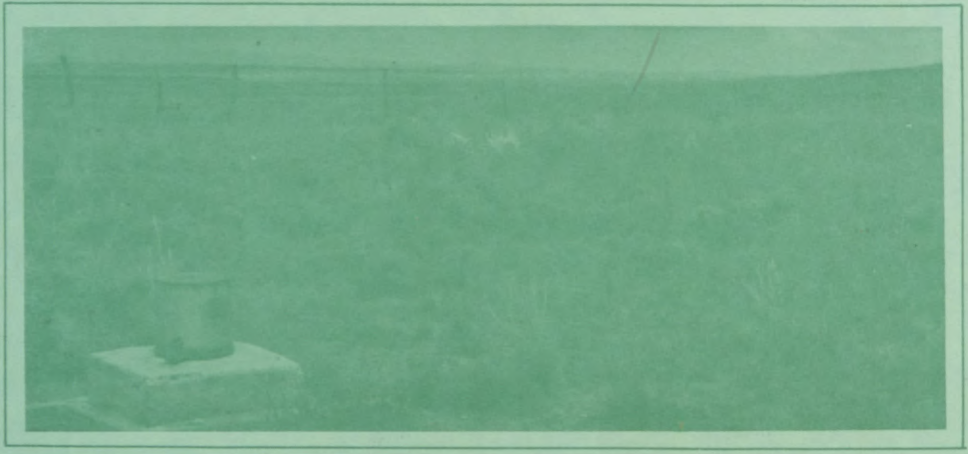
CHARACTERISTICS AND PROPERTIES OF THE BASIN-FILL AQUIFER DETERMINED FROM THREE TEST WELLS WEST OF ALBUQUERQUE, BERNALILLO COUNTY, NEW MEXICO

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 86-4187

Prepared in
cooperation with the
CITY OF ALBUQUERQUE

TEST WELL 1



TEST WELL 2

TEST WELL 3

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by D.W. Wilkins

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Albuquerque, New Mexico
1987

DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound units	By	To obtain metric units
acre	0.4047	hectare
acre-foot	0.001233	cubic hectometer
acre-foot per year	0.001233	cubic hectometer per year
cubic foot	0.02832	cubic meter
cubic foot per day	0.02832	cubic meter per day
cubic foot per second	0.02832	cubic meter per second
cubic yard	0.7646	cubic meter
foot	0.3048	meter
foot per day	0.3048	meter per day
foot per mile	0.1894	meter per kilometer
foot squared per day	0.09294	meter squared per day
gallon per minute	0.06309	liter per second
gallon per day	3.785	liter per day
inch	25.40	millimeter
mile	1.609	kilometer
pound	0.4536	kilogram
square foot	0.09294	square meter

Chemical concentrations are given only in metric units--milligrams per liter (mg/L) and micrograms per liter (μg/L).

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD 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 "Mean Sea Level of 1929."

CHARACTERISTICS AND PROPERTIES OF THE BASIN-FILL AQUIFER DETERMINED FROM THREE TEST WELLS WEST OF ALBUQUERQUE, BERNALILLO COUNTY, NEW MEXICO

By D.W. Wilkins

ABSTRACT

Three test wells were drilled west of Albuquerque, New Mexico, as part of the Southwest Alluvial Basins Regional Aquifer-Systems Analysis project. Two test wells are on the mesa west of the city. The third test well is near the Rio Grande flood plain, west of the river.

The southwesternmost test well, test well 1, was drilled to a depth of 1,204 feet, the last 24 feet being in volcanic rocks. The casing is open to the alluvial zone of the aquifer from 980 to 1,121 feet and to the volcanic zone from 1,139 to 1,179 feet below land surface. Transmissivity of perforated intervals in the alluvial zone ranges from 3.1 to 3.9 feet squared per day, and horizontal hydraulic conductivity from 2×10^{-2} to 3×10^{-2} foot per day. Vertical hydraulic conductivity of the semiconfining layer between the alluvial and volcanic zones is estimated to range from 3.1×10^{-4} to 3.1×10^{-3} foot per day. Transmissivity of the volcanic zone is about 81 feet squared per day, and horizontal hydraulic conductivity is about 2.0 feet per day. Dissolved-iron and dissolved-manganese concentrations exceed recommended constituent limits for a public water supply. Vertical flow is upward; the potentiometric surface in the volcanic zone is about 2 feet higher than in the alluvial zone. Water levels are about 883 feet below land surface.

Test well 2 was drilled to a depth of 1,828 feet below land surface with seven intervals open to the aquifer. During development, fine sand and silt entered the casing, filling the casing to a depth of 1,500 feet. The dissolved-cadmium concentration exceeds the maximum contaminant level and the dissolved-manganese concentration exceeds the recommended constituent limit for a public water supply. The vertical flow gradient is downward; the potentiometric surface in the middle and lower zones is about 17 feet lower than in the upper zones. Depth to water in the upper zone is about 767 below land surface and in the lower two zones the depth to water is about 784 feet below land surface.

Test well 3 was drilled to a depth of 1,050 feet with five intervals open to the aquifer. Only the interval from 490 to 590 feet below land surface could be used to calculate transmissivity. Transmissivity is about 1,300 feet squared per day; horizontal hydraulic conductivity is about 13 feet per day. Quality of water is acceptable for a public water supply. Vertical flow is downward; the potentiometric surface in the deepest interval is about 7 feet lower than that in the uppermost zone. In the shallow interval from 350 to 590 feet below land surface, depth to water is about 24 feet below land surface. In the interval from 710 to 790 feet below land surface, depth to water is about 29 feet below land surface and in the interval from 870 to 1,050 feet below land surface, depth to water is 31 feet below land surface.

INTRODUCTION

Three test wells were drilled west of the Rio Grande near Albuquerque as part of the Southwest Alluvial Basins Regional Aquifer-Systems Analysis project. This project evaluated the water-resource system associated with basin-fill alluvial aquifers (hereafter referred to as aquifer) from the San Luis Valley in southern Colorado, south along the Rio Grande and adjacent areas, to Presidio, Texas. As part of this evaluation, the water resources of the Albuquerque-Belen Basin were studied. The three test wells were drilled in cooperation with the City of Albuquerque to better define the aquifer system west of the Rio Grande.

Albuquerque is in central New Mexico (fig. 1) in the Rio Grande rift and is one of the rapidly expanding metropolitan areas in the Southwest. The Sandia Mountains to the east rise to more than 10,000 feet above sea level and the West Mesa forms a highland west of the city. The Albuquerque-Belen Basin is about 75 miles long and contains, in addition to Albuquerque, the cities of Bernalillo to the north and Los Lunas and Belen to the south (fig. 1). Bernalillo County, of which Albuquerque is the population center, had a population of 262,000 during 1960, 316,000 during 1970, and 420,000 during 1980 (U.S. Department of Commerce, 1982, p. 33-100).

This report presents lithologic data and interpretations from cuttings obtained during drilling of the three test wells. Chemical-quality analyses of ground water from selected zones are presented, and concentrations of particular constituents are compared with established maximum and recommended concentrations for public water supplies. Aquifer-test results from selected perforated intervals in the test wells are presented.

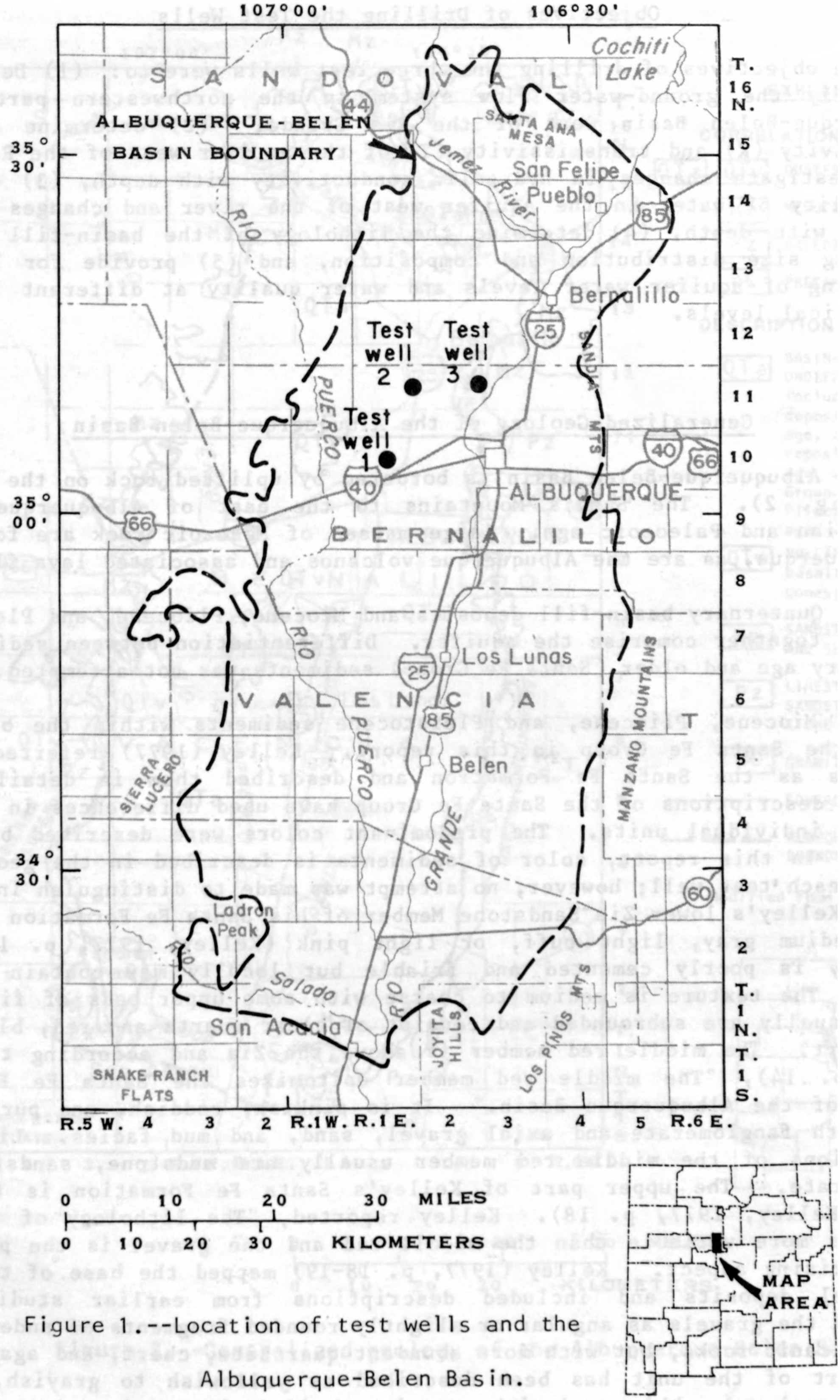

Figure 1.--Location of test wells and the Albuquerque-Belen Basin.

Objectives of Drilling the Test Wells

The objectives of drilling the three test wells were to: (1) Define more accurately the ground-water flow system in the northwestern part of the Albuquerque-Belen Basin west of the Rio Grande, (2) determine hydraulic conductivity (K) and transmissivity (T) of the aquifer west of the Rio Grande and investigate changes in hydraulic conductivity with depth, (3) determine the quality of water in the aquifer west of the river and changes in water quality with depth, (4) determine the lithology of the basin-fill deposits including size distribution and composition, and (5) provide for long-term monitoring of aquifer water levels and water quality at different locations and vertical levels.

Generalized Geology of the Albuquerque-Belen Basin

The Albuquerque-Belen Basin is bordered by uplifted rock on the east and west (fig. 2). The Sandia Mountains to the east of Albuquerque are of Precambrian and Paleozoic age. Large masses of Mesozoic rock are found west of Albuquerque, as are the Albuquerque volcanos and associated lava flows.

The Quaternary basin-fill deposits and Miocene, Pliocene, and Pleistocene deposits together comprise the aquifer. Differentiation between sediments of Quaternary age and older (Santa Fe Group) sediments was not attempted.

The Miocene, Pliocene, and Pleistocene sediments within the basin are called the Santa Fe Group in this report. Kelley (1977) referred to the sediments as the Santa Fe Formation and described them in detail. Some previous descriptions of the Santa Fe Group have used differences in color to identify individual units. The predominant colors were described by Kelley (1977). In this report, color of sediments is described in the geologist's log for each test well; however, no attempt was made to distinguish individual units. Kelley's lower Zia Sandstone Member of his Santa Fe Formation is light gray, medium gray, light buff, or light pink (Kelley, 1977, p. 12). It generally is poorly cemented and friable but locally may contain mud and gravel. The texture is medium to coarse with some upper beds of fine sand. Grains usually are subrounded and consist of clear quartz and red, black, and gray chert. The middle red member is above the Zia and according to Kelley (1977, p. 14), "The middle red member epitomizes the Santa Fe Formation [Group] of the Albuquerque Basin." It is pinkish, reddish, and purplish in color with fanglomerate and axial gravel, sand, and mud facies. Lithologic descriptions of the middle red member usually are mudstone, sandstone, or fanglomerate. The upper part of Kelley's Santa Fe Formation is the Ceja Member (Kelley, 1977, p. 18). Kelley reported, "The lithology of the Ceja Member is more variable than the middle red and the gravel is the principal characterizing aspect." Kelley (1977, p. 18-19) mapped the base of this unit at gravel deposits and included descriptions from earlier studies that described the gravels as angular or slightly rounded fragments of andesite and other volcanic rocks, but with more abundant quartzite, chert, and agate. The upper part of the unit has been described as yellowish to grayish, sandy-pebble gravel and pebbly sand with some interbedded clay, mud, and sand.

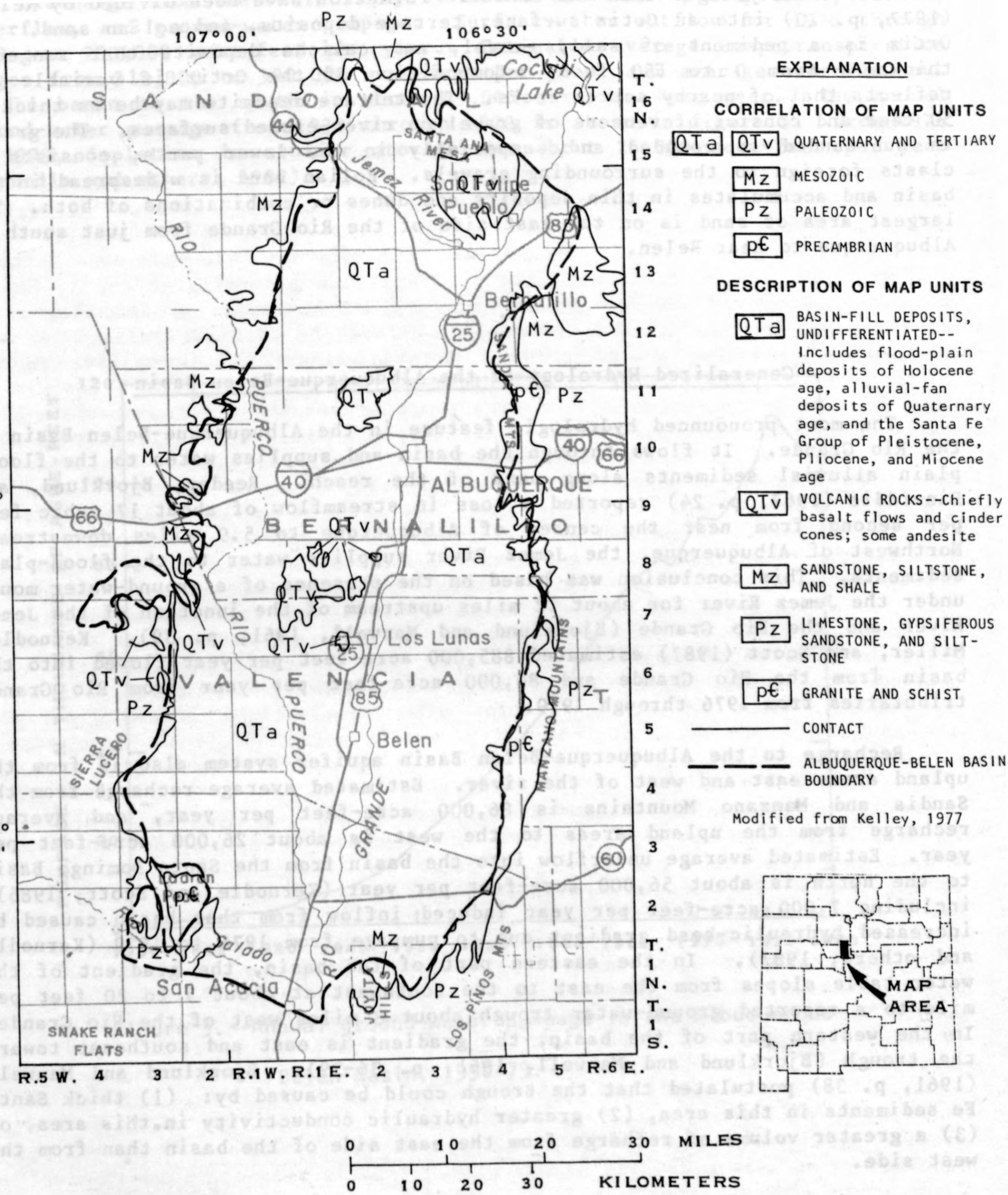

Figure 2.--Generalized geology of the Albuquerque-Belen Basin.

Sediments younger than the Santa Fe Formation have been divided by Kelley (1977, p. 20) into an Ortiz surface, terrace deposits, and eolian sand. The Ortiz is a pediment of sand, gravel, and caliche deposits that range in thickness from 0 to 150 feet. Composition of the Ortiz is variable and reflects that of nearby source rocks. The terrace deposits may be as thick as 50 feet and consist of veneers of gravel on river-eroded surfaces. The gravel is subrounded to rounded and, especially in the lower parts, consists of clasts foreign to the surrounding gravels. Eolian sand is widespread in the basin and accumulates in thin deposits and dunes or combinations of both. The largest area of sand is on the east side of the Rio Grande from just south of Albuquerque to near Belen.

Generalized Hydrology of the Albuquerque-Belen Basin

The most pronounced hydrologic feature in the Albuquerque-Belen Basin is the Rio Grande. It flows through the basin and supplies water to the flood-plain alluvial sediments along part of the reach. Reeder, Bjorklund, and Dinwiddie (1967, p. 24) reported a loss in streamflow of about 17 cubic feet per second from near the center of Albuquerque to 5.9 miles downstream. Northwest of Albuquerque, the Jemez River supplies water to the flood-plain sediments. This conclusion was based on the presence of a ground-water mound under the Jemez River for about 12 miles upstream of the junction of the Jemez River and the Rio Grande (Bjorklund and Maxwell, 1961, p. 39). Kernodle, Miller, and Scott (1987) estimated 885,000 acre-feet per year flowed into the basin from the Rio Grande and 80,000 acre-feet per year from Rio Grande tributaries from 1976 through 1979.

Recharge to the Albuquerque-Belen Basin aquifer system also is from the upland areas east and west of the river. Estimated average recharge from the Sandia and Manzano Mountains is 86,000 acre-feet per year, and average recharge from the upland areas to the west is about 26,000 acre-feet per year. Estimated average underflow into the basin from the Santo Domingo Basin to the north is about 56,000 acre-feet per year (Kernodle and Scott, 1986), including 7,000 acre-feet per year induced inflow from that basin caused by increased hydraulic-head gradient due to pumpage from 1976 to 1979 (Kernodle and others, 1987). In the eastern part of the basin, the gradient of the water table slopes from the east to the southwest at about 5 to 20 feet per mile to a reported ground-water trough about 8 miles west of the Rio Grande. In the western part of the basin, the gradient is east and southeast toward the trough (Bjorklund and Maxwell, 1961, p. 36-39). Bjorklund and Maxwell (1961, p. 38) postulated that the trough could be caused by: (1) thick Santa Fe sediments in this area, (2) greater hydraulic conductivity in this area, or (3) a greater volume of recharge from the east side of the basin than from the west side.

Discharge from the basin is by river and drain flow, evapotranspiration, underflow, and ground-water pumpage. Surface-water outflow for 1976 through 1979 was 753,000 acre-feet per year. Estimated average evapotranspiration ranges from 310,000 to 390,000 acre-feet per year, and average underflow out of the basin to the south is about 49,000 acre-feet per year. The annual ground-water pumpage from 1930 through 1979 is shown in figure 3. From 1976 to 1979, depletion in aquifer storage was about 25,000 acre-feet per year (Kernodle and others, 1987).

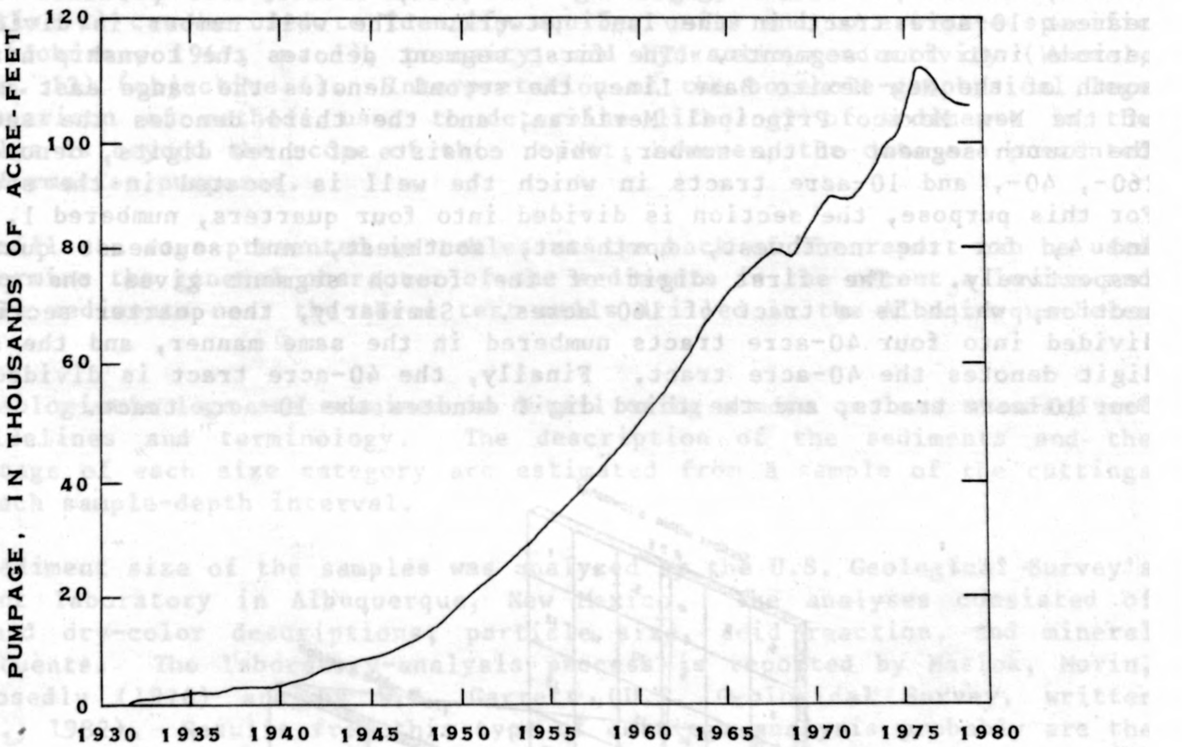

Figure 3.--Annual ground-water pumpage in the Albuquerque-Belen Basin, 1930-79.

