HYDROLOGIC DATA AND HYDROLOGIC BUDGET FOR SUMMIT LAKE RESERVOIR, HENRY COUNTY, EAST-CENTRAL INDIANA, WATER YEARS 1989 AND 1990

By Richard F. Duwelius

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	*By*	*To obtain*
foot (ft)	0.3048	meter
inch (in.)	25.40	millimeter
mile (mi)	1.609	kilometer
acre	0.4047	hectare
square mile (mi^2)	2.590	square kilometer
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	0.0283	cubic meter per second
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.1894	meter kilometer
foot squared per second (ft^2/s)	0.09294	meter squared per second
pounds per square inch (lb/in^2)	6.895	kilopascal

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) by the following equation:

$$^{\circ}C = (^{\circ}F - 32)/1.8$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

Hydrologic data were collected near Summit Lake Reservoir for 2 years beginning October 1, 1988, and ending September 30, 1990. The data-collection network consisted of 1 reservoir-stage gage, 2 precipitation gages, 1 evaporation pan, 2 streamflow gages, and 13 observation wells. Stage-area and stage-storage relations for the reservoir were used in combination with the hydrologic data to determine the reservoir's annual hydrologic budgets for water years 1989 and 1990.

Components of the hydrologic budget are considered either as inflow or outflow. Differences between inflow and outflow result in a change in reservoir storage. Components of inflow are direct precipitation, surface-water flow, and ground-water flow. Components of outflow are evaporation and ground-water flow. There was no surface-water outflow during the study.

The hydrologic budget was calculated by use of daily, monthly, and yearly values of precipitation and surface-water flow, monthly values of ground-water flow, and yearly values of evaporation and reservoir storage. Comparison of results from different time intervals indicates there is little difference between annual volumes for components calculated from daily and monthly values. Annual volumes calculated from yearly values differ by less than 5 percent from those calculated from daily and monthly values.

The total inflow to Summit Lake Reservoir was nearly identical for water years 1989 and 1990--about 10,360 acre-feet per year. Surface water was about 72 percent of the total inflow in water year 1989 and about 70 percent in water year 1990. Direct precipitation was about 18 percent of the total inflow in water year 1989 and about 23 percent in water year 1990. Ground-water inflow was about 10 percent of the total inflow in water year 1989 and about 7 percent in water year 1990.

The total outflow from evaporation and ground-water flow was 5,700 acre-feet in water year 1989 and 7,710 acre-feet in water year 1990--about 19 percent evaporation and 81 percent ground-water outflow for both water years. Reservoir storage increased during both years; the change in storage was about 4,330 acre-feet in water year 1989 and about 2,890 acre-feet in water year 1990. Discrepancies between inflow, outflow, and reservoir storage reflect errors in the budget resulting from regionalization or interpretation of hydrologic data and from errors inherent in all hydrologic measurements.

INTRODUCTION

Lakes are important natural resources and have long been considered desirable aesthetic features of the landscape. In areas not having natural lakes, man-made reservoirs have been constructed to provide flood control, water supply, and recreation. In Indiana, there are more than 500 natural lakes and reservoirs that have surface areas of 50 or more acres or storage capacities of 100 acre-ft or more (Clark, 1980, p. 46).

The importance of lakes in Indiana has been recognized by State legislators. In 1947, the Indiana State Legislature passed a law to establish legal water levels for natural and man-made lakes (Fowler, 1988, p. 1). This legislation protects lakes that have surface areas of 10 or more acres from actions that would lower the water surface of the lake below the established legal water level (Clark, 1980, p. 103).

The usefulness of a lake or reservoir depends in large part on the amount of water-surface fluctuation. Before effective planning and management of a lake can be implemented, hydrologic data collection is necessary to provide a better understanding of the lake's interaction with the natural hydrologic cycle, its hydrologic budget, and its potential for fluctuation.

In 1988, the U.S. Geological Survey, in cooperation with the Indiana Department of Natural Resources, began to collect hydrologic data at Summit Lake Reservoir. Information about the hydrologic budget of the reservoir was needed to aid in planning and managing facilities at the reservoir. Because the area around Summit Lake Reservoir was designated to be a state park, state officials were concerned that the water level in the reservoir had not reached the intended design water level since the reservoir began to fill in 1981.

Purpose and Scope

This report presents the results of a study to determine annual hydrologic budgets for Summit Lake Reservoir for the 1989 and 1990 water years[1]. The report includes the hydrologic data used to estimate the volume of each component of the budget equation and the methods used to calculate the hydrologic budget. Daily, monthly, and yearly values of precipitation and surface-water flow, monthly values of ground-water seepage, and yearly values of evaporation and reservoir storage are presented in the hydrologic budget.

Description of Study Area

Summit Lake Reservoir is located at Summit Lake State Park, approximately 8 mi northeast of the city of New Castle in Henry County, Indiana (fig. 1). The study area includes Summit Lake Reservoir, Summit Lake State Park, and the surrounding drainage area (fig. 2). The reservoir was designed to have a surface area of about 800 acres and a storage capacity of about 15,300 acre-ft of water at the principal spillway-crest altitude of 1,069.8 ft above sea level (A.M. Kinney, Inc., 1977, p. 11). The reservoir has a maximum depth of about 40 ft in the former channel of Big Blue River near the dam. Summit Lake State Park, which was established in 1988 as Indiana's nineteenth state park, includes an area of about 2,550 acres (Indiana Department of Natural Resources, undated). The drainage area upstream from the dam is 9.3 mi^2 and includes drainage from Big Blue River, Sweringen Ditch, and several small intermittent streams.

The headwaters of Big Blue River are in the southern part of the drainage area. The river flows to the north and then westward after entering the reservoir. Sweringen Ditch begins as field-tile drainage in the northeast part of the drainage area and flows westward to the reservoir. Small intermittent streams include Red Brook and Brown Run (U.S. Geological Survey, 1988). These streams begin in the southwest part of the drainage area and flow northward to the reservoir.

The reservoir was made by constructing an earth-fill dam across the Big Blue River where the river flows approximately westward from an upland area into a large glacial valley. The dam is located about 4.4 river mi downstream from the headwaters of the river. The dam, which was completed in 1981, consists of two sections--the main dam section and the low dam section. The main dam section is approximately 3,000 ft long and 22 ft wide at the top with a top elevation of 1,078.5 ft above sea level. The low dam section is approximately 2,400 ft long and 14 ft wide at the top with a top elevation the same as that of the main dam section. To control excess ground-water seepage beneath the dam and reservoir, areas of the reservoir bottom that did not have clay soils were covered with low-permeability material (mostly clay) ranging in thickness from 2 to 5 ft. The clay-blanket material had an average hydraulic conductivity of 1.36×10^{-3} ft/d (A.M. Kinney, Inc., 1975, p. 29). In addition to the clay blanket, a slurry trench was constructed beneath the main dam section. The slurry trench contains a soil-bentonite slurry and is approximately 2,700 ft long and 4 ft wide with a maximum depth of 40 ft (A.M. Kinney, Inc., 1977, p. 5-6).

[1] A water year is the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends. The water year ending on September 30, 1989, is called the 1989 water year.

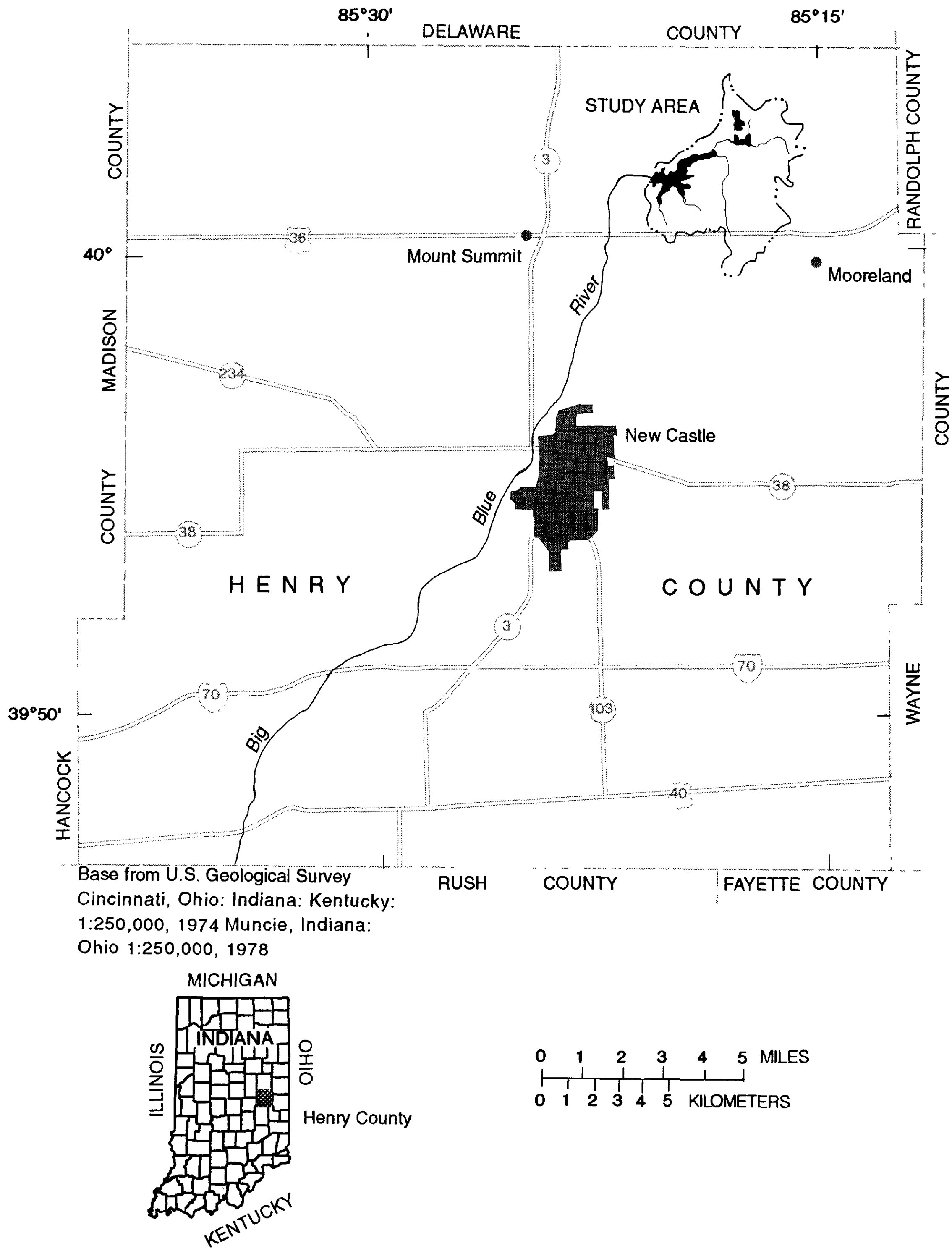


Figure 1. Location of study area in Henry County, Indiana.

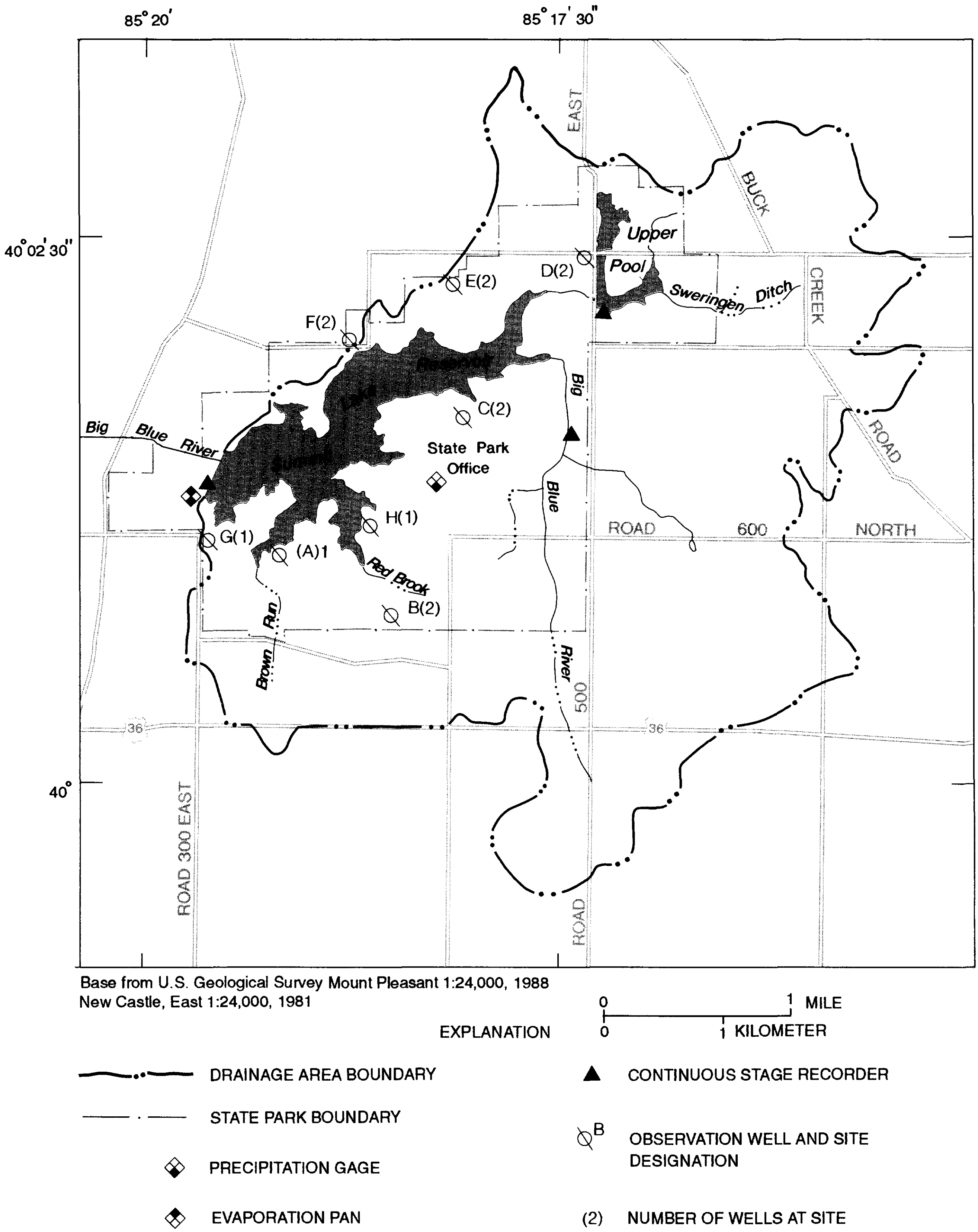


Figure 2. Data-collection network at Summit Lake Reservoir.

A second, smaller reservoir was built east of County Road 500 East to provide a wildlife refuge within the state park. This area, which is referred to in this report as the upper pool (fig. 2), is supplied by drainage from Sweringen Ditch. When the upper pool is full, Sweringen Ditch flows through the upper pool by way of a drop-box outlet located along the western edge of the upper pool.

Physiography and Climate

The study area is part of the Tipton Till Plain described by Malott (1922) and Schneider (1966). The Tipton Till Plain is characterized as a nearly flat to gently rolling glacial plain that is crossed by several end moraines, meltwater drainageways, and other glacial features (Schneider, 1966, p. 49-50). In the study area, upland areas are nearly flat to rolling and grade into gentle to moderate slopes near the streams. Land-surface altitudes range from about 1,020 ft above sea level at the deepest point in the reservoir to 1,130 ft above sea level in the uplands. The largest local relief (about 80 ft) is along and west of the main dam and abutments where the land surface slopes abruptly to the west toward the large glacial valley.

Henry County has a temperate climate with a mean annual temperature of 50.2 °F and a mean annual precipitation of 39.0 in. as determined from National Weather Service data collected at New Castle, Indiana. For the period 1951 through 1980, the mean monthly temperature ranged from 24.8 °F in January to 73.4 °F in July and the mean monthly precipitation ranged from 2.2 in. in February to 4.4 in. in June (National Oceanic and Atmospheric Administration, 1982).

Geology

The study area is underlain by dolomite and limestone bedrock of Silurian age (Gray and others, 1987). The altitude of the bedrock surface ranges from about 850 to 950 ft above sea level (Gray, 1982). Structurally, the bedrock is located on the western flank of the Cincinnati Arch (Gutschick, 1966, p. 15) and dips to the west or southwest at approximately 10 ft per mi (Schneider and Gray, 1966, p. 31). Overlying the bedrock are unconsolidated glacial deposits classified primarily as till (Gray, 1989). These deposits range in thickness from about 100 to 300 ft (Gray, 1983) and contain thick sections of clay and silt with intermixed and stratified sand and gravel. In the western part of the study area, beneath the reservoir, alluvial deposits containing mostly sand, gravel, and silt are found. Test drilling data collected during design and construction of the dam indicate that as much as 100 ft of sand and gravel may be present in places beneath the reservoir (A.M. Kinney, Inc., 1977, p. 19).

Acknowledgments

The author received cooperation and assistance from many people during the study. Sheldon Dynes of the U.S. Soil Conservation Service in New Castle, Indiana, supplied information about the reservoir design and construction and provided reservoir-stage data collected before the study and ground-water level data collected before and during the study. Jan Crider of the Big Blue River Conservancy District provided information about the reservoir and assisted during the design and installation of the data-collection network. The Indiana Geological Survey assisted with the installation of the observation wells. Employees of Summit Lake State Park assisted throughout the study and participated in collection of precipitation and evaporation data.

HYDROLOGIC DATA

The data-collection network at Summit Lake Reservoir consisted of 1 recording reservoir-stage gage, 1 recording and 1 manual precipitation gage, 1 evaporation pan, 2 recording streamflow gages, and 13 ground-water observation wells located at 8 sites (fig. 2). The gages were constructed and equipment was installed during August and September 1988. Levels were run to the gages in November 1988 to establish altitudes of measuring points and reference marks, and to provide a common reference for the data-collection network. Monthly trips were made to the study area to measure ground-water levels, retrieve data from recording gages, and service equipment. Data were collected for 2 water years beginning October 1, 1988, and ending September 30, 1990.

Reservoir Stage

Reservoir-stage data for Summit Lake Reservoir were collected at a continuous stage recorder located on the dam at the western edge of the reservoir (fig. 2). A submersible pressure transducer mounted on the outside of a 2-in.-inside-diameter steel pipe driven into the lakebed measured stage. The transducer had a pressure range of 0 to 5 pounds per square in. and was connected by a 40-ft-long cable to a programmable datalogger. The datalogger was housed in an electrical box mounted to a 4 in. by 6 in. wooden post on the dam. The datalogger converted the differential-voltage output of the transducer into stage by means of an equation developed during laboratory calibration of the transducer and datalogger and programmed into the datalogger during installation. The effect of waves on the reservoir, which caused incorrect measurements of stage, was reduced by programming the datalogger to sample the transducer output every 5 minutes and average the samples each hour. The average, maximum, and minimum stage for the previous hour were stored in the datalogger. A staff gage was installed at the site and read during monthly site visits to check the accuracy of the transducer data.

The gage was moved twice during the study because of rising reservoir stage. In addition, the breakup of lake ice in January 1989 bent the pipe to which the transducer was attached; in January 1990, the transducer was pulled out of the lakebed by ice during rising stage. New measuring-point altitudes were established from nearby references each time the gage was moved or repaired.

