WATER, ICE, AND METEOROLOGICAL MEASUREMENTS AT SOUTH CASCADE GLACIER, WASHINGTON, 1994 BALANCE YEAR

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 95-4162

U.S. DEPARTMENT OF THE INTERIOR
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Cover - Terminus area of South Cascade Glacier, September 26, 1994.

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1995

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, VERTICAL DATUM, SYMBOLS, AND MACHINE-READABLE FILES

Multiply	By	To obtain
millimeter (mm)	0.03937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
square kilometer (km^2)	0.3861	square mile
kilopascal (kPa)	0.1450	pound per square inch
degree Celsius (°C)	1.8, then add 32	degrees Fahrenheit

Vertical datum:

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

Symbols used in this report:

$\bar{b}_0$	The change in balance between the minimum balance near the beginning of the water year and October 1.
$\bar{b}_1$	The change in balance between the minimum balance near the end of the water year and September 30.
$\bar{b}_a$	The change in snow, firn, and ice storage between the beginning and end of some fixed period, which here is the water year.
$\bar{b}_m(s)$	The snow above the previously formed summer surface as measured directly by field work in late spring as near as possible to the time of greatest glacier mass.
$\bar{b}_n$	The change in snow, firn, and ice storage between times of minimum mass.
$\bar{b}_w(s)$	The maximum of snow mass during the balance year.
q	River discharge.
S	River stage.

Machine-readable files:

Most of the data contained in this report have been recorded on easily copied computer media. This machine-readable material is available from the World Data Center, Campus Box 449, University of Colorado, Boulder, CO 80309.

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Robert M. Krimmel

ABSTRACT

Winter snow accumulation and summer snow, firn, and ice melt were measured at South Cascade Glacier, Washington to determine the winter and net balances for the 1994 balance year. The 1994 winter balance, averaged over the glacier, was 2.39 meters, and the net balance was -1.60 meters. The winter balance was approximately that of the 1977-94 average winter balance. The net balance was more negative than the 1977-94 average net balance of -1.02 meters. Runoff was measured from the glacier and an adjacent non-glacierized basin. Air temperature, precipitation, barometric pressure, solar radiation, and wind speed were measured nearby. This report makes these data available to the glaciological and climatological community.

INTRODUCTION

South Cascade Glacier is a small valley glacier near the crest of the North Cascade Range, Washington State (fig. 1). Numerous variables relating to the glacier regime have been measured on and near South Cascade Glacier since the late 1950's. The long-term goal of this project is to understand the climate-glacier relation. A short-term goal is to document the measurements with sufficient detail so that an internally consistent record of conditions on and around the glacier can be assembled despite personnel changes, discontinuous records, and changing methods of data collection and analysis. Some periods of record at South Cascade Glacier have been documented. Work from 1957-64 is described by Meier and Tangborn (1965), work from 1965-67 is described by Meier and others (1971) and by Tangborn and others (1977). Hydrologic and meteorological data for 1957-67 are presented by Sullivan (1994). Mass balance results for 1958-85 are summarized by Krimmel (1989), and are presented in detail for 1992 (Krimmel, 1993) and for 1993 (Krimmel, 1994). The purpose of this report is to document the measurements of the 1994 balance year that are relevant to the relation between South Cascade Glacier and climate. These measurements include those of basin runoff, precipitation, solar radiation, humidity, wind speed, air temperature, snow thickness and density, ice ablation, and surface altitude.

Description and Climate of the Area

South Cascade Glacier (fig. 1) is located at the head of the South Fork of the Cascade River, a tributary to the Skagit River, which flows into Puget Sound about 100 km to the west. The region is dominated by steep terrain, with relief of more than 1,000 m. Areas within the basin not covered by glacier ice or water are underlain by bedrock. The bedrock is mantled either by a thin layer of soil and, in places, by scrub conifer, heather, or other vegetation typical of the high North Cascade Range, or is covered by glacial moraine or outwash material.

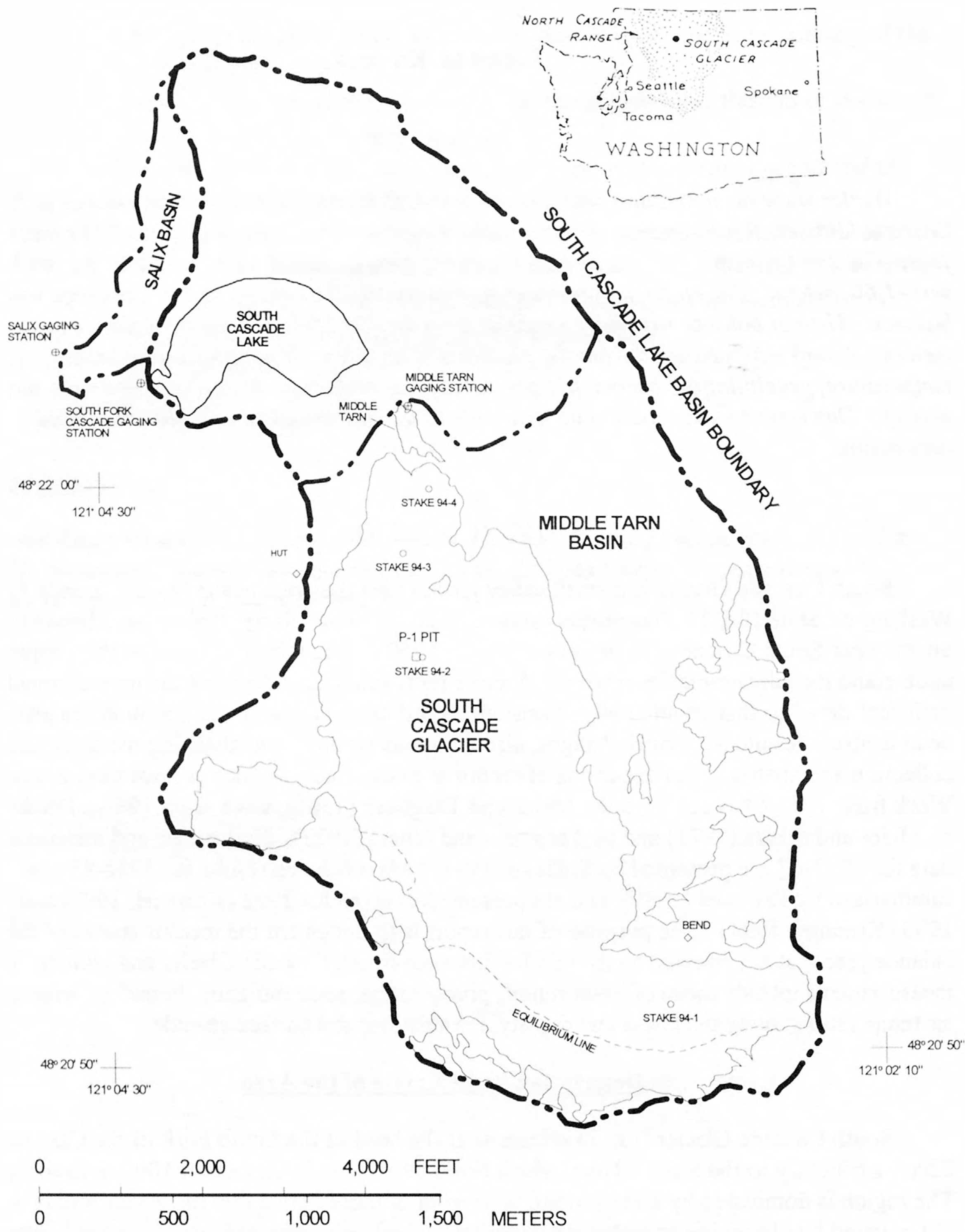

FIGURE 1. South Cascade Glacier and vicinity.

South Cascade Lake Basin (fig. 1) has an area[1] of 6.14 km², and spans from 1,615 to 2,518 m altitude. A sub-basin of the South Cascade Lake Basin is the 4.46-km² Middle Tarn Basin[2], which constitutes the southern two-thirds of the South Cascade Lake Basin. Virtually all icemelt[3] within the South Cascade Lake Basin takes place in the Middle Tarn Basin. Near the end of the 1994 melt season, the total snow- and ice-covered area in Middle Tarn Basin was 2.93 km².

Salix Basin (fig. 1) is an unglacierized basin adjacent to the South Cascade Lake Basin. It has an area[4] of 0.22 km², spans from 1,587 to 2,140 m altitude, and is predominantly south facing.

The climate of the region is maritime. Near the glacier, typical winter low temperatures are about -10°C, and typical summer high temperatures are about 20°C. Most of the precipitation, which commonly reaches 4.5 m annually (Meier and others, 1971), falls as snow in the period October to May.

Measurement Systems

Glacier mass balance definitions (Mayo and others, 1972) are adhered to in this report, and the stratigraphic system, which is more field compatible than the fixed date system, is usually used. The specific terms are defined when used. Other mass balance nomenclatures are in use, notably those described by Østrem and Brugman (1991), which could as well be used to report these results. The definitions by Mayo and others (1972) are used to maintain consistency with earlier reports on South Cascade Glacier work.

The balance year, defined by Mayo and others (1972) as the interval between the minimum glacier mass in one year and the minimum glacier mass the following year, is used when appropriate. The water year is the interval between October 1 of one year and September 30 of the following year; it is designated by the calendar year in which it ends.

All local coordinates are in meters, in which the local +Y axis is approximately true north. Vertical location is in meters above the National Geodetic Vertical Datum of 1929. Horizontal locations are defined by a local system that can be converted to Universal Transverse Mercator (UTM) zone 10 coordinates by:

UTM easting = local X (0.99985) + 642,000
UTM northing = local Y (0.99985) + 5,355,000.

Densities are given as a decimal fraction of the density of water, the density of which is considered to be 1,000 kilograms per cubic meter.

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[1] The area of this basin has been previously reported as 6.02 and 6.11 km². These differences are due to different interpretations of the drainage divide.
[2] "Middle Tarn" is an unofficial name.
[3] A small, debris-covered area of perennial ice lies outside of the Middle Tarn Basin.
[4] Salix Basin drainage divides are poorly defined.

1994 BALANCE YEAR DATA COLLECTION

Recorded Variables

Several variables are measured continuously: in this report these records are truncated to the water year (WY), October 1, 1993 through September 30, 1994. When information concerning these variables is required, but is outside of the WY, the required data are discussed. The continuous measurements may be stored on analog recorders, which give a continuous trace of the variable; on digital recorders, which store either instantaneous values, or for some variables a value that is averaged over some time interval; or are transmitted to Tacoma, Washington with a satellite link using a data collection platform (DCP) near the sensors. Some variables are stored on redundant analog and digital recorders.

Air temperature was measured at the Salix gaging station with a DCP, at the South Fork Cascade gaging station with a DCP and a redundant analog strip chart recorder, at the Hut with a DCP, and at Bend (fig. 1) with a digital recorder. Each of these records is shown graphically (fig. 2). The temperature records are estimated to be accurate to ±1°C.

Precipitation was measured at the Salix and Middle Tarn gaging stations during summer only (fig. 1). The tipping bucket gage catch was recorded four times each hour. The gage orifices were both 200 mm in diameter and neither had wind screens. The gage catch is shown graphically, cumulated to 1 hour (fig. 3.) The precipitation gages are sensitive to 0.024 mm of precipitation. Precipitation is known to vary significantly over short distances, especially in areas of high relief. Wind is also known to influence the catch of a precipitation gage. No attempt has been made to correct these precipitation records for those influences.

Salix Creek stage was recorded on a DCP and a redundant analog strip chart. The recorders shared a single float driven stage sensor. South Fork Cascade River stage was digitally recorded with a redundant analog strip chart recorder. Each recorder had independent float driven stage sensors, in independent wells, calibrated to each other. Middle Tarn stage was recorded with a DCP and with a redundant digital recorder. The recorders shared a single float driven stage sensor. These stage records are shown graphically (fig. 3). The stage recorders are sensitive to ±3 mm and are estimated to be accurate to ±3 mm.

Barometric pressure was recorded with a DCP at the South Fork gaging station and is estimated to be accurate to ±0.1 kPa. Pressure is shown graphically (fig. 4).

Wind speed was measured at the Middle Tarn gaging station and at the Hut, both with DCPs. The Hut wind speed measurement was electronically limited to just under 70 km/hour. Wind speed is estimated to be accurate to ±5 km/hour and is shown graphically (fig. 4). An attempt was made to measure the wind direction, but the electronic signal from the sensors has not been interpreted.

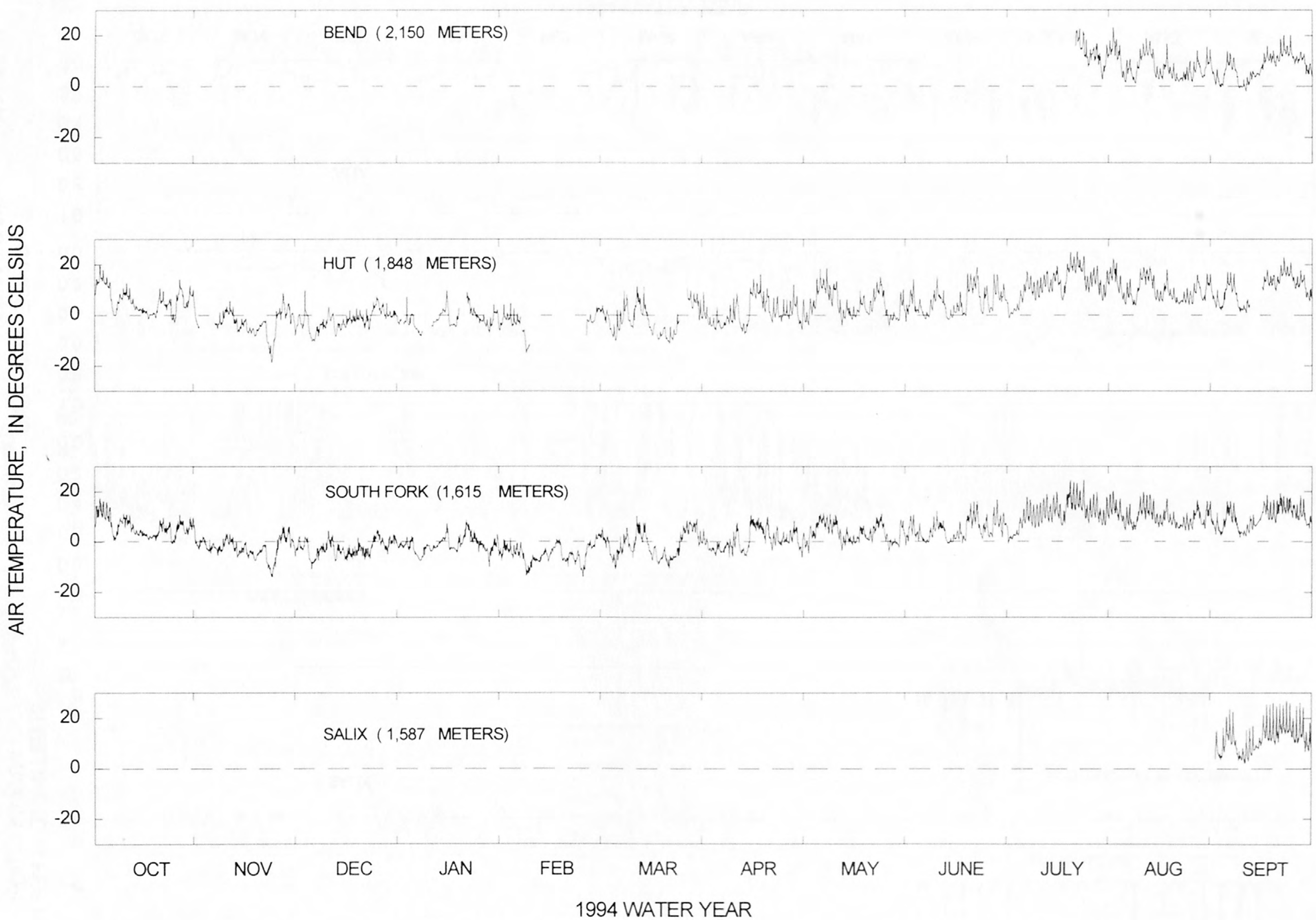

FIGURE 2. Air temperature near South Cascade Glacier during the 1994 water year.

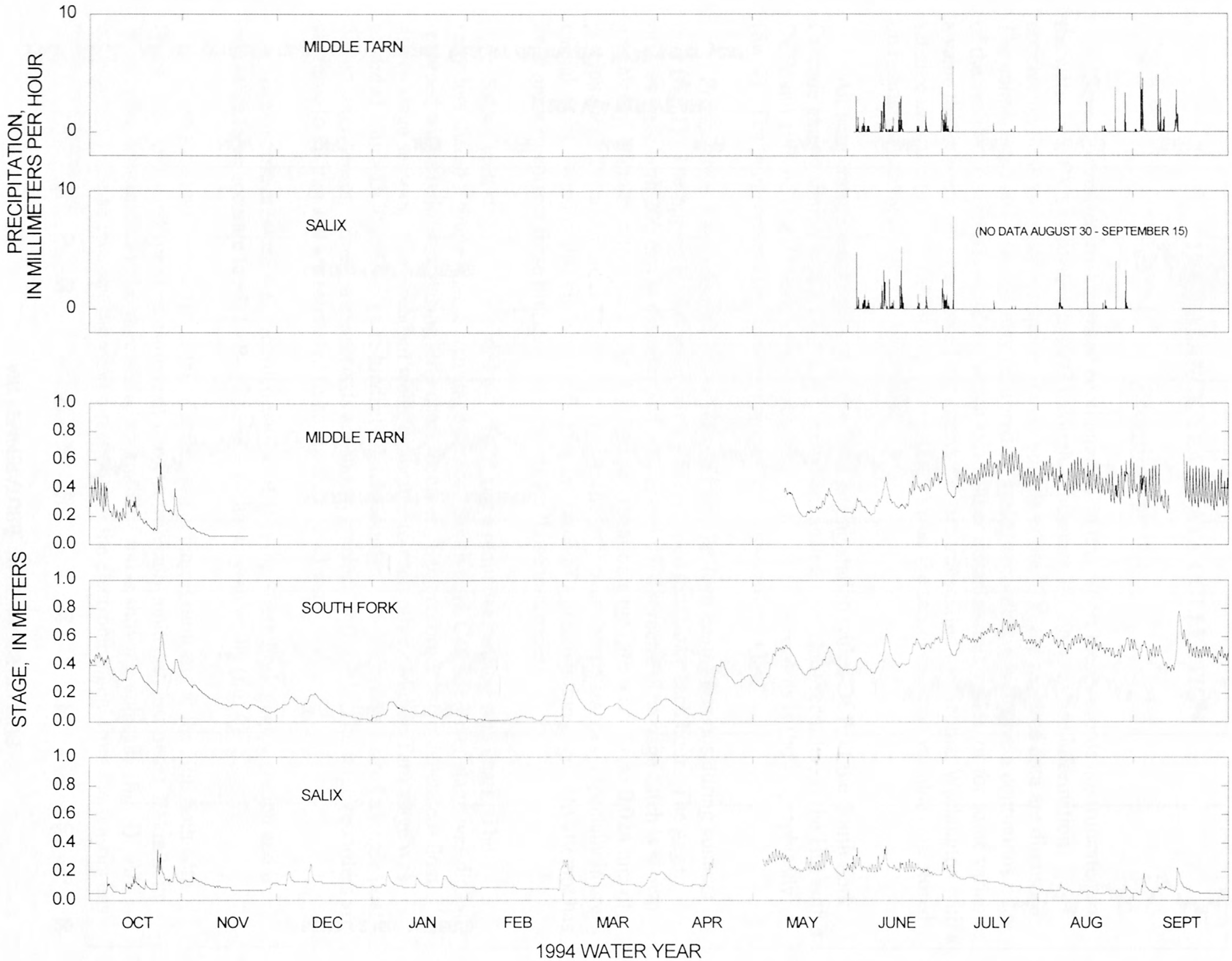

FIGURE 3. Precipitation and river stage near South Cascade Glacier during the 1994 water year.

