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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

# GEOHYDROLOGIC AND DRILL-HOLE DATA FOR TEST WELL USW H-4, YUCCA MOUNTAIN, NYE COUNTY, NEVADA

by

M. S. Whitfield, Jr., William Thordarson, and E. P. Eshom

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UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

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METRIC CONVERSION TABLE

For those readers who prefer to use inch-pound rather than metric units, conversion factors for the terms used in this report are listed below:

| *Metric unit* | *Multiply by* | *To obtain inch-pound unit* |
|---|---|---|
| cubic meter | $3.531 \times 10^{1}$ | cubic foot |
| degree Celsius | $1.8°C + 32$ | degree Fahrenheit |
| gram per cubic centimeter ($g/cm^3$) | $6.243 \times 10^{1}$ | pound per cubic foot |
| kilometer (km) | $6.214 \times 10^{-1}$ | mile |
| liter (L) | $2.642 \times 10^{-1}$ | gallon |
| liter per second (L/s) | $1.585 \times 10^{1}$ | gallon per minute |
| meter (m) | 3.281 | foot |
| milligram per liter | [1]1.0 | part per million |
| millimeter (mm) | $3.937 \times 10^{-2}$ | inch |

[1]Approximate.

*National Geodetic Vertical Datum of 1929*--A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level; it is referred to as sea level in this report.

# GEOHYDROLOGIC AND DRILL-HOLE DATA FOR TEST WELL USW H-4, YUCCA MOUNTAIN, NYE COUNTY, NEVADA

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## ABSTRACT

This report presents data on drilling operations, lithology, geophysical well logs, sidewall-core samples, water-level monitoring, pumping tests, injection tests, radioactive-tracer borehole flow survey, and water chemistry for test well USW H-4. The well is one of a series of test wells drilled in the southwestern part of the Nevada Test Site, Nye County, Nevada, in cooperation with the U.S. Department of Energy. These test wells are part of the Nevada Nuclear Waste Storage Investigations to identify sites for storage of high-level radioactive wastes.

Test well USW H-4 was drilled in ash-flow tuff to a total depth of 1,219 meters. Depth to water below land surface was 519 meters, or at an altitude of 730 meters above sea level. After test pumping at a rate of 17.4 liters per second for approximately 9 days, the drawdown was 4.85 meters. A radioactive borehole-flow survey indicated that the Bullfrog Member of the Crater Flat Tuff (Tertiary age) was the most productive geologic unit, producing 36.5 percent of the water in the well. The second most productive geologic unit was the Tram Member of the Crater Flat Tuff, which produced 32 percent of the water. The water in test well USW H-4 is predominantly a soft, sodium bicarbonate type of water typical of water produced in tuffaceous rocks in southern Nevada.

## INTRODUCTION

The U.S. Geological Survey has been conducting geologic and hydrologic investigations at Yucca Mountain, near Mercury, Nevada, to evaluate the suitability of this site for storing high-level nuclear waste in an underground mined repository. These investigations are part of the Nevada Nuclear Waste Storage Investigations being conducted in cooperation with the U.S. Department of Energy, Nevada Operations Office. Test drilling has been a principal method of investigation. This report presents geohydrologic data from hydrologic test well USW H-4. All data tables presented were compiled by the authors except where otherwise noted.

Test well USW H-4 is located in Nye County, Nev., approximately 45 km northwest of Mercury in the southern part of the State (fig. 1). The well site is in an easterly-draining canyon of Yucca Mountain, northwest of Jackass Flats. Location of the site is Nevada State Coordinate System Central Zone N. 761,642.6 and E. 563,911.0. Altitude of the land surface at the well site is 1,248.9 m above sea level. Survey of the site was done by Holmes & Narver, Inc., Mercury, Nevada.

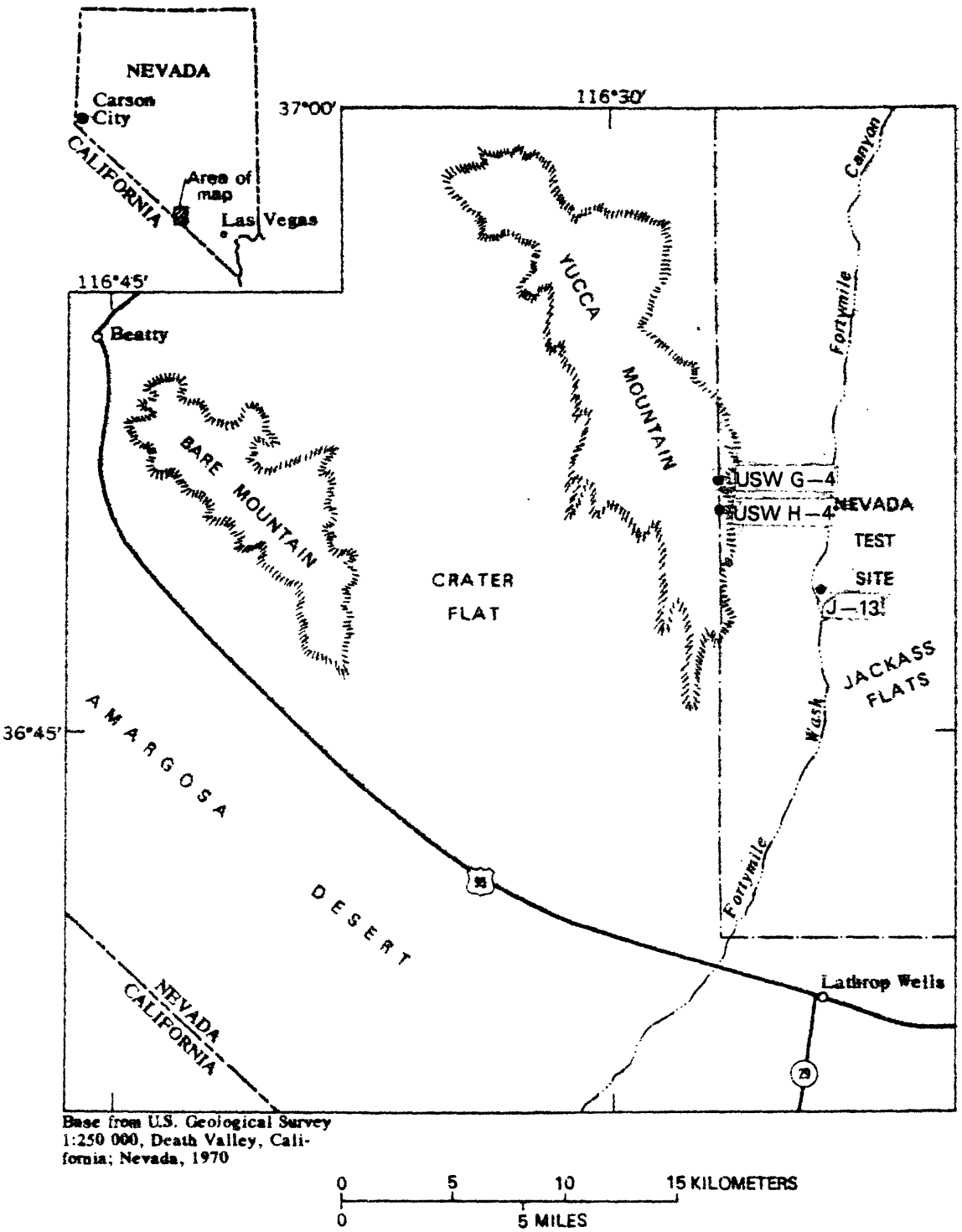


Figure 1.--Location of test well USW H-4 and nearby geographic features in southern Nevada.

