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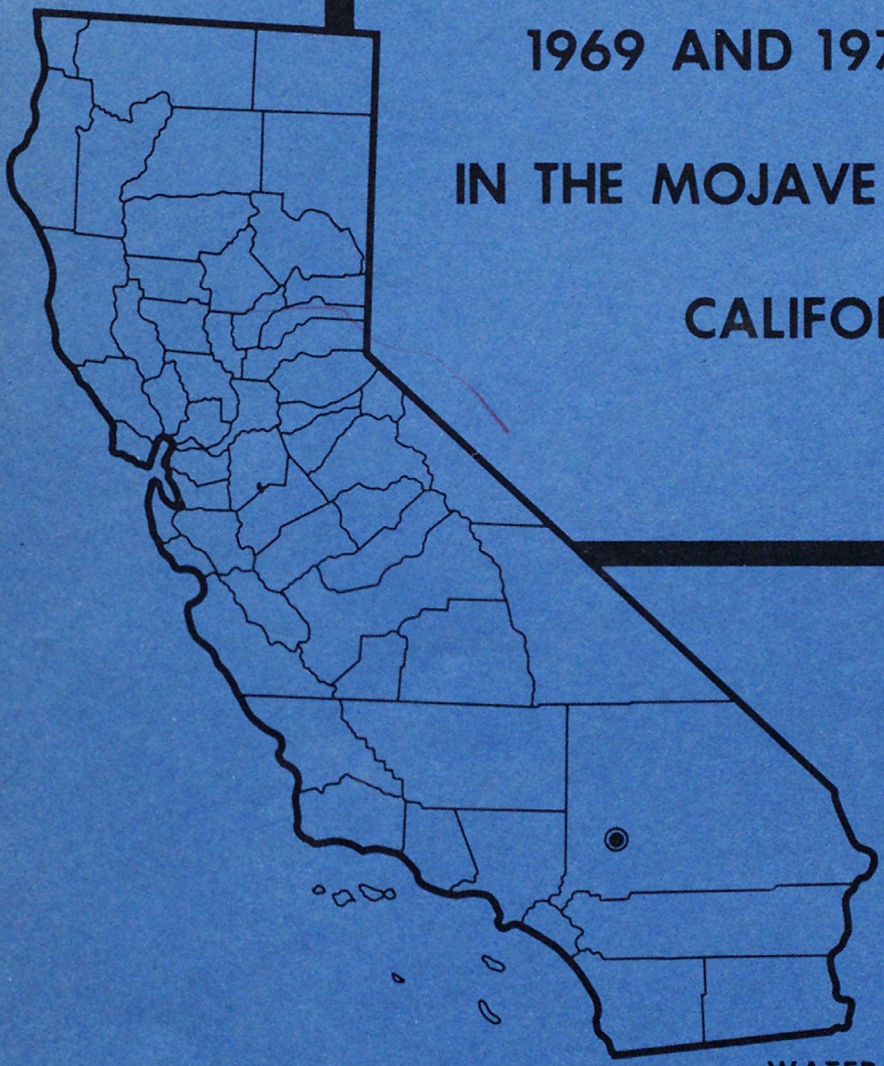

U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 80-207

Prepared in cooperation with the Mojave Water Agency

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By Anthony Buono and David J. Lang

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CONVERSION FACTORS

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

Multiply inch-pound unit	By	To obtain metric unit
acre-ft (acre-foot)	1,234	m^3 (cubic meter)
acre-ft/yr (acre-foot per year)	1,234	m^3/yr (cubic meter per year)
ft (foot)	3.048	m (meter)
ft^3/s (cubic foot per second)	28.32	L/s (liter per second)
inch	25.4	mm (millimeter)
mi (mile)	1.609	km (kilometer)
mi^2 (square mile)	2.590	km^2 (square kilometer)

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ABSTRACT

The Mojave River basin, a high desert area in southwestern San Bernardino County, Calif., received 2.3 times the normal annual precipitation during the 1969 and 1978 water years. Precipitation in the mountainous upper part of the watershed is the primary source of flow in the Mojave River. Total precipitation at Lake Arrowhead, representative of the mountainous area, was 98 inches in the 1969 water year and 93 inches in the 1978 water year. Of these totals, 94 inches in 1969 and 88 inches in 1978 fell during the rainy season, December through April. The resulting flood period in 1969 produced an instantaneous peak discharge of 18,000 cubic feet per second at Afton, about 100 miles downstream from Lake Arrowhead. This discharge had an approximate flood-recurrence interval of 30 years. An instantaneous peak of 24,800 cubic feet per second was measured during the 1978 floods at Deep Creek. This discharge had an approximate flood-recurrence interval of 20 years.

A comparison of the hydrologic data for the 1969 and 1978 flood periods indicates that although more precipitation occurred in 1969, more recharge occurred in 1978. The factors that caused the greater recharge were: (1) The more evenly distributed precipitation from December 1977 to April 1978, allowing for more uniform surface-water runoff in the Mojave River; (2) the dams constructed in the upper basin after 1969, which regulated floodflow peaks and allowed more water to stay in the basin; and (3) the lower water level in the aquifer in 1978, which made more space available to store the recharge water.

Total recharge resulting from the floods is estimated to have been 245,000 acre-feet in the 1969 water year and 282,000 acre-feet in 1978. At present (1979) costs of water from Silverwood Lake, the 1969 recharge would be worth about $4.6 million and the 1978 recharge about $5.2 million. If the water were derived from the turnout of the California Aqueduct, the undelivered costs would be about $4.9 million for 1969 and $5.6 million for 1978.

INTRODUCTION

Regional Setting

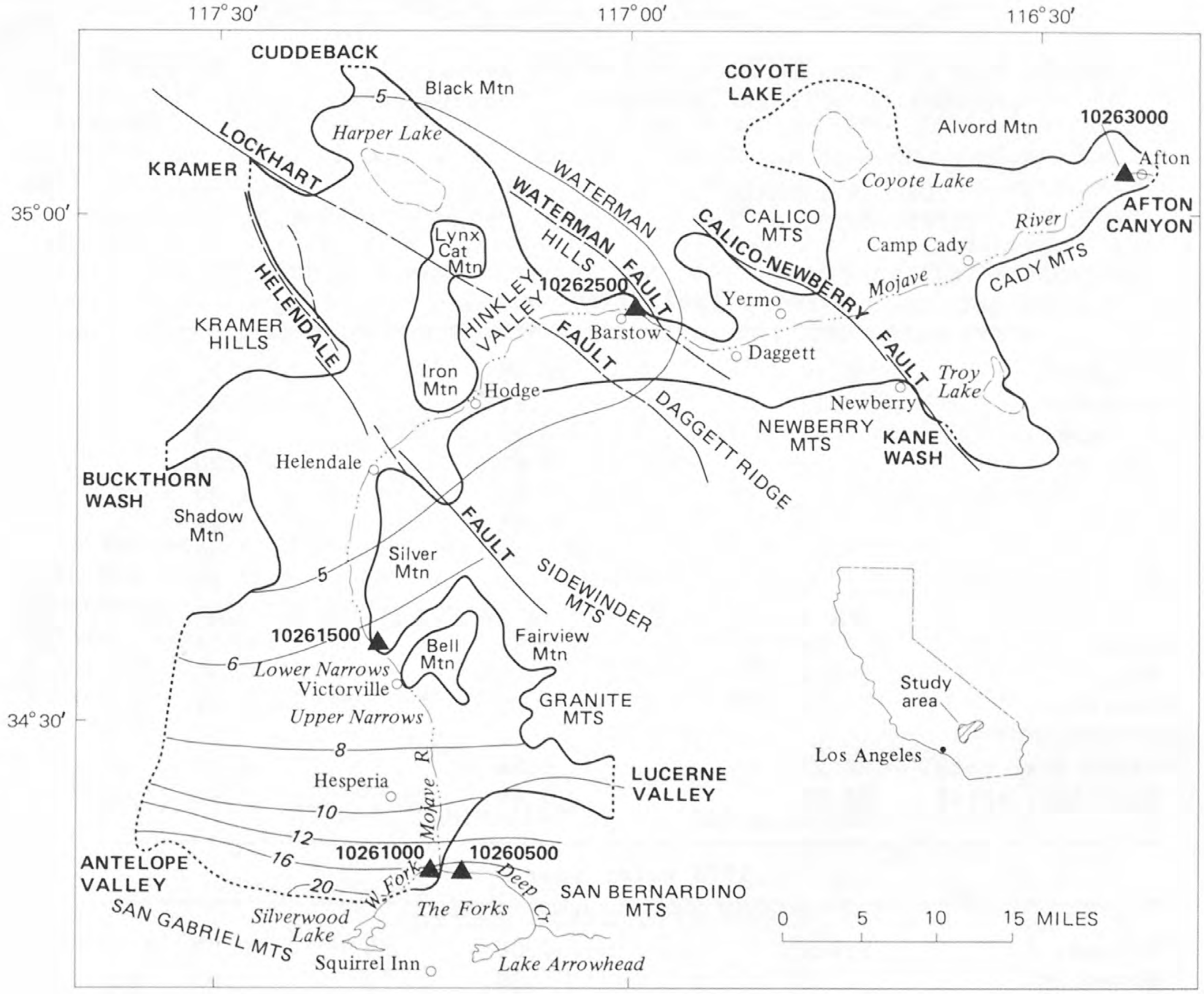
The Mojave River basin is in a high desert area in southwestern San Bernardino County, Calif. (fig. 1), and forms the western part of the Mojave Desert. The study was concerned with the influence of the Mojave River as a source of recharge to the 1,400-square-mile alluvial ground-water basin extending from The Forks at the confluence of the West Fork Mojave River and Deep Creek, at the north edge of the San Bernardino Mountains, to Afton, about 100 mi downstream, where outflow from the Mojave River basin is measured.

