RECONNAISSANCE WATER-BALANCE STUDY OF LAKE GREGORY, CALIFORNIA

By Christopher E. McConaughy

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CONVERSION FACTORS AND DEFINITIONS

The inch-pound system of units is used in this report. For readers who prefer metric (SI) units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
acres	0.004047	km^2 (square kilometers)
acre-ft (acre-feet)	0.001233	hm^3 (cubic hectometers)
ft (feet)	0.3048	m (meters)
ft^3/s (cubic feet per second)	0.02832	m^3/s (cubic meters per second)
inches	25.4	mm (millimeters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level.

Topographic Datum of 1892: A datum developed from a topographic survey of Houston Creek by Fred T. Perris in 1892. It is approximately 7.1 feet lower than National Geodetic Vertical Datum of 1929.

Water Year: The water year starts October 1 and ends September 30; it is designated by the calendar year in which it ends.

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ABSTRACT

A study was made to determine the magnitude and distribution of the surface-water inflow and outflow (water balance) of the Lake Gregory basin in southern California. Data were collected from April 1979 through June 1981. This study was needed to help define the availability of surface water for use by the growing mountain area to insure an adequate water supply for domestic use, fire protection, and recreation. Because of the short period of streamflow record available for analysis, a meaningful estimate of long-term yield from the basin was not determined.

Monthly streamflow data at the major inflow streams and at the lake outlet, along with precipitation, estimated evaporation from the lake, and change in lake storage, are presented in a water-balance equation. Inflow from the ungaged part of the basin is also estimated and presented in the equation. The effects of ground-water losses and gains on the system are not evaluated but are included as a residual factor along with accumulated error in measuring other components in the water-balance equation.

Runoff during the study period, April 1979 to June 1981, varied greatly with the majority of inflow occurring between December and May of each year. During 1980 and 1981 precipitation totals at Lake Gregory were the maximum and minimum for the 19-year period of record. The average annual precipitation for the 3-year period 1979-81 was 47.4 inches, almost 10 inches greater than the long-term average, 1962-81, of 37.8 inches. Surface-water runoff in the Lake Gregory basin is highly dependent on annual precipitation, and total outflow for the 1980 water year and partial total for the 1981 (through June) water year was 7,230 acre-feet and 400 acre-feet, respectively.

INTRODUCTION

Background/Problem

Lake Gregory, in the San Bernardino Mountains of southern California, is a small, picturesque mountain reservoir. The lake is approximately 60 miles east of the city of Los Angeles near the mountain community of Crestline, a popular resort area for residents of southern California (figs. 1 and 2). In recent years, growing permanent and tourist populations, a severe drought, and a near disasterous fire have increased awareness of the importance of adequate water supplies for domestic use and fire protection. In spring 1979, the U.S. Geological Survey, in cooperation with the Crestline-Lake Arrowhead Water Agency began a study of the surface-water runoff in the basin. Lake Gregory is a potential storage reservoir of water supplies for use by the Crestline-Lake Arrowhead Water Agency, and an understanding of the surface-water runoff and its effect on the reservoir under present conditions was needed.

Purpose and Scope

The purpose of the study was to determine the magnitude and distribution of surface-water flows to and from Lake Gregory. In addition, precipitation and changes in lake storage were monitored and lake evaporation was estimated to help define the inflow-outflow relations.

Three streamflow-gaging stations were constructed and a lake-stage station was reactivated (table 1) to continuously measure major tributary inflow, outflow, and changes in lake storage. Streamflow and lake stage data were collected April 1, 1979, to June 30, 1981. Monthly precipitation to and evaporation from the lake surface was estimated using existing data. Historical evaporation records at Lake Gregory were examined to determine reasonable estimates of evaporation for the study period.

TABLE 1. - U.S. Geological Survey gaging stations in the vicinity of Lake Gregory

Station No.	Name	Type of record	Period of record	Drainage area mi²	Drainage area acres
10260620	Houston Creek above Lake Gregory, at Crestline, CA	Daily surface-water discharge	Began 3-8-79[1]	0.35	224
10260630	Abondigas Creek above Lake Gregory, at Crestline, CA	Daily surface-water discharge	Began 3-8-79[1]	1.15	736
10260640	Lake Gregory at Crestline, CA	Continuous lake elevation	Began 8-8-78[2]	2.66	1,702
10260650	Houston Creek below Lake Gregory, at Crestline, CA	Daily surface-water discharge	Began 3-8-79[1]	2.68	1,715

[1]Station constructed as long-term data collection site.
[2]Records for September 1966 through November 1971 in files of California Department of Water Resources.