## DRILLING OPERATIONS

Drilling of test well USW H-4 started on March 22, 1982; total depth of 1,219 m was reached on April 28, 1982, and the well was completed on June 7, 1982. The rotary-drilling fluid was air foam, consisting of air, detergent, and water obtained from well J-13. Well deviation was less than 3° from the vertical. Bit, casing, and cementing data are listed in table 1. A detailed drilling history is contained in the files of the drilling contractor, Fenix & Scisson, Inc., Las Vegas, Nev.

Table 1.--*Bit and casing data*

| Drilled interval (meters) | Bit diameter (millimeters) | Cased interval (meters) | Casing inside diameter (millimeters) | Intervals cemented and volume of cement used | |
|---|---|---|---|---|---|
| | | | | Depth (meters) | Volume (cubic meters) |
| 0 to 11 | 914 | 0 to 11 | 743 | 0 to 11 | 6.8 |
| 11 to 47 | 660 | 0 to 95 | 381 | 0 to 95 | 20.4 |
| 47 to 96 | 508 | | | | |
| 96 to 564 | 375 | 0 to 561 | 253 | 548 to 561 | 2.8 |
| 564 to 1,219 | 222 | [1] | --- | ---------- | ---- |

[1]No casing set below a depth of 561 meters.

After the test well was drilled to a depth of 564 m, geophysical logs were run and water-level measurements were made. Sidewall sampling also was attempted, with minimal success. Then the hole was cased to a depth of 561 m and cemented at its base. The hole was drilled to its total depth and again logged; then the casing was perforated from 533 to 539 m, with two shots per 0.3048 m. Finally, hydrologic tests were conducted, mainly in the uncased part of the hole.

## LITHOLOGIC SAMPLING AND WELL LOGGING

### Lithology

A lithologic log of rocks of Tertiary age penetrated in the drilling of test well USW H-4 was made from rock cuttings and cores and is shown in table 2. Contacts between the geologic units were cross-checked with geophysical logs. Ash-flow tuff is the dominant rock type penetrated. The bases of the thick ash-flow beds are separated by five bedded, reworked units of tuff that range in thickness from 4 to 16 m. The tuffs have various degrees of welding and induration, as described in table 2.

### Hydrologic Properties of Sidewall-Core Samples

After drilling to a depth of 564 m, 22 zones were selected in the unsaturated and saturated sections for collecting sidewall samples. About 70 to 80 attempts were made to collect samples with a Hunt sidewall sampling tool.[1] However, only five samples could be collected, all from the tuffaceous beds of Calico Hills. Of these, three were analyzed by Holmes & Narver, Inc., Mercury, Nev. The samples were only analyzed for grain density and were from depths of 400, 443.5, and 472.5 m. Grain density was 2.40, 2.42, and 2.40 g/cm$^3$, respectively.

[1]Any use of trade names is for identification only and does not constitute endorsement by the U.S. Geological Survey.

Table 2.--*Lithologic log*

[Log compiled by Richard W. Spengler, U.S. Geological Survey, 1983]

| Stratigraphy and lithologic description | Thickness of interval (meters) | Depth of interval (meters) |
|---|---|---|
| Paintbrush Tuff | | |
| Tiva Canyon Member (0.0-61.6 meters) | | |
| Tuff, ash-flow, medium-gray to medium-light-gray, densely welded, devitrified; pumice, light-gray, very light gray; less than 2 percent phenocrysts; rare volcanic lithic fragments; may correlate with "Lower Lithophysal Subunit." | 27.4 | 0.0- 27.4 |
| Tuff, ash-flow, dark-yellowish-brown and brownish-gray, densely welded, devitrified; pumice, dark-yellowish-brown; less than 2 percent phenocrysts; rare dark-reddish-brown and grayish-red volcanic lithic fragments. | 17.4 | 27.4- 44.8 |
| Tuff, ash-flow, pale-brown and dark-yellowish-brown, devitrified; pumice, moderate-reddish-orange, devitrified (occasional pumice fragments altered to clay); 1-2 percent phenocrysts; rare grayish-red volcanic lithic fragments. | 8.2 | 44.8- 53.0 |
| Tuff, ash-flow, moderate-yellowish-brown and grayish-orange, partially to nonwelded, vitric; pumice, pale-yellowish-orange and grayish-orange, vitric; 1 percent phenocrysts (sanidine and plagioclase, rare biotite); rare light gray rhyolitic lithic fragments; abundant dark-yellowish-orange and black glass shards. | 8.6 | 53.0- 61.6 |
| Bedded tuff (61.6-65.2 meters) | | |
| Tuff, bedded, reworked, yellowish-gray, grayish-orange, light-red, vitric; abundant white, vitric pumice fragments. | 3.6 | 61.6- 65.2 |
| Topopah Spring Member (65.2-399.9 meters) | | |
| Tuff, ash-flow, moderate-reddish-orange and moderate-red, nonwelded, vitric; abundant grayish-orange, light-brown, and moderate-red, vitric pumice; 3-4 percent phenocrysts (sanidine, plagioclase, and bronze biotite). | 3.1 | 65.2- 68.3 |

