Hydrologic Effects of Small Reservoirs in Sandstone Creek Watershed, Beckham and Roger Mills Counties, Western Oklahoma

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1839-C

Prepared in cooperation with the U.S. Department of Agriculture, Soil Conservation Service

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By F. W. KENNON

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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By F. W. Kennon

ABSTRACT

A study was made of the hydrologic effects of a group of 22 flood-retarding reservoirs in Sandstone Creek watershed, Oklahoma. The reservoirs ranged in capacity from 102 to 4,192 acre-feet. Complete monthly water budgets for each reservoir were prepared for the period October 1, 1958, to September 30, 1960. Reservoir seepage was found to be almost equal to spillage. The seepage appears as surface flow in the principal stream channels below the reservoirs, and thus an ephemeral stream has become a perennial one. The perennial flow has accelerated the growth of riparian vegetation, which has led to a change in channel geometry and to a reduction in channel conveyance. Water losses attributable to the reservoirs were found to be about 20 percent of the natural runoff.

INTRODUCTION

Large numbers of small reservoirs are being built for upstream flood and erosion control, for sources of stock water, and for recreation. Knowledge of runoff and sediment production from small watersheds, which is needed for reservoir design, is generally inadequate throughout the West. Also, there is little detailed knowledge of the hydrologic effects of small reservoirs.

A cooperative study by the U.S. Geological Survey and the U.S. Soil Conservation Service was begun in 1951 at Sandstone Creek. Rainfall on the watershed, the inflow to 11 reservoirs, and the streamflow at three points below the reservoirs were determined. An interim report covering the findings of this study for the period 1951–56 has been released (Gilbert, 1959).

The objective of this report is to complement the above study for the 2-year period October 1958–September 1960 by extending reservoir observations to all flood-retarding and erosion-control reservoirs above stream-gaging station 3. The reservoir observations have been amplified to include the evaluation of evaporation and seepage as separate items. The hydrologic effects of the reservoir system at downstream points are described.

The study was made under the general supervision of G. E. Harbeck, Jr., then chief of the General Hydrology Branch, U.S. Geological Survey. Evaporation measurements were made under the supervision of G. E. Koberg and J. S. Meyers, of the same branch. Precipitation data and the geologic description of the area were furnished by personnel of the U.S. Soil Conservation Service. Personnel of the Oklahoma City district office of the Surface Water Branch, U.S Geological Survey, supplied the streamflow and reservoir water-stage records and rendered other assistance.

DESCRIPTION OF THE AREA

LOCATION AND TOPOGRAPHY

The Sandstone Creek watershed is in Beckham and Roger Mills Counties in western Oklahoma and largely within a triangle formed by the towns of Sayre, Elk City, and Cheyenne. Sandstone Creek drains in a northeasterly direction and enters the Washita River (pl. 1) about 8 miles southwest of Hammon. The watershed is about 107 square miles in area and includes four major tributaries, Currant Creek, Wild Cat Creek, East Branch Sandstone Creek, and an unnamed creek heading above reservoir 10. The study area described in this report comprises the drainage basin of 85.4 square miles above streamgaging station 3, which is 1.5 miles below the confluence of Sandstone Creek and East Branch Sandstone Creek.

Sandstone Creek watershed is composed of fairly rough upland, well drained by a system of V-shaped valleys. Elevations range from 1,800 to 2,400 feet above sea level. Both valley and upland slopes range from 2 to 20 percent. A view of the watershed is shown in figure 1.

GEOLOGY

Five stratigraphic units are recognizable in the Sandstone Creek watershed and have been mapped. In ascending order they are: the Cloud Chief Formation of Permian age, the Doxey and Elk City Members of the Quartermaster Formation of Late Permian age, the Ogallala Formation of Pliocene age, and stream-terrace deposits of Quaternary age.

Cloud Chief Formation crops out in a narrow, linear band along the foot of the valley slopes and adjacent to the flood plains of the drainageways. The formation consists of reddish silty sandstones interbedded with shale and siltstone, locally containing irregular lenses of selenite.

Doxey Member of the Quartermaster Formation crops out over the major part of the watershed. It consists principally of brown shale, but has several bench-forming beds of siltstone near the center.

FIGURE 1.—Sandstone Creek watershed, from reservoir 14 looking northwest.

Elk City Member of the Quartermaster Formation crops out along the southern part of the Sandstone Creek basin. It consists of brown sandstone which is irregularly bedded and friable, ranging in texture from very fine to medium. It contains much silt thoughout. In general it is very permeable.

Ogallala Formation crops out over an area of several square miles in the western part of the basin. It consists of moderately unconsolidated gravel, sand, and clay with sporadic caliche beds. It is very permeable.

Alluvium occurs in relatively narrow bands that form the flood plains along Sandstone Creek upstream from the mouth of Currant Creek. Downstream from this point the flood plain widens to about half a mile at stream-gaging station 3. The alluvium is a fairly permeable silt and sand.

SOILS, LAND USE, AND CLIMATE

Deep permeable soils, either sands or silts, mantle 31 percent of the watershed area. Their structure is open, and when wet their expansion is little or nothing. Sandy or silty loams cover 24 percent of the area. Their structure is open for about the surface foot, and when wet their expansion is moderate. The remaining 45 percent of the area has either no soil mantle or a shallow one only a few inches in depth.

About three-quarters of the area is used as pasture or rangeland and about one-quarter is cultivated cropland.

The mean annual precipitation is about 25 inches. The wettest month is May and the driest is January. On the average, about 41 percent of the total annual precipitation falls in April, May, and June, and much of it may occur in single intense storms. For example, 14 inches of rain fell in 6 hours at Cheyenne, April 3–4, 1934, and the total precipitation there for 1934 was only 28.30 inches.

Sandstone Creek watershed received 29.08 inches of precipitation during water year 1959, and 32.44 inches during water year 1960. The distribution of rainfall by months is shown in figure 2.

The mean annual temperature is about 60° F. The average maximum temperature for August, the hottest month, is 96° F. and the average minimum for January is 24° F. Extremes of 16° below zero and 112° above zero have been recorded. The average frost-free period is 208 days.

EROSION-CONTROL AND FLOOD-RETARDATION MEASURES

Measures to reduce runoff and to retard soil erosion as of January 1, 1959, include the following: Utilization of crop residue and contour farming on about 5,300 acres, 421 miles of terraces, 12 erosion-control reservoirs, and 24 flood retarding structures. Plate 1 shows the location of these erosion-control and flood-retarding structures, which control runoff from 64.3 sq mi of the 85.4-sq-mi study area above stream gaging station 3. Both kinds of structures are equipped with ungated drop-outlet pipes ranging from 6 to 34 inches in diameter. The capacities of flood-retarding reservoirs 2–21 at spillway elevation are shown in table 1. The combined capacity of these reservoirs in October 1958 was 20,834 acre-feet and in September 1960 was 20,449 acre-feet. These figures are based on planetable surveys of the reservoirs made at those times. The water-storage space below the invert of the drop-outlet pipe averages about 0.2 of the reservoir capacity at spillway elevation.

The combined capacity of erosion-control reservoirs 101–111 was 1,030 acre-feet in 1951, according to Gilbert (1959). If the average 1951–60 sedimentation rate for the flood-retarding structures, 3.4 acre-feet per square mile of drainage area per year,[1] is applied to the

[1] The reservoir sedimentation rate was obtained from data in table 1.

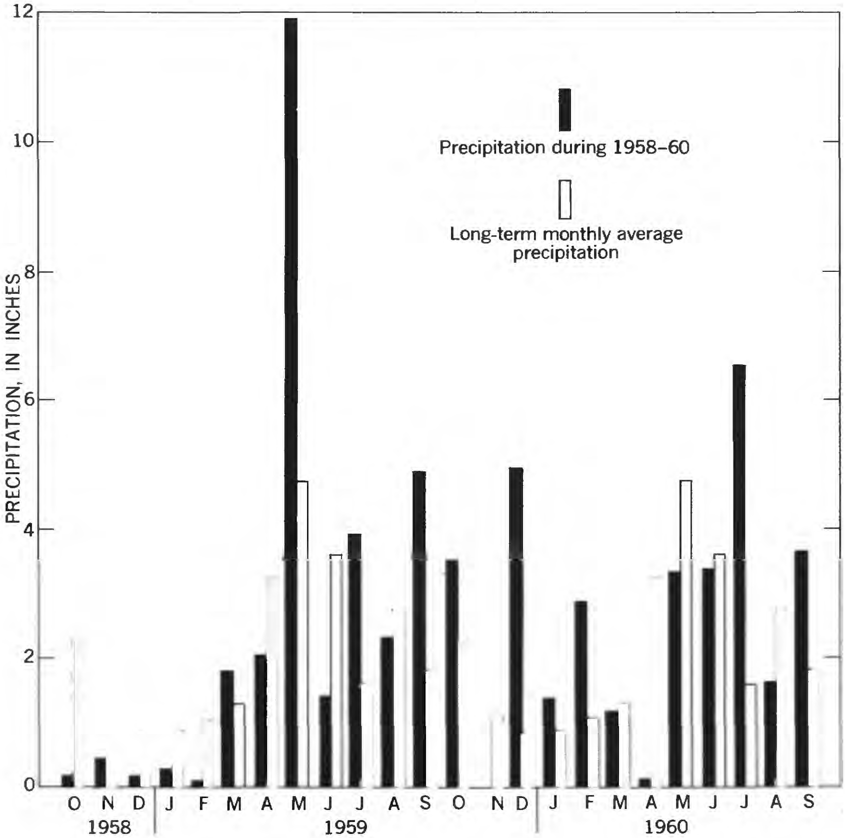

FIGURE 2.—Monthly precipitation on the Sandstone Creek watershed during water years 1959 and 1960.

erosion-control reservoirs, the estimated capacity of the 12 reservoirs in September 1960 is 846 acre-feet. These reservoirs control runoff rates and reduce sediment movement from 5.41 square miles upstream from flood-retarding reservoirs 4, 5, 6, and 10. Some slight additional control of both sediment movement and runoff is effected by numerous farm ponds throughout the watershed.

INSTRUMENTS USED

Plate 1 shows the location of the various hydrologic instruments. Precipitation was measured at 14 recording and 25 nonrecording rain gages. Water stage was recorded continuously at reservoirs 2, 3, 5, 6, 8, 9, 10, 10A, 12, 14, 16, 16A, and 17. Figure 3 shows a water-stage recorder installation. Water stages at each of the remaining reser-

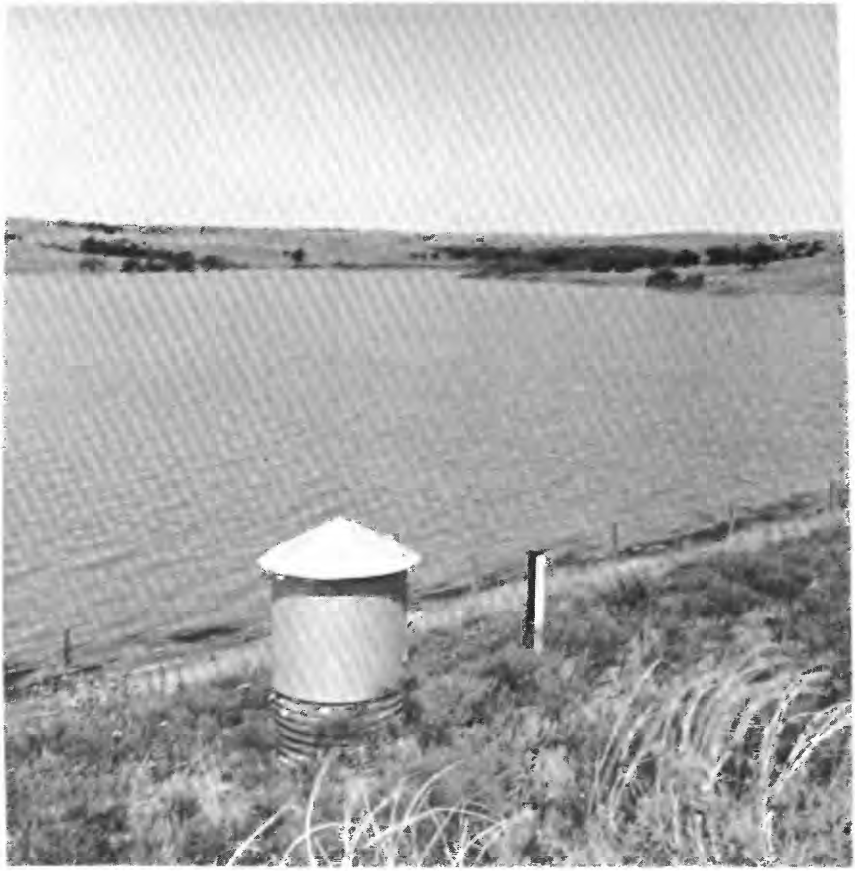

FIGURE 3.—Water-stage recorder installation at reservoir 16.

voirs were obtained by weekly readings of a staff gage, which included the elevations of high-water marks occurring between readings. Monthly staff-gage readings were made at the erosion-control reservoirs. Streamflow was measured at three stations equipped with continuous water-stage recorders. Stream-gaging stations 1 and 2, which were equipped with artificial controls as shown in figure 4, monitored the flow of upper Sandstone Creek and East Branch Sandstone Creek, respectively. Station 3 was used to measure streamflow below the confluence of Sandstone Creek and East Branch Sandstone Creek.

