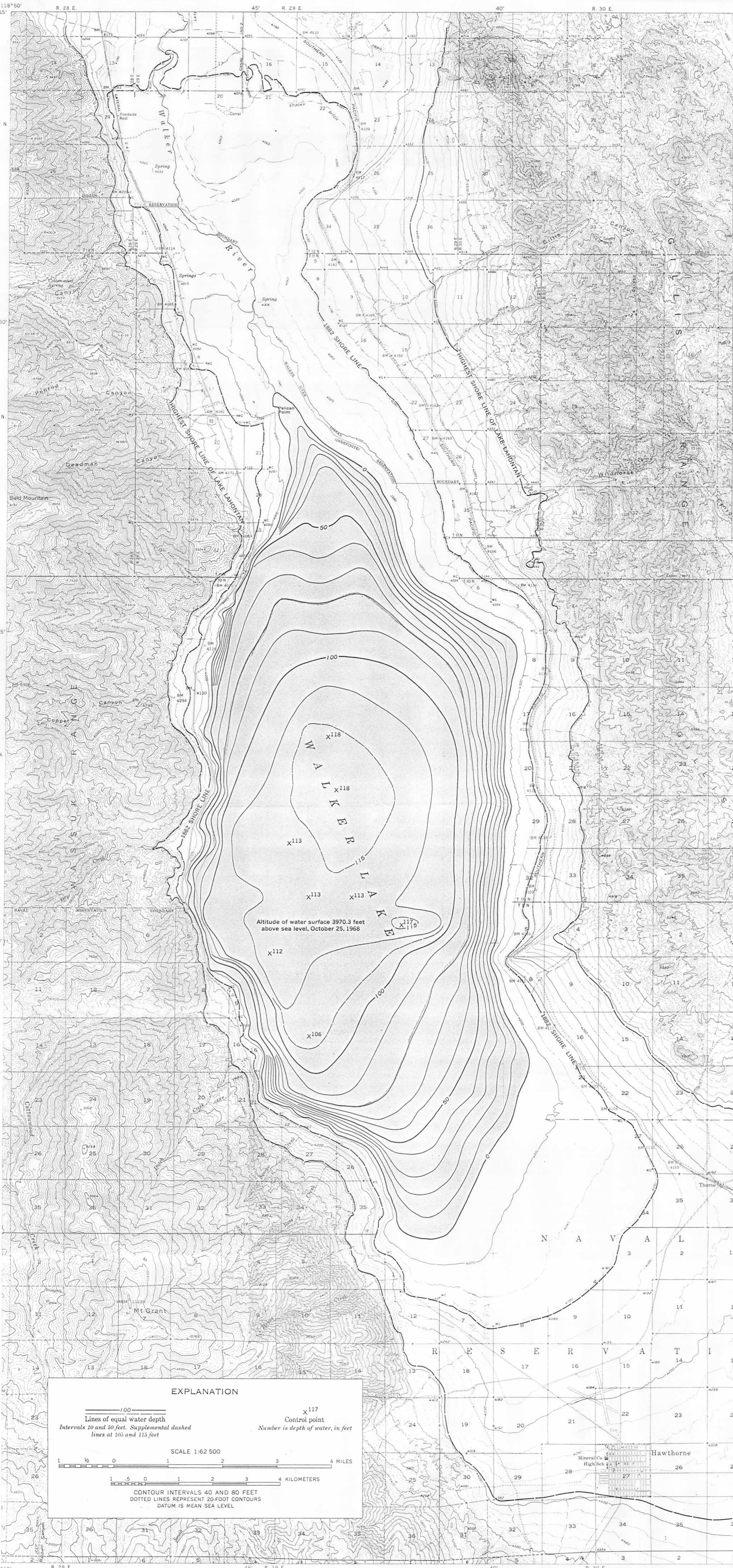
PREPARED IN COOPERATION WITH THE
NEVADA DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES



Base from U.S. Geological Survey Hawthorne, 1955; Mt. Grant, 1956; and Gillis Canyon and Schurz, 1964

