UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

GEOLOGICAL SURVEY
W. E. Wrather, Director

Water-Supply Paper 967

# NOTABLE LOCAL FLOODS OF 1939

PAPERS BY

J. S. GATEWOOD, FLOYD F. SCHRADER
AND MINER R. STACKPOLE




UNITED STATES
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[The letters in parentheses preceding the titles are those used to designate the separate chapters]



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## Part 1. FLOODS OF SEPTEMBER 1939 IN COLORADO RIVER BASIN BELOW BOULDER DAM

by

J. S. GATEWOOD

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# ILLUSTRATIONS



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# NOTABLE LOCAL FLOODS OF 1939

## Part 1. FLOODS OF SEPTEMBER 1939 IN COLORADO RIVER BASIN BELOW BOULDER DAM

By J. S. GATEWOOD

ABSTRACT

Although the flow of Colorado River has been controlled at Boulder Dam since February 1935, flood danger still exists in the basin below the dam. This report on the first general floods to occur below Boulder Dam since the dam was closed presents facts that should prove helpful in planning protection and reservoir operation to minimize the ill effects of future floods.

The floods of September 1939 were caused by a series of tropical disturbances that moved northwestward along the west coast of Mexico and culminated in unprecedently heavy rains in northwestern Mexico and southwestern United States. Three separate storms, occurring September 3-7, 8-13, and 23-26, moved across the lower Colorado River Basin. At many points in that area the mean annual precipitation was exceeded by the precipitation for September.

Because little rainfall preceded the storms, runoff from them was less than would have occurred under more unfavorable conditions. At streamflow measuring stations where past records are available no new records were set. On Gila River no flood occurred. On Colorado River the flood was not so great as those that had occurred almost every year prior to the closing of Boulder Dam. On Williams River, however, the peak discharge was of the magnitude of a major flood, and in many of the smaller drainage basins peaks occurred which probably have not been exceeded in the previous 50 to 100 years.

The relatively low flood peaks on Colorado River do not mean that there was no flood danger. The regulation of the river since Boulder Dam was closed has prevented the scouring of the channel by floods, has permitted the encroachment of vegetation in the channel, and has allowed the accumulation of sediment. As a result, flood stages today are about as high as they formerly were for discharges twice as large.

Flood peaks in Colorado River were greatly reduced by storage. Between September 5 and 20 Lake Mead stored 330,000 acre-feet of water. Between September 4 and 7 Havasu Lake stored 135,000 acre-feet, and the channel storage between Topock and Yuma, exclusive of Havasu Lake, accounted for about 110,000 acre-feet at the peak.

Storage in Havasu Lake is limited in relation to the flood flows that may enter it. When the September storms began, Havasu Lake was at normal minimum level. Had it not been low, the lake probably would have filled by the morning of September 6, and that day's peak inflow, which may have exceeded 75,000 second-feet, would necessarily have passed through with little reduction.

## INTRODUCTION

In September 1939 three separate storms, occurring September 3–7, 8–13, and 23–26, moved across the lower Colorado River Basin. The storms followed the same general path, but different distribution of rainfall caused the resulting floods to differ. In many of the small drainage basins the peak discharges probably exceeded any that occurred in the previous 50 to 100 years. However, flood discharges did not exceed previous records for Colorado River at measuring points that were established before Boulder Dam was built or for Williams River, where major floods have resulted from warm rains falling on heavy snow cover.

The flood discussed in this report embraces the drainage basin of Colorado River between Boulder Dam and the United States-Mexico boundary, including the basin of Williams River but excluding that of Gila River. (See pl. 1.) Also discussed in this report, but in less detail, is the basin of Salton Sea, which is closely associated with the lower Colorado River Basin. The storms causing the floods were not confined to this area. The first storm extended into southwestern Utah and the second into southeastern Utah; the third was particularly heavy in the area near Los Angeles, Calif. All were severe in those parts of Mexico adjacent to the storm areas in Arizona and California. Effects in those areas are considered only incidentally in this report.

The flow of Colorado River has been controlled at Boulder Dam since February 1935. The floods of September 1939 were the first of importance to occur below the dam since 1935, and though they were not large in comparison with floods that occurred before the river was controlled, they present valuable evidence of the uncontrolled flood inflow below Boulder Dam. As is generally recognized, a flood danger still exists in the lower Colorado River Basin, despite Boulder Dam and other dams. The facts presented here should be helpful in planning protection and reservoir operation to minimize the ill effects of future floods.

## ADMINISTRATION AND PERSONNEL

This report was prepared in the Water Resources Branch of the Geological Survey under the general direction of G. L. Parker, chief hydraulic engineer. The field and office work were done in the Surface Water Division, R. G. Kasel, chief, under the immediate direction of J. H. Gardiner, district engineer, Tucson, Ariz. The technical studies, assembling of materials, and preparation of the text were performed and supervised by J. S. Gatewood, engineer, under the general direction of Mr. Gardiner.

The report was reviewed in the Division of Water Utilization by W. S. Eisenlohr, Jr., associate engineer, under the general direction of R. W. Davenport, chief.

## ACKNOWLEDGMENTS

The Geological Survey, through the district office at Tucson, Ariz., cooperates with the Metropolitan Water District of Southern California in the stream-gaging work done between Boulder Dam and Parker, Ariz., and with the State of Arizona in all work done within that State. Acknowledgment is made to these two cooperating agencies

and also to the following agencies, which contributed much valuable information: United States Weather Bureau; Corps of Engineers, United States Army; Bureau of Reclamation; Office of Indian Affairs; California Division of Highways; Arizona Highway Department; Southern Pacific Co.; Atchison, Topeka & Santa Fe Ry.; Imperial Irrigation District; Palo Verde Irrigation District; and Coachella Valley County Water District. As credited in its heading, the section entitled "Meteorologic conditions" was prepared by D. C. Cameron, meteorologist, United States Weather Bureau.

## PHYSICAL FEATURES

The topography of the Colorado River Basin below Boulder Dam is typical of the southwestern desert. Numerous relatively low but steep and rugged mountain ranges rise above the smooth, steeply sloping desert floor. The area is drained by short, steep washes, which are dry throughout the year except for several hours or days after heavy storms. In the northern part of the area the mountain ranges seldom exceed 5,000 feet in altitude, and in the southern part they seldom exceed 3,000 feet.

The main valley of Colorado River is narrow, and only a small part lies above 3,000 feet. The Williams River Basin, adjoining the main valley on the east, is higher, about half of its area being above 3,000 feet. The lower Gila River Basin (below Gillespie Dam) is much lower in altitude, with almost no area above 3,000 feet and about half below 1,000 feet. The Salton Sea Basin, adjoining the southern part of the main valley on the west, is similar to the areas described except that the basin is rimmed on the west by mountains ranging in altitude from 5,000 to 8,000 feet above sea level and reaching 10,800 feet. A considerable part of the basin is below sea level, Salton Sea itself being about 240 feet below sea level.

The climate of the area is exceptionally hot and dry. Vegetation, even in the mountains, is sparse and consists of hardy desert varieties. No timber is found except in some very small tracts above about 6,000 feet altitude. Maximum temperatures exceeding 100° prevail throughout the summer, and the mean annual precipitation is less than 10 inches except at the higher altitudes.

Precipitation in appreciable amounts is almost entirely confined to two distinct seasons: November to March, when storms from the North Pacific Ocean extend into the region and result in rainfall, usually of moderate intensity; and July to September, when atmospheric conditions are favorable for rainfall of great intensity and short duration, generally in the form of thunderstorms and so-called cloudbursts. The floods of September 1939 were caused by storms of the latter type.

No perennial streams exist in the area except Colorado River and small, short streams at the higher altitudes. Williams River has a low-water flow of 10 to 15 second-feet, which moves underground except where forced to the surface in canyons. The lower Gila River has a small underground flow; no surface flow appears except during unusual storms, owing to extensive storage and diversions on Gila River and tributaries above Gillespie Dam. Except for the few stormy days during the year, Colorado River below Boulder Dam loses water continually by transpiration, by evaporation, and by seepage to the ground-water table, as well as by diversion for irrigation.

## METEOROLOGIC CONDITIONS AND PRECIPITATION

### METEOROLOGIC CONDITIONS

By D. C. CAMERON, meteorologist, United States Weather Bureau

The three periods of extremely heavy rain in the lower Colorado River Valley and adjacent desert and coastal areas during September 1939 were the direct result of a series of tropical disturbances that moved northwestward along the west coast of Mexico into the region of Lower California and were dissipated over the latter area or, as in the storm of September 14–25, over southern California.

Although such disturbances are not unusual, a succession of four storms in 3 weeks, three of them of more than average intensity, was remarkable. These storms were responsible for bringing into the far Southwest extremely moist tropical air and then, through processes of convection, convergence, and forced lift due to topography, releasing unprecedentedly heavy rain in an area seldom visited by deluges.

The unusually dry air of the lower Colorado River Valley, with its scattered afternoon mountain thunderstorms, was displaced by moist tropical air, and the region became the scene of intense rain-producing activity. In tropical cyclones the principal influx of moisture is to the right of the storm's path, and in the case of the storms moving up the western coast of Mexico this carried the moist air into the lower Colorado Valley and southern California.

The locations and paths of the four cyclonic storms are shown in figure 1.

### PRECIPITATION

In table 1 are listed all precipitation stations of the United States Weather Bureau in the area under discussion as well as those in adjacent territory that were used in preparing the isohyetal maps, plates 2–4. Owing to the sparse population, precipitation stations are so widely scattered in parts of the area that they give a very incomplete picture of the storms. For example, in an area west and northwest of Parker, Ariz., as large as the four smallest New England States combined, only one precipitation record is available.

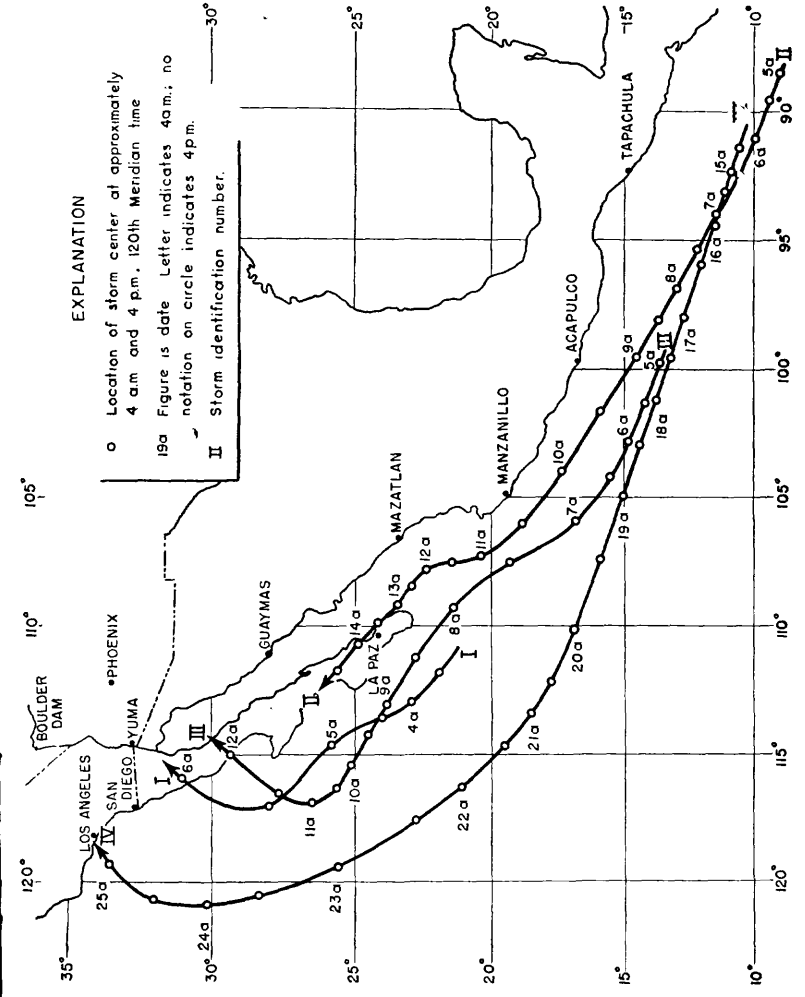


FIGURE 1.—Chart showing tracks of tropical disturbances along west coast of Mexico during September 1939.

TABLE 1.–*Daily precipitation, in inches, September 3–13, 23–26, 1939*

[U. S. Weather Bureau records. Measured in late afternoon except as noted. Tr., Less than 0.01 inch.]