Evaporation was determined by the energy-budget method (Anderson, 1954; Koberg, 1958) for reservoirs 6, 12, and 16. For that purpose a radiation-measuring station was established about half a mile east of stream-gaging station 2. Solar radiation was measured with a 10-junction Epply pyrheliometer. Total incoming radiation was measured by a Beckman and Whitley total hemispherical (or flatplate) radiometer. Wet-bulb and dry-bulb temperatures were measured by copper-constantan thermocouples to find the humidity of the local airmass. The thermocouples were mounted under a conical reflector (known as a coolie hat for its appearance), which was provided with vanes and louvers to allow free passage of outside air past the wet and dry junctions. Voltages generated by the radiation instruments and by thermocouples were recorded sequentially at 1-minute intervals on the strip chart of a recording potentiometer.

An instrument raft was anchored near the center of each of reservoirs 6, 12, and 16 for measurements of wind and of water temperatures. On each raft a standard 3-cup recording anemometer was mounted 2 meters above the water, and the sensing element of a 7-day recording thermometer was placed just below the surface of the water. Temperature checks and anemometer dial readings were made at weekly intervals. Approximately once a month, temperatures of the contents of the three reservoirs were measured from surface to bottom with a Whitney underwater thermometer—a portable electric instrument employing as the sensing element a small thermistor which forms one arm of a wheatstone bridge.

Energy-budget computations of evaporation from each of the three reservoirs were then made from the radiation station, raft, and thermal data, together with inflow, outflow, and rainfall.

FIGURE 4.—Artificial control at stream-gaging station 1.

COMPUTATION OF RESERVOIR INFLOW

Inflow to all reservoirs was computed from the relation—

inflow=reservoir pipe discharge+seepage+evaporation−precipitation on the reservoir±change in reservoir content,

all quantities being expressed in acre-feet. The several items of this water budget were derived as described in the following paragraphs.

RESERVOIR DROP-OUTLET PIPE DISCHARGE

All reservoir outflow except seepage was confined to discharge through the drop-outlet pipes. No reservoir was filled to spillway capacity. A curve of relation between head on the drop outlet and pipe discharge was prepared for each reservoir by making current-meter measurements of pipe discharge at various stages above the drop outlet. This curve, together with the reservoir stage record was used to compute reservoir drop-outlet pipe discharge.

RESERVOIR EVAPORATION

Monthly evaporation was obtained by the energy-budget method for reservoirs 6, 12, and 16, their capacities at spillway elevation being respectively 1,814, 491, and 4,192 acre-feet. The other reservoirs were compared with these three, and the evaporation measured at one of these three was assigned to each reservoir on the basis of closest similarity in capacity and exposure. Monthly evaporation, in acre-feet, was computed by multiplying the monthly evaporation, in feet, by the monthly average reservoir water surface, in acres.

PRECIPITATION ON THE RESERVOIR

Monthly precipitation on the reservoir, in feet, was obtained from records of the nearest rain gage or combination of rain gages. This value multiplied by the monthly average reservoir surface provided monthly values of precipitation on the reservoir, in acre-feet.

RESERVOIR CONTENTS

As previously mentioned (p. C4), reservoirs 2–21 were mapped in October 1958 and remapped in September 1960. Reservoir-capacity tables were prepared from these surveys. Reservoir capacities for dates between the initial and terminal surveys were interpolated on the basis of the ratio of the antecedent inflow to total inflow for the period.

RESERVOIR SEEPAGE

Reservoir seepage, in feet, was determined by preparing seepage-rating curves for each reservoir. During periods of no inflow or outflow, monthly seepage was computed by subtracting evaporation from the observed reservoir water-stage recession adjusted for precipitation on the pool. Because the flow of water through granular materials is directly proportional to the head and inversely proportional to the viscosity of water, monthly seepage was plotted against the ratio of monthly average depth of reservoir to monthly average specific viscosity of the bottom water, as shown in figure 5. The

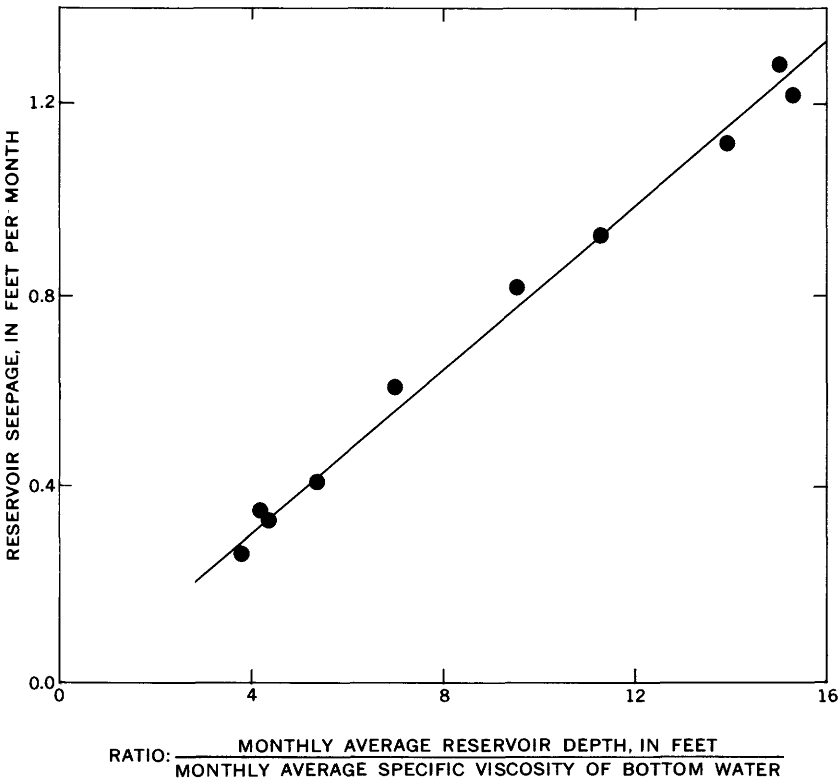

FIGURE 5.—Relation between the seepage rate and the ratio of monthly average reservoir depth to monthly average specific viscosity of water at reservoir 9.

values of specific viscosity were determined from temperature profiles of reservoirs 6, 12, and 16. Monthly volumes of seepage were computed by multiplying the monthly average reservoir surface area by the monthly seepage which is derived from the seepage-rating curve.

WATER BUDGET

Monthly water budgets (table 2) were prepared for each of the flood-retarding reservoirs above stream-gaging station 3. For reservoirs 5, 6, 10, and 16 two inflow values are given. The first value is the actual inflow and the second is the inflow which would have occurred if there were no upstream structures. There are four erosion-control reservoirs above each of reservoirs 5, 6, and 10. Flood-retarding structure 16A lies upstream from reservoir 16. The following formula was used to compute monthly inflow figures adjusted for upstream storage: Uncontrolled or natural inflow to reservoir=actual reservoir inflow+evaporation from upstream reservoirs±change in storage of upstream reservoirs−rain on upstream reservoirs.

The combined water budget for all flood-retarding reservoirs is shown in table 3.

Of the six items of the water budget, three were derived by simple, straightforward methods familiar to the average technical reader, and therefore they do not merit further discussion. These items are reservoir outflow, precipitation on the reservoir, and change in reservoir content. Evaporation as determined by the energy-budget method has been adequately discussed elsewhere (Anderson, 1954; Koberg, 1958). Inflow is merely the algebraic sum of the other five items. The remaining item, reservoir seepage, is a determination not so commonly made, and therefore more consideration of this item would appear to be warranted. Furthermore, in this watershed it is of particular interest because it is nearly as great in quantity as reservoir outflow.

The question of the ultimate disposition of seepage water naturally suggests itself. Because most of, if not all, the reservoirs are on beds of relatively impervious shale, loss of water by downward seepage is improbable. Such loss being negligible, most of the seepage water must flow under or around the various dams, and because of the geologic nature of the basin it should reappear as surface flow in the channels below the reservoirs. An obvious way to test this assumption is to measure the main-channel streamflow at successive points below the reservoirs after a fairly rainless period and compare the measured flow with the computed seepage loss rate of the upstream reservoirs. Such a test was made on January 28 and 29, 1959. The antecedent precipitation, for October 1958–January 1959, is shown below.

Month	*Precipitation (inches)*
October	0. 11
November	. 42
December	. 15
January	. 09

The January rain occurred on the 15th of the month which was 2 weeks prior to the series of test measurements. Because of the small amount of antecedent precipitation, it is reasonable to conclude that no appreciable gravitational water attributable to rainfall was draining from the narrow bands of alluvium bordering the main creek channels during the test period. The results of the test are ahown on plate 1.

It can be noted that the measured streamflow agrees very well with computed seepage rates from upstream reservoirs on Currant Creek and the main stem of Sandstone Creek above stream-gaging station 3. On the lower reach of East Branch Sandstone Creek and and at stream-gaging station 3, the measured streamflow is considerably greater than the computed upstream reservoir seepage. This discrepancy may result from the zero seepage assigned to reservoirs 3 and 8, which had recently gone dry. The bottom sediments of these reservoirs were probably still draining. It is also possible that irrigation water from a large alfalfa field adjacent to the creek near stream-gaging station 3 may have been draining into the channel above the gaging station.

A second test was made on December 4, 1959. There had been no rain since October 4, with the exception of one storm of 0.46 inch which occurred on October 30. The results of this test are shown on plate 1. The computed seepage rate of the combined reservoir system above stream-gaging station 3 was within 10 percent of the flow gaged at that station, but the agreement was not as good at a number of other points. It can be noted that the measured flow of Currant Creek is less than the computed seepage rate above reservoir 11, the actual flow decreasing from 0.74 cfs (cubic foot per second) below reservoir 17A to 0.29 cfs between reservoirs 18 and 19. In contrast, the flow in Sandstone Creek paralleling this losing reach of Currant Creek increased from 0.99 to 1.85 cfs, or from 82 to 126 percent of the computed seepage rate. This suggests that a part of the Currant Creek reservoir seepage is appearing as surface flow in Sandstone Creek between reservoirs 11 and 12. Below the confluence of Currant and Sandstone Creeks, the measured flow (3.06 cfs) is within 5 percent of the computed seepage rate (2.92 cfs). The seepage from reservoirs 9, 20, and 21 may be moving through the alluvium as underflow until near stream-gaging station 3, where it may be forced to the surface to appear as surface flow at that gaging station. This would explain the disparity between measured flow and computed seepage rates in Sandstone Creek and East Branch Sandstone Creek near their confluence.

These tests support the thesis that substantially all reservoir seepage reappears as surface flow in the main channels below the reservoirs. This thesis may be checked in another way. The ratio of basin runoff to rainfall upstream from groups of reservoirs may be compared with the same ratio for the uncontrolled areas between stream-gaging stations and the reservoirs. The basin runoff for the uncontrolled areas above stream-gaging stations 1 and 2 and the uncontrolled area between these stations and station 3 is derived as follows for water years 1959 and 1960.

