HYDRAULIC PROPERTIES OF ROCK UNITS AND CHEMICAL QUALITY OF WATER FOR INEL-1— A 10,365-FOOT DEEP TEST HOLE DRILLED AT THE IDAHO NATIONAL ENGINEERING LABORATORY, IDAHO

By Larry J. Mann

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 86-4020

Prepared in cooperation with the

U.S. DEPARTMENT OF ENERGY

Idaho Falls, Idaho

February 1986

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

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CONVERSION FACTORS

For readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
foot squared per day (ft^2/day)	0.09290	meter squared per day (m^2/day)
gallon per minute (gal/min)	0.06309	liter per second (L/s)

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

$$°F = 1.8\ °C + 32$$

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ABSTRACT

A 10,365-foot deep test hole drilled at the INEL (Idaho National Engineering Laboratory) in southeastern Idaho provided hydraulic information for rock units underlying the Snake River Plain aquifer. Four aquifer tests showed that the hydraulic conductivity decreased with depth—from an average of 0.03 feet per day for the interval from 1,511 to 2,206 feet below land surface to an average of 0.002 feet per day for the interval from 4,210 to 10,365 feet. In contrast, the hydraulic conductivity of the Snake River Plain aquifer ranges from 1 to 100 feet per day. The hydraulic head increased with depth; the head at depth was about 115 feet greater than that for the Snake River Plain aquifer.

Water temperature in the test hole increased from 26 °C (Celsius) at 600 feet below land surface to 146 °C at 9,985 feet. The gradient was nearly linear and averaged about 1.3 °C per one-hundred feet of depth. Water from the Snake River Plain aquifer contained 381 milligrams per liter of dissolved solids and had a calcium bicarbonate chemical composition. The dissolved solids concentration in underlying rock units ranged from 350 to 1,020 milligrams per liter and the water had a sodium bicarbonate composition.

Hydrologic data for the test hole suggest that the effective base of the Snake River Plain aquifer near the test hole is between 840 and 1,220 feet below land surface. The upward vertical movement of water into the Snake River Plain aquifer from underlying rock units could be on the order of 15,000 acre-feet per year at INEL.

INTRODUCTION

A 10,365-ft deep test hole was drilled in 1979 at Idaho National Engineering Laboratory (INEL). The main purpose of the test hole was to ascertain whether a hydrothermal resource existed beneath INEL and, if so, whether it would be economically feasible to develop the resource. Drilling and completion of the test hole was performed under a contract administered by the U.S. Department of Energy's Idaho Operations Office.

Few drill holes penetrate the rocks underlying the INEL more than 1,000 ft and most holes are less than 750 ft in depth. Because the test hole penetrated more than 7,000 ft of rocks that had not previously been explored by drill holes, the test hole also yielded new information on the physical, chemical and hydraulic properties of the rocks and the chemical characteristics of the ground water contained therein. This report presents aquifer hydraulic and ground-water chemical data collected as part of the test-drilling program. A geologic interpretation and lithologic log of the test hole was presented by Doherty and others (1979), and a general discussion of the drilling techniques and hydrogeology of the rocks penetrated was presented by Prestwich and Bowman (1980).

The INEL includes about 890 mi^2 of the eastern Snake River Plain in southeastern Idaho (fig. 1). It was established in 1949 and is used by the U.S. Department of Energy to test different types of nuclear reactors. The INEL is one of the main centers in the United States for developing peacetime uses of atomic energy.

The 10,365-ft test hole—referred to as INEL-1 on figure 1—was drilled in the SE¼NW¼NE¼ of section 1 in Township 3N, Range 29E. The altitude of the land surface at the drill site is 4,875 ft. Hydrologic data for a drill hole located about 200 ft south of the INEL-1 test hole are also described in this report. The drill hole was completed at a depth of 595 ft below land surface to supply water for the drilling of INEL-1 and is referred to as the Water-Supply well.

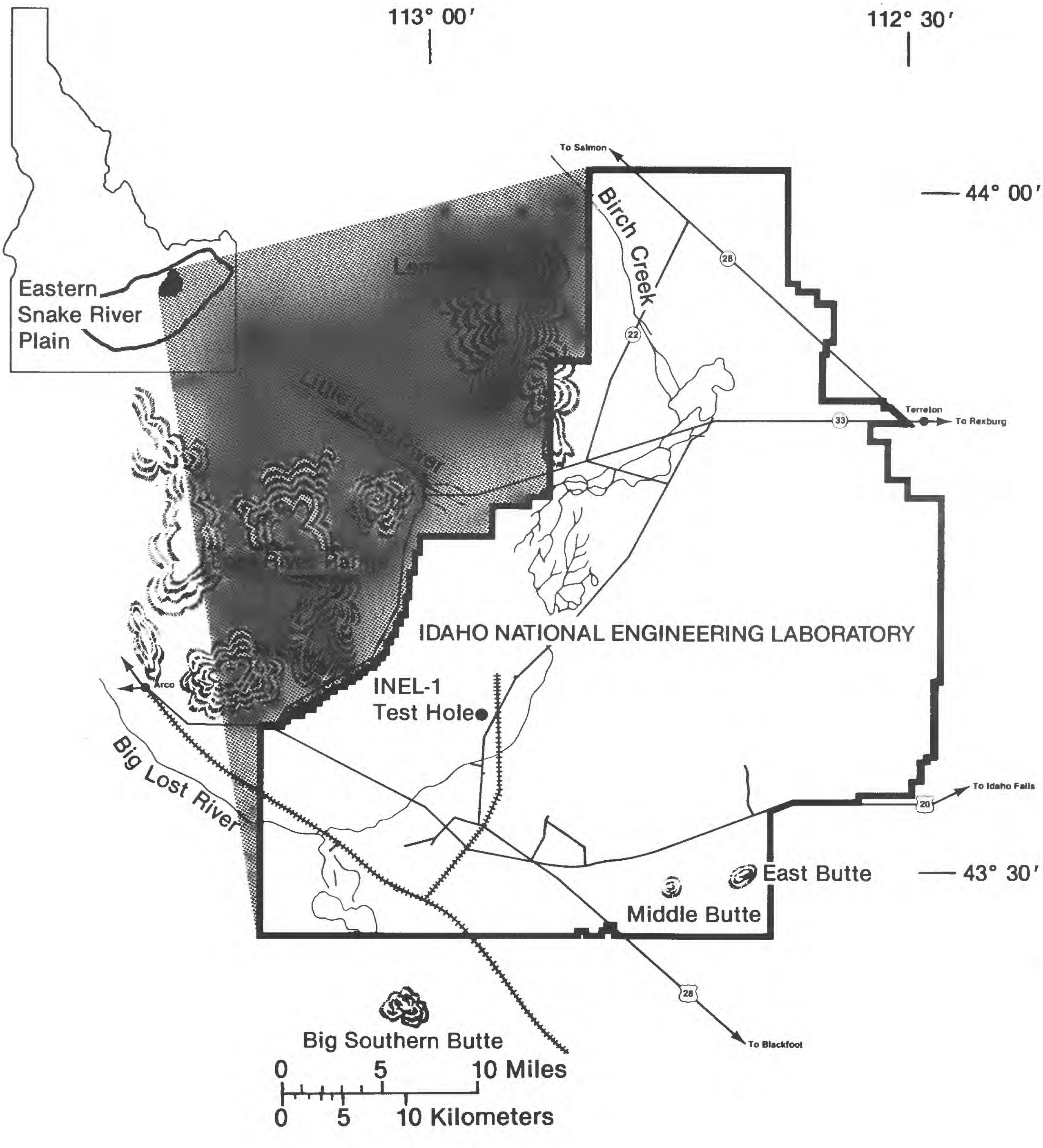


Figure 1.--Location of the Idaho National Engineering Laboratory and INEL-1 test hole.