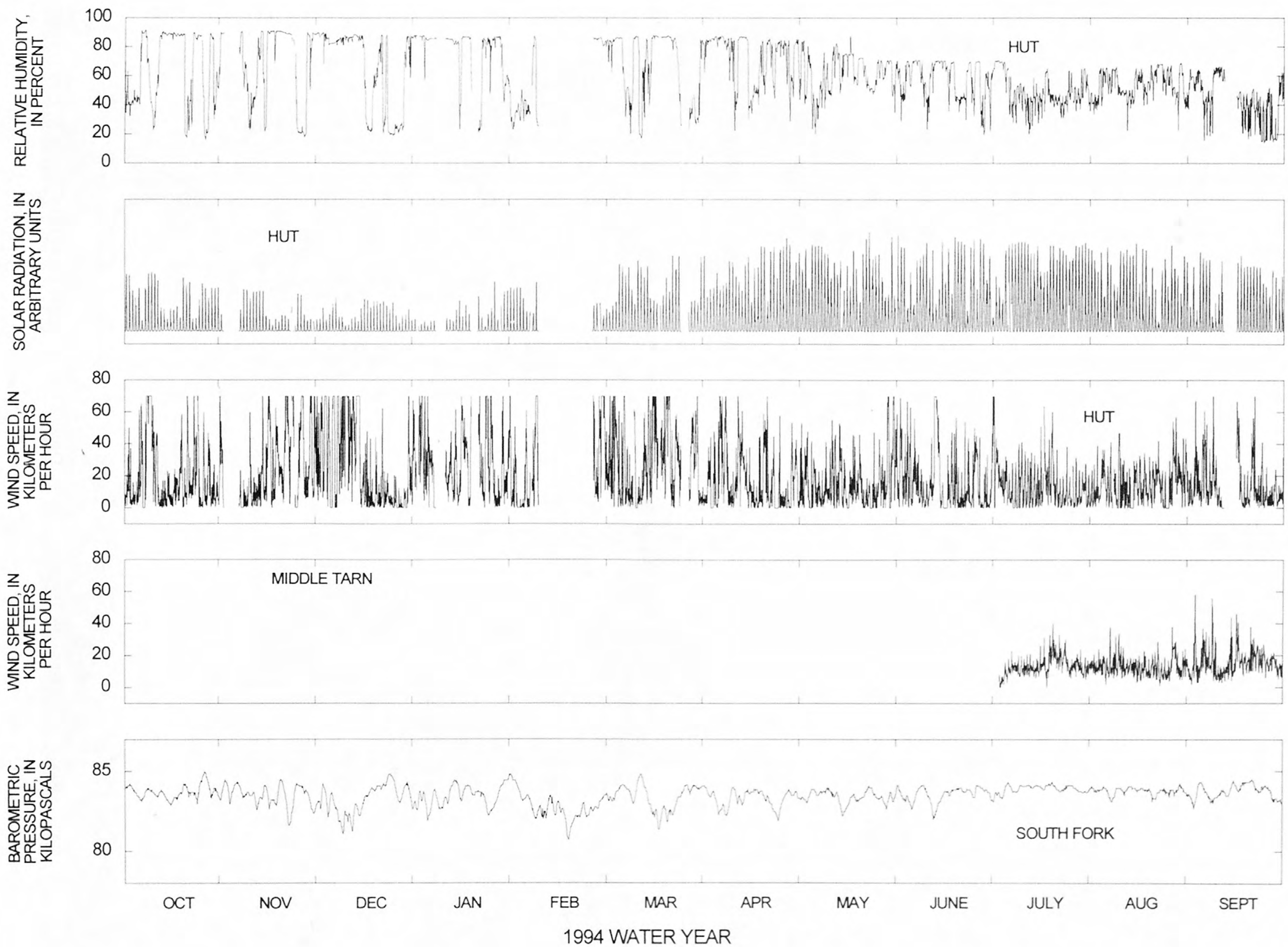

FIGURE 4. Relative humidity, solar radiation, wind speed, and barometric pressure near South Cascade Glacier during the 1994 water year.

Short-wave solar radiation was recorded at the Hut (fig. 4), using a DCP. The radiometer is uncalibrated, and the ordinate in figure 4 is arbitrary. An approximate calibration could be derived, but is beyond the scope of this report, by assuming a linear relation between the theoretical clear-day values on the summer and winter solstices.

Relative humidity was recorded at the Hut (fig. 4) using a DCP. The errors from this electronic sensor are thought to be large, estimated to be 30 percent. The sensor appeared to become progressively less sensitive with time. Early in the year, maximum humidity was about 90 percent, and by late in the year, maximum humidity was about 70 percent. The record presented here must be used with caution.

Aerial Photography

Aerial photography provides an accurate record of a glacier at a specific time. A calibrated 230 X 230-mm format camera with a 150-mm focal length lens was used for stereo vertical photography on September 6, 1994. The entire basin was photographed at a scale of about 1:16,000 (fig. 5), and most of the basin was photographed at a scale of about 1:8,000. Photogrammetry was used to measure the glacier perimeter (fig. 1), an altitude grid (fig. 6, table 1) and the terminus position (fig. 7). The altitude grid values (in X, Y, and Z) are estimated to be accurate to ±1.0 m, even though the horizontal location of the grid point may be several meters away from the nominal grid location (table 1).

On September 26, 1994, a 35-mm camera was used for oblique aerial photography of most of the South Cascade Glacier Basin. These photographs were used to measure the location of the transient snow line on that day, which was very close to the maximum altitude the snow line reached in 1994.

Many important glacier variables are measured from the aerial photography. The area of the glacier in 1993 was 2.078 km^2 (Krimmel, 1994). The area of ice loss, north of local Y=3300 m, between September 1, 1993 and September 6, 1994, was 0.0264 km^2. Using the same method as used in 1993 to measure the changing glacier area, where it is assumed the area south of Y=3300 m is unchanged, the area of the glacier in 1994 was 2.052 km^2. Retreat of the terminus between 1993 and 1994, which was taken as the change in length of the glacier, was about 25 m (fig. 7). Total area of snow, firn, and ice in the South Cascade Glacier Basin on September 6, 1994, was 2.397 km^2. The equilibrium line altitude, taken as the average altitude of the transient snow line just prior to the end of the balance year, was 2,005 m in the 1994 balance year. The area of snow remaining at the end of the 1994 balance year was 0.265 km^2; the accumulation area ratio for 1994 was 0.11.

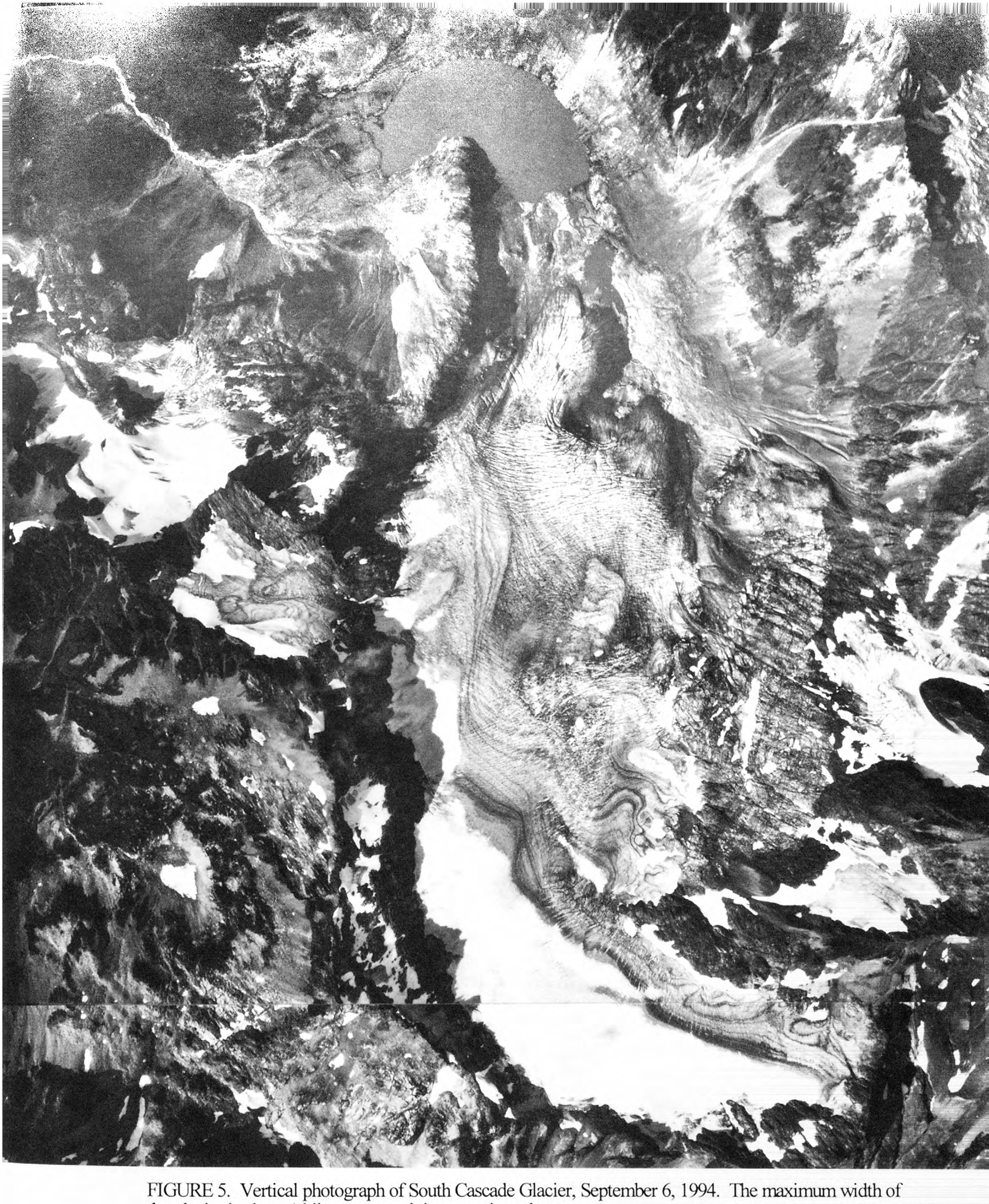

FIGURE 5. Vertical photograph of South Cascade Glacier, September 6, 1994. The maximum width of the glacier is about 1 kilometer, north is approximately up.

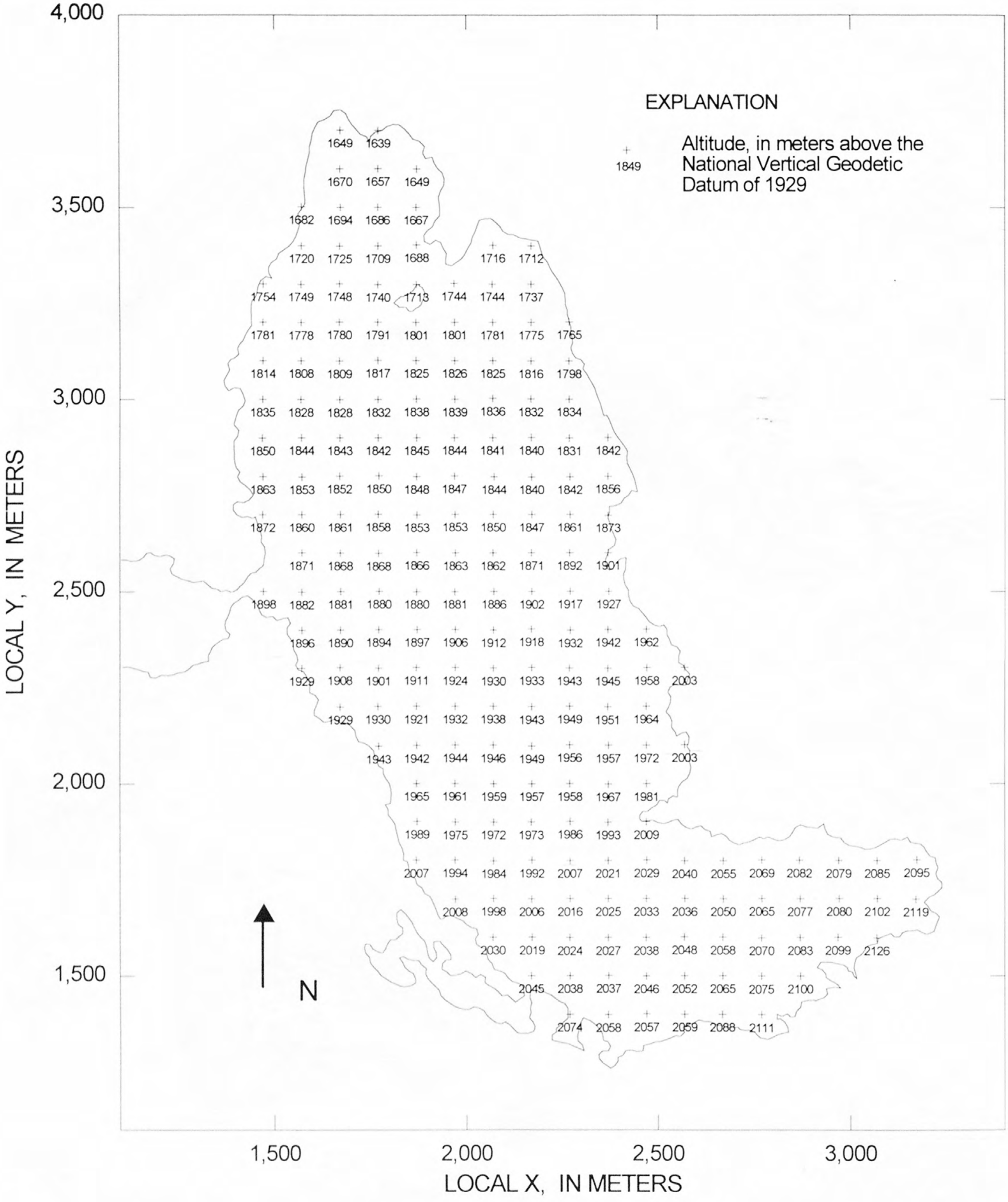

FIGURE 6. Altitude grid for South Cascade Glacier, measured from stereo vertical photographs taken on September 6, 1994.

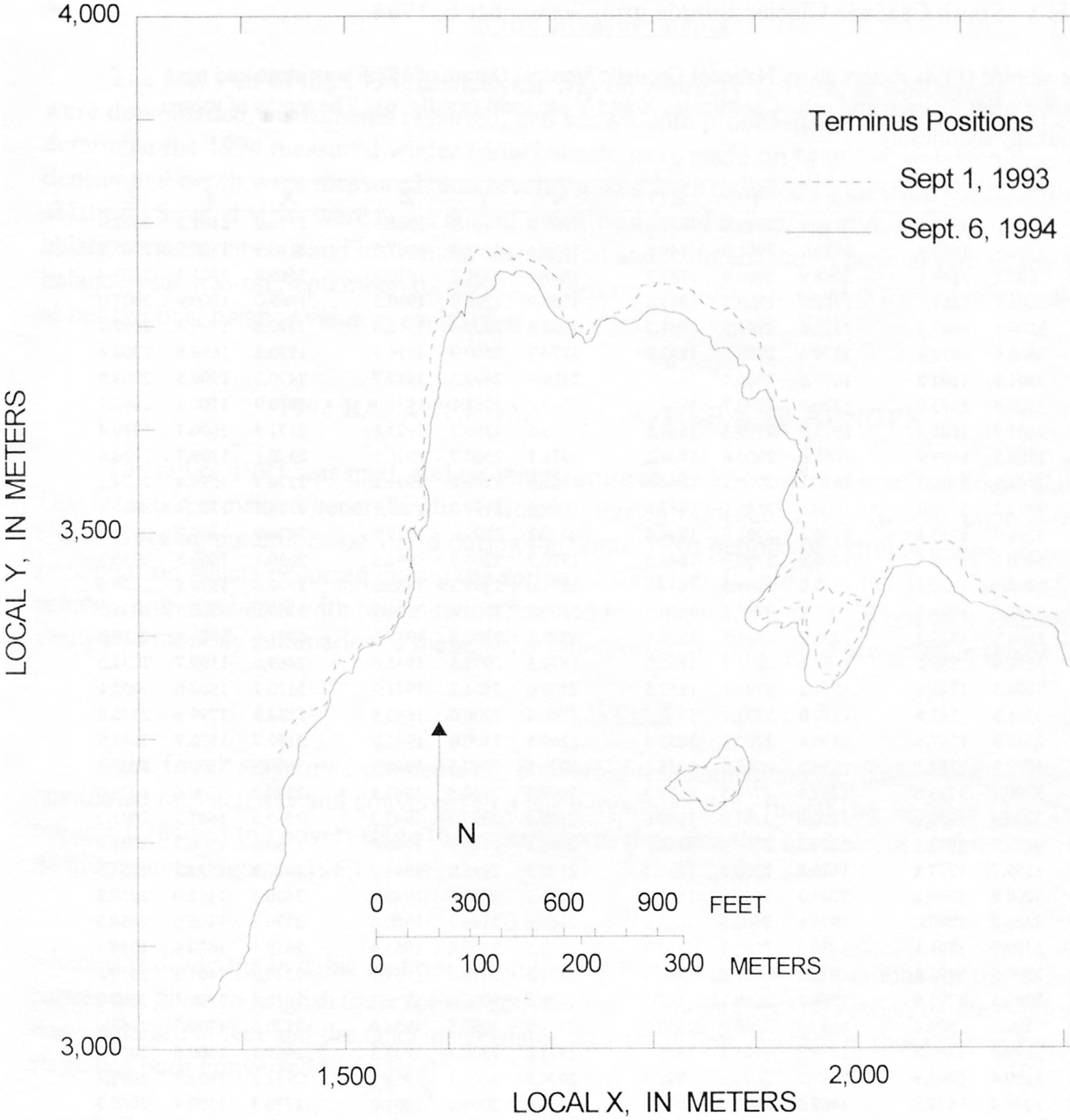

FIGURE 7. South Cascade Glacier terminus positions for September 1, 1993 and September 6, 1994.

