WATER RESOURCES REPORT NUMBER THIRTEEN

ARIZONA STATE LAND DEPARTMENT

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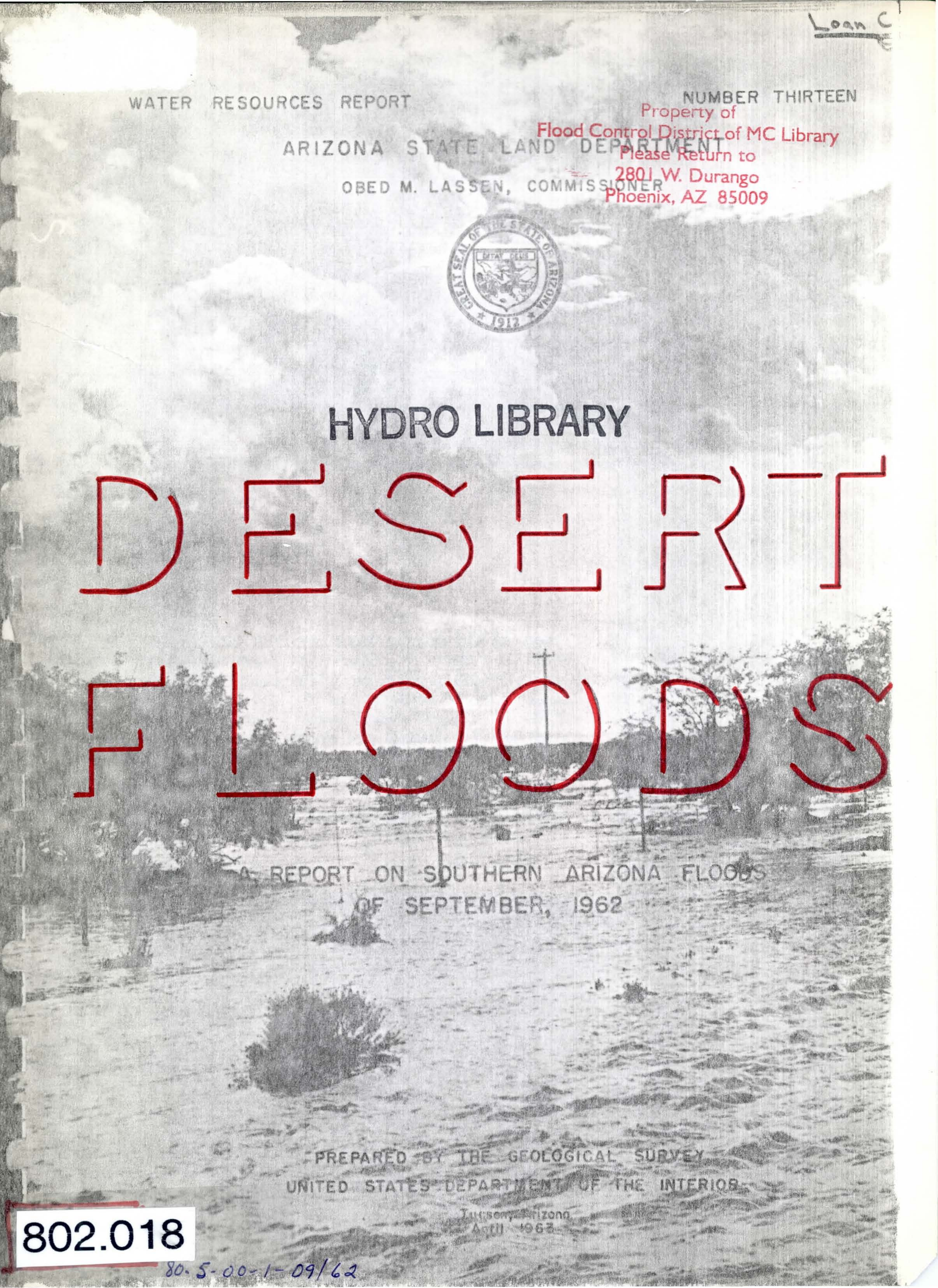

DESERT FLOODS

A REPORT ON SOUTHERN ARIZONA FLOODS OF SEPTEMBER, 1962

PREPARED BY THE GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

Tucson, Arizona
April 1963

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A REPORT ON SOUTHERN ARIZONA FLOODS OF SEPTEMBER, 1962

BY

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DESERT FLOODS

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BY

DOUGLAS D. LEWIS

Introduction.--

Major floods occur infrequently in the desert lowlands of Arizona. In normal years rainfall is scanty. Even during periods of heavy storm activity there is an extreme variability in rainfall, and it is improbable that high volumes and intensities of precipitation will be distributed over an entire drainage area. Thus, as a general rule, the floodwaters derive from only a part of the drainage basin, and both flood volumes and flood peaks are influenced by the comparatively small areas affected.

The floods of September 26-28, 1962 in southern Arizona are vivid examples of intense floods resulting from rainfall on small portions of a river basin. This report summarizes the data collected by several agencies on those floods.

The floods spread over the Santa Cruz River, Brawley Wash, Santa Rosa Wash, Sells Wash and some of the tributaries but at no time did the entire basin receive great amounts of rainfall.

Floods such as those of September 1962 are infrequent but are not rare. Figure 1 is a plotting of unit runoff against drainage areas for certain selected floods that have been recorded in Arizona. It must be emphasized that this illustration is not intended to define the maximum flood that may occur in the desert lowlands of Arizona but is offered as a graphic representation of floods for which records are available. Future floods may exceed those that have been recorded in the past. A wide areal distribution of the floods and the extremes in drainage area give some indication that no part of the State is free of the hazard.

In past years the sparse settlement of the desert lowlands has permitted some of the floods to develop, rage, and dissipate almost unnoticed. In some places this is still possible, but over much of the State floods are noticed more readily because the population has increased and land use has changed. The growth in population in the lowland areas during the past two decades has been phenomenal, and the development of ground-water irrigation has transformed large areas of the alluvial valleys into rich agricultural lands. Residential and urban developments have been built on flood plains that have been further utilized for cultivation of high-priced crops.

In some sections of Arizona the stream channels have been subjected to erosion and gullying to the extent that they have far greater capacities for transportation of floodwaters than they had when the first non-Indian explorers arrived in the State. However, many of the ephemeral streams of the area

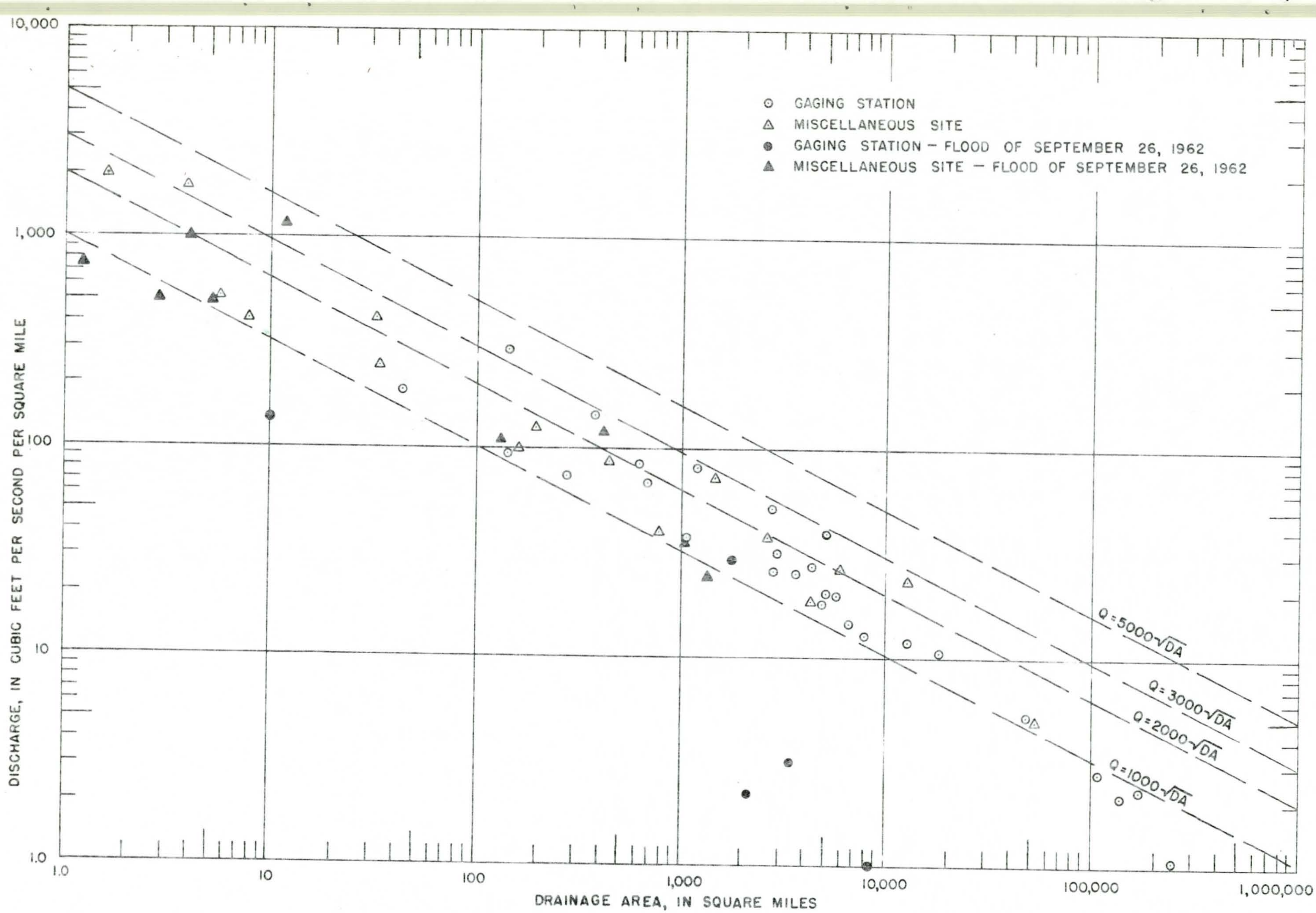


FIGURE 1.--ENVELOPING CURVES OF MAXIMUM DISCHARGES IN ARIZONA

retain their poorly defined channels, and during periods of floodflows the entire valley floor may be covered with water as shown in figure 2. It is doubtful that even the most seriously eroded channels in the State have adequate capacity to contain the discharge of major floods, and large overbank flows can be expected. Floods create a distinct hazard to the people who live in the valleys of the desert lowlands and to the property values that have been established there. For this reason floods deserve more study and attention than has been given to them in the past.

The storm.--

Meteorological conditions that caused the floods of September 26-28 in southern Arizona were described in a letter from Louis R. Jurwitz, Meteorologist in Charge of the U.S. Weather Bureau, Phoenix, as follows:

"Tropical storm Claudia moved on shore in the vicinity of Cedros Island late in the evening of September 22, 1962. The disturbance weakened rapidly and disappeared from surface charts shortly thereafter. The point where Claudia came inland was approximately 300 miles SSW of the southern Arizona border.

"Circulation patterns at 700 and 500 mb were from the south and southwest over northwestern Mexico and southwestern United States. Moist air from Claudia, as a result, was carried across the relatively low mountains of Lower California arriving over the Organ Pipe Cactus National Monument area September 24-25, 1962. That cooperative weather station measured 1.18 inches of rain for the 24-hour period ending on the evening of September 25, 1962. The trajectory of the main moist stream of air, which was about 70 miles wide, took it over Sells, the Tucson Mountains-Cortaro area, Oracle, Safford, to the Glenwood-Cliff, New Mexico area where it crossed the Continental Divide north of Silver City, New Mexico. Heaviest rain fell during the night of September 25th and most of September 26th. Totals reached 6.00 inches over the Avra Valley area southwest of Marana, around 4.00 inches in the Sells area, and from 2.00 to around 3.00 inches in the Safford-Clifton region.

"Dry, cool air moved over much of Arizona from the west and northwest on September 28-29, 1962, clearing out the last vestiges of tropical air that were originally associated with Claudia."