	Acre-feet
Gaged flow at stream-gaging station 1	11, 660
Seepage from reservoirs 11–19	−3, 951
Outflow from reservoirs 11–19	−5, 859
Channel evaporation between reservoirs and stream-gaging station 1	+313
Natural runoff from the watershed between stream-gaging station 1 and reservoirs 11–19	2, 163
Gaged flow at stream-gaging station 2	6, 904
Seepage from reservoirs 2–9	−2, 751
Outflow from reservoirs 2–9	−2, 559
Channel evaporation between reservoirs and stream-gaging station 2	+131
Natural runoff from the watershed between stream-gaging station 2 and reservoirs 2–9	1, 725
Gaged flow at stream-gaging station 3	23, 963
Gaged flow at stream-gaging station 1	−11, 660
Gaged flow at stream-gaging station 2	−6, 904
Seepage from reservoirs 10, 10A, 20, and 21	−1, 485
Outflow from reservoirs 10, 10A, 20, and 21	−624
Channel evaporation between stream-gaging station 3 and upstream gages and reservoirs	+665
Natural runoff from the watershed between stream-gaging station 3 and upstream gages and reservoirs	3, 955

The channel-evaporation values shown in the foregoing tabulation were estimated by multiplying the 2-year evaporation, in feet, measured at reservoir 12, by the wetted area of the main channel bottoms, in acres. These areas are 27.0 acres between stream-gaging station 1 and reservoirs 16 and 17; 25.5 acres between stream-gaging station 2 and reservoirs 5 and 6; and 55.9 acres between stream-gaging station 3 and stream-gaging stations 1 and 2 and reservoirs 10 and 10A.

The comparison of the ratio of runoff to rainfall for the described uncontrolled areas with the same ratio for four controlled areas above the reservoirs is shown in table 4.

The runoff-rainfall ratios in table 4 are plotted on a map of the basin (fig. 6) to aid in their comparison. The ratios for contiguous controlled and uncontrolled areas are clearly in very good agreement. Such agreement is evidence of both the accuracy of seepage computations and the assumption that reservoir seepage appears as surface flow in the main channels below the reservoirs. This conclusion is based on the fact that the runoff from uncontrolled areas was obtained as the difference between flow measured at the stream-gaging

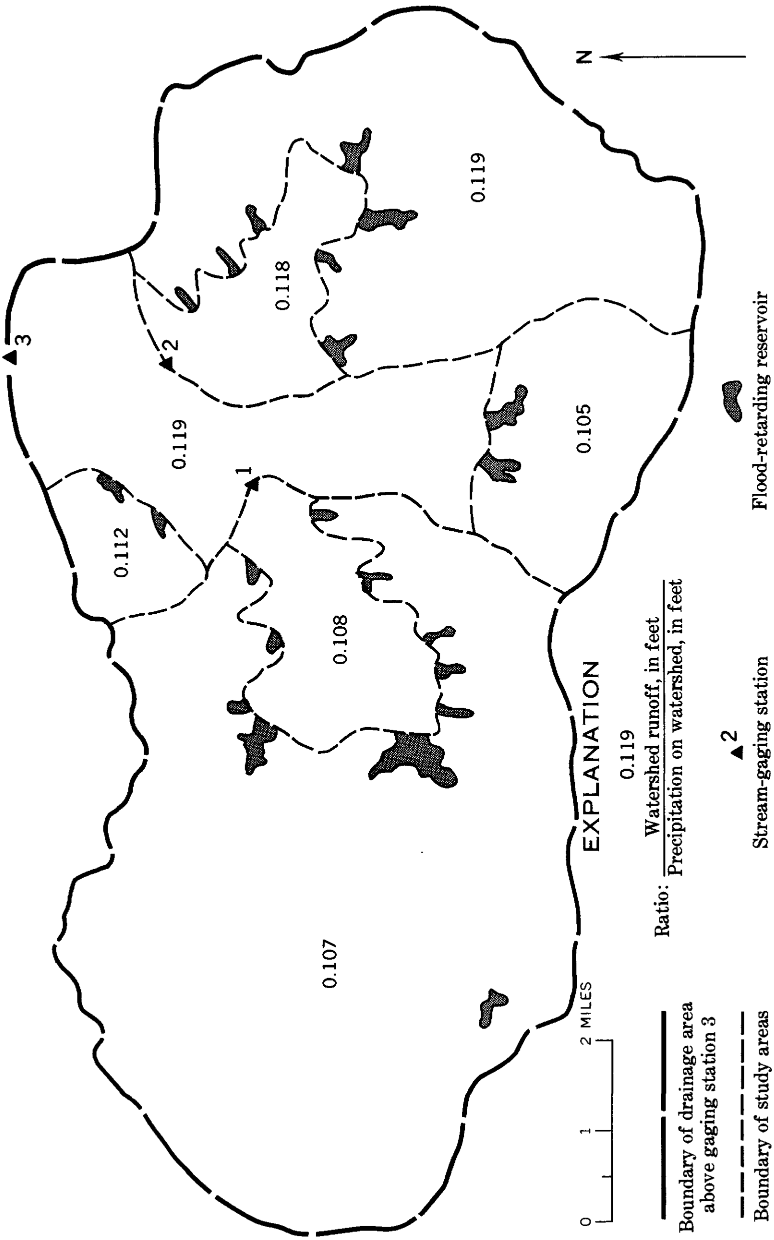

FIGURE 6.—Map of Sandstone Creek study area showing 2-year runoff-rainfall ratios for areas above and below groups of reservoirs.

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stations and the reservoir outflow composed of outflow and seepage corrected for estimated evaporation losses. Because reservoir seepage is similar in magnitude to the runoff from the uncontrolled areas, the runoff-rainfall ratios for these areas should differ appreciably from the same ratios for the controlled areas above the reservoirs if either the seepage computations were in serious error or an appreciable part of this seepage failed to pass the stream-gaging stations.

HYDROLOGIC EFFECTS OF THE RESERVOIRS

CHANGE IN BASE FLOW

There are no records of flow of Sandstone Creek prior to the construction of the reservoirs. However, long-time local residents are in agreement that Sandstone Creek was formerly an ephemeral stream. It remained an ephemeral stream for 6 years after the reservoirs were completed in 1951 and early 1952, as illustrated by table 5.

Sandstone Creek has been a perennial stream since November 1957 in the sense that continuous flow has existed between stream-gaging station 3 and the upstream reservoirs. It is conjectured that several years were required for reservoir seepage to build up in the valley alluvium below the reservoirs a ground-water body from which drainage would sustain continuous flow downstream. The flow at stream-gaging station 3 during the winter and spring of water years 1953 and 1959 is shown graphically in figures 7 and 8. The figures illustrate the marked change in base flow which has taken place. The distribution of rainfall is similar during both periods, but the total amount was actually greater in 1953, being 5.13 inches for that period and 4.67 inches for the 1959 period. The streamflow for the 1953 period was 57 acre-feet, whereas the flow for the 1959 period was 887 acre-feet.

CHANGE IN CHANNEL GEOMETRY

Prior to the reservoir construction, the Sandstone Creek channel was rectangular in cross section throughout a substantial part of its course and nearly free of vegetation (fig. 9). Loose material which had sloughed from the banks was carried away during high flows, and vertical bank faces were thus preserved. With the reduction in flood peaks and the establishment of perennial flow, a lush growth of vegetation developed on the bank material, anchoring it in place (fig. 10). Thus the channel is changing in cross section from rectangular to V-shaped, as shown in figures 11 and 12. The channel conveyance for medium and high flows has also been reduced. The changing channel geometry of Sandstone Creek is discussed in more detail by Sullivan and Bergman (1963).

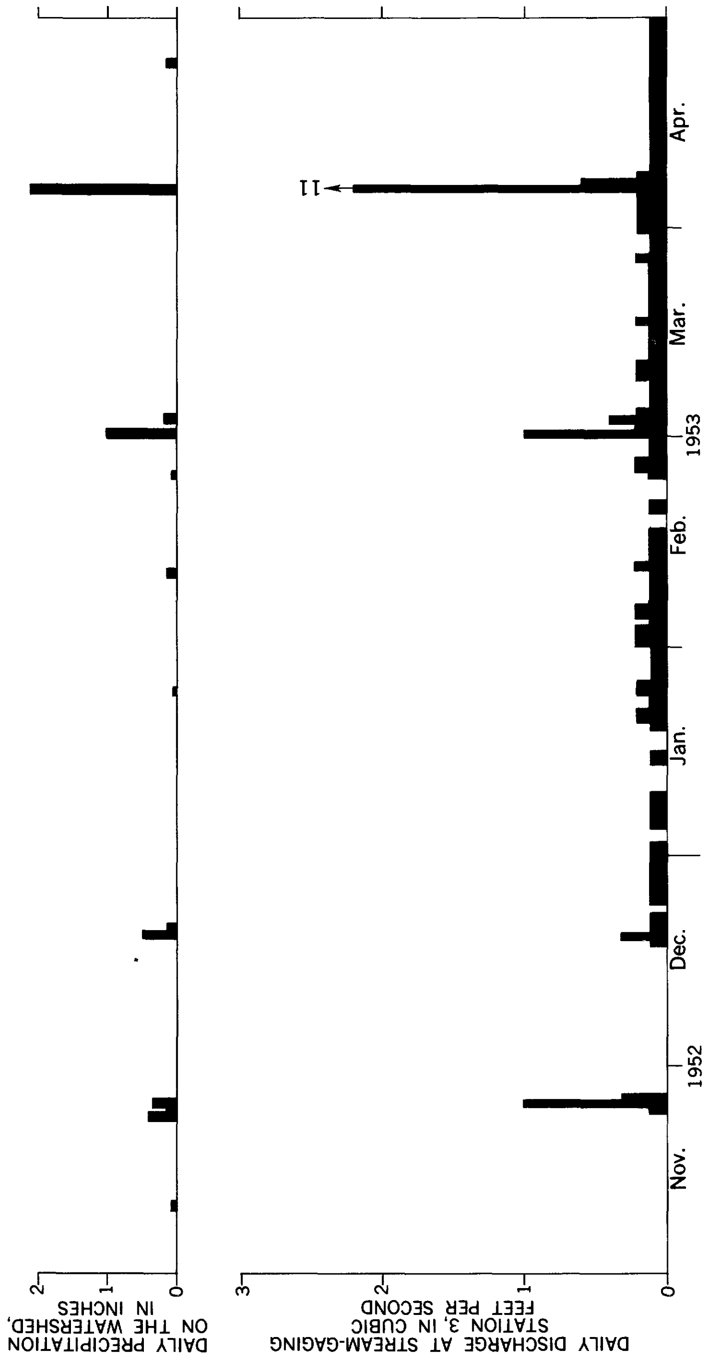

FIGURE 7.—Daily precipitation on and daily discharge from the watershed above stream-gaging station 3 from November 1952 to April 1953.

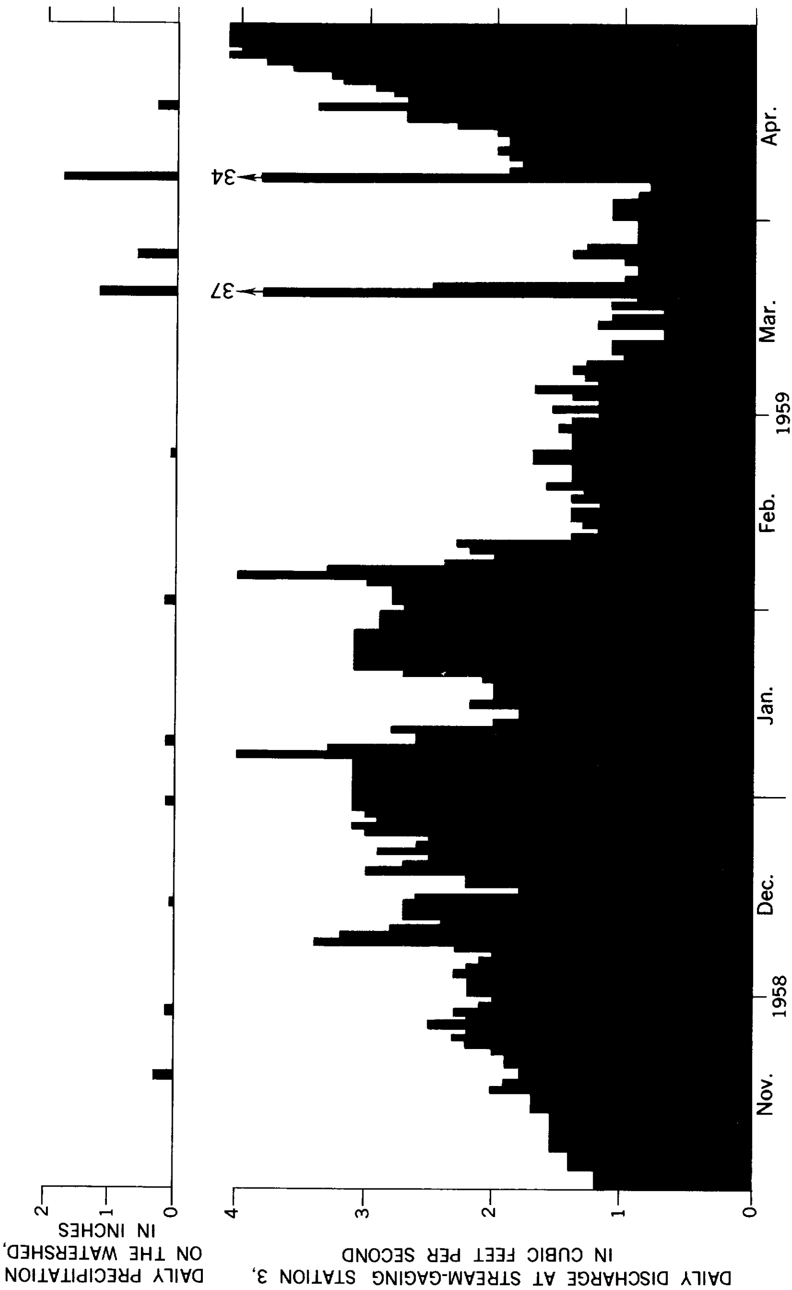

FIGURE 8.—Daily precipitation on and daily discharge from the watershed above stream-gaging station 3 from November 1958 to April 1959.