TABLE 1. South Cascade Glacier altitude grid, September 6, 1994

[Surface altitude (Z), in meters above National Geodetic Vertical Datum of 1929, was measured near the nominal point for each grid cell. Coordinates X and Y are local (see fig. 6). The tenths of meters are marginally significant]

X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
1769.6	3700.1	1639.1	2170.6	2798.9	1839.5	1969.9	2400.9	1905.5	2570.0	2101.2	2002.6
1670.0	3700.9	1648.9	2170.1	2901.0	1840.1	1669.4	2301.3	1907.5	2170.3	1700.0	2005.7
1870.9	3600.1	1649.1	2068.9	2900.9	1841.2	1869.2	2301.2	1910.6	2569.9	2301.3	2003.4
1769.1	3601.1	1657.1	1769.7	2900.5	1841.6	1768.7	2200.8	1930.3	1869.0	1800.9	2007.0
1869.7	3500.4	1667.4	2370.6	2901.3	1841.7	2069.6	2399.6	1912.3	2270.6	1799.6	2007.0
1669.7	3600.6	1670.4	2270.3	2799.7	1842.0	2270.3	2500.9	1916.9	1970.1	1699.8	2008.4
1570.3	3501.9	1682.2	1670.0	2900.2	1842.8	2169.4	2402.3	1917.7	2470.2	1900.5	2008.9
1769.2	3500.8	1685.9	1570.5	2900.7	1843.8	1869.9	2201.1	1921.3	2270.9	1700.4	2015.7
1870.9	3401.7	1688.3	2071.7	2799.3	1844.1	1970.5	2300.7	1923.8	2171.5	1600.7	2019.4
1671.4	3500.8	1693.9	1968.6	2900.6	1844.2	2371.2	2500.7	1926.5	2370.1	1799.7	2020.6
1769.7	3399.9	1709.4	1870.2	2900.3	1844.6	1569.8	2299.8	1929.2	2270.3	1599.4	2024.2
2170.8	3399.5	1712.0	1968.5	2801.5	1847.3	1669.8	2199.7	1929.4	2370.0	1700.4	2025.4
1870.9	3298.9	1713.4	2170.8	2701.0	1847.4	2070.2	2299.6	1929.5	2470.9	1800.9	2029.1
2070.7	3400.1	1715.6	1869.8	2799.9	1848.2	1970.7	2200.8	1931.8	2069.1	1600.5	2030.3
1570.2	3400.4	1720.2	1469.2	2899.5	1849.5	2271.0	2399.3	1932.2	2370.6	1599.8	2026.5
1669.9	3399.1	1724.5	2069.7	2700.8	1850.3	2170.7	2300.8	1932.9	2469.8	1700.3	2033.0
2170.8	3299.3	1737.2	1770.9	2801.9	1850.4	2070.1	2200.8	1937.6	2371.6	1501.4	2037.3
1770.3	3298.4	1739.8	1669.0	2801.5	1852.0	1870.3	2099.5	1941.6	2469.6	1599.7	2038.0
2069.0	3299.5	1743.6	1571.2	2799.1	1852.5	2369.0	2401.3	1941.9	2270.7	1500.6	2038.1
1969.2	3301.3	1743.9	1970.0	2701.1	1852.8	2170.9	2200.0	1942.5	2569.9	1799.2	2040.0
1669.7	3300.5	1747.5	1870.4	2700.1	1853.4	2269.5	2300.0	1943.0	2169.7	1500.7	2044.9
1569.2	3299.8	1749.3	2369.2	2801.0	1856.2	1770.5	2097.5	1943.1	2470.3	1500.3	2045.5
1470.8	3300.5	1753.6	1768.9	2701.5	1858.3	1970.7	2100.5	1943.9	2570.2	1700.6	2036.0
2270.1	3200.6	1765.0	1570.6	2701.0	1859.6	2369.2	2299.2	1945.2	2569.0	1601.3	2048.2
2170.8	3199.7	1775.4	2270.3	2701.0	1860.9	2069.8	2100.3	1946.0	2569.9	1500.7	2051.9
1569.7	3199.7	1777.8	1670.8	2700.8	1861.2	2170.7	2098.0	1948.7	2670.8	1799.2	2054.6
1669.9	3200.8	1780.2	2069.3	2600.9	1862.0	2270.1	2200.6	1949.2	2470.7	1402.0	2057.2
1470.6	3200.8	1780.6	1970.6	2600.3	1862.6	2369.5	2199.1	1950.6	2370.5	1400.0	2058.0
2070.3	3199.7	1781.1	1470.0	2800.1	1862.5	2269.6	2100.8	1955.6	2669.5	1600.6	2058.3
1770.2	3200.3	1790.8	1870.0	2601.8	1866.4	2371.1	2099.6	1957.1	2570.0	1401.5	2058.8
2269.4	3099.5	1797.6	1769.8	2600.1	1867.7	2170.8	2000.0	1957.2	2670.4	1700.1	2050.2
1869.9	3199.7	1800.8	1670.0	2600.6	1867.8	2270.1	2000.5	1958.0	2770.8	1700.7	2065.0
1970.3	3199.8	1800.8	1570.3	2601.1	1871.0	2471.2	2300.3	1958.3	2669.1	1500.6	2065.2
1570.2	3100.4	1807.7	2169.5	2601.0	1871.0	2070.8	2000.2	1959.0	2771.2	1801.1	2069.4
1669.8	3099.0	1808.8	1469.0	2700.7	1871.9	1970.0	2000.8	1961.0	2770.3	1599.4	2069.7
1470.9	3100.7	1814.1	2369.9	2699.5	1872.9	2468.9	2401.7	1962.0	2269.7	1400.8	2074.2
2170.1	3099.1	1815.5	1869.0	2500.1	1879.5	2469.7	2200.7	1963.7	2770.0	1499.8	2075.0
1770.4	3101.1	1817.1	1771.1	2501.0	1880.2	1869.4	2000.7	1964.5	2870.3	1700.2	2077.1
2070.0	3099.7	1824.9	1968.9	2499.7	1880.8	2370.7	1999.1	1967.1	2970.2	1800.0	2078.5
1869.8	3100.7	1825.2	1671.0	2500.3	1881.4	2070.1	1900.3	1971.6	2868.5	1800.7	2081.6
1970.4	3100.2	1826.1	1569.7	2498.9	1881.7	2470.5	2099.6	1971.6	2870.7	1599.9	2083.2
1569.3	2999.2	1828.3	2071.1	2500.2	1885.9	2169.0	1900.8	1972.7	3069.2	1799.7	2085.1
1670.3	2999.1	1828.3	1670.3	2399.9	1890.3	1970.3	1900.1	1974.9	2667.9	1401.0	2087.8
2269.4	2899.9	1831.1	2269.4	2601.2	1891.7	2470.5	1999.6	1981.3	2971.1	1700.9	2080.4
1770.2	2999.5	1832.0	1769.8	2401.1	1893.5	2070.5	1799.4	1984.4	3171.3	1801.7	2095.0
2169.5	3000.8	1832.2	1570.3	2399.5	1895.7	2270.5	1901.4	1986.0	2968.2	1600.2	2099.0
2269.5	3000.7	1833.5	1870.1	2400.9	1896.6	1870.6	1901.6	1988.6	2871.0	1500.3	2099.5
1470.2	3000.2	1834.9	1470.3	2500.6	1897.9	2170.8	1800.9	1991.6	3069.7	1700.9	2101.9
2069.6	3001.8	1836.0	2369.9	2601.7	1901.4	2369.6	1899.6	1992.9	2770.2	1399.9	2110.8
1870.2	3000.8	1837.6	1769.7	2299.9	1901.4	1969.8	1801.2	1993.5	3169.1	1699.6	2119.1
1970.2	3000.3	1838.5	2170.4	2500.3	1901.5	2070.1	1701.2	1997.5	3068.4	1599.1	2125.7

Field Measurements

The first visit of the 1994 balance year was on February 1, 1994, at which time data loggers were downloaded, instruments restarted, and snow depth probes made. Measurements to determine the 1994 measured winter snow balance were made on May 3-4, at which time snow density and depth were measured, and several stakes were installed to measure the summer's ablation. Several visits were made during the remainder of the spring and in the summer for ablation measurements and instrument installation and maintenance. The final visit of the 1994 balance year was on September 16, 1994. A visit on October 25, 1994 provided information about the final balance value at each stake.

1994 BALANCE YEAR WEATHER AND RUNOFF

The fall of 1993 was mild, and air temperature at the lower altitudes of the South Cascade Glacier Basin remained generally above freezing through October 1993. Several periods of above-freezing conditions occurred during the winter. No periods of extreme temperature or precipitation events occurred during the spring or summer. In mid-October 1994, below-freezing temperature combined with precipitation resulted in a snow cover that did not subsequently melt. Daily and monthly summaries of these, solar radiation, and wind speed are given in tables 2-10.

Salix Runoff

Salix Creek stage measurements are converted to instantaneous discharge values, which are cumulated for each day and converted to a basin-averaged daily runoff (fig. 8, table 11). The rating curve used to convert stage to discharge was the same that has been used since the measurements began in 1960:

$$q = S^{2.57} \times 2.71$$

where q is discharge in cubic feet per second and S is stage in feet. (Equations for the rating curves are given in English units for the convenience of the author and reader, as the original stage data are in feet and the machine-readable files are in feet. Except in these two instances, stage has been converted to meters).

Fall and winter rainstorms resulted in numerous minor periods of runoff from Salix Basin prior to the beginning of spring and summer snowmelt (fig. 3). There is no detailed stage record for Salix Creek between April 16 and May 4, and on May 11, 1994. An analog strip chart was in operation at that time, but the clock was erratic. From this chart, it is known that the stage began to climb on April 16 and remained between 0.15 and 0.33 m from April 16 to May 4. By May 4, the seasonal snowmelt runoff was well established. By early July, most of the snow had melted from the basin, and rainstorms were the only major source for runoff through the remainder of the balance year.

TABLE 2. Air temperature at 2,151 meters altitude, South Cascade Glacier Basin, July through September 1994

[Daily maximum, minimum, and average air temperature, in degrees Celsius. The temperature is sampled once every two hours at station BEND (fig. 1). A 99.0 indicates no data]

Day	July			Aug.			Sept.		
1	99.0	99.0	99.0	17.9	11.9	14.1	6.3	1.9	4.5
2	99.0	99.0	99.0	23.1	13.6	18.0	6.6	0.7	3.3
3	99.0	99.0	99.0	18.5	10.3	13.9	2.0	-0.2	0.8
4	99.0	99.0	99.0	16.1	5.8	11.9	6.2	0.3	3.0
5	99.0	99.0	99.0	6.1	2.2	4.2	13.9	6.5	9.4
6	99.0	99.0	99.0	10.3	1.6	5.6	13.1	6.5	9.7
7	99.0	99.0	99.0	10.5	5.2	7.6	11.3	6.2	8.5
8	99.0	99.0	99.0	4.9	1.6	3.1	6.7	0.4	3.8
9	99.0	99.0	99.0	9.6	1.3	5.1	0.3	-0.7	-0.1
10	99.0	99.0	99.0	14.7	6.8	10.6	2.6	-0.8	0.2
11	99.0	99.0	99.0	16.8	11.7	13.3	3.6	-1.9	1.1
12	99.0	99.0	99.0	18.8	12.1	14.0	5.8	0.9	3.6
13	99.0	99.0	99.0	17.8	11.6	14.3	6.1	3.6	4.7
14	99.0	99.0	99.0	14.6	5.2	10.6	5.2	4.0	4.7
15	99.0	99.0	99.0	7.8	3.4	5.1	7.8	4.1	6.0
16	99.0	99.0	99.0	7.0	2.7	4.4	13.1	6.5	9.7
17	99.0	99.0	99.0	8.8	2.8	6.2	15.9	10.0	12.1
18	99.0	99.0	99.0	16.7	6.4	10.1	12.9	9.2	11.1
19	99.0	99.0	99.0	7.5	3.5	5.6	14.0	8.3	11.2
20	99.0	99.0	99.0	9.0	2.9	5.0	12.3	7.7	10.2
21	99.0	99.0	99.0	5.2	2.0	3.0	18.7	10.0	13.2
22	22.1	15.9	19.0	3.3	1.9	2.7	20.2	11.7	15.4
23	22.8	14.4	17.4	5.7	2.0	3.6	16.0	11.8	13.9
24	21.5	11.6	16.5	7.5	2.3	4.3	20.1	12.3	14.9
25	18.4	7.7	12.2	9.9	2.0	6.2	11.9	8.6	10.5
26	14.4	8.5	11.4	9.6	1.9	5.2	11.9	9.1	10.5
27	15.4	10.0	13.1	14.0	5.4	9.5	13.6	10.1	11.5
28	16.8	10.4	13.5	9.2	4.3	7.0	12.8	8.7	10.8
29	13.0	4.7	9.3	6.7	3.3	4.2	8.5	4.9	6.6
30	8.1	2.8	5.5	15.6	7.3	9.9	8.9	4.1	6.7
31	16.2	7.6	11.8	14.4	6.9	9.9			
MONTHLY AVERAGE		--				8.0			7.7

TABLE 3. Air temperature at 1,848 meters altitude, South Cascade Glacier Basin, 1994 water year

[Daily maximum, minimum, and average air temperature, in degrees Celsius. The temperature is sampled once an hour at the Hut (fig. 1). A 99.0 indicates no data]

