UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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

By
D. A. Myers

Prepared in cooperation with the
State of Washington Department of Ecology

OPEN-FILE REPORT

Tacoma, Washington
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ABSTRACT

The 750-foot test-observation well drilled near Davenport, Wash., is one of several drilled to date (1972) to provide information on ground-water conditions in selected areas of the State. The well provides information on aquifer characteristics in this area which are not available from existing deep irrigation wells. The well was drilled by air-rotary methods and penetrates eight aquifer zones (A through H); the upper 75 feet of the well is cased, and the remainder of the hole is open in basalt.

Test pumping during drilling showed that the well had specific capacities of (1) 4.8 gpm (gallons per minute) per foot of drawdown when at the 255-foot depth and open to aquifers A through D, (2) 5.6 gpm per foot of drawdown when at the 640-foot depth and open to aquifers A through G, and (3) 76.5 gpm per foot of drawdown when at the full 750-foot

depth and open to all eight aquifers. The tests indicate that most of the water available to the well is from the deepest aquifer (zone H).

Borehole geophysical logging supplemented the driller's log of the well and provided information on natural gamma radiation, water temperature and resistivity, and borehole diameter. In the completed well each aquifer zone is isolated by cement seals, and piezometer pipes installed to zones B through H allow a basis for defining the vertical hydraulic gradient and ground-water movement in the area. The pipes also permit chemical-quality monitoring of water in the various aquifer zones. An additional pipe, installed for providing thermistor access, allows recording of the geothermal gradient in the well which provides a basis for estimating vertical ground-water movement in the area.

INTRODUCTION

The test-observation well described in this report was designed to yield key ground-water information for a highly productive agricultural area of Washington, where ground water is being used increasingly for irrigation. The data already obtained from the construction and testing of the well, and those expected in the future, are considered essential to the sound management of the ground-water resources of this area. Although some information on the ground water was available from previous studies, much of the knowledge being derived from this test-observation well could not have been obtained in any other way. This study will amplify and extend our understanding of the complex ground-water-flow system of this area.

This study is part of an overall project designed for drilling, testing, and periodically collecting data from test-observation wells in selected areas of the State. The wells are being drilled where there is a critical need for ground-water data for water-management purposes, and where the data cannot be obtained from existing wells or by other reasonable means. This project is part of a continuing cooperative program of water-resources investigations in Washington, and is financed jointly by the U.S. Geological

Survey and the State of Washington Department of Ecology. The data from this well will provide input to another current cooperative investigation--the development of a mathematical model, designed for analysis by use of a digital computer--of the ground-water-flow system in east-central Washington and of the relation between pumpage and decline of ground-water levels.

The locations of this and other test-observation wells drilled under this project during fiscal year 1971 are shown in figure 1.

In basalt, most ground water occurs and moves in well-defined permeable zones at or near the contacts between individual basalt flows. These water-bearing zones (aquifers) are separated from one another by the dense, nearly impermeable central parts of the flows. Hydraulic heads in the individual aquifers, as reflected by water levels in wells that tap them, usually vary with depth. In much of east-central Washington the levels are highest in the shallow basalt wells and lowest in the deeper wells.

Borehole geophysical logs and other data show that the shallower aquifers in this area are being drained almost continuously as a result of the short-circuiting effect of leakage in uncased deep wells. The deep wells simply act as