FIGURE 9.—View upstream from stream-gaging station 3 in 1954. Photograph by U.S. Department of Agriculture.

REDUCTION IN STREAMFLOW

The average of the evaporation measurements for reservoirs 6, 12, and 16 was 68.2 inches for water year 1959 and 70.6 inches for water year 1960. The evaporation from the entire reservoir system is compared in table 6 with reservoir inflow.

Thus the water loss attributable to the reservoirs at points immediately downstream from them averaged 12 percent for the 2-year study period. The actual annual reduction in streamflow immediately below the reservoirs would not be the same as the water losses computed above because of storage effects, as shown in table 7.

The considerable difference in the reduction in annual streamflow for the two years results from differences in reservoir contents prior to major inflows. Reservoir contents were very low prior to the major inflow of May 1959. Thus a considerable part of the inflow merely served to bring pool levels up to drop-outlet elevation. At the beginning of water year 1960 the pools were almost at drop-outlet elevation and remained so during most of that year. Also, seepage rates for the first 7 months of 1959 steadily decreased with receding water level in the reservoirs, but in 1960, with nearly full pools, the seepage rates remained high.

Change in the volume of streamflow attributable to a system of reservoirs may be stated with confidence for points immediately below them, but it is very difficult to evaluate such changes with the same

FIGURE 10.—View upstream from stream-gaging station 2 in 1961.

degree of confidence for points some distance downstream from the reservoirs. Under natural conditions streams periodically overtop their banks and saturate large areas of flood-plain sediments. After the return of the stream to its normal channel, most of the water stored in the valley sediments may be lost by evapotranspiration. If a reservoir system prevents overbank flooding, as the Sandstone system has done in the channel reach between the reservoirs and stream-gaging station 3, then it may be said that the reservoir system has enhanced streamflow at downstream points for some time after periods of flood-producing rainfall.

This beneficial effect, however, is negated to an unknown extent by increased channel evapotranspiration losses chargeable to the reservoirs. On an originally ephemeral stream the flood-retarding nature

FIGURE 11.—View upstream from stream-gaging station 3 in 1959. Photograph by U.S. Department of Agriculture.

FIGURE 12.—View upstream from stream-gaging station 3 in 1961.

of the reservoirs, of necessity, prolongs flow at downstream points and thus increases transmission losses.

Owing to these uncertainties, table 8 is considered to be an approximate assessment of the effect of the reservoirs on the volume of flow passing stream-gaging station 3.

The estimated reduction in flow at stream-gaging station 3 for the 2-year period is 20 percent. The reduction in flow immediately below the reservoirs was previously computed to be 22 percent.

RESERVOIR SEDIMENTATION

Table 1 shows capacities at spillway elevations for reservoirs 2–21 as determined by planetable mapping in September 1960. The original capacities of nine of these reservoirs also are shown, together with the sediment accretion rates as of September 1960. The sedimentation rates ranged from 2.3 to 4.3 acre-feet per square mile of contributing drainage area per year. When these rates were applied to the storage space reserved for sediment as of September 1960, it was found that this space would be filled during periods of time ranging from 12 years for reservoir 17 to 33 years for reservoir 10A.

IRRIGATION

With the development of perennial flow in Sandstone Creek, a dependable source of irrigation water was made available for riparian landowners. However, rainfall during the growing season in 1959 and 1960 was such that only small amounts of water were pumped from the creek for irrigation. In 1959 an estimated 7 acre-feet was taken from the creek above stream-gaging station 1, 25 acre-feet was pumped from the reach between this gage and stream-gaging station 3, and about 100 acre-feet was diverted just below stream-gaging station 3. No irrigation was reported or observed during 1960.

CONCLUSIONS

A system of 22 flood-retarding reservoirs which control the runoff from 64.3 square miles out of a total of 85.4 square miles above stream-gaging station 3 caused an estimated reduction of flow at this station of 20 percent for water years 1959 and 1960. These were years of above-normal precipitation. Sandstone Creek has changed from an ephemeral to a perennial stream as a result of substantial reservoir seepage, most of which appears as surface flow in the main channels below the reservoirs. As a result of the persistent streamflow, the main channel cross section is changing from rectangular to V-shaped. The growth of riparian vegetation sustained by the constant water supply is reducing the channel conveyance. Reservoir sedimentation rates were found to range from 2.3 to 4.3 acre-feet per square mile of drainage area per year. The reservoir storage space reserved for sediment as of September 1960 will be exhausted during periods of time ranging from 12 to 33 years on the basis of the foregoing sedimentation rates.

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TABLES 1–8

TABLE 1.—*Flood-retarding reservoir data*

Reservoir	Drainage area [1] (square miles)	Capacity at spillway elevation (acre-feet)		Capacity at elevation of drop outlet, September 1960, in acre-feet	Sediment increment (acre-feet)	Period since storage began (years)	Sediment accretion (acre-feet per square mile of drainage area per year)
		Original capacity [2]	Capacity, September 1960				
2	0.46		200	84			
3	.63	158	134	45	24	9.3	4.1
4	2.62		771	128			
5	3.89	1,273	1,188	250	85	9.7	2.3
6	6.01	2,061	1,814	441	247	9.5	4.3
8	.42		102	33			
9	[3] 3.31	1,275	1,178	175	97	9.5	3.5
10	3.38		1,024	290			
10A	2.77	1,048	949	348	99	9.4	3.8
11	.64		197	52			
12	1.30		491	141			
13	.96		392	148			
14	.91	321	287	95	34	9.0	4.2
15	1.18		301	70			
16	10.17	4,463	4,192	1,062	271	8.2	3.2
16A	[4] 9.10	2,066	1,944	234	122	8.7	2.5
17	11.10	3,585	3,348	316	237	9.0	2.4
17A	.82		235	53			
18	.60		205	71			
19	1.62		761	266			
20	.97		274	68			
21	1.47		462	101			

[1] Drainage areas planimetered from standard U.S. Geol. Survey 7½-min. quad. sheets.
[2] Figures supplied by U.S. Soil Conservation Service, Chickasha, Okla.
[3] Includes 0.37 sq mi of noncontributing area.
[4] Includes 3.60 sq mi of noncontributing area.

TABLE 2.—*Monthly water budget for water years 1959 and 1960*

[Values in acre-feet except as indicated]

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
Reservoir 2								
1958								
September	711.0	2.2						
October	710.0	.9	−1.3	2.0	0.6	0	0	1.3
November	708.9	.1	−.8	.6	.3	0	0	.1
December	708.5	0	−.1	.1	0	0	0	0
1959								
January	708.5	0	0	0	0	0	0	0
February	708.5	0	0	0	0	0	0	0
March	710.2	1.2	+1.2	.5	.2	.1	0	1.8
April	708.5	0	−1.2	.9	.6	.1	0	.2
May	726.05	52.3	+52.3	6.4	1.9	2.6	0	58.0
June	724.2	41.7	−10.6	16.6	3.6	.7	0	8.9
July	722.4	32.7	−9.0	13.7	3.0	1.0	0	6.7
August	720.24	23.7	−9.0	11.9	2.9	.9	0	4.9
September	719.54	21.1	−2.6	10.3	2.2	1.5	0	8.4
Total			+18.9	63.0	15.3	6.9	0	90.3

TABLE 2.—*Monthly water budget for water years 1959 and 1960*—Continued

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
Reservoir 2—Continued								
1959								
October	719.3	20.4	−.7	10.4	1.8	1.1	0	10.4
November	717.0	12.9	−7.5	8.2	.7	0	----------	1.4
December	719.28	20.4	+7.5	7.5	0	1.1	0	13.9
1960								
January	719.80	22.2	+1.8	9.2	.6	.3	0	11.3
February	724.20	41.8	+19.6	10.4	.8	.9	0	29.9
March	723.63	38.7	−3.1	14.3	1.1	.4	0	11.9
April	722.3	32.1	−6.6	14.0	3.5	.1	0	10.8
May	720.69	25.5	−6.6	12.0	3.8	1.0	0	8.2
June	718.73	18.4	−7.1	10.4	3.0	.9	0	5.4
July	718.04	16.2	−2.2	8.7	2.8	1.4	0	7.9
August	715.21	8.0	−8.2	7.3	3.0	.3	0	1.8
September	714.77	7.0	−1.0	5.5	1.0	.6	0	4.9
Total	----------	----------	−14.1	117.9	22.1	8.1	0	117.8
Reservoir 3								
1958								
September	70.94	4.4	----------	----------	----------	----------	----------	----------
October	69.89	2.6	−1.8	1.9	0.8	0	0	0.9
November	69.31	1.8	−.8	1.0	.5	0	0	.7
December	68.85	1.2	−.6	.6	.2	0	0	.2
1959								
January	68.47	.8	−.4	.4	.1	0	0	.1
February	67.99	.4	−.4	.3	.2	0	0	.1
March	70.10	3.0	+2.6	.5	.7	.3	0	3.5
April	70.17	3.1	+.1	1.9	1.2	.2	0	3.0
May	83.35	53.6	+50.5	11.9	2.7	3.8	49.0	110.3
June	79.41	30.4	−23.2	23.0	3.5	.6	8.1	10.8
July	76.50	17.5	−12.9	11.9	2.4	.9	0	.5
August	73.88	9.1	−8.4	10.1	2.3	.7	0	3.3
September	76.46	17.4	+8.3	8.8	2.0	1.3	0	17.8
Total	----------	----------	+13.0	72.3	16.6	7.8	57.1	151.2
1959								
October	75.25	13.2	−4.2	10 2	1.7	1.2	0	6.5
November	74.31	10.3	−2.9	5.0	.7	0	0	2.8
December	76.55	17.7	+7.4	5.2	0	1.1	0	11.5
1960								
January	76.63	18.0	+.3	7.2	.6	.3	0	7.8
February	80.46	36.0	+18.0	14.7	1.1	1.0	0	32.8
March	79.97	33.3	−2.7	20.2	1.2	.5	0	18.2
April	78.33	25.2	−8.1	20.0	3.6	.1	0	15.4
May	76.44	17.3	−7.9	14.4	3.7	1.0	0	9.2
June	74.70	11.4	−5.9	10.5	2.8	.8	0	6.6
July	77.70	22.4	+11.0	10.6	2.9	1.5	0	23.0
August	74.68	11.4	−11.0	10.3	3.8	.4	0	2.7
September	75.58	14.3	+2.9	7.1	1.3	.9	0	10.4
Total	----------	----------	−3.1	135.4	23.4	8.8	0	146.9