DAY	Oct.			Nov.			Dec.			Jan.			Feb.			Mar.			Apr.			May			June			July			Aug.			Sept.		
1	14.5	7.9	11.5	99.0	99.0	99.0	0.5	-3.5	-1.2	99.0	99.0	99.0	1.0	-2.0	-1.0	3.0	1.1	2.1	9.3	-1.5	2.1	6.3	-5.6	0.2	4.3	-2.5	0.9	6.1	1.3	4.9	18.9	11.9	15.5	9.2	4.7	7.0
2	19.8	12.8	15.3	99.0	99.0	99.0	-0.2	-5.3	-3.4	7.2	-3.2	-1.3	4.7	-4.3	-0.9	3.8	-2.1	1.1	3.3	-2.5	-0.2	1.3	-3.4	-1.6	10.1	0.3	6.3	1.2	-1.2	0.2	22.3	13.7	18.2	10.2	3.0	5.9
3	18.1	12.7	14.9	99.0	99.0	99.0	9.8	-0.2	1.3	0.6	-4.0	-2.0	2.8	-4.1	-2.5	2.2	-3.0	-0.1	-0.7	-4.2	-3.2	6.8	-3.9	2.1	14.4	1.5	7.6	2.7	0.4	1.6	20.6	10.8	15.1	5.4	1.8	3.3
4	15.3	11.3	12.8	99.0	99.0	99.0	-0.3	-8.8	-6.2	0.7	-4.5	-1.6	0.8	-3.9	-2.2	-1.0	-6.8	-4.3	-0.9	-5.4	-3.7	6.0	0.1	3.2	3.7	1.2	2.1	4.6	1.7	2.6	15.7	8.6	11.6	9.1	2.8	5.3
5	13.2	5.9	10.7	99.0	99.0	99.0	-8.9	-10.2	-9.8	-4.8	-7.0	-5.5	99.0	99.0	99.0	-3.6	-8.9	-7.3	3.4	-5.9	-2.5	15.0	2.6	7.8	6.5	0.9	3.8	9.7	1.9	6.3	8.9	5.1	7.4	17.1	9.4	12.2
6	6.6	0.1	2.3	-2.8	-5.4	-3.8	-4.1	-9.7	-6.6	-6.0	-8.1	-7.4	-5.7	-10.0	-6.7	2.0	-10.1	-5.8	-1.8	-5.4	-3.7	18.5	8.9	12.3	2.0	-1.2	0.3	12.1	4.9	8.5	12.9	4.2	7.9	17.0	9.6	13.0
7	5.7	-0.1	1.6	1.3	-4.1	-2.7	-3.2	-8.3	-5.2	99.0	99.0	99.0	-10.8	-14.9	-13.2	2.2	-6.2	-2.9	-2.7	-5.0	-4.1	14.8	10.4	12.3	1.2	-1.4	-0.3	17.4	8.8	13.4	14.3	6.9	9.7	16.4	9.1	11.7
8	8.7	4.7	6.4	2.0	-3.4	-1.3	-1.4	-5.4	-3.4	99.0	99.0	99.0	99.0	99.0	99.0	9.9	-3.4	1.4	0.0	-4.1	-1.9	18.7	8.7	12.2	6.5	-0.8	2.7	15.5	9.4	12.2	7.4	4.0	5.4	9.2	3.2	6.5
9	10.9	6.1	7.9	3.6	1.0	1.9	0.2	-5.1	-3.3	99.0	99.0	99.0	99.0	99.0	99.0	8.4	-1.5	3.9	4.2	-3.5	-0.7	12.0	5.3	8.4	9.8	1.7	5.5	13.1	6.7	9.9	10.8	3.8	7.0	3.2	1.3	2.4
10	12.8	7.5	9.1	5.6	0.4	1.8	3.3	-2.3	-0.2	-2.4	-4.4	-3.4	99.0	99.0	99.0	-1.8	-4.5	-2.8	6.9	-3.0	-0.1	12.4	3.6	8.1	15.4	5.3	9.5	13.9	5.8	9.6	18.4	9.7	13.4	4.2	2.0	2.7
11	10.9	4.7	7.4	3.6	-3.2	-0.2	1.2	-6.4	-1.2	-1.5	-2.7	-2.2	99.0	99.0	99.0	2.8	-5.2	-1.7	8.8	-1.5	4.7	13.5	3.3	9.9	8.0	6.0	7.1	14.9	6.9	10.7	19.0	13.8	16.1	6.4	0.8	3.5
12	6.9	3.3	4.9	-0.9	-6.5	-3.0	-2.7	-8.3	-6.3	0.8	-1.9	-0.2	99.0	99.0	99.0	11.6	3.3	6.7	3.9	-5.2	-2.4	6.2	-2.0	2.0	9.8	3.7	5.4	16.1	8.7	12.4	18.0	11.9	15.4	99.0	99.0	99.0
13	4.0	2.3	2.9	-3.3	-6.6	-5.2	-3.1	-6.1	-4.5	2.7	0.8	1.7	99.0	99.0	99.0	8.1	0.9	4.4	-3.1	-7.2	-5.1	2.3	-3.9	-0.8	3.4	-1.6	-0.1	17.4	10.5	14.1	19.5	13.3	16.4	99.0	99.0	99.0
14	2.8	1.6	2.3	-1.2	-4.4	-2.9	-1.3	-5.4	-3.3	9.9	1.2	4.9	99.0	99.0	99.0	11.5	-0.1	3.1	-2.6	-6.8	-5.0	6.3	-1.4	2.5	2.2	-1.7	-0.5	14.2	8.7	11.1	16.0	8.0	12.6	99.0	99.0	99.0
15	3.0	0.8	1.9	-1.3	-6.7	-3.9	-0.2	-4.8	-3.1	1.7	-4.4	-3.0	99.0	99.0	99.0	4.6	-1.6	1.0	11.1	-2.4	4.6	3.1	-0.9	0.8	4.0	-1.0	1.1	16.7	9.1	13.7	10.1	5.9	7.7	99.0	99.0	99.0
16	2.0	0.1	1.2	-4.7	-6.9	-6.0	2.1	-2.4	-1.3	-3.3	-4.0	-3.7	99.0	99.0	99.0	-1.9	-6.0	-4.6	14.7	7.6	10.0	3.8	-1.7	0.4	5.1	0.9	2.5	19.4	11.9	16.1	9.7	5.4	7.2	15.4	9.8	12.5
17	0.6	-1.3	-0.2	-5.0	-8.1	-6.2	0.4	-3.4	-1.8	-0.2	-4.6	-2.7	99.0	99.0	99.0	-3.1	-7.9	-5.6	12.8	6.5	9.3	2.3	-0.7	0.7	9.3	1.6	4.9	14.0	6.9	11.6	12.9	5.4	8.4	18.2	12.3	15.0
18	1.1	0.1	0.6	-5.5	-8.1	-6.8	2.8	-2.7	-1.1	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	99.0	16.3	7.2	9.7	9.8	1.0	4.2	4.2	-0.1	0.9	11.7	5.9	7.9	18.0	9.6	12.9	15.6	11.6	13.1
19	3.8	-0.9	0.9	-3.4	-6.2	-4.6	2.2	-2.0	-0.5	99.0	99.0	99.0	99.0	99.0	99.0	-6.5	-9.6	-8.1	9.4	1.8	5.0	8.2	3.2	5.6	16.4	-0.2	7.5	20.3	8.4	15.8	10.3	7.1	8.4	16.0	10.3	13.7
20	10.7	4.2	6.7	-2.2	-4.3	-2.9	0.4	-5.2	-2.2	99.0	99.0	99.0	99.0	99.0	99.0	-4.6	-7.7	-6.0	10.7	1.3	6.3	2.9	0.6	1.5	16.4	9.3	12.5	24.8	16.9	19.9	10.8	6.1	7.8	15.4	9.7	12.6
21	9.6	3.8	5.9	-2.1	-10.7	-6.1	2.6	-4.9	-1.6	7.0	0.5	3.9	99.0	99.0	99.0	-5.2	-10.2	-8.9	7.9	-1.8	1.3	5.9	0.3	2.7	15.4	8.5	11.9	23.2	17.4	19.8	7.2	4.6	5.6	19.9	12.5	15.7
22	4.7	2.1	3.8	-10.7	-16.9	-13.4	0.7	-5.7	-2.7	3.1	-0.1	1.0	99.0	99.0	99.0	-4.4	-11.2	-8.7	7.0	-2.9	0.8	10.6	1.4	5.6	18.9	10.2	14.8	25.2	16.5	20.3	5.9	4.3	5.1	22.9	15.6	18.2
23	6.6	-0.2	4.9	-9.0	-18.6	-14.3	5.4	0.6	2.5	1.4	-1.5	-0.2	99.0	99.0	99.0	-5.3	-9.7	-7.9	7.5	-0.9	3.1	13.3	6.0	9.5	10.0	1.5	5.5	22.0	17.4	19.3	9.2	5.0	6.6	19.4	15.4	17.0
24	0.6	-2.7	-1.2	1.7	-9.4	-3.2	7.7	2.9	5.4	-0.6	-3.3	-1.9	99.0	99.0	99.0	0.7	-7.5	-4.5	1.0	-2.4	-0.6	15.3	8.3	11.5	11.0	0.5	4.6	23.3	13.8	19.1	10.9	4.7	7.1	21.0	15.5	17.4
25	8.1	-2.8	3.0	2.9	-1.7	0.9	5.7	0.3	2.5	0.4	-3.3	-2.0	99.0	99.0	99.0	99.0	-3.2	69.4	6.3	-2.0	1.1	12.1	3.8	8.2	11.6	3.8	8.1	15.5	9.6	12.4	9.6	4.2	6.8	15.6	10.6	13.7
26	14.2	7.7	10.3	8.8	0.8	4.5	5.2	-0.3	2.6	-1.7	-5.9	-3.8	0.4	-3.0	-1.8	99.0	99.0	99.0	6.2	-0.3	1.2	3.3	-1.9	1.1	3.4	0.9	2.3	17.1	9.0	13.1	12.7	4.3	7.8	15.5	10.4	12.6
27	11.0	3.1	7.1	4.4	-1.4	1.0	4.9	-1.5	0.2	-1.0	-6.8	-4.3	-0.7	-3.1	-2.4	99.0	99.0	99.0	5.9	-1.4	2.0	0.3	-4.2	-1.8	16.3	1.6	8.4	19.0	11.2	15.4	16.0	8.6	12.0	17.8	10.9	13.9
28	5.3	3.0	3.7	4.8	-3.7	1.3	1.8	-1.0	0.1	4.3	-4.0	0.0	3.5	-0.4	1.7	9.9	5.0	7.0	12.2	0.2	4.8	1.2	-2.0	-0.6	16.1	8.0	11.8	19.6	11.8	15.2	13.5	6.9	10.5	16.2	10.7	13.8
29	12.0	4.5	8.0	1.0	-3.8	-0.5	1.9	-1.0	0.2	2.2	-3.5	0.6				8.9	2.6	5.1	7.5	0.0	3.8	-0.1	-2.1	-1.3	9.5	5.2	7.1	14.0	7.7	10.6	7.8	5.8	6.5	10.8	7.1	8.5
30	10.2	3.1	7.2	-2.1	-7.9	-5.1	1.4	-2.9	-0.5	-2.9	-6.1	-4.4				8.7	3.7	5.9	-1.0	-4.5	-2.8	9.1	-2.1	3.1	12.7	6.2	8.8	12.2	5.5	8.4	16.5	5.5	12.0	10.4	5.7	7.5
31	2.3	-4.1	-1.8				-1.6	-3.7	-2.5	4.2	-3.4	-0.4				6.2	-2.1	1.4				10.2	2.0	4.6				17.7	7.0	12.9	16.3	9.4	12.8			
MONTHLY AVERAGE			5.5			--			-1.8			--			--			--			1.1			4.3			5.4			11.9			10.2			--

TABLE 4. Air temperature at 1,615 meters altitude, South Cascade Glacier Basin, 1994 water year

[Daily maximum, minimum, and average air temperature, in degrees Celsius. The temperature is sampled once an hour at the South Fork Cascade River gaging station (fig. 1)]

DAY	Oct.			Nov.			Dec.			Jan.			Feb.			Mar.		
1	14.7	6.1	9.9	1.0	-2.9	-0.9	2.2	-2.9	-0.4	-1.0	-2.5	-1.6	-0.6	-4.1	-2.5	4.5	1.4	2.7
2	17.4	10.0	13.6	2.2	-0.2	0.9	1.0	-3.3	-1.9	2.2	-2.9	-0.4	1.4	-5.3	-3.2	5.7	-0.6	1.9
3	16.3	9.6	12.2	1.0	-3.3	-1.8	2.2	-1.0	1.0	2.2	-3.3	-0.9	-1.4	-6.9	-4.3	2.2	-2.5	0.4
4	15.9	8.8	11.4	1.0	-4.5	-3.0	-1.0	-8.4	-6.3	1.8	-4.9	-1.4	-0.6	-5.7	-3.1	-0.2	-6.9	-4.1
5	13.9	6.1	10.1	-0.2	-2.9	-1.6	-6.9	-10.8	-8.2	-4.1	-6.2	-5.1	-0.2	-6.5	-3.2	-4.9	-10.8	-7.4
6	8.0	0.6	3.6	-2.2	-5.3	-3.2	-2.5	-7.6	-5.5	-6.3	-7.6	-7.1	-3.9	-9.2	-6.1	-2.9	-10.8	-5.9
7	7.3	0.6	2.9	-1.4	-4.1	-2.8	-1.4	-7.3	-3.7	-1.8	-6.1	-4.3	-9.2	-13.5	-11.7	2.2	-4.9	-3.0
8	9.6	3.3	7.6	1.4	-3.7	-1.5	-0.2	-4.1	-2.5	-1.0	-2.9	-1.7	-7.3	-12.7	-9.9	3.3	-4.5	-0.6
9	11.2	7.3	9.0	3.3	0.2	1.9	1.8	-4.1	-1.9	-1.4	-3.7	-2.8	-5.3	-7.6	-6.7	5.7	-1.4	2.7
10	10.8	5.7	8.4	3.3	-1.0	0.5	4.5	-2.2	0.7	-1.4	-3.7	-2.5	-6.5	-8.0	-7.4	-0.6	-3.7	-2.3
11	10.8	4.1	7.8	2.2	-3.7	-0.7	2.9	-6.5	-0.8	-1.0	-2.5	-1.9	-5.3	-8.4	-7.1	0.6	-6.5	-2.6
12	7.3	3.7	5.4	-0.2	-6.1	-3.2	-0.6	-7.6	-5.1	0.6	-1.0	-0.1	-2.9	-5.3	-4.6	10.4	-1.0	4.6
13	4.9	2.9	3.6	-3.3	-5.3	-4.3	-1.0	-4.9	-3.3	1.8	0.2	1.1	-2.5	-8.0	-5.2	8.0	1.0	4.3
14	4.9	2.5	3.6	-0.6	-4.1	-2.6	-1.8	-7.3	-3.7	7.3	1.4	4.2	-2.9	-7.3	-4.8	7.6	-0.2	3.0
15	4.5	2.2	3.2	0.2	-5.7	-2.9	-2.2	-7.6	-5.7	1.4	-3.3	-2.2	-2.2	-4.1	-2.5	7.6	-1.4	1.7
16	3.3	1.8	2.6	-3.3	-6.5	-4.5	-1.0	-6.1	-4.0	-2.2	-2.9	-2.6	1.0	-1.0	-0.1	-1.0	-5.7	-3.6
17	2.5	1.0	1.6	-3.7	-7.3	-5.2	-2.5	-6.9	-4.7	0.6	-4.1	-2.9	1.0	-6.1	-1.6	-1.4	-7.3	-4.4
18	2.9	1.4	2.2	-4.5	-7.3	-6.1	1.8	-5.7	-3.9	2.9	-2.2	-0.1	-6.5	-7.6	-7.0	-1.4	-8.8	-5.9
19	3.7	0.6	2.2	-2.9	-5.3	-4.0	0.2	-3.7	-2.1	4.9	-1.0	1.4	-5.7	-10.0	-7.4	-6.1	-8.8	-7.3
20	8.8	2.5	5.9	-1.0	-4.1	-2.1	-1.8	-6.9	-4.0	8.8	1.8	6.2	-3.7	-6.5	-4.8	-1.8	-6.9	-4.4
21	9.6	4.1	6.4	-1.0	-10.4	-5.1	-2.2	-6.9	-3.9	7.3	-0.2	3.8	-4.1	-9.2	-6.4	-4.9	-9.6	-7.4
22	6.5	3.3	4.8	-8.8	-13.5	-10.9	-1.8	-6.5	-4.3	4.5	-0.6	1.7	-3.3	-8.0	-6.0	-5.3	-10.4	-7.5
23	8.0	0.2	5.4	-8.0	-13.9	-11.3	2.9	-2.2	0.4	2.5	-1.0	0.5	-4.9	-11.6	-9.0	-5.3	-7.3	-6.3
24	1.0	-0.6	0.0	1.0	-10.0	-4.7	4.9	-0.2	2.8	0.2	-4.1	-1.0	-5.7	-13.9	-11.0	-2.2	-6.1	-4.5
25	8.4	1.0	4.1	2.9	-2.9	0.9	4.5	-1.4	1.3	-0.6	-3.3	-1.9	-0.6	-6.1	-2.7	4.1	-5.3	-0.1
26	10.8	4.9	7.2	6.5	1.4	4.0	1.8	-3.3	-0.4	-2.5	-7.6	-3.9	0.6	-2.9	-1.5	6.5	0.6	3.9
27	8.4	3.7	6.5	5.3	-0.2	1.5	-1.4	-4.9	-2.5	-2.2	-10.0	-5.1	0.6	-2.5	-1.6	8.4	2.9	5.4
28	6.1	2.9	4.0	6.1	-2.5	2.2	2.5	-2.2	0.2	1.4	-3.7	-1.1	3.3	1.0	1.9	8.8	3.3	6.6
29	10.0	3.3	6.6	1.4	-2.5	-0.2	2.9	-1.0	1.2	2.9	-3.7	-0.2				8.0	4.1	6.0
30	9.6	4.5	6.9	-1.8	-5.7	-3.3	2.5	-2.5	-0.1	-2.5	-7.6	-4.8				9.2	1.4	5.4
31	3.3	-1.8	-0.3				0.2	-2.5	-1.4	1.0	-6.1	-2.1				4.5	-1.8	0.6
MONTHLY AVERAGE			5.8			-2.5			-2.3			-1.3			-5.0			-0.9

DAY	Apr.			May			June			July			Aug.			Sept.		
1	5.3	-0.6	1.6	3.7	-6.1	-0.5	2.9	-1.4	1.2	7.3	2.5	6.2	19.0	9.2	14.0	9.2	5.3	7.2
2	1.4	-2.5	-0.3	0.6	-3.3	-1.1	10.4	0.2	6.6	2.5	-0.6	1.3	20.2	10.8	15.3	11.6	2.9	6.8
3	-2.2	-3.7	-3.0	6.5	-4.5	2.4	10.8	2.5	6.1	2.9	1.0	2.1	16.7	10.0	13.0	6.1	2.5	4.2
4	-1.8	-4.5	-3.0	4.5	1.4	2.8	4.1	1.4	2.8	4.5	2.5	3.2	17.1	8.4	12.2	9.2	3.3	5.9
5	0.2	-5.3	-3.2	8.0	1.4	5.2	7.6	0.2	3.5	9.6	2.5	6.8	10.4	5.7	8.7	16.3	6.9	11.8
6	-0.2	-4.1	-2.7	11.2	6.9	9.0	2.2	-0.2	0.9	13.1	5.3	8.8	13.9	4.5	8.5	16.3	9.2	13.1
7	-1.4	-4.1	-3.3	11.6	6.1	8.9	1.0	-0.6	0.1	17.8	7.3	11.9	15.1	6.5	9.6	15.5	7.6	11.1
8	0.2	-2.5	-1.2	10.8	4.9	7.8	5.7	-0.2	2.8	16.7	8.0	11.6	8.0	4.5	6.2	10.8	4.1	7.5
9	1.4	-6.1	-1.4	11.2	3.3	6.8	10.0	1.8	4.8	14.7	6.1	9.9	10.0	4.9	7.1	4.5	1.8	3.7
10	4.1	-5.7	-0.9	9.2	2.9	6.1	12.4	4.1	7.2	15.1	5.3	10.1	18.2	10.4	13.4	4.5	2.5	3.7
11	7.6	-2.2	4.0	10.8	4.1	7.5	8.0	4.9	6.3	15.5	5.7	10.5	19.8	10.4	14.6	6.9	2.2	4.5
12	5.3	-4.5	-1.7	5.3	-1.8	2.4	8.4	4.1	5.7	17.4	7.3	12.1	18.6	8.8	13.5	10.4	3.3	6.8
13	-2.2	-5.3	-3.7	2.5	-3.3	-0.4	4.9	-0.6	0.9	19.0	9.2	13.3	19.0	10.4	14.5	10.8	4.9	6.8
14	-1.8	-5.7	-4.1	6.1	-1.4	2.6	1.4	-0.6	0.0	15.1	7.6	11.2	17.1	8.4	12.0	7.9	6.1	7.0
15	10.8	-2.2	4.4	2.2	-0.6	0.8	2.9	-0.2	1.3	18.6	7.6	12.9	11.2	7.3	8.9	10.7	8.0	9.1
16	9.2	6.1	7.7	2.9	-1.4	0.3	4.5	1.0	2.4	19.8	10.0	14.6	10.8	5.7	8.2	16.3	10.9	13.6
17	8.8	4.5	6.8	2.2	-0.6	0.8	8.0	1.0	4.2	15.1	7.3	11.4	12.7	6.1	9.0	18.6	9.6	13.5
18	9.6	4.9	6.8	6.5	-0.2	3.8	3.3	-0.6	1.2	12.4	6.5	8.4	17.1	8.8	12.9	15.9	8.8	11.3
19	6.5	1.4	4.0	6.5	2.2	4.4	10.4	0.2	5.9	19.0	7.3	14.3	11.2	7.6	8.7	16.7	8.8	11.9
20	10.0	-0.6	6.3	2.9	1.0	1.7	15.5	7.6	10.6	24.5	13.1	19.1	12.0	6.5	8.9	16.7	7.6	11.9
21	6.9	-1.4	1.8	5.7	0.6	2.5	15.9	5.3	9.8	23.7	12.7	17.1	8.0	5.3	6.6	19.4	11.2	15.8
22	3.7	-3.3	0.3	6.5	-0.6	3.6	16.3	6.9	11.3	23.3	12.7	17.0	6.9	5.3	6.0	18.2	11.2	14.4
23	6.5	-1.4	2.6	10.0	4.1	6.9	8.0	2.5	5.1	20.6	13.5	16.1	10.0	5.7	7.5	17.8	11.2	13.6
24	0.6	-1.4	-0.4	10.0	5.3	8.2	7.3	1.0	3.9	24.5	12.0	16.8	11.6	4.5	7.5	17.8	11.6	14.7
25	4.1	-1.4	1.4	11.2	3.3	6.3	11.2	3.7	7.1	14.7	9.2	11.3	9.2	4.5	7.1	14.7	9.6	12.8
26	3.3	-0.2	0.7	3.3	-1.0	1.6	3.7	1.8	2.8	17.4	7.3	11.9	12.7	4.9	8.6	15.1	8.8	11.3
27	4.9	-0.6	2.0	1.0	-4.1	-1.0	13.9	1.8	7.5	19.0	9.6	13.9	16.7	10.4	13.0	18.6	8.8	12.2
28	8.4	-0.2	3.1	1.4	-1.8	-0.4	16.7	6.5	10.4	19.8	9.6	13.8	14.7	7.6	11.0	17.1	8.8	12.6
29	6.1	-0.2	3.7	0.2	-1.0	-0.5	10.4	4.1	7.3	13.5	7.6	10.4	8.8	5.7	7.2	10.0	6.5	7.5
30	-0.2	-3.7	-2.3	8.8	-2.2	3.2	11.6	1.8	7.0	12.7	6.5	9.0	16.3	5.3	11.4	10.4	5.3	7.9
31				8.4	2.5	5.4				17.8	6.5	11.9	16.3	8.0	12.2			
MONTHLY AVERAGE			0.9			3.5			4.9			11.3			10.2			9.8

