INTRODUCTION

INDEX MAP OF IDAHO

The study area (see index map of Idaho), part of the Big Lost River drainage basin, is at the northern side of the eastern Snake River Plain. The lower Big Lost River Valley extends from the confluence of Antelope Creek and the Big Lost River to about 4 mi south of Arco and encompasses about 145 mi² (see map showing water-level contours). The study area is about 18 mi long and, at its narrowest, 4 mi wide. Arco, Butte City, and Moore, with populations of 1,016, 59, and 190, respectively, in 1990, are the only incorporated towns. The entire study area, except the extreme northwestern part, is in Butte County. The study area boundary is where alluvium and colluvium pinch out and abut against the White Knob Mountains (chiefly undifferentiated sedimentary rock with lesser amounts of volcanic rock) on the west and the Lost River Range (chiefly sedimentary rock) on the east. Gravel and sand in the valley fill compose the main aquifer. The southern boundary is approximately where Big Lost River valley fill intercalates with or abuts against basalt of the Snake River Group.

Spring ground-water levels and flow in the Big Lost River depend primarily on temperature and the amount and timing of precipitation within the entire drainage basin. Periods of abundant water supply and water shortages are, therefore, related to the amount of annual precipitation. Surface reservoir capacity in the valley (Mackay Reservoir, about 20 mi northwest of Moore) is only 20 percent of the average annual flow of the Big Lost River (Crosthwaite and others, 1970, p. 3). Stored surface water is generally unavailable for carryover from years of abundant water supply to help relieve drought conditions in subsequent years. Many farmers have drilled irrigation wells to supplement surface-water supplies and to increase irrigated acreage.

Average annual flow of the Big Lost River below Mackay Reservoir near Mackay (gaging station 13127000, not shown) in water years 1905, 1913–14, and 1920–90 was about 224,600 acre-ft; average annual flow of the Big Lost River near Arco (gaging station 13132500; see map showing water-level contours) in water years 1947–61, 1967–80, and 1983–90 was about 79,000 acre-ft (Harenberg and others, 1991, p. 254–255). Moore Canal and East Side Ditch divert water from the Big Lost River at the Moore Diversion, 3 mi north of Moore (see map showing water-level contours) and supply water for irrigation near the margins of the valley. When water supply is average or greater, water in the Big Lost River flows through the study area and onto the Snake River Plain, where it evaporates or infiltrates into the Snake River Plain aquifer. When water supply is below average, water in the Big Lost River commonly does not reach Arco; rather, it is diverted for irrigation in the interior of the valley, evaporates, or infiltrates to the valley-fill aquifer.

This report describes the results of a study by the U.S. Geological Survey, in cooperation with the Idaho Department of Water Resources, to collect hydrologic data needed to help address water-supply problems in the Big Lost River Valley. Work involved (1) field inventory of 81 wells, including 46 irrigation wells; (2) measurement of water levels in 154 wells in March 1991; (3) estimation of annual ground-water pumpage for irrigation from 1984 through 1990; and (4) analysis of results of an aquifer test conducted southwest of Moore. All data obtained during this study may be inspected at the U.S. Geological Survey, Idaho District office, Boise.

DESCRIPTION OF AQUIFER TEST

Fourteen irrigation wells are sited in a 1-mi² area about 1.5 mi southwest of Moore. All but two are clustered in an area known locally as the "Well Orchard" (see map showing water-level contours). The Well Orchard supplies water to the Blaine Canal near the western margin of the valley. An aquifer test was conducted in the Well Orchard April 3 through 5, 1991.