Some sections of the storm area were subjected to two periods of precipitation. The time at which rainfall occurred varied with the locality - the first heavy rainfall around Tucson occurred before 0800 the morning of September 26, and another period of intense precipitation started around noon. These two periods of highly intense rainfall are reflected in the floodmarks that were observed at many points along the stream channel. Two separate flood peaks left their marks in many of the channels, indicating that the first peak was the higher.

Records were obtained at precipitation stations maintained by the U.S. Weather Bureau. Several ranchers and farmers in the area have their own gages and have made their readings available. Records were obtained in other places by the Corps of Engineers, Soil Conservation Service, and the Geological Survey.

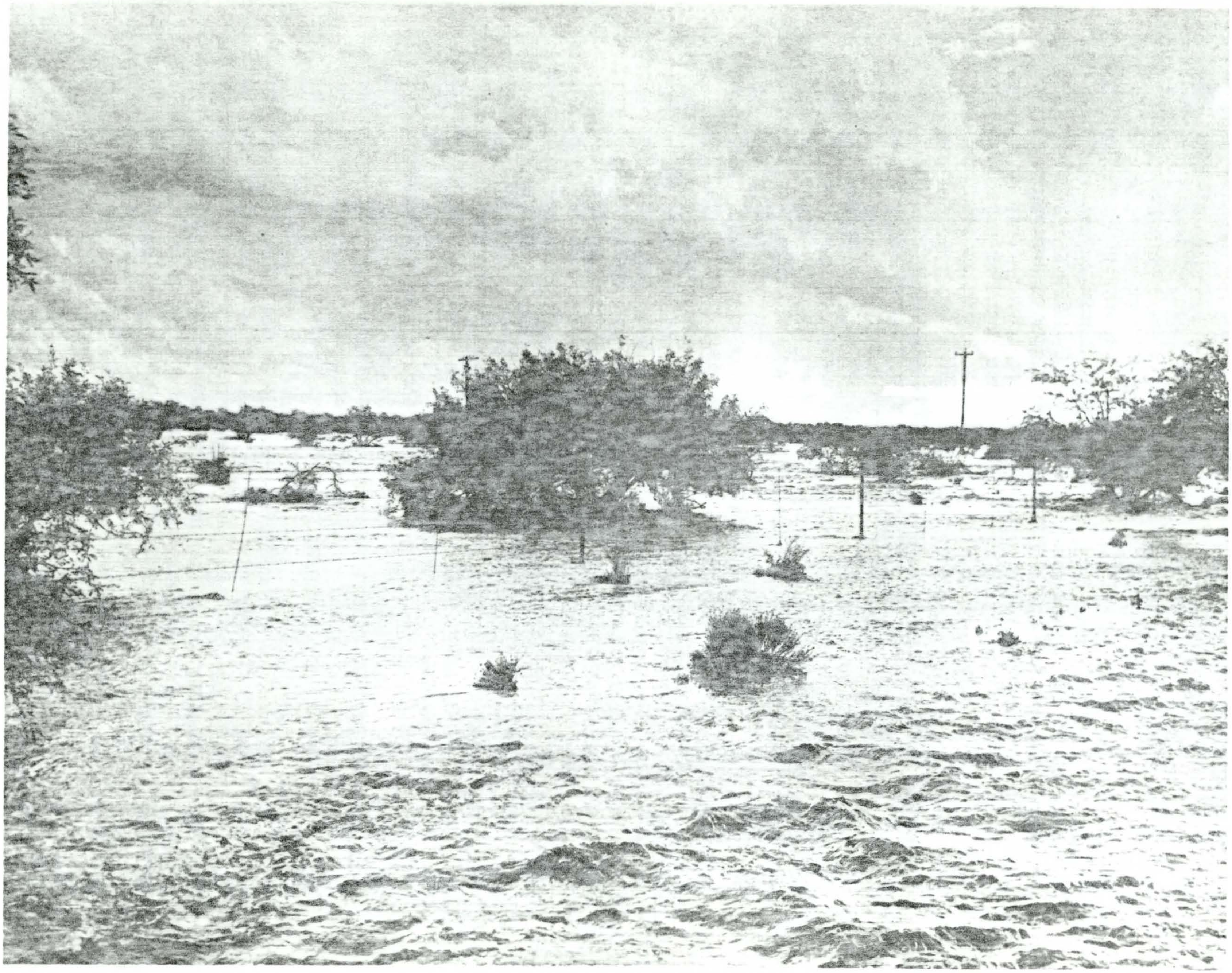


Figure 2.--Typical flood scene in desert. Photograph from Tucson Daily Citizen

The isohyetal map (fig. 3) shows the amounts and distribution of this rainfall. The points at which rainfall was measured and the amounts of rainfall are listed in table 1.

The flood.--

Figure 3 shows that the heaviest rainfall during the storm of September 25-26 occurred in a band that stretched from west to east across Sells Wash, Santa Rosa Wash, and Brawley Wash. At Tucson this intense precipitation had feathered out, and rainfall was neither as intense nor as great as in the areas to the west. Much of the area of heavy rainfall is sparsely settled, and the magnitude of the flood was not fully apparent in the early stages of development.

High intensity runoff was first noticed in Tucson because the large areas of impermeable street and roof surfaces allowed a high percentage of the rainfall to become surface runoff which quickly flooded streets and disrupted traffic. As the flood developed, roads, culverts, and bridges were damaged (fig. 4). A few vehicles trapped by the waters were swept downstream and destroyed. However, the flooding in the Tucson area was largely of a local nature and the effects were not particularly significant.

There is evidence of very intense runoff from all slopes of the Tucson Mountains except the southern ones. Observations after the flood indicated that runoff from the eastern slopes may have been greater than that from the western slopes. Silverbell Road was cut in several places where the intense runoff crossed, and severe gullying occurred in some arroyos (fig. 5). The rain gage at the Arizona-Sonora Desert Museum recorded 5.95 inches of precipitation, but this amount may not have been representative of the rainfall over the entire area.

Water from the upper part of Sells Wash inundated the village of Sells (fig. 6). Several people were left homeless and one life was lost in the floodwaters. Prompt action by relief agencies that rushed in food, water, medical supplies, cots, and bedding prevented the flood from becoming a major disaster. Much attention was focused on Sells because it was one of the first areas to report heavy damage. The flood of September 1962 appears to be the largest ever reported in that vicinity, but the unit runoff was not as great as that determined in other parts of the flood area.

Heavy precipitation on other mountains in the area of heavy rainfall must have run off about as rapidly as it did from the Tucson Mountains. As it reached the valley floor this water intermingled with water accumulated from local precipitation. The floodwave so created moved rapidly downstream although not as rapidly as it did where the streams left the mountains. The channels in these valleys are poorly defined, and their lack of capacity to handle the floodwater caused wide overflows.

Brawley Wash overtopped Ajo Highway (State Highway 86) near Three Points and caused some damage to the road shoulders and abutment fill. A few miles downstream from Three Points the flood reached the first of extensive

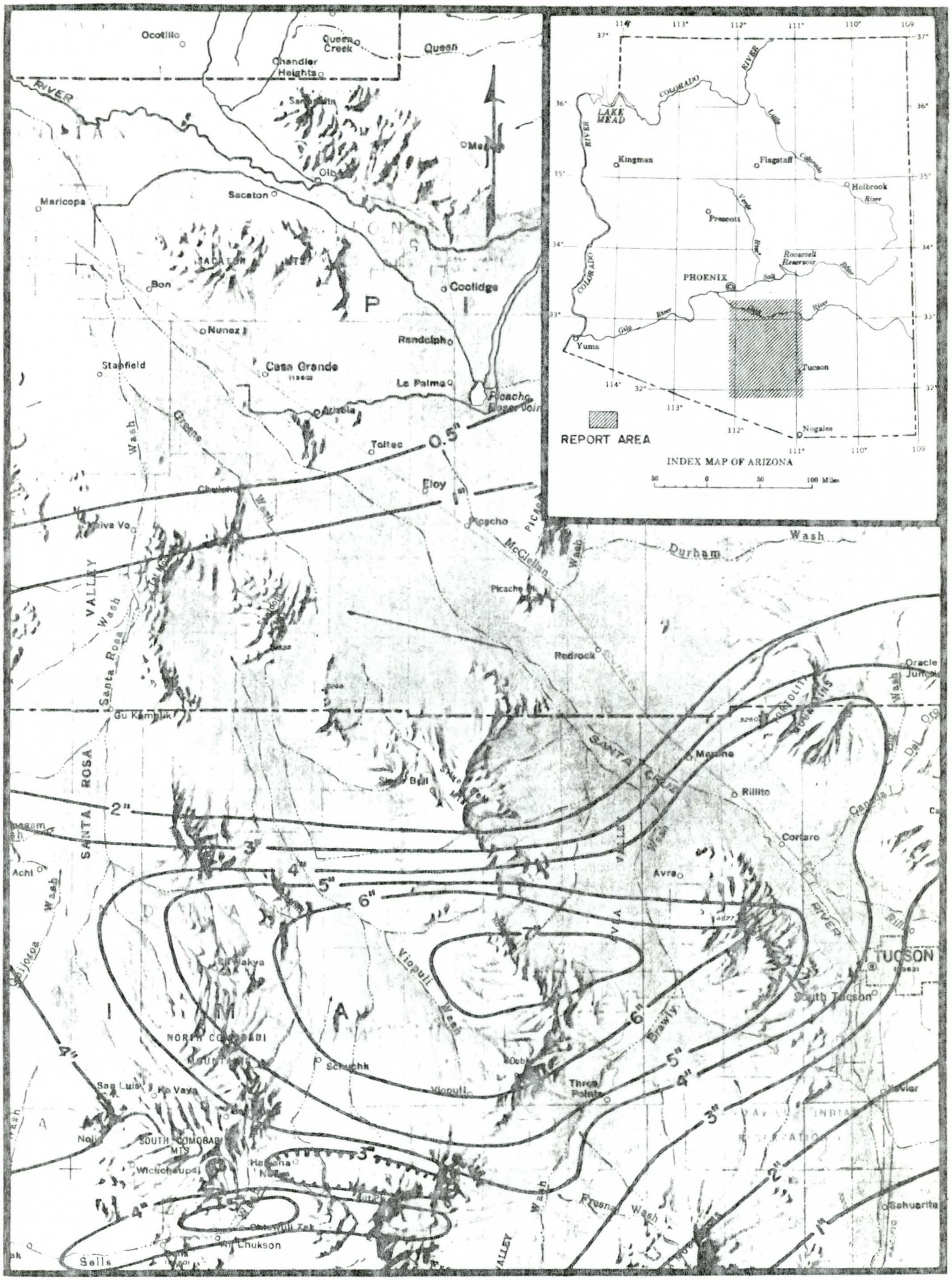


Figure 3.--Isohyetal map of southern Arizona. Storm of September 25-26, 1962

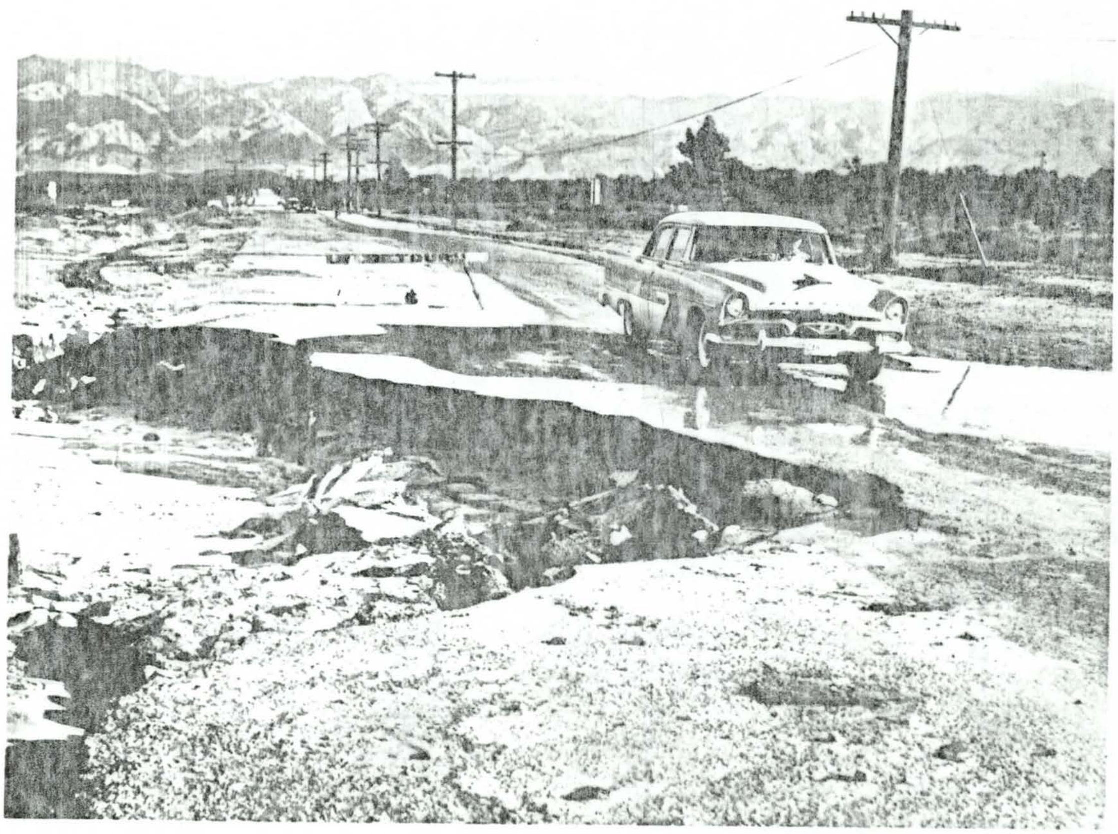
Table 1.