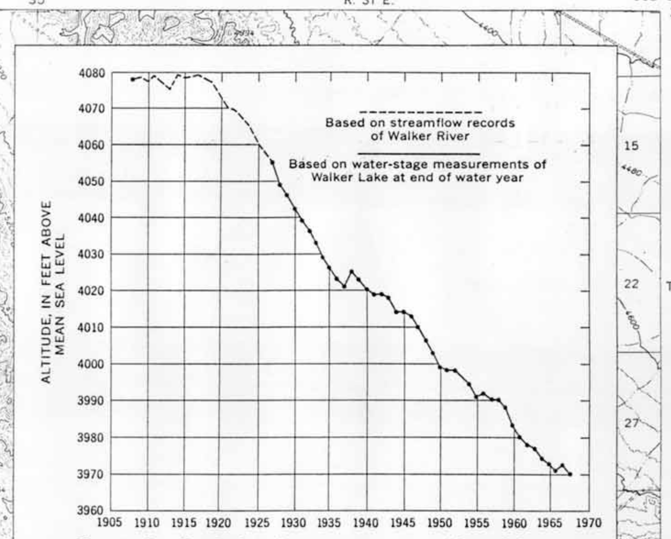


FIGURE 3.—*Variations in stage, 1908–68. Adapted from Everett and Rush (1967).*

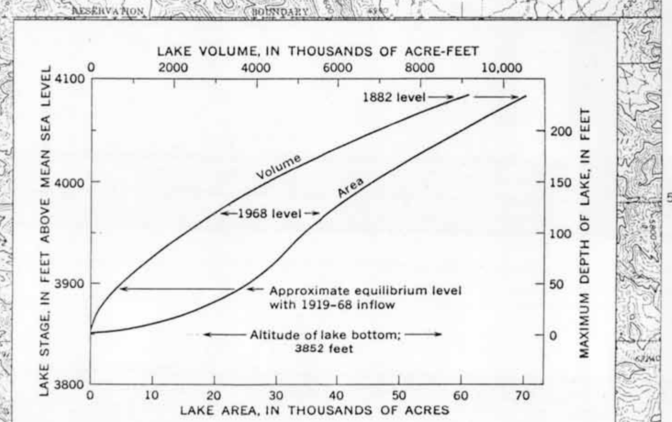


FIGURE 4.—*Area and volume curves.*

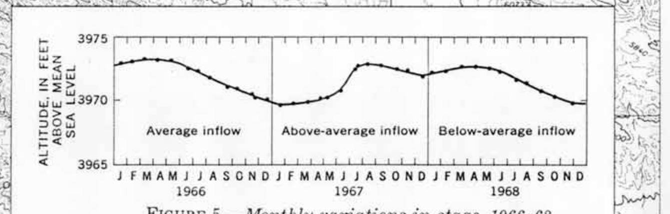


FIGURE 5.—*Monthly variations in stage, 1966–68.*

INTRODUCTION

Walker Lake is about 60 miles southeast of Carson City, Nev., as shown in figure 1. The town of Hawthorne, Nev., is near the south end of the lake. The lake is used principally for recreation—boating, water skiing, and fishing. However, there is considerable concern for the future of the lake because of its rapid stage recession. The altitude of the lake's surface has receded from about 4,083 feet in 1882 to 3,970 feet in 1968 and the surface area has decreased from nearly 69,000 acres to 38,000 acres. The maximum depth in 1968 was about 118 feet. At the present rate of recession, the lake may not reach new equilibrium until the lake level recedes another 70 feet, at which time the area might be approximately 25,000 acres and the depth 40 feet.

The purpose of this report is (1) to define the area and volume configurations of the lake and (2) to show the effects of recession processes on lake stage, area, volume, and dissolved-solids content.