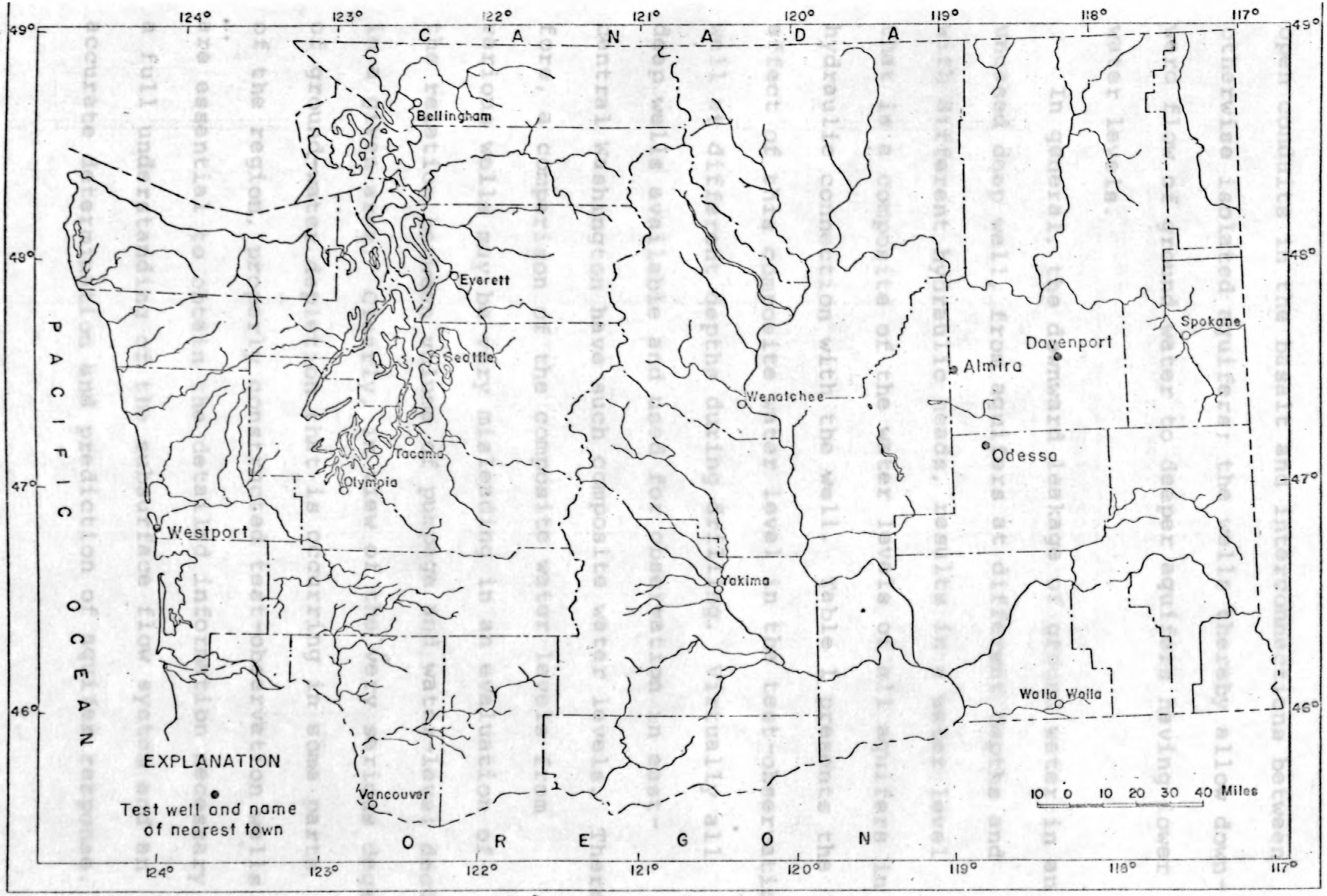

FIGURE 1.--Locations of test-observation wells in Washington.

open conduits in the basalt and interconnections between otherwise isolated aquifers; the wells thereby allow downward flow of ground water to deeper aquifers having lower water levels.

In general, the downward leakage of ground water in an uncased deep well, from aquifers at different depths and with different hydraulic heads, results in a water level that is a composite of the water levels of all aquifers in hydraulic connection with the well. Table 1 presents the effect of this composite water level in the test-observation well at different depths during drilling. Virtually all deep wells available and used for observation in east-central Washington have such composite water levels. Therefore, a comparison of the composite water levels from various wells may be very misleading in an evaluation of the relation between volume of pumpage and water-level declines in a given area. Clearly, in view of the very serious degree of ground-water depletion that is occurring in some parts of the region, properly constructed test-observation wells are essential to obtain the detailed information necessary for a full understanding of the subsurface flow system and an accurate determination and prediction of aquifer response.

TABLE 1.--Depth to water during drilling of Davenport test-observation well, September-October 1971

Date	Measurements in feet below land surface	
	Well depth	Water level
Sept. 25	190	33
26	262	32.25
28	400	33.2
30	450	40.0
Oct. 1	520	34.5
2	560	33.7
5	588	33.8
12	614	137.2
14	664	156.2
15	750	160.4

Background and Ground-Water Problems of the Area

The test-observation well is located near Davenport, Wash., in an area where the transition from dryland to irrigated wheat farming has recently begun. Water levels in the basalt-aquifer system are starting to decline locally. The Davenport area is thought to be in the same stage of ground-water development as that of the Odessa area to the south (fig. 1) during the 1960's.