**Colorado River Basin**

| Nos. on pls. 2-4 | Station | County | Elevation (feet) | September | | | | | Total Sept. 3-7 | September | | | | | | Total Sept. 8-13 | September | | | | Total Sept. 23-26 | Total for Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 3 | 4 | 5 | 6 | 7 | | 8 | 9 | 10 | 11 | 12 | 13 | | 23 | 24 | 25 | 26 | | |
| | ARIZONA | | | | | | | | | | | | | | | | | | | | | |
| 1 | Aguila | Maricopa | 2,280 | Tr. | 0.92 | 0.49 | 0.89 | 0.02 | 2.32 | ..... | ..... | ..... | 0.77 | 0.55 | 0.10 | 1.42 | ..... | Tr. | 1.99 | ..... | 1.99 | 5.73 |
| 2 | Ajo[1] | Pima | 1,763 | ..... | .15 | .13 | .91 | .03 | 1.22 | 0.01 | 0.38 | 0.01 | .07 | .59 | .53 | 1.59 | ..... | ..... | ..... | 0.05 | .05 | 2.86 |
| 3 | Ashdale Ranger Station | Maricopa | 3,300 | ..... | .25 | .65 | .98 | .28 | 2.16 | ..... | .03 | ..... | 1.28 | .14 | .66 | 2.11 | ..... | Tr. | .42 | .60 | 1.02 | 5.36 |
| 4 | Bagdad[1] | Yavapai | 3,200 | ..... | .73 | 1.32 | 2.43 | .37 | 4.85 | ..... | ..... | ..... | ..... | .32 | .75 | 1.07 | ..... | 0.02 | .08 | .52 | .62 | 6.70 |
| 5 | Bright Angel Ranger Station | Coconino | 8,400 | ..... | 1.62 | 2.72 | 1.54 | .67 | 6.55 | ..... | .18 | .81 | .82 | 1.30 | 1.04 | 4.15 | ..... | .. | .48 | 1.09 | 1.57 | 12.31 |
| 6 | Buckeye | Maricopa | 980 | ..... | 2.27 | .06 | .76 | .03 | 3.12 | ..... | ..... | ..... | .29 | .32 | .77 | 1.38 | ..... | .07 | ..... | ..... | .07 | 4.57 |
| 7 | Cedar Glade | Yavapai | 4,610 | 0.53 | (2) | (2) | 4.89 | ..... | 5.42 | ..... | ..... | .15 | .17 | ... | 1.15 | 1.47 | ..... | .06 | .32 | ..... | .38 | 7.29 |
| 8 | Cordes | .....do..... | 3,773 | ... | .20 | .43 | .79 | .03 | 1.45 | ..... | ..... | ..... | ..... | .48 | .96 | 1.44 | ..... | ..... | .36 | .04 | .40 | 3.29 |
| 9 | Crown King | .....do..... | 6,000 | ..... | .28 | .96 | 1.67 | .24 | 3.15 | ..... | ..... | ..... | (2) | (2) | 2.20 | 2.20 | ..... | ..... | 1.32 | ... | 1.32 | 6.67 |
| 10 | Fredonia | Coconino | 5,000 | .01 | .76 | .34 | 1.31 | .12 | 2.54 | ..... | ..... | .10 | .82 | 2.15 | .66 | 3.73 | ..... | ..... | .60 | .50 | 1.10 | 7.89 |
| 11 | Gila Bend | Maricopa | 737 | .40 | .48 | .20 | .45 | .15 | 1.68 | ..... | ..... | ..... | Tr. | ..... | .16 | .16 | ..... | Tr. | .02 | ..... | .02 | 1.86 |
| 12 | Grand Canyon | Coconino | 6,866 | ..... | .94 | 1.65 | 1.25 | .66 | 4.50 | 1.00 | Tr. | .92 | .99 | .51 | .47 | 3.89 | ..... | .06 | .02 | .17 | .25 | 8.64 |
| 13 | Jerome[1] | Yavapai | 5,250 | ..... | .14 | .25 | .79 | .30 | 1.48 | ..... | .34 | ..... | .07 | .05 | .55 | 1.01 | ..... | ..... | ..... | .30 | .30 | 2.79 |
| 14 | Junipine | Coconino | 5,124 | .03 | .27 | .93 | 1.03 | .57 | 2.83 | .02 | .03 | ..... | .07 | 1.01 | 1.54 | 2.67 | Tr. | .91 | .18 | ..... | 1.09 | 6.59 |
| 15 | Kingman | Mohave | 3,326 | ..... | .46 | 2.10 | 2.70 | .19 | 5.45 | ..... | ..... | .15 | .60 | .43 | ..... | 1.18 | ..... | ..... | 1.73 | .24 | 1.97 | 9.85 |
| 16 | Maricopa | Pinal | 1,186 | .04 | .80 | .42 | ..... | ..... | 1.26 | ..... | ..... | ..... | .76 | .30 | ..... | 1.06 | ..... | .43 | ..... | ..... | .43 | 2.75 |
| 17 | Mohawk | Yuma | 538 | ..... | 1.00 | .30 | .98 | ..... | 2.28 | ..... | ..... | .53 | 1.50 | 1.00 | ..... | 3.03 | ..... | ..... | ..... | ..... | ..... | 5.31 |
| 18 | Mount Trumbull | Mohave | 5,000 | ..... | 1.30 | .35 | 2.05 | ..... | 3.70 | ..... | ..... | .36 | 1.65 | 1.86 | ..... | 3.87 | ..... | .16 | .35 | ..... | .51 | 8.28 |
| 19 | Parker | Yuma | 350 | .10 | .13 | 3.43 | 1.66 | .13 | 5.45 | ..... | ..... | ..... | .08 | .23 | ..... | .31 | ..... | 1.51 | 1.28 | ..... | 2.79 | 8.85 |
| 20 | Phoenix Airport[1] | Maricopa | 1,112 | ..... | .31 | 1.88 | .55 | .14 | 2.88 | Tr. | Tr. | Tr. | Tr. | .57 | .56 | 1.13 | ..... | ..... | .01 | .20 | .21 | 4.23 |
| 21 | Phoenix[3] | .....do..... | 1,083 | .15 | 2.91 | .52 | .10 | .06 | 3.74 | ..... | Tr. | Tr. | 1.08 | .17 | .25 | 1.50 | ..... | Tr. | .17 | ..... | .17 | 5.41 |
| 22 | Prescott | Yavapai | 5,372 | Tr. | .13 | .71 | 1.07 | .59 | 2.50 | .05 | .11 | .3 | .09 | .13 | .45 | .86 | ..... | ..... | .46 | .20 | .66 | 4.05 |
| 23 | Salome | Yuma | 1,775 | ..... | .90 | 1.10 | 1.75 | ..... | 3.75 | ..... | ..... | ..... | .56 | 1.10 | .13 | 1.79 | ..... | ..... | .62 | ..... | .62 | 6.16 |
| 24 | Seligman[1] | Yavapai | 5,219 | .41 | 1.53 | 1.50 | .98 | Tr. | 4.42 | Tr. | Tr. | Tr. | Tr. | 1.70 | .48 | 2.18 | ..... | ..... | .69 | .39 | 1.08 | 8.27 |
| 25 | Sycamore Ranger Station | .....do..... | 4,000 | (4) | (4) | (4) | (4) | (4) | (4). | (4) | (4) | (4) | (4) | (4) | (4) | (4). | ..... | .01 | .65 | .14 | .80 | 3.10 |
| 26 | Truxton | Mohave | 3,997 | ..... | 3.32 | 1.16 | 2.02 | .05 | 6.55 | ..... | ..... | .45 | 1.18 | 1.10 | .10 | 2.83 | ..... | 1.10 | .71 | Tr. | 1.81 | 11.19 |
| 27 | Walnut Creek Ranger Station | Yavapai | 5,158 | ..... | .90 | 2.10 | 1.46 | .16 | 4.62 | Tr. | .25 | 1.65 | .40 | .48 | .57 | 3.35 | ..... | .20 | .51 | ..... | .71 | 8.91 |
| 28 | Walnut Grove | .....do..... | 3,469 | .26 | .46 | 1.43 | 1.15 | ... | 3.30 | Tr. | .78 | .07 | .55 | .71 | .56 | 2.67 | ..... | Tr. | .73 | ..... | .73 | 6.70 |
| 29 | Wickenburg[1] | Maricopa | 2,072 | ..... | 1.08 | .63 | .56 | .73 | 3.00 | ..... | ..... | ..... | ..... | .76 | .78 | 1.54 | ..... | ..... | ..... | .57 | .57 | 5.11 |
| 30 | Wickieup | Mohave | 1,950 | ..... | 1.89 | 3.67 | 1.47 | ..... | 7.03 | ..... | ..... | ..... | .61 | .92 | .45 | 1.98 | Tr. | .71 | .59 | ..... | 1.30 | 10.31 |
| 31 | Williams[1] | Coconino | 6,750 | ..... | .39 | 2.11 | 1.54 | 1.54 | 5.58 | ..... | ..... | .33 | .15 | .35 | .78 | 1.61 | ..... | .29 | .33 | ..... | .62 | 7.99 |
| 32 | Wittman[1] | Maricopa | 1,697 | ..... | .37 | .42 | .41 | .60 | 1.80 | ..... | ..... | ..... | ..... | .52 | .79 | 1.31 | ..... | ..... | ..... | 1.02 | 1.02 | 4.13 |
| 33 | Yaeger Canyon | Yavapai | 5,800 | (2) | (2) | (2) | 1.72 | ..... | 1.72 | .01 | ..... | .10 | ..... | ..... | 1.00 | 1.11 | ..... | ..... | (2) | .28 | .28 | 3.11 |
| 34 | Yarnell | Coconino | 4,782 | ..... | 1.69 | 1.87 | 2.92 | .02 | 6.50 | ..... | ..... | ..... | .52 | 1.55 | 1.19 | 3.26 | 1.99 | Tr. | ..... | ..... | 1.99 | 11.89 |
| 35 | Yuma[3] | Yuma | 138 | ..... | 2.17 | 2.03 | .25 | ..... | 4.45 | ..... | ..... | ..... | .51 | .10 | ..... | .61 | Tr. | ... | .07 | ... | .07 | 5.13 |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CALIFORNIA | | | | | | | | | | | | | | | | | | | | | |
| 36 | Blythe[1] | Riverside | 268 | | 0.15 | 1.50 | 2.47 | 0.50 | 4.62 | | Tr. | | | 0.12 | 0.18 | 0.30 | | | 0.72 | 0.08 | 0.80 | 5 72 |
| 37 | Needles[1] | San Bernardino | 480 | 0.02 | 1.18 | .98 | 2.94 | | 5.12 | | | | 0.12 | .02 | | .14 | | 1.23 | 1.12 | | 2.35 | 7.61 |
| 38 | Parker Reservoir[1] | do | 750 | | 1.99 | 1.61 | .94 | Tr. | 4.54 | | | 0.01 | .51 | .73 | | 1.25 | 0.01 | .86 | | .99 | 1.85 | 7.85 |
| | NEVADA | | | | | | | | | | | | | | | | | | | | | |
| 39 | Boulder City | Clark | 2,525 | .36 | .02 | 1.06 | | | 1 44 | | | .08 | .71 | .04 | | .83 | | .07 | 1.08 | .05 | 1 20 | 3.47 |
| 40 | Charleston Ranger Station | do | 7,165 | | .16 | .23 | .27 | Tr. | .66 | | 0 52 | | .25 | .02 | | .79 | | .28 | 2.48 | .54 | 3.30 | 4.75 |
| 41 | Indian Springs | do | 3,136 | | | | | | | | Tr. | .16 | .02 | | | .18 | | .09 | .25 | .54 | .88 | 1 06 |
| 42 | Las Vegas | do | 2,033 | .02 | | .48 | 1 08 | | 1.58 | | | | .04 | .22 | | .26 | | .10 | .35 | .30 | .75 | 2.59 |
| 43 | Las Vegas Airport | do | 1,876 | Tr. | .20 | .07 | .89 | | 1.16 | | Tr. | .01 | .42 | | | .43 | | .74 | 1.09 | .03 | 1.86 | 3.39 |
| 44 | Overton | do | 3,350± | | .76 | | .90 | | 1.66 | | | .20 | .10 | .55 | .03 | .88 | | | .32 | .64 | .96 | 3.50 |
| 45 | Searchlight | do | 1,445 | | .30 | .34 | 1.64 | | 2.28 | | | Tr. | .11 | 3.84 | .11 | 4.06 | .83 | 2.18 | .10 | | 3 11 | 8 45 |
| | UTAH | | | | | | | | | | | | | | | | | | | | | |
| 46 | Alton | Kane | 7,000 | | 1.57 | .10 | 1.70 | .24 | 3 61 | | | .39 | .27 | 1.57 | 1.12 | 3.35 | | .39 | .50 | | .89 | 7 97 |
| 47 | Hurricane | Washington | 3,280 | | .40 | | 1 20 | | 1.60 | | .18 | | 1.45 | .85 | | 2.48 | | .80 | | | .80 | 4.88 |
| 48 | Kanab | Kane | 4,925 | | 95 | .33 | 1.31 | .11 | 2.70 | | | | 1.01 | 1.90 | .77 | 3.68 | | | .25 | .53 | .78 | 7.26 |
| 49 | St. George | Washington | 2,880 | | .63 | .02 | .90 | | 1.55 | | | .17 | .30 | 1.44 | | 1 91 | | | .25 | .40 | .65 | 4 16 |
| 50 | Springdale | do | 4,048 | | 1.18 | .37 | 1.85 | .05 | 3.45 | | | .07 | .35 | 1.70 | .17 | 2.29 | | Tr. | .21 | .68 | .89 | 6.70 |

**Pacific Coast Basins**

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CALIFORNIA | | | | | | | | | | | | | | | | | | | | | |
| 51 | Aguanga[1] | Riverside | 3,100 | | | 0.26 | 1.09 | | 1.35 | | | | 1.00 | 0.39 | | 1.39 | | 0.45 | | | 0.45 | 3.19 |
| 52 | Alpine | San Diego | 1,900 | | | .73 | 1.53 | 0.55 | 2.81 | | 0.13 | 0.09 | | .09 | | .31 | | Tr. | 1.79 | | 1.79 | 4.91 |
| 53 | Barrett Dam[1] | do | 1,750 | | | .20 | 2.17 | 1.10 | 3.47 | | .05 | .11 | | | | .16 | | | 1.65 | 1.28 | 2.93 | 6.71 |
| 54 | Beaumont[1] | Riverside | 2,558 | | | | .20 | | .20 | | | .12 | .07 | .13 | | .32 | 2.36 | | | 1.06 | 3.42 | 4.41 |
| 55 | Campo[1] | San Diego | 3,000 | | | .24 | 2.40 | .87 | 3.51 | | .03 | .28 | .01 | .19 | | .51 | | .01 | .77 | .50 | 1.28 | 5.30 |
| 56 | Chula Vista[1] | do | 9 | | 0.26 | 1.19 | .67 | | 2.12 | Tr. | .20 | .01 | .06 | | | .27 | | .45 | .03 | | .48 | 2.93 |
| 57 | Claremont | Los Angeles | 1,196 | | | | | | | | | | .11 | Tr. | | .11 | Tr. | 1.29 | 3.20 | .40 | 4.89 | 5.22 |
| 58 | Corona[1] | Riverside | 850 | | | | | | | | | | | .12 | | .12 | | | 1.65 | .15 | 1.80 | 2.37 |
| 59 | Cuyamaca | San Diego | 4,677 | | | | 2.56 | 1.12 | 3.68 | | | .47 | | .38 | | .85 | | | 1.71 | 1.82 | 3.53 | 8.06 |
| 60 | El Cajon[1] | do | 560 | | | .14 | 1.12 | 1.35 | 2.61 | | .01 | .19 | .11 | .02 | | .33 | | Tr. | 1.14 | .51 | 1.65 | 5.03 |
| 61 | Elsinore | Riverside | 1,272 | | | | | | | | Tr. | .05 | .06 | .01 | | .12 | | .10 | 2.57 | .04 | 2.71 | 3.48 |
| 62 | Encinitas[1] | San Diego | 200 | | | | .55 | | .55 | | | .18 | .03 | .07 | | .28 | | | .77 | .13 | .90 | 1.73 |
| 63 | Escondido[1] | do | 750 | | | .03 | .65 | .10 | .78 | | | .17 | .14 | .16 | | .47 | | .03 | 1.26 | .61 | 1.90 | 3.26 |
| 64 | Fullerton | Orange | 336 | | | | | | | | | | .18 | | | .18 | | .16 | 5.49 | .32 | 5.97 | 6.24 |
| 65 | Laguna Beach | do | 205 | | | | | | | | Tr. | Tr. | Tr. | .12 | Tr. | .12 | | .10 | 2.00 | .16 | 2.26 | 2.38 |
| 66 | La Mesa[1] | San Diego | 539 | | | .86 | .89 | 1.24 | 2.99 | 0.01 | | .17 | .01 | .07 | Tr. | .26 | | Tr. | 1.00 | .12 | 1.12 | 4.52 |
| 67 | Mill Creek No. 2 | San Bernardino | 2,950 | | | .03 | Tr. | | .03 | | .05 | .10 | .49 | .56 | | 1.20 | Tr. | .40 | 2.68 | .17 | 3.25 | 4.48 |
| 68 | Mount Wilson[3] | Los Angeles | 5,850 | | | | | | | | | | Tr. | .04 | | .04 | | .98 | 9.02 | 1.60 | 11.60 | 11.78 |
| 69 | Point Loma[1] | San Diego | 302 | | | .37 | .50 | .43 | 1.30 | | .04 | .18 | .13 | .08 | | .43 | | .01 | .86 | .07 | .94 | 2.69 |
| 70 | Redlands | San Bernardino | 1,352 | | | | | | | | .03 | .03 | 1.03 | .41 | | 1.50 | .30 | 1.55 | .05 | | 1.90 | 3.45 |

TABLE 1.—*Daily precipitation, in inches, September 3–13, 23–26, 1939*—Continued

**Pacific Coast Basins—Continued**

| Nos. on pls. 2-4 | Station | County | Elevation (feet) | September 3 | 4 | 5 | 6 | 7 | Total Sept. 3-7 | September 8 | 9 | 10 | 11 | 12 | 13 | Total Sept. 8-13 | September 23 | 24 | 25 | 26 | Total Sept. 23-26 | Total for Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CALIFORNIA—Cont. | | | | | | | | | | | | | | | | | | | | | |
| 71 | Riverside[1] | Riverside | 895 | | | | 0.21 | | 0.21 | | | Tr. | Tr. | 0.16 | | 0.16 | 0.02 | 0.57 | 0.23 | | 0 80 | 1.19 |
| 72 | San Bernardino | San Bernardino | 1,172 | | | 0.02 | | | .02 | | | 0 02 | 0.13 | .17 | | .32 | | .10 | 1.72 | 0.06 | 1.88 | 2.22 |
| 73 | San Clemente | Orange | 135 | | | | | | | | Tr. | Tr. | | .05 | | .05 | | .09 | 3.28 | .15 | 3.52 | 3.57 |
| 74 | San Diego[3] | San Diego | 26 | | | .44 | .65 | 0.12 | 1.21 | | 0.06 | .33 | .02 | .30 | | .71 | | Tr. | .47 | Tr. | .47 | 2.58 |
| 75 | San Jacinto | Riverside | 1,550 | | | .17 | .05 | .03 | .25 | | .03 | .20 | .05 | .05 | | .33 | | .10 | 1.15 | | 1.25 | 4.73 |
| 76 | Santa Ana River | San Bernardino | 2,850 | | | .02 | | | .02 | | .05 | .04 | 1.07 | .59 | | 1.75 | | .55 | 3.71 | .17 | 3.43 | 6.91 |
| 77 | Sierra Madre | Los Angeles | 1,050 | | | | | | | | | | .05 | | | .05 | 4.79 | .54 | | | 5.33 | 6.62 |
| 78 | Squirrel Inn | San Bernardino | 5,700 | | | Tr. | | | Tr. | | Tr. | Tr. | .21 | Tr. | | .21 | | .41 | 8.00 | .61 | 9.02 | 9.23 |
| 79 | Tustin[1] | Orange | 125 | | | | | | | | | Tr. | | .27 | | .27 | | | 3.07 | .17 | 3.24 | 3.51 |
| 80 | Warner Springs | San Diego | 3,165 | | | .32 | 1.17 | 1.16 | 2.65 | | | .45 | .03 | .24 | | .72 | | | .68 | .88 | 1.56 | 4.93 |
| 81 | Yorba Linda | Orange | 405 | | | | | | | | | | .05 | .07 | | .12 | | | 2.70 | 1.15 | 3.85 | 4.08 |

**Salton Sea and other enclosed basins**

| Nos. on pls. 2-4 | Station | County | Elevation (feet) | September 3 | 4 | 5 | 6 | 7 | Total Sept. 3-7 | September 8 | 9 | 10 | 11 | 12 | 13 | Total Sept. 8-13 | September 23 | 24 | 25 | 26 | Total Sept. 23-26 | Total for Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CALIFORNIA | | | | | | | | | | | | | | | | | | | | | |
| 82 | Banning | Riverside | 2,305 | | | 0.36 | 0.23 | | 0.59 | 0.08 | 0.03 | 0.14 | 0.01 | | 0.02 | 0.28 | | 0.70 | 3.30 | 0.04 | 4.04 | 4.94 |
| 83 | Brawley | Imperial | —119 | | | 2.53 | 3.80 | | 6.33 | | | | Tr. | 0.42 | | .42 | | | | | | 6.75 |
| 84 | Cow Creek | Inyo | —152 | | | | | | | | | | | | | | | .01 | 1.09 | | 1.10 | 1.49 |
| 85 | El Centro[1] | Imperial | — 52 | | 0.02 | 1.73 | 2.56 | Tr. | 4.31 | | | | Tr. | | .72 | .72 | | | .10 | | .10 | 5.13 |
| 86 | Greenland Ranch | Inyo | —178 | | | | | | | | Tr. | | | | | Tr. | | .01 | .96 | | .97 | 1.57 |
| 87 | Hayfield Reservoir | Riverside | 1,460 | | | 2.59 | 3.05 | 0.40 | 5.95 | | Tr. | | .02 | | | .02 | | | 1.60 | 1.20 | 2.80 | 8.77 |
| 88 | Imperial[1] | Imperial | —65 | | | .39 | 4.08 | .55 | 5.02 | | .01 | | Tr. | | 1.84 | 1.85 | | | .16 | .02 | .18 | 7.06 |
| 89 | Indio | Riverside | —20 | | .15 | 1.15 | .65 | .08 | 2.03 | | .03 | | .03 | 0.09 | | .15 | | 6.45 | .33 | | 6.78 | 8.96 |
| 90 | Kingston | San Bernardino | 2,475 | | | | .70 | | .70 | | | 0.21 | | | | .21 | | .42 | .48 | | .90 | 1.81 |
| 91 | Llano | Los Angeles | 3,400 | | | | | | | | | .07 | | | | .07 | 0.05 | .10 | 1.58 | Tr. | 1.73 | 1.86 |
| 92 | Trona | San Bernardino | 1,656 | | | | | | | | | | | | | | | 1.42 | .81 | | 2.23 | 2.77 |
| 93 | Yucca Grove | do | 3,951 | | .01 | Tr. | .80 | .01 | .82 | | .07 | .10 | .45 | .05 | | .67 | | .28 | .22 | .07 | .57 | 2.22 |

[1]Precipitation measured in the morning, the amount recorded is for the preceding 24 hours.
[2]Included in following measurement.
[3]Precipitation is for the 24-hour period midnight to midnight.
[4]Record missing.

The unusual magnitude of the rainfall in September is brought out by the following table:

TABLE 2.–*Precipitation at stations of the United States Weather Bureau in Arizona and California*

| Station | Length of record (years) | Precipitation (inches) | |
|---|---|---|---|
| | | Mean annual | September 1939 |
| El Centro, Calif. | 8 | 2.97 | 5.13 |
| Imperial, Calif. | 20 | 3.21 | 7.06 |
| Indio, Calif. | 62 | 3.23 | 8.96 |
| Kingman, Ariz. | 37 | 10.81 | 9.85 |
| Needles, Calif. | 50 | 4.69 | 7.61 |
| Parker, Ariz. | 44 | 5.16 | 8.85 |
| Quartzite, Ariz. | 27 | 5.73 | 6.16 |
| Wikieup, Ariz. | ..... | 10.52 | 10.31 |
| Yuma, Ariz. | 70 | 3.47 | 5.13 |

Previous precipitation records were exceeded at many points in the area. A typical example is Parker, Ariz., where 3.43 inches was recorded in 24 hours September 5; in the previous 44 years 1.95 inches was the maximum recorded for a similar period.

At Imperial, Calif., 5.02 inches was recorded in 48 hours September 5–7. This is greater than the annual precipitation in each of the years since 1914, with 3 exceptions, and only 1½ inches less than the greatest annual precipitation since 1914.

At Needles, Calif., 2.70 inches was recorded between 4:30 a.m. and 10:30 a.m. September 6, and almost all of this fell between 7 a.m. and 10:30 a.m.

At Thermal, Calif., the Coachella Valley County Water District reported that about 11 inches of rain fell in 6 hours on September 4.

At Yuma, Ariz., 2.17 inches of rain was recorded between noon and 1:30 p.m. September 4, and the greatest 24-hour fall was 3.70 inches, which exceeds the average annual precipitation of 3.47 inches.