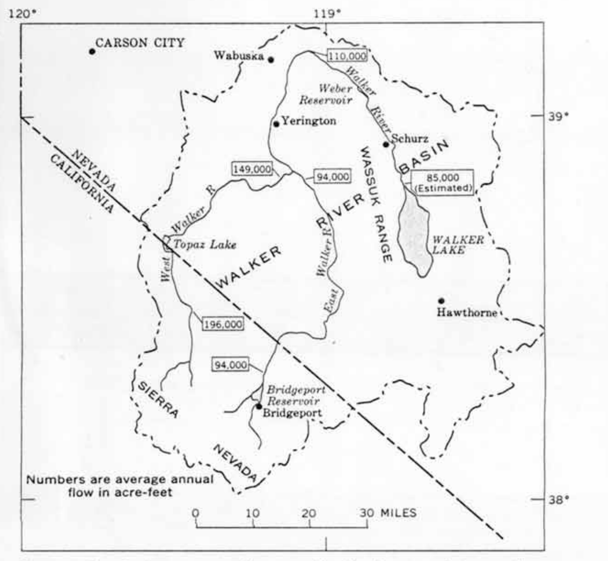


FIGURE 1.—*Index map and generalized volumes of streamflow.*

SETTING

Walker Lake is the lowest permanent body of water in the Walker River Basin (fig. 1), one of the 14 hydrographic regions of Nevada (Rush, 1968) and part of the Great Basin. The Walker River Basin, which includes about 4,000 square miles of Nevada and California, is drained mostly by Walker River and its two principal tributaries, East and West Walker Rivers. Most of the streamflow originates in the Sierra Nevada of California. Between the water-source areas and Walker Lake the flow is greatly reduced by diversions for irrigation and seepage losses to the ground-water system.

Within the basin, the Sierra Nevada rises to a maximum altitude of 12,440 feet, with crests commonly above 10,000 feet. Topaz Lake (fig. 1), on the West Walker River, has a surface altitude of 4,978 feet; Bridgeport Reservoir on the East Walker River, 6,427 feet. The confluence of East and West Walker Rivers is at an altitude of 4,490 feet; Weber Reservoir spillway, on the Walker River, is at 4,204 feet. The surface of Walker Lake on October 25, 1968, was at an altitude of 3,970.3 feet, the reference datum and stage for this report.

Almost all the streamflow in the basin is derived from precipitation. Precipitation in the basin is greatest in the Sierra Nevada, where the average annual quantity is as much as 50 inches. At Bridgeport, Calif., the average annual precipitation is about 13 inches. Yerington, Nev., and Hawthorne receive an average of about 5 inches per year. The estimated average annual precipitation on the lake is 4 inches (Everett and Rush, 1967, p. 7). Figure 1 shows the generalized distribution of streamflow at selected points.

BASIC DATA

Bathymetric soundings at 877 points were made in July 1957 by the Department of the Navy, Twelfth Naval District, San Bruno, Calif. The lake surface in July 1957 was 3,991.2 feet above sea level. To adjust the data to the 1968 level, 20.9 feet was subtracted from the 1957 data, and the water depths were rounded to the nearest foot.

Lake-stage data have been collected by the U.S. Geological Survey in cooperation with the Nevada Department of Conservation and Natural Resources, beginning in 1908 (no record for period 1909–26), and are published in the following Geological Survey publications.

Period	*Publication*
1908, 1927–50	Water-Supply Paper 1314, Part 10
1950–60	Water-Supply Paper 1734, Part 10
1960–64	Surface Water Records of Nevada, 1961, 1962, 1963, and 1964
1964–68	Water Resources Data for Nevada, 1965, 1966, 1967, and 1968

The summary of streamflow for the Walker River Basin is based on data also published in the above publications, and on interpretations by Everett and Rush (1967, p. 26), and Lamke and Moore (1965, table 1). Lake-stage data prior to 1908 are from Harding (1965, p. 143–150) and Russell (1885, p. 70).