Precipitation on September 25-27, 1962
in the drainage basins of Santa Cruz River,
Santa Rosa Wash, and Brawley Wash

U.S. Weather Bureau stations	Precipitation (inches) September 25	26	27
Anvil Ranch		4.30	
Arivaca		.40	
Cortaro		4.75	
Eloy	.15	.44	.17
Kitt Peak		2.60	
Lazy H Ranch		1.26	
Red Rock	.52	1.25	
Ruby Star Ranch		1.50	
Sabino Canyon		1.78	
Sahuarita		.84	
Santa Rosa School	.15	3.45	
Sells		3.55	.45
Silver Bell	.06	.94	1.05
Tucson, Campbell Avenue		2.92	
Tucson, Magnetic Observatory		.84	1.23
Tucson, University of Arizona		2.84	
Tucson, Weather Bureau Airport		2.40	
Miscellaneous sites			
Arizona-Sonora Desert Museum		5.95	
Tucson, West Sunset Road near Silverbell Road		5.12	
El Paso Natural Gas Co. compressor station at NE¼ sec.25, T.12 S., R.9 E.		3.0	
American Smelter & Refining Co. Silverbell unit at sec.11, T.12 S., R.8 E.		1.99	
Wallis Ranch, in sec.8, T.14 S., R.11 E.		*6.0+	
Ranch in sec.9, T.14 S., R.11 E.		*6.0+	
St. Peter & Paul Mission, about sec.8, T.17 S., R.6 E.		5.1	
Ray Garcia Ranch, about sec.29, T.17 S., R.6 E.		4.75	
Tucson, Wilmot Rd. at 29th St.		2.52	
Elkhorn Ranch, SE¼ sec.27, T.18 S., R.8 E.		3.5	
Hoskings Ranch, about sec.24, T.15 S., R.10 E.		5.0	

* 6-inch capacity rain gage overflowed about an hour before end of intense rainfall.

Flood at Campbell Ave. and 15th St.



Highway damage on Pantano Road

Photographs from Tucson Daily Citizen

Figure 4.--Results of flood at Tucson

County Road near Tucson Mountains cut by floodwaters.

Figure 5.--Floodflows at Silver Bell Road near Tucson.
Photographs from Tucson Daily Citizen

farmlands. These farms are largely planted to cotton, and they are irrigated by ground water. Dikes built around the cropped lands of most of these farms indicate that they have been subject to floods in the past. The flood of September 1962 quickly overtopped and crevassed these dikes. Most of the crop damage occurred in these agricultural lands.

Severe flooding occurred all along Brawley, Blanco, and Los Robles Washes. Figure 7 shows floodwaters around Marana School, and Figure 8 shows some of the effects of the flood southeast of Maricopa.

There was considerable inundation of the flood plain along Santa Rosa Wash but there was little damage because the valley is undeveloped and sparsely populated. In Greens Wash conditions were much the same upstream from the village of Chuichu, but in Chuichu, many residents were left homeless when the village was inundated by the flood.

As the flows of Santa Rosa Wash, Greens Wash, and Brawley Wash converged, the hydrologic picture became quite confused. The intermingling of these waters inundated areas as much as 10 miles wide. A large part of the inundated land was farmland, and agricultural damage ran very high.

The Casa Grande-Stanfield Highway (State Highway 84) was kept open even though wide overflows impeded traffic for several hours. A large area to the north of Highway 84 was inundated although the discharge diminished rapidly in both volume and intensity. There was little damage beyond the village of Maricopa.

There are only two gaging stations, Santa Rosa Wash near Vaiva Vo and Santa Cruz River at Cortaro, in the area of greatest flooding. The gaging station on Santa Cruz River at Tucson provided data pertaining to runoff at the upper end of the flood area. Stations on Santa Cruz River near Laveen and Gila River at Gillespie Dam provided data on the progress of the flood downstream. As soon as the unusual nature of the flood became apparent, a water-stage recorder was installed in an unused gage well on Gila River at Jackrabbit Road, near Buckeye.

Nearly 5,000 square miles of drainage area above the gaging station on the Santa Cruz River near Laveen contributed to this flood, and the data obtained at the gaging stations were entirely inadequate for a hydrologic analysis. Additional information was obtained by indirect discharge measurements of peak flows. Discharges were determined by applying hydraulic formulas to data obtained from field surveys. An attempt was made to measure the peak discharge along transections across the flood area with supplemental discharge determinations at certain points of intense discharge such as Sells Wash and the arroyos draining the Tucson Mountains. Development of a rigid plan was not practical because of widely varying conditions. Unfavorable or uncertain hydraulic conditions at some places where discharge determinations would have been desirable made it necessary to relocate some of the sites. As field studies developed, the need for discharge data at other points became apparent. Peak discharges were measured at the sites listed in table 2.

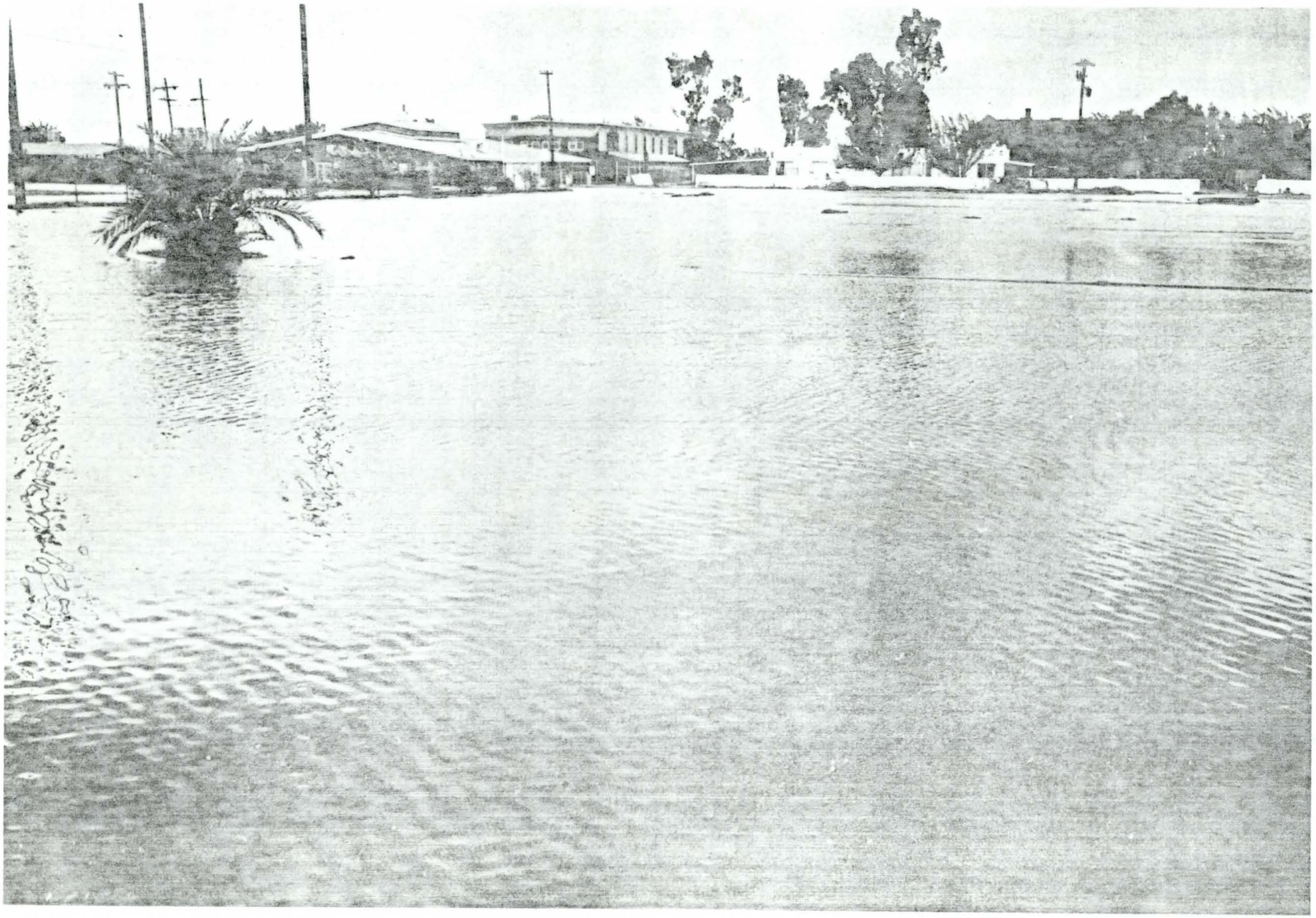
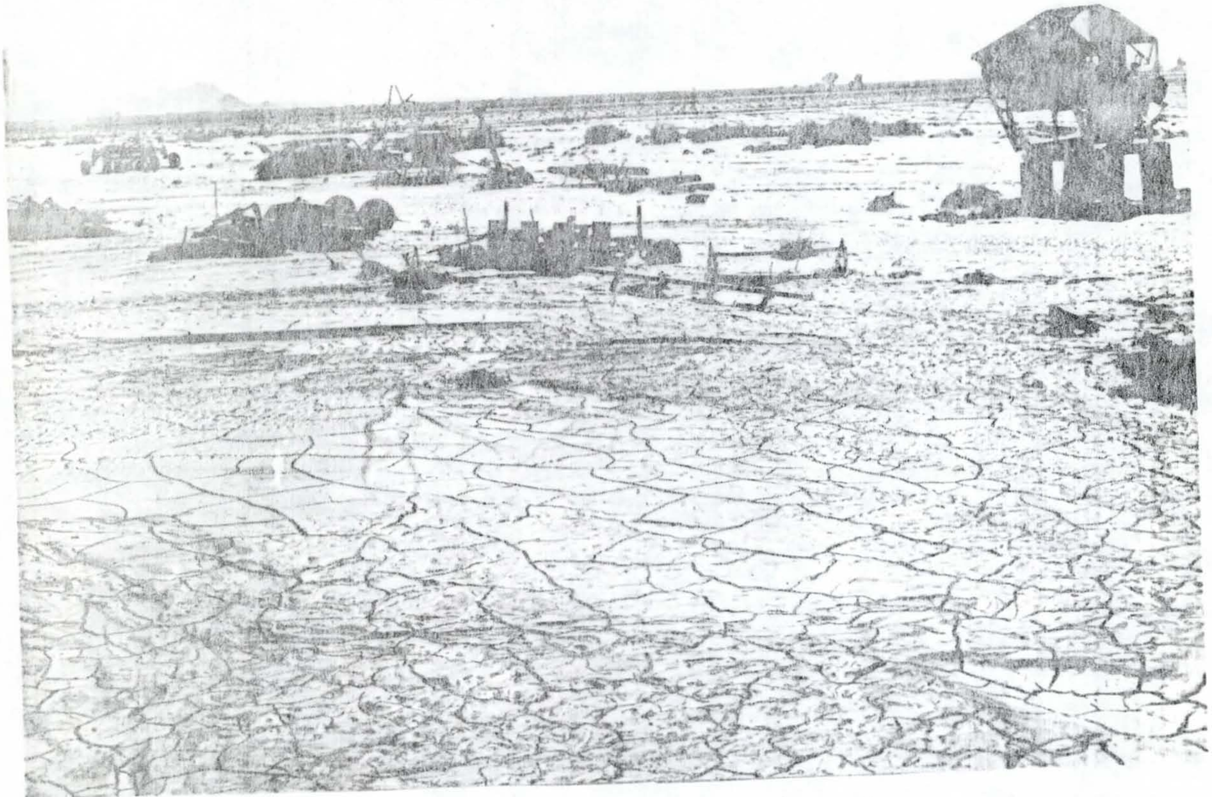
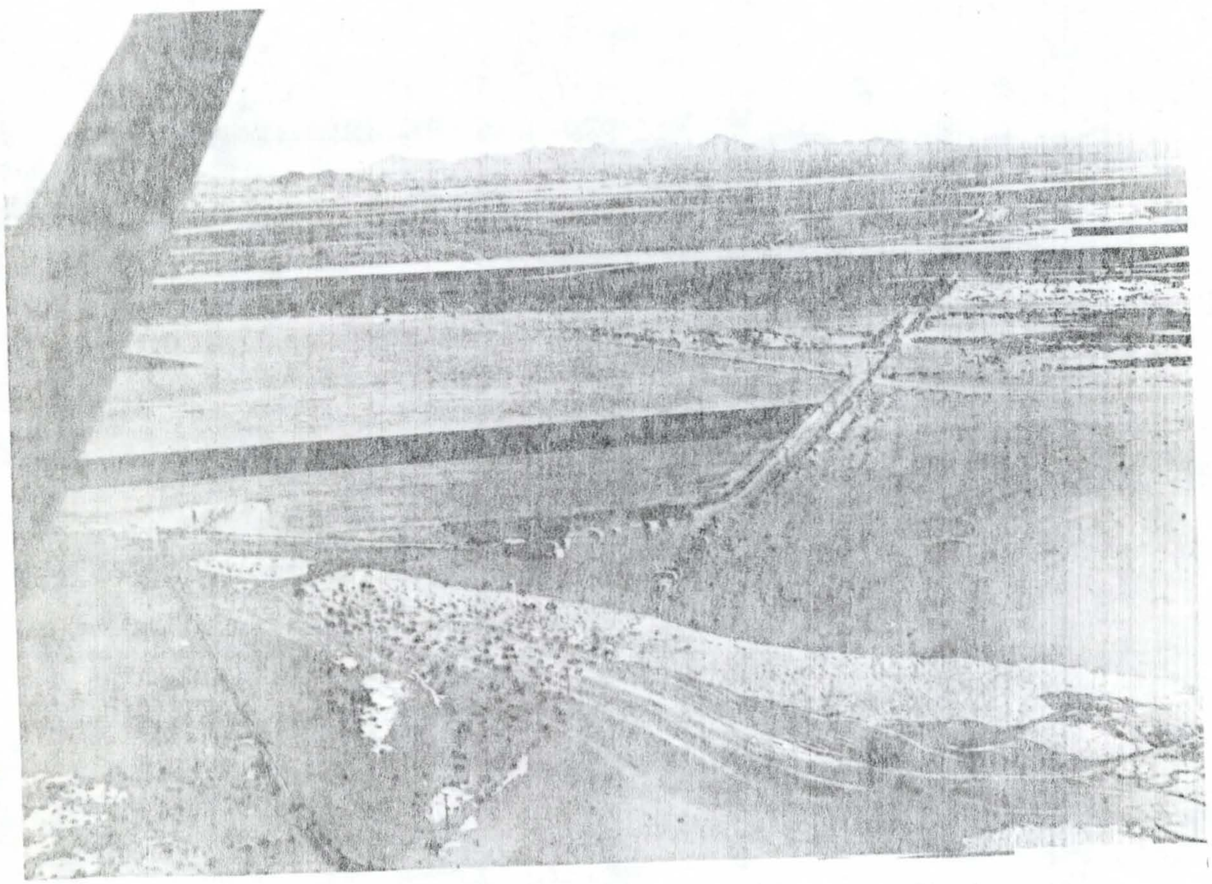