No recording rain gage was in operation in the area covered by this report, but the U. S. Weather Bureau recording gage at Phoenix, Ariz., east of the area and near the outer edge of the first two storms, gave the following record:

TABLE 3.–*Precipitation, in inches, at Phoenix, Ariz., during the 2 hours of greatest intensity of the storms of September 4 and 11, 1939*

| Date | Time period (minutes) | Precipitation (inches) | Date | Time period (minutes) | Precipitation (inches) |
|---|---|---|---|---|---|
| Sept. 4 | 5 | 0.25 | Sept. 11 | 5 | 0.21 |
| | 10 | .43 | | 10 | .42 |
| | 20 | .69 | | 20 | .71 |
| | 30 | .78 | | 30 | .76 |
| | 45 | .98 | | 45 | .81 |
| | 60 | 1.41 | | 60 | .85 |
| | 80 | 1.64 | | 80 | .89 |
| | 120 | 2.20 | | 120 | 1.01 |

The greatest total rainfall and the highest intensity records were set by the first storm, September 3–7, which was general over the entire area. As shown on plate 2, the heaviest rainfall extended from the vicinity of Salton Sea in California northeast to the Grand Canyon

in Arizona. Heavy rainfall occurred in areas outside the scope of this report along Colorado River above Lake Mead. The axis of the second storm, September 8–13, extended from the southern tip of Nevada to Grand Canyon, Ariz., and into southern Utah; a large part of this storm was over drainage basins upstream from Boulder Dam. The third storm, September 23–26, centered in the area about Los Angeles, Calif., and only the fringe touched the area considered in this report.

As seen in table 4, little rainfall preceded the storms of September, and the ground was in its normal parched condition for that time of year. No hail fell in any of the storms.

TABLE 4.–*Precipitation, in inches, August 1 to September 2, 1939, at a few typical stations of the United States Weather Bureau in Arizona and California*

| Station | Elevation above mean sea level (feet) | Precipitation Aug. 1 to Sept. 2, 1939 (inches) |
|---|---|---|
| Wikieup, Ariz. | 1,950 | 1.82 |
| Needles, Calif. | 480 | .80 |
| Parker, Ariz. | 350 | .34 |
| Yuma, Ariz. | 138 | .12 |
| El Centro, Calif. | —52 | .03 |

The topography of the basin had less than the usual effect on precipitation. Normally, precipitation at the lower altitudes increases with the altitude, as illustrated in table 4, but for the storms of September this was not generally true. Detailed study of the relation between rainfall and topography is not possible, owing to the lack of rainfall records in sufficiently large areas and at enough different elevations.

## GENERAL FEATURES OF THE FLOODS

### LOCAL REPORTS

The first of the three floods was by far the most severe in the Colorado River Basin below Boulder Dam. A good index of the relative size of each flood is shown by the total runoff of Williams River at Planet, Ariz., for the highest 4-day period of each flood:

| *Period* | *Runoff in acre-feet* |
|---|---|
| Sept. 5–8 | 123,700 |
| 12–15 | 55,300 |
| 25–28 | 26,700 |

Floods exceeding in magnitude the one of September 25–28 occur frequently. For this reason, that flood has not been considered in detail in this report, and hourly discharge has not been listed for dates later than September 20.

A general idea of the floods is given by the following statements from the Needles (Calif.) Nugget, a weekly newspaper:

Issue of September 8:

Santa Fe train service through Needles was halted as an aftermath of the storm, due to several bridges east of Needles being completely washed out * * *. Highway 66 east of Needles was reported to be in a serious condition with complete washouts of the road in several places.

Issue of September 15:

Damage to the Santa Fe tracks as a result of the latest storm—the second in 10 days—was estimated by officials to be in the neighborhood of $200,000, with damage to crops and property in the desert area from Needles south to Imperial Valley resulting from both storms figured close to one million dollars.

Although but little rain fell in Needles September 11 compared to the torrential deluge of the previous week, the downpour in the desert west of Needles was estimated at nearly 6 inches, with flood waters raging through dry washes, ripping out whole sections of track, undermining highways and creating havoc with all travel and communication lines. A solid wall of water ripped down Piute Wash the night of September 11 and tore out a huge section of Highway 66.

Issue of September 22:

Heaviest loser as a result of the desert deluge is the Santa Fe Railway with approximately 30 miles of track out between Homer, Calif., and Yucca, Ariz., including several bridges. Replacement costs for this damage will run close to $800,000, it was tentatively estimated by J. W. Simpson of the Arizona division.

Issue of September 29:

Needles counted damage to streets and property in and near the city in thousand-dollar figures as the unleashed flood waters of the latest storm caused what is believed to be the most disastrous year in Needles history from the standpoint of storm havoc.

The Mohave Miner (Kingman, Ariz., weekly newspaper) reported September 8 that the storm between September 3 and 7 was the heaviest since 1907. On October 6 this paper reported that along Detrital Wash vegetation was almost completely destroyed. A yucca tree 102 years old, based on tree-ring count, was washed out, indicating it might have been at least that long since a storm of similar intensity had occurred.

The Yuma Sun (Yuma, Ariz., daily newspaper) for September 5 said:

It was the heaviest rainstorm since 1909 * * *. Yuma was virtually isolated. The Southern Pacific Lines suspended train service. The main canal of the Yuma project in California was washed out south of Laguna at Picacho Wash. Water was cut off and the Water Users' hydroelectric plant was closed.

In the city, storm drains were taxed beyond capacity, and sidewalks and paved ways were undermined and washed out. Many motorists from Los Angeles and San Diego said they experienced much difficulty and noticed numerous cars swept away by flash floods in the washes and abandoned.

The Yuma Sun for September 6 reported:

In Imperial Valley, most of which is below sea level, the runoff from higher ground was reported unprecedented, leaving Brawley under a foot of water. One fatality was reported there. With several thousand acres of the Yuma Indian Reservation under water as result of the record rainfall of the past 2 days and overflow of a drainage canal, about 90 Indian families are homeless. The Red Cross is furnishing food for the refugees.

## FLOOD LOSSES

Accurate estimates of losses are impossible to ascertain, particularly as some of the heavier losses were indirect, owing to loss of use, delay, and partial damage. The figures here given cover actual losses due to destruction of property, as measured, in most cases, by the cost of replacement. Information was gathered by correspondence with some of the heaviest losers, from newspaper reports, and where losses were known to have occurred but no figures were available, by estimate based on comparable losses elsewhere. Views of typical forms of flood damage are shown in plates 5 and 6.

Estimated minimum flood losses in the area covered by this report are tabulated below:

| *Type of property* | *Cost of flood damage* |
|---|---|
| Highways | $260,000 |
| Railroads | 3,200,000 |
| Canals | 440,000 |
| Crops | 350,000 |
| Other damage | 70,000 |
| Total | $4,320,000 |

Of the total losses about $1,700,000 occurred in Arizona and $2,620,000 in California. The heaviest single loser was the Atchison, Topeka & Santa Fe Railway, which rebuilt three times, or after each of the three storms, certain parts of its line between Homer, Calif., and Kingman, Ariz. Considerably more than half the damage was caused by the storm of September 3–7; that due to the storm of September 23–26 was relatively small. In a thickly settled area, total flood damage would have been many times greater.

Loss of life due to the flood was small; only two deaths were reported, one from electrocution in Brawley and one from drowning in Phoenix. In the southern California coastal region, however, outside the area covered by this report, the yearly summary for California compiled by the Weather Bureau states that the storm of September 23–26 caused a loss of 45 lives at sea and $2,000,000 damage.

## MEASUREMENT OF FLOOD DISCHARGE

At all regularly operated stream-gaging stations flood discharges were obtained from the gage-height record by means of stage-discharge relations. These relations were defined by current-meter measurements over the usual range of discharge and were extended to cover higher discharges by the methods described in Stream-gaging procedure.[1]

The peak discharge was measured at several points other than gaging stations by the slope-area method, the results of which are given in table 5. Detailed descriptions of slope-area methods, with illustrative examples, will be found in other Geological Survey flood reports, particularly Water-Supply Papers 773–E, 796–G, and 816.

Of the peak discharge in Williams River below the confluence of Big Sandy and Santa Maria Rivers, most of the water is believed to have come from Big Sandy River. On Big Sandy below Burro Creek in the vicinity of Signal, Ariz., where the drainage area is 2,670 square miles, the peak discharge probably approached 100,000 second-feet.

Arroyo Seco with a drainage area of 450 square miles enters Colorado River from the California side about 25 miles upstream from the gaging station Colorado River near Picacho, Calif. At this station there occurred between 2 and 5 a.m. September 5 a peak discharge of 40,800 second-feet. Arroyo Seco, the nearest and only large tributary, must have been the source of this flood, as the flow of Colorado River from upstream at the time was only 9,000 second-feet. Making reasonable assumptions for the flattening of the peak in the 25-mile reach from Arroyo Seco to the Picacho gaging station and for inflow from small

[1]Corbett, D. M., and others, Stream-gaging procedure, a manual describing methods and practices of the Geological Survey: U. S. Geol. Survey Water-Supply Paper 888, pp. 98-109, 1942 [1943].

*A.* KINGMAN TO BOULDER DAM HIGHWAY IN DETRITAL VALLEY.
Photograph by F. S. Anderson.

*B.* SANTA FE RAILWAY AT MOHAVE GAP ON SACRAMENTO WASH NEAR HAVILAND, ARIZ.

Steel bridge crossing wash in upper left corner had to be entirely rebuilt. Complete washout in foreground made construction of long temporary track necessary. Photograph furnished by Atchison, Topeka & Santa Fe Railway.

## TYPICAL FLOOD DAMAGE

*A.* IRRIGATION STRUCTURES IN IMPERIAL VALLEY.
Photograph furnished by Imperial Irrigation District.

B. LARGE FILL IN COLORADO RIVER
Caused by small unnamed wash 4 miles northwest of Topock, Ariz. Railroad bridges and much of the track were destroyed. Photograph furnished by Atchison, Topeka & Santa Fe Railway.

## TYPICAL FLOOD DAMAGE

tributaries, the peak discharge of Arroyo Seco was probably about 40,000 second-feet.

The extremely high peak discharge of Picacho Wash—37,000 second-feet from a drainage area of 41.5 square miles—as compared with nearby streams is not inconsistent with outstanding flood flows in other parts of the country. It should be realized also that the precipitation during the storm of September 3–7 varied greatly in short distances and that actual records of precipitation in this area are very meager.

It is interesting to note that the California Division of Highways concluded from its study of the floods of September 1939 in Imperial Valley that, for practical purposes in computing size of culvert openings, a discharge runoff rate of 200 second-feet per square mile was reasonably safe.

## STAGES AND DISCHARGES AT STREAM-GAGING STATIONS

Records of daily mean discharge for the entire water year 1939 at regular gaging stations in the area covered by this report will be found in Geological Survey Water-Supply Paper 879, Surface Water Supply of the United States, 1939, Part 9, Colorado River Basin. Such records, however, are generally insufficient for the detailed analysis involved in flood studies, which require knowledge of the rate of discharge and corresponding stages at more frequent intervals. To provide such detailed information is one of the principal aims of this report. Therefore, on succeeding pages will be found records for stream-gaging stations, consisting of a description of the place for which the record is given and details concerning the collection and computation of the record. The record includes the daily mean discharge for September 1939, the monthly figures of mean and total runoff, a table of gage heights and discharges at indicated times at stations for which discharges are given, and comparable data for stations at which gage heights only are observed.

At most gaging stations in the area covered by this report the stage-discharge relation is not stable because of shifting of the stream bed. This is illustrated in figure 2, which shows the variation in the average elevation of the bed of Colorado River near Topock, Ariz., from July 1938 to April 1940. The amount of the shift must be taken into account when computing the discharge record. Where this has been done the discharge record is stated as having been obtained by the shifting-control method. Under shifting conditions there is no direct relation between stage and discharge for long periods.

Hydrographs for many of the gaging stations are plotted in figures 3–5.

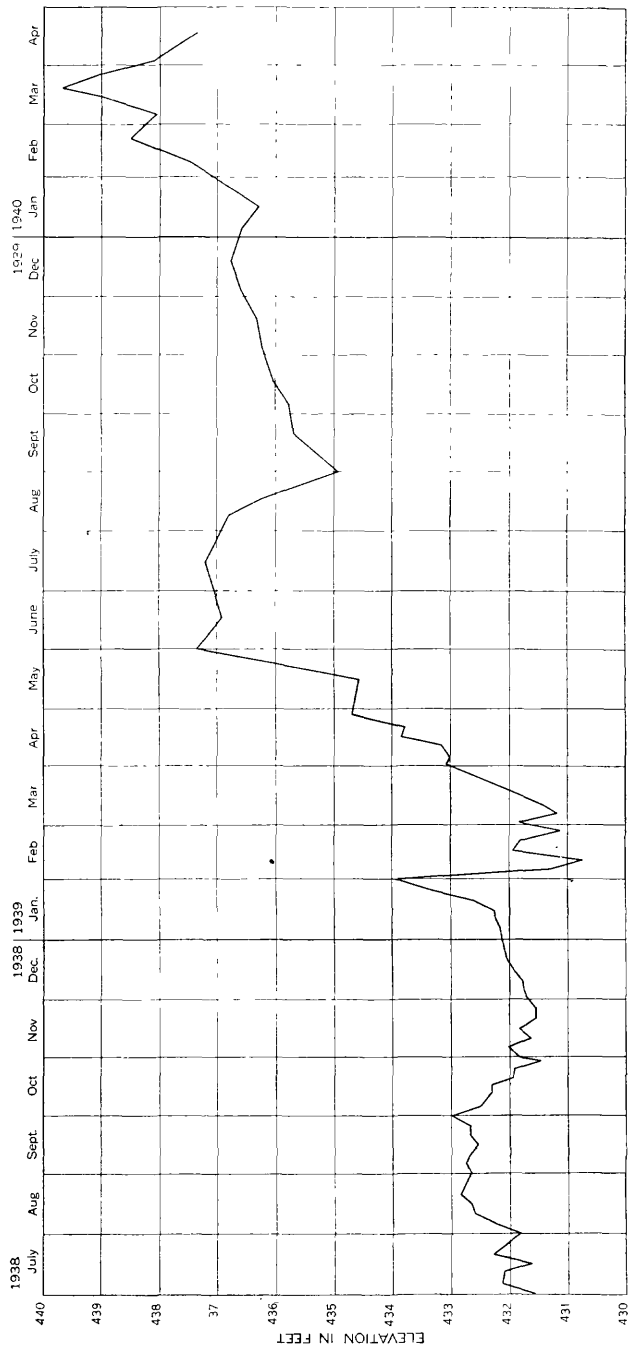


FIGURE 2.—Average height of river bed under cableway at stream-gaging station on Colorado River near Topock, Ariz.

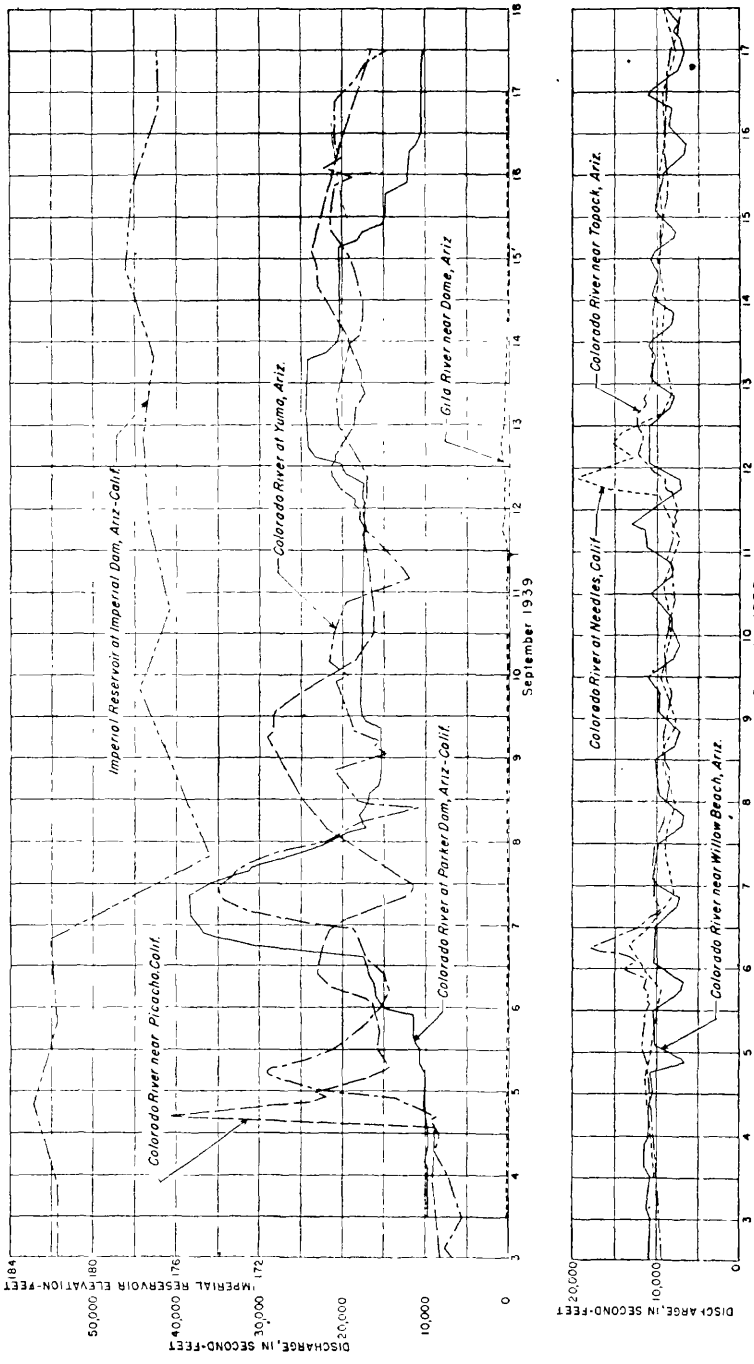


FIGURE 3.—Hydrographs showing discharge at stream-gaging stations in Colorado River Basin and elevations of Imperial Reservoir during flood of September 1939.

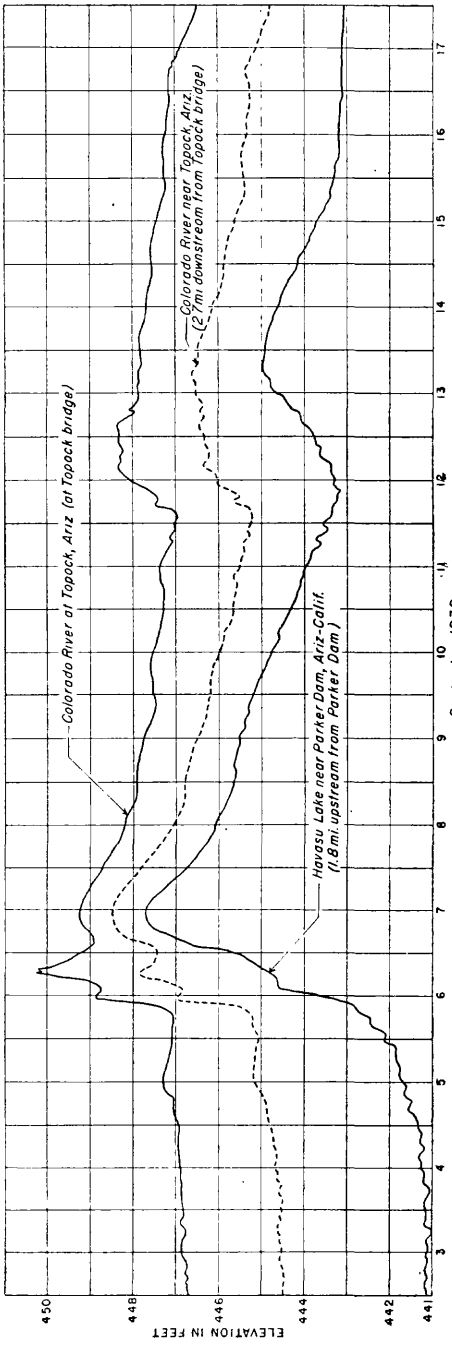


FIGURE 4.—Hydrographs showing elevations of flood stages at stations in Colorado River Basin, September 1939.

