WATER RESOURCES OF THE UPPER BIG WOOD RIVER BASIN, IDAHO

By S.A. Frenzel

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CONVERSION FACTORS

For readers who prefer to use metric (International System) units, conversion factors for inch-pound units used in this report are listed below. Constituent concentrations are given in mg/L (milligrams per liter), or µg/L (micrograms per liter), which are equal to parts per million or parts per billion, respectively. Specific conductance is expressed as µS/cm (microsiemens per centimeter at 25 degrees Celsius.)

Multiply inch-pound unit	By	To obtain SI unit
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	0.028317	cubic meter per second
foot (ft)	0.3048	meter
foot squared per day (ft^2/d)	0.09290	meter squared per day
gallon per minute (gal/min)	0.06308	liter per second
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square foot (ft^2)	0.09294	square meter
square mile (mi^2)	2.590	square kilometer

Temperature in °C (degrees Celsius) can be converted to °F (degrees Fahrenheit) as follows:

$$°F = (°C)(1.8) + 32$$

Water temperatures are reported to the nearest 0.5 °C.

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

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ABSTRACT

The upper Big Wood River basin in south-central Idaho has undergone increases in urban development and sewage disposal that may impose stresses on the quantity and quality of the water resources.

Mean annual water yields for a base period from 1940 to 1979 were estimated using the water-budget method. Estimated yields for the upper Big Wood River basin above Glendale Road and for its major tributaries, Trail Creek, Warm Springs Creek, and East Fork Big Wood River, were 410,000, 50,000, 60,000, and 50,000 acre-feet, respectively. Mean annual water yield for the upper Big Wood River basin also was estimated using an empirical method. Results from the empirical method were similar to results from the water-budget method; however, the water-budget method is considered to be more accurate because of the large surface-water component, which is measured rather than estimated. Yields also were estimated for 1986 and 1987 water years when data were collected for comparison with long-term average values. During 1986, yields estimated for upper Big Wood River basin, Trail Creek, Warm Springs Creek, and East Fork Big Wood River were 580,000, 61,000, 83,000, and 60,000 acre-feet, respectively. During 1987, yields estimated for the respective basins were 230,000, 26,000, 32,000, and 28,000 acre-feet. Availability of surface and ground water varies seasonally; the greatest quantity is available during spring snowmelt, and the least is available during mid- to late winter.

Nutrient concentrations in sampled ground and surface water were near or below detection levels throughout the basin, which indicates that water quality has not been impaired by increased urban development and sewage disposal. Fluoride concentrations were elevated in Warm Springs Creek, probaby due to inflow of thermal water.

INTRODUCTION

Purpose and Scope

This report describes results of a study to evaluate water resources in the upper Big Wood River basin. Emphasis of the study was on determining water yield of the basin and some of its major tributaries. The scope of this study included:

(1) Collection of historical geologic, hydrologic, water-use, and water-quality data to determine average conditions of the water resources.

(2) Measurement of ground-water levels and aquifer thickness near the basin outlet to determine volume of ground-water underflow from the basin.

(3) Evaluation of ground-water and surface-water relations.

(4) Collection of ground- and surface-water quality data to determine whether urban development and sewage disposal have affected water quality.

(5) Estimation of water yield from the upper Big Wood River basin, Trail Creek, Warm Springs Creek, and East Fork Big Wood River.

Data were collected from February 1986 through November 1987.

Physical Setting

The upper Big Wood River basin is in Blaine County, north of Twin Falls, in south-central Idaho (fig. 1). For this study, only the area upstream (generally north) from Glendale Road (fig. 2) was considered. Generally, the upper Big Wood River valley is narrow and has a maximum width of about 2 mi at the southern boundary of the study area. Steep mountains surround the valley to the north, east, and west. Altitudes range from 5,060 ft above sea level at Glendale Road to 11,913 ft in the surrounding mountains, and the basin area above Glendale Road is 752 mi^2. Sun Valley, Ketchum, Hailey, and Bellevue are communities in the basin.

Climate of the upper Big Wood River basin is one of cold, wet winters and warm, dry summers. At Sun Valley, mean minimum temperatures of about -1 °F (-18 °C) are recorded in January, and mean maximum temperatures of about 82 °F (28 °C) are recorded in July. Mean annual precipitation at Sun Valley (1937-73) is 17.6 in. and, at Hailey (1917-82), is 15.0 in. Half the annual precipitation falls from November through February.

Between 1970 and 1980, population in Blaine County increased from 5,749 to 9,841; population in the study area is about 90 percent of the total in Blaine County (Luttrell and Brockway, 1982, p. 8, 9). The 1990 population for the study area was projected to be about 15,000, and maximum population was estimated to be 22,000 (Luttrell and Brockway, 1982, p. 26, 27). In addition to the permanent residents, thousands of people annually visit the area for winter and summer recreation.

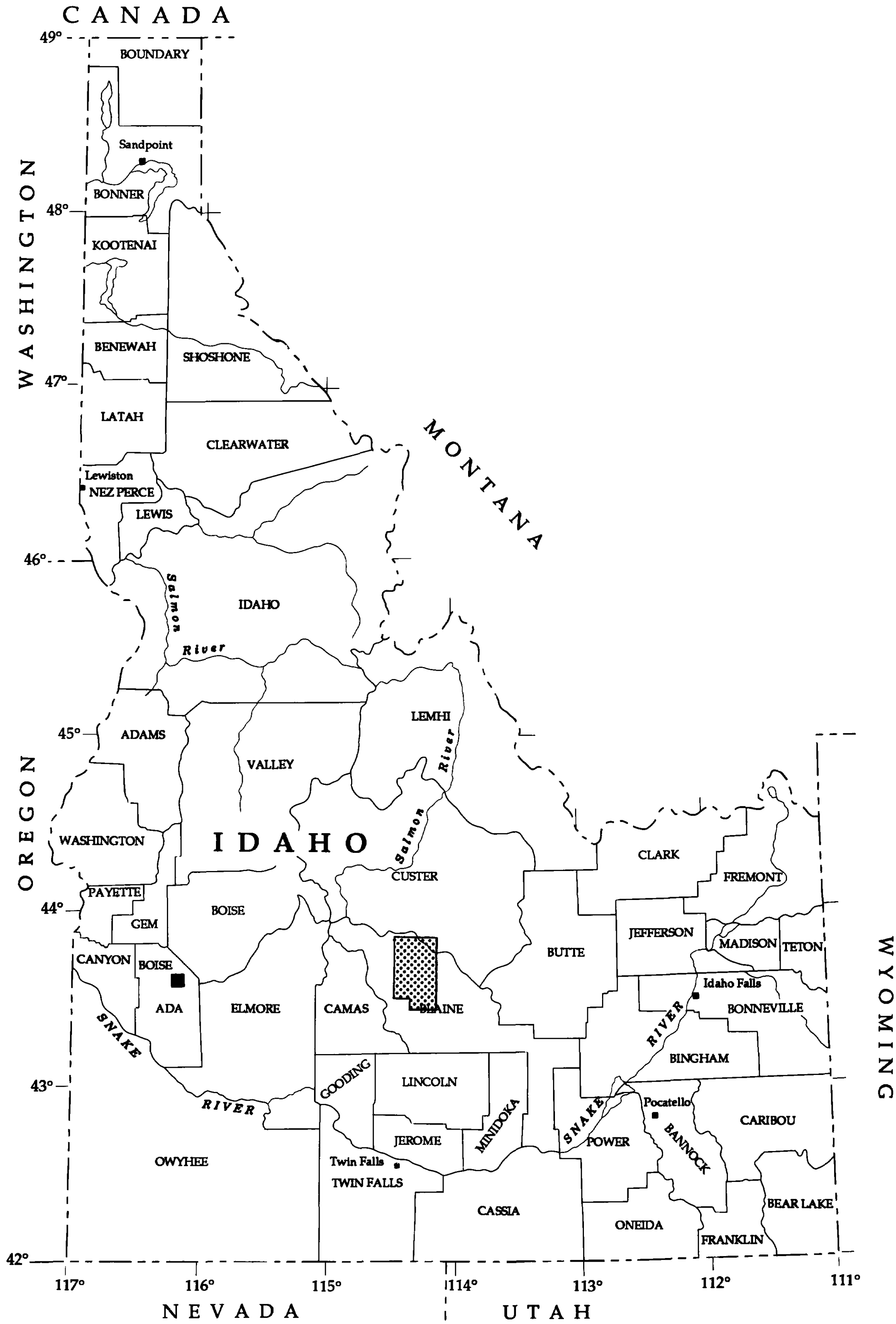

Figure 1.--Location of study area.

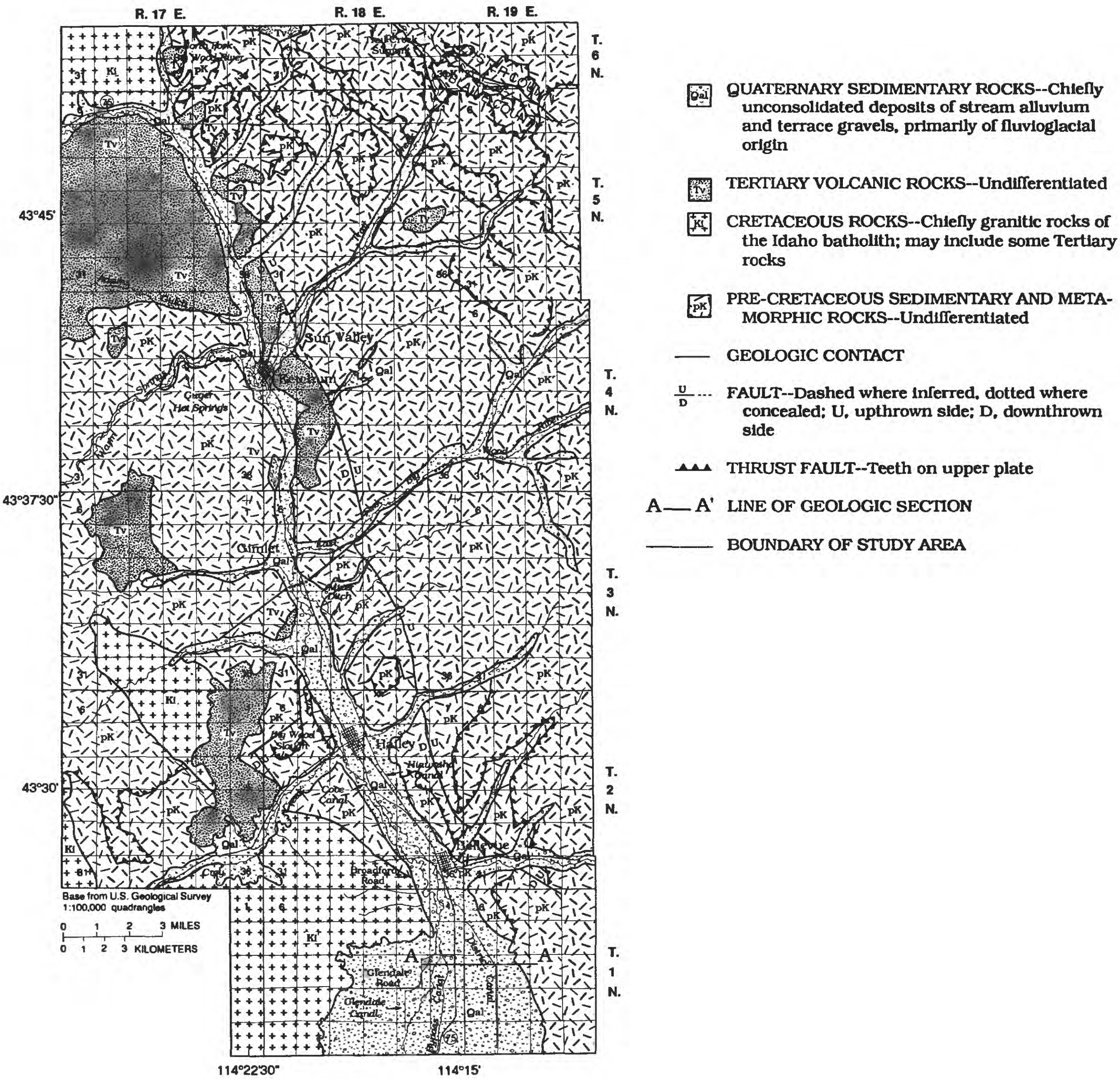

Figure 2.--Generalized geology.

Geologic Setting

Geology of the region was described in detail by Umpleby and others (1930) and is shown in figure 2 as modified from Rember and Bennett (1979). The mountains in the area are composed of Pre-Cretaceous sedimentary and metamorphic rocks, Cretaceous granitic rocks, and Tertiary volcanic rocks. Thickness of the sedimentary and igneous rocks totals about 32,000 ft (Umpleby and others, 1930, p. IX). Extensive faulting and folding have resulted in complex structure (Luttrell and Brockway, 1984, p. 10). Valleys are filled with Quaternary glacial and alluvial deposits that constitute the aquifer in the study area (Luttrell and Brockway, 1984, p. 13). Terraces in the study area are composed of alluvial deposits. Most of the valley fill is stream and delta clay, sand, and gravel deposited before the Wisconsin glaciation and is overlain by a thin sheet of fluvioglacial sediments (Smith, 1959, p. 16).