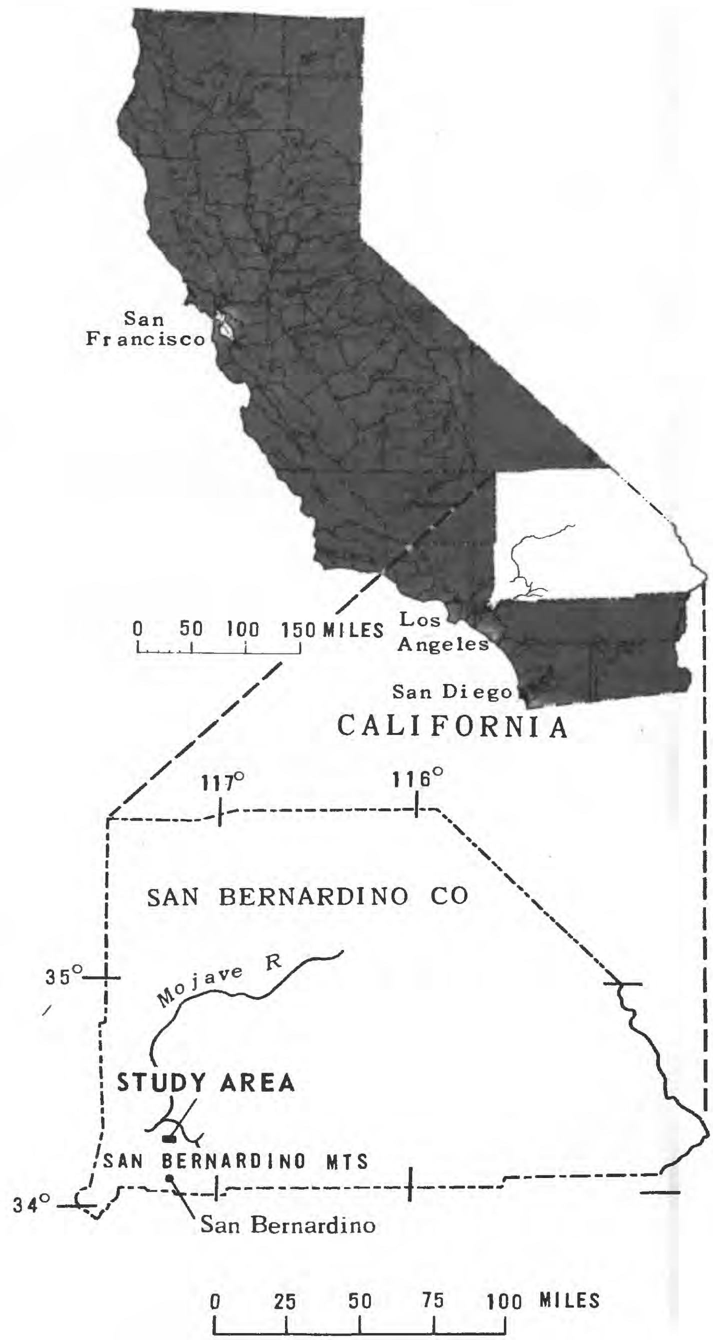
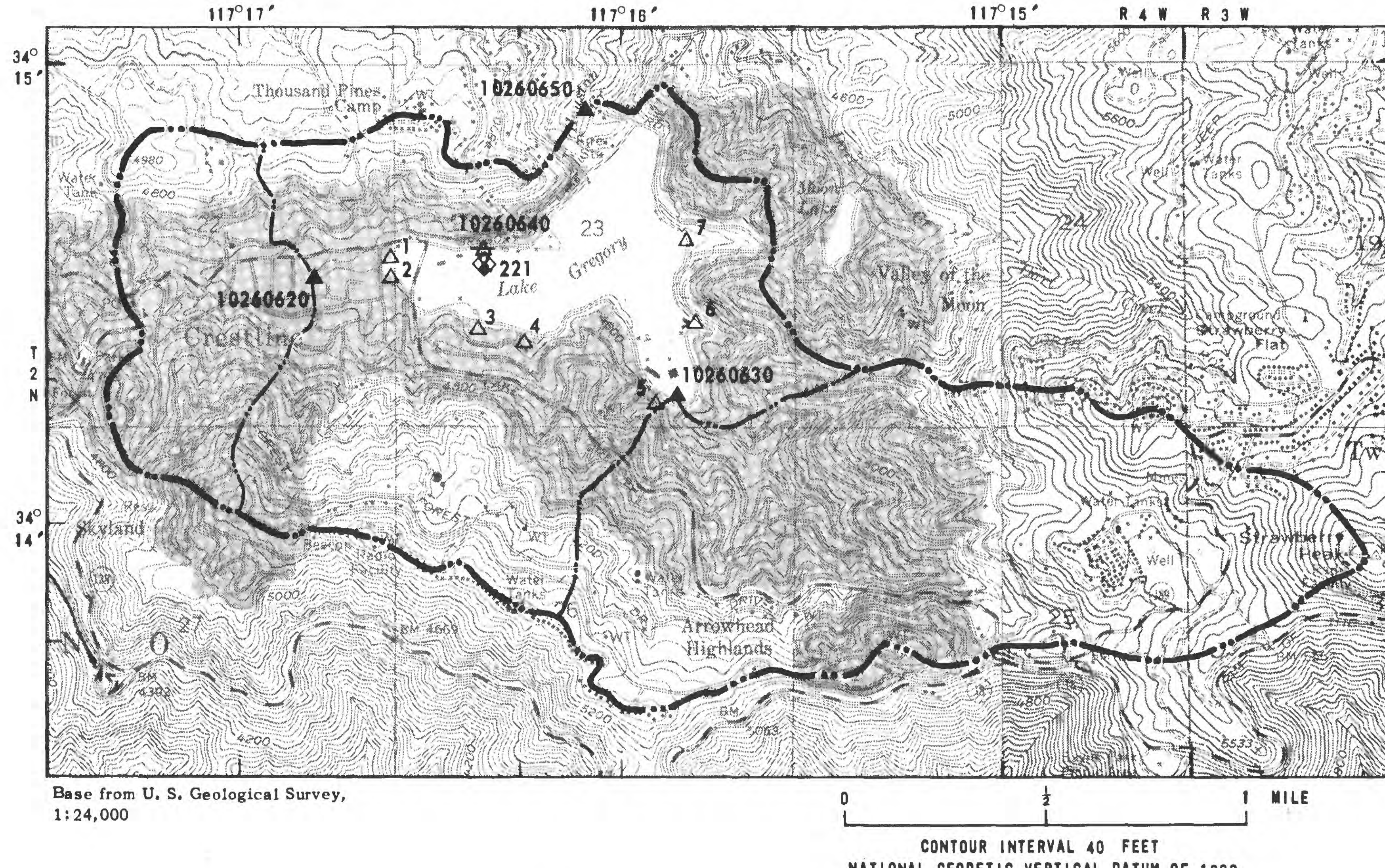


FIGURE 1.-- Location of study area.



EXPLANATION

10260620 STREAM-GAGING STATION AND **U. S. GEOLOGICAL SURVEY NUMBER**

10260640 LAKE STAGE STATION AND NUMBER

5 UNGAGED MEASURING SITE AND NUMBER

221 PRECIPITATION STATION AND SAN BERNARDINO COUNTY FLOOD CONTROL DISTRICT NUMBER

DRAINAGE BASIN BOUNDARY

SUBBASIN BOUNDARY

FIGURE 2.--Lake Gregory drainage basin and location of hydrologic data-collection sites.

Basin Description

Lake Gregory lies at the upper end of the Houston Creek basin, which is tributary to the Mojave River. For purposes of this report, that part of the Houston Creek basin upstream from Lake Gregory is defined as the Lake Gregory basin. Lake Gregory was formed by the completion of an earthen-type dam on Houston Creek in 1938. At a spillway lip elevation of 4,517 ft (topographic datum of 1892), the lake has a surface area of 86 acres, a capacity of 2,070 acre-ft, and a shoreline of about 2 mi. The drainage area of the basin at the outlet station, Houston Creek below Lake Gregory, is 2.68 mi^2 including the lake.

Topography in the Lake Gregory basin is typically mountainous, with slopes in the 30 to 50 percent range, and reflects the geologic youth of the San Bernardino Mountains (fig. 2). The area is underlain by a basement complex of Mesozoic granitic rocks that form a large part of the San Bernardino Mountains. An east-west trending fault (Gregory fault, not shown in fig. 2) has been mapped (T. W. Dibblee, Jr., U.S. Geological Survey, written commun., 1963) that runs just north of Crestline, under the lake and east through Moon Lake. An analysis of the effect of the fault on seepage to or from the lake is beyond the scope of this study.

Soils in the basin range in depth from 0 to 15 inches on the steeper slopes to about 30 inches in flatter areas, are well drained, brown, and usually composed of sandy loam (Retelas, 1980). Vegetation is characterized by a conifer forest, with broadleaf trees (hardwood) in the riparian zones (Jeanine Derby, U.S. Forest Service, San Bernardino, Calif., oral commun., 1981).

