can be used to illustrate the effect. It will be recalled from previous discussion in paragraph 2.07g (4) that the County requires sufficient storage, retention, detention, or a combination of both, such that the peak discharge, generated by a 100-year, 2-hour rainfall, leaving the developed subdivision, does not exceed the predevelopment peak, computed from the same storm. Detention storage is envisioned to react similar to a reservoir with an outlet, the maximum capacity of the outlet being equal to the predevelopment 100-year peak discharge. Retention storage can be likened to a reservoir with an overflow spillway; the reservoir capacity would be equal to the accumulated volume of the developed condition 100-year hydrograph up to the point on the recession limb of that hydrograph equal to the predevelopment 100-year peak discharge.

b. Plate 35 is a graphical description of the effect of each type of storage on a hydrograph. Note that the magnitude of the developed subbasin peak after taking on-site storage into account is significantly less than before the adjustment, but still greater than the predevelopment peak. This occurs in this case because SPF volume is greater than 100-year flood volume on which on-site storage is based. The volume of runoff from the developed subbasin has increased due to urbanization, but not as much as might be expected because of the assumption that half of the area would use retention type storage.

c. Plates 36 and 37 show the progression of floodwaters from subarea to subarea through a basin. Plate 36 represents the predeveloped condition; plate 37 shows the effect of on-site storage and routing on magnitude and timing of the peak. It can be seen that the magnitude of the peak, when on-site storage is considered, does not increase as much as might be expected with increased urbanization, and, indeed, may actually decrease.

d. The effect of on-site storage will vary both with the amount of rainfall (frequency of storm) and the land use of the basin before development. If the magnitude of the considered storm is small, runoff may not occur from a subbasin with retention type storage. Also, the peak discharge allowed from a subbasin which had been in agricultural use before development would be somewhat smaller than the allowable peak from, say, a basin in its natural state before urbanization because of the relative difference in predevelopment runoff potential. Since the allowable peak discharges would be different, the required storage volumes would also be different.

6.03 DISCUSSION OF RESULTS.

a. A few specific examples will best illustrate the concepts discussed in the foregoing paragraphs. Table 1 shows that most of the SPF peak discharges and volumes are very much greater than the corresponding 100-year flood peaks and volumes. The large difference at CP's 1220, 1304, 1310A, and 1310B is explained by the agricultural land use of the subbasins and the magnitude of the storm causing runoff. Point rainfall hyetographs for the standard project and 100-year storms are shown on plate 38. Note that the required storage for agricultural land use - 2 inches - is not satisfied until near the end of the 100-year storm. The intense portion of the 100-year storm can be seen to be ineffective in producing high runoff from agricultural areas. However, the maximum intensities of the standard project storm are not significantly affected.

b. Additional contributing drainage area for SPF is also responsible for some of the large differences between SPF and 100-year peaks and volumes. This situation occurs with CP 1751, 1753, 1223, and 1224. The additional area contributes runoff to these points because of levee breaches or overflow from RWCD Floodway during SPF.

c. The pattern of large SPF peaks and volumes compared with 100-year values is also apparent in table 2. In this case, the difference in peak is due to the on-site storage requirement for future development. The 100-year future condition peak is of the same order of magnitude as the 100-year present condition peak, which is the intention of the on-site storage requirement. The future condition volume is greater, however, but there is not as much difference as might be expected because of the assumption that half of the developed subareas would have retention type on-site storage.

6.04 COMPARISON WITH OTHER STUDIES.

a. Soil Conservation Service RWCD Floodway Design Study. Plate 39 shows a comparison of SCS and Corps 100-year flood peak discharge values at selected locations along the proposed RWCD Floodway. The SCS discharge values will be used in the design of the floodway. The Corps values were computed using the linear reservoir procedure described in this report. The results obtained from the two different methods are within approximately 25 percent of eachother, which is considered acceptable in this case. The average difference is about 15 percent.

b. Superstition Freeway, Conceptual Study for Drainage. Only one location in this study, CP 1701, corresponds directly to concentration points determined for the Superstition Freeway conceptual drainage study (reference 11). The freeway drainage study, done by Yost and Gardner Engineers for the Arizona Department of Transportation, employed a modified Rational Method to compute 50-year flood peaks. Fifty-year flood peaks at CP 1701, computed by the two different methods, were almost identical. However, the 50-year, 6-hour volume given in the freeway study is about 10 to 25 percent higher than the Corps volume (392 acre-feet vs. 360-300 acre-feet) depending on whether present or future conditions are being compared. The difference is mainly due to different assumptions regarding potential ponding behind canal levees. Since the main purpose of the freeway study was to provide protection for the freeway, conservative assumptions may be justified.

c. City of Mesa Flood Insurance Study. Discharges presented in the flood insurance study (FIS) for the City of Mesa are not directly comparable to those given in the Gila Floodway study, although the computation methods are the same. The FIS was done for 1975 conditions, while the Gila Floodway study considers base year conditions to be conditions existing in 1980. The Superstition Freeway and RWCD Floodway are expected to be in place for base year conditions; in addition, future urbanization must consider Mesa's on-site storage requirement. These factors will serve to reduce the flood potential in Mesa from what it is today.

TABLE 1

PEAK DISCHARGES AND TOTAL STORM VOLUMES
BASE YEAR CONDITIONS WITHOUT PROJECT

CP	Contributing Drainage Area SPF (sq mi)	Contributing Drainage Area Other (sq mi)	Standard Project Flood	100-Year Flood	50-Year Flood	25-Year Flood
			City of Mesa			
1701	96	33	6,700 cfs (3,350 AF)	3,500 cfs (570 AF)	2,300 cfs (360 AF)	1,400 cfs (210 AF)
1751	260	29	4,500 cfs (4,300 AF)	600 cfs (380 AF)	--- ---	--- ---
1220	6	6	3,400 cfs (1,080 AF)	550 cfs (210 AF)	300 cfs (100 AF)	100 cfs (50 AF)
			Vicinity of Gilbert			
1753	240	20	4,000 cfs (2,520 AF)	600 cfs (320 AF)	*100 cfs (10 AF)	*50 cfs (10 AF)
			Vicinity of Chandler			
1223	14	5	5,000 cfs (2,330 AF)	1,000 cfs (190 AF)	500 cfs (90 AF)	350 cfs (50 AF)
1224	17	3	4,800 cfs (2,680 AF)	500 cfs (100 AF)	200 cfs (60 AF)	50 cfs (10 AF)
			Gila Floodway			
1304	18	18	4,300 cfs (2,750 AF)	400 cfs (330 AF)	--- ---	--- ---
1310A	37	37	9,700 cfs (5,680 AF)	1,100 cfs (800 AF)		

Table 1 - Continued

CP	Contributing Drainage Area SPF (sq mi)	Contributing Drainage Area Other (sq mi)	Standard Project Flood	100-Year Flood	50-Year Flood	25-Year Flood
1310B	70	70	19,000 cfs (11,600 AF)	2,500 cfs (1,770 AF)	1,500 cfs (800 AF)	700 cfs (330 AF)
1362	95	95	18,000 cfs (13,100 AF)	3,100 cfs (2,400 AF)	--- ---	--- ---
1372	117	117	17,000 cfs (15,700 AF)	4,000 cfs (3,130 AF)	--- ---	--- ---
1382	136	136	16,000 cfs (18,000 AF)	4,100 cfs (3,900 AF)	2,900 cfs (2,500 AF)	2,000 cfs (1,520 AF)

*Consolidated Canal in subarea 653 does not breach for 50-year and 25-year floods.

TABLE 2

PEAK DISCHARGES AND TOTAL STORM VOLUMES
FUTURE CONDITIONS WITHOUT PROJECT

CP	Contributing Drainage Area SPF (sq mi)	Contributing Drainage Area Other (sq mi)	Standard Project Flood	100-Year Flood	50-Year Flood	25-Year Flood
			City of Mesa			
1701	96	33	6,700 cfs (3,630 AF)	3,300 cfs (490 AF)	2,000 cfs (300 AF)	1,100 cfs (160 AF)
1751	260	29	4,600 cfs (4,280 AF)	800 cfs (690 AF)	--- ---	--- ---
1220	6	6	3,000 cfs (1,160 AF)	700 cfs (380 AF)	300 cfs (280 AF)	300 cfs (240 AF)
			Vicinity of Gilbert			
1753	240	20	4,000 cfs (2,540 AF)	650 cfs (350 AF)	*150 cfs (20 AF)	*100 cfs (20 AF)
			Vicinity of Chandler			
1223	14	5	5,200 cfs (2,450 AF)	800 cfs (250 AF)	600 cfs (200 AF)	550 cfs (170 AF)
1224	17	3	5,400 cfs (2,900 AF)	500 cfs (180 AF)	200 cfs (150 AF)	200 cfs (120 AF)

Table 2 - Continued

CP	Contributing Drainage Area SPF (sq mi)	Contributing Drainage Area Other (sq mi)	Standard Project Flood	100-Year Flood	50-Year Flood	25-Year Flood
			Gila Floodway			
1304	18	18	4,900 cfs (3,080 AF)	700 cfs (840 AF)	--- ---	--- ---
1310A	37	37	10,000 cfs (6,060 AF)	2,200 cfs (1,810 AF)	--- ---	--- ---
1310B	70	70	19,000 cfs (10,300 AF)	4,000 cfs (2,480 AF)	2,900 cfs (1,810 AF)	2,300 cfs (1,340 AF)
1362	95	95	18,000 cfs (13,200 AF)	4,300 cfs (3,540 AF)	--- ---	--- ---
1372	117	117	17,000 cfs (15,700 AF)	4,300 cfs (4,300 AF)	--- ---	--- ---
1382	136	136	16,000 cfs (18,000 AF)	4,300 cfs (5,060 AF)	3,000 cfs (3,620 AF)	2,300 cfs (2,620 AF)

*Consolidated Canal in subarea 653 does not breach for 50-year and 25-year floods.

TABLE 3

Effective Impervious Cover Estimates

Land Use	Units Per Acre	Percent Effective Impervious Cover
Agricultural		0
Low density residential	5	25
Medium density residential	5-10	35
High density residential	Over 10	40
Commercial		90
Industrial		70

TABLE 4

History of Storms and Floods
Gila Floodway Basin and Vicinity

Year	Description	Source of Data*
1953	Rain began about 10:00 p.m. on 16 July. Storm was pretty general over the area north and east of Williams Air Force Base and extending into Superstition Mountains. Precipitation averaged about 0.75 inch in a 2-hour period. Peak discharge estimated at Queen Creek Road (now called Santan Road) bridge crossing the waterway just east of RWCD canal was 1,330.	1
1953	At about 4:00 p.m. on 29 July, precipitation began in the area. The most damaging storm was located in the Chandler Heights area, extending south into the Santan Mountains and east about 8 miles. During the storm, which lasted until about 10:00 a.m. on 30 July, 1.20 inches of rain is said to have fallen in 20 minutes. Highwater marks on Sonqui Creek at Power Road indicates a peak discharge of 425 cfs.	2
1954	19 August; see paragraph 3.01a.	
1957	31 October; see paragraph 3.01b.	
1959	Storm occurred on 17 August. West of Florence Junction, Queen Creek came to within 2 feet of floor of bridge. In the town of Queen Creek, creek overflowed, running into homes, damaging crops and irrigation ditches.	3
1963	On evening of 16 August, unstable masses of moist air moved into eastern Maricopa County from northeast and from southeast. Storm was multicellular event with most intense cell centered over Glendale. Another cell was centered just north of U.S. Highway 60-70-80-89 west of Apache Junction and east of Mesa. The average duration of the storm was about 4 hours. A maximum storm total of about 3.5 inches was estimated. Just over 1 inch fell in the City of Mesa. Many businesses along the highway were flooded by runoff from the hills. Residential yards were subjected to both scouring and sedimentation. Several county roads were extensively damaged, and RWCD Canal was breached in 16 places, mostly between Broadway Road and Southern Avenue. Most farmland damage was in conjunction with canal breaks and ponded water trying to get into and over canal. Damage consisted of inundation of crops, sedimentation, and some scouring.	4

TABLE 4 - Continued

Year	Description	Source of Data*
1969	On 14 September, the Tempe-Mesa-Chandler area was hit by an intense thunderstorm, causing some severe flash flooding. The Weather Service rain gage near Baseline Road and 56th Street recorded 3.52 inches between 6:00 p.m. and 7:00 p.m. Guadalupe reported 2.73 inches in the same period. Chandler recorded 0.61 inch for the hour. The areal coverage of the storm was fairly small. A Weather Service employee living in South Phoenix estimated the diameter of the cloud shaft to be 3 miles, with the shaft extending to 50,000 feet. Runoff flooded streets and irrigation ditches, and canals in the area filled to overflowing.	5, 6
1971	Just after midnight on 16 August, the area around Apache Junction began to experience flooding. Heavy precipitation must have occurred in the Goldfield Mountains. The Weather Service reported 3.40 inches at Horse Mesa Dam and the Forest Service recorded 3 inches at Tortilla Flat. A large crew spent all day clearing sediment from Apache Trail.	7
1972	General precipitation began in the Gila Floodway basin at about 6:00 p.m. on 18 October. By 8:00 p.m. on the 19th the storm was pretty well over. Twenty-six hour rainfall amounts ranged from about 1.5 inches in the Mesa-Chandler-Gilbert area to about 4.5 inches in the Queen Creek-Magma basins. In the Queen Creek area, the cotton crop yield was reduced 10-60 percent by flood damage, depending on the water depth. The depth of flooding in the fields varied from 0.5 feet to 2.6 feet. Floodwaters ponded behind and overtopped the railroad tracks at several locations. The flood retarding structures in the basins north of Queen Creek controlled the runoff emenating from the mountains above them, thus significantly reducing damage in the lower portions of the watershed.	8

*Source of data.

1. SCS-Phoenix files, Office Memorandum dated 17 July 1953.
2. SCS-Phoenix files, Office Memorandum dated 31 July 1953.
3. SCS-Phoenix files, Office Memorandum dated 18 August 1959.
4. SCS-Phoenix files, Office Memorandum dated 28 October 1963.
5. Letter from Maricopa County Flood Control District to Los Angeles District Corps of Engineers dated 8 October 1969.
6. Newspaper article, ''The Arizona Republic'' Phoenix, Monday, September 15, 1969.
7. SCS-Phoenix files, handwritten note.
8. SCS-Phoenix files, Administrator's General Memorandum dated 23 April 1973.

REFERENCES

1. Hydrology Report for Type 15 Flood Insurance Study, Mesa, Arizona (and subsequent revisions), U.S. Army Engineer District, Los Angeles, Corps of Engineers, 30 April 1975.

2. Gila River Basin, New River and Phoenix City Streams, Arizona, Design Memorandum No. 2, Hydrology, Part I, U.S. Army Engineer District, Los Angeles, Corps of Engineers, October 1974.

3. USDA Environmental Impact Statement (Draft), Buckhorn-Mesa Watershed, Maricopa and Pinal Counties, Arizona, USDA Soil Conservation Service, February 1975.

4. Watershed Work Plan, Buckhorn-Mesa Watershed, Maricopa and Pinal Counties, Arizona, USDA Soil Conservation Service, January 1963.

5. Watershed Work Plan, Apache Junction-Gilbert Watershed, Maricopa and Pinal Counties, Arizona, USDA Soil Conservation Service, January 1963.

6. Watershed Work Plan, Williams-Chandler Watershed, Maricopa and Pinal Counties, Arizona, USDA Soil Conservation Service, January 1963.

7. Stormwater Drainage for the City of Mesa, Yost and Gardner Engineers, Phoenix, Arizona, Project No. 71-6, November 1973.

8. Soil Survey, Eastern Maricopa and Northern Pinal Counties Area, Arizona, USDA Soil Conservation Service, November 1974.

8. General Soil Map, Maricopa County, Arizona, SUDA Soil Conservation Service, 1973.

10. Gila River Basin, Arizona and New Mexico, Design Memorandum No. 1, Hydrology for Whitlow Ranch Reservoir, Queen Creek, Arizona, U.S. Army Engineer District, Los Angeles, Corps of Engineers, July 1957.

11. Superstition Freeway, Conceptual Study for Drainage (Tempe Canal to RWCD Canal), Project No. F-028-1-402 PE, Yost and Gardner Engineers, February 1975.

12. Report on Flood of 19 August 1954, Queen Creek and Vicinity, Arizona, U.S. Army Corps of Engineers, Los Angeles District, 24 September 1954.

13. Report on Floods of 31 October 1957, Santa Rosa Wash, Queen Creek and Vicinity, Arizona, U.S. Army Engineer District, Los Angeles, Corps of Engineers, 28 February 1958.

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15. Overland Flow and Groundwater Flow from a Steady Rainfall of Finite Duration, F.M. Henderson and R.A. Wooding, Journal of Geophysical Research, Vol. 69, No. 8, April 15, 1964.

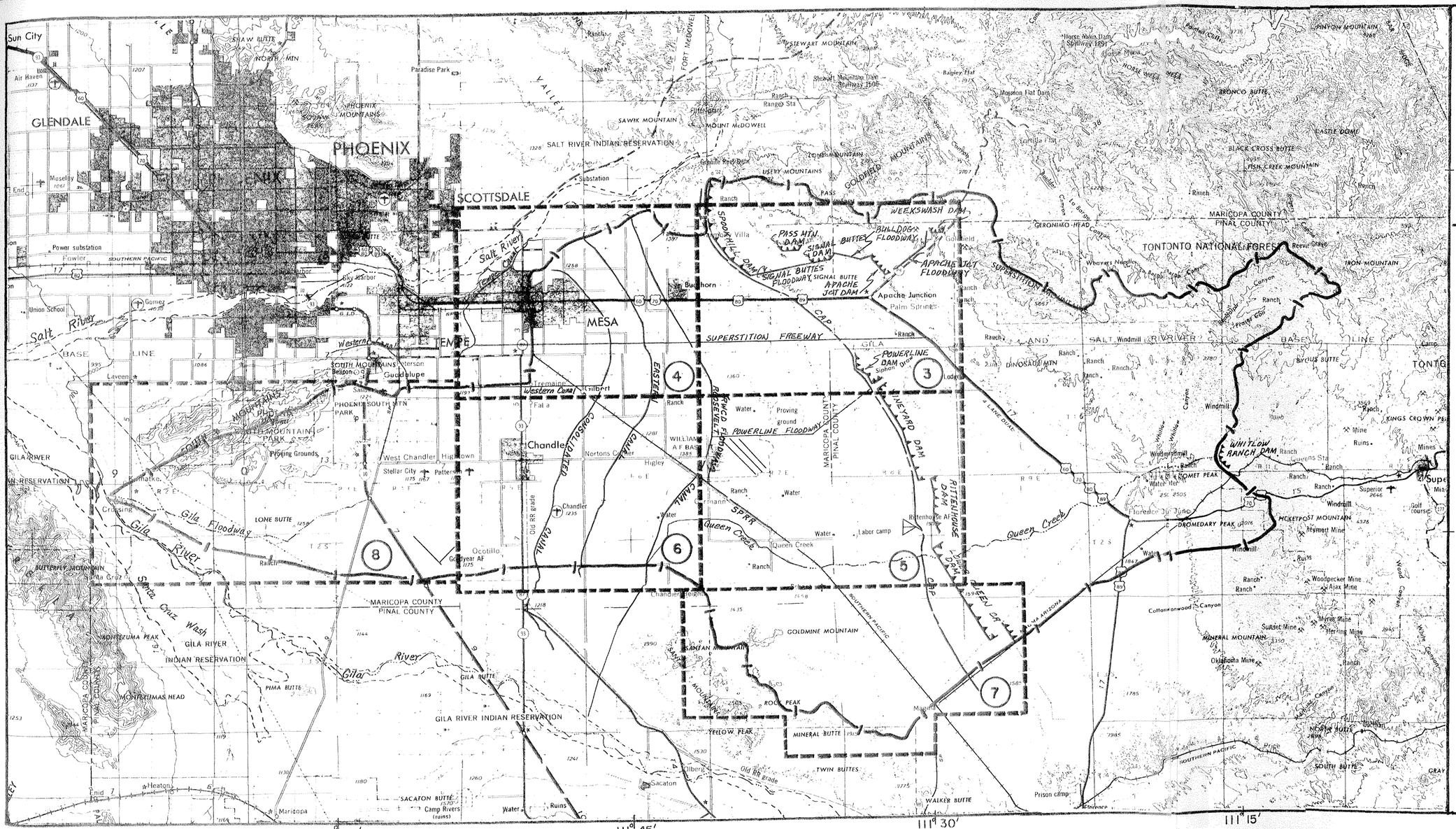
16. Kinematic Wave Nomograph for Times of Concentration, R.M. Ragan and J.O. Durn, Journal of Hydraulics Division, Proceedings of the American Society of Civil Engineers, HY 10, October 1972.

17. Runoff from Impervious Surfaces, Y.S. Yu and J.S. McNown, U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, Contract Report No. 2-66, February 1963.

18. Open-Channel Hydraulics, Ven Te Chow, McGraw-Hill Book Company, 1959.

19. Precipitation-Frequency Atlas of the Western United States, Vol. VIII, Arizona, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, 1973.

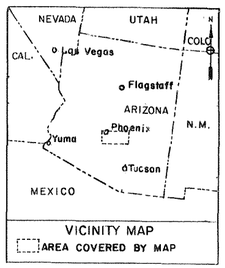
20. Storm Water Management Model, Volume I-Final Report, by Metcalf and Eddy, Inc., University of Florida, and Water Resources Engineers, Inc. for the Environmental Protection Agency, July 1971.



LEGEND

BOUNDARY OF DRAINAGE AREA.

(3) PLATE 3 THROUGH 8



VICINITY MAP
AREA COVERED BY MAP

SCALE IN MILES

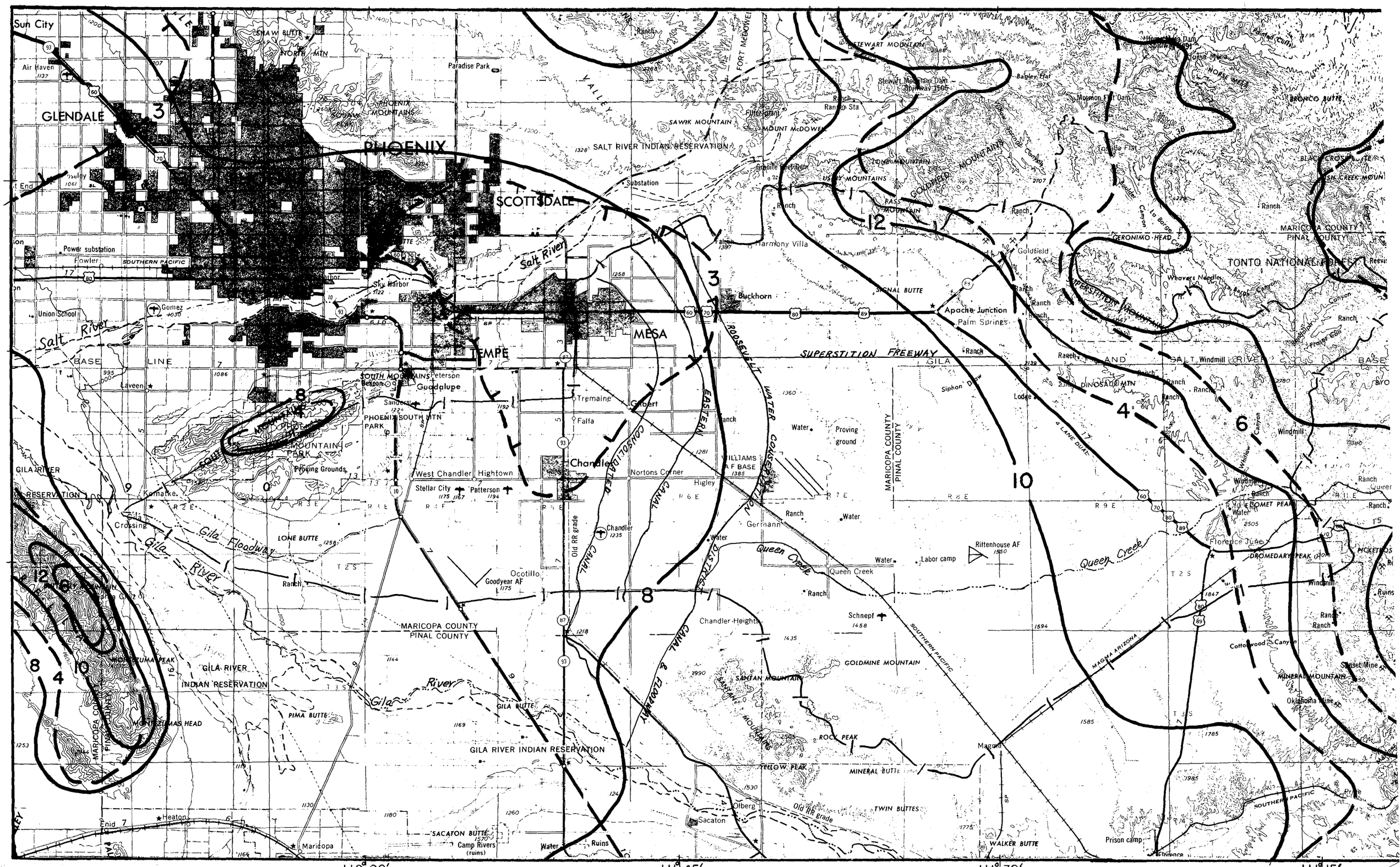
5 0 5

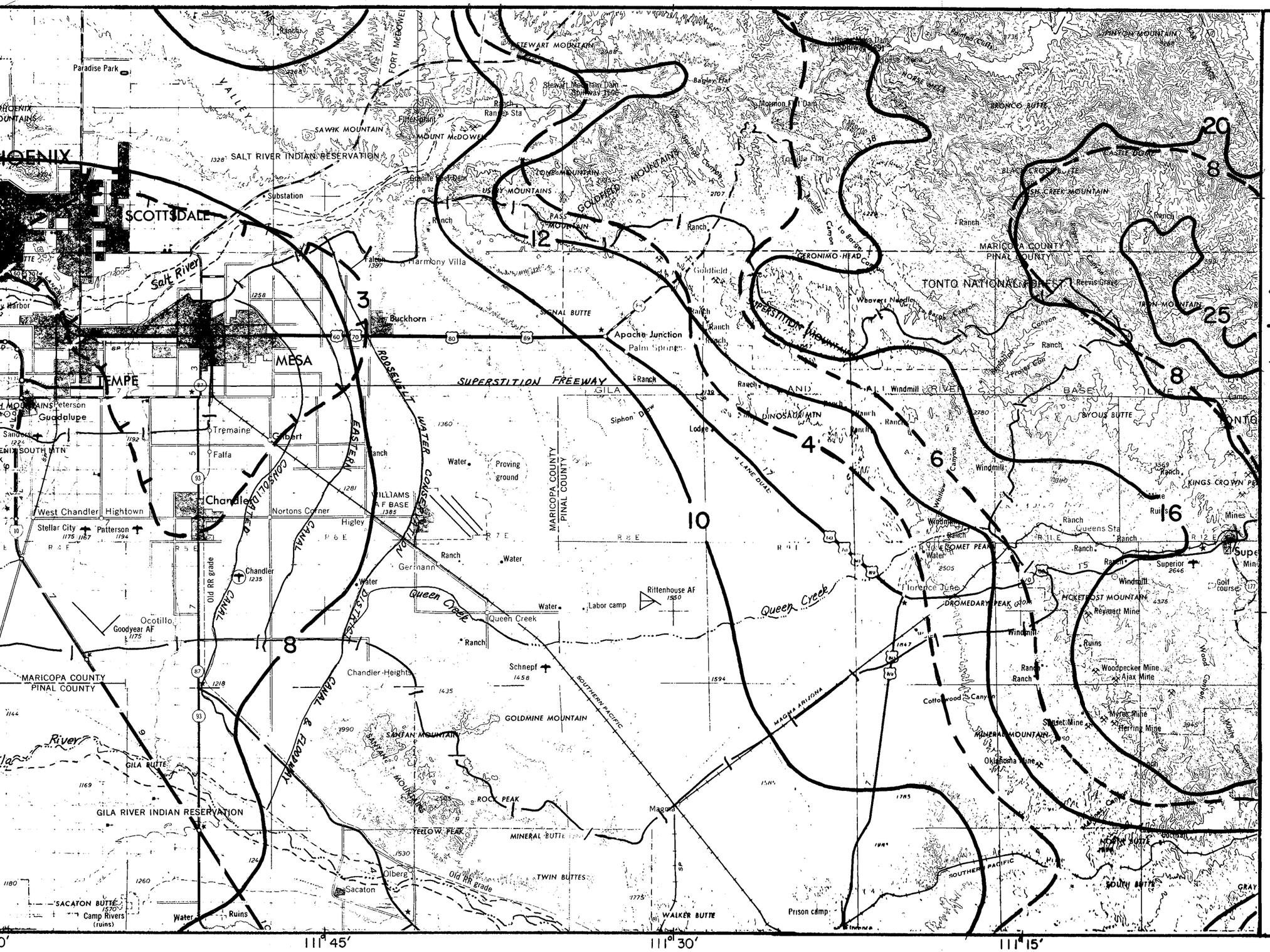
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

INDEX MAP

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

PLATE 1


Sun City
Air Haven
GLENDALE
PHOENIX
SCOTTSDALE
TEMPE
MESA
Chandler
Apache Junction
Palm Springs
Goldfield
Harmony Villa
Buckhorn
Sky Harbor
Paradise Park
Powder substation
Fowler
SOUTHERN PACIFIC
Union School
Gomez
Salt River
BASE LINE
Laveen
Guadalupe
Peterson
Tremaine
Gilbert
Falfa
PHOENIX SOUTH MTN PARK
Proving Grounds
West Chandler
Hightown
Stellar City
Patterson
Nortons Corner
Higley
WILLIAMS A F BASE
Germann
Queen Creek
Labor camp
Rittenhouse AF
Schnepf
Chandler Heights
Ocotillo
Goodyear AF
Komatke
Gila Crossing
GILA RIVER RESERVATION
Gila River
Gila Floodway
LONE BUTTE
MARICOPA COUNTY
PINAL COUNTY
GILA RIVER INDIAN RESERVATION
MONTEZUMA PEAK
MONTEZUMAS HEAD
PIMA BUTTE
GILA BUTTE
SACATON BUTTE
Camp Rivers (ruins)
Maricopa
Enid
Heaton
Sacaton
Olberg
Ruins
Water
Old RR grade
CONSOLIDATED CANAL
EASTERN ARIZONA COLONIES CANAL
ROOSEVELT WATER CONSERVATION DISTRICT
SUPERSTITION FREEWAY
SIGNAL BUTTE
SUPERSTITION MOUNTAINS
GOLDFIELD MOUNTAINS
TONTO NATIONAL FOREST
GERONIMO HEAD
SAWK MOUNTAIN
MOUNT McDOWELL
SALT RIVER INDIAN RESERVATION
PHOENIX MOUNTAINS
SOUTH MOUNTAINS
STEWART MOUNTAIN
Stewart Mountain Dam
Mormon Flat Dam
Horse Mesa Dam
BRONCO BUTTE
BLACK ROCK BUTTE
SILVER CREEK MOUNTAIN
Weaver's Needle
Bagley Flat
Tortilla Flat
Windmill
DINOSAUR MTN
COMET PEAK
DROMEDARY PEAK
Florence Junction
Queen Creek
GOLDMINE MOUNTAIN
SANTAN MOUNTAIN
ROCK PEAK
YELLOW PEAK
MINERAL BUTTE
TWIN BUTTES
WALKER BUTTE
Magma
Prison camp
Florence
MINERAL MOUNTAIN
Sunset Mine
Oklahoma Mine
Cottonwood Canyon
SOUTHERN PACIFIC
MAGMA ARIZONA
112° 00′
111° 45′
111° 30′
111° 15′



— 10 — ISOLINES OF NORMAL ANNUAL PRECIPITATION IN INCHES.

— 8 — ISOLINES OF NORMAL MAY-SEPTEMBER PRECIPITATION IN INCHES.

— 1 — BOUNDARY OF DRAINAGE AREA.

GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

HYDROLOGIC MAP

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

PLATE 2

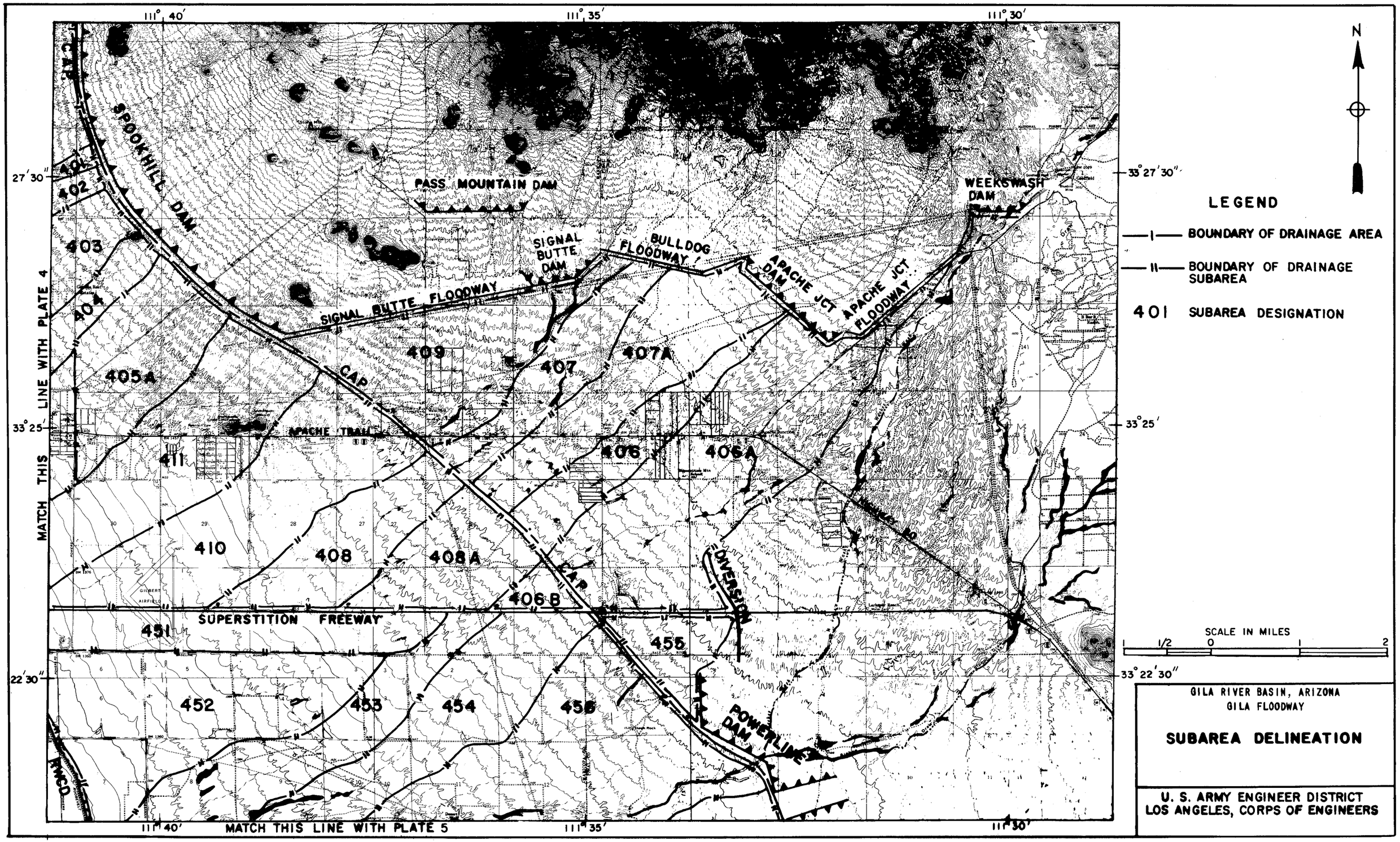
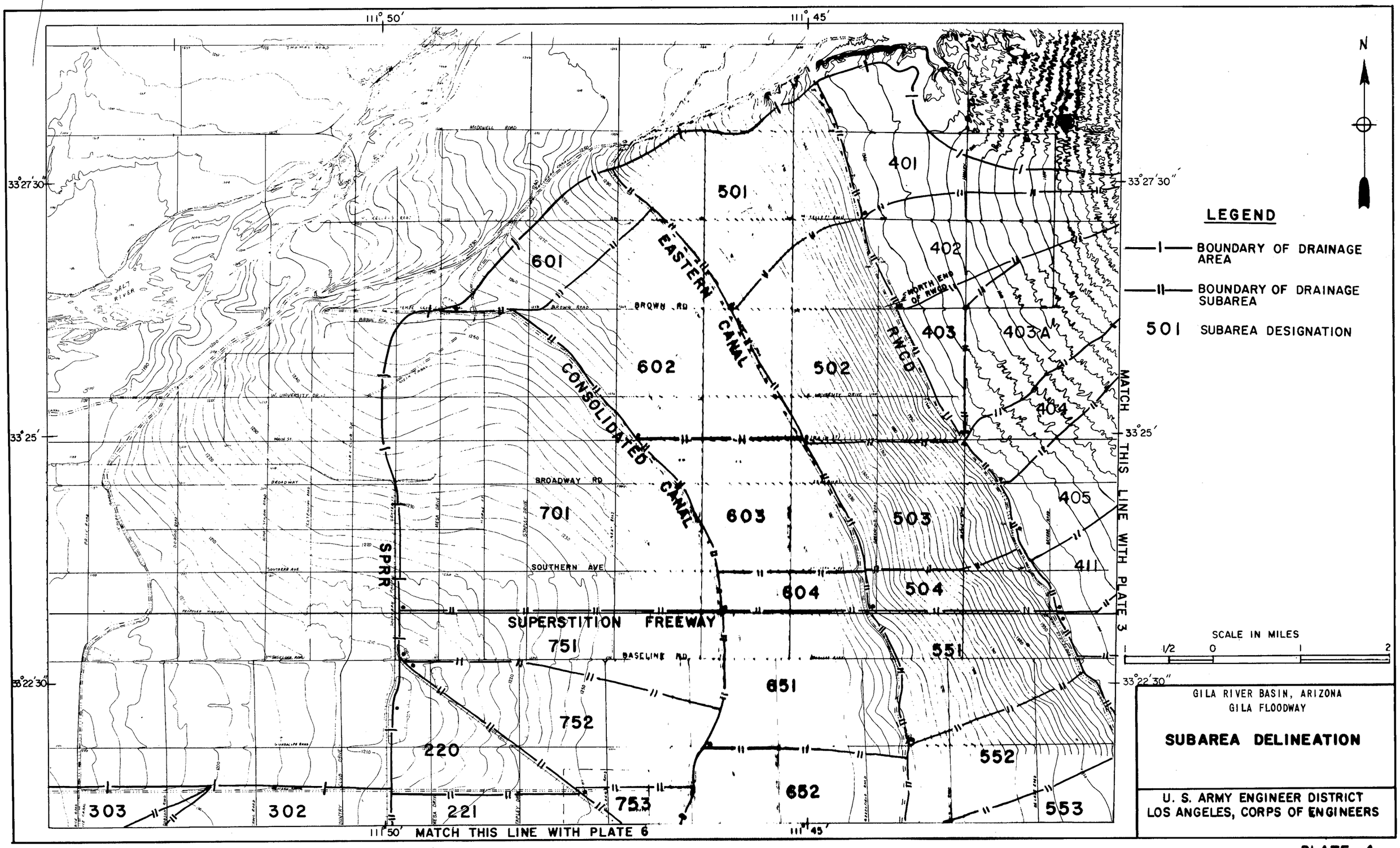

111° 40′
111° 35′
111° 30′
33° 27′ 30″
33° 25′
33° 22′ 30″
MATCH THIS LINE WITH PLATE 4
MATCH THIS LINE WITH PLATE 5
SPOOKHILL DAM
PASS MOUNTAIN DAM
SIGNAL BUTTE DAM
BULLDOG FLOODWAY
APACHE JCT DAM
APACHE JCT FLOODWAY
WEEKSWASH DAM
SIGNAL BUTTE FLOODWAY
CAP
APACHE TRAIL
DIVERSION
POWERLINE DAM
SUPERSTITION FREEWAY
PWCD
401
402
403
404
405A
406
406A
406B
407
407A
408
408A
409
410
411
451
452
453
454
455
456
N
LEGEND
BOUNDARY OF DRAINAGE AREA
BOUNDARY OF DRAINAGE SUBAREA
401 SUBAREA DESIGNATION
SCALE IN MILES
1 1/2 0 1 2
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY
SUBAREA DELINEATION
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE 3

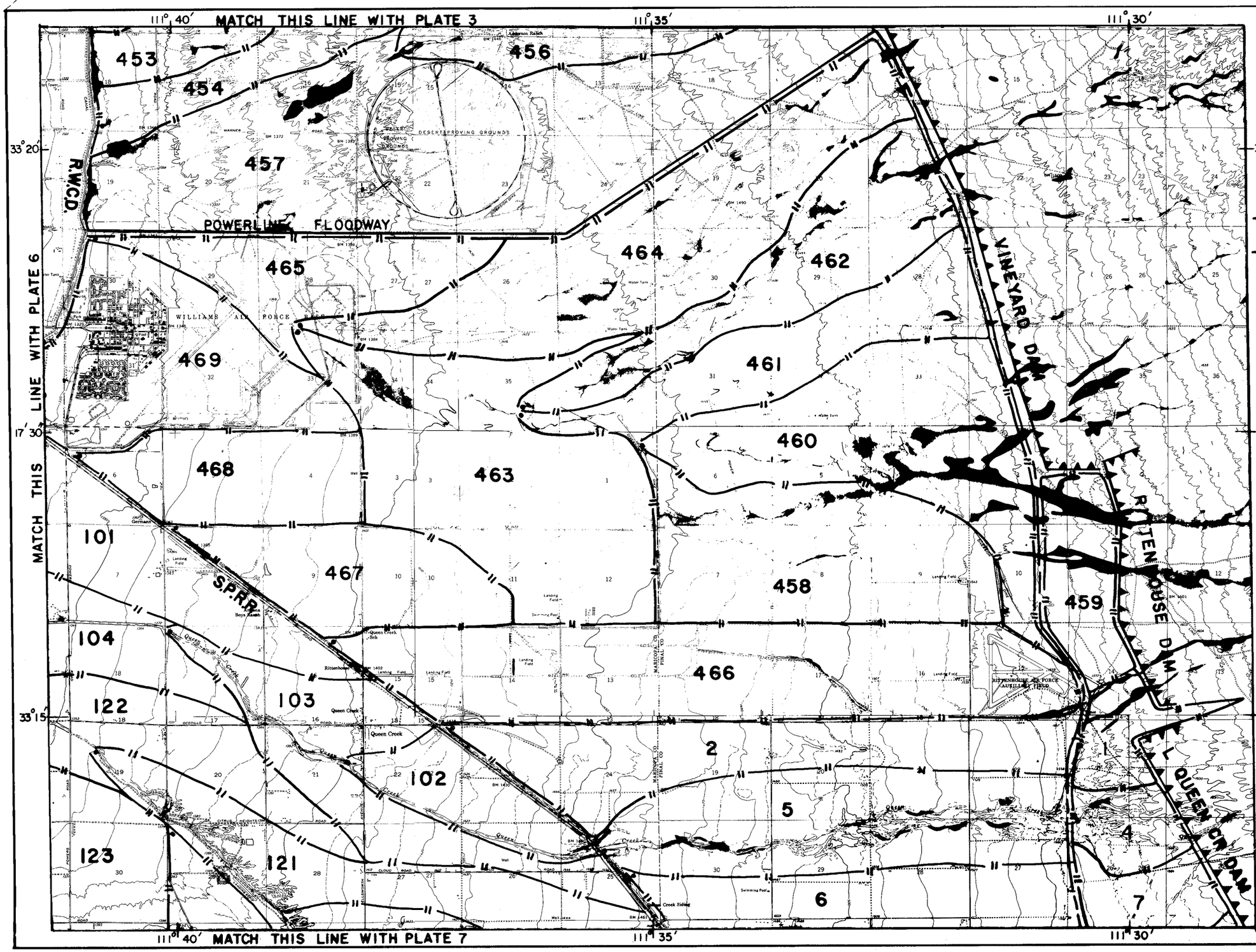


GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

SUBAREA DELINEATION

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE 4



LEGEND

—— I —— BOUNDARY OF DRAINAGE AREA

—— II —— BOUNDARY OF DRAINAGE SUBAREA

101 SUBAREA DESIGNATION

N

SCALE IN MILES

1 1/2 0 1 2

GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

SUBAREA DELINEATION

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE 5

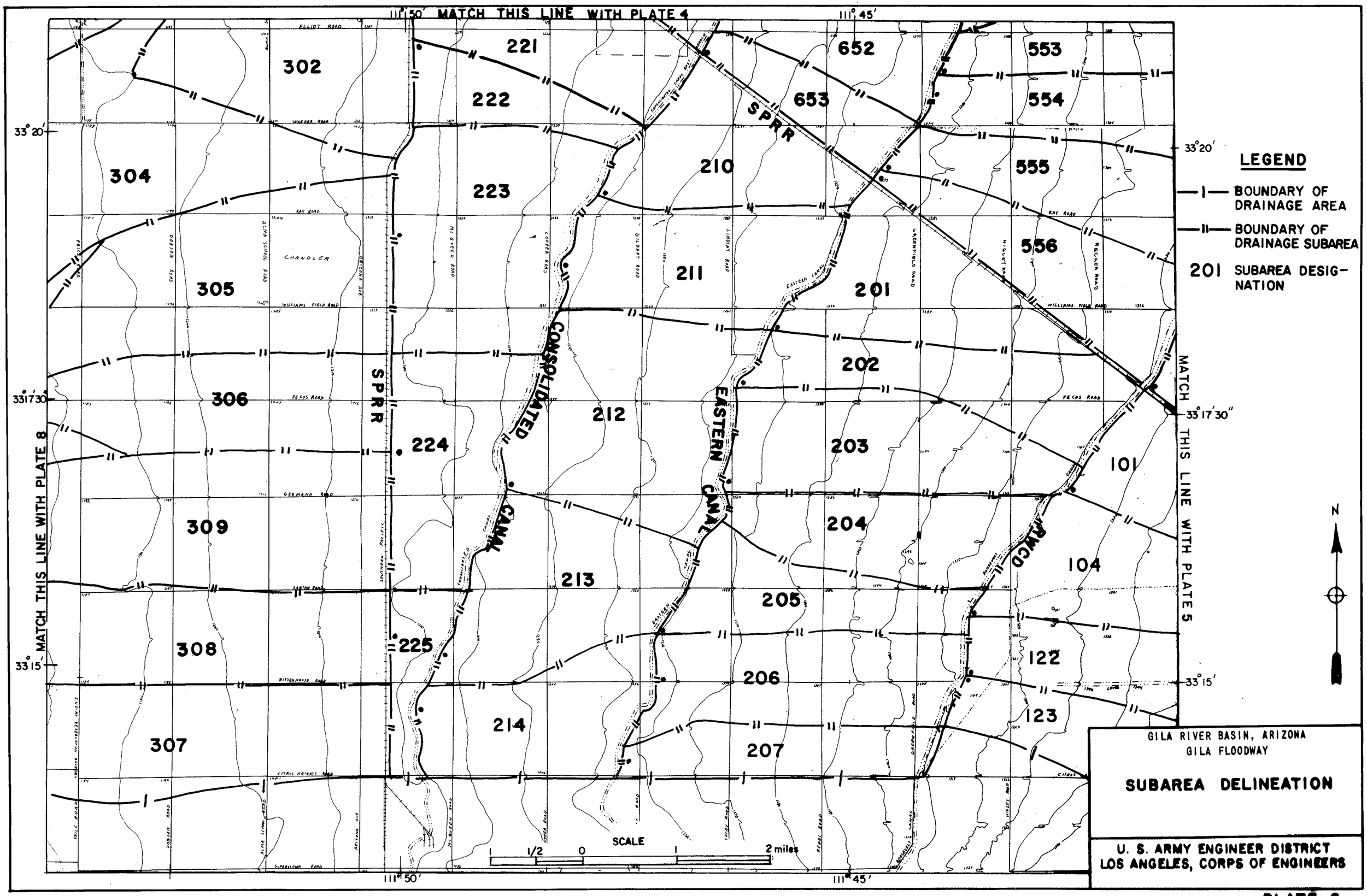
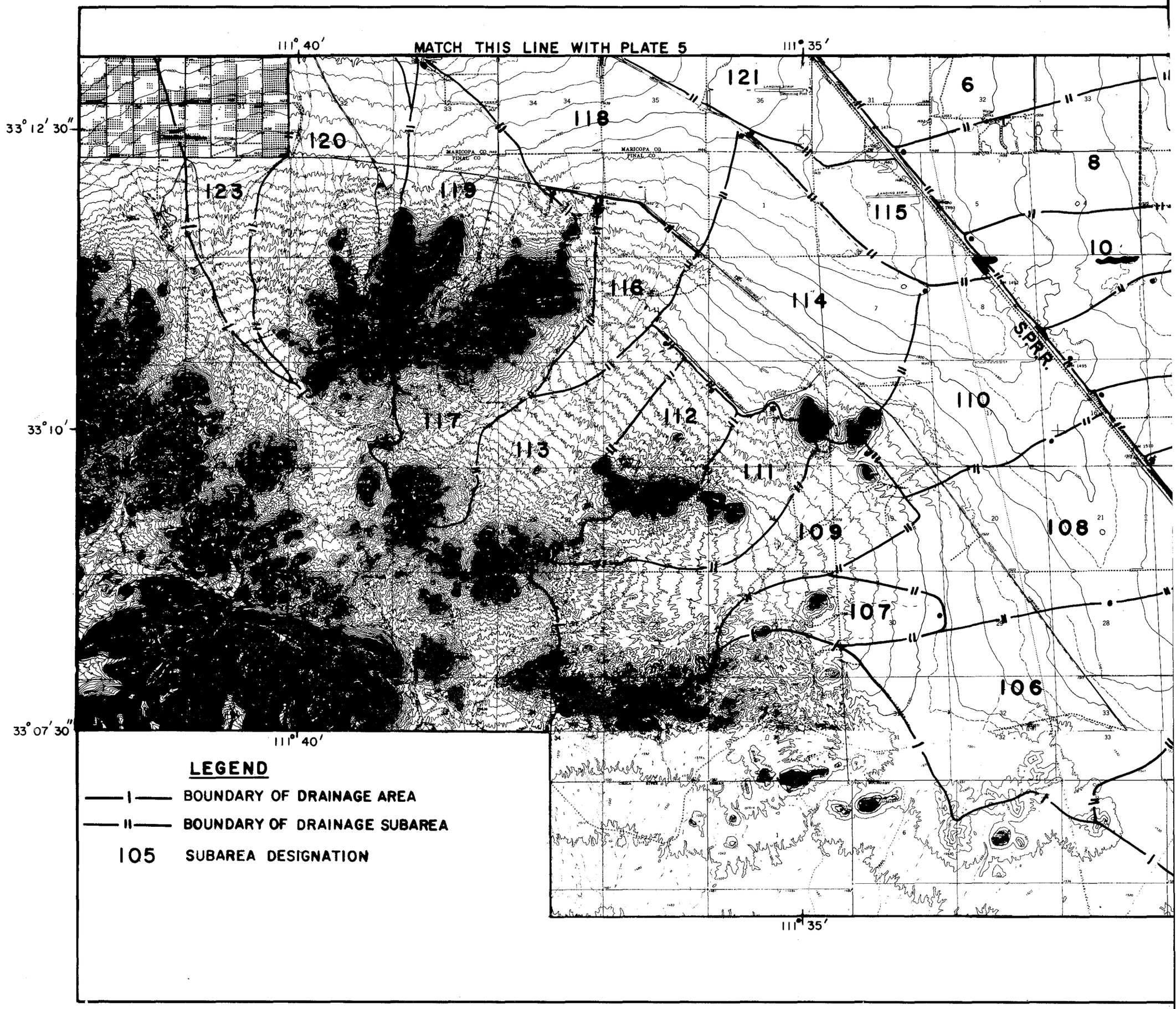
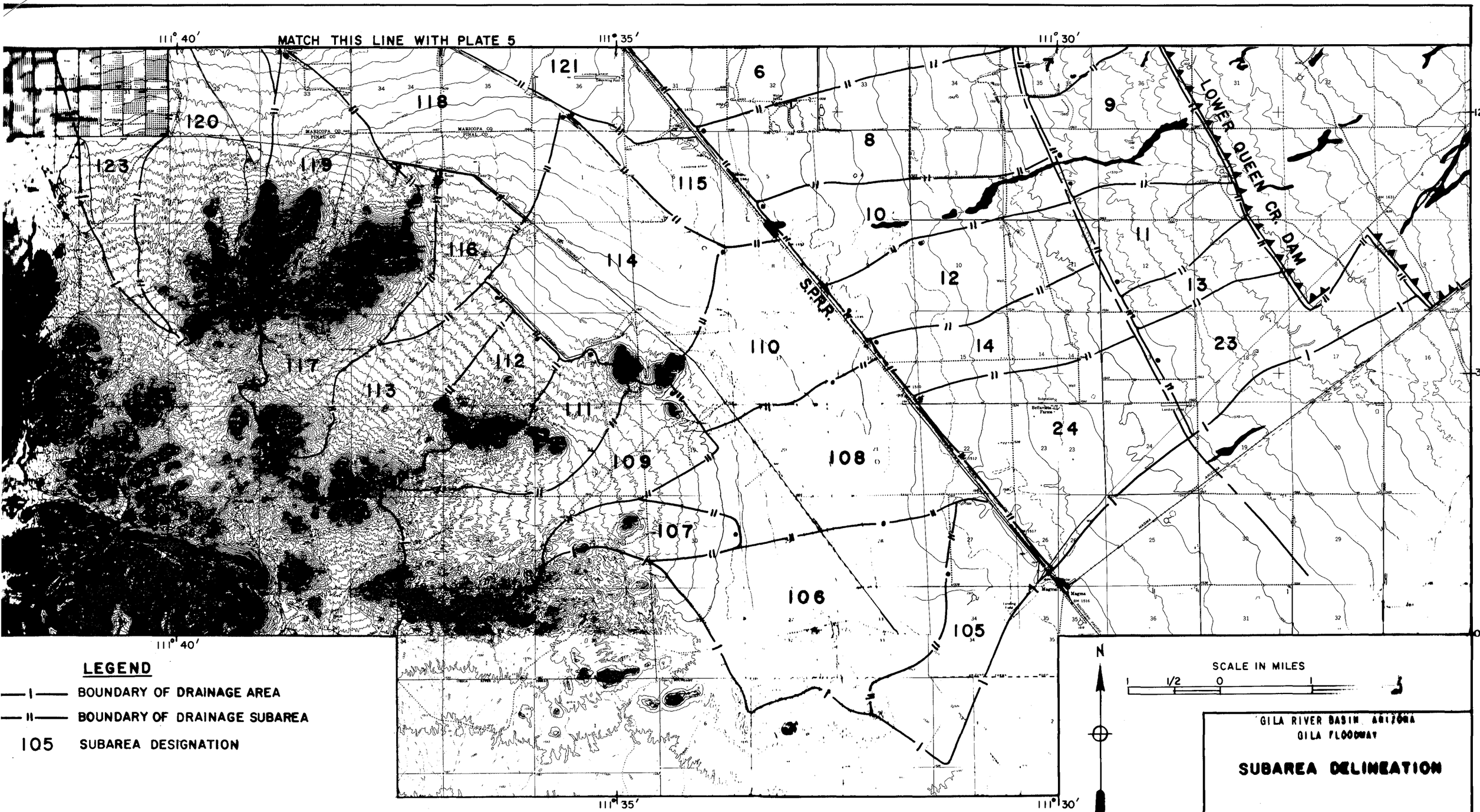

MATCH THIS LINE WITH PLATE 4
111°50'
111°45'
33°20'
33°17'30"
33°15'
MATCH THIS LINE WITH PLATE 8
MATCH THIS LINE WITH PLATE 5
302
221
652
553
222
653
554
304
210
555
223
556
305
211
201
306
202
212
224
203
101
309
204
104
213
205
308
225
206
122
214
123
207
307
SPRR
CONSOLIDATED CANAL
EASTERN CANAL
PWCD
ELLIOT ROAD
WARNER ROAD
RAY ROAD
CHANDLER
WILLIAMS FIELD ROAD
PECOS ROAD
GERMANN ROAD
SANTAN ROAD
RITTENHOUSE ROAD
CITRUS HEIGHTS ROAD
SUPERSTITION ROAD
LEGEND
BOUNDARY OF DRAINAGE AREA
BOUNDARY OF DRAINAGE SUBAREA
201 SUBAREA DESIGNATION
N
SCALE
1/2 0 1 2 miles
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY
SUBAREA DELINEATION
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE 6


MATCH THIS LINE WITH PLATE 5
111° 40′
111° 35′
33° 12′ 30″
33° 10′
33° 07′ 30″
111° 40′
111° 35′
121
6
118
120
8
123
119
115
10
116
114
S.P.R.R.
110
117
112
113
111
109
108
107
106
MARICOPA CO
PINAL CO
LANDING STRIP
Swimming Pool
LEGEND
I BOUNDARY OF DRAINAGE AREA
II BOUNDARY OF DRAINAGE SUBAREA
105 SUBAREA DESIGNATION

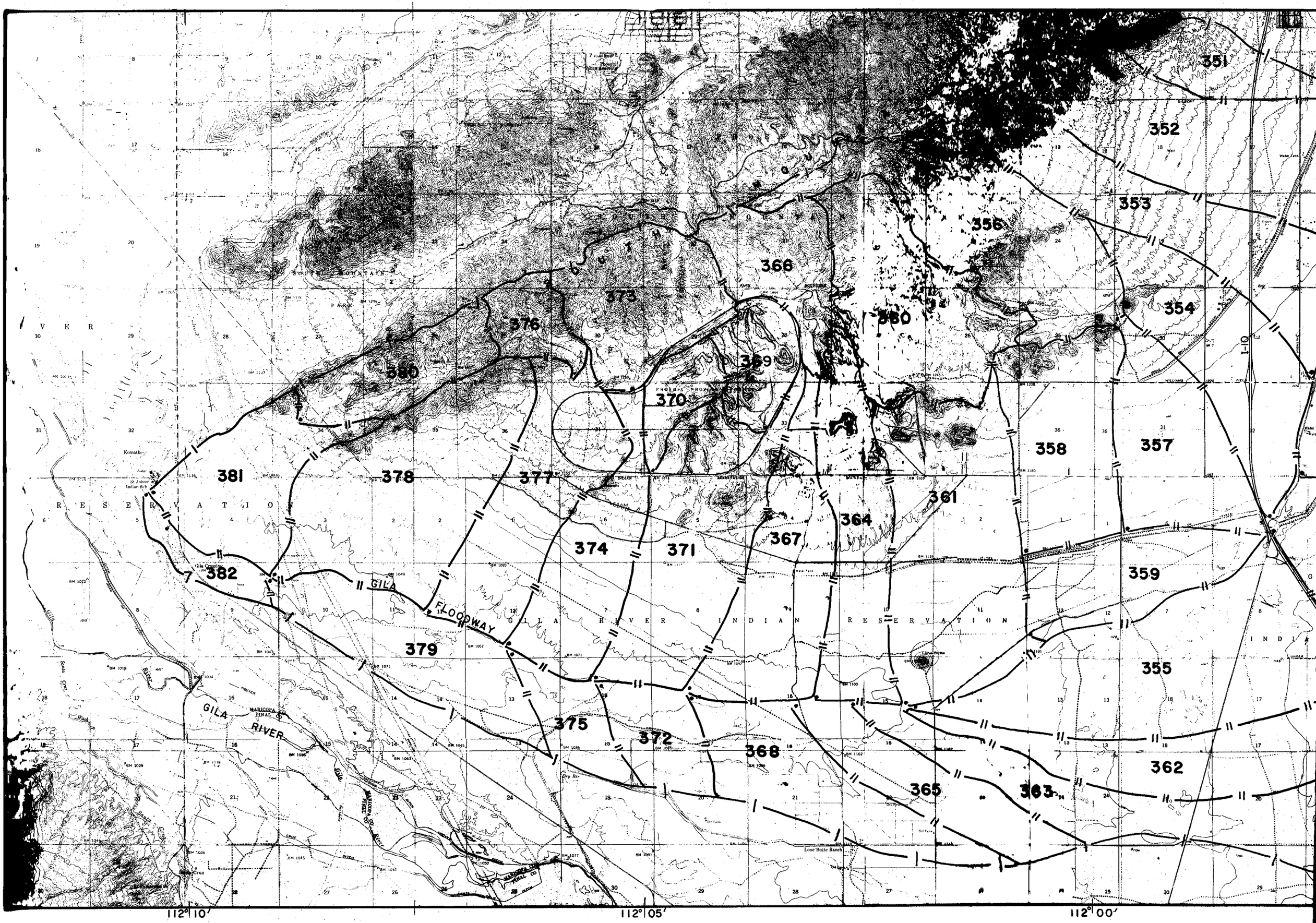


GILA RIVER BASIN ARIZONA
GILA FLOODWAY

SUBAREA DELINEATION

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE 7


351
352
353
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357
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362
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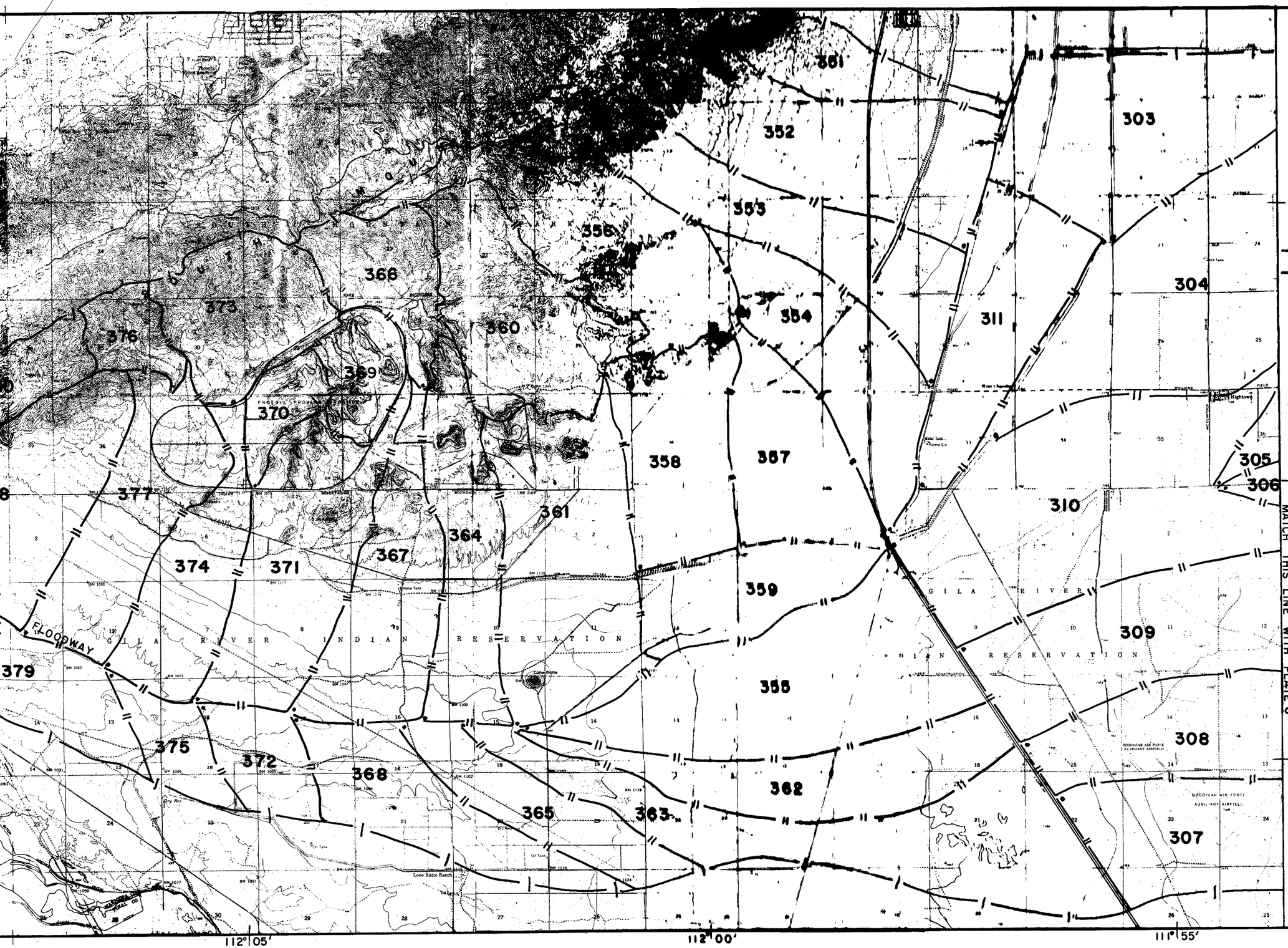
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
GILA FLOODWAY
GILA RIVER
GILA RIVER INDIAN RESERVATION
MARICOPA FINAL CO
Lone Butte Ranch
Komatke
112°10′
112°05′
112°00′

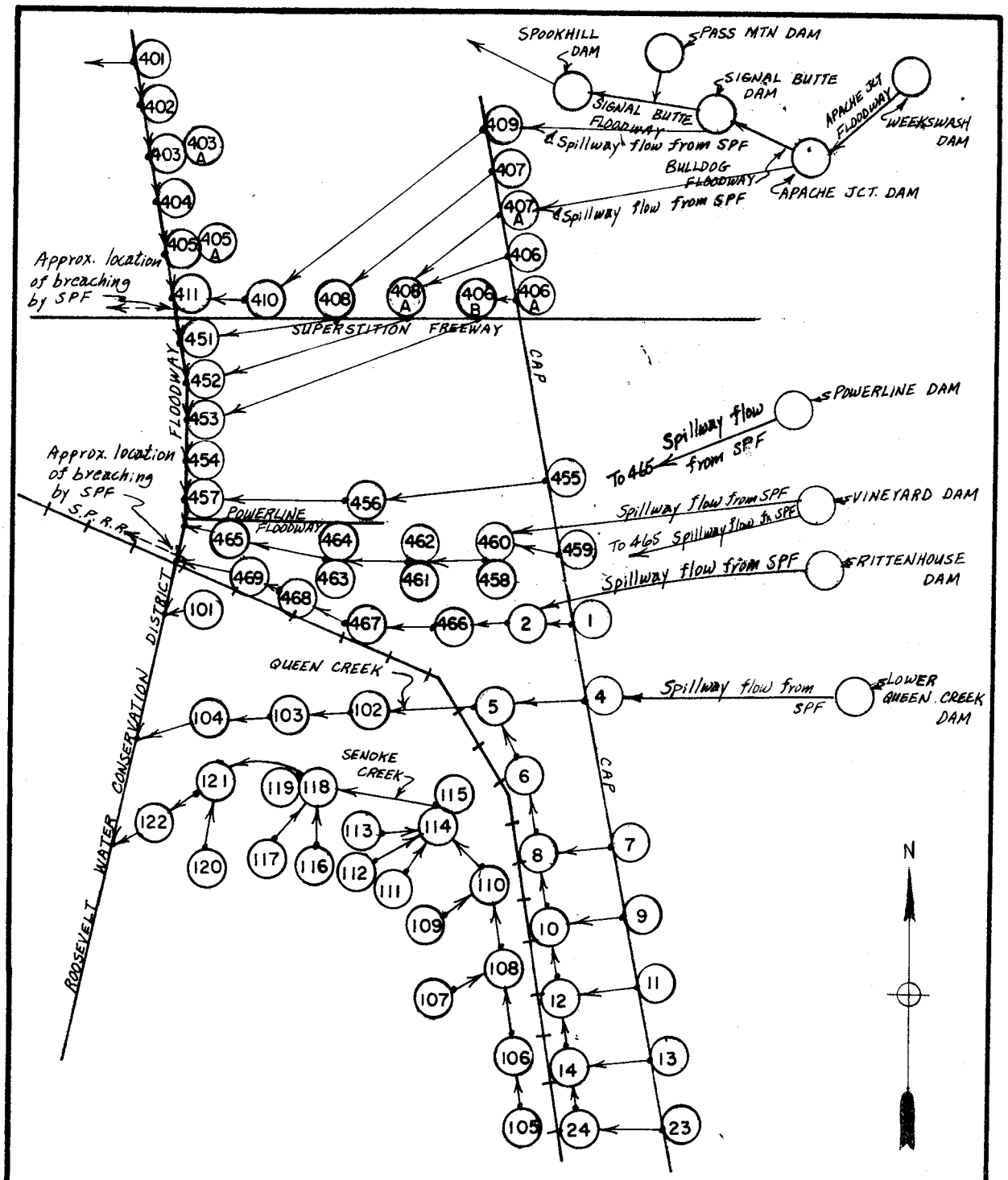


GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

SUBAREA DELINEATION

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE 8



LEGEND

ZERO ROUTING

ROUTING REACH

(105) SUBAREA

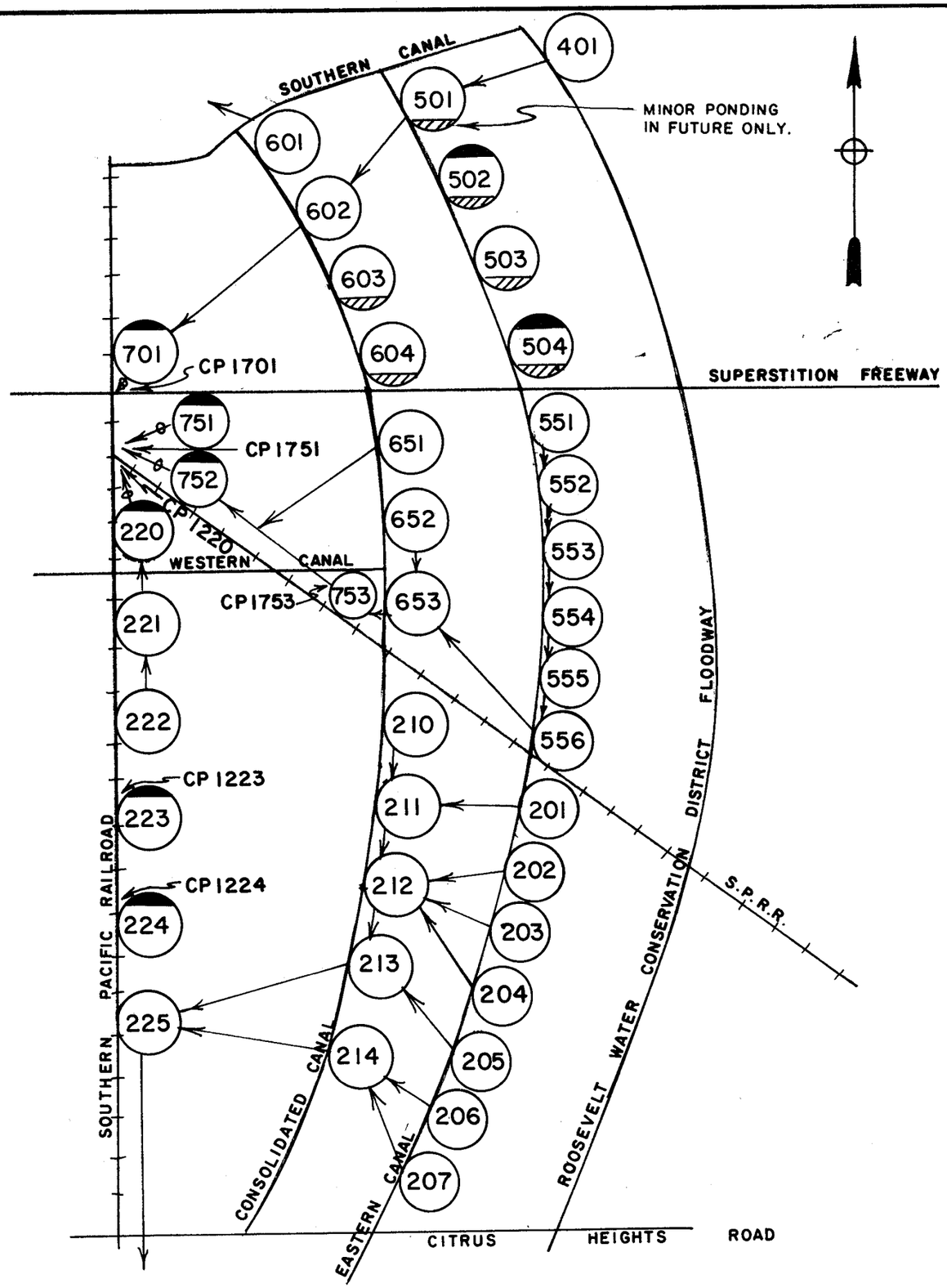
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

SCHEMATIC FLOW DIAGRAM

AREA EAST OF RWCD FLOODWAY

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE 9



LEGEND

501	Subarea
CP 1701	Concentration Point
←	Routing Reach
← 0	Zero Routing
701	Total runoff volume ponded behind barrier.
604	Minor ponding due to street runoff. On-site storage ordinance in effect.
502	Total runoff volume ponded behind barrier in present conditions. Minor ponding due to street runoff in future conditions; on-site storage ordinance in effect.

GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

SCHEMATIC FLOW DIAGRAM

100-YEAR FLOOD ROUTING
AREA BETWEEN RWCD
AND R.R. TO CHANDLER

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

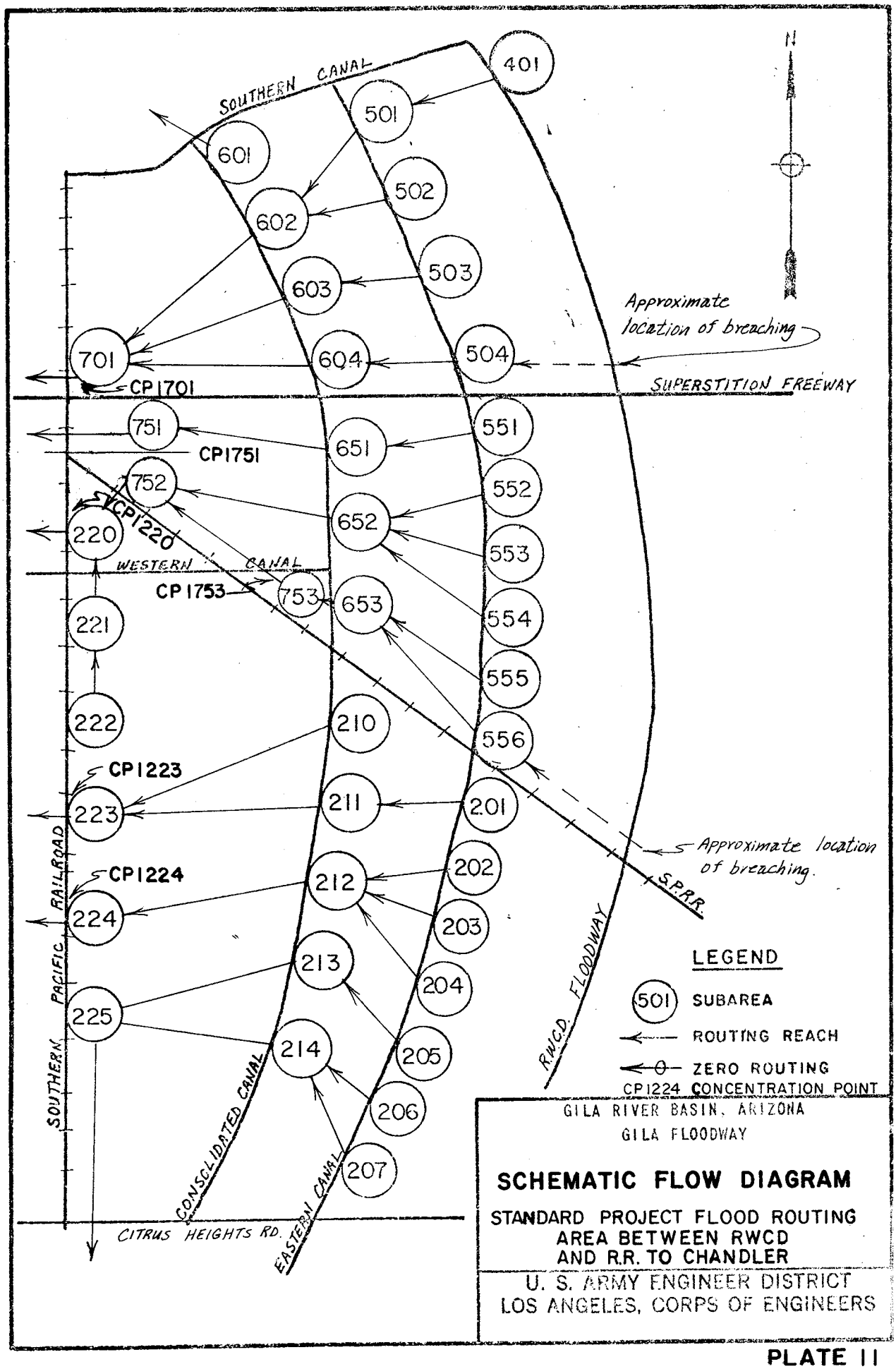
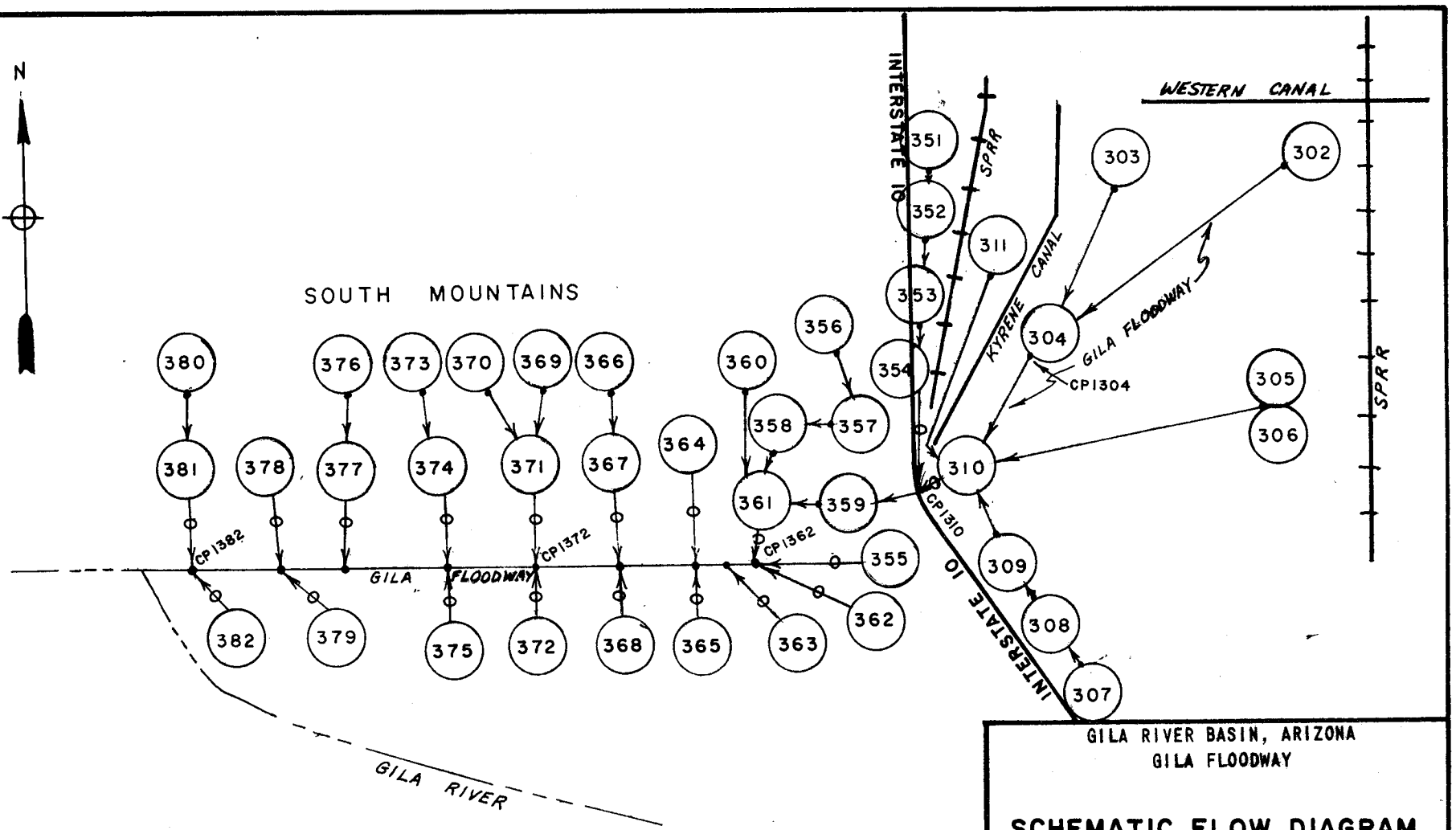

N
SOUTHERN CANAL
401
501
601
502
602
503
603
504
604
701
CP1701
Approximate location of breaching
SUPERSTITION FREEWAY
751
CP1751
651
551
752
552
CP1220
652
220
553
WESTERN CANAL
CP1753
753
653
554
221
555
222
210
556
CP1223
223
211
201
Approximate location of breaching.
S.P.R.R.
CP1224
202
212
224
203
213
204
225
214
205
206
207
SOUTHERN PACIFIC RAILROAD
CONSOLIDATED CANAL
EASTERN CANAL
RWCD FLOODWAY
CITRUS HEIGHTS RD.
LEGEND
501 SUBAREA
ROUTING REACH
ZERO ROUTING
CP1224 CONCENTRATION POINT
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY
SCHEMATIC FLOW DIAGRAM
STANDARD PROJECT FLOOD ROUTING
AREA BETWEEN RWCD
AND R.R. TO CHANDLER
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE 11



GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

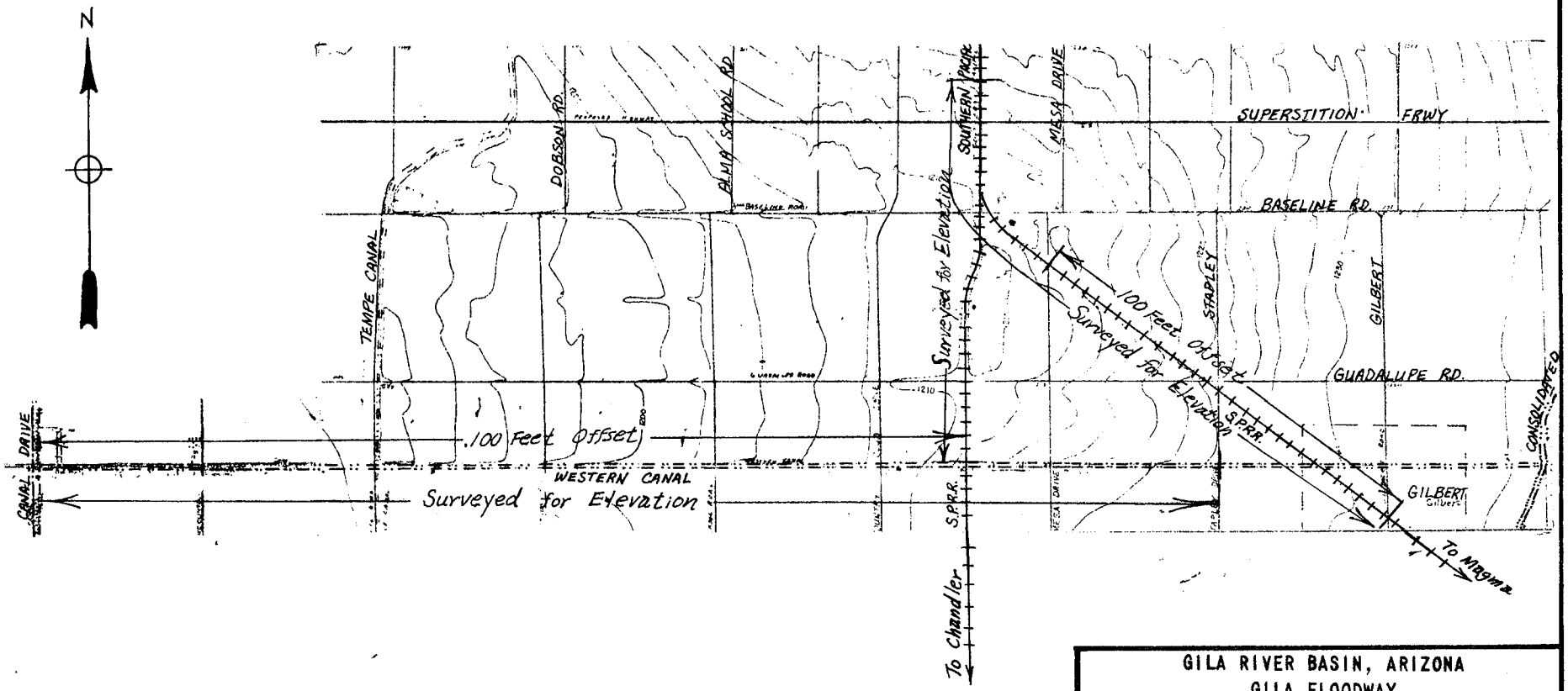
SCHEMATIC FLOW DIAGRAM
AREA WEST OF RR TO CHANDLER

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

LEGEND

302 SUBAREA
ROUTING REACH
ZERO ROUTING
CP1382 CONCENTRATION POINT

PLATE 12

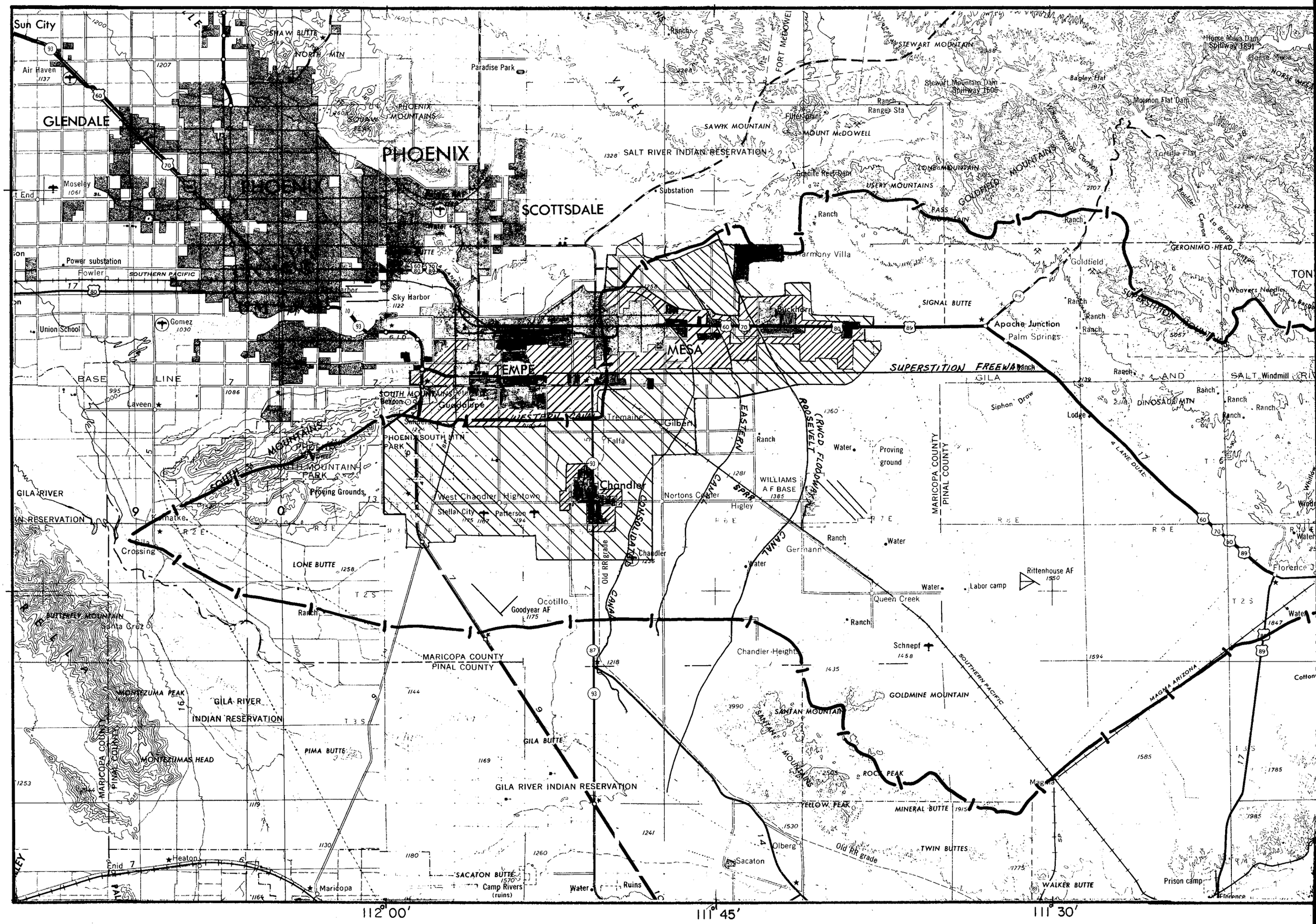


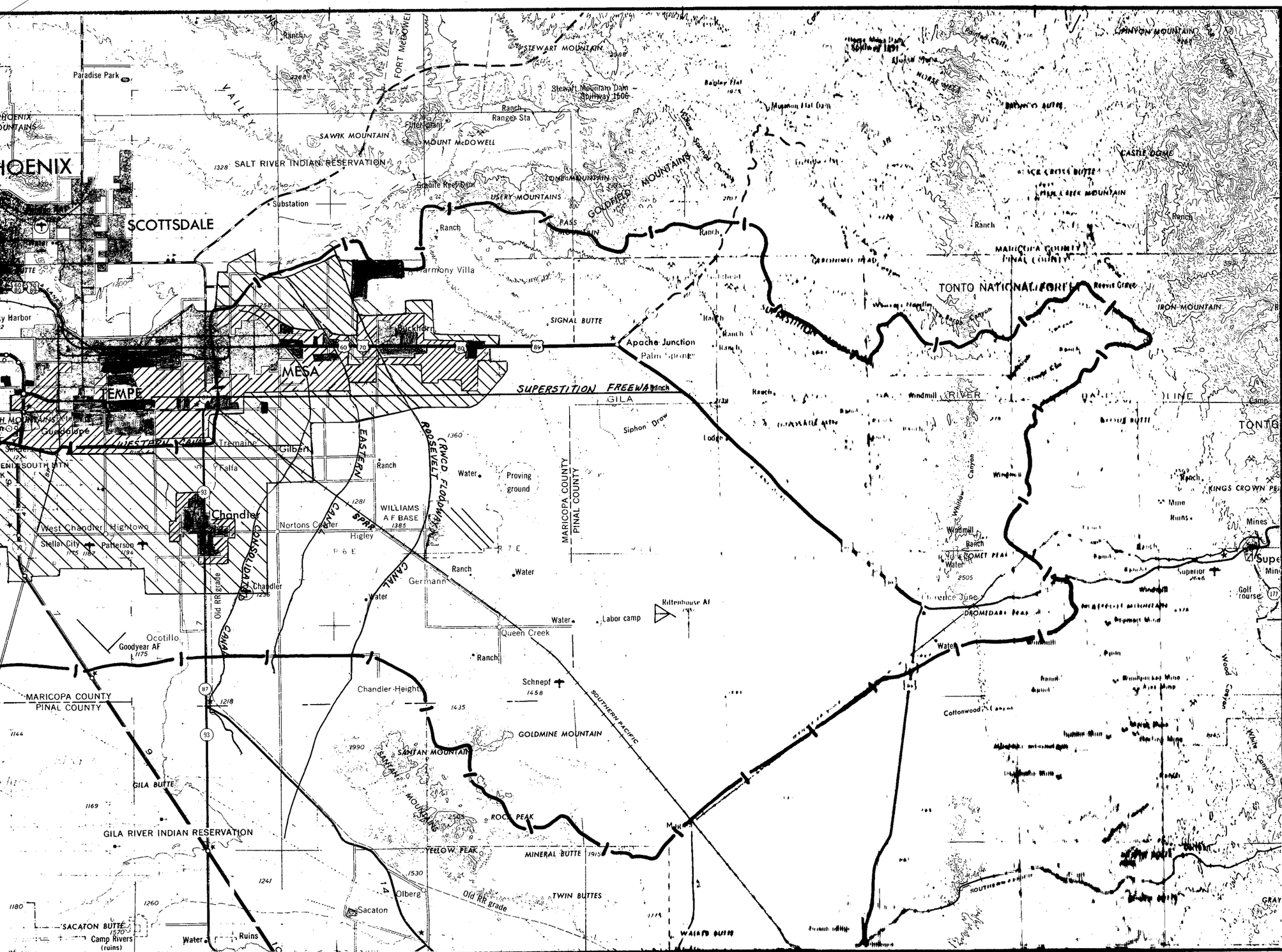
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

EXTENT OF CORPS SURVEY

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE 13


Sun City
Air Haven
GLENDALE
Moseley
PHOENIX
SCOTTSDALE
Paradise Park
SHAW BUTTE
NORTH MTN
PHOENIX MOUNTAINS
SALT RIVER INDIAN RESERVATION
SAWK MOUNTAIN
MOUNT McDOWELL
STEWART MOUNTAIN
Stewart Mountain Dam Spillway 1906
Horse Mesa Dam Spillway 1891
Mormon Flat Dam
Bagley Flat
Tortilla Flat
Granite Reef Dam
USERY MOUNTAINS
GOLDFIELD MOUNTAINS
PASS MOUNTAIN
Harmony Villa
Goldfield
GERONIMO HEAD
SUPERSTITION MOUNTAINS
Weavers Needle
SIGNAL BUTTE
Apache Junction
Palm Springs
SUPERSTITION FREEWAY
Power substation
Fowler
SOUTHERN PACIFIC
Sky Harbor
Union School
Gomez
BASE LINE
Laveen
TEMPE
MESA
Blackhorn
SOUTH MOUNTAINS
Guadalupe
WESTERN CANAL
Tremaine
Gilbert
Falfa
PHOENIX SOUTH MTN PARK
SOUTH MOUNTAINS
Proving Grounds
GILA RIVER
Chandler
West Chandler
Hightown
Stella City
Patterson
Nortons Corner
Higley
WILLIAMS A F BASE
EASTERN CANAL
ROOSEVELT (RWCD) FLOOD CHANNEL
Siphon Draw
Lodge
DINOSAUR MTN
SALT
Windmill
Water
Proving ground
MARICOPA COUNTY
PINAL COUNTY
Germann
Queen Creek
Labor camp
Rittenhouse AF
Florence
Cotton
Tomatke
Crossing
LONE BUTTE
BUTTERFLY MOUNTAIN
Santa Cruz
Ocotillo
Goodyear AF
Old RR grade
CHANDLER CANAL
Chandler Heights
Schnepf
GOLDMINE MOUNTAIN
SANTAN MOUNTAIN
ROCK PEAK
MINERAL BUTTE
YELLOW PEAK
TWIN BUTTES
WALKER BUTTE
Magma
MAGMA ARIZONA
SOUTHERN PACIFIC
Prison camp
MONTEZUMA PEAK
GILA RIVER INDIAN RESERVATION
MONTEZUMAS HEAD
PIMA BUTTE
GILA BUTTE
GILA RIVER INDIAN RESERVATION
Enid
Heaton
Maricopa
SACATON BUTTE
Camp Rivers (ruins)
Ruins
Sacaton
Olberg
112° 00'
111° 45'
111° 30'



N

LEGEND

BOUNDARY OF DRAINAGE AREA

1975

1980

2030

SCALE IN MILES

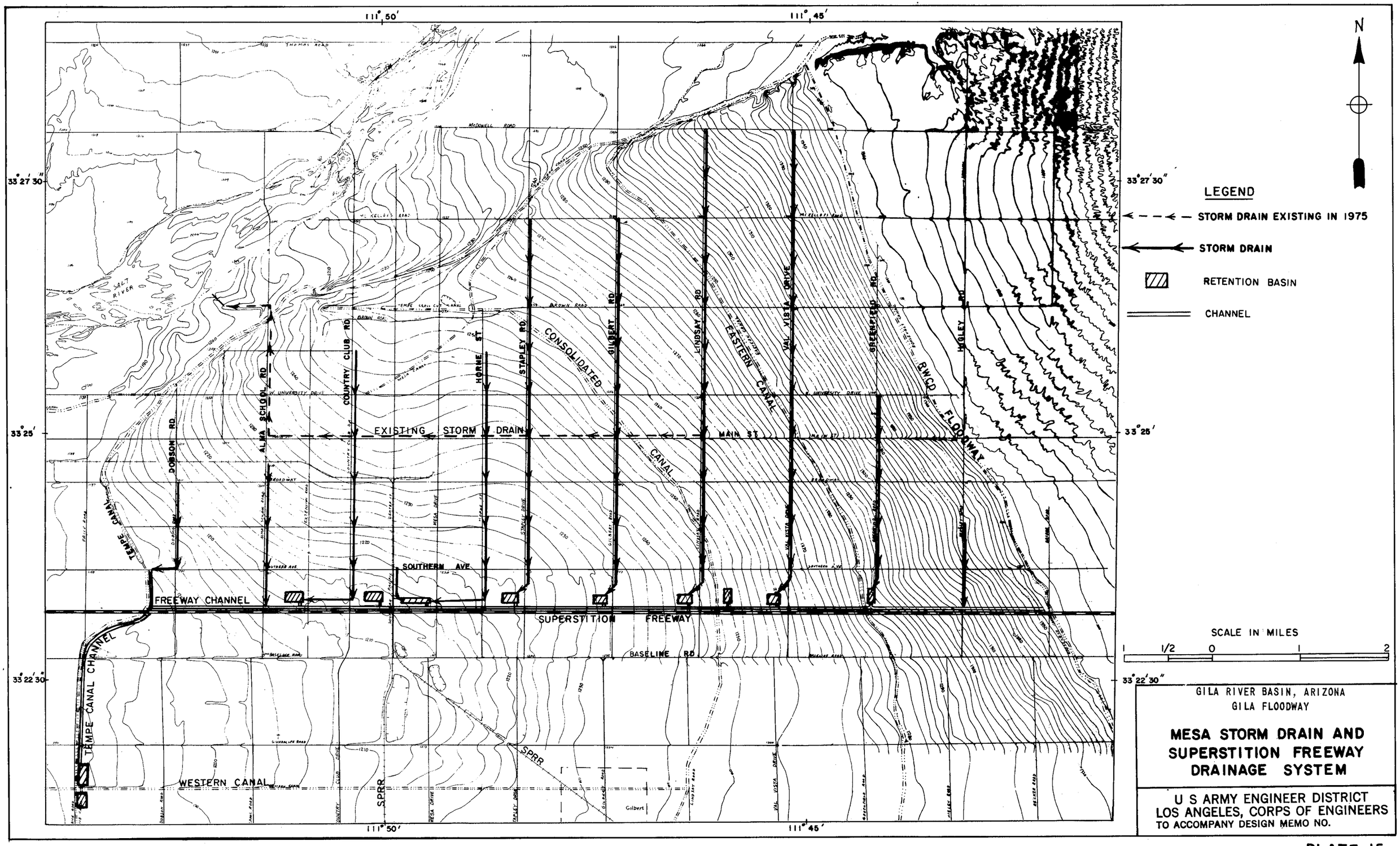
5 0 5

GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

URBAN DEVELOPMENT

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

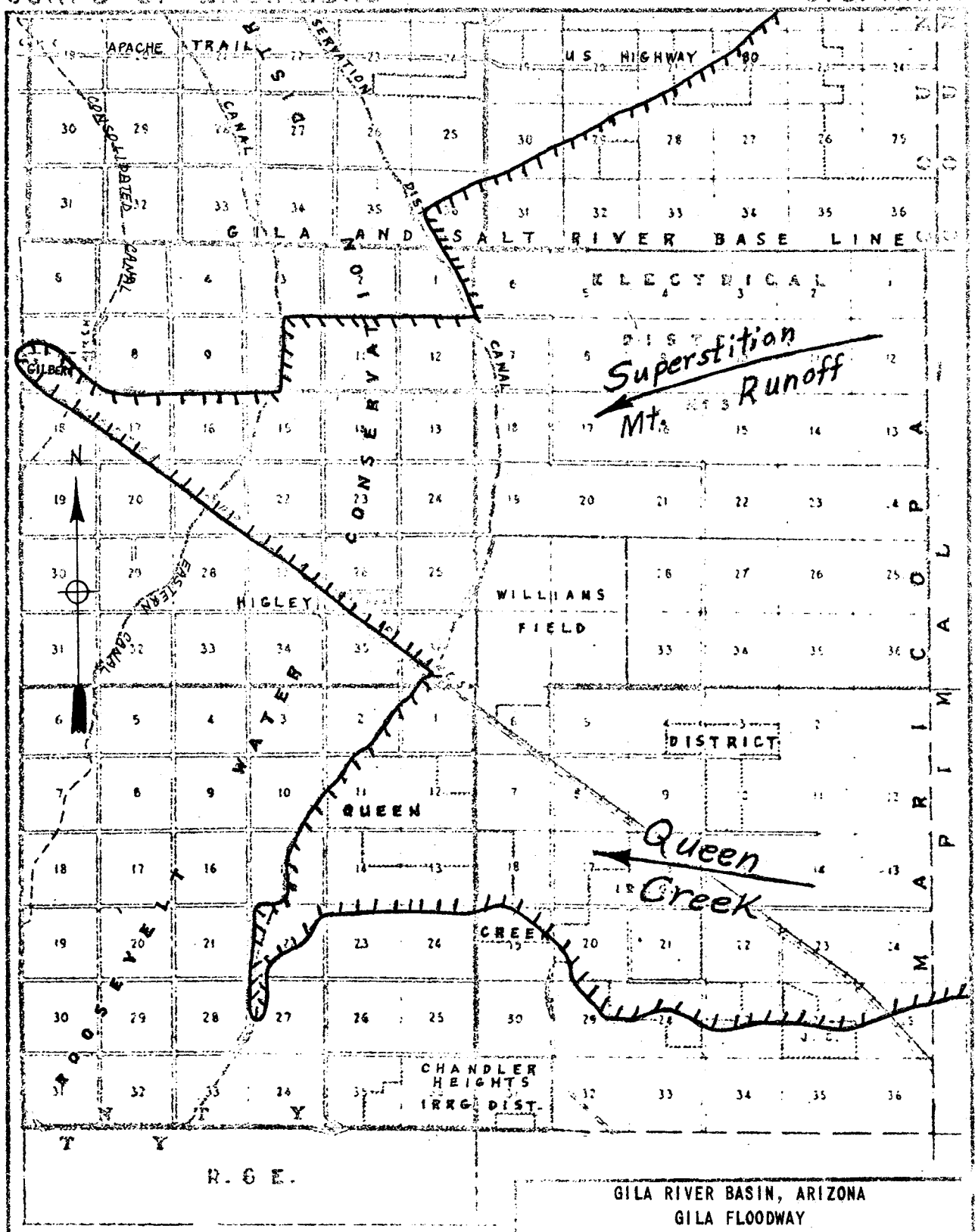
PLATE 14



GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

MESA STORM DRAIN AND SUPERSTITION FREEWAY DRAINAGE SYSTEM

U S ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY DESIGN MEMO NO.