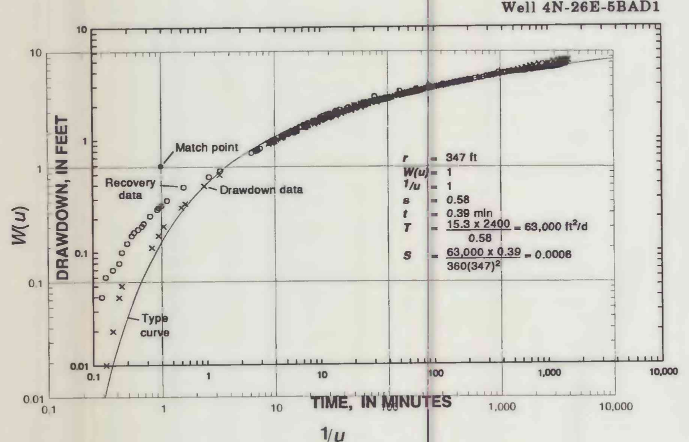
Most wells in the Well Orchard are 200 to 250 ft deep and are cased from land surface to the bottom of the hole. The casing is perforated from 50 to 60 ft below land surface to the bottom of the hole. Static water levels in April 1991 were 100 to 140 ft below land surface. Drillers' logs indicate that the aquifer consists of layered gravel, sand, and clay. The water level in one well rose 2 to 3 ft after a clay layer was penetrated, indicating local artesian conditions.

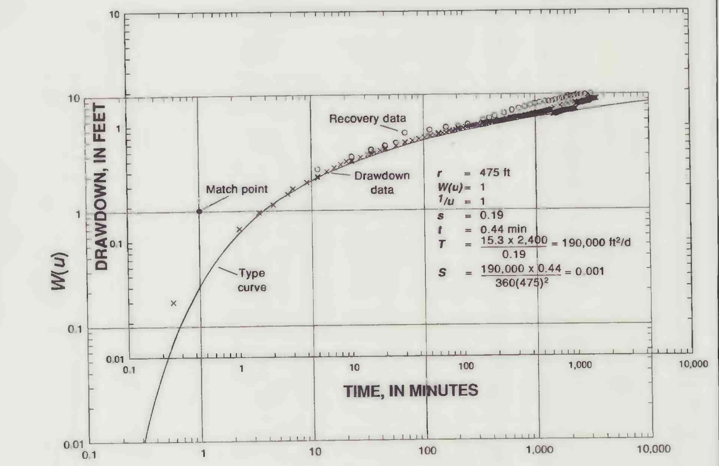
Water levels were measured in nine wells in the Well Orchard (see inset map showing aquifer test site) for 2 days prior to the start of the aquifer test. During that time, water levels declined slightly. No precipitation was recorded in the area for more than 3 weeks prior to the test.

Discharge from the pumped well (4N-26E-5BAD2) was routed from the test site through 1,500 ft of 10-in. mainline irrigation pipe to prevent local recharge during the test. Observation wells 4N-26E-5BAD1, 4N-26E-5BDA1, and 4N-26E-5BDD1 and the pumped well were instrumented with pressure transducers and data loggers. Water levels in all observation wells were measured periodically with electrical or steel tapes throughout the test. The transducer in the pumped well failed and reliable water-level measurements were not possible in that well during the test.

Well 5BAD2 was turned on at 0930 on April 3, 1991, and was pumped continuously for 25 hours until 1030 on April 4, 1991. During the first 30 minutes of pumping and recovery, water-level measurements were made as frequently as possible in all wells to help define aquifer response. Data logger-transducer data were compared with measurements made with electrical and steel tapes to verify results and to correct for measurement error and instrument drift. Discharge from the pumped well was estimated by using a noninvasive sonic flow meter. Discharge ranged from about 2,400 gal/min at the start of the test to about 2,300 gal/min after 25 hours of pumping.

THEIS ANALYSIS





Drawdown was detected almost instantaneously in nearly all observation wells. Instantaneous drawdown, drillers' reports of clay layers, and the reported rise in water level after a clay layer was penetrated indicate that water in the aquifer is confined locally to some degree. Assumptions in the development of the Theis equation are most nearly met by confined aquifers (Heath, 1983, p. 37). Thus, the Theis type-curve method, as described by Lohman (1972, p. 15–19), was used to analyze the aquifer-test data. Logarithmic plots of time as a function of drawdown and time as a function of recovery were constructed for each observation well; resultant curves were matched to the Theis type curve. Convenient match points were chosen and transmissivities and storage coefficients were calculated by using the method developed by Lohman (1972, p. 15–19), modified to allow for different units:

