Storage Capacity, Detention Time, and Selected Sediment Deposition Characteristics for Gull and Silver Lakes, Mono County, California

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CONVERSION FACTORS, VERTICAL DATUM, AND DEFINITION

Conversion Factors

Multiply	By	To obtain
acre	0.4047	hectare
acre-foot (acre-ft)	1,233	cubic meter
foot (ft)	0.3048	meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
mile (mi)	1.609	kilometer
square mile (mi^2)	259.0	hectare

Vertical Datum

Sea level: In this report, "sea level" refers to the 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 Sea Level Datum of 1929.

Definition

Water year: A water year is a 12-month period that begins October 1 and ends September 30 and is designated by the calendar year in which it ends. In this report, years are water years unless otherwise noted.

Storage Capacity, Detention Time, and Sediment Deposition Characteristics for Selected Sites on Gull and Silver Lakes, Mono County, California

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ABSTRACT

Bathymetric surveys made in September 1994 indicate the maximum storage capacity of Gull and Silver Lakes, California, is about 2,400 and 3,000 acre-feet, respectively. During March through October 1994, the lake level dropped 0.7 feet at both Gull Lake and Silver Lake. The associated change in storage was 60 acre-feet at Gull Lake and 80 acre-feet at Silver Lake. The flow detention time for average annual flow conditions at Gull Lake is about 2.5 years and for Silver Lake, the average detention time is about 19 days.

Sediment deposition at the inlet to Silver Lake has been monitored since 1951 using aerial photography. During 1963 through 1994, the area of sediment deposition increased from 0.32 to about 2.4 acres. Analyses of these data indicate that the rate of deposition was lower during 1951-72 than the rate during 1973-94. Sediment deposition at the lake inlet is a continuing phenomenon.

INTRODUCTION

Increased tourism and expanded development in the June Lake area, which includes the community of June Lake and Gull and Silver Lakes in Mono County, California (fig. 1), have raised concerns about the effects of urbanization on the water quality of these lakes. Specific concerns are increased eutrophication of Gull Lake and Silver Lake and accelerated sedimentation at the inlet to Silver Lake. This and a companion study by Wang and others (1995) was done by the U.S. Geological Survey, in cooperation with the Mono County Energy Management Department, to address these concerns.

This report presents data on lake stage, content, and storage changes for Gull and Silver Lakes. These data were collected between March and mid-October 1994 and were supplemented by using streamflow records collected at the Rush Creek above Grant Lake gage. Bathymetric surveys of Gull and Silver Lakes were made in September 1994. In addition, changes in the area of sediment deposition at the inlet to Silver Lake during 1951-94 were studied.

LAKE STORAGE CAPACITY

The surface area and volume of Gull and Silver Lakes were surveyed on September 27-29, 1994. The lakebed geometry was mapped using a fathometer with an electronic distance-measuring (EDM) theodolite to provide horizontal control. Bathymetric contours of Gull and Silver Lakes were

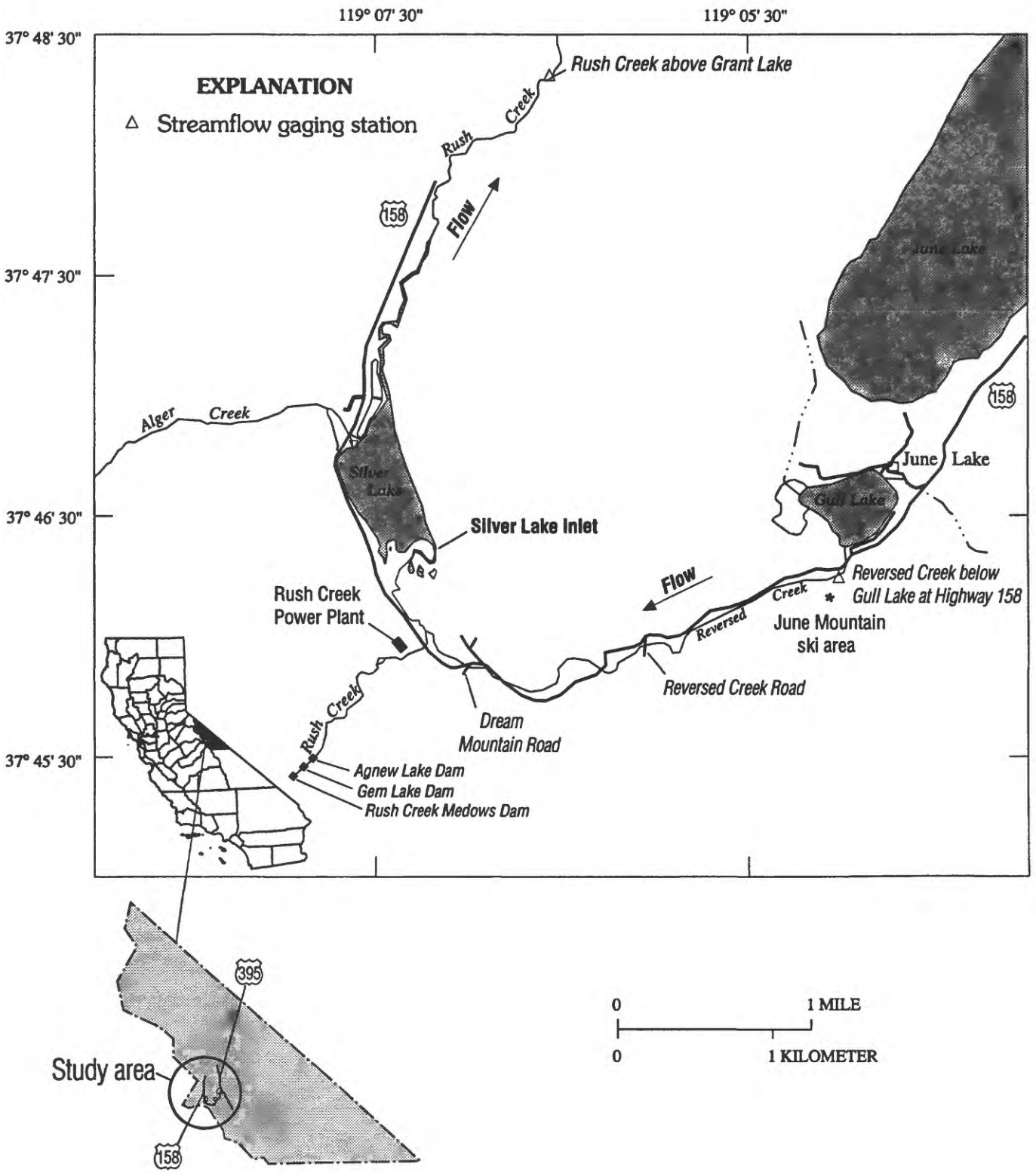

Figure 1. Location of study area and streamflow gaging stations, Mono County, California.