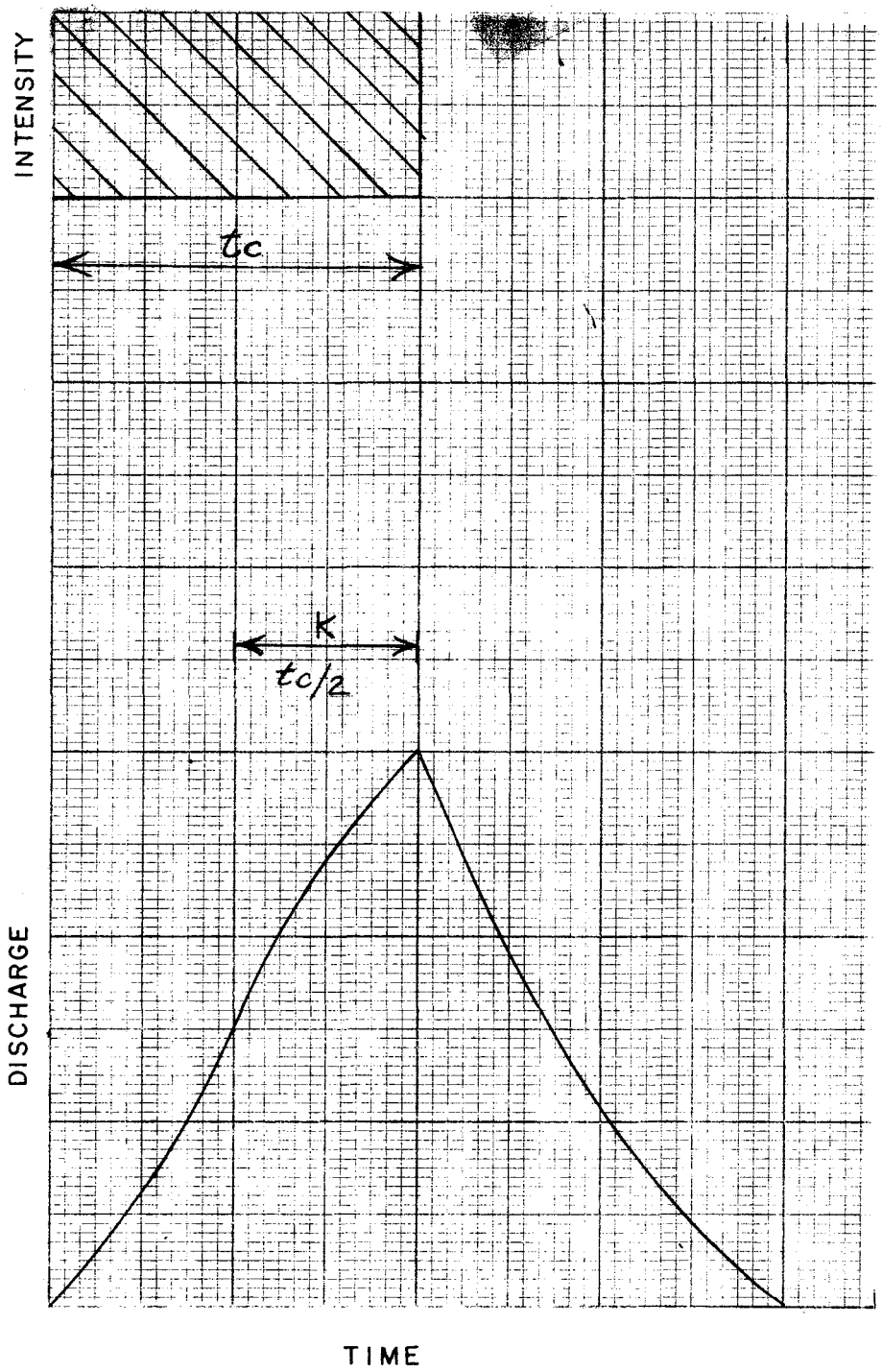
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

QUEEN CR OVERFLOW AREA
19 AUGUST 1954 FLOOD

(SOURCE: REFERENCE 12)

OFFICE OF THE DISTRICT ENGINEER
LOS ANGELES, CALIFORNIA

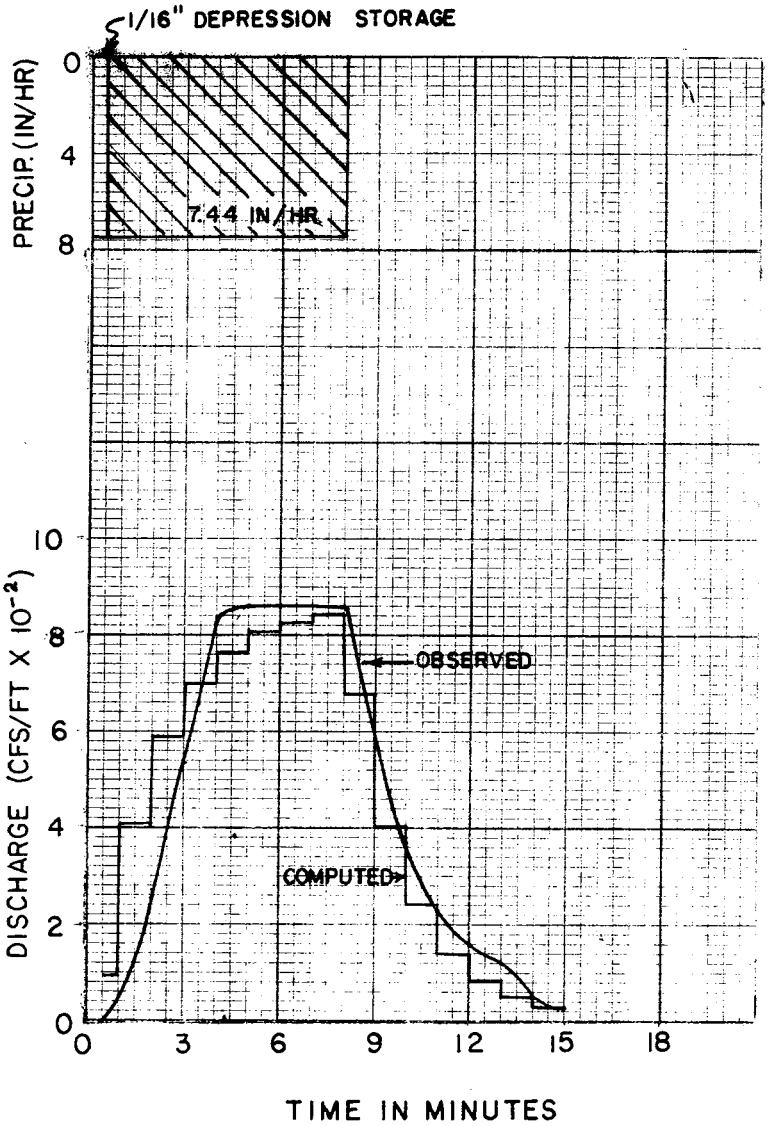
PLATE 16



GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

DETERMINATION OF COEFFICIENT K

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:



SURFACE = CONCRETE

n = .012

SLOPE = .02

L = 500 ft.

Te = 3.59 min.

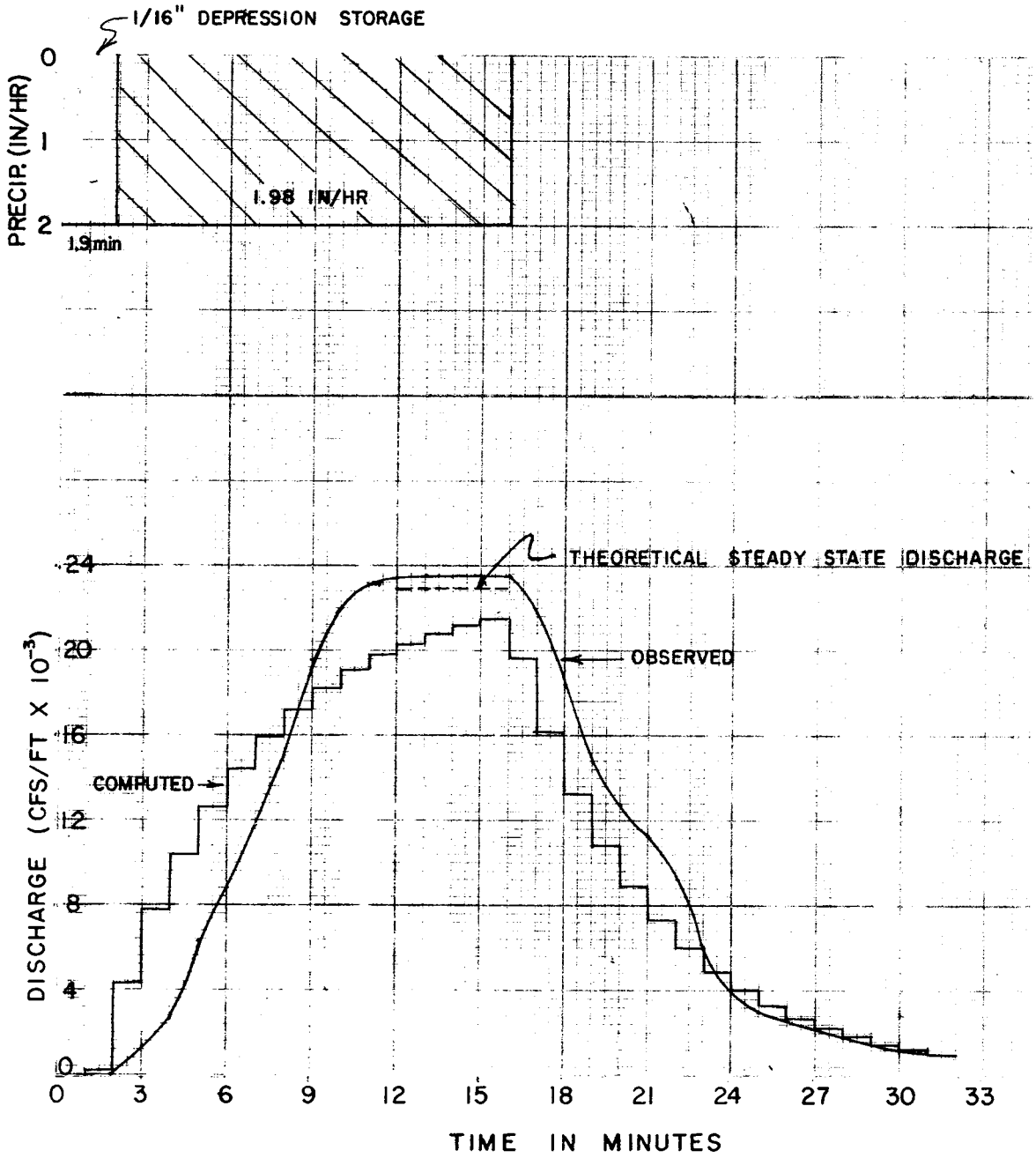
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

RECONSTITUTION

CASE I

(SOURCE: REFERENCE 17)

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:



SURFACE = CONCRETE

n = .012

SLOPE = .005

L = 500 ft.

Te = 10.16 min

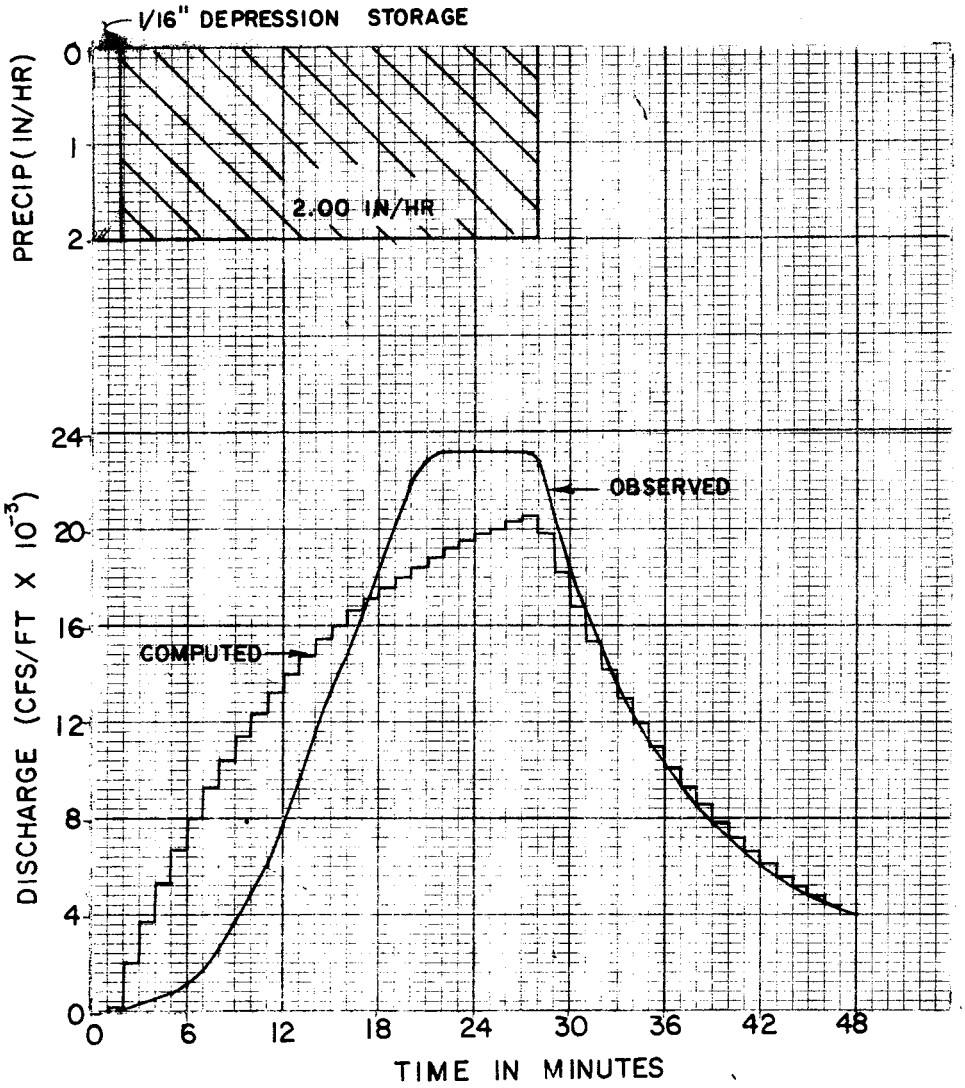
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

RECONSTITUTION

CASE II

(SOURCE: REFERENCE 17)

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:



SURFACE = SIMULATED TURF

n = .05

SLOPE = .005

L = 500 ft

Te = 23.83 min.

GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

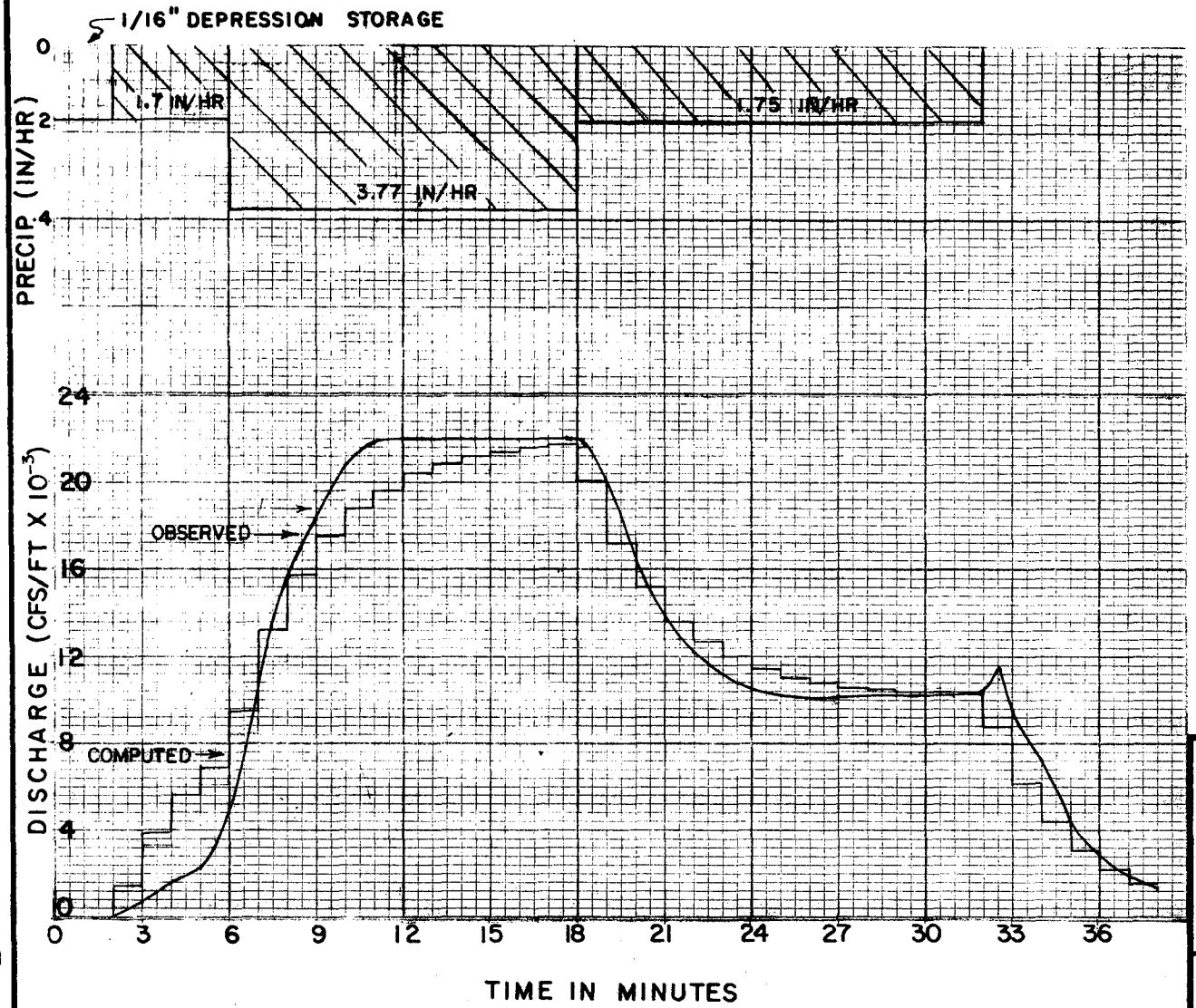
RECONSTITUTION

CASE III

(SOURCE: REFERENCE 17)

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

TO ACCOMPANY REPORT DATED:



SURFACE = CONCRETE

n = .012

SLOPE = .005

L = 252 ft

Te = 7.31 min

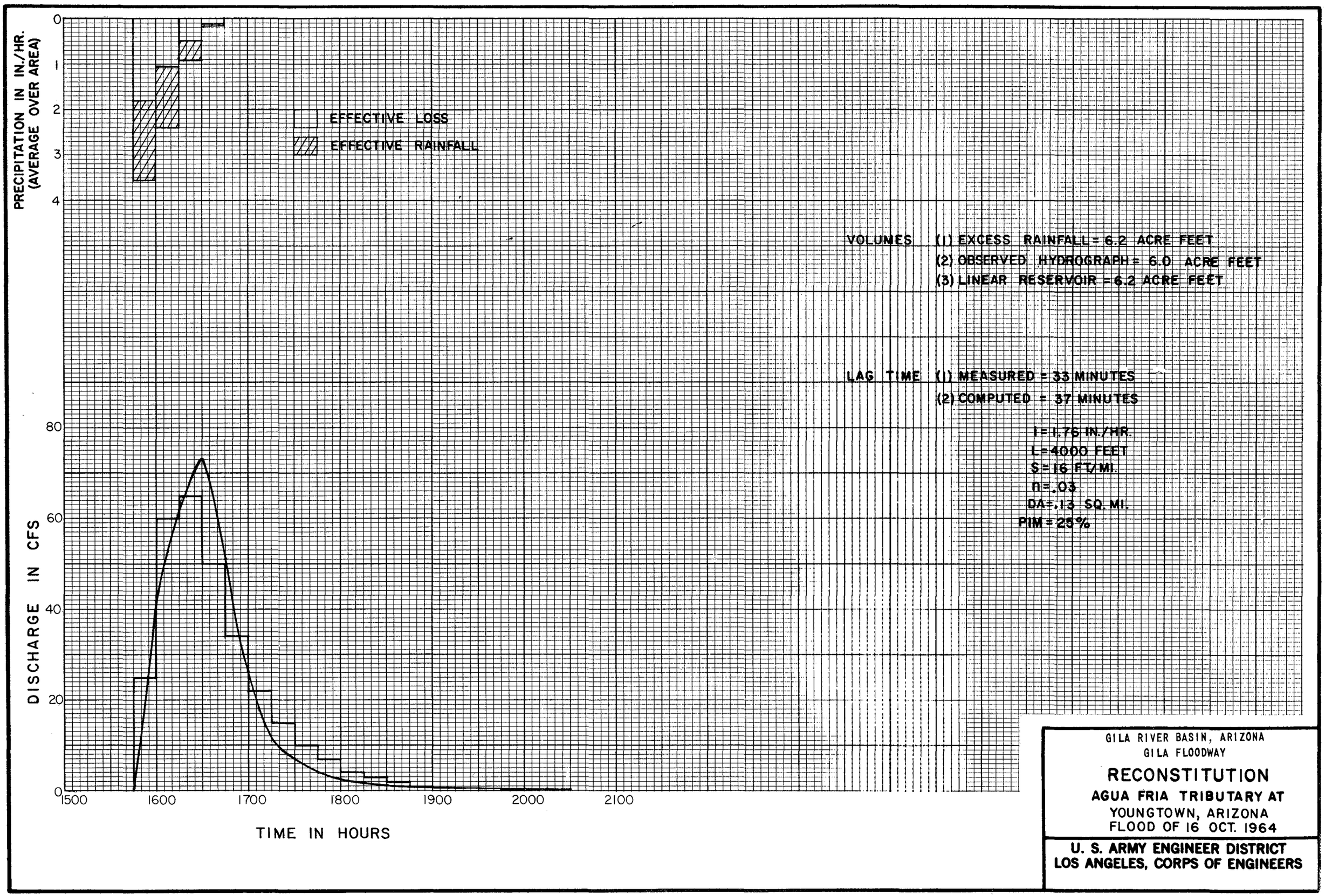
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

RECONSTITUTION

CASE IV

(SOURCE: REFERENCE 17)

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

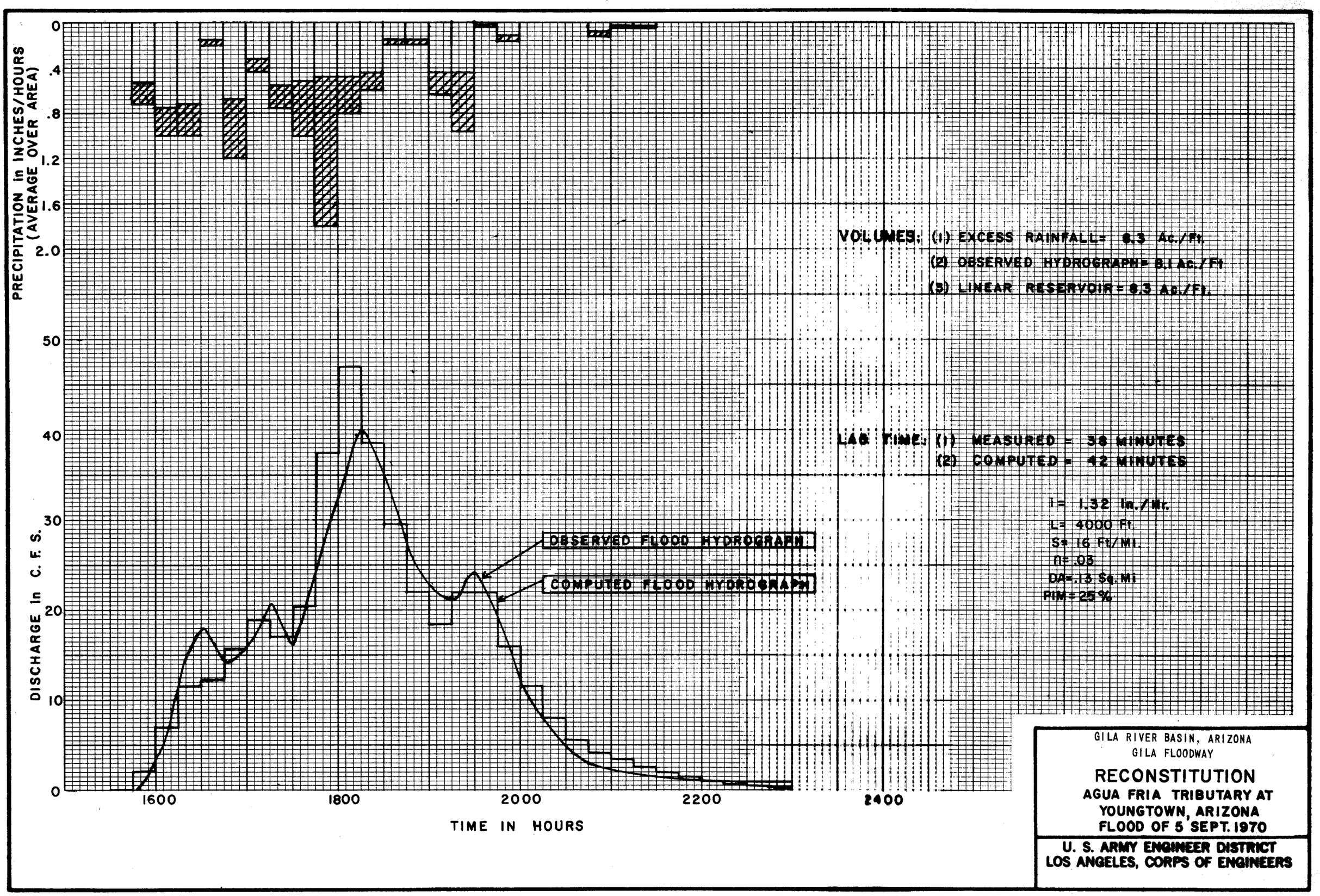


GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

RECONSTITUTION

AGUA FRIA TRIBUTARY AT
YOUNGTOWN, ARIZONA
FLOOD OF 16 OCT. 1964

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

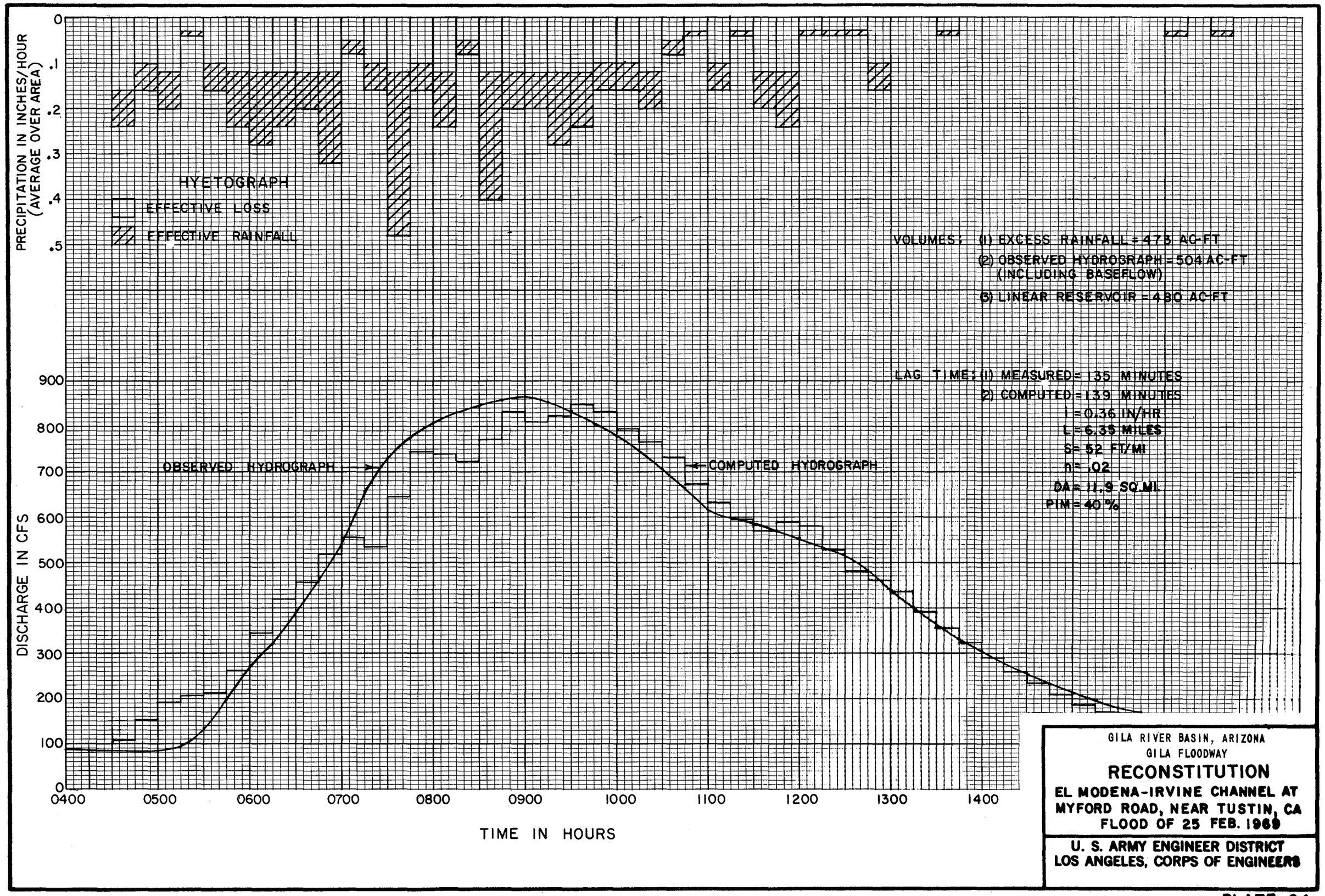


GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

RECONSTITUTION

AGUA FRIA TRIBUTARY AT YOUNGTOWN, ARIZONA FLOOD OF 5 SEPT. 1970

U. S. ARMY ENGINEER DISTRICT LOS ANGELES, CORPS OF ENGINEERS

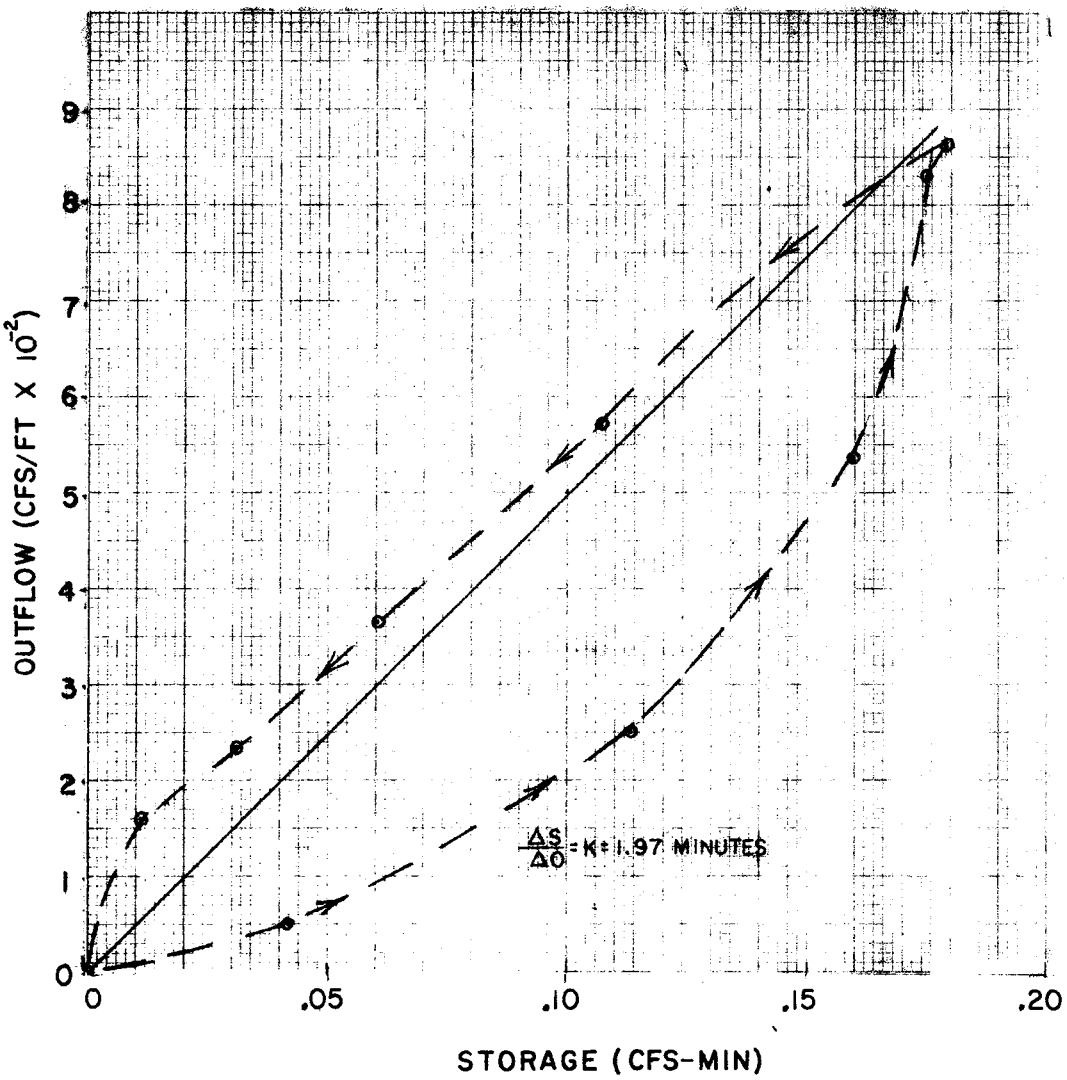


GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

RECONSTITUTION

EL MODENA-IRVINE CHANNEL AT MYFORD ROAD, NEAR TUSTIN, CA
FLOOD OF 25 FEB. 1969

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

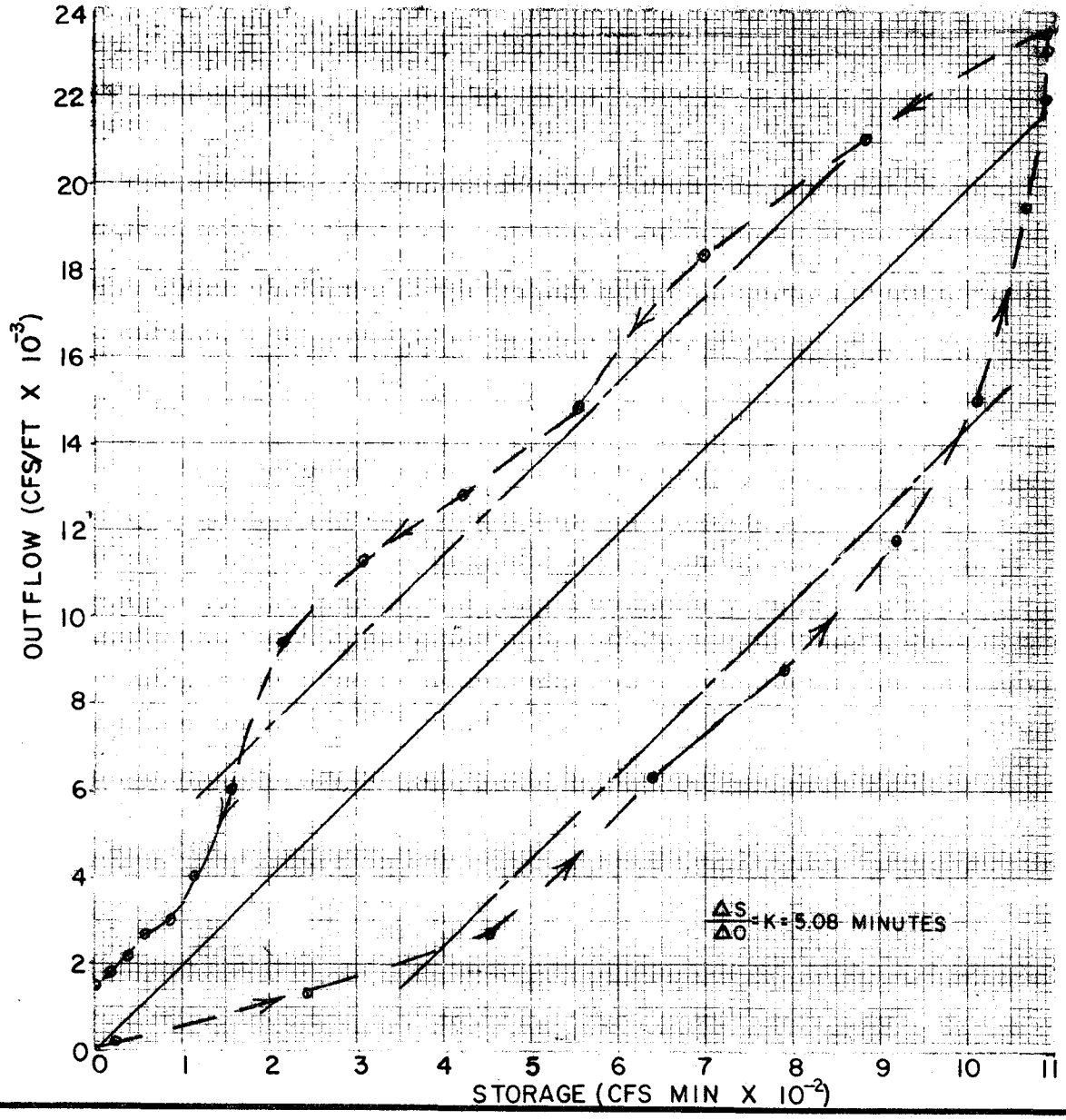


GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

STORAGE-OUTFLOW LOOP
CASE I

(SOURCE: REFERENCE 17)