In the Odessa area, local areas of ground-water-level decline were noticed in the early 1960's. By 1968 the declines had increased and the areas of decline had coalesced and covered about 700 square miles (Luzier and others, 1968), and by 1971 the area of decline had increased to more than 1,000 square miles. Widespread declines of water levels--but at substantially lower annual rates--also have occurred in shallow aquifers tapped by numerous domestic and stock wells. Because these shallow wells normally are not much deeper than the level of the water they tap, an annual decline of only 1 or 2 feet may lower the water below the well bottoms, causing much inconvenience and added expense to the owners.

RESULTS OF THE STUDY

Construction of the Well

The Davenport test-observation well was drilled by the air-rotary method, and tested during the period September 23, 1970-May 14, 1971 by Adcock Drilling Co. of Lewiston, Idaho. Table 2 provides the driller's log of the 750-foot well. The well is cased to a depth of 75 feet and is open in basalt the remaining depth.

Because water levels in wells that are open to all aquifers penetrated are composites of the hydraulic heads of all the aquifers, the well was designed to permit isolation and individual measurement of water levels in the eight aquifer zones penetrated. After final test pumping, 1¼-inch pipes were suspended in the test hole, with short well screens opposite each aquifer to be monitored. The hole then was back-filled around the pipes with permeable gravel, and a cement plug was placed at the base and top of each monitored zone to isolate it; additional plugs were placed between these major seals to prevent vertical circulation of water in the well. The diagrammatic sketch of the well in figure 2 shows aquifers A through H, the depths at which the cement plugs and piezometer pipes are set and the water levels of each aquifer just after installation, on September 8, 1971.

