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TEST-OBSERVATION WELL NEAR PATERSON, WASHINGTON

DESCRIPTION AND PRELIMINARY RESULTS

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By

H. E. Pearson

U.S. GEOLOGICAL SURVEY Water Resources Division

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1973

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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TEST-OBSERVATION WELL NEAR PATERSON, WASHINGTON: DESCRIPTION AND PRELIMINARY RESULTS

By H. E. Pearson

ABSTRACT

Initial irrigation development in the Horse Heaven Hills area started near the towns of Paterson and Plymouth along the Columbia River and has relied on surface water from the river. The first stages of irrigation of land farther from the river created a need for more complete data on ground-water conditions than that provided from the few existing irrigation wells in the area. For this reason, a 860-foot test-observation well, 10 to 6 inches in diameter, was drilled in the Horse Heaven Hills about 8 miles north of Paterson, in the valley of the East Branch of Glade Creek. The test well is one of several drilled since 1970 to provide information on ground-water conditions in areas for which little or no information has been available.

The well, drilled by the air-rotary method, penetrates productive aquifer zones at the 735- and 860-foot depths. Test pumping showed that the well had specific capacities of 58 gallons per minute per foot of drawdown at the 735-foot depth and 148 gallons per minute per foot of drawdown at the 860-foot and final depth. The aquifer tests indicate that large amounts of water occur only at these--and possibly greater--depths.

Data from the test-observation well--such as results of the pump tests of the aquifers and chemical analysis of the water, and that obtained from geophysical logs--will provide valuable guidance in management of the area's ground-water resources.

INTRODUCTION

This report describes the Paterson test-observation well which was designed to yield ground-water information in the Horse Heaven Hills area of Washington. Where other information is lacking such exploratory drilling is the most direct method of learning the hydrogeologic properties of the subsurface materials as they relate to an area's ground-water resources.

According to a team study from Washington State University (1970, p. 1-3), the Horse Heaven Hills area has a potential of 600,000 acres of land for irrigated crops, but dryland wheat farming and summer fallow on approximately 400,000 acres continue to be the principal bases of the area's economy. Only in the past several years has surface water from the Columbia River (Lake Umatilla) been applied to land at lower elevations adjacent to the river. From the time of the earliest settlement to the present, wells of moderate depth have provided the few farm houses of the area with limited supplies of domestic water. Today, an interest has grown among the farmers, operators, and public officials in the availability of ground water for irrigation in the Horse Heaven Hills. The discovery in 1970 of deep aquifers yielding large quantities of water under flowing artesian conditions gave added impetus to the desire to learn more about the ground-water system beneath the area.

The test well was drilled from March to September 1972, to furnish data necessary for effective management of the ground water in the area. Such data include the location, depth, and potential yield of water-bearing strata, their water levels, and the degree of hydraulic interconnection between the strata. In addition, water-quality characteristics and rock-unit relationships were determined.

The well is the sixth in a project designed for drilling, testing, and periodically collecting data from test-observation wells in selected areas of Washington. These wells are being drilled in areas where there is a critical need for ground-water data necessary for water-management purposes and where the data cannot be obtained from existing wells or by other reasonable means. The project is part of a continuing cooperative program financed jointly by the U.S. Geological Survey and the State of Washington Department of Ecology. The locations of this and other test-observation wells drilled since the project started in 1970 are shown in figure 1.