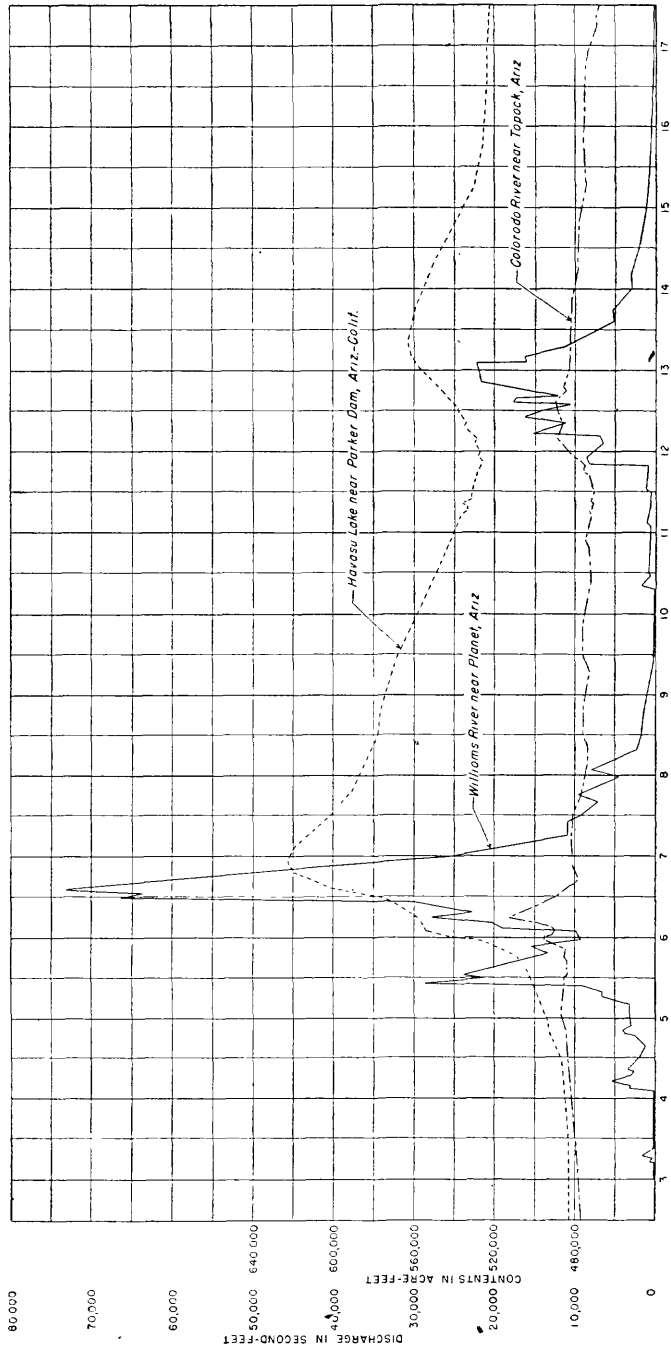


FIGURE 5.—Hydrographs showing discharge at stream-gaging stations in Colorado River Basin and contents of Havasu Lake during flood of September 1939.

## COLORADO RIVER BASIN

### COLORADO RIVER NEAR WILLOW BEACH, ARIZ.

LOCATION.—Lat. 35°53'30", long. 114°41'15", in sec. 19, T. 29 N., R. 22 W., Gila and Salt River meridian, 2 miles upstream from Willow Beach and 10 miles downstream from Boulder Dam. Datum of gage is 595.4 feet (revised) above mean sea level, datum of 1929 (subject to correction).

DRAINAGE AREA.—168,400 square miles (revised).

GAGE-HEIGHT RECORD.—Water-stage recorder graph.

DISCHARGE RECORD.—Stage-discharge relation defined by current-meter measurements. Shifting-control method used.

MAXIMA.—September 1939: Discharge, 13,500 second-feet September 21 (gage height, 27.99 feet).

1935 to August 1939 (regulated): Discharge, 48,400 second-feet February 13, 1939 (gage height, 36.72 feet).

REMARKS.—Discharge completely regulated at Boulder Dam since February 1, 1935. Records computed on basis of mountain standard time.

*Daily discharge, September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 10,700 | 11 | 10,400 | 21 | 12,100 |
| 2 | 10,900 | 12 | 9,750 | 22 | 11,500 |
| 3 | 11,000 | 13 | 9,780 | 23 | 11,600 |
| 4 | 11,100 | 14 | 9,620 | 24 | 9,500 |
| 5 | 9,860 | 15 | 9,410 | 25 | 11,500 |
| 6 | 9,150 | 16 | 8,200 | 26 | 11,800 |
| 7 | 9,170 | 17 | 7,870 | 27 | 11,700 |
| 8 | 8,780 | 18 | 8,990 | 28 | 11,700 |
| 9 | 9,060 | 19 | 10,000 | 29 | 11,500 |
| 10 | 8,570 | 20 | 11,300 | 30 | 9,970 |

Mean ..... second-feet 10,220
Total ..... acre-feet 607,900

*Gage height and discharge at indicated time, 1939*

| Time | Gage height (feet) | Discharge (second-feet) | Time | Gage height (feet) | Discharge (second-feet) | Time | Gage height (feet) | Discharge (second-feet) |
|---|---|---|---|---|---|---|---|---|
| *Sept. 2* | | | *Sept. 8* | | | *Sept. 14* | | |
| 12 p.m. | 27.07 | 11,000 | 5 a.m. | 25.60 | 7,140 | 5 a.m. | 26.06 | 8,240 |
| *Sept. 3* | | | 8 | 25.43 | 6,720 | 7:30 | 25.96 | 7,980 |
| 12 m. | 26.98 | 10,800 | 2 p.m. | 26.61 | 9,780 | 12 m. | 26.75 | 10,100 |
| 3:30 p.m. | 27.11 | 11,100 | 12 | 26.76 | 10,200 | 1:30 p.m. | 26.87 | 10,400 |
| 12 | 26.99 | 10,800 | *Sept. 9* | | | 8 | 26.70 | 9,940 |
| *Sept. 4* | | | 4 a.m. | 25.96 | 7,980 | 12 | 27.00 | 10,800 |
| 4 a.m. | 27.23 | 11,500 | 8 | 25.68 | 7,260 | *Sept. 15* | | |
| 10 | 27.22 | 11,400 | 1:30 p.m | 26.52 | 9,590 | 2 a.m. | 26.84 | 10,300 |
| 1 p.m. | 27.04 | 10,900 | 12 | 26.97 | 10,900 | 8 | 25.92 | 7,870 |
| 12 | 26.91 | 10,600 | *Sept. 10* | | | 2 p.m. | 26.83 | 10,300 |
| *Sept. 5* | | | 5 a.m. | 25.95 | 8,130 | 12 | 26.50 | 9,400 |
| 6 a.m. | 27.03 | 10,800 | 9 | 25.65 | 7,360 | *Sept. 16* | | |
| 9 | 25.46 | 6,720 | 2 p.m. | 26.02 | 8,320 | 6 a.m. | 25.50 | 6,820 |
| 10 | 25.56 | 6,960 | 12 | 26.88 | 10,600 | 8:30 | 25.38 | 6,520 |
| 2 p.m. | 26.80 | 10,200 | *Sept. 11* | | | 2 p.m. | 26.18 | 8,550 |
| 12 | 26.87 | 10,400 | 5 a.m. | 26.08 | 8,390 | 7 | 26.02 | 8,130 |
| *Sept. 6* | | | 7 | 26.00 | 8,190 | 12 | 26.98 | 10,700 |
| 4 a.m. | 25.93 | 7,870 | 1 p.m. | 27.17 | 11,300 | *Sept. 17* | | |
| 8 | 25.53 | 6,760 | 8 | 27.80 | 13,100 | 6 a.m. | 25.84 | 7,620 |
| 1:30 p.m. | 26.88 | 10,400 | 12 | 27.11 | 11,200 | 11 | 25.50 | 6,760 |
| 12 | 26.80 | 10,200 | *Sept. 12* | | | 3:30 p.m. | 25.70 | 7,260 |
| *Sept. 7* | | | 6 a.m. | 25.65 | 7,190 | 5:30 | 26.03 | 8,110 |
| 6 a.m. | 25.69 | 7,390 | 1 p.m. | 27.11 | 11,100 | 8 | 25.76 | 7,420 |
| 12 m. | 26.64 | 9,880 | 12 | 27.10 | 11,000 | 12 | 26.29 | 8,780 |
| 1:30 p.m. | 26.82 | 10,400 | *Sept. 13* | | | | | |
| 12 | 26.60 | 9,780 | 5 a.m. | 26.14 | 8,420 | | | |
| | | | 8:30 | 25.96 | 7,950 | | | |
| | | | 1 p.m. | 26.95 | 10,600 | | | |
| | | | 8 | 26.83 | 10,300 | | | |
| | | | 12 | 27.04 | 10,800 | | | |

### COLORADO RIVER AT NEEDLES, CALIF.

LOCATION.—Lat. 34°50'50", long. 114°36'15", in NW¼ sec. 29, T. 9 N., R. 23 E. San Bernardino meridian, at Needles, Calif., 18 miles upstream from gaging station near Topock, Ariz., 57.5 miles upstream from Parker Dam, and 98 miles downstream from Boulder Dam. Datum of gage is 466.23 feet, datum of 1929, or 466.39 feet, adjustment of 1912, above mean sea level.

DRAINAGE AREA.—170,600 squre miles.

GAGE-HEIGHT RECORD.—Water-stage recorder graph. Gage readings have been reduced to elevation above mean sea level, datum of 1929.

DISCHARGE RECORD.—Stage-discharge relation defined by comparison with discharge at gaging stations near Topock and near Willow Beach during periods of normal flow, allowance being made for time interval and normal loss in flow. Shifting-control method used.

MAXIMA.—September 1939: Discharge, 19,500 second-feet 2 a.m. Sept. 12 (elevation, 470.29 feet).

1935 to August 1939 (regulated): Discharge, about 36,000 second-feet Feb. 1, 1939 (elevation, 471.13 feet).

1931–34 (unregulated): Elevation, 472.10 feet June 25, 1933.

REMARKS.—Discharge completely regulated at Boulder Dam since Feb. 1, 1935. No diversions below Boulder Dam. Records computed on basis of mountain standard time.

*Daily discharge, September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 10,300 | 11 | 8,220 | 21 | 10,600 |
| 2 | 9,610 | 12 | 14,300 | 22 | 11,200 |
| 3 | 9,890 | 13 | 9,210 | 23 | 11,100 |
| 4 | 10,600 | 14 | 9,310 | 24 | 11,900 |
| 5 | 10,600 | 15 | 9,560 | 25 | 11,300 |
| 6 | 10,800 | 16 | 9,340 | 26 | 11,800 |
| 7 | 8,580 | 17 | 8,320 | 27 | 11,800 |
| 8 | 8,560 | 18 | 8,470 | 28 | 11,400 |
| 9 | 8,610 | 19 | 8,420 | 29 | 11,200 |
| 10 | 8,820 | 20 | 9,560 | 30 | 10,400 |

Mean ..... second-feet 10,130
Total ..... acre-feet 602,600

*Elevation and discharge at indicated time, 1939*

| Time | Elevation (feet) | Discharge (second-feet) | Time | Elevation (feet) | Discharge (second-feet) | Time | Elevation (feet) | Discharge (second-feet) |
|---|---|---|---|---|---|---|---|---|
| *Sept. 3* | | | *Sept. 9* | | | *Sept. 13* | | |
| 12 p.m. | 468.97 | 10,100 | 4 a.m. | 468.76 | 8,970 | 4 a.m. | 468.83 | 9,340 |
| *Sept. 4* | | | 10 | 468.52 | 7,790 | 9 | 468 61 | 8,220 |
| 12 m. | 469.06 | 10,600 | 12 m. | 468.52 | 7,790 | 1 p.m. | 468.70 | 8,660 |
| 12 p.m. | 469.11 | 10,900 | 12 p.m. | 468.87 | 9,560 | 12 | 468.87 | 9,560 |
| *Sept. 5* | | | *Sept. 10* | | | *Sept. 14* | | |
| 4 a.m. | 469,13 | 11,100 | 12 m. | 468.63 | 8,320 | 12 m. | 468 76 | 8,970 |
| 12 m. | 469.09 | 10,800 | 4 p.m. | 468.63 | 8,320 | 12 p.m. | 468 93 | 9,890 |
| 12 p.m. | 468.93 | 9,890 | 12 | 468.77 | 9,020 | *Sept. 15* | | |
| *Sept. 6* | | | *Sept. 11* | | | 9 a.m. | 468.80 | 9,180 |
| 6 a.m. | 468.87 | 9,560 | 3 a.m. | 468.79 | 9,130 | 12 p.m | 468 91 | 9,780 |
| 11 | 469.15 | 11,200 | 4 p.m. | 468.39 | 7,210 | *Sept. 16* | | |
| 3 p.m. | 469.03 | 10,500 | 12 | 468.73 | 8,820 | 12 m. | 468 76 | 8,970 |
| 7 | 469.46 | 13,200 | *Sept. 12* | | | 12 p.m. | 468.82 | 9,290 |
| 12 | 469.10 | 10,900 | 4 a.m. | 468.90 | 9,720 | *Sept. 17* | | |
| *Sept. 7* | | | 6 a.m. | 469.80 | 15,700 | 12 m. | 468 51 | 7,750 |
| 10 a.m. | 468.50 | 7,700 | 9 | 470.29 | 19,500 | 12 p.m. | 468.74 | 8,870 |
| 12 m. | 468.53 | 7,840 | 3 p.m. | 469.42 | 12,900 | | | |
| 10 p.m. | 468.77 | 9,020 | 5 | 469.63 | 14,400 | | | |
| 12 | 468.77 | 9,020 | 7 | 469.73 | 15,200 | | | |
| *Sept. 8* | | | 10 | 469.58 | 14,100 | | | |
| 4 a.m. | 468.73 | 8,820 | 12 | 469.37 | 12,600 | | | |
| 11 | 468.52 | 7,790 | | | | | | |
| 10 p.m. | 468.83 | 9,340 | | | | | | |
| 12 | 468.82 | 9,290 | | | | | | |

### COLORADO RIVER AT TOPOCK, ARIZ.

LOCATION.—Lat. 34°42'55", long. 114°29'10", in SE¼NE¼ sec. 8, T. 7 N., R. 24 E., San Bernardino meridian, at highway bridge at Topock, immediately downstream from Sacramento Wash, 2.7 miles upstream from gaging station Colorado River near Topock, 42.2 miles upstream from Parker Dam, and 113 miles downstream from Boulder Dam. Datum of gage is 436.35 feet, datum of 1929, or 436.52 feet, adjustment of 1912, above mean sea level.

GAGE-HEIGHT RECORD.—Water-stage recorder graph. Gage readings have been reduced to elevation above mean sea level, datum of 1929.

MAXIMA.—1939: Elevation, 450.20 feet 6:15 p.m. Sept. 6.
1935–38 (regulated): Elevation, 445.25 feet Nov. 16, 1938.

REMARKS.—This station operated as an auxiliary to the station near Topock to measure the fall between the two. Station affected by back-water from Havasu Lake since November 4, 1938. Records computed on basis of mountain standard time.

*Elevation at indicated time, 1939*

| Time | Elevation (feet) | Time | Elevation (feet) | Time | Elevation (feet) | Time | Elevation (feet) |
|---|---|---|---|---|---|---|---|
| *Sept. 1* | | *Sept. 6* | | *Sept. 10* | | *Sept. 13* | |
| 12 p.m. | 446.93 | 6:35 p.m. | 450.18 | 8 a.m. | 447.58 | 1:30 p.m. | 448.34 |
| *Sept. 2* | | 9 | 449.66 | 11 | 447.57 | 3:30 | 448.39 |
| 12 p.m. | 446.73 | 10 | 449.49 | 12 p.m. | 447.31 | 6:30 | 447.96 |
| *Sept. 3* | | 12 | 449.19 | *Sept. 11* | | 7:30 | 448.10 |
| 12 p.m. | 446.86 | *Sept. 7* | | 8 a.m. | 447.39 | 8:30 | 448.05 |
| *Sept. 4* | | 2 a.m. | 448.96 | 1 p.m. | 447.38 | 12 m. | 447.90 |
| 12 p.m. | 446.96 | 3 | 448.90 | 5 | 447.18 | 5 p.m. | 447.90 |
| *Sept. 5* | | 4 | 448.92 | 7 | 447.09 | 12 | 447.86 |
| 8 a.m. | 447.10 | 5 | 448.97 | 8 p.m. | 447.14 | *Sept. 14* | |
| 10:30 | 447.30 | 7 | 449.14 | 9 | 447.08 | 5:30 a.m. | 447.87 |
| 12 p.m. | 447.11 | 9 | 449.24 | 12 | 447.03 | 7 p.m. | 447.57 |
| *Sept. 6* | | 12 m | 449.24 | *Sept. 12* | | 12 | 447.58 |
| 1:30 a.m. | 447.08 | 3 p.m. | 449.13 | 1:40 a.m. | 446.97 | *Sept. 15* | |
| 6:30 | 447.13 | 6 | 449.03 | 4:50 | 447.19 | 8 a.m. | 447.60 |
| 8:30 | 447.29 | 12 | 448.77 | 5:30 | 447.42 | 6 p.m. | 447.33 |
| 9:30 | 447.74 | *Sept. 8* | | 9 | 447.59 | 12 | 447.30 |
| 11 | 448.45 | 6 a.m. | 448.51 | 11 | 447.94 | *Sept. 16* | |
| 11:30 | 448.74 | 11 | 448.30 | 12 m | 448.05 | 7 a.m. | 447.34 |
| 12:30 p.m. | 448.86 | 3 p.m. | 448.09 | 3 p.m. | 448.34 | 1 p.m. | 447.25 |
| 1 | 448.82 | 12 | 447.94 | 4 | 448.37 | 12 | 447.16 |
| 2 | 448.78 | *Sept. 9* | | 9 | 448.24 | *Sept. 17* | |
| 3:15 | 448.87 | 7 a.m. | 447.90 | 12 | 448.36 | 6 a.m. | 447.15 |
| 4:30 | 449.35 | 10 | 447.86 | | | 9 | 447.09 |
| 5 | 449.76 | 7 p.m. | 447.52 | | | 5 p.m. | 446.69 |
| 6:15 | 450.20 | 12 | 447.52 | | | 12 | 446.55 |

### COLORADO RIVER NEAR TOPOCK, ARIZ.

LOCATION.—Lat. 34°41'15", long. 114°27'45", in NW¼ sec. 13, T. 15 N., R. 21 W., Gila and Salt River meridian, in Mohave Canyon, 2.7 miles downstream from Topock, 39.5 miles upstream from Parker Dam, and 116 miles downstream from Boulder Dam. Datum of gage is 423.02 feet, datum of 1929, or 423.08 feet, adjustment of 1912, above mean sea level.