In 1989, several short periods of record were lost at the reservoir-stage gage. Moisture, that had entered the electrical box through holes cut for mounting the box to the wooden post, condensed on metal surfaces of the datalogger and caused erroneous data by shorting between electrical terminals. This problem was resolved by caulking the holes, increasing the amount of dessicant in the box, and coating the rubber door-gasket with silicon grease. Six days of record were lost in April, 15 days in June, and 1 day in July. Periods of lost record were estimated by interpolating between data values.

Daily means of reservoir stage for water years 1989-90 are shown on figure 3. Reservoir stage was 1,050.7 ft above sea level at the beginning of the study and 1,065.0 ft above sea level at the end of the study. Reservoir stage ranged from 1,049.6 ft above sea level in December 1988 to 1,065.9 ft above sea level in June 1990. The mean reservoir stage was 1,054.0 ft above sea level for water year 1989 and 1,062.5 ft above sea level for water year 1990. Reservoir-stage data are listed in tables 1 and 2 at the end of the report.

Precipitation

Precipitation data were collected at two sites in the study area (fig. 2). A recording float-type gage was constructed west of the reservoir near the southern end of the dam. The recording gage consisted of an 8-in.-diameter collector mounted on top of an aluminum shelter fastened to the top of a 6 in. by 6 in. wooden post. The top of the collector was approximately 10 ft above the ground surface. Precipitation was funneled from the collector into a 3-in.-diameter plastic storage pipe attached to the post below the shelter. Changes in water level in the storage pipe were sensed by a

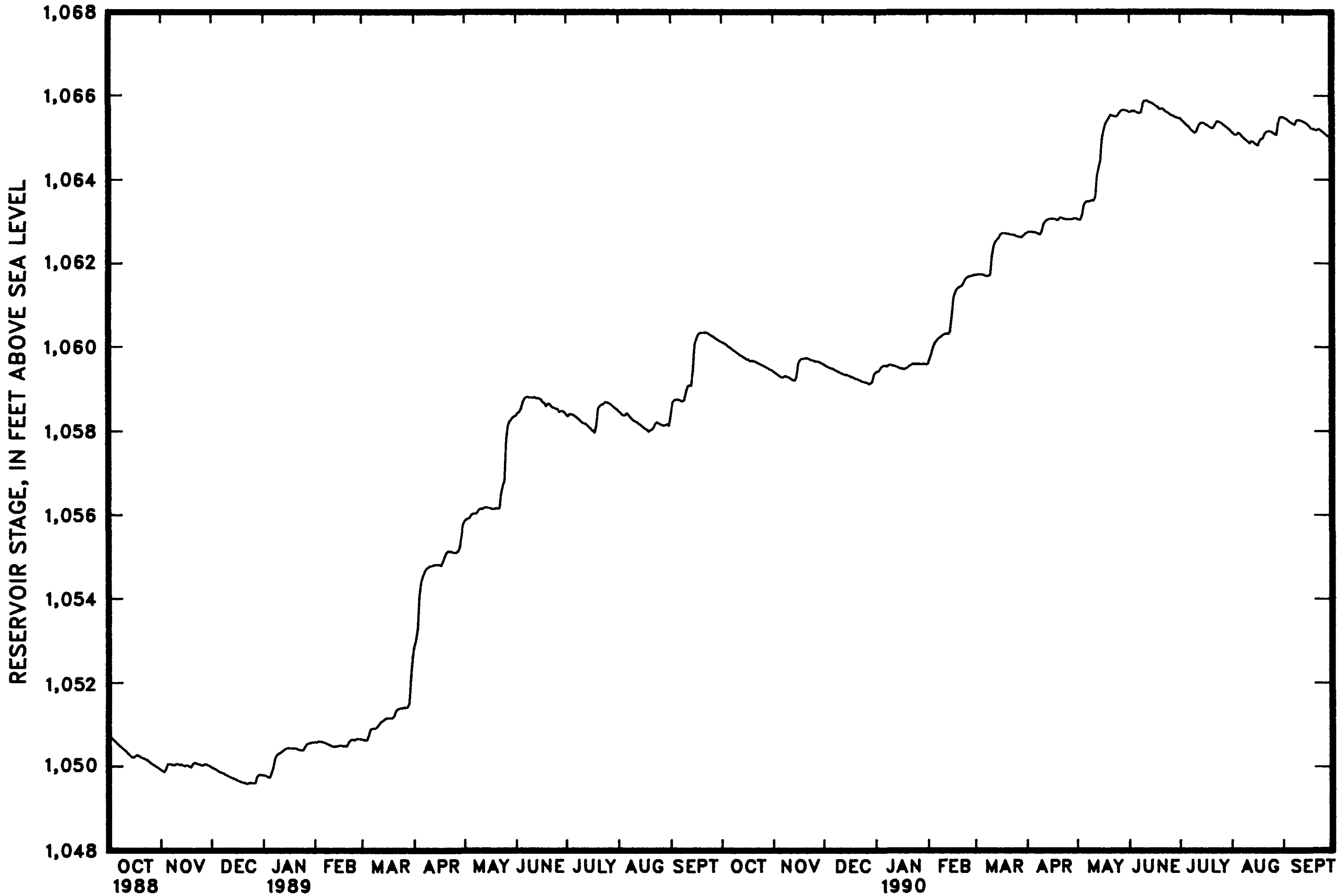


Figure 3. Daily mean stage for Summit Lake Reservoir, water years 1989-90.

float connected by a counter-weighted cable to a digital water-stage recorder housed in the shelter. The recorder punched coded values of precipitation on a paper tape at 15-minute intervals. The collector and tubing leading to the storage pipe were heated with electrical heating tape to melt snowfall. During the winter months, alcohol was added to the water in the storage pipe to prevent freezing.

Loss of record for the recording precipitation gage occurred during parts of August and September 1989 as a result of debris plugging the collector funnel and tubing. Data for these intervals were estimated by use of data from the manual precipitation gage.

A manual precipitation gage was located near the state park office, south of the reservoir (fig. 2). The three piece metal gage, operated and maintained by state park employees, consisted of a funnel, measuring tube, and overflow can. The top of the funnel is 7 5/8 in. in diameter. Liquid precipitation falling on the gage is funneled into the measuring tube. Precipitation amounts, up to 0.5 in., are read directly from a graduated measuring stick inserted into the measuring tube. Precipitation in excess of 0.5 in. is measured by pouring water from the overflow can into the empty measuring tube for direct measurement with the stick. The gage was set on the ground and normally was read at noon each day. The recorded precipitation was for the previous 24-hour period.

Monthly precipitation totals for the recording and manual gages are shown on figure 4. Monthly totals ranged from 0.79 in. at the recording gage in October 1989 to 8.87 in. at the manual gage in August 1990. Annual precipitation totals for the recording gage were 53.35 in. for water year 1989 and 48.76 in. for water year 1990. Annual precipitation totals for the manual gage were 51.62 in. for water year 1989 and 47.34 in. for water year 1990. Precipitation data collected at both gages are listed in tables 3 through 6 at the end of the report.

Evaporation

Evaporation data were collected from a standard Class A evaporation pan installed near the recording precipitation gage at the west edge of the reservoir (fig. 2). The evaporation pan has a cylindrical shape, a 47.5-in. inside diameter, and a 10-in. depth. The pan was placed on a level wooden platform enclosed in a 10 ft by 10 ft area by a 6-ft-high chain link fence to prevent animals from disturbing the pan. The evaporation pan was maintained by state park employees who made daily measurements of the water level in the pan by use of a hook gage in a stilling well. The hook gage is graduated in increments of one-thousandths of an inch. The stilling well provided an undisturbed water surface around the hook gage and also provided support for the gage. The water level was maintained between 2 and 3 in. below the top of the pan; water was added or removed as necessary.

Monthly totals of evaporation measured in the pan are shown on figure 5. Evaporation data were collected during three periods--October 1 through December 1, 1988; April 24 through December 4, 1989; and April 2 through September 30, 1990. The evaporation pan was not operated during winter months when air temperatures would cause water in the pan to freeze. Monthly pan evaporation totals ranged from 1.975 in. for November 1989 to 7.978 in. for July 1989. The total measured pan evaporation was 36.830 in. for water year 1989 and 38.197 in. for water year 1990. Pan-evaporation data are listed in table 7 at the end of the report.

Streamflow

Streamflow data were collected at two recording gages upstream from the reservoir--Big Blue River and Sweringen Ditch (fig. 2). Artificial controls were used at both streamflow gages to facilitate calculation of stage-discharge relations. Data obtained from these gages consisted of a continuous record of stage and individual measurements of streamflow throughout a range of stages. The data were used to compute continuous records of streamflow.

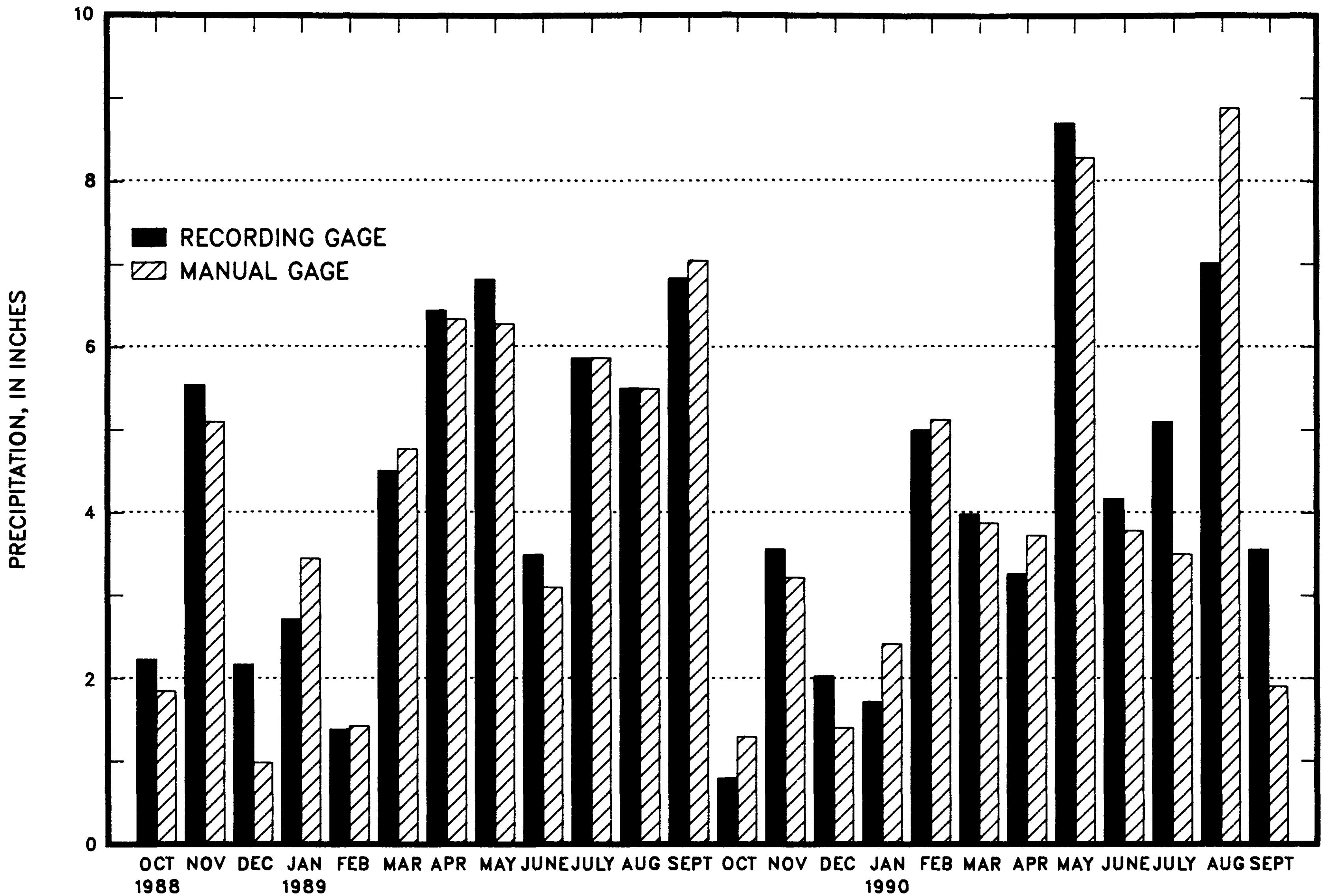


FIGURE 4. Total monthly precipitation for the recording and manual gages, water years 1989-90.

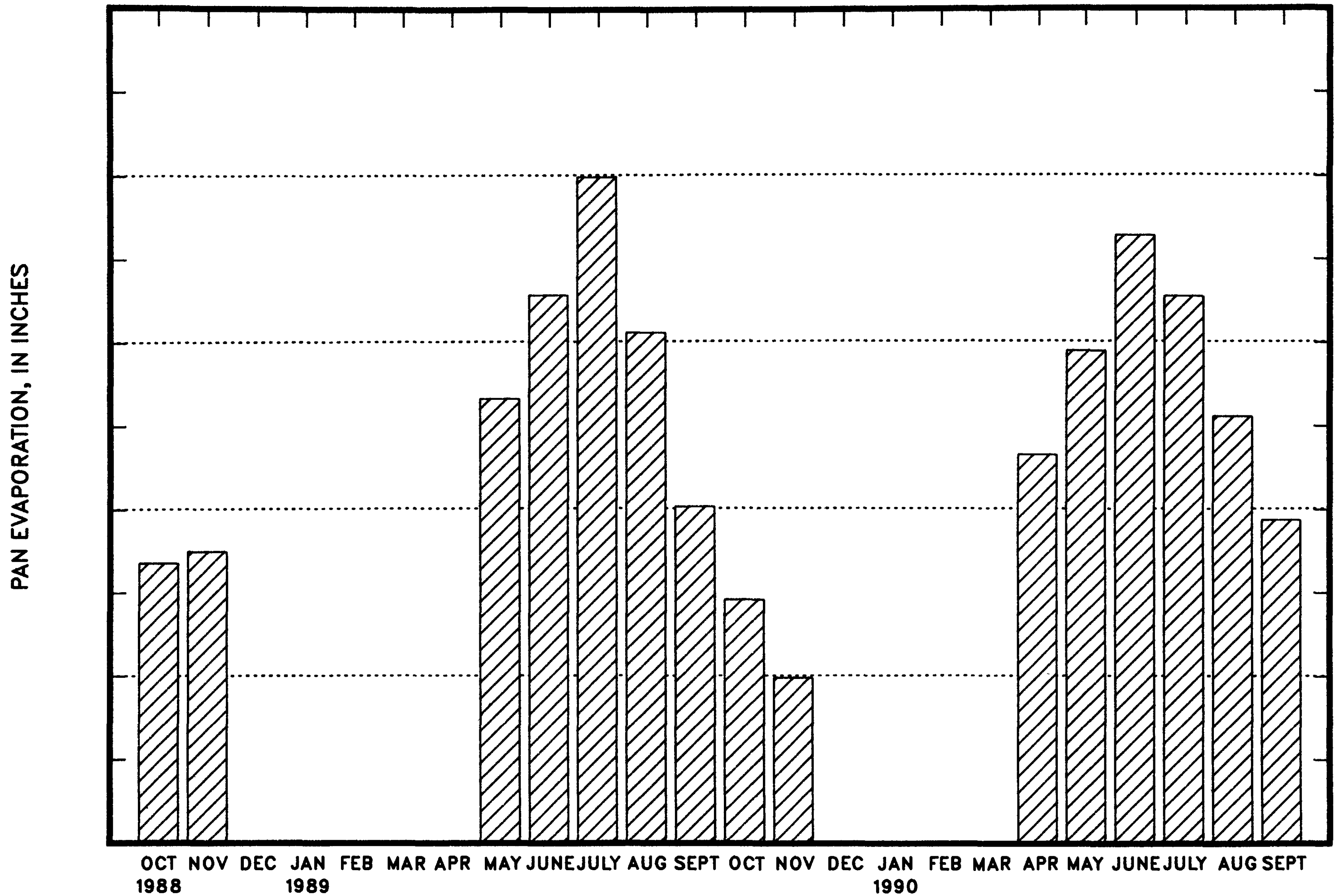


Figure 5. Total monthly pan evaporation, water years 1989-90.

A compound V-notch weir with sloping extensions was constructed across the Big Blue River channel at the gaging site. The weir was designed to conform to the channel cross section and provide minimum impedance to streamflow. The central portion of the weir was 7 ft wide and made from a 3/8-in.-thick steel plate having a 120-degree V-notch. The altitude of the lowest point of the V-notch was 1,063.2 ft above sea level. The sloping wooden extensions, that formed an angle of 12 degrees from horizontal, were made from 2 in. by 6 in. treated tongue and groove boards. The joints between boards were sealed with siliconized caulking. The entire structure measured 37 ft across and could accommodate a 5-ft stage in the upstream pool before water would begin to flow around the sides of the weir. The highest recorded pool stage during the study was 4.86 ft.

Stage was sensed by a float in a 24-in.-inside-diameter stilling well that was connected to the upstream pool by three 2-in.-inside-diameter intake pipes. The float was connected by a counter-weighted metal tape to a digital water-stage recorder. The recorder punched values of stage on a paper tape at selected intervals. A 15-minute punch interval was used from October 1, 1988, through February 7, 1989. A 5-minute punch interval was used from February 8, 1989, through September 30, 1990, to avoid missing peak streamflows.

The stage-discharge relation for the compound weir consists of a two-part rating--one for the lower 120-degree V-notch and one for the upper 12-degree angle from horizontal formed by the wooden boards. On the basis of on-site observations, a pool stage of 2.3 ft was required before discharge through the weir began to overflow the wooden boards. Therefore, the change from one rating equation to the other occurred at a stage of 2.3 ft.

The general equation for discharge through a V-notch weir neglecting approach velocity is (Brakensiek and others, 1979, p. 82)

$$Q = C\frac{8}{15}\sqrt{2g}\ \tan\frac{\theta}{2}H^{2.5}\ , \qquad (1)$$

where Q = discharge in ft^3/s;

C = coefficient of discharge;

g = gravitational acceleration in ft^2/s ;

θ = angle of V-notch opening; and

H = head above the lowest point of the V-notch, in ft.

The equation is often reduced to the form

$$Q = CH^{2.5}\ , \qquad (2)$$

in which the constant C replaces $C\frac{8}{15}\sqrt{2g}\ \tan\frac{\theta}{2}$ in equation 1 (King, 1954, p. 4-13). For the 120-degree V-notch weir at stages below 2.3 ft, the following equation was used:

$$Q = 4.33\ \mathrm{H}^{2.5}. \qquad (3)$$

For pool stages of 2.3 ft and above, the relation between stage and discharge is a straight-line plot on log-log paper (U.S. Department of the Interior, 1963, p. 7). This part of the rating was determined by measuring discharge downstream from the weir at several pool stages above 2.3 ft and plotting stage versus discharge on log-log paper. This resulting plot was a straight line that was extended to include stages up to 5 ft--the maximum stage for the weir.