GEOLOGIC SETTING

The eastern Snake River Plain is a structural basin about 200 mi long and 50 to 70 mi wide. The plain is underlain by a bedded sequence of basaltic lava flows and cinder beds intercalated with alluvium and lake-bed sedimentary deposits. Individual flows range from 10 to 50 ft in thickness, although the average thickness may be from 20 to 25 ft (Mundorff and others, 1964, p. 143). The sedimentary deposits consist mainly of lenticular beds of sand, silt and clay with lesser amounts of gravel. Locally, rhyolitic lava flows and tuffs are at the land surface or occur at depth. The basaltic lava flows and intercalated sedimentary deposits combine to form the Snake River Plain aquifer which is the main source of ground water on the plain. The total thickness of the sequence of the volcanic rocks and the nature of the underlying rocks are poorly defined in all but a few places on the plain.

At the INEL-1 drill site, basaltic rocks that are highly fractured occur at the land surface. The highly-fractured basalts likely extend downward to at least 840 ft as evinced by geophysical logs and the loss of circulation of drilling fluids. Circulation was first lost at 137 ft and was not regained until casing was set to a depth of 1,511 ft (Prestwich and Bowman, 1980, p. 14). Above a depth of 840 ft the test hole penetrated mostly basalt and cinders although three sedimentary units were encountered (fig. 2). At 840 ft, a 120-ft thick bed of sand, silt, and clay was penetrated; from 840 to 1,530 ft the material penetrated was largely sedimentary deposits with 20 to 80 ft layers of basalt. From 1,530 to 2,160 ft, the test hole penetrated a thick sequence of basalts with one 20-ft thick sedimentary unit (fig. 2). Below a depth of about 1,600 ft the basaltic rocks were altered and mineralized (Doherty and others, 1979, p. 3).

Between 2,160 and 2,435 ft tuffaceous interbeds were penetrated (fig. 2); a 5-ft core recovered between 2,340 and 2,361 ft showed a calcareous and occasionally silty claystone (Prestwich and Bowman, 1980, p. 15). From 2,435 to 8,080 ft, the material penetrated mainly consisted

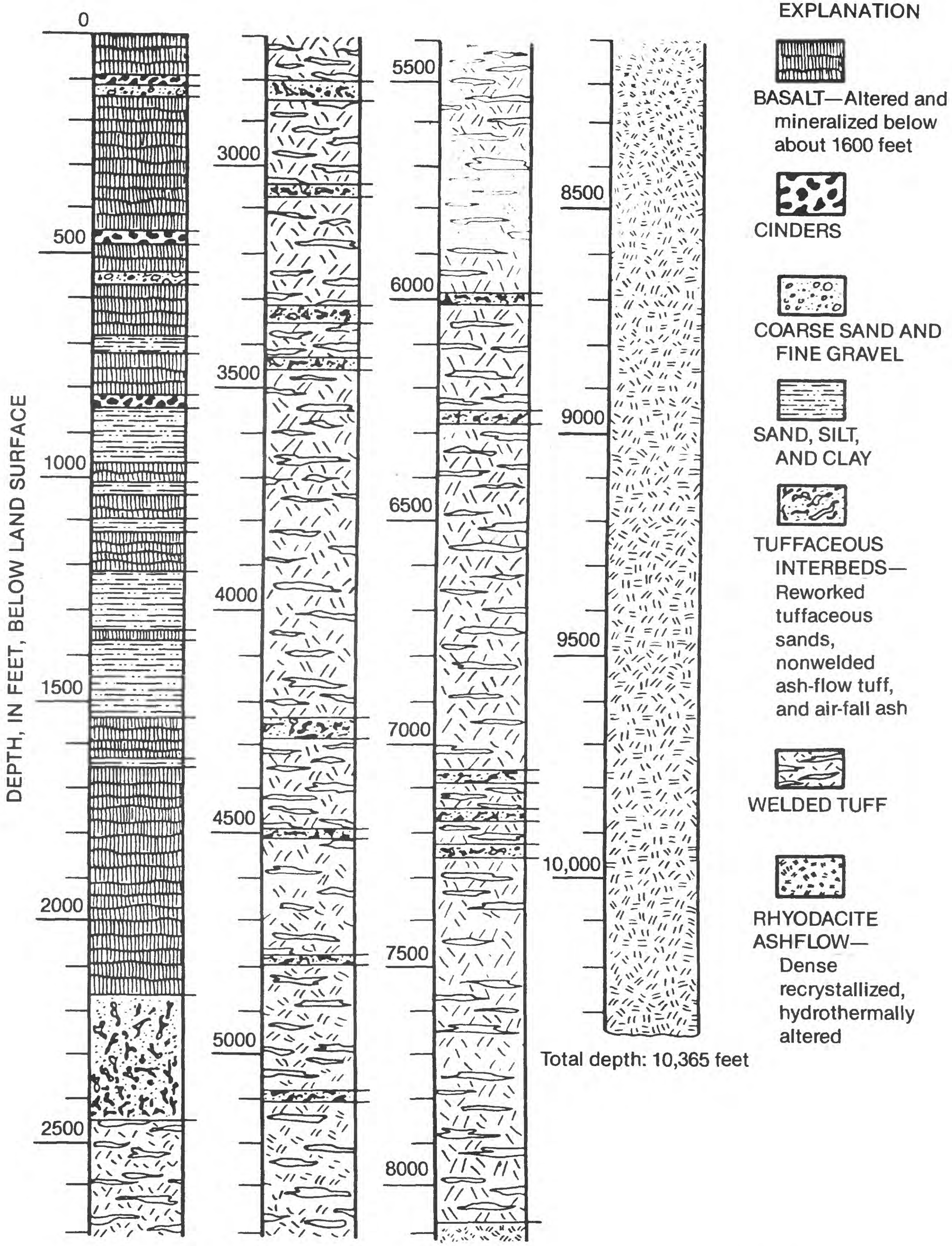


Figure 2.--Generalized lithologic log of rock units penetrated by INEL-1 test hole (modified from Doherty and others, 1979).

of welded tuff with several 20- to 40-ft thick tuffaceous interbeds. And from 8,080 to 10,365 ft the test hole penetrated a hydrothermally altered rhyodacite ash flow.