LAKE AREA AND STAGE

Walker Lake, together with Pyramid and Honey Lakes, are remnants of Lake Lahontan, a larger Quaternary age lake. According to Snyder and others (1964), Lake Lahontan had a maximum area of 8,665 square miles, mostly in northwestern Nevada, and was sustained by a 42,322-square-mile drainage basin. The lake's maximum surface altitude was about 4,380 feet. Walker Lake now occupies part of what was the southernmost arm of Lake Lahontan.

The deepest part of Lake Lahontan was at the present site of Pyramid Lake (100 miles northwest of Walker Lake), where the maximum depth was about 920 feet (Harris, 1970). At the present location of Walker Lake, as well as on the Carson, Smoke Creek, and Black Rock Deserts (broad alluvial areas north of Walker Lake), the maximum depth of water was about 530 feet. With increased dryness, water levels receded, and Walker River Basin became hydrologically isolated from Lake Lahontan.

Figure 2 shows a generalized interpretation of long-term fluctuations in precipitation, starting with the year 800 A.D. Until 1810, the wet periods generally were longer and had greater departures from average conditions than dry periods. This suggests that Walker Lake may have remained at a rather high level prior to 1810. A drought period, 1810 to 1860, was followed by a wet period from about 1860 to 1920. Figure 3 indicates the wet period probably ended about 1918. Morrison (1964, p. 106) described the climate of the area as being very dry in the 1840's, and abnormally wet from 1850 to 1923. The author, therefore, concludes that during the first part of the 19th century, the lake stage probably receded, and thereafter the stage probably rose to a maximum late in the century. Harding (1965, p. 145) indicated that the lake stage may have been as low as 4,035 feet above sea level in 1845, and that it then rose to about 4,082 feet in 1862 and 4,089 in 1868. The levels in 1862 and 1868 were based by Harding on information that the Indian Agent's home and garden at Schurz, Nev., (fig. 1) were flooded by a rising Walker Lake. James Long, Bureau of Indian Affairs, Stewart, Nev. (oral commun., 1969), after reviewing Bureau documents for that period concluded that (1) the Indian Agent's home was situated at an altitude of about 4,200 feet in the area now occupied by Weber Reservoir (fig. 1), which was the principal area of agricultural development prior to construction of the Weber Reservoir dam, and therefore at least 5 miles from Walker Lake and (2) the Indian Agent's home and garden probably were flooded by Walker River due to rapid spring and summer snowmelt in the Sierra Nevada, rather than by Walker Lake.

By 1882 the water level of Walker Lake was at an altitude of about 4,083 feet, as computed from data presented by Russell (1885, pl. 15) and using the Navy's bathymetric data as altitude control. Harding (1965, p. 143) computed a lake-surface altitude of 4,086 feet on the basis of Russell's data. Russell reported a maximum sounded depth of 225 feet, but unknown to him and Harding, this was not at the deepest part of the lake, as determined from the Navy's bathymetric data. In 1882, the lake probably had a maximum depth of 231 feet, an area of about 68,600 acres, and a volume of about 9,000,000 acre-feet (fig. 4).

In 1908, the U.S. Geological Survey made the first of a series of lake-stage observations, at which time the altitude of the lake surface was 4,078 feet, or 5 feet lower than the 1882 stage. The next known observation was not made until 1927, but by that time the lake level had receded 23 feet to an altitude of 4,055 feet. Because a wet period in the Sierra Nevada continued through most of the intervening 20 years (fig. 2). much of the recession probably was caused by large-scale river diversions for irrigation. From about 1918 to 1968, the trend in stage has been a marked recession, averaging about 2 feet per year. Figure 3 shows lake stage for the period 1908–68.

The general stage recession of Walker Lake during most years has been interrupted by small, short-term rises in stage. For example, figure 5 shows monthly stage data for 1966–68, a 3-year period that included above-average, near-average, and below-average inflow.