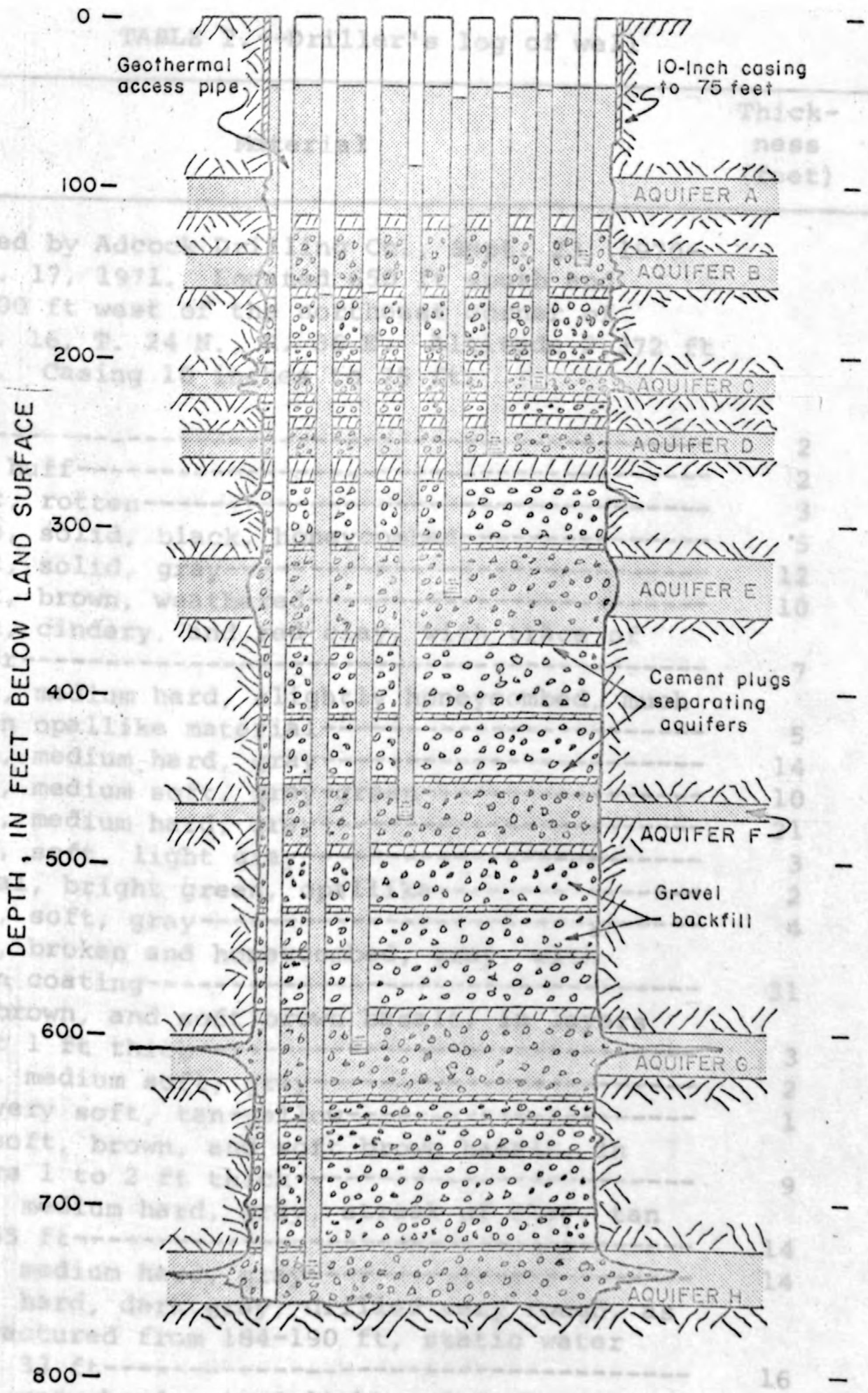

FIGURE 2.--Diagrammatic sketch of the test-observation well near Davenport, showing aquifer zones monitored by piezometer pipes, water levels in the pipes on September 8, 1971.

TABLE 2.--Driller's log of well

Material	Thick-ness (feet)	Depth (feet)
Drilled by Adcock Drilling Co., Sept. 23, 1970-Mar. 17, 1971. Located 650 ft south and 1,200 ft west of the northeast corner of sec. 16, T. 24 N., R. 36 E. Altitude 2,372 ft msl. Casing 10 inches to 75 ft.		
Silt	2	2
Clay, buff	2	4
Basalt, rotten	3	7
Basalt, solid, black, honeycombed	5	12
Basalt, solid, gray	12	24
Basalt, brown, weathered	10	34
Basalt, cindery, and red clay, with trace of water	7	41
Basalt, medium hard, slightly honeycombed, much green opallike material	5	46
Basalt, medium hard, gray	14	60
Basalt, medium soft, gray-green	10	70
Basalt, medium hard, gray	21	91
Basalt, soft, light gray	3	94
Material, bright green, opallike	2	96
Basalt, soft, gray	4	100
Basalt, broken and honeycombed, gray, with brown coating	31	131
Clay, brown, and soft brown basalt, in layers about 1 ft thick	3	134
Basalt, medium soft, gray	2	136
Clay, very soft, tan-yellow	1	137
Clay, soft, brown, and soft brown basalt, in layers 1 to 2 ft thick	9	146
Basalt, medium hard, gray, streak of clay, tan at 155 ft	14	160
Basalt, medium hard, gray	14	174
Basalt, hard, dark gray, drilled very rough, as if fractured from 184-190 ft, static water level 33 ft	16	190
Basalt, very hard, mixed light and dark gray, appears to be fractured, some water at 195 ft	16	206

(continued)

TABLE 2.--Driller's log of well--Continued

Material	Thick-ness (feet)	Depth (feet)
Basalt, very hard, creviced at 213 ft, lost some water at about 216-218 ft in fractured rock	22	228
Basalt, hard, gray, with crevice at 229 ft and 247-250 ft	22	250
Basalt, hard, gray, some small creviced zones, static water level 32.25 ft	12	262
Basalt, gray, drilled a little faster than above	16	278
Basalt, very soft, broken, brown, may be water-bearing	3	281
Clay, black	2	283
Basalt, medium hard, black to dark gray, slightly fractured	38	321
Clay, black	9	330
Clay, tan-brown	8	338
Clay, red	7	345
Clay, green	4	349
Basalt, fractured, gray, with some soft streaks (clay?) 357-360 ft	11	360
Basalt, medium soft, dark gray	23	383
Basalt, medium hard, gray	17	400
Basalt, medium hard, gray, with some fractures at 403 and 420 ft	29	429
Basalt, honeycomb or decomposed, drilled fast	1	430
Basalt, medium hard, fractured, dark gray	4	434
Basalt, medium hard, dark gray	10	444
Basalt, medium hard, fractured, dark gray	4	448
Basalt, medium hard, dark gray	2	450
Basalt, medium soft, dark gray	11	461
Basalt, hard to medium hard, dark gray	4	465
Basalt, soft, fractured, lost some drilling water	4	469
Basalt, medium hard, dark gray, fractured at 494 ft	41	510
Basalt, fractured, dark gray	3	513
Basalt, medium hard, dark gray, some fractures 529-532 ft	27	540
Basalt, very hard, fractured, dark gray	3	543