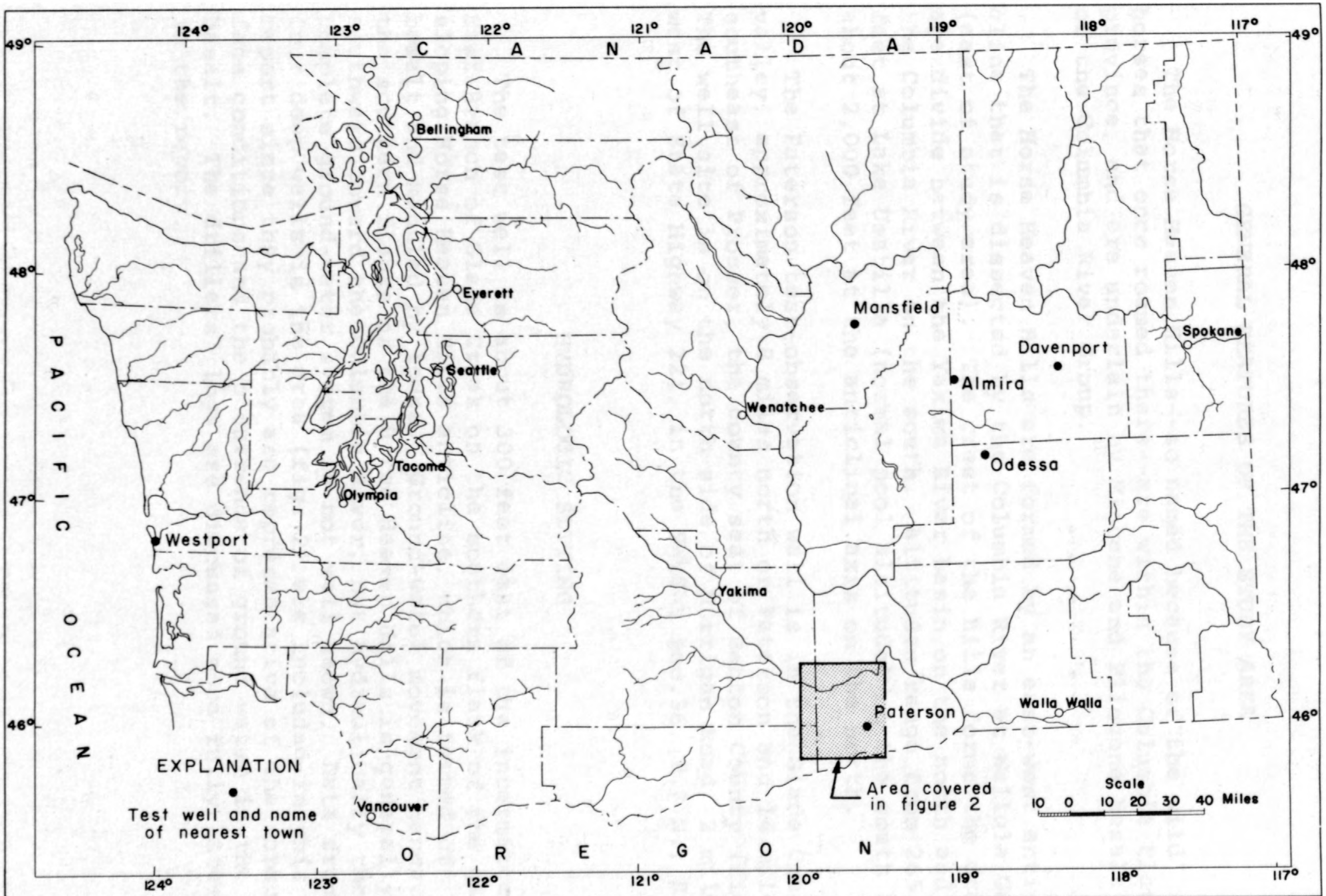

FIGURE 1.--Locations of test-observation wells in Washington.

GENERAL FEATURES OF THE STUDY AREA

The Horse Heaven Hills--so named because of the wild horses that once roamed there--are within the Columbia Plateau province, and are underlain by Miocene and Pliocene basalt of the Columbia River Group.

The Horse Heaven Hills are formed by an east-west anticline that is dissected by the Columbia River at Wallula Gap (east of study area). The crest of the hills forms the drainage divide between the Yakima River basin on the north and the Columbia River on the south. Altitudes range from 265 feet at Lake Umatilla (normal pool altitude) on the south to about 2,000 feet at the anticlinal axis on the north.

The Paterson test-observation well is in the Glade Creek valley, approximately 8 miles north of Paterson and 14 miles southeast of Prosser, the county seat of Benton County (fig. 2). The well site is on the north side of Horrigan Road, 2 miles west of State Highway 221, in the SW¼SW¼ sec.36, T.7 N., R.25 E.

HYDROLOGIC SETTING

The test well is about 300 feet east of the intermittent East Branch of Glade Creek on the southern flank of the gently sloping Horse Heaven Hills anticline, which is formed of basalt and mantled by loess. Ground-water movement beneath the southern flanks of the Horse Heaven Hills is generally southward toward the Columbia River, but hydraulically the complete ground-water system is not well known. Data from four deep wells in the area (fig. 2) are included in this report since they probably are representative of the subsurface conditions and the occurrence of ground water in the basalt. The drillers' logs are discussed more fully later in the report.