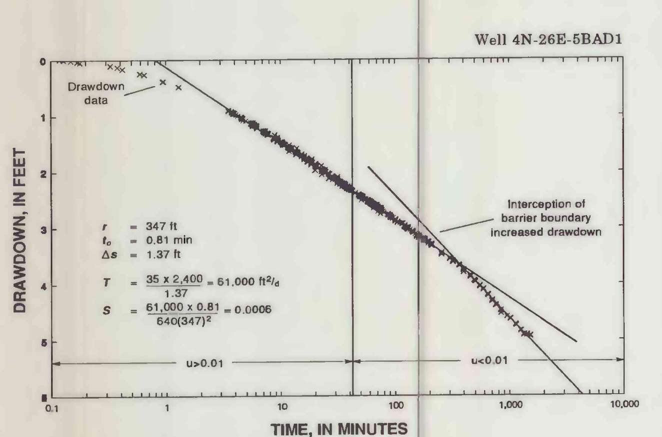
$$T=15.3Q\,W(u)/s \quad (1)$$

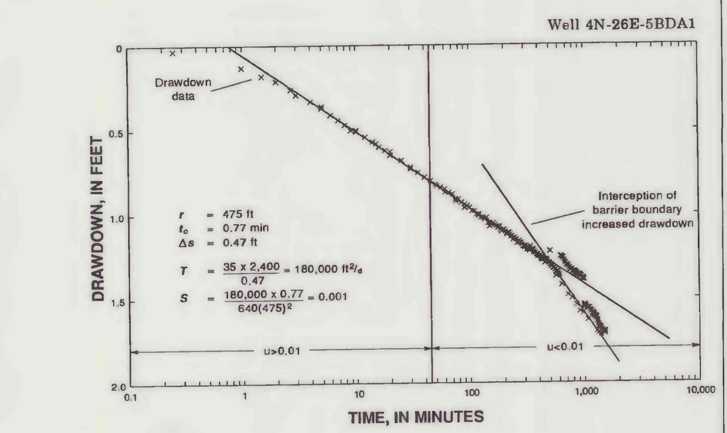
where T is transmissivity, in feet squared per day; Q is discharge, in gallons per minute; $W(u)$ is the well function of u from the match point of the type curve; and s is drawdown, in feet; and

$$S=Ttu/360\,r^2 \quad (2)$$

where S is storage coefficient, dimensionless; T is transmissivity, in feet squared per day; t is time, in minutes; u is the match point from the type curve; and r is distance from the pumped well to the observation well, in feet.

JACOB ANALYSIS





Semilogarithmic plots of drawdown as a function of time were constructed for each observation well and analyzed by using the straight-line method developed by Jacob (Heath, 1983, p. 36). The Jacob method is applicable only to that part of the cone of depression where steady-shape conditions prevail or to the entire cone only after steady-state conditions have developed. These conditions are met when $u=(r^2S)/(4Tt)$ is less than 0.01 (Lohman, 1979, p. 22). Steady-shape conditions were achieved when (modified from Heath, 1983, p. 38):

$$t=36,000\,r^2S/T \quad (3)$$

where t is the time steady-shape conditions develop, in minutes; r is distance from the pumped well, in feet; S is storage coefficient; and T is transmissivity, in feet squared per day.

Only data collected after steady-shape conditions developed were used to calculate transmissivities and storage coefficients by the equation:

$$T=35\,Q/\Delta s \quad (4)$$

where T is transmissivity, in feet squared per day; Q is discharge, in gallons per minute; and Δs is drawdown, in feet, across one log cycle; and

$$S=Tt_o/640\,r^2 \quad (5)$$

where T is transmissivity, in feet squared per day; t_o is the time, in minutes, when the straight line intersects the zero-drawdown line; and r is distance from the pumped well, in feet.