The study area has warm, dry summers and cold, wet winters, typical of mountainous areas of southern California. Air temperature ranges from highs in the mid-eighties in July and August to lows in the mid-teens in January and February. Mean annual precipitation at Lake Gregory for the 1962-81 water years was 37.85 inches. Some of the precipitation occurs as snow or frozen rain.

Lake Gregory is a popular recreational area for residents of southern California, particularly during the summer. The permanent population of the Lake Gregory area is about 900 residents according to preliminary figures from the 1980 census (San Bernardino County Planning Department, written commun., 1981). About 50 percent of the domestic water supply for the Crestline area is imported California State Water Project water distributed by the Crestline-Lake Arrowhead Water Agency. The remainder is supplied by local wells and purveyors (Robert Massey, Crestline-Lake Arrowhead Water Agency, oral commun., 1980).

WATER-BALANCE EQUATION

A water balance is an account of the movement of all water to and from and storage in a given body of water. In order to illustrate the relative magnitudes and distributions of flows to and from Lake Gregory, data are presented on a monthly basis in the following water-balance equation (table 2).

$$\overbrace{(I + P)}^{\text{Inflow}} - \overbrace{(O + E)}^{\text{Outflow}} - \Delta S = R \qquad (1)$$

where

I = surface inflow to lake, in acre-feet,

P = direct precipitation onto lake surface (inflow), in acre-feet,

O = surface outflow from lake, in acre-feet,

E = evaporation from lake surface (outflow), in acre-feet,

ΔS = change in lake storage, in acre-feet (decreases in storage carry a negative sign and must be treated algebraically), and

R = residual, in acre-feet. Value needed to balance equation; physically it represents net ground-water inflow and/or outflow and accumulated error in estimating/measuring other components in the equation.

The basic premise of the equation is that inflow (including precipitation) equals outflow (including evaporation) plus or minus the change in lake storage. The equation is arranged so that all components that were measured or estimated were placed on the left side of the equation and the remainder was designated as the residual, R, and placed on the right side. Measurement of the contribution or loss to lake storage from ground water was not within the scope of the study, and net changes in ground water are reflected in the residual. Data used in the water-balance equation and presented in table 2 were derived from the hydrologic data-collection sites shown in figure 2 and table 1.

TABLE 2. - Water balance for the Lake Gregory basin for the period April 1, 1979, to June 30, 1981

[Values in acre-feet; totals are rounded to three significant figures]

Month and year	Total surface inflow: Houston Creek above Lake Gregory (10260620)[1]	Abondigas Creek above Lake Gregory (10260630)[1]	Ungaged drainage area Q_u	Total (sum of columns 1+2+3)	Precipitation on lake surface	Total surface outflow: Houston Creek below Lake Gregory (10260650)[1]	Estimated lake evaporation	Change in lake storage[2]	Residual[3]
				(I	+ P)	- (O	+ E)	- ΔS	= R
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1979 water year									
Apr 1979	67	243	215	525	0	220	22	+160	123
May	22	120	96	238	6	243	30	- 20	- 9
June	8	22	21	51	0	21	38	- 40	32
July	5.1	11	12	28	2	3.1	47	- 10	- 10
Aug	2.9	1.9	3.9	8.7	4	2.5	44	- 20	- 14
Sept 1979	1.1	0.3	1.2	2.6	0	2.4	34	- 30	- 4
Partial total 1979 water year	106	398	349	853	12	492	215	+ 40	118
1980 water year									
Oct 1979	9.5	28	26	64	26	120	25	- 80	25
Nov	0.7	4.0	3.2	7.9	1	5	14	0	- 10
Dec	1.5	4.4	4.2	10	8	11	9	+ 20	- 22
Jan 1980	265	488	555	1,310	185	1,350	9	+ 40	96
Feb	706	1,100	1,350	3,160	208	3,000	11	+ 50	307
Mar	444	741	883	2,070	97	1,800	19	- 90	438
Apr	86	195	203	484	13	418	22	+ 60	- 3
May	58	159	154	371	16	329	30	- 10	38
June	16	69	58	143	0	55	38	+ 50	0
July	6.5	24	21	52	0	6.9	47	+ 20	- 22
Aug	2	10	8.1	20	0	5.9	44	- 20	- 10
Sept 1980	0.9	4.3	3.5	8.7	0	129	34	-140	- 14
Total 1980 water year	1,600	2,830	3,270	7,700	554	7,230	302	-100	822
1981 water year									
Oct 1980	0.6	3.9	3.0	7.5	6	2.1	25	0	- 14
Nov	0.3	5.6	3.8	9.7	2	3.5	14	0	- 6
Dec	4.8	13	13	31	11	16	9	+ 30	- 13
Jan 1981	49	35	68	152	39	106	9	+ 10	66
Feb	10	13	18	41	17	59	11	0	- 12
Mar	35	36	56	127	35	195	19	- 10	- 42
Apr	25	28	41	94	19	9.1	22	+ 90	- 8
May	7.1	13	15	35	7	6.1	30	+ 10	- 4
June 1981	3.8	3.6	5.8	13	0	3.2	38	- 30	2
Partial total 1981 water year	136	151	224	510	136	400	177	+100	- 31
Study period total	1,840	3,380	3,840	9,060	702	8,120	694	+ 40	908
1980 climatic year July 1, 1979 to June 30, 1980	1,600	2,800	3,250	7,650	560	7,100	302	- 20	828
1981 climatic year July 1, 1980 to June 30, 1981	145	189	256	590	136	542	302	- 40	- 78

Example (1981 climatic year): Total surface inflow (I + P) - total surface outflow (O + E) = (590 + 136) - (542 + 302) = -118; 40 of which come from storage (ΔS), leaving the residual (R) of -78.

[1]1979 and 1980 water-year data from U.S. Geological Survey (1981). 1981 water-year data unpublished at the time of this report and subject to revision.

[2]Volume changes computed from 2400-hour lake reading at station 10260640, Lake Gregory at Crestline, the last day of every month. Algebraic sign of change in lake storage indicates actual change; the value should be treated algebraically in the water-balance equation.

[3]Value needed to balance equation; physically it represents inflow and/or outflow and accumulated error in measuring other components in the equation.

Surface Inflow

Principal inflow to Lake Gregory is measured at two Geological Survey gaging stations, one on Houston Creek and the other on Abondigas Creek. Surface inflow from these two streams and ungaged land areas accounted for 90 percent of the inflow to Lake Gregory. The largest contributor, Abondigas Creek, enters from the southeast and drains 43 percent of the total basin area. Flow from Abondigas Creek accounted for 35 percent of the total surface inflow for the study period. Houston Creek, entering from the west, drains 13 percent of the basin and accounted for 19 percent of the total surface inflow.