Streamflow data for Big Blue River were lost beginning on May 4, 1990, when the stage of Summit Lake Reservoir reached the altitude of the V-notch weir. The stage continued to rise and remained above the V-notch through the end of the study. Streamflow for Big Blue River from May 4 through September 30, 1990, was estimated by means of the method of hydrographic comparison described by Rantz and others (1982, pp. 370 and 575). Two nearby recording streamflow-gaging stations having continuous streamflow records were selected for comparison--Whitewater River near Economy, Indiana (U.S. Geological Survey streamflow-gaging station 03274650), located approximately 9 mi southeast of the gage on Big Blue River; and Whitewater River near Hagerstown, Indiana (U.S. Geological Survey streamflow-gaging station 03274750), located approximately 12.5 mi south-southeast of the gage on Big Blue River. Streamflow data for these gaging stations are published in Water Resources Data--Indiana, Water Years 1989 and 1990 (Thompson and Nell, 1990; Stewart and Nell, 1991).

A comparison of streamflow for Big Blue River and the two gaging stations on Whitewater River (fig. 6) indicates there is a good relation of runoff patterns for the three stations. In addition, the unit yield, or runoff per square mile, for the three streams is nearly equal. Both gaging stations on Whitewater River had unit peak flows that were similar to those for Big Blue River during the concurrent period of record October 1, 1988, through May 4, 1990. Unit low flows for Whitewater River near Economy generally were smaller than unit low flows for Big Blue River, and unit low flows for Whitewater River near Hagerstown generally were larger than those for Big Blue River.

Daily means of streamflow for Big Blue River are shown on figure 7. Daily mean streamflow ranged from 0.12 to 100 ft^3/s for the period of study. Annual mean streamflow was 3.68 ft^3/s for water year 1989 and 3.25 ft^3/s for water year 1990. The minimum recorded instantaneous streamflow was 0.12 ft^3/s at a gage height of 0.24 ft for several days in October 1988. The maximum recorded instantaneous streamflow was 270 ft^3/s at a gage height of 4.86 ft on May 26, 1989. Streamflow data for Big Blue River are listed in tables 8 and 9 at the end of the report.

The streamflow gage for Sweringen Ditch consisted of a lake-stage gage constructed at the southern edge of the upper pool. The gage was similar to the stage gage on Summit Lake Reservoir and consisted of a submersible pressure transducer and programmable datalogger. Sweringen Ditch is the principal inflow to the upper pool. Outflow is through a drop outlet (a 48-in.-inside-diameter corrugated steel culvert) along County Road 500 East at the western edge of the upper pool. The crest of the outlet has an altitude of about 1,070 ft above sea level.

Continuous streamflow records for Sweringen Ditch were calculated by means of the lake-stage data and a theoretical stage-discharge relation for the drop outlet. The general equation for weir flow through a drop outlet as given by Brakensiek and others (1979, p. 117), is

$$Q = CLH^{1.5},$$

where Q = discharge, in ft^3/s;

C = coefficient of discharge;

L = length of the weir crest, in feet; and

H = head above the weir crest, in feet.

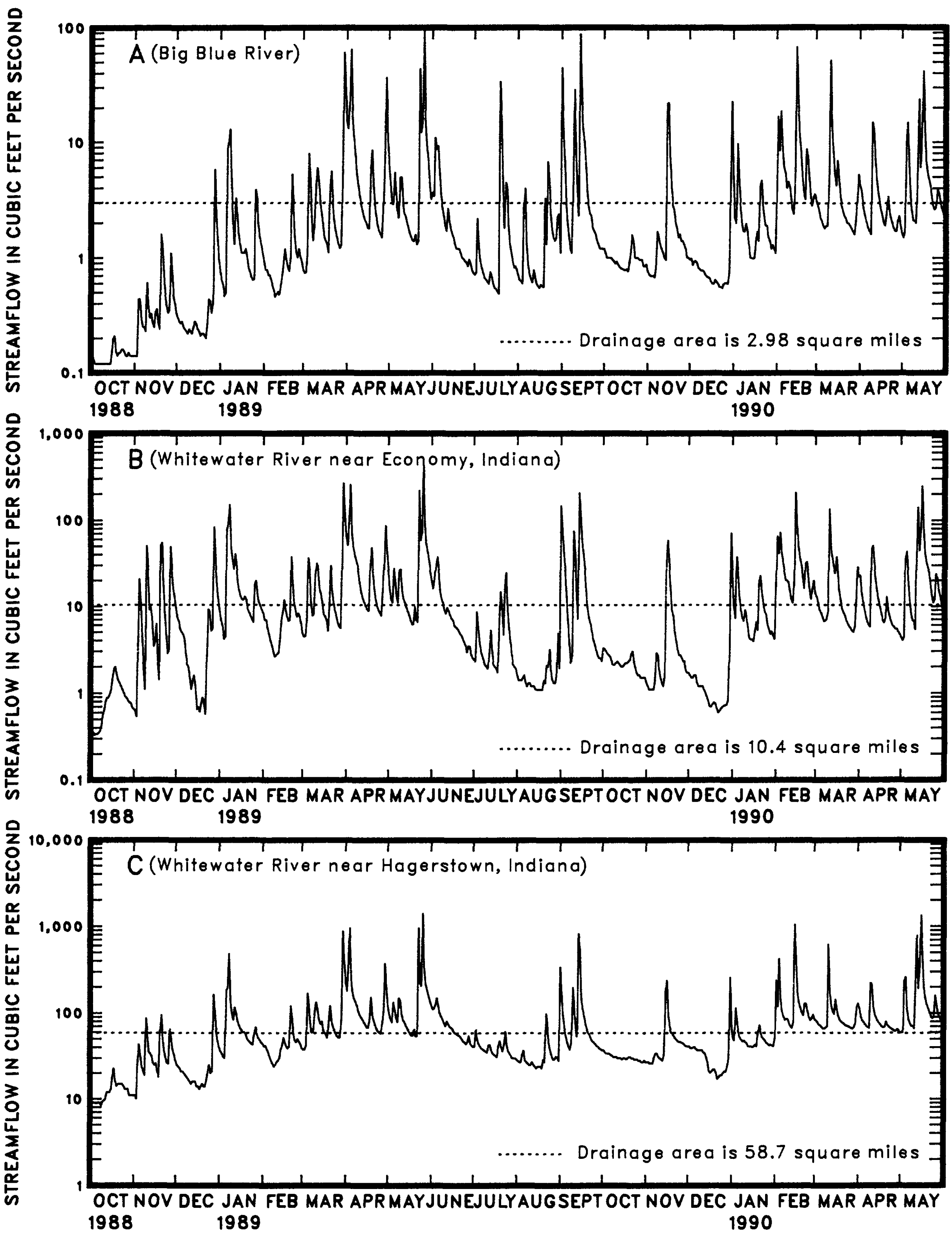


Figure 6. Daily mean streamflow for (A) Big Blue River, (B) Whitewater River near Economy, Indiana, and (C) Whitewater River near Hagerstown, Indiana. October 1, 1988, through June1, 1990.

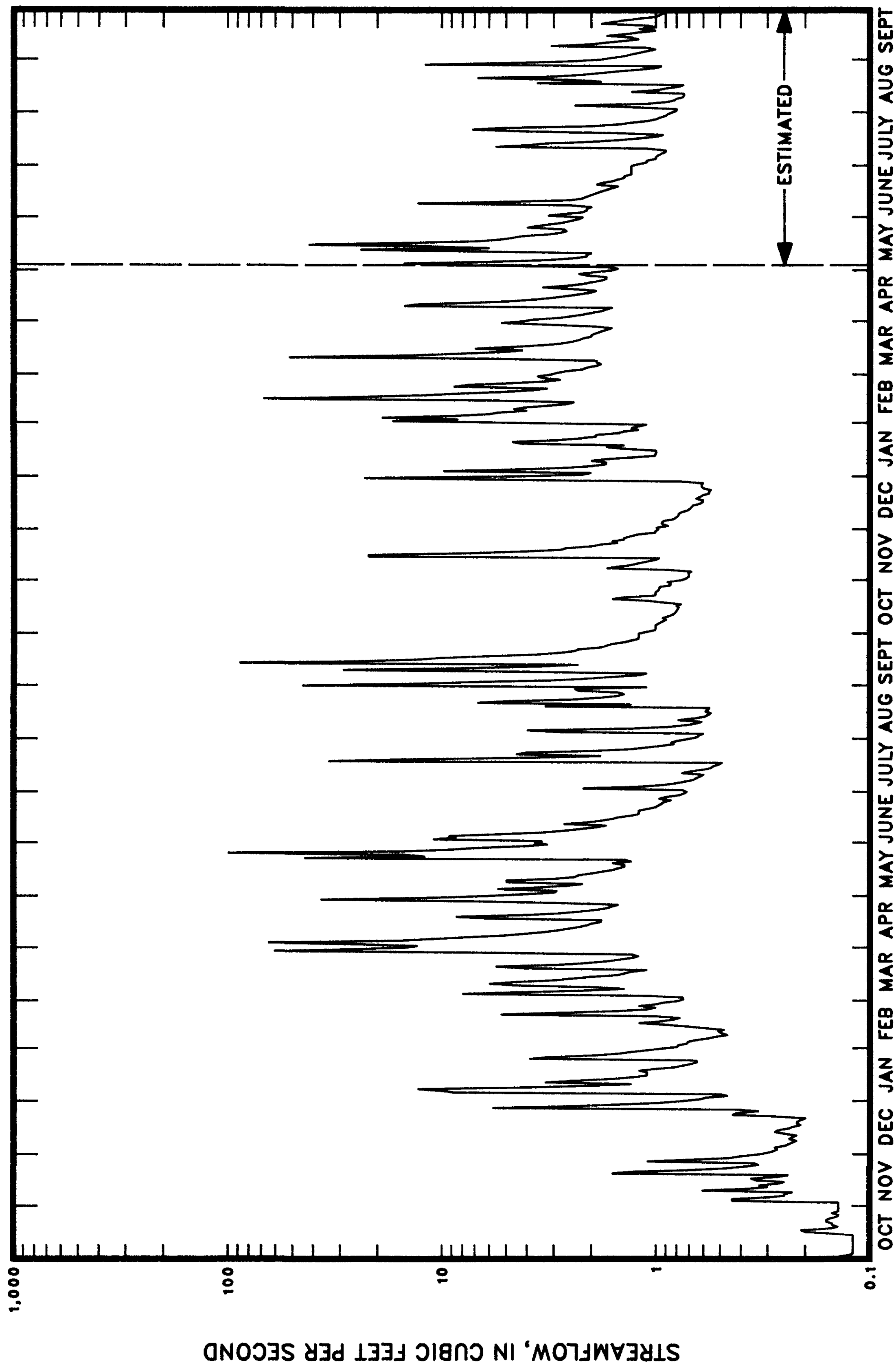


Figure 7. Daily mean streamflow for Big Blue River, water years 1989-90.

Three problems were associated with the theoretical rating for the drop outlet. First, the crest of the outlet was not level and water did not flow uniformly across the crest. Field level notes indicated that the altitude of the crest varied by as much as 0.03 ft. Second, a protective cage designed to keep people or large objects from falling into the drop outlet was bolted to the crest and caused diversions of flow around the support brackets. Third, weeds and debris were caught by the drop outlet and altered the flow of water over the crest. The first two problems were alleviated, to some extent, by dividing the length of the crest into four sections, subtracting the width of the support brackets, and assigning an altitude to each section on the basis of field level notes. Streamflow was calculated for each of the four sections for every 0.01-ft increment of stage, and the results were added to produce the total volume of flow through the drop outlet. The third problem was minimized by removing accumulated debris from the drop outlet during monthly site visits.

Daily means of streamflow for Sweringen Ditch are shown on figure 8. Daily mean streamflow ranged from 0 to 40 ft^3/s during the period of study. Annual mean streamflow was 2.57 ft^3/s for water year 1989 and 3.45 ft^3/s for water year 1990. A relatively long period of no flow occurred from October 1, 1988, through January 5, 1989, when the stage of the upper pool was below the crest of the drop outlet. Short periods of no flow occurred in June, July, and August 1989 and in July and August 1990. The maximum recorded instantaneous streamflow is 56 ft^3/s at a stage of 1,071.2 ft above sea level in the upper pool on May 26, 1989. Stage data for the upper pool are listed in tables 10 and 11 at the end of the report. Streamflow data for Sweringen Ditch are listed in tables 12 and 13 at the end of the report.

Ground-Water Levels

Ground-water levels were measured once a month in 13 wells located at 8 sites around the perimeter of Summit Lake Reservoir (fig. 2). There are two wells located at each of five sites and one well at each of the remaining three sites. The wells were installed in upland areas around the perimeter of the reservoir by use of hollow-stem augers to depths ranging from about 20 to 77 ft below land surface. The wells were completed by allowing the natural formation material to collapse around the screen. Bentonite clay was used above the screen to prevent vertical flow in the annular space. The wells are cased with 2-in.-inside-diameter black steel and have 1.25-in.-inside-diameter well screens. Screen lengths are either 2 or 3 ft. Each well is designated by an alphabetical character followed by a number. The alphabetical character defines the site, and the number defines a particular well at that site. At sites with two wells, the shallow well is denoted by a 1 and the deep well is denoted by a 2. Information about the wells is listed in table 14.

In addition to wells installed for the study, approximately 70 small-diameter wells or piezometers were installed during the design and construction of the dam. These wells are located primarily along the downstream side of the dam west of the reservoir. The U.S. Soil Conservation Service measures water levels in these wells about every 3 months (Sheldon Dynes, U.S. Soil Conservation Service, written commun., 1990). These measurements were used to supplement the measurements made in the 13 wells installed for this study.

Ground water in the study area generally is under semiconfined or confined conditions because of the large amount of low-permeability clay in the glacial sediments. The wells are screened in sand and gravel layers that generally contain clay. The sand and gravel layers are relatively thin (less than 10 ft) and probably are not continuous throughout the study area. The sediments in the valley beneath the reservoir contain sand and gravel deposits that are thicker and have less clay than the sediments in the upland areas. Ground water may have been unconfined in the valley before construction of the reservoir; however, the clay-blanket material on the reservoir bottom probably confines ground water under the reservoir.

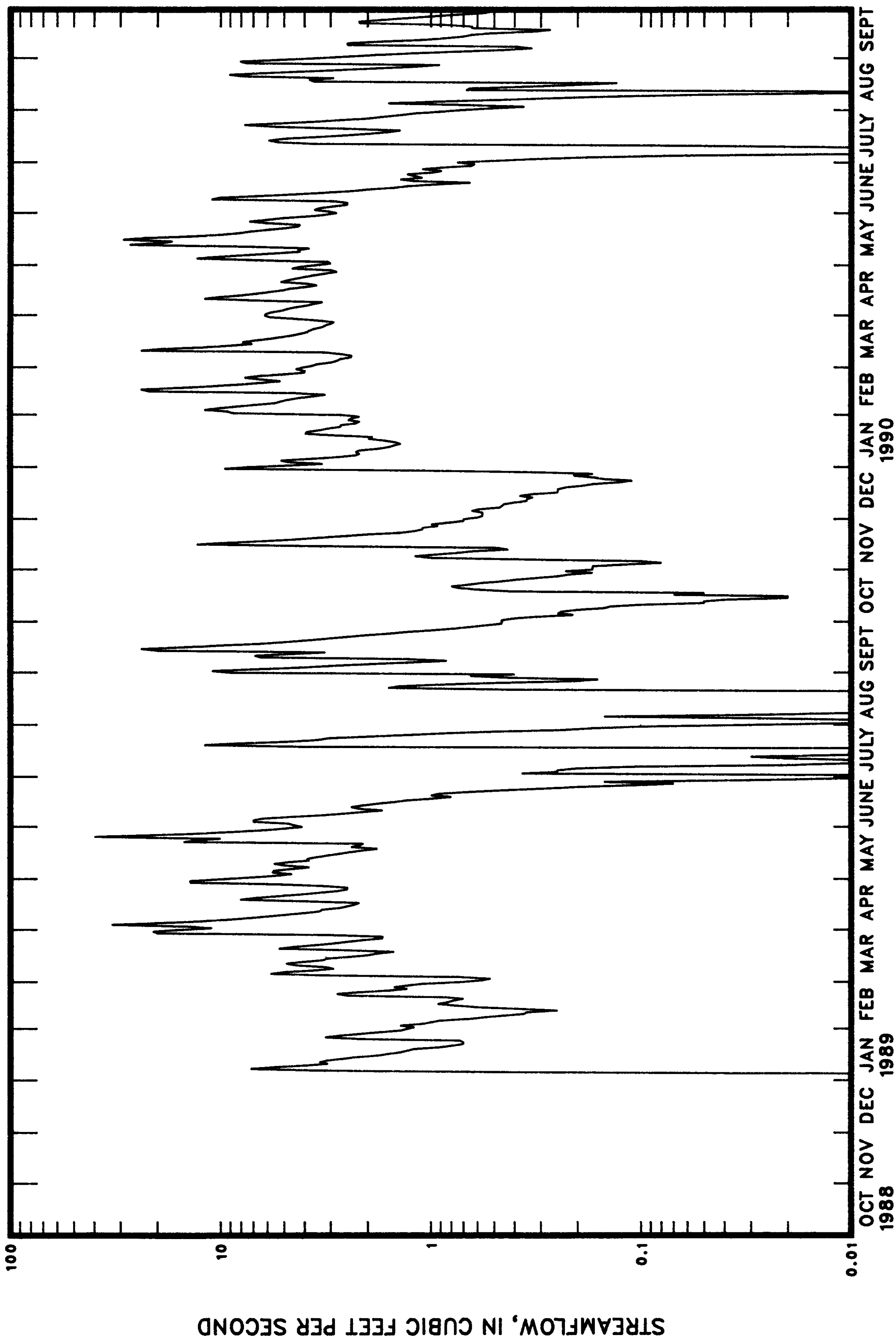


Figure 8. Daily mean streamflow for Sweringen Ditch, water years 1989-90.

Table 14. *Description of observation wells at Summit Lake Reservoir*

[°, degrees; ’, minutes; ”, seconds]

Well number	Latitude	Longitude	Date drilled	Depth (feet below land surface)	Screen length (feet)	Altitude of index measuring point (feet above sea level)	Altitude of land surface (feet above sea level)	Altitude of screen midpoint (feet above sea level)
A-1	40°01’02”	85°19’11”	8/03/88	62.3	3	1081.30	1078	1017.2
B-1	40°00’46”	85°18’33”	8/02/88	20.8	3	1082.61	1079	1059.7
B-2	40°00’46”	85°18’33”	8/02/88	37.5	3	1082.16	1079	1043.0
C-1	40°01’39”	85°18’04”	8/04/88	20.3	3	1075.41	1072	1053.2
C-2	40°01’39”	85°18’04”	8/04/88	42.0	3	1074.74	1072	1031.5
D-1	40°02’25”	85°17’22”	8/09/88	37.0	2	1079.66	1079	1043.0
D-2	40°02’25”	85°17’22”	8/09/88	57.8	3	1079.97	1078	1021.7
E-1	40°02’16”	85°18’10”	8/11/88	24.0	3	1085.70	1085	1062.5
E-2	40°02’16”	85°18’10”	8/11/88	43.0	3	1087.18	1085	1043.5
F-1	40°02’01”	85°18’46”	8/09/88	31.0	2	1078.51	1076	1046.0
F-2	40°02’01”	85°18’46”	8/08/88	63.7	3	1078.69	1075	1012.8
G-1	40°01’06”	85°19’37”	8/10/88	77.4	3	1077.22	1075	999.1
H-1	40°01’11”	85°18’38”	8/12/88	37.8	3	1070.21	1067	1030.7

During the study, measured ground-water levels ranged from about 1 ft below land surface in well E-1 during April 1989 to about 50 ft below land surface in well G-1 during December 1988. Water levels in the shallow well E-1 were the highest water levels measured in the study area and may represent a perched water table at this location. Ground-water levels measured at Summit Lake Reservoir are listed in table 15 at the end of the report.