WATER BUDGET

A water budget for a lake relates the various components of water inflow, outflow, and change in storage:

$$\text{Inflow} = \text{Outflow} \pm \text{Change in storage.} \qquad (1)$$

For Walker Lake, where the change in storage has been an overall marked depletion, equation (1) is modified as follows:

$$I_R + I_L + I_{GW} + P = E - \Delta S, \qquad (2)$$

where the elements of inflow are: I_R, inflow from Walker River; I_L, local surface-water inflow; I_{GW}, ground-water inflow; and P, precipitation directly on the lake surface. Because no known subsurface flow occurs to adjacent valleys the only element of outflow is evaporation from the lake surface, E; and ΔS is the decrease in storage of the lake associated with lake-stage recession.

An approximate average annual water budget for the lake was compiled for the period 1919–68, the 50-year period during which most of the historical recession of stage had occurred.

I_R was estimated to average about 85,000 acre-feet per year, on the basis of streamflow records for stations at Wabuska, Nev., and Schurz (fig. 1), on streamflow seepage losses and diversions, and on ground-water recharge and underflow estimated by Everett and Rush (1967).

I_L was estimated by Everett and Rush (1967, p. 9) to be 3,000 acre-feet per year. I_{GW} was computed from published information (Everett and Rush, 1967) to be about 3,000 acre-feet per year. P was computed to be about 17,000 acre-feet per year. E was computed by using figures 3 and 4, data from Harding (1965, p. 147), and data from Kohler and others (1954, pl. 1) to be about 200,000 acre-feet per year. ΔS, as computed from figures 3 and 4, was about 110,000 acre-feet per year.

Equation (2) produces the following result:

$$\begin{aligned} I_R + I_L + I_{GW} + P &= 85{,}000 + 3{,}000 + 3{,}000 + 17{,}000 \\ &= 108{,}000 \text{ acre-feet per year} \\ E - \Delta S &= 200{,}000 - 110{,}000 \\ &= 90{,}000 \text{ acre-feet per year} \\ \text{Imbalance} &= 18{,}000 \text{ acre-feet per year} \end{aligned}$$

Because of errors in estimates or unresolved hydrologic problems, the equation does not balance. Neither side of the equation was considered more accurate than the other; so the average of the two values, or about 100,000 acre-feet, was selected to approximate both inflow and outflow plus decrease in storage.

During the period 1909–18, the lake stage was nearly constant (fig. 3) and in order to maintain this high stage, average annual inflow from all sources probably was more than 250,000 acre-feet. That part entering the lake from Walker River probably was at least 80 percent of the total inflow, or at least 200,000 acre-feet per year. Inflow from Walker River during the period 1860–1908 probably was even greater, because of the previously discussed rise in lake stage.

DISSOLVED-SOLIDS CONTENT OF THE LAKE

In 1882, Russell (1885, p. 69) collected and analyzed what probably was the first sample of Walker Lake water (table 1). Because of the high stage of the lake at that time, the lake water probably had about its lowest solute concentration since the dry period of early 19th century. Not until 1930 were additional samples collected (Miller and others, 1953, p. 38).

The main factor controlling the variation in concentration of dissolved solids in the lake is the volume of lake water that dilutes the dissolved solids. The concentration of dissolved solids from 1882 to 1918 was probably similar to that sampled in 1882, because of the almost constant lake stage and volume during this period. By 1966 the lake volume had diminished by a factor of 2.9 and the dissolved-solids concentration increased by a factor of 3.4.

The total dissolved-solids content of the lake, in tons, had not changed as dramatically as the concentration, as illustrated by figure 6.

A reconnaissance three-dimensional sampling survey of the lake was made by the Geological Survey on October 6, 1965, during which 28 samples were collected. On the basis of these data, the principal conclusions regarding the lake and its inflow at that time are as follows: (1) The lake was almost homogeneous chemically; for example, the chloride concentrations ranged from 2,020 mg/1 (milligrams per liter), near the mouth of Walker River, to 2,240 mg/1. Only calcium varied appreciably; it ranged from about 2 to about 9 mg/1. (2) Water temperature decreased with water depth, as illustrated in figure 7.