Previous Investigations

Work by Smith (1959) dealt with areas that partly overlap the upper Big Wood River basin. The primary objective of Smith's study was to determine the quantity of water available for additional irrigation in the middle Big Wood River area. Geology and mineral resources of the Hailey-Bellevue mining district and upper Big Wood River basin were studied by Anderson and others (1950). Jones (1952) examined discharge records in the Big Wood River basin with emphasis on identification of all diversions above gaging stations. Smith (1960) evaluated discharge records in the Big Wood River basin to determine whether the gaged discharges adequately represented basin yield.

Castelin and Chapman (1972) studied the water resources of the Big Wood River-Silver Creek area as far north as Hailey. Objectives of their study included: (1) Identification of relations between water-table, artesian, and regional (Snake River Plain) aquifers, (2) development of a water budget for the area, and (3) determination of reaches of gains and losses in Silver Creek. Moreland (1977) included the area around Bellevue in his study of ground-water and surface-water relations in the Silver Creek area.

Castelin and Winner (1975) studied the upper Big Wood River basin to: (1) Determine physical characteristics of local aquifers, (2) determine relations between ground and surface water, (3) describe the level of urbanization in terms of water use, (4) determine quality of ground and surface water, and (5) establish a hydrologic data base. Luttrell and Brockway (1982, 1984) studied impacts of onsite sewage-disposal systems on water quality in the upper Big Wood River basin to: (1) Evaluate water-quality problem areas on the basis of density of sewage-disposal sites, (2) establish a ground-water quality monitoring network and data base, (3) evaluate the ground-water flow system, and (4) determine river/aquifer hydraulic relations.

Well-Numbering System

The well-numbering system (fig. 3) used by the U.S. Geological Survey in Idaho indicates the location of wells within the official rectangular subdivision of public lands, with reference to the Boise base line and Meridian. The first two segments of the number designate the township (north or south) and range (east or west). The third segment gives the section number; three letters, which indicate the 1/4 section (160-acre tract), 1/4-1/4 section (40-acre tract), and 1/4-1/4-1/4 section (10-acre tract); and serial number of the well within the tract.

Quarter sections are designated by the letters A, B, C, and D in counterclockwise order from the northeast quarter of each section. Within the quarter sections, 40-acre and 10-acre tracts are lettered in the same manner. For example, well 2N-18E-9BDC1 is in the SW1/4SE1/4NW1/4 sec. 9, T. 2 N., R. 18 E., and is the first well inventoried in that tract.

WATER RESOURCES

Average quantity of water in the upper Big Wood River basin was estimated by using data from 1940 to 1979 water years (October 1 to September 30). This base period was selected because the greatest quantity of pertinent data were available during those years. The type of data, location, and period of record for which data are available include:

(1) Discharge, Big Wood River at Hailey, 1915-88.
(2) Discharge, Warm Springs Creek, 1940-58.
(3) Discharge, Big Wood River near Ketchum, 1948-71.
(4) Precipitation, Hailey, 1917-82.
(5) Precipitation, Sun Valley/Ketchum, 1937-88.
(6) Snowpack, several locations, minimum record, 1961-88.

Precipitation

Precipitation data were collected at Hailey from 1917 to 1982 and at Sun Valley from 1937 to 1973, when the site was moved to its present (1988) location in Ketchum. Mean annual precipitation for the 1940-79 base period was 16.0 in. at Hailey and 17.5 in. at Sun Valley/Ketchum. During 20 of these years, precipitation at Hailey was greater than the mean for the period of record.

Hailey and Sun Valley/Ketchum precipitation sites are at relatively low altitudes in the basin and, because precipitation

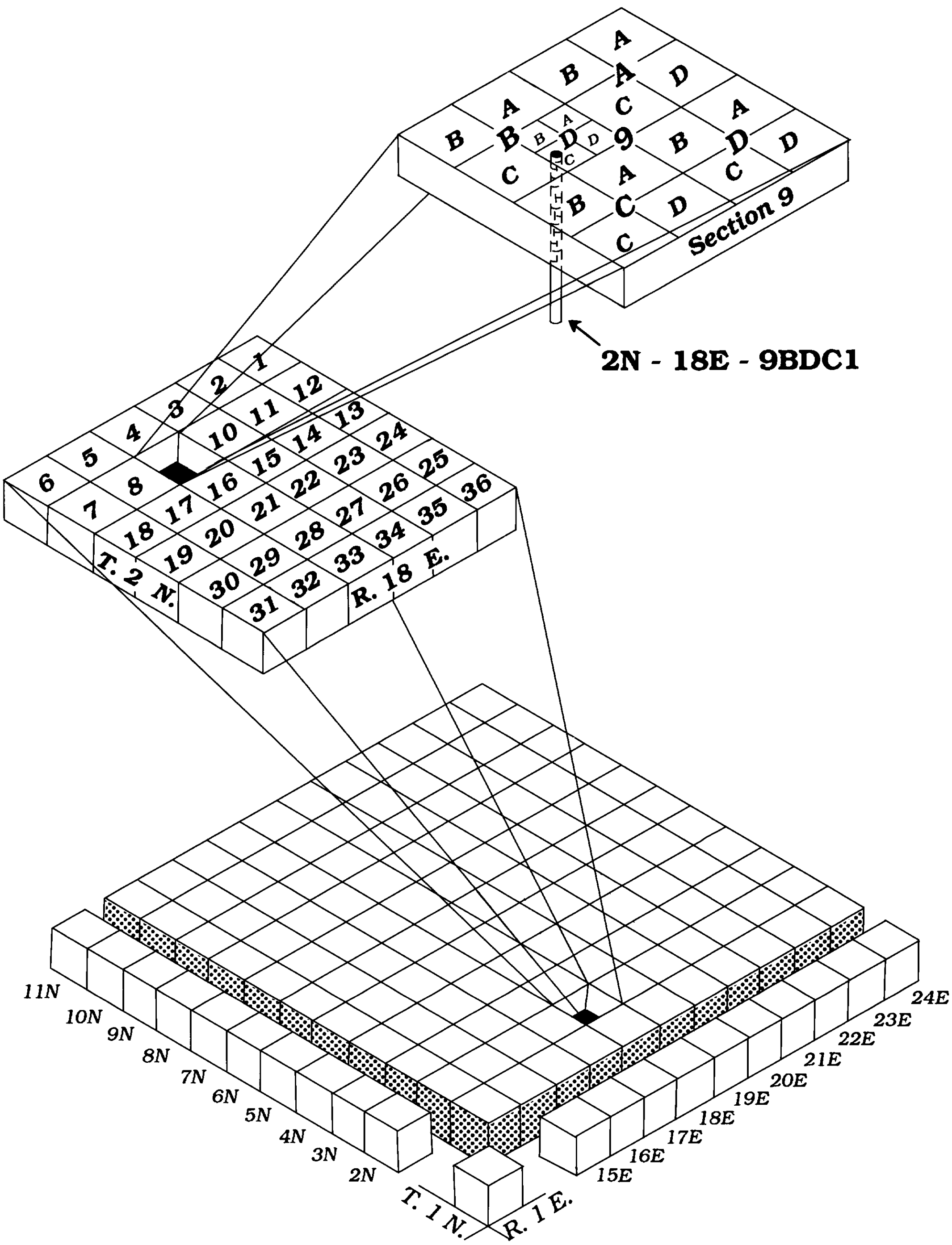

Figure 3.--Well-numbering system.

varies with altitude (Hanson, 1982, p. 875), it was necessary to estimate precipitation for higher altitudes. Mean annual precipitation at eight snow courses in the area as determined from a regional precipitation map was about 1 1/2 times the mean April 1 water content measured at the snow courses. Four snow courses recently were equipped to measure annual precipitation, and these sites also show annual precipitation to be about 1 1/2 times the April 1 water content. A precipitation-altitude relation (fig. 4) was determined by linear regression using estimated mean annual precipitation at the snow courses (eight sites) and measured annual precipitation (two sites).

The regression equation was used to determine mean annual precipitation for the average altitude of the upper Big Wood River basin. Annual precipitation for individual years from 1940 to 1979 was determined by adjusting mean annual precipitation by the same quantity that the annual precipitation at Hailey differed from the mean at Hailey. For example, the average altitude for Warm Springs Creek is 7,660 ft and the mean annual precipitation is 28 in. If, for a given year, precipitation at Hailey were 19 in. (3 in. greater than the mean), then precipitation for Warm Springs Creek is estimated to be 31 in.

Because precipitation data no longer are collected at Hailey and because data from Ketchum do not correlate well with data from Hailey (r^2 = 0.42, using annual data from 1974 to 1982), annual precipitation for the upper Big Wood River basin for the 1986 and 1987 water years was estimated using data from the eight snow courses and the precipitation-altitude relation shown in figure 4.

Surface Water

A continuous record of discharge for the Big Wood River at Hailey has been collected since June 1915. Recording gaging stations also were located on the Big Wood River near Ketchum (0.25 mi above North Fork Big Wood River) from 1948 to 1971 and on Warm Springs Creek at Guyer Hot Springs from 1940 to 1958. Other surface-water data have been collected periodically.

Discharge at Hailey (combined flow of Big Wood River and Big Wood Slough) ranged from 15 to 6,150 ft^3/s and averaged 460 ft^3/s from 1916 to 1987 (U.S. Geological Survey, 1956, p. 234; Harenberg and others, 1988, p. 243). Mean discharge for 7 and 30 consecutive days were as low as 88 and 98 ft^3/s, respectively, at intervals averaging 10 years (fig. 5).

Discharge of the Big Wood River near Ketchum ranged from 8.5 to 1,690 ft^3/s and averaged 167 ft^3/s for the period of record (U.S. Geological Survey, 1972, p. 163). Mean discharge for 7 and 30 consecutive days were as low as 35 and 37 ft^3/s, respectively, at intervals averaging 10 years (fig. 5).

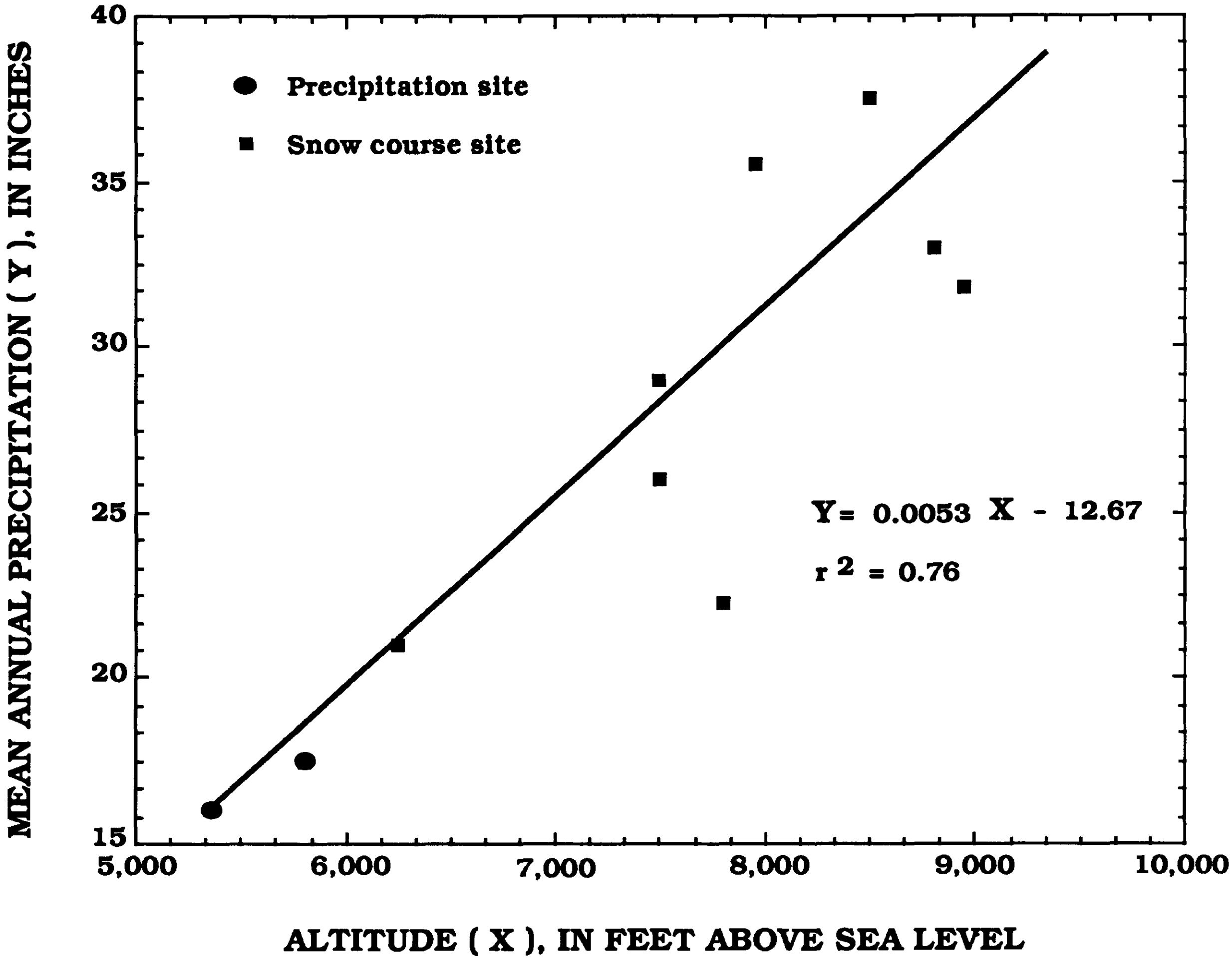

Figure 4.--Relation of mean annual precipitation to altitude.