Location of Test Wells

Location of the three test wells is shown in figure 1. Test wells 1 and 2 were located because of nearness to the reported ground-water trough (Bjorklund and Maxwell, 1961) and because of lack of knowledge of the flow system near this reported feature. Aquifer characteristics, including water levels, were not available between the area of volcanic rocks west of Albuquerque and the Rio Puerco (fig. 3). Test well 3 was located near the flood plain of the Rio Grande to provide aquifer and vertical-flow information at depth in this area.

The location of each test well is identified according to the system of numbering wells used in New Mexico (fig. 4). This system of numbering wells is based on the common subdivision of public lands into sections. The well number, in addition to designating the well, locates its position to the nearest 10-acre tract in the land network. The well number is divided by periods into four segments. The first segment denotes the township north or south of the New Mexico Base Line, the second denotes the range east or west of the New Mexico Principal Meridian, and the third denotes the section. The fourth segment of the number, which consists of three digits, denotes the 160-, 40-, and 10-acre tracts in which the well is located in the section. For this purpose, the section is divided into four quarters, numbered 1, 2, 3, and 4, for the northwest, northeast, southwest, and southeast quarters, respectively. The first digit of the fourth segment gives the quarter section, which is a tract of 160 acres. Similarly, the quarter section is divided into four 40-acre tracts numbered in the same manner, and the second digit denotes the 40-acre tract. Finally, the 40-acre tract is divided into four 10-acre tracts, and the third digit denotes the 10-acre tract.

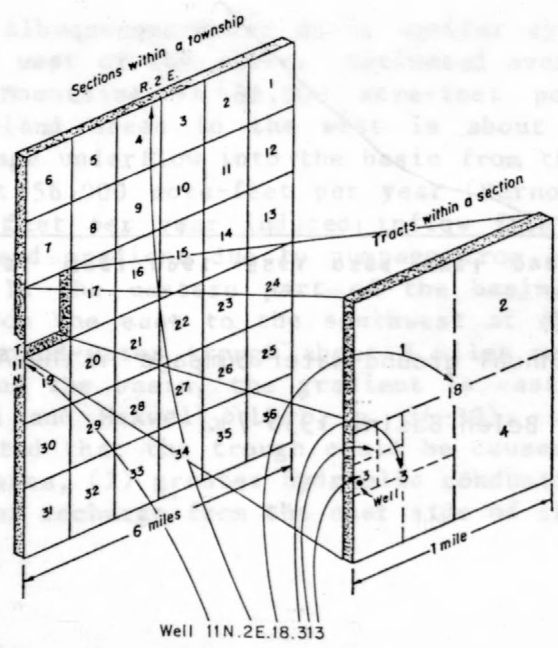

Figure 4.--System of numbering wells in New Mexico.

GENERAL TEST-WELL CONSTRUCTION AND METHODS OF DATA COLLECTION

The test wells were drilled by hydraulic rotary method to a depth of 1,000 feet below the potentiometric surface or until drilling could not be continued. Drilling mud was used to extract cuttings from the borehole. Cuttings were ejected from the mud discharge pipe through a hole drilled in the bottom of the pipe and caught in a strainer. Samples of cuttings were collected and described by the driller. They were bagged, labeled, and given to a geologist for detailed description. Although the samples were washed by the driller, they contained some drilling mud when percentages of different material were estimated and listed by the geologist.

Driller's logs, geologist's logs, borehole-geophysical logs, and results of drill-cutting analyses are presented to partially fulfill objectives 2 and 4, presented previously in the report. Lithology of the aquifer sediments (objective 2) can be used to identify aquifer units and to estimate specific yield (Johnson, 1967, p. 1), porosity, and hydraulic conductivity (Wenzel, 1942, p. 13) (objective 4). Interpretation of the borehole-geophysical logs or comparison of methods used to determine lithology of sediments in the boreholes is beyond the scope of this report; however, the data are presented for information purposes.

Driller's logs presented in tables at the back of the report can be used to determine the general character of the sediments in the recent alluvium and Santa Fe sediments near the three test wells drilled in the Albuquerque-Belen Basin.

Geologist's logs are examined in detail using a more or less standard set of guidelines and terminology. The description of the sediments and the percentage of each size category are estimated from a sample of the cuttings from each sample-depth interval.

Sediment size of the samples was analyzed by the U.S. Geological Survey's sediment laboratory in Albuquerque, New Mexico. The analyses consisted of wet- and dry-color descriptions, particle size, acid reaction, and mineral constituents. The laboratory-analysis process is reported by Matlok, Morin, and Posedly (1976) and by W.B. Garrett (U.S. Geological Survey, written commun., 1982). Results from this type of cuttings analysis probably are the most appropriate in estimating aquifer properties using sediment-size data. Using sediment-size data and tables 1 and 2, estimates of specific yield (table 1), porosity, and hydraulic conductivity (table 2) at selected depths below land surface or for the total saturated interval can be made. Porosity and hydraulic-conductivity estimates using sediment-size data, modified from Wenzel (1942, p. 13), are presented in table 2. Well numbers have been eliminated from the table and percentages of sediments in selected size categories have been summed up to correspond to the size categories used in the sediment-size analysis of this study. These estimates will be approximate and should be used only as a general guide to the range of aquifer-property values that may be expected near the borehole from where the samples were collected.

Specific yield, the ratio of the volume of water that will drain by gravity from a saturated rock to the total volume of the rock, is useful in estimating the volume of ground water that might be drained from an aquifer. Porosity is the total volume of void space in a volume of rock and is a measure of the quantity of water contained in a unit volume of saturated aquifer material. Both specific yield and porosity are expressed as percentages. Hydraulic conductivity is a measure of the capability of aquifer material to transmit water and is important in calculating the productivity of wells and well fields. It is defined as the volume of water in cubic feet that will flow through an area 1 foot square under a hydraulic gradient of 1 foot per foot. It is expressed in units of feet per day. Several investigators have presented relations between these three characteristics and size of aquifer material. Johnson (1967, p. 1) presented a summary table resulting from the compilation of specific-yield values estimated from aquifer material size data. A modified form of this table is presented as table 1.

Table 1. Estimates of specific yield using sediment-size data

[Modified from Johnson, 1967]

Material	Specific yield		
	Maximum	Minimum	Average
Clay	5	0	2
Silt	19	3	8
Sandy clay	12	3	7
Fine sand	28	10	21
Medium sand	32	15	26
Coarse sand	35	20	27
Gravelly sand	35	20	25
Fine gravel	35	21	25
Medium gravel	26	13	23
Coarse gravel	26	12	22

Table 2. Estimates of porosity and hydraulic conductivity using sediment-size data

Percent grain size				
Clay and silt (mean diameter ≤0.062 millimeter)	Sand (mean diameter 0.062≤2.0 millimeters)	Very fine to coarse gravel (mean diameter >2.0 millimeters)	Porosity (percent)	Hydraulic conductivity (feet per day)
65.0	35.0	--	58.2	2.7×10^{-5}
94.6	4.4	--	55.5	2.7×10^{-2}
65.5	34.8	--	45.1	8.0×10^{-1}
49.0	50.4	--	54.2	2.7×10^{0}
1.5	77.6	19.6	37.0	4.0×10^{0}
6.8	94.0	--	39.3	6.0×10^{0}
1.3	98.8	--	46.6	8.0×10^{0}
3.3	96.8	--	34.3	1.1×10^{1}
33.9	66.4	--	52.2	1.3×10^{1}
6.0	78.3	15.4	26.3	2.0×10^{1}
4.7	80.4	14.3	41.8	2.9×10^{1}
1.4	80.8	17.3	30.2	4.7×10^{1}
.6	69.6	29.7	27.1	6.4×10^{1}
4.3	76.5	17.7	33.2	7.9×10^{1}
3.1	69.1	27.4	25.6	9.6×10^{1}
.6	82.5	15.9	31.2	1.2×10^{2}
.2	77.4	21.1	28.9	1.3×10^{2}
.4	80.4	17.9	31.4	1.6×10^{2}
.6	67.9	31.3	26.1	1.8×10^{2}
.6	82.5	16.8	32.3	2.0×10^{2}
.4	90.9	8.5	29.7	2.4×10^{2}
5.3	72.4	20.6	25.0	2.8×10^{2}
.4	72.5	25.9	30.0	3.2×10^{2}
.3	52.7	46.9	27.5	3.4×10^{2}
.4	59.1	40.4	27.2	3.5×10^{2}
.5	68.1	31.3	33.3	4.6×10^{2}
.2	36.4	63.3	25.4	5.3×10^{2}
.2	24.1	75.2	23.4	5.6×10^{2}
2.3	48.9	48.1	28.1	5.9×10^{2}
.4	28.0	71.7	31.9	8.3×10^{2}
.4	75.7	23.4	33.3	1.1×10^{3}
.2	31.3	68.2	25.6	1.7×10^{3}
4.8	15.4	79.8	25.1	2.8×10^{3}
.2	30.4	70.0	36.8	3.3×10^{3}
.1	10.1	90.0	38.0	1.2×10^{4}

Modified from Wenzel, 1942, p. 13
Note: Percentages may not add up to 100 because of rounding.

After the final depth of the borehole was reached, a suite of geophysical logs was run in each borehole as summarized in the following table and shown on plates 1, 2, and 3:

Test well	Gamma	Spontaneous potential	Resistivity	Neutron	Bulk density 5-inch	6-inch	13-inch	17-inch	Normal	Temperature
1	X	X	X	X	X	--	--	X	--	X
2	X	X	X	X	--	X	X	--	X	X
3	X	--	X	X	X	--	--	X	--	X

These logs were used to select intervals that would be cased with either blank or 0.04-inch mill-slot perforated casing. Perforated intervals were selected opposite beds of sand and gravel. The perforated intervals were separated by beds of clay and silt that would restrict vertical leakage of water along the casing between the perforated intervals. Selected bulk-density logs were made to ensure there were no large void spaces between the casing and the borehole wall that would allow hydraulic communication between perforated intervals. This finished well configuration allowed monitoring of hydraulic head and water quality from selected aquifer zones.

After blank and mill-slot casing was set in each borehole, the well was developed using air to surge the aquifer. If surging resulted in relatively sand-free water, the well was considered developed. While developing test well 2, sand entered the well through the perforated intervals and it could not be developed or tested as described below for test wells 1 and 3. For test wells 1 and 3, a submersible electric pump was placed in the 6-inch casing and the well was pumped. This initial pumping was set up as an aquifer step test. The purpose was to test pump the aquifer and to check that the well was developed using the analysis method reported by Birsoy and Summers (1980). If the well was not developed, pumping continued until full development was likely.

During pumping, the discharge water was continuously monitored for temperature, specific conductance, and pH. Monitoring was done by diverting about 1 gallon per minute from the discharge pipe and circulating this flow through a plastic bucket in which monitoring probes for these water-quality properties were placed. The data were recorded on a three-channel strip-chart recorder. If a significant change occurred in any of these properties, a water sample was collected for chemical analyses. The data also were used to determine that a representative water sample was collected. Samples of the discharge water were collected periodically during the test to assure that samples would be available for analysis prior to any change in water quality during pumping. Water samples were collected and prepared for analysis as specified by Brown, Skougstad, and Fishman (1970) and Wood (1976) and analyzed by the U.S. Geological Survey's laboratory in Lakewood, Colorado.

Packer tests were made by U.S. Geological Survey personnel based in Lakewood, Colorado. Gas-inflatable packers were separated by a set distance (straddle) unique for each test well that allowed each selected production interval in the test well to be pumped without changing the straddle. The submersible electric pump and a pressure transducer were located between packers. Pressure transducers also were located above the top packer and below the bottom packer. If both packers were inflated, changes in hydraulic head could be monitored in the pumped interval and above and below the pumped interval. By moving the drill stem and packers within the casing and inflating different combinations of packers, various intervals and combinations of intervals could be pumped and monitored for changes in hydraulic head and water quality. A generalized configuration of the system of packers, transducers, and pump used in testing test wells 1 and 3 is illustrated in figure 5.

Pressure transducers were calibrated by lifting and lowering the drill stem, usually 30 feet. Hydraulic heads monitored by the three transducers were recorded on a strip-chart recorder. If only one packer was inflated, then two transducers would be monitoring pressure in the pumped zone. The distance a 1-foot change in hydraulic head would cause the pen to move on the recorder chart was set differently for the two transducers in the pumped zone. The duplication of data was used as a check for hydraulic-head change, as a backup in case of transducer failure, and as a backup in case of exceeding the monitoring range of one of the transducers.

After the aquifer zones had been tested and water samples collected for each selected zone in wells 1 and 3 and after bailing was stopped in well 2, two strings of schedule 20 2-inch PVC pipe with a 5-foot plastic screen section were placed inside the 6-inch casing. The screened section was placed adjacent to a selected perforated interval of the 6-inch casing. The casing was filled with gravel to a point above the top of the perforated interval and bentonite clay pellets were laid over the top of the gravel to isolate the selected interval from intervals above. After expansion, the clay seal was about 20 feet thick. The next higher interval to be monitored was then finished as previously explained.

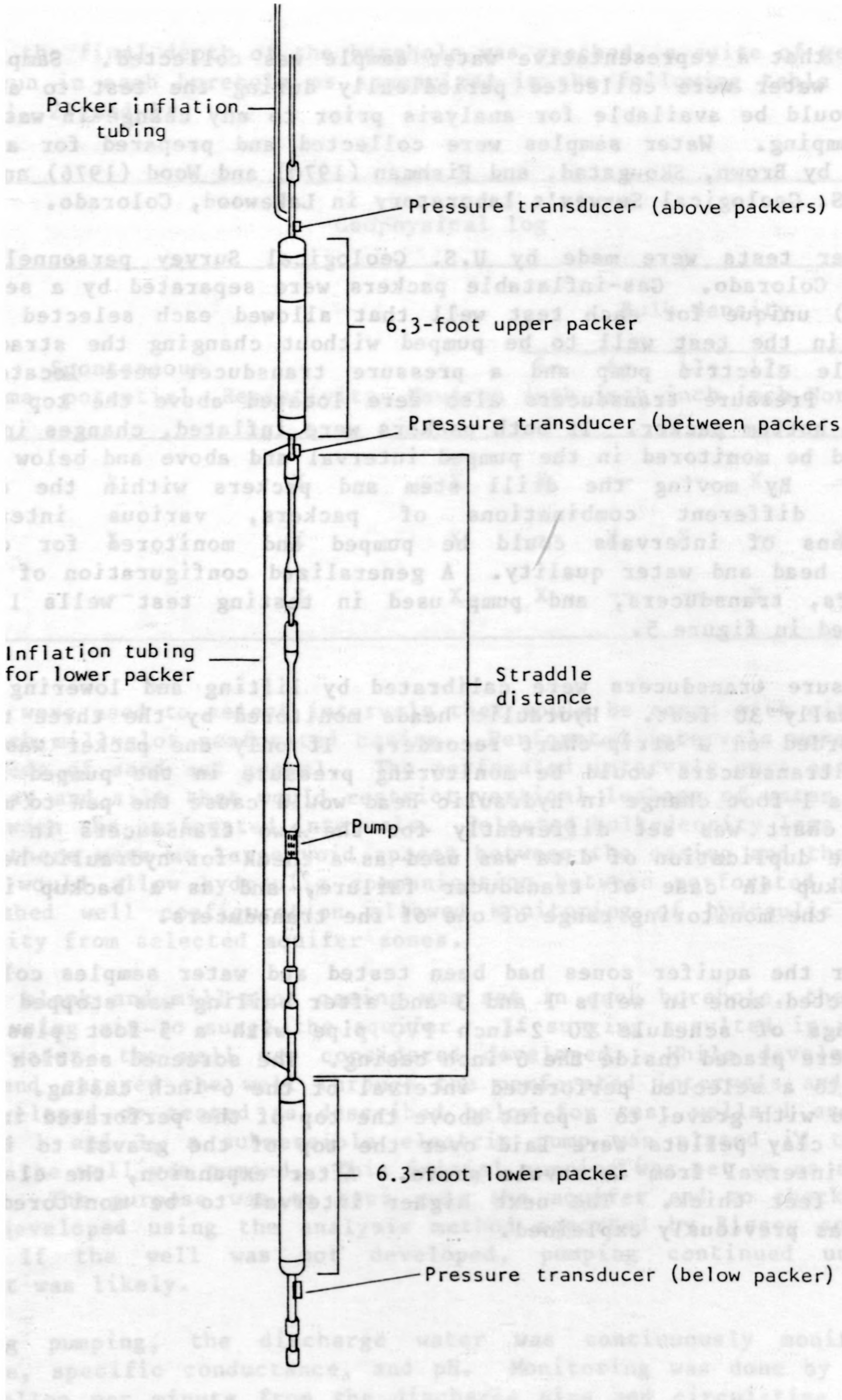

Figure 5.--Packer, transducer, and pump configuration used for aquifer tests.

CHARACTERISTICS AND PROPERTIES OF THE AQUIFER AT THE SITE OF TEST WELL 1

Test well 1 was located at 10N.1E.22.322 (fig. 1) for a number of reasons. Few hydrologic data are available and the reported ground-water trough is in this area. The site is not close to any commercial or housing development and the test well should provide water-level data under unstressed conditions for several years. In addition, surface geophysical studies and shallow ground temperature logs in this area, completed by the University of New Mexico, could be benefited by the borehole information.

Drilling History, Well Construction, and Geophysical Logs

Two boreholes were drilled at this site. The first borehole was started May 15, 1981, using an 8 3/4-inch bit. Circulation of drilling fluid was lost on May 22 at 1,211 feet below land surface in loose volcanic scoria. The drill string was being pulled when the borehole apparently caved and trapped the string. On June 2, the drill string was shot off, leaving about 80 feet of the string and the bit in the borehole. This borehole was plugged with 6 cubic yards of concrete. The drill rig was moved about 8 feet east and another borehole started.

Drilling began on the second borehole on June 8 and ceased June 12 at 1,178 feet so gamma, resistivity, spontaneous-potential, and neutron logs could be made (pl. 1). Continued drilling resulted in lost circulation at 1,188 feet, but the borehole was drilled to 1,204 feet without fluid return. Blank and 0.040-inch mill-slot perforated casing was set to a depth of 1,179 feet (fig. 6); no gravel pack or sealing material was placed between the borehole wall and the casing. After the water temperature reached equilibrium, the borehole was logged with a temperature sonde. Prior to conducting packer tests in the test well, bulk-density logs (pl. 1) were made below the water table, using spans between the emitter and receiver of 5 and 17 inches, respectively, to determine that there were no extended annular spaces adjacent to the casing that might allow leakage of water along the outside of the casing.

Characteristics of Deposits Penetrated

The driller's log of deposits penetrated during drilling of test well 1 is shown in table 3. The geologist's descriptions of cuttings below the potentiometric surface are listed in table 4. Results of the laboratory cuttings analysis are shown in figure 7. The percentage of fine to coarse gravel (greater than 4.0 millimeters mean diameter) decreases with depth. Near land surface, this size material comprises about 35 percent of the total sediments. From about 500 feet below land surface to the bottom of the borehole, this size material generally is not present. As the percentage of gravel decreases, the percentage of clay and silt increases from about 15 to 35 percent of the total material. At 830 feet below land surface, the percentage of clay and silt generally tends to decrease and the percentage of sand increases. Estimates of specific yield, porosity, and hydraulic conductivity are possible using sediment-size data such as that presented in figure 7 and tables 1 and 2.

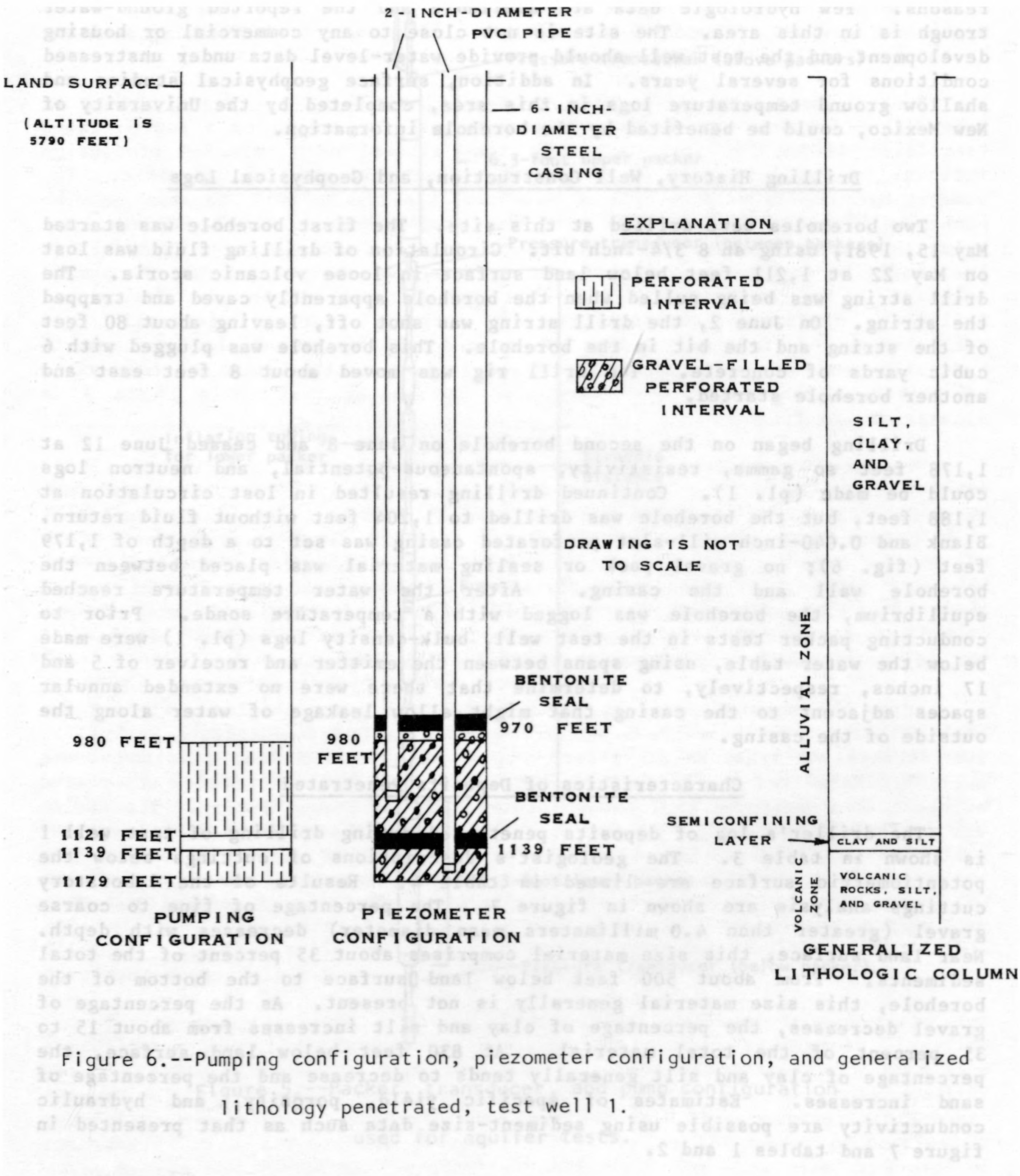

Figure 6.--Pumping configuration, piezometer configuration, and generalized lithology penetrated, test well 1.