(continued)

TABLE 2.--Driller's log of well--Continued

Material	Thickness (feet)	Depth (feet)
Basalt, very hard, dark gray, fractured at 572.5 and 577-582 ft	45	588
Basalt, very hard, dark gray	11	599
Basalt, very hard, fractured, dark gray	4	603
Cavity, water-yielding	2	605
Basalt, fractured	1	606
Clay	3	609
Basalt, soft	2	611
Clay with some basalt or hard streaks	3	614
Clay or basalt, soft	1	615
Basalt, soft, fractured, dark gray	2	617
Basalt, medium hard, fractured, dark gray	13	630
Basalt, medium hard, dark gray	16	646
Basalt, hard, dark gray	6	652
Basalt, hard, fractured, dark gray	4	656
Basalt, medium hard, dark gray	8	664
Basalt, medium hard with soft streaks, fractured	6	670
Basalt, soft, and dark clay	6	676
Basalt, medium hard, dark gray, with some fractures	4	680
Basalt, soft, fractured, and some dark clay(?)	6	686
Basalt, medium hard, with some fractures	6	692
Basalt, soft, fractured	3	695
Basalt, medium hard, dark gray, with some fractures	5	700
Basalt, medium soft, dark gray, with some fractures	12	712
Basalt, medium hard, dark gray, with some fractures	13	725
Basalt, hard, dark gray	5	730
Basalt, medium hard, dark gray, with large fractures	3	733
Basalt, soft, and dark clay	5	738
Basalt, medium hard, fractured	12	750

Table 3 lists the actual water levels measured by steel tape in each aquifer on that date.

Natural vertical movement or leakage of water from one aquifer to another, through cracks and joint systems in the dense rock, may have a warming or cooling effect on the pattern of natural heat flow outward through the earth, thereby causing a distortion in the geothermal gradient. By careful measurement of this distortion, the rate of vertical ground-water movement--and recharge of one aquifer by an adjacent aquifer of higher head--may be calculated with greater precision and at far less expense than by most other methods available. For this purpose, a 1¼-inch pipe (fig. 2) was installed to the full depth of the hole to accommodate a thermistor (sensitive temperature-measuring device).

Pumping Tests

The Davenport well was test pumped during drilling, when it had reached depths of 255, 640, and 750 feet (final depth). The test at the 255-foot depth, with the well open to aquifers A through D, used a rig-mounted bailer. At a rate of 26 gpm (gallons per minute) for 6 hours, the drawdown was 5.4 feet, indicating a specific capacity of 4.8 gpm per foot of drawdown.

TABLE 3.--Water levels of aquifer zones A through H, Sept. 8, 1971

Aquifer	Depth to water (ft)
A	41.04
B	41.26
C	41.59
D	42.91
E	48.50
F	87.91
G	165.43
H	165.64

Utilizing a turbine pump for the testing at the 640-foot depth, open to aquifers A through G, the well was pumped at 510 gpm for 21 hours; the resultant drawdown of 90 feet indicated a specific capacity of about 5.7 gpm per foot. The final test at the 750-foot depth--with the well open to aquifers A through H--also utilized a turbine pump; at a rate of 536 gpm for 21 hours, with a resultant drawdown of 6.8 feet, the specific capacity was 78.8 gpm per foot. The tests indicate that most of the water pumped from the well comes from the aquifer zones below 640 feet.

Determinations of the transmissivity of the aquifer system were attempted from both the drawdown and recovery data of the final pumping test. In the absence of nearby wells to serve as observation wells, estimates of transmissivity were made by the graphical (straight-line) analysis of drawdown and residual drawdown in the test well versus time (Jacob, 1950; Theis, 1935). Recovery water levels during the test were erratic and, therefore, not suitable for determination of aquifer characteristics. However, the levels during pumping were more regular, and the calculated value of transmissivity was 40,000 square feet per day (300,000 gallons per day per foot) for the drawdown part of the test.