Table 2.--*Lithologic log*--Continued

| Stratigraphy and lithologic description | Thickness of interval (meters) | Depth of interval (meters) |
|---|---|---|
| Paintbrush Tuff--Continued | | |
| Topopah Spring Member--Continued | | |
| Tuff, ash-flow(?), partly to moderately welded, very light gray, vitric [lower 0.3-0.6 m pale-reddish-brown vitrophyre(?)]. | 8.5 | 68.3- 76.8 |
| Tuff, ash-flow, brownish-gray, densely welded, devitrified; pumice, brownish-gray, devitrified; 10 percent phenocrysts (sanidine, plagioclase, and bronze biotite); (caprock). | 0.6 | 76.8- 77.4 |
| Tuff, ash-flow, pale-red and grayish-red, moderately welded, vapor-phase crystallization; pumice, commonly pale-red and light-brownish-gray, vapor-phase; 5-7 percent phenocrysts (sanidine, plagioclase, and bronze biotite). | 37.2 | 77.4- 114.6 |
| Tuff, ash-flow, light-gray and light-brownish-gray, densely welded, devitrified, lithophysal zone(?); pumice, light-gray, very light gray, and light-brownish-gray, devitrified; 3-6 percent phenocrysts (sanidine, plagioclase, and rare biotite); size of bit cuttings decrease conspicuously below 155.4 m. | 63.7 | 114.6- 178.3(?) |
| Tuff, ash-flow, brownish-gray, light-brown, and moderate-brown, densely welded, devitrified; pumice, brownish-gray and moderate-brown, devitrified; less than 1 percent phenocrysts (sanidine and plagioclase); television camera indicates a lithophysal zone from 215.8 to 305.7 m. Within zone, bit cuttings are relatively larger and mottled. | 182.9 | 178.3- 361.2 |
| Tuff, ash-flow, black, glassy vitrophyre. | 9.7 | 361.2- 370.9 |
| Tuff, ash-flow, pale-yellowish-orange, partly welded, vitric; contains abundant black glass shards. | 4.0 | 370.9- 374.9 |
| Tuff, ash-flow, pinkish-gray, and yellowish-gray, nonwelded (friable), vitric [slightly argillic(?)]; pumice, grayish-pink, vitric and argillic; | | |

Table 2.--*Lithologic log*--Continued

| Stratigraphy and lithologic description | Thickness of interval (meters) | Depth of interval (meters) |
|---|---|---|
| Paintbrush Tuff--Continued | | |
| Topopah Spring Member--Continued | | |
| abundant black glass shards; interval from 393.8 m to base contains abundant large lithic fragments; no bedded interval recognized at base of interval. | 25.0 | 374.9- 399.9 |
| Rhyolite lavas and tuffs of Calico Hills (undivided) | | |
| Tuffaceous beds of Calico Hills (informal usage) (399.9-495.9 meters) | | |
| Tuff, ash-flow, moderate-orange-pink, very pale-orange, and grayish yellow, nonwelded to partly welded, devitrified and zeolitized(?); upper 11 m silicified(?), pumice, white, pink, and grayish-yellow, zeolitized(?); less than 1 percent phenocrysts (quartz and biotite); abundant light-gray and medium-light-gray, and grayish-red rhyolitic lithic fragments. Side-wall samples collected at 399.9, 432.8, 442.9, and 472.4 m; all sidewall samples vary in color; in descending order, colors include very pale orange, grayish-orange pink and light brown; all samples are non-welded, zeolitized(?), and partly silicified; sample at 432.8 m indicates a decrease in degree of silicification. | 80.2 | 399.9- 480.1 |
| Bedded Tuff (480.1-495.9 meters) | | |
| Tuff, bedded, reworked, yellowish-gray, pale-reddish-brown, grayish-yellow, devitrified and zeolitized(?); lower 4.6 m, pale-red, highly silicified. | 15.8 | 480.1- 495.9 |
| Crater Flat Tuff | | |
| Prow Pass Member (495.9-689.8 meters) | | |
| Tuff, ash-flow, grayish-yellow, nonwelded, zeolitic; pumice, grayish-yellow, zeolitic; | | |

Table 2.--*Lithologic log*--Continued

| Stratigraphy and lithologic description | Thickness of interval (meters) | Depth of interval (meters) |
|---|---|---|
| Crater Flat Tuff--Continued | | |
| Prow Pass Member--Continued | | |
| 10 percent phenocrysts of quartz, sanidine, and biotite. | 4.0 | 495.9- 499.9 |
| Tuff, ash-flow, pale-reddish-brown, partly welded, devitrified (some vapor-phase pumice); appears moderately silicified; 7-8 percent phenocrysts (quartz, sanidine, biotite); rare pale-reddish brown mudstone lithic fragments; sidewall sample collected 504.7 m is light-olive-gray, partly welded, devitrified (vapor-phase crystallization; pumice, light-brown, vapor phase; 5 percent phenocrysts (quartz, sanidine, plagioclase); rare mudstone lithic fragments. | 4.9 | 499.9- 504.8 |
| Tuff, ash-flow, yellowish-gray, light-gray, and medium-light-gray, partly welded, devitrified; pumice, light-gray, devitrified, white to moderate-orange-pink and slightly zeolitic(?) from 536.4 m to base; 5-10 percent phenocrysts [quartz, plagioclase, sanidine, biotite, and pyroxene(?)]; sparse moderate-reddish-brown mudstone lithic fragments; contaminated samples from 539.5 to 573.0 m. | 91.1 | 504.8- 595.9 |
| Tuff, ash-flow, dusky-yellow, partly welded, highly zeolitic(?) and silicified; pumice, dusky-yellow, zeolitized(?) and silicified; 10 percent phenocrysts (quartz, sanidine, plagioclase, and biotite); sparse moderate-reddish-brown mudstone lithic fragments. | 25.9 | 595.9- 621.8 |
| Tuff, ash-flow, yellowish-gray, moderate-orange-pink, and dusky-yellow; partly welded, zeolitic and vitric(?) [appears only slightly zeolitized(?)]; pumice, white, pale-greenish-yellow, and dusky-yellow, zeolitic and vitric(?); 10 percent phenocrysts (quartz, sanidine, plagioclase, and biotite); sparse moderate-reddish-brown mudstone lithic fragments; x-ray analysis | | |