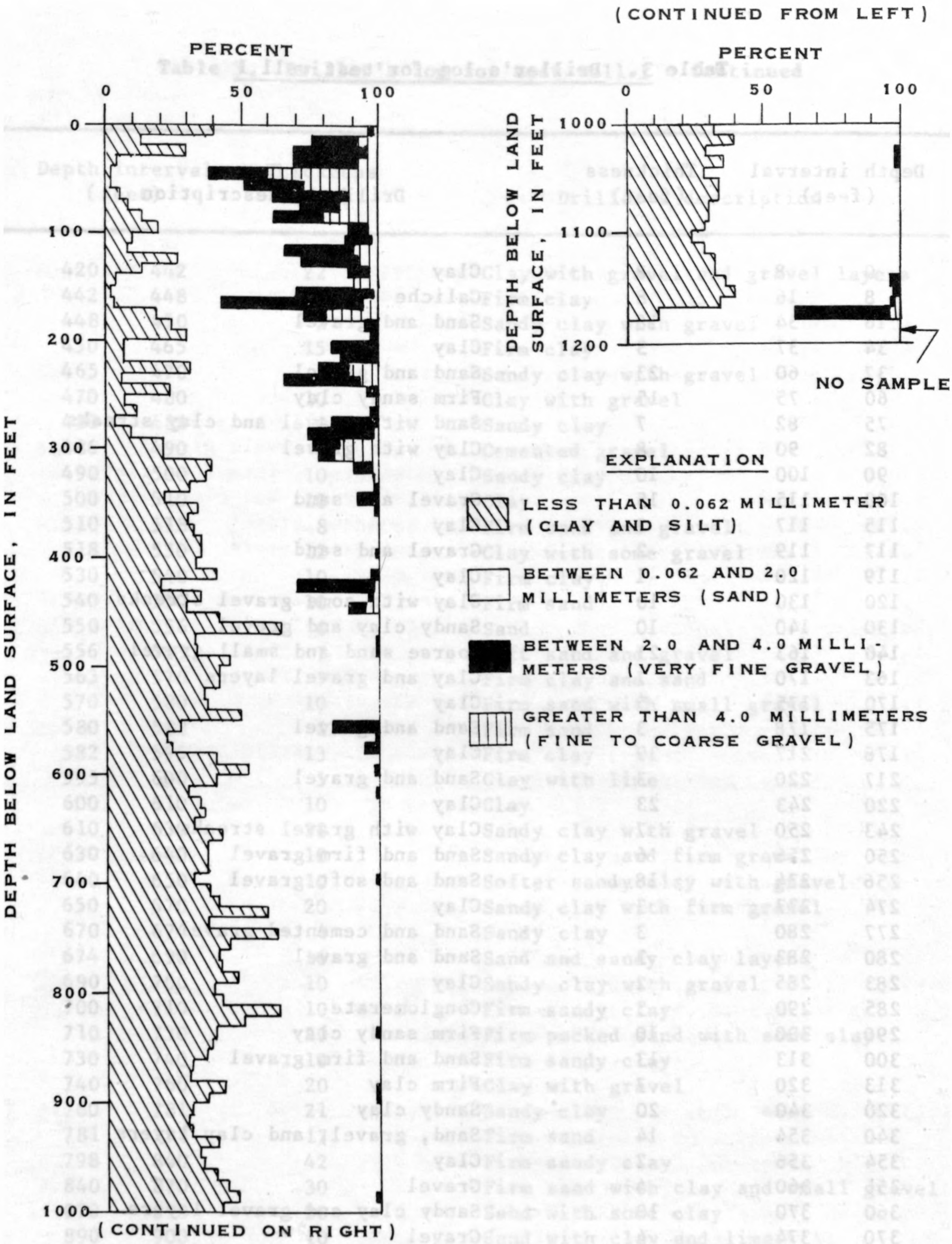

Figure 7.--Percentage of selected sediment sizes in drill-cutting material from test well 1.

Table 3. Driller's log for test well 1

Depth interval (feet)		Thickness (feet)	Driller's description
0	8	8	Clay
8	16	8	Caliche
16	34	18	Sand and gravel
34	37	3	Clay
37	60	23	Sand and gravel
60	75	15	Firm sandy clay
75	82	7	Sand with gravel and clay streaks
82	90	8	Clay with gravel
90	100	10	Clay
100	115	15	Gravel and sand
115	117	2	Clay
117	119	2	Gravel and sand
119	120	1	Clay
120	130	10	Clay with some gravel streaks
130	140	10	Sandy clay and gravel
140	163	23	Coarse sand and small gravel
163	170	7	Clay and gravel layers
170	175	5	Clay
175	178	3	Sand and gravel
178	217	39	Clay
217	220	3	Sand and gravel
220	243	23	Clay
243	250	7	Clay with gravel streaks
250	256	6	Sand and firm gravel
256	274	18	Sand and soft gravel
274	277	3	Clay
277	280	3	Sand and cemented gravel
280	283	3	Sand and gravel
283	285	2	Clay
285	290	5	Conglomerate
290	300	10	Firm sandy clay
300	313	13	Sand and firm gravel
313	320	7	Firm clay
320	340	20	Sandy clay
340	354	14	Sand, gravel, and clay layers
354	356	2	Clay
356	360	4	Gravel
360	370	10	Sandy clay and gravel layers
370	374	4	Gravel
374	378	4	Firm clay
378	386	8	Sandy clay with gravel
386	390	4	Sand and gravel
390	410	20	Sandy clay with gravel
410	420	10	Gravel and sandy clay layers

Table 3. Driller's log for test well 1 - Continued

Depth interval (feet)		Thickness (feet)	Driller's description
420	442	22	Clay with gravel and gravel layers
442	448	6	Firm clay
448	450	2	Sandy clay with gravel
450	465	15	Firm clay
465	470	5	Sandy clay with gravel
470	480	10	Clay with gravel
480	486	6	Sandy clay
486	490	4	Cemented gravel
490	500	10	Sandy clay
500	510	10	Clay
510	518	8	Firm sand and gravel
518	530	12	Clay with some gravel
530	540	10	Firm clay
540	550	10	Firm sand
550	556	6	Sand
556	563	7	Soft sand and gravel
563	570	7	Firm clay and sand
570	580	10	Firm sand with small gravel
580	582	2	Firm sand
582	595	13	Firm clay
595	600	5	Clay with lime
600	610	10	Clay
610	630	20	Sandy clay with gravel
630	640	10	Sandy clay and firm gravel
640	650	10	Softer sandy clay with gravel
650	670	20	Sandy clay with firm gravel
670	674	4	Sandy clay
674	690	16	Sand and sandy clay layers
690	700	10	Sandy clay with gravel
700	710	10	Firm sandy clay
710	730	20	Firm packed sand with some clay
730	740	10	Firm sandy clay
740	760	20	Clay with gravel
760	781	21	Sandy clay
781	798	17	Firm sand
798	840	42	Firm sandy clay
840	870	30	Firm sand with clay and small gravel
870	890	20	Sand with some clay
890	900	10	Sand with clay and lime
900	910	10	Firm sand
910	930	20	Sand
930	960	30	Sandy clay with some gravel
960	977	17	Sandy clay
977	988	11	Softer sandy clay

Table 3. Driller's log for test well 1 - Concluded

Depth interval (feet)		Thickness (feet)	Driller's description
988	995	7	Sandy clay
995	1,000	5	Soft clay
1,000	1,005	5	Clay
1,005	1,010	5	Firm sandstone
1,010	1,025	15	Sandy clay
1,025	1,030	5	Sand
1,030	1,040	10	Sand with small gravel
1,040	1,070	30	Firm sand with small gravel
1,070	1,090	20	Sand and gravel with some clay
1,090	1,100	10	Sand and gravel and clay layers
1,100	1,110	10	Firm sand and gravel
1,110	1,130	20	Clay and sand layers
1,130	1,142	12	Sandy clay
1,142	1,147	5	Sandstone streaks and clay layers
1,147	1,157	10	Cemented gravel and clay layers
1,157	1,170	13	Firm sandy clay with some gravel
1,170	1,175	5	Gravel layers, rough drilling
1,175	1,180	5	Clay and gravel
1,180	1,188	8	Hard basalt
1,188	1,204	16	Basalt, no cuttings returned

Table 4. Geologist's log for test well 1

Depth interval (feet)		Cuttings description
800	810	Silt, light-tan (95 percent); gray to white, fine-grained, subrounded sand, quartz (5 percent).
810	820	Silt, light-brown (50 percent); brown clay (50 percent).
820	830	Silt, light-brown (80 percent); light-brown clay (20 percent).
830	850	Silt, light-brown (95 percent); gray to white, fine-grained sand, quartz (5 percent); sparse brown clay.
850	860	Silt, light-brown (80 percent); gray to white, fine- to very fine grained, subrounded sand, quartz (20 percent).
860	890	Silt, light-brown (70 percent); gray to white, fine- to very fine grained, subangular to subrounded sand with 90 percent quartz (30 percent).
890	900	Silt, light-brown (60 percent); gray to white, fine- to very fine grained, subangular to subrounded sand with 90 percent quartz (40 percent).
900	910	Silt, light-brown (80 percent); gray to white, fine- to very fine grained, subangular to subrounded sand with 90 percent quartz and sparse basalt (20 percent).
910	930	Silt, light-brown (60 percent); gray to white, fine-grained, subangular to subrounded sand with 90 percent quartz (40 percent).
930	950	Silt, light-brown (80 percent); gray to white, fine- to very fine grained, subangular to subrounded sand with 90 percent quartz and sparse basalt (20 percent).
950	990	Silt, light-brown (60 percent); light-brown clay (40 percent).

Table 4. Geologist's log for test well 1 - Continued

Depth interval (feet)		Cuttings description
990	1,000	Silt, light-brown (60 percent); light-brown clay (35 percent); medium- to fine-grained, subangular to subrounded sand with quartz and basalt (5 percent).
1,000	1,010	Silt, light-brown (80 percent); gray to white, medium- to fine-grained, subangular to subrounded sand with 90 percent quartz and very sparse basalt (20 percent).
1,010	1,020	Silt, light-brown (80 percent); gray to white, fine-grained, subangular to subrounded sand with 90 percent quartz and very sparse basalt (20 percent).
1,020	1,030	Silt, light-brown (60 percent); gray to white, medium- to fine-grained, subangular to subrounded sand with 90 percent quartz (40 percent).
1,030	1,040	Silt, light-brown (60 percent); gray to white, medium-grained, subangular to subrounded sand with 90 percent quartz (40 percent).
1,040	1,070	Silt, light-brown (80 percent); gray to white, medium- to fine-grained, subangular to subrounded sand with 90 percent quartz (20 percent).
1,070	1,080	Silt, light-brown (80 percent); gray to white, medium- to fine-grained, subangular to subrounded sand with quartz and sparse basalt (20 percent).
1,080	1,090	Silt, light-brown (90 percent); gray to white, fine-grained, subangular to subrounded sand with quartz (10 percent).
1,090	1,120	Silt, light-brown (80 percent); gray to white, fine-grained, subangular to subrounded sand with quartz (20 percent).
1,120	1,130	Silt, orange to brown (80 percent); gray to white, fine-grained, subangular to subrounded sand with quartz (20 percent).

Table 4. Geologist's log for test well 1 - Concluded

Depth interval (feet)		Cuttings description
1,130	1,140	Silt, orange to brown (90 percent); gray to white, fine-grained, subangular to subrounded sand (10 percent).
1,140	1,150	Silt, brown (80 percent); gray to white, medium- to fine-grained, subangular to subrounded sand with quartz (20 percent).
1,150	1,160	Silt, brown to orange (60 percent); gray basalt (40 percent).
1,160	1,170	Silt, brown; basalt.
1,170	1,188	Volcanic - poor sample.

Water Quality

Water samples for chemical analysis were collected from test well 1 during initial testing of the well (all perforated intervals open to the pump) and during packer tests (selected perforated intervals open to the pump). In each case, discharge water was continuously monitored for temperature, pH, and specific conductance. Samples were collected periodically to ensure representative water would be available for water-quality analysis if large changes in water chemistry developed during pumping; no such changes were noted. The chemical characteristics of water from test well 1 are listed in table 5. Analytical results are for all intervals contributing water to the pump, for only the volcanic zone contributing water, and for only the alluvial zone contributing water.

Because water on the West Mesa probably will be used for a municipal supply, the analyses have been compared to maximum levels for constituents that are harmful to humans (maximum contaminant levels) (U.S. Environmental Protection Agency, 1977, p. 5) and for constituents that affect the desirability of a water for municipal purposes but do not constitute a health hazard (recommended constituent levels) (National Academy of Sciences-National Academy of Engineering, 1973, p. 50-104). Maximum contaminant and recommended constituent levels for selected dissolved constituents are listed in table 6. The percent concentration of a given constituent compared to the maximum contaminant or recommended constituent level is shown in figure 8 using a diagram developed by Dulas (1978). The 100-percent line is the maximum contaminant or the recommended constituent level. Dissolved-manganese concentrations were always greater than the recommended constituent level. This constituent is not harmful to humans, but may cause encrustation and staining problems to plumbing systems. Dissolved-sulfate concentration exceeded the recommended constituent level for a sample collected when all perforated intervals were supplying water and was within 88 and 96 percent of the recommended constituent level in samples collected from the volcanic and alluvial zones, respectively. No analyzed constituents that are health hazards exceeded the maximum contaminant level.

Table 5. Analysis of water samples from water-producing zones in test well 1

[All constituents are dissolved; mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 °Celsius; °C, degrees Celsius]

Property or constituent	U.S. Geological Survey All zones	U.S. Geological Survey Volcanic zone	U.S. Geological Survey Alluvial zone	City of Albuquerque All zones
Alkalinity, total as calcium carbonate (mg/L)	210	207	201	-
Arsenic (µg/L)	-	31	-	28
Barium (µg/L)	-	19	-	50
Bicarbonate (field) (mg/L)	270	250	240	-
Boron (µg/L)	430	-	-	-
Cadmium (µg/L)	-	1	-	2
Calcium (mg/L)	22	22	21	-
Chloride (mg/L)	100	100	91	-
Chromium (µg/L)	-	10	-	8
Copper (µg/L)	-	4	-	30
Fluoride (mg/L)	0.9	0.8	0.8	-
Hardness, carbonate (mg/L)	76	77	71	-
Iron (µg/L)	99	500	83	2,100
Lead (µg/L)	-	9	-	9
Magnesium (mg/L)	5.1	5.2	4.5	-
Manganese (µg/L)	120	88	120	220
Mercury (µg/L)	-	0.2	-	1
Nickel (µg/L)	-	-	-	15
Nitrogen, nitrite plus nitrate as nitrogen (mg/L)	0.10	0.18	0.10	-
pH (field)	7.9	7.8	7.7	-
Potassium (mg/L)	8.1	7.4	6.2	7.1
Selenium (µg/L)	-	1	-	5
Silica (mg/L)	48	49	25	-
Silver (µg/L)	-	1	-	5
Sodium (mg/L)	250	240	230	220

Table 5. Analysis of water samples from water-producing zones in test well 1 - Concluded

Property or constituent	U.S. Geological Survey: All zones	U.S. Geological Survey: Volcanic zone	U.S. Geological Survey: Alluvial zone	City of Albuquerque: All zones
Specific conductance (field) (µS/cm)	1,160	1,250	1,125	-
Sulfate (mg/L)	270	220	240	-
Water temperature (°C)	33	32	30.5	-
Zinc (µg/L)	-	21	-	250

Table 6. **Maximum contaminant and maximum recommended levels for selected water-quality constituents**

Maximum contaminant levels[1]

Contaminant	Level (milligrams per liter)
Arsenic	0.05
Barium	1.0
Cadmium	.010
Chromium	.05
Lead	.05
Mercury	.002
Nitrate (as N)	10
Selenium	.01
Silver	.05
Fluoride (maximum annual average air temperature of 63.9 to 70.6 °F)	1.8

Maximum recommended levels[2]

Constituent	Level (milligrams per liter)
Chloride	250
Copper	1
Iron	.3
Manganese	.05
Sulfate	250
Zinc	5

[1] U.S. Environmental Protection Agency, 1977, p. 5.

[2] National Academy of Sciences - National Academy of Engineering, 1973, p. 50-104.

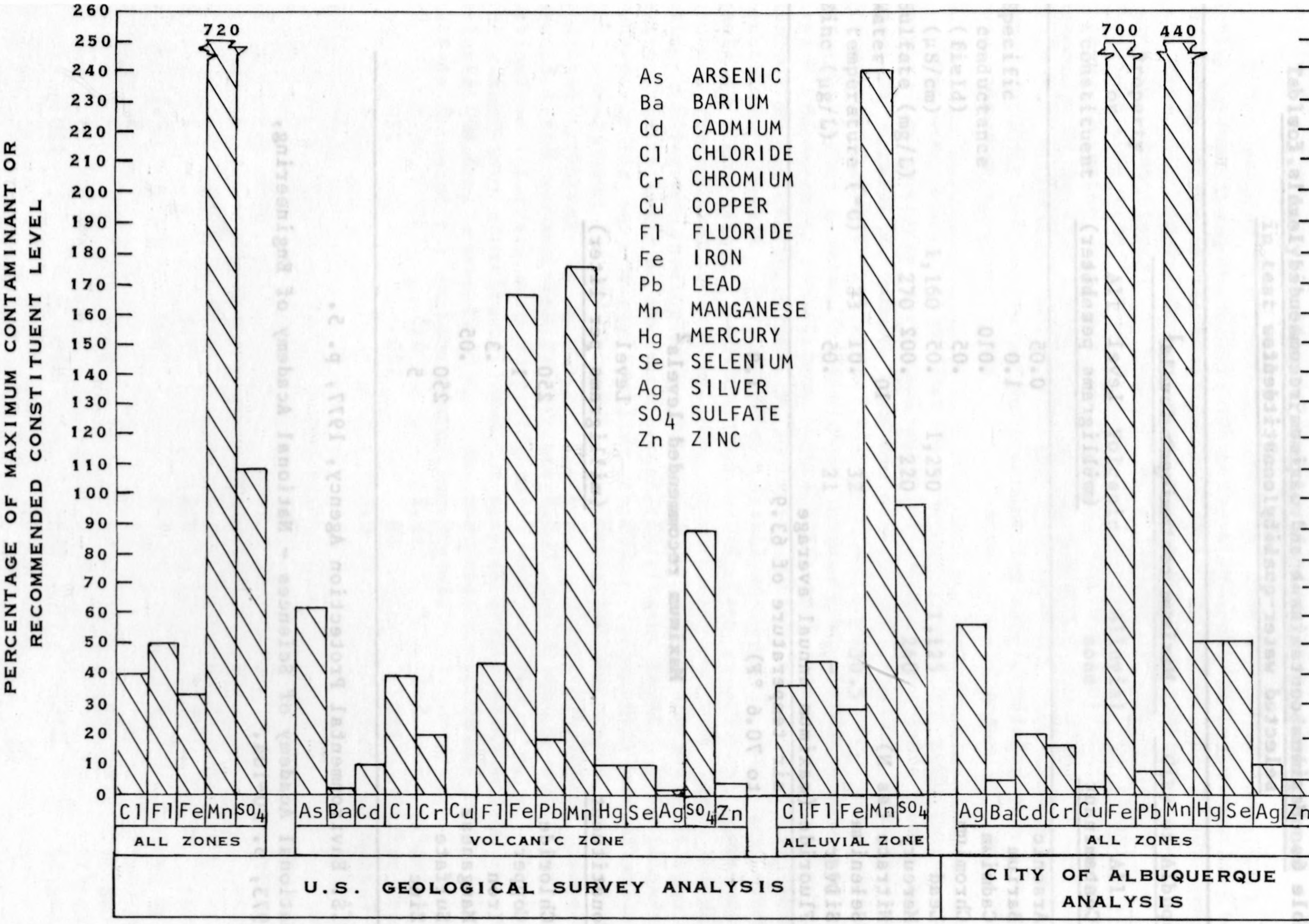

Figure 8.--Relation of dissolved constituents in water from test well 1 to maximum contaminant and recommended constituent levels.

Aquifer Tests and Related Estimates of Aquifer Properties

Air-inflatable packers were used to isolate and test two aquifer zones in test well 1, the volcanic zone (perforated interval from 1,139 to 1,179 feet below land surface) and the alluvial zone (perforated interval from 980 to 1,121 feet below land surface).

Volcanic Zone

The volcanic zone was isolated and pumped on January 15, 1983, with the bottom packer deflated and the top packer inflated at 1,136 feet below land surface. The pump was set at 1,158 feet below land surface. The change in hydraulic head during pumping and recovery for about 77 hours (4,500 minutes) of aquifer testing in the volcanic zone is shown in figure 9. Also shown in figure 9 are the change in hydraulic head monitored in the alluvial zone, changes in atmospheric pressure, and hydraulic-head corrections due to atmospheric-pressure changes during testing of the volcanic zone.

From drill cuttings, borehole-log information (tables 3 and 4 and fig. 7), and monitored hydraulic-head response to pumpage in the volcanic zone (fig. 10), the aquifer system appears to be a leaky confined aquifer system. The location and character of the lower boundary of the volcanic zone are not known. The interval from 980 to 1,139 feet below land surface of clay and silt overlying the volcanic zone is considered to be the semiconfining layer of the volcanic zone (fig. 6).

An estimate of transmissivity (Tv) and hydraulic conductivity (Kv) of the volcanic zone adjacent to the perforated interval can be made by analyzing the hydraulic-head changes during pumping. To correctly analyze the data, the part of the logarithmic plot (fig. 10) that matches the Theis-type curve (Theis, 1935) was selected. Data from about 30 to 400 minutes after pumping started were matched to the Theis nonequilibrium-type curve. The computed value of Tv is 81 feet squared per day; Kv was calculated by dividing Tv by the perforated interval (40 feet), resulting in a value of about 2.0 feet per day.

To assist in analyzing the aquifer response to pumping, drawdown data were plotted on semilogarithmic paper (fig. 11). This plot shows three distinct slopes. Slope 1 was established during early pumping and probably was affected by well development and filling of the pump column with water. Slope 2 was established when the aquifer was responding within the assumptions made for the Theis-type curve solution (fig. 10). Slope 3 consists of four-line segments with shifts to the right and then back to the left. The shift to the right is a result of lack of additional drawdown in the pumped zone from about 1,140 to 1,400 minutes after the pump was turned on. The shifts to the left are a result of increased drawdown. The first and last segments of slope 3 can be connected by a continuous line. The lack of additional drawdown may be caused by fine material being removed from the perforated interval of the volcanic zone (aquifer development); a nearby production well, completed at the approximate same depth, being turned off; or a change in the discharge rate. The nearest production well is about 2.5 miles southwest of test well 1. The production well is 1,385 feet deep and the reported water level is 935 feet below land surface (Bjorklund and Maxwell, 1961, p. 76). The production well probably is too far away to affect drawdown in test well 1. Pump discharge was checked periodically during the aquifer test without any variation in the measured rate.