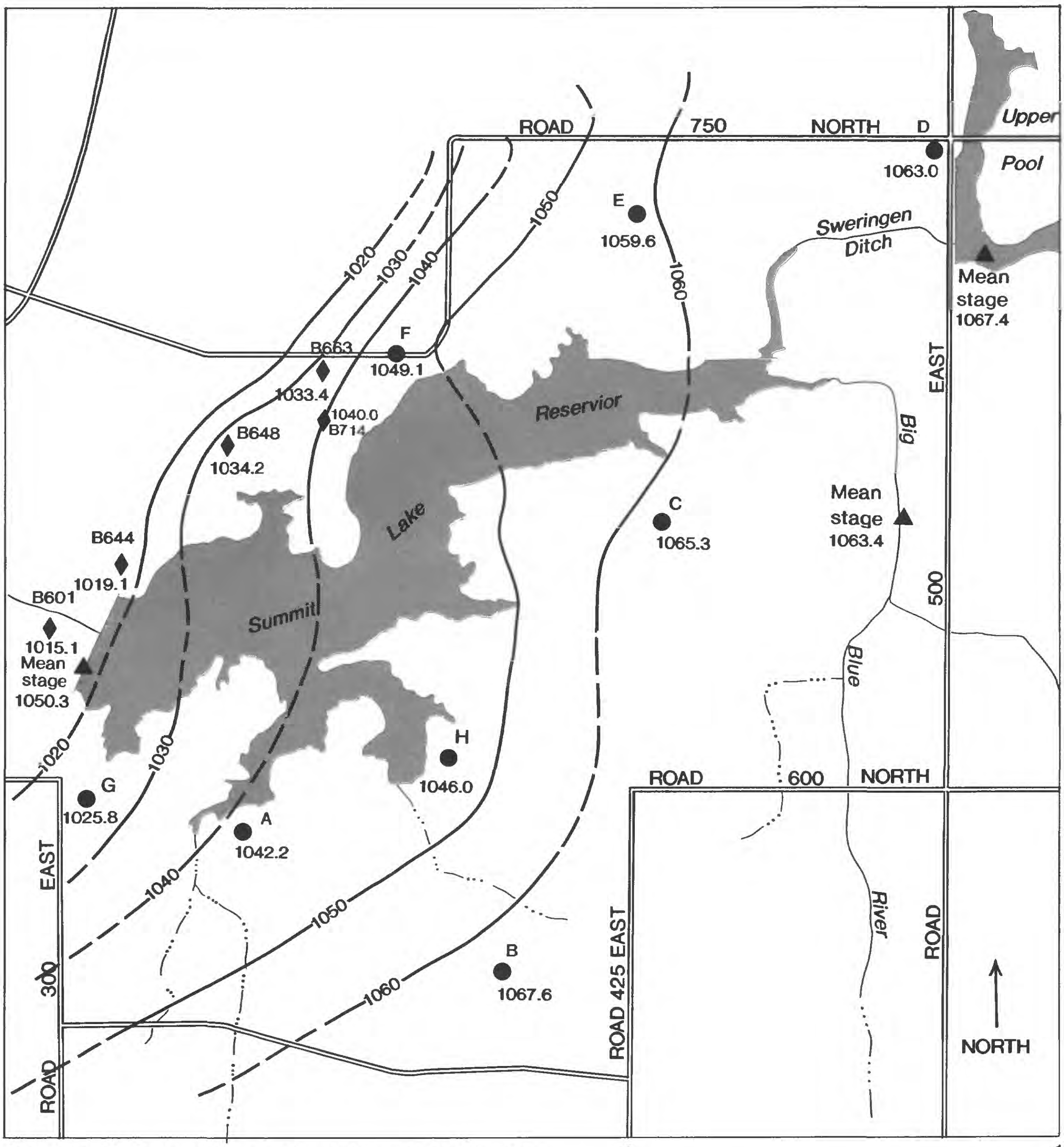
Ground-water levels fluctuate in response to the volume and distribution of recharge and discharge. Ground water in the study area is recharged by infiltration of precipitation and by seepage from the reservoir. Discharge occurs naturally by evapotranspiration and seepage to surface-water bodies and artificially by pumping. Ground-water levels fluctuate seasonally--they generally are highest in the spring and lowest in the fall. Fluctuations of ground-water levels near the reservoir are primarily controlled by the stage of the reservoir. Ground-water levels generally were lowest at the beginning of the study and highest at the end of the study because the lake stage increased during the study. Ground-water fluctuations during the study ranged from about 4 ft at well B-2 to about 16 ft at well F-1. The average fluctuation for all wells was about 9 ft.

Vertical hydraulic gradients were determined at the five sites where two wells were screened at different depths. The difference between water levels at individual sites was usually less than 1 ft at site D, but sometimes exceeded 20 ft at sites E and F. Water levels in shallow wells at sites B, E, and F were always higher than those in the deeper wells, indicating downward flow. Water levels in the shallow well at site D were always lower than those in the deeper well, indicating upward flow. At the beginning of the study, water levels in the shallow well at site C were higher than those in the deeper well; but, at the end of the study, water levels in the shallow well were lower, indicating a change in the direction of vertical flow at this site. Vertical hydraulic gradients were determined by dividing the difference between average water levels by the vertical distance between the screened interval of each pair of wells. Vertical hydraulic gradients between wells ranged from 2.9×10^{-2} to 7.3×10^{-1} ft/ft and averaged 2.8×10^{-1} ft/ft.

Ground-water levels were plotted on maps and contoured to determine the horizontal direction of ground-water flow near the reservoir. The contour maps illustrate a potentiometric surface representative of static water levels in the upper 80 feet of the unconsolidated glacial sediments. At sites where two wells were screened at different depths, water levels in the shallow well were used to draw the contour map. Site E was an exception; here, water levels in the deep well (E-2) were used. The contour maps were compared to determine if any changes in flow direction had occurred during the study. Although water levels in individual wells changed as much as 16 ft, no substantial differences in horizontal-flow direction were noticed.

Ground-water levels measured October 1988 were generally the lowest during the study; ground-water levels measured June 1990 were generally the highest during the study. Contour maps of ground-water levels measured October 1988 and June 1990 were selected to illustrate water levels during the study (figs. 9 and 10). The U.S. Soil Conservation Service piezometers were not measured during June 1990; therefore, water levels measured in the piezometers during April 1990 are plotted on figure 10. The direction of flow is perpendicular to the contour lines and was generally toward the west and northwest. The distance between contour lines indicates the slope of the ground-water surface or horizontal hydraulic gradient. Hydraulic gradients increased in the direction of ground-water flow and were steepest along the west and northwest edges of the reservoir. Ground-water levels were higher than reservoir stage at well sites B, C, D, and E, indicating flow of ground water toward the reservoir. Ground-water levels were lower than reservoir stage at sites A, F, G, and H, indicating flow of water away from the reservoir.

Before construction of the reservoir, shallow ground water probably flowed toward, and discharged to, the streams. Big Blue River and Sweringen Ditch flowed even during long periods of no precipitation, indicating they are supplied by ground-water discharge. As the reservoir filled with water, ground-water levels rose because of infiltration into the underlying sediments. Ground-water levels in the large glacial valley west of the dam are 35 to 50 ft below the reservoir stage--the lowest



Base from U.S. Geological Survey Mount pleasant 1:24,000, 1988

0 — 1 MILE

0 — 1 KILOMETER

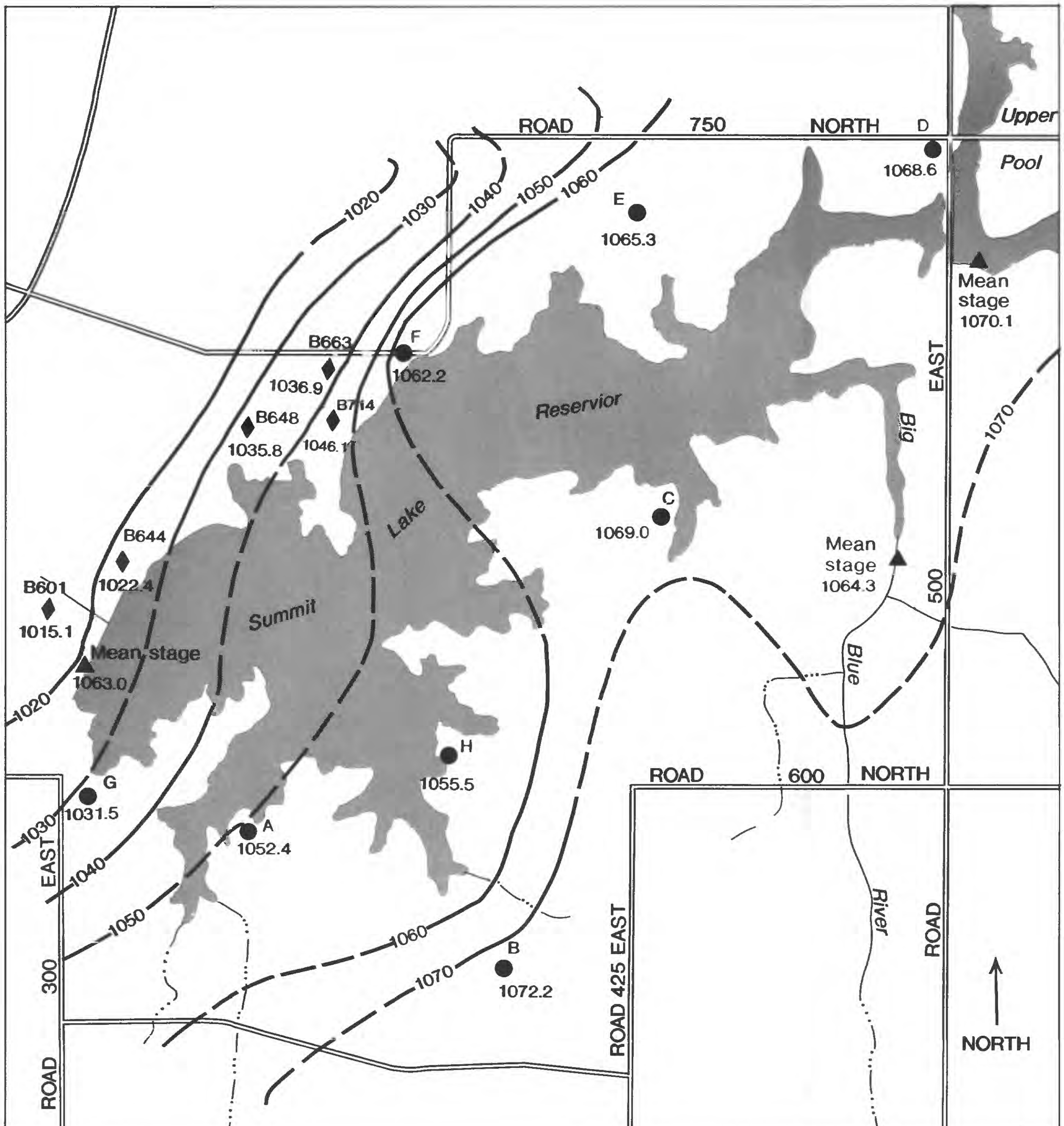
EXPLANATION

1060 — WATER-LEVEL CONTOUR--shows altitude at which water would have stood in tightly-cased wells. Dashed where approximately located. Contour interval 10 feet. Datum is sea level.

A ● 1052.4 — OBSERVATION WELL AND SITE DESIGNATION--well installed for study. Number is water-level altitude, in feet above sea level.

B601 ◆ 1015.1 — PIEZOMETER AND SITE DESIGNATION-- piezometer installed for U.S. Soil Conservation Service. Number is water-level altitude, in feet above sea level.

Figure 9. Ground-water levels near Summit Lake Reservoir, October 1988.



Base from U.S. Geological Survey Mount pleasant 1:24,000, 1988

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EXPLANATION

1060 — WATER-LEVEL CONTOUR-- shows altitude at which water would have stood in tightly-cased wells. Dashed where approximately located. Contour interval 10 feet. Datum is sea level.

A ● 1052.4 — OBSERVATION WELL AND SITE DESIGNATION-- well installed for study. Number is water-level altitude, in feet above sea level.

B601 ♦ 1015.1 — PIEZOMETER AND SITE DESIGNATION-- piezometer installed for U.S. Soil Conservation Service. Number is water-level altitude, in feet above sea level.

FIGURE 10. Ground-water levels near Summit Lake Reservoir, April 1990.

measured in the study area. Ground water in the study area is ultimately discharged to the large glacial valley. The low ground-water levels in the valley and the probable large hydraulic conductivity of the sand and gravel deposits limit the rise in ground-water levels beneath the reservoir, particularly along the western edge of the reservoir.

HYDROLOGIC BUDGET

Components of the Hydrologic Budget

The hydrologic budget for a reservoir is expressed by the following general equation:

Inflow = Outflow + Change in reservoir storage.

Components on the inflow side of the equation are direct precipitation (P), surface-water inflow (SWI), and ground-water inflow (GWI). Outflow from the reservoir is by evaporation (E), surface-water outflow (SWO), and ground-water outflow (GWO). Differences between volumes of inflow and outflow result in a change in the volume of water stored in the reservoir (ΔS). The expanded equation is

$$P + SWI + GWI = E + SWO + GWO + \Delta \mathrm{S}.$$

The volume of each component in the hydrologic budget equation was estimated using the collected data. In some cases, computer programs were written to facilitate calculations. The U.S. Soil Conservation Service (Sheldon Dynes, written commun., 1988) provided graphs of stage-area and stage-storage relations (fig. 11) developed during design and construction of the reservoir. The graphs were digitized to provide coordinate data used by the computer programs.

During the study, the reservoir stage varied by more than 16 ft and the surface area of the reservoir ranged from about 340 to 660 acres. Volumes for each component were calculated using various time intervals to determine how the variability of the reservoir area affected the results of the hydrologic budget. The time intervals were selected according to the type of data and the method of calculation.

Direct Precipitation

The volume of water from direct precipitation on the reservoir surface was estimated using precipitation data from both the recording and the manual precipitation gages. Precipitation volumes were calculated separately for each gage by multiplying the amount of precipitation for the selected time interval by the mean surface area of the reservoir; the mean surface area was determined from the mean reservoir stage for each time interval and the stage-area relation. The average of the two gages was used in the hydrologic budget. Daily, monthly, and yearly time intervals were used for precipitation data from the recording gage. Daily totals were added to provide monthly and annual totals. Because of uncertainties about the exact time of precipitation, monthly and yearly time intervals were used for precipitation data from the manual gage. Monthly totals were added to provide annual totals.

Precipitation volumes are listed in table 16. Monthly volumes of precipitation ranged from 27.8 acre-ft for the manual gage in December 1988 to 473 acre-ft for the manual gage in August 1990. Depending on the time interval used for calculation, annual precipitation volumes for the recording gage ranged from 1,820 to 1,910 acre-ft for water year 1989, and from 2,330 to 2,420 acre-ft for water year 1990. Annual precipitation volumes for the manual gage are 1,850 acre-ft using monthly values and 1,760 acre-ft using yearly values for water year 1989 and 2,340 acre-ft using monthly values and

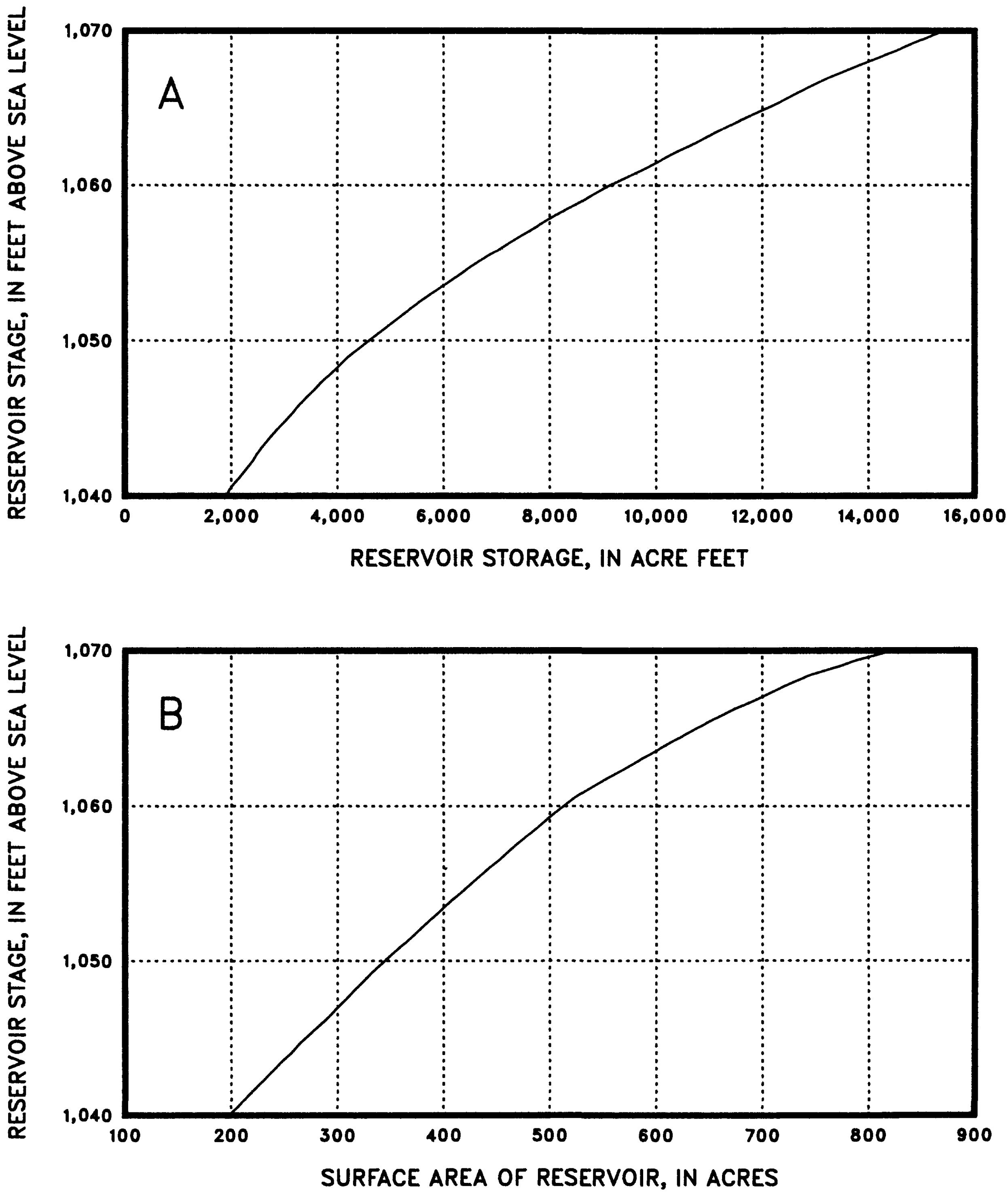

Figure 11. Reservoir stage-storage (A) and stage-area (B) relations for Summit Lake Reservoir.