Table 2.--*Lithologic log*--Continued

| Stratigraphy and lithologic description | Thickness of interval (meters) | Depth of interval (meters) |
|---|---|---|
| Crater Flat Tuff--Continued | | |
| Prow Pass Member--Continued | | |
| of bit cuttings indicates the presence of clinoptilolite and mordenite (estimated at 50 percent). | 68.0 | 621.8- 689.8 |
| Bedded tuff (689.8-693.4 meters) | | |
| Tuff, bedded, reworked, light-red, moderate-reddish-orange, zeolitized(?). | 3.6 | 689.8- 693.4 |
| Bullfrog Member (693.4-805.9 meters) | | |
| Tuff, ash-flow, medium-gray and pale-yellowish-brown, partly welded, devitrified; pumice, very light gray to light-gray, devitrified [vapor-phase crystallization(?)]; 15 percent phenocrysts (quartz, sanidine, plagioclases, and bronze biotite). | 58.8 | 693.4- 752.2 |
| Tuff, ash-flow, light-gray and light-brownish-gray, partly welded, vapor-phase crystallization(?); pumice, medium-light-gray, vapor phase; 10 percent phenocrysts (quartz, plagioclase, sanidine, and biotite). | 9.8 | 752.2- 762.0 |
| Tuff, ash-flow, light-brown and moderate-yellowish-brown, moderate to densely welded, slightly, altered to zeolites(?); pumice, light-brown, silicified(?); 5-7 percent phenocrysts (quartz, plagioclase, sanidine, and biotite); rare grayish-red volcanic lithic fragments; pumice fragments are black and glassy from 765.0 to 774.2 m. | 25.9 | 762.0- 787.9 |
| Tuff, ash-flow, grayish-orange-pink and light-brown, nonwelded to partly welded, devitrified; pumice, light-brown, devitrified; 10 percent phenocrysts (quartz, plagioclase, sanidine, and biotite); rare medium-light-gray volcanic lithic fragments; bit-cutting samples are contaminated from 792.5 to 826.0 m. | 18.0 | 787.9- 805.9 |

Table 2.--*Lithologic log*--Continued

| Stratigraphy and lithologic description | Thickness of interval (meters) | Depth of interval (meters) |
|---|---|---|
| Crater Flat Tuff--Continued | | |
| Bedded tuff (805.9-812.0 meters) | | |
| Tuff, bedded, reworked, white to grayish-pink, devitrified. | 6.1 | 805.9- 812.0 |
| Tram Member (812.0-1,154.6 meters) | | |
| Note: Samples are highly contaminated from 832.1-841.2 m, 844.3 to 847.3 m, 896.1 to 902.2 m, and 920.5 to 981.5 m; samples from 832.1 to 841.2 m dominantly contain cuttings from the Prow Pass Member; samples from 896.1 to 899.2 m and 944.9 to 957.1 m dominantly contain cuttings from the Bullfrog Member; no samples were collected from 902.2 to 920.5 m. | | |
| Tuff, ash-flow(?), partly welded(?), devitrified(?); this interval is based on geophysical characteristics correlated with other drill holes where both core and geophysical logs exist. | 99.4 | 812.0- 911.4? |
| Tuff, ash-flow, light-brownish-gray and light-olive-gray, moderately welded, devitrified; pumice, white, light-gray to light-brownish-gray, devitrified; 10 percent phenocrysts (quartz, sanidine, plagioclase, black and bronze biotite); rare light-brownish-gray and brownish-gray silicic to intermediate volcanic lithic fragments; based on a similar electric log response found in other drill holes, the interval from 917.4 to 956.8 m probably is highly zeolitized and silicified. | 73.1 | 911.4- 984.5 |
| Tuff, ash-flow, light-gray, olive-gray, and light-brownish-gray, partly welded(?), devitrified [slightly zeolitized(?)]; pumice, light-gray to brownish-gray, argillic(?) and zeolitic(?); abundant brownish-gray and light-gray silicic to intermedite lithic fragments. | 34.1 | 984.5-1,018.6 |
| Tuff, ash-flow, grayish-yellow-green, light-gray, light-greenish-gray, moderate-yellow-green, and greenish-gray, partly welded(?), zeolitic(?); pumice, light-greenish-gray and light-gray, | | |

Table 2.--*Lithologic log*--Continued

| Stratigraphy and lithologic description | Thickness of interval (meters) | Depth of interval (meters) |
|---|---|---|
| Crater Flat Tuff--Continued | | |
| Tram Member--Continued | | |
| zeolitic(?), argillic(?); abundant medium-light gray and brownish-gray volcanic lithic fragments; rare pyrite(?) present in lithic fragments and occasionally in groundmass. | 136.0 | 1,018.6-1,154.6 |
| Bedded tuff (1,154.6-1,164.0 meters) | | |
| Tuff, bedded, reworked, dark-greenish-gray, greenish-gray, grayish-yellow-green, zeolitic(?); abundant zeolitic(?) pumice, sparse lithic fragments, rare biotite. | 9.4 | 1,154.6-1,164.0 |
| Lithic Ridge Tuff (1,164.0-1,219.2 meters) | | |
| Tuff, ash-flow, grayish-orange, moderate-yellowish-brown, partly welded, devitrified; pumice, white, grayish-orange, devitrified; 5 percent phenocrysts (quartz, sanidine, plagioclase, and abundant black biotite); sparse lithic fragments; samples highly contaminated below 1,182.6 m. | 55.2 | 1,164.0-1,219.2 |
| | Total depth: | 1,219.2 |

## Geophysical Well Logs

Geophysical well logs were run in test well USW H-4 for three purposes: (1) To determine a more exact depth of major lithologic changes, (2) to obtain porosity and fracture data, and (3) to gage the diameter of the open hole for selecting packer seats. The types of logs and the depth intervals logged are listed in table 3.

Caliper logs were run to determine a vertical profile of hole diameters. A vertical distribution of the depths where out-of-gage sections of the hole occurred is shown in figure 2; the percent of out-of-gage hole for each stratigraphic unit penetrated is summarized in table 4. "Out-of-gage" is defined in this report as a diameter 100 mm greater than the diameter of the bit used to drill the hole. Out-of-gage zones of the well bore exceeding 300 mm generally cannot be tested by inflatable packers. Some of the enlarged zones identified by the caliper log are associated with rock fracturing; these zones are summarized in table 5.

Table 3.--*Geophysical well logs*

| Geophysical log | Depth interval (meters) |
|---|---|
| Acoustic fraclog gamma ray borehole compensated-- | 576 to 1,218 |
| Acoustilog gamma ray borehole compensated-------- | 576 to 1,218 |
| Caliper---------- | 93 to 95 |
| Caliper---------- | 79 to 560 |
| Caliper---------- | 549 to 1,218 |
| Caliper---------- | 546 to 1,216 |
| Densilog gamma ray---------- | 500 to 1,219 |
| Densilog gamma ray---------- | 556 to 1,216 |
| Density, borehole compensated---------- | 76 to 561 |
| Electric---------- | 546 to 1,219 |
| Epithermal neutron porosity---------- | 27 to 567 |
| Epithermal neutron porosity---------- | 30 to 561 |
| Fluid density for water location---------- | 515 to 524 |
| Fluid density for water location---------- | 504 to 527 |
| Gamma ray---------- | 0 to 561 |
| Gamma ray---------- | 27 to 563 |
| Geophone survey---------- | 556 to 1,216 |
| Induction---------- | 6 to 94 |
| Induction electric log---------- | 91 to 560 |
| Induction electric log---------- | 90 to 560 |
| Neutron, borehole compensated---------- | 500 to 1,219 |
| Radioactive tracer survey---------- | 488 to 1,219 |
| Spectralog gamma ray---------- | 0 to 1,219 |
| Temperature---------- | 0 to 561 |
| Temperature---------- | 549 to 1,219 |
| Television-camera videotape---------- | 0 to 505 |