HYDRAULIC PROPERTIES OF ROCK UNITS

The hydraulic properties of rock units underlying the eastern Snake River Plain below a depth of about 1,500 ft were, for the most part, undefined prior to drilling the INEL-1 test hole. During and subsequent to the drilling and completion of the test hole, four tests were conducted that define the transmissivity and hydraulic conductivity of selected intervals of rock. Aquifer test 1 tested the interval from 1,511 to 2,206 ft; test 2, the interval from 3,559 to 3,713 ft; test 3, the interval from 3,559 to 4,879 ft; and test 4, the interval from 4,210 to 10,365 ft. Each test consisted of a pumping phase and a recovery phase. On the basis of depth-to-water measurements made during the recovery phase of the aquifer tests, the hydraulic head increases with increasing depth.

Aquifer Test 1: Interval from 1,511 to 2,206 feet

On March 23 and 24, 1979, the interval of rocks from 1,511 to 2,206 ft below land surface was tested to define the transmissivity and hydraulic conductivity. Prior to testing, 20-in. casing was set and grouted from the surface to 1,511 ft. A 17-1/2 in. hole was drilled from 1,511 to 2,518 ft. At the beginning of the test the hole was open from 1,511 to 2,518 ft, but during the test sediment filled the hole from 2,206 to 2,518 ft; the tuffaceous interbeds from 2,160 to 2,450 ft were probably the source of the sediment. It is likely that the sediment filling began when the viscosity of the fluid in the hole began to decrease as a result of pumping. Therefore, it can be safely assumed that the interval tested was from 1,511 to 2,206 ft and that units below that interval were effectively sealed off by an admixture of sediment and drilling mud.

The aquifer test was plagued with pump motor problems. The test was started at 0800 hours on March 23 and the pump was pulled later on that day to replace the motor. Subsequent to the replacement of the motor, the pump repeatedly overloaded and tripped a circuit breaker until about 2255 hours. Beginning at about 2255 hours and continuing until 0814 hours on March 24, the pump functioned without fail.

The depth to water, pumping rate, and temperature of the water pumped from the test hole from 1530 hours on March 23 to 1100 hours on March 24 are shown in figure 3; prior measurements are not shown because of the pump problems. Depth to water in the test hole at the beginning of the test was about 104 ft below land surface. However, ground-water levels measured during the recovery phase of the test indicate that the static water level was about 330 ft below land surface.

An analysis of the drawdown data does not give a reliable estimate of transmissivity because of the sporadic failure of the pump prior to 2255 hours on March 23; drawdown cannot be calculated because the water-level trend for the previous 5 hours was eratic owing to the repeated failure of the pump.

The recovery phase of the aquifer test shows that the transmissivity of the interval from 1,511 to 2,206 ft is on the order of 20 ft^2/day. The average hydraulic conductivity, therefore, is about 0.03 ft/day.

Aquifer Test 2: Interval from 3,559 to 3,713 feet

Following aquifer test 1, the test hole was drilled to a depth of 3,713 ft and 13-3/8 in. casing was set and grouted from the land surface to a depth of 3,559 ft. From 3,559 to 3,663 ft the diameter of the borehole was 12-1/4 in. and from 3,663 to 3,713 ft it was 7-7/8 in. The welded tuff in the interval from 3,559 to 3,713 ft (fig. 2) was tested on April 6 to 8, 1979 to define the transmissivity of the unit.

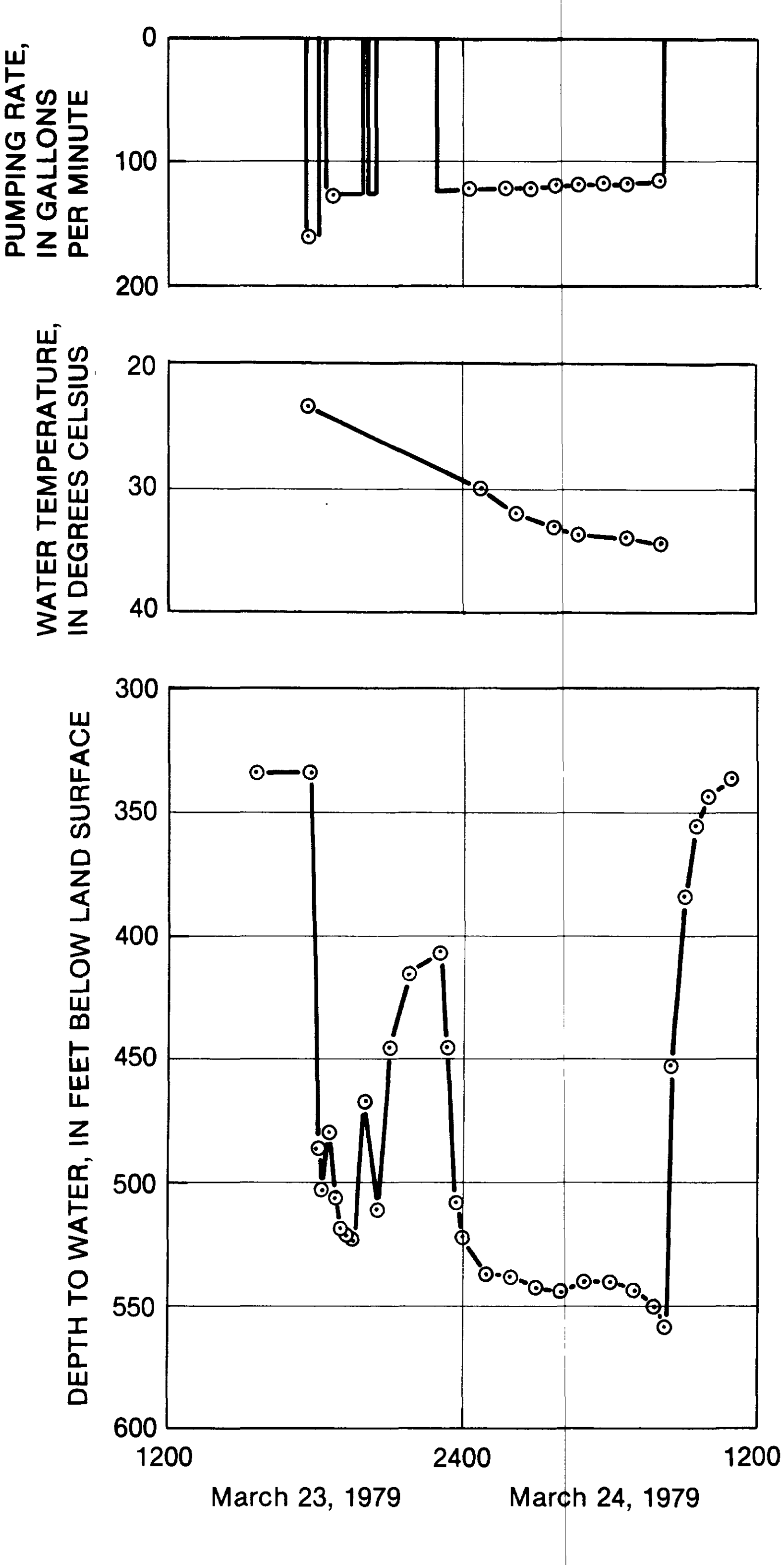


Figure 3.--Depth to water, pumping rate and water temperature for aquifer test 1.