Table 16. *Precipitation volumes calculated for the recording and manual gages by use of daily, monthly, and yearly values, water years 1989-90*

[Numbers in columns may not add to column totals because of rounding. Dashes indicated value not determined]

Month, water year 1989	A Precipitation volume from recording gage by use of daily values[1] (acre-feet)	B Precipitation volume from recording gage by use of monthly values[2] (acre-feet)	C Precipitation volume from manual gage by use of monthly values[2] (acre-feet)	D Average volume (A+C)/2 (acre-feet)	E Average volume (B+C)/2 (acre-feet)	F Precipitation volume from recording gage by use of yearly values[3] (acre-feet)	G Precipitation volume from manual gage by use of yearly values[3] (acre-feet)	H Average volume (F+G)/2 (acre-feet)
October	64.5	64.6	53.6	59.0	59.1	---	---	---
November	159	159	146	152	153	---	---	---
December	61.0	61.3	27.8	44.4	44.5	---	---	---
January	78.1	78.6	100	89.1	89.3	---	---	---
February	40.6	40.7	41.8	41.2	41.2	---	---	---
March	138	136	144	141	140	---	---	---
April	224	226	223	223	224	---	---	---
May	257	257	237	247	247	---	---	---
June	141	142	126	134	134	---	---	---
July	235	236	236	236	236	---	---	---
August	220	220	220	220	220	---	---	---
September	281	287	297	289	292	---	---	---
Annual total	1,900	1,910	1,850	1,880	1,880	1,820	1,760	1,790

Table 16. *Precipitation volumes calculated for the recording and manual gages by use of daily, monthly, and yearly values, water years 1989-90*--Continued

Month, water year 1990	A Precipitation volume from recording gage by use of daily values[1] (acre-feet)	B Precipitation volume from recording gage by use of monthly values[2] (acre-feet)	C Precipitation volume from manual gage by use of monthly values[2] (acre-feet)	D Average volume (A+C)/2 (acre-feet)	E Average volume (B+C)/2 (acre-feet)	F Precipitation volume from recording gage by use of yearly values[3] (acre-feet)	G Precipitation volume from manual gage by use of yearly values[3] (acre-feet)	H Average volume (F+G)/2 (acre-feet)
October	33.4	33.5	54.6	44.0	44.0	---	---	---
November	148	149	135	141	142	---	---	---
December	84.2	84.3	58.4	71.3	71.3	---	---	---
January	71.9	71.9	101	86.4	86.4	---	---	---
February	218	220	225	222	222	---	---	---
March	187	188	183	185	186	---	---	---
April	158	158	181	169	170	---	---	---
May	446	453	432	439	443	---	---	---
June	227	228	207	217	217	---	---	---
July	274	274	188	231	231	---	---	---
August	373	373	473	423	423	---	---	---
September	191	191	102	147	147	---	---	---
Annual total	2,410	2,420	2,340	2,380	2,380	2,330	2,260	2,290

[1] Volume is the sum of the products of daily precipitation and daily mean reservoir area.
[2] Volume is the product of monthly precipitation and monthly mean reservoir area.
[3] Volume is the product of yearly precipitation and yearly mean reservoir area.

2,260 acre-ft using yearly values for water year 1990. Although annual precipitation was less in water year 1990 than in water year 1989, the volume of direct precipitation in the hydrologic budget was larger in water year 1990 because the reservoir stage was higher; therefore, the surface area was larger.

Comparison of average volumes (table 16, columns D, E, and H) indicate there is little difference between annual totals calculated using daily and monthly values; however, annual totals calculated using yearly values are 3 to 5 percent less than those calculated using daily and monthly values.

Evaporation

Pan evaporation data were used to estimate the volume of water removed from the reservoir surface by evaporation. The data consist of measurements of the water level in the pan--the difference between successive measurements is the amount of evaporation from the pan for the time interval between measurements if no precipitation has occurred. For intervals having precipitation, the amount of precipitation recorded at the nearby gage was added to the difference in pan water levels to determine the amount of evaporation. Evaporation amounts were added to provide monthly totals.

Because the evaporation pan was not operated during winter months, the collected data represent seasonal pan evaporation and not the total annual pan evaporation. Studies by the U.S. Weather Bureau show that evaporation that occurs from May through October is, on average, 80 percent of the annual total (Kohler and others, 1959, plate 4). Pan evaporation measured from May through October was 33.338 in. for water year 1989 and 31.577 in. for water year 1990. Assuming these amounts are 80 percent of the annual totals, the estimated annual totals are 41.67 in. for water year 1989 and 39.47 in. for water year 1990.

The volume of evaporation from the pan is generally considered to be larger than that occurring from the reservoir, primarily because of differences in water temperature in the pan and reservoir and because of air circulation around the pan (Brakensiek and others, 1979, p. 230). Previous studies have related pan evaporation to lake evaporation by means of a pan coefficient. Monthly pan coefficients can be quite variable and never have been well defined. Annual pan coefficients, representing the average of the monthly coefficients, provide a method for estimating evaporation from the reservoir using pan-evaporation data on a yearly basis. A pan coefficient of 0.77 for the location of this study was determined from a map of annual pan coefficients for the United States (Kohler and others, 1959, plate 3). Applying the pan coefficient to the extrapolated annual pan-evaporation totals results in an estimated reservoir evaporation of 32.09 in. for water year 1989 and 30.39 in. for water year 1990.

The volume of evaporation was calculated by multiplying the estimated annual reservoir evaporation by the mean surface area of the reservoir. The mean surface area was determined from the mean reservoir stage for each year and the stage-area relation. The mean reservoir surface area was 410 acres in water year 1989 and 573 acres in water year 1990. The volume of evaporation is 1,100 acre-ft for water year 1989 and 1,450 acre-ft for water year 1990. Because of the previously discussed limitations of pan to lake coefficients, estimates of reservoir evaporation using this method are not as reliable for time intervals of less than 1 year.

Surface-Water Inflow and Outflow

The volume of surface-water inflow to the reservoir was estimated using data from the two recording streamflow gages (fig. 2) and by extrapolating data to the ungaged part of the drainage basin using the method of equal unit yield. The method of equal unit yield (Rantz and others, 1982, p. 576) assumes an equal volume of runoff per square mile for the gaged and ungaged parts of the basin. The drainage areas of Big Blue River (3.0 mi^2) and Sweringen Ditch (2.4 mi^2) account for about 60 percent of the area that drains to the reservoir. The remaining ungaged part of the drainage basin varies in size depending on the surface area of the reservoir. The reservoir area ranged in size from about 0.5 to 1.0 mi^2 and averaged about 0.8 mi^2 during the study; the ungaged part of the drainage basin ranged from about 2.9 to 3.4 mi^2 and averaged about 3.1 mi^2. The variability in size of the ungaged area was included in the calculations by subtracting the reservoir area from the total ungaged area before applying equal unit yield.

Daily, monthly, and yearly values of streamflow were used in the calculations. Because of problems with the stage-discharge relation for Sweringen Ditch (discussed in the "Streamflow" section), and because there were several periods of no flow from the upper pool, equal unit yield for the ungaged part of the drainage area was determined using data from Big Blue River. The total surface-water inflow was obtained by combining streamflow for Big Blue River, Sweringen Ditch, and the calculated streamflow for the ungaged part of the drainage area. Results from daily time intervals were added to obtain monthly and annual totals. Results from monthly time intervals were added to obtain annual totals.

Volumes of surface-water inflow are listed in table 17. Monthly volumes of surface-water inflow range from 18.4 acre-ft in October 1988 to 1,590 acre-ft in April 1989. Depending on the time interval used for calculation, volumes of annual surface-water inflow range from 7,420 to 7,470 acre-ft for water year 1989 and 7,240 to 7,250 acre-ft for water year 1990. There is little difference between volumes of annual surface-water inflow calculated from daily, monthly, and yearly values; however, monthly values produced the smallest annual volumes, and yearly values produced the largest annual volumes for both water years.

No surface water flowed out of the reservoir during the study. The highest reservoir stage was 1,065.9 ft in June 1990, about 4 ft below the crest of the principal spillway. In addition, no water was released through pipes extending through the dam in order that the reservoir might be allowed to fill.

Ground-Water Inflow and Outflow

The volume of ground-water flow into and out of the reservoir was estimated using Darcy's law and ground-water-level maps drawn from the monthly water-level measurements. Darcy's law states that

$$Q = KIA,$$

where Q = rate of ground-water flow, in ft^3/d;

K = hydraulic conductivity, in ft/d;

I = hydraulic gradient, in ft/ft, and

A = area through which flow occurs, in ft.

This method assumes that horizontal ground-water flow interactions with the reservoir are small and can be considered negligible in comparison with vertical flow. In many ground-water and lake-water interactions, horizontal flow is dominant; however, the assumption made here for Summit Lake Reservoir may be reasonable for several reasons. The reservoir represents a high hydraulic head superimposed on the low hydraulic head of the existing ground-water-flow system. Ground-water levels have risen as the reservoir level has increased; however, ground-water levels may not yet be in equilibrium with the reservoir.

Table 17. *Streamflow volumes calculated by use of daily, monthly, and yearly values, water years 1989-90*

[Numbers in columns may not add to column totals because of rounding. Dashes indicate value not determined]

Month, water year 1989	Streamflow volume by use of daily values (acre-feet)	Streamflow volume by use of monthly values (acre-feet)	Streamflow volume by use of yearly values (acre-feet)
October	18.5	18.4	---
November	57.0	57.3	---
December	77.2	77.8	---
January	426	426	---
February	183	183	---
March	941	942	---
April	1,590	1,590	---
May	1,570	1,560	---
June	445	441	---
July	431	431	---
August	214	215	---
September	1,490	1,480	---
Annual total	7,440	7,420	7,470

Month, water year 1990	Streamflow volume by use of daily values (acre-feet)	Streamflow volume by use of monthly values (acre-feet)	Streamflow volume by use of yearly values (acre-feet)
October	140	140	---
November	480	479	---
December	240	240	---
January	464	464	---
February	1,470	1,470	---
March	967	967	---
April	712	711	---
May	1,350	1,350	---
June	433	434	---
July	365	365	---
August	389	390	---
September	228	228	---
Annual total	7,240	7,240	7,250

In the early stages of reservoir filling, vertical flow would probably dominate, and horizontal flow would dominate only after the reservoir and ground water were at equilibrium. The geologic materials adjacent to the edges of the reservoir are less permeable than the materials beneath the clay liner under the reservoir; therefore, there would be better hydraulic connection through the bottom of the reservoir than through the sides. Vertical hydraulic gradients were determined from ground-water levels measured at well sites where two wells were screened at different depths. At two such sites, E and F, the vertical gradients were much larger than horizontal gradients determined between wells. The presence of large vertical gradients indicates that vertical ground-water flow is not uncommon in the study area.

In many hydrologic-budget studies, the ground-water component is considered as the residual after the other components of the budget equation have been determined. The residual method only provides a net ground-water component. For a lake where ground water flows both in and out, the residual method would provide the difference between inflow and outflow but would not provide the total inflow or total outflow. Use of Darcy's law can provide estimates of inflow and outflow and, therefore, an improved hydrologic budget.

A total of 24 contour maps of ground-water levels were drawn, representing each month that water levels were measured. The area of the reservoir was drawn on the maps by tracing the topographic contour corresponding to the mean lake stage for each month. Ground-water-level contours (figs. 9 and 10) cross the reservoir and divide the total area of the reservoir into smaller areas. Each area of the reservoir between ground-water contours was digitized, and a computer program was used to calculate the area. The sum of the smaller areas was compared to the value obtained from the stage-area relation to assure that the areas were consistent. The hydraulic gradient was determined from the reservoir stage, the average ground-water level between contours, and an assumed lakebed thickness of 1 ft. An initial estimate of vertical hydraulic conductivity of the lakebed was used with data collected during October 1988, and the result determined from application of Darcy's law was compared with the result determined as the residual. Vertical hydraulic conductivity was adjusted until the best match between the two methods was obtained.

The lakebed vertical hydraulic conductivity providing the best match is 4.0×10^{-3} ft/d. This value compares favorably with the average hydraulic conductivity value of 4.8×10^{-7} centimeters per second (1.36×10^{-3} ft/d) reported as the average value of the clay materials used to blanket the lakebed (A.M. Kinney, Inc., 1975, p. 29). If a lakebed thickness of 3 ft is assumed to approximate the average thickness of the clay blanket, a vertical hydraulic conductivity of 1.33×10^{-3} ft/d is necessary to produce the same results. Once the vertical hydraulic conductivity was determined, the same value was used for all calculations of rates of ground-water flow.

The daily volume of inflow to or outflow from the reservoir was calculated for each area of the reservoir between ground-water-level contours by application of Darcy's law. The total daily inflow and total daily outflow were obtained by summing the calculated volumes of either inflow or outflow. The total daily volumes of inflow and outflow were multiplied by the number of days in a month to obtain monthly volumes of inflow or outflow. Monthly volumes were summed to obtain yearly volumes. The net reservoir inflow or outflow was determined by subtracting total calculated volumes of outflow from total calculated volumes of inflow. A positive volume indicated a net flow of water into the reservoir; a negative volume indicated a net flow of water out of the reservoir.

Ground-water-flow rates and monthly and annual totals calculated by use of Darcy's law are listed in table 18. Ground-water outflow from the reservoir exceeded inflow to the reservoir in every month of the study period. The rate of inflow ranged from 0.50 acre-ft/d during August 1990 to 3.9 acre-ft/d during May 1989. The rate of outflow ranged from 11 acre-ft/d during October and December 1988 to 22 acre-ft/d from June through August 1990. The net rate of ground-water flow ranged from 8.3 acre-ft/d during December 1988, to 22 acre-ft/d during August 1990. The total inflow was 1,060 acre-ft during water year 1989, and 740 acre-ft during water year 1990. Total outflow was 4,600 acre-ft during water year 1989 and 6,260 acre-ft during water year 1990.

Table 18. *Ground-water seepage rates and monthly and annual totals calculated by use of Darcy's law, water years 1989-90*

[Numbers in columns may not add to column totals because of rounding]

Month, water year 1989	Daily seepage in (acre-feet)	Daily seepage out (acre-feet)	Daily net seepage out (acre-feet)	Monthly seepage in (acre-feet)	Monthly seepage out (acre-feet)
October	1.9	11	9.3	59	350
November	2.3	12	9.9	70	370
December	2.7	11	8.3	85	340
January	2.5	12	9.0	78	360
February	3.2	13	9.3	90	350
March	3.1	12	9.3	95	380
April	3.6	14	9.9	110	400
May	3.9	15	11	120	460
June	2.8	14	12	85	430
July	3.0	13	9.6	93	390
August	2.2	13	10	69	380
September	3.6	13	9.3	110	390
Annual total				1,060	4,600

Month, water year 1990	Daily seepage in (acre-feet)	Daily seepage out (acre-feet)	Daily net seepage out (acre-feet)	Monthly seepage in (acre-feet)	Monthly seepage out (acre-feet)
October	2.7	13	10	83	410
November	2.1	13	11	64	390
December	3.0	13	10	94	410
January	2.1	15	13	65	480
February	3.0	15	12	85	420
March	2.8	14	12	87	440
April	2.7	17	14	82	500
May	1.8	18	17	57	570
June	1.5	22	20	45	650
July	1.1	22	21	33	700
August	.50	22	22	16	690
September	1.0	20	19	32	610
Annual total				740	6,260

Reservoir Storage

The volume of water in the reservoir was determined directly from the stage-storage relation (fig. 11A). The daily mean stage, in feet above sea level, was 1,050.7 on October 1, 1988; 1,060.1 on September 30 and October 1, 1989; and 1,065.0 on September 30, 1990. The change in storage, in acre-ft, was obtained by subtracting the volume of water in the reservoir on September 30 from the volume of water in the reservoir on October 1 for each water year. The volumes of reservoir storage corresponding to these stages are 4,860, 9,190, and 12,080 acre-ft. The change in reservoir storage was 4,330 acre-ft during water year 1989 and 2,890 acre-ft during water year 1990.

Budget for Water Years 1989 and 1990

Annual hydrologic budgets for water years 1989 and 1990 are listed in table 19. The total inflow was similar during both water years; total inflow averaged 10,350 acre-ft during water year 1989 and 10,330 during water year 1990. Outflow from evaporation and ground-water seepage was 5,700 acre-ft during water year 1989 and about 7,710 acre-ft during water year 1990. The volume of water stored in the reservoir increased during both water years and was added to the outflow side of the equation to balance the hydrologic budget (table 19).

Surface water, the largest component of inflow during both water years, was about 72 percent of the total inflow during water year 1989 and about 70 percent of the inflow during water year 1990. Direct precipitation was about 18 percent of the total inflow during water year 1989 and about 23 percent for water year 1990. Ground-water flow into the reservoir was about 10 percent of the total inflow during water year 1989 and about 7 percent during water year 1990.

Ground-water outflow, which was the largest component of outflow during the two water years, comprised about 81 percent of the outflow during both water years 1989 and 1990. Evaporation, the only other component of outflow during the study, comprised about 19 percent of the outflow during both water years. During water year 1989, the increase in reservoir storage was about 43 percent, ground-water outflow was about 46 percent, and evaporation was about 11 percent of the total outflow plus reservoir storage. During water year 1990, the increase in reservoir storage was about 27 percent, ground-water outflow was about 59 percent, and evaporation was about 14 percent of the total outflow plus reservoir storage.

The hydrologic budget should be evaluated in the context of the accuracy of the collected data and the methods used in the calculations. All hydrologic measurements, no matter how carefully made, are subject to a certain amount of error. Comparison of the inflow and outflow sides of the hydrologic budget (table 19) indicates that the budget is not exact. The total outflow, including reservoir storage, is about 3 percent less than the total inflow during water year 1989 and about 3 percent more than the total inflow during water year 1990.

Generally, errors can be classified into two types--those resulting from measurement and those resulting from regionalization or interpretation (Winter, 1981, p. 82). Because the hydrologic budget is determined from interpretation of measurements of hydrologic data, both types of errors are likely to occur. The absolute magnitude of error is difficult to evaluate and is beyond the scope of this report. Readers interested in a detailed discussion of errors and their effect in hydrologic-budget studies are referred to the report by Winter (1981).

Table 19. *Annual hydrologic budgets for Summit Lake Reservoir, water years 1989-90*

[All values are in acre-feet]

Water year 1989					
Inflow				Outflow and reservoir storage	
	Volume from daily values	Volume from monthly values	Volume from yearly values		Volume from monthly values
Precipitation	1,880	1,880	1,790	Evaporation	[2]1,100
Surface-water inflow	7,440	7,420	7,470	Surface-water outflow	0
Ground-water seepage	[1]1,060	1,060	[1]1,060	Ground-water seepage	4,600
				Reservoir storage	[2]4,330
Total inflow	10,380	10,360	10,320	Total	10,030
Average		10,350			

Water year 1990					
Inflow				Outflow and reservoir storage	
	Volume from daily values	Volume from monthly values	Volume from yearly values		Volume from monthly values
Precipitation	2,380	2,380	2,290	Evaporation	[2]1,450
Surface-water inflow	7,240	7,240	7,250	Surface-water outflow	0
Ground-water seepage	[1]740	740	[1]740	Ground-water seepage	6,260
				Reservoir storage	[2]2,890
Total inflow	10,360	10,360	10,280	Total	10,600
Average		10,330			

[1]Volume determined by use of monthly values.
[2]Volume determined by use of yearly value.