TABLE 2.—*Monthly water budget for water years 1959 and 1960*—Continued

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
			Reservoir 4					
1958								
September	68.44	24.5						
October	66.84	12.3	−12.2	8.8	3.6	0.1	0	0.1
November	66.36	9.5	−2.8	7.0	2.2	.3	0	6.1
December	66.04	7.7	−1.8	6.0	1.1	.1	0	5.2
1959								
January	65.50	5.0	−2.7	5.2	.5	.1	0	2.9
February	64.55	1.6	−3.4	3.2	.5	0	0	.3
March	66.35	9.4	+7.8	2.7	2.0	.3	0	12.2
April	66.56	10.5	+1.1	7.1	4.3	1.2	0	11.3
May	77.00	144	+133.5	17.6	10.0	16.0	146	291.1
June	74.90	101	−43.0	27.7	12.1	2.9	14	7.9
July	73.84	82.5	−18.5	24.6	11.0	5.1	0	12.0
August	73.3	74.5	−8.0	22.4	11.0	3.4	0	22.0
September	76.5	133.0	+58.5	25.7	10.6	6.5	4.8	93.1
Total			+108.5	158.0	68.9	36.0	164.8	464.2
1959								
October	76.02	122.4	−10.6	29.2	9.6	7.6	0	20.6
November	75.22	107	−15.4	25.0	4.4	0	0	14.0
December	76.6	134.5	+27.5	26.8	.2	10.6	85	128.9
1960								
January	76.7	136.5	+2.0	29.6	3.8	2.7	35	67.7
February	76.92	141	+4.5	29.8	4.7	5.8	29	62.2
March	76.52	132	−9.0	31.8	5.1	2.0	33	58.9
April	76.3	128.5	−3.5	31.8	15.7	.2	11	54.8
May	76.3	128.5	None	31.5	19.3	6.3	2.7	47.2
June	75.17	106	−22.5	29.2	15.8	5.2	0	17.3
July	76.4	130	+24.0	29.4	17.2	12.8	35	92.8
August	74.85	100.5	−29.5	28.2	20.7	2.3	0	17.1
September	75.7	116	+15.5	24.5	7.6	4.5	0	43.1
Total			−17.0	346.8	124.1	60.0	230.7	624.6

Reservior 5

[Italic inflow figures exclude effect of upstream reservoirs]

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
1958								
September	53.39	18.4						
October	52.19	12.1	−6.3	4.9	2.5	0	0	1.1 *0*
November	51.51	9.1	−3.0	3.7	1.5	0.1	0	2.1 *.7*
December	50.98	7.0	−2.1	2.8	.7	.1	0	1.3 *.1*
1959								
January	50.28	4.7	−2.3	2.2	.3	.1	0	.1 *0*
February	49.62	2.9	−1.8	1.4	.5	0	0	.1 *0*
March	52.81	15.2	+12.5	2.0	1.3	.6	0	15.0 *24.9*
April	54.30	24.0	+8.8	6.0	3.5	1.2	0	17.1 *27.1*
May	72.05	396.0	+372.0	26.0	14.4	19.8	140.4	533.0 *550.4*
June	67.88	247.6	−148.4	50.1	24.8	4.4	126.7	48.8 *26.6*
July	68.08	253.4	+5.8	44.4	19.6	10.8	36.9	95.9 *103.3*
August	66.68	215.0	−38.4	42.0	18.7	4.1	0	18.2 *13.0*
September	70.53	334.8	+119.8	45.2	18.9	17.8	77.8	243.9 *253.4*
Total			+316.4	230.7	106.7	59.0	381.8	976.6 *999.5*

TABLE 2.—*Monthly water budget for water years 1959 and 1960*—Continued

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
Reservior 5—Continued								
1959								
October	68.08	253.4	−81.4	50.1	10.9	11.4	111.8	80.0 *79.5*
November	67.06	224.9	−28.5	35.2	7.7	0	0	14.4 *13.1*
December	68.35	261.5	+36.6	35.7	1.5	12.8	33.5	94.5 *96.2*
1960								
January	68.30	260.0	−1.5	38.7	10.8	3.2	22.3	67.1 *67.0*
February	68.55	267.5	+7.5	41.8	15.6	9.6	174.5	229.8 *228.5*
March	68.46	264.8	−2.7	41.8	10.6	3.1	20.6	67.2 *63.4*
April	67.99	250.8	−14.0	41.9	18.4	.2	1.2	47.3 *46.1*
May	67.55	238.3	−12.5	41.3	22.0	6.8	0	44.0 *50.1*
June	66.37	207.2	−31.1	38.8	18.4	5.3	0	20.8 *21.6*
July	68.48	265.4	+58.2	40.5	20.6	19.4	64.3	164.2 *169.9*
August	66.65	214.2	−51.2	40.4	19.9	2.3	0.6	7.4 *8.4*
September	66.92	221.2	+7.0	36.1	10.4	8.6	0	44.9 *50.8*
Total	----------	----------	−113.6	482.3	166.8	82.7	428.8	881.6 *894.6*
Reservoir 6								
1958								
September	69.88	97.7	----------	----------	----------	----------	----------	----------
October	68.77	82.0	−15.7	9.2	6.7	0.2	0	0 *0*
November	67.91	70.9	−11.1	7.8	4.3	.4	0	0.6 *.8*
December	67.31	63.7	−7.2	6.8	2.2	.2	0	1.6 *2.3*
1959								
January	66.71	56.8	−6.9	6.2	1.2	.2	0	.3 *.6*
February	66.16	50.8	−6.0	5.4	1.9	0	0	1.3 *1.6*
March	66.21	51.4	+.6	5.7	4.4	1.7	0	9.0 19.4
April	66.69	56.6	+5.2	6.4	6.2	1.6	0	16.2 *25.2*
May	84.04	490.9	+434.3	15.4	15.5	24.4	298.1	738.9 *753.3*
June	82.51	419.7	−71.2	31.7	32.2	8.7	21.0	5.0 *0*
July	81.95	395.8	−23.9	31.8	27.8	13.6	0	22.1 *22.8*
August	80.86	352.2	−43.6	29.5	26.7	6.8	0	5.8 *8.5*
September	81.98	397.2	+45.0	28.8	24.8	14.1	0	84.5 *84.2*
Total	----------	----------	+299.5	184.7	153.9	71.9	319.1	885.3 *919.7*

TABLE 2.—*Monthly water budget for water years 1959 and 1960*—Continued

Reservior 6—Continued

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
1959								
October	82.28	409.8	+12.6	30.6	13.3	13.2	0	43.3 *42.3*
November	81.66	383.9	−25.9	27.5	11.6	0	0	13.2 *10.9*
December	82.59	423.3	+39.4	27.6	2.2	17.2	3.8	55.8 *61.5*
1960								
January	80.34	332.7	−90.6	26.3	14.4	4.6	69.4	14.9 *13.4*
February	80.70	346.1	+13.4	26.7	19.8	9.6	80.5	130.8 *132.5*
March	79.20	293.0	−53.1	23.9	12.3	3.8	85.1	64.4 *61.0*
April	78.36	265.9	−27.1	21.8	19.6	4.4	43.0	52.9 *52.0*
May	77.72	246.4	−19.5	20.4	22.8	7.4	20.0	36.3 *42.7*
June	77.36	236.0	−10.4	20.6	20.4	7.4	0	23.2 *24.6*
July	83.19	450.2	+214.2	24.3	25.6	19.0	45.0	290.1 *298.3*
August	82.26	409.0	−41.2	31.8	31.7	4.4	.3	18.2 *17.9*
September	83.06	444.3	+35.3	30.9	17.5	18.6	1.7	66.8 *70.7*
Total			+47.1	312.4	211.2	109.6	348.8	809.9 *827.8*

Reservoir 8

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
1958								
September	725.22	4.8						
October	724.1	2.6	−2.2	1.6	1.0	0	0	0.4
November	723.5	1.7	−.9	.9	.6	.1	0	.5
December	723.05	1.1	−.6	.5	.2	0	0	.1
1959								
January	722.36	.4	−.7	.3	.1	0	.3	0
February	721.5	0	−.4	.1	0	0	.3	0
March	723.58	1.8	+1.8	.2	.3	.1	0	2.2
April	723.5	1.7	−.1	.9	1.0	.2	0	1.6
May	737.16	54.0	+52.3	8.0	3.1	4.5	14.3	74.9
June	731.9	22.3	−31.7	10.2	3.1	1.0	26.3	6.9
July	731.21	19.2	−3.1	8.3	2.8	1.5	0	6.5
August	729.8	13.7	−5.5	7.6	2.8	.7	0	4.2
September	732.67	26.1	+12.4	9.2	2.7	1.6	0	22.7
Total			+21.3	47.8	17.7	9.7	41.2	118.3

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
1959								
October	731.48	20.4	−5.7	8.7	2.2	1.6	9.6	13.2
November	729 96	14.2	−6.2	5.3	.9	0	0	0
December	732.2	23.8	+9.6	5.2	.1	1.6	0	13.3
1960								
January	732.30	24.3	+.5	6.8	.8	.5	0	7.6
February	733.38	29.8	+5.5	8.8	1.1	1.3	27.9	42.0
March	733.72	31.8	+2.0	11.7	1.2	.6	7.5	21.8
April	732.54	25.4	−6.4	12.3	3.8	.1	.9	10.5
May	731.41	20.1	−5.3	10.2	4.2	1.2	0	7.9
June	730.2	15.1	−5.0	8.3	3.3	1.1	0	5.5
July	732.13	23.4	+8.3	8.1	3.5	2.2	0	17.7
August	729.82	13.7	−9.7	6.7	4.5	.4	0	1.1
September	730.93	18.1	+4.4	6.0	1.5	1.6	0	10.3
Total			−8.0	98.1	27.1	12.2	45.9	150.9

TABLE 2.—*Monthly water budget for water years 1959 and 1960*—Continued

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
Reservoir 9								
1958								
September	62.59	48.5						
October	61.51	38.1	−10.4	5.9	4.7	0.1	0	0.1
November	60.79	31.8	−6.3	3.8	3.0	.2	0	.3
December	60.30	27.8	−4.0	3.0	1.5	.1	0	.4
1959								
January	59.87	24.4	−3.4	2.4	1.1	.1	0	0
February	59.47	21.3	−3.1	2.2	1.3	0	0	.4
March			[1] +2.1	[1] 3.0	[1] 3.2	[1] 1.3	0	[1] 7.0
April	59.7	23.0	[1] −.4	[1] 4.0	[1] 4.2	[1] 1.1	0	[1] 6.7
May	76.47	302.8	+279.8	15.0	11.4	19.6	178.9	465.5
June	72.78	196.5	−106.3	29.1	18.8	5.0	69.8	6.4
July	72.87	198.8	+2.3	31.8	16.3	8.2	0	42.2
August	71.49	166.9	−31.9	29.3	15.4	3.9	0	8.9
September	72.49	189.6	+22.7	27.9	14.1	8.0	0	56.7
Total			+141.1	157.4	95.0	47.6	248.7	594.6
1959								
October	73.04	203.0	+13.4	28.8	8.0	8.0	1.3	43.5
November	71.97	177.4	−25.6	18.6	6.5	0	.5	0
December	74.05	229.2	+51.8	19.9	1.3	9.8	0	63.2
1960								
January	74.50	241.9	+12.7	24.1	10.1	3.1	9.2	53.0
February	76.78	313.3	+71.4	33.3	16.2	5.3	12.8	128.4
March	77.13	325.4	+12.1	40.0	12.1	3.6	18.7	79.3
April	76.40	300.5	−24.9	42.5	21.3	.4	8.9	47.4
May	72.80	197.0	−103.5	35.8	21.7	6.7	77.8	25.1
June	71.93	176 6	−20.4	28.7	16.4	6.0	0	18.7
July	72.50	189.8	+13.2	27.9	17.2	13.7	125.5	170.1
August	70.34	143.6	−46.2	24.6	15.2	2.1	19.5	11.0
September	70.4	144.7	+1.1	20.1	7.4	7.9	17.8	38.5
Total			−44.9	344.3	153.4	66.6	292.0	678.2
Reservoir 10								
1958								
September	714.5	17.3						
October	713.52	10.2	−7.1	3.8	3.5	0.2	0	0 *0*
November	712.7	5.2	−5.0	3.2	2.0	.2	0	0 *0*
December	712.04	2.8	−2.4	1.9	.7	.1	0	0.1 *0*
1959								
January	711.44	1.7	−1.1	1.0	.2	0	0	.1 *0*
February	710.97	1.1	−.6	.7	.2	0	0	.3 *0*
March	712.27	3.6	+2.5	1.0	.9	.4	4.1	8.1 *29.1*
April	709.86	.2	−3.4	.4	.4	.2	2.8	0 *13.2*
May	732.05	347.3	+347.1	7.7	8.5	15.3	49.0	397.0 *447.4*
June	730.83	307.8	−39.5	23.1	23.4	7.3	9.2	8.9 *0*
July	731.26	321.9	+14.1	24.4	21.5	14.4	1.3	46.9 *65.1*
August	730.16	286.5	−35.4	23.8	21.5	6.7	0	3.2 *0*
September	730.04	282.7	−3.8	22.2	19.3	11.5	0	26.2 *49.8*
Total			+265.4	113.2	102.1	56.3	66.4	490.8 *604.6*

[1] Partly estimated.