Approximately 39 percent (1.05 mi^2) of the basin is ungaged land surface and drains directly to the lake through much smaller channels. To compute the inflow contribution from the ungaged area, the assumption was made that runoff characteristics of the ungaged part of the basin were similar to those of the gaged part. The ungaged part of the basin was divided by arbitrarily drawing a north-south trending line at the west end of the lake. Monthly runoff volumes were estimated by indexing the western part of the ungaged area to the Houston Creek gage (10260620), and the eastern part to the Abondigas Creek gage (10260630), by use of the following equation:

$$Q_u = \left(\frac{A_{uw}}{A_h} \times Q_h\right) + \left(\frac{A_{ue}}{A_a} \times Q_a\right) \qquad (2)$$

where

Q_u = monthly discharge of ungaged drainage area, in acre-feet,

A_{uw} = drainage area of the western part of the ungaged drainage area, in square miles,

A_h = drainage area of Houston Creek above Lake Gregory, in square miles,

Q_h = monthly discharge of Houston Creek above Lake Gregory, in acre-feet,

A_{ue} = drainage area of the eastern part of the ungaged drainage area, in square miles,

A_a = drainage area of Abondigas Creek above Lake Gregory, in square miles, and

Q_a = monthly discharge of Abondigas Creek above Lake Gregory, in acre-feet.

The east and west parts represented 0.72 mi^2 and 0.33 mi^2 of the total 1.05 mi^2 of ungaged drainage. Runoff from the ungaged area of the basin accounted for 42 percent of the total surface inflow. Periodic discharge measurements were made at seven miscellaneous sites (fig. 2) around the lake. These measurements were intended to aid in calculating the contribution of surface inflow from the ungaged part of the basin; however, insufficient data were available to develop a reliable relation between gaged and ungaged drainages. The discharge measurements are provided as supplemental data at the end of this report.

The lake surface represents the remaining 5 percent of surface area in the basin. Inflow from direct precipitation onto the lake surface was computed from the precipitation record collected at Lake Gregory by the county of San Bernardino (table 3). Direct precipitation onto the lake surface provided 7 percent of the total inflow for the study period. Monthly inflow data collected and estimated during the study period is presented in table 2. Figure 3 graphically shows the relative magnitudes of each inflow component on a monthly basis. Clearly, most inflow occurs between December and May of each year.

TABLE 3. - Monthly precipitation at Lake Gregory for the period October 1979 to September 1981

[San Bernardino County Flood Control District, Station No. 221, written commun., 1981]

Month	Water year 1979 (inches)	Water year 1980 (inches)	Water year 1981 (inches)
October	0.35	3.55	0.82
November	6.74	.19	.20
December	8.31	1.08	1.65
January	12.53	25.90	5.46
February	6.17	29.14	2.44
March	9.35	13.65	4.99
April	.02	1.85	2.70
May	.85	2.22	.89
June	0	0	0
July	.20	0	Trace
August	.59	0	.18
September	.02	0	.04
Total	45.13	77.58	19.37

Average for 3-year period: 47.36 inches.

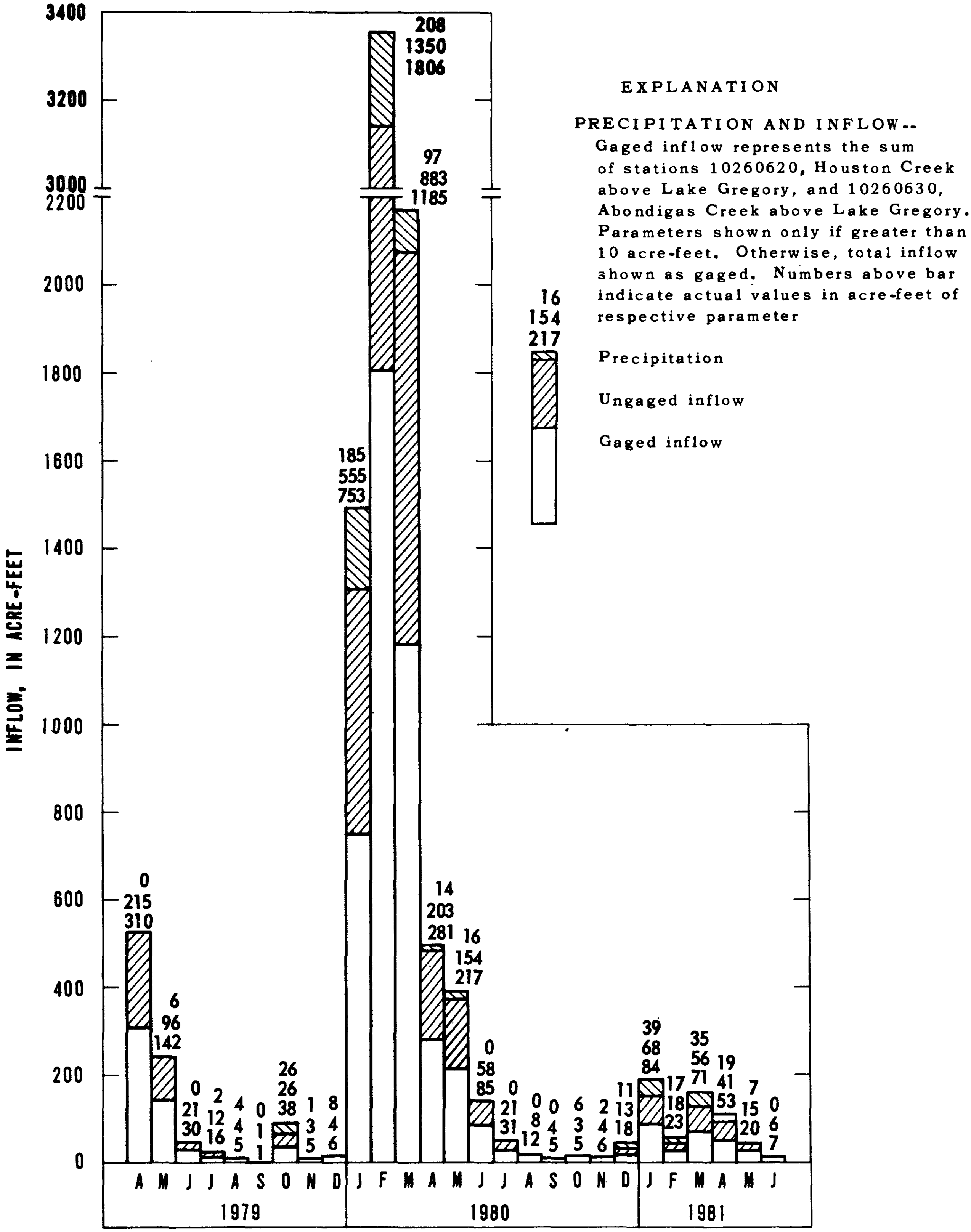


FIGURE 3.--Surface-water inflow to Lake Gregory and precipitation on the lake surface.