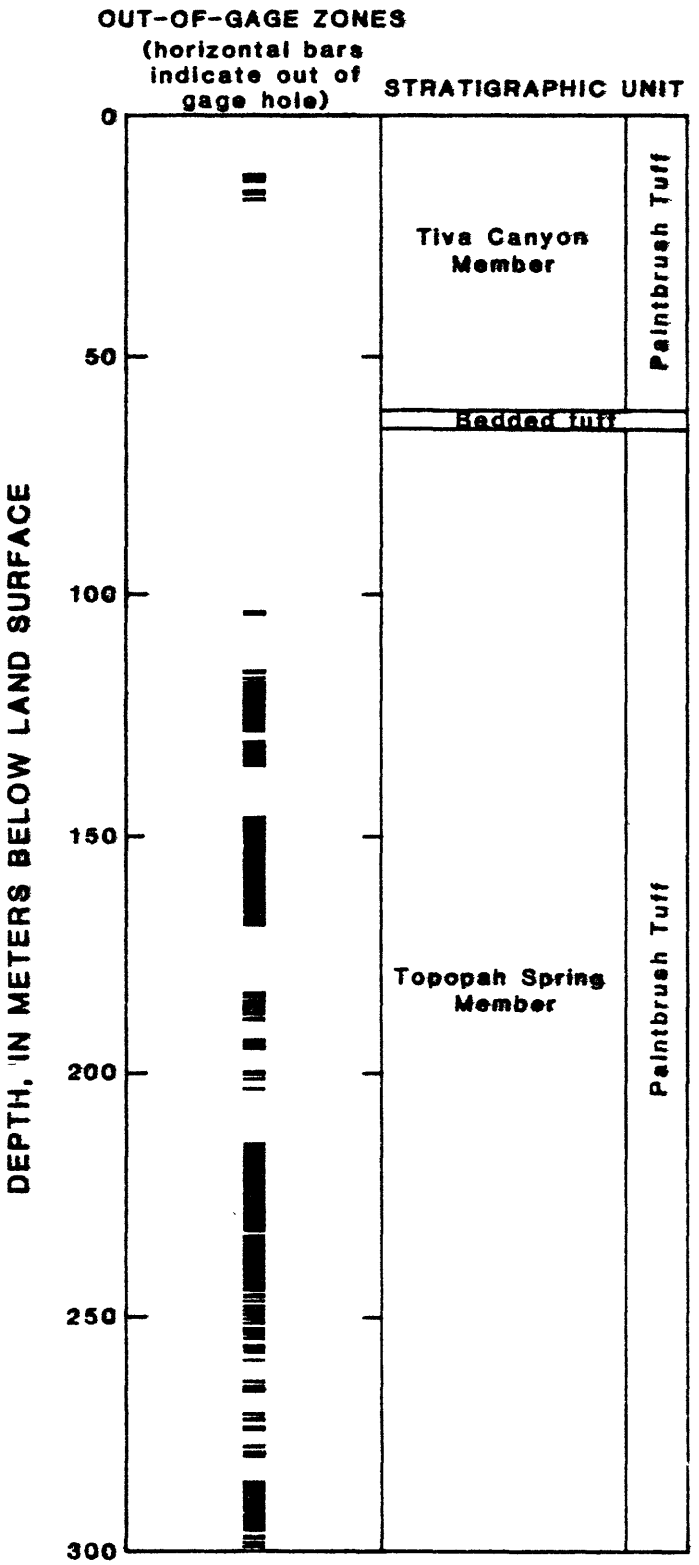


Figure 2.--Generalized vertical distribution of out-of-gage hole.

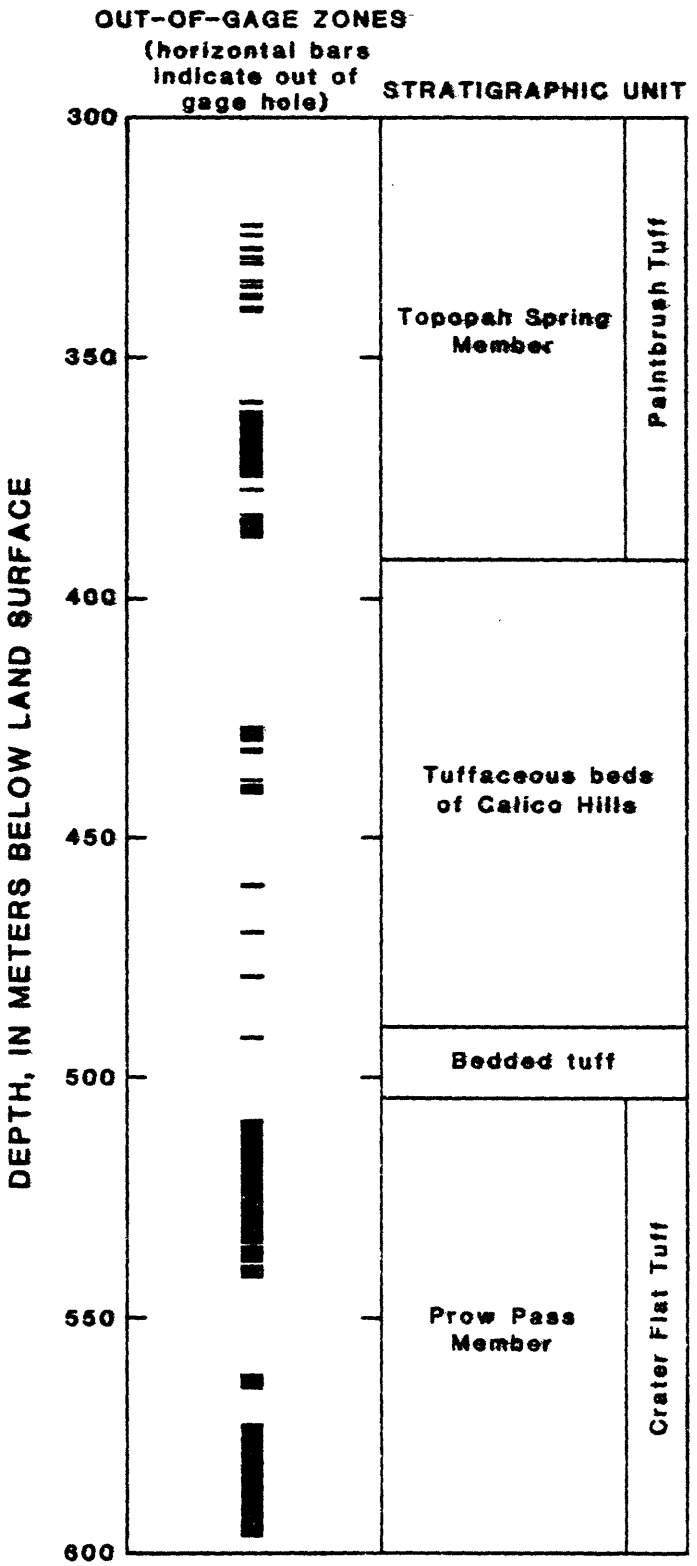


Figure 2.--Generalized vertical distribution of out-of-gage hole--Continued.