TABLE 2.—*Monthly water budget for water years 1959 and 1960*—Continued

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
Reservoir 10—Continued								
1959								
October	730.28	290.2	+7.5	22.6	9.8	10.0	3.6	33.5 *27.1*
November	729.45	264.7	−25.5	19.2	8.4	0	0	2.1 *0*
December	730.11	284.9	+20.2	18.8	1.6	14.4	0	26.2 *45.8*
1960								
January	730.07	283.7	−1.2	19.8	11.2	3.1	0	26.7 *26.3*
February	730.98	312.6	+28.9	21.4	16.1	8.6	7.7	65.5 *70.1*
March	729.03	252.3	−60.3	21.6	11.2	3.8	65.3	34.0 *.4*
April	727.74	216.3	−36.0	18.3	17.0	.2	21.8	20.9 *9.3*
May	727.29	204.4	−11.9	17.8	20.2	7.1	0	19.0 *56.4*
June	726.61	187.2	−17.2	17.3	17.6	7.0	0	10.7 *40.3*
July	731.73	337.8	+150.6	19.7	20.7	14.2	139.9	316.7 *320.1*
August	730.62	301.0	−36.8	23.7	23.6	4.7	23.8	29.6 *37.1*
September	731.19	319.6	+18.6	23.5	13.1	14.2	15.1	56.1 *56.1*
Total	----------	----------	+36.9	243.7	170.5	87.3	277.2	641.0 *689.0*
Reservoir 10A								
1958								
September	68.51	71.4	----------	----------	----------	----------	----------	----
October	67.20	53.6	−17.8	10.9	7.2	0.3	0	0
November	66.16	42.0	−11.6	8.3	3.9	.3	0	0.3
December	65.32	34.0	−8.0	6.5	1.7	.2	0	0
1959								
January	64.59	27.9	−6.1	5.6	.8	.2	0	.1
February	63.92	23.1	−4.8	4.8	1.2	0	0	1.2
March	63.77	22.1	−1.0	4.6	2.7	1.0	0	5.3
April	63.25	18.8	−3.3	4.9	3.6	1.0	0	4.2
May	79.84	363.6	+344.8	12.6	10.7	16.2	16.2	368.1
June	78.80	324.8	−38.8	30.3	26.3	8.1	.6	10.3
July	79.59	354.1	+29.3	32.2	23.9	15.9	0	69.5
August	78.36	309.0	−45.1	32.6	24.4	7.6	0	4.3
September	78.13	300.8	−8.2	31.1	21.9	13.0	0	31.8
Total	----------	----------	+229.4	184.4	128.3	63.8	16.8	495.1
1959								
October	78.35	308.6	+7.8	26.8	11.0	11.1	0	34.5
November	77.51	279.4	−29.2	20.1	9.6	0	0	.5
December	78.70	321.2	+41.8	18.6	1.8	16.6	0	45.6
1960								
January	78.73	322.3	+1.1	22.4	13.1	3.6	0	33.0
February	79.37	345.8	+23.5	25.2	18.4	9.8	0	57.3
March	78.0	296.3	−49.5	26.0	12.8	4.3	91.2	76.2
April	77.09	265.4	−30.9	23.6	20.9	.3	27.6	40.9
May	76.68	252.0	−13.4	23.8	25.1	8.8	0	26.7
June	76.07	232.7	−19.3	22.9	22.0	8.8	0	16.8
July	79.87	364.8	+132.1	25.2	24.7	22.4	44.2	203.8
August	78.87	327.3	−37.5	30.0	26.6	5.3	1.6	15.4
September	79.33	344.3	+17.0	29.0	14.7	15.8	.2	45.1
Total	----------	----------	+43.5	293.6	200.7	106.8	164.8	595.8

TABLE 2.—*Monthly water budget for water years 1959 and 1960*—Continued

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
Reservoir 11								
1958								
September	10.14	0.7	----------	----------	----------	----------	----------	----------
October	9.68	.4	−0.3	0.3	0.4	0	0	0.4
November	9.05	.1	−.3	.1	.2	0	0	0
December	8.7	0	−.1	0	.1	0	0	0
1959								
January	8.7	0	0	----------	(2)	(2)	----------	0
February	8.7	0	0	----------	(2)	(2)	----------	0
March	11.62	3.7	+3.7	.4	.6	.1	0	4.6
April	10.51	1.3	−2.4	1.2	1.8	.4	0	.2
May	21.55	59.4	+58.1	4.3	3.7	5.2	32.8	93.7
June	19.8	43.7	−15.7	10.2	5.4	.7	5.1	4.3
July	19.5	41.3	−2.4	10.5	5.5	3.1	6.5	17.0
August	17.2	25.3	−16.0	7.8	4.9	1.0	6.8	2.5
September	17.25	25.6	+.3	7.2	4.0	2.2	0	9.3
Total	----------	----------	+24.9	42.0	26.6	12.7	51.2	132.0
1959								
October	15.55	16.1	−9.5	14.4	2.7	1.8	5.6	11.4
November	12.7	5.0	−11.1	4.5	.9	0	5.7	0
December	13.63	8.4	+3.4	2.4	.1	1.3	2.8	7.4
1960								
January	13.06	6.2	−2.2	3.3	.6	.3	0	1.4
February	12.9	5.7	−.5	2.8	.7	.8	0	2.2
March	11.4	1.7	−4.0	2.3	.7	.3	4.8	3.5
April	10.7	.4	−1.3	.6	1.1	0	.8	1.2
May	13.2	6.7	+6.3	2.7	1.5	.9	0	9.6
June	13.37	7.4	+.7	5.7	2.9	.9	0	8.4
July	14.9	13.2	+5.8	8.6	3.5	1.9	1.8	17.8
August	12.2	3.4	−9.8	5.0	3.8	.6	4.6	3.0
September	12.04	3.0	−.4	1.9	1.2	.8	0	1.9
Total	----------	----------	−22.6	54.2	19.7	9.6	26.1	67.8
Reservoir 12								
1958								
September	720.78	43.7	----------	----------	----------	----------	----------	----------
October	718.74	29.0	−14.7	11.3	3.5	0.1	0	0
November	717.2	19.5	−9.5	7.6	2.1	.2	0	0
December	715.8	12.2	−7.3	6.5	.9	.1	0	0
1959								
January	715.21	9.5	−2.7	4.8	.4	.1	0	2.4
February	715.0	8.6	−.9	4.1	.5	0	0	3.7
March	715.9	8.2	−.4	4.1	2.7	.7	0	5.7
April	715.48	10.7	+2.5	5.1	2.9	.9	0	9.6
May	731.36	140.5	+129.8	12.0	5.8	7.3	40.4	180.7
June	729.00	109.3	−31.2	24.1	8.0	.9	0	0
July	730.40	127.1	+17.8	21.9	7.5	5.2	0	42.0
August	728.46	102.9	−24.2	23.4	8.6	2.2	0	5.6
September	728.64	105.0	+2.1	20.9	6.8	4.6	0	25.2
Total	----------	----------	+61.3	145.8	49.7	22.3	40.4	274.9
1959								
October	728.33	101.4	−3.6	21.8	5.6	3.5	0	20.3
November	726.68	83.8	−17.6	17.5	2.4	0	0	2.3
December	727.08	87.9	+4.1	16.5	.1	4.8	0	15.9
1960								
January	726.4	81.0	−6.9	16.4	1.7	1.2	0	10.0
February	727.11	88.2	+7.2	16.2	2.0	2.7	0	22.7
March	726.8	85.0	−3.2	18.1	2.3	1.2	0	16.0
April	725.48	72.1	−12.9	17.6	7.0	.1	0	11.6
May	724.56	63.8	−8.3	16.1	8.1	2.3	0	13.6
June	723.70	56.5	−7.3	15.2	6.9	2.3	0	12.5
July	725.58	73.0	+16.5	14.7	7.2	4.4	0	34.0
August	723.51	54.9	−18.1	15.1	9.2	1.5	0	4.7
September	722.34	45.8	−9.1	13.0	3.3	2.4	0	4.8
Total	----------	----------	−59.2	198.2	55.8	26.4	0	168.4

[2] Reservoir empty.

TABLE 2.—*Monthly water budget for water years 1959 and 1960*—Continued

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
Reservoir 13								
1958								
September	728.4	68.7						
October	727.7	61.7	−7.0	8.6	4.7	0.1	0	6.2
November	726.9	54.2	−7.5	7.1	3.2	.3	0	2.5
December	726.1	47.1	−7.1	5.8	1.6	.1	0	.2
1959								
January	720.8	13.0	−34.1	3.6	.6	.1	30.0	0
February	716.3	.1	−12.9	.4	.8	0	11.7	0
March	716.2	0	−.1	0	.1	0	0	0
April	721.3	14.3	+14.3	1.9	2.9	.2	0	18.9
May	735.1	144.5	+130.2	7.4	6.8	9.7	21.0	155.7
June	733.4	119.7	−24.8	16.9	8.9	1.0	0	0
July	734.3	131.8	+12.1	15.8	8.4	5.9	0	30.4
August	733.4	119.7	−12.1	18.6	9.8	2.6	0	13.7
September	733.4	119.7	0	17.3	8.2	5.6	0	19.9
Total			+51 0	103 8	55 6	25 6	62 7	247 5
1959								
October	733.3	118.5	−1.2	15.6	6.3	4.0	0	16.7
November	732.0	101.7	−16.8	8.4	2.9	0	5.5	0
December	733.6	122.3	+20.6	11.1	.2	6.2	0	25.7
1960								
January	733.2	117.0	−5.3	11.7	2.2	1.6	0	7.0
February	734.4	133.6	+16.6	14.3	3.0	3.8	0	30.1
March	734.2	130.8	−2.8	16.9	3.3	1.7	0	15.7
April	733.26	118.0	−12.8	18.0	9.9	.1	0	15.0
May	733.35	119.0	+1.0	17.6	12.1	3.5	0	27.2
June	732.52	108.0	−11.0	17.2	10.6	3.6	0	13.2
July	734.55	136.0	+28.0	17.8	11.6	7.2	0	50.2
August	733.2	117.0	−19.0	18.0	15.1	2.5	0	11.6
September	734.3	132.4	+15.4	16.5	5.7	4.2	0	33.4
Total			+12.7	183.1	82.9	38.4	5.5	245.8
Reservoir 14								
1958								
September	77.34	13.4						
October	76.36	9.7	−3.7	2.3	1.8	0	0	0.4
November	75.67	7.5	−2.2	1.6	1.1	0.1	0	.4
December	75.24	6.3	−1.2	1.2	.5	.1	0	.4
1959								
January	74.80	5.1	−1.2	1.1	.2	0	0	.1
February	74.37	4.1	−1.0	.9	.3	0	0	.2
March	74.42	4.2	+.1	.8	1.4	.4	0	1.9
April	74.24	3.8	−.4	1.0	1.6	.3	0	1.9
May	88.93	105.9	+102.1	5.2	4.0	5.2	13.6	119.7
June	87.52	88.0	−17.9	17.2	7.7	1.1	.6	6.5
July	86.87	80.4	−7.6	15.7	7.3	4.0	0	11.4
August	85.51	65.4	−15.0	15.8	8.9	3.0	0	6.7
September	85.05	60.8	−4.6	11.2	5.9	4.0	0	8.5
Total			+47.4	74.0	40.7	18.2	14.2	158.1
1959								
October	84.99	60.2	−.6	11.6	4.6	2.6	0	13.0
November	83.82	49.3	−10.9	7.7	2.1	0	1.1	0
December	84.78	58.1	+8.8	7.1	.1	3.5	0	12.5
1960								
January	84.97	60.0	+1.9	8.1	1.6	.9	0	10.7
February	86.02	70.8	+10.8	10.1	2.2	2.1	0	21.0
March	86.16	72.3	+1.5	13.0	2.4	1.1	0	15.8
April	85.5	65.3	−7.0	14.2	7.6	.1	0	14.7
May	84.81	58.4	−6.9	11.3	8.1	2.6	0	9.9
June	84.17	52.4	−6.0	12.4	7.6	2.8	0	11.2
July	85.14	61.6	+9.2	11.5	7.8	4.4	0	24.1
August	84.00	50.9	−10.7	11.8	10.0	1.4	0	9.7
September	82.90	41.7	−9.2	9.3	3.5	2.4	0	1.2
Total			−19.1	128.1	57.6	23.9	1.1	143.8