Precipitation

Precipitation averages less than 5 inches per year in 40 percent of the ground-water basin (fig. 1), with more than 40 inches per year at Lake Arrowhead (altitude 5,205 ft) in the mountainous upper part of the watershed. Precipitation in the San Bernardino and San Gabriel Mountains is the primary source for flow in the Mojave River. Table 1 shows the precipitation totals recorded at Lake Arrowhead, Victorville, and Barstow for the 1969 and 1978 water years.

Annual precipitation at Lake Arrowhead was 98 inches in water year 1969 and 93 inches in 1978 (table 1). This is 2.3 times the 30-year normal based on 1944-73 data (National Oceanic and Atmospheric Administration, 1974, p. 14). Of the totals, 94 inches in 1969 and 88 inches in 1978 fell during the period December through April. The intense precipitation during these months resulted in flooding of the river. Flood damage to property and structures in the basin for the 1969 water year was estimated between $6 million and $12 million (Hardt, 1969, p. 2), and for the 1978 water year damage was reported as $4 million (San Bernardino County Communications and Emergency Services Department, Flood Control District, and Transportation Department, and the Santa Fe Railroad Co., oral communs., February 1979). Reported damage to personal property and public structures for both years was similar and included the undermining or washing away of bridges, roadways, and revetments.

In contrast with the destructive forces usually associated with flooding, the floods for both years had a beneficial effect on the local ground-water system. In the Mojave River basin, as in all desert areas, water is a scarce resource that is often purchased and imported from other areas to meet local needs. Flooding in both years brought an unusually large volume of water to the area. The flood water recharged the ground-water basin naturally by water percolating through the riverbed to the water table. The ground-water system is the only natural reservoir in the basin and is the primary source of water used locally. Any resulting rise in ground-water levels benefits the local pumper because the decreased pumping lifts require less power to withdraw ground water.



EXPLANATION

FAULT—Dashed where approximately located

BOUNDARY OF ALLUVIAL GROUND-WATER BASIN—Dashed where recharge enters or leaves basin

8 LINE OF EQUAL MEAN ANNUAL PRECIPITATION—Interval variable, in inches. (From Rantz, 1969)

▲10260500 SURFACE-WATER GAGING STATION

FIGURE 1.--Location map showing boundary of alluvial ground-water basin, mean annual precipitation, 1880-1952, and surface-water gaging stations.

TABLE 1. - Monthly precipitation, in inches, in the Mojave River basin, water years[1] 1969 and 1978

[Data from U.S. Environmental Services Administration, 1969; and National Oceanic and Atmospheric Administration, 1978]

Date	Lake Arrowhead Altitude 5,205 ft	Victorville Altitude 2,858 ft	Barstow Altitude 2,160 ft
1969 water year			
October	0.38	0.05	0.21
November	.92	.27	.34
December	3.95	.25	.13
January	45.92	1.87	1.00
February	35.94	3.93	2.20
March	5.34	.18	.24
April	2.87	.23	.36
May	2.69	.48	.47
June	Trace	.61	.07
July	.18	.59	.84
August	Trace	.00	.05
September	.05	.08	.67
Water year total	98.24	8.54	6.58
Dec.-Apr. total	94.02	6.46	3.93
1978 water year			
October	Trace	0.00	0.02
November	1.05	.08	.03
December	14.65	1.77	1.94
January	16.95	1.93	1.74
February	21.36	3.14	1.99
March	27.61	4.98	2.20
April	7.51	.61	.42
May	.32	.09	.08
June	.00	.00	.00
July	Trace	.00	Trace
August	.37	.11	.18
September	3.21	.80	.31
Water year total	93.03	13.51	8.91
Dec.-Apr. total	88.08	12.43	8.29

[1]A water year is the 12-month period ending September 30 and is designated by the calendar year in which it ends.

Purpose and Scope

The purpose of this investigation was to assess the rise in ground-water levels adjacent to the Mojave River resulting from the floods in the 1978 water year and to compare the results with those measured following the flood in the 1969 water year (Hardt, 1969). The study concentrated on the area within 2 mi of the river channel and consisted of (1) appraising streamflow records for five gaging stations well distributed in the basin; (2) measuring water levels in selected wells during the 1978 water year and comparing them with the water levels measured during the 1969 water year; (3) estimating the amount of recharge to the ground-water basin; and (4) comparing estimates of recharge resulting from the floods of the 1969 and 1978 water years.

Acknowledgments

The investigation was made by the U.S. Geological Survey in cooperation with the Mojave Water Agency. The authors express their appreciation to the Southern California Water Co. for water-level data from its production wells in the Barstow area, to Burt D. Lackyard for his monthly water-level measurements of his observation wells, and to Robert H. Richey of the Mojave Water Agency for his assistance in collecting and compiling ground-water-level data.

DETERMINATION OF AQUIFER RECHARGE

Surface-Water Loss Method

Continuous surface-water discharge records were computed from river gage-height and direct riverflow measurements by the Geological Survey at five stations in the Mojave River basin (fig. 1). The gaging stations were Deep Creek near Hesperia (10260500), West Fork Mojave River near Hesperia (10261000), Mojave River at lower narrows, near Victorville (10261500), Mojave River at Barstow (10262500), and the Mojave River at Afton (10263000).

Since the floods of 1969, two dams that partly control the flow of the Mojave River, particularly during floodflows, have been completed in the upper basin. The dams are the Mojave River Forks Reservoir at The Forks--the confluence of the West Fork Mojave River and Deep Creek--and Cedar Springs Dam on the West Fork Mojave River at Silverwood Lake. The primary purpose of the installation of The Forks Reservoir, a U.S. Army Corps of Engineers project, was flood control. Cedar Springs Dam serves as a storage facility for water from the State Water Project. During major floods, water is released from both reservoirs more slowly than would naturally occur, attenuating flood peaks and spreading flood recessions over a longer period. The benefits of flood control are the reduction of flood damage downstream and increased ground-water recharge as a result of the retention of flood waters within the basin for a longer time, allowing for a larger volume of surface-water recharge through the riverbed.

The Forks Reservoir is the primary structure for flood control in the basin, and it controls flows of 7,250 ft^3/s or more (Ernie Perea, U.S. Army Corps of Engineers, Los Angeles District, oral commun., June 1979). Discharges less than this amount flow through the dam practically uncontrolled. A peak discharge of 14,000 ft^3/s from the Mojave River Forks Reservoir was recorded in February 1978 by the U.S. Army Corps of Engineers (oral commun., Los Angeles District, June 1979). The largest peak discharges recorded by the Survey that month at Deep Creek and West Fork Mojave River stations were 12,000 and 11,300 ft^3/s, respectively.

Cedar Springs Dam has less effect on flows downstream because it controls only a part of the flow at the West Fork Mojave River near Hesperia (10261000). From December 1977 to April 1978 about 57 percent of the discharge from West Fork Mojave River came from releases from Cedar Springs Dam totaling 65,330 acre-ft (R. E. Angelos, written commun., record of California Department of Water Resources releases from the dam, Sept. 1978). Total discharge from West Fork Mojave River was 113,650 acre-ft at the gaging station about 5 mi downstream from the dam. The remaining 43 percent of the discharge came from Horsethief Canyon (off fig. 1 to south), a tributary to West Fork Mojave River, about 1.5 mi downstream from Cedar Springs Dam.

Maximum peak discharges in the Mojave River basin (table 2) during the 1978 water year were 24,800 ft^3/s at Deep Creek, 11,300 ft^3/s (severely regulated) at West Fork, 13,600 ft^3/s at the lower narrows, 11,600 ft^3/s at Barstow, and 6,970 ft^3/s at Afton. The peaks represented recurrence intervals (the average interval of time between occurrence of discharge peaks of a particular or greater magnitude) ranging from 9 years at West Fork to 20 years at Deep Creek. Maximum peak flows during the 1969 water-year flooding were 23,000 ft^3/s at Deep Creek, 20,000 ft^3/s (uncontrolled) at West Fork, 34,500 ft^3/s at lower narrows near Victorville, 30,000 ft^3/s at Barstow, and 18,000 ft^3/s at Afton. These peaks represented recurrence intervals ranging from 17 years at Deep Creek to 30 years at Afton. Recurrence intervals were calculated by computer, using the Log-Pearson Type III frequency analysis according to the U.S. Water Resources Council (1976) method. No peaks with greater than a 5-year recurrence interval were recorded between the 1969 and 1978 water years.