SUMMARY

Summit Lake Reservoir is located in east-central Indiana at Summit Lake State Park, approximately 8 mi northeast of New Castle in Henry County, Indiana. Construction of the earth-fill dam was completed in 1981. The reservoir was designed to contain about 15,300 acre-ft of water and have a surface-area of about 800 acres. In 1988, the reservoir contained only about 4,600 acre-ft of water and had a surface area of about 350 acres. The reservoir has a drainage area of about 9.3 mi^2 and receives streamflow from Big Blue River, Sweringen Ditch, and several small intermittent streams.

Hydrologic data, which included reservoir stage, precipitation, evaporation, streamflow, and ground-water-level data were collected near Summit Lake Reservoir during 2 water years, October 1, 1988, through September 30, 1990. The data were used in conjunction with the reservoir stage-area and stage-storage relations to determine the annual hydrologic budget during each of the two water years. Components of the hydrologic budget are direct precipitation, evaporation, surface-water flow, ground-water seepage, and reservoir storage. The hydrologic budget was calculated from daily, monthly, and yearly values of precipitation and surface-water inflow, monthly values of ground-water seepage, and yearly values of evaporation and reservoir storage.

Inflow to Summit Lake Reservoir was about 10,350 acre-ft during each of the 2 years of study. Surface water was about 72 percent of the total inflow during water year 1989 and about 70 percent during water year 1990. Direct precipitation comprised about 18 percent of the total inflow during water year 1989 and about 23 percent during water year 1990. Ground-water inflow comprised about 10 percent of the total inflow during water year 1989 and about 7 percent during water year 1990.

Outflow from evaporation and ground-water flow was about 5,700 acre-ft during water year 1989 and about 7,710 acre-ft during water year 1990--about 19 percent evaporation and 81 percent ground-water flow during both years. There was no surface-water outflow during the study. The volume of reservoir storage increased during both water years and the change in storage was about 4,330 acre-ft during water year 1989 and about 2,890 acre-ft during water year 1990.

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Table 1. *Daily mean reservoir stage for Summit Lake Reservoir, water year 1989*

[Stage in feet above sea level; e, estimated value]

Day	October	November	December	January	February	March	April	May	June	July	August	September
1	1050.7	1049.9	1050.0	1049.8	1050.6	1050.6	1052.9	1055.9	1058.4	e1058.4	1058.5	1058.4
2	1050.7	1049.9	1050.0	1049.8	1050.6	1050.6	1053.0	1055.9	1058.4	1058.4	1058.4	1058.7
3	1050.7	1049.9	1049.9	1049.8	1050.6	1050.6	1053.3	1055.9	1058.5	1058.4	1058.4	1058.8
4	1050.6	1049.9	1049.9	1049.8	1050.6	1050.6	1054.1	1055.9	1058.5	1058.4	1058.4	1058.8
5	1050.6	1050.1	1049.9	1049.8	1050.6	1050.8	1054.4	1056.0	1058.7	1058.4	1058.4	1058.8
6	1050.6	1050.1	1049.9	1049.9	1050.6	1050.9	1054.5	1056.0	1058.8	1058.4	1058.4	1058.8
7	1050.5	1050.0	1049.8	1050.0	1050.6	1050.9	1054.6	1056.0	1058.8	1058.3	1058.4	1058.7
8	1050.5	1050.0	1049.8	1050.2	1050.6	1050.9	1054.7	1056.0	1058.8	1058.3	1058.3	1058.7
9	1050.4	1050.0	1049.8	1050.3	1050.5	1050.9	1054.8	1056.1	e1058.8	1058.3	1058.3	1058.8
10	1050.4	1050.1	1049.8	1050.3	1050.5	1051.0	1054.8	1056.2	e1058.8	1058.2	1058.3	1059.0
11	1050.4	1050.1	1049.8	1050.3	1050.5	1051.0	1054.8	1056.2	e1058.8	1058.2	1058.2	1059.1
12	1050.3	1050.0	1049.8	1050.4	1050.5	1051.1	1054.8	1056.2	e1058.8	1058.2	1058.2	1059.1
13	1050.3	1050.0	1049.7	1050.4	1050.5	1051.1	1054.8	1056.2	1058.8	1058.2	1058.2	1059.1
14	1050.2	1050.0	1049.7	1050.4	1050.5	1051.1	1054.8	1056.2	e1058.8	1058.1	1058.2	1059.5
15	1050.2	1050.0	1049.7	1050.4	1050.5	1051.2	e1054.8	1056.2	1058.8	1058.1	1058.1	1060.1
16	1050.2	1050.0	1049.7	1050.4	1050.5	1051.2	e1054.8	1056.2	e1058.8	1058.0	1058.1	1060.2
17	1050.2	1050.0	1049.7	1050.4	1050.5	1051.2	e1054.8	1056.2	e1058.7	1058.0	1058.1	1060.3
18	1050.3	1050.0	1049.6	1050.4	1050.5	1051.2	e1054.9	1056.2	1058.7	1058.0	1058.0	1060.3
19	1050.2	1050.0	1049.6	1050.4	1050.5	1051.2	e1055.0	1056.2	1058.6	1058.2	1058.0	1060.4
20	1050.2	1050.1	1049.6	1050.4	1050.5	1051.2	e1055.1	1056.2	1058.7	1058.6	1058.0	1060.4
21	1050.2	1050.1	1049.6	1050.4	1050.6	1051.3	1055.1	1056.2	1058.7	1058.6	1058.0	1060.4
22	1050.2	1050.1	1049.6	1050.4	1050.6	1051.4	1055.1	1056.2	e1058.6	1058.6	1058.1	1060.4
23	1050.2	1050.1	1049.6	1050.4	1050.6	1051.4	1055.1	1056.5	1058.6	1058.6	1058.2	1060.3
24	1050.2	1050.0	1049.6	1050.4	1050.6	1051.4	1055.1	1056.7	e1058.6	1058.7	1058.2	1060.3
25	1050.1	1050.0	1049.6	1050.4	1050.6	1051.4	1055.1	1056.8	e1058.5	1058.7	1058.2	1060.3
26	1050.1	1050.0	1049.6	1050.5	1050.7	1051.4	1055.1	1057.8	e1058.5	1058.7	1058.2	1060.2
27	1050.0	1050.1	1049.6	1050.5	1050.7	1051.4	1055.2	1058.1	e1058.5	1058.7	1058.2	1060.2
28	1050.0	1050.0	1049.8	1050.6	1050.7	1051.4	1055.2	1058.2	e1058.5	1058.6	1058.1	1060.2
29	1050.0	1050.0	1049.8	1050.6		1051.5	1055.5	1058.3	e1058.5	1058.6	1058.2	1060.2
30	1050.0	1050.0	1049.8	1050.6		1052.1	1055.8	1058.3	e1058.5	1058.6	1058.2	1060.1
31	1050.0		1049.8	1050.6		1052.6		1058.4		1058.5	1058.1	
Mean	1050.3	1050.0	1049.8	1050.3	1050.6	1051.2	e1054.7	1056.6	e1058.6	1058.4	1058.2	1059.6
Maximum	1050.7	1050.1	1050.0	1050.6	1050.7	1052.6	1055.8	1058.4	1058.8	1058.7	1058.5	1060.4
Minimum	1050.0	1049.9	1049.6	1049.8	1050.5	1050.6	1052.9	1055.9	1058.4	1058.0	1058.0	1058.4

Table 2. *Daily mean reservoir stage for Summit Lake Reservoir, water year 1990*

[Stage, in feet above sea level; e, estimated value]

Day	October	November	December	January	February	March	April	May	June	July	August	September
1	1060.1	1059.4	1059.6	e1059.4	1059.6	1061.7	1062.7	1063.1	1065.6	1065.5	1065.2	1065.5
2	1060.1	1059.4	1059.6	e1059.4	1059.8	1061.7	1062.8	1063.0	1065.6	1065.4	1065.1	1065.5
3	1060.1	1059.4	1059.6	e1059.4	1059.8	1061.7	1062.8	1063.0	1065.6	1065.4	1065.1	1065.4
4	1060.0	1059.3	1059.5	e1059.5	1060.0	1061.7	1062.8	1063.2	1065.6	1065.4	1065.1	1065.4
5	1060.0	1059.3	1059.5	e1059.6	1060.1	1061.7	1062.8	1063.4	1065.6	1065.3	1065.1	1065.4
6	1060.0	1059.3	1059.5	e1059.6	1060.2	1061.7	1062.8	1063.5	1065.6	1065.3	1065.1	1065.4
7	1060.0	1059.3	1059.5	e1059.6	1060.2	1061.7	1062.7	1063.5	1065.6	1065.2	1065.0	1065.3
8	1059.9	1059.3	1059.5	e1059.6	1060.2	1061.7	1062.7	1063.5	1065.6	1065.2	1065.0	1065.3
9	1059.9	1059.3	1059.4	e1059.6	1060.3	1061.7	1062.7	1063.5	1065.8	1065.2	1065.0	1065.4
10	1059.9	1059.3	1059.4	e1059.6	1060.3	1061.7	1062.8	1063.5	1065.9	1065.1	1064.9	1065.4
11	1059.8	1059.3	1059.4	e1059.6	1060.3	1062.2	1063.0	1063.5	1065.9	1065.2	1064.9	1065.4
12	1059.8	1059.2	1059.4	e1059.6	1060.3	1062.4	1063.0	1063.6	1065.9	1065.3	1064.9	1065.4
13	1059.8	1059.2	1059.4	e1059.6	1060.3	1062.5	1063.0	1064.1	1065.9	1065.4	1064.9	1065.4
14	1059.8	1059.2	1059.4	e1059.5	1060.4	1062.6	1063.1	1064.3	1065.8	1065.4	1064.9	1065.4
15	1059.7	1059.3	1059.4	e1059.5	1060.7	1062.6	1063.1	1064.5	1065.8	1065.4	1064.9	1065.3
16	1059.7	1059.6	1059.3	e1059.5	1061.2	1062.7	1063.1	1065.0	1065.8	1065.3	1064.8	1065.3
17	1059.7	1059.7	1059.3	e1059.5	1061.3	1062.7	1063.1	1065.2	1065.8	1065.3	1064.8	1065.3
18	1059.7	1059.7	1059.3	e1059.5	1061.4	1062.7	1063.1	e1065.4	1065.7	1065.3	1064.9	1065.2
19	1059.7	1059.7	1059.3	e1059.5	1061.4	1062.7	1063.0	e1065.4	1065.7	1065.3	1065.0	1065.2
20	1059.7	1059.7	1059.3	e1059.5	1061.4	1062.7	1063.0	e1065.5	1065.7	1065.2	1065.0	1065.2
21	1059.7	1059.7	1059.2	e1059.6	1061.5	1062.7	1063.1	1065.6	1065.7	1065.2	1065.1	1065.2
22	1059.6	1059.7	1059.2	e1059.6	1061.5	1062.7	1063.1	1065.5	1065.7	1065.3	1065.2	1065.2
23	1059.6	1059.7	1059.2	e1059.6	1061.6	1062.7	1063.1	1065.5	1065.6	1065.4	1065.2	1065.2
24	1059.6	1059.7	1059.2	e1059.6	1061.7	1062.7	1063.1	1065.5	1065.6	1065.4	1065.2	1065.2
25	1059.6	1059.7	1059.2	e1059.6	1062.7	1062.7	1063.1	1065.5	1065.6	1065.4	1065.2	1065.1
26	1059.6	1059.7	1059.2	e1059.6	1061.7	1062.6	1063.1	1065.6	1065.6	1065.4	1065.1	1065.1
27	1059.5	1059.7	1059.2	1059.6	1061.7	1062.6	1063.1	1065.6	1065.5	1065.3	1065.1	1065.1
28	1059.5	1059.7	e1059.1	1059.6	1061.7	1062.6	1063.1	1065.7	1065.5	1065.3	1065.1	1065.0
29	1059.5	1059.6	e1059.1	1059.6		1062.6	1063.1	1065.7	1065.5	1065.3	1065.4	1065.0
30	1059.5	1059.6	e1059.2	1059.6		1062.7	1063.1	1065.7	1065.5	1065.2	1065.5	1065.0
31	1059.5		e1059.4	1059.6		1062.7		1065.6		1065.2	1065.5	
Mean	1059.8	1059.5	e1059.3	e1059.6	1060.8	1062.3	1063.0	1064.6	1065.7	1065.3	1065.1	1065.3
Maximum	1060.1	1059.7	1059.6	1059.6	1061.7	1062.7	1063.1	1065.7	1065.9	1065.5	1065.5	1065.5
Minimum	1059.5	1059.2	1059.1	1059.4	1059.6	1061.7	1062.7	1063.0	1065.5	1065.1	1064.8	1065.0

Table 3. *Daily and monthly precipitation totals at the recording gage, water year 1989*

[Precipitation, in inches; e, estimated value]

Day	October	November	December	January	February	March	April	May	June	July	August	September
1	0.25	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00	e2.06
2	.00	.00	.01	.00	.05	.00	.59	.09	.00	.28	.00	.00
3	.02	.04	.00	.01	.01	.00	1.52	.00	.83	.92	.00	.00
4	.00	1.86	.00	.01	.04	.25	.18	.58	.00	.01	.00	.00
5	.00	.22	.00	.55	.01	.44	.00	.13	.45	.00	e.34	.00
6	.00	.02	.00	.26	.01	.01	.05	.01	.00	.00	e1.21	.00
7	.00	.10	.00	.37	.08	.01	.00	.00	.00	.00	.00	.00
8	.00	.04	.00	.00	.00	.02	.21	.09	.00	.00	.00	.00
9	.00	.24	.00	.00	.00	.00	.01	.56	.00	.00	.00	1.21
10	.00	.46	.00	.00	.07	.00	.00	.00	.00	.00	.00	.70
11	.00	.00	.01	.15	.00	.00	.00	.00	.00	.05	.00	.00
12	.00	.20	.00	.21	.00	.00	.20	.05	.74	.49	e.14	.00
13	.00	.13	.00	.00	.10	.00	.01	.13	.00	.02	.00	.00
14	.00	.00	.00	.23	.01	.09	.00	.00	.13	.00	.00	e2.59
15	.00	.00	.00	.05	.19	.01	.06	.09	.00	.00	.00	.00
16	.53	.38	.02	.00	.00	.00	.00	.00	.00	.00	.00	e.26
17	.80	.00	.00	.00	.00	.00	.41	.00	.00	.00	.00	.00
18	.01	.00	.00	.00	.00	.05	.74	.00	.00	.00	.00	.00
19	.00	.47	.00	.00	.00	.00	.00	.33	.15	3.39	.00	.00
20	.00	.70	.01	.00	.47	.85	.00	.00	.00	.00	e1.60	.00
21	.23	.00	.00	.00	.16	.01	.00	.00	.00	.11	e.50	.00
22	.01	.00	.25	.00	.00	.00	.00	.95	.00	.01	e.70	.00
23	.24	.00	.19	.00	.02	.00	.00	.92	.00	.45	e.18	.00
24	.00	.00	.34	.00	.00	.00	.00	.00	.00	.07	.00	.00
25	.00	.00	.00	.50	.08	.00	.04	2.00	.00	.01	.00	.00
26	.00	.53	.02	.35	.08	.00	.00	.57	.00	.00	.00	.00
27	.10	.12	.77	.00	.00	.00	.50	.00	.43	.01	.00	.00
28	.03	.00	.26	.00	.00	.50	.64	.00	.00	.00	e.49	.00
29	.00	.02	.04	.01		.64	1.27	.30	.00	.00	e.33	.00
30	.00	.00	.22	.00		1.24	.00	.00	.00	.02	.00	.00
31	.00		.01	.00		.37		.00		.01	.00	
Total	2.22	5.53	2.16	2.70	1.38	4.49	6.43	6.80	3.48	5.85	e5.49	e6.82

Table 4. *Daily and monthly precipitation totals at the recording gage, water year 1990*

[Precipitation, in inches; e, estimated value]

Day	October	November	December	January	February	March	April	May	June	July	August	September
1	0.00	0.00	0.01	0.02	0.57	0.03	0.14	0.00	0.00	0.00	0.00	0.00
2	.00	.00	.01	.06	.23	.00	.05	.00	.58	.00	.00	.00
3	.00	.00	.04	.00	.33	.00	.00	.54	.20	.00	.00	.00
4	.00	.00	.00	.41	.12	.03	.01	1.22	.00	.00	1.29	.00
5	.00	.01	.00	.00	.10	.00	.01	.03	.00	.00	.00	.00
6	.08	.00	.10	.00	.09	.01	.00	.00	.08	.00	.00	.00
7	.01	.44	.10	.00	.00	.00	.00	.00	.00	.00	.00	.18
8	.00	.46	.07	.00	.01	.13	.00	.00	.89	.00	.00	.24
9	.00	.03	.07	.12	.25	.00	.00	.05	.83	.00	.00	1.45
10	.08	.01	.02	.00	.00	1.12	1.36	.50	.00	.00	.00	.00
11	.00	.00	.02	.01	.08	1.12	.10	.00	.00	1.31	.00	.00
12	.00	.00	.13	.00	.01	.02	.00	2.13	.00	1.17	.03	.00
13	.00	.00	.05	.01	.01	.00	.00	.36	.00	.00	1.19	.00
14	.00	.35	.07	.00	.37	.00	.14	.00	.00	.62	.01	.29
15	.00	1.69	.01	.00	1.65	.48	.00	1.48	.00	.00	.00	.00
16	.04	.07	.02	.00	.10	.04	.00	.76	.00	.00	.00	.02
17	.10	.10	.04	.12	.00	.01	.06	.06	.00	.00	.00	.00
18	.01	.04	.05	.01	.00	.01	.03	.00	.00	.00	1.52	.09
19	.17	.04	.05	.11	.00	.01	.00	.38	.00	.00	.09	.30
20	.16	.00	.05	.38	.01	.04	.61	.11	.71	.39	.07	.01
21	.00	.00	.03	.07	.00	.00	.02	.01	.00	.24	1.38	.81
22	.01	.00	.00	.00	.70	.00	.00	.00	.10	1.35	.00	.14
23	.00	.09	.05	.03	.06	.00	.00	.00	.25	.00	.00	.01
24	.00	.05	.02	.00	.02	.02	.00	.00	.00	.00	.00	.00
25	.00	.00	.00	.14	.10	.01	.00	.52	.00	.01	.00	.00
26	.00	.04	.07	.00	.06	.00	.00	.40	.36	.00	.00	.00
27	.00	.08	.00	.00	.10	.00	.00	.01	.01	.00	.00	.00
28	.00	.02	.00	.00	.01	.00	.72	.12	.00	.00	.10	.00
29	.00	.02	.41	.17		.48	.00	.00	.00	.00	1.32	.01
30	.00	.01	.27	.05		.36	.00	.01	.15	.00	.00	.00
31	.13		.26	.00		.05		.00		.00	.00	
Total	0.79	3.55	2.02	1.71	4.98	3.97	3.25	8.69	4.16	5.09	7.00	3.55

Table 5. *Daily and monthly precipitation totals at the manual gage, water year 1989*

[Precipitation, in inches]