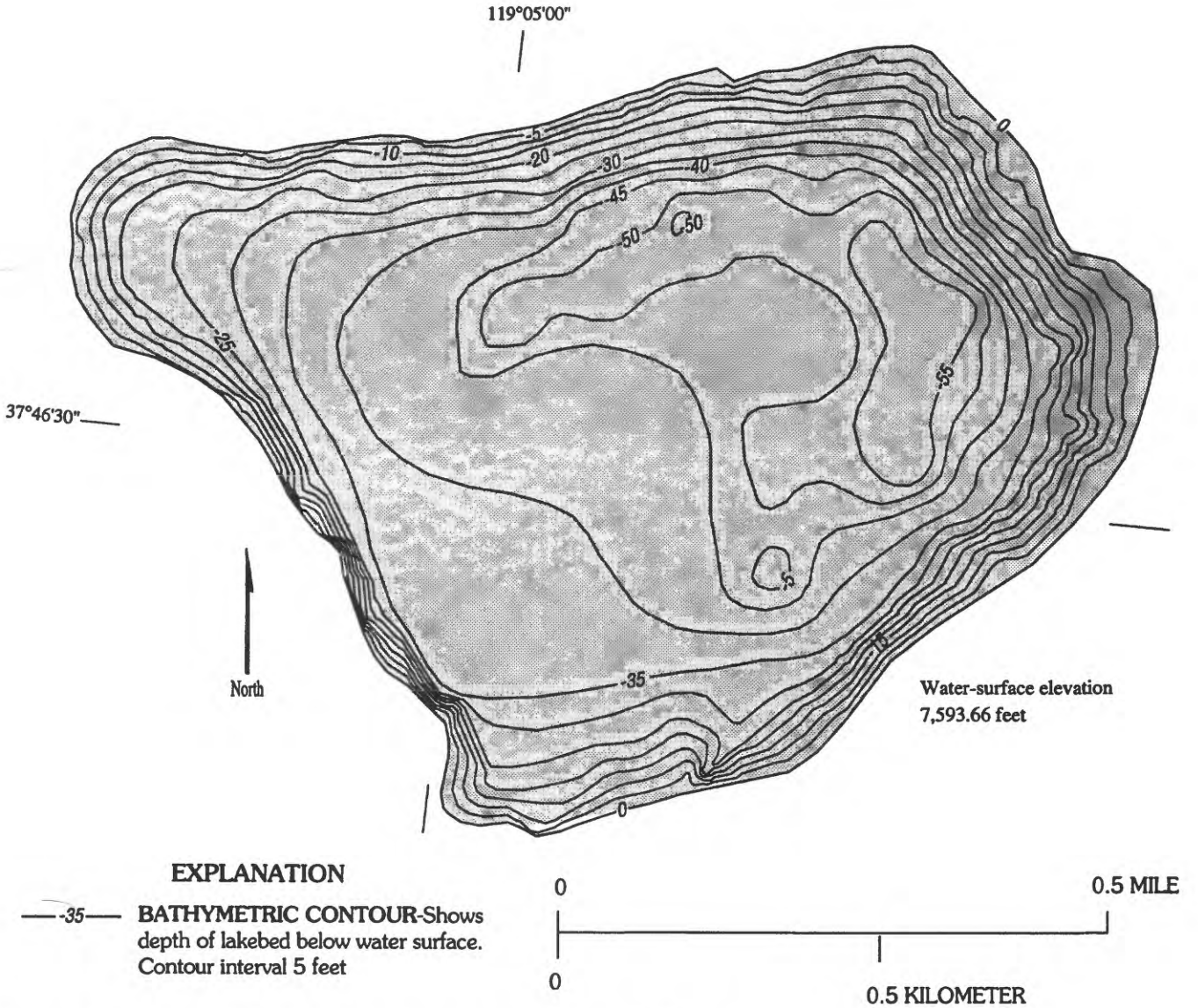

Figure 2. Bathymetric contours, Gull Lake, Mono County, California.

mapped at 5-ft intervals (figs. 2 and 3). Using these data, the surface area and volume of both lakes were calculated (tables 1 and 2 and figs. 4 and 5). The lake volumes were calculated using the average surface areas between contours, which were then combined to indicate volume above the lowest point of the lakebed.

Table 1. Area-volume data for Gull Lake, Mono County, California

Elevation (feet)	Depth (feet)	Area (acres)	Cumulative volume (acre-feet)
7,595.0	0	70.2	2,412.6
7,593.7	1.3	69.0	2,322.1
7,583.7	11.3	61.6	1,669.1
7,573.7	21.3	54.5	1,088.6
7,563.7	31.3	45.2	590.1
7,553.7	41.3	28.5	221.6
7,543.7	51.3	8.2	38.1
7,534.4	60.6	0	0

CHANGE IN LAKE VOLUMES BETWEEN MARCH AND SEPTEMBER 1994

The change in volume of Gull and Silver Lakes was measured using staff gages tied to a known vertical datum. Staff gages were placed at the marina on the east side of Gull Lake and at the