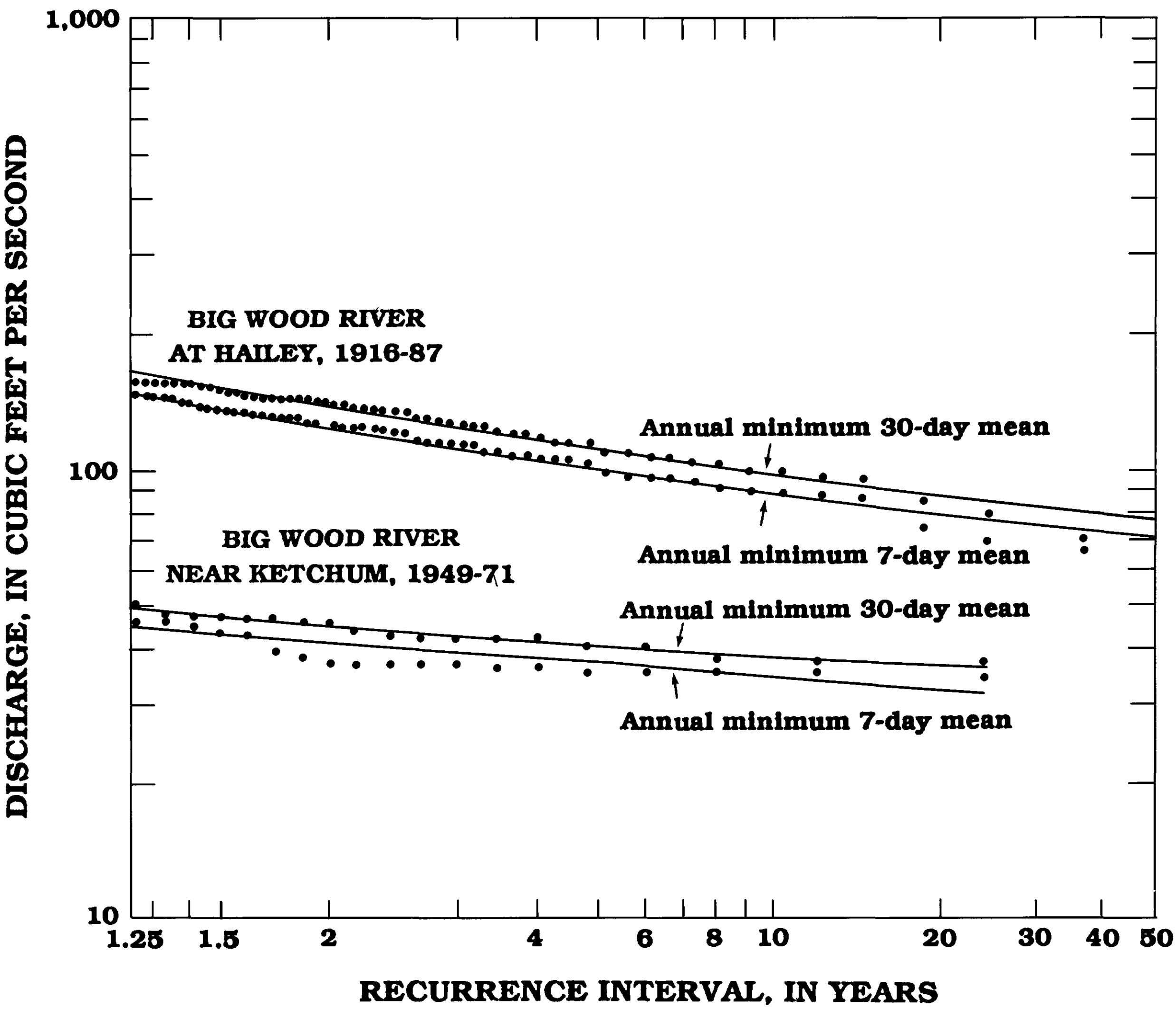

Figure 5.--Frequency curves of annual minimum 7-day and 30-day mean discharge for the Big Wood River at Hailey and near Ketchum.

Discharge of Warm Springs Creek at Guyer Hot Springs ranged from 6.0 to 961 ft^3/s and averaged 87 ft^3/s for the period of record (U.S. Geological Survey, 1963, p. 115). Typically, discharge in the study area was highest during spring snowmelt and lowest during the winter. Mean monthly discharge of the Big Wood River at Hailey from 1916 to 1987 was highest in June (1,500 ft^3/s) and was lowest in February (154 ft^3/s). More than half the annual discharge was during May and June.

Major tributaries to the Big Wood River include North Fork Big Wood River, Trail Creek, Warm Springs Creek, and East Fork Big Wood River (fig. 2). Discharge of Trail Creek, Warm Springs Creek, and East Fork Big Wood River was measured monthly from February 1986 through November 1987.

Ground Water

Water exists in the alluvial deposits under water-table conditions. Significance and water-bearing capacity of pre-Cretaceous sedimentary and metamorphic rocks were not determined; however, water yield from these rocks is probably low. Recharge to the aquifer is from precipitation and from percolation of surface water from streams, canals, and irrigated fields. The rate of movement and volume of ground water discharged from the basin depends on the hydraulic gradient, hydraulic conductivity, and cross-sectional area of the aquifer.

Storage of ground water in any given location in the study area is largely a function of the areal extent and thickness of the aquifer at that location. The quantity of ground water in storage depends on the volume of aquifer material and specific yield. Specific yield (Sy) is the ratio of (1) the volume of water which saturated rock will yield by gravity to (2) the volume of rock (Lohman and others, 1972, p. 12). The volume of aquifer material was estimated by subdividing the aquifer and representing each part as a half-conical section (fig. 6). Cross-sectional areas of the aquifer at Adams Gulch, Gimlet, and Hailey were estimated on the basis of the basin width and aquifer thickness determined from well-drillers' logs and from data reported by Luttrell and Brockway (1984, p. 14-15). Cross-sectional area of the aquifer at Glendale Road was determined from seismic refraction work during this study. Specific yield was estimated as 0.2, which was about the average for unconsolidated alluvium reported by Johnson (1967, p. D68). The quantity of ground water in storage from Adams Gulch to Glendale Road was estimated to be about 400,000 acre-ft. Storage of ground water also varies seasonally; the greatest quantity is available during spring snowmelt, and the least quantity is available during mid- to late winter.

Withdrawals vary seasonally; the greatest quantities are withdrawn during the summer and winter recreation periods.

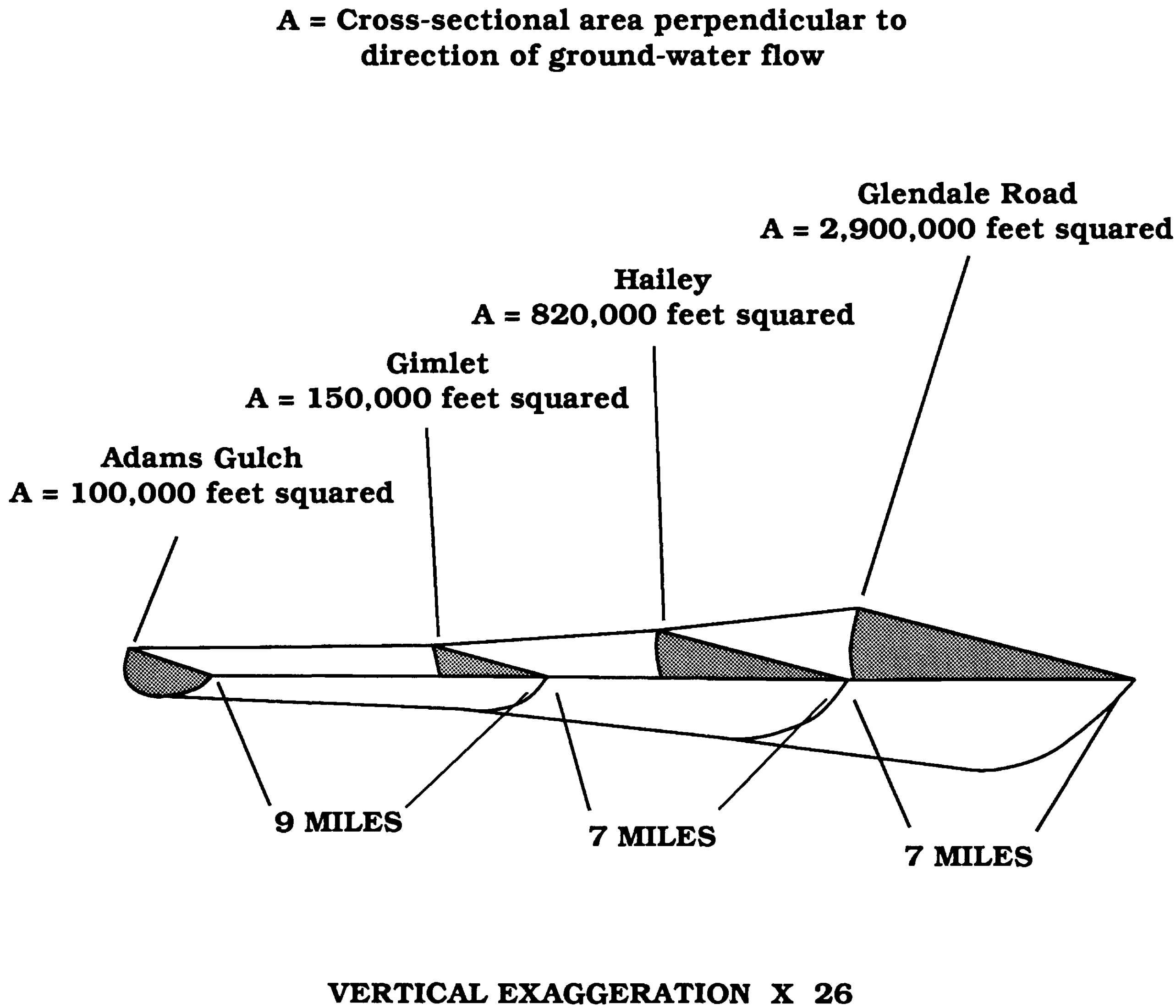

Figure 6.--Conceptual block diagram showing cross-sectional areas of the alluvial aquifer from Adams Gulch to Glendale Road.

Municipal wells normally withdraw 3,500 to 4,500 acre-ft of water annually to supply the Sun Valley/Ketchum area from well fields near Trail Creek and the Big Wood River (J.T. Brown, Sun Valley Water and Sewer District, written commun., 1987; S.A. Hansen, City of Ketchum, written commun., 1988).

Water levels were measured in 84 wells in April 1986 (table 1) to define the water table prior to diversion of surface water into irrigation canals. Water-level data were used to construct a water-table contour map (fig. 7) to show direction of ground-water movement and to determine hydraulic gradients. Direction of ground-water flow is perpendicular to water-table contours and is generally southward, parallel to the long axis of the upper Big Wood River basin. Hydraulic gradients were used to compute ground-water discharge.

Aquifer Characteristics and Estimates of Ground-Water Discharge

Hydraulic conductivity (K) is a measure of the ability of aquifer material to conduct water, is dependent on the nature of the pore space, and is expressed in feet per day (Lohman and others, 1972, p. 4). Transmissivity (T) is a measure of the rate at which water moves through a unit width of the aquifer under a unit hydraulic gradient and is expressed in feet squared per day (Lohman and others, 1972, p. 13). Transmissivity is equal to K multiplied by the saturated thickness (b) of the aquifer. Specific capacity (C) of a well is the rate of discharge, in gallons per minute, divided by the water-level drawdown in the well, in feet.