TABLE 2. - Peak discharges in the Mojave River, 1932-78[1]

Station No.	Station name	Period of record	Drainage area (mi^2)	Peak discharge, in cubic feet per second: Date	Discharge
10260500	Deep Creek near Hesperia	1904-22 1929-78	136	Feb. 9, 1932	7,900
				Feb. 14, 1937	6,800
				Mar. 2, 1938	46,600
				Jan. 23, 1943	19,000
				Nov. 22, 1965	21,700
				Dec. 29, 1965	20,800
				Jan. 25, 1969	23,000
				Feb. 25, 1969	17,600
				Jan. 15, 1978	8,750
				Feb. 10, 1978	12,000
				Mar. 1, 1978	8,000
				Mar. 4, 1978	24,800
				Mar. 31, 1978	6,610
10261000	West Fork Mojave River near Hesperia	1904-22 1929-78	74.6	Feb. 8, 1932	8,500
				Mar. 13, 1937	4,100
				Mar. 2, 1938	26,100
				Jan. 23, 1943	23,000
				Nov. 22, 1965	8,420
				Dec. 29, 1965	21,200
				Jan. 25, 1969	13,200
				Feb. 25, 1969	20,000
				Jan. 15, 1978	2,920
				Feb. 10, 1978	11,300
				Mar. 4, 1978	7,400
10261500	Mojave River at lower narrows, near Victorville	1899-1906 1930-78	514	Feb. 9, 1932	12,500
				Feb. 14, 1937	8,880
				Mar. 2, 1938	70,600
				Jan. 23, 1943	32,000
				Nov. 23, 1965	17,100
				Dec. 30, 1965	32,800
				Jan. 25, 1969	33,800
				Feb. 25, 1969	34,500
				Jan. 15, 1978	4,160
				Feb. 10, 1978	14,000
				Mar. 4, 1978	13,000
				Mar. 31, 1978	6,690

See footnotes at end of table.

TABLE 2. - Peak discharges in the Mojave River, 1932-78[1] - Continued

Station No.	Station name	Period of record	Drainage area (mi^2)	Peak discharge, in cubic feet per second	
				Date	Discharge
10262500	Mojave River at Barstow	1930-78	1,290	Feb. 9, 1932	8,300
				Feb. 15, 1937	6,000
				Mar. 3, 1938	64,300
				Jan. 23, 1943	26,000
				Nov. 23, 1965	4,600
				Dec. 30, 1965	8,970
				Jan. 25, 1969	29,000
				Feb. 25, 1969	30,000
				Feb. 10, 1978	10,300
				Mar. 5, 1978	11,600
10263000	Mojave River at Afton	1929-32 1952-78	2,120	Feb. 10, 1932	3,550
				Nov. 23, 1965	8
				Dec. 31, 1965	4,150
				Jan. 26, 1969	18,000
				Feb. 25, 1969	16,400
				Feb. 10, 1978	6,970
				Mar. 5, 1978	([2])

[1]1978 water year data are provisional and subject to revision.
[2]Significant peak; instantaneous discharge unknown.

Table 3 shows the total discharge at the five stations in water years 1969 and 1978. Changes in discharge between stations result from channel losses of water percolating to the water table (ground-water recharge) or from ground-water discharges adding to surface-water flow. Surface-water losses were observed between The Forks and Afton between December and April of both water years, with the exception of March 1969. For this month an increase in flow was recorded between The Forks and lower narrows. The increase probably was from ground-water discharge to the river upstream from the lower narrows.

Surface-water flow decreased between The Forks and Afton during the 1969 and 1978 water-year floods (table 3). During the December 1968-April 1969 period about 245,000 acre-ft of water was lost in the channel. During the same months in the 1978 water year nearly 282,000 acre-ft was lost. Comparing these data with precipitation totals at Lake Arrowhead (94 inches, December 1968-April 1969 and 88 inches, December 1977-April 1978) shows that more water was lost to ground-water recharge in the 1978 water year, even though 6 percent less precipitation was recorded.

TABLE 3. - Monthly discharges (in acre-feet) at stations in the Mojave River basin, water years 1969 and 1978

Date	(1) 10260500 Deep Creek near Hesperia	(2) 10261000 West Fork Mojave River near Hesperia	(3) The Forks (1) + (2)	(4) 10261500 Mojave River at lower narrows, near Victorville[1]	(5) 10262500 Mojave River at Barstow	(6) 10263000 Mojave River at Afton[1]
			1969 water year			
October	264	0	264	1,330	0	0
November	468	0	468	1,350	0	0
December	461	0	461	1,910	0	25
January	71,980	32,890	104,870	74,770	45,940	21,310
February	64,990	64,190	129,180	111,200	71,480	39,180
March	28,420	15,870	44,290	53,970	14,640	8,590
April	32,410	6,390	38,800	30,340	13,970	3,350
May	12,480	3,110	15,590	8,930	567	66
June	3,360	1,020	4,380	1,940	0	48
July	1,590	266	1,856	2,000	2	38
August	739	0	739	1,800	0	29
September	589	0	589	1,590	2	89
Water year total	217,751	123,736	341,487	291,130	146,601	72,725
Dec.-Apr. total	198,261	119,340	317,601	272,190	146,030	72,455

See footnotes at end of table.

TABLE 3. - Monthly discharges (in acre-feet) at stations in the Mojave River basin, water years 1969 and 1978 - Continued

Date	(1) 10260500 Deep Creek near Hesperia	(2) 10261000 West Fork Mojave River near Hesperia	(3) The Forks (1) + (2)	(4) 10261500 Mojave River at lower narrows, near Victorville[1]	(5) 10262500 Mojave River at Barstow	(6) 10263000 Mojave River at Afton[1]
			1978 water year[2]			
October	183	0	183	1,650	0	8
November	183	0	183	1,860	0	12
December	5,360	1,680	7,040	2,650	0	25
January	18,130	11,930	30,060	9,540	18	46
February	58,350	35,390	93,740	51,520	15,450	9,770
March	94,620	40,540	135,160	92,150	68,950	26,820
April	39,770	14,510	54,280	25,090	6,920	1,290
May	9,040	18,200	27,240	16,040	12	63
June	2,500	10,070	12,570	9,340	0	45
July	911	0	911	1,250	0	39
August	586	0	586	964	0	35
September	677	0	677	1,150	0	45
Water year total	230,310	132,320	362,630	213,204	91,350	38,198
Dec.-Apr. total	216,230	104,050	320,280	180,950	91,338	37,951

[1]Includes ground-water discharge where figure is greater than that for preceding station.
[2]Provisional records--subject to revision.

Further evaluation of the data in table 3 shows that discharge losses, as a percentage of the total discharge between stations on the Mojave River, increased in 1978 compared to 1969. Overall in the basin, losses between The Forks and Afton during the December-April period were 77 percent in 1969 and 88 percent in 1978. Percentages of total discharge lost between the five stations during both years are summarized below.

Station	Total discharge December-April (acre-feet)	Losses between stations (acre-feet)	Losses as a percentage of flow
	1969		
The Forks	317,601		
Lower narrows, at Victorville	272,190		
		45,411	14.3
Lower narrows, at Victorville	272,190		
Barstow	146,030		
		126,160	46.3
Barstow	146,030		
Afton	72,455		
		73,575	50.4
The Forks	317,601		
Afton	72,455		
		245,146	77.2
	1978		
The Forks	320,280		
Lower narrows, at Victorville	180,950		
		139,330	43.5
Lower narrows, at Victorville	180,950		
Barstow	91,338		
		89,612	49.5
Barstow	91,338		
Afton	37,951		
		53,387	58.4
The Forks	320,280		
Afton	37,951		
		282,329	88.2

Records from February 1899 to September 1906 and October 1930 to September 1978 indicate that during the dry season ground-water discharge always contributes to flow at the lower narrows (U.S. Geological Survey, 1963, p. 194; 1977, p. 205, 206, and 208). The subsurface geologic structure and the resulting configuration of the ground-water basin form a barrier to ground-water movement above the lower narrows. The barrier acts as a subsurface dam, piling up water behind it and spilling any excess over the top. The excess is ground-water discharge to the surface-water system. The spillway is the Mojave River at the lower narrows, and the volume of water discharged from the subsurface dam to the river is observed as the increase in flow between The Forks and the lower narrows. Presumably, however, ground-water discharge to the Mojave River is not restricted to the dry period but occurs year round. If ground-water discharges occur during the dry season when ground-water levels are at the annual low, it follows that discharges would also occur during the rainy season when ground-water levels are at or near the annual high. These discharges normally go unobserved, however, because of the large volumes of surface flow during the rainy season. Channel losses farther upstream between The Forks and the lower narrows may be larger than the ground-water discharge at the lower narrows. This would result in the observation of a decrease in flow between the stations, even though ground-water discharges are still occurring.