Quality of Water

During each of the pump tests, samples of the water were collected for chemical analysis. The results of these analyses, shown in table 4, indicate that the water from all the zones is of very good to excellent quality, suitable for all common uses.

Geophysical Logs

Borehole geophysical logs were run on May 13, 1971, and provided data on fluid temperature and resistivity, hole diameter, and natural gamma radiation (fig. 3). In addition, a flowmeter was used to determine the rate of vertical water movement in the borehole.

The caliper log shows differences in the diameter of the borehole; an increase in diameter indicates a soft or broken zone in the basalt, which could be a source of water. The trace of the caliper log (fig. 3) is reproduced approximately in figure 2 to show its relation to the zones selected for monitoring. Variations in hole diameter and in the character of the rock materials also are reflected in the gamma log, which is a measure of the small amount of natural gamma radiation in the borehole.

TABLE 4.--Chemical analysis of water from aquifer zones A-D, A-F, and A-H

Item	Values in milligrams per liter unless otherwise indicated		
	Well depth (ft)		
	255 (zones A-D)	640 (zones A-F)	750 (zones A-H)
Silica (SiO_2)	40	45	55
Calcium (Ca)	23	12	12
Magnesium (Mg)	8.3	5.5	5.9
Sodium (Na)	12	29	31
Potassium (K)	2.7	3.9	3.6
Bicarbonate (HCO_3)	102	128	142
Carbonate (CO_3)	0	0	0
Sulfate (SO_4)	15	9.0	9.5
Chloride (Cl)	8.2	3.9	3.5
Fluoride (F)	.3	.8	.8
Nitrate (NO_3)	8.6	.4	.3
Total dissolved solids	179	173	192
Hardness:			
as $CaCO_3$	92	53	54
Noncarbonate	8	0	0
Temperature (°C)	11	17.2	17.1
pH, in units	7.9	7.9	8.3
Specific conductance (micromhos per centimeter at 25°C)	246	231	238