The change from slope 2 to slope 3 indicates an intersection of the cone of depression with a boundary. Volcanic aquifer material that transmits water after a pumping time of 400 minutes apparently has a lower value of transmissivity than material encountered by the cone of depression prior to 400 minutes. The boundary may be a near-surface geologic structural feature. Jiracek (1982, p. 46, 52, and 55) located an electrical resistive ridge about 2 miles west of the well site using surface resistivity surveys. He reported a horstlike structure resulting from the uplift of underlying Cretaceous rocks that may be a barrier to ground-water flow. Volcanic sills occur north of the well site (Jiracek, 1982, p. 59). If the cone of depression reached a sill, the transmissivity of sediments supplying water to the well would be decreased and the slope could change as shown in figure 11. Which barrier was encountered by the cone of depression, if either, could not be determined because no observation well was available to define the expanding cone of depression.

Hydraulic head in the alluvial zone was monitored during pumping in the volcanic zone (fig. 9). Initially, there was an increase in hydraulic head of about 1 foot with the start of pumping. When the pump was turned off 2,900 minutes later, there was a decrease in hydraulic head of the same magnitude as the initial increase. The increasing hydraulic head probably resulted from compression of the aquifer around the well casing as a result of filling the pipe column with about 1,200 pounds of water. The decrease in hydraulic head from about 2,900 to 3,025 minutes probably was from water draining from the pipe column. The draining took about 70 minutes, whereas the filling was completed in about 36 minutes. The draining resulted from a leaky foot valve at the bottom of the pump column.

From 1,140 minutes to the time the pump was turned off, hydraulic head in the alluvial zone was higher than the drawdown trend (fig. 9) projected from the earlier data. From 1,140 minutes, there are three periods of time when drawdown in the volcanic zone was zero (for about 1,140 to 1,450; 1,875 to 2,025; and 2,390 to 2,720 minutes after the pump was started). The hydraulic-head increases in the alluvial zone do not appear to be related to atmospheric-pressure changes. Assuming a barometric efficiency of 0.75, the maximum change in hydraulic head caused by an atmospheric-pressure change from the time the pump started was a 0.33-foot increase at about 3,000 minutes into the test. Hydraulic-head adjustments of about +0.3 foot apply for most of the aquifer test (fig. 9).

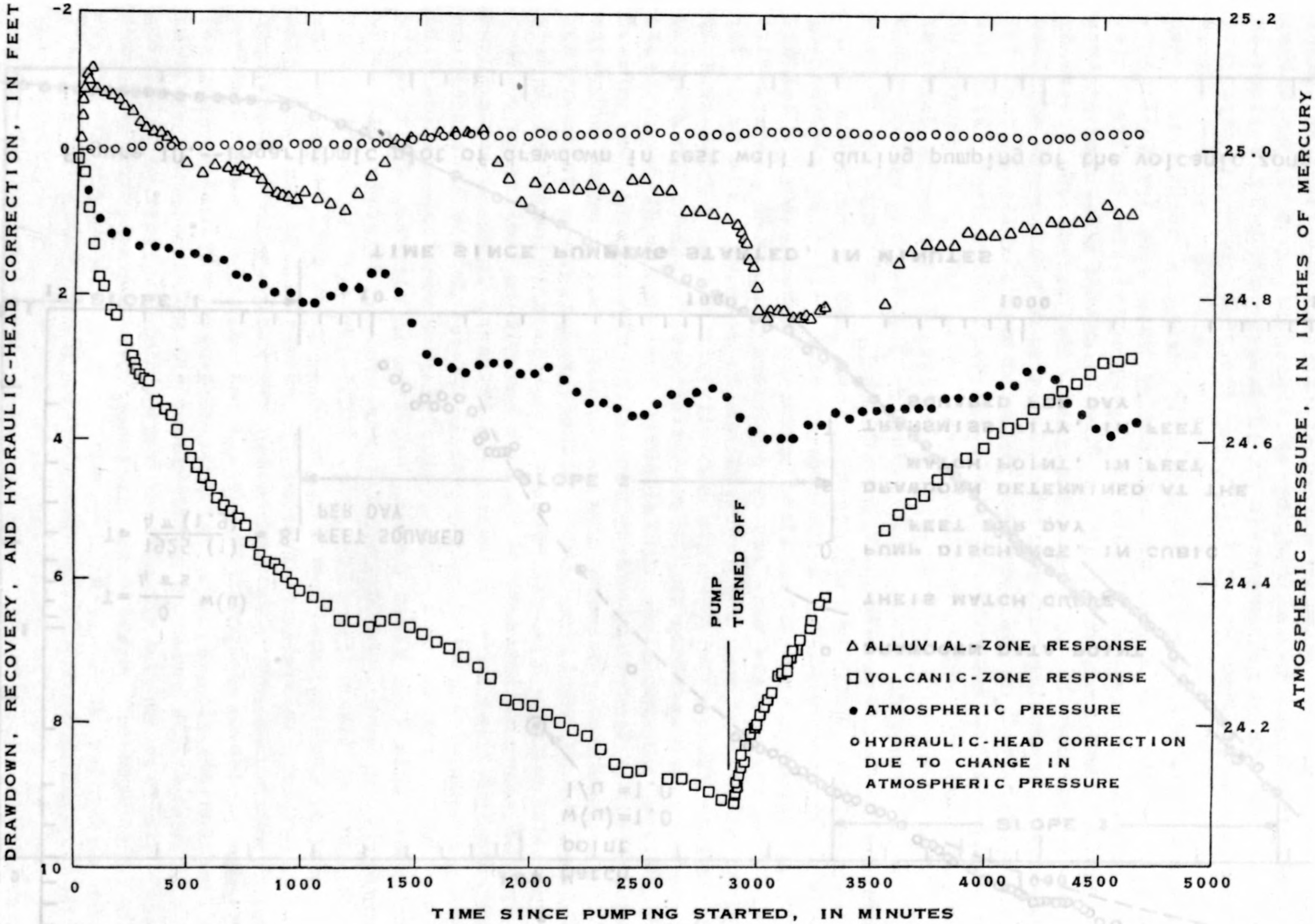

Figure 9.--Drawdown and recovery in the alluvial and volcanic zones, atmospheric pressure, and corrections to hydraulic heads due to changes in atmospheric pressure during testing of the volcanic zone in test well 1.

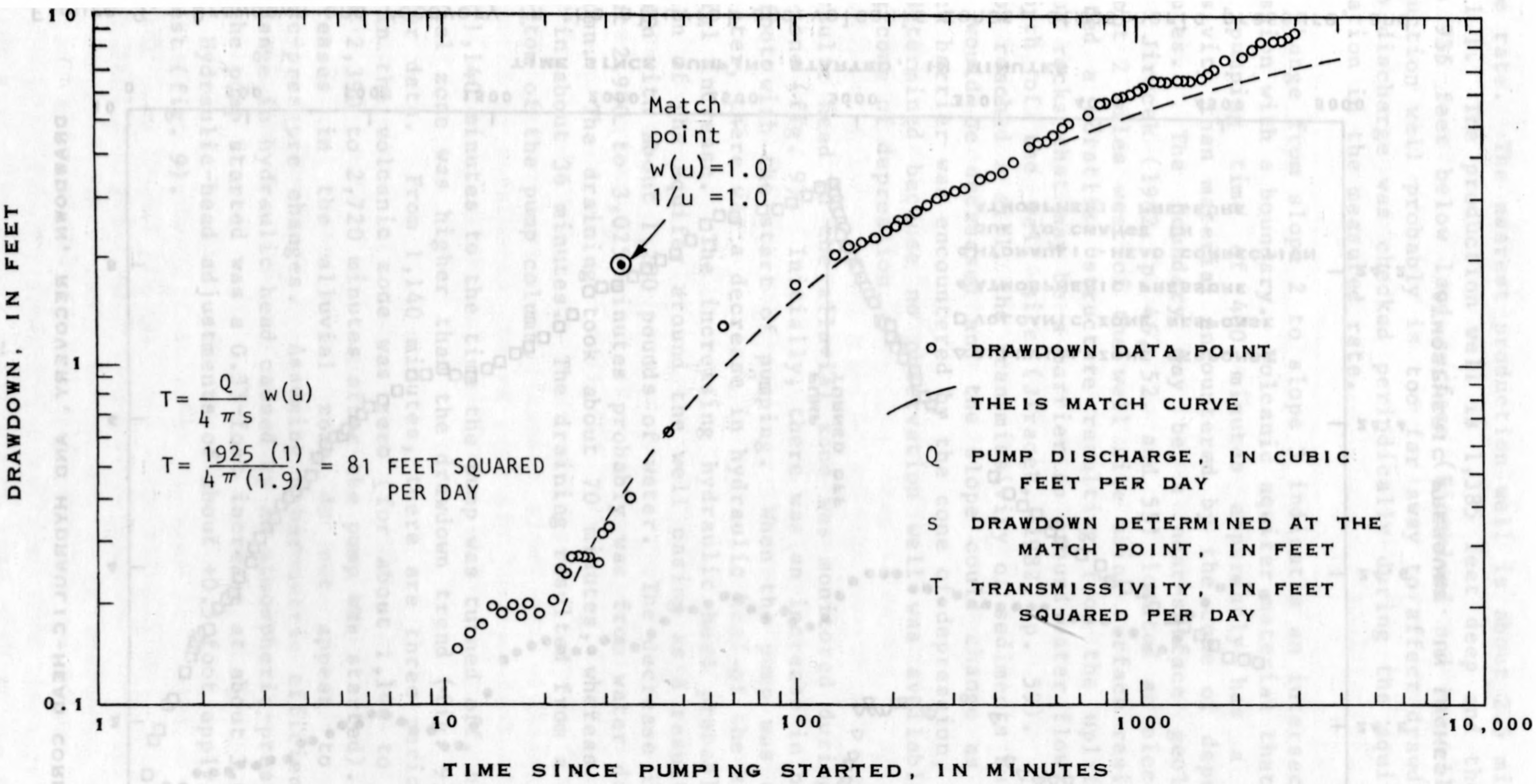

Figure 10.--Logarithmic plot of drawdown in test well 1 during pumping of the volcanic zone.

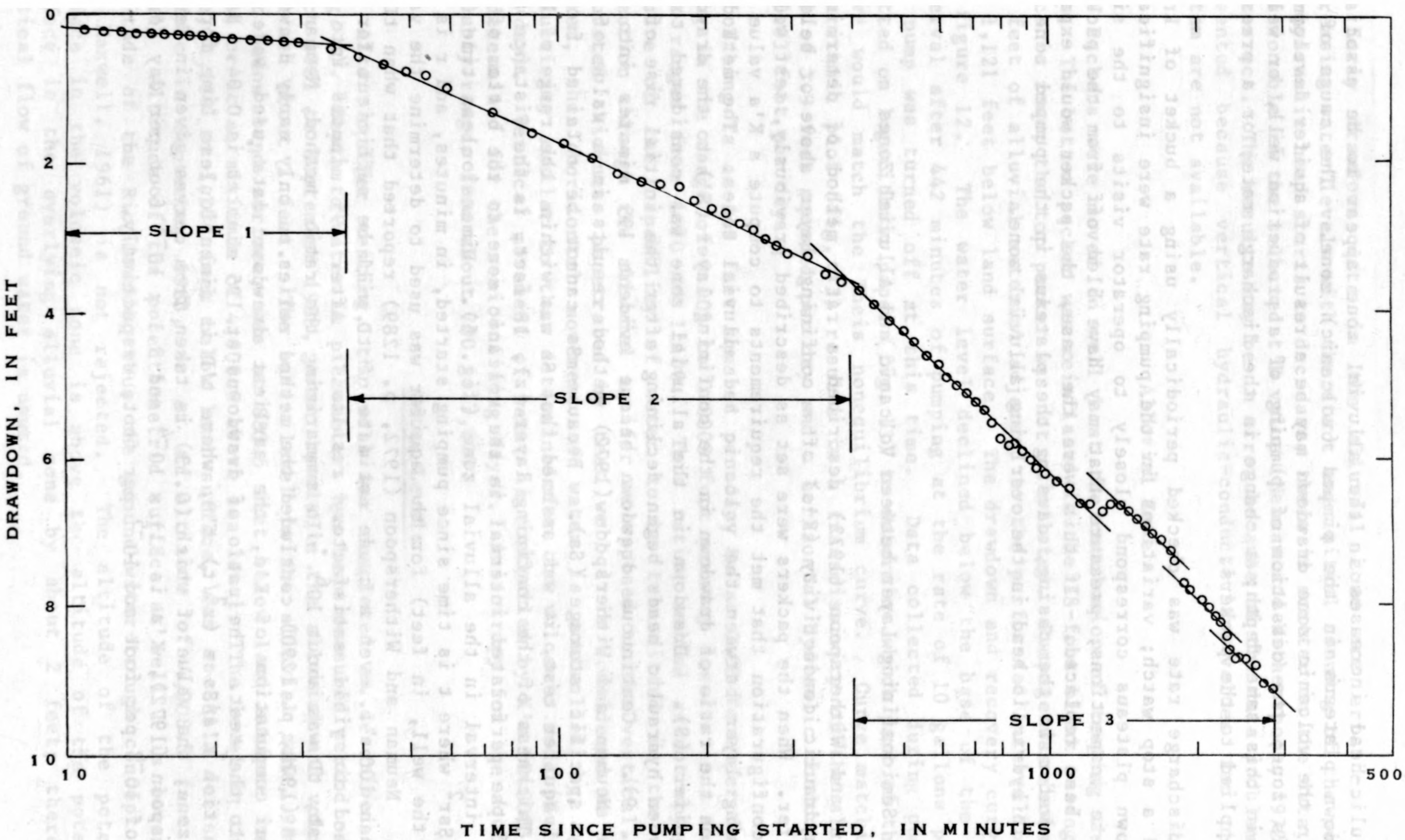

Figure 11.--Semilogarithmic plot of drawdown in test well 1 during pumping of the volcanic zone.

Hydraulic-head increases in the alluvial zone appear to be associated with drawdown plateaus in the pumped (volcanic) zone. The cause of the plateaus in the volcanic zone drawdown may be a result of aquifer development within this zone; the cessation of pumping of a production well, or wells, completed in this same depth; a change in the discharge rate; or a pressure increase applied to the packers.

The discharge rate was checked periodically using a bucket of known volume and a stop watch; variations in the pumping rate were insignificant. The drawdown plateaus correspond closely to operator visits to the site. During these inspections, pressure that may have bled off from the packers could have been replaced. If this were the case, the packer would expand, displacing water in the casing, causing the plateaus in the pumped zone and increases in hydraulic head in the overlying alluvial zone.

Semiconfining Layer between Volcanic and Alluvial Zones

Neuman and Witherspoon (1972) described a ratio method of determining vertical hydraulic conductivity (K'a) of a confining layer above or below a leaky aquifer. When the packers were set as described previously, test well 1 was in a configuration that met the requirements to compute a K'a value for the confining layer between the volcanic and alluvial zones. The method is dependent on the ratio of drawdown in the confining layer (S') to the drawdown in the aquifer (S). Drawdown in the alluvial zone was considered to be starting when hydraulic heads began declining after the initial rise of 1.2 feet (fig. 9). Continuous drawdown became evident 195 minutes into the test. The Neuman and Witherspoon (1972) method results in a value of K'a divided by specific storage (Ss). Because Ss cannot be obtained from a single-well aquifer test, it was assumed that Ss was within the range of 10^{-5} to 10^{-6}. Thickness of the confining layer (z), 18 feet, is the distance from the top of the perforated interval in the volcanic zone to the bottom of the perforated interval in the alluvial zone (fig. 6). Dimensionless time (tD) ($tD = Tvt/Ssr^2$ where t is time since pumping started, in minutes, and r is the radius of the well, in feet) for the aquifer was used to determine the value of K'a/Ss. Neuman and Witherspoon (1972, p. 1289) reported that when tD is greater than 100 "...even a crude estimate of tD will be sufficient for the ratio method to yield satisfactory results." After 195 minutes into the aquifer test, tD was about 10^6. In summarizing the ratio method, Neuman and Witherspoon (1972, p. 1290) concluded the method relies on only early drawdown data. For computation of K'a, the earliest drawdown data used were 195 minutes into the test. The ratio of drawdowns at 195 minutes is 0.04. Based on the equation $K'a/Ss = (z^2/t)\ t'D$, where t'D is dimensionless time for the confining zone, the value of which (0.13) is taken from curves given in Neuman and Witherspoon (1972), K'a is 3.1×10^{-4} and 3.1×10^{-3} foot per day for Ss estimates of 10^{-6} per foot and 10^{-5} per foot, respectively.

Early drawdown data in the alluvial zone are erratic. There are increasing water levels with the start and initial running of the pump. After the hydraulic head starts to decrease, there is scatter in the data, making it questionable if the selected t'D value (Neuman and Witherspoon, 1972, p. 1289) is correct. The results may be in error because of the data problems, but are presented because vertical hydraulic-conductivity values for the aquifer system are not available.

Alluvial Zone

Packers were moved in well 1 at the conclusion of testing the volcanic zone. The bottom packer was reinflated in the 18-foot blank casing above the volcanic zone; the top packer was not reinflated. Pumpage was isolated to the 141 feet of alluvial material adjacent to the perforated interval between 980 and 1,121 feet below land surface. The drawdown and recovery curve is shown in figure 12. The water level declined below the base of the perforated interval after 442 minutes of pumping at the rate of 10 gallons per minute; the pump was turned off at this time. Data collected during pumping were plotted on logarithmic paper (fig. 13) to determine which part of the drawdown curve would match the Theis nonequilibrium curve. Curve matching on the logarithmic plot (fig. 13) results in a transmissivity of the alluvial zone (Ta) of 3.9 feet squared per day and a horizontal hydraulic conductivity (Ka) of 0.03 foot per day.

Taking Ta as 3.9 feet squared per day, Ka as 0.03 foot per day, and K'a being in the range of 0.003 to 0.0003 foot per day results in a Ka/K'a ratio that ranges from 1:10 to 1:100. This ratio, called anisotropy, may be a measure of the capability of water to be transmitted in the horizontal direction through the alluvial aquifer as opposed to the vertical. If total saturated thickness penetrated by test well 1 is considered as an aquifer system, then horizontal movement of water is controlled by a hydraulic conductivity similar to that determined for the volcanic zone (Kv = 2.0 feet per day). Vertical movement of water is controlled by K'a (0.0003 to 0.003) as determined for the semiconfining layer. Anisotropy for the aquifer system probably ranges from about 700 to 7,000.

Water Levels

After aquifer testing, the well was completed as described previously (fig. 6). Depth to water in piezometers has been measured periodically. From March 1983 to September 1983, water levels in the alluvial and volcanic zones declined about 2 feet. The water level in the alluvial zone, 980 to 1,121 feet below land surface, was at 883.5 feet below land surface in September 1983, or at an altitude of 4,906.5 above sea level. The level in the volcanic zone, 1,139 to 1,204 feet below land surface, was at 881.4 feet below land surface in September 1983, or at an altitude of 4,908.6 feet above sea level. Altitude of the potentiometric surface at well 1 is lower than the altitude of the Rio Grande, thus the ground-water-trough concept (Bjorklund and Maxwell, 1961) is not rejected. The altitude of the potentiometric surface in the volcanic zone is above the altitude of the potentiometric surface in the overlying alluvial zone by about 2 feet; therefore, the vertical flow of ground water is upward.

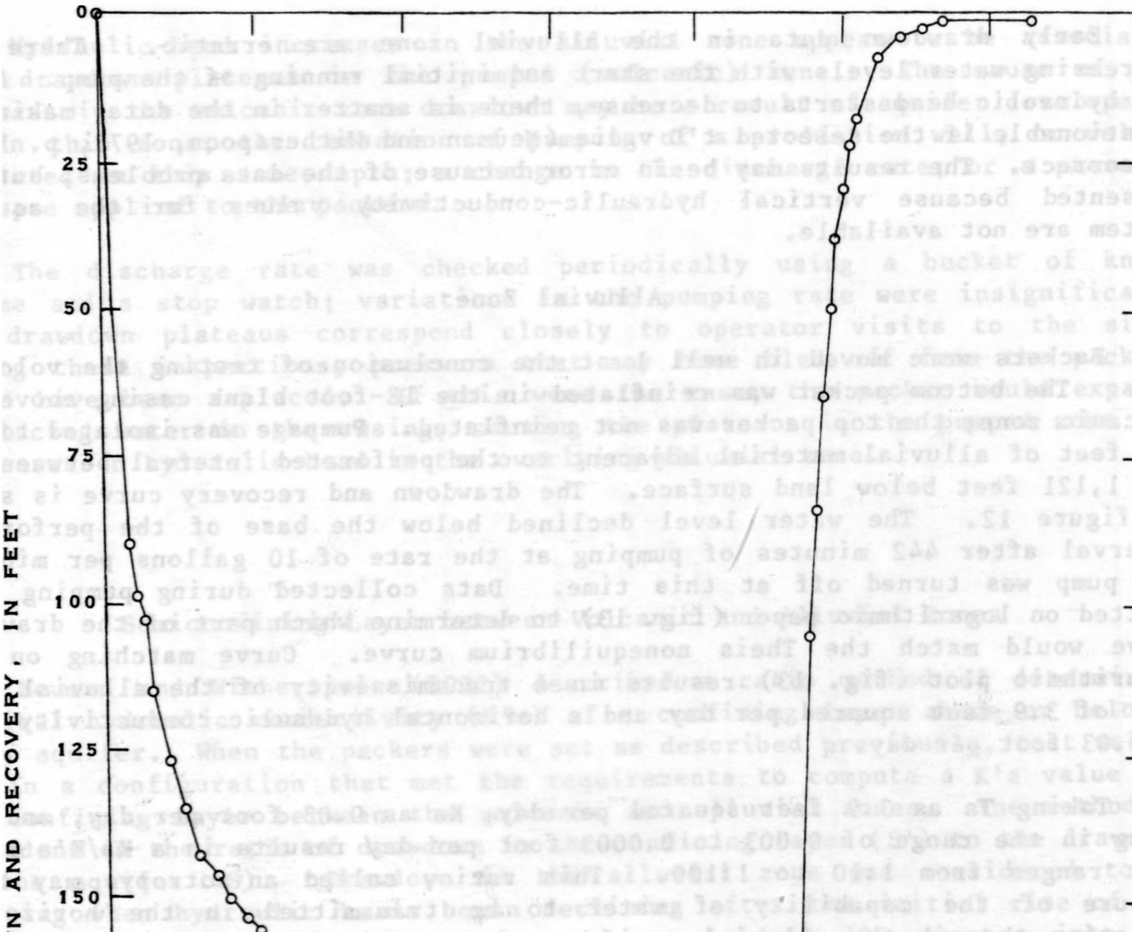

Figure 12.--Drawdown and recovery in test well 1 during pumping of the alluvial zone.