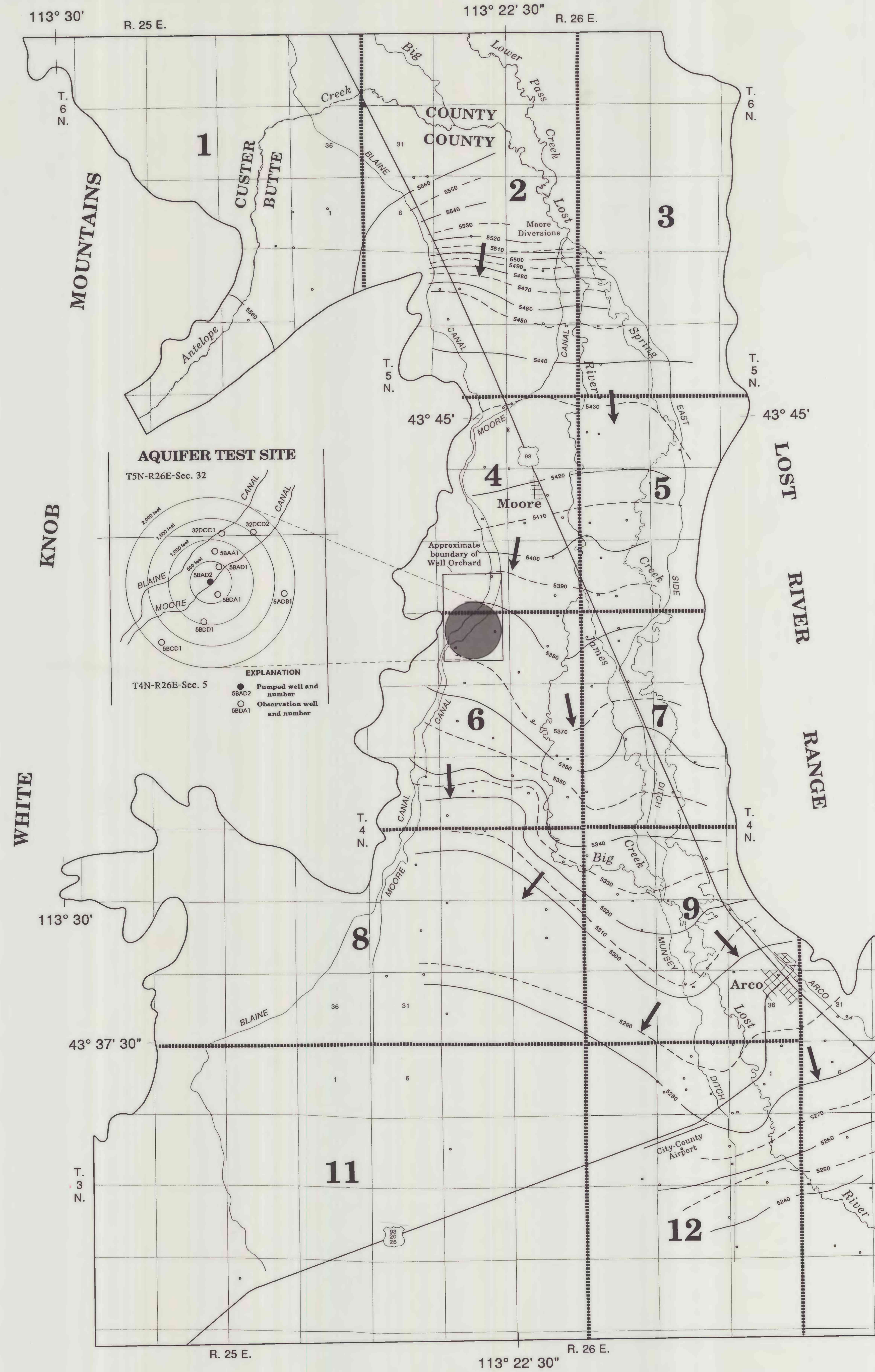
RESULTS OF AQUIFER TEST

The Theis type-curve analysis indicated that aquifer transmissivity ranged from 61,000 to 330,000 ft²/d; values of 130,000 to 200,000 ft²/d were most probable (see table at right). Storage coefficients ranged from 0.0001 to 0.02; the value of about 0.001 was most probable. The Jacob method could be applied to two observation wells assuming 0.01 as a maximum value for u. Jacob's method yielded transmissivity values of 61,000 and 180,000 ft²/d and storage coefficients of 0.0006 and 0.001. Changes in drawdown per unit time indicate that the cone of depression intercepted a barrier boundary. The barrier boundary is believed to be where permeable unconsolidated valley fill abuts relatively impermeable consolidated sedimentary or crystalline bedrock.