TABLE 5. Air temperature at 1,587 meters altitude, Salix Basin, September 1994

[Daily maximum, minimum, and average air temperature, in degrees Celsius. The temperature is sampled once an hour at the Salix Creek gaging station (fig. 1)]

Day	Max.	Min.	Avg.	Day	Max.	Min.	Avg.
1				16	21.4	9.9	14.5
2	15.1	3.8	10.1	17	25.5	11.8	15.9
3	6.3	3.6	5.2	18	25.4	11.0	14.6
4	16.3	4.4	8.3	19	26.0	10.4	15.1
5	20.5	8.6	13.8	20	24.8	9.3	14.6
6	23.6	9.6	14.1	21	25.8	10.4	16.9
7	22.5	9.6	13.8	22	25.3	13.9	17.4
8	11.3	4.6	7.9	23	26.9	13.8	17.2
9	7.0	3.2	4.5	24	26.0	14.1	17.2
10	8.2	2.2	4.8	25	20.1	10.8	14.7
11	15.4	2.2	6.0	26	24.9	10.1	13.6
12	16.1	3.0	7.9	27	26.2	10.2	15.7
13	16.9	5.2	8.8	28	24.4	10.6	15.4
14	9.4	7.5	8.4	29	14.7	6.7	10.3
15	12.4	7.8	9.7	30	18.2	6.8	10.2
				MONTHLY AVERAGE			8.8

TABLE 6. Precipitation at 1,587 meters altitude, Salix Basin, June through September 1994

[Precipitation is sampled once every 15 minutes, and the daily sum is given in millimeters; an * indicates no data]

Day	June	July	Aug.	Sept.
1		17.3	0.0	*
2		11.4	0.0	*
3	8.9	2.3	0.0	*
4	4.6	3.3	0.0	*
5	0.8	11.4	0.0	*
6	6.9	0.0	0.0	*
7	4.1	0.0	1.3	*
8	0.8	0.0	16.5	*
9	0.0	0.0	0.0	*
10	0.0	0.0	0.0	*
11	3.1	0.0	0.0	*
12	20.6	0.0	0.0	*
13	9.9	0.0	0.0	*
14	6.4	0.0	0.0	*
15	3.8	0.0	0.0	*
16	0.0	0.0	4.1	0.0
17	4.8	1.0	0.0	0.0
18	18.8	1.0	0.0	0.0
19	0.5	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0
21	0.0	0.0	0.8	0.0
22	0.0	0.0	2.3	0.0
23	3.8	0.3	0.5	0.0
24	1.3	0.3	0.0	0.0
25	0.0	0.0	0.0	0.0
26	8.4	0.0	4.3	0.0
27	0.0	0.0	0.0	0.0
28	0.0	0.0	1.0	0.0
29	0.0	0.0	10.7	0.0
30	0.0	0.0	0.0	0.0
31		0.0	*	
SUM	107.2	48.3	41.4	

TABLE 7. Precipitation at 1,631 meters altitude, Middle Tarn, June through September 1994

[Precipitation is sampled once every 15 minutes, and the daily sum is given in millimeters]

Day	June	July	Aug.	Sept.
1		22.6	0.0	0.5
2		13.5	0.0	0.3
3	7.1	3.1	0.0	37.6
4	5.8	3.3	0.0	0.5
5	1.3	8.1	0.0	0.0
6	6.4	0.0	0.0	0.0
7	4.6	0.0	1.0	0.0
8	1.0	0.0	26.9	10.2
9	0.0	0.0	0.0	7.6
10	0.0	0.0	0.0	5.8
11	3.3	0.0	0.0	0.0
12	21.3	0.0	0.0	0.0
13	13.0	0.0	0.0	0.8
14	1.0	0.0	0.0	24.9
15	3.3	0.0	0.0	4.1
16	0.0	0.0	3.6	0.0
17	6.1	0.8	0.0	0.0
18	18.8	1.8	0.0	0.0
19	0.3	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0
21	0.0	0.0	0.5	0.0
22	0.0	0.0	2.5	0.0
23	3.6	0.3	0.5	0.0
24	1.3	0.8	0.0	0.0
25	0.3	0.0	0.0	0.0
26	9.4	0.0	5.1	0.0
27	0.0	0.0	0.0	0.0
28	0.0	0.0	1.0	0.0
29	0.0	0.0	9.1	0.0
30	0.0	0.0	0.0	0.0
31		0.0	0.0	
SUM	107.7	54.1	50.3	92.2

TABLE 8. Shortwave solar radiation at 1,848 meters altitude, South Cascade Glacier Basin, 1994 water year

[Daily average radiation, in arbitrary units, recorded once an hour at the Hut (fig. 1.). A -99.0 indicates no data]

DAY	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	154.7	-99.0	24.6	-99.0	80.4	52.9	210.7	271.5	218.3	50.8	284.9	53.8
2	136.8	-99.0	39.9	11.7	79.7	43.3	93.0	185.9	295.3	149.5	232.6	194.1
3	111.9	-99.0	23.8	21.4	54.3	64.5	119.6	270.5	242.4	133.0	130.3	40.5
4	-99.0	-99.0	29.6	9.9	36.2	81.4	129.8	145.7	83.8	104.5	224.6	188.3
5	116.2	-99.0	44.1	19.9	-99.0	158.5	164.1	304.2	170.5	290.1	122.9	231.1
6	26.0	52.6	52.4	21.8	42.3	173.1	124.4	297.1	101.2	-99.0	262.4	209.3
7	89.8	79.3	27.6	-99.0	94.2	143.4	132.1	298.6	200.1	-99.0	145.2	203.3
8	136.2	76.9	26.5	-99.0	-99.0	164.8	149.5	296.8	256.6	320.1	-99.0	34.5
9	156.1	57.1	12.4	-99.0	-99.0	120.0	199.9	257.3	261.3	335.2	134.8	48.9
10	145.6	73.7	13.4	23.1	-99.0	79.6	185.2	226.2	283.9	337.2	254.6	80.9
11	89.9	67.4	23.0	23.6	-99.0	188.9	153.2	160.4	149.3	327.3	265.3	150.0
12	54.4	77.1	28.0	22.4	-99.0	158.5	146.4	192.6	143.0	319.7	247.5	-99.0
13	48.9	56.1	21.8	42.6	-99.0	119.0	121.6	163.3	94.3	207.6	250.9	-99.0
14	27.9	38.2	35.4	52.4	-99.0	169.4	180.7	-99.0	159.3	239.1	244.1	-99.0
15	50.6	20.5	45.7	26.4	-99.0	91.4	219.5	103.6	242.1	312.4	164.5	-99.0
16	50.7	12.4	44.4	51.7	-99.0	76.9	91.1	189.0	165.7	237.8	128.3	189.5
17	61.9	22.1	42.1	39.1	-99.0	78.0	141.2	132.8	224.3	-99.0	180.3	166.5
18	33.5	22.3	44.3	-99.0	-99.0	-99.0	145.9	246.8	101.4	189.3	257.2	197.9
19	109.9	38.9	42.7	-99.0	-99.0	110.7	213.1	192.6	360.1	314.1	83.7	194.7
20	99.1	32.5	47.2	69.8	-99.0	121.6	262.1	87.5	340.2	306.3	168.4	194.6
21	113.2	26.1	43.2	27.6	-99.0	113.7	81.8	242.7	324.8	223.7	77.9	196.9
22	22.3	-99.0	35.7	10.7	-99.0	166.4	259.2	282.5	300.5	293.2	30.7	185.7
23	20.3	-99.0	37.9	35.8	-99.0	171.9	256.7	278.1	66.0	220.8	171.3	189.7
24	68.1	60.7	38.5	46.0	-99.0	227.0	152.3	244.6	256.8	270.4	222.0	139.4
25	112.0	59.6	22.4	67.5	64.6	-99.0	237.9	208.6	271.8	-99.0	118.1	119.9
26	91.4	30.7	14.7	26.5	70.8	-99.0	158.1	199.9	110.9	-99.0	234.1	105.0
27	61.8	27.2	22.5	-99.0	-99.0	-99.0	290.4	176.2	351.0	301.9	-99.0	-99.0
28	77.2	26.2	26.5	70.4	37.6	91.4	272.3	109.0	336.4	305.0	126.4	154.0
29	92.6	-99.0	34.9	83.5		97.2	169.6	111.4	189.3	292.5	93.6	76.1
30	91.1	27.1	19.0	78.3		73.4	208.4	316.9	267.6	252.2	245.0	107.5
31	31.2		23.4	76.7		182.5		112.6		293.1	190.5	

TABLE 9. Wind speed at 1,848 meters altitude, South Cascade Glacier Basin, 1994 water year

[Daily average wind speed, in kilometers per hour, recorded once an hour at the Hut (fig. 1.). A -99.0 indicates no data]

DAY	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	8.8	-99.0	34.4	-99.0	10.6	26.1	5.4	9.7	18.7	43.1	7.8	10.5
2	23.6	-99.0	35.4	50.9	0.5	34.5	12.8	17.3	39.0	25.8	8.9	9.5
3	5.4	-99.0	50.4	31.2	4.6	35.9	17.2	22.2	15.9	22.9	11.9	26.6
4	6.8	-99.0	34.3	29.3	23.5	46.3	14.1	13.3	25.7	15.7	14.1	12.8
5	19.5	-99.0	39.7	29.7	4.3	21.7	9.6	8.2	23.0	17.0	24.7	27.9
6	30.8	7.1	17.2	8.0	15.9	20.8	46.9	17.8	22.4	11.5	13.0	27.5
7	16.0	4.0	44.4	-99.0	57.4	30.9	27.2	8.8	19.1	10.8	15.4	11.4
8	67.6	4.0	47.0	-99.0	-99.0	14.3	47.3	6.2	12.4	8.4	10.2	23.9
9	58.9	23.4	62.0	-99.0	-99.0	9.4	7.0	12.1	8.6	12.7	5.4	17.3
10	23.0	6.5	46.5	19.2	-99.0	31.1	5.8	12.4	6.3	18.6	25.7	5.4
11	23.6	6.9	47.6	27.4	-99.0	4.1	14.0	21.0	9.9	12.4	14.4	2.0
12	3.1	10.3	43.9	15.7	-99.0	8.0	36.2	24.5	15.0	11.0	9.2	-99.0
13	6.0	28.6	70.0	29.9	-99.0	26.5	36.7	13.6	63.6	13.7	8.0	-99.0
14	7.2	19.0	14.5	11.1	-99.0	31.7	22.4	30.5	35.8	12.8	5.5	-99.0
15	5.8	60.7	19.6	52.0	-99.0	21.1	11.5	10.8	6.0	10.8	20.0	-99.0
16	9.2	15.6	10.4	39.4	-99.0	51.7	8.6	4.0	0.0	16.0	15.9	47.8
17	11.9	30.7	6.1	10.9	-99.0	44.8	4.7	11.9	12.0	23.4	8.8	18.6
18	24.4	31.0	3.6	-99.0	-99.0	-99.0	6.9	16.3	19.1	17.2	19.1	4.8
19	15.5	17.9	12.7	-99.0	-99.0	36.7	11.6	13.3	17.4	18.0	12.7	8.0
20	22.5	44.7	5.6	46.5	-99.0	48.8	36.4	23.8	13.9	32.2	13.2	12.6
21	16.9	46.4	20.2	19.2	-99.0	56.1	27.2	6.9	4.6	12.2	16.8	36.7
22	21.7	40.7	9.9	20.7	-99.0	13.5	6.5	4.6	7.9	5.8	23.6	10.9
23	34.9	29.5	5.4	44.7	-99.0	34.0	16.6	7.3	14.5	6.1	12.5	8.7
24	27.0	14.2	4.0	47.3	-99.0	27.3	0.0	5.6	8.0	10.0	6.1	16.8
25	15.0	56.0	5.7	9.8	44.6	-99.0	15.5	9.0	20.6	7.6	2.2	9.2
26	12.4	32.1	2.3	6.0	13.1	-99.0	3.6	21.1	32.4	8.7	15.7	4.6
27	27.7	15.3	0.8	15.6	36.4	-99.0	5.9	15.9	10.0	9.9	36.9	4.8
28	6.6	52.0	3.9	25.1	67.8	35.3	2.4	9.1	3.3	7.8	26.0	13.2
29	10.0	30.4	29.2	22.3		38.1	26.4	42.3	10.0	10.2	19.3	6.2
30	12.0	33.2	20.9	34.4		31.2	28.8	17.6	2.9	15.2	19.7	9.4
31	40.5		33.0	14.7		5.4		40.3		7.0	22.1	
MONTHLY AVERAGE	19.8	26.4	25.2	26.4	--	29.1	17.2	15.4	16.6	14.7	15.0	14.9

TABLE 10. Wind speed at 1,631 meters altitude, South Cascade Glacier Basin, July through September, 1994

[Daily average wind speed, in kilometers per hour, recorded once every 15 minutes at Middle Tarn (fig. 1.)]

DAY	July	Aug.	Sept.
1		13.9	8.6
2		13.3	10.1
3		11.6	23.2
4	3.6	14.0	8.9
5	8.6	15.5	20.1
6	9.9	10.7	21.6
7	12.2	16.6	16.9
8	13.2	12.7	23.1
9	13.4	13.2	15.4
10	11.0	20.6	6.7
11	12.3	14.1	7.7
12	12.3	11.8	8.9
13	12.8	12.6	11.0
14	11.2	13.6	19.5
15	12.0	12.7	12.9
16	13.5	10.7	27.9
17	15.6	9.8	19.5
18	10.1	14.4	15.0
19	19.3	10.0	15.0
20	23.6	11.9	17.0
21	19.9	12.5	20.2
22	18.7	15.1	19.6
23	17.8	7.8	19.6
24	21.6	9.0	16.3
25	11.9	8.6	16.9
26	11.7	12.3	14.0
27	13.9	25.3	15.9
28	15.3	16.9	17.2
29	12.4	9.5	11.2
30	10.4	13.8	10.9
31	11.7	15.2	
MONTHLY AVERAGE	13.6	13.2	15.7

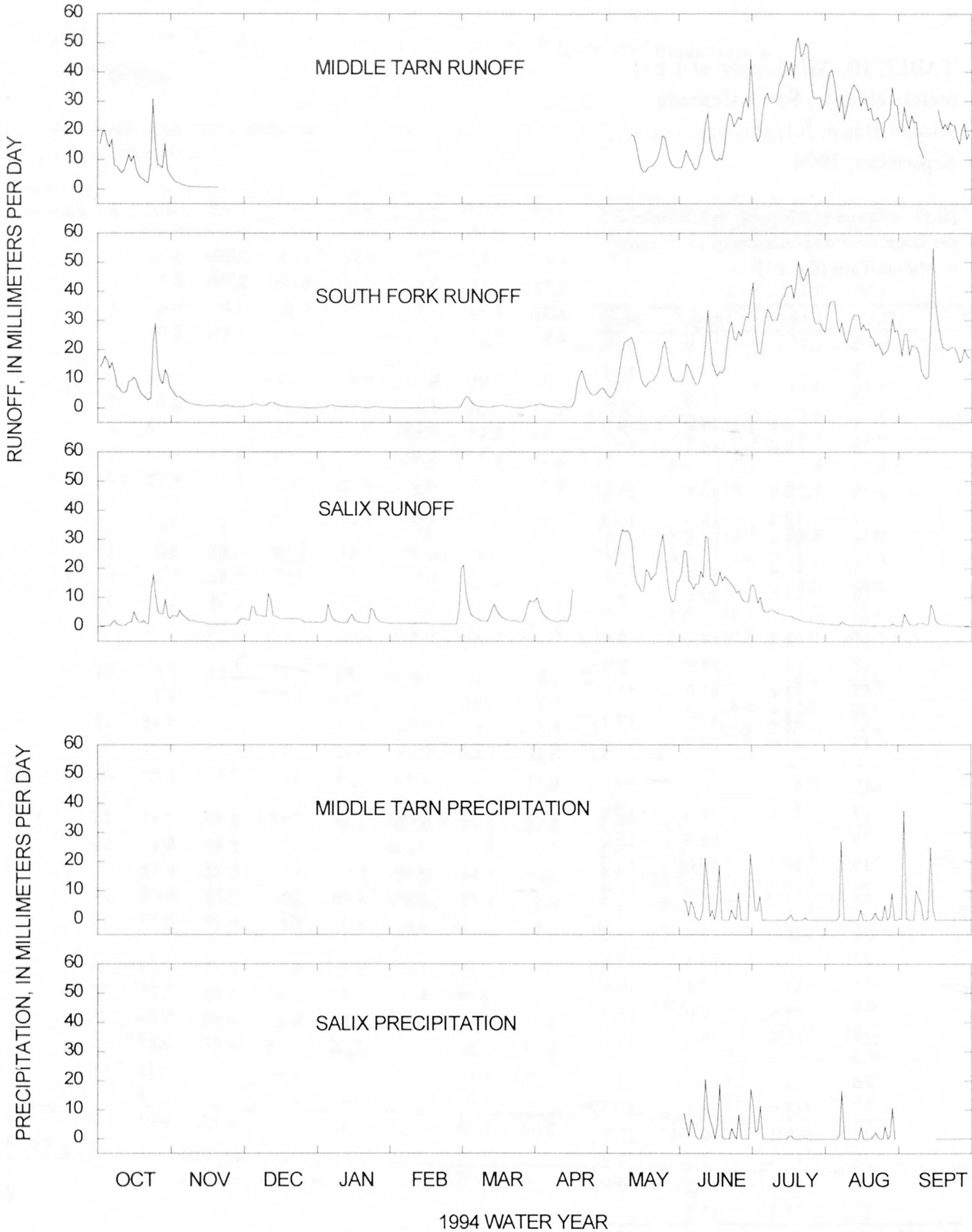

FIGURE 8. Runoff and precipitation near South Cascade Glacier during the 1994 water year.