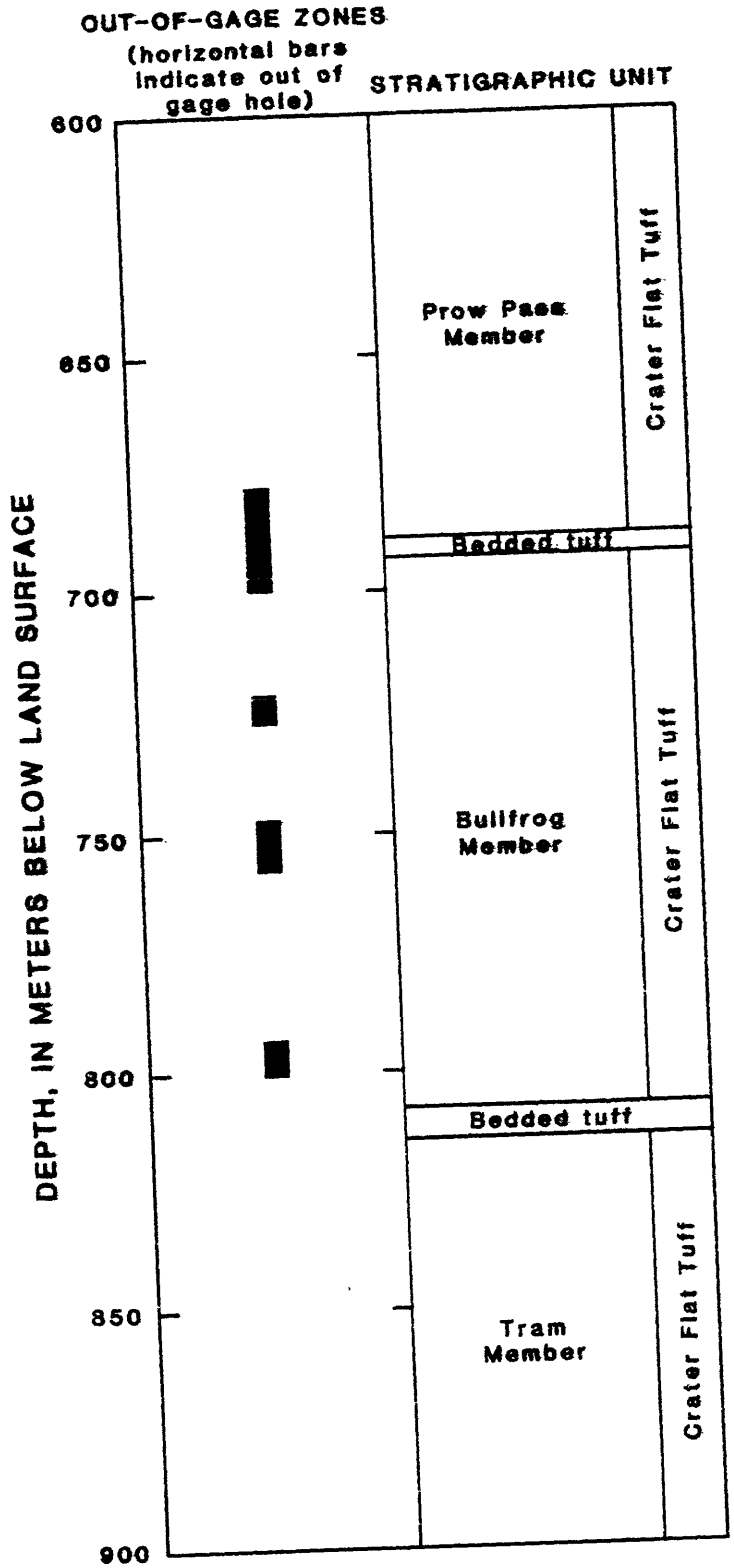


Figure 2.--Generalized vertical distribution of out-of-gage hole--Continued.