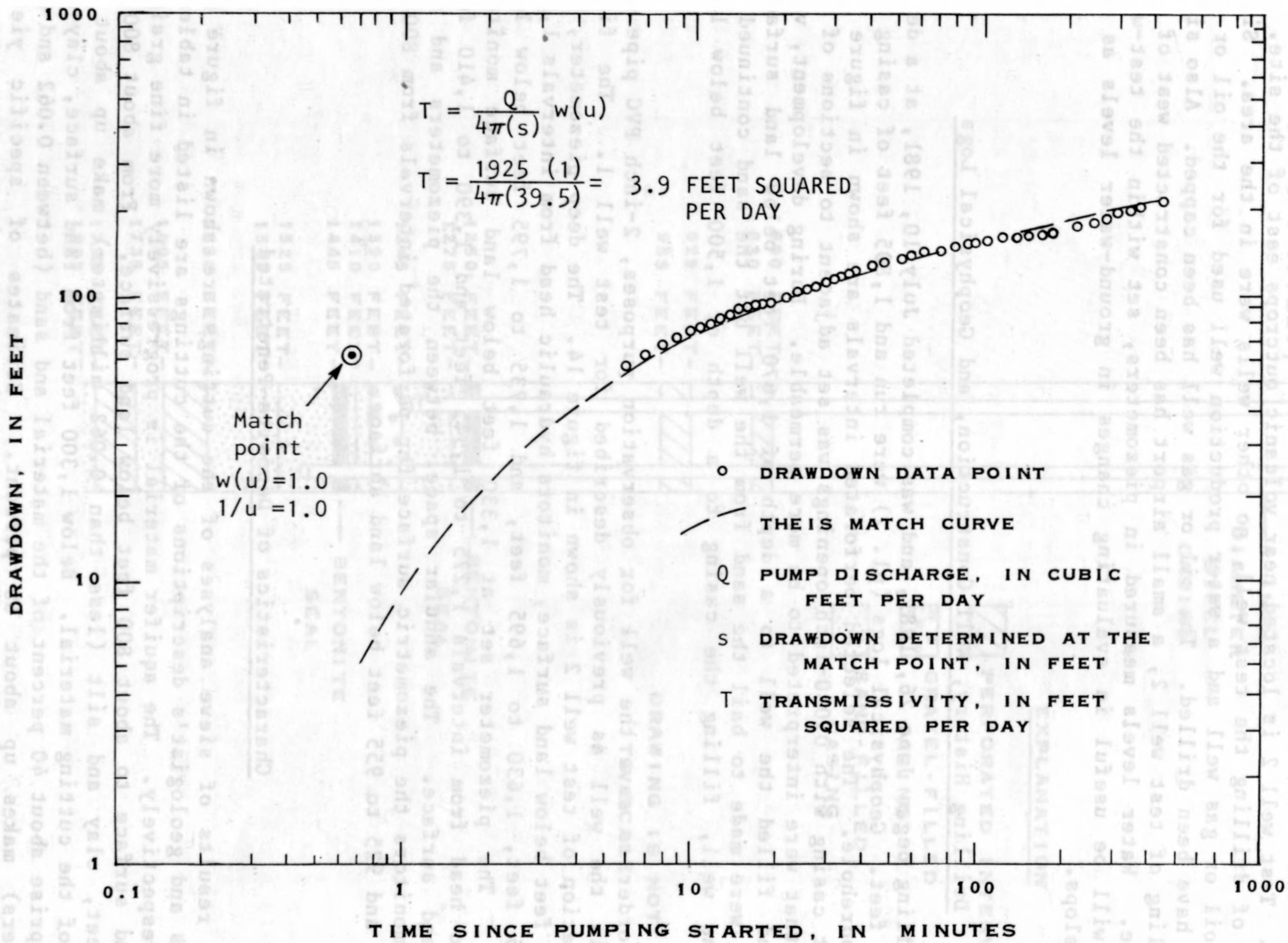

Figure 13.--Logarithmic plot of drawdown in test well 1 during pumping of the alluvial zone.

CHARACTERISTICS AND PROPERTIES OF THE AQUIFER AT THE SITE OF TEST WELL 2

Test well 2 (11N.2E.18.313) is about 10 miles northeast of test well 1 (fig. 1). Test well 2 is located near volcanic outcrops east of the site. At the time of drilling the test well, no other wells were in the area. Since then an oil or gas well and a water production well used for the oil or gas drilling have been drilled. The oil or gas well has been capped. Also since the drilling of test well 2, a small airport has been constructed west of the well site. Water levels measured in piezometers, set within the test-well casing, will be useful in evaluating changes in ground-water levels as the area develops.

Drilling History, Well Construction, and Geophysical Logs

Drilling began June 26, 1981, and was completed July 10, 1981, at a depth of 1,828 feet. Geophysical logs (pl. 2) were run and 1,805 feet of casing set in the borehole. The selected perforated intervals are shown in figure 14. Mill-slot casing with 0.040-inch openings was set adjacent to sections of the aquifer that were interpreted to be more permeable. During development, very fine sand filled the well to a depth of 1,670 feet below land surface. Attempts were made to bail the sand from the well but the sand continued to enter the well, filling the casing to a depth of 1,500 feet below land surface.

In order to save the well for observation purposes, 2-inch PVC pipe was placed in the well as previously described for test well 1. The final configuration of test well 2 is shown in figure 14. The deep piezometer, set at 1,500 feet below land surface, monitors hydraulic head from intervals 1,525 to 1,545 feet, 1,630 to 1,695 feet, and 1,735 to 1,795 feet below land surface. The piezometer set at 1,330 feet below land surface monitors hydraulic head from intervals 1,275 to 1,345 feet and 1,390 to 1,410 feet below land surface. The annular space, between the piezometers and the casing, monitors the piezometric surface for perforated intervals from 800 to 830 feet and 925 to 955 feet below land surface.

Characteristics of Deposits Penetrated

The results of sieve analyses of the cuttings are shown in figure 15. Driller's and geologist's descriptions of the cuttings are listed in tables 7 and 8, respectively. The aquifer material is progressively more fine grained from land surface to about 800 feet below land surface. From about 800 to 1,300 feet, clay and silt (less than 0.062 millimeter) make up about 50 percent of the cutting material. Below 1,300 feet from land surface, clay and silt comprise about 40 percent of the material and sand (between 0.062 and 2.0 millimeters) makes up about 60 percent. Estimates of specific yield, hydraulic conductivity, and porosity may be made using figure 15 and tables 1 and 2.

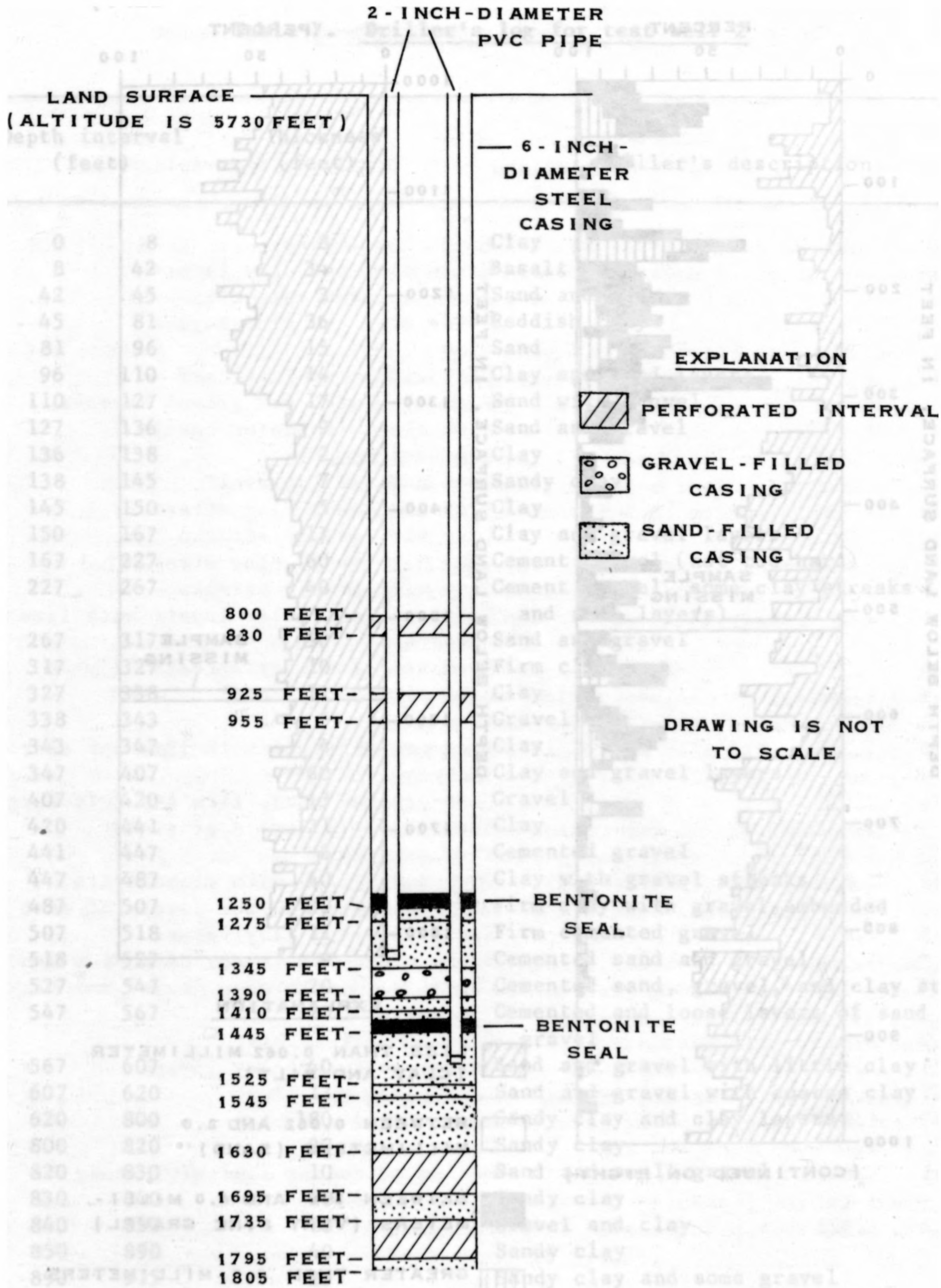

Figure 14.--Piezometer configuration, test well 2.

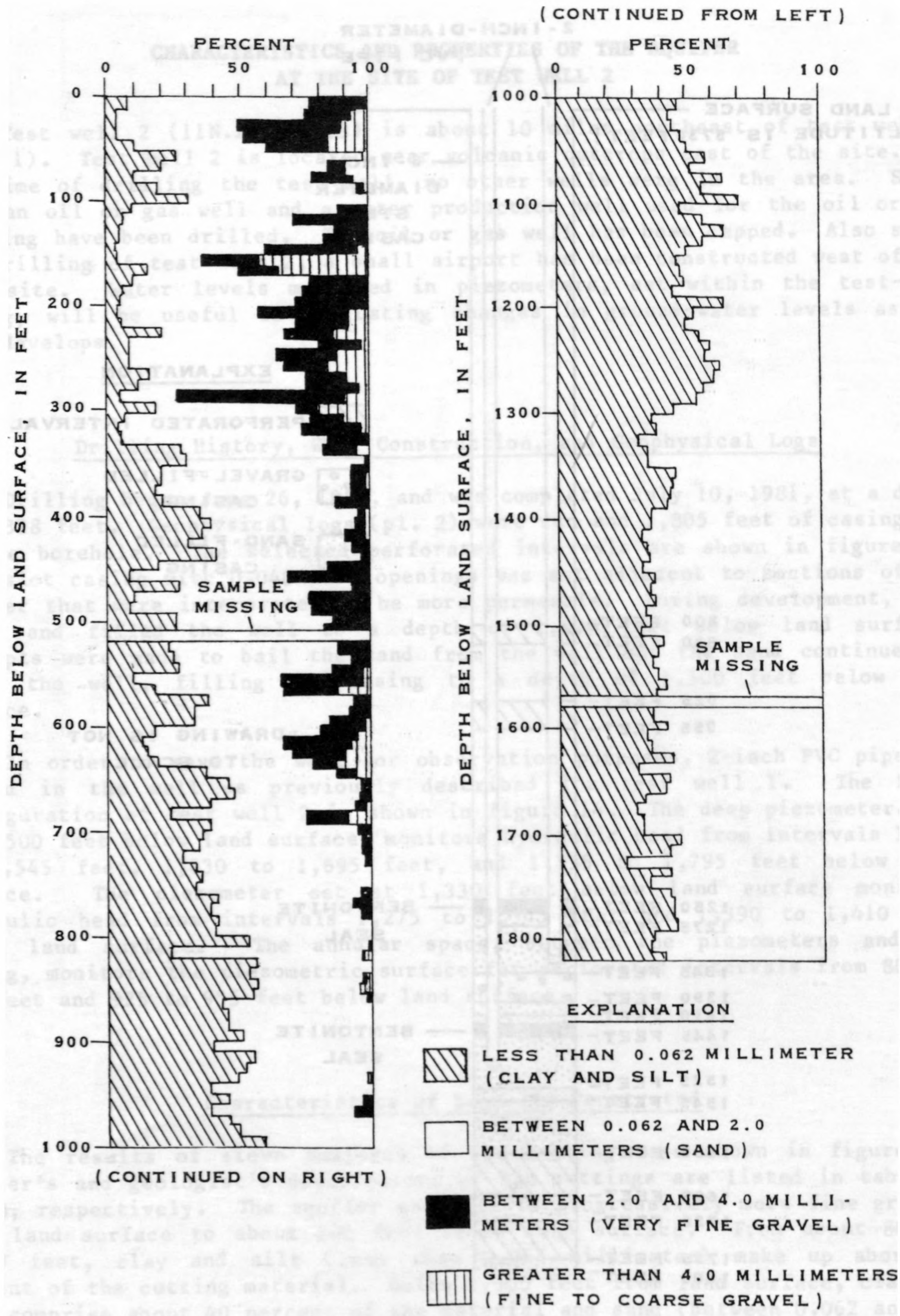

Figure 15.--Percentage of selected sediment sizes in drill-cutting material from test well 2.

Table 7. Driller's log for test well 2

Depth interval (feet)		Thickness (feet)	Driller's description
0	8	8	Clay
8	42	34	Basalt
42	45	3	Sand and clay
45	81	36	Reddish clay
81	96	15	Sand
96	110	14	Clay and sand layers
110	127	17	Sand with gravel
127	136	9	Sand and gravel
136	138	2	Clay
138	145	7	Sandy clay
145	150	5	Clay
150	167	17	Clay and gravel layers
167	227	60	Cement gravel (not too hard)
227	267	40	Cement gravel, some clay streaks (firm and soft layers)
267	317	50	Sand and gravel
317	327	10	Firm clay
327	338	11	Clay
338	343	5	Gravel
343	347	4	Clay
347	407	60	Clay and gravel layers
407	420	13	Gravel
420	441	21	Clay
441	447	6	Cemented gravel
447	487	40	Clay with gravel streaks
487	507	20	Firm clay with gravel embedded
507	518	11	Firm cemented gravel
518	527	9	Cemented sand and gravel
527	547	20	Cemented sand, gravel, and clay streaks
547	567	20	Cemented and loose layers of sand and gravel
567	607	40	Sand and gravel with little clay
607	620	13	Sand and gravel with coarse clay
620	800	180	Sandy clay and clay layers
800	820	20	Sandy clay
820	830	10	Sand and small gravel
830	840	10	Sandy clay
840	850	10	Gravel and clay
850	890	40	Sandy clay
890	915	25	Sandy clay and some gravel
915	923	8	Firm clay
923	950	27	Firm sandy clay
950	970	20	Sand clay and firm clay layers

Table 7. Driller's log for test well 2 - Concluded

Depth interval (feet)		Thickness (feet)	Driller's description
970	990	20	Firm clay layers
990	1,010	20	Sandy clay and clay layers
1,010	1,020	10	Firm sand and some clay
1,020	1,050	30	Sandy clay and sand layers
1,050	1,085	35	Clay
1,085	1,105	20	Clay with gravel streaks
1,105	1,145	40	Firm clay with few gravel streaks
1,145	1,165	20	Firm clay with color change
1,165	1,170	5	Sand and gravel
1,170	1,174	4	Sand and small gravel
1,174	1,190	16	Clay and sandy clay streaks
1,190	1,205	15	Clay with gravel streaks
1,205	1,245	40	Clay with sandy clay streaks
1,245	1,285	40	Clay with gravel streaks
1,285	1,305	20	Clay and sand, clay layers with lime spots
1,305	1,345	40	Firm sand and clay streaks
1,345	1,346	1	Sand with soft gravel
1,346	1,349	3	Firm clay
1,349	1,365	16	Fine-grained sand with lime and clay streaks
1,365	1,405	40	Fine-grained sand, firm and soft layers
1,405	1,412	7	Firm and soft layers of sand
1,412	1,425	13	Firm sandy clay
1,425	1,450	25	Firm sandy clay with clay layers
1,450	1,458	8	Clay with thin medium layers of sand
1,458	1,618	160	Sandy clay and clay layers
1,618	1,699	81	Sandy clay with layers of medium sand
1,699	1,719	20	Coarse sand with some gravel and clay layers
1,719	1,723	4	Firm and sticky clay
1,723	1,731	8	Coarse sand and clay layers
1,731	1,744	13	Sandy clay and clay
1,744	1,755	11	Medium sand and clay
1,755	1,761	6	Sandy clay
1,761	1,812	51	Medium to coarse sand with sandy clay layers
1,812	1,828	16	Sandy clay

Table 8. Geologist's log for test well 2

Depth interval (feet)		Cuttings description
700	710	Silt, light-tan (70 percent); white, fine- to very fine grained sand with 70 percent quartz (30 percent).
710	720	Silt, light-gray (70 percent); gray, fine-grained, angular sand with 70 percent quartz and 5 percent basalt (30 percent).
720	730	Silt, light-tan (60 percent); white, medium- to fine-grained, angular sand with 70 percent quartz (40 percent); some orange clay.
730	740	Silt, light-tan (50 percent); white, medium- to fine-grained, angular to subangular sand with 70 percent quartz (45 percent); basalt (5 percent).
740	750	Sand, gray to white, medium- to fine-grained, angular to subangular, with 70 percent quartz (50 percent); light-tan silt (45 percent); sparse basalt and orange clay (5 percent).
750	760	Sand, gray to white, medium- to fine-grained, angular to subangular, with 70 percent quartz (60 percent); light-tan silt (35 percent); sparse basalt and orange clay (5 percent).
760	770	Sand, gray to white, coarse- to fine-grained, angular to subangular, with 70 percent quartz (70 percent); light-tan silt (25 percent); sparse basalt and calcium carbonate bits (5 percent).
770	780	Silt, gray to tan (90 percent); white, fine-grained sand with 80 percent quartz (10 percent).
780	790	Silt, gray to tan (90 percent); white, fine-grained sand with 80 percent quartz (10 percent); sparse basalt.
790	800	Silt, gray to tan (80 percent); white, fine-grained sand with 70 percent quartz (15 percent); sparse basalt (5 percent).

Table 8. Geologist's log for test well 2 - Continued

Depth interval (feet)		Cuttings description
800	810	Silt, gray to tan (95 percent); white, fine-grained sand, quartz (5 percent).
810	820	Sand, gray to tan, very fine grained, subangular to subrounded, with 50 percent quartz (60 percent); gray to orange silt (40 percent); sparse basalt.
820	830	Silt, gray (90 percent); gray, very fine grained sand with 90 percent quartz (10 percent); sparse basalt.
830	840	Silt, gray (90 percent); gray, very fine grained sand (10 percent); very sparse basalt.
840	850	Silt, gray to brown (90 percent); gray, very fine grained silt with 90 percent basalt (10 percent); very sparse basalt.
850	860	Silt, gray to brown (90 percent); gray, very fine grained sand with 90 percent quartz (10 percent); very sparse basalt.
860	870	Silt, gray to brown (90 percent); gray, very fine grained sand with 90 percent quartz (10 percent).
870	890	Silt, gray to brown (90 percent); gray, very fine grained sand with 90 percent quartz (10 percent); sparse basalt.
890	900	Silt, brown to orange (80 percent); gray to white, medium- to fine-grained, subangular to subrounded sand with 50 percent quartz (20 percent); sparse red clay.
900	920	Silt, light-brown (80 percent); gray to white, medium- to fine-grained, subangular to subrounded sand with 50 percent quartz (20 percent).
920	930	Silt, light-brown (80 percent); gray to white, medium- to fine-grained, subrounded sand with 60 percent quartz (20 percent).

Table 8. Geologist's log for test well 2 - Continued

Depth interval (feet)		Cuttings description
930	940	Silt, light-brown (80 percent); gray to white, medium- to fine-grained, subangular to subrounded sand with 60 percent quartz (20 percent); sparse basalt.
940	950	Silt, light-brown (60 percent); gray to white, medium- to fine-grained, subangular to subrounded sand with 80 percent quartz (40 percent); sparse basalt.
950	960	Silt, light-brown (60 percent); gray to white, medium- to fine-grained, subrounded sand with 80 percent quartz (40 percent); sparse basalt.
960	970	Silt, light-brown (60 percent); gray to white, coarse- to fine-grained, subrounded sand with 80 percent quartz (40 percent); sparse basalt.
970	980	No sample.
980	990	Silt, gray to white (90 percent); gray to white, fine-grained sand with 90 percent quartz (10 percent).
990	1,000	Silt, gray to light-brown (95 percent); gray to white, very fine grained sand, quartz (5 percent).
1,000	1,010	Silt, gray to light-brown (95 percent); gray to white, very fine grained sand, quartz (5 percent); sparse brown clay.
1,010	1,070	Silt, light-brown (95 percent); gray to white, fine-grained, subangular to subrounded sand with 90 percent quartz (5 percent); sparse basalt.
1,070	1,080	Silt to clay, light-brown (95 percent); gray to white, fine-grained, subangular to subrounded sand with 90 percent quartz (5 percent); sparse basalt.