Specific capacity was determined from driller's logs for six wells that met the arbitrary criteria of a minimum pumping rate of 500 gal/min and a minimum pumping time of 2 hours. Specific capacity was used to estimate T by two empirical methods. The first method (Theis, 1963, p. 335) used the equation:

$$T' = 0.134\ (C)\ (F)\ (1{,}300 - 264 \log 5Sy + 264 \log t) \qquad (1)$$

where

- T' = estimate of transmissivity, in feet squared per day;
- 0.134 = constant to convert gallons per foot per day to feet squared per day;
- C = specific capacity of pumped well, in gallons per minute per foot of drawdown;
- F = factor to adjust for well radius and degree of well development (1.0 for 6-in. radius, 0.9 for 8-in. radius, and 0.8 for 10-in. radius wells were used);
- Sy = specific yield--0.2 (Johnson, 1967) was used as an average value for coarse alluvial material; and
- t = pumping time, in days,

Table 1.--*Ground-water levels during April 1986*

Well number	Well location (fig. 7)	Altitude of land surface (feet above sea level)	Day measured	Depth of water below land surface (feet)
1	5N-17E-25BCA1	6,038	9	16.68
2	36DBD1	5,970	9	1.84
3	4N-17E- 1DCD1	5,872	9	2.85
4	11CDA1	5,845	9	24.88
5	12ADB1	5,853	10	10.00
6	12CDD1	5,848	10	51.68
7	13AAB1	5,813	10	12.83
8	13ABA1	5,815	10	10.83
9	13ACA1	5,791	10	12.07
10	4N-18E-18CCB1	5,810	10	45.23
11	19DBB1	5,751	10	25.02
12	19DBB2	5,738	10	16.68
13	19DBD1	5,738	10	15.72
14	19DCD1	5,718	9	8.56
15	19DCD2	5,718	9	11.38
16	30ADB3	5,680	10	7.68
17	31DBD1	5,640	10	12.45
18	3N-18E- 6ABA1	5,630	11	6.36
19	6ADA1	5,605	12	12.62
20	6DDA1	5,590	12	20.55
21	7DAB1	5,570	7	7.72
22	7DBA1	5,600	8	45.48
23	7DDD1	5,556	7	19.38
24	8BBC1	5,582	7	20.33
25	8CBC3	5,573	7	16.17
26	17BCC1	5,520	8	10.81
27	17CCD1	5,545	8	37.29
28	18AAB1	5,558	12	18.65
29	18DAA1	5,515	12	7.79
30	20BDA1	5,520	8	38.85
31	20DCC1	5,475	8	27.58
32	29BDA1	5,438	8	10.38
33	29DCC1	5,415	12	4.15
34	32ABA1	5,416	8	10.08
35	32DBA1	5,388	12	6.58

Table 1.--*Ground-water levels during April 1986--Continued*

Well number	Well location	Altitude of land surface (feet above sea level)	Day measured	Depth of water below land surface (feet)
36	3N-18E-32DDD1	5,375	8	9.39
37	33CAB1	5,435	12	67.14
38	2N-18E- 4CBB1	5,353	8	15.44
39	4CCB1	5,340	8	9.79
40	5AAA1	5,370	11	16.54
41	9ABA1	5,370	8	48.87
42	9BDC1	5,324	7	16.74
43	9DDA1	5,324	7	37.25
44	10BAC1	5,358	9	54.06
45	10BAC2	5,355	11	51.88
46	10DCB1	5,334	7	47.41
47	15BAB1	5,322	9	34.09
48	15BAC1	5,315	9	34.20
49	15BCB1	5,303	12	25.52
50	15CBA1	5,288	11	17.79
51	15CCA1	5,270	9	17.13
52	15CDB1	5,275	9	20.30
53	15DBC1	5,287	9	31.58
54	22BDB1	5,255	9	8.68
55	22DDB1	5,223	9	5.93
56	23DCC1	5,234	9	34.14
57	23DDB1	5,240	7	40.25
58	23DDC1	5,232	7	45.55
59	26ABA1	5,219	7	36.25
60	26CBB1	5,197	9	4.50
61	35BAB1	5,178	9	4.99
62	35DCD1	5,147	11	6.77
63	36BCB1	5,158	10	4.43
64	36DAC1	5,195	11	62.14
65	36DCA1	5,173	9	42.49
66	2N-19E-31CAB1	5,235	9	90.80
67	31CCD1	5,200	11	75.29
68	1N-18E- 1ABC1	5,153	10	36.54
69	1ACA1	5,250	11	43.03
70	1DAA1	5,137	10	43.54

Table 1.--*Ground-water levels during April 1986--Continued*

Well number	Well location	Altitude of land surface (feet above sea level)	Day measured	Depth of water below land surface (feet)
71	1N-18E- 1DBB1	5,127	10	24.60
72	12ACA1	5,090	10	17.69
73	12DBD1	5,100	10	44.00
74	12DDC1	5,100	11	46.03
75	13DDB1	5,078	11	75.29
76	1N-19E- 6CBB1	5,137	10	43.58
77	7BAC1	5,115	10	51.19
78	7BCD1	5,115	11	49.11
79	18AAC1	5,078	10	59.77
80	18ADA1	5,070	10	61.85
81	18BBD1	5,095	11	47.34
82	18CAA1	5,082	10	108.73
83	19BAB1	5,065	11	69.18
84	20BAA1	5,041	10	79.35

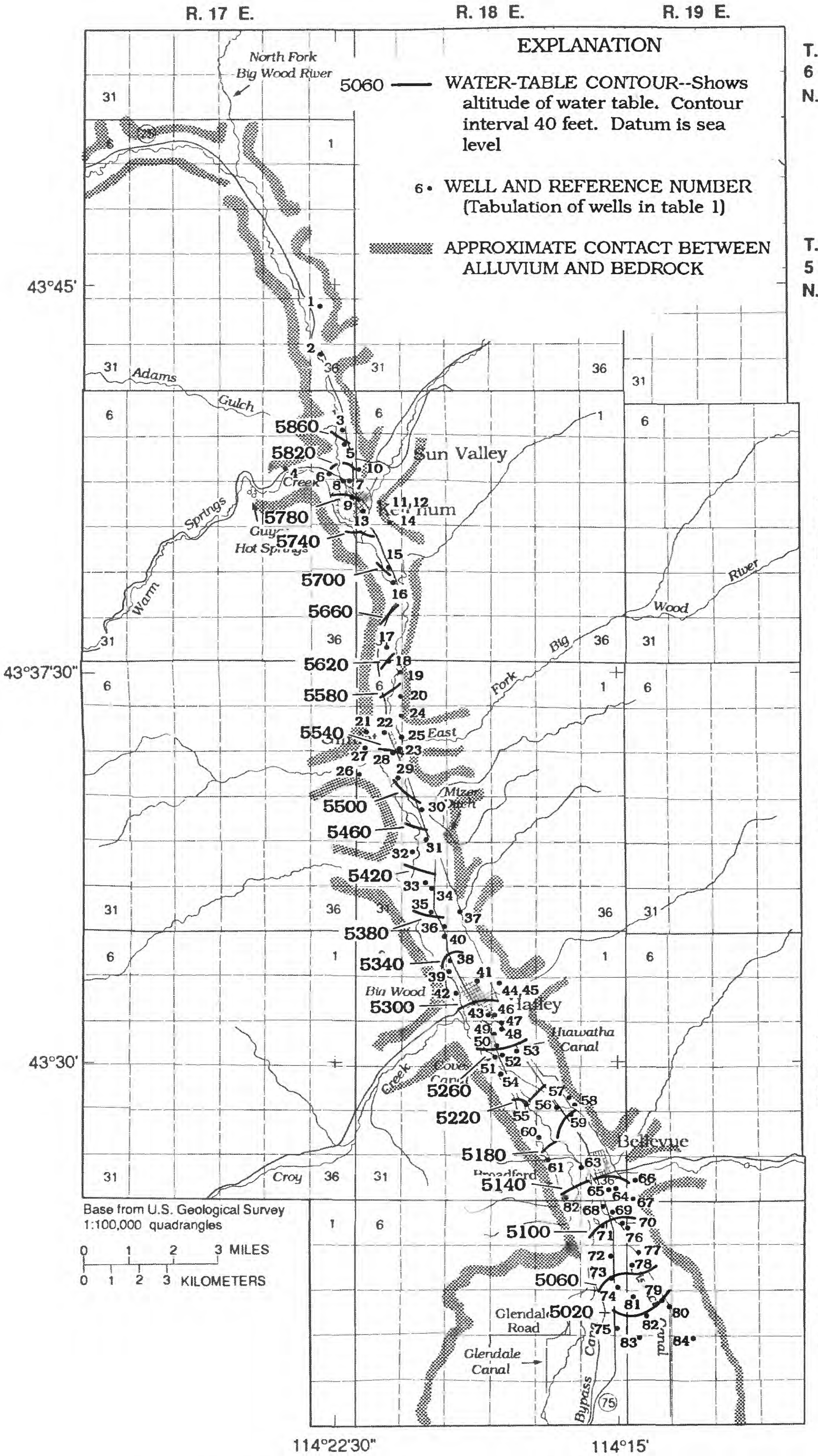

Figure 7.--Water-table contours in April 1986 and well locations

to estimate T in water-table aquifers of unconsolidated sediments. Theis (1963, p. 334) noted that where calculated T' values were greater than 13,300 ft^2/d, the actual T was greater than the estimated value.

The second empirical method is that of Thomasson and others (1960, p. 222), who noted that transmissivity of valley-fill sediments in California averaged 267 times specific capacity.

Estimates of hydraulic conductivity for the alluvial aquifer were obtained by dividing T by the saturated thickness of the aquifer. In the upper Big Wood River basin, K averaged 150 ft/d by use of Theis' method and 300 ft/d by use of Thomasson and others' method (table 2). Moreland (1977, p. 11) noted that transmissivity near Bellevue ranged from 30,000 to 70,000 ft^2/d (K ranged from 200 to 470 ft/d); his estimates were obtained by multiplying specific capacity by 267.

During this study, two Hailey City wells were pumped by the Idaho Department of Water Resources to determine pump efficiencies, and discharge and water-level drawdown were measured. Data from the pump efficiency tests were used in an image well analysis for an infinite strip aquifer with a recharge boundary and a barrier boundary. Hydraulic conductivity determined with this procedure was 310 ft/d at well 2N-18E-9BDC1 and 490 ft/d at well 2N-18E-9DDA1. Because of the limited quantity of data used to estimate hydraulic conductivity, a range of K values from 150 to 500 ft/d was used. Heath (1983, p. 13) showed that hydraulic conductivity values from 150 to 500 ft/d commonly were associated with coarse sand aquifers.

Ground-water discharge from a basin may be computed from the equation:

$$Q = 365/43{,}560\ KAh \qquad (2)$$

where

Q = annual ground-water discharge, in acre-feet per year;
365/43,560 = constant to convert cubic feet per day to acre-feet per year;
K = hydraulic conductivity, in feet per day;
A = cross-sectional area of aquifer, in feet squared; and
h = hydraulic gradient, in feet per mile.

Thickness of alluvial deposits at Glendale Road was estimated using seismic refraction techniques. The cross section (fig. 8) constructed with the seismic data is not perpendicular to the direction of ground-water flow. Estimates of flow through this cross section must be multiplied by the sine of 60 degrees to correct for the flow angle. Total saturated area of the cross

Table 2.--*Characteristics of wells and estimated hydraulic conductivity* (K)

[Estimated values are rounded]

Well location	Radius (in.)	Saturated thickness (ft)	Discharge (gal/min)	Drawdown (ft)	Pumping time (days)	Specific capacity [(gal/min)/ft]	K (Theis 1963) (ft/d)	K (Thomasson and others, 1960) (ft/d)
4N-18E-19	8	40	1,840	14	0.42	131	480	880
2N-18E- 9	6	150	2,240	32	.21	70	70	120
2N-18E- 9	8	150	2,000	60	.25	33	30	60
1N-18E- 1	10	190	3,300	49	.12	67	40	90
1N-19E- 7	10	190	2,600	8	.17	325	200	460
1N-19E-17	10	190	1,890	13	.25	145	90	200
Mean							150	300