TABLE 11. Runoff at Salix Basin, 1994 water year

[Daily values in millimeters, averaged over the basin; no data indicated by -99.0]

DAY	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	0.2	3.8	2.4	1.3	1.2	19.8	8.9	-99.0	16.2	14.2	0.9	-99.0
2	0.2	3.4	2.2	1.8	1.1	21.2	9.9	-99.0	-99.0	14.4	0.9	-99.0
3	0.2	5.7	7.0	2.1	1.2	11.6	7.6	-99.0	26.2	12.3	0.8	4.5
4	0.2	4.4	6.8	7.8	1.2	7.3	5.2	-99.0	25.8	8.0	0.8	2.6
5	0.2	3.4	4.0	4.5	1.2	4.3	4.0	20.8	15.8	10.4	0.7	0.9
6	1.4	2.8	3.9	2.7	1.2	3.5	3.2	25.6	15.0	6.1	0.7	0.6
7	2.1	2.1	3.9	2.1	1.2	3.2	2.6	30.1	12.9	5.2	0.7	0.5
8	0.8	2.1	3.5	1.8	1.2	2.7	2.2	33.5	14.8	5.1	1.8	0.7
9	0.5	2.0	3.3	1.5	1.2	2.1	2.0	32.7	14.5	5.7	1.1	1.4
10	0.5	1.7	11.5	1.4	1.2	2.0	1.8	33.2	19.2	5.7	0.8	1.4
11	0.4	1.5	8.9	1.3	1.2	1.9	1.8	32.2	16.9	5.3	0.6	1.2
12	0.9	1.5	3.8	1.3	1.2	1.9	2.1	28.9	31.2	4.7	0.5	0.8
13	1.5	1.4	3.7	3.0	1.2	3.4	2.1	19.0	30.4	4.5	0.5	0.6
14	1.7	1.2	3.2	4.3	1.2	6.0	2.0	15.1	16.4	4.4	0.5	7.7
15	5.2	0.9	2.7	2.5	1.1	7.8	1.9	13.9	15.9	4.1	0.5	5.8
16	2.7	0.8	2.7	1.9	1.1	5.8	4.3	12.2	14.0	3.8	0.5	2.0
17	1.8	0.8	2.7	1.5	0.9	4.4	12.7	12.2	14.5	3.7	0.6	1.2
18	1.3	0.8	2.7	1.4	0.9	3.5	-99.0	19.7	19.0	3.7	0.5	0.9
19	2.1	0.8	2.7	1.3	0.9	2.8	-99.0	18.6	15.7	3.2	0.4	0.7
20	1.2	0.8	2.7	1.3	0.9	2.5	-99.0	16.1	17.4	2.8	0.4	0.6
21	1.1	0.8	2.7	1.3	0.9	2.2	-99.0	17.2	16.5	2.6	0.4	0.5
22	11.5	0.8	2.7	6.3	0.9	2.1	-99.0	18.1	15.6	2.1	0.4	0.4
23	17.9	0.8	2.6	5.8	0.9	2.1	-99.0	23.3	14.6	2.0	0.5	0.4
24	10.6	0.8	2.2	3.2	0.9	2.1	-99.0	27.5	13.5	1.9	0.4	0.4
25	5.1	0.8	1.7	2.2	0.9	1.9	-99.0	31.7	11.7	1.8	0.2	0.2
26	4.5	0.8	1.5	1.8	0.9	1.5	-99.0	24.8	12.4	1.7	0.5	0.2
27	4.3	0.9	1.5	1.5	0.9	1.8	-99.0	15.8	10.0	1.5	0.2	0.2
28	9.4	2.4	1.5	1.3	5.7	3.4	-99.0	10.7	8.9	1.3	0.2	0.2
29	3.8	2.8	1.3	1.3		7.0	-99.0	8.5	8.6	1.2	1.1	0.2
30	2.8	2.6	1.7	1.2		9.0	-99.0	9.0	8.6	1.2	0.6	0.2
31	3.8		1.5	1.2		8.5		15.5		1.2	-99.0	
SUM	100.0	55.8	105.2	73.8	34.5	159.4	--	--	--	145.5	--	--

South Fork Cascade Runoff

Stage measurements were converted to instantaneous discharges by using a rating curve that is a modification of rating tables used for this station in previous years. The rating curve was established by using the curve shape of the plotted tabular values from previous years, but was necessarily displaced slightly by four discharge measurements made in the 1994 balance year. The curve is defined with a two-piece third degree polynomial: above a stage of 0.85 feet,

$$q = 17.448 - 43.138S + 40.945S2 - 0.90278S3,$$

and at a stage of 0.85 feet and below,

$$q = 0.00356 + 5.6207S - 5.568S2 + 14.738S3.$$

Runoff from the South Cascade Glacier Basin increased slightly during several storms during the winter (fig. 8, table 12). These periods of winter runoff occur during most winters, but in the 1994 balance year, they were more frequent than normal.

Middle Tarn Runoff

Stage measurements were converted to discharge using a rating curve determined from 14 discharge measurements made between September 8, 1992 and September 16, 1994. The outlet from Middle Tarn is a bedrock channel that does not change; therefore, the rating curve is expected to remain stable at Middle Tarn. For a stage above 0.35 feet,

$$q = 2.064 - 3.673S + 24.770S2,$$

and at a stage of 0.35 and below,

$$q = S^{1.809} \times 25.123.$$

The Middle Tarn well was frozen from late November to early May, resulting in lost stage record. The highest stage of the year probably occurred on September 15, nearly synchronously with that at South Fork Cascade River; unfortunately, the Middle Tarn float sensor was submerged around that time (fig. 8, table 13).

Precipitation

Middle Tarn precipitation correlated well with Salix Basin runoff during July 1993 (Krimmel, 1994), and it was stated that Salix runoff could be used as an indirect measure of basin precipitation after most of the snow was melted from Salix Basin. In 1994, most of the snow had melted from Salix Basin by the end of July. The periods of Middle Tarn precipitation during August and September 1994 correlate well with peaks in the Salix runoff; however, the precipitation magnitude was always several times that of the runoff (tables 7 and 11). Possible reasons for the precipitation-runoff discrepancy are the following: the precipitation at Middle Tarn gage was local; precipitation was absorbed into the ground in the Salix Basin and the runoff was delayed; or, for some reason, precipitation was over-measured or runoff under-measured. Salix runoff should not be used as an indication of precipitation without additional analysis.

TABLE 12. Runoff at South Cascade Glacier Basin, 1994 water year

[Daily values in millimeters, averaged over the basin]

DAY	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	14.0	4.7	0.7	0.3	0.1	0.8	1.0	5.5	9.2	37.5	26.0	23.2
2	15.5	3.7	0.9	0.3	0.1	2.6	1.3	4.3	9.0	43.1	31.2	17.7
3	17.9	4.0	1.0	0.4	0.1	4.0	1.4	3.6	10.4	26.2	36.0	25.2
4	16.3	3.3	1.6	0.7	0.1	3.7	1.4	4.2	15.2	19.2	36.6	25.5
5	13.6	2.6	1.5	1.1	0.1	2.4	1.1	6.0	14.3	18.5	36.7	18.1
6	15.7	2.1	1.1	1.0	0.1	1.5	0.9	8.3	12.0	23.9	29.2	21.5
7	12.2	1.8	1.0	0.8	0.1	1.0	0.8	13.8	9.9	30.4	26.0	21.1
8	7.6	1.5	0.9	0.7	0.1	0.8	0.6	19.2	8.3	34.0	29.4	20.9
9	6.7	1.3	1.0	0.6	0.1	0.6	0.5	22.6	8.1	32.5	24.5	19.0
10	5.6	1.2	1.6	0.5	0.1	0.5	0.4	22.9	10.6	30.0	22.3	12.9
11	5.2	1.0	1.9	0.5	0.1	0.4	0.3	23.7	14.1	30.2	26.1	11.0
12	5.9	0.9	2.0	0.5	0.1	0.3	0.4	24.2	21.3	30.0	29.7	10.0
13	9.3	0.9	1.5	0.4	0.2	0.3	0.4	21.6	33.6	33.5	31.9	10.9
14	9.5	0.8	1.2	0.4	0.2	0.4	0.4	18.0	22.7	37.0	31.7	31.9
15	10.6	0.9	0.9	0.5	0.2	0.7	0.3	13.9	15.4	38.4	31.9	54.8
16	9.6	0.9	0.7	0.5	0.3	0.8	0.4	10.2	12.7	41.3	26.9	35.9
17	6.9	0.9	0.6	0.4	0.2	0.8	0.8	8.1	11.0	41.6	28.7	29.4
18	5.0	0.9	0.5	0.3	0.2	1.0	2.6	7.3	12.5	42.3	26.7	24.0
19	4.3	0.7	0.4	0.3	0.2	0.9	8.5	8.7	12.0	37.7	27.3	20.7
20	3.5	0.7	0.4	0.2	0.1	0.7	11.4	9.2	13.5	43.0	24.3	20.5
21	2.7	0.8	0.3	0.2	0.1	0.6	13.0	9.3	20.9	50.5	23.9	19.8
22	3.4	0.9	0.3	0.3	0.1	0.5	10.4	10.7	26.9	45.5	21.2	20.6
23	23.2	0.8	0.3	0.4	0.3	0.4	7.2	12.1	29.6	43.6	22.3	20.9
24	28.9	0.7	0.2	0.5	0.3	0.3	6.0	15.3	23.8	45.8	20.4	20.6
25	13.7	0.6	0.2	0.4	0.3	0.2	4.7	20.8	23.2	48.0	18.2	18.6
26	9.7	0.5	0.2	0.4	0.3	0.2	4.6	22.9	26.4	38.8	19.0	15.6
27	8.3	0.4	0.1	0.3	0.3	0.2	4.9	17.8	24.6	32.1	20.0	16.5
28	13.4	0.5	0.1	0.3	0.3	0.3	5.7	12.9	27.9	28.8	23.1	20.4
29	11.1	0.5	0.1	0.2		0.5	6.7	10.7	31.6	29.1	30.8	18.3
30	7.2	0.6	0.1	0.2		0.7	6.9	9.2	30.9	29.1	26.1	17.0
31	6.0		0.2	0.1		0.8		9.2		26.9	27.0	
SUM	322.4	41.2	23.4	13.6	4.6	28.7	104.8	405.9	541.5	1088.4	835.4	642.6

TABLE 13. Runoff at Middle Tarn Basin, 1994 water year

[Daily values in millimeters, averaged over the basin; no data indicated by -99.0]

DAY	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	15.2	2.8	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	7.4	44.6	30.2	21.4
2	19.4	2.2	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	7.3	32.1	36.3	19.5
3	20.1	2.1	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	9.7	19.2	40.0	28.1
4	16.3	1.6	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	13.3	16.1	40.8	23.0
5	14.2	1.3	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	11.0	18.4	36.6	20.6
6	17.1	1.1	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	9.5	26.7	30.2	25.3
7	8.0	1.0	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	7.6	31.3	26.4	22.7
8	7.8	0.8	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	6.5	33.0	32.2	23.1
9	6.7	0.8	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	7.7	30.3	23.7	15.0
10	5.5	0.8	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	11.4	29.6	27.0	13.1
11	6.4	0.8	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	13.6	29.7	30.9	10.7
12	8.8	0.8	-99.0	-99.0	-99.0	-99.0	-99.0	18.6	21.8	30.9	34.0	-99.0
13	11.9	0.7	-99.0	-99.0	-99.0	-99.0	-99.0	18.2	26.0	36.0	35.8	-99.0
14	9.3	0.7	-99.0	-99.0	-99.0	-99.0	-99.0	15.4	15.8	37.2	34.4	-99.0
15	11.6	0.7	-99.0	-99.0	-99.0	-99.0	-99.0	10.4	12.3	40.1	33.1	-99.0
16	7.1	0.7	-99.0	-99.0	-99.0	-99.0	-99.0	7.4	10.3	43.9	28.3	-99.0
17	5.1	0.7	-99.0	-99.0	-99.0	-99.0	-99.0	5.9	9.7	39.0	31.1	27.0
18	3.7	0.7	-99.0	-99.0	-99.0	-99.0	-99.0	5.9	10.7	43.4	30.8	23.5
19	3.5	0.7	-99.0	-99.0	-99.0	-99.0	-99.0	7.4	9.9	38.0	26.9	20.6
20	2.5	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	7.8	14.3	49.1	27.8	22.2
21	2.2	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	8.0	21.6	52.0	23.7	20.2
22	8.3	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	9.2	26.0	45.2	23.5	22.9
23	30.9	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	10.5	24.9	46.3	24.6	21.7
24	15.9	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	13.3	21.3	50.0	22.4	21.8
25	8.3	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	18.3	22.9	48.5	17.5	17.6
26	8.0	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	17.7	24.7	37.4	23.4	15.4
27	7.2	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	13.8	23.7	31.5	24.0	20.0
28	15.6	-99.0	-99.0	-99.0	-99.0	-99.0	-99.0	10.3	28.4	30.9	25.5	22.5
29	6.8	-99.0	-99.0	-99.0		-99.0	-99.0	8.3	31.3	31.2	34.7	16.9
30	5.2	-99.0	-99.0	-99.0		-99.0	-99.0	7.5	28.0	31.4	28.9	18.8
31	4.0		-99.0	-99.0		-99.0		7.3		27.2	28.6	
SUM	312.5	--	--	--	--	--	--	--	488.4	1100.3	913.3	--

MASS BALANCE

Winter Balance

The balance was measured on May 4, 1994. Snow depths were measured using a probe rod at 48 points on the glacier (fig. 9), 5 points on the delta near the east end of South Cascade Lake, and at the snow course near the west end of South Cascade Lake. The locations of the probe points were determined in the field by pacing in estimated directions between estimated positions on the glacier. It is estimated that the horizontal location of the points is accurate to ±100 m. The altitudes of the points were measured photogrammetrically from the September 1, 1993 aerial photography, and are estimated to be accurate to ±10 m. The probed snow depths are estimated to be accurate to ±0.1 m. Probing was fairly easy, with no hard snow layers or ice layers that may have shown a false 1993 firn or ice horizon.

The grid-index (GI) method described by Krimmel (1993) was used to area-integrate the balance measurements at points to the glacier-averaged values. The glacier is gridded into 100-m by 100-m cells, and each cell is assigned an altitude. Mathematical functions are used to describe the variation with altitude of snow density and snow depth. A minor modification of the GI method described by Krimmel (1993) was used in 1994. In 1992 and 1993, mathematically defined curves were fit to the actual data (for instance, probed snow depths at specific altitudes). Usually a quadratic equation described the data well. However, with some data sets, a quadratic equation reverses sign within the bounds of the altitude range; this is contrary to what is expected in reality. Rather than using higher order polynomials or other functions when the quadratic did not behave well, a well-behaved interim quadratic equation was used. This interim quadratic was formed by taking data points from a hand-drawn curve that smoothed a scatter plot of all measured points. The quadratic equations used are shown, with the measured points, on figures 10 and 12. It is estimated that this use of an interim data set does not change the accuracy of the final mass balance values.

Snow density was measured at the P-1 pit location (fig. 1), altitude 1,840 m. The density was measured in the wall of a pit through the entire snowpack, with a depth of 4.63 m (table 14). Bulk snowpack density was 0.495. Bulk density was also measured at the snow course near the gaging station, where the average of eight samples was 1.65 m depth, with a density of 0.52 (table 15). A linear fit between the two density measurements was used to determine the density at any altitude on the glacier.

The altitude at each grid point was taken from the 1993 grid, except for a few upper glacier points where the altitude was not photogrammetrically measured in 1993; then the 1992 grid altitude was used. The density multiplied by the depth at each grid point is the water equivalence at the point and the sum of all 204 points is the total volume. Averaged over the glacier grid area, the measured winter balance was 2.39 m water equivalent (WE), which is $\bar{b}_m(s)$. On April 15, average daily temperature at the Hut rose above freezing, and except for occasional short periods, remained so for the rest of the ablation season. The snowpack probably absorbed most of the liquid precipitation that fell between April 15 and May 4. The maximum accumulation probably occurred very near May 4, and the measured snow balance, $\bar{b}_m(s)$ was essentially equal to $\bar{b}_w(s)$.

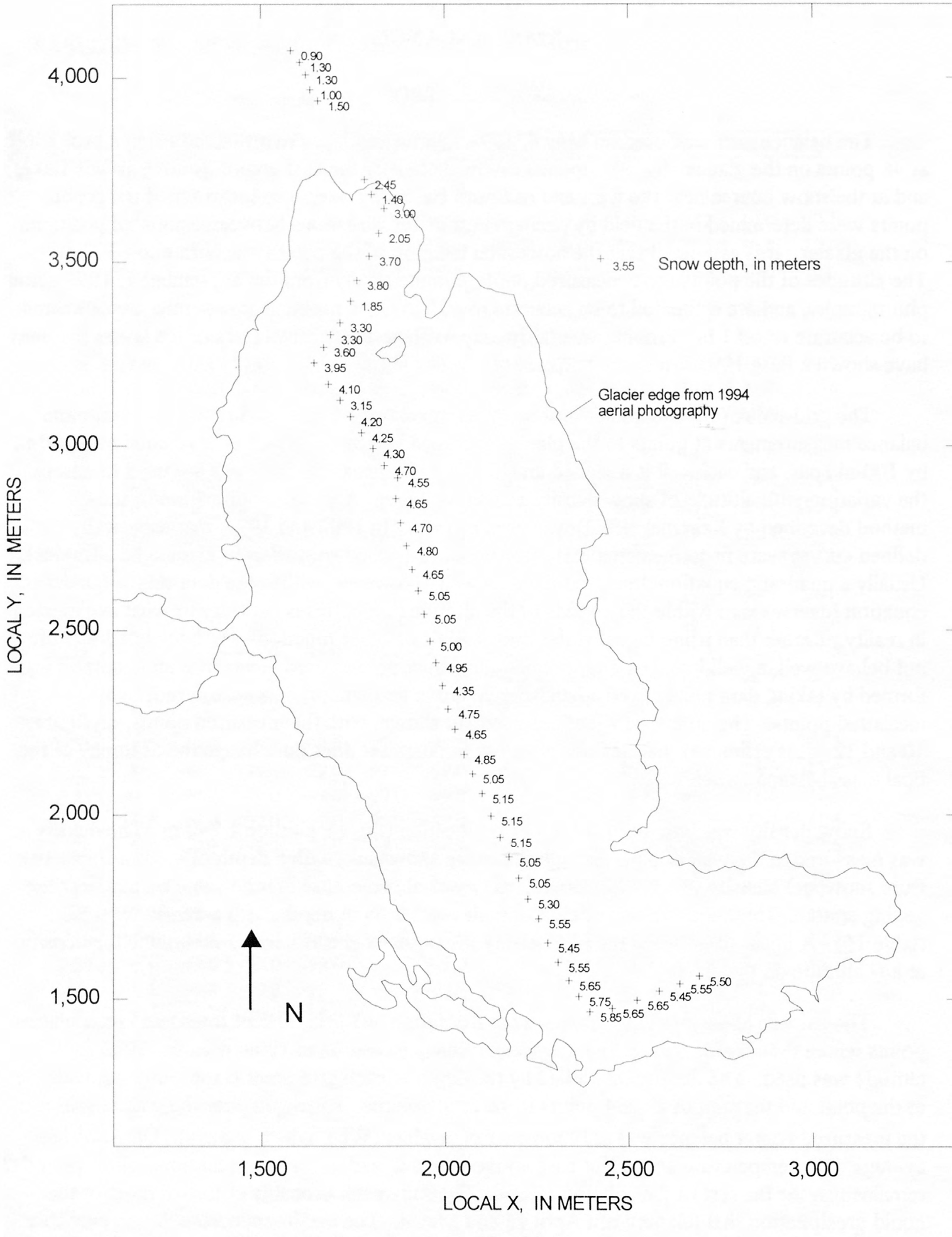

FIGURE 9. Snow depths on South Cascade Glacier on May 4, 1994.