Figure 7.--Floodwaters surround Marana School. Photograph from Tucson Daily Citizen



Silt deposits in equipment yard.



Floodwater rising around farmstead southeast of Maricopa.
Photographs from Soil Conservation Service

Figure 8.--Effects of flood of September 26-28, 1962.

Table 2.--Peak discharges at selected sites
Flood of Sept. 26, 1962

Stream and measuring site	Drainage area (sq mi)		Peak discharge (cfs)
GILA RIVER BASIN			
Santa Cruz River at gaging station at Tucson	2,222		4,980
Minor Santa Cruz River tributaries between Tucson and Cortaro			
No. 1 in NW$\frac{1}{4}$NE$\frac{1}{4}$ sec.6, T.14 S., R.13 E.	5.31		2,740
No. 2 in NW$\frac{1}{4}$SE$\frac{1}{4}$ sec.2, T.14 S., R.12 E.	1.26		940
No. 3 in E$\frac{1}{2}$ sec.25, T.13 S., R.12 E.	3.98		3,980
No. 4 in SW$\frac{1}{4}$SW$\frac{1}{4}$ sec.11, T.13 S., R.12 E.	2.77		1,400
Santa Cruz River at gaging station at Cortaro	3,503		11,200
Brawley Wash tributary in SE$\frac{1}{4}$NW$\frac{1}{4}$ sec.16, T.15 S., R.10 E., 3$\frac{1}{2}$ miles north of Three Points	11.9		13,800
Brawley Wash tributary No. 2 in NW$\frac{1}{4}$NW$\frac{1}{4}$ sec.1, T.14 S., R.11 E., 1 mile west of Arizona-Sonora Desert Museum	.08		69
Brawley Wash at Mile Wide Road and south edge of T.13 S., 15 miles west of Tucson	1,077		38,800
Los Robles Wash at confluence of Brawley and Blanco Washes, 8 miles west of Marana	1,350		32,600
Greens Canal at west line sec.4, T.10 S., R.8 E., 2$\frac{1}{2}$ miles southeast of Friendly Corners	*		24,100
Greens Wash at Indian Service Road at and near Chuichu	*		17,200
Santa Rosa Wash at gaging station near Vaiva Vo	1,782		53,100
Flow past State Highway 84 between Stanfield and Casa Grande			
Santa Cruz River	†	3,060	
Greens Wash	†	4,300	
Santa Rosa Wash	†	8,430	
Total			15,790

Stream and measuring site	Drainage area (sq mi)	Peak discharge (cfs)
GILA RIVER BASIN		
Santa Cruz River at gaging station near Laveen	8,581	9,200
SAN SIMEON WASH BASIN		
San Juan Wash at State Highway 86, 8 miles east of Sells	10	1,600
Ali Molina Wash at State Highway 86, 6 miles east of Sells	‡	430
Sells Wash tributary to State Highway 86 in Sells	‡	1,650
Total	27	2,080
Sells Wash at Sells	140	17,200

* Indeterminate. Greens Canal diverts practically all flow from Santa Cruz River into Greens Wash. Negligible flow from Aguirre Wash to Greens Wash.

† Indeterminate. Floodwaters of Santa Rosa Wash, Greens Wash, and Santa Cruz River intermingled upstream from Highway 84.

‡ Individual area indeterminate. Contributing area of both washes is 27 sq mi.

One important tool in the analysis of floods is the discharge hydrograph. At a gaging station a continuous record of gage heights from the water-stage recorder is obtained; and, if the relation between stage and discharge is known, no difficulty is experienced in constructing the hydrograph.

The flood inundated the gaging station on Santa Rosa Wash near Vaiva Vo, and the recorder clock stopped. The record for this station was reconstructed on the basis of peak stage obtained from floodmarks, gage-height record up to the time the recorder stopped, and records of the recession after the recorder had again been placed in operation. The stage-discharge relation was extended to the peak discharge on the basis of a slope-area measurement.

Shifting channel conditions on Santa Cruz River at Cortaro left some doubt as to the peak discharge, and here again a slope-area measurement was used to define the upper part of the rating. Satisfactory records of discharge were maintained at the other gaging stations affected by the flood.

On Brawley Wash near Mile Wide Road and on Greens Wash near Chuichu information was obtained from local people on the time the flooding began, the rate of rise, the time of flood crest, and duration of the flood. Records of gage heights were developed from this information and crude discharge hydrographs were constructed. The synthetic hydrographs so developed are shown on figure 9. The particular value of these hydrographs is in making an approximation of the flood volumes at each of these sites. Although the volumes computed at sites other than gaging stations are subject to rather large error, they are the best that can be developed with the existing field data.

The large areas inundated by the flood of September 26-28, 1962 have been mentioned previously. An attempt has been made to map these areas on the basis of aerial photographs obtained during the flood, newspaper reports, and observations by field parties. Figure 10 shows the approximate limits of this inundation. The flooded areas could have been more accurately delineated by a transit survey of the floodmarks, but adequate funds and personnel were not available for such a survey.

The times when the flood reached the gaging stations were accurately recorded at all stations except at Santa Rosa Wash near Vaiva Vo. The time of the arrival at Vaiva Vo was obtained from local residents. Individuals along the path of the flood were vitally interested in the flood peak and when it might reach their homes or farms. The times when flooding began at several places are shown on figure 11.

The hydrographs on figure 9 show that as the flood wave moved downstream there was a rapid and extreme attenuation of both flood peak and volume. The exact amount of water involved is uncertain. The Santa Cruz River at Tucson discharged 2,900 acre-feet, but because of heavy inflow this had increased to 6,700 acre-feet at Cortaro. In the past there have usually been severe channel losses between Tucson and Cortaro. Such losses undoubtedly occurred during the flood of September 1962 but were obscured by the heavy tributary inflow.