The depth to water, pumping rate and temperature of the water pumped from the test hole are shown in figure 4. The fluid level in the test hole was about 18 ft below land surface at the beginning of the test owing to the presence of the drilling mud. The level declined to nearly 800 ft below land surface in the first 90 minutes of the test. During the following 18 hours of pumping, the water level recovered to about 745 ft below land surface and remained near that level for the rest of the aquifer test. The recovery and stabilization of the water level was probably due to one or a combination of three factors: (1) the test hole was developing during the pumping phase of the test—that is, drilling fluids and mud used during drilling were being removed from the formation in the tested interval; (2) the pumping rate decreased by about 10 percent during the test; and (3) it is likely that there was vertical movement of water into the tested interval from overlying and underlying rock units.

The transmissivity of the welded tuff in the open interval from 3,559 to 3,713 ft was calculated using data collected during the recovery phase of the test. An analysis of the recovery data indicates that the transmissivity of the open interval is about 2 ft^2/day. The average hydraulic conductivity for the welded tuff in the 154-ft open interval is about 0.01 ft/day. Water levels at the end of the recovery test suggest that the static water level would be about 290 ft below land surface.

Aquifer Test 3: Interval from 3,559 to 4,879 feet

Once aquifer test 2 was completed, the test hole was deepened to 4,879 ft. A 12-1/4 in. diameter open hole was drilled from 3,663 to 4,839 ft and a 7-7/8 in. diameter core was collected between 4,839 and 4,879 ft. The rocks penetrated from 3,713 to 4,879 ft were similar to those from 3,559 to 3,713 ft except for a few thin tuffaceous interbeds (fig. 2).

On April 14 to 16, 1979, a third aquifer test was performed to define the transmissivity and hydraulic conductivity of the open interval

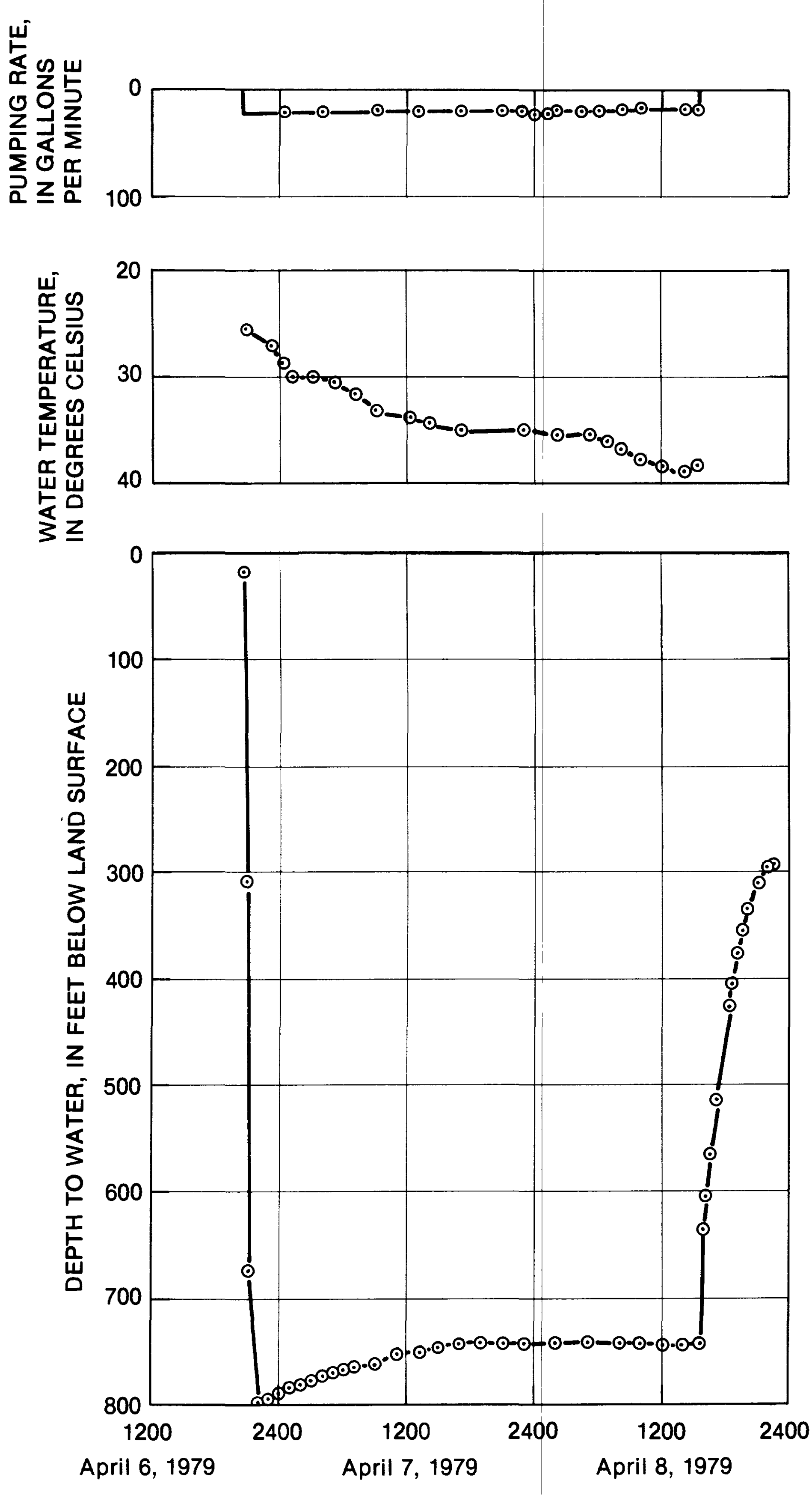


Figure 4.--Depth to water, pumping rate and water temperature for aquifer test 2.

from 3,559 to 4,879 ft. The transmissivity of the open interval was calculated using drawdown data collected between 1245 hours on April 14 and 0600 hours on April 15, and from about 3 hours of recovery data collected after pumping had stopped (fig. 5). An analysis of both the drawdown and recovery data shows that the transmissivity of rocks in the open interval is about 8 ft^2/day. The average hydraulic conductivity of the rocks in the open interval is about 0.006 ft/day. The depth to water at the end of the recovery test was about 290 ft below land surface.

Aquifer Test 4: Interval from 4,210 to 10,365 feet

On May 26, 1979 the test hole was completed at a depth of 10,365 ft below land surface. At completion, the test hole was cased from 3,282 to 6,796 ft with 9-5/8 in. casing; the casing was grouted at the top and bottom of this section and the mid-section was kept free of cement in the anticipation of perforating it. The casing was then perforated with 730 one-quarter inch holes between 4,210 and 6,266 ft. Below 6,796 ft the test hole was not cased. The open intervals through which water could flow from rock into the well bore, therefore, was from 4,210 to 6,266 ft and 6,796 to 10,365 ft.

During January 1981, a fourth aquifer test was run to define the transmissivity and hydraulic conductivity of rocks opposite the open intervals. The test hole was pumped for seven days. Water-level measurements were made to document the amount of drawdown owing to pumping and the rate of water-level recovery once pumping had stopped. Depth to water, pumping rate and temperature of water pumped from the test hole are shown on figure 6.

For the first 23 hours, the average pumping rate was 50 gal/min. After 23 hours of pumping the rate was increased and averaged about 57 gal/min for the remainder of the test. After the pumping rate was increased, the water level declined to about 570 ft below land surface and remained near that depth for the duration of the test.