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:



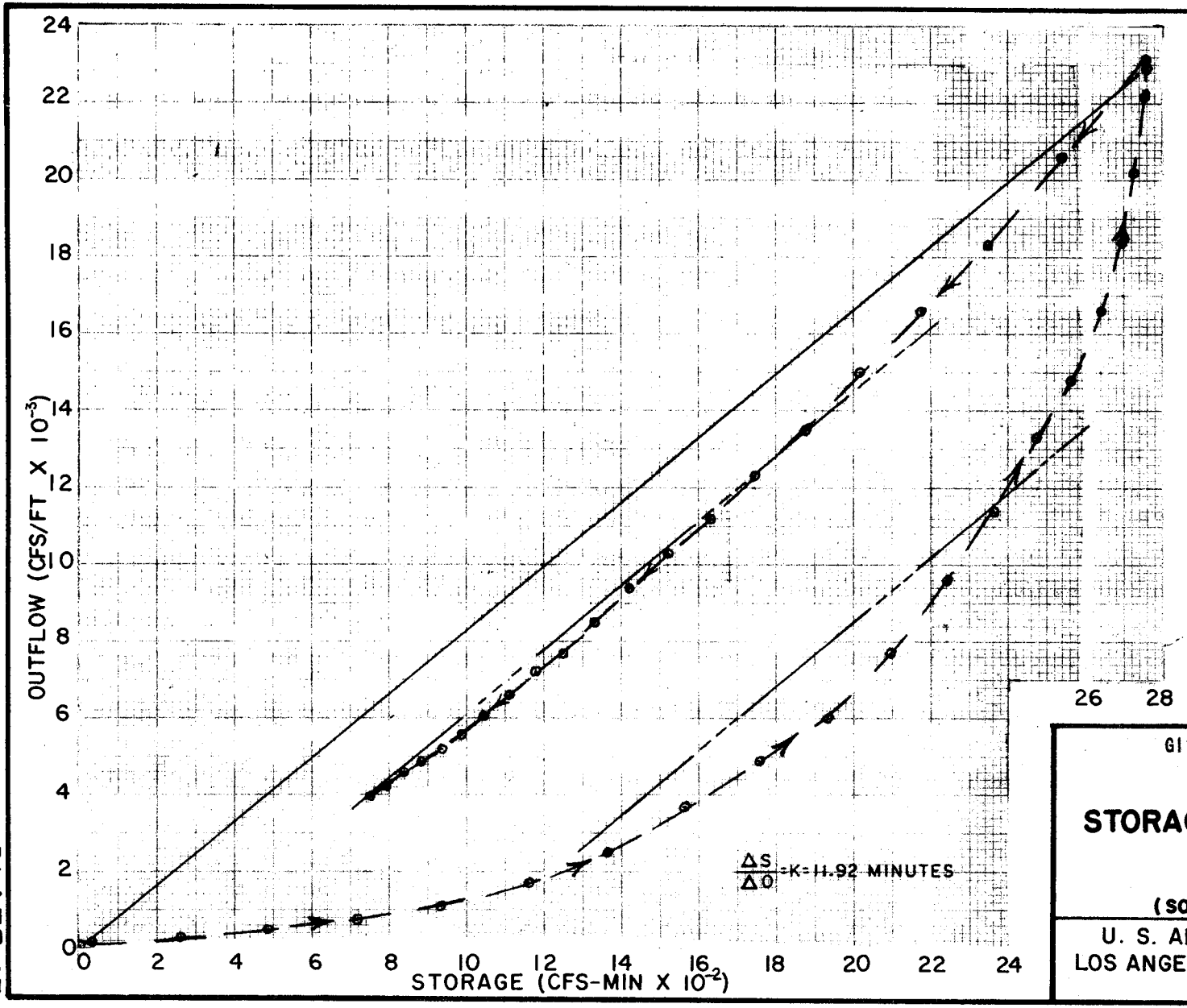
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

STORAGE-OUTFLOW LOOP

CASE II

(SOURCE: REFERENCE 17)

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS



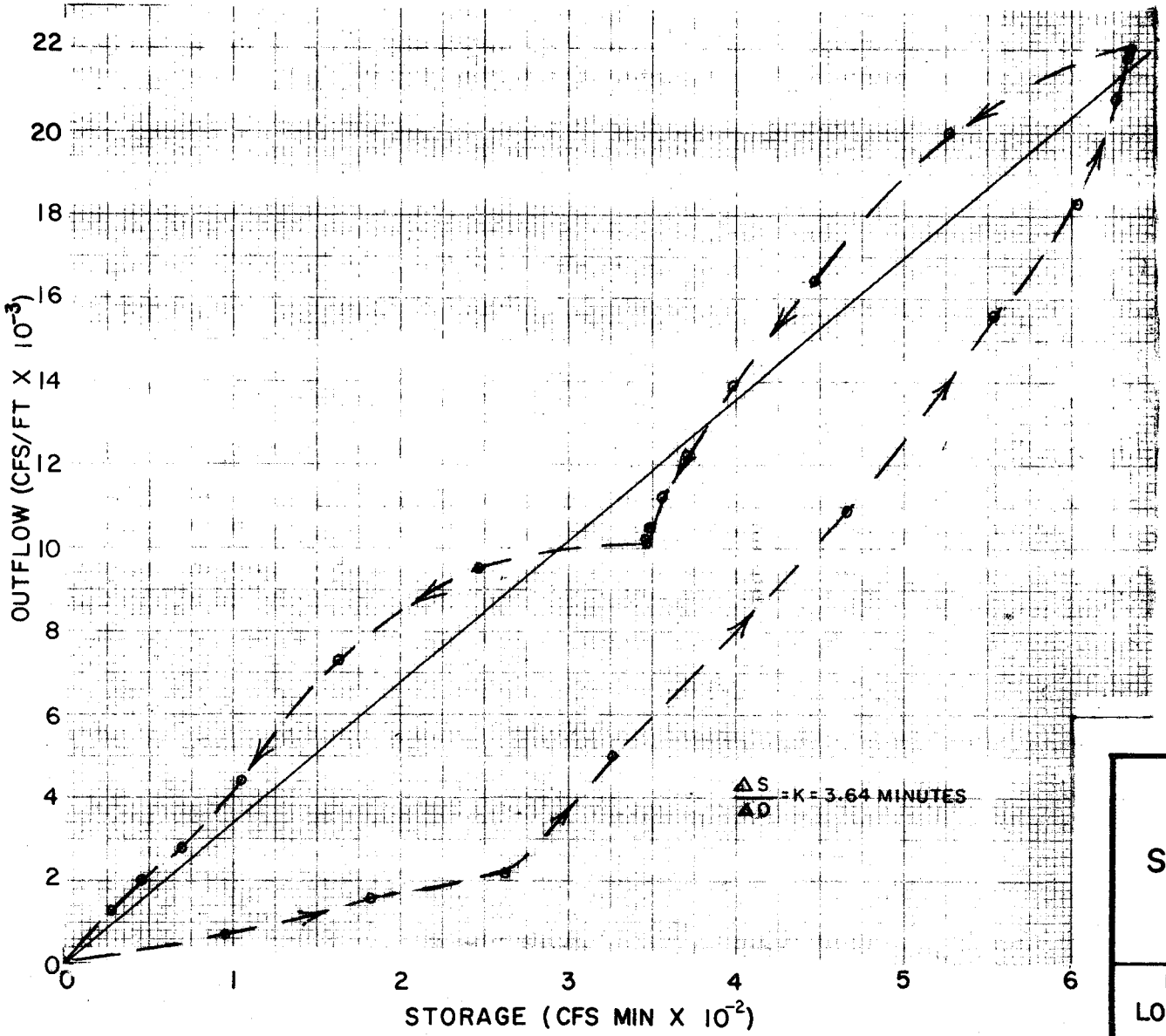
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

STORAGE - OUTFLOW LOOP

CASE III

(SOURCE: REFERENCE 17)

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

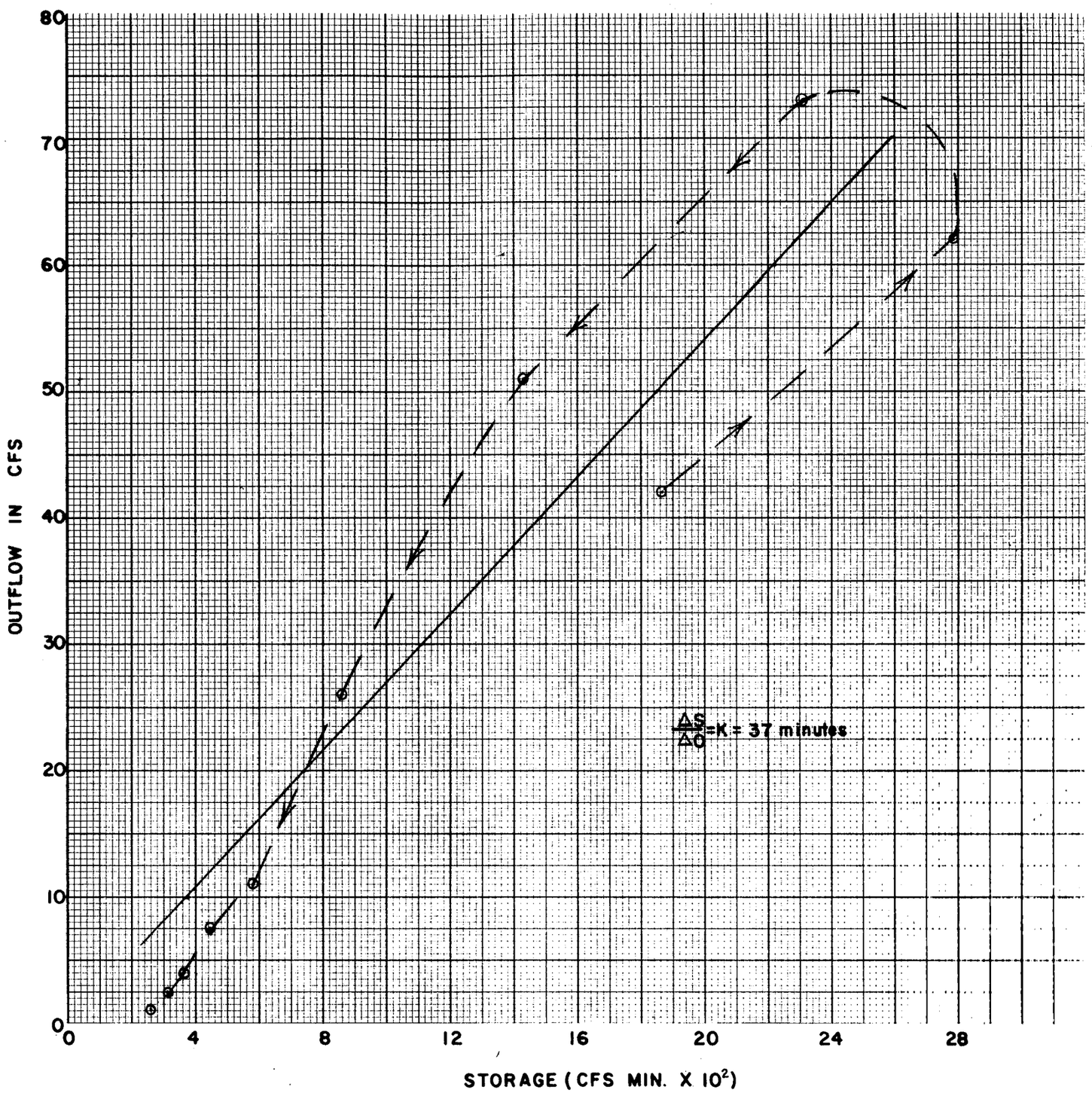


GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

STORAGE-OUTFLOW LOOP
CASE IV

(SOURCE: REFERENCE 17)

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

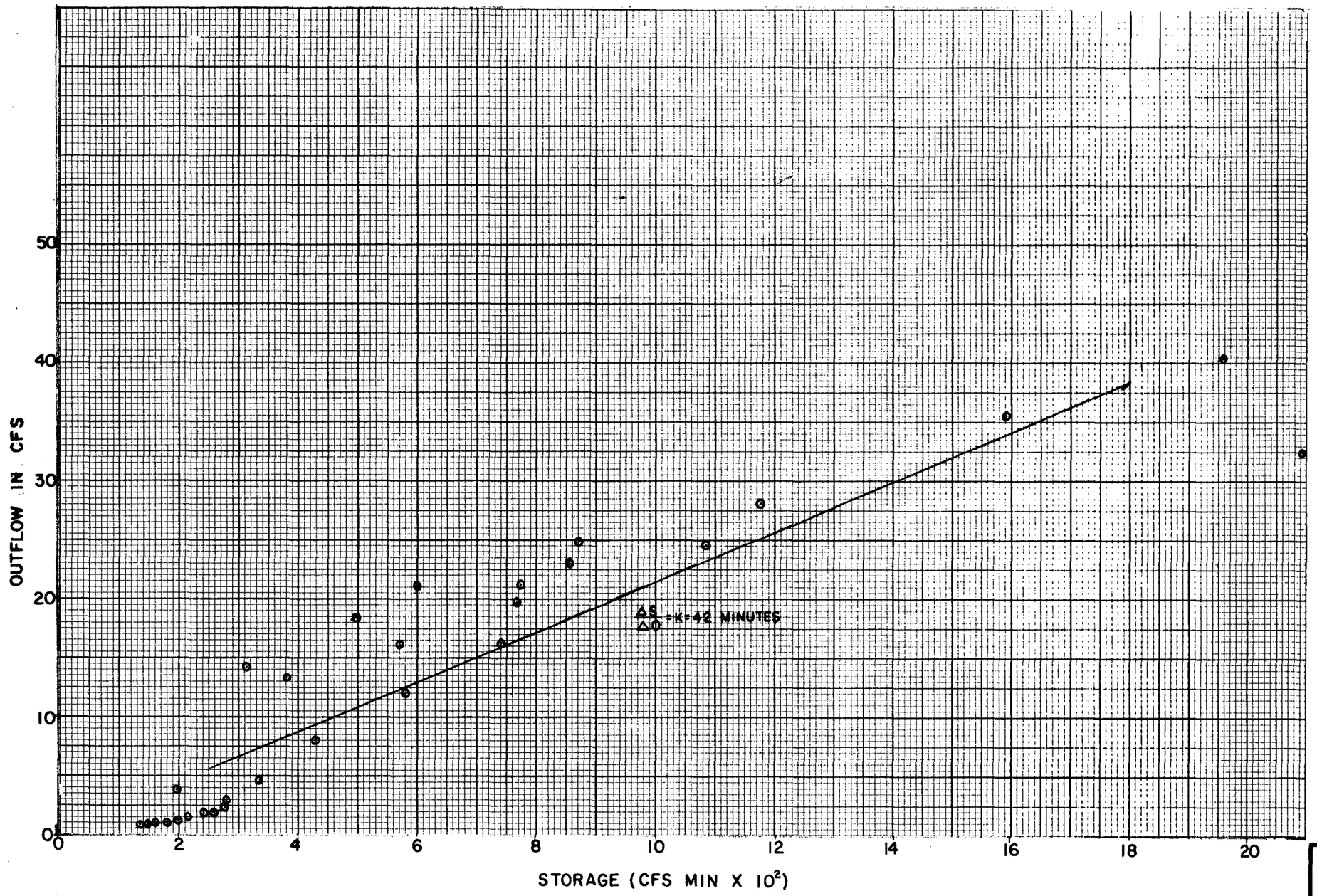


GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

STORAGE-OUTFLOW LOOP

AGUA FRIA TRIBUTARY AT
YOUNGTOWN, ARIZONA
FLOOD OF 16 OCT. 1964

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

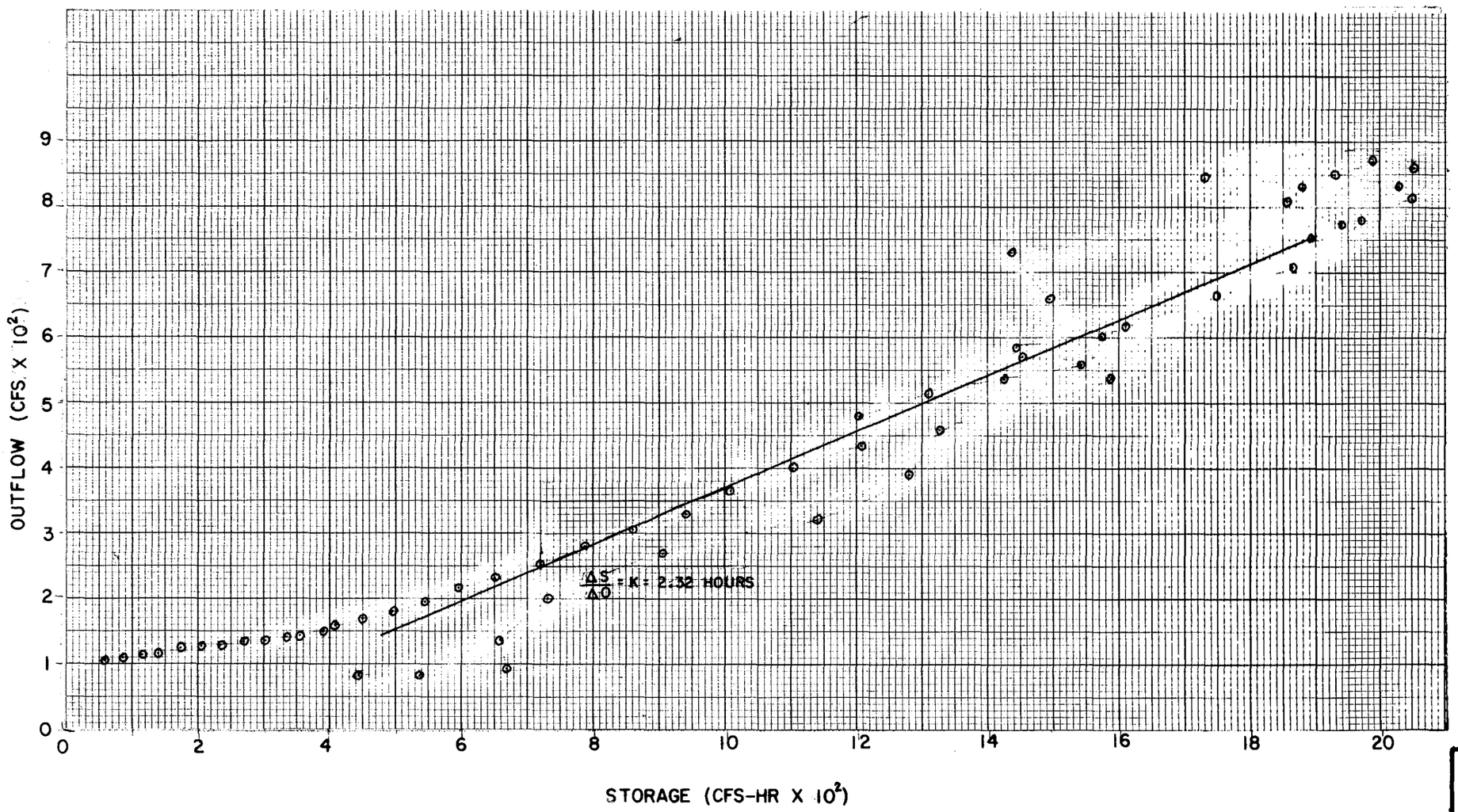


GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

STORAGE-OUTFLOW LOOP

AGUA FRIA TRIBUTARY AT
YOUNGTOWN, ARIZONA
FLOOD OF 5 SEPT. 1970

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

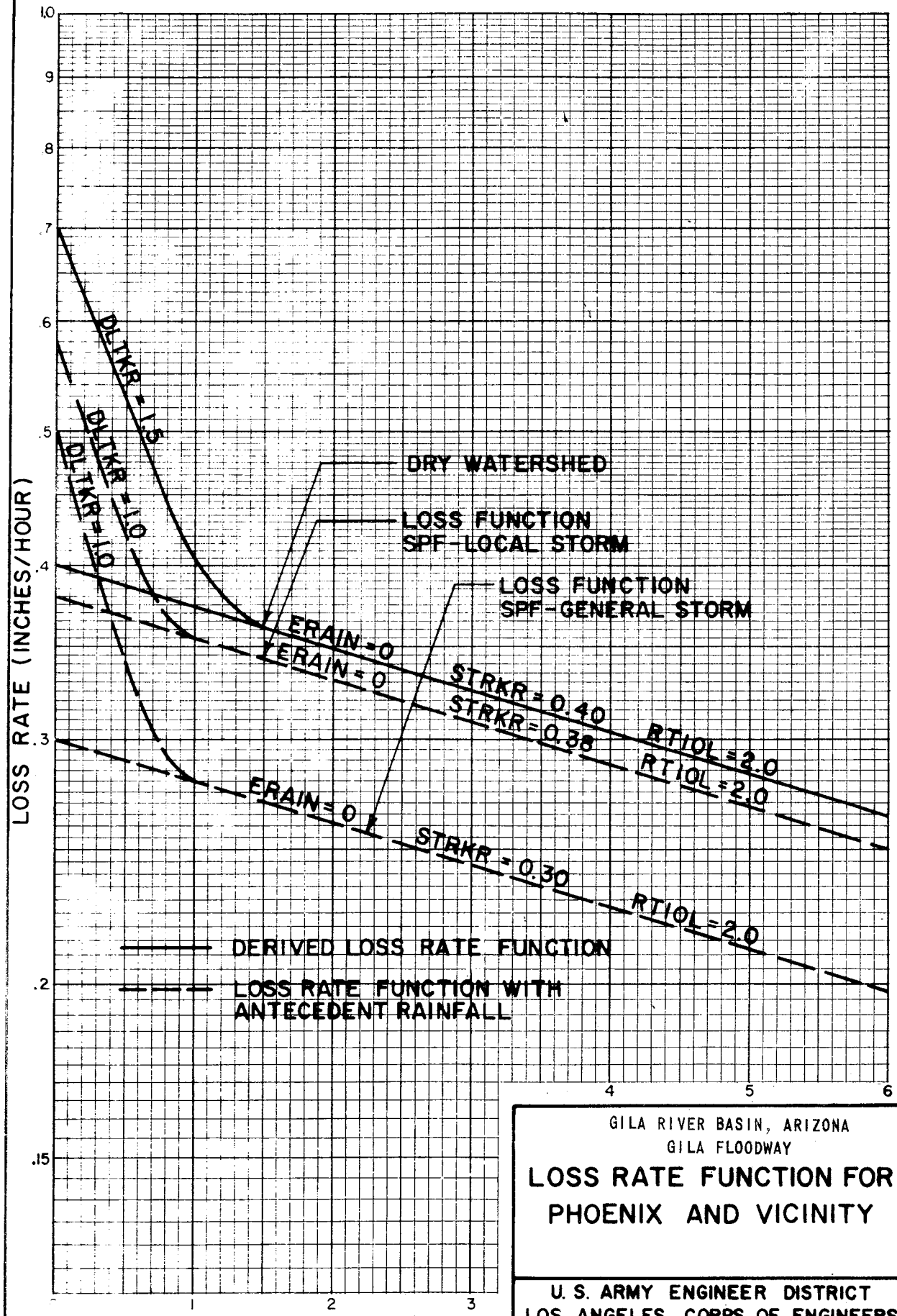


GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

STORAGE-OUTFLOW LOOP

EL MODENA IRVINE CHANNEL AT MYFORD ROAD, NEAR TUSTIN, CA.
FLOOD OF 25 FEB. 1969

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:



GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

LOSS RATE FUNCTION FOR PHOENIX AND VICINITY

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY

PLATE 32

THIS PLATE ILLUSTRATES THE DETERMINATION OF VOLUME OF STORAGE BEHIND CANAL LEVEES.

VOLUME

W, D and L in FEET.

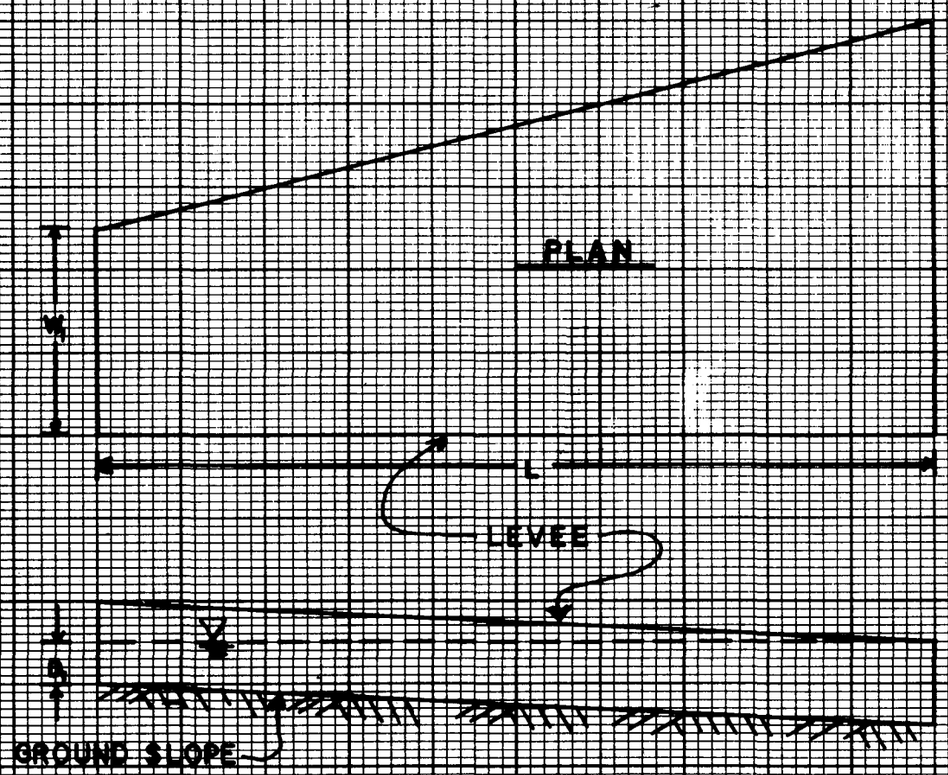
AVERAGE END-AREA METHOD.
VOLUME in ACRE-FEET.