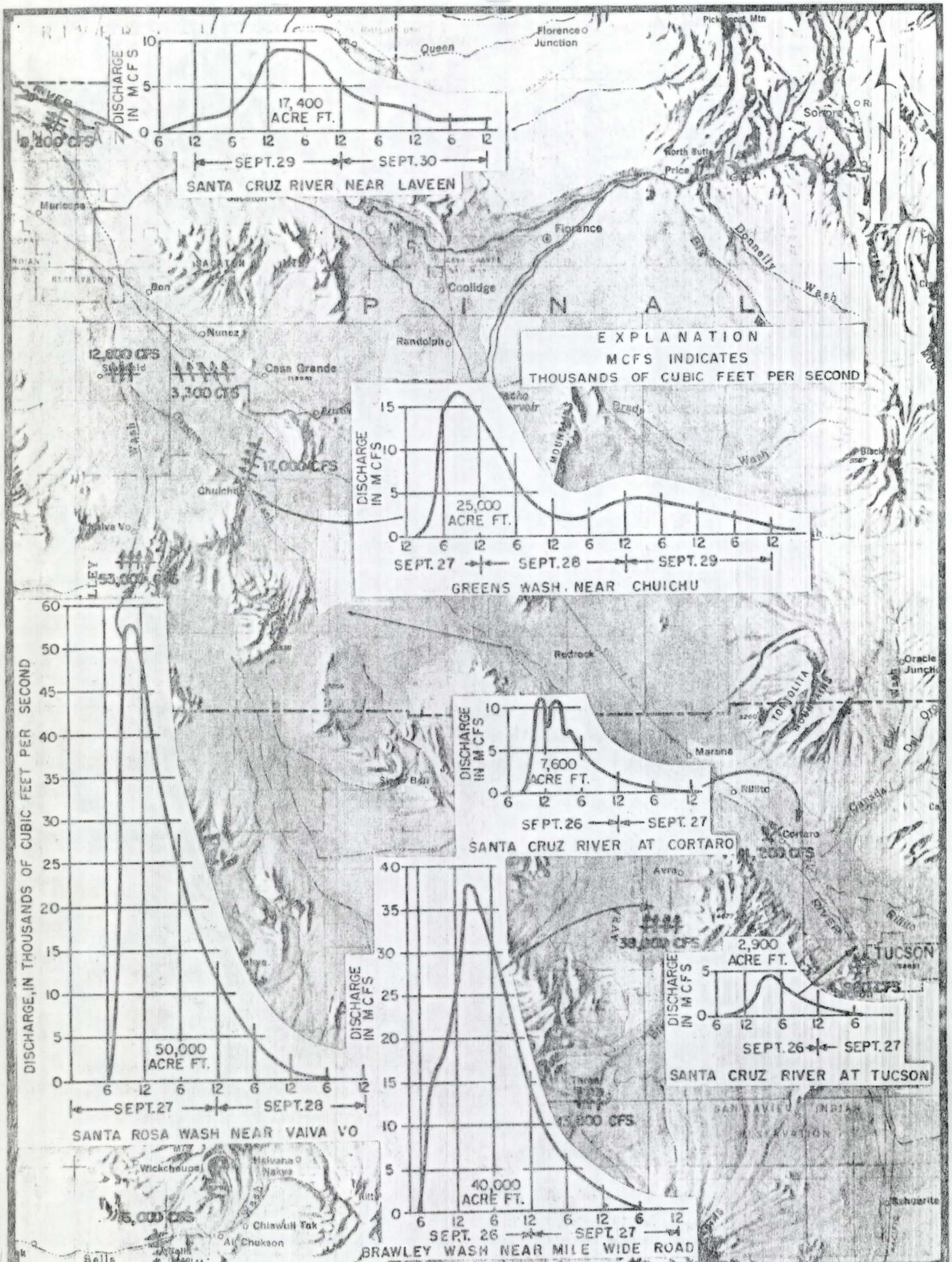


Figure 9.--Peak discharges and hydrographs at selected points.

Figure 10.--Approximate areas inundated

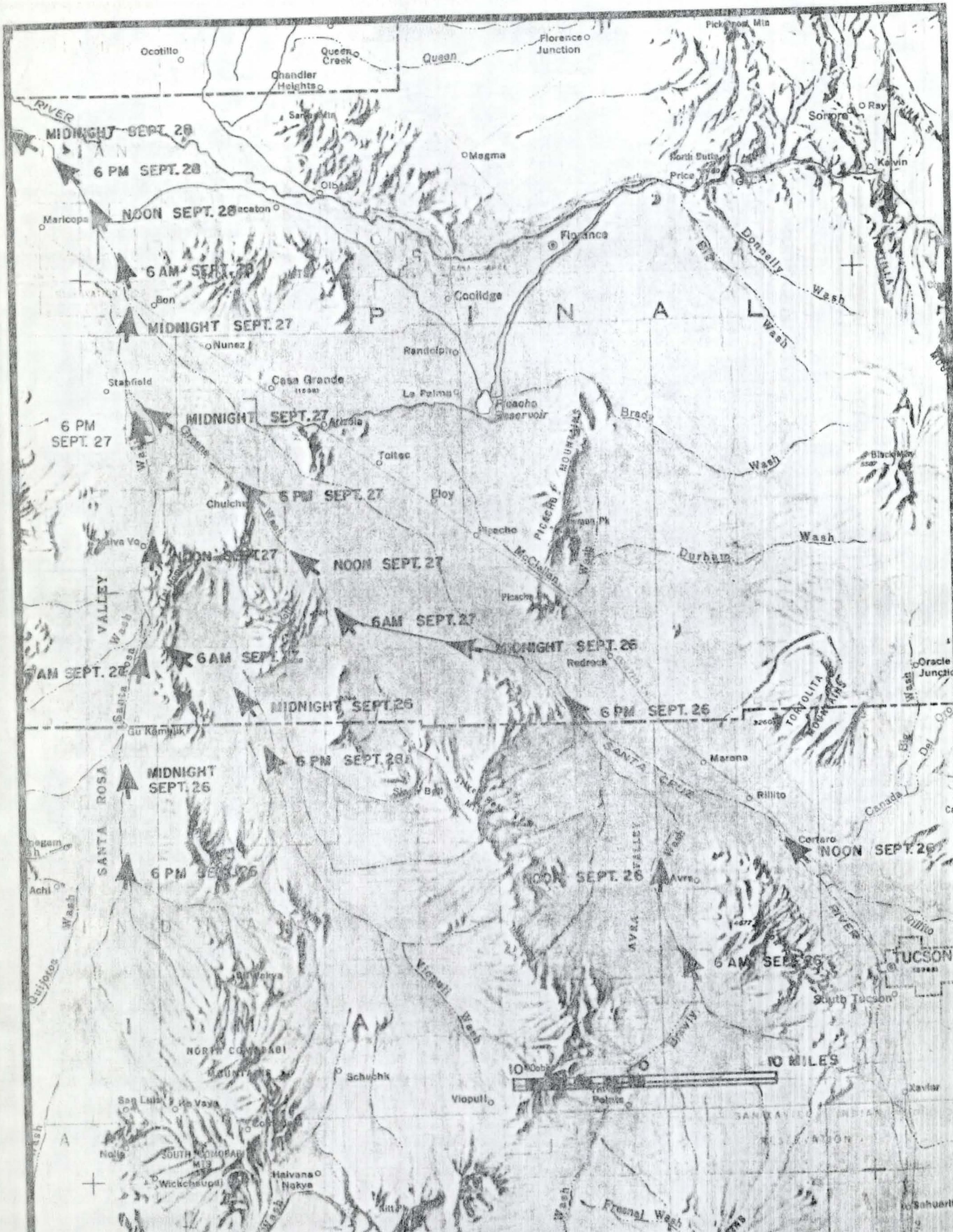


Figure 11.--Progress of the flood wave.

Severe channel losses occurred throughout the flood area. Figure 9 shows that the two main streams contributing to the flood, Brawley Wash and Santa Rosa Wash, discharged about 90,000 acre-feet. There is no measure of the water that may have been lost upstream from the measuring sites. There was a large unmeasured inflow from Blanco Wash and other tributaries to Brawley Wash downstream from Mile Wide Road. There was also some inflow from tributaries to the Santa Cruz River. The total surface runoff generated in the Santa Cruz River basin by the storm of September 25-26 must have been in excess of 125,000 acre-feet. Flow decreased steadily as the flood wave moved downstream. At the Santa Cruz River near Laveen gaging station, which measures all runoff from the flood area, the discharge had been reduced to 17,400 acre-feet.

The hydrographs on figure 12 show further progress of the flood along the Gila River. A temporary gage had been installed on the Gila River at Jackrabbit Road, near Buckeye, and the combined runoff of the Gila River and Buckeye Canal was less than 7,500 acre-feet. Although 6,700 acre-feet of water passed Gillespie Dam, most of this appeared to be return flow from upstream irrigation, and all but a small portion of it was diverted at the dam. None of the floodwater reached Painted Rock Dam farther downstream.

A major flood in the desert lowlands flashed into existence, carried its destruction over a rich agricultural community, and then completely died out. We can only speculate on how many other floods may have occurred in the past that went unnoticed because the area was so sparsely settled that no one was there to observe the flood. Hydrologically, the losses from streamflow are common phenomena in the alluvial valleys of the arid Southwest.

What became of the water? During the period October 5-16 the Ground Water Branch, U.S. Geological Survey, made a reconnaissance study of the area to determine the possibilities of recharge of the ground-water reservoir. For this study 66 selected observation wells distributed over the flood area were measured. Thirty-eight of these were remeasured in the spring of 1963. The results of these studies are summarized by J. T. Hollander and N. D. White (written communication 1963) who stated that "analysis of the available data indicates that some ground water has been added, or is being added, to the ground-water reservoir in the area from Stanfield to Maricopa from the flood of September 1962, but that no recharge or only a slight amount has taken place in the area to the southwest through Avra Valley to Three Points."

Water surface elevations are shown in figure 13. Hydrographs of seven selected wells are shown in figure 14.

Some of the photographs shown in this report show heavy deposition of silt by the floodwaters. Wherever deposited this fine material acted as an effective seal to prevent infiltration. The extent of this sealing is not known, but the extensive losses indicate that there was a large absorption of the water by the underlying soils.

One newspaper article described an earth crack that opened up near the center of sec.24, T.4 S., R.4 E. The report indicated that water poured into this crack for more than 20 hours and thereby prevented further damage.

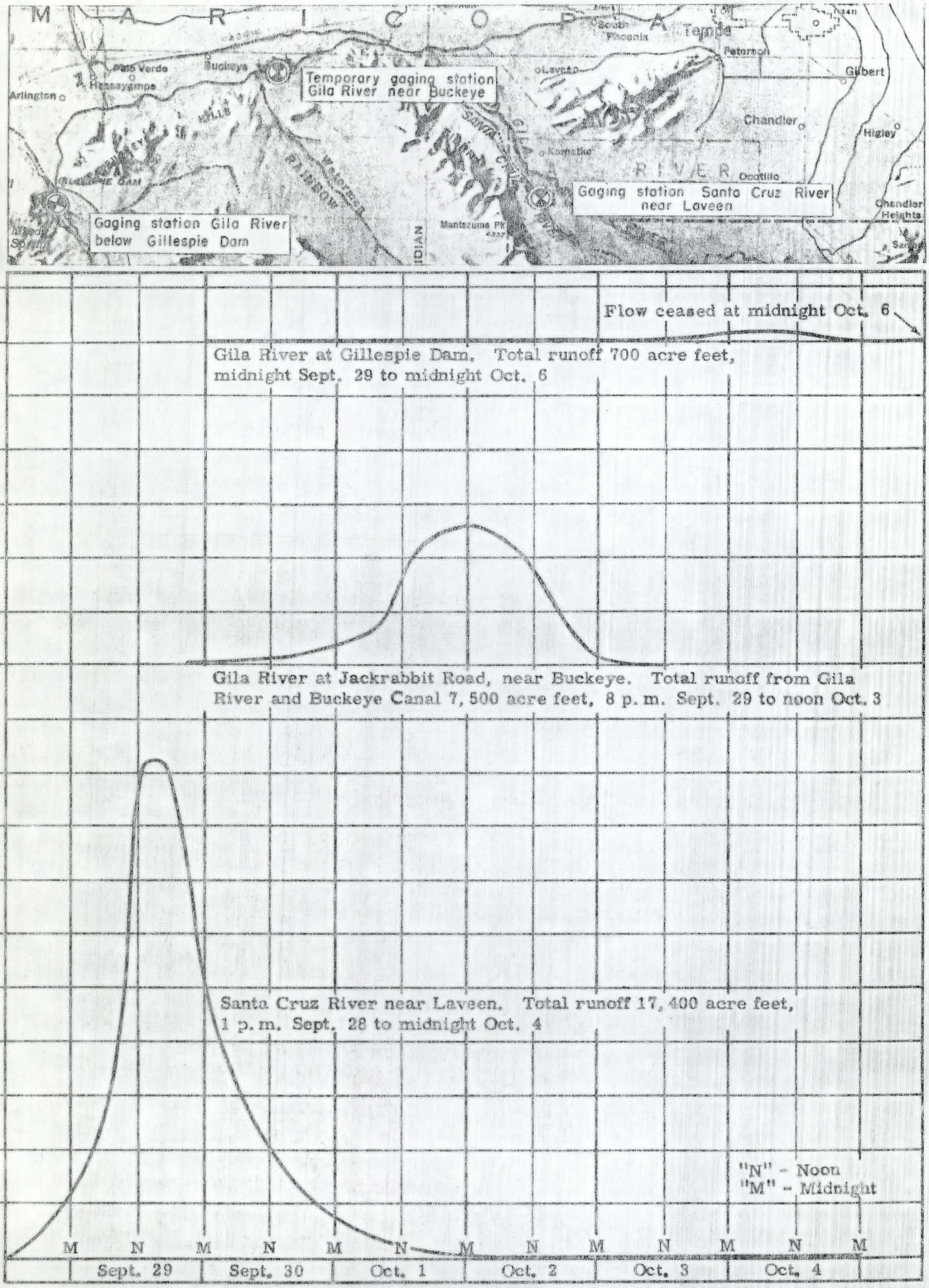


Figure 12.- Where did the water go? Attenuation of flow from Santa Cruz River near Laveen to Gila River at Gillespie Dam.