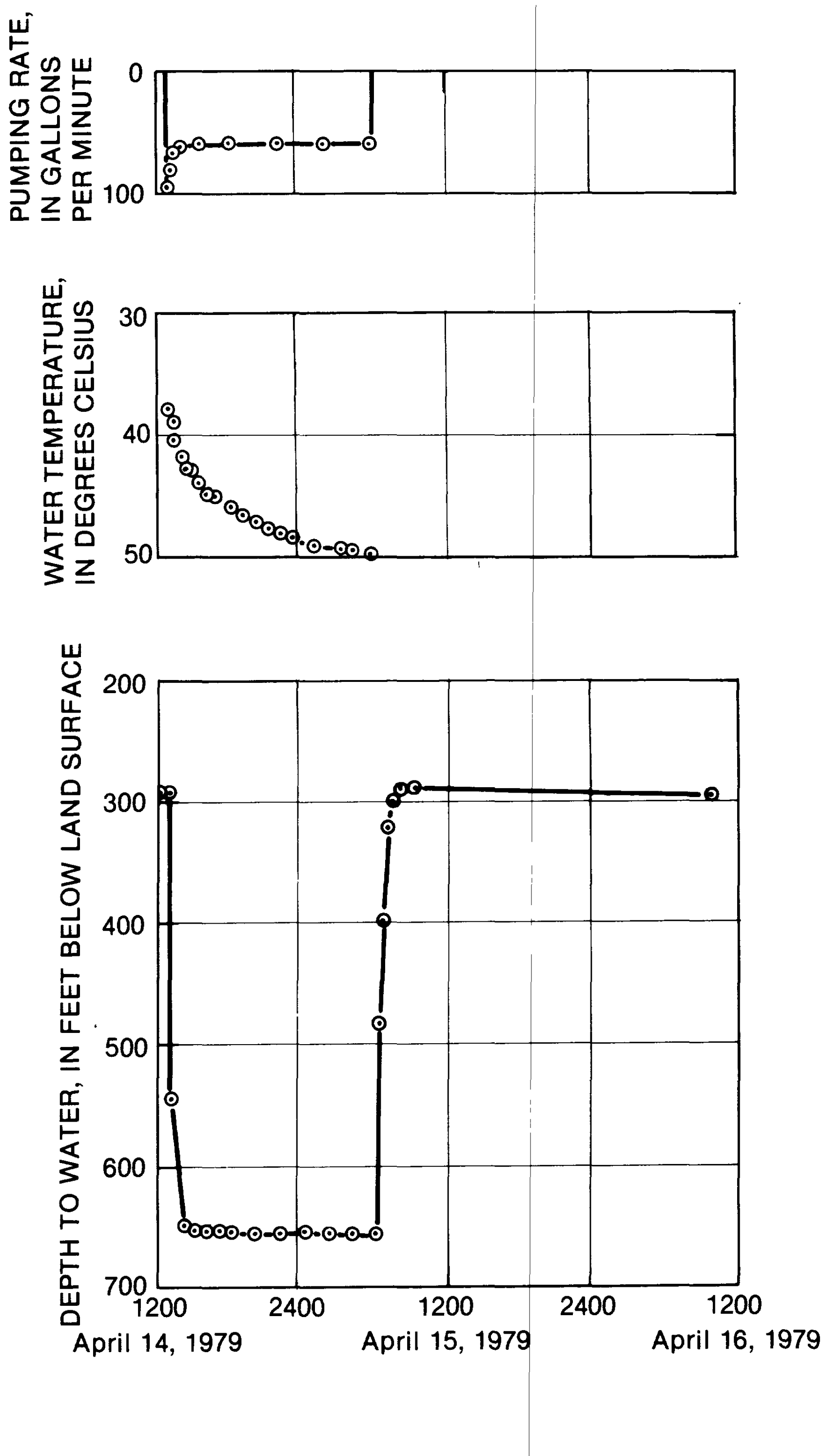


Figure 5.--Depth to water, pumping rate and water temperature for aquifer test 3.

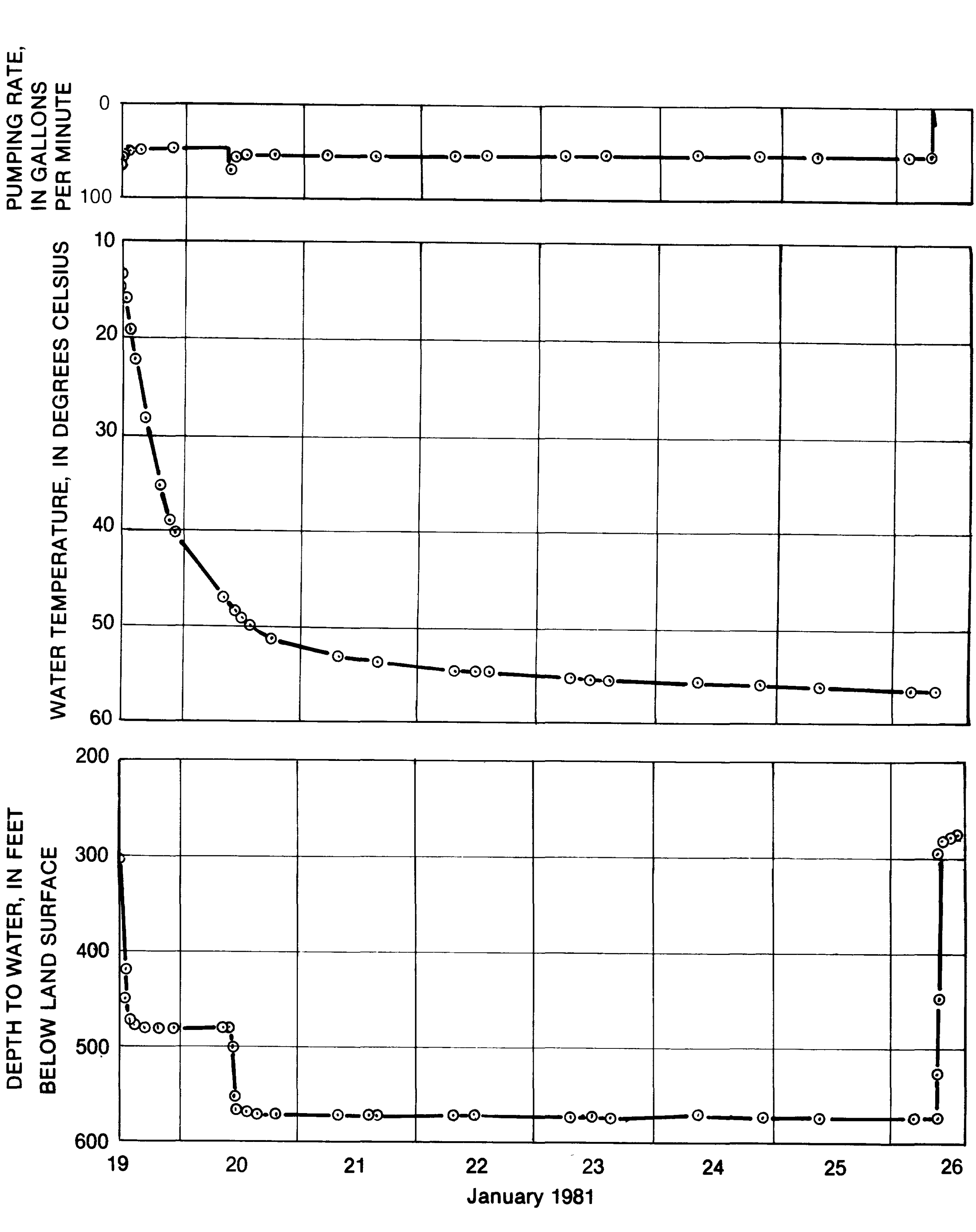


Figure 6.--Depth to water, pumping rate and water temperature for aquifer test 4.