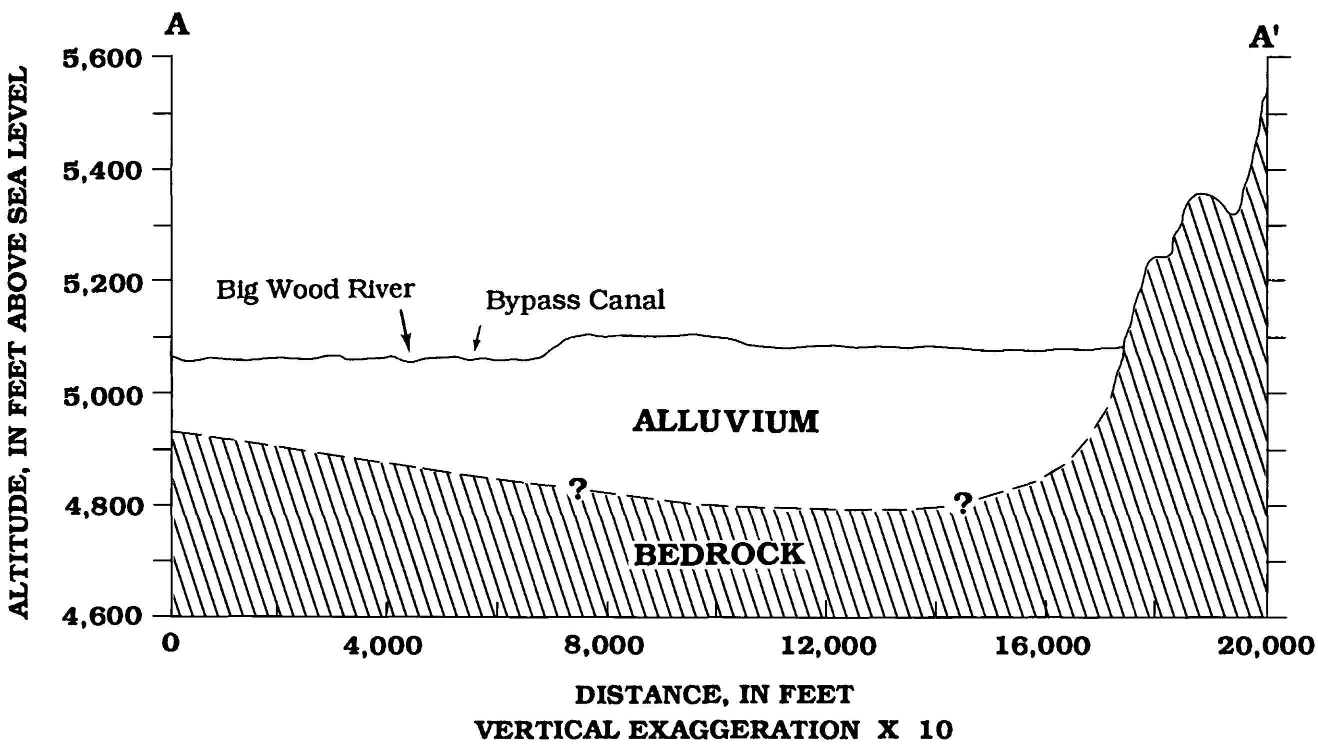

Figure 8.--Geologic section near Glendale Road.
(Location of section on figure 2)

section, which was estimated using the water-table altitude from April 1986, was 3,300,000 ft^2. Average annual ground-water discharge from the study area estimated by using K = 300 ft/d and h = 43 ft/mi (determined from April 1986 water-level measurements) is 59,000 acre-ft/yr. Ground-water discharge at Hailey was estimated for use in water-budget calculations. Average annual ground-water discharge at Hailey, estimated using K = 300 ft/d, A = 820,000 ft^2, and h = 33 ft/mi, is 13,000 acre-ft/yr. This estimated ground-water discharge is substantially smaller than the 34,000 acre-ft/yr estimated by Smith (1959, p. 21) and the 40,000 acre-ft/yr estimated by Luttrell and Brockway (1984, p. 58). Smith's (1959) analysis did not include effects of recharge from the Big Wood River on results of aquifer tests; therefore, his estimated K value of about 900 ft/d is probably high. Luttrell and Brockway (1984, p. 58) determined underflow by subtracting the average discharge for the Big Wood River at Hailey (not including the Big Wood Slough) from an empirically calculated water yield; therefore, their underflow value includes evapotranspiration from phreatophytes, crops, and rangeland, and surface water that bypasses the gaging station at Hailey.

Surface-Water and Ground-Water Relations

Surface-water and ground-water systems are interconnected in the upper Big Wood River basin. The Big Wood River gains or loses water with respect to the ground-water system, depending on local conditions. Where the altitude of the ground-water surface is higher than the altitude of the stream, some ground water may enter the stream channel, and discharge in the stream will increase. If the altitude of the ground-water surface is below that of the stream channel, discharge in the stream may decrease as a result of seepage losses.

During August 1986, a seepage study was made on the Big Wood River immediately upstream from Ketchum to Glendale Road. Discharge of the Big Wood River was measured below Adams Gulch, above the mouth of the East Fork Big Wood River, at the upper crossing of Broadford Road near Hailey, and at Glendale Road. Inflows to the river and diversions from the river were located and measured during the study. Inflows were measured as close to the mouth as possible, and diversions were measured below any spillback to the river. Gain from or loss to ground water in a given reach was calculated by adding diversions from the reach to the final river discharge and subtracting inflows to the reach and the initial river discharge. A positive result shows that the reach gained flow from ground water. During this seepage study, the river gained water from above Ketchum to between Hailey and Bellevue and lost from that point to Glendale Road (table 3). Hydrographs for four wells measured monthly from April 1986 through November 1987 and for the Big Wood River at Hailey are shown in figure 9; well locations are shown in figure 10. Seasonal variations in ground-water levels are similar to

Table 3.--*Inflows and diversions of the Big Wood River from above Ketchum to Glendale Road, August 1986*

[Values in cubic feet per second; gain or loss rounded]

Location	Big Wood River	Inflows	Diversions	Gain from ground water	Loss to ground water
Below Adams Gulch	181				
Unnamed tributary, left bank		0.2			
Unnamed tributary, right bank		1.5			
Unnamed tributary, left bank		13.2			
Warm Springs Creek		48.1			
Trail Creek		25.6			
Subtotal for reach		88.6	0		
Above East Fork Big Wood River	309			39	
East Fork Big Wood River		42.6			
Mizer Ditch			.5		
Unnamed tributary, left bank		.6			
Hiawatha Canal			50.5		
Unnamed tributary, right bank		.3			
Unnamed tributary, left bank		.9			
Croy Creek		4.8			
Cove Canal			11.7		
Unnamed diversion, right bank			23.3		
Subtotal for reach		49.2	86		
Upper crossing, Broadford Road	308			36	
Unnamed diversion, left bank			5.7		
District Canal			172		
Bypass Canal			58.6		
Glendale Canal			22.2		
Subtotal for reach		0	258		
Glendale Road	.7				49

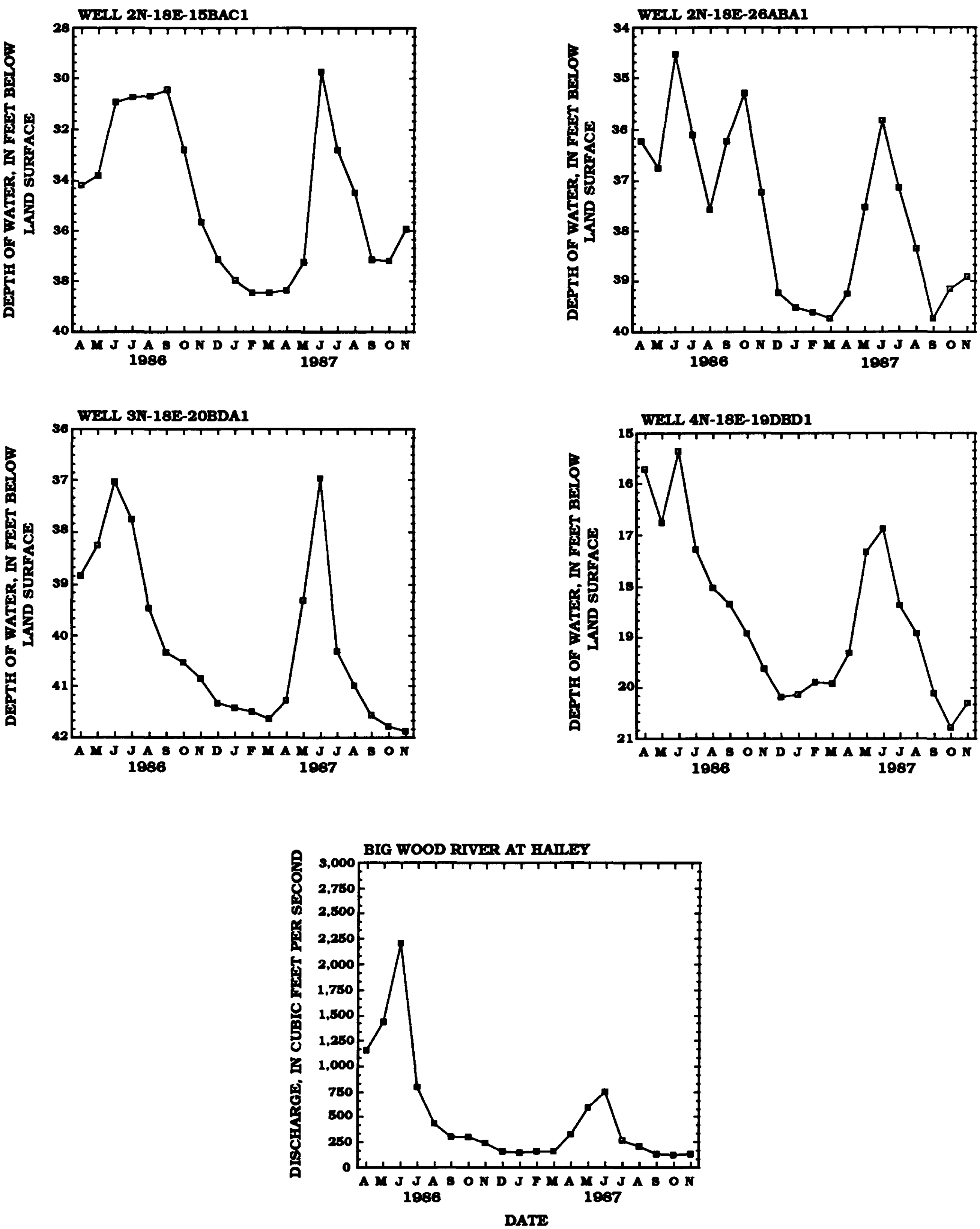

Figure 9.--Water levels for selected observation wells and discharge of the Big Wood River at Hailey. (Locations shown in figure 10)

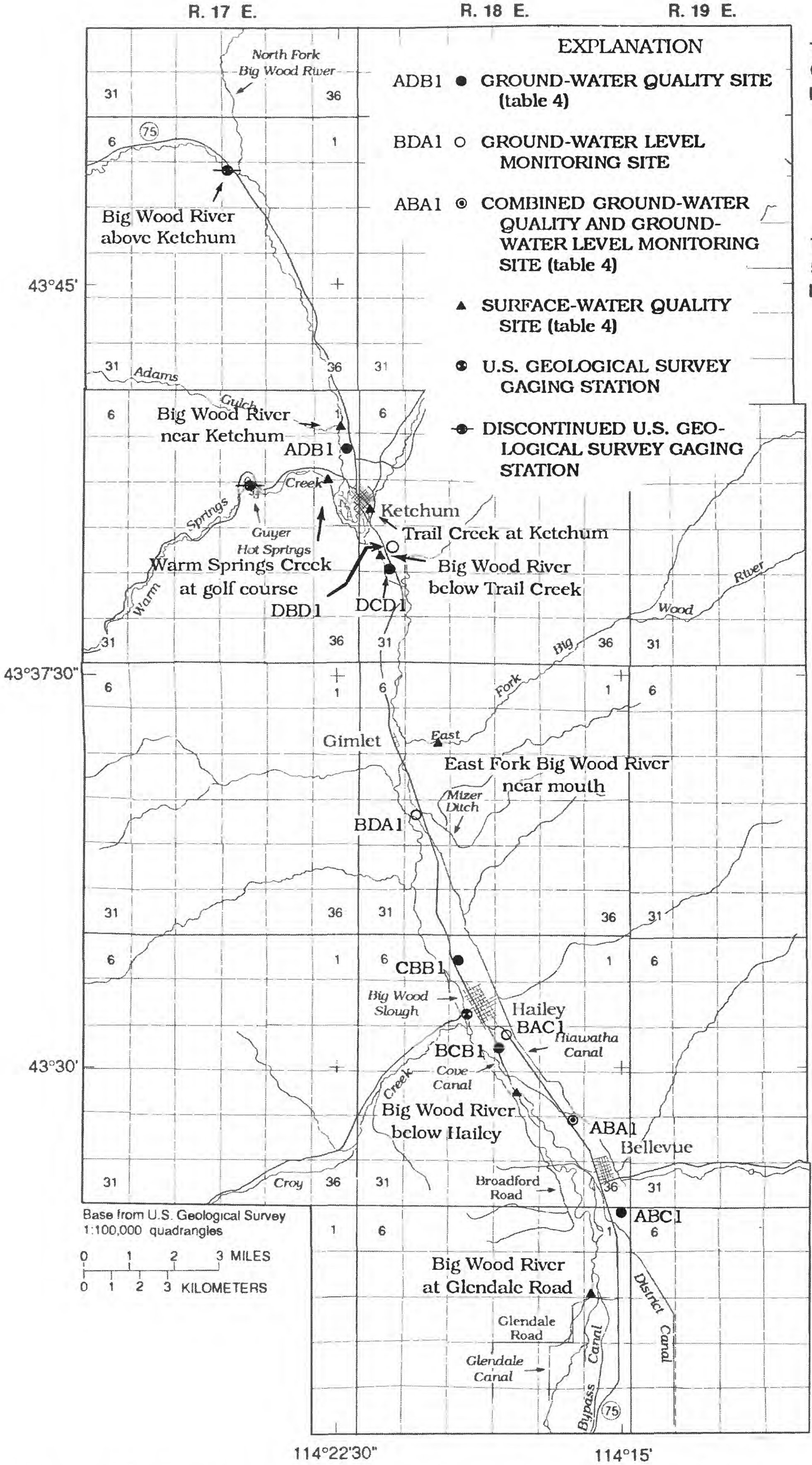

Figure 10.--Locations of water-quality and ground-water level monitoring sites.

variations in discharge of the Big Wood River and indicate a hydraulic connection between the systems. Ground-water levels are elevated by recharge from water seeping from canals, river channels, and irrigated fields. Water levels in wells 4N-18E-19DBD1 and 3N-18E-20BDA1 and the Big Wood River respond to the spring snowmelt and relatively dry summers. Water levels in well 2N-18E-15BAC1 are affected by surface-water diversions into a lateral from Hiawatha Canal, within 600 ft of the well. The sustained high water level during summer 1986 coincides with the period of diversions into Hiawatha Canal. During 1987, more water was diverted into Hiawatha Canal than during 1986 (Water District #37 and Water District #37M, 1986, p. 31; 1987, p. 41). However, because of below-normal runoff during 1987, most of the water was allocated to downstream users (Water District #37 and Water District #37M, 1986, p. 10; 1987, p. 7), and little water probably was diverted into the lateral near well 2N-18E-15BAC1. Water levels in well 2N-18E-26ABA1 also are affected by surface-water diversions. Cove Canal is within 700 ft of the well, and an adjacent field is surface-water irrigated.