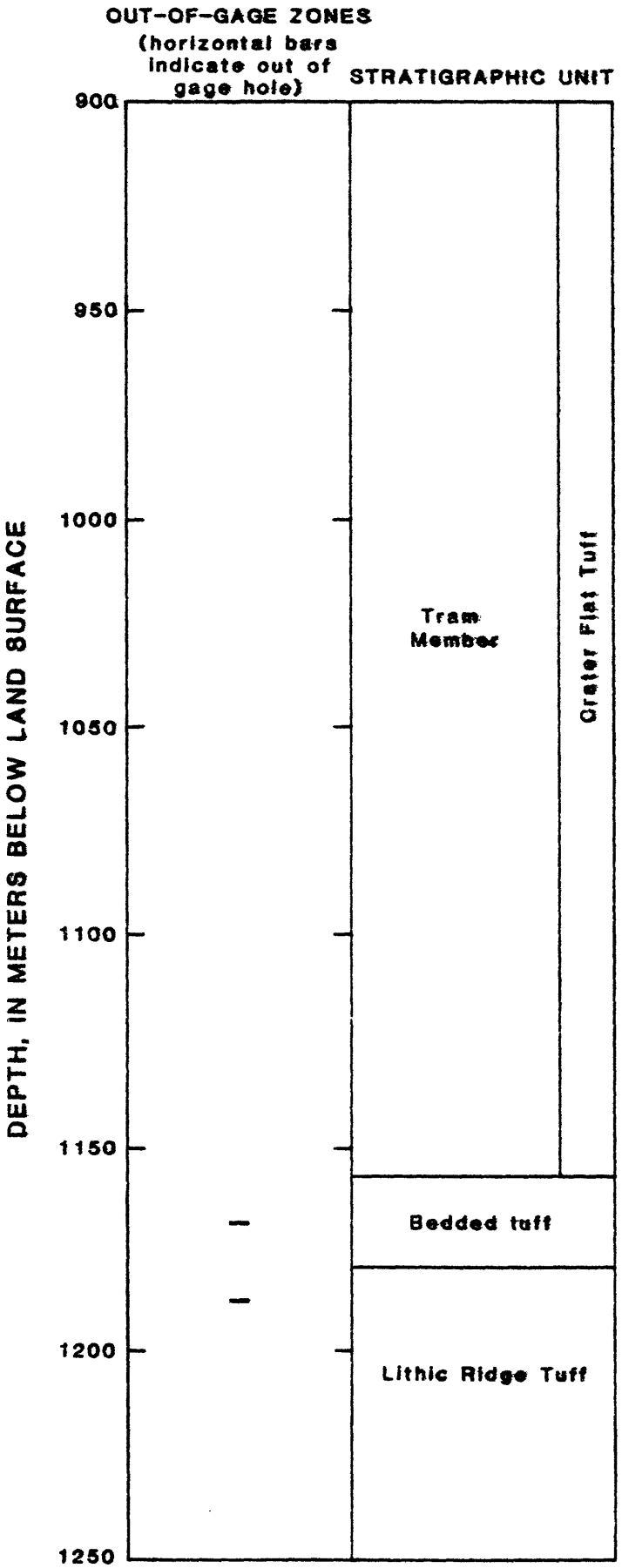


Figure 2.--Generalized vertical distribution of out-of-gage hole--Continued.

Table 4.--*Percent out-of-gage borehole for stratigraphic units drilled*

| Stratigraphic unit | Percent of unit out-of-gage | Distribution within stratigraphic unit |
|---|---|---|
| Tiva Canyon Member of Paintbrush Tuff[1] | 3.0 | Near top part of base of this member. |
| Topopah Spring Member of Paintbrush Tuff | 37 | Throughout unit, except top. |
| Tuffaceous beds of Calico Hills | 7 | Mainly at midinterval. |
| Prow Pass Member of Crater Flat Tuff | 38 | In upper one-half and at base. |
| Bullfrog Member of Crater Flat Tuff | 25 | Evenly spaced throughout unit. |
| Tram Member of Crater Flat Tuff[2] | 4 | In middle of bedded unit. |
| Lithic Ridge Tuff | 1 | Near top of unit. |

[1]Below casing starting at a depth of 10.7 meters.
[2]Underlying bedded unit included in this interval.

Table 5.--*Enlarged borehole intervals associated with fractures*

[Based on caliper-log data]

| Stratigraphic unit | Depth interval (meters) | Interval thickness (meters) | Remarks |
|---|---|---|---|
| Tiva Canyon Member of Paintbrush Tuff[1] | 11 to 21 | 10 | Near base of casing. |
| Topopah Spring Member of Paintbrush Tuff | 104 to 105 | 193 | Seven fractured zones; zones occur throughout the unit. |
| | 117 to 137 | | |
| | 147 to 169 | | |
| | 183 to 203 | | |
| | 216 to 300 | | |
| | 323 to 340 | | |
| | 358 to 387 | | |
| Tuffaceous beds of Calico Hills | 427 to 441 | 14 | ---------- |
| Prow Pass Member of Crater Flat Tuff[2] | 506 to 542 | 36 | Lower interval continues into underlying unit. |
| | 567 to 604 | 37 | |
| | 671 to 701 | 30 | |
| Bullfrog Member of Crater Flat Tuff | 719 to 728 | 9 | Fractured intervals are rough and V-shaped in upper part of unit, smooth and curved in lower part. |
| | 736 to 765 | 29 | |
| | 789 to 806 | 17 | |
| Tram Member of Crater Flat Tuff | ---------- | 0 | No fractured intervals identified in this unit. |
| Lithic Ridge Tuff | 1,186 to 1,189 | 3 | Only upper part of unit drilled. |
| | 1,202 to 1,207 | 5 | |
| | 1,214 to 1,215 | 1 | |

[1]Below casing, starting at a depth of 10.7 meters.
[2]Last interval includes a thin basal zone of bedded and reworked tuff.

## HYDROLOGIC TESTING AND WATER SAMPLING

### Drilling Fluid

A drilling medium of air foam, consisting of a small volume of detergent and water and a large unmeasured volume of air, was used to drill this test well. This drilling medium was selected to minimize fluid invasion and prevent reduction of fracture and rock-matrix permeability. Approximatly 30,000 L of detergent and 3,150,000 L of water were used during drilling. A vertical profile of fluid used in the drilling of USW H-4 is shown in figure 3.

### Water Levels

Water levels were measured in test well USW H-4 after drilling, and before, during, and after the pumping and injection tests. Water levels were measured for the following purposes: (1) To determine depth to the saturated zone; (2) to determine a composite hydraulic head for the test well; and (3) to determine a vertical profile of hydraulic heads for different water-producing zones. Water-level measurements for the drilling and hydraulic testing of this test well are listed in table 6.

### Pumping Tests

Drawdown and recovery tests were made during several pumping tests of the depth interval from 519 to 1,219 m. Drawdown and recovery data for tests are shown in table 7. Drawdown-test data were plotted using drawdown versus time after start of pumping as the coordinates. Recovery-test data were plotted with residual drawdown (recovery) versus time after pumping stopped as the coordinates.

Data plots for preliminary pumping tests 2 and 3 are presented in figures 4 and 5. The recovery plot for pumping test 2 is shown in figure 6; the recovery plot for pumping test 3 is shown in figure 7. Pumping test 6 was the principal pumping test with a pumping rate of 17.4 L/s and a pumping period of 12,818 minutes. Semilogarithmic and logarithmic graphs of water-level drawdown data during pumping test 6 are shown in figures 8 and 9. Water-level recovery data are shown in figure 10.

### Radioactive-Tracer Borehole Flow and Temperature Survey

A borehole flow survey using a radioactive tracer (iodine-131) and a temperature survey were made in conjunction with pumping test 6 to determine the depth and rate of flow for the productive zones in the saturated part of this test hole. A schematic diagram of this flow survey is shown in figure 11.