The transmissivity for the intervals open to the well bore was calculated using drawdown data for the first 23 hours of pumping and the recovery data. Transmissivity calculated using drawdown data was 10 ft^2/day and that using recovery data was 7 ft^2/day. Less weight is given to the 7 ft^2/day value because the recovery data would be affected by the increase in the pumping rate at the end of 23 hours of pumping. Using a transmissivity 10 ft^2/day, the average hydraulic conductivity for the 5,625 ft of rock open to the well bore is 0.002 ft/day. The recovery data indicated that the static water level would be about 280 ft below land surface.

Hydraulic Head

Hydraulic head differs from one interval to another as a function of the depth of a specific interval below the land surface. In general, the greater the depth that an interval is below land surface, the greater the hydraulic head. The head in intervals deeper than 3,559 ft below land surface is about 100 ft higher than the head in the upper 200 ft of basaltic rocks of the Snake River Plain aquifer (table 1).

Table 1.--Approximate depth to water and altitude of the water level for intervals tested in INEL-1 test hole

Interval open to test hole (feet below land surface)	Approximate depth to water (feet below land surface)	Altitude of water level (feet above sea level)
* 395 to 595	395	4,480
1,511 to 2,206	330	4,545
3,559 to 3,713	290	4,585
3,559 to 4,879	290	4,585
4,210 to 10,365	280	4,595

*Information is for the Water-Supply well which taps the upper 200 ft of the Snake River Plain aquifer

TEMPERATURE AND CHEMICAL QUALITY OF WATER

The physical and chemical properties of water pumped from the INEL-1 test hole differ with depth. Water temperature in the INEL-1 test hole gradually increased from 26 °C at 600 ft below land surface to 146 °C at 9,985 ft (fig. 7). The temperature log was run on July 19, 1979, after the test hole had been undisturbed for slightly more than one month.

The temperature of water in the test hole, however, had not come to equilibrium after being undisturbed for slightly more than one month. The temperature at a depth of 600 ft below land surface was still about 13 °C greater than the temperature of water at the same depth in the Snake River Plain aquifer. The greater temperature may be the result of the circulation of water in response to convection currents within the well bore. The temperature gradient in the test hole was nearly linear and averaged slightly less than 1.3 °C per one-hundred feet of depth below land surface. From 600 to about 4,000 ft, the temperature gradient was not as uniform as it was below 4,000 ft (fig. 7). In the interval from 1,300 to 1,600 ft, the temperature increased about 1 °C or about 0.3 °C per one-hundred feet. This decrease in gradient corresponds to the thick zone of sand, silt and clay (fig. 2). From 2,450 to 2,750 ft, the temperature increased about 1 °C (fig. 7), also about 0.3 °C per one-hundred feet. This decrease was near the contact between the tuffaceous interbeds that immediately underlie the lowermost basalt and the underlying welded tuff (fig. 2). The relatively low temperature gradient in the two intervals may result from the rocks having a slightly greater hydraulic conductivity than adjacent rocks.

The dissolved solids and chemical composition of the water pumped from INEL-1 change markedly with depth. Water from the Water-Supply well, which taps the upper 200 ft of the Snake River Plain aquifer, contained 381 mg/L (milligrams per liter) of dissolved solids and had a calcium bicarbonate type of chemical composition with significant amounts of magnesium and chloride (table 2).

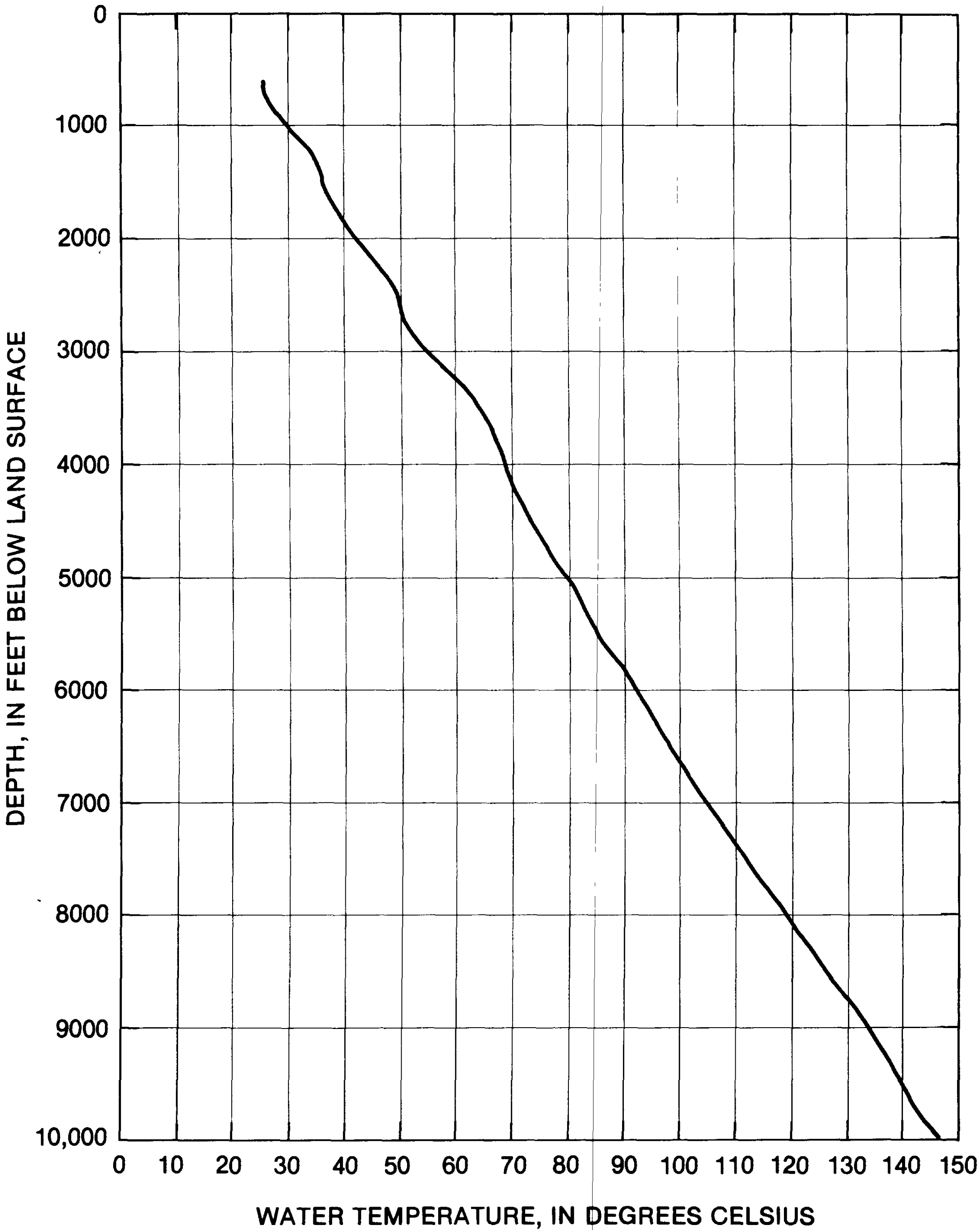


Figure 7.--Water-temperature profile for INEL-1 test hole.