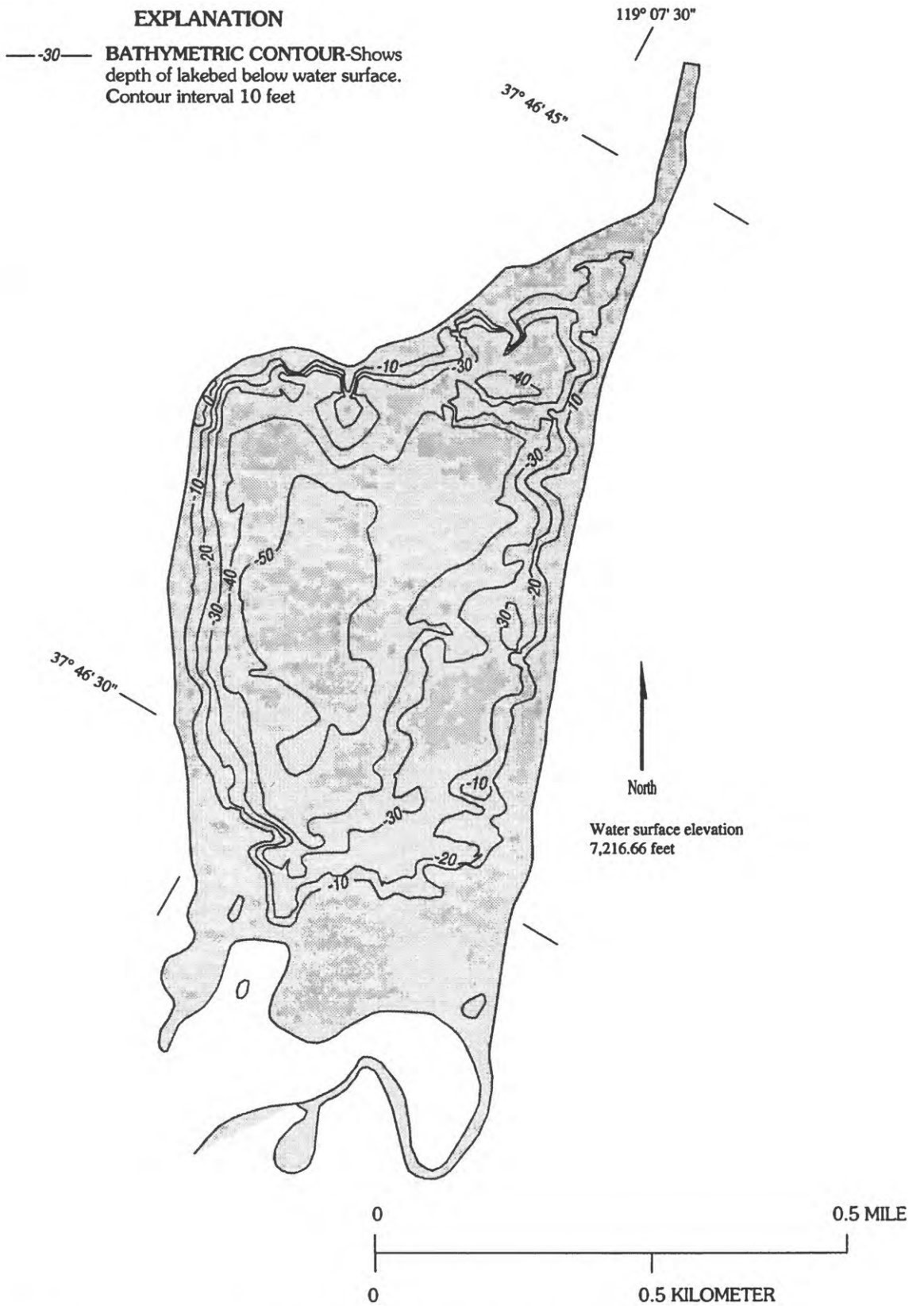

Figure 3. Bathymetric contours, Silver Lake, Mono County, California.

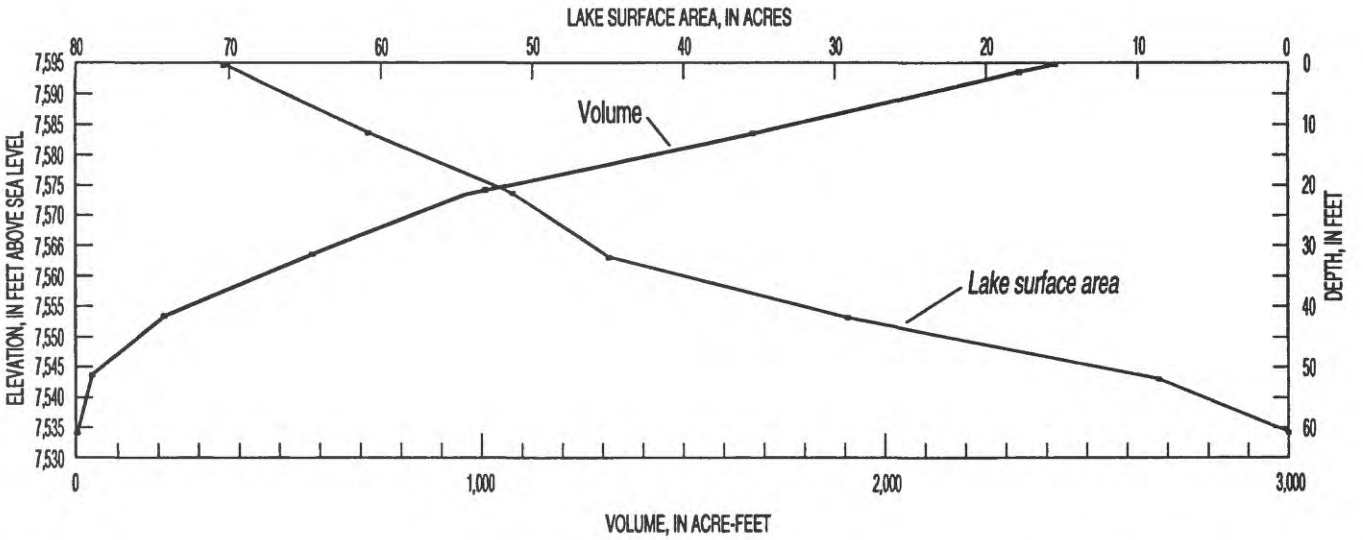

Figure 4. Area-volume curves for Gull Lake, Mono County, California. Date of survey September 27, 1994. All elevations based on California Department of Transportation bench mark CT 2, elevation 7,618.24 feet; center line hole punch on bolt head of fire plug at intersection of Leonard and Bruce Streets, June Lake.