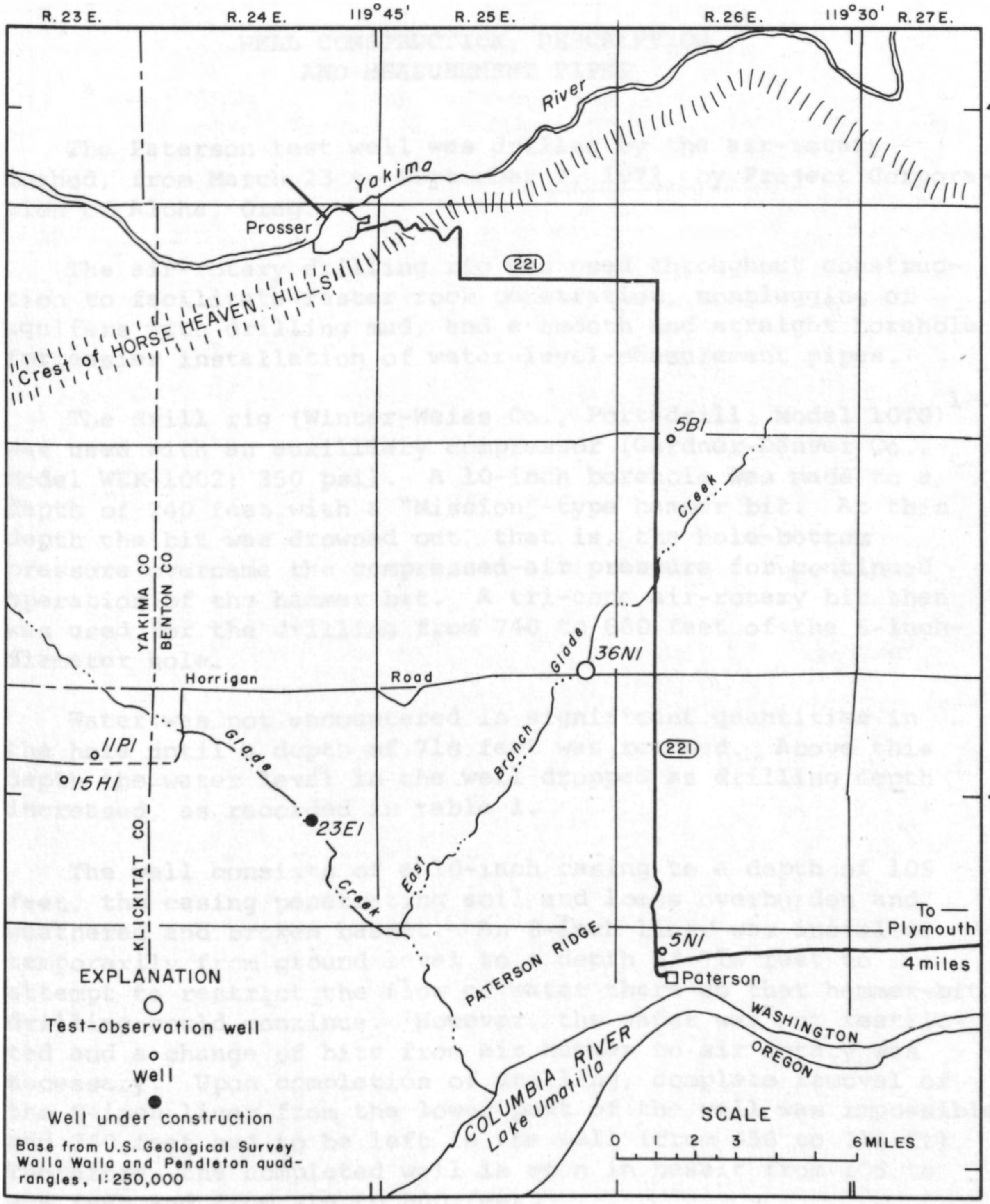

FIGURE 2.--Locations of test well and other selected deep wells in study area.

WELL CONSTRUCTION, DESCRIPTION, AND MEASUREMENT PIPES

The Paterson test well was drilled by the air-rotary method, from March 23 to September 7, 1972, by Project Corporation of Aloha, Oreg.

The air-rotary drilling rig was used throughout construction to facilitate faster rock penetration, nonplugging of aquifers with drilling mud, and a smooth and straight borehole for easier installation of water-level-measurement pipes.

The drill rig (Winter-Weiss Co., Portadrill, Model 10TG)[1] was used with an auxilliary compressor (Gardner-Denver Co., Model WEK-1002; 350 psi). A 10-inch borehole was made to a depth of 740 feet with a "Mission"-type hammer bit. At this depth the bit was drowned out, that is, the hole-bottom pressure overcame the compressed-air pressure for continued operation of the hammer bit. A tri-cone air-rotary bit then was used for the drilling from 740 to 860 feet of the 6-inch-diameter hole.

Water was not encountered in significant quantities in the hole until a depth of 716 feet was reached. Above this depth the water level in the well dropped as drilling depth increased, as recorded in table 1.

The well consists of a 10-inch casing to a depth of 105 feet, the casing penetrating soil and loess overburden and weathered and broken basalt. An 8-inch liner was installed temporarily from ground level to a depth of 716 feet to attempt to restrict the flow of water there so that hammer-bit drilling could continue. However, the water was not restricted and a change of bits from air hammer to air rotary was necessary. Upon completion of drilling, complete removal of the 8-inch liner from the lower part of the well was impossible and 260 feet had to be left in the well (from 456 to 716 ft). Therefore, the completed well is open in basalt from 105 to 456 feet and from 716 to 860 feet.

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[1]Mention of this and other proprietary names in this report does not imply endorsement of specific products by the U.S. Geological Survey or by the Washington State Department of Ecology. Equivalent products could have been used equally effectively.

TABLE 1.--Depth to water during drilling of Paterson test-observation well

Date (1972)	Feet below land-surface datum	
	Well depth at time of measurement	Water level
Apr. 12	110	75.5
May 2	205	112.0
25	325	120.5
June 5	440	120.0
July 13	547	166.5 (possibly cascading water)
Aug. 22	740	372.5
Sept. 7	860	371.5

Aquifer tests were made when the well was at a depth of 735 feet, and again at the final depth of 860 feet. The aquifer tests and the quality of the ground water obtained at these depths are discussed on pages 11 and 14, respectively.

Most basalt wells are open to all aquifers penetrated, hence the resultant head is the composite of all aquifers encountered. After the final test pumping of the test-observation well, to permit measurements of the water levels in the individual aquifers, a 1¼-inch pipe with a short well screen attached was installed to a depth opposite each aquifer. Permeable gravel was then backfilled around the screen. The aquifers were hydraulically isolated from each other by cement plugs at their bases and tops. Additional cement plugs were placed between aquifers to prevent vertical circulation of water in the well. Shortly after installation of the pipes, water levels of the four aquifers were measured and are presented in table 2.

Natural vertical movement of ground water from one aquifer to another, through cracks and (or) joints in the dense basalt, can have a warming or cooling effect on the pattern of natural heat flow outward from the earth, resulting in a distortion of the geothermal gradient. The rate of vertical ground-water movement--and therefore the rate of recharge of one aquifer by another with a higher head--can be calculated by careful measurement of this temperature distortion. To accomplish such measurement with greater precision and at less expense than by other methods available, a separate 1¼-inch pipe was installed in the well (fig. 3) to its full depth to permit access for a thermistor. The pipe is filled with water, but, being closed off to direct hydraulic connection with individual aquifers, it allows an accurate recording of the geothermal gradient for the full depth of the well.