Table 8. Geologist's log for test well 2 - Continued

Depth interval (feet)		Cuttings description
1,080	1,090	Silt, light-brown (95 percent); gray to white, fine-grained, subangular to subrounded sand with 90 percent quartz (5 percent); sparse basalt.
1,090	1,120	Silt to clay, light-brown (95 percent); gray to white, fine-grained, subrounded sand with 90 percent quartz (5 percent); sparse basalt.
1,120	1,140	Silt, light-brown (85 percent); gray, fine-grained, subrounded sand, quartz (5 percent); dark-brown clay (10 percent); sparse basalt.
1,140	1,150	Silt, light-brown (95 percent); gray, very fine grained, subrounded sand, quartz (5 percent); sparse basalt.
1,150	1,180	Silt, light-brown (90 percent); gray, very fine grained, subrounded sand, quartz (5 percent); dark-brown clay (5 percent).
1,180	1,240	Silt, light-brown (95 percent); gray, very fine grained, subrounded sand, quartz (5 percent).
1,240	1,250	Silt, light-brown (95 percent); gray, very fine grained, subrounded sand, quartz (5 percent); sparse basalt.
1,250	1,300	Silt, light-brown (95 percent); gray, very fine grained, subrounded sand, quartz (5 percent).
1,300	1,310	Silt, light-gray to brown (95 percent); gray, very fine grained, subrounded sand, quartz (5 percent).
1,310	1,340	Silt, light-gray to brown (90 percent); gray, very fine grained, subangular to subrounded sand, quartz (10 percent); sparse basalt.
1,340	1,350	Silt, light-gray to brown (60 percent); gray to white, fine-grained, subangular to subrounded sand with 70 percent quartz (40 percent); sparse basalt.

Table 8. Geologist's log for test well 2 - Continued

Depth interval (feet)		Cuttings description
1,350	1,360	Silt, light-brown (60 percent); gray to white, fine-grained, subangular to subrounded sand with 70 percent quartz (40 percent).
1,360	1,390	Silt, light-gray to brown (90 percent); gray to white, very fine grained, subrounded sand, quartz (10 percent).
1,390	1,460	Silt, light-gray to brown (95 percent); gray to white, very fine grained, subrounded sand, quartz (5 percent).
1,460	1,510	Silt, light-brown (95 percent); gray to white, very fine grained, subrounded sand, quartz (5 percent).
1,510	1,520	Silt, light-brown (95 percent); gray to white, very fine grained, subrounded sand, quartz (5 percent); sparse basalt.
1,520	1,530	Silt, light-brown (95 percent); gray to white, very fine grained, subrounded sand, quartz (5 percent).
1,530	1,540	Silt, light-brown (95 percent); gray to white, very fine grained, subrounded sand, quartz (5 percent); sparse basalt.
1,540	1,560	Silt, light-brown (95 percent); gray to white, very fine grained sand (5 percent).
1,560	1,570	Silt, brown (95 percent); gray to brown, very fine grained sand (5 percent); dark-brown clay.
1,570	1,580	No sample.
1,580	1,590	Silt, light-brown (95 percent); gray to brown, very fine grained sand, quartz, and feldspar (5 percent); brown clay.
1,590	1,600	Silt, light-brown (95 percent); gray to white, very fine grained sand, quartz (5 percent).

Table 8. Geologist's log for test well 2 - Continued

Depth interval (feet)		Cuttings description
1,600	1,620	Silt, light-brown (90 percent); gray to white, fine- to very fine grained sand, quartz (10 percent).
1,620	1,630	Silt, light-brown (90 percent); gray to white, very fine grained sand, quartz (10 percent).
1,630	1,660	Silt, light-brown (95 percent); gray to white, fine- to very fine grained sand, quartz (5 percent); sparse basalt.
1,660	1,670	Silt, light-brown (90 percent); gray to white, fine-grained, subrounded sand, quartz (10 percent); very sparse basalt.
1,670	1,680	Silt, light-brown (90 percent); gray to white, fine-grained, subangular to subrounded sand, quartz (10 percent); very sparse basalt.
1,680	1,700	Silt, light-brown (85 percent); gray to white, fine-grained, subangular to subrounded sand, quartz (15 percent); sparse basalt.
1,700	1,720	Silt, light-brown (95 percent); gray to white, fine- to very fine grained sand, quartz (5 percent).
1,720	1,730	Silt, light-brown (60 percent); gray to white, medium- to fine-grained, subangular to subrounded sand with 90 percent quartz (40 percent); sparse basalt.
1,730	1,740	Silt, light-brown (85 percent); gray to white, fine-grained, subangular to subrounded sand with 90 percent quartz (15 percent); sparse basalt.
1,740	1,750	Silt, brown (85 percent); gray to white, fine-grained, subangular to subrounded sand with 90 percent quartz (15 percent); sparse basalt with hematite stains.
1,750	1,760	Silt, brown (90 percent); gray to white, fine-grained, subangular to subrounded sand, quartz (10 percent); sparse basalt.

Table 8. Geologist's log for test well 2 - Concluded

Depth interval (feet)		Cuttings description
1,760	1,780	Silt, light-brown (90 percent); gray to white, fine- to very fine grained sand, quartz (10 percent); very sparse basalt.
1,780	1,790	Silt, light-brown (95 percent); gray to white, fine- to very fine grained sand, quartz (5 percent).
1,790	1,800	Silt, light-brown (90 percent); gray to white, fine-grained, subrounded sand, quartz (10 percent).
1,800	1,810	Silt, light-brown (85 percent); gray to white, fine-grained, subrounded sand, quartz (15 percent); sparse basalt.
1,810	1,820	Silt, light-brown (95 percent); gray to white, fine- to very fine grained sand, quartz (5 percent).

Water Quality

After piezometers had been placed in the casing, they were swabbed to obtain water samples. The water in the annular space could not be sampled because of the possibility of wrapping the swab cable around one of the piezometers. Results of water-quality analyses of water samples collected from the two piezometers are shown in table 9. The maximum contaminant levels and recommended constituent levels for selected water-quality constituents in water collected from the perforated interval 1,275 to 1,410 feet below land surface are shown in figure 16. Dissolved cadmium exceeds the maximum contaminant level (140 percent). Dissolved manganese greatly exceeds (780 percent) the recommended constituent level. The other constituents are within the recommended levels and maximum contaminant levels established for public water supplies (National Academy of Sciences-National Academy of Engineering, 1973; U.S. Environmental Protection Agency, 1977).

Water Levels

Water levels representative of perforated intervals monitored in the piezometers and annular space are shown in figure 17. The substantial fluctuations in water levels in the piezometers (1,275- to 1,410-foot and 1,525- to 1,795-foot perforated intervals) in May 1982 were affected by swabbing. During temperature logging inside the 1,500-foot piezometer in January 1984, the sonde could not be lowered more than about 1,130 feet below land surface. The pipe could be broken or bent at this depth. The short-term hydrographs in figure 17 indicate that the 1,500-foot piezometer is not necessarily monitoring the same zones as the 1,350-foot piezometer or the annular space, so the measured water levels may reflect the actual hydraulic head in the 1,525- to 1,795-foot perforated interval. The water levels through March 1982 may be adjusting to test-well completion work. The rising water levels through the low water-use months of late 1982 and early 1983 seem reasonable, as are the declining water levels in the deeper piezometers (below 1,275 feet below land surface) during the spring of 1983. The changes in water levels in the deeper monitored zones and the relatively stable water levels in the shallow zone indicate that most stress in the basin aquifer system occurs below 1,275 feet below land surface. Continued water-level measurements and verification of hydraulic connection between the piezometer and the aquifer are needed before seasonal trends or local fluctuations can be identified. Water levels in the deeper zones are about 17 feet lower than the upper zone, indicating a downward vertical gradient. Water levels in the deeper zones generally are lower than the channel of the Rio Grande at the gage in Albuquerque. The water level in the upper perforated interval is higher than the channel at the river gage.

Table 9. Analysis of water samples from selected water-producing intervals in test well 2

[All constituents are dissolved; mg/L, milligrams per liter; μg/L, micrograms per liter; μS/cm, microsiemens per centimeter at 25 °Celsius; °C, degrees Celsius]

Property or constituent	1,275- to 1,410-foot interval below land surface	1,525- to 1,795-foot interval below land surface
Alkalinity, total as calcium carbonate (mg/L)	109	157
Arsenic (μg/L)	1	-
Barium (μg/L)	120	-
Bicarbonate (field) (mg/L)	180	200
Cadmium (μg/L)	14	-
Calcium (mg/L)	14	19
Chloride (mg/L)	5.9	6.7
Chromium (μg/L)	10	-
Copper (μg/L)	1	-
Fluoride (mg/L)	0.9	1.0
Hardness, carbonate (mg/L)	46	57
Iron (μg/L)	190	23
Lead (μg/L)	1	-
Magnesium (mg/L)	2.6	2.3
Manganese (μg/L)	390	59
Mercury (μg/L)	0.1	-
Nickel (μg/L)	-	-
Nitrogen, nitrite plus nitrate as nitrogen (mg/L)	2.4	0.1
pH (field)	8.4	8.3
Potassium (mg/L)	3.2	3.8
Selenium (μg/L)	2	-
Silica (mg/L)	12	18
Silver (μg/L)	1	-
Sodium (mg/L)	54	63
Specific conductance (field) (μS/cm)	325	370
Sulfate (mg/L)	34	36
Water temperature (°C)	20.5	20
Zinc (μg/L)	260	-

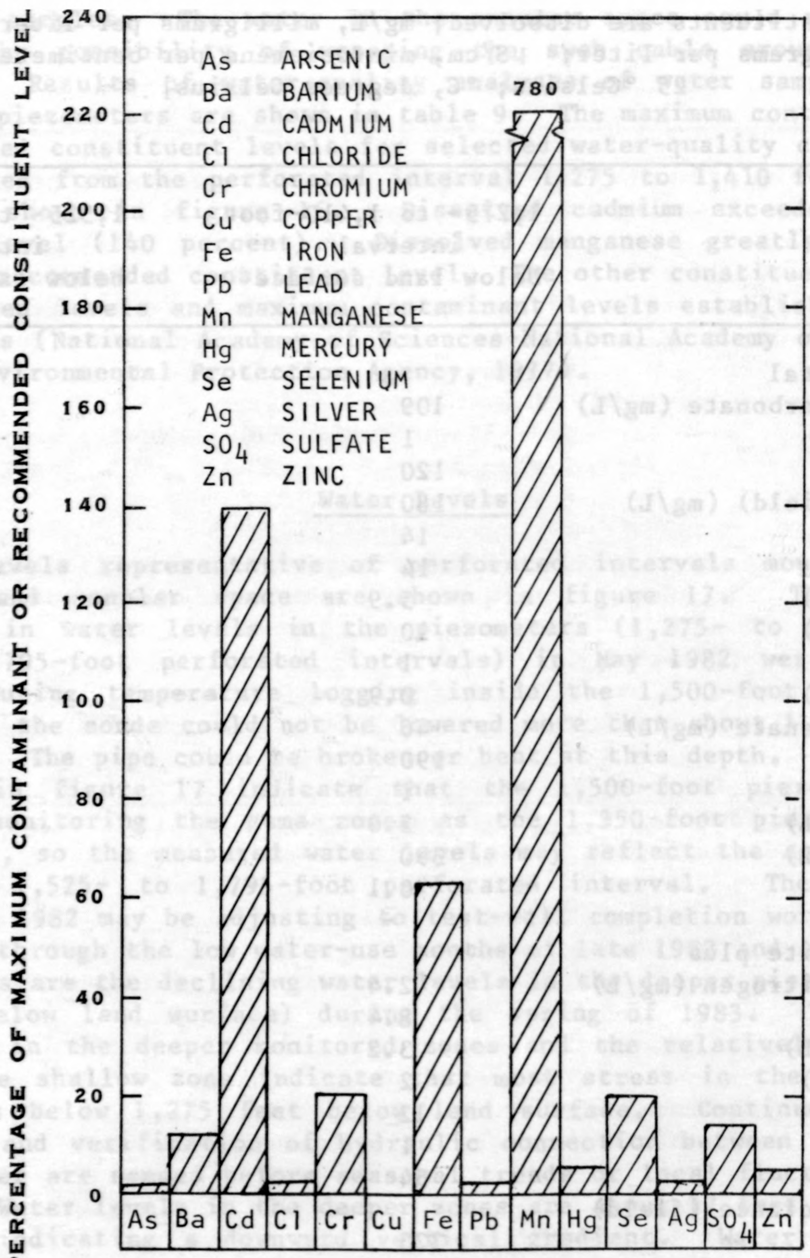

Figure 16.--Relation of dissolved constituents in water from test well 2 to maximum contaminant and recommended constituent levels.

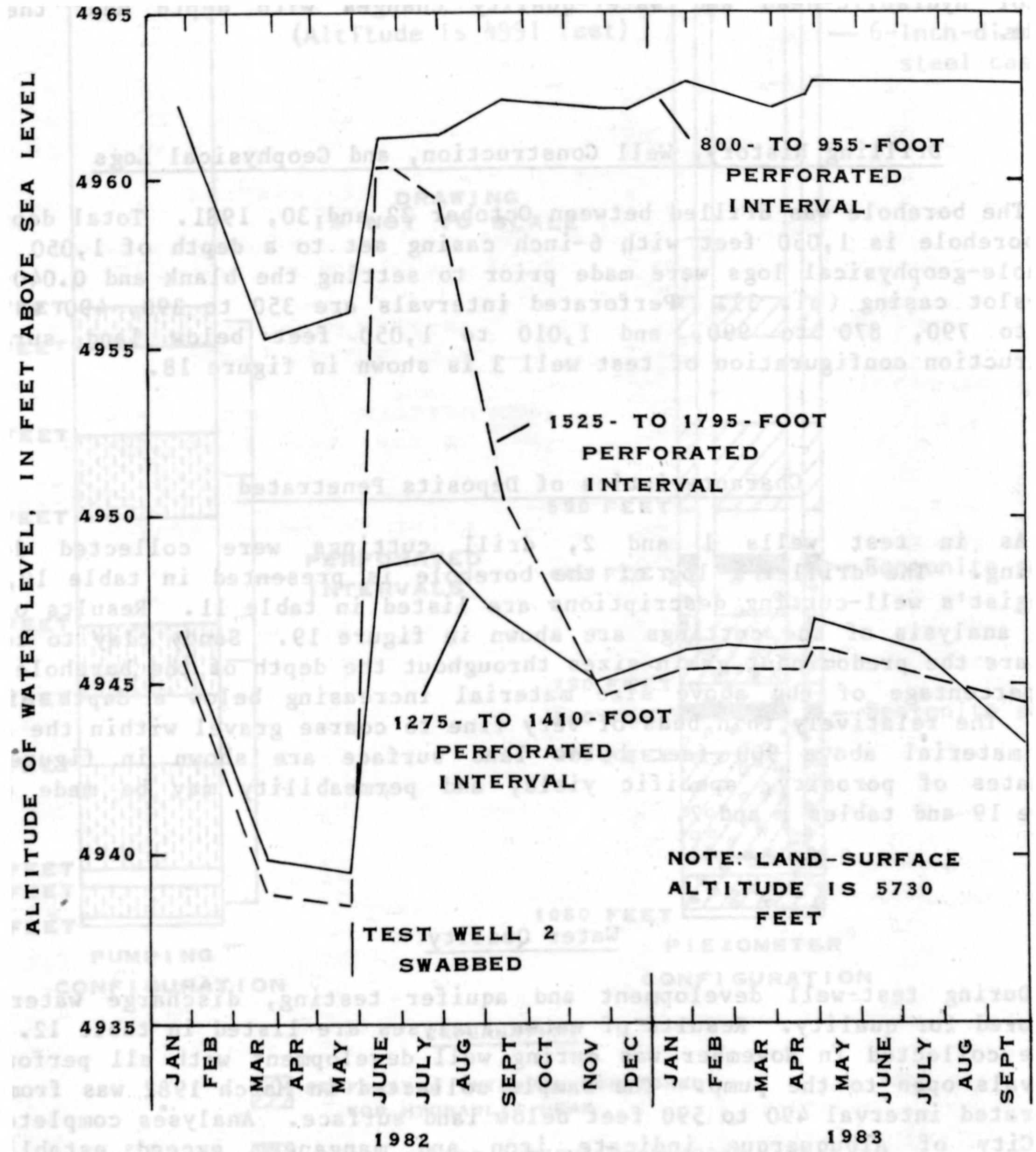

Figure 17.--Water levels in test well 2.

CHARACTERISTICS AND PROPERTIES OF THE AQUIFER AT THE SITE OF TEST WELL 3

Test well 3 (11N.3E.18.411) is located between the West Mesa and the flood plain of the Rio Grande (fig. 1). This location was selected to complete an east-trending line with other selected wells in the basin, and to monitor hydraulic-head and water-quality changes with depth near the Rio Grande.

Drilling History, Well Construction, and Geophysical Logs

The borehole was drilled between October 22 and 30, 1981. Total depth of the borehole is 1,050 feet with 6-inch casing set to a depth of 1,050 feet. Borehole-geophysical logs were made prior to setting the blank and 0.040-inch mill-slot casing (pl. 3). Perforated intervals are 350 to 390, 490 to 590, 710 to 790, 870 to 990, and 1,010 to 1,050 feet below land surface. Construction configuration of test well 3 is shown in figure 18.

Characteristics of Deposits Penetrated

As in test wells 1 and 2, drill cuttings were collected during drilling. The driller's log of the borehole is presented in table 10, and geologist's well-cutting descriptions are listed in table 11. Results of the sieve analysis of the cuttings are shown in figure 19. Sandy clay to coarse sand are the predominant grain sizes throughout the depth of the borehole with the percentage of the above size material increasing below a depth of 900 feet. The relatively thin beds of very fine to coarse gravel within the sand-size material above 900 feet below land surface are shown in figure 19. Estimates of porosity, specific yield, and permeability may be made using figure 19 and tables 1 and 2.

Water Quality

During test-well development and aquifer testing, discharge water was monitored for quality. Results of water analyses are listed in table 12. The sample collected in November was during well development with all perforated intervals open to the pump. The sample collected in March 1982 was from the perforated interval 490 to 590 feet below land surface. Analyses completed by the City of Albuquerque indicate iron and manganese exceed established recommended limits for the sample collected in November. Analyses completed by the U.S. Geological Survey laboratory indicate no constituents exceed established concentration limits for water samples collected in November 1981 or March 1982.

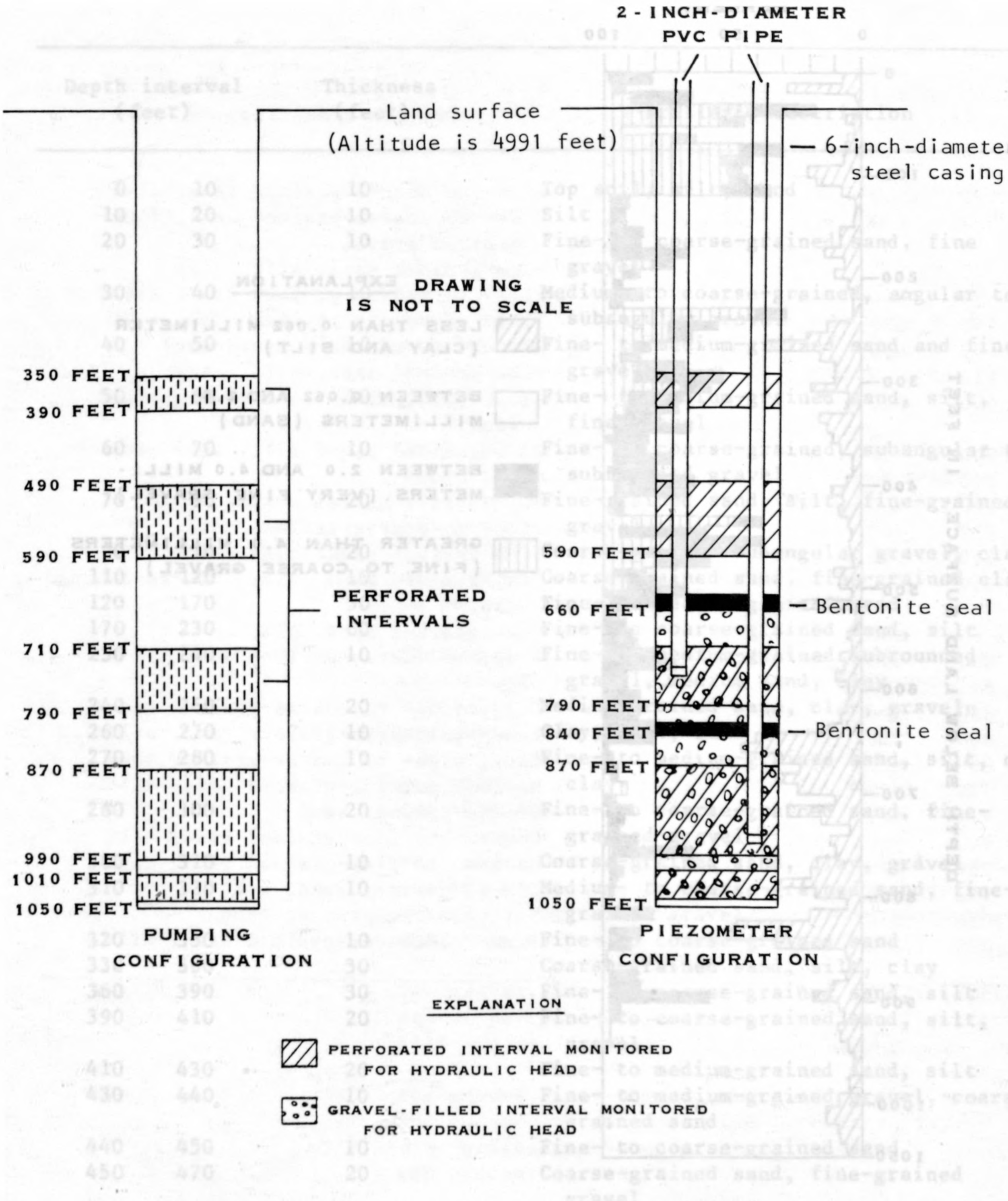

Figure 18.--Pumping configuration and piezometer configuration, test well 3.