Table 2.--Selected water-quality data for Water-Supply well and INEL-1 test hole

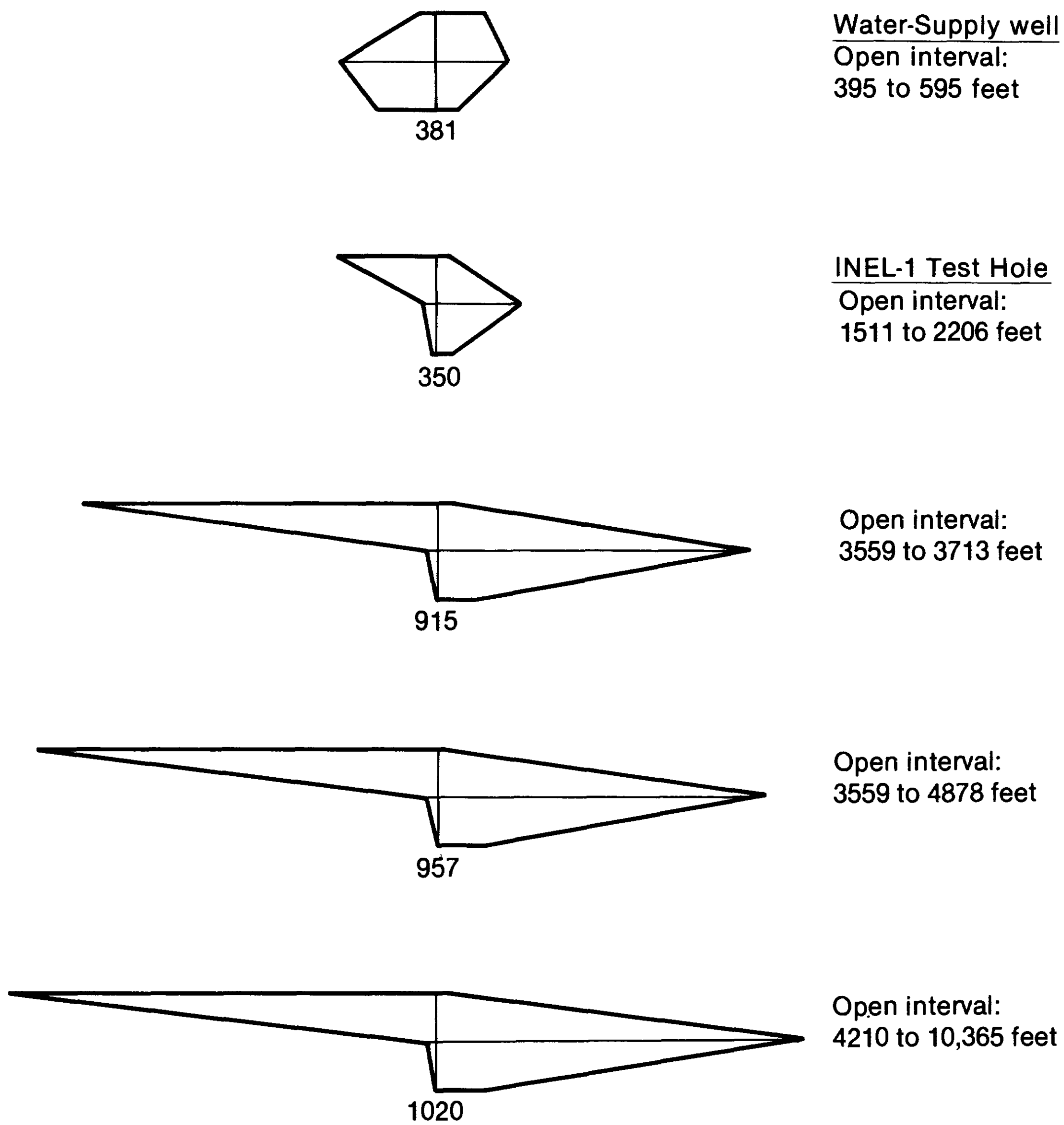
[Analyses are in milligrams per liter unless otherwise noted. Constituent concentrations in dissolved state unless otherwise noted. Abbreviation, μg/L, represents micrograms per liter.]

	Water-Supply Well	INEL-1 Test Hole			
Interval tested (feet below land surface)	395-595	1,511 2,206	3,559-3,713	3,559-4,878	4,210-10,365
Alkalinity	160	210	720	670	740
Arsenic (μg/L)	1	20	24	73	--
Bicarbonate	190	220	780	820	900
Boron (μg/L)	280	900	580	530	560
Calcium	76	10	8.1	8.9	7.3
Chloride	74	17	17	13	12
Chromium-total (μg/L)	20	20	10	10	0
Fluoride	0.2	1.1	12	13	13
Iron (μg/L)	0	0	770	1,200	1,100
Lead (μg/L)	0	0	0	0	--
Lithium (μg/L)	5	50	290	280	--
Magnesium	28	2.0	1.1	1.1	0.5
Manganese (μg/L)	0	20	110	60	50
pH	7.8	8.2	8.2	8.3	7.9
Potassium	3.0	10	9.2	8.1	7.5
Dissolved solids (calculated)	381	350	915	957	1,020
Selenium (μg/L)	2	1	0	0	--
Silica	24	60	33	39	47
Sodium	12	92	330	370	390
Strontium (μg/L)	370	100	120	140	150
Sulfate	50	32	69	97	99
Water temperature (°C)	12	34	38	50	57

The dissolved solids concentration increases from 350 to 915 mg/L in the interval between 2,206 and 3,559 ft. Whether the increase is gradual or abrupt is not known, because this interval was neither pumped nor was the water sampled. If the increase is abrupt, it may occur at the contact between the altered basalt and tuffaceous interbeds at about 2,160 ft below land surface; the vertical and horizontal hydraulic conductivity also would likely decrease at this depth. From 3,559 to 10,365 ft, the dissolved solids increase from 915 to 1,020 mg/L— a relatively small increase when compared to the 565 mg/L increase that occurs between 2,206 and 3,559 ft.

The smaller concentration of dissolved solids in the upper 2,200 ft of rocks tapped by INEL-1 is attributed to dilution by the infiltration of streamflow, rainfall and snowmelt and underflow from upgradient recharge areas. Streamflow in the Big Lost and Little Lost rivers has a calcium bicarbonate type of chemical composition (U.S. Geological Survey, 1982). The infiltration of streamflow along the channels of these rivers constitutes a significant part of the recharge to rocks that underlie the INEL.