Day	October	November	December	January	February	March	April	May	June	July	August	September
1	0.25	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	2.06
2	.00	.00	.00	.00	.02	.00	.21	.00	.91	.00	.00	.00
3	.02	.00	.00	.00	.20	.00	.40	.05	.00	1.00	.00	.00
4	.00	.81	.00	.00	.00	.42	1.50	.00	.18	.00	.00	.00
5	.00	.85	.00	.00	.00	.58	.00	.47	.42	.00	.34	.00
6	.00	.31	.00	1.85	.00	.50	.00	.03	.03	.00	1.21	.00
7	.00	.00	.00	.25	.00	.06	.05	.00	.00	.00	.00	.00
8	.00	.00	.00	.00	.00	.00	.04	.00	.00	.00	.00	.00
9	.00	.00	.00	.00	.00	.00	.00	.72	.00	.00	.00	.58
10	.00	.77	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.55
11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
12	.00	.04	.00	.32	.00	.00	.00	.00	.73	.45	.14	.00
13	.00	.00	.00	.00	.31	.00	.36	.20	.00	.12	.00	2.59
14	.00	.00	.00	.00	.06	.00	.00	.00	.17	.00	.00	.00
15	.00	.00	.00	.24	.08	.01	.06	.00	.00	.00	.00	.00
16	.41	.73	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04
17	.00	.00	.00	.00	.00	.00	.47	.00	.00	.00	.00	.22
18	.46	.00	.00	.00	.00	.00	.76	.00	.00	.00	.00	.00
19	.01	.00	.00	.00	.00	.00	.00	.00	.00	2.20	.00	.00
20	.00	.90	.00	.00	.24	.72	.00	.31	.19	1.10	.00	.00
21	.15	.08	.00	.00	.51	.08	.00	.00	.00	.00	1.60	.00
22	.12	.00	.00	.00	.00	.00	.00	.20	.00	.20	.50	.00
23	.27	.00	.00	.00	.00	.00	.00	2.04	.00	.63	.88	.00
24	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04	.00	.00
25	.00	.00	.00	.00	.00	.00	.02	.05	.00	.00	.00	.00
26	.00	.00	.00	.76	.00	.00	.00	1.97	.00	.00	.00	.00
27	.00	.60	.98	.00	.00	.00	.61	.00	.00	.00	.00	.00
28	.15	.00	.00	.00	.00	.00	.50	.00	.46	.00	.49	.00
29	.00	.00	.00	.00		.55	.96	.24	.00	.00	.33	.00
30	.00	.00	.00	.02		1.84	.00	.00	.00	.12	.00	.00
31	.00		.00	.00		.00		.00		.00	.00	
Total	1.84	5.09	.98	3.44	1.42	4.76	6.33	6.28	3.09	5.86	5.49	7.04

Table 6. *Daily and monthly precipitation totals at the manual gage, water year 1990*

[Precipitation in inches]

Day	October	November	December	January	February	March	April	May	June	July	August	September
1	0.00	0.00	0.00	0.00	0.12	0.00	0.60	0.00	0.00	0.00	0.00	0.00
2	.00	.00	.00	.00	.00	.00	.17	.00	.00	.00	.00	.00
3	.00	.00	.00	.00	1.00	.00	.00	.01	.60	.00	.00	.00
4	.00	.00	.00	.29	.00	.00	.00	1.12	.00	.00	.00	.00
5	.00	.00	.00	.00	.60	.00	.00	.70	.00	.00	2.50	.00
6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8	.00	.88	.00	.00	.00	.00	.00	.00	.50	.00	.00	.00
9	.00	.00	.00	.75	.29	.16	.00	.50	1.20	.00	.00	.00
10	.00	.00	.00	.00	.00	.00	1.17	.00	.00	2.65	.00	.00
11	.00	.00	.00	.00	.00	2.25	.21	.00	.00	.00	.00	.00
12	.00	.00	.00	.25	.00	.00	.00	1.11	.00	.00	.00	.00
13	.00	.00	.00	.00	.00	.00	.00	1.22	.00	.39	1.17	.00
14	.00	.00	.00	.00	1.64	.00	.30	.05	.00	.46	.00	.32
15	.00	.00	.00	.00	.46	.53	.00	.83	.00	.00	.00	.00
16	.20	2.26	.00	.00	.19	.00	.00	1.05	.00	.00	.00	.05
17	.00	.00	.00	.00	.00	.00	.06	.46	.00	.00	.00	.00
18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.62	.00
19	.00	.00	.00	.54	.00	.00	.13	.00	.00	.00	.00	.43
20	.00	.00	.00	.00	.00	.00	.00	.00	.60	.00	.12	.00
21	.95	.00	.00	.00	.00	.00	.50	.00	.00	.00	1.26	.00
22	.00	.00	.00	.00	.59	.00	.00	.00	.00	.00	.00	.00
23	.00	.00	.00	.00	.00	.00	.00	.00	.10	.00	.00	1.10
24	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
25	.00	.00	.00	.00	.00	.00	.00	.48	.00	.00	.00	.00
26	.00	.07	.00	.00	.00	.00	.00	.57	.00	.00	.00	.00
27	.00	.00	.00	.00	.22	.00	.00	.00	.58	.00	.00	.00
28	.00	.00	.00	.00	.00	.00	.58	.00	.00	.00	2.20	.00
29	.00	.00	.00	.58		.00	.00	.18	.00	.00	.00	.00
30	.00	.00	.93	.00		.57	.00	.00	.20	.00	.00	.00
31	.14		.47	.00		.36		.00		.00	.00	
Total	1.29	3.21	1.40	2.41	5.11	3.87	3.72	8.28	3.78	3.50	8.87	1.90

Table 7. *Monthly pan-evaporation totals, water years 1989-90*

[Evaporation, in inches; ---, no data]

Water year 1989

October	November	December	January	February	March	April	May	June	July	August	September
3.352	3.492	---	---	---	---	---	5.318	6.561	7.978	6.106	4.023

Total measured pan evaporation is 36.830 inches.

Water year 1990

October	November	December	January	February	March	April	May	June	July	August	September
2.909	1.975	---	---	---	---	4.645	5.886	7.270	6.540	5.105	3.867

Total measured pan evaporation is 38.197 inches.

Table 8. *Daily mean streamflow for Big Blue River, water year 1989*

[Streamflow, in cubic feet per second]

Day	October	November	December	January	February	March	April	May	June	July	August	September
1	0.17	0.14	0.33	0.76	0.93	0.78	15	6.3	3.7	0.72	0.70	45
2	.15	.14	.30	.63	.79	.74	13	4.2	3.4	.75	.64	13
3	.13	.14	.28	.58	.79	.75	26	3.0	11	2.2	.63	6.8
4	.12	.44	.27	.46	.71	1.1	65	2.9	8.6	1.2	.60	3.1
5	.12	.44	.28	.50	.71	8.0	16	5.5	9.3	.93	2.8	2.1
6	.12	.30	.25	8.8	.65	4.6	11	3.5	5.4	.81	4.0	1.6
7	.12	.25	.24	10	.57	2.2	7.6	2.6	3.4	.73	1.3	1.2
8	.12	.25	.23	13	.52	1.4	5.2	2.2	2.7	.67	.87	1.1
9	.12	.23	.22	4.0	.46	1.9	4.2	5.0	2.3	.65	.72	4.0
10	.12	.61	.24	2.0	.49	4.3	3.4	5.0	1.9	.62	.65	29
11	.12	.38	.23	1.3	.51	6.0	2.9	3.0	1.7	.60	.61	7.8
12	.12	.30	.22	3.3	.48	4.6	2.6	2.4	2.7	.76	.79	3.6
13	.12	.33	.25	2.4	.58	3.0	2.3	2.3	2.1	.69	.67	2.3
14	.12	.27	.28	1.6	.71	2.5	2.1	2.0	1.8	.60	.59	88
15	.12	.25	.27	1.3	.90	2.0	2.0	1.8	1.6	.55	.57	26
16	.15	.34	.24	1.1	1.2	1.5	1.8	1.6	1.5	.54	.55	13
17	.20	.36	.23	1.1	.95	1.4	1.8	1.5	1.3	.51	.59	10
18	.21	.27	.21	1.1	.83	1.3	6.1	1.4	1.2	.49	.57	6.2
19	.15	.24	.22	1.2	.77	1.1	8.6	1.4	1.2	34	.56	3.6
20	.14	1.6	.22	1.0	1.0	4.1	4.0	1.6	1.2	15	3.3	2.8
21	.15	1.3	.21	.81	5.3	5.6	2.8	1.3	1.1	3.9	1.3	2.4
22	.15	.68	.20	.75	2.8	2.9	2.3	1.4	1.0	1.8	6.8	2.3
23	.16	.47	.28	.68	1.5	2.1	1.9	44	.98	4.5	4.7	1.8
24	.16	.38	.44	.64	1.1	1.7	1.7	12	.94	4.0	2.4	1.7
25	.15	.33	.42	.65	1.0	1.5	1.6	15	.92	1.9	1.8	1.6
26	.14	.35	.33	3.9	1.2	1.3	1.5	100	.85	1.3	1.5	1.4
27	.14	1.1	.41	3.2	1.0	1.2	2.8	15	.97	1.1	1.4	1.3
28	.15	.69	5.8	1.9	.92	1.3	7.3	9.2	.90	.93	1.5	1.2
29	.14	.45	2.6	1.5		5.7	37	6.9	.78	.82	2.3	1.2
30	.14	.40	1.5	1.3		61	12	4.1	.74	.85	2.4	1.2
31	.14		.96	1.1		27		3.2		.78	1.1	
Total	4.36	13.43	18.16	72.56	29.37	164.57	271.5	271.3	77.18	84.90	48.91	286.3
Mean	.14	.45	.59	2.34	1.05	5.31	9.05	8.75	2.57	2.74	1.58	9.54
Maximum	.21	1.6	5.8	13	5.3	61	65	100	11	34	6.8	88
Minimum	.12	.14	.20	.46	.46	.74	1.5	1.3	.74	.49	.55	1.1

Table 9. *Daily mean streamflow for Big Blue River, water year 1990*

[Streamflow, in cubic feet per second; e, estimated value]

Day	October	November	December	January	February	March	April	May	June	July	August	September
1	1.2	0.76	0.97	4.7	4.3	3.1	4.2	1.6	e2.2	e1.3	e0.84	e1.8
2	1.1	.72	.99	2.2	17	2.9	3.8	1.5	e3.2	e1.2	e.80	e1.6
3	1.0	.70	.87	2.0	8.4	2.6	2.9	1.7	e2.7	e1.1	e.80	e1.4
4	1.0	.70	.93	9.8	19	2.2	2.5	e9.7	e2.2	e1.1	e1.3	e1.3
5	1.0	.70	.94	4.7	8.7	2.1	2.2	e15	e2.1	e1.0	e2.4	e1.2
6	1.0	.68	.91	2.7	6.0	1.9	2.0	e6.0	e2.1	e1.0	e1.1	e1.1
7	.96	.87	.82	2.0	5.4	1.8	1.8	e3.2	e2.0	e.98	e.90	e1.0
8	.93	1.7	.80	1.7	4.0	1.9	1.7	e2.5	e2.5	e.94	e.82	e1.1
9	.89	1.5	.78	1.7	4.6	1.9	1.6	e2.1	e13	e.90	e.80	e3.1
10	.93	1.3	.78	2.0	4.1	5.0	15	e2.1	e5.0	e.90	e.74	e2.0
11	.87	1.2	.76	1.7	3.2	52	13	e2.0	e2.5	e1.1	e.74	e1.7
12	.83	1.1	.71	1.3	2.6	14	7.0	e6.0	e2.2	e5.6	e.74	e1.4
13	.81	1.0	.69	1.0	2.4	8.2	4.6	e24	e2.1	e4.0	e1.3	e1.2
14	.80	.96	.68	1.0	5.7	5.2	3.6	e6.0	e2.0	e3.3	e1.0	e1.3
15	.79	22	.67	.99	68	4.2	3.0	e12	e1.9	e2.0	e.90	e1.7
16	.78	22	.62	1.0	25	7.0	2.6	e42	e1.8	e1.5	e.78	e1.4
17	.80	7.3	.60	1.4	12	4.7	2.3	e15	e1.7	e1.2	e.74	e1.2
18	.76	4.1	.60	1.7	8.3	3.4	2.0	e6.8	e1.6	e1.0	e3.6	e1.0
19	.92	2.8	.65	1.4	5.1	2.8	1.9	e5.4	e1.5	e.92	e1.8	e1.2
20	1.1	2.6	.62	4.2	3.7	2.5	2.4	e4.7	e1.9	e1.5	e2.5	e1.0
21	1.6	2.0	.60	4.7	3.2	2.3	3.4	e4.2	e1.8	e4.0	e6.8	e1.1
22	1.4	1.8	.56	2.9	8.8	2.2	2.6	e3.2	e1.6	e7.2	e3.0	e1.8
23	1.0	1.5	.56	2.3	7.4	2.0	2.2	e2.8	e1.5	e5.2	e2.2	e1.6
24	1.0	1.6	.55	1.9	4.7	2.0	2.0	e2.6	e1.4	e2.0	e1.8	e1.4
25	1.0	1.4	.60	1.9	3.3	1.9	1.8	e2.7	e1.4	e1.5	e1.5	e1.2
26	.97	1.4	.61	1.5	2.8	1.8	1.7	e4.0	e1.3	e1.3	e1.2	e1.0
27	.96	1.3	.61	1.4	3.4	1.7	1.7	e3.6	e1.3	e1.1	e1.0	e.96
28	.96	1.2	.60	1.2	3.6	1.6	2.1	e3.1	e1.3	e1.0	e.94	e.93
29	.85	1.0	.76	1.3		2.0	2.3	e2.7	e1.3	e.96	e12	e.90
30	.85	1.0	4.8	1.2		3.1	1.9	e2.5	e1.3	e.90	e4.7	e.90
31	.88		23	1.1		5.3		e2.3		e.88	e2.5	
Total	29.94	88.89	48.64	70.59	254.7	155.3	101.8	e203.0	e70.4	e58.58	e62.24	e40.49
Mean	.97	2.96	1.57	2.28	9.10	5.01	3.39	e6.55	e2.35	e1.89	e2.01	e1.35
Maximum	1.6	22	23	9.8	68	52	15	e42	e13	e7.2	e12	e3.1
Minimum	.76	.68	.55	.99	2.4	1.6	1.6	e1.5	e1.3	e.88	e.74	e.90

Table 10. *Daily mean reservoir stage for the upper pool of Summit Lake Reservoir, water year 1989*

[Stage, in feet above sea level; e, estimated value]

Day	October	November	December	January	February	March	April	May	June	July	August	September
1	1067.6	1067.3	1068.7	1069.4	1069.8	1069.8	1070.4	1070.2	1070.0	1069.7	1069.7	1070.1
2	1067.6	1067.3	1068.7	1069.4	1069.8	1069.8	1070.2	1070.1	1070.0	1069.7	1069.7	1070.2
3	1067.6	1067.3	1068.7	1069.4	1069.8	1069.8	1070.3	1070.0	1070.0	e1069.7	1069.7	1070.1
4	1067.6	1067.4	1068.7	1069.4	1069.8	1069.8	1070.8	1070.0	1070.1	e1069.7	1069.7	1070.0
5	1067.5	1067.6	1068.7	1069.5	1069.8	1069.9	1070.5	1070.0	1070.1	e1069.7	1069.7	1069.9
6	1067.5	1067.6	1068.7	1069.7	1069.8	1070.0	1070.3	1070.0	1070.1	1069.8	1069.8	1069.9
7	1067.5	1067.7	1068.7	1070.0	1069.8	1070.0	1070.2	1070.0	1070.0	1069.7	1069.7	1069.8
8	1067.5	1067.7	1068.7	1070.1	1069.8	1070.0	1070.1	1070.0	1070.0	1069.7	1069.7	1069.8
9	1067.4	1067.7	1068.7	1070.0	1069.8	1069.9	1070.1	1070.0	1069.9	1069.7	1069.7	1069.8
10	1067.4	1067.8	1068.7	1070.0	1069.8	1069.9	1070.0	1070.0	1069.9	1069.7	1069.7	1070.1
11	1067.4	1067.8	1068.7	1069.9	1069.8	1070.0	1070.0	1070.0	1069.9	1069.7	1069.6	1070.1
12	1067.4	1067.8	1068.7	1070.0	1069.8	1070.0	1070.0	1070.0	1069.9	1069.7	1069.6	1070.0
13	1067.4	1067.9	1068.7	1069.9	1069.8	1070.0	1070.0	1070.0	1069.9	1069.7	1069.6	1069.9
14	1067.4	1067.9	1068.7	1069.9	1069.8	1070.0	1069.9	1070.0	1069.9	1069.7	1069.6	1070.4
15	1067.3	1067.9	1068.7	1069.9	1069.8	1069.9	1069.9	1069.9	1069.9	1069.7	1069.6	1070.6
16	1067.3	1068.0	1068.7	1069.9	1069.8	1069.9	1069.9	1069.9	1069.8	1069.7	1069.6	1070.3
17	1067.4	1068.0	1068.7	1069.9	1069.8	1069.9	1069.9	1069.9	1069.8	1069.7	1069.6	1070.2
18	1067.5	1068.0	1068.7	1069.8	1069.8	1069.9	1070.0	1069.9	1069.8	1069.6	1069.6	1070.1
19	1067.4	1068.0	1068.7	1069.8	1069.8	1069.9	1070.1	1069.9	1069.8	1069.9	1069.6	1070.0
20	1067.4	1068.2	1068.7	1069.8	1069.8	1069.9	1070.1	1069.9	1069.8	1070.3	1069.6	1070.0
21	1067.4	1068.4	1068.7	1069.8	1069.9	1070.0	1070.0	1069.9	1069.8	1070.1	1069.7	1069.9
22	1067.4	1068.4	1068.7	1069.8	1069.9	1070.0	1070.0	1069.9	1069.8	1070.0	1069.8	1069.9
23	1067.4	1068.5	1068.7	1069.8	1069.9	1070.0	1070.0	1070.3	1069.8	1070.0	1069.9	1069.9
24	1067.4	1068.5	1068.7	1069.8	1069.9	1069.9	1069.9	1070.3	1069.7	1069.9	1069.8	1069.9
25	1067.4	1068.5	1068.8	1069.8	1069.8	1069.9	1069.9	1070.2	1069.7	1069.9	1069.8	1069.8
26	1067.4	1068.5	1068.8	1069.9	1069.9	1069.9	1069.9	1070.9	1069.7	1069.8	1069.8	1069.8
27	1067.4	1068.6	1068.8	1069.9	1069.8	1069.9	1069.9	1070.5	1069.7	1069.8	1069.8	1069.8
28	1067.4	1068.7	1069.1	1069.9	1069.8	1069.9	1070.0	1070.3	e1069.7	1069.8	1069.8	1069.8
29	1067.4	1068.7	1069.3	1069.9		1069.9	1070.3	1070.2	e1069.7	1069.8	1069.8	1069.8
30	1067.4	1068.7	1069.3	1069.9		1070.5	1070.3	1070.0	1069.7	1069.8	1069.8	1069.8
31	1067.4		1069.4	1069.9		1070.5		1070.0		1069.7	1069.8	
Mean	1067.4	1068.0	1068.8	1069.8	1069.8	1070.0	1070.1	1070.1	1069.9	1069.8	1069.7	1070.0
Maximum	1067.6	1068.7	1069.4	1070.1	1069.9	1070.5	1070.8	1070.9	1070.1	1070.3	1069.9	1070.6
Minimum	1067.3	1067.3	1068.7	1069.4	1069.8	1069.8	1069.9	1069.9	1069.7	1069.6	1069.6	1069.8