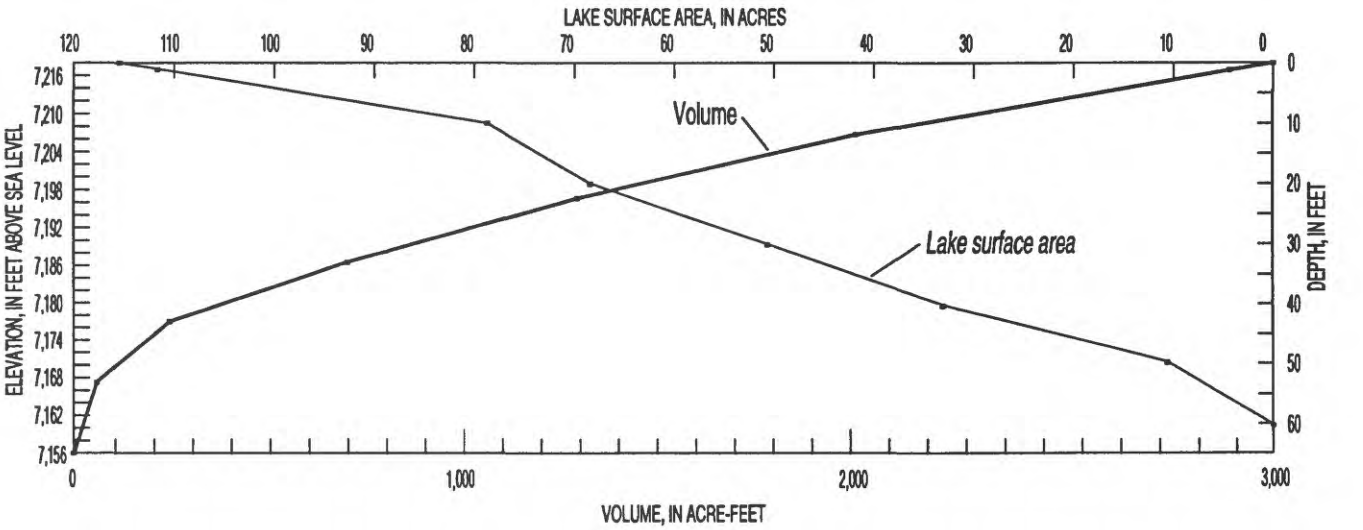

Figure 5. Area-volume curves for Silver Lake, Mono County, California. Date of survey September 29, 1994. All elevations based on California Department of Transportation bench mark PM 7.07, elevation 7,226.31 feet; aluminum cap on 1-in. IP, 0.3 feet below ground, 1 foot east of right edge of pavement, 14.4 feet right of centerline stripe of Highway 158, Mono County, across from entrance to Silver Lake Resort Trailer Park, 10.5 feet west of metal witness post.

Table 2. Area-volume data for Silver Lake, Mono County, California

Elevation (feet)	Depth (feet)	Area (acres)	Cumulative volume (acre-feet)
7,217.5	0	116.0	3,060.0
7,216.7	.8	112.2	2,979.8
7,206.7	10.8	78.6	2,025.8
7,196.7	20.8	68.2	1,291.9
7,186.7	30.8	50.4	698.9
7,176.7	40.8	33.6	279.0
7,166.7	50.8	10.8	57.4
7,156.0	61.5	0	0

public boat ramp on the north end of Silver Lake. Staff readings at the lakes were obtained at various intervals, usually once or twice a week from March 30 through October 1994. The changes in lake levels during March through October 1994 are shown on figures 6 and 7. The lake stages were referenced to sea level datum using nearby bench marks established by the California Department of Transportation (Caltrans). The change in volumes of Gull and Silver Lakes between maximum and minimum stage during 1994 is presented in table 3.

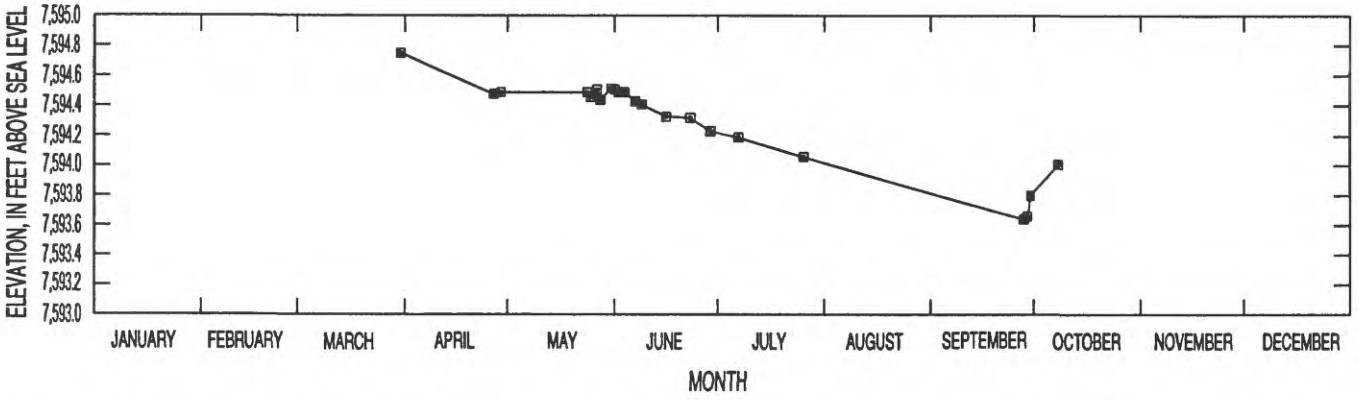

Figure 6. Water levels in Gull Lake, Mono County, California, March through October 1994.

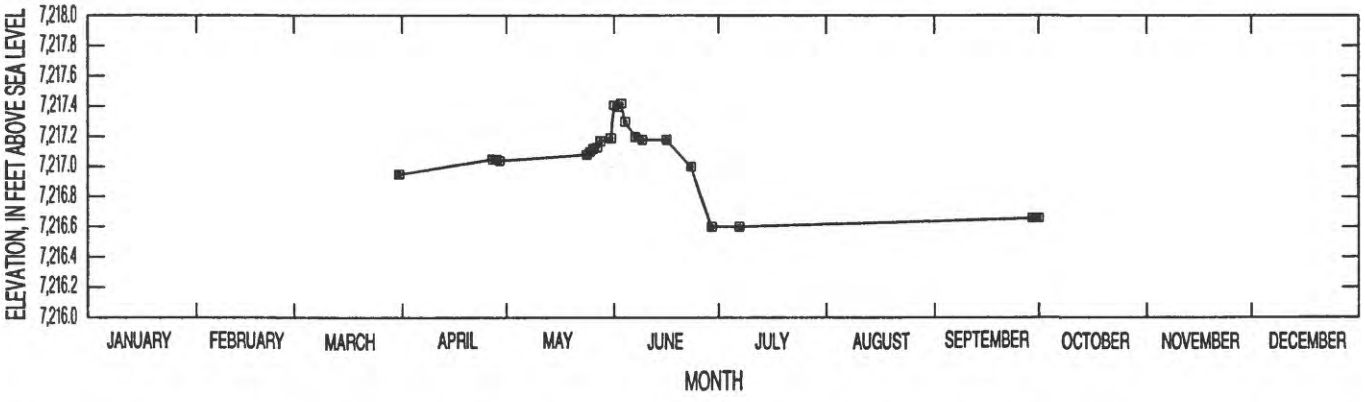

Figure 7. Water levels in Silver Lake, Mono County, California, March through October 1994.