DRAINAGE AREA.—172,300 square miles (revised).

GAGE-HEIGHT RECORD.—Water-stage recorder graph. Gage heights have been reduced to elevation above mean sea level, datum of 1929.

DISCHARGE RECORD.—Fall between auxiliary gage at Topock bridge and this station was used as a factor in obtaining discharge. Stage-discharge relation for normal fall defined by current-meter measurements and by comparison with discharge at gaging station near Willow Beach, allowance being made for time interval and normal loss in flow. Shifting-control method used. Owing to rapidly shifting control, fall, and backwater Sept. 6 and 7, discharge at indicated times is fair; for all other periods, excellent.

MAXIMA.—September 1939: Discharge, 18,000 second-feet 6:15 p.m. Sept. 6 (elevation, 447.87 feet); elevation, 448.55 feet Sept. 7.
1935 to August 1939 (regulated): Discharge, 34,900 second-feet Feb. 2, 1939 (elevation, 447.20 feet).
1917–34 (unregulated): Discharge, probably exceeded 200,000 second-feet June 22, 1921.

REMARKS.—Discharge regulated at Boulder Dam since Feb. 1, 1935. Station affected by backwater from Havasu Lake since Nov. 4, 1938. No diversions below Boulder Dam. Records computed on basis of mountain standard time.

*Daily discharge, September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 10,900 | 11 | 8,330 | 21 | 9,740 |
| 2 | 10,600 | 12 | 10,300 | 22 | 11,200 |
| 3 | 10,300 | 13 | 11,200 | 23 | 11,300 |
| 4 | 10,400 | 14 | 10,400 | 24 | 12,000 |
| 5 | 11,400 | 15 | 9,460 | 25 | 12,100 |
| 6 | 13,000 | 16 | 8,890 | 26 | 11,300 |
| 7 | 10,400 | 17 | 8,060 | 27 | 11,200 |
| 8 | 9,270 | 18 | 7,360 | 28 | 11,400 |
| 9 | 8,610 | 19 | 7,560 | 29 | 11,300 |
| 10 | 8,820 | 20 | 8,420 | 30 | 11,100 |

Mean ..... second-feet 10,180
Total ..... acre-feet 605,600

*Elevation and discharge at indicated time, 1939*

| Time | Elevation (feet) | Discharge (second-feet) | Time | Elevation (feet) | Discharge (second-feet) | Time | Elevation (feet) | Discharge (second-feet) |
|---|---|---|---|---|---|---|---|---|
| *Sept. 1* | | | *Sept. 7* | | | *Sept. 12* | | |
| 12 p.m. | 444.69 | 11,000 | 2 a.m. | 447.56 | 11,200 | 4:50 a.m. | 445.36 | 8,100 |
| *Sept. 2* | | | 4 | 448.08 | 9,960 | 6:30 | 445.64 | 8,880 |
| 12 p.m. | 444.51 | 10,100 | 5 | 448.27 | 9,520 | 9 | 445.68 | 9,340 |
| *Sept. 3* | | | 9 | 448.53 | 10,200 | 11 | 446.00 | 10,600 |
| 12 p.m. | 444.57 | 10,300 | 3 p.m. | 448.41 | 10,300 | 1 p.m. | 446.10 | 11,300 |
| *Sept. 4* | | | 12 | 447.83 | 10,200 | 4 | 446.35 | 12,200 |
| 12 p.m. | 444.79 | 11,000 | *Sept. 8* | | | 7:30 | 446.25 | 11,700 |
| *Sept. 5* | | | 6 a.m. | 447.41 | 9,390 | 12 | 446.33 | 12,200 |
| 8 a.m. | 444.98 | 11,000 | 3 p.m. | 446.96 | 8,510 | *Sept. 13* | | |
| 1 p.m. | 445.21 | 11,700 | 12 | 446.78 | 8,840 | 1:30 a.m. | 446.61 | 12,300 |
| 12 | 445.12 | 11,300 | *Sept. 9* | | | 5:30 | 446.37 | 11,500 |
| *Sept. 6* | | | 7 a.m. | 446.69 | 8,970 | 8:30 | 446.41 | 11,300 |
| 1:30 a.m. | 445.12 | 10,800 | 7 p.m. | 446.31 | 8,210 | 2 p.m. | 446.55 | 10,700 |
| 5 | 445.21 | 10,900 | 12 | 446.23 | 8,930 | 12 | 446.50 | 10,700 |
| 6:30 | 445.28 | 11,200 | *Sept. 10* | | | *Sept. 14* | | |
| 9:30 | 445.95 | 11,900 | 8 a.m. | 446.14 | 9,090 | 5:30 a.m | 446.37 | 10,600 |
| 11 | 446.86 | 13,100 | 10 p.m. | 445.72 | 7,960 | 12 p.m. | 445.89 | 9,770 |
| 11:30 | 446.95 | 13,600 | 12 | 445.69 | 7,970 | *Sept. 15* | | |
| 1 p.m. | 446.86 | 12,900 | *Sept. 11* | | | 8 a.m. | 445.79 | 9,690 |
| 2 | 446.88 | 12,400 | 8 a.m. | 445.62 | 8,260 | 12 p.m. | 445.44 | 8,780 |
| 4:30 | 447.35 | 14,700 | 9:30 | 445.66 | 8,610 | *Sept. 16* | | |
| 5 | 447.68 | 16,500 | 5 p.m. | 445.42 | 7,990 | 7 a.m. | 445.47 | 9,050 |
| 6:15 | 447.87 | 18,100 | 6:30 | 445.46 | 8,130 | 12 p.m. | 445.31 | 8,690 |
| 9 | 447.56 | 15,000 | 8 | 445.37 | 7,820 | *Sept. 17* | | |
| 10 | 447.48 | 14,000 | 9 | 445.33 | 7,770 | 6 a.m. | 445.23 | 8,700 |
| 12 | 447.43 | 12,200 | 12 | 445.29 | 7,640 | 1 p.m. | 445.14 | 8,110 |
| | | | | | | 5 p.m. | 444.96 | 7,480 |
| | | | | | | 12 | 444.86 | 7,180 |

### HAVASU LAKE NEAR PARKER DAM, ARIZ.-CALIF.

LOCATION.—Gage is at lat. 34°19′, long. 114°09′, in SW¼ sec. 28, T. 3 N., R. 27 E., San Bernardino meridian, at intake pumping plant of Metropolitan Water District of Southern California, 1.3 miles upstream from Williams River and 1.8 miles upstream from Parker Dam, which is 156 miles downstream from Boulder Dam. Datum of gage is 400.54 feet, datum of 1929, or 400.00 feet adjustment of 1912, above mean sea level.

DRAINAGE AREA.—178,800 square miles (revised) at Parker Dam.

GAGE-HEIGHT RECORD.—Water-stage recorder graph. Gage heights have been reduced to elevation above mean sea level, datum of 1929.

CONTENTS RECORD.—Stage-contents relation defined by capacity table based on surveys by the Metropolitan Water District of Southern California and measurement by planimeter of areas within the contours as plotted from the surveys. Contents during flood were computed by applying elevation of water surface to capacity table.

MAXIMA.—September 1939: Contents, 622,500 acre-feet 10 a.m. Sept. 7 (elevation, 447.72 feet).

1938 to August 1939: Contents, 524,300 acre-feet Feb. 2, 1939 (elevation, 433.16 feet).

REMARKS.—Storage in lake was begun July 1, 1938. Lake is used for flood control, for re-regulation of river for irrigation demand, and as a basin from which water is pumped to Colorado River aqueduct. Usable capacity of reservoir 688,000 acre-feet, between elevations 400.54 feet (sill of regulating gates) and 450.54 feet (top of regulating gates). Contents not available for release and not included above, 28,600 acre-feet below elevation 400.54 feet. Draw-down below elevation 440.54 feet (contents, 472,000 acre-feet) not legally permissible except in an emergency affecting the safety of the dam or by consent of the Metropolitan Water District of Southern California. Records computed on basis of mountain standard time.

During storm runoff, elevation of water surface at the gage may not necessarily be representative of the elevation of the lake as a whole because storm inflow, concentrated at certain points, cannot affect the general lake elevation instantaneously. For this reason, rates of storm inflow for short intervals of time cannot be computed accurately from the rate of increase in contents as recorded at any one point, such as at this gaging station.

*Elevation at 12 p.m. and usable contents, September 1939*

| Day | Elevation (feet) | Contents (acre-feet) | Day | Elevation (feet) | Contents (acre-feet) |
|---|---|---|---|---|---|
| 1 | 441.10 | 482,700 | 16 | 443.14 | 523,900 |
| 2 | 441.12 | 483,100 | 17 | 443.02 | 521,600 |
| 3 | 441.14 | 483,500 | 18 | 442.88 | 518,400 |
| 4 | 441.32 | 486,900 | 19 | 442.66 | 514,000 |
| 5 | 442.14 | 503,500 | 20 | 442.62 | 513,200 |
| 6 | 445.66 | 577,100 | 21 | 442.66 | 514,000 |
| 7 | 446.74 | 600,900 | 22 | 442.84 | 517,600 |
| 8 | 445.70 | 577,800 | 23 | 442.98 | 520,500 |
| 9 | 445.24 | 568,000 | 24 | 443.24 | 526,200 |
| 10 | 444.34 | 549,300 | 25 | 444.06 | 543,400 |
| 11 | 443.50 | 531,400 | 26 | 444.36 | 549,500 |
| 12 | 443.82 | 538,400 | 27 | 444.54 | 553,500 |
| 13 | 444.94 | 561,700 | 28 | 444.62 | 555,200 |
| 14 | 444.18 | 545,900 | 29 | 444.66 | 555,800 |
| 15 | 443.36 | 528,700 | 30 | 444.42 | 550,800 |

Change in contents, in acre-feet ..... +68,700

*Elevation and usable contents at indicated time, 1939*

| Time | Elevation (feet) | Contents (acre-feet) | Time | Elevation (feet) | Contents (acre-feet) | Time | Elevation (feet) | Contents (acre-feet) |
|---|---|---|---|---|---|---|---|---|
| *Sept. 1* | | | *Sept. 7* | | | *Sept. 12* | | |
| 12 p.m. | 441.10 | 482,700 | 7 a.m. | 447.55 | 618,700 | 11 a.m. | 443.34 | 528,300 |
| *Sept. 2* | | | 10 | 447.72 | 622,500 | 3 p.m. | 443.42 | 530,000 |
| 12 p.m. | 441.12 | 483,100 | 3 p.m. | 447.57 | 619,200 | 7:30 | 443.66 | 535,000 |
| *Sept. 3* | | | 12 | 446.74 | 600,900 | 12 | 443.82 | 538,400 |
| 12 p.m. | 441.14 | 483,500 | *Sept. 8* | | | *Sept. 13* | | |
| *Sept. 4* | | | 6 a.m. | 446.37 | 592,800 | 1:30 a.m. | 443.86 | 539,200 |
| 12 p.m. | 441.32 | 487,100 | 3 p.m. | 445.98 | 584,200 | 3:30 | 444.00 | 542,200 |
| *Sept. 5* | | | 12 | 445.70 | 578,000 | 6:30 | 444.13 | 544,900 |
| 8 a.m. | 441.63 | 493,300 | *Sept. 9* | | | 8:30 | 444.40 | 550,600 |
| 10:30 | 441.66 | 493,900 | 7 a.m. | 445.64 | 576,700 | 2 p.m. | 444.81 | 559,200 |
| 1 p.m. | 441.74 | 495,500 | 7 p.m. | 445.37 | 570,900 | 8 | 444.96 | 563,000 |
| 12 | 442.14 | 503,500 | 12 | 445.24 | 568,200 | 12 | 444.94 | 561,900 |
| *Sept. 6* | | | *Sept. 10* | | | *Sept. 14* | | |
| 1:30 a.m. | 442.11 | 502,900 | 8 a.m. | 444.92 | 561,500 | 5:30 a.m. | 444.85 | 560,000 |
| 5 | 442.47 | 510,100 | 12 p.m. | 444.34 | 549,300 | 7 p.m. | 444.43 | 551,200 |
| 8:30 | 442.82 | 517,400 | *Sept. 11* | | | 12 | 444.18 | 545,900 |
| 11 | 443.25 | 526,400 | 8 a.m. | 444.10 | 544,300 | *Sept. 15* | | |
| 11:30 | 443.45 | 530,600 | 1 p.m. | 443.94 | 540,900 | 8 a.m. | 443.90 | 540,100 |
| 12:30 p.m. | 444.09 | 544,000 | 5 | 443.76 | 537,100 | 6 p.m. | 443.48 | 531,200 |
| 2 | 444.54 | 553,500 | 7 | 443.59 | 533,600 | 12 | 443.36 | 528,700 |
| 4:30 | 444.69 | 556,600 | 9 | 443.61 | 534,000 | *Sept. 16* | | |
| 6:15 p.m. | 444.82 | 559,400 | 12 | 443.50 | 531,200 | 7 a.m. | 443.23 | 526,000 |
| 9 | 445.16 | 566,500 | *Sept. 12* | | | 12 p.m. | 443.14 | 524,100 |
| 12 | 445.66 | 577,100 | 1:40 a.m. | 443.42 | 530,000 | *Sept. 17* | | |
| *Sept. 7* | | | 5:30 | 443.33 | 528,100 | 6 a.m. | 443.14 | 524,100 |
| 2 a.m. | 446.57 | 597,200 | 7:30 | 443.28 | 527,000 | 5 p.m. | 443.09 | 523,000 |
| 4 | 447.03 | 607,300 | 9 | 443.25 | 526,400 | 12 | 443.02 | 521,600 |

### COLORADO RIVER BELOW PARKER DAM, ARIZ.-CALIF.

LOCATION.—Lat. 34°15'30", long. 114°09'10", in NE¼ sec. 32, T. 11 N., R. 18 W., Gila and Salt River meridian, 4.1 miles downstream from Parker Dam, 14 miles northeast of Parker, Ariz., and 160 miles downstream from Boulder Dam. Datum of gage is 346.16 feet, datum of 1929, or 345.61 feet, adjustment of 1912, above mean sea level.

DRAINAGE AREA.—178,800 square miles (revised).

GAGE-HEIGHT RECORD.—Water-stage recorder graph.

DISCHARGE RECORD.—Stage-discharge relation defined by current-meter measurements up to 24,000 second-feet and extended above on basis of area-velocity curve studies. Shifting-control method used.

MAXIMA.—1939: Discharge, 38,500 second-feet 9 p.m. Sept. 7 (gage height, 30.31 feet).

1935–38 (regulated): Discharge, 42,400 second-feet Feb. 8, 1937 (gage height, 33.07 feet).

REMARKS.—Flow regulated at Boulder Dam and food inflow below Boulder Dam partially regulated at Parker Dam. Records computed on basis of mountain standard time.

*Daily discharge, September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 9,910 | 11 | 17,500 | 21 | 9,440 |
| 2 | 9,910 | 12 | 17,800 | 22 | 9,440 |
| 3 | 9,930 | 13 | 24,000 | 23 | 9,480 |
| 4 | 9,950 | 14 | 21,800 | 24 | 9,480 |
| 5 | 10,200 | 15 | 19,100 | 25 | 9,960 |
| 6 | 14,000 | 16 | 12,700 | 26 | 10,800 |
| 7 | 33,200 | 17 | 10,500 | 27 | 10,800 |
| 8 | 23,700 | 18 | 9,900 | 28 | 10,900 |
| 9 | 15,800 | 19 | 9,520 | 29 | 11,200 |
| 10 | 17,800 | 20 | 9,480 | 30 | 13,800 |
| Mean | | | | | second-feet 13,730 |
| Total | | | | | acre-feet 817,200 |

*Gage height and discharge at indicated time, 1939*

| Time | Gage height (feet) | Discharge (second-feet) | Time | Gage height (feet) | Discharge (second-feet) | Time | Gage height (feet) | Discharge (second-feet) |
|---|---|---|---|---|---|---|---|---|
| *Sept. 3* | | | *Sept. 7* | | | *Sept. 12* | | |
| 12 p.m. | 21.32 | 9,920 | 9 p.m. | 30.31 | 38,500 | 10 p.m. | 25.60 | 19,800 |
| *Sept. 4* | | | 12 | 29.81 | 36,200 | 12 | 25.79 | 20,300 |
| 2:30 p.m. | 21.33 | 9,940 | *Sept. 8* | | | *Sept. 13* | | |
| 3:55 | 21.41 | 10,100 | 4 a.m. | 28.74 | 31,300 | 3 a.m. | 26.75 | 24,300 |
| 12 | 21.33 | 9,900 | 11 | 26.70 | 23,200 | 12 p.m. | 27.02 | 24,300 |
| *Sept. 5* | | | 3 p.m. | 25.45 | 19,300 | *Sept. 14* | | |
| 6:30 a.m. | 21.42 | 10,100 | 5 | 24.83 | 17,600 | 7:30 a.m. | 26.96 | 24,100 |
| 12 p.m. | 21.78 | 10,800 | 8 | 24.99 | 18,000 | 9 | 26.30 | 21,900 |
| *Sept. 6* | | | 12 | 24.58 | 16,900 | 12 p.m. | 25.86 | 20,500 |
| 2 a.m. | 21.96 | 11,300 | *Sept. 9* | | | *Sept. 15* | | |
| 9:50 | 22.09 | 11,500 | 2 a.m. | 24.53 | 16,800 | 3:15 p.m | 25.86 | 20,500 |
| 1 p.m. | 23.63 | 15,500 | 6 | 24.02 | 15,600 | 7:15 | 24.80 | 17,500 |
| 4 | 23.85 | 16,100 | 9 p.m. | 23.98 | 15,500 | 12 | 23.73 | 14,900 |
| 12 | 24.12 | 16,900 | 12 | 24.81 | 17,600 | *Sept. 16* | | |
| *Sept. 7* | | | *Sept. 10* | | | 10 a.m. | 22.55 | 12,300 |
| 3 a.m. | 24.36 | 17,600 | 12 p.m. | 24.87 | 17,700 | 12 p.m. | 21.69 | 10,500 |
| 6:20 | 28.21 | 30,500 | *Sept. 11* | | | *Sept. 17* | | |
| 9 | 29.62 | 35,800 | 12 p.m. | 24.76 | 17,400 | 12 p.m. | 21.48 | 10,200 |
| 10 | 29.86 | 36,700 | *Sept. 12* | | | | | |
| 3 p.m | 30.23 | 28,300 | 4 p.m. | 24.84 | 17,600 | | | |

### COLORADO RIVER NEAR PICACHO, CALIF.

LOCATION.—Lat. 33°02'00", long. 114°33'00", in NW¼ sec. 22, T. 13 S., R. 23 E., San Bernardino meridian, 4 miles downstream from Picacho, 14.5 miles upstream from Imperial Dam, 133 miles downstream from Parker Dam, and 289 miles downstream from Boulder Dam. Datum of gage is 167.38 feet above mean sea level, datum of 1929.