TABLE 2.--Water levels of aquifers isolated in Paterson test-observation well

Aquifer	Feet below land-surface datum		
	Depth interval of aquifer	Well screen setting (top of screen)	Depth to water Nov. 1, 1972
A	105-185	None	133.5
B	200-290	231	Water below top of well screen this date
C	720-755	731	374.3
D	770-860	820	373.2

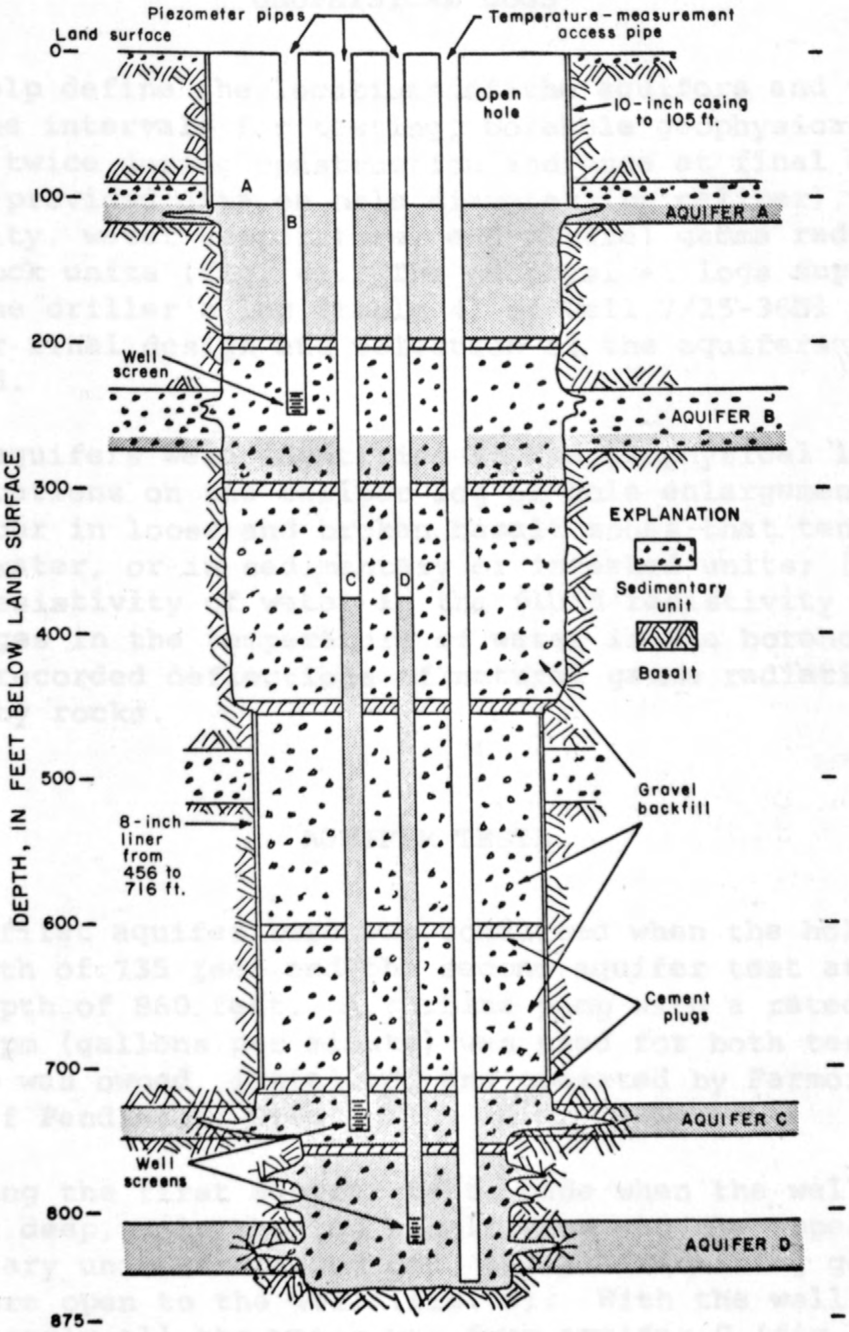


FIGURE 3.--Diagrammatic sketch of Paterson test-observation well.

GEOPHYSICAL LOGS

To help define the locations of the aquifers and to select the intervals for testing, borehole geophysical logs were run twice during construction and once at final depth. The logs provided data on hole diameter (by caliper), fluid resistivity, water temperature, and natural gamma radiation of the rock units (fig. 4). The geophysical logs supplemented the driller's log (table 4) of well 7/25-36N1 as a basis for final design and selection of the aquifers to be monitored.

The aquifers were identified in the geophysical logs by (1) indications on the caliper log of hole enlargements, which occur in loose and broken basalt zones that tend to contain water, or in sedimentary or interbed units; (2) changes in the resistivity of water in the fluid-resistivity log; (3) changes in the temperature of water in the borehole; and (4) the recorded deflections of natural gamma radiation emitted by rocks.

AQUIFER TESTS

The first aquifer test was conducted when the hole was at a depth of 735 feet and the second aquifer test at the final depth of 860 feet. A turbine pump with a rated capacity of 500 gpm (gallons per minute) was used for both tests. The pump was owned, installed, and operated by Farmore Service Center of Pendleton, Oreg.

During the first aquifer test, made when the well was 735 feet deep, only the top basalt flow and the uppermost sedimentary unit were cased off, and all remaining geologic units were open to the well (fig. 5). With the well at this depth, nearly all the water was from aquifer C (fig. 3) and the static water level was 372 feet below land surface. At a pumping rate of about 690 gpm (above the rated pump capacity) for 24 hours, the drawdown of water level was 12 feet (to 384 ft below land surface), indicating a specific capacity of about 58 gpm per foot of drawdown.