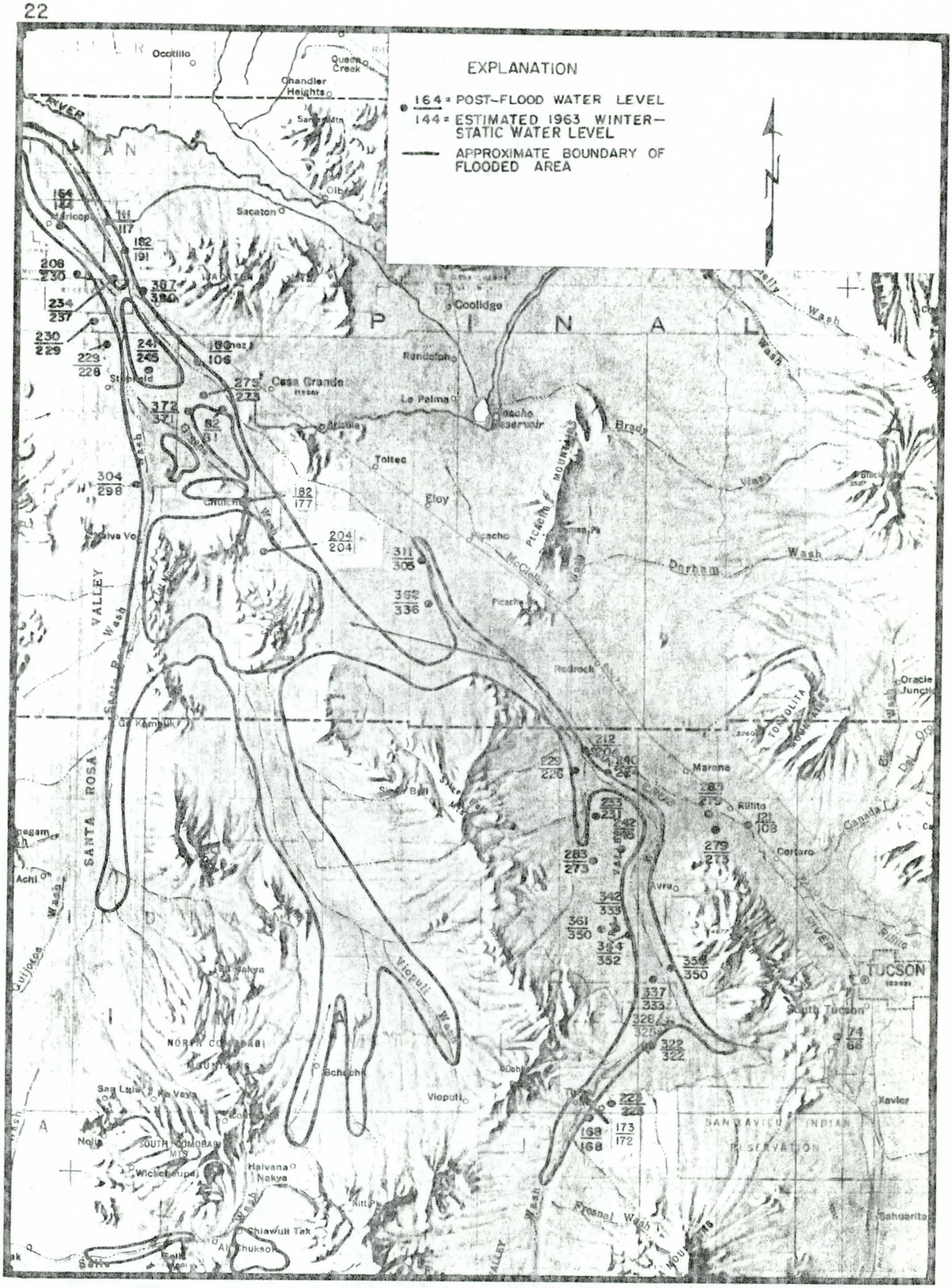


Figure 13.--Post-flood and estimated 1963-winter-static water levels in selected wells

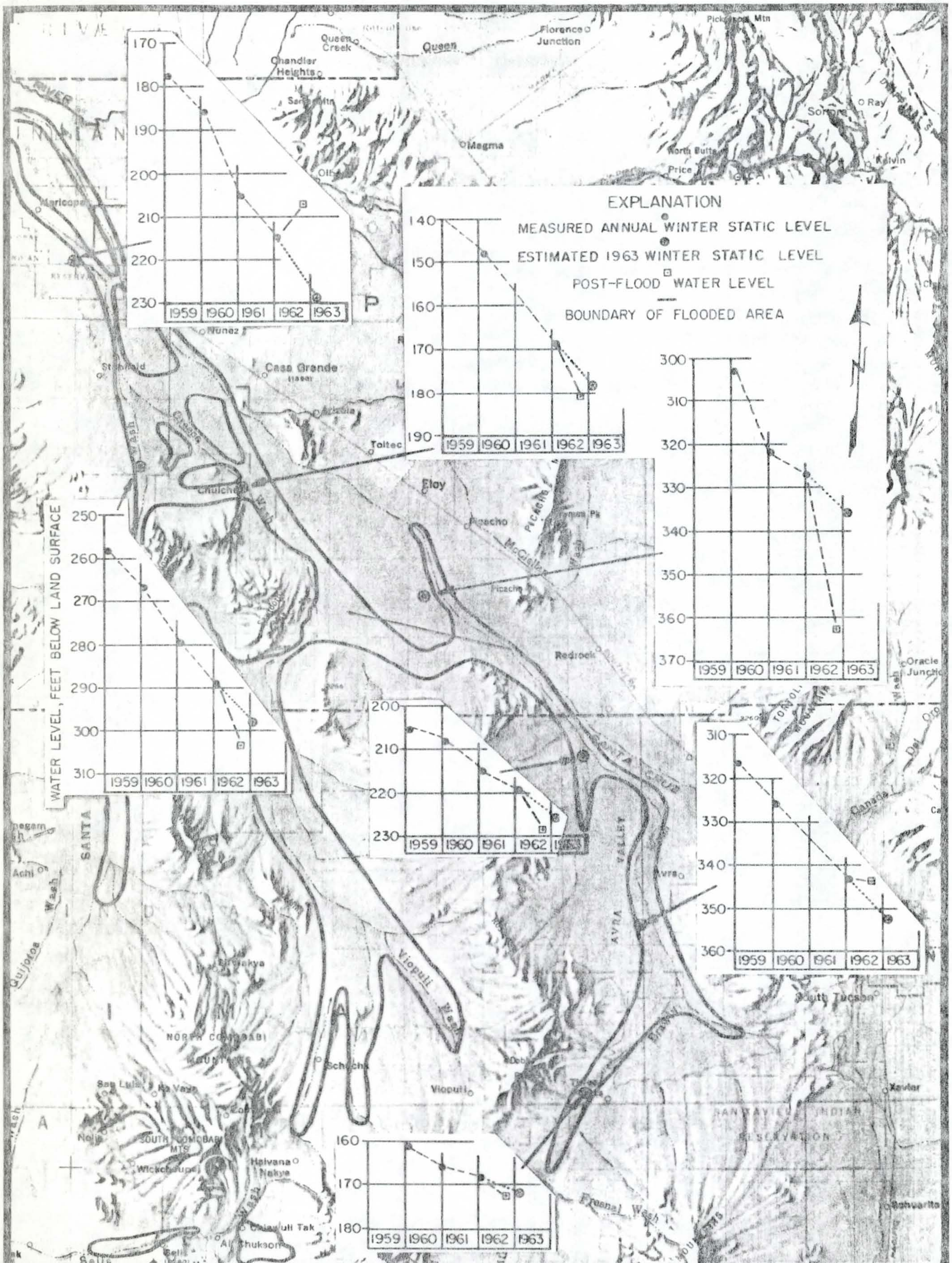


Figure 14.--Water levels in selected wells, Pinal and Pima Counties, 1959-1963

Fred Pashley and T. M. Davey of the Geological Survey investigated this crack and found that it was about 1,000 feet long and ranged in width from a few inches to about 5 feet. At the time of inspection the crack was about 10 feet at the deepest place. At two places erosion channels indicated that water did flow into the crack, but at many places the edges were sharp and fresh and gave no indication that water flowed over the edge. The conclusion was that the water that discharged into this crack was not significant when compared with the total volume produced by this flood.

Other cracks have formed in this area in the past, either following a heavy rainstorm or a sudden deluging of normally dry land by flood or irrigation waters. Whether these cracks are the result of shallow subsidence caused by the sudden onslaught of water on sediments that have never been compacted or whether they reflect deep subsidence caused by a general lowering of the regional water table by pumpage is not known.

One other conclusion on the losses to streamflow seems inescapable. Whether significant recharge occurred or not, a large part of the floodwater must have been retained as soil moisture, to be released later as direct evaporation.

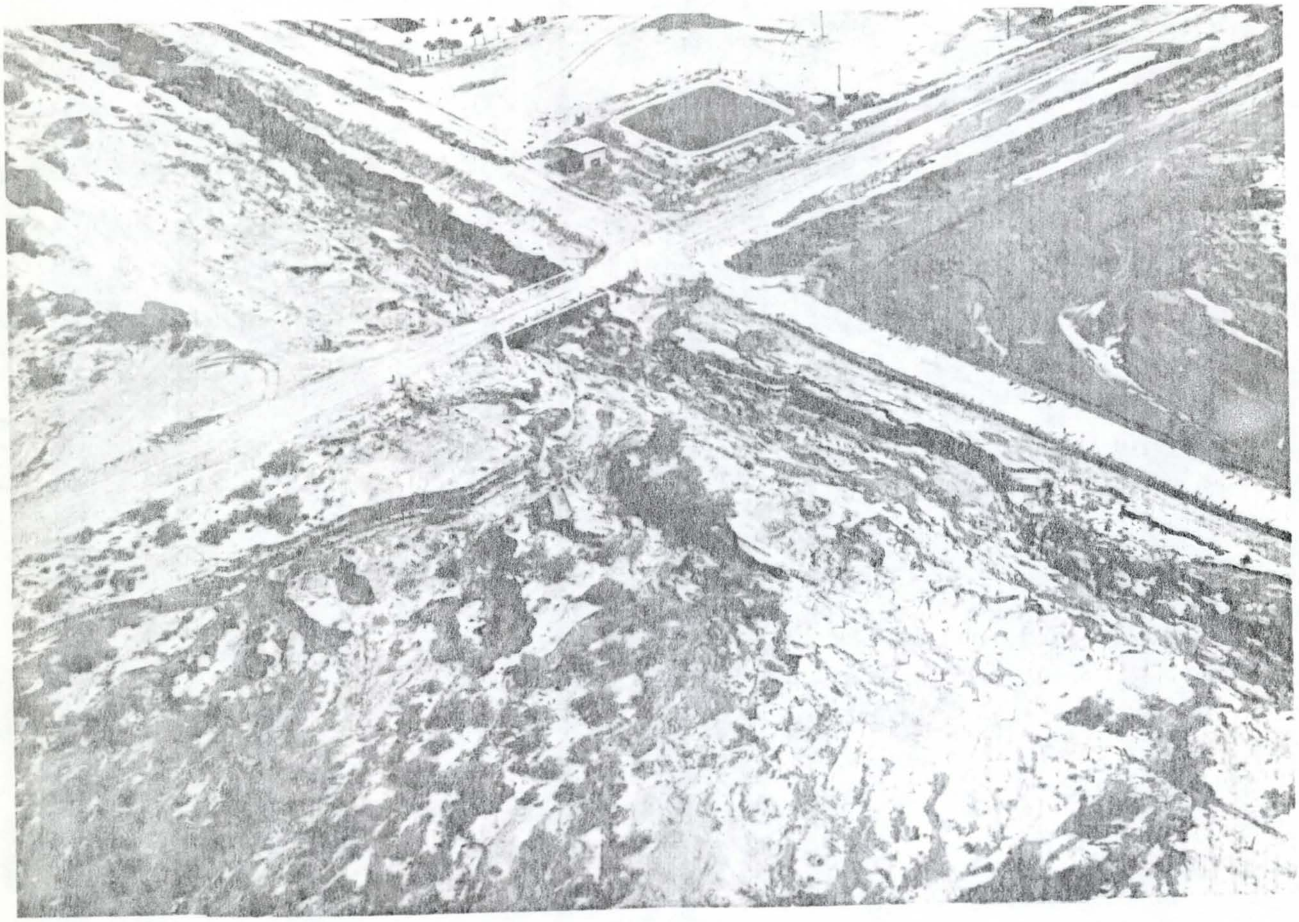
Flood damage.--

Accurate estimates of flood damage are difficult to obtain. The U.S. Department of Agriculture State Disaster Committee reports total damages of $3,200,000 to 35 farms in Pima County and 100 farms in Pinal County. The average cost of restoring each farm is $23,700.