DRAINAGE AREA.—184,100 square miles (revised).

GAGE-HEIGHT RECORD.—Water-stage recorder graph. Gage heights have been reduced to elevation above mean sea level, datum of 1929.

DISCHARGE RECORD.—Stage-discharge relation defined by current-meter measurements up to 25,000 second-feet and extended above. Shifting-control method used.

MAXIMA.—1939: Discharge, 40,800 second-feet 4:50 a.m. Sept. 5 (elevation, 186.13 feet).

1935–38 (regulated): Discharge, 26,900 second-feet Feb. 10, 1937 (elevation, 179.47 feet).

REMARKS.—Flow regulated at Boulder Dam and flood inflow between Boulder and Parker Dams partially regulated at Parker Dam; inflow below Parker Dam unregulated. Diversions between station and Parker Dam had no effect on flood flow. Elevation of spillway crest of Imperial Dam 181.0 feet. Records computed on basis of mountain standard time.

*Daily discharge September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 8,470 | 11 | 16,600 | 21 | 8,900 |
| 2 | 8,500 | 12 | 18,700 | 22 | 8,990 |
| 3 | 8,500 | 13 | 19,100 | 23 | 9,720 |
| 4 | 8,960 | 14 | 19,400 | 24 | 10,100 |
| 5 | 21,100 | 15 | 23,100 | 25 | 10,400 |
| 6 | 18,100 | 16 | 21,400 | 26 | 12,100 |
| 7 | 18,800 | 17 | 15,400 | 27 | 10,900 |
| 8 | 18,500 | 18 | 10,300 | 28 | 10,900 |
| 9 | 27,400 | 19 | 9,490 | 29 | 10,700 |
| 10 | 21,800 | 20 | 8,940 | 30 | 11,000 |

Mean ..... second-feet 14,210
Total ..... acre-feet 845,500

*Elevation and discharge at indicated time, 1939*

| Time | Elevation (feet) | Discharge (second-feet) | Time | Elevation (feet) | Discharge (second-feet) | Time | Elevation (feet) | Discharge (second-feet) |
|---|---|---|---|---|---|---|---|---|
| *Sept. 3* | | | *Sept. 7* | | | *Sept. 12* | | |
| 12 m | 182.65 | 8,410 | 11 a.m. | 184.14 | 21,500 | 9 a.m. | 183.61 | 18,000 |
| 12 p.m. | 182.72 | 8,680 | 1 p.m. | 183.97 | 20,300 | 3 p.m. | 183.69 | 18,500 |
| *Sept. 4* | | | 9 | 182.43 | 12,100 | 5:30 | 183.95 | 20,300 |
| 11 a.m. | 182.84 | 9,170 | 12 | 182.24 | 11,500 | 12 | 184.12 | 21,600 |
| 12 p.m. | 182.80 | 8,940 | *Sept. 8* | | | *Sept. 13* | | |
| *Sept. 5* | | | 4 p.m. | 183.91 | 22,000 | 2 a.m. | 184.04 | 21,000 |
| 1:40 a.m. | 182.80 | 8,940 | 12 | 184.24 | 24,800 | 12 m | 183.74 | 18,800 |
| 3 | 184.94 | 27,000 | *Sept. 9* | | | 12 p.m. | 183.57 | 17,700 |
| 4:50 | 186.13 | 40,800 | 6 p.m. | 184.72 | 29,000 | *Sept. 14* | | |
| 9 | 184.54 | 24,200 | 12 | 184.68 | 28,400 | 3 a.m. | 183.58 | 17,800 |
| 10:40 | 184.29 | 22,000 | *Sept. 10* | | | 1 p.m. | 183.85 | 19,600 |
| 11:45 | 184.41 | 23,100 | 2 a.m. | 184.65 | 28,000 | 12 | 184.17 | 22,000 |
| 4 p.m. | 183.64 | 16,800 | 8 | 184.35 | 24,300 | *Sept. 15* | | |
| 6 | 183.38 | 14,900 | 4 p.m. | 183.72 | 18,700 | 10 a.m. | 184.32 | 23,200 |
| 12 | 183.52 | 16,000 | 12 | 183.38 | 16,400 | 12 p.m. | 184.27 | 22,800 |
| *Sept. 6* | | | *Sept. 11* | | | *Sept. 16* | | |
| 5 a.m. | 183.46 | 15,600 | 6 a.m. | 183.36 | 16,300 | 12 m | 184.12 | 21,600 |
| 3 p.m. | 183.71 | 17,500 | 12 p.m. | 183.49 | 17,200 | 12 p.m. | 183.87 | 19,300 |
| 6 | 184.15 | 21,300 | *Sept. 12* | | | *Sept. 17* | | |
| 12 | 184.34 | 23,000 | 7 a.m. | 183.51 | 17,300 | 12 m | 183.20 | 15,300 |
| | | | | | | 12 p.m. | 182.56 | 11,500 |

### IMPERIAL RESERVOIR AT IMPERIAL DAM, ARIZ.-CALIF.

LOCATION.—Lat. 32°52′, long. 114°28′, in lot 3, sec. 9, T. 15 S., R. 24 E., San Bernardino meridian, at Imperial Dam, 14.5 miles downstream from Picacho stream-gaging station, 19 miles upstream from Yuma, and 148 miles downstream from Parker Dam. Datum of gage is mean sea level, datum of 1929.

GAGE-HEIGHT RECORD.—Water-stage indicator read to hundredths once daily about 8 a.m.

REMARKS.—Normal operating level of Imperial Reservoir is 179.5 feet; elevation of spillway crest of Imperial Dam is 181.0 feet. Contents of Imperial Reservoir not known because silting has rapidly decreased storage capacity since reservoir was formed in April 1938; original storage capacity was such that, at elevation of spillway crest, 1 foot change in stage represented about 7,000 acre-feet change in contents. Record of elevations furnished by Bureau of Reclamation.

*Elevations September 1939*

| Day | Feet | Day | Feet | Day | Feet |
|---|---|---|---|---|---|
| 1 | 179.42 | 11 | 174.27 | 21 | 177.14 |
| 2 | 179.54 | 12 | 175.32 | 22 | 178.18 |
| 3 | 179.55 | 13 | 175.57 | 23 | 179.23 |
| 4 | 179.55 | 14 | 175.08 | 24 | 179.64 |
| 5 | 180.90 | 15 | 176.36 | 25 | 179.55 |
| 6 | 179.74 | 16 | 176.10 | 26 | 179.66 |
| 7 | 180.03 | 17 | 174.81 | 27 | 179.62 |
| 8 | 172.36 | 18 | 175.00 | 28 | 179.72 |
| 9 | 173.61 | 19 | 175.97 | 29 | 179.64 |
| 10 | 175.71 | 20 | 176.07 | 30 | 179.73 |

### COLORADO RIVER AT YUMA, ARIZ.

LOCATION.—Lat. 32°43′45″, long. 114°37′15″, in NW¼NE¼ sec. 35, T. 16 S., R. 22 E., San Bernardino meridian, 1,800 feet downstream from highway bridge at Yuma, 5 miles downstream from Gila River, 19 miles downstream from Imperial Dam, and 7 and 29 miles upstream from the boundaries of California and Arizona, respectively, with Mexico. Datum of gage is 102.79 feet above mean sea level, datum of 1912 and 1929.

DRAINAGE AREA.—242,900 square miles (revised).

GAGE-HEIGHT RECORD.—Water-stage recorder graph.

DISCHARGE RECORD.—Stage-discharge relation defined by current-meter measurements. Shifting-control method used.

MAXIMA.—1939: Discharge, 34,900 second-feet 11 p.m. Sept. 7 (gage height, 24.57 feet).
1935–38 (regulated): 23,200 second-feet Feb. 10, 1937 (gage height, 24.22 feet).
1902–34 (unregulated): 250,000 second-feet Jan. 22, 1916 (gage height, 34.0 feet).

REMARKS.—Flow regulated at Boulder Dam and flood inflow below Boulder Dam partially regulated at Parker and Imperial Dams. No reduction in flood flow by diversions. For water bypassed around gaging station, see records for Yuma main canal wasteway and Pilot Knob wasteway. Records computed on basis of mountain standard time.

*Daily discharge September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 6,900 | 11 | 16,600 | 21 | 6,170 |
| 2 | 6,630 | 12 | 17,100 | 22 | 5,370 |
| 3 | 6,630 | 13 | 20,000 | 23 | 4,030 |
| 4 | 7,430 | 14 | 18,900 | 24 | 6,440 |
| 5 | 18,400 | 15 | 19,500 | 25 | 7,150 |
| 6 | 16,300 | 16 | 20,700 | 26 | 7,720 |
| 7 | 24,800 | 17 | 19,200 | 27 | 10,600 |
| 8 | 23,700 | 18 | 12,400 | 28 | 8,870 |
| 9 | 18,500 | 19 | 8,090 | 29 | 9,110 |
| 10 | 20,700 | 20 | 8,470 | 30 | 9,230 |

Mean ..... second-feet 12,850
Total ..... acre-feet 764,900

*Gage height and discharge at indicated time, 1939*

| Time | Gage height (feet) | Discharge (second-feet) | Time | Gage height (feet) | Discharge (second-feet) | Time | Gage height (feet) | Discharge (second-feet) |
|---|---|---|---|---|---|---|---|---|
| *Sept. 2* | | | *Sept. 7* | | | *Sept. 13* | | |
| 3 a.m. | 18.42 | 5,620 | 5 p.m. | 24.19 | 32,200 | 12 m. | 22.73 | 20,400 |
| 3 p.m. | 19.14 | 7,810 | 7 | 24.44 | 33,800 | 12 p.m. | 22.73 | 20,400 |
| *Sept. 3* | | | 11 | 24.57 | 34,900 | *Sept. 14* | | |
| 12 p.m. | 18.16 | 5,790 | 12 | 24.54 | 34,700 | 11 a.m. | 22.41 | 19,300 |
| *Sept. 4* | | | *Sept. 8* | | | 12 p.m. | 22.03 | 17,600 |
| 12 m. | 19.01 | 7,400 | 1 a.m. | 24.51 | 34,200 | *Sept. 15* | | |
| 6 p.m. | 19.50 | 9,000 | 4 | 24.34 | 32,800 | 12 m. | 22.21 | 18,900 |
| 12 | 19.32 | 8,400 | 9 | 23.67 | 28,000 | 12 p.m. | 22.76 | 21,600 |
| *Sept. 5* | | | 12m. | 23.05 | 22,400 | *Sept. 16* | | |
| 4 a.m. | 19.62 | 9,410 | 3 p.m. | 22.35 | 20,100 | 9 a.m. | 22.84 | 21,000 |
| 5 | 19.40 | 8,730 | 6 | 21.73 | 17,700 | 11:30 | 22.26 | 18,800 |
| 8 | 20.13 | 11,300 | 9 | 19.87 | 10,700 | 2:30 p.m. | 23 08 | 22,000 |
| 10 | 20.66 | 13,400 | 12 | 21.85 | 18,200 | 5 | 22.59 | 20,100 |
| 11 | 21.50 | 17,100 | *Sept. 9* | | | 12 | 22.80 | 20,900 |
| 12 m. | 22.14 | 21,700 | 9 a.m. | 22.53 | 21,000 | *Sept. 17* | | |
| 1 p.m. | 22 67 | 23,300 | 12 m. | 21.67 | 17,000 | 10 a.m. | 22.76 | 20,700 |
| 3 | 23.13 | 26,600 | 1:30 p.m. | 21.23 | 15,000 | 4 p.m. | 22.17 | 18,400 |
| 5 | 23.43 | 28,900 | 3:30 | 21.65 | 16,700 | 12 | 21.20 | 14,800 |
| 6 | 23.18 | 29,200 | 5:30 | 21.52 | 16,200 | *Sept. 18* | | |
| 7 | 23 38 | 28,400 | 12 | 22.29 | 19,300 | 2 a.m. | 20.93 | 13,700 |
| 9 | 22.82 | 24,600 | *Sept. 10* | | | 12 p.m. | 19.80 | 9,880 |
| 12 | 22.27 | 21,200 | 10:30 a.m. | 22.65 | 20,800 | *Sept. 19* | | |
| *Sept. 6* | | | 12 m. | 22.37 | 19,500 | 9 a.m. | 19.03 | 7,520 |
| 6 a.m. | 21.73 | 17,900 | 12 p.m. | 22.74 | 21,300 | 1 p.m. | 19.00 | 7,440 |
| 5 p.m. | 21.12 | 14,500 | *Sept. 11* | | | 3 | 19.08 | 7,660 |
| 12 | 21.53 | 16,200 | 9 a.m. | 22.52 | 19,700 | 5 | 18.75 | 6,790 |
| *Sept. 7* | | | 4 p.m. | 20 78 | 12,000 | 12 | 19.46 | 8,750 |
| 2 a.m. | 21.68 | 17,200 | 12 | 21.53 | 14,900 | *Sept. 20* | | |
| 11 | 21.98 | 18,800 | *Sept. 12* | | | 6 a.m. | 19.40 | 8,780 |
| 12 m. | 22 57 | 22,000 | 6 a.m. | 22.14 | 17,200 | 12 p.m. | 18.61 | 6,610 |
| 2 p.m. | 23.52 | 27,400 | 12 m. | 22.23 | 17,600 | | | |
| 3 | 23.79 | 29,300 | 9 p.m. | 22.14 | 17,200 | | | |
| 4 | 24.01 | 31,100 | 12 | 22.26 | 17,800 | | | |

## WILLIAMS RIVER BASIN

### WILLIAMS RIVER AT PLANET, ARIZ.

LOCATION.—Lat. 34°16′, long. 113°59′, in NE¼ sec. 36, T. 11 N., R. 17 W., 1 mile west of Planet and 6 miles upstream from Havasu Lake when lake is at elevation 450 feet above mean sea level. Datum of gage is 556.33 feet above mean sea level, datum of 1929.

DRAINAGE AREA.—5,140 square miles.

GAGE-HEIGHT RECORD.—Water-stage recorder graph.

DISCHARGE RECORD.—Stage-discharge relation defined by current-meter measurements up to 44,000 second-feet, slope-area measurement at 51,000 second-feet, and extended above. Shifting-control method used.

MAXIMA.—1939: Discharge, 73,000 second-feet 2 a.m. Sept. 7 (gage height, 11.7 feet).

1928–38: Discharge, 92,500 second-feet Feb. 7, 1937 (gage height, 13.1 feet). Floods estimated as 175,000 second-feet or greater occurred about Feb. 21, 1891, and about Jan. 19, 1916.

REMARKS.—Flood flow not affected by diversions or regulation. Most of flood flow was contributed by Big Sandy River. Records computed on basis of mountain standard time.

*Daily discharge September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 13 | 11 | 788 | 21 | 177 |
| 2 | 13 | 12 | 6,860 | 22 | 148 |
| 3 | 155 | 13 | 15,500 | 23 | 139 |
| 4 | 1,340 | 14 | 4,060 | 24 | 365 |
| 5 | 5,470 | 15 | 1,480 | 25 | 5,170 |
| 6 | 20,000 | 16 | 718 | 26 | 4,960 |
| 7 | 31,500 | 17 | 376 | 27 | 2,470 |
| 8 | 5,380 | 18 | 251 | 28 | 860 |
| 9 | 1,020 | 19 | 238 | 29 | 470 |
| 10 | 286 | 20 | 196 | 30 | 320 |
| Mean | | | | | second-feet 3,691 |
| Total | | | | | acre-feet 219,600 |

*Gage height and discharge at indicated time, 1939*

| Time | Gage height (feet) | Discharge (second-feet) | Time | Gage height (feet) | Discharge (second-feet) | Time | Gage height (feet) | Discharge (second-feet) |
|---|---|---|---|---|---|---|---|---|
| *Sept. 3* | | | *Sept. 6* | | | *Sept. 12* | | |
| 12 m. | 2.39 | 14 | 6 p.m. | 7.98 | 27,700 | 1 a.m. | 4.15 | 1,320 |
| 4:45 p.m. | 2.38 | 14 | 7:45 | 7.50 | 22,800 | 8 | 4.05 | 1,050 |
| 5 | 3.19 | 859 | 10:30 | 8.20 | 30,000 | 8:30 | 5.70 | 8,370 |
| 5:50 | 2.86 | 303 | 12 | 11.2 | 66,300 | 10 | 5.89 | 8,680 |
| 6:45 | 3.49 | 1,780 | *Sept. 7* | | | 2:30 p.m. | 5.40 | 6,580 |
| 9:15 | 2.50 | 52 | 1 a.m. | 11.0 | 63,700 | 5 | 5.50 | 7,090 |
| 12 | 2.40 | 27 | 2 | 11.7 | 73,000 | 5:45 | 6.83 | 15,400 |
| *Sept. 4* | | | 12 m. | 6.35 | 25,300 | 8:30 | 6.25 | 11,300 |
| 2:15 p.m. | 2.30 | 15 | 6 p.m. | 4.55 | 11,000 | 10:35 | 7.02 | 16,300 |
| 3 | 3.82 | 3,150 | 12 p.m. | 4.30 | 9,200 | 12 | 6.80 | 14,400 |
| 5:05 | 4.79 | 5,520 | *Sept. 8* | | | *Sept. 13* | | |
| 7 | 4.00 | 3,000 | 4 a.m. | 3.98 | 7,100 | 2:05 a.m. | 6.22 | 10,800 |
| 7:50 | 3.90 | 2,730 | 6 | 4.35 | 9,600 | 3 | 7.23 | 17,900 |
| 8:40 | 4.18 | 3,490 | 11:45 | 3.58 | 4,500 | 4:30 | 6.5 | 12,100 |
| 12 | 3.64 | 2,080 | 1:25 p.m. | 4.14 | 7,500 | 9 | 7.9 | 21,700 |
| *Sept. 5* | | | 7:30 | 3.77 | 2,500 | 2:15 p.m. | 8.0 | 22,400 |
| 4 a.m. | 3.27 | 1,240 | 12 | 4.04 | 1,750 | 2:45 | 7.2 | 16,300 |
| 7 | 3.80 | 2,470 | *Sept. 9* | | | 7 | 6.5 | 11,600 |
| 7:45 | 4.30 | 3,850 | 7 a.m. | 4.03 | 1,500 | 12 | 5.85 | 7,720 |
| 8:30 | 4.35 | 4,000 | 6 p.m. | 3.72 | 600 | *Sept. 14* | | |
| 1 p.m. | 4.10 | 3,270 | 12 | 3.50 | 129 | 2:30 a.m. | 5.40 | 5,360 |
| 4 | 4.06 | 3,160 | *Sept. 10* | | | 6 | 5.43 | 5,510 |
| 6:30 | 5.09 | 6,730 | 7:30 p.m. | 3.40 | 70 | 12 m. | 5.00 | 3,310 |
| 9:40 | 5.60 | 9,110 | 8:15 | 4.20 | 1,460 | 4:30 p.m. | 5.02 | 3,360 |
| 10-30 | 8.33 | 28,700 | 8:45 | 4.31 | 1,810 | 12 | 4.86 | 2,330 |
| 12 | 7.45 | 21,100 | 11 | 3.92 | 749 | *Sept. 15* | | |
| *Sept. 6* | | | 12 | 4.00 | 925 | 12 m. | 4.80 | 1,410 |
| 12:45 a.m. | 7.78 | 23,700 | *Sept. 11* | | | 12 p.m. | 4.57 | 903 |
| 7-30 | 6.35 | 13,400 | 10 a.m. | 3.90 | 705 | *Sept. 16* | | |
| 9:30 | 6.65 | 15,400 | 2 p.m. | 3.86 | 629 | 12 m. | 4.49 | 771 |
| 11:40 | 5.65 | 9,360 | 3 | 4.09 | 1,150 | 12 p.m. | 4.30 | 451 |
| 2 p.m. | 5.75 | 9,880 | 7 | 3.95 | 815 | *Sept. 17* | | |
| 2:45 | 7.05 | 19,000 | 12 | 3.89 | 686 | 12 m. | 4.24 | 403 |
| 4:30 | 7.20 | 20,200 | | | | 12 p.m. | 4.12 | 264 |

## DIVERSIONS BETWEEN BOULDER DAM AND GILA RIVER

### COLORADO RIVER AQUEDUCT NEAR PARKER DAM, ARIZ.-CALIF.

LOCATION.—Lat. 34°19′, long. 114°09′, in SW¼ sec. 28, T. 3N., R. 27 E., San Bernardino meridian, on Havasu Lake, at intake pumping plant of Metropolitan Water District of Southern California 1.8 miles upstream from Parker Dam, which is 156 miles downstream from Boulder Dam.