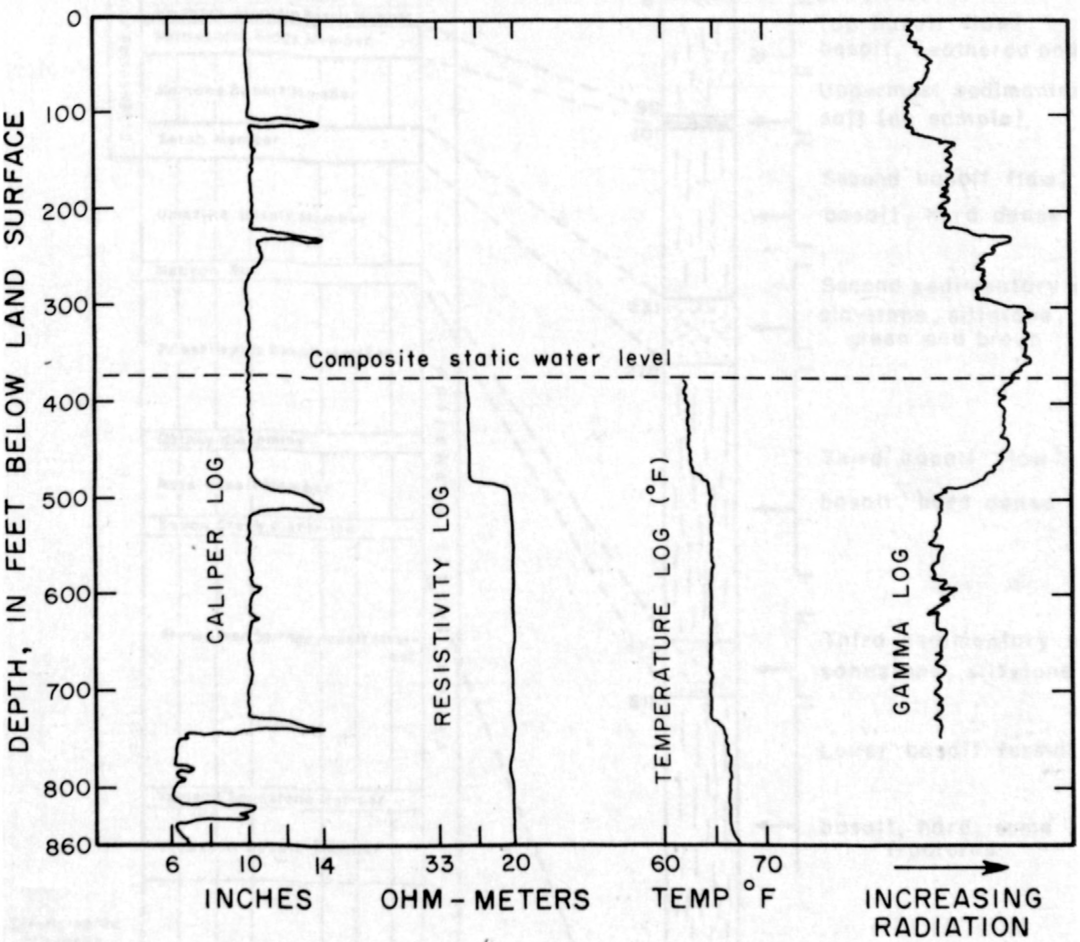


FIGURE 4.--Geophysical logs of the Paterson test-observation well.