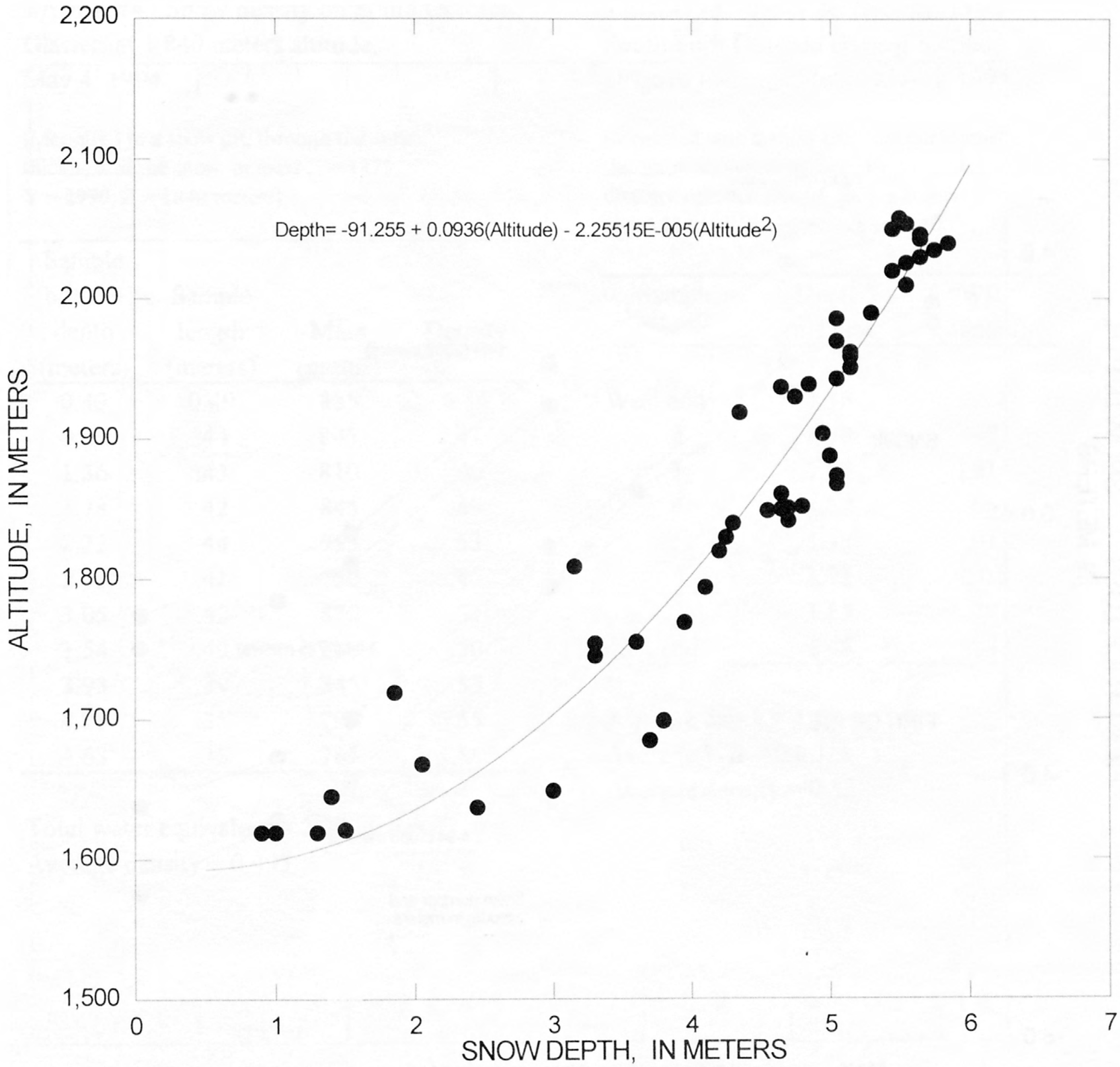

FIGURE 10. Snow depth as a function of altitude at South Cascade Glacier, May 4, 1994.

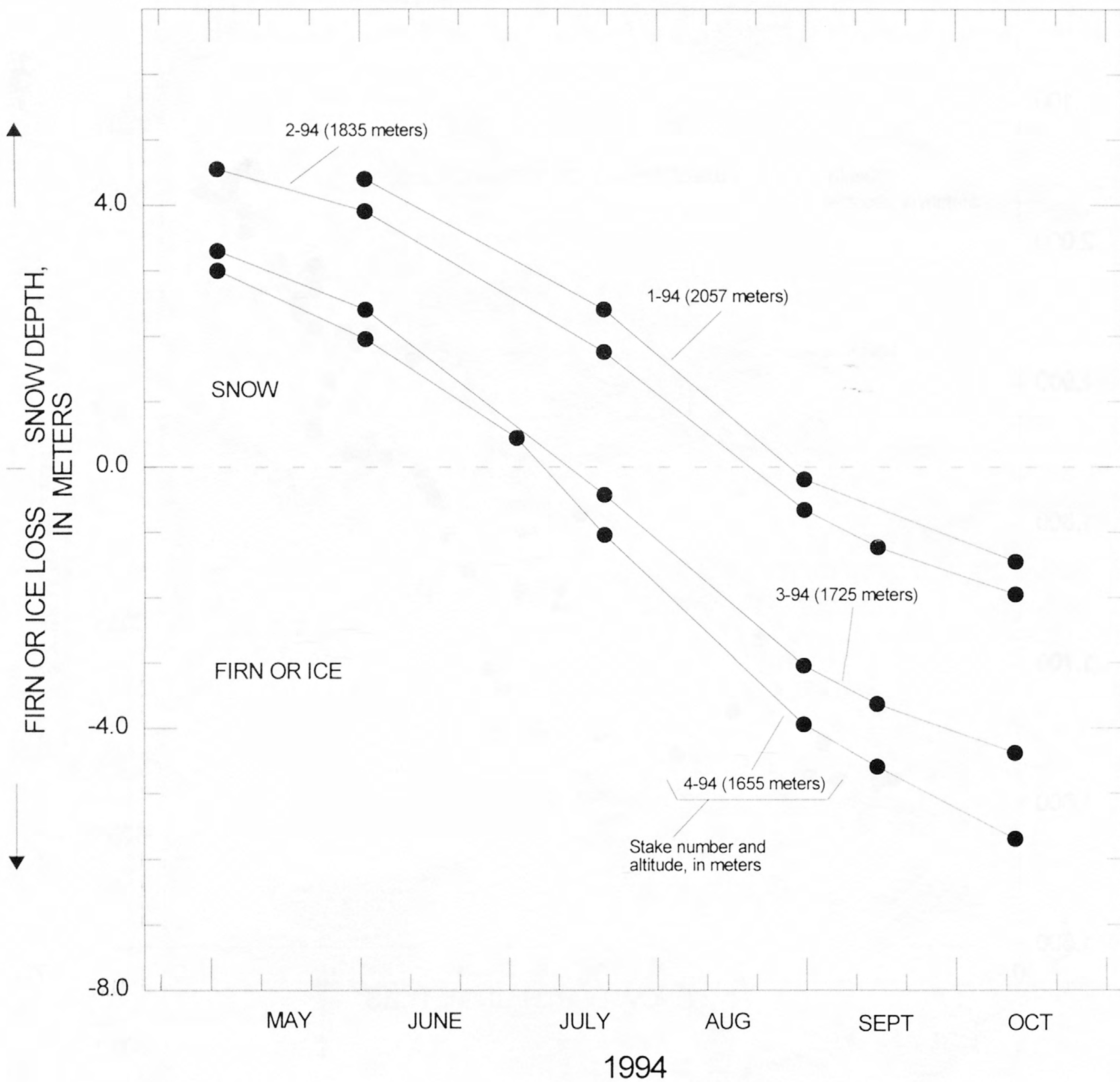

FIGURE 11. Snow depth and firn or ice loss at South Cascade Glacier at each 1994 stake. Depths are accurate to 0.1 meter. (Stake locations shown on figure 1.)

TABLE 14. Snow density on South Cascade Glacier, at 1,840 meters altitude, May 4, 1994

[Measured in a snow pit, through the entire thickness of the snow, at local X = 1775, Y = 2990, Z = 1840 meters]

Sample bottom depth (meters)	Sample length (meters)	Mass (grams)	Density
0.49	0.49	885	0.44
0.93	.44	845	.47
1.36	.43	810	.46
1.78	.42	845	.49
2.22	.44	955	.53
2.63	.41	750	.45
3.05	.42	870	.51
3.54	.49	100	.50
3.93	.39	845	.53
4.28	.35	795	.55
4.63	.35	785	.55

Total water equivalent = 2.29 meters
Average density = 0.495

TABLE 15. Snow density near the South Fork Cascade Gaging Station, at 1,618 meters altitude, May 4, 1994

[Measured with a snow tube that penetrated the entire snowpack in one sample. The distance between sample locations was about 15 m. WE = water equivalent]

Sample	Depth (meters)	WE (meters)
West end	1.55	0.84
2	1.70	.99
3	1.57	.81
4	1.52	.66
5	1.73	.91
6	1.91	1.04
7	1.55	.79
East end	1.65	.84

Average depth = 1.65 m
Average WE = 0.86 m
Average density = 0.52

Net Balance

Net balance data consisted of the minimum balance readings on four stakes (fig. 11; table 16) and the equilibrium line altitude, all plotted on figure 12. The GI method was used to area-integrate the point measurements. Altitude for each GI cell was measured photogrammetrically from the September 7, 1994 photography. A fabricated set of points was used to form a quadratic equation that approximately fits the five data points. The 1994 net balance, $\bar{b}_n$, was -1.60 m averaged over the glacier.

Balance Year to Water Year Adjustments

The final balance increment, $\bar{b}_1$, for the 1993 balance year was estimated at -0.20 m WE (Krimmel, 1994). This value is the initial balance increment, $\bar{b}_0$, of the 1994 balance year.

The last balance measurements of the 1994 balance year were on September 15, 1994. Ablation continued after that visit. On October 25, 1994 there was 0.66 m and 0.31 m of new snow at stakes 1-94 and 4-94 respectively. This new snow did not completely melt from any of the stakes, thus the date of the 1994 final balance increment was prior to October 25. The level of the summer surface, buried by the new snow, was measured on each of the stakes, and indicated the minimum balance at each stake. The date on which the end of the 1994 balance year ended was determined by subjectively considering the precipitation and temperature record from Salix, and the temperature record from Bend. Snow probably fell on the upper glacier on October 10, when there was precipitation and the temperature at Bend was below freezing. The entire glacier was probably snow covered on October 13, when there was precipitation and the air temperature at Salix was near freezing. Additional precipitation occurred on October 19-20, with sub-freezing temperatures at Salix. The $\bar{b}_1$ probably occurred near October 13, and is estimated to have been -0.10 m WE.

The annual balance, $\bar{b}_a$, is defined by Mayo and others (1972) as the change in snow, firn, and ice storage between the beginning and end of some fixed period, which here is the water year. The measured values of $\bar{b}_0$, $\bar{b}_1$, and $\bar{b}_n$ at South Cascade Glacier for the 1994 balance year can be used to derive the annual balance, $\bar{b}_a$, where $\bar{b}_a = \bar{b}_n + \bar{b}_0 - \bar{b}_1 = -1.70$ m.

TABLE 16. Stake measurements at South Cascade Glacier in the 1994 balance year

[Surface material may be snow (s), firn (f), or ice (i); density estimated based on interpolation between measurements made in early May, and assumed density of firn of 0.7. Balance is the gain or loss of material, referenced to the previous year's melt horizon, in water content. Local X, Y, and Z coordinates (in meters) given for each stake. Stake locations shown on fig. 1]

Date	Surface material	Depth (meters)	Density	Balance (meters)
Stake 1-94 [X = 2713, Y = 1701, Z =2056]				
June 2	s	4.40	0.55	2.42
July 21	s	2.41	.58	1.40
Aug. 31	f	-0.19	.70	-0.13
Minimum[1]	f	-1.45	.70	-1.02
Stake 2-94 [X = 1786, Y = 2989, Z =1834]				
May 3	s	4.55	0.50	2.28
June 2	s	3.91	.55	2.15
July 21	s	1.76	.57	1.00
Aug. 31	i	-0.66	.90	-0.59
Sept. 15	i	-1.23	.90	-1.11
Minumum	i	-1.95	.90	-1.76
Stake 3-94 [X = 1716, Y = 3378, Z =1724]				
May 3	s	3.30	0.50	1.65
June 2	s	2.41	.55	1.33
July 21	i	-0.43	.90	-0.39
Aug. 31	i	-3.04	.90	-2.74
Sept. 15	i	-3.63	.90	-3.27
Minimum	i	-4.38	.90	-3.94
Stake 4-94 [X = 1812, Y = 3619, Z =1655]				
May 3	s	3.00	0.50	1.50
June 2	s	1.96	.55	1.08
July 3	s	0.44	.56	0.25
July 21	i	-1.04	.90	-0.94
Aug. 31	i	-3.94	.90	-3.55
Sept. 15	i	-4.59	.90	-4.13
Minimum	i	-5.69	.90	-5.12

[1] Minimum level of material at each stake was determined by measuring the level of the summer surface on October 25, after the snow accumulation began. The date on which the minimum level occurred, determined from temperature and precipitation records, was October 13, over the entire glacier.

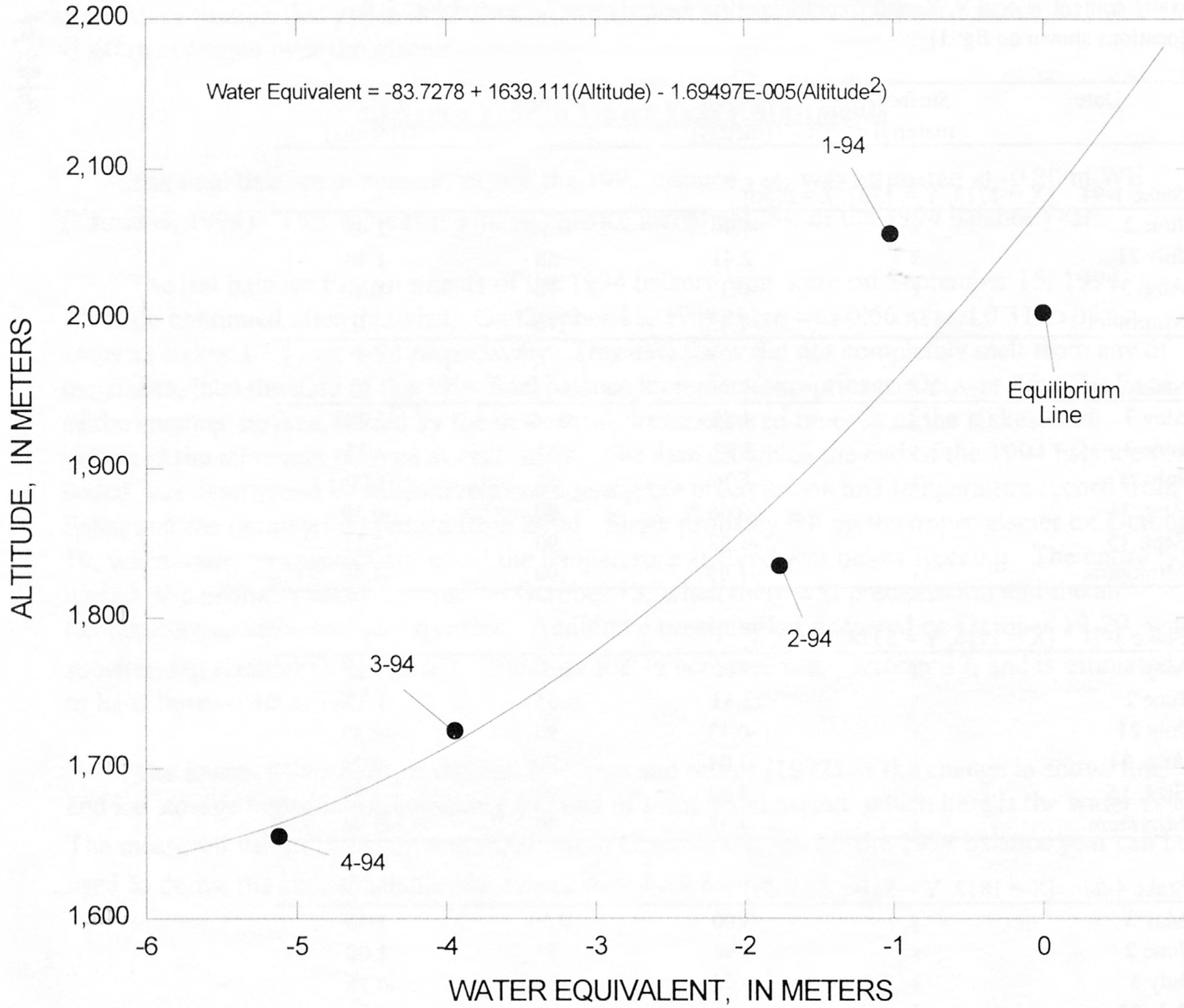

FIGURE 12. Net balance as a function of altitude at South Cascade Glacier, 1994.

Balance Measurement Errors

Errors in glacier balance measurements are difficult to quantify. In prior years of balance measurements at South Cascade Glacier, error values ranging around 0.10 m were placed on the balance values (Meier and others, 1971). For 1965 and 1966, more information was used to derive the balances than in 1992-94. The availability of less information in 1994 would suggest that greater errors should be assigned to the 1994 balance. This relative paucity of data for 1994 is offset somewhat, however, by the experience gained since the mid-1960's, when 20-30 ablation stakes were used and it was found that variations in balance distribution were similar from year to year. Estimated errors are $\bar{b}_m(s)$, $\bar{b}_w(s)$, and $\bar{b}_n$, ±0.20 m; $\bar{b}_0$ and $\bar{b}_1$, ±0.05 m; and the calculated error for $\bar{b}_a$ is ±0.21 m. Although other factors that affect the balance, such as internal accumulation of ice, superimposed ice, internal melt, and basal melt, are possible, they are not considered in this report. These unknowns are thought to be small and do not change the error estimations.

ICE VELOCITY

Ice velocity can be calculated by measuring the displacement between surface features identified on both the September 1, 1993, and September 6, 1994, vertical photography. The methodology used for the velocity measurements in 1994 was identical to that used in 1993 (Krimmel, 1994). Locations of features are given in table 17, where the error in the horizontal locations is dominated by misidentification of the feature after slightly more than 1 year of deformation and ablation, and is estimated to be 2 m. The calculated velocities, shown on figure 13, are for the horizontal component of displacement and are adjusted to a 1-year period.