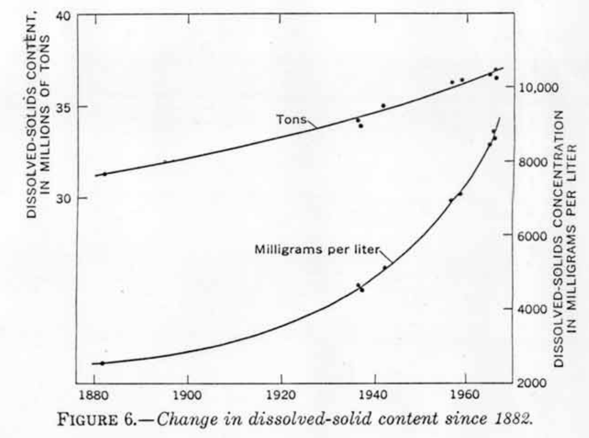


FIGURE 6.—*Change in dissolved-solid content since 1882.*

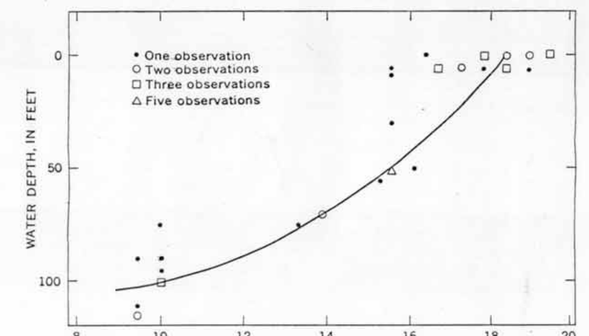


FIGURE 7.—*Generalized vertical temperature distribution on October 6, 1965.*

OUTLOOK FOR THE FUTURE

To maintain Walker Lake at its 1968 stage of 3,970 feet above sea level, an average annual inflow from Walker River of nearly 140,000 acre-feet would have to be sustained. This would provide a lake having a volume of about 3 million acre-feet and an area of about 38,000 acres, as shown in figure 4. Since 1918 the average annual inflow from the river has been about 85,000 acre-feet; obviously, present-day inflow will not be enough to maintain the present lake stage, area, and volume. The lake stage, therefore, will continue to recede until average annual evaporation is decreased enough to balance, rather than exceed, the average annual inflow from all sources. For example, if the inflow of Walker River to the lake is sustained at its present long-term average rate (about 85,000 acre-feet per year), equilibrium would be reached when the lake had an area of roughly 25,000 acres, a stage of about 3,896 feet above sea level, and a volume of about 600,000 acre-feet. This equilibrium stage would be some 70 feet below the 1968 stage and the maximum depth of the lake would be only about 40 feet, compared to a 1968 depth of 118 feet. When general equilibrium is reached, lake stage would continue to fluctuate in a narrow range related to annual variations in inflow.

Projecting the slope of the stage curve in figure 3, the estimated equilibrium stage (3,896 feet) would be reached between the years 2010 and 2060. Because upstream irrigation demands may increase, the average annual inflow from Walker River may decrease, thereby hastening the recession of the lake and consequently lowering its equilibrium level.

What will be the future dissolved-solids content of Walker Lake? The obvious answer is larger tonnages and high concentrations. Projecting trends shown in figure 6, the anticipated amount of dissolved solids at the estimated equilibrium stage (3,896 feet) may be about 40 million tons, and the dissolved-solids concentration would be nearly 50,000 mg/1.

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TABLE 1.—*Chemical analyses of Walker Lake water.*
[Constituents in milligrams per liter, except as indicated; analyses by U.S. Geological Survey.]

Date of collection	September 1882	February 18, 1966
Water temperature (°C)		5
Silica (SiO_2)		.5
Calcium (Ca)	27	4.2
Magnesium (Mg)	39	124
Sodium (Na)	858	3,040
Potassium (K)		160
Bicarbonate (HCO_3)		1,640
Carbonate (CO_3)		486
Sulfate (SO_4)	528	1,930
Chloride (Cl)	588	2,020
Fluoride (F)		20
Boron (B)		21
Dissolved solids (calculated)	[a]2,560	8,610
Hardness as $CaCO_3$	228	520
Specific conductance (micromhos per cm at 25°C)		12,100
pH		9.3

[a]Estimated.