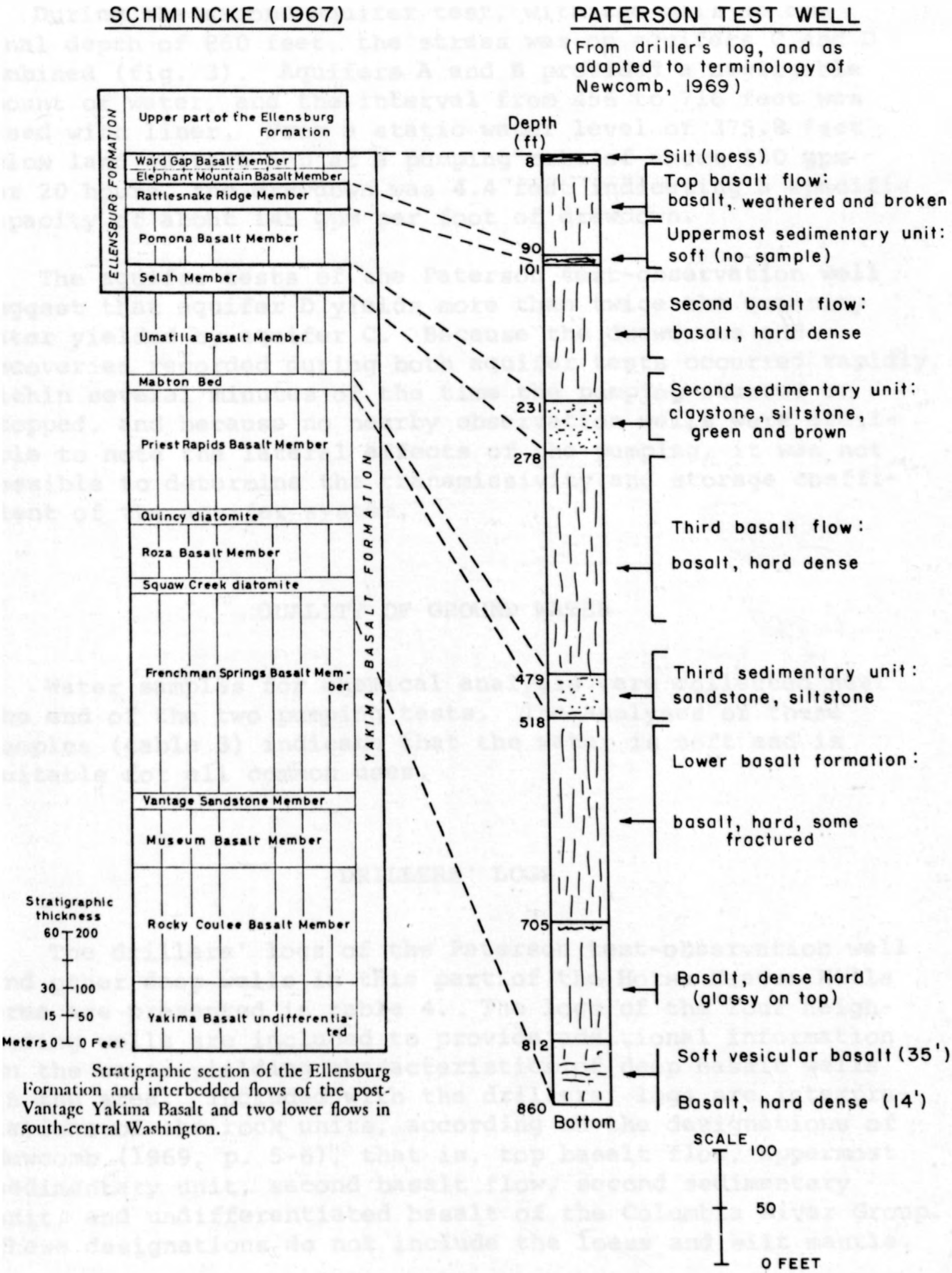


FIGURE 5.--Generalized section at Paterson test-observation well compared to stratigraphic classification of Schmincke (1967, fig. 2).

During the second aquifer test, with the well at the final depth of 860 feet, the stress was on aquifers C and D combined (fig. 3). Aquifers A and B provided a negligible amount of water, and the interval from 456 to 716 feet was cased with liner. From a static water level of 375.8 feet below land surface and at a pumping rate of about 650 gpm for 20 hours, the drawdown was 4.4 feet indicating a specific capacity of about 148 gpm per foot of drawdown.

The aquifer tests of the Paterson test-observation well suggest that aquifer D yields more than twice the quantity water yielded by aquifer C. Because the drawdowns and recoveries recorded during both aquifer tests occurred rapidly, within several minutes of the time the pumping started or stopped, and because no nearby observation wells were available to note the lateral effects of the pumping, it was not possible to determine the transmissivity and storage coefficient of the aquifer system.

QUALITY OF GROUND WATER

Water samples for chemical analysis were collected near the end of the two pumping tests. The analyses of these samples (table 3) indicate that the water is soft and is suitable for all common uses.

DRILLERS' LOGS

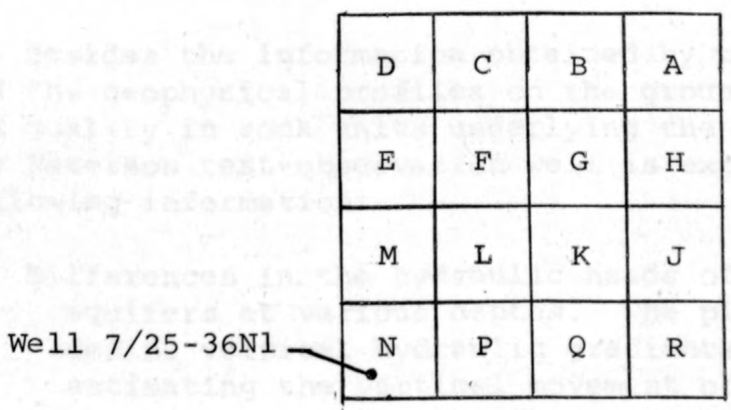
The drillers' logs of the Paterson test-observation well and other deep wells in this part of the Horse Heaven Hills area are presented in table 4. The logs of the four neighboring wells are included to provide additional information on the water-yielding characteristics of deep basalt wells in the area. Included with the drillers' logs are interpretations of the rock units, according to the designations of Newcomb (1969, p. 5-6), that is, top basalt flow, uppermost sedimentary unit, second basalt flow, second sedimentary unit, and undifferentiated basalt of the Columbia River Group. These designations do not include the loess and silt mantle.

TABLE 3.--Chemical analyses of water from different depths in Paterson test-observation well

Item	Values in milligrams per liter unless otherwise indicated	
Date of collection	8-4-72	10-5-72
Depth of well, in feet	735	860
Silica (SiO_2)	61	52
Aluminum (Al)	.01	.01
Iron (Fe)	.02	.03
Manganese (Mn)	.00	.01
Calcium (Ca)	4.5	5.6
Magnesium (Mg)	1.4	1.7
Sodium (Na)	92	81
Potassium (K)	14	14
Bicarbonate (HCO_3)	225	209
Carbonate (CO_3)	0	0
Sulfate (SO_4)	18	24
Chloride (Cl)	18	16
Fluoride (F)	1.2	1.1
Nitrite plus nitrate as nitrogen (N)	.02	.08
Dissolved solids (calculated)	321	299
Hardness as $CaCO_3$	17	21
Noncarbonate hardness	0	0
Specific conductance (micromhos at 25 °C)	454	430
pH (units)	8.2	8.2
Water temperature (°C)	21.8	21.6
Color (platinum-cobalt units)	5	0

Also interpreted are a third basalt flow, a third sedimentary unit, and a lower basalt flow. The rock-unit designations are used to compare the geologic section by Schmincke (1967, p. 1390) with materials logged in the Paterson test-observation well (fig. 5; table 4, well 7/25-36N1).