Table 3. Change in lake volume for selected periods, Gull and Silver Lakes, Mono County, California, water year 1994

Date	Water-surface elevation (feet above sea level)	Volume (acre-feet)	Change in volume
Gull Lake			
5-30-94	7,594.5	2,400	
9-29-94	7,593.8	2,340	-60
Silver Lake			
6-02-94	7,217.4	3,060	
9-30-94	7,216.7	2,980	-80

FLOW DETENTION TIME

Gull Lake

Outflow from Gull Lake was calculated from periodic streamflow data collected during water years 1979, 1986, and 1994 at the Reversed Creek below Gull Lake at Highway 158 gage (fig. 1). The measured average monthly streamflow of Reversed Creek below Gull Lake for April through September 1994 was 0.25 ft^3/s. By using corresponding records from the Rush Creek above Grant Lake gage (10287400, operated by City of Los Angeles Department of Water and Power) (fig. 1), the annual mean streamflow of Reversed Creek for water year 1994 was calculated to be about 0.25 ft^3/s, which matches the measured average monthly streamflow.

The 1979 and 1986 streamflow data for Reversed Creek were selected because streamflow data were collected at the Reversed Creek below Gull Lake at Highway 158 gage during all months of the year. The periodic streamflow data were adjusted to monthly mean streamflows on the basis of corresponding streamflow records for Rush Creek above Grant Lake gage (fig. 1). The measured annual mean streamflow of Reversed Creek below Gull Lake during 1979 and 1986 was about 0.98 and 2.45 ft^3/s, respectively. Streamflow data for the 1979 water year were obtained from the June Lake area water resources assessment study (Department of Water Resources, 1981). The streamflow data for the 1986 water year were obtained from June Lake Public Utility District records. On the basis of 57 years of record (1938-94) at the Rush Creek above Grant Lake gage, streamflows of Reversed Creek below Gull Lake during 1979 and 1986 were 104 and 137 percent, respectively, greater than the long-term mean. The adjusted long-term annual mean streamflow of Reversed Creek below Gull Lake would then be about 0.94 (1979) and 1.8 ft^3/s (1986), with an average streamflow of 1.4 ft^3/s.

The flow detention time in Gull Lake was calculated assuming an average lake volume of 2,400 acre-ft (table 1) and the long-term average streamflow of 1.4 ft^3/s for Reversed Creek below Gull Lake (fig. 1). The flow detention time is about 864 days or nearly 2.5 years. The effect of possible ground-water inflow and outflow on flow detention time was not determined.

Silver Lake

The gaging station on Rush Creek above Grant Lake (10287400, fig. 1), about 2.1 mi downstream from Silver Lake, has a drainage area of 51.3 mi^2. The additional drainage area between the lake outlet and the gage is about 4.2 mi^2. The amount of inflow downstream from the lake is considered insignificant most of the year; therefore, flows at the Rush Creek above Grant Lake gage are considered to be representative of outflow from Silver Lake. The long-term mean annual streamflow (1938-94) of Rush Creek is 81.5 ft^3/s (G.L. Singley, City of Los Angeles Department of Water and Power, unpub. data, 1944). The annual mean streamflow for the 1994 water year was 50.6 ft^3/s, about 62 percent of the long-term average.

The assumed average annual volume of Silver Lake is about 3,000 acre-ft (table 2). By using this value for lake volume and the annual mean streamflow of 50.6 ft^3/s at the Rush Creek above Grant Lake gage, the average detention time for a complete change in the volume of Silver Lake during water year 1994 is calculated to be about 19 days.

CHARACTERISTICS OF SEDIMENT DEPOSITION AT SILVER LAKE INLET

Sediment transported by Rush Creek has been depositing at the inlet to Silver Lake since 1963. A high altitude aerial photograph of the lake, which was taken in 1951, indicates no sediment deposition at the inlet similar to that observed in 1963. Aerial photographs of the lake taken between 1963 and 1993 indicate that the area of sediment deposits increased from 0.3 to 2.2 acres (table 4). Field surveys in 1994 indicate that the area of deposition has since increased to 2.4 acres.

The first major development in the Rush Creek basin upstream of Silver Lake began with the construction of a series of hydropower dams. Between 1916 and 1925, the Rush Creek Meadows, Gem Lake, and Agnew Lake Dams (fig. 1) were constructed by Southern California Edison. Agnew Lake Dam, the lowest of the three dams, has a crest elevation of 8,499 ft (California Department of Water Resources, 1988).

There was some development in the upper Rush Creek basin as a result of the construction of recreational summer homes in the vicinity of June Lake, Gull Lake, and Silver Lake. The permanent population of the June Lake community in 1985 was about 650, and the best estimates of growth projected a rather slow and steady increase from 1985 through 1989 (Mono County, 1985).

Another major development in the upper Rush Creek basin was the construction of the June Mountain ski area in the early 1970's (fig. 1). In 1975, the State Water Quality Control Board, Lahontan Region, assigned waste-discharge requirements to the ski area. Since 1975, most of the ski runs were vegetated, and sediment trap basins were constructed. An erosion-prevention plan for the ski area also was implemented by the U.S. Forest Service in 1982. This plan is periodically reviewed and revised (U.S. Forest Service, 1989).

Analyses of the aerial photography and of the field surveys obtained during 1963 and 1994 indicate that most of the sediment is deposited along the eastern shoreline of Silver Lake (fig. 8).

Table 4. Centroid of sediment deposits at the inlet to Silver Lake, Mono County, California, 1963-94

[USGS, U.S. Geological Survey; NRCS, National Resources Conservation Service; Caltrans, California Department of Transportation]

Date of aerial photography	Source of data	Coordinates of sediment deposit (feet) X Axis	Y Axis	Area of deposit (acres)
8-10-51	USGS	not calculated		none
8-23-63	NRCS	121	76	0.32
8-14-72	NRCS	134	68	.32
8-27-83	NRCS	273	110	2.05
8-11-85	NRCS	282	98	1.88
7-05-87	NRCS	270	102	3.12
10-04-89	Caltrans	286	105	2.17
9-24-93	NRCS	306	101	2.22
[1]9-29-94	USGS	316	101	2.42

[1]Field surveys by U.S. Geological Survey, Sacramento, Calif.