In March 1969, an increase in flow was observed between The Forks and lower narrows. The increase resulted from a combination of the saturated river-channel conditions that allowed little or no water infiltration between the station, normal ground-water discharge that occurs in the vicinity of the lower narrows, and the discharge of water from bank storage following the recession of the January and February flood levels.

The main factors that caused more ground-water recharge in 1978 are the longer period and more even distribution of precipitation and streamflow from December 1977 through April 1978, the detention structures in the upper basin, and the lower water levels in the aquifer in 1978. Both the longer period and more even distribution of precipitation and the detention structures contributed to the longer duration of flow in the river, allowing more time for channel losses to occur. The lower water levels in the aquifer in 1978 increased the space available for recharge. Figures 2 through 6 graphically compare daily precipitation at Lake Arrowhead with the daily discharge at the five stations measured along the Mojave River during both water years. The illustrations show that two major storms accounted for 87 percent of the precipitation between December 1968 and April 1969. In January 45.92 inches and in February 35.94 inches were recorded at Lake Arrowhead (see table 1). The precipitation at the lake during the 1978 water year is seen to have been more evenly spread over the period (table 1 and fig. 2).

To estimate the net recharge to the aquifer for the 1969 and 1978 water years, both natural and man-induced withdrawals from the ground-water system must be subtracted from total recharge. The natural withdrawal is the consumptive use of water by riparian vegetation. The man-induced withdrawals include consumptive use of water withdrawn for agriculture, domestic supply, industry, and recreation. The net change in ground-water storage for the flood years of 1969 and 1978 is tabulated below.

	1969 water year (acre-feet)	1978 water year (acre-feet)
Total recharge to the ground-water system, December-April (channel losses)	245,000	282,000
Total natural withdrawal by riparian vegetation, October-September (consumptive use)[1]	-41,000	-41,000
Total man-induced withdrawal, October-September[2] (consumptive use)	-75,000	-78,000
Net recharge to the system (increase in ground water in storage resulting from the December-April floods)	129,000	163,000

[1]The value used by Hardt (1969) was 20,000 acre-ft/yr as estimated by the U.S. Bureau of Reclamation. The Mojave Water Agency uses 41,000 acre-ft/yr (California Department of Water Resources, 1967) in its management predictions.

[2]Estimates from Ruchlewicz (1978b).

At the 1979 cost of water purchased from Silverwood Lake of $18.50 per acre-foot (Jon Edson, Mojave Water Agency, oral commun., May 1979), gross recharge totals are worth $4.6 million for 1969 and $5.2 million for 1978. The undelivered costs for the same volumes, if purchased from the California Aqueduct turnout (the discharge facility for the release of the Mojave Water Agency's entitlement), would have the higher values of $4.9 million and $5.6 million, respectively. These costs are based on a value of $20.00 per acre-foot (Jon Edson, Mojave Water Agency, oral commun., May 1979).

The above value estimates are based on gross recharge totals rather than net recharge because of the similarity between natural recharge from floods and artificial recharge by the current practices of the Mojave Water Agency. Artificial recharge of the ground-water system is accomplished by the release of water purchased from Silverwood Lake into the West Fork Mojave River. The releases are subject to the same evapotranspirative losses as the floodwaters.

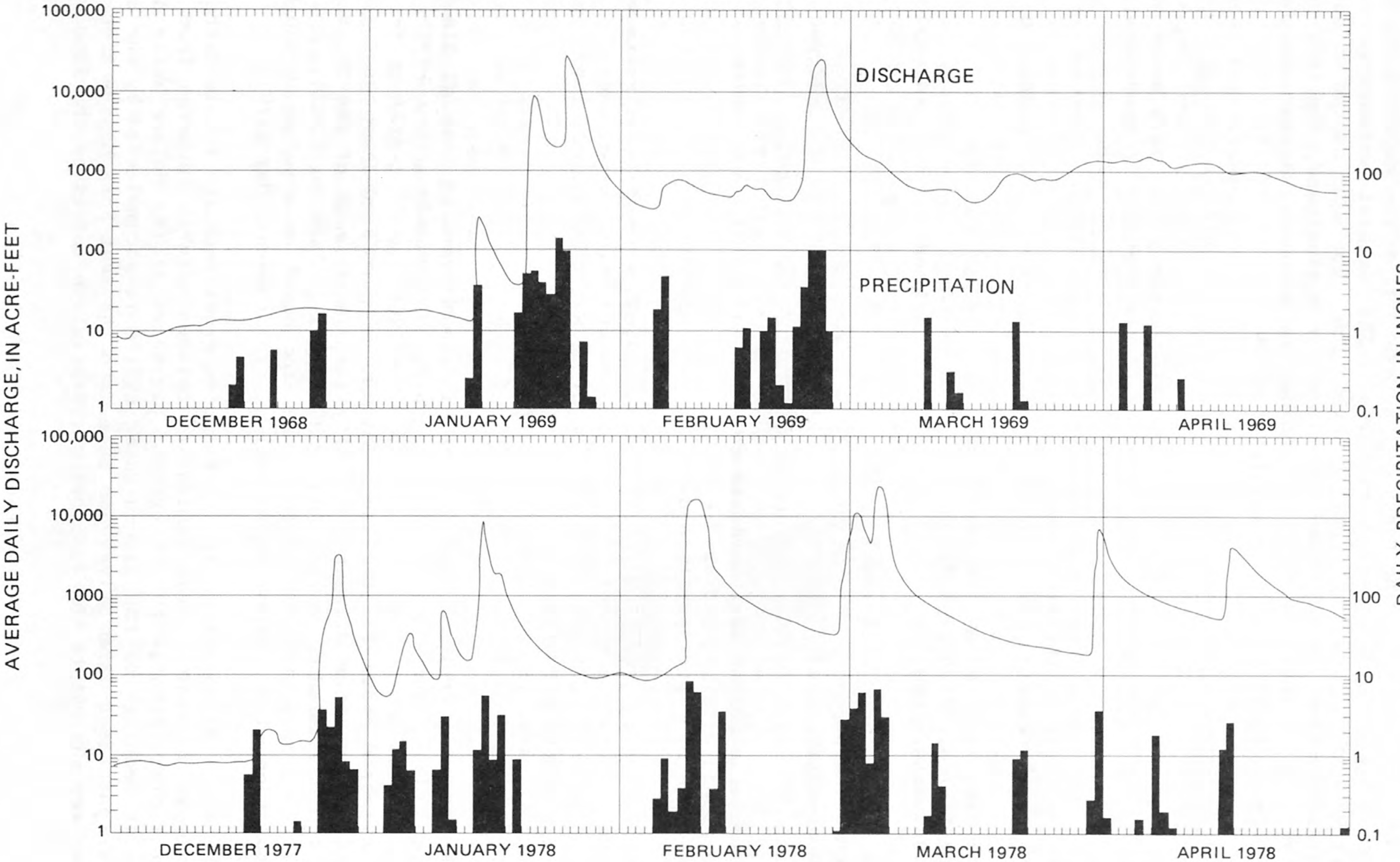


FIGURE 2.--Relation of river discharge at Deep Creek near Hesperia (10260500) to precipitation at Lake Arrowhead.