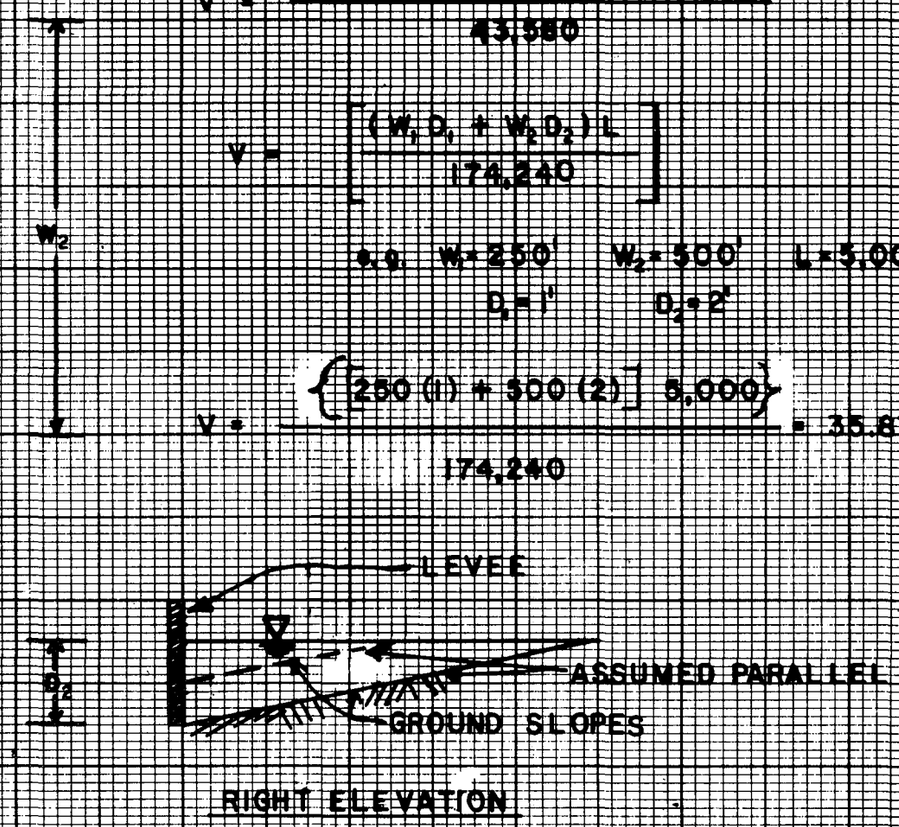
$$V = \frac{\left\{\left[\frac{\left(\frac{1}{2} W_1 D_1 + \frac{1}{2} W_2 D_2\right)}{2}\right] L\right\}}{43,560}$$

$$V = \left[\frac{(W_1 D_1 + W_2 D_2) L}{174,240}\right]$$

e.g. $W_1 = 250'$ $W_2 = 500'$ $L = 5,000'$
$D_1 = 1'$ $D_2 = 2'$

$$V = \frac{\left\{\left[250 (1) + 500 (2)\right] 5,000\right\}}{174,240} = 35.87 \text{ ACRE-FEET.}$$

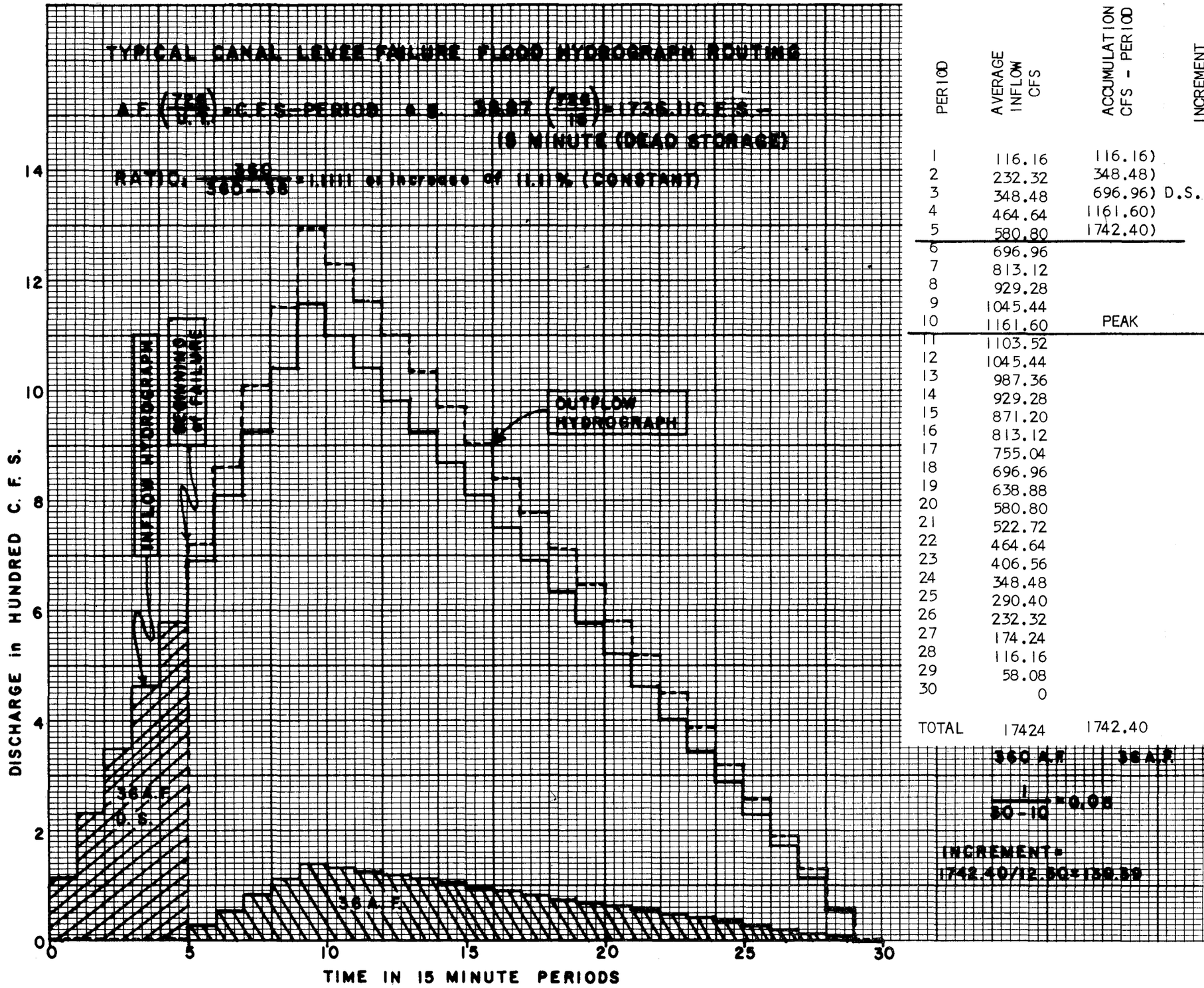




GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

LEVEE STORAGE WEDGE

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

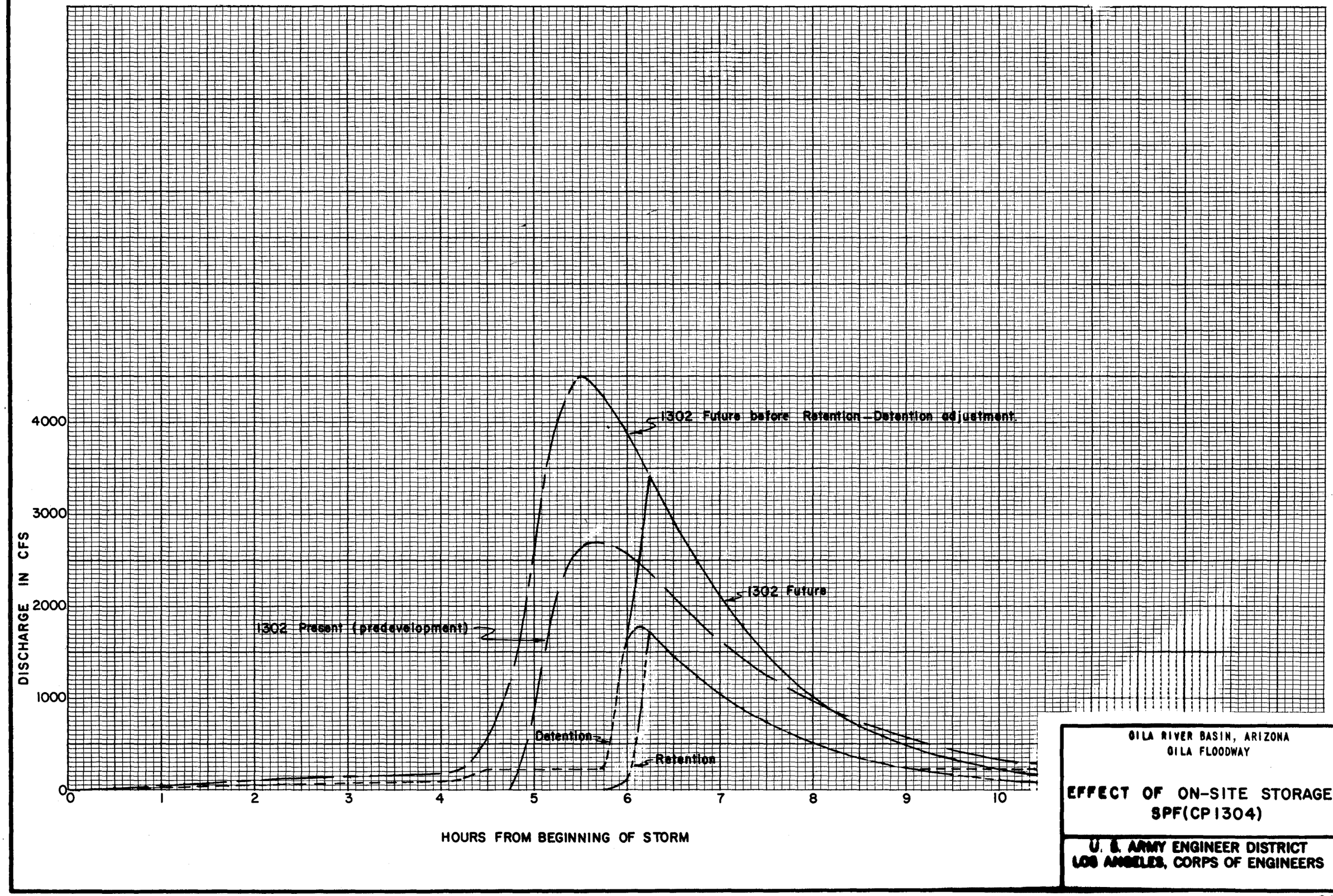


PERIOD	AVERAGE INFLOW CFS	ACCUMULATION CFS - PERIOD	INCREMENT DISTRIBUTION FACTOR	INCREMENT CFS	AVERAGE OUTFLOW CFS	PERCENT INCREASE
1	116.16	116.16)			0	
2	232.32	348.48)			0	
3	348.48	696.96) D.S.			0	
4	464.64	1161.60)			0	
5	580.80	1742.40)	0	0	0	
6	696.96		0.20	27.88	724.84	4.00
7	813.12		0.40	55.76	868.88	6.86
8	929.28		0.60	83.63	1012.91	9.00
9	1045.44		0.80	111.51	1156.95	10.67
10	1161.60	PEAK	1.00	139.39	1300.99	12.00
11	1103.52		0.95	132.42	1235.94	12.00
12	1045.44		0.90	125.45	1170.89	12.00
13	987.36		0.85	118.48	1105.84	12.00
14	929.28		0.80	111.51	1040.79	12.00
15	871.20		0.75	104.54	975.74	12.00
16	813.12		0.70	97.57	910.69	12.00
17	755.04		0.65	90.60	845.64	12.00
18	696.96		0.60	83.63	780.59	12.00
19	638.88		0.55	76.66	715.54	12.00
20	580.80		0.50	69.70	650.50	12.00
21	522.72		0.45	62.73	585.45	12.00
22	464.64		0.40	55.76	520.40	12.00
23	406.56		0.35	48.79	455.35	12.00
24	348.48		0.30	41.82	390.30	12.00
25	290.40		0.25	34.85	325.25	12.00
26	232.32		0.20	27.88	260.20	12.00
27	174.24		0.15	20.91	195.15	12.00
28	116.16		0.10	13.94	130.10	12.00
29	58.08		0.05	6.97	65.05	12.00
30	0		0	0	0	
TOTAL	17424	1742.40	12.50	1742.38	17423.98	270.53

GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

LEVEE FAILURE HYDROGRAPH

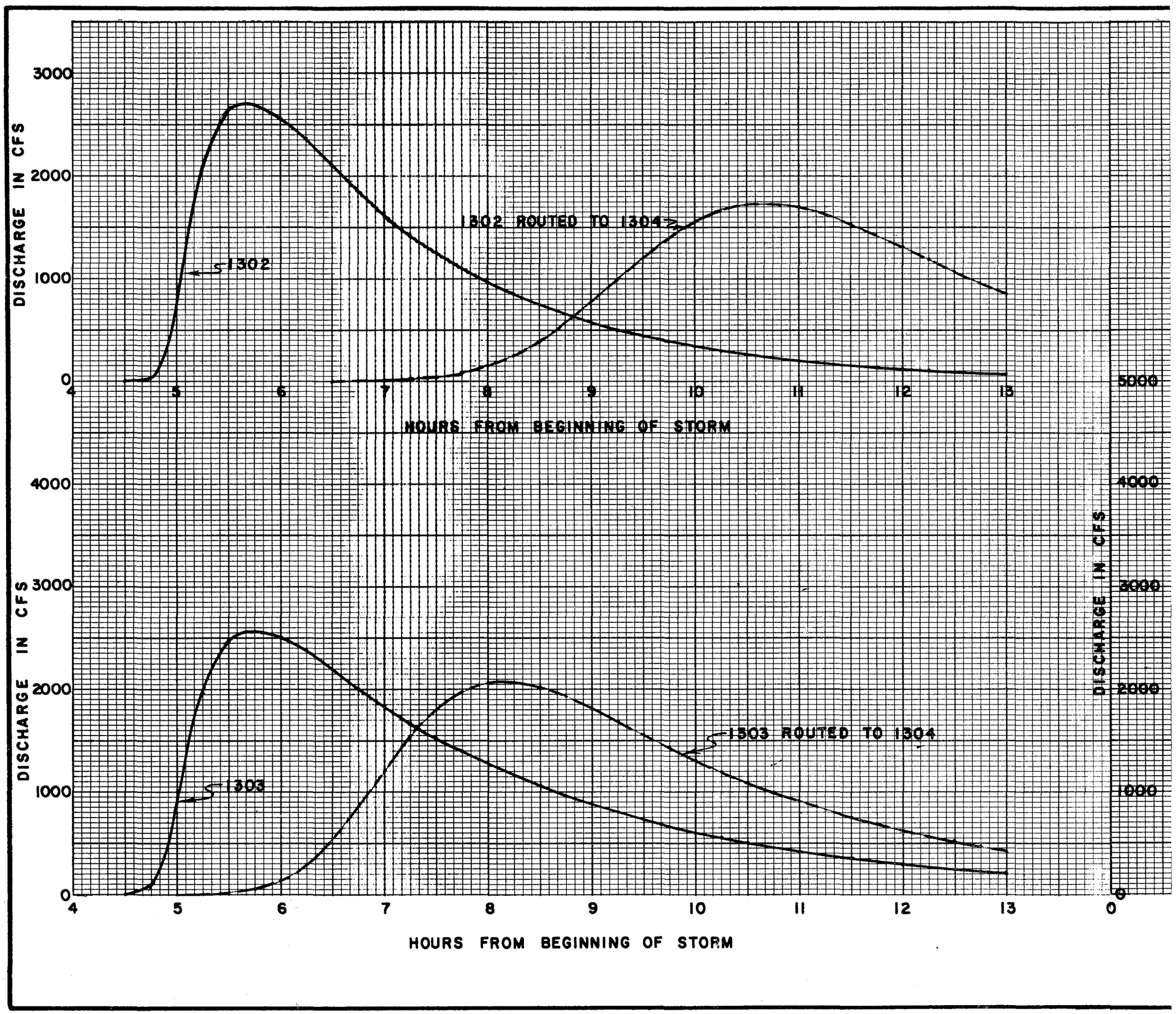
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

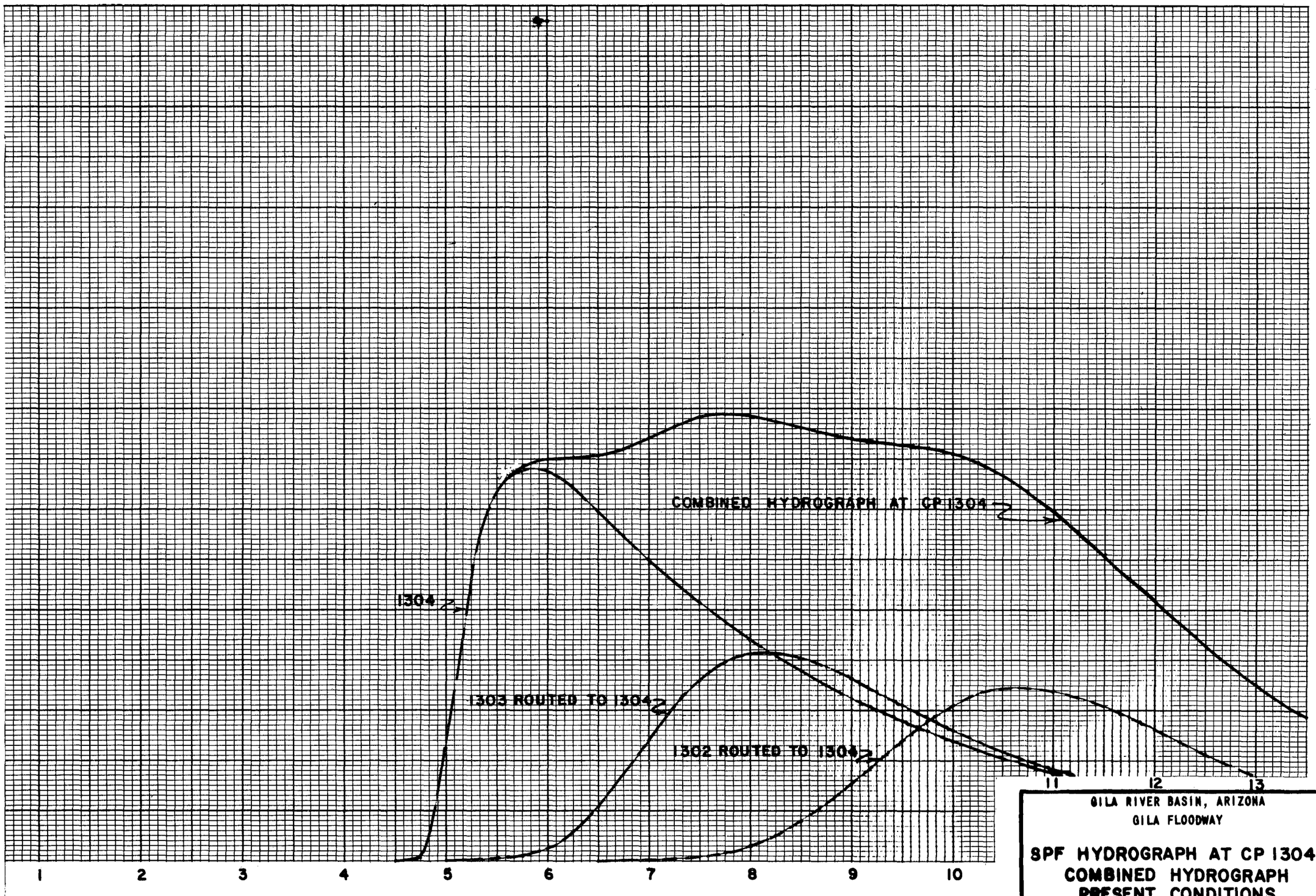


GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

EFFECT OF ON-SITE STORAGE
SPF(CP1304)

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

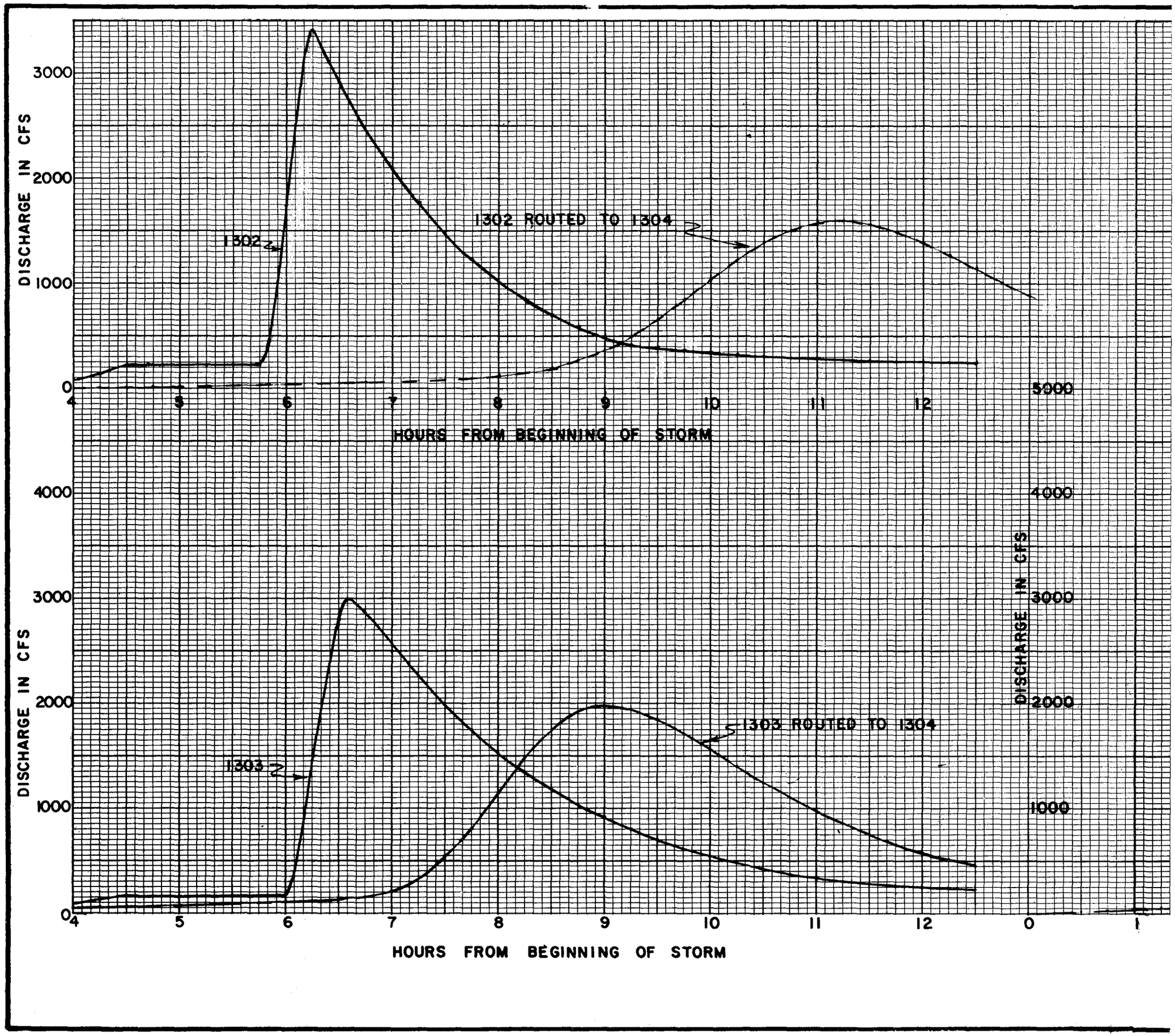

DISCHARGE IN CFS
3000
2000
1000
0
1302
1302 ROUTED TO 1304
4
5
6
7
8
9
10
11
12
13
HOURS FROM BEGINNING OF STORM
5000
4000
3000
2000
1000
0
DISCHARGE IN CFS
1303
1303 ROUTED TO 1304
4
5
6
7
8
9
10
11
12
13
0
HOURS FROM BEGINNING OF STORM

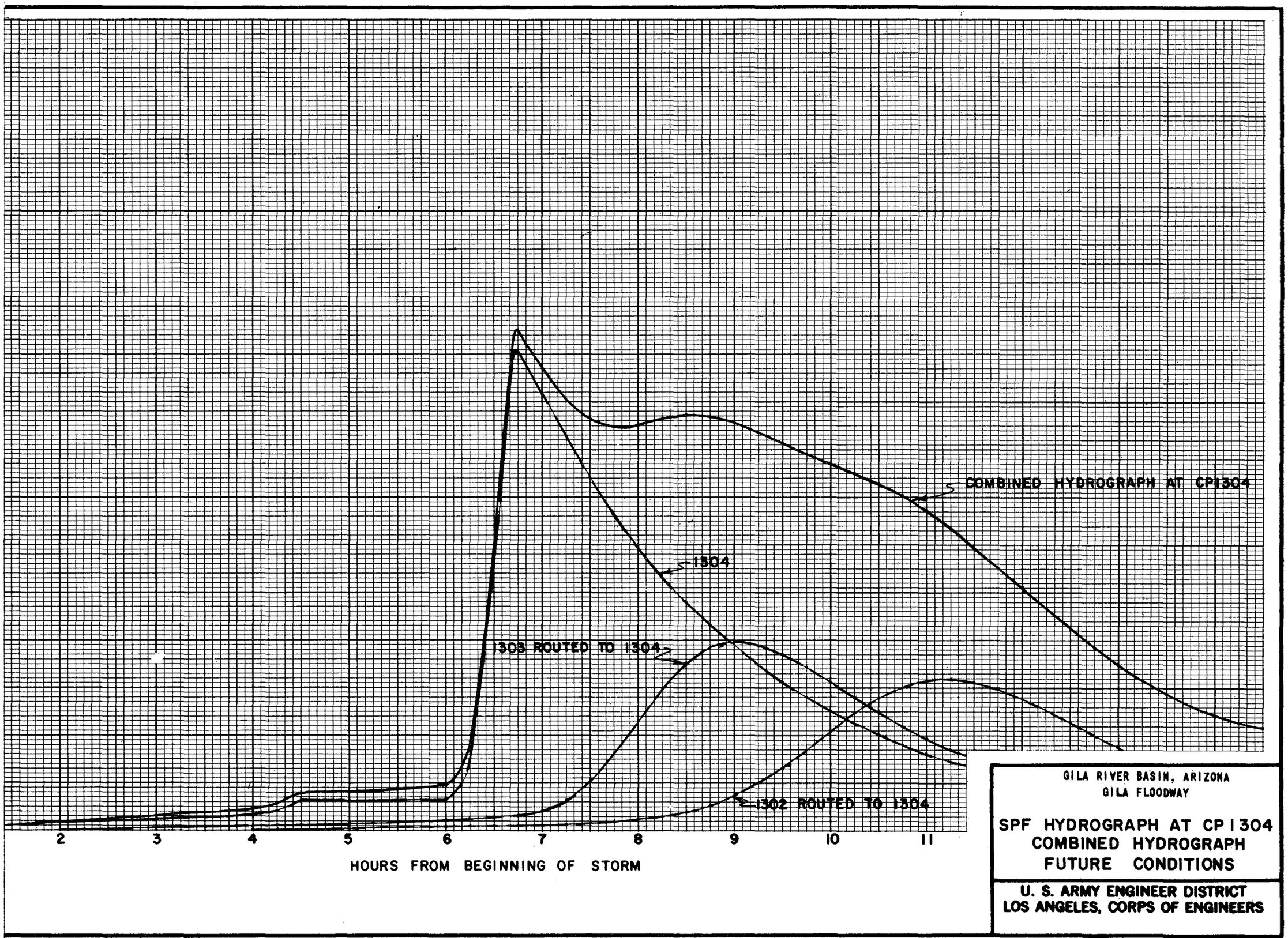


GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

SPF HYDROGRAPH AT CP 1304
COMBINED HYDROGRAPH
PRESENT CONDITIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

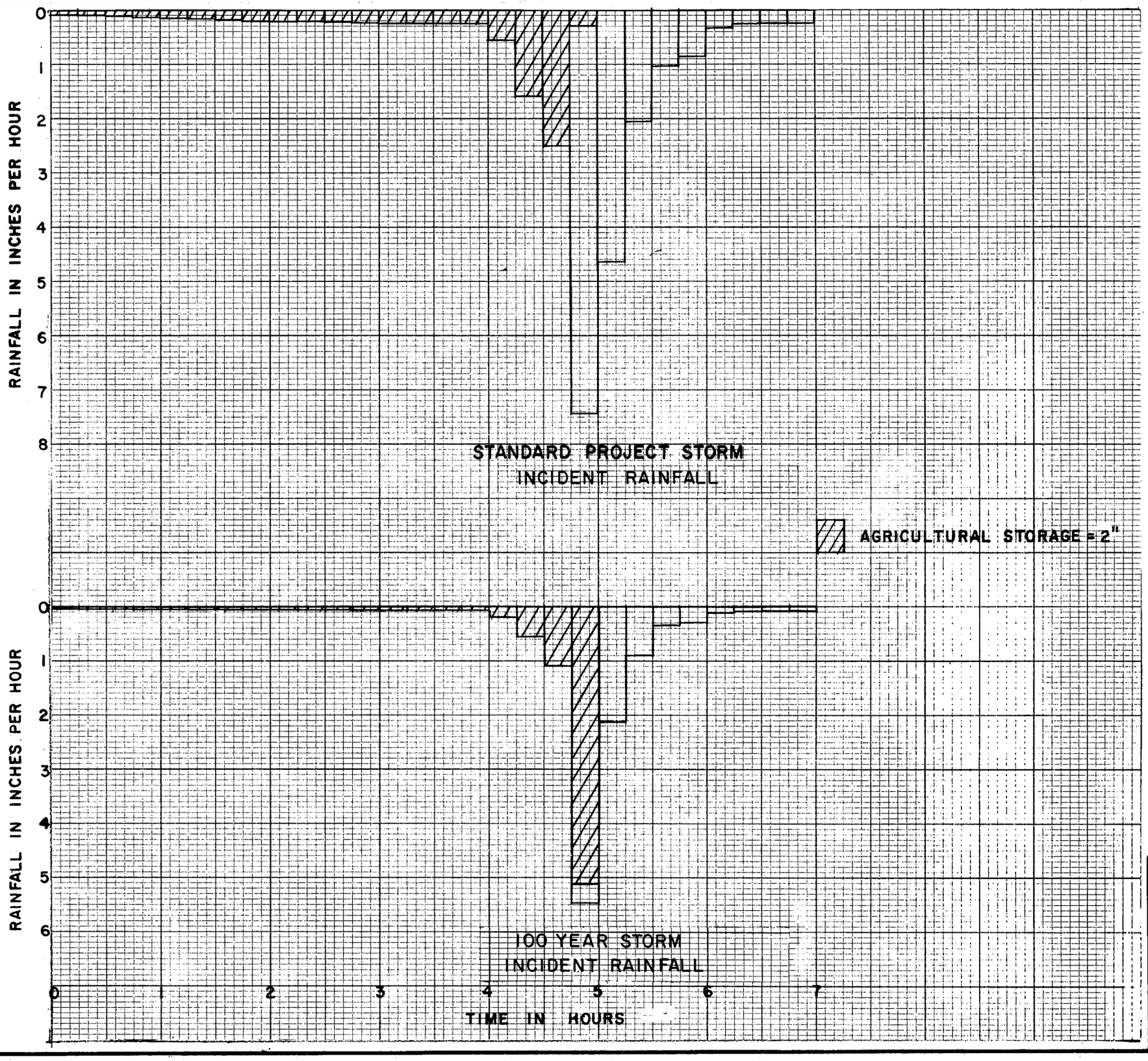

DISCHARGE IN CFS
3000
2000
1000
0
1302
1302 ROUTED TO 1304
4
5
6
7
8
9
10
11
12
HOURS FROM BEGINNING OF STORM
5000
4000
3000
2000
1000
DISCHARGE IN CFS
DISCHARGE IN CFS
4000
3000
2000
1000
0
1303
1303 ROUTED TO 1304
4
5
6
7
8
9
10
11
12
0
1
HOURS FROM BEGINNING OF STORM



GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

SPF HYDROGRAPH AT CP 1304
COMBINED HYDROGRAPH
FUTURE CONDITIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

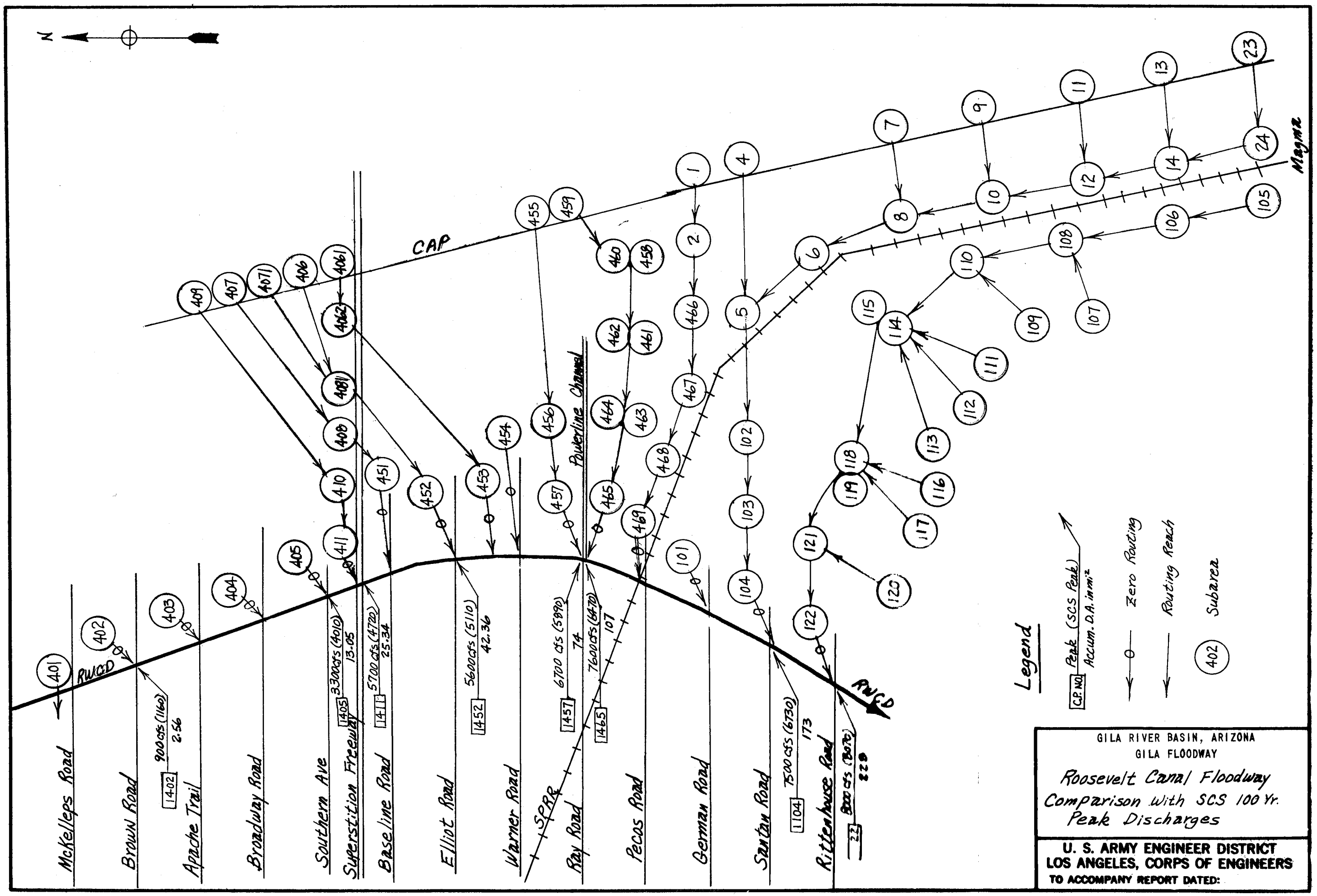


GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

POINT RAINFALL HYETOGRAPH

(SOURCE: REFERENCE 2)

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:


N
CAP
Magma
Powerline Channel
SPRR
RWCD
McKelleps Road
Brown Road
Apache Trail
Broadway Road
Southern Ave
Superstition Freeway
Baseline Road
Elliot Road
Warner Road
Ray Road
Pecos Road
German Road
Santan Road
Ritterhouse Road
900 cfs (1160)
2.56
3300 cfs (4010)
13.05
5700 cfs (4720)
25.34
5600 cfs (5110)
42.36
6700 cfs (5890)
74
7600 cfs (6470)
107
7500 cfs (6730)
173
Legend
Peak (SCS Peak)
Accum. D.A. in mi²
Zero Routing
Routing Reach
Subarea
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY
Roosevelt Canal Floodway
Comparison with SCS 100 Yr.
Peak Discharges
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

Appendix 2

ECONOMICS
GILA FLOODWAY
MARICOPA AND PINAL COUNTIES, ARIZONA

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Appendix 2

ECONOMICS

I. ECONOMIC BASE

1.01 Population. Maricopa County, which coincides with the Phoenix Standard Metropolitan Statistical Area (SMSA), is one of the fastest growing metropolitan areas in the United States and one of the major centers of economic activity in the Southwest. From 41st in size among 157 such areas in 1960, the Phoenix SMSA grew to become the 34th largest SMSA in 1970, being exceeded in growth rate by only nine of these SMSA's between 1960 and 1970.

Now (1975) containing 53.1 percent of Arizona's population, Maricopa County accounted for 56 percent of the State's growth during the period of 1960-1975. The population of Maricopa County increased from 186,000 people in 1940 to 1,180,000 people in 1975, or approximately 534 percent. Prior to 1950, the principle factors influencing growth in Maricopa County and the Phoenix urban area were agriculture, tourism, government, and some food and fibre processing. From 1950 until recently, however, high nationwide birth rates that occurred in the 1950's and 1960's, national migration to the Pacific Southwest including a significant number of retirees, and the effects of an accelerated defense and aerospace program, in addition to the growth of electronics oriented industries not directly related to defense and aerospace, have become the principle stimuli for expansion. The projections used in this report reflect a slowdown in growth that is expected because of the current trend in birth rates.

The historic and projected populations for Maricopa County and the Cities of Phoenix, Tempe, and Mesa are shown in the following tabulation. Future population figures are based on series ''E'' projections for Maricopa County made by the Bureau of Economic Analysis of the U.S. Department of Commerce and the Economic Research Service of the U.S. Department of Agriculture (OBERS). These projections were allocated among the various cities on the basis of data provided by the Maricopa Association of Governments (MAG), historical trends, and recent development patterns, including data provided by the 1975 special census.

Year	Maricopa County	Phoenix	Tempe	Mesa
1950	331,800	106,800	7,700	16,800
1960	663,500	439,200	24,900	33,800
1970	968,500	581,600	63,600	62,900
1975	1,180,000	670,000	93,000	100,000
1980	1,290,000	730,000	105,000	105,000
2000	1,885,000	1,025,000	185,000	185,000
2020	2,345,000	1,260,000	220,000	235,000

Sources: 1950-1970, Census: 1975, special Census: 1980-2020, OBERS ''E'' projections for Maricopa County, allocated by the Corps to various cities.