Table 11. *Daily mean reservoir stage for the upper pool of Summit Lake Reservoir, water year 1990*

[Stage, in feet above sea level]

Day	October	November	December	January	February	March	April	May	June	July	August	September
1	1069.8	1069.7	1069.8	1070.1	1069.9	1070.0	1070.0	1069.9	1069.9	1069.8	1069.8	1069.9
2	1069.8	1069.7	1069.8	1070.0	1070.1	1069.9	1070.0	1069.9	1069.9	1069.8	1069.8	1069.9
3	1069.7	1069.7	1069.8	1069.9	1070.1	1069.9	1070.0	1069.9	1069.9	1069.7	1069.7	1069.8
4	1069.7	1069.7	1069.8	1070.0	1070.2	1069.9	1070.0	1070.1	1069.9	1069.7	1069.8	1069.8
5	1069.7	1069.7	1069.8	1070.0	1070.2	1069.9	1070.0	1070.2	1069.9	1069.7	1069.8	1069.8
6	1069.7	1069.7	1069.8	1069.9	1070.1	1069.9	1070.0	1070.2	1069.9	1069.7	1069.8	1069.8
7	1069.7	1069.7	1069.8	1069.9	1070.1	1069.9	1069.9	1070.1	1069.9	1069.7	1069.8	1069.7
8	1069.7	1069.8	1069.8	1069.9	1070.0	1069.9	1069.9	1070.0	1069.9	1069.6	1069.7	1069.7
9	1069.7	1069.8	1069.8	1069.9	1070.0	1069.9	1069.9	1070.0	1070.2	1069.6	1069.7	1069.9
10	1069.7	1069.8	1069.8	1069.9	1070.0	1069.9	1070.0	1070.0	1070.2	1069.6	1069.7	1069.9
11	1069.7	1069.8	1069.7	1069.9	1070.0	1070.5	1070.2	1069.9	1070.0	1069.7	1069.7	1069.8
12	1069.7	1069.8	1069.7	1069.8	1069.9	1070.4	1070.2	1070.1	1070.0	1069.9	1069.7	1069.8
13	1069.7	1069.8	1069.7	1069.8	1069.9	1070.2	1070.1	1070.6	1069.9	1070.0	1069.8	1069.8
14	1069.7	1069.8	1069.7	1069.8	1070.0	1070.1	1070.1	1070.4	1069.9	1070.0	1069.8	1069.8
15	1069.7	1069.9	1069.7	1069.8	1070.5	1070.1	1070.0	1070.4	1069.8	1070.0	1069.7	1069.8
16	1069.7	1070.2	1069.7	1069.8	1070.5	1070.1	1070.0	1070.6	1069.8	1069.9	1069.7	1069.8
17	1069.7	1070.1	1069.7	1069.8	1070.3	1070.1	1070.0	1070.5	1069.8	1069.9	1069.7	1069.7
18	1069.7	1070.0	1069.7	1069.8	1070.2	1070.0	1070.0	1070.3	1069.8	1069.8	1069.9	1069.7
19	1069.8	1070.0	1069.7	1069.8	1070.1	1070.0	1069.9	1070.2	1069.8	1069.8	1069.9	1069.8
20	1069.8	1069.9	1069.8	1069.9	1070.0	1070.0	1069.9	1070.2	1069.8	1069.8	1069.9	1069.8
21	1069.8	1069.9	1069.7	1070.0	1070.0	1070.0	1070.0	1070.1	1069.8	1069.9	1070.1	1069.8
22	1069.8	1069.8	1069.7	1069.9	1070.0	1069.9	1070.0	1070.0	1069.8	1070.0	1070.1	1069.9
23	1069.8	1069.8	1069.7	1069.9	1070.1	1069.9	1070.0	1070.0	1069.8	1070.1	1070.0	1069.9
24	1069.8	1069.8	1069.7	1069.9	1070.0	1069.9	1070.0	1070.0	1069.8	1070.0	1070.0	1069.8
25	1069.8	1069.8	1069.7	1069.9	1070.0	1069.9	1069.9	1070.0	1069.8	1069.9	1069.9	1069.8
26	1069.7	1069.8	1069.7	1069.9	1070.0	1069.9	1069.9	1070.0	1069.8	1069.9	1069.8	1069.8
27	1069.7	1069.8	1069.7	1069.9	1070.0	1069.9	1069.9	1070.1	1069.8	1069.8	1069.8	1069.8
28	1069.7	1069.8	1069.7	1069.9	1070.0	1069.9	1069.9	1070.0	1069.8	1069.8	1069.8	1069.8
29	1069.7	1069.8	1069.7	1069.9		1069.9	1070.0	1070.0	1069.8	1069.8	1070.1	1069.8
30	1069.7	1069.8	1069.8	1069.9		1070.0	1070.0	1069.9	1069.8	1069.8	1070.1	1069.8
31	1069.7		1070.2	1069.9		1070.0		1069.9		1069.8	1070.0	
Mean	1069.7	1069.8	1069.8	1069.9	1070.1	1070.0	1070.0	1070.1	1069.9	1069.8	1069.8	1069.8
Maximum	1069.8	1070.2	1070.2	1070.1	1070.5	1070.5	1070.2	1070.6	1070.2	1070.1	1070.1	1069.9
Minimum	1069.7	1069.7	1069.7	1069.8	1069.9	1069.9	1069.9	1069.9	1069.8	1069.6	1069.7	1069.7

Table 12. *Daily mean streamflow for Sweringen Ditch, water year 1989*

[Streamflow, in cubic feet per second; e, estimated]

Day	October	November	December	January	February	March	April	May	June	July	August	September
1	0.00	0.00	0.00	0.00	1.3	0.72	16	9.7	4.1	0.00	0.03	9.0
2	.00	.00	.00	.00	1.2	.57	11	7.2	4.5	.00	.00	11
3	.00	.00	.00	.00	1.4	.52	14	5.6	4.8	e.37	.00	6.9
4	.00	.00	.00	.00	1.1	.73	33	4.6	7.0	e.25	.00	4.3
5	.00	.00	.00	.00	1.0	3.2	20	5.7	7.0	e.25	.03	3.0
6	.00	.00	.00	.50	.90	5.8	13	5.6	6.3	.20	.15	2.0
7	.00	.00	.00	3.6	.65	5.0	9.2	4.6	4.6	.11	.03	1.3
8	.00	.00	.00	7.2	.55	3.6	7.3	3.8	3.3	.02	.00	.84
9	.00	.00	.00	5.5	.45	2.9	6.0	4.9	2.6	.00	.00	1.3
10	.00	.00	.00	3.9	.36	3.2	4.9	5.6	2.1	.00	.00	6.5
11	.00	.00	.00	3.1	.35	4.4	4.0	4.8	1.7	.00	.00	6.9
12	.00	.00	.00	3.4	.25	4.9	3.4	3.8	2.2	.02	.00	4.7
13	.00	.00	.00	3.1	.37	4.1	3.3	3.9	2.4	.03	.00	3.2
14	.00	.00	.00	2.6	.60	3.3	2.7	3.5	2.1	.01	.00	20
15	.00	.00	.00	2.3	.77	3.1	2.5	3.1	1.8	.00	.00	24
16	.00	.00	.00	1.8	.93	2.4	2.3	2.7	1.5	.00	.00	15
17	.00	.00	.00	1.6	.83	2.0	2.2	2.4	1.3	.00	.00	10
18	.00	.00	.00	1.4	.78	1.8	4.0	2.1	.99	.00	.00	6.8
19	.00	.00	.00	1.3	.70	1.5	8.1	1.8	.80	4.1	.00	5.1
20	.00	.00	.00	1.2	.86	2.6	6.8	2.4	1.0	12	.00	4.0
21	.00	.00	.00	.91	2.5	5.3	5.4	2.2	.91	8.0	.00	3.2
22	.00	.00	.00	.79	2.8	4.5	4.2	2.1	.65	4.9	.44	2.6
23	.00	.00	.00	.70	2.2	3.6	3.5	15	.46	3.5	1.6	2.1
24	.00	.00	.00	.70	1.6	2.9	2.8	13	.30	3.1	1.4	1.6
25	.00	.00	.00	.73	1.3	2.5	2.5	10	.20	2.0	.87	1.3
26	.00	.00	.00	2.1	1.5	2.1	2.5	40	.11	1.3	.46	1.0
27	.00	.00	.00	3.2	1.3	1.7	3.2	22	.07	.87	.20	.78
28	.00	.00	.00	2.7	1.1	1.7	5.4	13	e.15	.49	.16	.64
29	.00	.00	.00	2.2		3.1	14	8.9	e.03	.23	.42	.55
30	.00	.00	.00	1.8		20	14	6.4	.00	.17	.65	.46
31	.00		.00	1.4		21		5.0		.10	.40	
Total	0.00	0.00	0.00	59.73	29.65	124.74	231.2	225.4	64.97	42.02	6.84	160.07
Mean	.000	.000	.000	1.93	1.06	4.02	7.71	7.27	2.17	1.36	.22	5.34
Maximum	.00	.00	.00	7.2	2.8	21	33	40	7.0	12	1.6	24
Minimum	.00	.00	.00	.00	.25	.52	2.2	1.8	.00	.00	.00	.46

Table 13. *Daily mean streamflow for Sweringen Ditch, water year 1990*

[Streamflow, in cubic feet per second; e, estimated]

Day	October	November	December	January	February	March	April	May	June	July	August	September
1	0.46	0.17	0.70	7.4	2.7	4.1	6.2	3.6	2.8	0.75	0.72	3.6
2	.46	.17	.60	4.8	8.8	3.7	6.1	3.0	3.1	.51	.51	2.5
3	.40	.17	.57	3.3	9.3	3.5	5.7	3.1	3.6	.33	.36	1.8
4	.31	.12	.57	4.8	12	3.0	5.1	7.1	3.4	.18	.69	1.2
5	.21	.08	.57	5.2	10	2.8	4.8	13	2.9	.07	1.6	.74
6	.25	.10	.64	3.8	8.2	2.7	4.4	9.9	2.5	.01	.93	.45
7	.24	.35	.59	2.8	6.8	2.4	3.9	7.4	2.5	.00	.49	.33
8	.20	1.0	.47	2.3	5.5	2.4	3.6	5.6	2.9	.00	.27	.39
9	.15	1.2	.46	2.2	5.2	2.7	3.3	4.2	11	.00	.13	2.5
10	.14	.95	.45	2.3	4.8	3.2	6.9	4.3	10	.00	.05	2.5
11	.10	.74	.40	2.2	4.3	24	12	3.8	6.7	.09	.01	1.7
12	.05	.63	.35	1.8	3.7	19	10	7.5	4.6	3.6	.00	1.1
13	.05	.43	.35	1.6	3.2	12	8.0	27	3.3	5.4	.68	.86
14	.04	.49	.33	1.5	4.5	8.8	6.8	19	2.4	5.9	.65	.70
15	.02	3.5	.38	1.4	22	7.1	5.9	17	2.0	5.0	.36	.64
16	.02	13	.33	1.5	24	7.9	5.1	29	1.5	3.7	.21	.52
17	.07	9.0	.25	1.7	16	6.9	4.7	23	1.3	2.6	.13	.33
18	.05	6.2	.25	2.0	11	5.9	4.0	14	.96	2.0	3.6	.27
19	.42	4.5	.25	1.9	8.0	5.2	3.5	10	.65	1.6	3.8	.64
20	.60	3.5	.23	2.9	6.3	4.6	3.9	8.2	1.2	1.4	2.9	.64
21	.74	2.6	.19	4.0	5.2	4.2	5.2	7.2	1.4	2.6	7.7	.87
22	.80	2.0	.17	3.9	6.5	3.9	4.8	6.0	1.1	5.4	9.1	2.2
23	.66	1.4	.13	3.4	7.7	3.8	4.4	5.0	1.2	7.7	6.3	2.2
24	.57	1.2	.11	3.1	6.5	3.6	4.0	4.3	1.3	5.4	4.1	1.7
25	.46	1.1	.15	2.7	5.0	3.3	3.6	4.2	.99	3.7	2.7	1.3
26	.39	1.1	.17	2.7	4.0	3.2	3.2	6.0	.89	2.7	1.8	1.0
27	.31	.93	.21	2.3	4.0	3.0	2.8	7.3	1.1	2.0	1.2	.76
28	.25	1.0	.17	2.2	4.4	2.9	3.0	6.0	.89	1.7	.91	.56
29	.22	.82	.30	2.5		3.5	4.6	5.1	.64	1.4	7.5	.51
30	.17	.70	1.1	2.4		4.4	4.2	3.9	.62	1.2	8.1	.41
31	.23		9.6	2.2		5.9		3.2		.91	5.3	
Total	9.04	59.15	21.04	88.8	219.6	173.6	153.7	277.9	79.44	67.85	72.80	34.92
Mean	.29	1.97	.68	2.86	7.84	5.60	5.12	8.96	2.65	2.19	2.35	1.16
Maximum	.80	13	9.6	7.4	24	24	12	29	11	7.7	9.1	3.6
Minimum	.02	.08	.11	1.4	2.7	2.4	2.8	3.0	.62	.00	.00	.27

Table 15. *Ground-water levels measured at Summit Lake Reservoir and summary statistics, water years 1989-90*

[Water-level altitude in feet above sea level; n.m., not measured]

Date measured	Well A1	Well B1	Well B2	Well C1	Well C2	Well D1	Well D2	Well E1	Well E2	Well F1	Well F2	Well G1	Well H1
10/03/88	1042.8	1068.0	1067.5	1065.5	1064.0	1063.1	1063.9	1072.2	1060.0	1049.7	1035.2	1026.2	1046.2
10/31/88	1042.2	1067.6	1067.2	1065.3	1063.7	1063.0	1063.7	1072.2	1059.6	1049.1	1034.7	1025.8	1046.0
11/09/88	1042.0	1068.1	1067.9	1066.5	1063.9	1063.5	1063.8	1073.0	1060.3	1048.8	1034.2	1025.4	1045.8
11/21/88	1042.0	1068.1	1067.6	1066.5	1063.9	1063.4	1063.8	1072.9	1060.3	1048.8	1034.2	1025.4	1045.8
12/01/88	1041.8	1068.1	1067.6	1066.2	1063.9	1063.6	1064.2	1073.6	1061.0	1048.8	1034.2	1025.4	1045.8
12/22/88	1041.4	1067.8	1067.3	1065.9	1063.8	1063.4	1064.0	1074.1	1061.5	1048.5	1033.8	1025.0	1045.4
1/05/89	1041.6	1068.3	1067.9	1066.2	1064.2	1063.8	1064.6	1075.5	1061.3	1048.5	1033.9	1025.0	1045.3
2/07/89	1042.1	1068.8	1068.5	1066.7	1065.0	1064.7	1065.3	1080.4	1062.1	1048.9	1034.0	1025.2	1045.9
3/01/89	1042.2	1069.0	1068.6	1066.6	1065.1	1064.8	1065.4	1080.6	1062.2	1048.8	1033.8	1025.1	1046.2
4/03/89	1044.3	1070.2	1068.5	1067.9	1066.8	1066.8	1067.5	1084.0	1063.7	1052.0	1035.5	1026.5	1048.0
5/01/89	1046.8	1070.7	1068.5	1069.0	1067.8	1067.6	1068.0	1083.8	1064.2	1054.5	1037.7	1028.6	1050.8
6/01/89	1049.9	1071.7	1069.7	1069.8	1068.5	1067.7	1068.9	1081.8	1064.7	1057.1	1039.7	1030.4	1052.4
6/28/89	n.m.	1071.3	1069.7	1068.7	1067.6	1066.9	1067.9	n.m.	n.m.	1057.2	1039.8	1030.8	n.m.
7/05/89	1050.5	1071.1	1070.1	1068.1	1067.0	1066.8	1067.7	1077.8	1063.0	1057.1	1039.8	1031.9	1053.6
8/02/89	1050.7	1071.6	1069.5	1068.0	1067.1	1066.6	1067.4	1077.6	1064.7	1057.3	1040.0	1030.9	1053.3
8/28/89	1050.3	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	1063.3	n.m.	n.m.	n.m.	1053.2
9/05/89	1050.9	1071.6	1070.0	1068.0	1067.2	1067.0	1067.4	1080.3	1064.9	1057.8	1040.3	1030.9	1053.1
10/02/89	1052.0	1071.7	1070.1	1068.0	1067.9	1067.3	1068.0	1080.1	1064.4	1059.6	1041.8	1031.6	1054.2
11/01/89	1050.9	1071.0	1069.9	1067.6	1067.1	1066.6	1067.2	1077.7	1063.8	1058.8	1041.1	1030.8	1054.2
12/04/89	1050.5	1071.0	1069.8	1067.3	1067.2	1066.7	1067.4	1080.6	1064.3	1059.1	1041.3	1030.5	1054.1
1/03/90	1049.5	1070.6	1069.7	1066.9	1066.8	1066.7	1067.0	1080.4	1063.7	1058.7	1040.4	1030.0	1053.9
2/01/90	1049.6	1070.8	1069.6	1067.0	1067.1	1066.7	1067.3	1082.2	1064.0	1058.9	1040.2	1029.8	1053.9
3/06/90	1051.2	1072.0	1070.1	1068.0	1068.5	1068.1	1068.9	1082.6	1065.3	1061.0	1041.3	1030.8	1054.7
4/01/90	1052.4	1072.2	1070.5	1069.0	1068.5	1068.6	1069.2	1083.3	1065.3	1062.2	1042.2	1031.5	1055.5
5/02/90	1052.6	1072.1	1070.7	1068.6	1068.6	1068.4	1068.9	1081.5	1065.2	1062.2	1042.1	1031.5	1056.0
6/04/90	1054.7	1072.9	1071.5	1069.6	1069.8	1069.5	1069.9	1081.7	1066.0	1064.7	1043.8	1032.9	1058.2
7/02/90	1054.6	1072.1	1071.4	1068.7	1068.9	1068.8	1069.0	1078.0	1065.0	1064.4	1043.8	1032.8	1058.6
8/01/90	1054.5	1071.9	1071.2	1068.0	1068.6	1068.5	1068.8	1077.8	1064.8	1064.1	1043.8	1032.7	1058.5
9/04/90	1054.7	1072.0	1070.9	1068.1	1068.8	1068.6	1068.9	1079.7	1065.2	1064.5	1044.3	1032.7	1058.4
Number of measurements	28	28	28	28	28	28	28	27	28	28	28	28	28
Mean	1048.2	1070.4	1069.3	1067.6	1066.7	1066.3	1066.9	1078.7	1063.3	1056.1	1038.8	1029.1	1051.7
Median	1050.1	1071.0	1069.7	1067.9	1067.1	1066.7	1067.4	1080.1	1063.9	1057.2	1039.9	1030.4	1053.2
Minimum	1041.4	1067.6	1067.2	1065.3	1063.7	1063.0	1063.7	1072.2	1059.6	1048.5	1033.8	1025.0	1045.3
Maximum	1054.7	1072.9	1071.5	1069.8	1069.8	1069.5	1069.9	1084.0	1066.0	1064.7	1044.3	1032.9	1058.6

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