In this report wells are designated by symbols that indicate their locations according to the official rectangular public-land survey. For example, in the symbol 7/25-36N1, the number for the Paterson test-observation well, the part preceding the hyphen indicates successively the township and range (T.7 N., R.25 E.) north and east of the Willamette base line and meridian. Because the report area lies entirely north and east of the base line and meridian, the letters indicating the directions north and east are omitted. The first number following the hyphen indicates the section (sec.36), and the letter "N" gives the 40-acre subdivision of the section, as shown in the figure below. The numeral "1" indicates that this well is the first one listed within the subdivision.



Well 5/26-5N1, owned by the Prior Land Company, is about 8 miles south of the test well site. This relatively low-yielding well supplies several families in the unincorporated town of Paterson.

Wells 6/23-11P1 and 6/23-15H1, owned jointly by George Smith and Bob Andrews, are about 12 miles west of the test well and are two of the more productive flowing wells in the State. In early 1970, after being deepened to their present depths, they had artesian flows of 2,500 and 2,200 gpm, respectively. During the summer of 1972, for pump-assisted irrigation, the wells produced enough water for multiple sprinkler application with about 50-100 acres in pasture and about a full section in silage crops.

Well 7/26-5B1, owned by John Moon, is about 6 miles to the north of the test well. When this well was deepened in 1970 additional water yield was gained but with a drop in static water level of about 200 feet. The well is currently unused.

A private test well (6/24-23E1) about 7 miles to the southwest of the Paterson test well (fig. 2) was being drilled for Columbia River Farms (Lamb-Weston, Inc.). By mid-October 1972, the well depth was 360 feet with an eventual goal of 1,000 feet. If sufficient water is obtained, it will serve for further irrigation development and a well log (not yet available) may provide additional information.

ADDITIONAL INFORMATION EXPECTED

Besides the information obtained by the driller's log and the geophysical profiles on the ground-water occurrence and quality in rock units underlying the Horse Heaven Hills, the Paterson test-observation well is expected to produce the following information:

1. Differences in the hydraulic heads of the monitored aquifers at various depths. The piezometer pipes will define vertical hydraulic gradients, data essential to estimating the vertical movement of water through the ground-water reservoir for a quantitative understanding of the ground-water-flow system. For example, in the Odessa area in east-central Washington a test-observation well has shown changes in hydraulic heads that have resulted from deeper irrigation wells in the area draining shallow aquifers. This situation possibly could have been prevented if there had existed a previous knowledge of the area's ground-water conditions, and if cement seals and casings had sealed off the shallow aquifer zones tapped by the deep irrigation wells.

2. Seasonal fluctuation of water levels in the respective piezometer pipes will identify the heavily pumped aquifers. For example, in the Odessa area the withdrawal

of ground water in excess of the recharge has resulted in "mining" of the stored ground-water reservoir, and water levels have declined, with the consequence of increased pumping depths and associated costs. If measurements had been available by piezometer pipes over a period of several years, such declines could have been defined and the general trend of water-level lowering might have been prevented by remedial action on the part of water-management agencies.

3. The piezometer pipes are available for monitoring changes in ground-water quality by means of downhole conductivity sensors or, if required, by withdrawal of water for chemical analysis.

4. Accurate temperature-gradient measurements through the access pipe will aid in the interpretation of the general pattern of ground-water flow, and may also provide an independent method for estimating vertical ground-water movement across the basalt sequence.

In summary, the data already provided by the Paterson test-observation well constitute valuable information needed for water-management decisions. These data could not have been obtained by other practical methods. Additional data expected from the well may prove to be even more helpful for management of the ground-water resources of the region.

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Newcomb, R. C., 1969, Geologic map of the proposed Paterson Ridge pumped-storage reservoir, south-central Washington: U.S. Geol. Survey open-file report, 8 p.

Schmincke, H. U., 1967, Stratigraphy and petrography of four upper Yakima Basalt flows in south-central Washington: Geol. Soc. America Bull., v. 78, p. 1385-1422.

Washington State University, 1970, Horse Heaven Hills irrigation and development potential: College of Agr., Pullman, Wash., 119 p.

TABLE 4.--Drillers' logs of wells

Material	Thickness (feet)	Depth (feet)
Well 5/26-5N1. Prior Land Company. Altitude 437 ft. Drilled by Moore and Anderson, 1964.		
Surficial deposits:		
Sand and gravel	9	9
Top basalt flow:		
Rock, brown	19	28
Rock, gray	68	96
Uppermost sedimentary unit:		
Clay, brown	7	103
Clay, blue	44	147
Gravel and clay	8	155
Second basalt flow:		
Rock, gray	8	163
Rock, brown	22	185
Rock, gray	141	326
Second sedimentary unit:		
Clay, rocky, gray	8	334
Shale, blue	20	354
Casing, 10 inch to 157 ft; static water-level 97 ft below lsd Sept. 2, 1964; test pumped 100 gpm for 6 hrs, with 175 ft drawdown.		
Well 6/23-11P1. George Smith and Bob Andrews well no. 2. Altitude 1,010 ft. Deepened 1970 by Moore and Anderson.		
Original depth (no log available)	670	670
Lower basalt formation:		
Rock, gray	207	877
Water level at 120 ft when well 738 ft		
Do. 80 ft do. 800 ft		
Do. 58 ft do. 835 ft		
Water flowing when well 855 ft		
Rock, black to brown, flowed 2,500 gpm	10	887
Rock, black	2	889
Rock, gray	3	892
Valved artesian pressure 35 psi, March 1970.		