DISCHARGE RECORD.—Obtained from venturi meters individually rated by the salt-velocity method.

REMARKS.—Table shows quantity of water pumped to aqueduct. No flow returned to Havasu Lake from Gene Reservoir or to Colorado River from Copper Basin Reservoir. Records computed on basis of Pacific standard time. Records furnished by Metropolitan Water District of Southern California.

*Daily discharge, September 1939*

| *Day* | *Second-feet* | *Day* | *Second-feet* | *Day* | *Second-feet* |
|---|---|---|---|---|---|
| 1 | 544 | 11 | 566 | 21 | 441 |
| 2 | 0 | 12 | 435 | 22 | 441 |
| 3 | 0 | 13 | 439 | 23 | 442 |
| 4 | 0 | 14 | 440 | 24 | 420 |
| 5 | 0 | 15 | 226 | 25 | 442 |
| 6 | 0 | 16 | 0 | 26 | 443 |
| 7 | 0 | 17 | 0 | 27 | 445 |
| 8 | 0 | 18 | 279 | 28 | 445 |
| 9 | 152 | 19 | 438 | 29 | 414 |
| 10 | 463 | 20 | 443 | 30 | 0 |

Mean ..... second-feet 279
Total ..... acre-feet 16,580

### DIVERSIONS FOR COLORADO RIVER INDIAN RESERVATION NEAR PARKER, ARIZ.

LOCATION.—Lat. 34°09′, long. 114°18′, in SE¼ sec. 2, T. 9 N., R. 20 W., Gila and Salt River meridian, on Colorado River Indian Reservation 1 mile southwest of Parker (revised) and 17 miles downstream from Parker Dam.

DISCHARGE RECORD.—Computed from records of pump operation checked by current-meter and Parshall-flume measurements.

REMARKS.—No diversion in September 1939. Records furnished by Office of Indian Affairs.

### PALO VERDE CANAL NEAR BLYTHE, CALIF.

LOCATION.—Lat. 33°43′, long. 114°31′, in SW¼ sec. 19, T. 5 S., R. 24 E., San Bernardino meridian, below settling basin three-quarters of a mile downstream from intake on Colorado River, 9¼ miles northeast of Blythe, and 58 miles downstream from Parker Dam.

DISCHARGE RECORD.—Flow diverted from river computed on basis of head on gate openings and occasional current-meter measurements. Figures in table show flow diverted less waste water returned to river by canal wasteways. Flow in wasteways estimated in field by employees of Palo Verde Irrigation District.

REMARKS.—Records furnished by Palo Verde Irrigation District.

*Daily discharge, September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 300 | 11 | 20 | 21 | 90 |
| 2 | 280 | 12 | 20 | 22 | 90 |
| 3 | 210 | 13 | 20 | 23 | 110 |
| 4 | 210 | 14 | 20 | 24 | 90 |
| 5 | 0 | 15 | 20 | 25 | 90 |
| 6 | 0 | 16 | 20 | 26 | 90 |
| 7 | 0 | 17 | 20 | 27 | 90 |
| 8 | 0 | 18 | 60 | 28 | 90 |
| 9 | 20 | 19 | 60 | 29 | 90 |
| 10 | 20 | 20 | 90 | 30 | 90 |

Mean ..... second-feet 77.0
Total ..... acre-feet [1]4,580

[1]Figure supersedes that published in Water-Supply Paper 879.

### ALL-AMERICAN CANAL NEAR IMPERIAL DAM, ARIZ.-CALIF.

LOCATION.—Lat. 32°52′10″, long. 114°28′48″, in SE¼NE¼ sec. 17, T. 15 S., R. 24 E., San Bernardino meridian, 6,000 feet downstream from canal intake at Imperial Dam.

DISCHARGE RECORD.—Daily discharge computed from a discharge hydrograph based on 17 discharge measurements made in period September 10–26, well distributed with respect to time.

REMARKS.—Except for small losses in first 6,000 feet of canal, record shows total diversion at California end of Imperial Dam. No diversion in September at Arizona end. Results of discharge measurements furnished by Bureau of Reclamation.

*Daily discharge, September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 0 | 11 | 1,340 | 21 | 760 |
| 2 | 0 | 12 | 1,180 | 22 | 820 |
| 3 | 0 | 13 | 1,150 | 23 | 800 |
| 4 | 0 | 14 | 1,010 | 24 | 470 |
| 5 | 0 | 15 | 870 | 25 | 450 |
| 6 | 0 | 16 | 800 | 26 | 320 |
| 7 | 0 | 17 | 780 | 27 | 0 |
| 8 | 0 | 18 | 770 | 28 | 0 |
| 9 | 50 | 19 | 820 | 29 | 0 |
| 10 | 700 | 20 | 850 | 30 | 0 |

Mean ..... second-feet 465
Total ..... acre-feet 27,650

### YUMA MAIN CANAL AT LAGUNA DAM, ARIZ.-CALIF.

LOCATION.—Lat. 32°50′, long. 114°30′, in NE¼ sec. 25, T. 15 S., R. 23 E., San Bernardino meridian, 200 feet below canal intake at right end of Laguna Dam.

GAGE-HEIGHT RECORD.—Staff gage read two or more times daily.

DISCHARGE RECORD.—Stage-discharge relation defined by current-meter measurements. Shifting-control method used.

REMARKS.—No water diverted into canal between 3:30 a.m. September 5 and late September 22, owing to serious breaks in canal caused by destructive floods in washes crossing canal. Water diverted is used on Yuma project of Bureau of Reclamation or returned to Colorado River through Yuma main canal wasteway half a mile below Yuma. Daily discharge record furnished by Bureau of Reclamation.

*Daily discharge, September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 1,770 | 11 | 0 | 21 | 0 |
| 2 | 1,420 | 12 | 0 | 22 | 140 |
| 3 | 1,740 | 13 | 0 | 23 | 1,020 |
| 4 | 1,540 | 14 | 0 | 24 | 1,390 |
| 5 | 250 | 15 | 0 | 25 | 1,540 |
| 6 | 0 | 16 | 0 | 26 | 1,570 |
| 7 | 0 | 17 | 0 | 27 | 1,560 |
| 8 | 0 | 18 | 0 | 28 | 1,500 |
| 9 | 0 | 19 | 0 | 29 | 1,460 |
| 10 | 0 | 20 | 0 | 30 | 726 |

| | | |
|---|---|---|
| Mean | second-feet | 588 |
| Total | acre-feet | 34,960 |

#### NORTH GILA IRRIGATION DISTRICT CANAL AT LAGUNA DAM, ARIZ.-CALIF.

LOCATION.—Lat. 32°49′, long. 114°30′, in SW¼ sec. 14, T. 7 S., R. 22 W., Gila and Salt River meridian, a quarter of a mile downstream from canal intake at left end of Laguna Dam.

DISCHARGE RECORD.—Estimated by watermaster, based on flow delivered to water-users' gates and other available information.

REMARKS.—Table shows net diversion from river. Record furnished by Bureau of Reclamation.

*Daily discharge, September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 60 | 11 | 0 | 21 | 0 |
| 2 | 20 | 12 | 0 | 22 | 0 |
| 3 | 20 | 13 | 0 | 23 | 90 |
| 4 | 30 | 14 | 0 | 24 | 90 |
| 5 | 0 | 15 | 0 | 25 | 90 |
| 6 | 0 | 16 | 0 | 26 | 80 |
| 7 | 0 | 17 | 0 | 27 | 70 |
| 8 | 0 | 18 | 0 | 28 | 70 |
| 9 | 0 | 19 | 0 | 29 | 70 |
| 10 | 0 | 20 | 0 | 30 | 70 |

| | | |
|---|---|---|
| Mean | second-feet | 26.3 |
| Total | acre-feet | 1,570 |

## GILA RIVER BASIN

#### GILA RIVER BELOW GILLESPIE DAM, ARIZ.

LOCATION.—Lat. 33°14′, long. 112°45′, in SE¼NE¼ sec. 28, T. 2 S., R. 5 W., at Gillespie Dam, 8 miles downstream from Hassayampa River. Average elevation of crest of dam is 753.46 feet above mean sea level, datum of 1929.

DRAINAGE AREA.—49,600 square miles (revised).

GAGE-HEIGHT RECORD.—Water-stage recorder graph.

DISCHARGE RECORD.—Stage-discharge relation defined by current-meter measurements. Record consists of flow over crest and through sluice gates of Gillespie Dam but does not include water diverted at left end of dam by Gillespie canal and at right end by Enterprise canal.

MAXIMA.—1939: Discharge, 3,240 second-feet Sept. 13 (height over crest of dam, 0.97 foot).

1921–38: Discharge, 70,000 second-feet Dec. 28, 1923 (height over crest of dam, 6.0 feet).

Greater flood occurred February 1891, discharge estimated at 250,000 second-feet.

REMARKS.—Many diversions for irrigation above Gillespie Dam. Flow of Gila River and tributaries above Gillespie Dam is regulated by San Carlos Reservoir on Gila River; by a series of four reservoirs on Salt River, including Roosevelt Reservoir; by Bartlett Reservoir on Verde River; and by Lake Pleasant on Agua Fria River.

*Daily discharge, September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 0 | 11 | 0 | 21 | 0 |
| 2 | 0 | 12 | 1,560 | 22 | 0 |
| 3 | 0 | 13 | 2,720 | 23 | 0 |
| 4 | 360 | 14 | 1,000 | 24 | 0 |
| 5 | 1,760 | 15 | 305 | 25 | 0 |
| 6 | 1,500 | 16 | 180 | 26 | 0 |
| 7 | 1,170 | 17 | 80 | 27 | 0 |
| 8 | 610 | 18 | 50 | 28 | 0 |
| 9 | 216 | 19 | 0 | 29 | 0 |
| 10 | 32 | 20 | 0 | 30 | 0 |

Mean ..... second-feet 385
Total ..... acre-feet 22,900

**GILA RIVER NEAR DOME, ARIZ.**

LOCATION.—Lat. 32°45'30", long. 114°25'15", in SW¼ sec. 4, T. 8 S., R. 21 W., 3 miles west of Dome and 12 miles upstream from mouth. Datum of gage is 148.18 feet above mean sea level, datum of 1929.

DRAINAGE AREA.—58,100 square miles.

GAGE-HEIGHT RECORD.—Water-stage recorder graph.

DISCHARGE RECORD.—Stage-discharge relation defined by current-meter measurements. Shifting-control method used.

MAXIMA.—1939: Discharge, 905 second-feet 4:30 a.m. Sept. 13 (gage height, 7.47 feet).

1903–38: Discharge, 230,000 second-feet about Jan. 22, 1916, at the mouth.

REMARKS.—Flow regulated by numerous reservoirs above station. No regulation below Gillespie Dam.

*Daily discharge, September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 0 | 11 | 0 | 21 | 0 |
| 2 | 0 | 12 | 531 | 22 | 0 |
| 3 | 0 | 13 | 632 | 23 | 0 |
| 4 | 0 | 14 | 264 | 24 | 0 |
| 5 | 72 | 15 | 75 | 25 | 0 |
| 6 | 186 | 16 | 6 | 26 | 0 |
| 7 | 17 | 17 | 0 | 27 | 0 |
| 8 | 0 | 18 | 0 | 28 | 0 |
| 9 | 0 | 19 | 0 | 29 | 0 |
| 10 | 0 | 20 | 0 | 30 | 0 |

Mean ..... second-feet 59.4
Total ..... acre-feet 3,540

*Gage height and discharge at indicated time, 1939*

| Time | Gage height (feet) | Discharge (second-feet) | Time | Gage height (feet) | Discharge (second-feet) | Time | Gage height (feet) | Discharge (second-feet) |
|---|---|---|---|---|---|---|---|---|
| *Sept. 5* | | | *Sept. 7* | | | *Sept. 13* | | |
| 6 a.m. | ..... | 0 | 4 a.m. | 1.62 | 42 | 2 a.m. | 7.00 | 834 |
| 8 | 1.90 | 68 | 8 | 1.20 | 14 | 4:30 | 7.47 | 905 |
| 10 | 2.30 | 102 | 12 m. | .93 | 5 | 6 | 7.33 | 868 |
| 12 m. | 2.00 | 77 | 12 p.m. | ..... | 0 | 11 | 6.25 | 604 |
| 4 p.m. | 1.27 | 22 | *Sept. 8* | | | 6 p.m. | 5.81 | 509 |
| 5 | 1.37 | 27 | 12 p.m. | ..... | 0 | 12 | 5.40 | 431 |
| 7 | 2.76 | 144 | *Sept. 11* | | | *Sept. 14* | | |
| 9 | 3.34 | 203 | 8:30 p.m. | ..... | 0 | 12 m. | 4.15 | 250 |
| 12 | 3.45 | 216 | 10 | 0.50 | 1 | 12 p.m. | 3.25 | 153 |
| *Sept. 6* | | | 11:15 | ..... | 0 | *Sept. 15* | | |
| 6 a.m. | 3.02 | 170 | 12 | 1.20 | 10 | 12 m. | 2.32 | 70 |
| 11 | 2.71 | 139 | *Sept. 12* | | | 12 p.m. | 1.65 | 20 |
| 1 p.m. | 3.30 | 199 | 3 a.m. | 5.12 | 417 | *Sept. 16* | | |
| 3:30 | 3.97 | 276 | 4 | 6.08 | 610 | 12 m. | 1.25 | 7 |
| 6 | 3.58 | 230 | 5 | 6.55 | 721 | 12 p.m. | .90 | 2 |
| 12 | 2.25 | 98 | 6:30 | 6.72 | 763 | *Sept. 17* | | |
| | | | 8 | 6.59 | 731 | 12 m. | ..... | 0 |
| | | | 12 m. | 6.10 | 615 | | | |
| | | | 10 p.m. | 5.11 | 415 | | | |
| | | | 12 | 5.75 | 538 | | | |

## RETURN FLOW BELOW YUMA

### YUMA MAIN CANAL WASTEWAY AT YUMA, ARIZ.

LOCATION.—Lat. 32°44'00", long. 114°37'15", in SW¼SE¼ sec. 26, T. 16 S., R. 22 E., San Bernardino meridian, 500 feet upstream from intake of Colorado River siphon on Yuma main canal, half a mile north of Yuma, and 3 miles downstream from siphon-drop power plant.

DISCHARGE RECORD.—Discharge is computed difference between discharge at gaging stations on Yuma main canal at siphon-drop power plant and Yuma main canal below Colorado River siphon, with deduction for small irrigation diversions made from Yuma main canal between these stations.

REMARKS.—All flow in Yuma main-canal wasteway is returned to Colorado River half a mile downstream from gaging station on Colorado River at Yuma, and all flow bypasses that station. Flow in wasteway September 1–5 was water diverted from Colorado River through Yuma main canal at Laguna Dam and flow September 11–22 was water diverted from Colorado River through All-American Canal at Imperial Dam. Record of diversions for irrigation from main canal furnished by Bureau of Reclamation.

*Daily discharge, September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 1,120 | 11 | 208 | 21 | 110 |
| 2 | 999 | 12 | 518 | 22 | 35 |
| 3 | 1,310 | 13 | 516 | 23 | 374 |
| 4 | 1,170 | 14 | 458 | 24 | 871 |
| 5 | 167 | 15 | 346 | 25 | 769 |
| 6 | 0 | 16 | 400 | 26 | 777 |
| 7 | 0 | 17 | 362 | 27 | 748 |
| 8 | 0 | 18 | 176 | 28 | 751 |
| 9 | 0 | 19 | 132 | 29 | 794 |
| 10 | 0 | 20 | 124 | 30 | 412 |

| | | |
|---|---|---|
| Mean | second-feet | 455 |
| Total | acre-feet | 27,070 |

### PILOT KNOB WASTEWAY NEAR YUMA, ARIZ.

LOCATION.—Lat. 32°44'15", long 114°42'55", in NW¼ SW¼ sec. 25, T. 16 S., R 21 E., San Bernardino meridian, at All-American Canal, a quarter of a mile west of heading of Alamo Canal, about a mile north of the California-Mexico boundary, 6 miles west of Yuma, and 20.8 miles downstream from intake of All-American Canal at Imperial Dam.

DISCHARGE RECORD.—Computed from several field estimates of flow and from difference in flow of All-American Canal above and below the wasteway, adjusted for losses in seepage and evaporation.

REMARKS.—No flow prior to 10 a.m. September 24 except for leakage through waste gate. Water from wasteway enters Alamo Canal immediately below its head.

*Daily discharge, September 1939*

| Day | Second-feet | Day | Second-feet | Day | Second-feet |
|---|---|---|---|---|---|
| 1 | 0 | 11 | 5 | 21 | 2 |
| 2 | 0 | 12 | 5 | 22 | 5 |
| 3 | 0 | 13 | 5 | 23 | 5 |
| 4 | 0 | 14 | 5 | 24 | 210 |
| 5 | 0 | 15 | 3 | 25 | 350 |
| 6 | 0 | 16 | 2 | 26 | 320 |
| 7 | 0 | 17 | 2 | 27 | 200 |
| 8 | 0 | 18 | 2 | 28 | 15 |
| 9 | 0 | 19 | 2 | 29 | 0 |
| 10 | 5 | 20 | 2 | 30 | 0 |

| | | |
|---|---|---|
| Mean | second-feet | 38.2 |
| Total | acre-feet | 2,270 |

## SUMMARY OF FLOOD STAGES AND DISCHARGES

Table 5 summarizes the flood stages and discharges given elsewhere in this report. It also gives the discharge at a few miscellaneous measuring points. Water-Supply Paper 847 contains a summary of maximum flood discharges through September 1938 at all stream-measurement stations in the country. Table 5 has been prepared with a view to its use as a supplement to tables 9 and 9–A in Water-Supply Paper 847. Therefore, the index numbers are the same for corresponding stream-measurement points in all tables. Where additional points have been added for this report, index numbers have been assigned in accordance with the same decimal system used in table 9–A of Water-Supply Paper 847. The headings of the other columns of table 5 are self-explanatory. The period of record refers to the inclusive calendar years for which gaging-station records are available. In describing how the maximum discharge was obtained, the note "gaging-station record" is used to indicate places for which the gaging-station records are given in the preceding section of the report.