TRANSMISSIVITY AND STORAGE COEFFICIENTS ESTIMATED FROM THEIS AND JACOB ANALYSES

Well number	Transmissivity (Theis), in feet squared per day	Storage coefficient	Transmissivity (Jacob), in feet squared per day	Storage coefficient
5N-26E-32DCC1	130,000	0.0001	—	—
32DCD2	330,000	.001	—	—
4N-26E-5ADB1	190,000	.02	—	—
5BAA1	61,000	.002	—	—
5BAD1	63,000	.0006	61,000	0.0006
5BCD1	160,000	.01	—	—
5BDA1	190,000	.001	180,000	.001
5BDD1	200,000	.001	—	—

— Jacob method not applicable.



Base from U.S. Geological Survey
1:100,000 quadrangles

1 0 1 2 3 MILES
1 0 1 2 3 KILOMETERS

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
foot (ft)	0.3048	meter
foot squared per day (ft²/d)	0.09290	meter squared per day
gallon per minute (gal/min)	0.06309	liter per second
inch (in.)	25.4	millimeter
kilowatthour (kWh)	3,600,000	joule
mile (mi)	1.609	kilometer

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

EXPLANATION

5400 — Water-level contour—Shows altitude of first-encountered water, March 1991. Contour interval 20 feet. Dashed lines represent supplemental contours. Datum is sea level

→ **General direction of ground-water flow**

3 **Boundary of pumpage zone and number**

Well

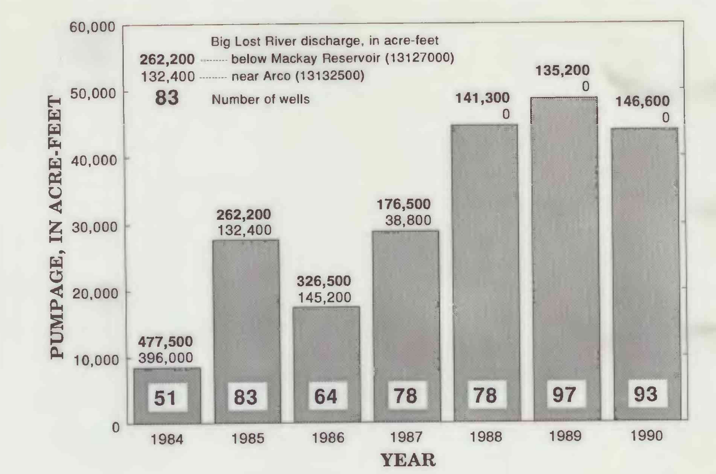
13132500 ▲ **Gaging station and number**

Boundary of study area

WATER-LEVEL CONTOURS, GENERAL DIRECTION OF GROUND-WATER FLOW, AND GROUND-WATER PUMPAGE ZONES

At the top of the zone of saturation, ground water moves generally southward, toward the Snake River Plain. The map above is based on measurements of first-encountered water in March 1991. Gradient of the water surface ranged from about 15 ft/mi in most of the study area to nearly 90 ft/mi from near Antelope Creek to about 1 mi south of the Moore Diversion. A comparison of water-level contours with the altitude of the Big Lost River indicates that, in March 1991, the altitude of first-encountered water from the Moore Diversion to the Snake River Plain was ten to several tens of feet below the altitude of the river.

GROUND-WATER PUMPAGE FOR IRRIGATION



Ground-water pumpage for irrigation was estimated from electrical-power records obtained from Lost River Electrical Cooperative, Inc., for 1984 through 1990. Annual pumpage volumes were estimated by using the relation described by Bigelow and others (1987, sheet 1):

$$Q=kWh/[(K)(TH)] \quad (6)$$

where Q is pumpage, in acre-feet; kWh is kilowatthours used; K is kilowatthours required to lift 1 acre-ft of water 1 ft; and TH is total head (pumping lift plus system head), in feet. At 100-percent efficiency, K equals 1.02 kWh/acre-ft; that is, it takes just over 1 kilowatthour to lift 1 acre-ft of water 1 ft (Goodell, 1988, p. E19). Actual values of K are much higher owing to inefficiencies of irrigation pumps. A K value of 1.92, developed from efficiency data reported by Lost River Electrical Cooperative, Inc., was used for this study. The pumping lift part of total head includes static lift plus pumping drawdown. Assigned system head was based on irrigation-system type; low-head pivots were assigned 63 ft, impact pivots 208 ft, and other sprinkler types (hand lines and wheel lines) 116 ft. No additional head was assigned to wells with open discharge to canals or ditches.