Surface Outflow

The principal water outlet from Lake Gregory is Houston Creek. Outflow may also occur in the form of seepage (fracture flow) in the bedrock; however, no significant seepage has been observed in or near the channel on numerous field visits to the outflow gage. Water discharge from the lake to Houston Creek is primarily through the lake spillway and is partly regulated by San Bernardino County Regional Parks between April 1 and September 10 of each year. Water may also be released from the lake to Houston Creek through a 12-inch diversion outlet tunnel. Normal operation procedures are to install flashboards in the spillway lip about April 1 of each year to impound water for seasonal recreational use; the flashboards are usually removed about October 1 in anticipation of winter inflows (San Bernardino County Park Rangers, Lake Gregory Regional Park, oral commun., 1980).

Outflow from both the spillway and diversion outlet is measured at the gaging station on Houston Creek below Lake Gregory (station 10260650) which is approximately 500 ft below the spillway. During the study period, total discharge from the basin was 8,120 acre-ft. To illustrate the effects of flashboard removal during the study period, daily discharge hydrographs for Houston Creek (10260650) and lake stages for Lake Gregory (10260640) were plotted for the period September 15 to October 15 for 1979 and 1980 (fig. 4). Total discharge measured at Houston Creek for these periods was 79 and 130 acre-ft for 1979 and 1980, respectively.

Evaporation was not measured during the study. Evaporation data collected by the California Department of Water Resources (1977, p. 128) at Lake Gregory, from May 1967 to November 1971, were used to estimate a total annual evaporation of 3.5 ft. Because of insufficient data, the annual rate of evaporation was held constant although it probably varies somewhat from year to year. Estimates of monthly evaporation were made by determining the mean monthly percentage of total evaporation at the California Department of Water Resources evaporation sites at Cedar Springs, Pilot Rock, Lake Gregory, and Palmdale. Volume estimates were made from monthly evaporation estimates, lake-stage records, and the stage-area curve developed by Crest Forest County Water District from a topographic survey of Houston Creek by Fred T. Perris in 1892 (California Department of Water Resources, Division of Safety of Dams, written commun., 1980).

Outflow data collected and estimated during the study period are presented in table 2. Figure 5 illustrates monthly distribution and magnitude of total surface-water outflow (including evaporation) during the study period.

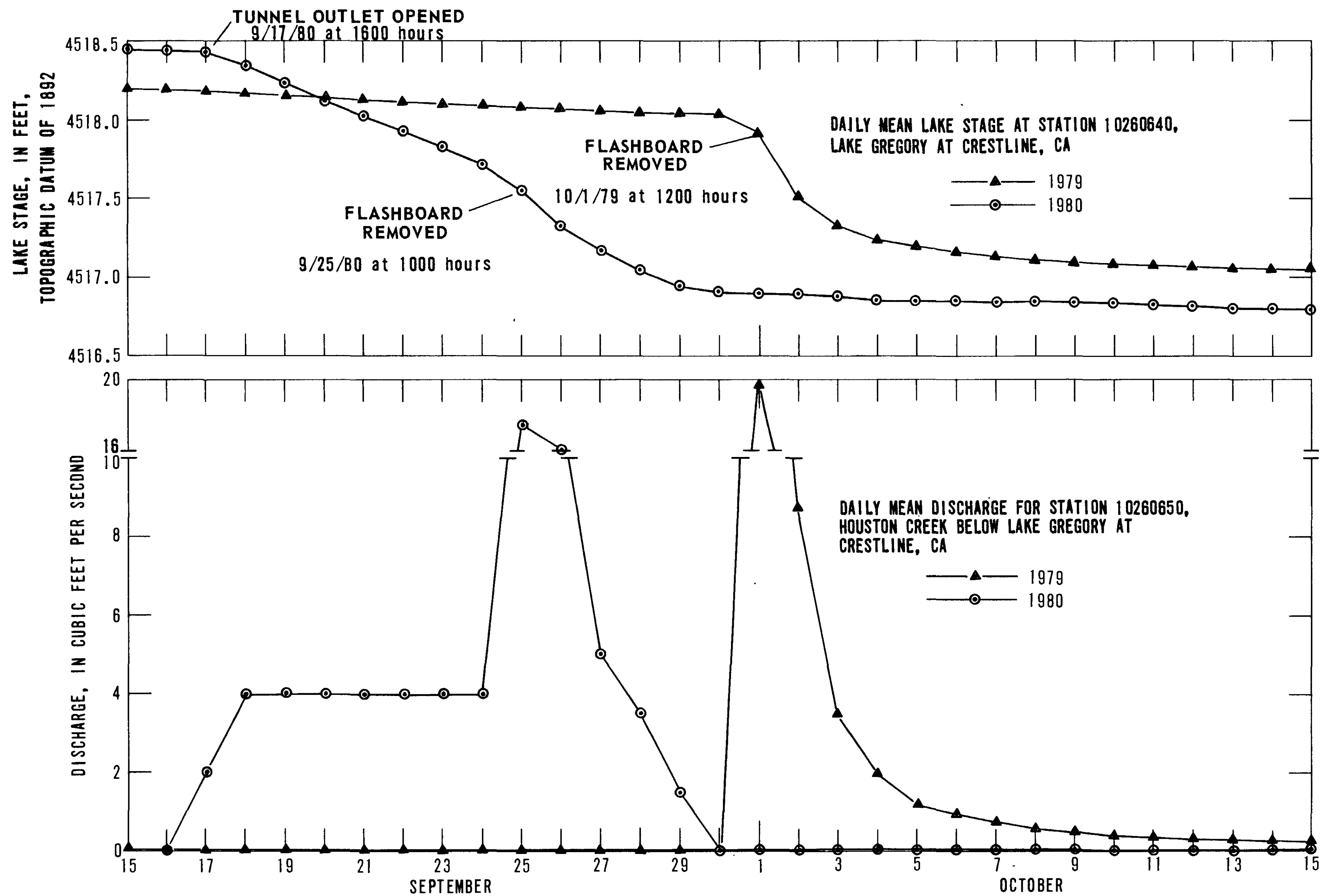


FIGURE 4.--Daily mean lake stage of Lake Gregory and outflow at Houston Creek for the period September 15 through October 15 for 1979 and 1980.