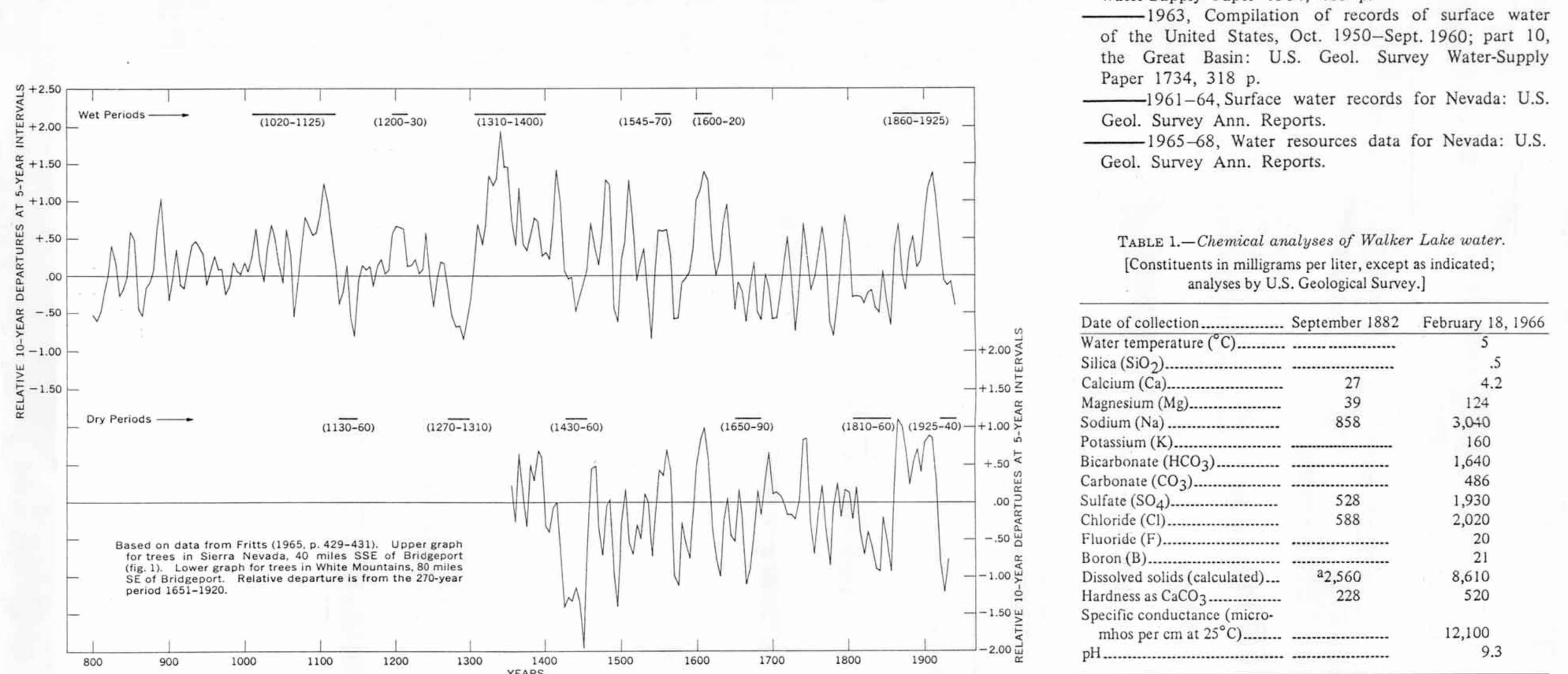

FIGURE 2.—*Generalized long-term fluctuations in precipitation as interpreted from data on dated tree-ring widths.*

HYDROLOGIC REGIMEN OF WALKER LAKE, MINERAL COUNTY, NEVADA

By
F. Eugene Rush

1970