TABLE 2.—*Monthly water budget for water years 1959 and 1960*—Continued

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
Reservoir 15								
1958								
September	717.8	27.0						
October	716.41	18.9	−8.1	5.5	2.9	0	0	0.3
November	715.43	14.0	−4.9	3.4	1.7	0.1	0	.1
December	714.60	10.8	−3.2	2.9	.8	.1	0	.4
1959								
January	714.16	9.1	−1.7	1.8	.3	0	0	.4
February	713.96	8.4	−.7	1.7	.4	0	0	1.4
March	714.50	10.4	+2.0	1.9	2.2	.6	0	5.5
April	714.76	11.4	+1.0	2.6	2.7	.5	0	5.8
May	728.30	134.0	+122.6	11.9	6.1	8.8	67	198.8
June	722.6	58.0	−76.0	19.1	12.0	1.1	64	18.0
July	722.46	56.6	−1.4	13.7	6.0	3.3	0	15.0
August	720.90	42.0	−14.6	15.0	6.4	2.1	0	4.7
September	722.0	52.0	+10.0	14.1	5.5	3.7	0	25.9
Total			+25.0	93.6	47.0	20.3	131	276.3
1959								
October	722.5	56.9	+4.9	13.7	4.5	2.6	0	20.5
November	721.74	49.5	−7.4	9.7	2.2	0	0	4.5
December	724.0	73.7	+16.0	9.7	.1	3.9	0	21.9
1960								
January	723.42	66.5	+1.0	11.7	1.8	1.1	0	13.4
February	723.72	70.0	+3.5	15.5	2.5	2.4	0	19.1
March	723.6	69.0	−1.0	19.4	2.7	1.2	0	19.9
April	722.85	60.4	−8.6	18.2	7.7	.1	0	17.2
May	723.3	65.2	+4.8	17.3	9.2	2.6	0	28.7
June	721.85	50.7	−14.5	15.8	7.7	2.8	0	6.2
July	723.3	65.2	+14.5	16.6	8.5	4.8	0	34.8
August	721.5	47.4	−17.8	15.9	10.6	1.5	6.2	13.4
September	724.0	73.7	+26.3	14.4	4.1	2.7	8.4	50.5
Total			+21.7	177.9	61.6	25.7	14.6	250.1
Reservoir 16								
1958								
September	61.70	782.1						
October	60.79	705.2	−76.9	45.5	40.4	0.8	0	8.2 *8.9*
November	60.15	655.2	−50.0	36.7	26.0	2.9	0	9.8 *16.3*
December	59.64	617.9	−37.3	30.1	12.9	.8	0	4.9 *13.7*
1959								
January	59.16	584.7	−33.2	28.1	6.1	1.0	0	0 *9.2*
February	58.69	553.6	−31.1	25.2	11.0	0	0	5.1 *12.3*
March	58.29	528.1	−25.5	26.6	26.0	8.7	0	18.4 *32.1*
April	58.00	510.2	−17.9	30.6	34.3	11.3	0	35.7 *51.9*
May	68.62	1,458.6	+948.8	50.8	60.4	91.6	1,277	2,245.0 *2,275.6*
June	64.94	980.9	−477.7	68.0	89.0	8.7	348.8	19.4 *27.8*
July	65.33	1,026.7	+45.8	70.9	81.1	43.1	0	154.7 *157.2*
August	64.24	905.2	−121.5	76.6	81.1	22.7	0	13.5 *4.0*
September	65.31	1,024.3	+119.1	66.5	71.9	39.6	0	217.9 *245.3*
Total			+242.2	555.6	540.2	231.2	1,625.8	2,732.6 *2,854.3*

TABLE 2.—*Monthly water budget for water years 1959 and 1960*—Continued

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
Reservoir 16—Continued								
1959								
October	65.22	1,013.6	−10.7	65.4	49.6	33.7	88.2	158.8 *170.6*
November	64.69	952.8	−60.8	45.2	22.6	0	0	7.0 *14.1*
December	65.77	1,080.7	+127.9	45.7	4.7	66.9	142	253.4 *246.9*
1960								
January	65.76	1,079.4	−1.3	48.8	32.5	15.5	114	178.5 *183.2*
February	65.10	999.4	−80.0	48.5	44.8	30.8	347	329.5 *336.4*
March	63.97	878.2	−121.2	54.7	26.8	11.9	307	255.4 *260.1*
April	63.18	804.3	−73.9	56.4	40.3	.7	113	135.1 *149.4*
May	63.58	840.8	+36.5	57.6	62.3	26.8	0	129.6 *142.2*
June	64.13	894.0	+53.2	64.6	76.5	28.8	0	165.5 *168.2*
July	65.60	1,059.6	+165.6	71.0	86.1	55.2	134	401.5 *408.8*
August	65.11	1,000.6	−59.0	75.6	104.6	17.6	0	103.6 *109.0*
September	65.23	1,014.8	+14.2	70.8	50.0	29.0	0	106.0 *113.4*
Total	----------	----------	−9.5	704.3	600.8	316.9	1,245.2	2,223.9 *2,302.3*
Reservoir 16A								
1958								
September	67.32	183.5	----------	----------	----------	----------	----------	----------
October	66.88	174.5	−9.0	7.8	9.8	0.1	0	8.5
November	66.91	175.1	+.6	6.4	6.8	.9	0	12.9
December	67.17	180.4	+5.3	5.9	3.6	.1	0	14.7
1959								
January	67.53	187.9	+7.5	5.8	2.1	.4	0	15.0
February	67.7	191.5	+3.6	6.0	3.6	0	0	13.2
March	68.03	198.8	+7.3	6.9	9.1	2.7	0	20.6
April	68.35	205.8	+7.0	8.0	12.4	3.2	0	24.2
May	70.07	246.2	+40.4	10.6	17.1	26.9	526.8	568.0
June	69.78	239.1	−7.1	10.8	17.4	1.9	19.4	38.6
July	69.48	231.9	−7.2	12.2	15.6	5.9	0	14.7
August	68.55	210.3	−21.6	11.8	15.5	3.4	0	2.3
September	69.47	231.7	+21.4	11.6	14.5	8.5	0	39.0
Total	----------	----------	+48.2	103.8	127.5	54.0	546.2	771.7
1959								
October	69.93	242.7	+11.0	10.8	7.3	6.5	37.6	60.2
November	69.95	243.2	+.5	7.9	6.6	0	5.2	20.2
December	70.05	245.6	+2.4	7.7	1.3	10.2	194.1	195.3
1960								
January	70.02	244.9	−.7	8.4	8.7	3.3	79.3	92.4
February	70.06	245.9	+1.0	9.2	12.0	6.1	114.6	130.7
March	70.00	244.4	−1.5	10.1	8.4	2.2	87.4	102.2
April	69.98	243.9	−.5	11.1	15.0	.2	25.1	50.5
May	70.00	244.4	+.5	12.0	18.6	6.5	32.9	57.5
June	69.74	238.2	−6.2	12.2	16.6	7.7	32.5	47.4
July	69.91	242.2	+4.0	12.0	17.7	14.4	44.7	64.0
August	69.58	234.3	−7.9	11.8	16.9	3.6	0	17.2
September	69.80	239.6	+5.3	11.5	9.5	7.4	0	18.9
Total	----------	----------	+7.9	124.7	138.6	68.1	653.4	856.5

TABLE 2.—*Monthly water budget for water years 1959 and 1960*—Continued

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
Reservoir 17								
1958								
September	95.20	252.1						
October	94.35	217.7	−34.4	19.3	15.5	0.4	0	0
November	94.33	217.0	−.7	12.4	11.3	1.0	0	22.0
December	94.69	230.9	+13.9	6.8	10.5	.2	0	31.0
1959								
January	95.16	250.4	+19.5	3.7	10.6	.6	0	33.2
February	95.55	267.4	+17.0	7.4	11.8	0	0	36.2
March	95.90	283.4	+16.0	18.9	13.5	4.6	0	43.8
April	96.40	307.0	+23.6	26.5	16.6	7.7	0	59.0
May	98.0	365.0	+58.0	37.5	24.9	63.2	1,042	1,099.2
June	96.57	296.8	−68.2	32.4	19.6	2.3	71.8	53.3
July	96.95	314.1	+17.3	31.2	21.8	13.5	17.3	74.1
August	96.22	289.3	−24.8	32.6	22.7	7.2	9.1	32.4
September	97.07	319.7	+30.4	27.9	23.3	17.8	210.8	274.6
Total			+67.6	202.1	256.6	118.5	1,351.0	1,758.8
1959								
October	97.04	318.3	−1.4	20.0	18.7	12.4	129	153.9
November	97.03	317.8	−.5	14.8	9.2	0	18.8	42.3
December	97.09	320.6	+2.8	14.0	1.9	18.0	154	154.7
1960								
January	97.09	320.6	0	14.4	12.1	3.9	115	137.6
February	97.11	321.6	+1.0	14.9	16.8	10.7	170	192.0
March	97.12	322.0	+.4	18.3	11.7	4.4	152	178.0
April	97.02	317.3	−4.7	22.3	20.9	.3	53.0	91.2
May	97.04	318.3	+1.0	22.3	32.1	11.9	39.5	83.0
June	96.67	301.4	−16.9	22.6	35.0	13.0	75.0	102.7
July	96.89	311.3	+9.9	23.1	36.4	22.6	168	214.8
August	96.22	281.5	−29.8	22.1	38.5	5.2	0	25.6
September	96.77	305.9	+24.4	20.2	19.7	10.7	0	53.6
Total			−13.8	229.0	253.0	113.1	1,074.3	1,429.4
Reservoir 17A								
1958								
September	84.14	22.4						
October	83.46	19.2	−3.2	5.3	2.4	0.1	0	4.4
November	82.86	16.3	−2.9	4.2	1.6	.2	0	2.7
December	82.25	13.6	−2.7	3.3	.8	0	0	1.4
1959								
January	81.44	10.4	−3.2	2.9	.4	.1	0	0
February	80.74	8.0	−2.4	2.3	.4	0	0	.3
March	80.04	5.6	−2.4	2.0	2.1	.4	0	1.3
April	81.16	9.4	+3.8	2.5	2.4	.6	0	8.1
May	91.94	69.6	+60.2	8.6	4.8	6.2	58.4	125.8
June	87.94	36.5	−33.1	11.2	4.5	.4	17.8	0
July	91.84	68.8	+32.3	11.3	4.4	2.6	29.6	75.0
August	87.54	34.3	−34.5	12.5	4.9	1.6	25.5	6.8
September	89.84	50.0	+15.7	13.4	4.6	3.4	0	30.3
Total			+27.6	79.5	33.3	15.6	131.3	256.1
1959								
October	89.50	47.4	−2.6	13.2	3.9	2.4	8.2	20.3
November	87.84	36.0	−11.4	8.0	1.6	0	1.8	0
December	87.94	36.4	+.4	6.7	.1	2.2	0	5.0
1960								
January	86.87	30.1	−6.3	6.4	1.0	.5	0	.6
February	88.20	38.1	+8.0	7.7	1.3	1.3	0	15.7
March	87.68	35.0	−3.1	9.1	1.4	.7	0	6.7
April	86.64	29.0	−6.0	9.3	4.2	.1	0	7.4
May	86.11	26.0	−3.0	8.3	5.0	1.8	0	8.5
June	86.45	27.9	+1.9	9.2	4.6	1.6	0	14.1
July	89.24	45.3	+17.4	9.6	5.2	2.7	0	29.5
August	85.84	24.5	−20.8	9.1	6.3	.7	13	6.9
September	89.14	44.5	+20.0	8.1	2.5	1.3	0	29.3
Total			−5.5	104.7	37.1	15.3	23	144.0