TABLE 4.--Drillers' logs of wells--Continued

Material	Thickness (feet)	Depth (feet)
Well 6/23-15H1. George Smith and Bob Andrews well no. 3. Altitude 1,045 ft. Drilled by Moore and Anderson, 1968. Deepened from 633 to 950 ft in 1971		
Soil and hardpan	5	5
Top basalt flow:		
Rock, brown, black, and gray	77	82
Uppermost sedimentary unit:		
Shale with clay, gray	29	111
Second basalt flow:		
Rock, black and gray	175	286
Rock, gray-brown, with clay	7	293
Second sedimentary unit:		
Clay, yellow	10	303
Clay, gray and brown	10	313
Third basalt flow:		
Rock, brown (static water level 101 ft)	38	351
Rock, black and gray (static water level 103 ft)	139	490
Rock, with green clay	47	537
Third sedimentary unit:		
Clay, green (static water level 103 ft)	22	559
Lower basalt formation:		
Rock, black	15	574
Rock, black and dark brown (static water level 77 ft)	9	583
Rock, dark brown (static water level 45 ft)	5	588
Rock, dark brown and black (static water level 37 ft)	5	593
Rock, brown and black (static water level 14 ft)	2	595
Rock, black (water level rising from 11 to 1 ft)	29	624
Rock, gray	34	658
Basalt, black	17	675
Rock, gray (flowing 500 gpm)	163	838

(continued)

TABLE 4.--Drillers' logs of wells--Continued

Material	Thickness (feet)	Depth (feet)
Well 6/23-15H1.--Continued		
Lower basalt formation--continued		
Basalt, black (flowing 2,200 gpm)----------	100	938
Rock, gray---------------------------------	12	950
Casing, 12 inch to 128 ft; liners, 10 inch from 268 to 323 ft, 8 inch from 440 to 560 ft; valved artesian pressure 35 psi, February 1971, and flow of 2,200 gpm.		

Material	Thickness (feet)	Depth (feet)
Well 7/25-36N1. Paterson test-observation well. Altitude 730 ft. Drilled by Project Corporation, March-September 1972.		
Silt (loess)-------------------------------	8	8
Gravel, basaltic, medium to coarse-------------	3	11
Top basalt flow:		
Basalt, medium hard, gray-black------------	17	28
Basalt, medium hard, light gray-green------	16	44
Basalt, broken and weathered---------------	7	51
Clay, brown and lenses of broken basalt----	10	61
Basalt, broken and high vesicular----------	12	73
Basalt, medium hard------------------------	6	79
Basalt, very vesicular, probably pillow zone--	11	90
Uppermost sedimentary unit:		
No sample return, medium to soft-----------	11	101
Second basalt flow:		
Basalt, hard, dense------------------------	36	137
Basalt, fractured, some water--------------	3	140
Basalt, hard, dense, gray-black------------	91	231
Second sedimentary unit:		
Claystone, green and brown fragments, little water---------------------------	47	278
Third basalt flow:		
Basalt, hard, dense, gray-black------------	201	479

(continued)

TABLE 4.--Drillers' logs of wells--Continued

Material	Thickness (feet)	Depth (feet)
Well 7/25-36N1.--Continued		
Third sedimentary unit:		
Siltstone, brown, little sample return-----	9	488
Clay, sandy and sticky----------------------	22	510
Sandstone, fine grained, water level dropped--------------------------------------	8	518
Lower basalt formation:		
No sample, harder drilling------------------	8	526
Basalt, medium hard, dark gray-------------	20	546
Basalt, hard, dark gray--------------------	44	590
Basalt, fractured, increased drilling rate, most water at 601 ft, estimated 100 gpm--	24	614
Basalt, medium fractured, gray-black-------	46	660
Basalt, fractured, total water estimated 200 gpm----------------------------------	4	664
Basalt, fine grained, gray-black-----------	41	705
Basalt, glassy or vesicular, soft----------	11	716
Basalt, fractured and broken in places-----	29	745
Basalt, medium hard, gray-black------------	67	812
Basalt, vesicular, chocolate brown and gray, more water--------------------------------	35	847
Basalt, hard, gray-black-------------------	13	860

Casing, 10 inch from ground surface to 105 ft; liner, 8 inch from 456 to 716 ft; 6-inch hole from 740 to 860 ft.

TABLE 4.--Drillers' logs of wells--Continued

Material	Thickness (feet)	Depth (feet)
Well 7/26-5B1. John Moon. Altitude 1,125 ft. Drilled by Barnett, 1969. Deepened in 1970; no log available 780 to 1,070 ft.		
Overburden	20	20
Rock, soft, broken	25	45
Top basalt flow:		
Basalt, hard	9	54
Rock, soft, black	21	75
Basalt, hard	25	100
Uppermost sedimentary unit(?):		
Rock, soft, broken, black	11	111
Second basalt flow:		
Basalt, hard	10	121
Rock, medium hard	14	135
Basalt, hard, gray	37	172
Rock, soft, broken	25	197
Basalt, hard, gray	43	240
Second sedimentary unit:		
Sandstone	65	305
Sand, white, and clay	80	385
Third basalt flow:		
Basalt, hard, gray	224	609
Third sedimentary unit:		
Rock, broken, with water, caving at 652 ft	72	681
Lower basalt formation:		
Basalt, hard, gray	67	748
Rock, soft, broken	32	780
Casing, 8 inch to 350 ft; test pumped 162 gpm with 97-ft drawdown after 8 hrs; static water level, 403 ft below lsd (4-17-69); after well deepened, static water level about 610 ft.		

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