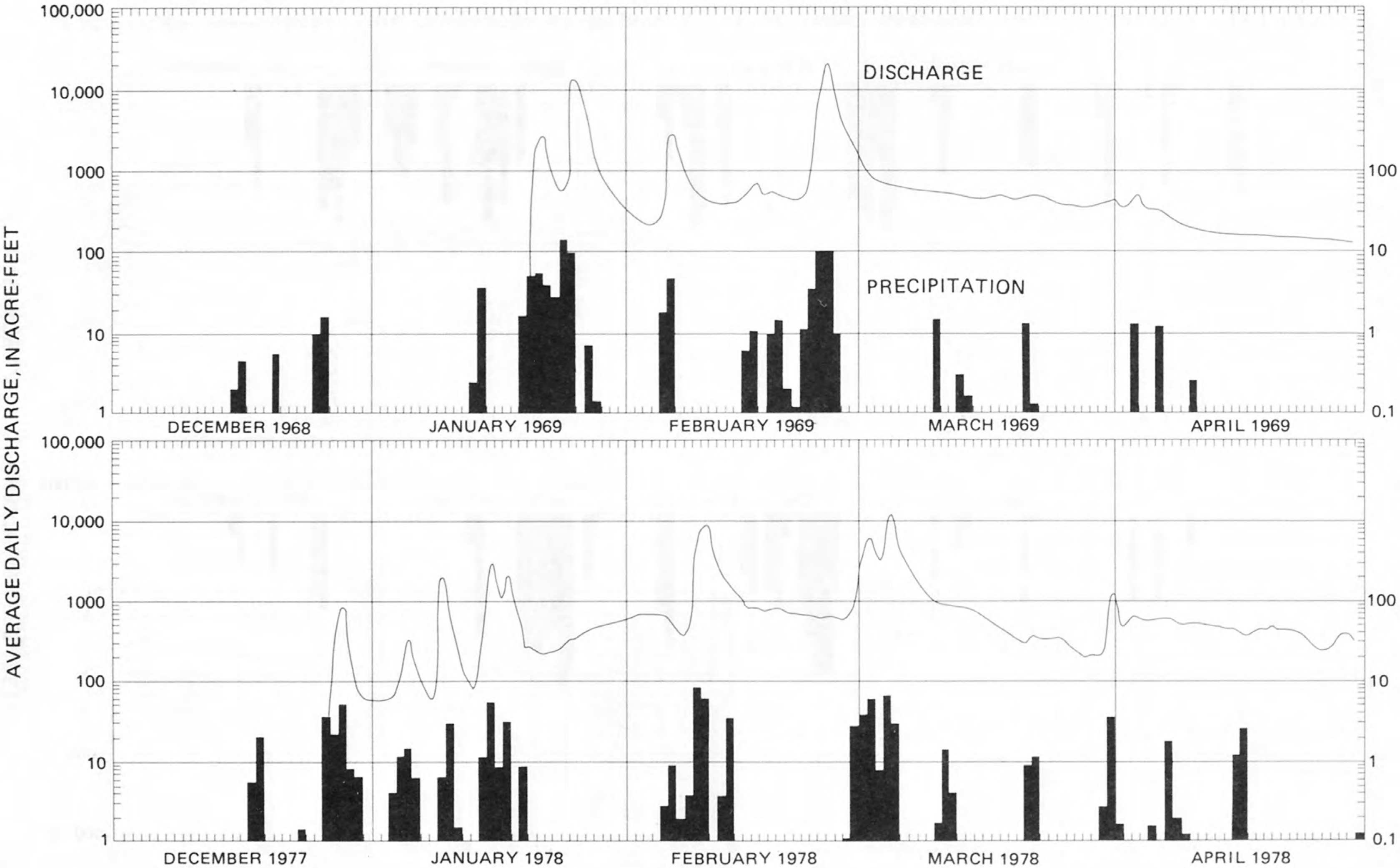


FIGURE 3.--Relation of river discharge at West Fork Mojave River near Hesperia (10261000) to precipitation at Lake Arrowhead.

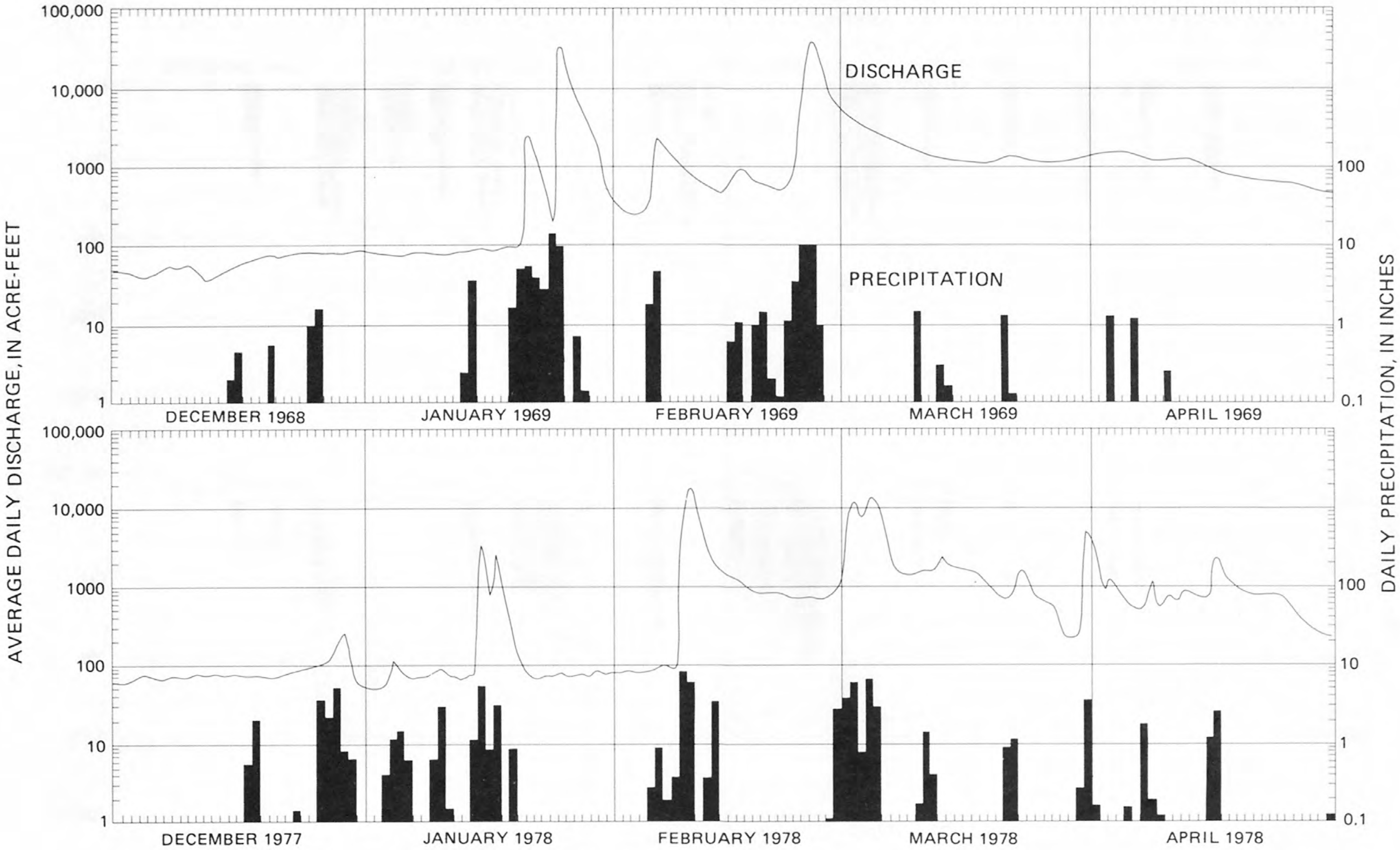


FIGURE 4.--Relation of discharge at Mojave River at lower narrows, near Victorville (10261500) to precipitation at Lake Arrowhead.