1.02 CURRENT AND FUTURE LAND USE. The patterns of current and future land use in the Phoenix metropolitan area are discussed in the following paragraphs.

Plate 1 depicts the patterns of urbanization during the 1960's in the Phoenix metropolitan area. The major feature of the urban expansion is that contiguous development has occurred in every direction from the urban core, given topographical and manmade constraints. The urban core of the Phoenix metropolitan area is generally within a 2-mile radius of downtown Phoenix. Located within this radius are most of the highest valued industrial, commercial, public, and high-density residential properties in the Phoenix metropolitan area.

II. CONSTRAINTS ON DEVELOPMENT

2.01 The constraints on development have partly influenced (determined) the urbanization pattern. Plate 1 shows the topographic constraints of mountains, flood plains and the Indian lands now affecting development on the east; in the near future, the Indian lands are expected to be less of a constraint. Additional constraints on growth are the national forest preserves, Federal and State parks and monuments, and military reservations.

2.02 The slope of the land is another constraint. Empirical analysis of past patterns of development in the Phoenix metropolitan area shows that most development during the initial period of spillover into a given area is on land of less than 25 percent slope. Steep precipitous hillsides are not considered suitable for high-density urban development; they are relatively costly to develop and the community opposes any scarring of the picturesque desert mountains. Although these lands may be developed when other developable lands close to one of the regions become scarce, the development that ultimately occurs on slopes greater than 25 percent is usually of very low density (less than one unit per acre).

III. LAND-USE TRENDS

3.01 The following discussion of land-use patterns is based on the latest and most comprehensive land-use data obtainable from city general plans and the Maricopa Association of Governments (MAG). In its continual outward expansion during the past 20 years, the Phoenix metropolitan area has absorbed smaller neighboring communities, thus forming an extensive continuous urban area within the constraints of topography and floodways. This growth resulted in the rapid development of the City of Scottsdale, which experienced a 570-percent increase in population from 1960 (10,000 people) to 1970 (67,000 people); single-family dwelling units predominated, with concomitant development of a supporting urban complex.

3.02 The urban expansion in the 1960's also spread to the southeast into the Tempe area, causing a 163-percent increase in the population from 1960 (24,900 people) to 1970 (62,900 people); to the north into Deer Valley; and to the west into the Maryvale part of the City of Phoenix, and into the vicinity of the City of Glendale. The wide flood plain of the Salt River has slowed the spread of urbanization southward.

3.03 This increase in population required the use of over 30,000 additional acres in Maricopa County in the 1960's. Both the increase in densities in the developed parts of the Phoenix metropolitan area and the development of large, new communities of low-density absorbed the population growth. The increased demand for land caused by the growth in population has led to rising property values. Because development on land adjacent to the urban core is increasingly being recycled to multiple-unit buildings, new single-family units are being forced to outlying areas where land cost is lower.

3.04 Projected population increases, combined with the availability of large tracts of privately held acreage, make it unlikely that any profound change will occur in the development pattern.

3.05 Future urban development in the Phoenix metropolitan area is shown on plate 2. These patterns of development are based on population projections discussed previously.

3.06 Development is expected to occur as follows:

a. The current rapid development in Tempe and Mesa to the southeast of Phoenix is expected to continue. Spreading along Interstate 10 to the south and the Superstition Freeway to the east during the period 1975-1990, this development is expected to envelop the City of Chandler by 2020.

b. Planned development (such as the McCormick Ranch developed by the Kaiser Aetna Corporation) and low-density ''horse-acre'' development is expected to continue to the northeast of Phoenix in Paradise Valley. Development should reach to the Paradise Valley detention dike (under construction) by 2020.

c. Northward urban expansion along the Black Canyon Highway is anticipated to reach the Union Hills by 2020.

d. During the period 1975-1990, urban development will be filling in areas to the northwest between the Cities of Phoenix and Glendale. This development will generally proceed along U.S. Highways 60, 70, and 89, finally encompassing the Sun City (Youngtown) by 2020.

e. Following construction of the proposed Interstate 10 west of Phoenix, urban development will spread to engulf Avondale by 2020.

f. Development will continue at a slow rate to the south of Phoenix. The Salt River flood plain and the South Phoenix Mountains will remain as constraints on rapid development in this area.

3.07 Along with these general development trends contiguous to the present urbanized area, planned communities beyond the periphery of the present development continue to be popular with the developers in the Phoenix metropolitan area. As of March 1975, nine large-scale developments having design populations greater than 20,000 were either in existence or being proposed. Sun City (present population 32,300), about 15 miles northwest of downtown Phoenix on U.S. Highway 60-70-89, and the more recent developments of Dobson Ranch in Mesa and McCormick Ranch in Scottsdale are prime examples of such planned developments.

IV. FLOOD DAMAGES

4.01 Flood damages were analyzed in seven primary reaches: (1) the City of Mesa along the north bank of the Superstition Freeway; (2) the City of Tempe; (3) ponding area at the intersection of Baseline Road and the Southern Pacific Railroad; (4) flooding in the vicinity of the Dobson Ranch development; (5) the City of Chandler; (6) the Town of Gilbert, and; (7) the main floodway in the vicinity of Interstate 10. Approximately 13,473 acres lie within the SPF overflow area of which 4,355 acres are currently in urban use.

4.02 Future development was projected to conform to OBERS series "E" projections for Maricopa County, the Maricopa Association of Governments (MAG) composite land use plan (pl. 3), the National Flood Disaster Protection Act of 1973, and local flood plain ordinances. A summary of present and future land use in the Standard Project Flood overflow area is shown in table 1.

4.03 Estimates of existing (1975) property values were made by using (a) county assessor's records, (b) recent sales data, and (c) Marshall and Stevens Valuation Appraisal Manual. Contents values for residential development were based on average values of representative development. The future value of contents per residence was projected at the OBERS projected increase of per-capita income (approximately 2.6 percent annually). The value of residential contents were projected at the per-capita growth rate to a maximum of 75 percent of the residential structures. Values were not projected after the first 50 years of project life.

4.04 Damages were estimated for each of selected flood magnitudes by the following procedure:

a. Hydraulic studies were made to determine the extent of the overflow area, the depth of inundation, and the velocity of flow. Average depths were as follows:

Reach	Average Depth (feet) SPF	100 Year
Mesa, north of freeway	3	.75
Tempe	.75	---
Ponding area	2.5	1
Dobson Ranch vicinity	1.5	---
Gilbert	2	1
Chandler		
Ponding	2.75	1.25
Overflow	.9	---
Main floodway	1.25	.5

Velocities ranged from 0 to 2 feet per second.

b. Depth-damage relationships, based on records of past floods, primarily the Phoenix 1972 flood, were applied to each property subject to inundation.

c. The individual damages to each property type were totaled. Damages from floods of selected magnitudes are shown by reach in table 4. In most reaches (except the ponding areas) damages from the 50-year flood were negligible.

d. By applying each flood's frequency of occurrence to the damages corresponding to the flood, the probable damages expected to occur at any one year were calculated by reach. These probable annual damages were then discounted to the base year (1980), summed, and then converted to equivalent annual damages (6-1/8 percent, 100 year). Probable and equivalent annual damages are shown by reach in table 5.

4.05 Alternative plans were evaluated to estimate the potential for reducing flood damage. Because the 100-year flows are relatively minimal, plans scaled at this size produced minimal benefits from flood damage reduction. For simplicity purposes, alternatives designed to control the Standard Project Flood were assumed to prevent all damages. A summary of the feasibility of alternative plans analyzed is presented in the main report.

TABLE 1

Present and Projected Development by Type of Development for the Standard Project Flood (Acres)

Development	1975	1979	1989	1999	2079
MESA NORTH OF FREEWAY					
Residential	235	327	664	1,690	1,690
Trailer parks	24	24	24	24	24
Public	121	121	121	121	121
Agriculture	1,455	1,363	1,026	0	0
Total	1,835	1,835	1,835	1,835	1,835
TEMPE					
Residential	1,578	2,045	2,045	2,045	2,045
Commercial	45	45	45	45	45
Public	114	114	114	114	114
Vacant	467	0	0	0	0
Total	2,204	2,204	2,204	2,204	2,204
PONDING AREA					
Residential	59	59	185	185	185
Commercial	45	45	45	45	45
Agriculture	819	819	693	693	693
Total	923	923	923	923	923
DOBSON RANCH VICINITY					
Residential	858	1,518	1,646	1,646	1,646
Golf courses	110	110	110	110	110
Agriculture	788	128	0	0	0
Total	1,756	1,756	1,756	1,756	1,756
GILBERT					
Residential	71	71	71	571	571
Trailer parks	2	2	2	2	2
Commercial	24	24	24	24	24
Public	1	1	1	1	1
Agriculture	3,550	3,550	3,550	3,050	3,050
Total	3,648	3,648	3,648	3,648	3,648

TABLE 1 – Continued

Development	1975	1979	1989	1999	2079
			CHANDLER PONDING		
Residential	94	94	94	94	94
Trailer park	10	10	10	10	10
Commercial	89	89	89	89	89
Total	193	193	193	193	193
			CHANDLER OVERFLOW		
Residential	667	667	667	667	667
Commercial	70	70	70	70	70
Public	103	103	103	103	103
Total	840	840	840	840	840
			MAIN FLOODWAY		
Residential	0	0	2,039	2,039	2,039
Industrial	35	35	35	35	35
Agriculture	2,039	2,039	0	0	0
Total	2,074	2,074	2,074	2,074	2,074

TABLE 2

Estimated Present (1975) Value of
Development by Property Type
(1975 prices - $1,000)

	SPF	100 Year	50 Year
MESA NORTH OF FREEWAY			
Residential			
Structures	$20,807	$3,106	0
Contents	8,738	1,304	0
Trailer parks	810	0	0
Public	8,806	0	0
Agricultural	430	55	0
Total	$39,591	$4,465	0
TEMPE			
Residential			
Structures	$101,402	0	0
Contents	42,589	0	0
Commercial	42,253	0	0
Public	10,254	0	0
Total	$196,498	0	0
PONDING AREA			
Residential			
Structures	$225	$165	0
Contents	94	69	0
Commercial	900	720	0
Agricultural	215	143	$38
Total	$1,434	$1,097	$38
DOBSON RANCH VICINITY			
Residential			
Structures	$78,091	0	0
Contents	32,798	0	0
Golf courses	306	0	0
Agricultural	235	0	0
Total	$111,430	0	0
GILBERT			
Residential			
Structures	$3,369	$2,359	$887
Contents	1,415	991	373
Trailer parks	106	106	0
Commercial	2,477	1,718	432
Public	284	284	0
Agricultural	240	90	50
Total	$7,891	$5,548	$1,742

TABLE 2 – Continued

	SPF	100 Year	50 Year
		CHANDLER PONDING	
Residential			
Structures	$ 7,280	$ 4,030	$ 3,172
Contents	3,057	1,693	1,332
Trailer parks	1,079	1,079	1,012
Commercial	10,366	10,366	8,416
Total	$21,782	$17,168	$13,932
		CHANDLER OVERFLOW	
Residential			
Structures	$ 42,302	0	0
Contents	17,767	0	0
Commercial	7,162	0	0
Public	16,543	0	0
Total	$ 83,774	0	0
		MAIN FLOODWAY	
Residential			
Structures	0	0	0
Contents	0	0	0
Industrial	$ 8,064	0	0
Agricultural	612	0	0
Total	$ 8,676	0	0

TABLE 3

Estimated Present (1975) and Projected Value of
Development for Various Sized Floods
($1,000's)

Flood	1975	1979	1989	1999	2009	2019	2029	2079
MESA NORTH OF FREEWAY								
SPF	39,591	52,609	105,034	265,349	272,219	272,219	272,219	272,219
100 Yr	4,465	4,618	5,081	5,435	5,435	5,435	5,435	5,435
50 Yr	0	0	0	0	0	0	0	0
TEMPE								
SPF	196,498	262,326	283,633	302,452	302,452	302,452	302,452	302,452
100 Yr	0	0	0	0	0	0	0	0
50 Yr	0	0	0	0	0	0	0	0
PONDING AREA								
SPF	1,434	1,446	1,472	20,290	21,131	21,131	21,131	21,131
100 Yr	1,097	1,105	1,130	1,152	1,152	1,152	1,152	1,152
50 Yr	38	38	38	38	38	38	38	38
DOBSON RANCH VICINITY								
SPF	111,430	201,106	239,833	259,337	259,337	259,337	259,337	259,337
100 Yr	0	0	0	0	0	0	0	0
50 Yr	0	0	0	0	0	0	0	0
GILBERT								
SPF	7,891	8,060	8,572	114,393	119,118	119,128	119,128	119,128
100 Yr	5,548	5,668	6,030	6,352	6,352	6,352	6,352	6,352
50 Yr	1,742	1,785	1,917	2,034	2,034	2,034	2,034	2,034

TABLE 3 – Continued

Flood	1975	1979	1989	1999	2009	2019	2029	2079
				CHANDLER PONDING				
SPF	21,782	22,172	23,357	24,447	24,504	24,504	24,504	24,504
100 Yr	17,168	17,398	18,098	18,759	18,817	18,817	18,817	18,817
50 Yr	13,932	14,119	14,686	15,227	15,280	15,280	15,280	15,280
				CHANDLER OVERFLOW				
SPF	83,774	85,850	92,160	97,734	97,734	97,734	97,734	97,734
100 Yr	0	0	0	0	0	0	0	0
50 Yr	0	0	0	0	0	0	0	0
				MAIN FLOODWAY				
SPF	8,676	8,676	408,504	454,005	458,275	458,275	458,275	458,275
100 Yr	8,325	8,325	8,325	8,325	8,325	8,325	8,325	8,325
50 Yr	0	0	0	0	0	0	0	0

TABLE 4

Estimated Present (1975) and Projected Value of Damages for Various Sized Floods ($1,000's)

Flood	1975	1979	1989	1999	2009	2019	2029	2079
MESA NORTH OF FREEWAY								
SPF	2,969	4,223	9,016	20,930	21,546	21,546	21,546	21,546
100 Yr	230	240	265	290	300	300	300	300
50 Yr	0	0	0	0	0	0	0	0
TEMPE								
SPF	8,187	11,538	12,826	13,964	13,964	13,964	13,964	13,964
100 Yr	0	0	0	0	0	0	0	0
50 Yr	0	0	0	0	0	0	0	0
PONDING AREA								
SPF	309	312	315	2,432	2,562	2,562	2,562	2,562
100 Yr	89	89	92	93	93	93	93	93
50 Yr	25	25	25	25	25	25	25	25
DOBSON RANCH VICINITY								
SPF	5,388	9,725	11,526	12,404	12,404	12,404	12,404	12,404
100 Yr	0	0	0	0	0	0	0	0
50 Yr	0	0	0	0	0	0	0	0
GILBERT								
SPF	1,064	3,527	3,753	3,868	3,868	3,868	3,868	3,868
100 Yr	346	357	393	423	423	423	423	423
50 Yr	71	73	80	87	87	87	87	87

TABLE 4 – Continued

Flood	1975	1979	1989	1999	2009	2019	2029	2079
CHANDLER PONDING								
SPF	2,975	3,074	3,374	3,648	3,660	3,660	3,660	3,660
100 Yr	805	824	882	936	938	938	938	938
50 Yr	361	368	392	414	415	415	415	415
CHANDLER OVERFLOW								
SPF	5,028	5,227	5,830	6,363	6,363	6,363	6,363	6,363
100 Yr	0	0	0	0	0	0	0	0
50 Yr	0	0	0	0	0	0	0	0
MAIN FLOODWAY								
SPF	1,077	1,077	35,375	40,922	41,443	41,443	41,443	41,443
100 Yr	100	100	100	100	100	100	100	100
50 Yr	0	0	0	0	0	0	0	0

TABLE 5

Probable and Equivalent Annual Damages
by Type of Development
($1,000's)

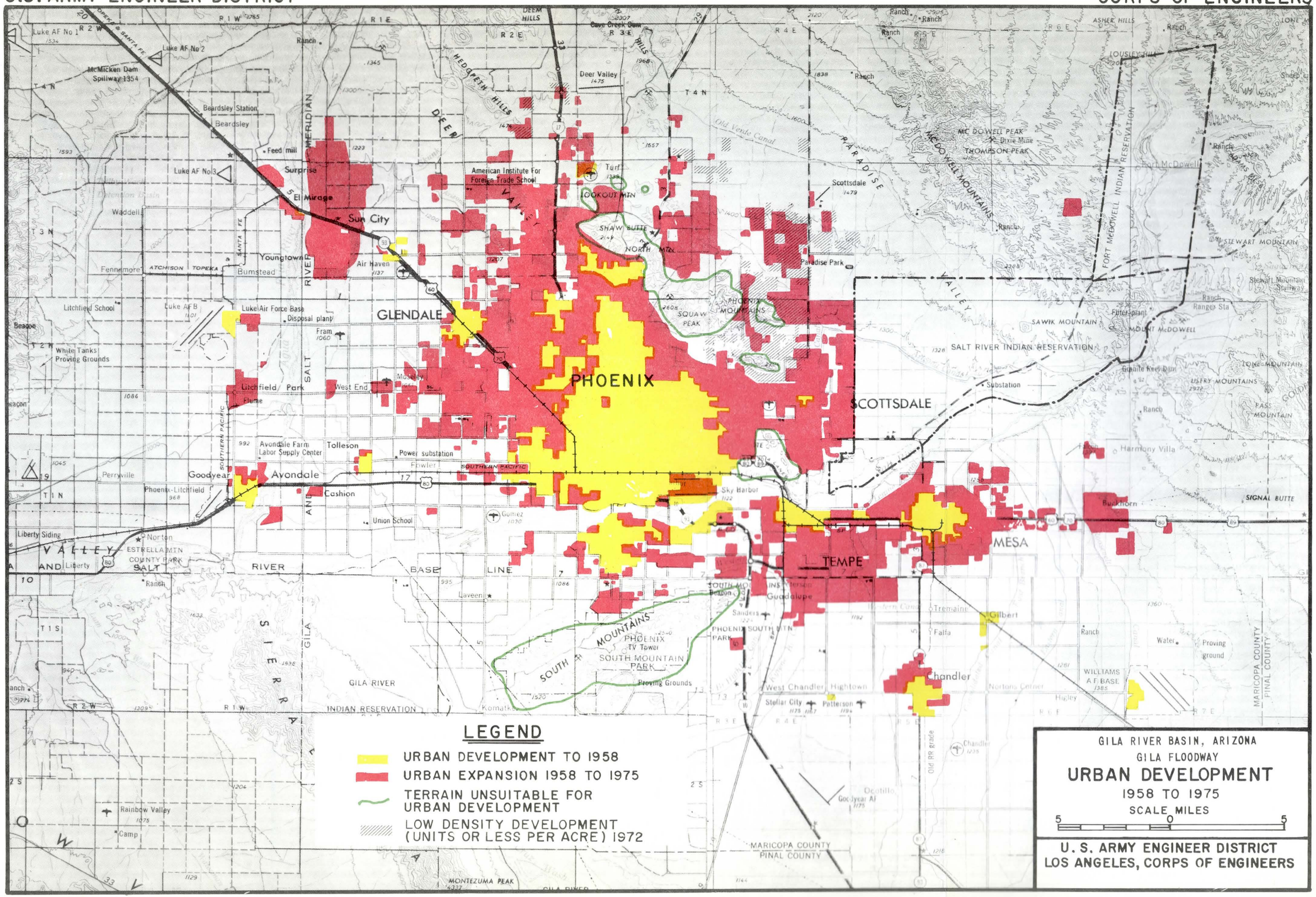
Land Use	Present (1975)	Projected 1979	1989	1999	2009	2019	2029	2079	Equivalent Annual Damages (6.125%, 100 Yrs)
MESA NORTH BANK OF PROPOSED SUPERSTITION FREEWAY									
Residential structures	7	8	17	43	43	43	43	43	26
Residential contents	5	8	18	48	51	51	51	51	29
Trailer parks	0	0	0	0	0	0	0	0	0
Public	1	1	1	1	1	1	1	1	1
Total	13	16	36	92	95	95	95	95	56
TEMPE									
Residential structures	11	15	15	15	15	15	15	15	15
Residential contents	6	10	13	16	16	16	16	16	14
Commercial	3	3	3	3	3	3	3	3	3
Public	0	0	0	0	0	0	0	0	0
Total	20	28	31	34	34	34	34	34	32
PONDING AT CENTER STREET AND SPRR									
Residential structures	0	0	0	7	8	11	14	14	4
Residential contents	0	0	0	9	12	14	19	19	5
Commercial	0	0	0	1	1	2	2	2	1
Agriculture	2	2	4	5	8	12	15	15	5
Total	2	2	4	22	29	39	50	50	15

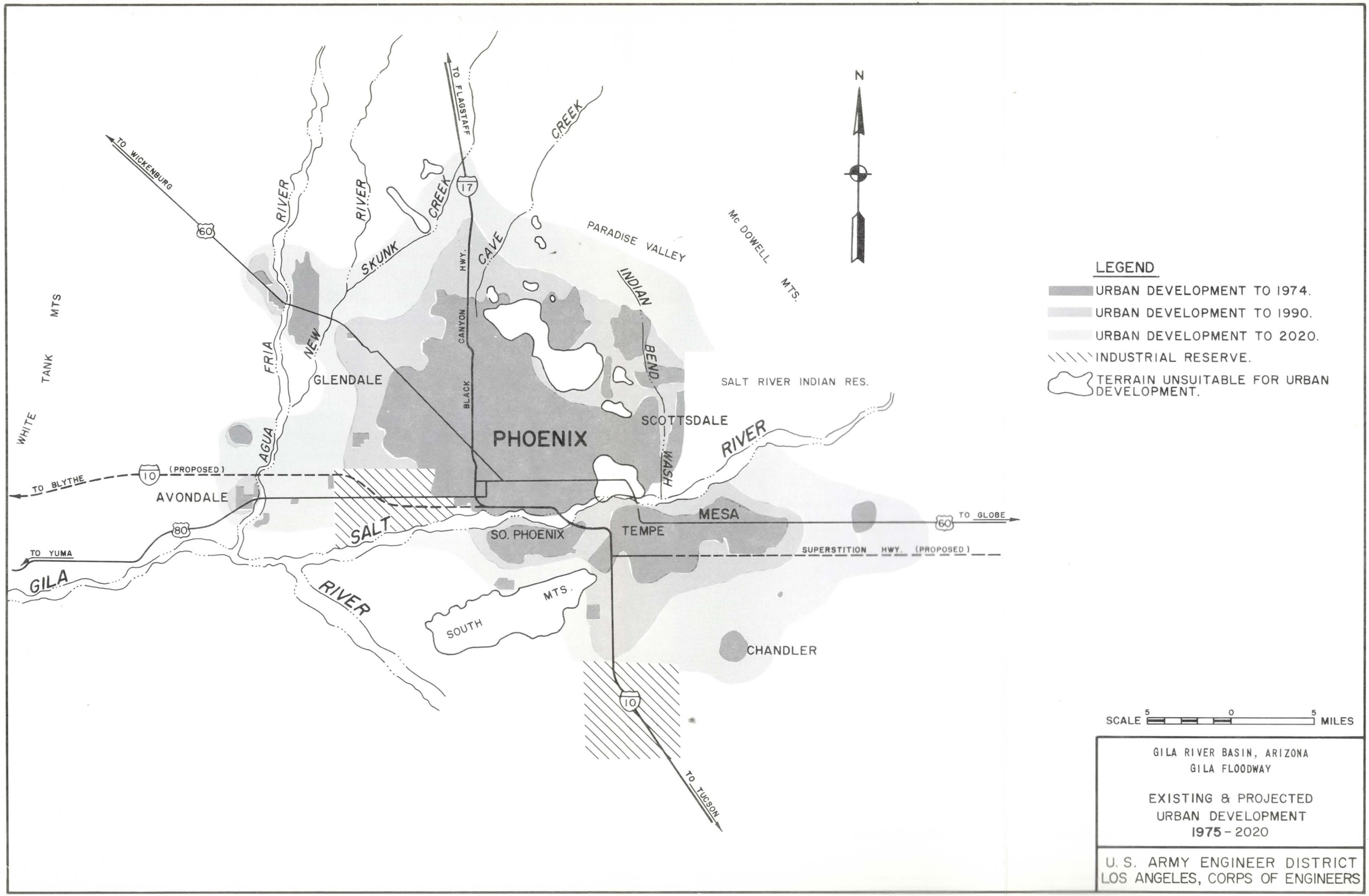
TABLE 5 - Continued

Land Use	Present (1975)	Projected 1979	1989	1999	2009	2019	2029	2079	Equivalent Annual Damages (6.125%, 100 Years)
DOBSON RANCH VICINITY									
Residential structures	7	13	15	16	17	18	18	18	15
Residential contents	3	6	8	11	11	12	12	12	9
Golf courses	0	0	0	0	0	0	0	0	0
Total	10	19	23	27	28	30	30	30	24
GILBERT									
Residential structures	4	4	4	10	10	10	10	10	7
Residential contents	3	3	4	9	10	10	10	10	6
Trailer parks	2	2	2	2	2	2	2	2	2
Commercial	0	0	0	0	0	0	0	0	0
Public	0	0	0	0	0	0	0	0	0
Total	9	9	10	21	22	22	22	22	15
CHANDLER PONDING									
Residential structures	7	7	7	8	8	9	11	11	8
Residential contents	6	7	9	11	11	12	13	13	10
Trailer parks	2	2	2	2	2	3	3	3	2
Commercial	8	8	8	8	9	9	11	11	8
Total	23	24	26	29	30	33	38	38	28
CHANDLER OVERFLOW									
Residential structures	6	6	6	6	6	6	6	6	6
Residential contents	4	4	5	7	7	7	7	7	6
Commercial	1	1	1	1	1	1	1	1	1
Public	1	1	1	1	1	1	1	1	1
Total	12	12	13	15	15	15	15	15	14

TABLE 5 - Continued

Land Use	Present (1975)	Projected 1979	1989	1999	2009	2019	2029	2079	Equivalent Annual Damages (6.125%, 100 Yrs.)
MAIN FLOODWAY									
Residential structures	0	0	67	67	67	67	67	67	52
Residential contents	0	0	67	88	90	90	90	90	59
Industrial	3	3	3	3	3	3	3	3	3
Agriculture	2	2	0	0	0	0	0	0	1
Total	5	5	137	158	160	160	160	160	115
SUMMARY TOTAL (ALL REACHES)									
Residential structures	42	53	131	172	174	179	184	184	133
Residential contents	27	38	124	199	208	212	218	218	138
Trailer parks	4	4	4	4	4	5	5	5	4
Commercial	12	12	12	13	14	15	17	17	13
Industrial	3	3	3	3	3	3	3	3	3
Public	2	2	2	2	2	2	2	2	2
Golf courses	0	0	0	0	0	0	0	0	0
Agricultural	4	4	4	5	8	12	15	15	6
Total	94	116	280	298	413	428	444	444	299


LEGEND
URBAN DEVELOPMENT TO 1958
URBAN EXPANSION 1958 TO 1975
TERRAIN UNSUITABLE FOR URBAN DEVELOPMENT
LOW DENSITY DEVELOPMENT (UNITS OR LESS PER ACRE) 1972
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY
URBAN DEVELOPMENT
1958 TO 1975
SCALE MILES
5 0 5
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
PHOENIX
GLENDALE
SCOTTSDALE
TEMPE
MESA
Sun City
Surprise
El Mirage
Youngtown
Avondale
Goodyear
Tolleson
Litchfield Park
Chandler
Gilbert
Guadalupe
Tempe
Sky Harbor
Deer Valley
Paradise Valley
Scottsdale
Luke AF No 1
Luke AF No 2
Luke AF No 3
Luke Air Force Base
Luke AFB
McMicken Dam
Beardsley Station
Beardsley
Feed mill
Waddell
Fennemore
Bumstead
Litchfield School
White Tanks Proving Grounds
Air Haven
Fram
Moseley
West End
Avondale Farm Labor Supply Center
Power substation
Fowler
Cashion
Union School
Perryville
Phoenix-Litchfield
Liberty Siding
Liberty
Norton
ESTRELLA MTN COUNTY PARK
Laveen
Rainbow Valley
Camp
Komatke
Sanders
Stellar City
Petterson
West Chandler
Hightown
Tremaine
Falfa
Norton's Corner
Higley
Harmony Villa
Buckhorn
Water
Proving ground
WILLIAMS A.F. BASE
Ocotillo
Goodyear Al
Chandler
Old RR grade
Cave Creek Dam
Turf
LOOKOUT MTN
SHAW BUTTE
NORTH MTN
PHOENIX MOUNTAINS
SQUAW PEAK
Paradise Park
American Institute For Foreign Trade School
Old Verde Canal
MC DOWELL PEAK
Dixie Mine
THOMPSON PEAK
MC DOWELL MOUNTAINS
FORT MCDOWELL INDIAN RESERVATION
Fort McDowell
STEWART MOUNTAIN
Stewart Mountain Spillway
Ranger Sta
Filter plant
MOUNT McDOWELL
SAWIK MOUNTAIN
SALT RIVER INDIAN RESERVATION
Granite Reef Dam
Substation
LONE MOUNTAIN
USERY MOUNTAINS
PASS MOUNTAIN
SIGNAL BUTTE
ASHER HILLS
LOUSLEY HILLS
HEDGPETH HILLS
DEEM HILLS
SOUTH MOUNTAINS
PHOENIX TV Tower
SOUTH MOUNTAIN PARK
Proving Grounds
GILA RIVER INDIAN RESERVATION
SIERRA
MONTEZUMA PEAK
MARICOPA COUNTY
PINAL COUNTY
SALT RIVER VALLEY
GILA RIVER BASE LINE
SALT RIVER MERIDIAN
SOUTHERN PACIFIC
ATCHISON TOPEKA & SANTA FE



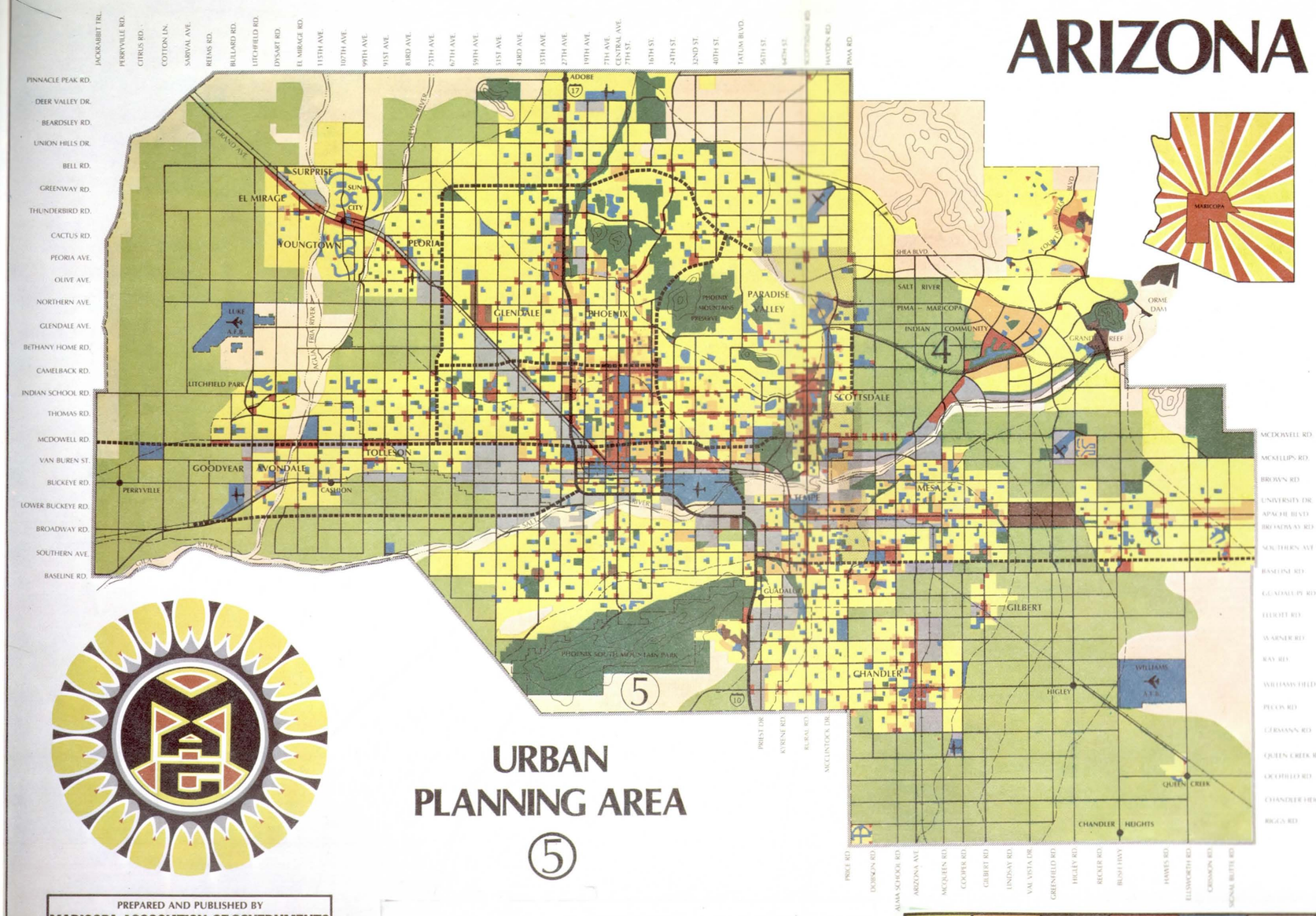
GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

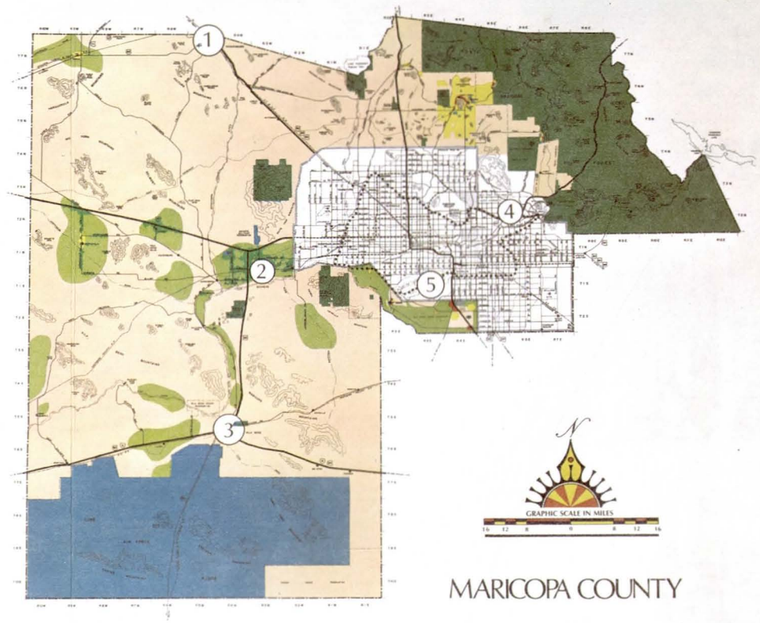
EXISTING & PROJECTED
URBAN DEVELOPMENT
1975 - 2020

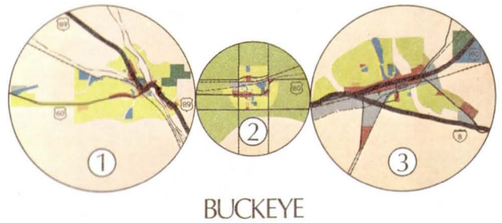
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE 2

COMPOSITE LAND USE PLAN FOR MARICOPA COUNTY, ARIZONA







URBAN PLANNING AREA

5

PREPARED AND PUBLISHED BY

MARICOPA ASSOCIATION OF GOVERNMENTS

MARICOPA COUNTY, ARIZONA

PREPARED FROM PLANS OF MAG MEMBER AGENCIES

The preparation of this map was financed in part through funds from the Federal Highway Administration, the Department of Housing and Urban Development, and the Urban Mass Transportation Administration, and was prepared on the 15th day of May, 1973.