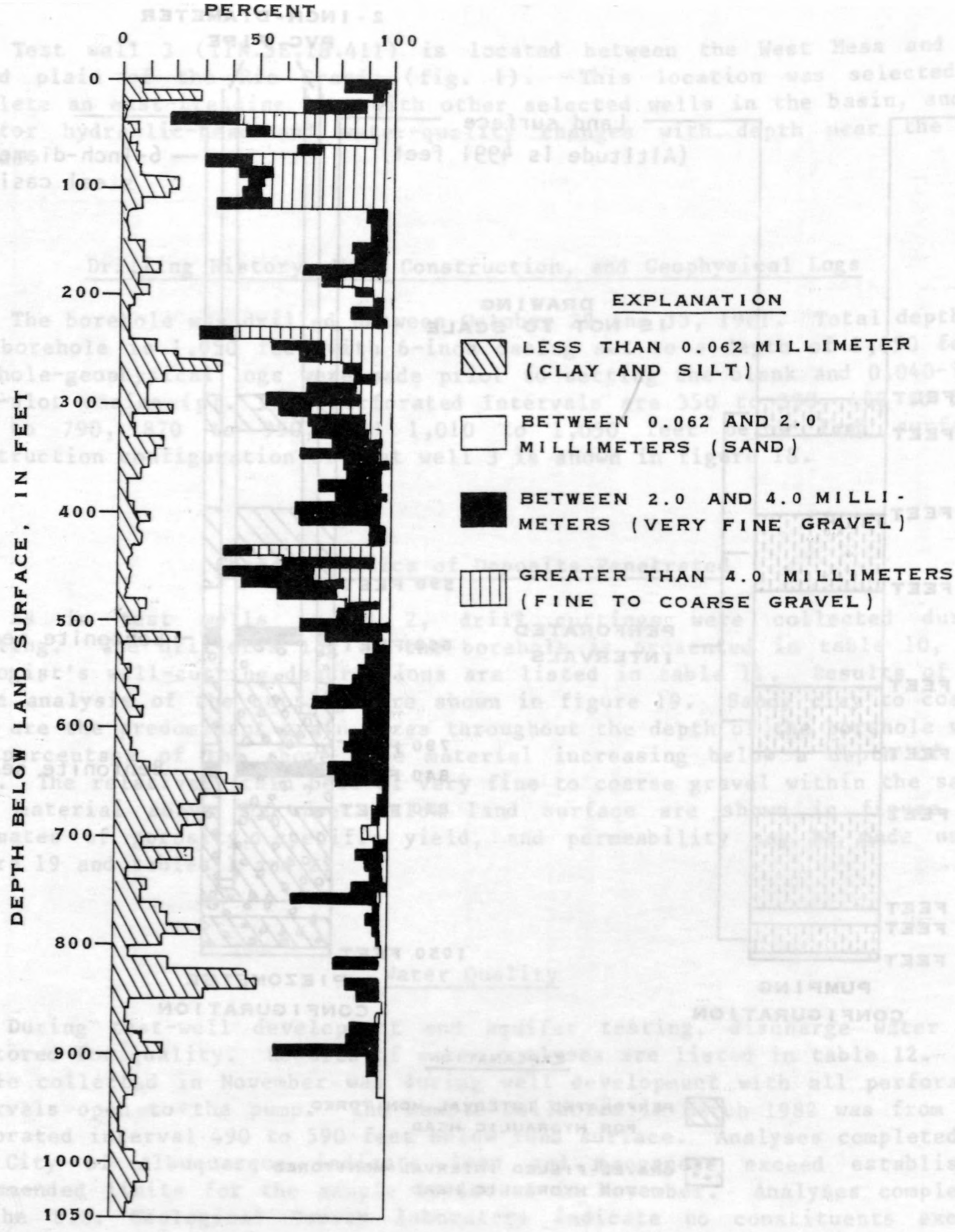

Figure 19.--Percentage of selected sediment sizes in drill-cutting material from test well 3.

Table 10. Driller's log for test well 3

Depth interval (feet)		Thickness (feet)	Driller's description
0	10	10	Top soil, silt, sand
10	20	10	Silt
20	30	10	Fine- to coarse-grained sand, fine gravel
30	40	10	Medium- to coarse-grained, angular to subangular gravel
40	50	10	Fine- to medium-grained sand and fine gravel
50	60	10	Fine- to medium-grained sand, silt, fine gravel
60	70	10	Fine- to coarse-grained, subangular to subrounded gravel
70	90	20	Fine-grained sand, silt, fine-grained gravel
90	110	20	Coarse-grained subangular gravel, clay
110	120	10	Coarse-grained sand, fine-grained clay
120	170	50	Fine- to medium-grained sand
170	230	60	Fine- to coarse-grained sand, silt
230	240	10	Fine- to medium-grained subrounded gravel, medium sand, clay
240	260	20	Medium-grained sand, clay, gravel
260	270	10	Clay, silt, sand
270	280	10	Fine- to medium-grained sand, silt, or clay
280	300	20	Fine- to coarse-grained sand, fine-grained gravel
300	310	10	Coarse-grained sand, clay, gravel
310	320	10	Medium- to coarse-grained sand, fine-grained gravel
320	330	10	Fine- to coarse-grained sand
330	360	30	Coarse-grained sand, silt, clay
360	390	30	Fine- to coarse-grained sand, silt
390	410	20	Fine- to coarse-grained sand, silt, gravel
410	430	20	Fine- to medium-grained sand, silt
430	440	10	Fine- to medium-grained gravel, coarse-grained sand
440	450	10	Fine- to coarse-grained sand
450	470	20	Coarse-grained sand, fine-grained gravel
470	480	10	Medium- to coarse-grained sand, fine-grained gravel

Table 10. Driller's log for test well 3 - Concluded

Depth interval (feet)		Thickness (feet)	Driller's description
480	500	20	Fine- to coarse-grained sand, silt
500	510	10	Fine- to coarse-grained sand, fine-grained gravel
510	520	10	Fine-grained sand, silt, clay
520	540	20	Fine- to medium-grained sand, silt
540	620	80	Fine- to coarse-grained sand, silt
620	630	10	Medium- to coarse-grained sand
630	640	10	Fine-grained sand, silt, clay
640	700	60	Clay, silt, fine- to medium-grained sand
700	710	10	Fine-grained sand, silt, some clay
710	720	10	Silt, clay
720	730	10	Silt, clay, medium-grained sand
730	740	10	Fine- to coarse-grained sand
740	750	10	Fine-grained sand, clay
750	760	10	Fine-grained sand, clay, coarse-grained sand
760	800	40	Fine-grained sand, clay
800	810	10	Fine- to coarse-grained sand
810	820	10	Clay
820	860	40	Clay, fine- to coarse-grained sand
860	880	20	Fine- to coarse-grained sand, silt
880	900	20	Clay, fine- to coarse-grained sand
900	930	30	Medium- to fine-grained sandy silt
930	940	10	Coarse-grained sand
940	960	20	Coarse- to fine-grained sand, silt
960	990	30	Medium- to fine-grained sand, silt
990	1,020	30	Coarse-grained sand, silt
1,020	1,030	10	Silt, coarse-grained sand
1,030	1,050	20	Fine- to coarse-grained sand, silt

Table 11. Geologist's log for test well 3

Depth interval (feet)		Cuttings description
0	10	Sand, gray, very coarse to medium-grained, with 40 percent quartz, 40 percent volcanics, and 10 percent feldspar (90 percent); brown silt and clay (10 percent).
10	20	Sand, brown, fine- to very fine grained, subangular to subrounded, with 80 percent quartz and 10 percent odd grains (90 percent); pea gravel (10 percent).
20	30	Sand, gray, very coarse to fine-grained, angular, with 50 percent quartz, 30 percent volcanics, and 10 percent feldspar (90 percent); pea gravel (10 percent).
30	50	Pea gravel, very angular, with 40 percent quartz, 40 percent volcanics, and chert.
50	60	Sand, gray, coarse- to fine-grained, angular to subangular, with 50 percent quartz, 40 percent volcanics, and 10 percent feldspar (85 percent); pea gravel (15 percent).
60	70	Pea gravel, very angular, with 40 percent quartz and 40 percent volcanics.
70	90	Pea gravel, very angular, with 40 percent quartz and 40 percent volcanics (60 percent); gray, coarse- to medium-grained, angular to subangular sand with 60 percent quartz (40 percent).
90	100	Pea gravel, very angular, with 40 percent quartz and 40 percent volcanics (40 percent); light-gray silt and sand, quartz (60 percent).
100	120	Pea gravel, very angular, with 40 percent quartz and 40 percent volcanics (40 percent); gray, fine-grained, subangular sand, quartz (60 percent).
120	130	Sand, gray, medium-grained, subangular, with 70 percent quartz, 20 percent volcanics, and 10 percent feldspar (100 percent); sparse pea gravel.

Table 11. Geologist's log for test well 3 - Continued

Depth interval (feet)		Cuttings description
130	140	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 60 percent quartz, 30 percent volcanics, and 10 percent feldspar.
140	150	Sand, gray, coarse- to medium-grained, subangular to subrounded, with 60 percent quartz, 30 percent volcanics, and 10 percent feldspar.
150	170	Sand, gray, coarse- to medium-grained, subangular, with 50 percent quartz, 40 percent volcanics, and 10 percent feldspar (90 percent); silt (10 percent).
170	180	Sand, gray, coarse- to medium-grained, subangular, with 50 percent volcanics, 40 percent quartz, and 10 percent feldspar (90 percent); light-gray silt (10 percent).
180	200	Sand, gray, medium- to fine-grained, subangular to subrounded, with 60 percent volcanics, 30 percent quartz, and 10 percent feldspar (90 percent); pea gravel (10 percent).
200	220	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 50 percent volcanics, 30 percent quartz, and 20 percent feldspar.
220	230	Sand, gray, medium- to fine-grained, subangular to subrounded, with 50 percent quartz, 40 percent volcanics, and 10 percent feldspar.
230	240	Pea gravel, angular, with 50 percent quartz, 40 percent volcanics, and 10 percent feldspar.
240	250	Clay, gray to purple; subangular pea gravel, with 70 percent volcanics and 30 percent quartz.
250	260	Clay, gray to purple; angular pea gravel, with 80 percent volcanics and 20 percent quartz.
260	270	Clay, gray to purple (90 percent); pea gravel (10 percent).

Table 11. Geologist's log for test well 3 - Continued

Depth interval (feet)		Cuttings description
270	280	Clay, gray to purple (90 percent); fine-grained, subangular to subrounded sand with 60 percent quartz (10 percent).
280	290	Sand, gray, very coarse to fine-grained, subangular to subrounded, with 70 percent quartz, 20 percent volcanics, and 10 percent feldspar (90 percent); pea gravel (10 percent).
290	300	Sand, gray, very coarse to fine-grained, subangular to subrounded, with 70 percent quartz, 20 percent volcanics, and 10 percent feldspar.
300	310	Clay, gray to brown (50 percent), pea gravel (40 percent); medium- to fine-grained sand (10 percent).
310	330	Sand, gray to white, coarse- to fine-grained, subangular to subrounded, with 50 percent quartz, 40 percent volcanics, and 10 percent feldspar (90 percent); pea gravel (10 percent).
330	350	Sand, gray to white, coarse- to fine-grained, subangular to subrounded, with 50 percent quartz, 40 percent volcanics, 10 percent feldspar (80 percent); tan silt to clay (20 percent).
350	390	Sand, gray to white, coarse- to fine-grained, subangular to subrounded, with 50 percent quartz, 40 percent volcanics, 10 percent feldspar (90 percent); tan silt to clay (10 percent).
390	400	Sand, gray to white, coarse- to fine-grained, subangular to subrounded, with 50 percent quartz, 40 percent volcanics, and 10 percent feldspar (90 percent); pea gravel (10 percent).
400	430	Sand, gray to white, coarse- to fine-grained, subangular to subrounded, with 60 percent quartz, 30 percent volcanics, and 10 percent feldspar.

Table 11. Geologist's log for test well 3 - Continued

Depth interval (feet)		Cuttings description
430	440	Pea gravel, subangular to subrounded, with 60 percent quartz, 30 percent volcanics, and 10 percent feldspar.
440	450	Sand, gray to white, coarse- to fine-grained, subangular to subrounded, with 60 percent quartz, 30 percent volcanics, and 10 percent feldspar.
450	460	Pea gravel, subangular to subrounded, with 50 percent quartz, 40 percent volcanics, and 10 percent feldspar.
460	470	Sand, coarse- to fine-grained, subangular to subrounded (30 percent); subangular to subrounded pea gravel, with 50 percent quartz, 40 percent volcanics, and 10 percent feldspar (70 percent).
470	480	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 50 percent quartz, 40 percent volcanics, and 10 percent feldspar (90 percent); pea gravel (10 percent).
480	490	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 50 percent quartz, 40 percent volcanics, and 10 percent feldspar (90 percent); brown silt (10 percent).
490	500	Sand, gray, medium- to fine-grained, subangular to subrounded, with 60 percent quartz, 30 percent volcanics, and 10 percent feldspar; sparse pea gravel.
500	510	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 60 percent quartz, 20 percent volcanics, and 20 percent feldspar.
510	520	Sand, gray to brown, medium- to fine-grained, subangular to subrounded, with 60 percent quartz, 30 percent volcanics, and 10 percent feldspar (95 percent); gray silt and clay; very angular pea gravel (5 percent).

Table 11. Geologist's log for test well 3 - Continued

Depth interval (feet)		Cuttings description
520	530	Sand, gray to brown, medium- to fine-grained, subangular to subrounded, with 60 percent quartz, 30 percent volcanics, and 10 percent feldspar; magnetite.
530	540	Sample missing.
540	570	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 60 percent quartz, 20 percent volcanics, and 20 percent feldspar; magnetite.
570	580	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 70 percent quartz, 20 percent feldspar, and 10 percent volcanics.
580	600	Sand, gray, medium- to fine-grained, subangular to subrounded, with 70 percent quartz, 20 percent feldspar, and 10 percent volcanics.
600	630	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 70 percent quartz, 20 percent volcanics, and 10 percent feldspar.
630	640	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 70 percent quartz, 20 percent volcanics, and 10 percent feldspar.
640	660	Clay and silt (70 percent); gray, coarse-grained, angular to subangular sand with quartz and volcanics (30 percent).
660	670	Clay and silt (70 percent); gray, medium- to fine-grained, subangular sand with quartz and volcanics (30 percent).
670	680	Clay and silt, brown (50 percent); gray, medium- to fine-grained, subangular sand with 60 percent volcanics and 40 percent quartz (50 percent).
680	690	Clay and silt, brown (70 percent); gray, medium- to fine-grained, subangular sand with 60 percent volcanics and 40 percent quartz (30 percent).

Table 11. Geologist's log for test well 3 - Continued

Depth interval (feet)		Cuttings description
690	700	Clay and silt, brown (50 percent); gray, medium- to fine-grained, subangular sand with 60 percent volcanics and 40 percent quartz; sparse pea gravel (50 percent).
700	710	Sand, gray, medium- to fine-grained, subangular to subrounded, with 60 percent quartz, 20 percent volcanics, and 10 percent feldspar (80 percent); brown clay and silt (20 percent).
710	720	Silt, brown (70 percent); coarse-grained, angular to subangular sand with quartz and feldspar; sparse pea gravel (30 percent).
720	730	Sand, gray, medium- to fine-grained, subangular to subrounded, with 60 percent quartz, 30 percent volcanics, and 10 percent feldspar (80 percent); brown clay and silt (20 percent).
730	740	Sand, gray, medium- to fine-grained, subangular to subrounded, with 60 percent quartz, 30 percent volcanics, and 10 percent feldspar.
740	750	Clay and silt, brown (70 percent); gray, coarse-grained, subangular to subrounded sand with 60 percent volcanics, 30 percent quartz, and 10 percent feldspar (30 percent).
750	760	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 60 percent volcanics, 30 percent quartz, and 10 percent feldspar (80 percent); clay and silt (10 percent); pea gravel (10 percent).
760	800	Silt, brown (60 percent); gray, medium- to fine-grained, subangular to subrounded sand with quartz, volcanics, and feldspar (40 percent).
800	810	Sand, gray, medium- to fine-grained, subangular to subrounded, with 60 percent quartz, 30 percent volcanics, and 10 percent feldspar (80 percent); brown silt and clay (20 percent).

Table 11. Geologist's log for test well 3 - Continued

Depth interval (feet)		Cuttings description
810	820	Sand, gray, coarse-grained, angular to subangular, with 60 percent quartz, 20 percent volcanics, and 20 percent feldspar (70 percent); brown silt and clay (30 percent).
820	850	Silt and clay, brown (90 percent); coarse-grained, angular sand with quartz, volcanics, and feldspar (10 percent).
850	860	Sand, gray, medium- to fine-grained, subangular to subrounded, with 60 percent quartz, 30 percent volcanics, and 10 percent feldspar (80 percent); brown silt and clay (20 percent).
860	880	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 60 percent quartz, 30 percent volcanics, and 10 percent feldspar (90 percent); brown silt and clay (10 percent).
880	900	Sand, gray, medium- to fine-grained, subangular to subrounded, with quartz, volcanics, and feldspar (60 percent); brown silt and clay (40 percent).
900	910	Sand, gray, medium- to fine-grained, subangular to subrounded, with 70 percent quartz, 20 percent volcanics, and 10 percent feldspar.
910	940	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 70 percent quartz, 20 percent volcanics, and 10 percent feldspar; sparse pea gravel.
940	990	Sand, gray, medium- to fine-grained, subangular to subrounded, with 70 percent quartz, 20 percent volcanics, and 10 percent feldspar.
990	1,020	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 70 percent quartz, 20 percent volcanics, and 10 percent feldspar.

Table 11. Geologist's log for test well 3 - Concluded

Depth interval (feet)		Cuttings description
1,020	1,030	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 70 percent quartz, 20 percent volcanics, and 10 percent feldspar (80 percent); brown silt and clay (20 percent).
1,030	1,050	Sand, gray, coarse- to fine-grained, subangular to subrounded, with 70 percent quartz, 20 percent volcanics, and 10 percent feldspar.

Table 12. Analysis of water samples from test well 3

[All constituents are dissolved; mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 °Celsius; °C, degrees Celsius; gal/min, gallons per minute]

Property or constituent	U.S. Geological Survey Sample collected November 1981	U.S. Geological Survey Sample collected March 1982	City of Albuquerque Sample collected November 1981
Alkalinity, total as calcium carbonate (mg/L)	110	110	-
Arsenic (µg/L)	-	-	33
Barium (µg/L)	-	-	90
Bicarbonate (field) (mg/L)	-	130	-
Cadmium (µg/L)	-	-	1
Calcium (mg/L)	40	40	-
Chloride (mg/L)	19	13	-
Chromium (µg/L)	-	-	4
Copper (µg/L)	-	-	5
Fluoride (mg/L)	0.3	0.2	-
Hardness, carbonate (mg/L)	130	120	-
Iron (µg/L)	71	55	800
Lead (µg/L)	-	-	5
Magnesium (mg/L)	6.5	5.9	-
Manganese (µg/L)	22	10	60
Mercury (µg/L)	-	-	1
Nickel (µg/L)	-	-	5
Nitrogen, nitrite plus nitrate as nitrogen (mg/L)	0.1	0.1	-
pH (field)	8.0	7.8	-
Potassium (mg/L)	7.7	7.0	6.7
Selenium (µg/L)	-	-	5
Silica (mg/L)	63	60	-
Silver (µg/L)	-	-	-
Sodium (mg/L)	18	18	16
Specific conductance (field) (µS/cm)	330	320	-
Sulfate (mg/L)	44	43	-
Water temperature (°C)	17	21	-
Zinc (µg/L)	-	-	150
Well yield (gal/min)	192	15	192

Aquifer Tests and Related Estimates of Aquifer Properties

Preliminary aquifer testing and well-development checks (Birsoy and Summers, 1980) were made using step-drawdown aquifer tests with all perforated intervals open to the pump. It is likely that during well development only the upper two perforated intervals (350 to 390 and 490 to 590 feet below land surface) were developed with most development in the interval from 350 to 390 feet below land surface. The pump was set 100 feet below land surface and maximum discharge was 192 gallons per minute. Three aquifer zones were tested using inflatable packers: from 490 to 590 feet below land surface, 710 to 790 feet below land surface, and 870 to 1,050 feet below land surface.

The packers were first set to isolate and pump the perforated interval from 870 to 1,050 feet below land surface. The perforated interval from 710 to 790 feet below land surface also was isolated and hydraulic head monitored during pumping in the lower perforated interval. Drawdown in the pumped interval (870 to 1,050 feet below land surface) and also in the interval from 710 to 790 feet below land surface is shown in figure 20. With a discharge rate of about 14 gallons per minute, it took less than 30 seconds for a drawdown of 153 feet to occur in the pumped interval. The hydraulic head then gradually increased during 24 hours of pumping. Superimposed on this trend are effects of what may be discharge from a well at an unknown location. When the pump was turned off, the water level in the test well recovered almost instantaneously to within about 2 feet of the original water level. The very fast drawdown and recovery in the pumped interval made data analysis impossible. The sudden hydraulic-head changes probably are a result of large well entrance losses in the pumped interval. The rising hydraulic head during pumping indicates well development throughout the aquifer test.

To test the perforated interval between 710 and 790 feet below land surface, the top packer was set at 697 feet below land surface and the bottom packer at 815 feet. The time-drawdown relation in the pumped interval and for perforated intervals above and below is shown in figure 21. The hydraulic head in the pumped interval declined rapidly with 205 feet of drawdown and then recovered for the 48 hours of continued pumping with a constant discharge rate of about 14 gallons per minute. This perforated interval probably was developing during pumping. When the pump was turned off, the hydraulic head recovered to within 4 feet of static hydraulic head almost instantaneously. Superimposed on the drawdown are fluctuations in hydraulic head that might be the result of a pumping well located some distance from test well 3. The perforated interval 870 to 1,050 feet below land surface showed a general downward trend, probably caused from pumping in test well 3, and fluctuations as great as 3 feet that may be the result of some external stress. Changes in hydraulic head in the perforated intervals above the pumped interval (above 590 feet below land surface) again showed the general downward trend. Effects of a possible external stress above 590 feet below land surface are subdued compared to those in the deeper monitored perforated interval. The smaller amplitude of fluctuations in the upper perforated intervals compared to those in the interval below that pumped may be the result of a large coefficient of storage in the upper zone of the aquifer.

The stress, assuming it is caused by a well some distance from test well 3, may be extracting water from an aquifer zone at approximately the same depth as the lower monitored perforated interval. The combined effect of a small coefficient of storage and extraction of water from a common lower aquifer zone may cause the larger fluctuations in the lower perforated interval of test well 3.

The perforated interval from 490 to 590 feet below land surface was pumped with packers set at 480 feet and 598 feet below land surface. Drawdown in the pumped, upper (350 to 390 feet below land surface), and lower perforated intervals (below 710 feet below land surface) is shown in figure 22. Drawdown in the pumped interval was very rapid to about 15 feet; the rate of drawdown then decreased. Final drawdown was 16.1 feet after 203 minutes of pumping at 14 gallons per minute. A short circuit in the electrical system caused pumping to end after 203 minutes. Recovery was fast and complete. Using the modified Theis solution (fig. 23) resulted in a T of 1,300 feet squared per day with a K of 13 feet per day.

The upper and lower perforated intervals relative to the pumped interval had 0 and 0.2 foot of drawdown, respectively. Hydraulic head in both intervals increased about 0.5 foot and then decreased.

Analysis of the step-drawdown test data is presented because the upper perforated interval of 350 to 390 feet below land surface was not pumped during aquifer tests using packers. The data, when analyzed using the method suggested by Birsoy and Summers (1980), indicate the well was developed. However, the pump was set 100 feet below land surface with a maximum discharge rate of 192 gallons per minute; it is unlikely that all perforated intervals were contributing water to the well during the step test. The upper two perforated intervals (350 to 390 and 490 to 590 feet below land surface) may be fairly well developed; the lower ones probably are not developed. A semilogarithmic plot of the step-drawdown aquifer-test data is shown in figure 24. Analysis results are a computed T of 3,900 feet squared per day and a K of 28 feet per day, assuming 140 feet of perforated interval contributed water to the well.