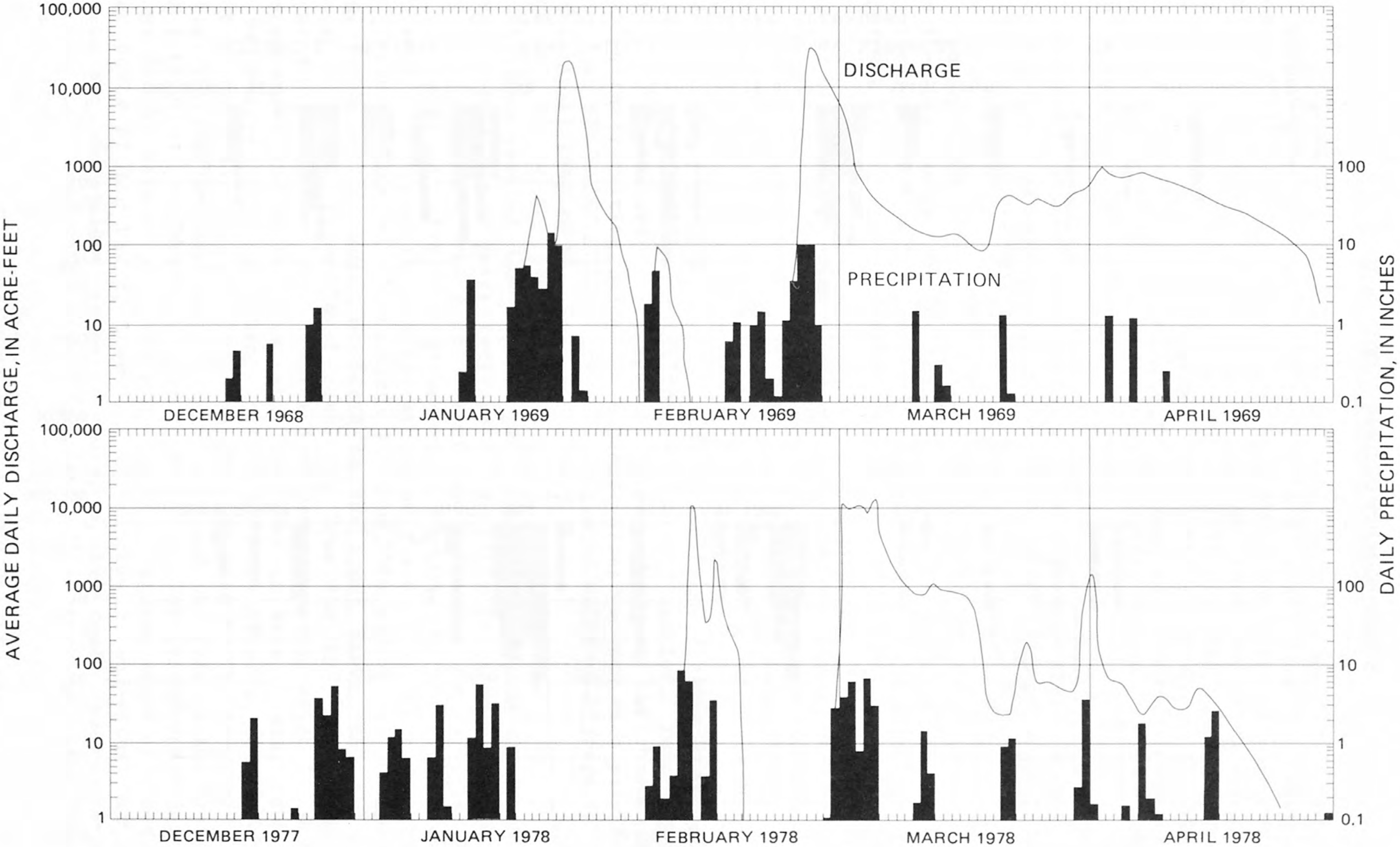


FIGURE 5.--Relation of river discharge at Mojave River at Barstow (10262500) to precipitation at Lake Arrowhead.

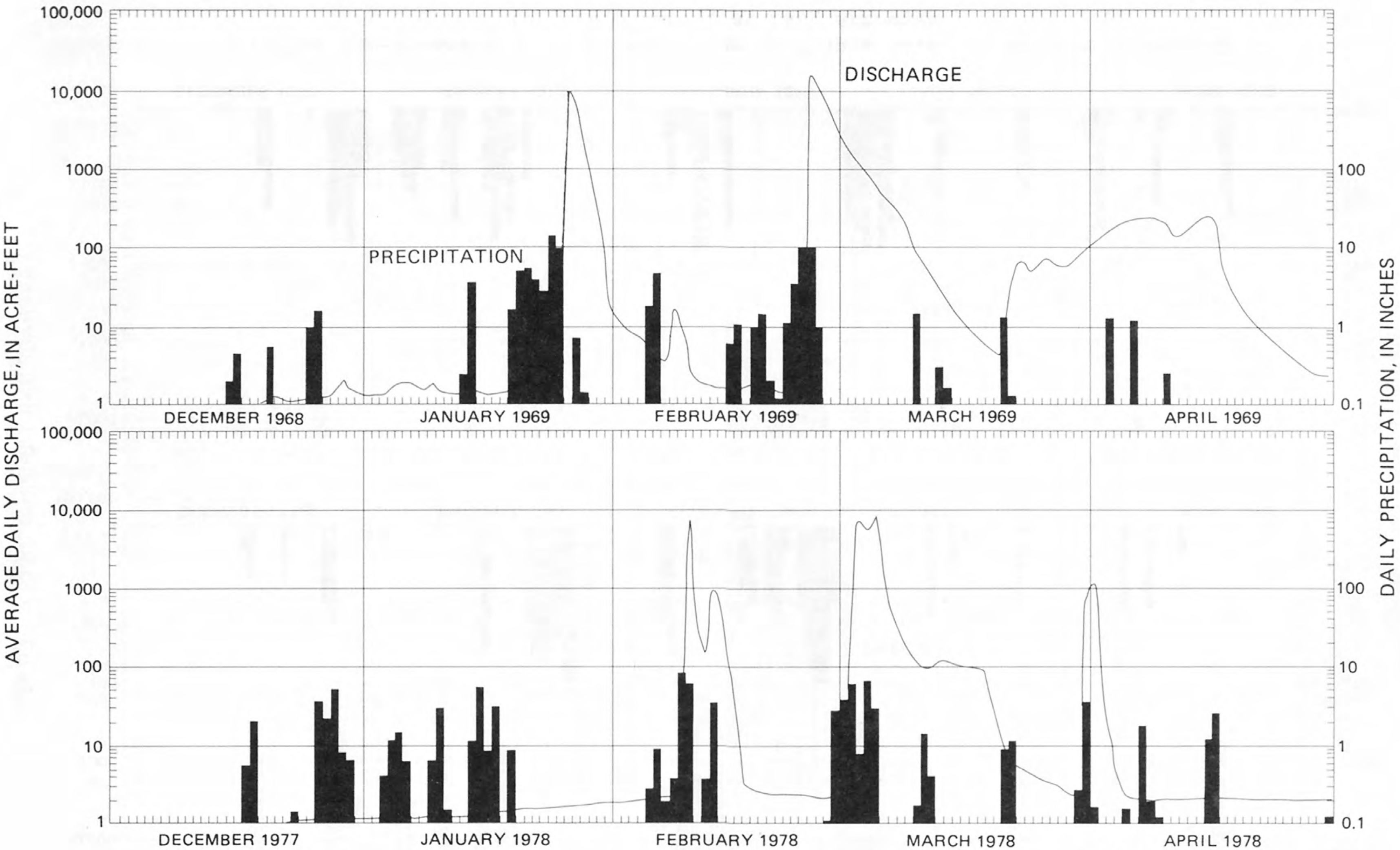


FIGURE 6.--Relation of river discharge at Mojave River at Afton (10263000) to precipitation at Lake Arrowhead.

Ground-Water-Level Change Method

Ground-water levels were measured in 83 wells (fig. 7) between April 25 and May 7, 1978, following the 1978 floods. The wells were generally within 2 mi of the Mojave River channel, between The Forks and Afton. Wells close to the river were selected as most representative of rises in ground-water levels resulting from water percolating through the riverbed to the water table. Water-level measurements for 1978 were compared to measurements of the same wells following the 1969 water-year flooding (Hardt, 1969), and the net changes were contoured in figure 7.

A direct estimate of the recharge to the ground-water system could not be made for 1978 by using the ground-water-level change method because no preflood measurements were made.

Ground-water levels following the floods in 1978 were generally lower than those following the floods in 1969, except in four areas within 1.5 mi of the river channel (fig. 7). The areas of rise totaled 64 mi^2, about 44 percent of the area contoured.

The change in storage of ground water between April 1969 and April 1978 was determined for the contoured area along the Mojave River in figure 7. Estimates of specific yield for the aquifer in the contoured area ranged from 15 to 20 percent adjacent to the river, and 20 to 25 percent in the river channel (California Department of Water Resources, 1967). The area between adjacent contours was multiplied by half the sum of those contour values to obtain the changes in saturated thickness of the aquifer. This value was then multiplied by the respective specific yield to obtain the change in storage. Totaling the resulting change in storage values between each pair of contours yielded an estimated 25,000 acre-ft less ground water in storage in April 1978 than in April 1969 in the contoured area.

A comparison of the net changes that resulted from the floods for the 1969 and 1978 water years indicates that although ground-water levels were generally lower and less ground water was in storage in 1978, the 1978 flood had a greater net effect on ground-water recharge in the river area. Hydrographs of four wells (figs. 8-11) within half a mile of the river channel show the ground-water-level fluctuations between 1966 and 1979. The Lackyard well (fig. 8, 3N/4W-12), near The Forks in the upper basin, had a 1 ft greater change in static water level resulting from the 1978 water-year flooding compared with that of 1969. Three Southern California Water Co. wells in the Barstow area also showed a greater net rise in static water level in 1978. The water-level rise in Robinson Plant well 16 (fig. 9, 9N/2W-10A2) was at least 12 ft greater in 1978 than in 1969, the rise in the Arrowhead Plant well 4 (fig. 10, 10N/1W-31L8) was 13 ft greater, and the rise in the Bradshaw Plant well 1 (fig. 11, 9N/2W-1F2) was 21 ft greater. The ground-water-level fluctuations in the Barstow area are probably not representative of fluctuations in other parts of the basin, however. The narrow ground-water channel in the Barstow area (described by Hardt, 1971, p. 59) could cause more pronounced responses to ground-water withdrawal, as well as recharge, here than in other areas of the basin.