Pumpage during 1984–90 ranged from about 10,000 acre-ft in 1984 to nearly 50,000 acre-ft in 1989. The average annual ground-water pumpage for irrigation in the study area was about 31,000 acre-ft. Pumpage was minimum in 1984 when flow in the Big Lost River was above normal and 51 wells were pumped. Pumpage was maximum in 1989 when flow in the Big Lost River was below normal and 97 irrigation wells were pumped. During the low-water years of 1988–90, no water reached the Big Lost River gaging station near Arco.

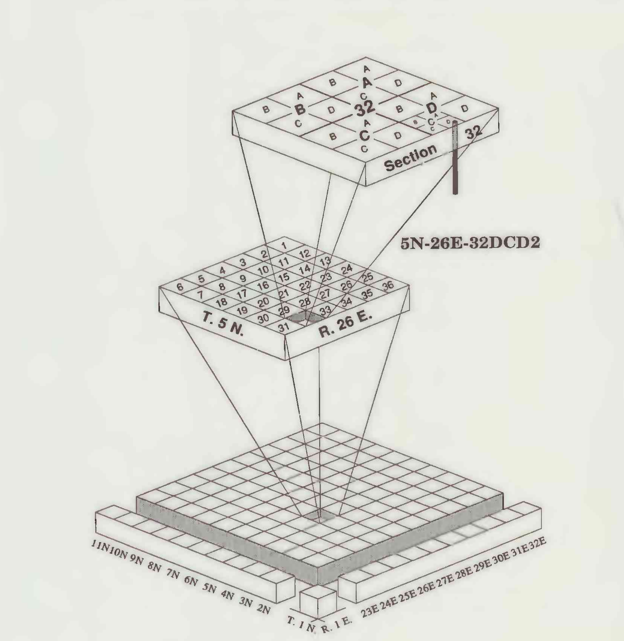
Ground-water pumpage zones (see map showing water-level contours) were established to show areal variations in annual pumpage. The table below shows annual ground-water pumpage by zone.

ANNUAL GROUND-WATER PUMPAGE BY ZONE

(Values in acre-feet)

Zone number	1984	1985	1986	1987	1988	1989	1990
1	630	1,200	330	1,300	1,400	1,300	1,500
2	1,200	1,800	2,100	1,700	1,100	3,000	3,200
3	790	1,600	900	1,300	1,600	1,900	1,600
4	820	4,100	2,500	4,100	8,800	9,400	7,900
5	1,100	2,700	1,100	3,500	4,400	6,500	5,700
6	1,600	7,300	4,300	10,000	14,000	13,000	13,000
7	560	3,500	1,400	2,700	5,600	5,600	4,300
8	410	2,400	2,100	2,300	3,900	3,600	3,500
9	0	1,300	1,100	760	1,800	1,800	1,200
10	50	11	0	0	120	38	120
11	0	0	0	0	0	0	0
12	1,200	1,500	1,400	1,000	1,900	2,800	1,800
TOTAL	8,400	27,000	17,000	29,000	45,000	49,000	44,000

WELL-NUMBERING SYSTEM



The well-numbering system used by the U.S. Geological Survey in Idaho indicates the location of wells within the official rectangular subdivision of the 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, followed by three letters that indicate the 1/4 section (160-acre tract), 1/4-1/4 section (40-acre tract), and the 1/4-1/4-1/4 section (10-acre tract), and the serial number of the well within the tract.

Quarter sections are lettered 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. Well 5N-26E-32DCD2 is in the SE1/4 SW1/4 SE1/4, sec. 32, T. 5 N., R. 26 E., and was the second well inventoried in that tract.

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AQUIFER-TEST RESULTS, DIRECTION OF GROUND-WATER FLOW, AND 1984-90 ANNUAL GROUND-WATER PUMPAGE FOR IRRIGATION, LOWER BIG LOST RIVER VALLEY, IDAHO

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