The transition from a calcium bicarbonate to sodium bicarbonate type of chemical composition occurs in the interval between 595 and 1,511 ft below land surface (fig. 8). It is not known whether the transition is gradual or abrupt because the interval was not pumped and samples were not collected. The transition most likely occurs in the interval from 850 to 1,220 ft which is mainly sand, silt and clay (fig. 2). The change in chemical composition is caused by an increase in sodium and a decrease in calcium in the water. Dilution of the sodium type of water with a calcium type of water, ion exchange, and precipitation of calcite accounts for the change in the chemical composition of water. In the vicinity of the INEL-1 test hole, dilution is the prime controlling factor. The sodium-type water at depths greater than 1,511 ft below land surface vertically moves upward in response to a higher hydraulic head. It is diluted by the calcium-type water present in the shallow basaltic rocks.



EXPLANATION

CHEMICAL-QUALITY DIAGRAM—Shows major constituents in milliequivalents per liter. The diagrams are in a variety of shapes and sizes, which provides a means of comparing, correlating, and characterizing similar or dissimilar types of water. Number, 381, is the dissolved solids concentration in milligrams per liter.

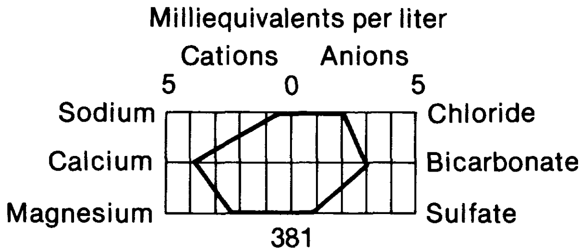


Figure 8.--Chemical quality of water for open intervals in Water-Supply well and INEL-1 test hole.

Water samples collected from the Water-Supply well and INEL-1 test hole were analyzed for selected trace elements in addition to dissolved solids and common ions (table 2). In general, the concentrations of trace elements increased with depth. The larger concentrations are likely associated with the higher water temperature and the hydrothermal alteration of rock units below a depth of 1,600 ft.

Chromium and selenium, on the other hand, were present in slightly greater concentrations in water from the Water-Supply well which taps the upper 200 ft of the Snake River Plain aquifer than in the deeper rock units tapped by INEL-1 (table 2). Strontium was present in a significantly greater concentration in the aquifer—370 μg/L (micrograms per liter)—than in deeper units—100 to 150 μg/L. For the observed concentrations in water from the Snake River Plain aquifer, chromium, selenium and strontium are likely introduced into the ground-water flow system via water recharged along the major stream channels or is derived from minerals in the sand, silt and clay deposits that are intercalated with the basalts.

Boron and silica concentrations were greater in the interval from 1,511 to 2,206 ft than in underlying or overlying units (table 2). The reasons for these greater concentrations are not known, but probably are associated with the altered and mineralized basaltic rocks that occur from 1,600 to 2,160 ft below land surface (fig. 2).

HYDROLOGIC IMPLICATIONS OF THE DATA

Geohydrologic data collected during the drilling and testing phases of the INEL-1 test hole and the Water-Supply well can be used to make some general statements regarding the ground-water hydrology of INEL. The hydraulic head increases with depth below land surface. If these conditions persist over most of the INEL, it is likely that water locally recharged to the basaltic rocks of the Snake River Plain aquifer does not circulate to depths of more than 1,000 to 2,000 ft. This supposition is supported by the age of the water pumped from the interval between 3,559 and 10,365 ft below land surface. Carbon-14 age dating indicates that the water is on the order of 35,000 years old (J.T. Barraclough, EG&G Idaho, Inc., written communication, August 1985). If significant quantities of water moved downward to depths greater than 2,000 ft, the water would be markedly younger. Circulation to greater depths could occur along the mountain fronts that bound the Snake River Plain or deep-seated fracture systems such as the rift zones delineated by Kuntz (1978).

The hydraulic conductivity of rocks below 1,500 ft is markedly less than that of the upper 200 to 800 ft of basaltic rocks. The basaltic rocks generally have a hydraulic conductivity of 1 to 100 ft/day. By comparison, the hydraulic conductivity of rocks below a depth of about 1,500 ft is from 0.002 to 0.03 ft/day—two to five orders of magnitude less than that of the upper 200 to 800 ft of basaltic rocks.

The marked reduction in the hydraulic conductivity may be coincident with the sand, silt and clay in the interval from 1,220 to 1,540 ft below land surface. But, it also could be associated with the sand, silt and clay in the interval from 850 to 960 ft. On the basis of data from INEL-1, the effective base of the Snake River Plain aquifer near the test hole is somewhere between 850 and 1,220 ft below land surface. These sand, silt and clay beds are likely to be continuous over most, if not all, of INEL. Similar sedimentary deposits have been penetrated in other deep holes drilled at INEL. The change in the chemical quality of water with depth, carbon-14 age dating, and the increase in hydraulic head with depth also support this conclusion.

Although the rocks below 1,220 ft have a small hydraulic conductivity when compared to the basaltic rocks of the Snake River Plain aquifer, the higher hydraulic head at depth indicates that there is an upward component of flow. The amount of vertical flow across the interval between 595 and 1,511 ft can be crudely estimated on the basis of field measurements and laboratory data, using the following equation:

$$Q = K_v IA \tag{1}$$

where Q = vertical flow (ft^3/day);

K_v = vertical hydraulic conductivity (ft/day);

I = vertical hydraulic (ft/ft); and

A = unit area through which the vertical flow occurs (ft^2).

The vertical hydraulic conductivity of the sedimentary deposits which make up a large part of the rocks from 595 to 1,511 ft is estimated to be on the order of 0.001 ft/day. This order of magnitude estimate is based on values for fine-grained sediment as shown by Bouwer (1978), and Freeze and Cherry (1979).

The hydraulic gradient across the interval from 595 to 1,511 ft is based on the field measurements shown in table 1. The depth to water for the interval from 395 to 595 ft is 395 ft, and the interval from 1,511 to 2,206 ft is 330 ft. The vertical hydraulic gradient, therefore, is 65 ft per 916 ft or 0.071 ft/ft.

By substituting these estimates plus a unit area (A) into equation 1, it follows that the vertical flow across the interval from 595 to 1,511 ft is on the order of 0.00007 (ft^3/day)/ft^2. If the geohydrologic conditions at the INEL-1 test hole are widespread, inflow into the basalts of the Snake River Plain aquifer from underlying rocks on the 890-mi^2 INEL area could be on the order of 15,000 acre-ft/year.

Given that the vertical movement of water into the Snake River Plain aquifer from underlying rocks could be on the order of 15,000 acre-ft/year at INEL, this amount of inflow could have an influence on the way the aquifer would respond to applied stresses. The contribution of water to the aquifer could be of significant importance, although of a smaller magnitude than the 130,000 acre-ft/year of recharge from the Big Lost River estimated by Robertson (1974, p. 26). Geologic and hydraulic information is inadequate, however, to define the magnitude of this inflow and the effective base of the aquifer at all but a few locations at the INEL and on the Snake River Plain.

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