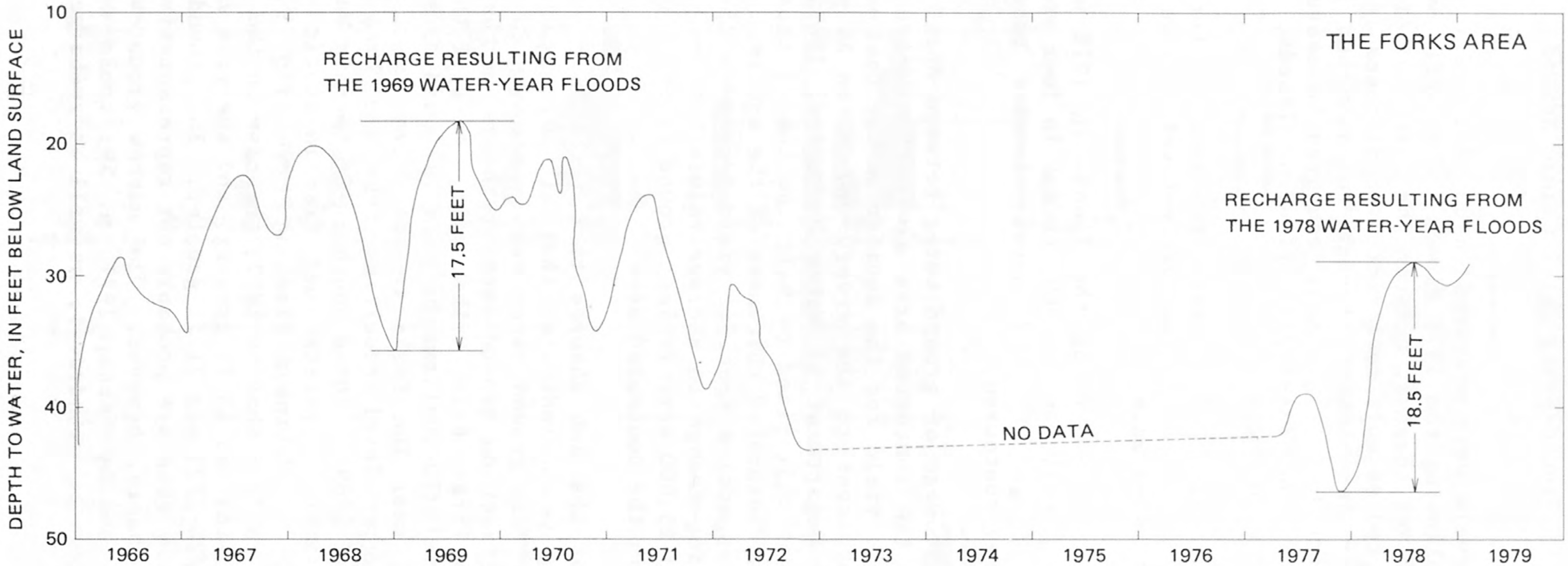


FIGURE 8.--Hydrograph of the Lackyard well (3N/4W-12) adjacent to the Mojave River in the upper basin.

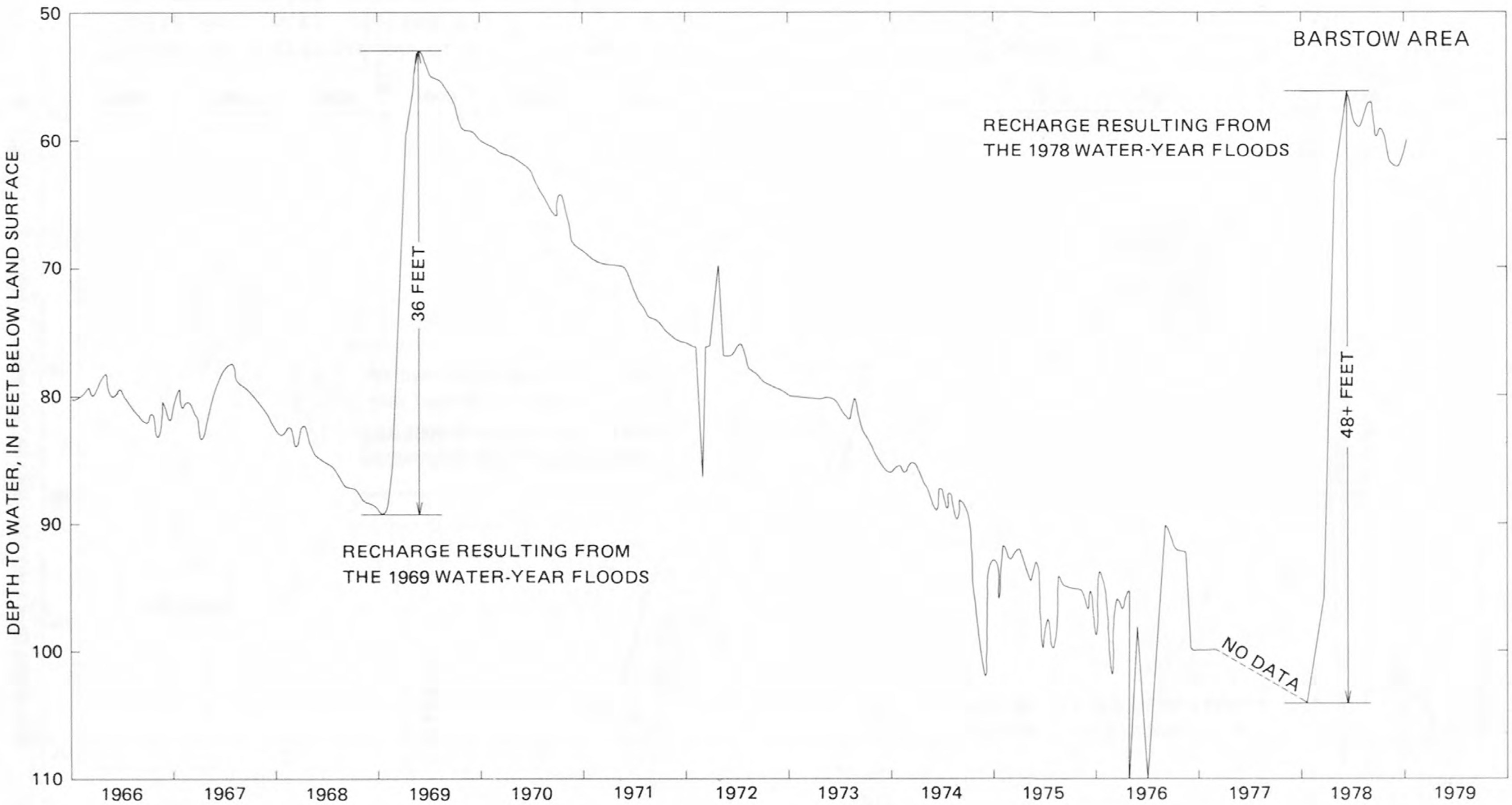


FIGURE 9.--Hydrograph of the Southern California Water Co. Robinson Plant well 16 (9N/2W-10A2) adjacent to the Mojave River in the middle basin. (Water-level data obtained from the Southern California Water Co., Los Angeles, Calif.)