TABLE 2.—*Monthly water budget for water years 1959 and 1960*—Continued

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
			Reservoir 18					
1958								
September	63.62	8.0						
October	63.22	7.0	−1.0	2.0	1.1	0	0	2.1
November	62.84	6.1	−.9	1.6	.8	0.1	0	1.4
December	62.43	5.1	−1.0	1.3	.4	0	0	.7
1959								
January	62.02	4.4	−.7	1.2	.2	0	0	.7
February	61.66	3.6	−.8	1.1	.2	0	0	.5
March	61.12	2.6	−1.0	.9	1.1	.2	0	.8
April	60.96	2.4	−.2	.9	1.1	.3	0	1.5
May	74.98	65.8	+63.4	4.9	2.8	6.4	52.0	116.7
June	71.4	40.3	−25.5	12.4	4.4	.5	9.2	0
July	71.36	40.0	−.3	10.9	4.0	2.7	0	11.9
August	69.7	30.4	−9.6	10.1	4.0	1.1	0	3.4
September	70.25	33.4	+3.0	9.6	3.4	2.1	0	13.9
Total			+25.4	56.9	23.5	13.4	61.2	153.6
1959								
October	69.2	27.8	−5.6	7.5	2.5	1.4	0	3.0
November	68.2	23.0	−4.8	4.9	1.1	0	0	1.2
December	68.0	22.0	−1.0	4.5	.1	1.7	0	1.9
1960								
January	67.43	19.6	−2.4	3.9	.8	.4	0	1.9
February	70.72	36.0	+16.4	6.6	1.2	1.0	0	23.2
March	70.3	33.8	−2.2	8.7	1.3	.6	0	7.2
April	68.34	23.6	−10.2	8.0	3.8	0	0	1.6
May	67.3	18.8	−4.8	6.2	4.1	1.2	0	4.3
June	65.75	12.7	−6.1	5.6	3.5	1.2	0	1.8
July	67.08	17.8	+5.1	4.7	3.4	1.8	0	11.4
August	65.83	13.0	−4.8	4.7	4.3	.6	0	3.6
September	65.66	12.4	−.6	3.5	1.4	.8	0	3.5
Total			−21.0	68.8	27.5	10.7	0	64.6
			Reservoir 19					
1958								
September	170.33	66.0						
October	168.93	52.2	−13.8	14.3	4.8	0.1	[3]0	5.2
November	167.56	40.8	−11.4	11.0	2.8	.2	0	2.2
December	166.23	31.0	−9.8	8.6	1.3	.1	0	0
1959								
January	165.12	24.0	−7.0	6.5	.6	0	0	.1
February	164.39	20.0	−4.0	5.5	.7	0	0	2.2
March	164.27	19.2	−.8	5.2	3.5	.6	0	7.3
April	164.23	18.8	−.4	5.4	3.6	.9	0	7.7
May	181.65	238	+219.2	14.3	7.4	11.3	0	229.6
June	179.35	183.2	−54.8	41.0	15.4	1.6	0	0
July	180.14	200.2	+17.0	35.1	12.4	8.2	0	56.3
August	178.1	166.7	−33.5	39.9	14.6	4.0	0	17.0
September	179.5	186.7	+20.0	38.7	12.4	7.5	0	63.6
Total			+120.7	225.5	79.5	34.5	0	391.2
1959								
October	178.8	172.7	−14.0	36.7	9.7	5.4	[3]0	27.0
November	177.72	150.2	−22.5	28.3	4.3	0	0	10.1
December	180.22	202.7	+52.5	30.6	.2	7.3	0	76.0
1960								
January	180.78	216.2	+13.5	35.4	3.8	1.8	0	50.9
February	183.29	283.2	+67.0	44.6	5.5	5.0	0	[4]112.1
March	183.58	291.7	+8.5	51.6	6.4	2.8	0	63.7
April	182.85	270.7	−21.0	54.1	20.7	.2	0	53.6
May	181.77	240.7	−30.0	51.6	24.2	7.2	0	38.6
June	181.55	235.0	−5.7	50.2	21.0	7.1	0	58.4
July	182.30	254.9	+19.9	48.6	22.1	12.1	0	78.5
August	180.97	220.7	−34.2	48.4	27.4	3.5	0	38.1
September	180.2	202 6	−18.1	43.5	10.1	5.4	0	30.1
Total			+15.9	523.6	155.4	57.8	0	637.1

[3] Outlet pipe is plugged.
[4] A small dam failed upstream, releasing some stored water.

TABLE 2.—*Monthly water budget for water years 1959 and 1960*—Continued

Period	Month end stage (feet)	Contents	Change in contents	Seepage	Evaporation	Rainfall on pool	Discharge through outlets	Inflow to reservoir
Reservoir 20								
1958								
September	66.0	5.9						
October	65.1	3.5	−2.4	3.1	1.5	0	[3] 0	2.2
November	64.0	.8	−2.7	2.0	.8	0.1	0	0
December	63.5	.4	−.4	.8	.2	0	0	.6
1959								
January	63.9	.6	+.2	.7	.1	0	0	1.0
February	64.0	.8	+.2	1.1	.2	0	0	1.5
March	[5] 63.0	0	−.8	.5	.5	.1	0	.1
April	[5] 63.0	0	0	0	0	0	0	0
May	81.6	124.2	+124.2	10.8	3.5	5.6	0	132.9
June	78.1	81.6	−42.6	36.5	7.2	1.1	0	0
July	78.4	84.2	+2.6	29.0	6.2	3.4	0	34.4
August	76.6	67.5	−16.7	32.3	6.9	1.6	0	20.9
September	77.1	71.8	+4.3	29.1	5.7	3.3	0	35.8
Total			+65.9	145.9	32.8	15.2	0	229.4
1959								
October	75.6	58.0	−13.8	24.7	4.2	2.7	0	12.4
November	73.6	42.4	−15.6	15.1	1.8	0	0	1.3
December	76.1	62.2	+19.8	15.2	.1	2.7	0	32.4
1960								
January	75.4	56.3	−5.9	16.8	1.4	.6	0	11.7
February	77.8	78.4	+22.1	23.1	2.1	1.9	0	45.4
March	77.5	75.8	−2.6	28.7	2.3	.8	0	27.6
April	77.1	71.8	−4.0	30.9	7.1	.1	0	33.9
May	78.0	80.0	+8.2	32.8	9.1	2.7	0	47.4
June	75.6	58.0	−22.0	30.6	7.8	2.7	0	13.7
July	74.3	47.3	−10.7	21.7	6.8	3.1	0	14.7
August	72.1	31.6	−15.7	17.5	7.6	1.1	0	8.3
September	70.3	20.9	−10.7	12.1	2.6	1.4	0	2.6
Total			−50.9	269.2	52.9	19.8	0	251.4
Reservoir 21								
1958								
September	59.2	21.3						
October	58.0	12.2	−9.1	5.8	4.0	0.1	0	0.6
November	57.3	7.8	−4.4	3.1	2.1	.2	0	.6
December	56.7	5.1	−2.7	2.0	.8	0	0	.1
1959								
January	56.6	4.8	−.3	1.5	.3	.7	0	1.4
February	56.3	4.0	−.8	1.4	.4	0	0	1.0
March	56.0	3.1	−.9	1.1	1.6	.3	0	1.5
April	57.1	7.0	+3.9	3.1	3.6	2.1	0	8.5
May	68.6	136.2	+129.2	19.7	9.9	14.9	6.36	207.5
June	64.7	70.5	−65.7	28.2	9.4	1.5	35.5	5.9
July	65.2	77.4	+6.9	20.8	7.8	3.9	0	31.6
August	64.1	62.0	−15.4	27.2	9.4	2.1	0	19.1
September	64.3	65.9	+3.9	24.8	7.9	4.7	0	31.9
Total			+44.6	138.7	57.2	29.9	99.1	309.7
1959								
October	63.1	50.1	−15.8	19.1	5.6	3.5	0	5.4
November	62.03	38.9	−11.2	10.8	2.4	0	0	2.0
December	61.83	37.0	−1.9	9.0	.1	3.3	0	3.9
1960								
January	61.25	31.6	−5.4	8.2	1.6	1.0	0	3.4
February	60.85	27.8	−3.8	8.0	1.9	2.0	0	4.1
March	60.28	22.6	−5.2	8.7	2.0	.7	0	4.8
April	59.47	15.5	−7.1	7.6	5.9	.1	0	6.3
May	59.03	12.1	−3.4	5.8	6.8	2.0	0	7.2
June	58.88	11.0	−1.1	4.8	5.6	1.9	0	7.4
July	59.22	13.5	+2.5	5.2	6.3	2.8	0	11.2
August	59.00	12.0	−1.5	5.2	7.9	1.1	0	10.5
September	58.8	10.5	−1.5	4.2	2.8	1.5	0	4.0
Total			−55.4	96.6	48.9	19.9	0	70.2

[3] Outlet pipe is plugged.
[5] Reservoir is dry. Elevation shown is that of the low point of the reservoir.

TABLE 3.—*Combined annual water budget, in acre-feet, for reservoirs 2–21*

	Water year	
	1959	*1960*
Change in content: gain (+) or loss (—)	+2, 368	—267
Evaporation	2, 202	2, 852
Seepage	3, 075	5, 112
Rainfall on pool	1, 030	1, 375
Outflow	4, 864	4, 178
Inflow	11, 479	10, 500

TABLE 4.—*Comparison of ratios of runoff to rainfall on controlled and uncontrolled areas for the period October 1, 1958 to September 30, 1960*

Area	Runoff (acre-feet)	Area (acres)	Runoff (feet)	Rainfall (feet)	Runoff: rainfall
Controlled					
Above reservoirs 2–9	6, 779	10, 860	0. 624	5. 31	0. 118
Above reservoirs 10 and 10A	2, 385	3, 936	. 606	5. 77	. 105
Above reservoirs 11–19	11, 954	22, 273	. 537	5. 01	. 107
Above reservoirs 20 and 21	861	1, 562	. 551	4. 91	. 112
Uncontrolled					
Between stream-gaging station 1 and reservoirs 11–19	2, 163	3, 981	. 543	5. 01	. 103
Between stream-gaging station 2 and reservoirs 2–9	1, 725	2, 848	. 606	5. 10	. 119
Between stream-gaging station 3 and upstream gages and reservoirs	3, 955	6, 662	. 594	4. 98	. 119

TABLE 5.—*Number of days of zero flow at stream-gaging station 3 for water years 1952–57*

Water year	*Precipitation (inches)*	*Days of zero flow*	*Water year*	*Precipitation (inches)*	*Days of zero flow*
1952	14. 48	222	1955	21. 25	39
1953	15. 09	185	1956	13. 10	87
1954	23. 00	114	1957	23. 35	94

TABLE 6.—*Comparison of reservoir evaporation with reservoir inflow*

	Water year	
	1959	*1960*
Reservoir inflow ... acre-feet	11, 479	10, 500
Reservoir evaporation ... acre-feet	2, 202	2, 852
Precipitation on the pools ... acre-feet	1, 030	1, 375
Net evaporation ... acre-feet	1, 172	1, 477
Net evaporation ... percent of inflow	10. 2	14. 1

TABLE 7.—*Comparison of reservoir annual inflow, outflow, and change in storage*

	Water year		
	1959	*1960*	*1959–60*
Change in storage: gain (+) or loss (−) acre-feet	+2, 368	−267	+2, 101
Inflow acre-feet	11, 479	10, 500	21, 979
Outflow [1] acre-feet	7, 939	9, 290	17, 229
Inflow minus outflow acre-feet	3, 540	1, 210	4, 750
Reduction in annual streamflow percent	31	12	22

[1] Includes both drop-outlet discharge and reservoir seepage.

TABLE 8.—*Computation of the reduction in annual streamflow at stream-gaging station 3 attributable to reservoirs 2–21*

	Water year	
	1959	*1960*
Reservoir inflow acre-feet	11, 479	10, 500
Runoff between stream-gaging station 3 and upstream reservoirs [1] acre-feet	+4, 033	+3, 810
Estimated flow at stream-gaging station 3 under natural conditions acre-feet	15, 512	14, 310
Measured flow at stream-gaging station 3 acre-feet	−11, 436	−12, 527
Reduction in flow at stream-gaging station 3 acre-feet	4, 076	1, 783
Reduction in flow percent	26	12

[1] This is the sum of the runoff from the three uncontrolled areas above stream-gaging stations 1, 2, and 3 as computed on pages C11 and C12.