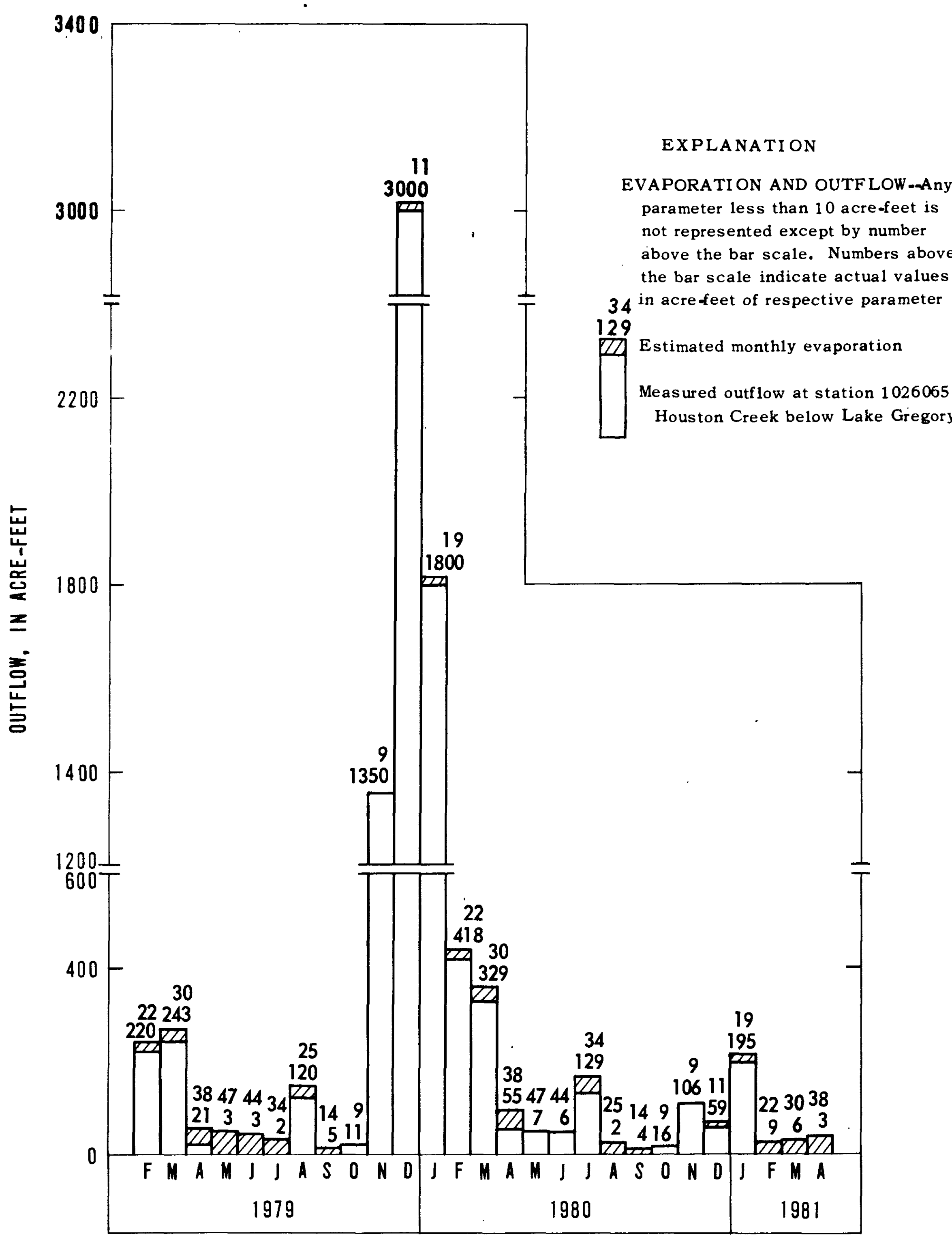


FIGURE 5.--Surface-water outflow and evaporation from Lake Gregory.

Change in Lake Storage

If direct precipitation onto the lake, P, and evaporation, E, are considered to be parameters of surface inflow and outflow respectively, then change in lake storage, ΔS, accounts for the difference between surface inflow and outflow. In this study, a residual factor, R, is needed to balance the equation to allow for ground-water losses and gains and for measurement error.

During this study, continuous lake-stage records were collected by the Survey at the Lake Gregory boathouse in Lake Gregory Regional Park. Changes in storage were computed (see table 4) from a stage-capacity curve developed by Crest Forest County Water District (California Department of Water Resources, Division of Safety of Dams, written commun., 1980). Some question exists about the absolute datum of the gage with respect to NGVD of 1929 and the topographic datum of 1892. On March 31, 1981, levels were run from a temporary bench mark that was set by a local consultant to determine gage datum. The levels showed the gage to be reading about 7.1 ft low with respect to the NGVD of 1929. Levels were not run to the spillway lip, but by water level on March 31 (the same day) the approximate elevation of the spillway lip with respect to the existing gage plate was 4,517.2 ft. This elevation agrees reasonably well (within 0.2 ft) with the elevation shown as the spillway lip (4,517.0 ft) on the stage-capacity curve. Thus, gage datum is apparently not NGVD of 1929 and will be referred to hereafter as topographic datum of 1892.

Sedimentation occurring in the lake and the datum discrepancy discussed above lend question to the validity of the absolute contents of the lake at a given elevation. The assumption is made for this report, however, that the change between given elevations (slope of the stage-capacity curve) is still reasonably consistent with the original curve. If a future lake survey showed that the slope of the stage-capacity curve had indeed changed, four columns of table 2 would be affected; P, E, ΔS, and R could be recomputed using the revised values for lake-surface area.

Residual Factor

The residual factor, R, in table 2 represents the numerical value needed to equalize the water-balance equation. Physically, it represents ground-water losses and gains and accumulated error in estimating or measuring other components in the equation. If interpretations are to be made about ground-water losses and gains using the computed residual, careful consideration should be given to error analysis of all other hydrologic components of the equation.

TABLE 4. - Elevation and contents data at Lake Gregory for the period March 31, 1979, to June 30, 1981

Date	Recorded lake elevation[1] at 2400 hours	Lake contents[2] (acre-feet)	Change in lake contents (acre-feet)
3-31-79	4,517.53	2,120	--
4-30-79	4,519.47	2,280	+160
5-31-79	4,519.16	2,260	-20
6-30-79	4,518.75	2,220	-40
7-31-79	4,518.61	2,210	-10
8-31-79	4,518.34	2,190	-20
9-30-79	4,518.04	2,160	-30
10-31-79	4,517.09	2,080	-80
11-30-79	4,517.13	2,080	0
12-31-79	[3]4,517.28	2,100	+20
1-31-80	[3]4,517.76	2,140	+40
2-29-80	[3]4,518.38	2,190	+50
3-31-80	[3]4,517.36	2,100	-90
4-30-80	[3]4,518.00	2,160	+60
5-31-80	4,517.94	2,150	-10
6-30-80	4,518.52	2,200	+50
7-31-80	4,518.69	2,200	+20
8-31-80	4,518.51	2,200	-20
9-30-80	4,516.90	2,060	-140
10-31-80	4,516.85	2,060	0
11-30-80	4,516.86	2,060	0
12-31-80	4,517.22	2,090	+30
1-31-81	4,517.28	2,100	+10
2-28-81	4,517.29	2,100	0
3-31-81	4,517.23	2,090	-10
4-30-81	4,518.26	2,180	+90
5-31-81	4,518.42	2,190	+10
6-30-81	4,518.02	2,160	-30

[1]Datum of gage is 4,510.00 feet based on topographic survey by Fred T. Perris in September 1892; approximately 4,517.1 feet National Geodetic Vertical Datum of 1929.