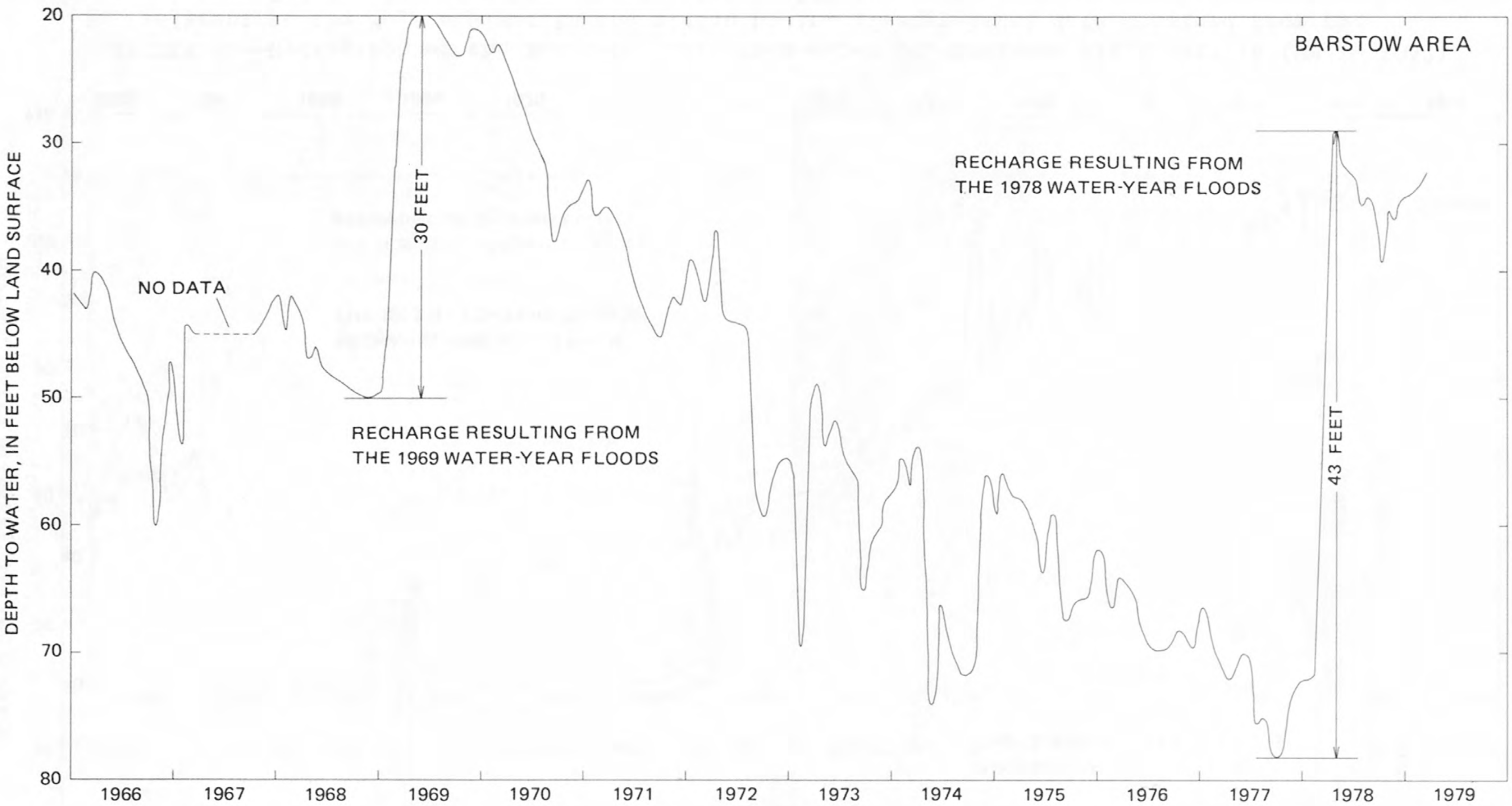


FIGURE 10.--Hydrograph of the Southern California Water Co. Arrowhead Plant well 4 (10N/1W-31L8) adjacent to the Mojave River in the middle basin. (Water-level data obtained from the Southern California Water Co., Los Angeles, Calif.)

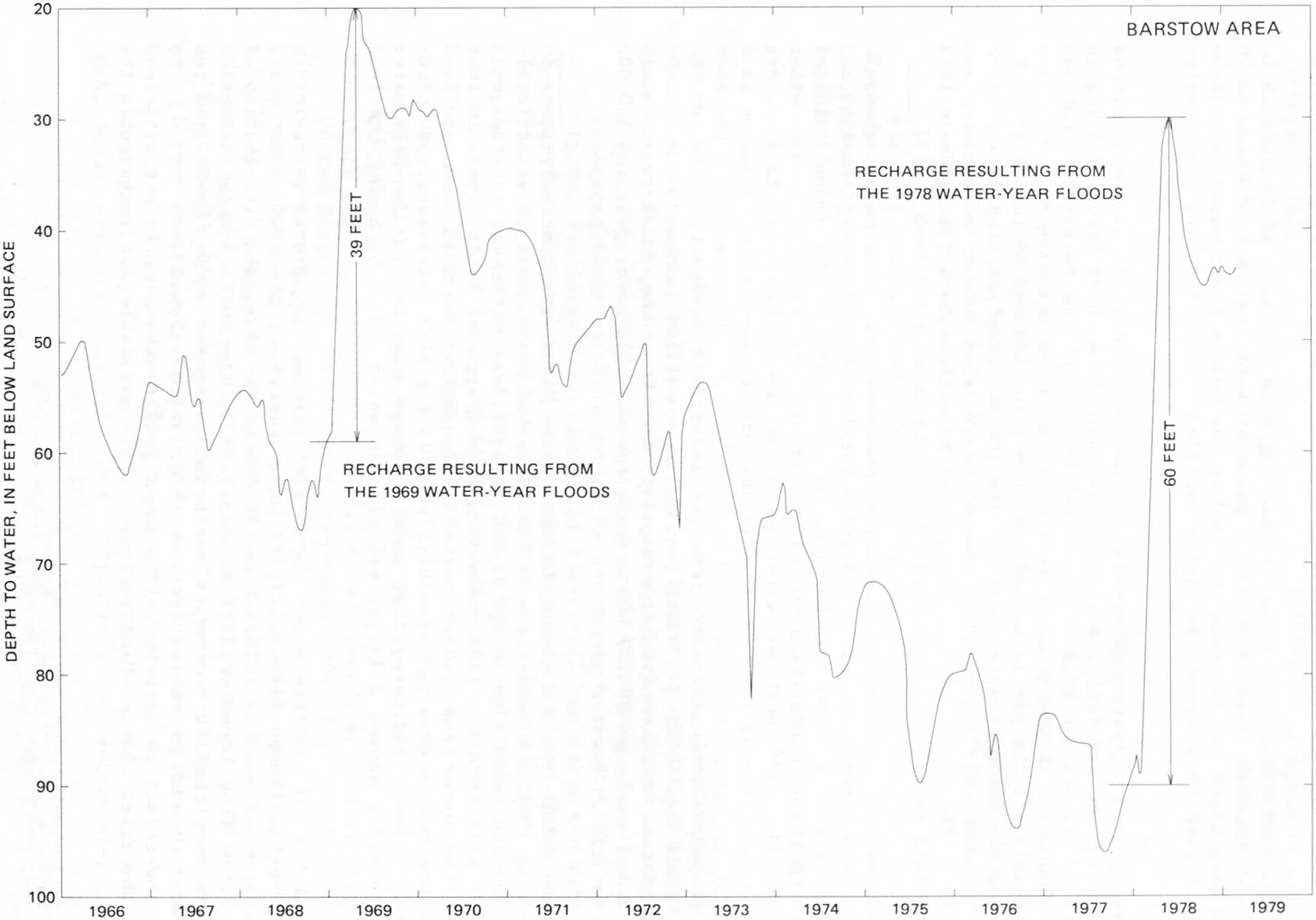


FIGURE 11.--Hydrograph of Southern California Water Co. Bradshaw Plant well 1 (9N/2W-1F2) adjacent to the Mojave River in the middle basin. (Water-level data obtained from the Southern California Water Co., Los Angeles, Calif.)

SUMMARY AND CONCLUSIONS

Floods with recurrence intervals ranging from 17 years at Deep Creek to 30 years at Afton in 1969, and from 9 years at West Fork Mojave River to 20 years at Deep Creek in 1978 were recorded in the Mojave River basin, resulting from the higher than normal precipitation that occurred during those water years.

Water-year precipitation totals at Lake Arrowhead, in the mountainous upper part of the watershed, were 2.3 times normal, with 98 inches falling in 1969 and 93 inches in 1978. Precipitation in the San Bernardino and San Gabriel Mountains is the primary source of surface-water flow in the Mojave River. Nearly all the precipitation, 94 inches in 1969 and 88 inches in 1978, fell during the December-April period. The intense precipitation during these months resulted in flooding that caused considerable damage to property and structures in the area. Damage estimates of $6 million to $12 million in 1969 and $4 million in 1978 were reported.

Considerable ground-water recharge occurred near the river channel. Channel losses between The Forks and Afton totaled 245,000 acre-ft in 1969 and 282,000 acre-ft in 1978 for December through April. The channel losses resulted from the percolation of water through the riverbed to the water table. At the 1979 cost of water purchased from Silverwood Lake, gross recharge totals resulting from the floods are estimated to be worth $4.6 million for the 1969 flood and $5.2 million for the 1978 flood. If the same volume of water were purchased from the California Aqueduct, costs at the turnout would be about $4.9 million and $5.6 million, respectively. Subtracting annual estimates of consumptive use from the water-year totals yielded a net recharge of 129,000 acre-ft for the 1969 water year and 150,000 acre-ft for the 1978 water year.

Ground-water levels adjacent to the Mojave River were generally lower in 1978 than in 1969. A comparison of the two water years, using a water-level-change map, indicated that about 25,000 acre-ft less water was in storage in April 1978 than in April 1969. However, hydrographs of water levels in four wells in the upper and middle parts of the basin indicated that preflood ground-water levels were considerably lower in the 1978 water year, and post-flood water levels indicated that more recharge occurred in the 1978 water year. The wells showed a larger net rise in water level following the 1978 floods.

Estimates of surface-water loss and changes in ground-water-levels indicate that although more precipitation occurred in the 1969 water year, more recharge occurred in 1978. This was due to the more even distribution of precipitation from December 1977 to April 1978, the surface-water detention structures completed in the upper basin following the 1969 floods, and the lower water levels in the aquifer in 1978, which allowed more recharge to occur. These factors contributed to lower peak discharges, longer sustained flow in the river channel, and increased space available for recharge in the aquifer.

A systematic measurement of ground-water levels in the Mojave River basin would provide knowledge of fluctuations in ground-water levels resulting from planned pumping, natural recharge resulting from floods, or artificial recharge. This information would aid water-resource managers in planning for the future. For example, preflood water levels in the 1978 water year would have been of great benefit in evaluating the effects of that year's floods on the ground-water system.

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POCKET CONTAINS

1 ITEMS.

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