Water Quality

Water-quality data were collected during November 1986, March 1987, and August 1987 at seven surface-water sites and six ground-water sites above and below population centers (fig. 10). Sampling represented times when seasonal population was low, October through November, and when seasonal population was high, January through March. Samples were analyzed for nutrients (NO_2, NO_2+NO_3, and PO_4) and chloride to determine effects of upstream urban development and sewage disposal on ground- and surface-water quality, and for cadmium, lead, and zinc because of historical intensive mining in the region.

Specific conductance, pH, alkalinity, water temperature, and dissolved oxygen (surface water only) were measured onsite. Surface-water samples were collected by using cross-sectional and depth-integrating methods described by Guy and Norman (1970, p. 30-32). Ground-water samples were collected using methods described by Wood (1976, p. 4). Samples for laboratory analysis were filtered onsite through a 0.45-micrometer filter. Filters were rinsed with 250 mL (milliliters) of distilled water and 50 mL of sample water before being used to filter water to be analyzed. Samples for metals analysis were preserved with nitric acid. Samples for nutrient analysis were placed in an opaque bottle, preserved with mercuric chloride, and chilled. Water-quality data are shown in table 4. In general, concentrations of most constituents increased downgradient as a result of dissolution of minerals in soils and the aquifer.

Fluoride concentrations in surface and ground water ranged from 0.10 to 1.5 mg/L (table 4). Hem (1985, p. 120) noted that fluoride concentrations in most natural water are less than 1.0

Table 4.--*Water-quality data*

[Site locations in figure 10; --, no data available; <, less than]

Site location	Date	Time (24-hour)	Water temper-ature (°C)		Alkalinity (mg/L as $CaCO_3$) Field	Alkalinity (mg/L as $CaCO_3$) Lab	Dissolved oxygen (mg/L)	Percent saturation	Solids, dissolved (mg/L)
Surface Water									
Big Wood River above Ketchum	11- 4-86	1545	7.0	8.3	98	98	10.4	106	125
	3- 3-87	1615	3.5	8.4	102	102	10.7	--	120
Warm Springs Creek at golf course	11- 5-86	1300	9.5	8.6	105	105	10.2	111	151
	3- 4-87	1600	9.5	8.8	110	112	9.4	--	147
Trail Creek at Ketchum	11- 6-86	1200	5.0	8.5	188	192	11.2	110	242
	3- 5-87	1130	1.5	8.6	193	192	9.5	--	254
Big Wood River below Trail Creek	11- 3-86	1630	7.0	8.2	114	115	10.1	102	146
	3- 4-87	1300	5.0	8.6	117	116	11.0	--	144
East Fork Big Wood River near mouth	11- 6-86	0800	2.5	8.2	150	151	11.1	101	219
	3- 5-87	1000	.0	8.5	168	165	11.3	--	260
Big Wood River below Hailey	11- 3-86	1400	7.5	8.7	132	129	11.3	114	173
	3- 4-87	1030	3.5	8.5	137	133	11.7	--	171
Big Wood River at Glendale Road	11- 3-86	1130	7.0	8.6	135	135	11.1	110	175
	3- 3-87	1130	4.0	8.7	136	137	11.5	--	175

Table 4.--*Water-quality data*--Continued

Site location	Date	Time (24-hour)	Specific conductance (µS/cm) Field	Specific conductance (µS/cm) Lab	Nitrite, dissolved (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)	Ortho-phosphate, dissolved (mg/L as P)	Fluoride, dissolved (mg/L as F)
			Surface Water--Continued					
Big Wood River above Ketchum	11- 4-86	1545	211	209	<0.010	<0.100	<0.010	0.20
	3- 3-87	1615	209	194	<.010	<.100	<.010	.20
Warm Springs Creek at golf course	11- 5-86	1300	238	236	<.010	<.100	<.010	1.5
	3- 4-87	1600	228	245	<.010	<.100	<.010	1.4
Trail Creek at Ketchum	11- 6-86	1200	409	411	<.010	<.100	<.010	.10
	3- 5-87	1130	418	434	<.010	<.100	<.010	.20
Big Wood River below Trail Creek	11- 3-86	1630	234	246	<.010	<.100	<.010	.40
	3- 4-87	1300	234	253	<.010	<.100	<.010	.60
East Fork Big Wood River near mouth	11- 6-86	0800	354	357	<.010	<.100	<.010	.10
	3- 5-87	1000	403	426	<.010	<.100	<.010	.10
Big Wood River below Hailey	11- 3-86	1400	286	280	<.010	<.100	.010	.40
	3- 4-87	1030	282	299	<.010	.230	.021	.40
Big Wood River at Glendale Road	11- 3-86	1130	294	290	<.010	<.100	<.010	.40
	3- 3-87	1130	290	305	<.010	.190	<.010	.40

Table 4.--*Water-quality data*--Continued

Site location	Date	Time (24-hour)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Cadmium, dissolved (µg/L as Cd)	Lead, dissolved (µg/L as Pb)	Zinc, dissolved (µg/L as Zn)
			Surface Water--Continued				
Big Wood River	11- 4-86	1545	0.80	10	<1	<5	8
above Ketchum	3- 3-87	1615	1.2	13	--	--	--
Warm Springs Creek	11- 5-86	1300	2.0	12	<1	<5	4
at golf course	3- 4-87	1600	2.1	15	--	--	--
Trail Creek	11- 6-86	1200	1.5	46	<1	8	10
at Ketchum	3- 5-87	1130	2.6	52	--	--	--
Big Wood River	11- 3-86	1630	1.2	14	<1	<5	8
below Trail Creek	3- 4-87	1300	1.5	17	--	--	--
East Fork Big Wood	11- 6-86	0800	1.5	43	<1	<5	9
River near mouth	3- 5-87	1000	2.2	68	--	--	--
Big Wood River	11- 3-86	1400	1.9	19	<1	5	17
below Hailey	3- 4-87	1030	2.7	22	--	--	--
Big Wood River at	11- 3-86	1130	1.8	20	<1	<5	6
Glendale Road	3- 3-87	1130	2.9	23	--	--	--

Table 4.--*Water-quality data*--Continued

Site location	Date	Time (24-hour)	Water temperature (°C)	pH	Alkalinity (mg/L as $CaCO_3$) Field	Alkalinity (mg/L as $CaCO_3$) Lab	Solids dissolved (mg/L)
			Ground Water				
4N-17E-12ADB1	11- 5-86	0845	9.0	7.6	122	121	151
	3- 3-87	1545	7.0	7.8	117	117	137
	8- 5-87	1510	9.0	--	--	--	--
4N-18E-19DCD1	11- 5-86	1100	8.5	7.8	153	150	196
	3- 4-87	1520	4.5	7.8	150	149	187
2N-18E- 4CBB1	11- 4-86	1400	12.0	7.6	166	168	205
	3- 3-87	1430	9.5	7.8	165	163	193
	8- 5-87	1420	10.5	--	--	--	--
2N-18E-15BCB1	11- 4-86	1220	11.0	7.6	174	173	219
	3- 4-87	0945	10.0	7.6	184	181	213
	8- 5-87	1150	12.0	--	--	--	--
2N-18E-26ABA1	11- 4-86	0900	10.0	7.6	189	188	230
	3- 4-87	0900	11.0	7.7	184	182	210
	8- 5-87	1130	10.0	--	--	--	--
1N-18E- 1ABC1	11- 4-86	1030	12.5	7.6	140	140	170
	3- 3-87	1300	4.0	7.9	135	134	167
	8- 5-87	1345	12.0	--	--	--	--

Table 4.--*Water-quality data*--Continued

Site location	Date	Time (24-hour)	Specific conductance (µS/cm) Field	Specific conductance (µS/cm) Lab	Nitrite, dissolved (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)	Ortho-phosphate, dissolved (mg/L as P)	Fluoride, dissolved (mg/L as F)
				Ground Water--Continued				
4N-17E-12ADB1	11- 5-86	0845	234	248	<0.010	0.110	<0.010	0.20
	3- 3-87	1545	241	246	<.10	.140	<.010	.20
	8- 5-87	1510	239	--	--	--	--	--
4N-18E-19DCD1	11- 5-86	1100	326	332	<.010	.250	.010	.30
	3- 4-87	1520	325	334	<.010	.240	<.010	.40
2N-18E- 4CBB1	11- 4-87	1400	333	348	<.010	.450	<.010	.30
	3- 3-87	1430	330	348	<.010	.460	<.010	.30
	8- 5-87	1420	341	--	--	--	--	--
2N-18E-15BCB1	11- 4-86	1220	366	365	<.010	.970	.021	.30
	3- 4-87	0945	358	373	<.010	.530	<.010	.30
	8- 5-87	1150	370	--	--	--	--	--
2N-18E-26ABA1	11- 4-86	0900	381	388	<.010	1.40	.021	.20
	3- 4-87	0900	358	374	<.010	.750	.010	.20
	8- 5-87	1130	372	--	--	--	--	--
1N-18E- 1ABC1	11- 4-86	1030	295	300	<.010	.171	.010	.30
	3- 3-87	1300	277	301	<.010	.300	<.010	.30
	8- 5-87	1345	287	--	--	--	--	--

Table 4.--*Water-quality data*--Continued

Site location	Date	Time (24-hour)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Cadmium, dissolved (µg/L as Cd)	Lead, dissolved (µg/L as Pb)	Zinc, dissolved (µg/L as Zn)
			Ground Water--Continued				
4N-17E-12ADB1	11- 5-86	0845	0.80	10	<1	<5	56
	3- 3-87	1545	1.0	13	--	--	--
	8- 5-87	1510	--	--	--	--	20
4N-18E-19DCD1	11- 5-86	1100	1.6	25	<1	5	5
	3- 4-87	1520	1.9	27	--	--	--
2N-18E- 4CBB1	11- 4-86	1400	1.8	15	<1	<5	26
	3- 3-87	1430	2.5	19	--	--	--
	8- 5-87	1420	--	--	--	--	20
2N-18E-15BCB1	11- 4-86	1220	3.7	17	1	5	219
	3- 4-87	0945	3.1	18	--	--	--
	8- 5-87	1150	--	--	--	--	120
2N-18E-26ABA1	11- 4-86	0900	2.7	15	<1	<5	120
	3- 4-87	0900	2.6	17	--	--	--
	8- 5-87	1130	--	--	--	--	100
1N-18E- 1ABC1	11- 4-86	1030	1.8	17	<1	<5	430
	3- 3-87	1300	2.4	21	--	--	--
	8- 5-87	1345	--	--	--	--	80

mg/L. Warm Springs Creek was the only site where fluoride concentrations were greater than 0.60 mg/L. Fluoride concentrations as high as 16 mg/L were reported by Young and Mitchell (1973, p. 23) in thermal water from Guyer Hot Springs. Thermal water flowing from Guyer Hot Springs into Warm Springs Creek probably is the source for elevated fluoride concentrations.

Many constituents sampled were in concentrations less than analytical detection levels. Nutrient concentrations in surface water were near or below detection levels (table 4), which indicates insignificant changes in water quality due to upstream urban development and sewage disposal. Cadmium and lead concentrations were generally below detection levels, but zinc concentrations were as high as 430 μg/L (table 4). The drinking water standard for zinc is 5,000 μg/L (U.S. Environmental Protection Agency, 1986). The two highest zinc concentrations were detected in ground water immediately downgradient from Hailey and Bellevue during November 1986. Most ground-water quality sites were resampled in August 1987 to confirm previous analyses of zinc concentrations. The length of time wells were pumped prior to sample collection was approximately tripled from the November sampling. Zinc concentrations were lower in August, possibly because of the increased pumping time, which reduces the chance of contamination of the sample from contact with the well casing or with any galvanized pipe in the discharge line.

Ranges of nutrient data collected during this and previous studies are presented in table 5. Data from these reports and this study show that nutrient levels in the upper Big Wood River basin have not changed substantially during the past 30 years and that water quality is adequate for drinking and agricultural uses.