This pattern of deposition has been tracked by calculating the centroid of the sand deposit mass (fig. 9) using a constant point of reference. The centroid of an area is defined as the point corresponding to the center of gravity of an area of infinitesimal thickness (Singer, 1954). During 1963-94, the centroid moved north about 95 ft and west about 29 ft. Some variations in the location of the centroid (table 4) for the various years are attributed to difficulties in calculating the exact scale of the aerial photographs. Another source of error is the change in the area of sediment deposition caused by erosion of the distributary channels of Rush Creek at the lake inlet. The continued enlargement of the delta at the inlet to Silver Lake between 1963 and 1994 is shown in figure 10. The areas of sediment deposition were obtained from aerial photographs taken from 1963 through 1993 and from field surveys done in 1994 (table 4).

The temporal trend of the centroid movement between 1963 and 1994 (fig. 11) indicates that the increase in the area of the sediment deposit at the inlet to Silver Lake is a continuing phenomenon. The large displacement in the location of the centroid between 1972 and 1983 (fig. 11) may represent different sediment transport conditions during the years 1963-72, 1973-82, and 1983-94. For this reason, a least squares regression trend line for all of the data for 1963-94 was not calculated.

Figure 8. Sediment deposition at inlet to Silver Lake, Mono County, California, on October 4, 1989. Photograph courtesy of California Department of Transportation.

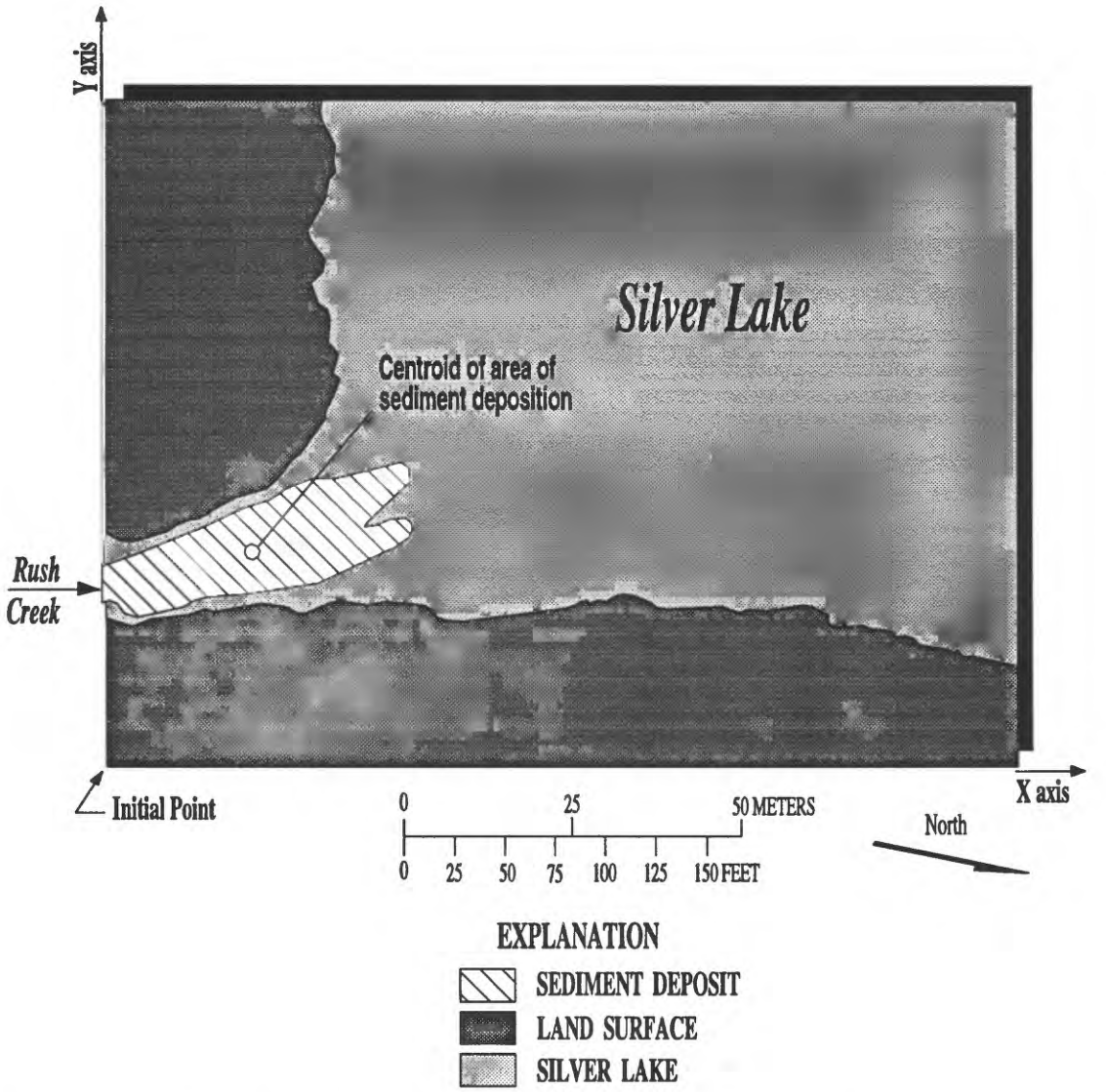

Figure 9. Centroid of typical sediment deposition at inlet to Sliver Lake, Mono County, California.