[2]Elevation-capacity table derived from expansion of original elevation-capacity curve developed by Crest Forest County Water District, dated 1936 (California Department of Water Resources, Division of Safety of Dams, written commun., 1980).

[3]Elevation from observers reading at 0800 hours on first day of following month.

Comparison to the Long-Term Record

Surface-water runoff in the Lake Gregory basin is highly dependent on annual precipitation. Average annual precipitation at Lake Gregory for the period 1962-81 is 37.85 inches (table 5). In comparison, average annual precipitation for the 3-year period 1979-81 was 47.36 inches, almost 10 inches greater. Important to note is the wide variance in annual precipitation during the study period, 1979-81. Precipitation in the 1980 water year is the maximum recorded for the 20-year period of record; the 1981 water year is the minimum recorded annual precipitation. Flow data for the rainy period of the most climatically normal year, 1979, is largely absent because data collection did not begin until March 1979.

To illustrate the relative wetness of the study period to the long term, an annual precipitation frequency curve (fig. 6) was plotted for the 89-year record, 1893-1981, at Lake Arrowhead Fire Station No. 1 (San Bernardino County Flood Control District, 1893-1938, 1939-79). Because the Lake Gregory and Lake Arrowhead sites show good correlation (standard error of estimate = ±7.2 inches) the probabilities of occurrence of the 1979-81 annual precipitation totals at Lake Gregory should be comparable to those at Lake Arrowhead. From figure 6, there is a 92-percent probability that the annual total precipitation for the 1981 water year (at Lake Arrowhead) will be exceeded in any year. The exceedance probabilities for 1979 and 1980 water years at Lake Arrowhead are 19 and 7 percent, respectively.

TABLE 5. -- Annual precipitation at Lake Gregory for the period 1962 to 1981

[Data from San Bernardino County Flood Control District for station No. 221, written commun., 1981]

Water year	Precipitation (inches)	Water year	Precipitation (inches)	Water year	Precipitation (inches)
1962	27.18	1969	65.73	1976	33.36
1963	21.41	1970	21.15	1977	26.32
1964	22.35	1971	24.43	1978	77.27
1965	30.77	1972	24.04	1979	45.13
1966	40.87	1973	40.46	1980	77.58
1967	69.14	1974	23.72	1981	19.37
1968	No record	1975	28.88		
		Average annual precipitation-----------			37.85

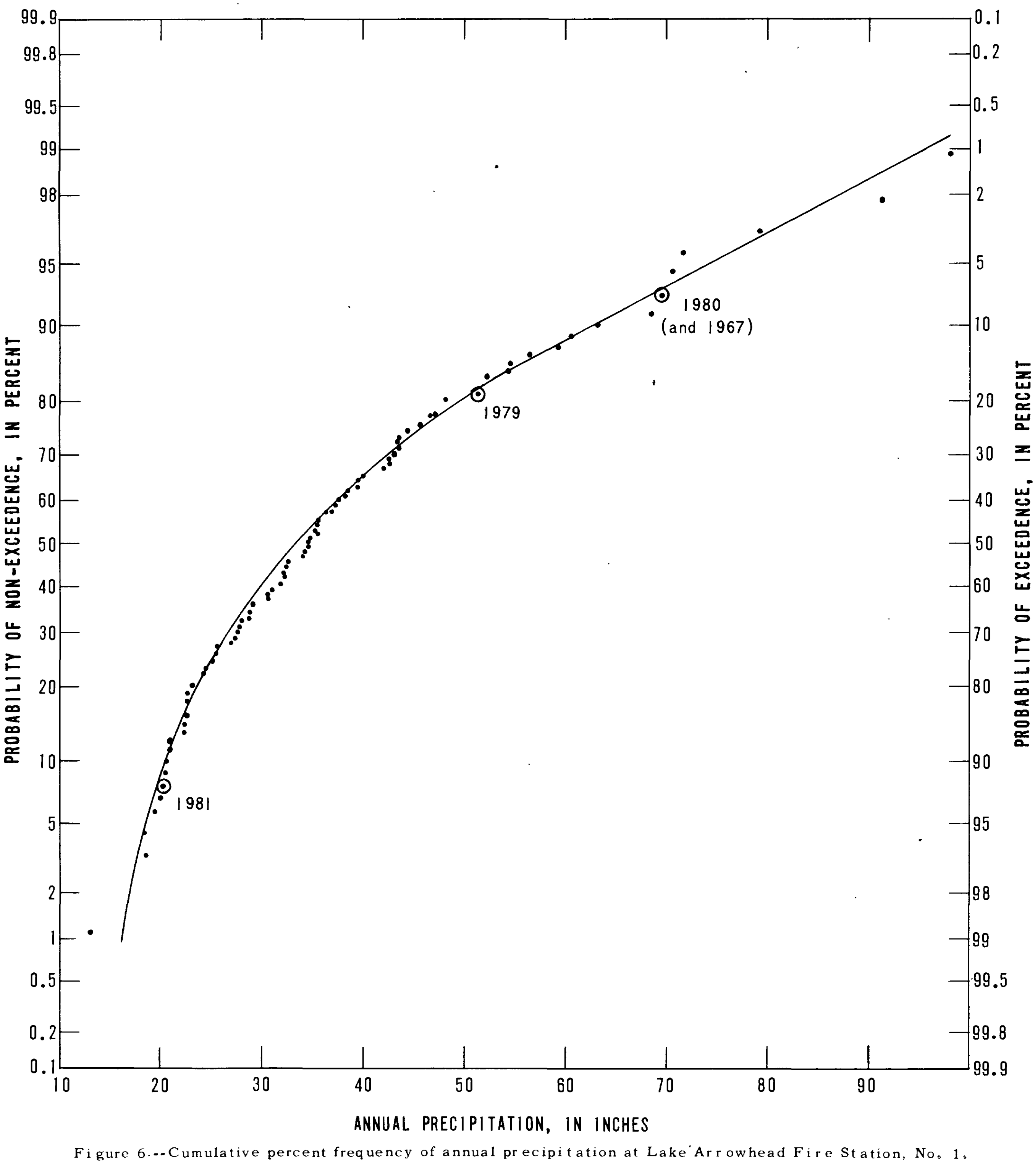


Figure 6.--Cumulative percent frequency of annual precipitation at Lake Arrowhead Fire Station, No. 1.