GRAPHIC SCALE IN MILES

TRANSPORTATION CORRIDORS	
URBAN PLANNING AREA	*OTHER MARICOPA COUNTY*
EXISTING FREEWAY	MAJOR HIGHWAY
PLANNED FREEWAY, EXPRESSWAY ROUTE	OTHER ROADS
MAJOR STREET	SUN CIRCLE HIKING AND RIDING TRAIL

LOW DENSITY RESIDENTIAL	MEDIUM DENSITY RESIDENTIAL	HIGH DENSITY RESIDENTIAL	COMMERCIAL	PUBLIC AND SEMI-PUBLIC	INDUSTRIAL	PARKS	AGRICULTURAL	CONSERVATION
0 TO 5 HOUSING UNITS PER GROSS ACRE	5 TO 15 HOUSING UNITS PER GROSS ACRE	15 & OVER HOUSING UNITS PER GROSS ACRE						

GILA RIVER BASIN, ARIZONA
GILA FLOODWAY

MARICOPA ASSOCIATION OF GOVERNMENT COMPOSITE LAND USE PLAN

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

Appendix 3

ENVIRONMENTAL SETTING
GILA FLOODWAY
MARICOPA AND PINAL COUNTIES, ARIZONA

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Appendix 3

ENVIRONMENTAL SETTING

I. TOPOGRAPHY AND DRAINAGE

1.01 Situated within the Gila River Basin, the Salt River Valley lies near the north-central edge of the desert region in the Basin and Range Lowland Province. The area is bounded on the east by the Superstition Mountains, on the north by the Salt River, on the west by South Mountain and the Gila River, and on the south by the Gila River and Queen Creek, and encompasses a drainage area of approximately 1,000 square miles.

1.02 The region is characterized by parallel, generally north-south trending mountain ranges, which are separated by broad, flat, alluvium-filled valleys. Although the mountain ranges, rising sharply from the valley floor, are characterized by rugged, steep terrain, the mountain peaks are rarely over 4,000 feet high, and the relief is generally less than 2,000 feet.

1.03 The general gradient through the area is from east to west, ranging from 25 feet a mile in the northeast part to 10 feet a mile or less in the southeast part. The western part of the area is nearly flat.

1.04 In recent geologic past, the Salt River underwent a period of downcutting, during which a deep channel was eroded in the old flood plain. Since that time, coarse, unconsolidated, recent alluvium has been redeposited in the 2-mile-wide channel. To the west of the project area, the river channel once again merges with the flat, broad flood plain. The natural drainage is diverted by South Mountain to the Salt River on the north and to the Gila River on the south. Steep escarpments, up to 50 feet high still mark the edge of the river to the north and east of the City of Mesa. Consequently, drainage from most of the City of Mesa must flow southwesterly, towards the Gila River, some 30 miles distant.

1.05 Due to the slight gradients, the semi-arid climate, and the ephemeral nature of even the major streams, few well-defined natural drainages have developed in the area. Extensive farming and irrigation in the valley has resulted in the obliteration of any drainage courses that may have existed.

1.06 With no natural washes to contain floodflows, the area experiences sheet-flow-type runoff during periods of intense rainfall. Floodwaters, unless obstructed, flow uniformly overland, in broad, shallow sheets, in ill-defined flood plains.

1.07 Manmade obstructions, resulting from on-going residential, commercial and agricultural development, are increasingly altering the natural drainage patterns in much of the study area.

II. GEOLOGY

2.01 The mountain ranges surrounding the study area are composed of a variety of igneous, metamorphic, and sedimentary rocks ranging in age from Precambrian to Quaternary. The present topography is mainly a result of Tertiary block faulting, which elevated the subparallel mountain ranges, followed by filling of the intermontane basins with alluvial material eroded from the mountains. In addition, the Tertiary was a period of extensive volcanic activity. This served to alter or completely block drainage patterns, and many basins developed closed drainage systems. Clay and other fine sediments were deposited in these playas; in several of the larger basins many thousands of feet of sediment were deposited. Well into the Quaternary period major streams, such as the Salt and Gila Rivers, probably occupied channels far removed from their present-day courses.

2.02 The entire study area is underlain by alluvium. The unconsolidated alluvial sediments thin rapidly to the south and west, where bedrock is exposed in South Mountain and Gila Butte; however in most of the area the thickness of the alluvium exceeds 1,200 feet. The alluvium, derived from the nearby mountains, shows significant lateral as well as vertical variation, with coarse fan deposits interfingering with the fine playa deposits. Deep wells drilled near the center of the basin indicate that many thousand feet of sedimentary and volcanic rocks, including evaporite deposits, overlie the igneous and metamorphic basement rocks. Surface exposures of the sedimentary Papago formation north of Tempe dip to the southwest. However, subsurface structure and stratigraphy in the basin are poorly known. Quaternary faulting has not been identified in the greater Phoenix area.

III. SOILS

3.01 The soils in the study area fall into four associations or distinct patterns. The associations all consist of deep, well drained, nearly level soils formed from mixed alluvium. The soils are predominantly sandy loams and light loams, with minor amounts of silt loam and clay loam.

3.02 In general, the water holding capacity of the soils are high. Permeabilities range from slow (0.06-0.2 inches/hour) to moderately rapid (2.0-6.3 inches/hour). Roots are capable of penetrating to a depth of 60 inches or more (ref. 5).

3.03 All the soils are suitable for growing the irrigated crops found in the area, including cotton, sorghum, alfalfa, small grains, vegetables, sugar beets, and citrus. The soils have few deficiencies that restrict the choice of crops that can be successfully cultivated. The soils are moderately alkaline, but the degree of alkalinity does not affect the commonly grown crops.

3.04 In some of the steeper areas, adequate erosion protection must be provided, but erosion by wind and water is not a significant problem in most of the project area.

3.05 The soils in the study area are commonly affected by salts produced by the weathering of rock-forming minerals and deposited by surface runoff. Because seepage from rainfall is usually not sufficient to carry the salts down to the water table, they accumulate in the soil as the water evaporates. In portions of the study area, calcium carbonate has accumulated in the underlying material, but not in concentrations that affect the arability of the soil.

IV. EARTHQUAKES

4.01 The study area is located in zone 2, Seismic Risk Map of the United States, and the earthquake potential is low. Although severe earthquakes in California and Mexico have been widely felt throughout Arizona, only a few weak earthquakes have had epicenters in south central Arizona. Since 1927 there is no record of an earthquake greater than magnitude 4 (Richter Scale) with an epicenter within 50 miles of the study area. The maximum recorded intensity in Phoenix for a distant earthquake was V on the Modified Mercalli Scale, which ranges from I (weak) to XII (very strong). This was the result of the 1934 magnitude 7.1 Baja earthquake (intensity X, MM Scale) which had an epicenter 180 miles to the southwest in Baja California, Mexico.

V. NATURAL RESOURCES

5.01 The only natural resources in the area that are currently being developed are sand and gravel. No other type of mining operation is anticipated in this thickly alluviated area. A possible natural resource within the area that is under investigation is geothermal energy. Near the town of Higley, west of Williams Air Force Base, two deep geothermal wells were completed in 1973. No information on these 9,000 and 10,000 foot deep wells has been published and the importance of this area as a geothermal energy source remains questionable. However, due to the general geologic setting and the occurrence of scattered thermal wells in the area, future exploration and development of geothermal energy facilities are a possibility.

VI. CLIMATE

6.01 The project area is located in the Sonoran Desert Climatic Zone, a zone characterized by long hot summers, short mild winters, low annual rainfall, low relative humidity, and a high percentage of possible hours of sunshine. From late fall until early spring, the climate of the study area is mild. In winter, temperatures generally range from the high thirties or low forties near daybreak, to the high sixties in the afternoon. During warmer periods in the winter, the maximum temperature in the afternoon sometimes exceeds 80 degrees. Freezing temperatures are not common.

6.02 Summers are warm. From early June until late in September, temperatures range from 70 degrees near sunrise to 100 degrees in early afternoon. Readings of 110 degrees or higher occur regularly.

6.03 The study area has a dry climate, receiving less than 8 inches of rainfall in most years (ref. 4). Late spring is especially dry. The most consistent and reliable rains occur in mid-summer, when thunderstorms form over the eastern mountains during the afternoon and often spread out over the surrounding valley during the early evening. Precipitation tends to be moderate to heavy, but rarely lasts more than 30 minutes. These storms often produce little more than gusty winds and light showers. In some years, unusually heavy or prolonged rains are caused by weak tropical disturbances moving northward from the Pacific Ocean. These unusual storms sometimes produce an amount of rainfall during a 24-hour period as great as that normally received during an entire summer.

6.04 Precipitation is much less dependable in the winter, and the amount varies greatly from year to year. Most winter rainfall is associated with middle-latitude storms that have moved inland from the Pacific Ocean. The most severe weather conditions in the study area occur when one of these storms moves unusually far south, or intensifies off the coast of southern California. Snow is rare in the study area, with mountain peaks above 4,000 feet receiving the only significant amounts.

6.05 The area has an average relative humidity ranging from 24 percent in the summer to 54 percent in the cooler, moister winter. Relative humidity is increasing in the project area as a result of large irrigated areas, open canal systems and introduced urban plantings.

6.06 The area, on the average, enjoys 86 percent of the possible hours of sunshine annually, with monthly averages ranging from 77 percent in December to 94 percent in June. Winds in the project area are generally from the east, having an average velocity of about 6 miles per hour. Peak gusts occasionally reach as much as 50 miles per hour.

6.07 The combination of high temperatures, low relative humidity, maximum amounts of sunshine and wind causes a high evaporation rate. The evaporation rate within the study area is estimated at 6.5 feet per year.

VII. SURFACE HYDROLOGY

7.01 The project area does not contain well-defined watercourses. Due to naturally flat terrain and leveling for irrigation purposes, most storm runoff occurs as sheet flow, during and after periods of heavy rains. These sheet flows are interrupted and concentrated by natural and manmade structures.

7.02 A significant factor affecting the drainage pattern in the Mesa area is the proposed Superstition Freeway, with its attendant drainage facilities. Traversing the study area from east to west, the freeway will divert flow from its normal northeast to southwest flow path, forcing floodwaters to travel due west. The freeway drainage system, designed for a ''50-year'' flood according to Arizona Highway Department criteria, consists of cross-drainage structures east of RWCD Floodway and a system of retention basins, to be constructed as part of the City of Mesa storm drain system, and connecting channel west of RWCD Floodway.

7.03 The major irrigation canals, including the Roosevelt, Consolidated, Eastern, Tempe, and Western canals have an influence on the general drainage pattern of the area. Being somewhat higher than the surrounding land, the canals tend to act as barriers in many places, diverting flows southward in the swale formed between their east bank and the adjoining, gently rising land to the northeast. The gradients of the unimproved swales are very flat and irregular rendering the swales inefficient and unpredictable as floodways. While affording minor flood protection at times, considerable damage more often results from ponding behind the canal embankments. Storms regularly overtop the banks and breach the canal levees. Although the existing system of canals has been operated as emergency flood control channels in the past, these canals were not designed to carry floodflows.

7.04 The Southern Pacific Railroad has several lines crossing the study area. The tracks are elevated an average of 3 to 6 feet. The embankments serve as obstructions, ponding and redirecting floodwaters. During the severe thunderstorm of August 1954, the town of Gilbert suffered extensive damage from floodwaters of Queen Creek, diverted north into the city by the Southern Pacific Railroad embankment.

7.05 Two major existing highways, Interstate 10 and U.S. Highway 60, 80, 89 (Apache Trail) represent partial barriers to sheet flow in the same manner as the canals and the railroad embankments. Major storm flows pass overland under the influence of natural ground contours, redirected only by major obstacles. However, in cases of moderate rainfall, where associated runoff is not deep, many other structures have an affect on the path and concentration pattern of surface runoff. Street systems act as channels, redirecting and containing flows. A multitude of small irrigation channels that criss-cross the area intercept and impound storm runoff.

7.06 Increasing urban development has expanded the area sealed to infiltration of rainwater and altered the natural contours of the land. This has increased and concentrated sheet flow, sometimes causing flooding in areas that had previously been safe.

7.07 Maricopa County and the Cities of Mesa, Chandler, Tempe, and the town of Gilbert have passed legislation requiring that all plans for new development include some method of containing within the boundaries of the land to be developed the runoff produced by some specified storm. If this policy is enforced, the affect on runoff from urban areas will be significant.

VIII. HISTORICAL FLOODING

8.01 Although general winter storms cause flooding in the study area, the most severe conditions usually result from local summer thunderstorms. Historically, the most severe summer thunderstorm to occur within the State of Arizona was the Queen Creek thunderstorm of August 19, 1954, which caused extensive damages in the southeastern portion of the study area. The basin has experienced a number of storms that have caused damage in other parts of the valley. Floods have occurred in 1926, 1930, 1933, 1936, 1941, 1946, 1954, and 1959. Floods of significant proportions occurred in 1941, 1946, 1954, and 1959. The flood of 1954 is the largest on record. More recently, floods have occurred in 1963, 1969, 1971, and 1972.

8.02 Storm and Flood of 18 and 19 October 1972. As a result of the storm of October 1972, a total of 3.42 inches of rain fell on the Gila Floodway and lower Queen Creek watershed. This resulted in both agricultural and nonagricultural damages. At the time of the storm, the cotton harvest was about to begin, and preparation of land for planting alfalfa and other grain crops was underway. The primary crop planted at this time was cotton, and damage varied from 10-60 percent reduction in yield, depending upon the depth of the floodwaters. The water depth varied from 0.5 to 2.6 feet. Damage resulted from sediment and debris deposition in rows and low-lying areas, requiring extensive field releveling and debris removal.

8.03 Farmland ready for fall planting was eroded and required additional operations to prepare for planting. Harvest and planting of crops was delayed several weeks due to the water-soaked fields.

8.04 Many concrete lined irrigation systems were completely filled with sediment and had to be cleaned before any irrigation could begin. Other concrete ditches were washed out, requiring partial or complete replacement. Farm roads were severely eroded and dikes were washed out.

8.05 Residential flood damage was not severe since farm houses are sparsely located throughout the watershed. Most of the homes that were damaged were on the Gila River Indian Reservation. Values of the houses ranged from $5,000 to $10,000. Floodwaters entered the first floor of these homes and damage to property was sufficient to require cleanup operations to the interior and exterior of the homes.

8.06 Many local unimproved roads were impassable due to high water and sediment deposition. Floodwater ponded behind and overtopped the railroad tracks at several locations, washing out the roadbed and eroding the embankments.

8.07 A newly installed sewage treatment plant serving the residents of the Gila River Indian Reservation was damaged. Floodwaters flowed into the pond and several days work was required to get the plant into operation.

8.08 Crop and pasture damage accounted for over half of the total damages estimated to have occurred because of the storm. The remaining damage was primarily to residential property, highways, and railroad property.

8.09 The damages incurred as a result of this storm are representative of the aftermath of storms and storm runoff in most of the study area.

IX. FLOODED AREA

9.01 The Standard Project Flood represents the flood that would result from the most severe combination of meteorologic and hydrologic conditions considered reasonably characteristic of the region. Normally larger than any past recorded flood in the area, it can be expected to be exceeded in magnitude only on rare occasions. Thus it constitutes a standard for design that will provide a high degree of flood protection.

9.02 The August 1954 thunderstorm that centered over the Queen Creek drainage area, in the southeast corner of the study area, was determined by the Corps of Engineers to be the local storm with the most severe flood peak that may be reasonably expected to occur in the area.

X. EXISTING AND PROPOSED WATER RESOURCE FACILITIES AFFECTING FLOOD CONTROL

10.01 Salt River Project. The Salt River project was the first multipurpose project authorized under the Federal Reclamation Act of 1902. It includes an irrigation project managed by the Salt River Valley Water Users' Association and a power project managed by the Salt River Project Agricultural Improvement Power District. The association manages the 13,000 square mile watershed of the Salt and Verde Rivers and operates and maintains the transmission and distribution system that provides water for municipal, industrial and agricultural uses within the project's 250,000-acre area. The Salt River project's storage and distribution system consists of six storage dams, one diversion dam and 1,300 miles of transmission canals, distribution laterals and ditches. The Tempe, Eastern, Consolidated and Western canals are part of the distribution system in the project area.

10.02 Whitlow Ranch Dam. In 1954 the Corps of Engineers received authorization to construct Whitlow Ranch Dam, located on Queen Creek approximately 10 miles west of Superior. The dam, completed in 1960, controls the major portion of the Queen Creek watershed.

10.03 Soil Conservation Service Structures. In 1963 the Soil Conservation Service (SCS) published three watershed work plans (Buckhorn-Mesa, Apache Junction-Gilbert and Williams-Chandler) that comprised part of a flood-control program for the area east of Mesa and Chandler, between the Salt River and Queen Creek. Construction of seven retarding structures and a floodway along the Roosevelt Water Conservation District canal was proposed. Three of the structures have been completed. The other dams and the floodway are expected to be completed within the next 10 years.

10.04 The SCS is currently preparing a watershed work plan for the lower Queen Creek area. The plan includes the construction of a floodwater retarding reservoir. When all the proposed SCS structures are completed, they will provide 100-year flood protection to the entire area immediately east of the Roosevelt Water Conservation District canal, and the flows will be provided with an outlet to the Gila River.

10.05 The SCS has prepared a watershed work plan for the Guadalupe watershed, which is on the west side of the study area, immediately west of the community of Guadalupe. Construction of the floodwater retarding structure proposed in the plan has recently been completed. These measures provide protection to the community of Guadalupe and Interstate Highway 10.

10.06 Central Arizona Project. The Central Arizona Project (CAP) is an authorized project of the U.S. Bureau of Reclamation. Major project features involve the construction of four dams; four aqueducts, including tunnels and pumping plants; and power-transmission facilities to the pumping plants. Water would be transported from Lake Havasu on the Colorado River by the

aqueduct system for multipurpose uses in the CAP area. It would provide municipal and industrial water for the Tucson and Phoenix metropolitan areas and water for lands in Maricopa, Pinal, and Pima Counties in Arizona.

10.07 In general, to protect the aqueduct from floodflows, low earth dikes would be constructed uphill from the aqueduct to collect and convey floodflows (up to 50-year frequency) to drainage structures such as culverts and overchutes.

10.08 Maricopa County Storm Drains. In 1970 Yost and Gardner Engineers prepared a report entitled ''Storm Drainage Report for Maricopa Association of Governments.'' Based on population projections to 1995, the report recommends a storm drain construction program that would be accomplished in 25 years for an area of 480 square miles in Maricopa County, Arizona. In general, protection for the 1-year flood is recommended; however, in certain critical and high value areas, a greater degree of protection is recommended.

10.09 City of Mesa Storm Drains. In 1973 Yost and Gardner prepared a report entitled ''Storm Water Drainage for the City of Mesa.'' The report recommends that the City of Mesa construct a storm drain system capable of handling the street runoff from a 2-year storm, with certain collectors in the system being capable of handling the runoff from a 10-year storm. Portions of the City of Mesa's present storm drain system meet these requirements. The report includes suggestions as to what portions of the existing system must be upgraded and how the upgrading could be accomplished. The report recommends the use of retention basins in conjunction with the storm drains. A series of retention basins has been suggested. The right-of-way for some of the proposed basins is presently being acquired; the necessary capacity of the basins has not been determined.

10.10 Yost and Gardner Engineers have prepared a report for the State Highway Department on the drainage requirements for the Superstition Freeway. Because of the location of the freeway, they have stressed the desirability of coordinating the drainage control plans of the City of Mesa and the State Highway Department. Yost and Gardner Engineers revised their report on the storm drainage requirements within the City of Mesa to reflect the needs and effects of the state highway's plans. A conceptual study incorporating Mesa's drainage system with the Superstition Freeway's system was published in February 1975 titled ''Superstition Freeway Conceptual Study for Drainage'' (Tempe Canal to RWCD Canal).

XI. GROUND WATER

11.01 Most of the ground-water basins in southern Arizona are interconnected by thick accumulations of alluvium, and their hydrologic basin boundaries are arbitrarily chosen. The majority of the study area is located in the Salt River ground water basin; the southern portion, along the Gila River is considered part of the Lower Santa Cruz Basin.

11.02 Saturated alluvial deposits form the main ground water reservoir in the study area. The alluvium in the Salt River Basin varies in thickness from 0 feet near bedrock exposures to 2,000 feet near the center of the basin. The sediments range from impervious silt, clays and caliche to clean sand, cobble and boulder strata, which readily yield water to wells. Although locally perched water does exist in places, all aquifers below the regional water table are interconnected. Depth to ground water varies from about 80 feet between South Mountain and the Gila River to about 360 feet near Higley. Because the character of the alluvium can change radically, both laterally and vertically, individual aquifers exhibit varying specific yields and water quality.

11.03 Historically, ground water has been of major importance in the study area. Nearly two-thirds of the State of Arizona's water supply comes from ground water reservoirs. The Salt River Valley, as one of the State's largest agricultural areas, accounts for a large percentage of a total withdrawal. Out of a total of 5 million acre-feet of water pumped for all of Arizona in 1972, 1.8 million acre-feet was pumped from wells in the Salt River Valley.

11.04 Recharge to the ground water basin is derived from (a) seepage from canals and irrigated lands, (b) surface flow in streams and washes, (c) underflow along major streams in the area, and (d) rainfall. Most important of these sources is seepage from canals and irrigation. It has been estimated that 15 to 20 percent of the water applied to land for irrigation is returned to the ground water reservoir (ref. 19). Rainfall contributes little recharge to the ground water storage.

11.05 Since 1920, when the rate of pumping first exceeded the rate of replenishment, there has been a general decline in the ground water level in the Salt River Basin. The drop in the water table has averaged about 100 feet, but some areas have experienced drops of as much as 360 feet since 1920. Water levels are expected to drop 50 feet between 1974 and 1984 (ref. 9).

11.06 Because of the declining water levels brought on by excessive pumping of ground water, the State of Arizona has declared the Salt River Valley a critical ground-water basin. In critical ground-water areas the landowner defined as one in which no new wells may be developed for agricultural cannot increase his extraction of ground water for irrigation purposes by drilling additional wells. The pumping rate can be increased on existing wells (ref. 22). The overdraft of ground water is one of the primary reasons for the

development of the Central Arizona Project. Future legal and legislative decisions can be expected to control more closely the use of water within the basin. The legality of ground water use for esthetics or promotional displays is currently being questioned as a beneficial use by the Arizona Water Commission and State Land Department.

11.07 In the study area, land subsidence and earth-fissuring are related to the large-scale withdrawal of ground water and the resultant water-level declines in the alluvial sediment. Earth fissures generally begin as thin linear features - less than 1-inch wide and as much as a mile long. The cracks may be widened to as much as 30 feet at the land surface due to the erosive effect of irrigation water and rainfall runoff. The effects of subsidence and fissuring has damaged water wells, irrigation systems and roads. There has been minimal subsidence on the extreme east side of the project area, where it has been estimated that from 1 to 3 feet of subsidence has occurred. Several earth fissures have been mapped immediately north of the Santan Mountains, directly southeast of the study area.

XII. WATER QUALITY

12.01 The water quality index used in this report is based on the quantity of total dissolved solids (TDS) in a unit volume of water. TDS does not include suspended mineral sediments or solid material usually found to some degree in all water.

12.02 The use of ground water is limited by both the TDS content and the type of salts and mineral solids dissolved in the water. The TDS content in the ground water is related to the presence and availability of soluble minerals in the alluvium deposits of the basin and to the composition of the rocks and soil in the recharge area. The U.S. Public Health Service Drinking Water Standards (1962), applicable to all public water sources, indicate that domestic water supplies should not exceed a TDS content of 500 milligrams per liter (mg/1). Ground water in the project area has a TDS content ranging from 1,000 to 3,000 mg/1, depending on the source. Water in this concentration range is obtained from deposits that contain gypsum (calcium sulfate) or other soluble salts. It is used successfully for irrigation of salt-tolerant crops on well-drained soils. Generally, in this locality, water containing more than 1,000 mg/1 TDS is not preferred for public supply without treatment. However, most water that contains more than 1,000 mg/1 TDS does not constitute a health hazard unless specific undesirable constituents are present. TDS data is taken from discharge wells that range in depth from a few hundred feet to more than 1,500 feet below land surface. It must be noted that the quality of water discharged from a well is a composite of different quality water entering the well from various sediment layers. By selectively perforating wells, it is possible to isolate aquifers lower in TDS content.

12.03 The Central Arizona Project is a potential source of municipal water for the study area. The Colorado River, at its entrance into the CAP system at Parker Dam, had an average TDS content of 740 mg/1, for the period 1963-1967 (ref. 21).

12.04 In public water supplies, large concentrations of fluorides, hardness and nitrates are undesirable features. Each of these features are common in the ground water of the study area. Water that has these characteristics may be suitable for irrigation, industrial or other uses and commonly is used for public supply if better water is not available.

12.05 Fluoride in drinking water is a health problem if ingestion by children is sufficient to cause mottling of the teeth. A small quantity of fluoride in the water strengthens teeth and helps prevent tooth caries. Because the amount of water consumed and, therefore, the amount of fluorides ingested by humans partly depends on air temperature, the optimum fluoride concentration in drinking water is based on the annual average of maximum daily air temperature; for the study area a fluoride concentration of more than 1.4 mg/1 constitutes grounds for the rejection of the water for public use. Throughout a large portion of the Gila River Indian Reservation the ground water contains more than the allowed concentration of fluorides.

12.06 Hardness - the soap-consuming property of water - is caused mainly by the calcium and magnesium content. Hardness reduces the effectiveness of soap by forming an insoluble residue and causing incrustation on pipes, utensils, and appliances that come in contact with heated water.

12.07 Hardness is not known to be a health hazard and therefore no optimum hardness concentration has been set. For domestic water supplies that contain more than about 150 mg/1 hardness, it is often desirable to reduce the disadvantages of incrustation and soap consumption by use of water-softening systems. For the most part, the ground water in the study area exceeds 150 mg/1 hardness.

12.08 Nitrate concentrations of more than 45 mg/1 in drinking water can have serious effects on infants. Nitrates can enter the ground water through the application of nitrate fertilizers applied in agricultural areas or naturally occurring organic material in the alluvial deposits. Presently, there is no problem with excessive nitrate concentrations in the ground water of the project area.

XIII. AIR QUALITY

13.01 The project area is located in the Phoenix-Tucson Air Quality Control Region (AQCR), which is one of four regions into which the State of Arizona has been divided. The Phoenix-Tucson AQCR, which has been designated as an example region because it contains 81 percent of the State's population, measures the highest concentrations of pollutants, and contains most types of emission sources found in the State. As required by Federal law, the State of Arizona has identified those areas where either current air quality or projected growth rates indicate a potential for exceeding national standards within a 10-year period. The Phoenix Standard Metropolitan Statistical Area (SMSA), which includes all of Maricopa County, was identified as such an area for carbon monoxide and oxidants. The Phoenix SMSA has continuing difficulty meeting the Federal carbon monoxide standards. The population density in the region and particularly within Maricopa County (which has 67 percent of the population in the AQCR) leads to high concentrations of motor vehicles and motor vehicle-associated pollutants, i.e., carbon monoxide, oxides of nitrogen, hydrocarbons, and photochemical oxidants. Emissions from automobiles constitute an estimated 83 percent of the total atmospheric loading (ref. 14). The problem is aggravated by atmospheric conditions that are generally present in the study area - clear skies and dry air at night. These conditions favor the development of temperature inversions that may persist for as much as two-thirds of a day. When combined with periods of weak winds, or stagnant air, they permit pollutants to accumulate. Certain reactants, thus trapped by meteorological conditions, are acted upon by ultraviolet energy, resulting in photochemical smog.

13.02 Air quality data on carbon monoxide concentrations for the central Phoenix station, provided by Maricopa County Health Department, is compared to Federal 8-Hour Standards in the following table.

Year	Number of Times Federal 8-Hour Standards were Exceeded (Max. of 3 times per day possible)
1967	369
1968	370
1969	290
1970	232
1971	174
1972	186
1973	114
1974	102

13.03 Due to the generally dry environment, a natural problem with particulates exists, especially in agricultural and desert areas. The Maricopa County Health Department operates intermittent particulate samplers in Mesa, Chandler, and Guadalupe. The sampling results from 1974 are summarized in the following table.

Station	Days Sampled	Days Exceeding Federal Standards	Days Exceeding State Standards
Mesa	50	19	40
Chandler	57	20	47
Guadalupe	55	41	44

The annual average concentrations of SO_2 and NO_2 have not exceeded Federal Standards since continuous monitoring was initiated in the region. Efforts are being made to control air pollution in the area before it reaches a critical stage. The State of Arizona and Maricopa County share the responsibility for air pollution control in the study area. The Arizona State Air Pollution Control Division of the Department of Health has jurisdiction over all sources that emit 75 tons of particulates a day, as well as over all mobile sources of pollution. The Maricopa County Bureau of Air Pollution Control has justification over any other source of air pollution. The county air implementation program requires permits for equipment that discharges pollutants into the atmosphere, and also monitors air quality.

13.04 A plan devised by the State provides for the attainment of State air quality standards instead of national air quality standards. These State standards are equal to or more stringent than the national secondary standards. Indications from the State Air Implementation Plan are that a 2-year extension will be needed before carbon monoxide is controlled, but no extension will be needed for particulates, hydrocarbons, and photochemical oxidants. By 1975, the State expects to meet all other air quality standards using a closed-loop operational strategy controls to achieve ambient air standards for sulfur dioxide and utilizing the Federal auto emissions standards for the control of nitrogen dioxide.

XIV. ESTHETICS

14.01 In general the project area is a wide expanse of farmland, broken only by distant mountains and buttes. On a clear day visibility of 50 miles or more enhances the sense of open space. Declining air quality has begun to limit visibility, but has not yet diminished the feeling of spaciousness nor detracted from the spectacular skies, common at sunrise, sunset, and during summer thunderstorms. It is possible to travel from the urban environment, through planted or fallow fields to the sparse and sometimes desolate desert in a matter of minutes.

14.02 Moving southward from the Cities of Mesa and Tempe, man's encroachment is evident as planted fields, cross-crossed by lines of wind-break trees and irrigation canals. Scattered homes and buildings and the Cities of Chandler and Gilbert lie among the fields. Beyond the farmland lies the desert, relatively quiet and undisturbed. In the spring, the feeling of desolation is dispelled as the perennial vegetation blooms and greens, and annual flowers carpet the desert floor.

14.03 As land close to the urban core becomes more densely populated with multifamily and commercial construction, single-family developments move out into the desert and agricultural lands in a leapfrog fashion. More and more of the desert lands are being subjected to urban sprawl as large scale developments, complete with recreational lakes and green, irrigated parkways are built or planned for future construction.

XV. HISTORIC AND CULTURAL RESOURCES

15.01 Research into the archeological and historical resources in the study area was carried out by Arizona State University, Department of Anthropology, under contract with the Corps of Engineers. Information presented in this section was obtained from the report ''An Archeological Overview of the Proposed Gila Floodway, Maricopa County, Arizona,'' prepared for that contract.

15.02 Since the late 1800's, a good deal of archeological survey work has been carried out in the Mesa-Tempe-Chandler area. Several expeditions and surveys were conducted in the early 1900's. Since the 1950's, sporadic small survey scale excavations have been carried out at a number of sites in the Mesa-Tempe area by Arizona State University (ASU) and Arizona State Museum (ASM), but most of this work was done outside the study area.

15.03 A substantial number of sites have been recorded in the eastern portion of the study area, and the extensive prehistoric canal systems have been explored and mapped in some detail.

15.04 The western section of the study area, lying outside the vicinity of the canal system, has received much less archeological attention. Most of the available information on the area was derived from intensive survey work done by ASM (70-72).

15.05 All the sites in the area are representative of various periods in the Hohokam Indian culture. The Hohokam culture was comprised of two branches. The river Hohokams occupied the area surrounding the Salt and Gila Rivers. The river Hohokams were sedentary village dwellers who practiced irrigation agriculture and developed an extensive irrigation system to support their agricultural economy. A total of 19 sites are known in the eastern portion of the study area, most of them closely associated with the canal system. Although information on some of the sites is nebulous, all of them are probably remnants of villages.

15.06 In the western portion of the study area a total of 33 sites are known. A few large village sites exist at the extreme west end of the area, but most of the recorded sites are less substantial scatters of sherds and/or other debris.

15.07 The long history of archeological interest in this region has resulted in records of many sites which have not been investigated in several decades. Most of the sites, particularly in the eastern area, have been leveled or otherwise disturbed by agricultural activities; more recently housing construction has encroached on the area.

15.08 As a result, it is hard to evaluate the present significance of many of the sites. At the present time, no sites from the study area are included on the National Register of Historic Places. However, any of the archeological

sites might be included in the National Register because of major changes in archeological theory and methods. All Hohokam sites in the eastern portion of the study area are potentially important.

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