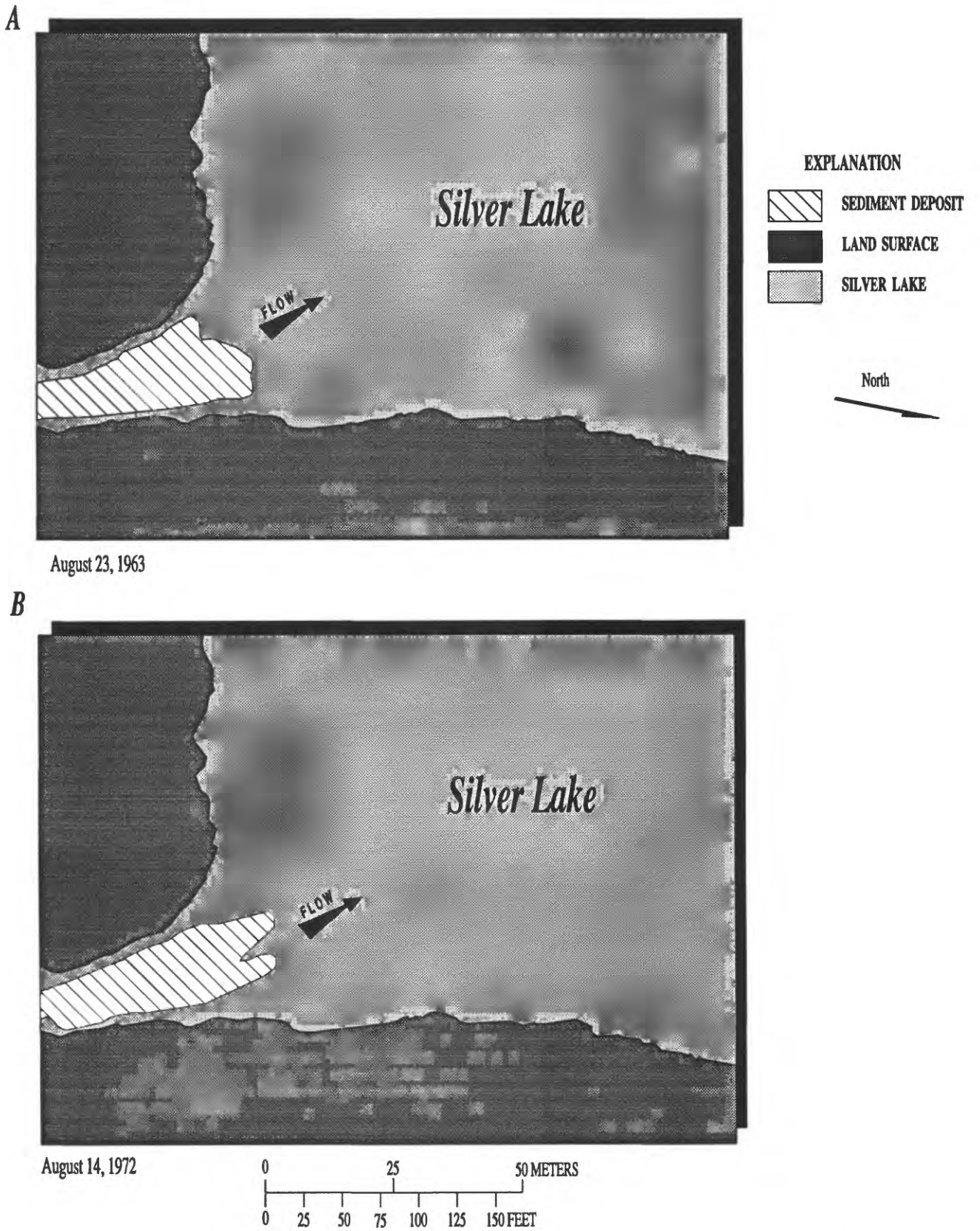

Figure 10. Location and size of sedimentation area at inlet to Silver Lake, Mono County, California.