Water-Balance Reliability

Monthly evaporation and ungaged inflow estimates represent the least accurate components of the water-balance equation; however, the annual evaporation figure should be more accurate than estimates for the individual months. It is important to note that the accuracy of water-balance studies increases as longer periods of time are considered; thus the annual balance has greater reliability than the monthly balance.

The water-balance data presented in table 2 show the distribution and magnitude of monthly flows for both a very high flow year (1980) and a very low flow year (1981). Total monthly inflows and outflows vary dramatically between the same months in 1980 and 1981 water years. Total inflow for February 1981 was 41 acre-ft and for February 1980 was 3,160 acre-ft, some 77 times greater. For the 3-month period January-March 1980, total inflow was 20 times (outflow 17 times) greater than the same period in 1981. In order to compare two complete years of data, the period July 1, 1979, to June 30, 1981, was divided into two periods beginning July 1 and ending June 30 (sometimes designated as the climatic year). Totals for these two periods are shown at the bottom of table 2. The rates of inflow and outflow are as much as 13 times greater in 1980 than in 1981 for these periods. For convenience, the water-year totals for 1980 and partial totals for 1979 and 1981 are shown following their respective periods; study period totals are given at the bottom of table 2.

In analyzing what relation the mean or average year has to these years, in terms of basin yield, one might be tempted to average the total outflow to obtain a mean. The figures for 1980 and 1981 climatic years would show 7,650 and 590 acre-ft for a total of 8,240 acre-ft and an average of 4,120 acre-ft. In actuality, the long-term average runoff from Lake Gregory is likely to be considerably less. As noted earlier, surface runoff in the basin is highly dependent on annual precipitation and for the period 1979-81, average annual precipitation was almost 10 inches greater than for the longer period, 1962-81. Also, the assumption is made that high-runoff years occur with equal frequency as do low-runoff years when in fact the distribution is usually skewed toward the low-runoff years.

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SUPPLEMENTAL DATA: Discharge measurements at ungaged inflow sites in the Lake Gregory basin

[E indicates estimated discharge. Location of sites are shown in figure 2]

Date	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6		Site 7	
	Dis-charge (ft^3/s)	Hour	Dis-charge (ft^3/s)	Hour	Dis-charge (ft^3/s)	Hour	Dis-charge (ft^3/s)	Hour	Dis-charge (ft^3/s)	Hour	Dis-charge (ft^3/s)	Hour	Dis-charge (ft^3/s)	Hour
							1979 water year							
3-14-79	0.4E	1500	(1)		0.2E	1500	0.3E	1510	0.4E	1515	0.25E	1520	0.15E	1530
3-22-79	.6E	1400	(1)		.3E	1410	.2E	1415	.15E	1420	.5E	1540	.10E	1545
3-23-79	.32	1155	(1)		.14	1150	.13	1150	.30	1145	.65	1005	.08	1000
3-27-79	3.7	1300	(1)		2.0	1305	.60	1310	4.0	1315	1.2	1510	3.0	1515
4-04-79	.25E	1500	(1)		.10	1505	.43	1505	.43	1510	.60	1700	.08	1710
4-30-79	.25E	1440	(1)		.21	1445	.05	1455	.17	1450	.13	1555	.01	1605
5-29-79	.01E	1530	0	1530	.23	1540	0	1540	.15	1545	.08	1645	0	1650
7-09-79	.01E	1240	(1)		.16	1245	0	1245	.02	1250	0	1430	0	1430
7-30-79	0	1315	0	1315	.08	1320	0	1320	0	1330	0	1335	0	1335
8-30-79	0	0930	0	0930	.08	0945	0	0950	0	0955	0	1045	0	1045
							1980 water year							
10-04-79	0	1215	0	1215	.05	1220	0	1220	0	1220	0	1245	0	1245
11-04-79	0	1100	0	1100	.05	1105	0	1115	0	1120	0	1240	0	1240
11-10-79	0	1200	0	1200	.05	1205	0	1210	0	1215	0	1315	0	1315
11-30-79	0	1100	0	1100	.05	1105	0	1110	0	1115	0	1140	0	1140
1-05-80	0	1140	0	1140	.05	1140	0	1150	0	1200	0	1220	0	1220
1-09-80	.78	1230	1.3	1245	.23	1315	No measurement		1.3	1415	.45	1535	.02E	1545
1-14-80	1.0	1200	2.8	1215	1.1	1300	No measurement		2.8	1330	1.1	1430	.83	1440
1-30-80	.25E	1320	.25E	1320	.10	1325	.6E	1330	.10E	1340	1.6	1440	.17	1450
2-05-80	.11	1230	.15E	1235	.14E	1240	.18E	1245	.18E	1250	.15	1430	.05	1445
2-18-80	1.5	1200	3.2	1215	.83	1245	2.1	1310	7.7	1435	2.5	1450	4.5E	1515
3-05-80	.52	1010	.62	1015	.13	1020	.28	1030	1.1	1110	1.0	1420	.48	1430
4-08-80	.12	1330	.11	1325	.09	1340	.10	1350	.36	1525	.13	1545	.13	1555
5-09-80	.07	0830	.08	0840	.09	0905	.10	0920	.35	1055	.07	1120	.01E	1140
6-11-80	.04	1230	.02	1235	.10	1215	.13	1145	.16	0945	.04	0935	0	0915
7-01-80	.02	1320	0	1320	.10	1330	.04	1335	.09	1505	.02	1515	0	1530
7-30-80	0	1130	0	1135	.06	1145	.01	1150	.05	1200	0	1215	0	1220
8-28-80	.01E	0945	.01E	0955	.10	0955	.01E	1000	.04	1000	0	1030	0	1040
							1981 water year							
10-03-80	0	1630	0	1630	.08	1615	0	1605	.01E	1600	0	1545	0	1545
11-07-80	0	1425	0	1425	.04	1420	0	1420	0	1415	0	1245	0	1245
1-13-81	0	1130	0	1130	.08	1240	.01E	1245	.01E	1250	0	1430	0	1430
2-12-81	.03E		.03E		.10		0		.05		.02E		0	
2-27-81	.01E	1015	0	1015	.10	1025	0	1035	.01E	1045	.01E	1200	0	1205
3-02-81	.09	1245	.22	1250	.12	1700	.05E	1650	.05	1645	.10	1540	.01E	1530
3-11-81	.05E		.05E		.09		.02E		.05		.03		0	
3-20-81	.04	1320	.05	1325	.10	1315	.03E	1310	.07	1305	.04	1200	0	1145
4-16-81	.10		.10		.07		.07		.07		.05		0	
5-28-81	0		0		.07E		0		.06		.02		0	
7-01-81	0		0		.05		0		0		0		0	

[1]Discharge included with site 1.

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