WATER YIELD

Water is supplied to the study area by precipitation and is discharged from the area by ET (evapotranspiration), by surface water in the Big Wood River and canals, by ground-water underflow, and by consumptive domestic uses. Yield is used in this report to represent the quantity of water leaving the upper Big Wood River basin or tributary and does not include ET from the mountainous areas. Yield was estimated by using the water-budget method as follows:

$$Y = ETR + ETC + ETP + SW + GW + CU \qquad (3)$$

where

ETR = ET from nonirrigated rangeland,
ETC = ET from irrigated crops,
ETP = ET from phreatophytes,
SW = discharge of the Big Wood River and canals,
GW = ground-water discharge (underflow), and
CU = consumptive use by domestic water users.

Table 5.--*Ranges of nutrient concentrations, 1959-87*

[--, no data available; <, less than]

Source	Nitrate as N (mg/L)		Orthophosphate as P (mg/L)	
	Ground water	Surface water	Ground water	Surface water
Smith (1959)	<0.1 - 3.0	0.4 - 0.6	--	--
Castelin and Winner (1975)	.1 - 1.4	<.1 - .2	--	--
Manuel and others (1978)	--	.1 - .4	--	<0.01 - 0.10
Luttrell and Brockway (1984)	.1 - 2.2	.3 - .7	<0.01 - 0.06	<.01 - .06
1986 to 1987	.1 - 1.4	<.1 - .2	<.01 - .02	<.01 - .02

Water-budget components were calculated for each year from 1940 to 1979; the average annual yield is shown in table 6.

Previous studies were examined to determine appropriate ET rates for the water budget. Smith (1959, p. 22) used the following ET rates in his water budget for the Big Wood River: irrigated crops, 1.8 ft/yr; nonirrigated lands, 1.0 ft/yr; and phreatophytes, 3.5 ft/yr. Meyers (1962, p. 91) estimated that evaporation from small streams in the Snake River basin was about 2.7 to 2.9 ft/yr. Williams and Young (1982, p. 18) estimated ET rates of 1.0 to 1.3 ft/yr for several basins in southern Idaho where mean annual precipitation is similar to that on the Big Wood River basin floor. For this study, the following ET rates were assigned: irrigated crops, 1.8 ft/yr; nonirrigated rangeland, 1.0 ft/yr; and phreatophyptes, 2.5 to 3.5 ft/yr.

An empirical method of estimating yield was developed by Langbein (Nace and others, 1961, p. 36-47). This method is based on relations between (1) altitude and temperature, (2) temperature and potential ET, and (3) the ratio of potential ET to precipitation and the ratio of yield to potential ET. To calibrate this method for the upper Big Wood River basin, the temperature-altitude equation was adjusted to result in the correct mean annual temperature at Hailey. Langbein (Nace and others, 1961, p. 46) noted that yield is not entirely explained by climatic variables and the method needs to be tested by comparing results with local measurements of yield and, if necessary, adjusting the coefficients in the yield equation. For this study, the coefficient by which potential ET was multiplied was determined by comparing calculated average yields with mean annual discharges for the Big Wood River near Ketchum and Warm Springs Creek at Guyer Hot Springs for their respective periods of record. The equations as adapted for conditions in the upper Big Wood River area are:

$$\begin{aligned} t &= -0.0035\ (\text{altitude}) + 62 \\ PET &= 0.73\ (t) - 12.25 \\ Y &= 0.75\ (P) - 0.59\ (PET) \end{aligned} \qquad (4)$$

where

t = mean annual temperature, in degrees Fahrenheit;
PET = potential evapotranspiration, in inches;
Y = annual water yield, in inches; and
P = annual precipitation, in inches.

To convert yield in inches to acre-feet, multiply by the basin area (in acres) and divide by 12.

Basin areas and mean altitudes were determined for North Fork Big Wood River, Warm Springs Creek, Trail Creek, and East Fork Big Wood River basin. Basin area and mean altitude for the Big Wood River near Ketchum were obtained from a report by Kjelstrom and

Table 6.--*Ranges of water-yield estimates based on water years 1940-79*

[Values, in acre-feet per year, are rounded]

Water-budget component	Hailey			Glendale Road		
	Low	Average	High	Low	Average	High
ETR	18,000	21,000	24,000	24,000	27,000	30,000
ETC	2,800	3,200	3,600	6,700	7,300	7,900
ETP	5,000	6,000	7,000	8,500	10,000	12,000
SW	320,000	360,000	400,000	280,000	310,000	340,000
GW	5,900	13,000	25,000	22,000	59,000	120,000
CU	100	200	400	150	250	450
Total	350,000	400,000	460,000	340,000	410,000	510,000

ETR = ET from nonirrigated rangelands, 16,000 acres (Hailey), 20,000 acres (Glendale Road).

Low estimate: -1/2 standard deviation from average estimate.
High estimate: +1/2 standard deviation from average estimate.

ETC = ET from irrigated crops, determined by subtracting the quantity of diversions that bypass a reach from total diversions above the reach and multiplying by 0.1 to account for return flows and nonirrigation diversions included in the total.

Low estimate: -1/2 standard deviation from average estimate.
High estimate: +1/2 standard deviation from average estimate.

ETP = ET from phreatophytes, 2,000 acres (Hailey), 3,400 acres (Glendale Road).

Low estimate: 2.5 acre-ft/acre.
Average estimate: 3.0 acre-ft/acre.
High estimate: 3.5 acre-ft/acre.

SW = Discharge of the Big Wood River (gaged at Hailey) and canals. Average at Glendale Road estimated by adding SW, ETC, ETP, and GW at Hailey and subtracting ETC, ETP, and GW at Glendale Road.

Low estimate: -10 percent of average estimate.
High estimate: +10 percent of average estimate.

GW = Ground-water discharge based on the following characteristics:

	Low	Average	High
Hailey	K = 150 ft/d	300 ft/d	500 ft/d
	A = 820,000 ft^2	820,000 ft^2	820,000 ft^2
	h = 30 ft/mi	33 ft/mi	38 ft/mi
	f = 90 degrees	90 degrees	90 degrees
Glendale Road	K = 150 ft/d	300 ft/d	500 ft/d
	A = 3,300,000 ft^2	3,300,000 ft^2	3,300,000 ft^2
	h = 33 ft/mi	43 ft/mi	51 ft/mi
	f = 60 degrees	60 degrees	60 degrees

K = Hydraulic conductivity,
A = cross-sectional area of the aquifer,
h = hydraulic gradient, and
f = angle of flow through cross section.

CU = Consumptive use by domestic water users. Estimates based on consumptive use of water withdrawn for domestic and commercial use in Idaho (Solley and others, 1988, p. 17).

Moffatt (1981, p. 96). Basin areas and mean altitudes for other areas not listed above were determined but not separated other than to identify them as either above Hailey or between Hailey and Glendale Road. Basin areas, mean altitudes, and mean annual precipitation are shown in table 7.

Yield was calculated for the basin above Hailey and for the basin above Glendale Road. Yields at Hailey estimated by the water-budget method are compared graphically with gaged surface-water discharge at Hailey (fig. 11), which provides a useful measure for examining the reliability of estimated yields. Variations in surface-water discharge and estimated yield are similar because surface-water discharge is much larger than any other component included in yield estimates (fig. 12). Mean annual yield at Hailey, estimated using the water-budget method, was about 400,000 acre-ft and, using the Langbein method, was about 420,000 acre-ft (table 8). Mean annual surface-water discharge at Hailey, including diversions that bypass the gage, for the same period was 360,000 acre-ft. Mean annual yield at Glendale Road, estimated using the water-budget method, was 410,000 acre-ft and, using the Langbein method, was 460,000 acre-ft (table 8).

Average yield for 1940-79, estimated using the Langbein method, was greater than the average value of the water-budget method but was less than the high value shown in table 6. The results verify the Langbein method and indicate that it could be used if data for a water budget were not available. The water-budget method is probably more accurate because a large percentage of the water budget is surface water, which is measured rather than estimated.

The Langbein method is based on average climatic conditions and can be expected to produce reasonable results for years when climatic conditions are near average or over a long time period. When precipitation is extreme (low or high), this method does not produce reasonable results, such as in 1987 when precipitation was about half of average and was reflected by the subsequent low runoff (fig. 13).

During 1986, precipitation in the basin was about 7 in. (26 percent) above average. Yield for the basin above Glendale Road during 1986, estimated using the water-budget method, was 580,000 acre-ft and, using the Langbein method, was 660,000 acre-ft. Yield during 1987, estimated using the water-budget method, was 230,000 acre-ft and, using the Langbein method, was 94,000 acre-ft.

Tributary Yield

Yields were estimated for three major tributary basins in the study area. Few historical discharge data were available for

Table 7.--*Drainage areas, mean altitudes, and mean annual precipitation for various parts of the upper Big Wood River basin*

Drainage	Area (square miles)	Mean altitude (feet above sea level)	Mean annual precipitation (inches)
Big Wood River near Ketchum	137	8,120	31
North Fork Big Wood River	40	8,630	33
Trail Creek	65	8,120	31
Warm Springs Creek	96	7,660	28
East Fork Big Wood River	85	7,870	29
Valley floor	36	5,800	17
Other	177	7,120	25
Total above Hailey.................	636	7,640	28
Hailey to Glendale Road	105	6,500	22
South valley floor	11	5,100	15
Total above Glendale Road..........	752	7,440	27

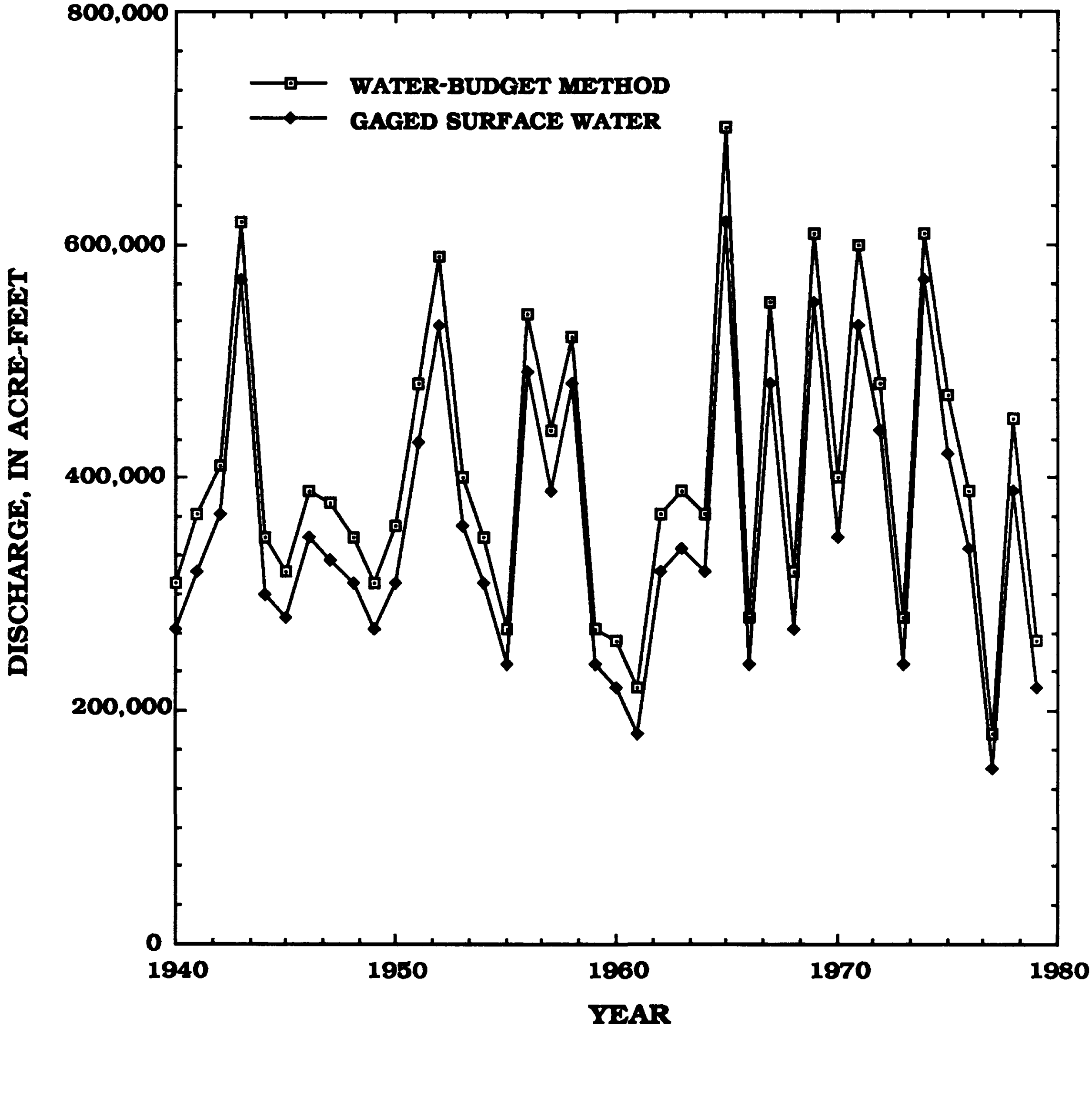

Figure 11.--Yield estimated by water-budget method and gaged surface-water discharge at Hailey, 1940-79.