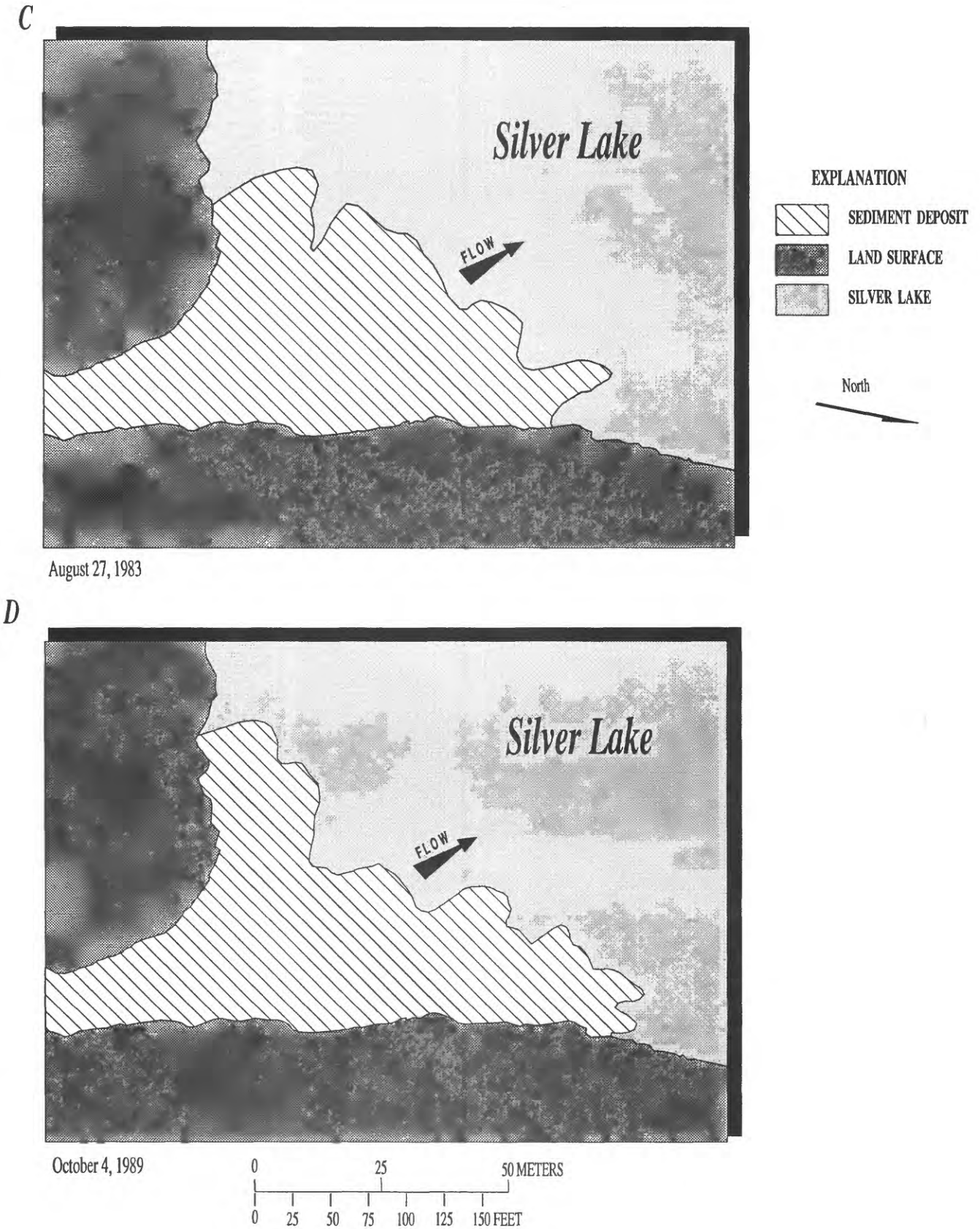

Figure 10. *Continued.*

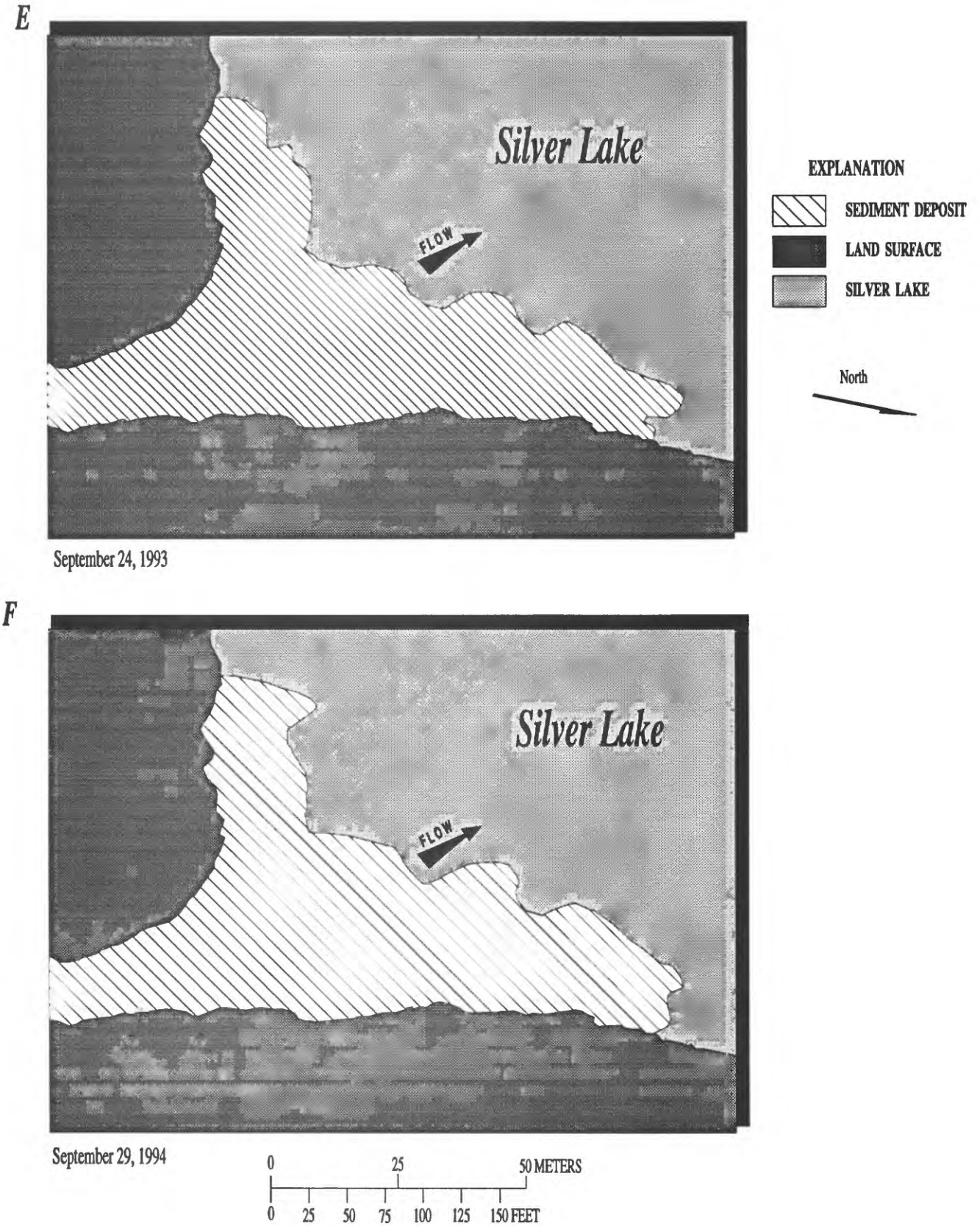

Figure 10. *Continued.*

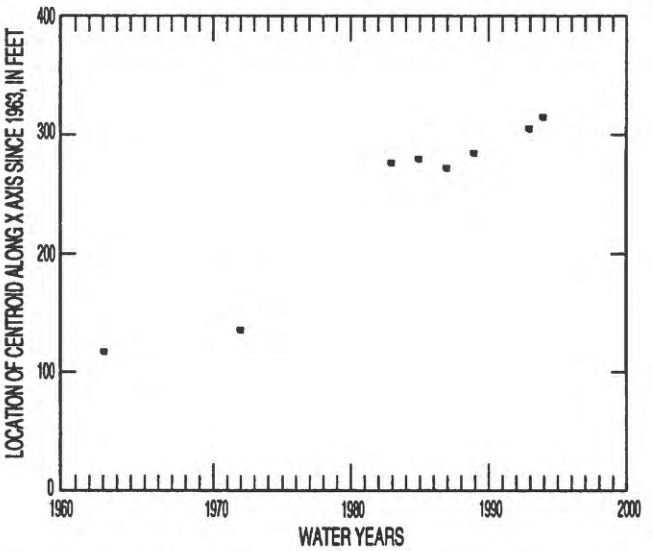

Figure 11. Movement of centroid of sediment deposition at inlet to Silver Lake, Mono County, California, 1963-94.

SUMMARY

Bathymetric surveys made in September 1994 indicate that the maximum storage capacities of Gull and Silver Lakes are about 2,400 and 3,000 acre-feet, respectively. From March through October 1994, lake levels dropped 0.7 feet at Gull Lake and at Silver Lake. The associated reduction in volume was 60 acre-feet at Gull Lake and 80 acre-feet at Silver Lake. The flow detention time for average annual streamflow conditions at Gull Lake is about 2.5 years. For Silver Lake, the average annual detention time is about 19 days.

Through the use of aerial photography, sediment deposits at the inlet to Silver Lake have been monitored since 1951. During 1963-94, the area of sediment deposition increased from 0.32 to about 2.4 acres. Analyses of the sediment deposition data indicate that the rate of deposition was lower during 1963-72 than during 1983-94. These data also indicate that sediment continues to deposit at the inlet to Silver Lake.

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