The velocities are expected to be nearly the same for the 1993-94 period as they were for the 1992-93 period, because the change in ice thickness has only been a few meters at most. The 1993-94 data are presented only because they increase the spatial coverage and data density. Velocities measured for the 1992-93 and 1993-94 periods can be considered as one data set without adjustment for possible change in the velocity field over the 2-year period. Inconsistencies may be attributed to error.

TABLE 17. Positions of velocity features on South Cascade Glacier on September 1, 1993 and September 6, 1994

[Coordinates X, Y, and Z are local, in meters]

Sept. 1, 1993			Sept. 6, 1994			Sept. 1, 1993			Sept. 6, 1994		
X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
1677.3	3661.3	1662.0	1675.8	3667.4	1655.3	1877.0	2792.6	1850.7	1875.8	2802.4	1849.1
1656.5	3546.3	1686.6	1655.5	3560.2	1677.7	1935.2	2867.5	1848.1	1934.6	2877.2	1845.2
1749.4	3528.7	1689.2	1751.5	3541.7	1682.1	1968.5	2788.4	1850.0	1968.9	2796.6	1846.6
1680.9	3436.3	1716.9	1683.2	3451.0	1710.3	2034.9	2856.7	1846.4	2035.5	2863.8	1843.9
1723.7	3382.8	1729.0	1727.8	3395.9	1722.4	2051.2	2759.9	1848.9	2051.6	2767.4	1845.5
1723.1	3349.4	1737.6	1726.1	3367.1	1729.4	2110.1	2836.6	1843.0	2112.3	2842.6	1840.1
1651.6	3332.3	1743.8	1653.2	3347.8	1736.5	2211.5	2881.0	1840.1	2212.4	2882.9	1836.0
1564.4	3337.2	1744.1	1564.8	3348.4	1735.3	1791.0	2694.8	1860.3	1791.2	2704.6	1856.9
1856.7	3429.2	1683.3	1859.4	3433.8	1676.4	1864.4	2706.9	1856.9	1865.5	2716.8	1853.9
1931.9	3355.8	1718.4	1931.6	3357.7	1712.8	1820.3	2612.0	1867.5	1820.8	2622.3	1863.9
2047.0	3300.4	1745.8	2047.8	3307.6	1738.2	1890.1	2621.2	1864.1	1889.6	2631.5	1862.3
1651.4	3169.7	1792.5	1649.4	3186.2	1784.2	1982.9	2710.3	1853.6	1983.4	2718.1	1850.9
1586.6	3171.3	1791.1	1588.1	3185.4	1782.4	2077.2	2669.7	1854.8	2077.1	2677.1	1852.5
1452.8	3235.9	1774.8	1454.2	3236.1	1771.9	2147.3	2755.6	1845.4	2147.0	2760.7	1842.9
1480.6	3172.3	1792.7	1481.8	3175.9	1788.2	2158.3	2682.8	1853.1	2158.3	2687.5	1849.9
1586.2	3141.3	1799.4	1584.5	3156.0	1792.4	2227.2	2810.5	1841.0	2227.3	2813.4	1837.0
1641.6	3135.3	1802.9	1640.4	3153.1	1794.8	2308.0	2844.6	1845.0	2307.9	2845.8	1841.0
1708.3	3139.8	1806.4	1705.4	3158.3	1797.2	1803.7	2489.5	1883.3	1802.9	2500.0	1880.0
1754.0	3173.9	1803.8	1749.9	3190.7	1794.7	1826.3	2527.0	1878.5	1825.6	2536.9	1875.2
1536.5	2959.5	1839.7	1535.2	2966.7	1835.0	1826.5	2574.3	1873.4	1825.5	2584.1	1868.3
1588.0	3040.2	1824.1	1586.5	3052.3	1818.8	1880.5	2525.1	1878.3	1878.7	2535.4	1872.7
1705.6	3013.7	1830.0	1702.7	3028.3	1825.8	1950.4	2565.1	1871.8	1948.7	2575.2	1866.4
1817.9	3075.3	1828.8	1814.6	3088.9	1823.6	2023.1	2581.6	1868.4	2022.1	2590.8	1863.4
1831.7	3134.7	1821.5	1830.5	3147.2	1815.4	2073.7	2635.5	1858.8	2073.0	2642.0	1855.0
1892.5	3086.1	1830.7	1892.0	3098.6	1824.5	2127.4	2671.4	1853.1	2126.4	2677.2	1849.0
1949.4	3167.6	1816.0	1950.9	3178.1	1810.6	1874.7	2324.3	1909.7	1870.8	2334.2	1907.5
2013.8	3171.1	1809.9	2015.4	3181.0	1800.7	1970.2	2357.4	1917.2	1964.6	2368.4	1913.0
2064.9	3133.7	1818.5	2065.3	3143.2	1813.3	2019.9	2416.0	1908.7	2016.2	2425.9	1904.6
2007.8	3082.8	1832.7	2008.1	3091.9	1827.9	2074.0	2479.3	1895.4	2072.1	2487.6	1889.7
2093.7	3081.5	1828.4	2096.4	3088.8	1823.8	2303.4	2479.3	1923.4	2303.1	2483.1	1919.4
2195.0	3064.9	1823.3	2196.1	3070.0	1819.6	2376.8	2444.4	1937.9	2375.7	2445.2	1935.1
2156.2	3033.2	1830.1	2157.8	3038.2	1825.4	2032.0	2266.2	1931.6	2025.0	2275.2	1929.0
2261.8	3032.6	1826.3	2262.5	3034.6	1823.2	2069.0	2324.6	1927.5	2063.0	2335.2	1923.5
1680.8	2936.4	1840.5	1680.4	2948.0	1835.9	2252.2	2379.6	1934.9	2251.6	2383.3	1932.7
1752.3	2910.9	1844.1	1751.5	2922.7	1839.5	2193.4	2316.2	1934.0	2190.7	2318.8	1932.7
1791.3	2989.7	1837.9	1788.9	3002.4	1832.9	2157.3	2234.3	1939.9	2153.0	2240.6	1937.9
1881.7	2991.7	1841.6	1881.2	3002.5	1837.5	2248.6	2266.8	1944.5	2247.9	2268.9	1942.1
1973.5	2996.7	1842.1	1975.3	3007.3	1838.8	2276.9	2177.6	1953.0	2275.5	2179.0	1951.4
2048.1	2996.8	1840.7	2048.1	3004.0	1837.9	2357.8	2229.2	1950.4	2358.2	2230.5	1948.6
2022.6	2937.5	1844.4	2024.0	2944.8	1841.6	2320.1	1923.1	1980.6	2316.7	1928.4	1977.7
2094.4	2941.2	1842.7	2095.4	2946.4	1839.2	2286.8	1889.3	1990.7	2280.7	1896.9	1987.1
2190.6	2971.7	1836.1	2191.9	2974.9	1832.8	2294.0	1852.1	2001.9	2288.0	1858.5	1998.9
1610.7	2777.7	1854.4	1609.1	2782.4	1852.2	2374.5	1886.2	1998.9	2370.8	1888.9	1997.4
1728.6	2857.7	1848.3	1728.3	2867.5	1845.5	2420.3	1861.3	2011.8	2417.0	1866.4	2009.4
1739.3	2803.1	1852.6	1739.5	2813.5	1849.2	2356.7	1818.0	2014.3	2351.4	1822.7	2012.6
1837.1	2906.7	1845.4	1835.9	2917.4	1842.2	2352.7	1902.0	1991.5	2349.0	1906.8	1987.4
1834.9	2832.7	1849.2	1834.7	2841.9	1846.5						

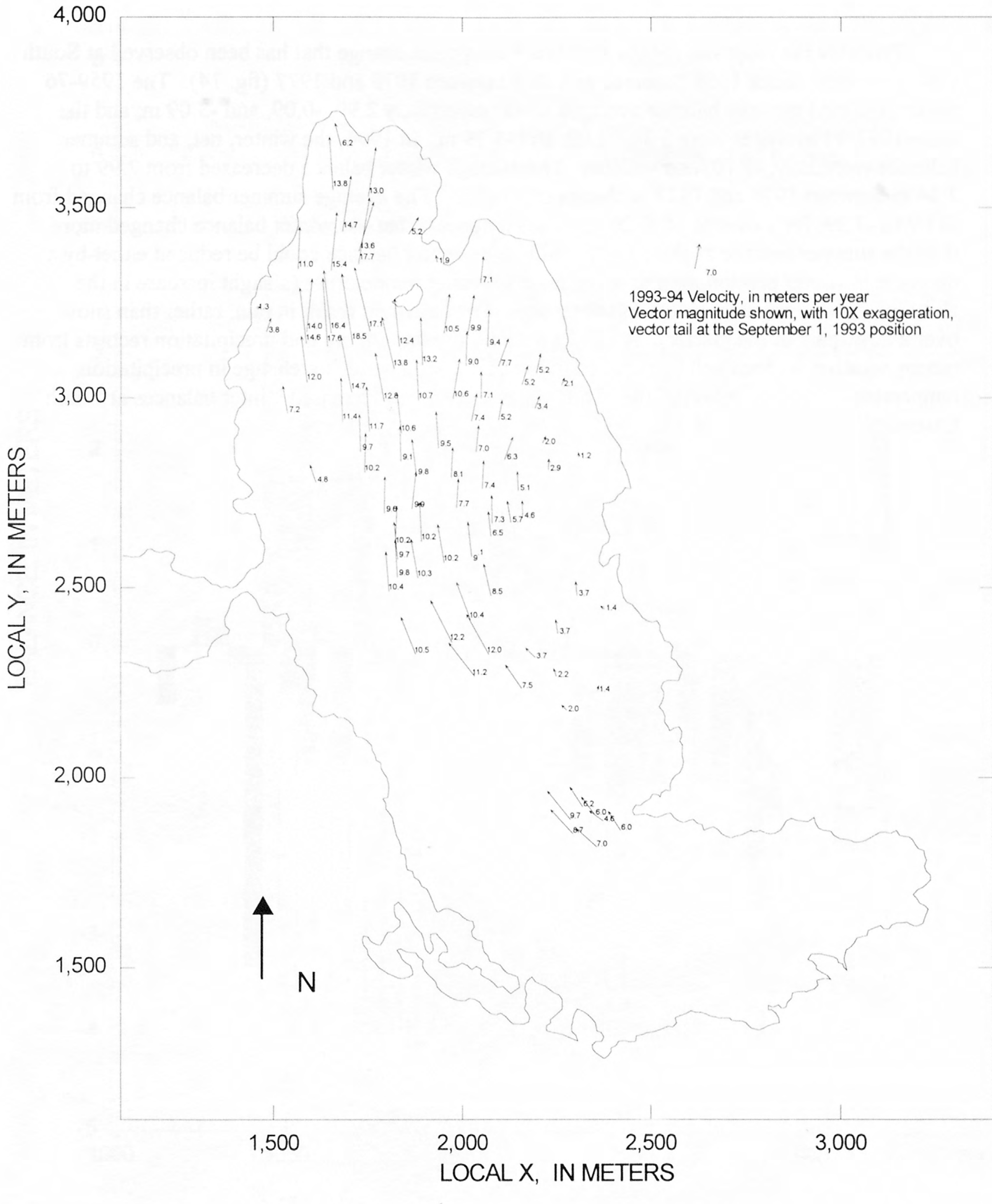

FIGURE 13. South Cascade Glacier velocity, measured from vertical photographs taken on September 1, 1993 and September 6, 1994.

CONCLUSIONS

Probably the most statistically significant long-term change that has been observed at South Cascade Glacier since 1959 occurred as a shift between 1976 and 1977 (fig. 14). The 1959-76 winter, net, and summer balance averages were respectively 2.99, -0.09, and -3.09 m; and the same 1977-94 averages were 2.34, -1.02, and -3.29 m. In 1994, the winter, net, and summer balances were 2.39, -1.70, and -4.09 m. The average winter balance decreased from 2.99 to 2.34 m between 1976 and 1977, a change of -0.65 m. The average summer balance changed from -3.09 to -3.29, for a change of -0.20 m. Thus it appears that the winter balance changed more than the summer balance at the 1976/77 shift. The winter balance could be reduced either by a decrease in winter precipitation or an increase in winter temperature (a slight increase in the altitude of the freezing level during winter precipitation would result in rain, rather than snow, over a large part of the glacier). A careful analysis of temperature and precipitation records from nearby weather stations will be required to determine whether it is a change in precipitation, temperature, or combination of the two that has caused the decreased winter balances at South Cascade Glacier since 1976.

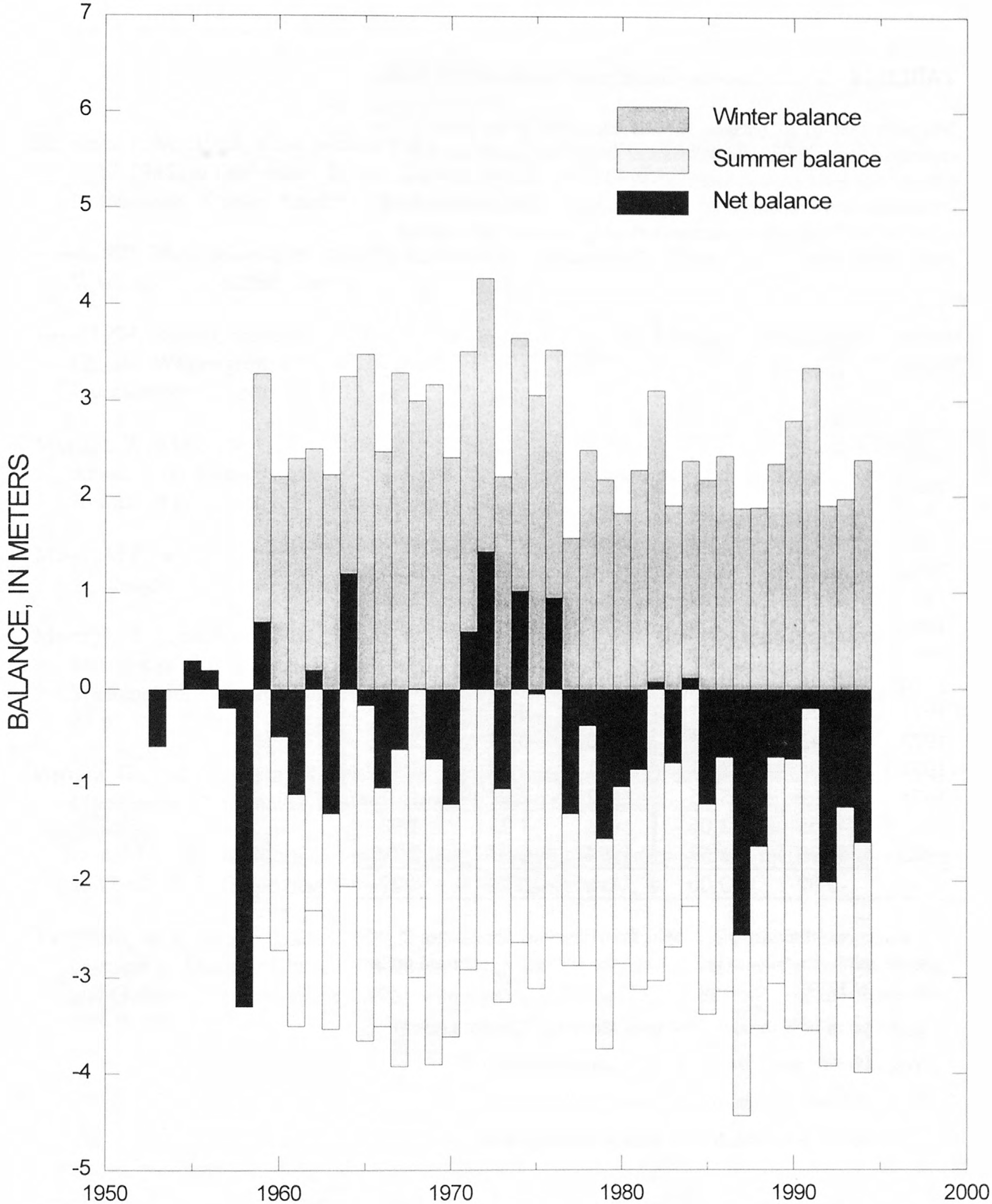

FIGURE 14. Winter, summer, and net mass balances for South Cascade Glacier, 1953-94. Data from Meier and Tangborn (1965) and Krimmel (1994).

TABLE 18. South Cascade Glacier mass balance time series

[For years 1986-91 net balance, $\bar{b}_n$, was determined by the index regression method discussed in Krimmel (1989) and has an error of 0.23 m. For years 1959-64 and 1968-82 winter balance, $\bar{b}_w$ (s), from unpublished snow accumulation maps, and has an error of 0.12 m. For years 1983-1991, $\bar{b}_w$ (s) was determined using a similar index station regression as discussed in Krimmel (1989), and has an error of 0.23 m]

Year[1]	$\bar{b}_n$ (meters)	$\bar{b}_w$ (s) (meters)	Year[1]	$\bar{b}_n$ (meters)	$\bar{b}_w$ (s) (meters)
[2]1959	0.70	3.28	1977	-1.30	1.57
1960	-0.50	2.21	1978	-0.38	2.49
1961	-1.10	2.40	1979	-1.56	2.18
1962	0.20	2.50	1980	-1.02	1.83
1963	-1.30	2.23	1981	-0.84	2.28
1964	1.20	3.25	1982	0.08	3.11
[3]1965	-0.17	3.48	1983	-0.77	1.91
1966	-1.03	2.47	1984	0.12	2.38
[4]1967	-0.63	3.29	1985	-1.20	2.18
[5]1968	0.01	3.00	1986	-0.71	2.43
1969	-0.73	3.17	1987	-2.56	1.88
1970	-1.20	2.41	1988	-1.64	1.89
1971	0.60	3.51	1989	-0.71	2.35
1972	1.43	4.27	1990	-0.73	2.80
1973	-1.04	2.21	1991	-0.20	3.35
1974	1.02	3.65	1992	-2.01	1.91
1975	-0.05	3.06	1993	-1.23	1.98
1976	0.95	3.53	1994	-1.02	2.39
Avg	-0.09	3.00	Avg	-0.98	2.27

[1] Balance year (for example, 1959 is from the minimum balance in 1958 to the minimum balance in 1959, and the 1959 $\bar{b}_w$ (s) occurred in the spring of 1959)

[2] $\bar{b}_n$ for years 1959 through 1964 from Meier and Tangborn (1965)

[3] Years 1965 through 1966 from Meier and others (1971)

[4] Year 1967 from Tangborn and others (1977)

[5] $\bar{b}_n$ for years 1968 through 1985 from Krimmel (1989)

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