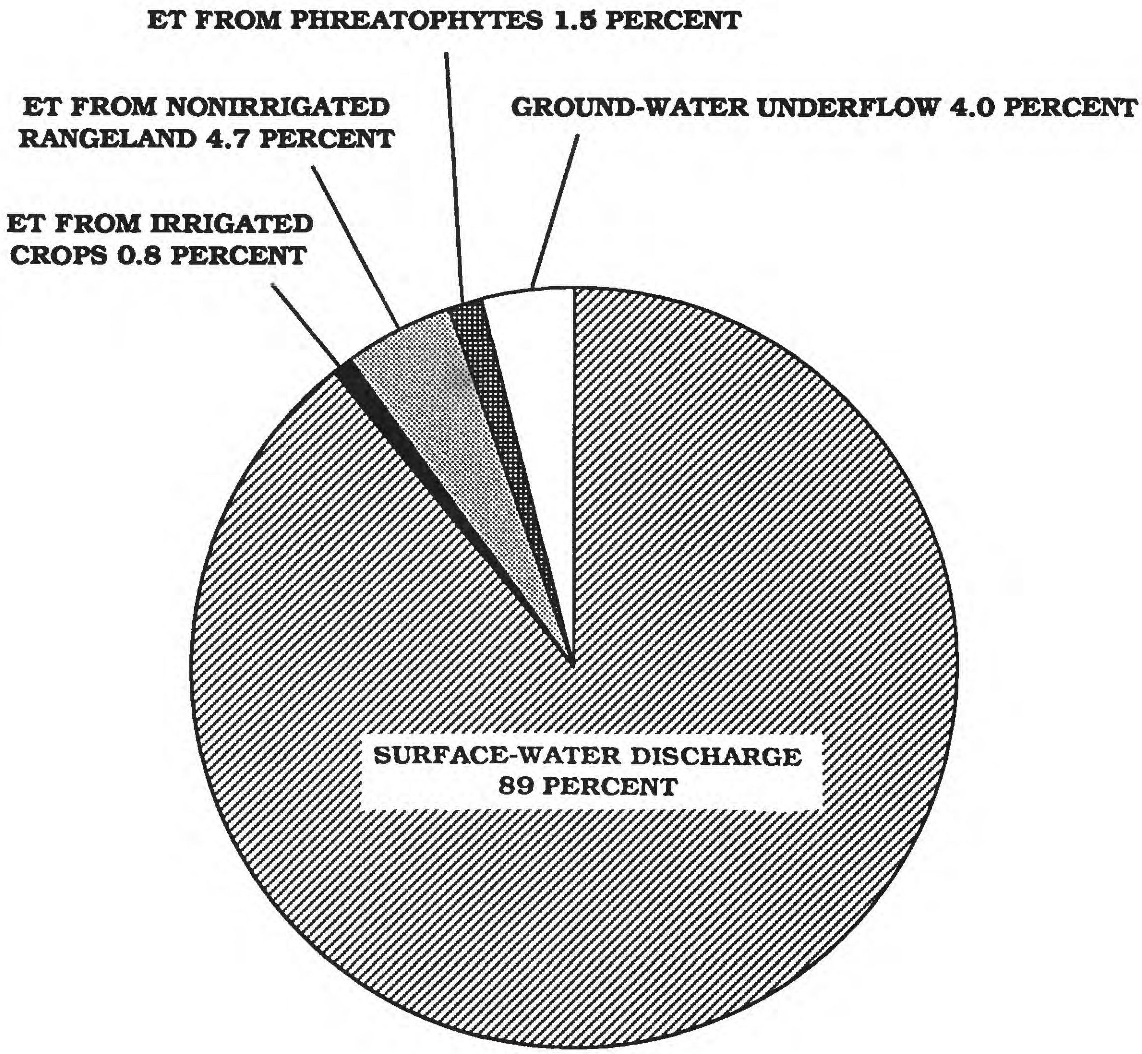

Figure 12.--Relative percentage of water-budget components for yield from basin above Hailey.

Table 8.--*Estimated water yield and standard deviation of average estimates*

Location and period of estimate	Water-budget method (acre-feet)	Langbein (1961) method (acre-feet)
Above Hailey		
1940-79	400,000	420,000
Standard deviation	120,000	100,000
1986	560,000	590,000
1987	220,000	110,000
Above Glendale Road		
1940-79	410,000	460,000
Standard deviation	120,000	120,000
1986	580,000	660,000
1987	230,000	94,000

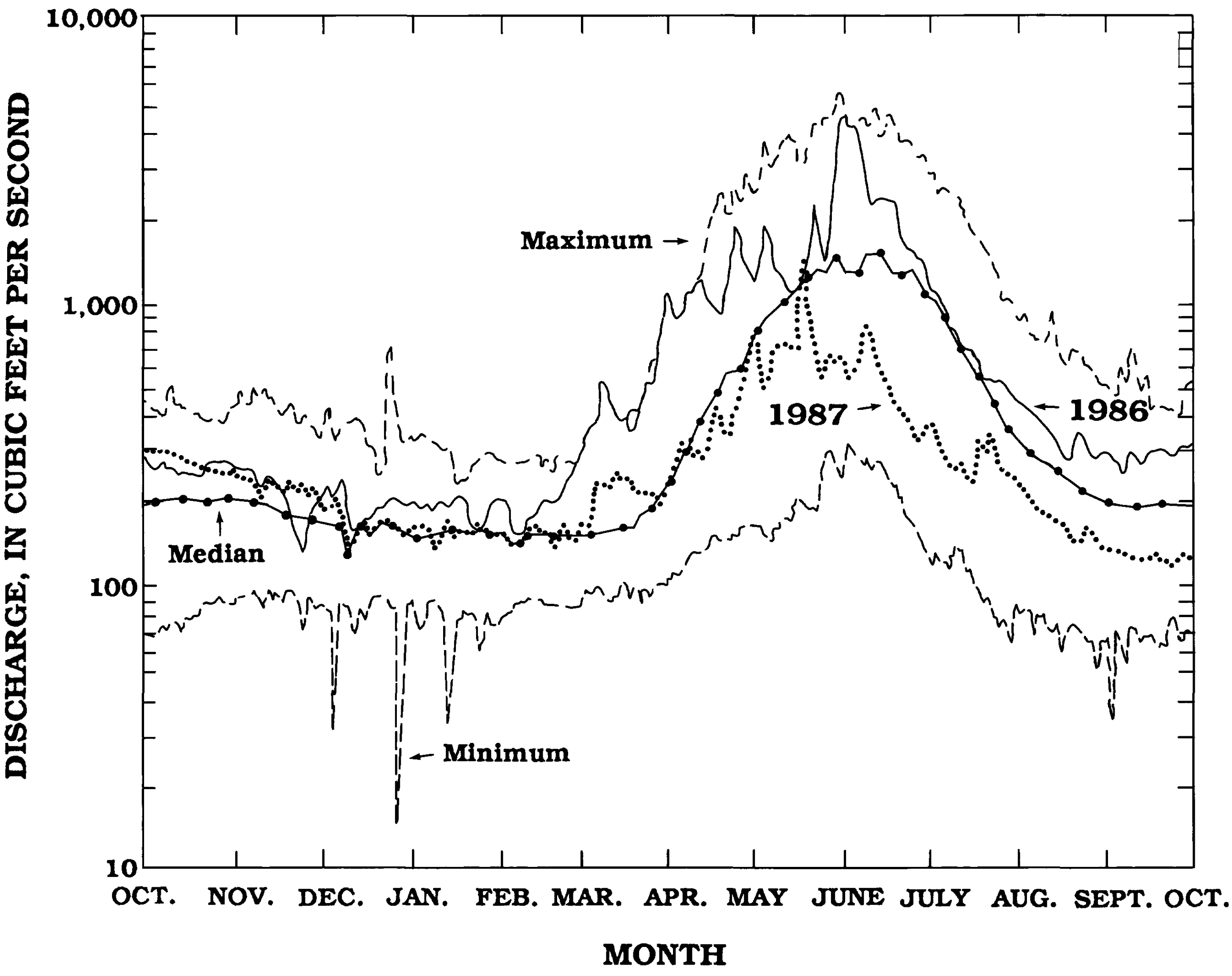

Figure 13.--Maximum, median, and minimum mean daily discharge of the Big Wood River at Hailey, water years 1915-86, compared with mean daily discharge during water years 1986 and 1987.

Trail Creek and East Fork Big Wood River; a continuous record of discharge for Warm Springs Creek was collected from 1940 to 1958. During 1986 and 1987, tributary basin yields were calculated from monthly discharge measurements. The Riggs (1969) method correlates monthly discharge measurements on ungaged streams to mean daily discharge on gaged streams for the date of the discharge measurement. The ratio of daily discharges on ungaged and gaged streams is used to calculate monthly mean discharge for the ungaged stream from the monthly mean discharge of the gaged stream. Monthly mean discharges are summed for the year and divided by 12 to give the mean annual surface-water discharge. The mean annual surface-water discharge from a basin is equal to the basin yield where ground-water underflow is insignificant. Ground-water underflow from Trail Creek, Warm Springs Creek, and East Fork Big Wood River is probably small. Smith (1960, p. 34) estimated that underflow at the Warm Springs Creek gaging station was less than 1 percent of the yield.

Gaging stations used in the Riggs method of calculating yield for Warm Springs Creek, Trail Creek, and East Fork Big Wood River were Big Wood River at Hailey and North Fork Big Lost River at Wild Horse. Accuracy of the Riggs method depends on the hydrologic similarity of gaged and ungaged basins. The North Fork Big Lost River basin (114 mi^2) is adjacent to the headwaters of Trail Creek and has a mean altitude of 8,540 ft.

Tributary yields were calculated for the 1986 and 1987 water years and are shown in table 9. In 1986, the yields from Trail Creek, Warm Springs Creek, and East Fork Big Wood River were about 61,000, 83,000, and 60,000 acre-ft, respectively. In 1987, the yields were about 26,000, 32,000, and 28,000 acre-ft. The average annual yield from the tributaries was estimated from the 1986 and 1987 yields and the percentage of average precipitation during those water years. The average annual yields (reported to 1 significant figure) from Trail Creek, Warm Springs Creek, and East Fork Big Wood River were about 50,000, 60,000, and 50,000 acre-ft, respectively.

SUMMARY

The water resources of the upper Big Wood River basin were studied to provide water planners and managers with tools to evaluate their present water-use policies and to help make future water-management decisions.

Availability of surface and ground water varies seasonally; the greatest quantity is available during spring snowmelt, and the least is available during mid- to late winter. Results of a seepage study conducted during August 1986 showed that the Big Wood River gained water from the ground-water system from Ketchum to below Hailey and lost water to the ground-water system from below Hailey to Glendale Road.

Table 9.--*Estimated water yield and precipitation for upper Big Wood River basin tributaries during 1986 and 1987*

[Yield in acre-feet per year; precipitation in inches]

	Trail Creek	Warm Springs Creek	East Fork Big Wood River
		1986	
Riggs (1969) method			
([1])	60,000	78,000	56,000
([2])	64,000	88,000	64,000
Average	61,000	83,000	60,000
Precipitation	38	35	36
Percentage of 1940-79[3]	123	125	124
		1987	
Riggs (1969) method			
([1])	25,000	30,000	27,000
([2])	26,000	35,000	28,000
Average	26,000	32,000	28,000
Precipitation	18	15	16
Percentage of 1940-79[3]	58	54	55

[1]Correlated using streamflow data from Big Wood River at Hailey.
[2]Correlated using streamflow data from Big Lost River at Wildhorse.
[3]Estimated from snow course data and precipitation-altitude relation shown in figure 4.

Water-quality data showed that nutrient concentrations in surface and ground water were near or below detection levels, which indicated negligible changes in water quality due to upstream urban development and sewage disposal. Fluoride concentrations were elevated in Warm Springs Creek, probably due to inflow of thermal water from Guyer Hot Springs.

Mean annual water yield for the upper Big Wood River basin above Glendale Road, estimated by using a water-budget method, was 410,000 acre-ft and, by using an empirical method, was 460,000 acre-ft. Yield estimated by using the water-budget method is probably more accurate because a large percentage of the water budget is surface water, which is measured rather than estimated. Yield estimated by using the water-budget method was 580,000 acre-ft during 1986 and 230,000 acre-ft during 1987.

During 1986 and 1987, yields from tributary basins were calculated on the basis of monthly discharge measurements. Yields during 1986 for Trail Creek, Warm Springs Creek, and East Fork Big Wood River were 61,000, 83,000, and 60,000 acre-ft; and during 1987, were 26,000, 32,000, and 28,000 acre-ft for the respective basins. Mean annual yields for Trail Creek, Warm Springs Creek, and East Fork Big Wood River, estimated using 1986 and 1987 yields and the percentage of average precipitation during those water years, were 50,000, 60,000, and 50,000 acre-ft, respectively.

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