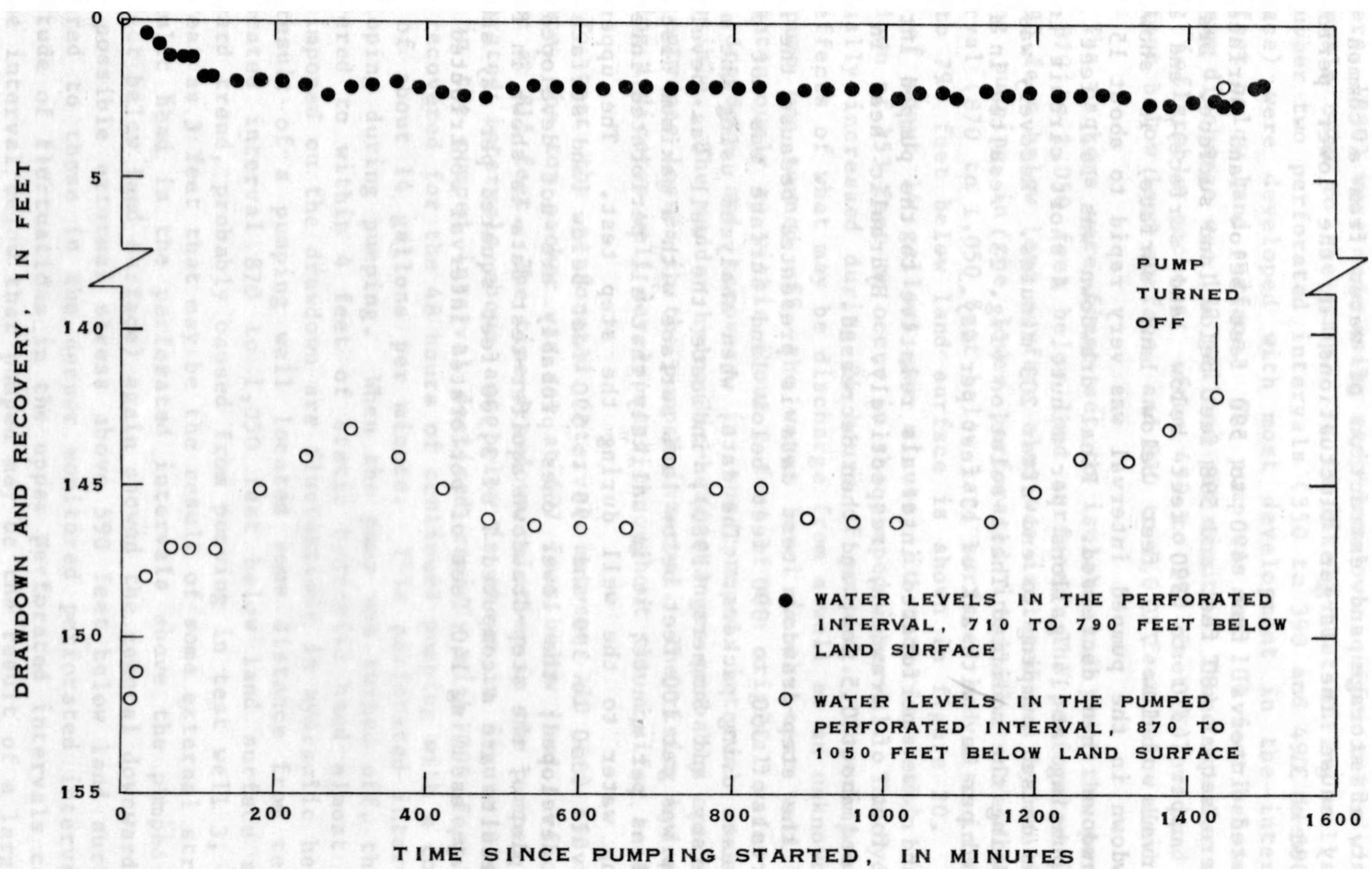

Figure 20.--Drawdown and recovery in the 870- to 1,050- and 710- to 790-foot perforated intervals of test well 3 during pumping in the 870- to 1,050-foot perforated interval.

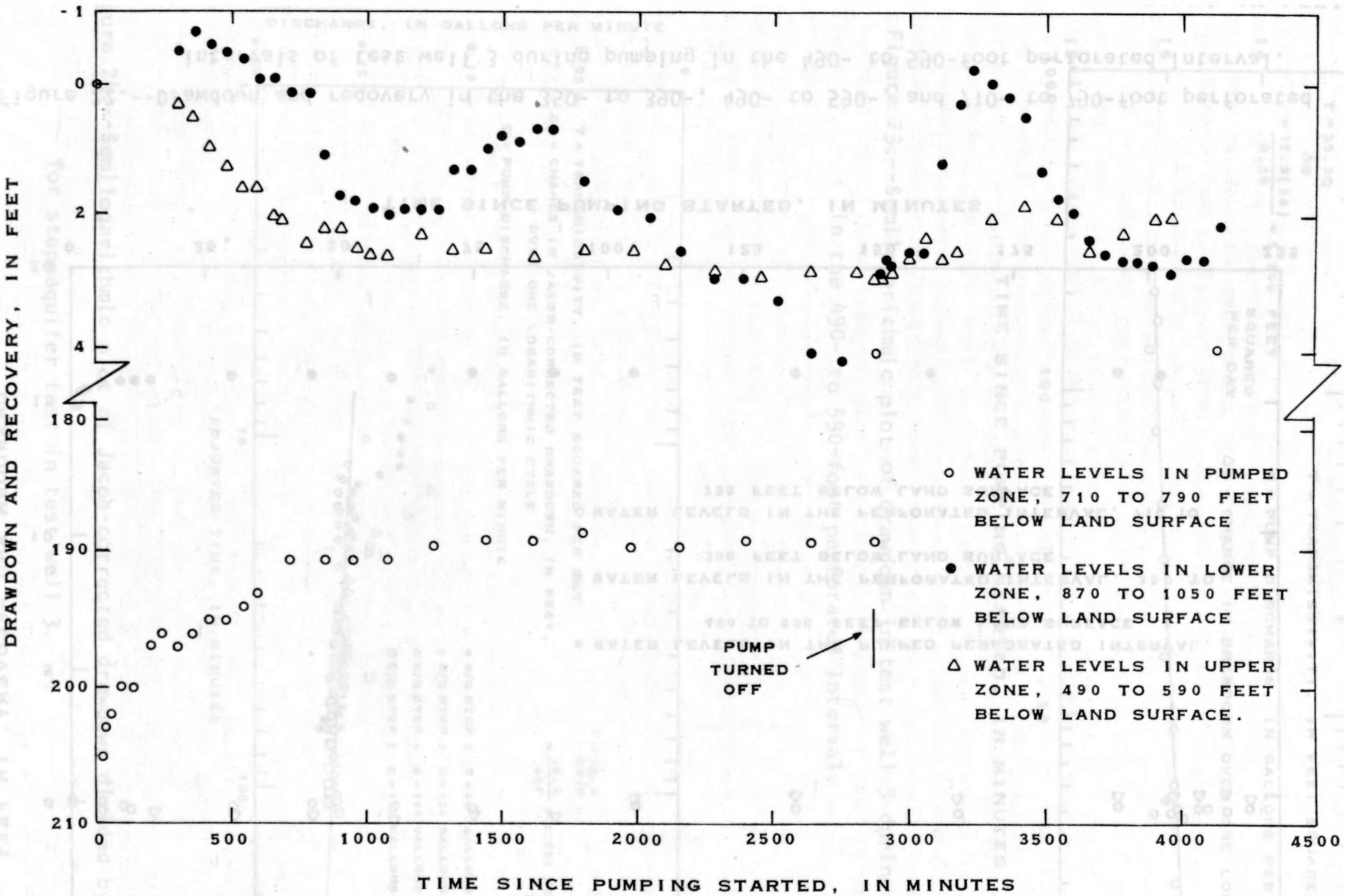

Figure 21.--Drawdown and recovery in the 490- to 590-, 710- to 790-, and 870- to 1,050-foot perforated intervals of test well 3 during pumping in the 710- to 790-foot perforated interval.

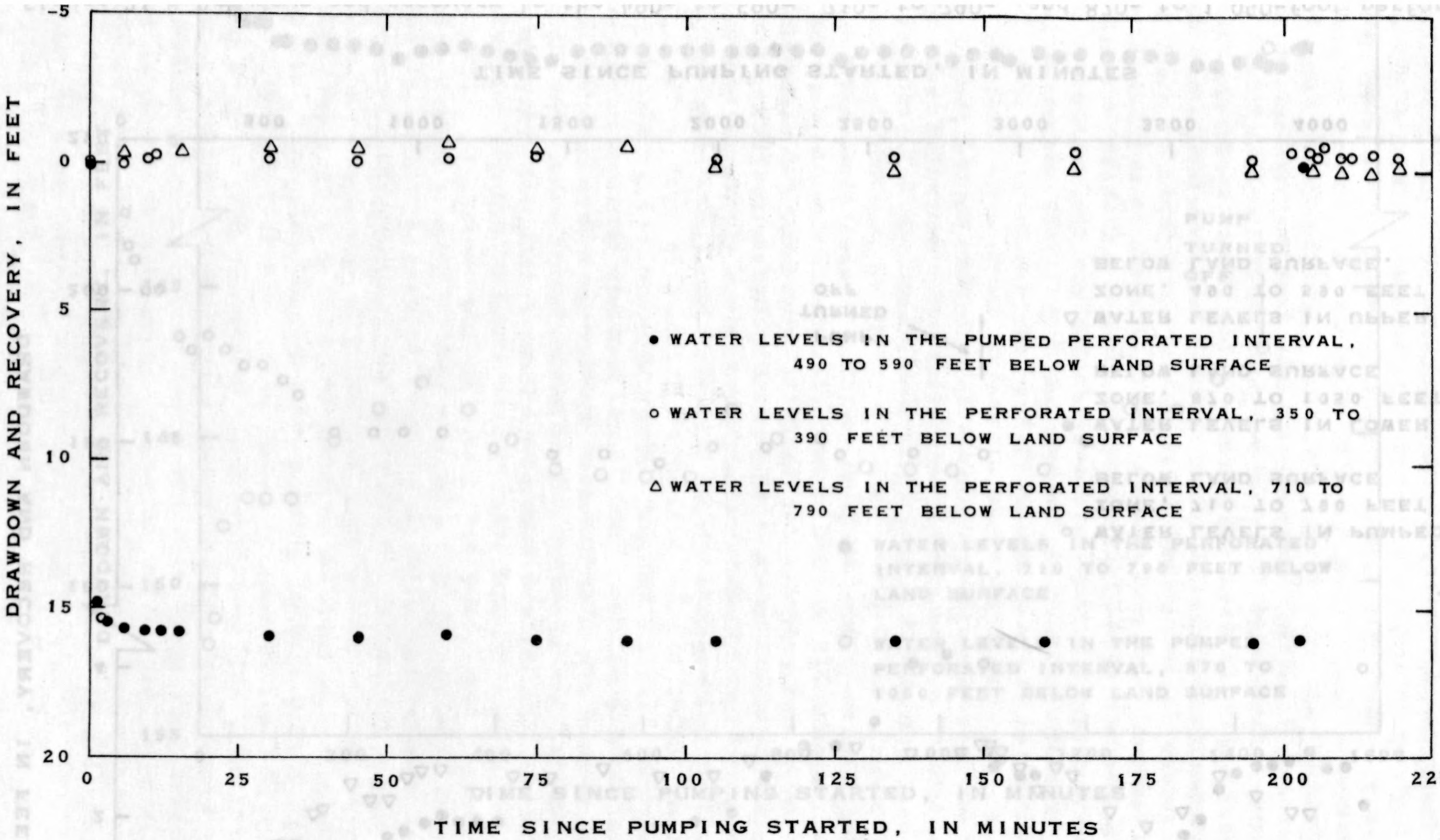

Figure 22.--Drawdown and recovery in the 350- to 390-, 490- to 590-, and 710- to 790-foot perforated intervals of test well 3 during pumping in the 490- to 590-foot perforated interval.

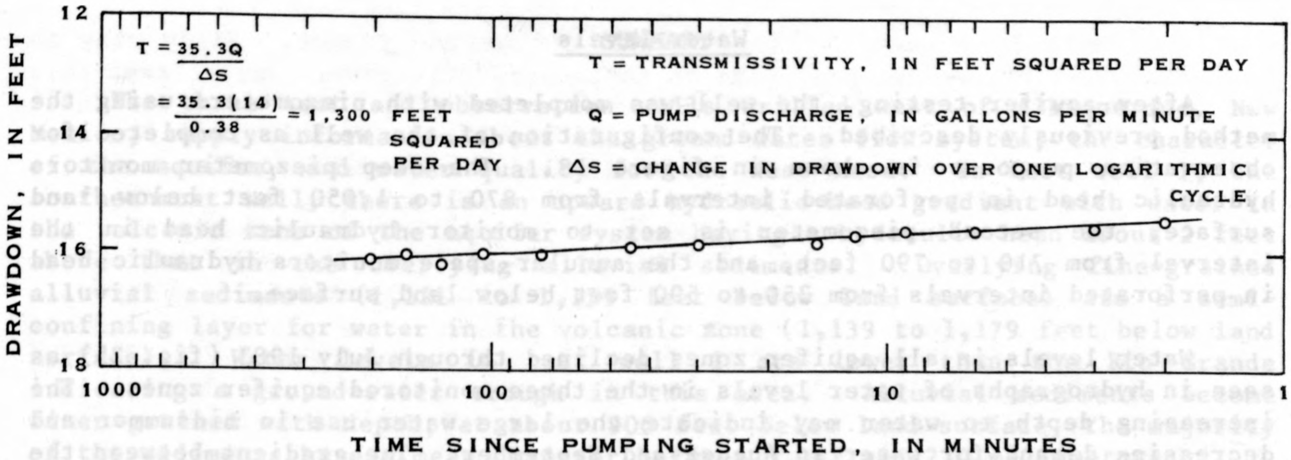

Figure 23.--Semilogarithmic plot of drawdown in test well 3 during pumping in the 490- to 590-foot perforated interval.

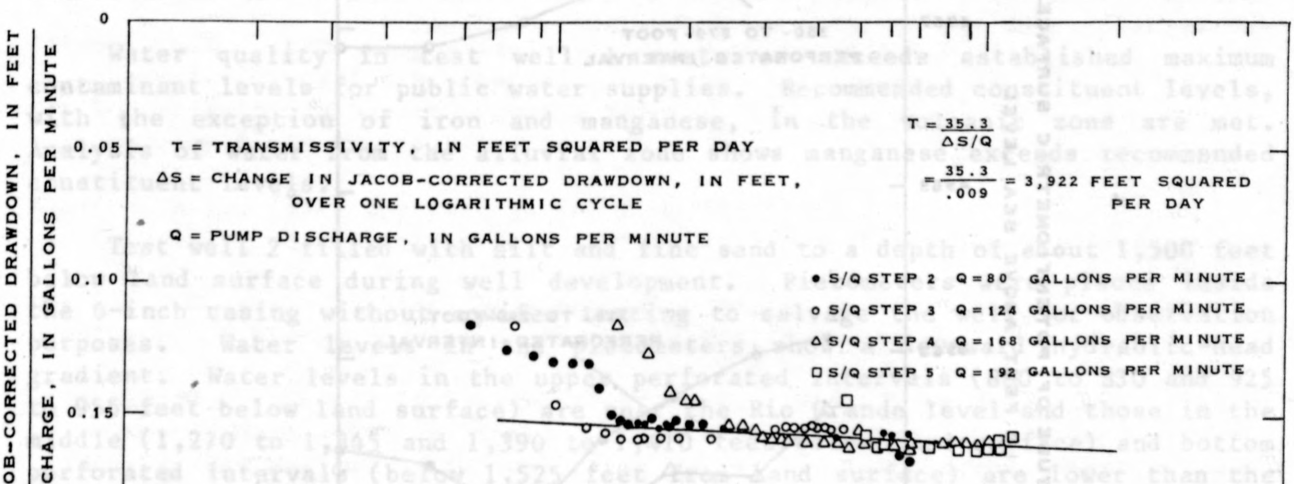

Figure 24.--Semilogarithmic plot of Jacob-corrected drawdown divided by discharge for step-aquifer test in test well 3.

Water Levels

After aquifer testing, the well was completed with piezometers using the method previously described. The configuration of the well as completed for observation purposes is shown in figure 18. The deep piezometer monitors hydraulic head in perforated intervals from 870 to 1,050 feet below land surface, the second piezometer is set to monitor hydraulic head in the interval from 710 to 790 feet, and the annular space monitors hydraulic head in perforated intervals from 350 to 590 feet below land surface.

Water levels in all aquifer zones declined through July 1983 (fig. 25) as seen in hydrographs of water levels in the three monitored aquifer zones. The increasing depth to water may indicate the large water use in midsummer and decreasing demand for water in August and September. The gradient between the three aquifer zones defines a downward vertical flow with a hydraulic-head difference of about 7 feet. Water levels in the annular space are above Rio Grande channel level and in the piezometers they are near river channel level. The downward flow direction indicates that flood-plain sediments are a source of water to the surrounding Santa Fe Group in this part of the basin.

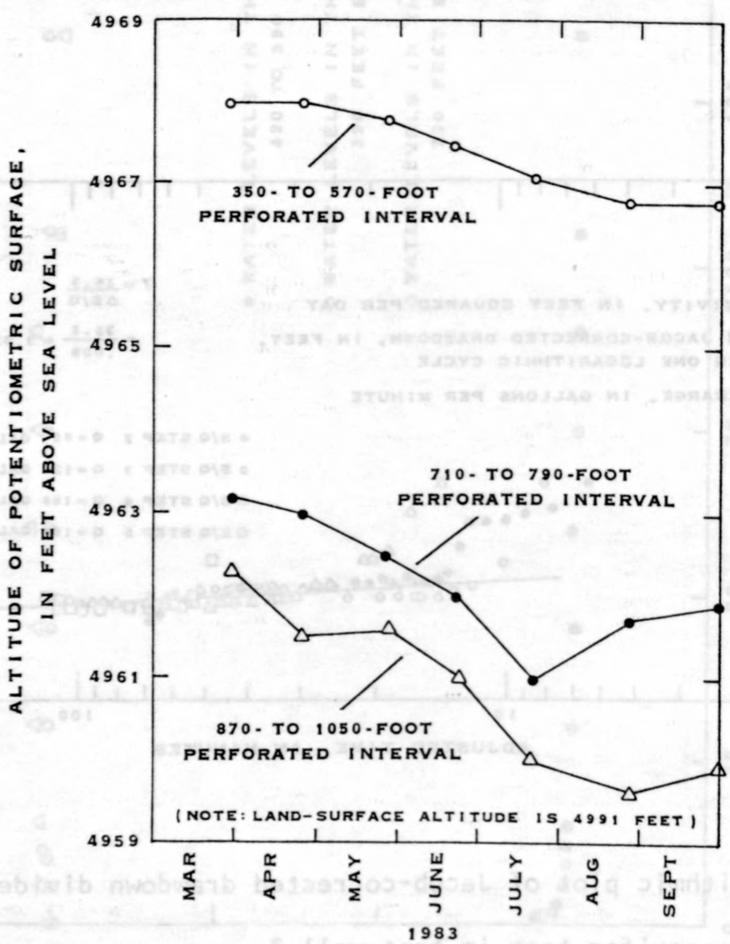

Figure 25.--Water levels in test well 3.

SUMMARY

The three test and observation wells drilled west of Albuquerque, New Mexico, supply information about the ground-water flow system, the character of the aquifer, and water quality for the West Mesa. In test well 1, the southernmost well, there is an upward hydraulic-head gradient with water in the volcanic zone of the aquifer system having a hydraulic head about 2 feet above that in the overlying alluvial sediments. Overlying fine-grained alluvial sediments (1,121 to 1,139 feet below land surface) are a semi-confining layer for water in the volcanic zone (1,139 to 1,179 feet below land surface). Water levels in test well 1 are lower than the Rio Grande indicating a ground-water trough in this area. Alluvial sediments become finer grained with depth; at about 900 feet below land surface, the majority of the sediments have a mean diameter between 0.062 and 2.0 millimeters.

Results of aquifer tests in test well 1 indicate a transmissivity for the alluvial aquifer of about 3.9 feet squared per day, and horizontal hydraulic conductivity of about 0.03 foot per day. Vertical hydraulic conductivity of the confining layer ranges from 3.1×10^{-4} to 3.1×10^{-3} feet per day. Transmissivity for the volcanic zone is about 81 feet squared per day and horizontal hydraulic conductivity is about 2.0 feet per day. The thickness and areal extent of the volcanic zone are not known. This zone may be an important water-producing zone for future production wells. Drilling into the volcanic zone may encounter problems of lost circulation of the drilling fluid.

Water quality in test well 1 meets or exceeds established maximum contaminant levels for public water supplies. Recommended constituent levels, with the exception of iron and manganese, in the volcanic zone are met. Analysis of water from the alluvial zone shows manganese exceeds recommended constituent levels.

Test well 2 filled with silt and fine sand to a depth of about 1,500 feet below land surface during well development. Piezometers were placed inside the 6-inch casing without aquifer testing to salvage the well for observation purposes. Water levels in the piezometers show a downward hydraulic-head gradient. Water levels in the upper perforated intervals (800 to 830 and 925 to 955 feet below land surface) are near the Rio Grande level and those in the middle (1,270 to 1,345 and 1,390 to 1,410 feet below land surface) and bottom perforated intervals (below 1,525 feet from land surface) are lower than the river level. Geologist's descriptions of cuttings and sieve analysis show the dominant grain sizes of sediments are less than 0.062 and between 0.062 and 2.0 millimeters in mean diameter for the total depth of the borehole. Water-quality analysis for the zone from 1,275 to 1,410 feet below land surface, which is probably representative of the vertical section of the aquifer above 1,800 feet at this location, shows manganese and cadmium concentrations exceed the recommended constituent level and the maximum contaminant level, respectively.

Test well 3 is near the flood plain of the Rio Grande. Sandy clay to coarse sand is the predominant size of sediments. The percentage of sand-size material tends to increase below 900 feet below land surface. Aquifer tests in the 710- to 790- and 870- to 1,050-foot perforated intervals of the well could not be used to calculate transmissivity and hydraulic conductivity because of almost instantaneous response at the beginning of pumping and water-level recovery during continued pumping. These zones probably were not fully developed. Aquifer tests in the perforated interval from 490 to 590 feet below land surface resulted in a transmissivity of about 1,300 feet squared per day. Aquifer step tests, in which most water probably came from the 350- to 390-foot zone, resulted in a transmissivity of about 3,900 feet squared per day. Water-level data indicate that ground water flows in the downward direction. Water levels in the 350- to 590-foot perforated intervals are higher than the Rio Grande channel, and water levels in the middle and lower aquifer zones (710 to 790 and 870 to 1,050 feet below land surface, respectively) are near river level. Water quality does not change significantly with depth and does not exceed maximum contaminant or recommended constituent levels.

Drilling test holes would be beneficial before drilling production wells in this area. Problems with sand flowing into test well 2 show that fine sand and silt can enter a well casing if the well is not completed correctly. In a production well this could severely limit the production and life of the installation. Water-quality information shows that iron and manganese concentrations can exceed recommended constituent limits and might cause encrustation problems in the pump and delivery system.

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