The locations of all stream-measurement points have been plotted on plate 1.

## STORAGE AND ITS EFFECT

### LAKE MEAD

Storage in Lake Mead behind Boulder Dam is so great that storms like those of September 1939 affect it but slightly. The contents of Lake Mead in September increased from a minimum of 23,520,000 acre-feet on September 5 to a maximum of 23,850,000 acre-feet on September 20. This increase of 330,000 acre-feet was caused by the storms of September 3–7 and 8–13, principally the latter. The completely controlled release from Boulder Dam was reduced from an average of about 11,000 second-feet prior to September 4 to an average of 9,200 second-feet September 5–18. For a flow of about 10,000 second-feet, the time interval from Boulder Dam to Parker Dam is about 2 days and to Imperial Dam about 4 days. This makes it impossible to shut off the water released at Boulder Dam in time to reduce flood peaks on the lower river that are due to short, sudden inflows such as those of September 1939.

### HAVASU LAKE

Havasu Lake behind Parker Dam is normally kept higher than 440.54 feet above mean sea level, datum of 1929, by the terms of an agreement between the Metropolitan Water District of Southern California, which pumps water from the lake for its Colorado River aqueduct, and the Bureau of Reclamation, which has charge of regulating the river. The purpose is to insure a lake level high enough for efficient operation of the pumps. A lower level is legally allowable only in emergency or with the consent of the Metropolitan Water District. The allowable upper limit of the lake level at Parker Dam is 450.54 feet above mean sea level, datum of 1929. This is the height for which the dam was designed, and considerable valuable land above the dam would be flooded if the water were higher. As will be seen by table 5, the highest lake level as recorded 1.8 miles upstream from Parker Dam was 2.8 feet below the allowable maximum.

TABLE 3.—Summary of flood stages and discharges in Colorado River basin below Boulder Dam for the flood of September 1939

| No. | Stream and place of determination | Drainage area (square miles) | Period of record[1] | Maximum flood previously known | | | | Maximum during present flood | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Date | Gage height (feet) | Discharge | | Time | Gage height (feet) | Discharge | | |
| | | | | | | Second-feet | Second-feet per square mile | | | Second-feet | Second-feet per square mile | |
| 15 | Colorado River near Willow Beach, Ariz. | [2]168,400 | 1935–39 | Feb. 13, 1939 | 36.72 | 48,400 | | Sept. 6, 1:30 p.m.<br>Sept. 11, 8 p.m.<br>Sept. 21 | 26.88<br>27.80<br>27.99 | 10,400<br>13,100<br>13,500 | | Gaging-station record.<br>Do.<br>Do. |
| 16.5 | Colorado River at Needles, Calif | [2]170,600 | 1931–34<br>1935–39 | June 25, 1933<br>Feb. 1, 1939 | [3]472.10<br>[3]471.13 | [4]36,000 | | Sept. 6, 7 p.m.<br>Sept. 12, 9 a.m. | [3]469.46<br>[3]470.29 | 13,200<br>19,500 | | Do.<br>Do. |
| A | Colorado River at Topock, Ariz | | 1935–39 | Nov. 16, 1938 | [3]445.25 | | | Sept. 6, 6:15 p.m.<br>Sept. 13, 3:30 a.m. | [3]450.20<br>[3]448.39 | | | Do.<br>Do. |
| 17 | Colorado River near Topock, Ariz | [2]172,300 | 1917–34<br>1935–39 | June 22, 1921<br>Feb. 2, 1939 | [3]447.20 | [5]200,000<br>34,900 | 1.2 | Sept. 6, 6:15 p.m.<br>Sept. 13, 1:30 a.m. | [3]447.87<br>[3]446.41 | 18,100<br>12,300 | | Do.<br>Do. |
| B | Havasu Lake near Parker Dam, Ariz.-Calif | 178,800 | 1938–39 | Feb. 2, 1939 | [3]443.16 | | | Sept. 7, 10 a.m. | [3]447.72 | | | Do. |
| 18 | Colorado River below Parker Dam, Ariz.-Calif. | [6]178,800 | 1935–39 | Feb. 8, 1937 | 33.07 | 42,400 | | Sept. 7, 9 p.m. | 30.31 | 38,500 | | Do. |
| 19 | Colorado River near Picacho, Calif. | [6]184,100 | 1935–39 | Feb. 10, 1937 | [3]179.47 | 26,900 | | Sept. 5, 4:50 a.m. | [3]186.13 | 40,800 | | Do. |
| 20 | Colorado River at Yuma, Ariz. | [7]242,900 | 1902–34<br>1935–39 | Jan. 22, 1916<br>Feb. 10, 1937 | 34.0<br>24.22 | [8]250,000<br>23,200 | | Sept. 7, 11 p.m. | 24.57 | 34,900 | | Do. |
| 350.2 | Piute Wash at box canyon 8.5 miles northwest of Needles, Calif. | 770 | | | | | | Sept. 12, 3 a.m.[4] | | 30,000 | 39 | Slope-area measurement; n = 0.035. |
| 350.4 | Sacramento Wash at mouth, near Topock, Ariz. | 1,430 | | | | | | Sept. 6, 5 p.m.[4] | | 15,000 | 10 | Slope-area measurement; n = 0.035. |
| 350.6 | Chemehuevi Wash at Needles-Vidal highway, near Needles, Calif. | 270 | | | | | | Sept. 25 | | 12,000 | 44 | Slope-area measurement; n = 0.040. |
| 350.8 | Williams River at confluence of Big Sandy and Santa Maria Rivers, above Alamo, Ariz. | 4,330 | | | | | | Sept. 6, between 6 and 10 p.m. | | 77,000 | 18 | Slope-area measurement; n = 0.040. |
| 351 | Williams River at Planet, Ariz. | 5,140 | 1928–39 | Feb. 7, 1937[9] | 13.1 | 92,500 | 18.0 | Sept. 7, 2 a.m. | 11.7 | 73,000 | 14 | Gaging-station record. |
| 351.2 | Santa Maria River near Alamo, Ariz. | 1,520 | | 1937 or 1938 | 12.0 | | | Sept. 6, 12 p.m.[4] | 10.0 | 15,000 | 9.9 | Slope-area measurement; n = 0.040 |
| 351.5 | Unnamed Wash at All-American Canal, near Yuma, Ariz. | 35.3 | | | | | | Sept. 5 | | 5,000 | 140 | Record furnished by Bureau of Reclamation. |
| 351.8 | Picacho Wash at All-American Canal, near Yuma, Ariz. | 41.5 | | | | | | Sept. 5 | | 37,000 | 890 | Do. |
| 366 | Gila River below Gillespie Dam, Ariz. | [7]49,600 | 1921–39 | Dec. 28, 1923[10] | 6.0 | [11]170,000 | | Sept. 13 | .97 | 3,240 | | Gaging-station record. |
| 367 | Gila River near Dome, Ariz | [7]58,100 | 1903–39 | Jan. 22, 1916 | | [12]230,000 | 3.4 | Sept. 13, 4:30 a.m. | 7.47 | 905 | | Do. |

[1]Records for Colorado River stations are given in two parts, before and after start of regulation at Boulder Dam Feb. 1, 1935.
[2]167,800 square miles affected by storage in Lake Mead since Feb. 1, 1935.
[3]Elevation above mean sea level, datum of 1929.
[4]About. [5]Probably exceeded by other floods.
[6]Affected by storage in Lake Mead since Feb. 1, 1935, and Havasu Lake since July 1, 1938.
[7]Affected by storage.
[8]Flood flow principally from Gila River; effective drainage area uncertain.
[9]Greater flood occurred about Feb. 21, 1891; discharge estimated at about 200,000 cubic feet per second.
[10]Greater flood occurred February 1891; discharge estimated at 250,000 cubic feet per second.
[11]Observed. [12]At mouth of river.

The capacity table for Havasu Lake was computed for conditions as they existed prior to the closing of Parker Dam in July 1938. The table was not based on detailed surveys and may be somewhat in error. By September 1939 some silting had occurred, mostly at the upper end of the reservoir. The capacity of the reservoir was thus reduced but probably not to a material extent within the range of stage of the September floods. Filling has continued since the flood. As an evidence of the filling, figure 2 shows the mean elevation of the river bottom at the cableway measuring section at the gaging station Colorado River near Topock, Ariz., between July 1938, when Parker Dam was closed, and April 1940.

The stage of Havasu Lake, as observed at the pumping plant of the Metropolitan Water District of Southern California 1.8 miles upstream from Parker Dam, rose from elevation 441.32 at midnight September 4 to a peak of 447.72 feet at 10 a.m. September 7 and then fell to 442.62 feet at midnight September 20. The increase in contents from midnight September 4, before the flood began, to the peak on September 7 was 135,000 acre-feet. Inflow into Havasu Lake at the two points at which it is measured—Colorado River near Topock and Williams River near Planet—for this same period was approximately 150,000 acre-feet, or only about 15,000 acre-feet more than was stored. It therefore appears that the release at Parker Dam during the same period did not greatly exceed the unmeasured inflow to Havasu Lake.

Fortunately, Havasu Lake was near the normal minimum level when the September storms began. Otherwise there would have been very little time to lower the lake, as the rise of September 6 came with only a few hours warning. If the lake had been at or near elevation 450 feet on the morning of September 6 the heavy inflow that occurred about noon, before the Williams River flood arrived, would necessarily have passed through with little reduction of the peak. This peak inflow may have exceeded 75,000 second-feet. It cannot be computed exactly, owing to uncertainties as to location of the points at which this inflow occurred, allowance of proper time interval between gaging stations, accuracy of table of reservoir capacity, and other factors. The Williams River flood peak, which arrived in the early morning of September 7, likewise would have passed through without reduction in discharge unless the contents of the reservoir had been reduced by large release following the peak on September 6.

In considering the contents of Havasu Lake, particularly the rate of increase in reservoir contents, it should be remembered that the rate of increase as indicated by the lake gage 1.8 miles above Parker Dam does not necessarily indicate the rate of increase in the reservoir as a whole. Because of lack of sufficient information as to reservoir elevations at points between the Metropolitan Water District pumping plant and the Topock gaging station, no definite conclusions as to maximum contents are possible. The capacity table for Havasu Lake was computed from areas determined by planimeter measurements along contour lines. Under normal conditions the capacity so determined is very close to actual capacity; estimates by the Metropolitan Water District indicate that, under normal flow conditions and over the lake area as a whole, the elevation of the water-surface would average not more than 0.1 foot higher than the elevation shown by the gage 1.8 miles above Parker Dam. Under flood conditions actual

storage may be either greater or less than that computed from the gage 1.8 miles above the dam. When Williams River is in flood, elevations at the gage are higher than normal for short periods, and storage computed therefrom is probably greater than actually exists. When Colorado River is in flood, elevations at the gage are lower than normal for short periods, and storage computed therefrom is probably less than actually exists.

### IMPERIAL RESERVOIR

At Imperial Reservoir the normal operating elevation of 179.5 feet above mean sea level, datum of 1929, is maintained by adjustment of sluice gates in Imperial Dam. The reservoir elevation is read once a day. The maximum elevation probably occurred early on September 5 just before the gage reading of 180.90 feet at 8 a.m. was made. The maximum was but little higher because it is known that no water went over the spillway crest, which is at an elevation of 181.0 feet.

Since the reservoir was formed water has been over the spillway crest only once, in January 1939 during controlled flow, and has not approached the crest at any other time except in September 1939. Because of this, the rise of September 5 flooded much ground that had not been covered for a long time and much water was absorbed in bank storage.

A capacity curve for Imperial Reservoir was made before the dam was closed in April 1938. Silting occurred so rapidly that by September 1939 the curve was believed to be much in error, and contents have not been computed. The original capacity was relatively small—about 7,000 acre-feet per foot of depth at elevation of the spillway crest. Much of the reservoir area is a river-bottom wilderness, and when flooded after a long interval bank storage is great. Much of the stored water is trapped in swamps and lagoons and never returns to the river. For this reason the loss of water between Picacho and Yuma gaging stations was relatively large.

### NATURAL CHANNEL STORAGE

Natural channel storage is an important factor in reducing flood peaks. It accounts for about 110,000 acre-feet of water on the Colorado River between the Topock and Yuma gaging stations when the discharge increases from 10,000 to 40,000 second-feet. Considerable channel storage also exists between Boulder Dam and Topock gage, particularly in the wide channel near Needles, Calif. Natural channel storage will continue to be effective in reducing flood peaks below Boulder Dam after much of the effectiveness of the reservoirs is destroyed by silting.

## DIVERSIONS

Record of all diversions from Colorado River between Boulder Dam and the California-Mexico boundary is given in the tables of discharge except those for Alamo Canal, which diverts from the right bank 1 mile upstream from the boundary. Most of the diversion canals were shut down immediately after flood flow started in the river, either as a precautionary measure or because the canals had been broken by the storm. The tables show that the diversions had a negligible effect in modifying the flood flows.

A small amount of diverted water was returned to the Colorado River. This is shown in the discharge tables for Yuma main canal wasteway and Pilot Knob wasteway.

## SALTON SEA BASIN

The storm of September 3–7 was unusually severe in Salton Sea Basin; that of September 8–13 did not touch the basin; that of September 23–26 was severe in the northwestern part. No discharge record or flood-peak measurements of streams in this basin are available, but surface runoff and later gains from increased ground-water infiltration are reflected by the change in contents of Salton Sea. The elevation of the sea is measured once a month or oftener near Figtree John Spring 9 miles south of Mecca. The change in contents, as shown in table 6, was computed from measurements of area taken from a topographic map made and furnished by the Imperial Irrigation District.

TABLE 6.—*Change in contents, in acre-feet, of Salton Sea between August 1, 1939, and April 1, 1940*

| Date | Elevation, in feet, below mean sea level | Change in contents, in acre-feet, from last previous reading | Date | Elevation, in feet, below mean sea level | Change in contents, in acre-feet, from last previous reading |
|---|---|---|---|---|---|
| *1939* | | | *1940* | | |
| Aug. 1 | 244.1 | ..... | Feb. 2 | 242.1 | +98,500 |
| Sept. 1 | 244.3 | — 37,900 | Mar. 1 | 241.8 | +59,900 |
| Sept. 11 | 243.1 | +230,800 | Apr. 1 | 241.7 | +20,100 |
| Sept. 16 | 243.2 | — 19,300 | | | |
| Oct. 2 | 243.3 | — 19,300 | | | |
| Nov. 1 | 243.2 | + 19,300 | | | |
| Dec. 1 | 242.9 | + 58,400 | | | |
| Dec. 29 | 242.6 | + 59,100 | | | |

The first storm apparently was the only one causing heavy surface runoff. The third storm, although heavy in the vicinity of Thermal and Indio, covered such a small area that total runoff was small. The increase in contents of Salton Sea beginning about November 1939 and extending into April 1940 is attributed largely to greatly increased ground-water storage and subsequent drainage caused by the floods of September 1939. The Coachella Valley County Water District reports that "these floods added to the underground water supply on the east side of the valley, where the cloudbursts were the most intense. Records of deep-well water levels April 1, 1940, show an average reading 3.2 feet above that of April 1939. On the west side of the valley a drop of 1.45 feet is shown, which is normal."

## PREVIOUS FLOODS

On Colorado River itself the spring floods of almost every year prior to the closing of Boulder Dam exceeded the floods of September 1939. Maximum discharge at Topock on June 22, 1921, probably exceeded 200,000 second-feet. In early July 1884 a flood computed as 300,000 second-feet at Grand Canyon passed down the river. Within the period 1857–68 and most likely in 1862 or 1867 discharge in excess of 400,000 second-feet occurred at Topock. At Yuma a peak discharge of 250,000

second-feet occurred January 22, 1916, mostly from Gila River. The relatively low flood discharge of September 1939 does not mean that there was no flood danger. The freedom from floods since the closing of Boulder Dam in February 1935 has permitted vegetation to encroach on the channel and has caused the sediment to remain where it was carried into the main stream, with the result that today flood stages at some points are about as high as they formerly were for discharges twice as large. No serious damage by flooding of Colorado River occurred in September, but a flood of the magnitude of 100,000 second-feet would cause enormously greater damage today than 10 years ago.

On Williams River, floods with peaks greater than 50,000 second-feet occurred four times during the period 1931–38. The highest flood discharge since October 1928, when continuous stream gaging was begun, was that of 92,500 second-feet on February 7, 1937. Studies of earlier floods have indicated flood peaks estimated as follows: 125,000 second-feet about February 16, 1927; 175,000 second-feet about January 19, 1916; and 200,000 second-feet about February 21, 1891. None of these floods caused serious damage on Williams River, as the lower valley has almost no population or developed property. Each flood caused some damage in the Lower Colorado River, especially near Yuma. Floods on Williams River have never coincided with floods coming from upper Colorado River and of themselves have not been a serious menace. Floods such as those of 1891 and 1916, closely related to unusual floods on Gila River, helped to make flood conditions worse below the mouth of Gila River.

Gila River at its mouth has carried large floods in the past, but in September 1939 this river contributed little flow because of the many storage reservoirs on it and its tributaries. On January 22, 1916, the daily discharge was estimated as 200,000 second-feet. The flood of February 1891 may have been greater. The development of storage reservoirs has not entirely removed the flood menace, as it is possible for flood runoff from areas below points of storage to cause great floods. In addition, the reservoirs might be too full to function adequately as flood-control reservoirs. None of the reservoirs in the Gila River Basin are operated primarily for flood control.

Reliable information on flood discharge from washes and small areas in the lower Colorado River Basin is almost nonexistent. Extremely high rates of discharge are known to occur in almost all the washes at one time or another, usually as the result of a so-called cloudburst. The effect of such floods on the larger streams or on Colorado River, however, is slight because the flood result from intense rainfall on a small area is of short duration. For example, the flood of September 6–7, 1939, in Sacramento Wash, which had a peak discharge of 15,000 second-feet, is estimated on the basis of the best information available to have consisted of only about 7,500 acre-feet.

In Truxton Wash, 40 miles northeast of Kingman, Ariz., on the headwaters of Big Sandy River, flood discharge on August 2, 1904, was estimated at 49,000 second-feet.[2] This evidently high rate of discharge is what may be expected at almost any time from small areas in the lower Colorado River Basin.

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[2]The damage caused by this flood is described in Murphy, E. C., Destructive floods in the United States in 1904: U. S. Geol. Survey Water-Supply Paper 147, pp. 115-118, 1905.

# INDEX



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