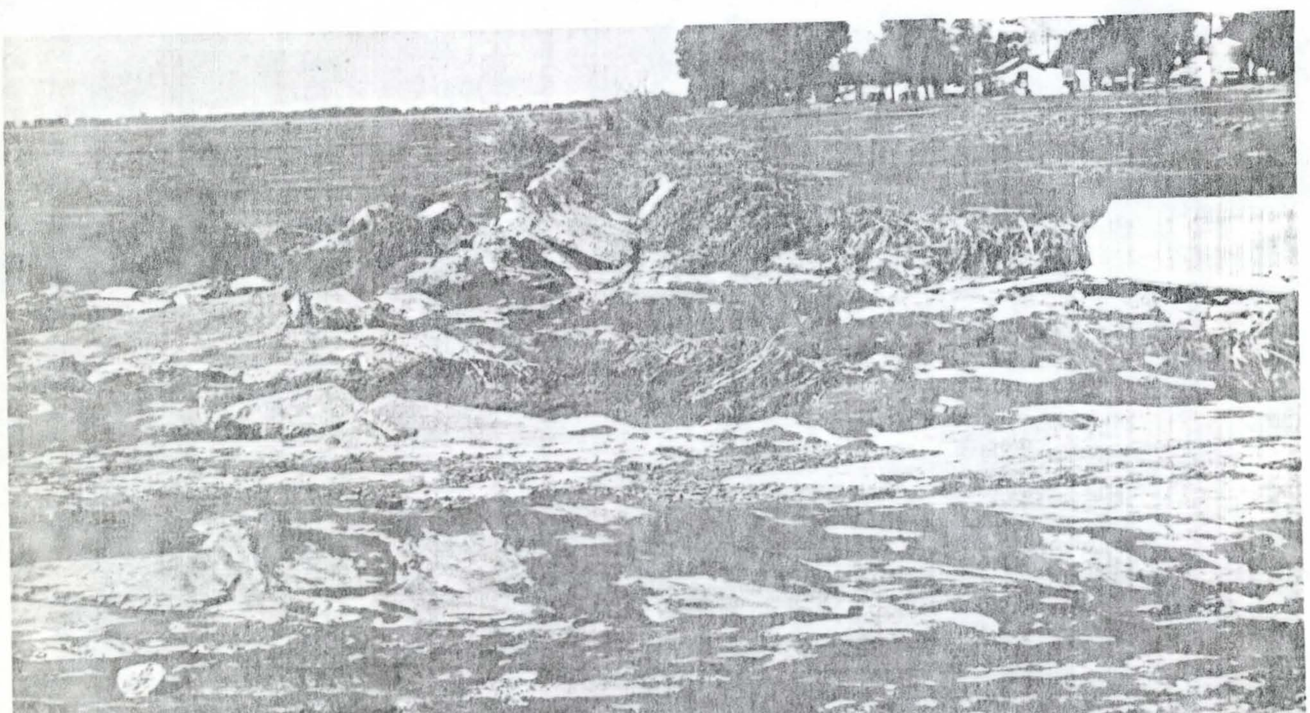
Dikes constructed by the farmers to protect their fields have been adequate to divert floodwaters from the cultivated areas in most years. Many of these dikes were breached by the flood of September 26-28, 1962. Potholes and gullies formed at the breaks. Some of the gullies extended out for several hundred feet. In places heavy deposits of silt were left. The re-leveling of this land was a major operation. Breaks in the dikes had to be repaired before the fields could be safely returned to production, and long, washed out stretches of concrete lined irrigation ditches (fig. 15) required replacement. Cleaning the silt from farm buildings, machinery, and feed yards (figs. 16-18) was a tremendous task.

The actual crop loss is difficult to estimate. Much of the cultivated land was planted to cotton, and the floodwater pulled the cotton from the open bolls. Deterioration in quality caused by the muddy water occurred in other bolls that were not fully opened. Future reduction in production as a result of the flood is dependent in part upon the rapidity with which damages to the land were repaired and, in part, upon changes in the fertility of the soil.

Emergency repairs to most of the roads and highways damaged by the flood were accomplished promptly. However, the added maintenance costs that may be required because of the lack of thorough compaction of a new fill or through the washing of compacted gravel from the roadbed are most difficult to determine.

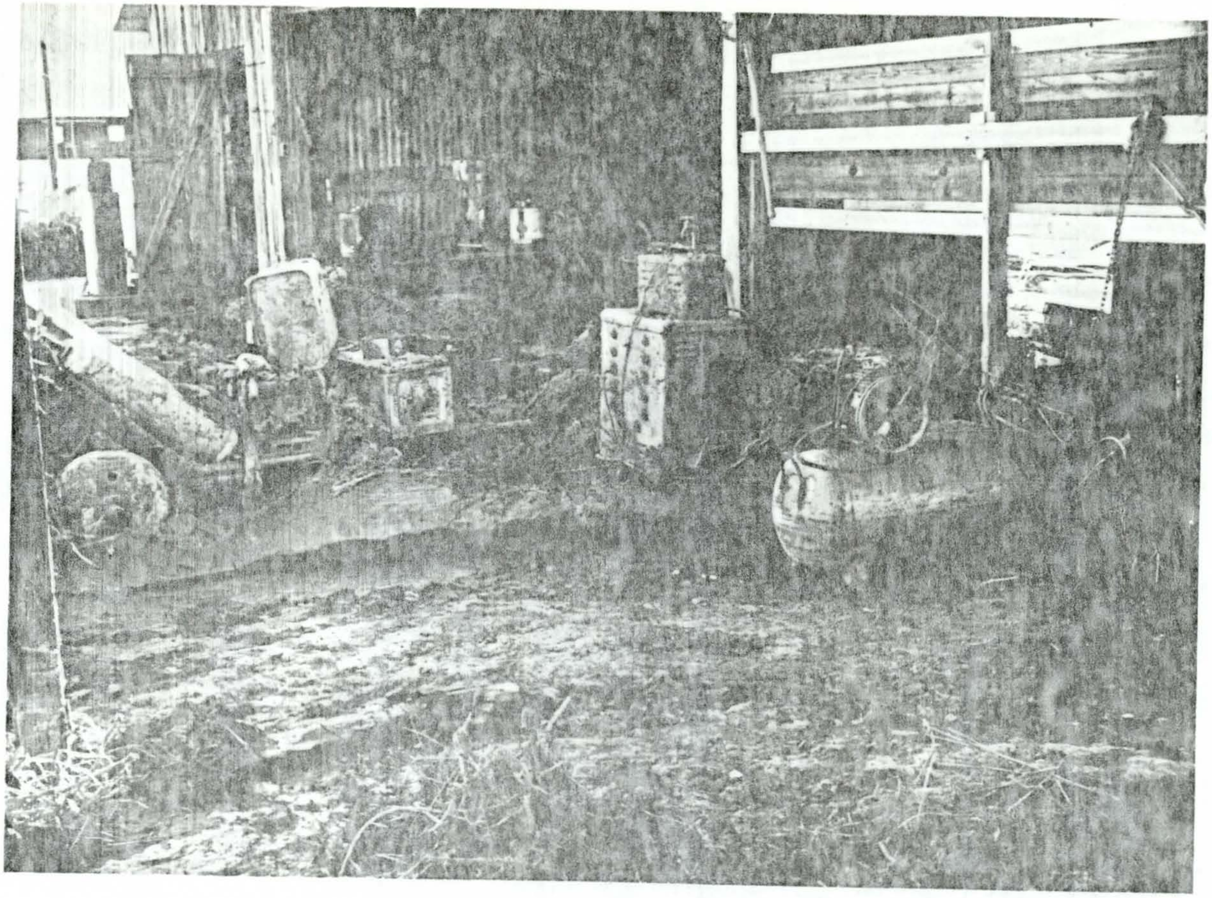


Erosion in wash near Marana.



Destruction of concrete ditch at Charles Wright Farm near Greens Reservoir.
Photographs from Soil Conservation Service

Figure 15.--Flood damage.



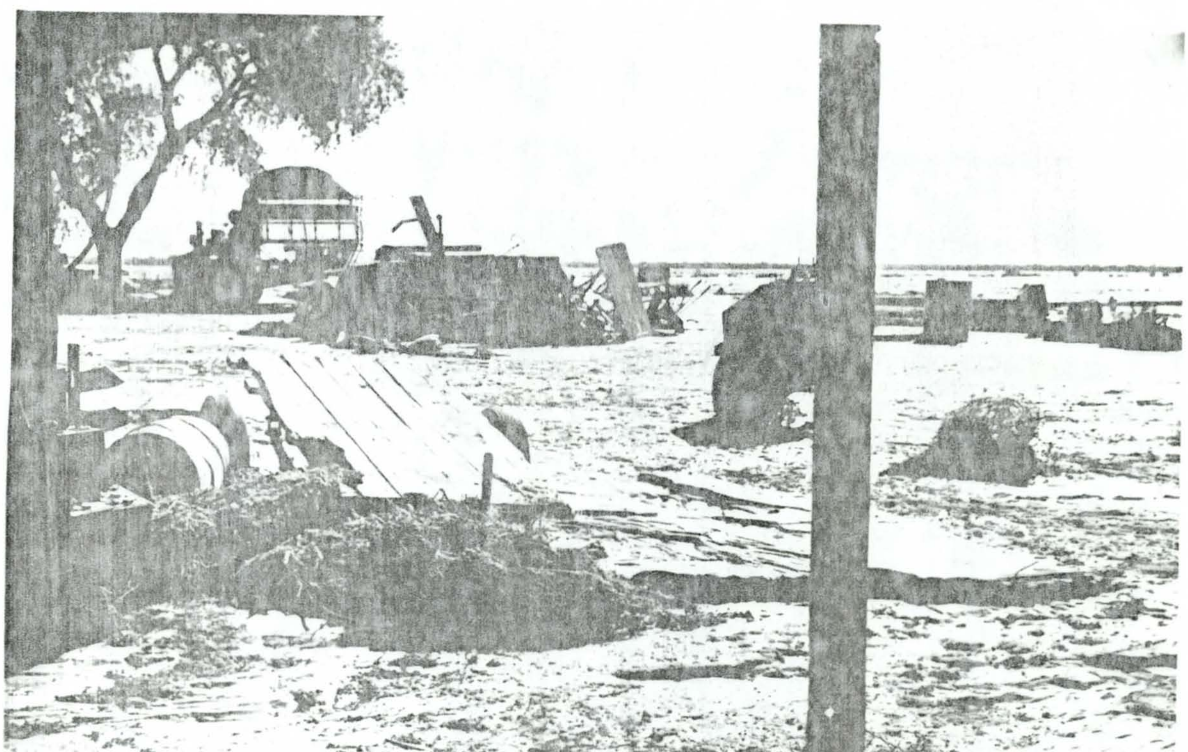


Figure 16.--Flood damage at Charles Wright Farm near Greens Reservoir.
Photographs f· ı Soil Conservation Service