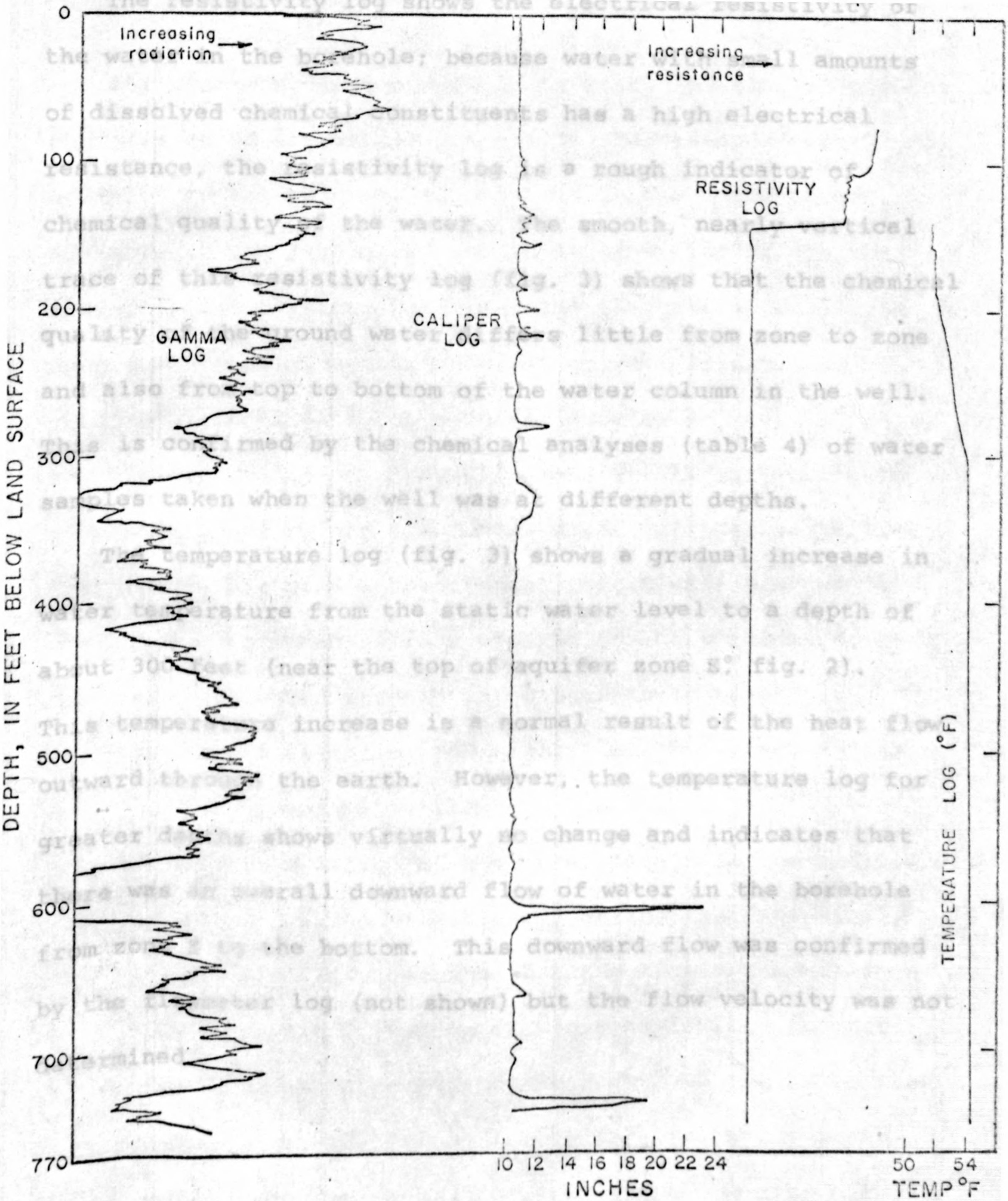

FIGURE 3.--Geophysical logs of the Davenport test-observation well.

The resistivity log shows the electrical resistivity of the water in the borehole; because water with small amounts of dissolved chemical constituents has a high electrical resistance, the resistivity log is a rough indicator of chemical quality of the water. The smooth, nearly vertical trace of this resistivity log (fig. 3) shows that the chemical quality of the ground water differs little from zone to zone and also from top to bottom of the water column in the well. This is confirmed by the chemical analyses (table 4) of water samples taken when the well was at different depths.

The temperature log (fig. 3) shows a gradual increase in water temperature from the static water level to a depth of about 300 feet (near the top of aquifer zone E, fig. 2). This temperature increase is a normal result of the heat flow outward through the earth. However, the temperature log for greater depths shows virtually no change and indicates that there was an overall downward flow of water in the borehole from zone E to the bottom. This downward flow was confirmed by the flowmeter log (not shown) but the flow velocity was not determined.

ADDITIONAL INFORMATION EXPECTED

The test-observation well is in a key location to monitor the effects of irrigation pumpage in the Davenport area. In addition to the information obtained on the sequence of aquifers at the test site, the relative yields of various zones, the geophysical profiles, and the general quality of the ground water, the test-observation well is expected to yield additional data, as summarized below.

1. Differences in the hydraulic head at the various depths monitored by the piezometer pipes will define vertical hydraulic gradients. These in turn will provide the basis for meaningful estimates of the vertical movement of water through the ground-water reservoir, which are essential for a quantitative understanding of the ground-water-flow system.
2. Seasonal fluctuation of the water levels in the individual piezometer pipes will clearly define the intensively pumped aquifers, and should allow a better evaluation of the vertical leakage from one aquifer to another.
3. Accurate temperature measurements through the thermistor access pipe will assist in the interpretation of the general pattern of ground-water flow, and also may

provide the basis for an independent method of estimating vertical ground-water movement through the basalt sequence.

4. The piezometer pipes are available to monitor any sizable future changes in ground-water quality by means of downhole conductivity sensors and, if necessary, by withdrawal of water for chemical analysis.

In summary, the data already provided by the test-observation well constitute valuable guidance for critical water-management decisions that are needed for the area. These data could not have been obtained by other practical means. Additional data that are expected from the well may prove to be even more helpful for management of the area's valuable ground-water resource.

REFERENCES CITED

Jacob, C. E., 1950, Flow of ground water, chap. 5, in Rouse, Hunter, Engineering hydraulics: New York, John Wiley & Sons.

Luzier, J. E., Bingham, J. W , Burt, R. J., and Barker, R. A., 1968, Ground-water survey, Odessa-Lind area, Washington: Washington Dept. Water Resources Water Supply Bull. 36, 31 p.

Theis, C. V., 1935, Relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., pt. 2, p. 519-524.