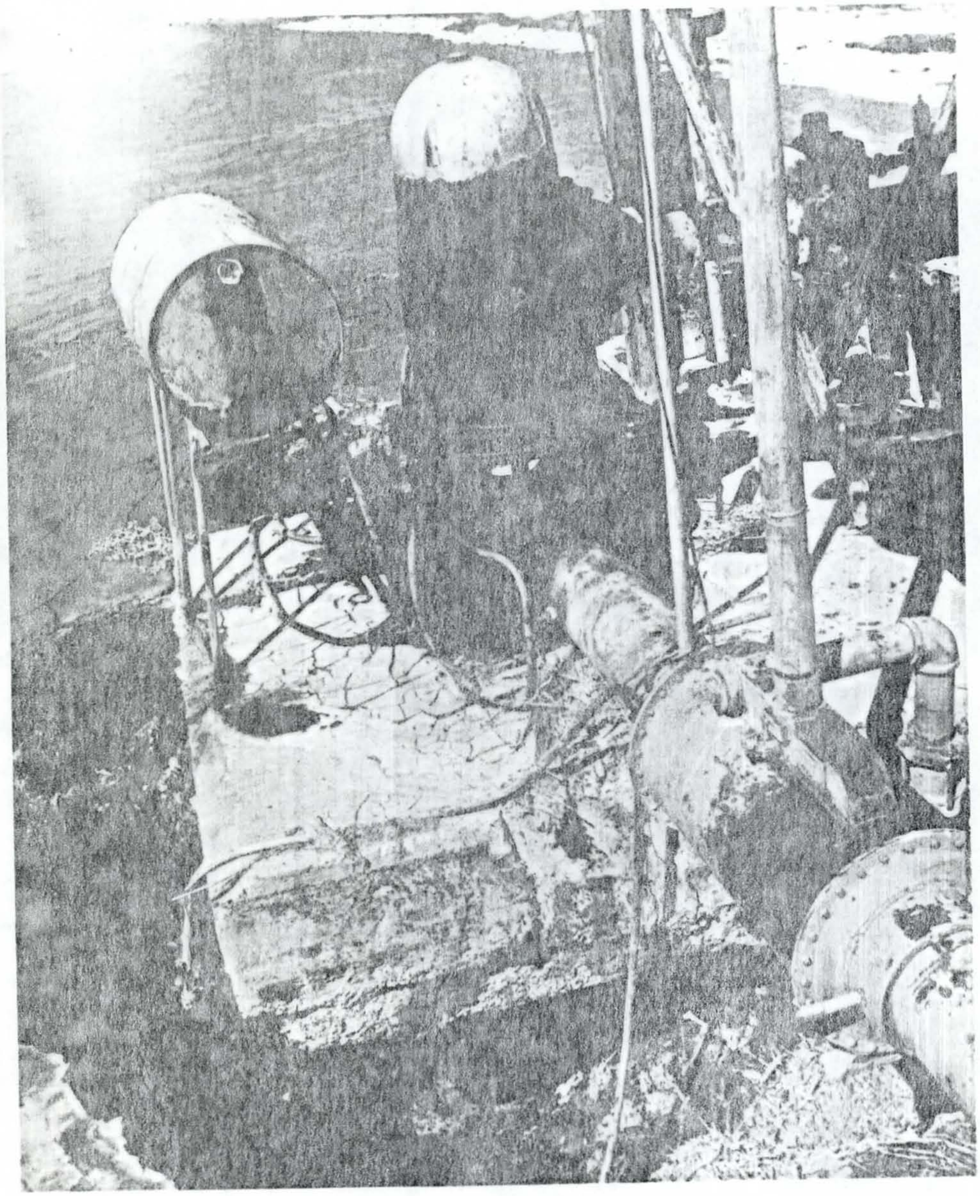


Figure 17.--Damage to irrigation well because of erosion.
Photograph from Soil Conservation Service

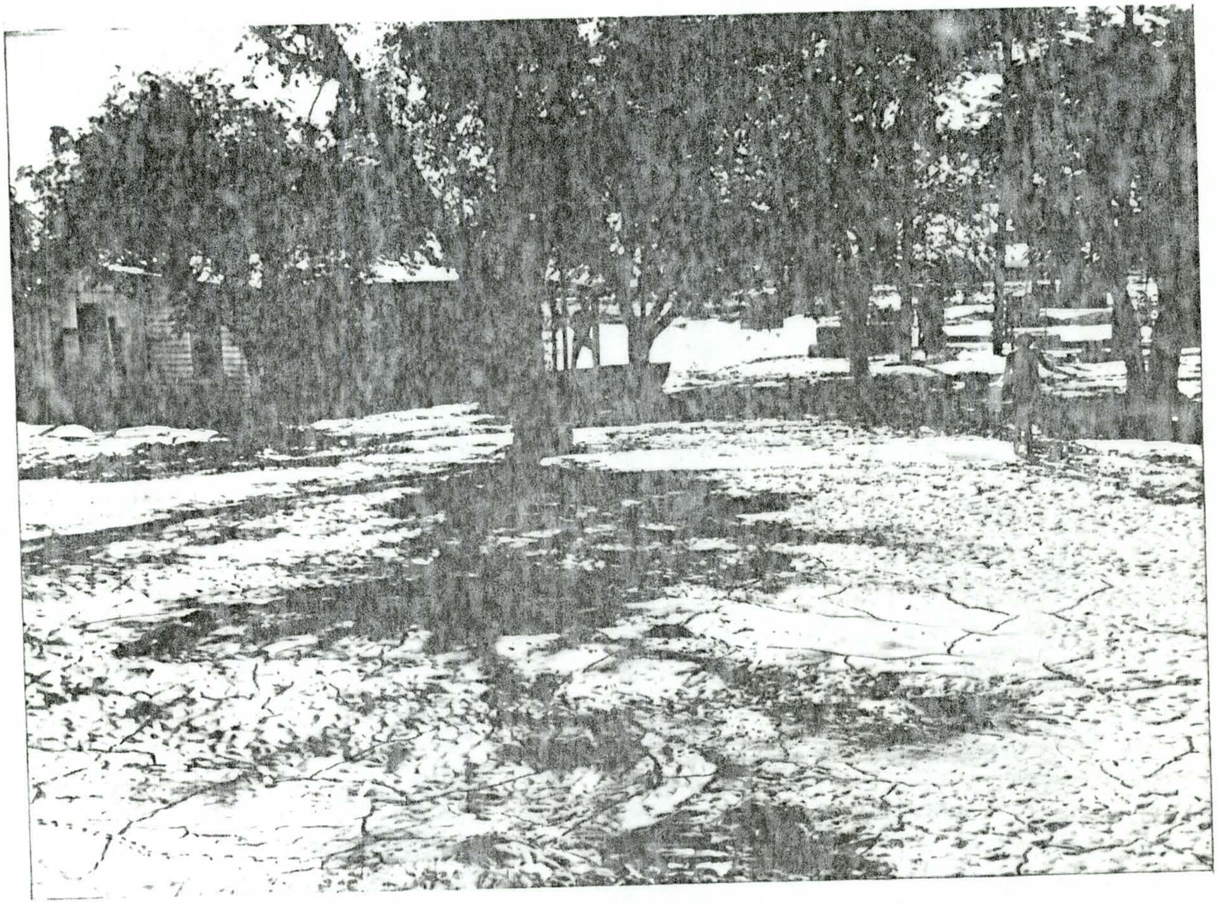


Figure 18.--Silt deposits at Charles Wright Farm near Greens Reservoir.
Silt in yard from 8 to 18 inches deep.

Photograph from Soil Conservation Service

Summary.--

The enveloping curve for floods in Arizona (fig. 1) for which factual knowledge is available is defined by the general equation $Q = 2800\sqrt{DA}$. Q represents the peak discharge in cubic feet per second per square mile and DA is the drainage area in square miles. The curve serves little purpose in estimating the potential of floods in this region, and it cannot be used to define the recurrence interval of floods of any given magnitude. Its primary purpose is to provide a comparison between the magnitude of floods from drainage areas of different sizes. All factors that may affect the peak discharge, other than drainage area alone, are thus excluded from this comparison.

For the flood of September 26-28, only one of the discharge determinations is greater than those represented by the enveloping curve. This one exception was the discharge of a tributary to Brawley Wash above Three Points. Why the intensity of discharge at this point should be greater than that at other points in the flood area is not known. We may speculate that some exceptionally high rainfall of which there was no record occurred over this tributary.

Factors that affected the size of this flood included the intensity and pattern of the rainfall, topography and shape of the individual drainage basins, and the geology of the area. The capacity of the flood plains to rapidly absorb large volumes of water played a dominant part in determining both flood peaks and volumes.

The flood is the maximum known in the area but it is possible that other major floods may have occurred in recent years because, except for a few years of streamflow record on Santa Rosa Wash near Vaiva Vo, there are practically no data on past floods. Information furnished by local residents dates back only about 20 years to the time when the agricultural development began. Prior to that time there were a few widely scattered Indians and ranchers. A major flood could have occurred and been as completely dissipated as the one of September 1962 without causing any concern.

The dikes that have been built around many of the cultivated fields give clear indication that the area has been troubled with minor floods. Prior to the flood of September 1962 these dikes had provided adequate protection to the area.

Again, we may speculate as to the flood discharges that might have occurred if the storm center had moved a few miles in any direction, or if the storm axis had rotated to produce the greatest peaks the precipitation could have developed. For example, if the storm was centered so that it straddled the Santa Cruz River and Pantano Wash, property damage in the Tucson metropolitan area could have been much greater than it was. Or if the storm center had moved to the north a few miles, the resulting flood could have been disastrous to Casa Grande or Stanfield.

One area that is less open to speculation concerns the development of residential areas in the desert lowlands. Major urbanized areas are now being developed at Arizona City and Toltec with others in the planning stage. Some of these may be so situated that they will seldom or never be subjected to flood damage. Others might well be located in the center of most intense runoff from storms such as the one of September 1962. The degree of flood protection for such developments may well depend upon the available knowledge relating to the magnitude and frequency of floods.

Conservation of floodwaters is another area worthy of serious consideration. The records show that at least 125,000 acre-feet of water was dissipated in the desert lowlands during this flood. The total loss may have been considerably greater. Some of this water apparently went into the ground-water reservoir, but a large part of it evidently was retained as soil moisture that could evaporate later.

The water lost from this flood would meet the present municipal requirements of metropolitan Tucson for a period of about 3 or 4 years, or it would supply adequate irrigation water for 50,000 acres for most of a year. Thus the water itself would have a very significant economic value.

The flood of September 26-28, 1962, in southern Arizona was an unusual flood. The present program of investigation of the water resources of Arizona is not adequate to provide information upon the frequency of recurrence of floods of similar or lesser magnitude. The available data will not permit rigid design of flood protection works, nor will they serve as the basis for hydrologic and economic studies directed toward the conservation of floodwater. Full consideration should be given toward filling the gaps in hydrologic data in the desert lowlands.

Acknowledgements.--

The author is grateful for the assistance and data furnished by several other agencies and individuals. Data on precipitation at weather stations near the flood area and a description of meteorological conditions that caused the storm were supplied by the U.S. Weather Bureau. Additional information on precipitation and on certain areas inundated by floodwater was obtained from the Corps of Engineers. The U.S. Department of Agriculture State Disaster Committee provided the estimates of the damage to farmland. Information on ground-water recharge and the land cracks was extracted from unpublished reports prepared by the district office of the Ground Water Branch of the Geological Survey. Many individuals contributed information based on personal observations of the flood.