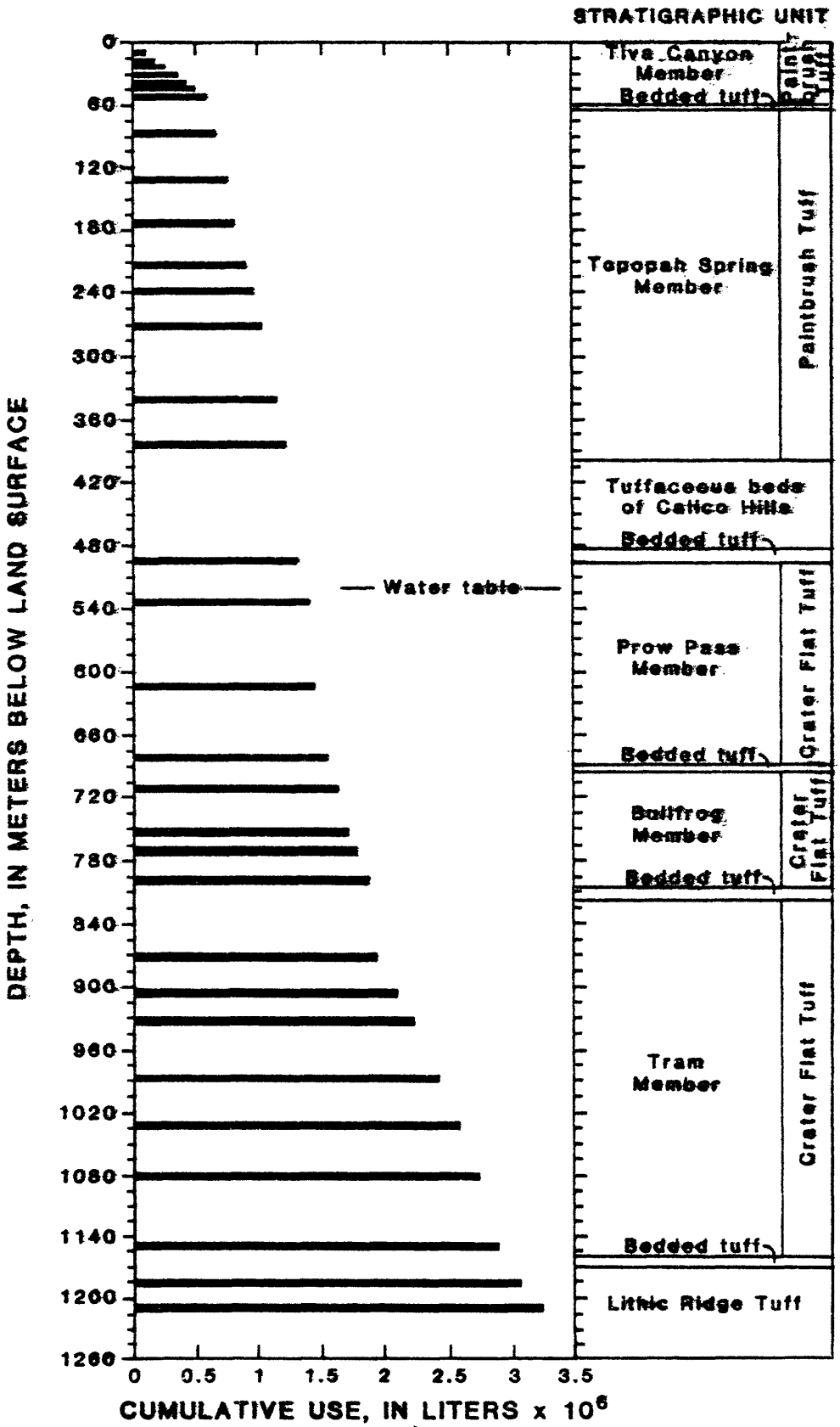


Figure 3.--Drilling-fluid use.

Table 6.--*Water-level measurements made during drilling and for pumping and packer-injection tests.*

[Altitude of land surface at well is 1,248.9 meters; water level accurate to ±0.5 meter]

| Date of measurement | Depth of hole or packed-off interval (meters) | Depth to water below land surface (meters) | Altitude of water surface above sea level (meters) | Remarks |
|---|---|---|---|---|
| 4/8/82 | 338 | 338 | 911 | Topopah Spring Member of Paintbrush Tuff. Airlifted <0.03 liter of water per second for 5 minutes. |
| 4/11/82 | 564 | 519.01 | 729.89 | Prow Pass Member of Crater Flat Tuff. |
| 4/13/82 | 564 | 518.98 | 729.92 | Prow Pass Member of Crater Flat Tuff. Water level measured after running geophysical logs. |
| 4/15/82 | 564 | 519.98 | 729.92 | Prow Pass Member of Crater Flat Tuff. Water level measured just before casing down to the water level. |
| 5/07/82 | 1,219 | 519.05 | 729.85 | Composite water-level measurement made just before pumping. |
| 5/22/82 | 1,219 | 519.10 | 729.80 | Composite water level measured after pumping tests, and just prior to packer-injection tests. |
| 6/03/82 | 604-652 | 519.71 | 729.19 | Prow Pass Member of Crater Flat Tuff. |
| 6/03/83 | 652-701 | 519.53 | 729.37 | Prow Pass and Bullfrog Members of Crater Flat Tuff. |
| 5/29/82 | 703-735 | 519.04 | 729.86 | Bullfrog Member of Crater Flat Tuff. |
| 5/30/82 | 735-767 | 518.78 | 730.12 | ----------do.---------- |
| 6/04/82 | 783-832 | 519.47 | 729.43 | Lower Bullfrog Member and Upper Tram Member of Crater Flat Tuff. |
| 5/27/82 | 836-855 | 519.16 | 729.74 | Tram Member of Crater Flat Tuff. |
| 5/27/82 | 855-873 | 519.47 | 729.43 | ----------do.---------- |
| 5/26/82 | 873-892 | 519.42 | 729.48 | ----------do.---------- |
| 5/26/82 | 892-910 | 518.88 | 730.02 | ----------do.---------- |
| 5/24/82 | 910-928 | 519.31 | 729.59 | ----------do.---------- |
| 5/26/82 | 931-1,219 | 519.42 | 729.48 | ----------do.---------- |
| 5/23/82 | 1,174-1,192 | 519.31 | 729.59 | Lithic Ridge Tuff. |

Table 7.--*Pumping-test data*

| Test number | Test interval (meters) | Stratigraphic unit tested | Type of test | Pumping rate (liters per second) | Pumping or recovery period (minutes) |
|---|---|---|---|---|---|
| 2 | 519 to 1,219 | Prow Pass Member of Crater Flat Tuff and underlying units | | | |
| | | | Drawdown | 18.7 | 29 |
| 2 | ----do------- | -----do-------- | Recovery | [1]18.7 | 28 |
| 3 | ----do------- | -----do-------- | Drawdown | 16.5 | 30 |
| 3 | ----do------- | -----do-------- | Recovery | [1]16.5 | 28 |
| 6 | ----do------- | -----do-------- | Drawdown | 17.4 | 12,818 |
| 6 | ----do------- | -----do-------- | Recovery | [1]17.4 | 2,920 |

[1]For pumping period prior to recovery test.

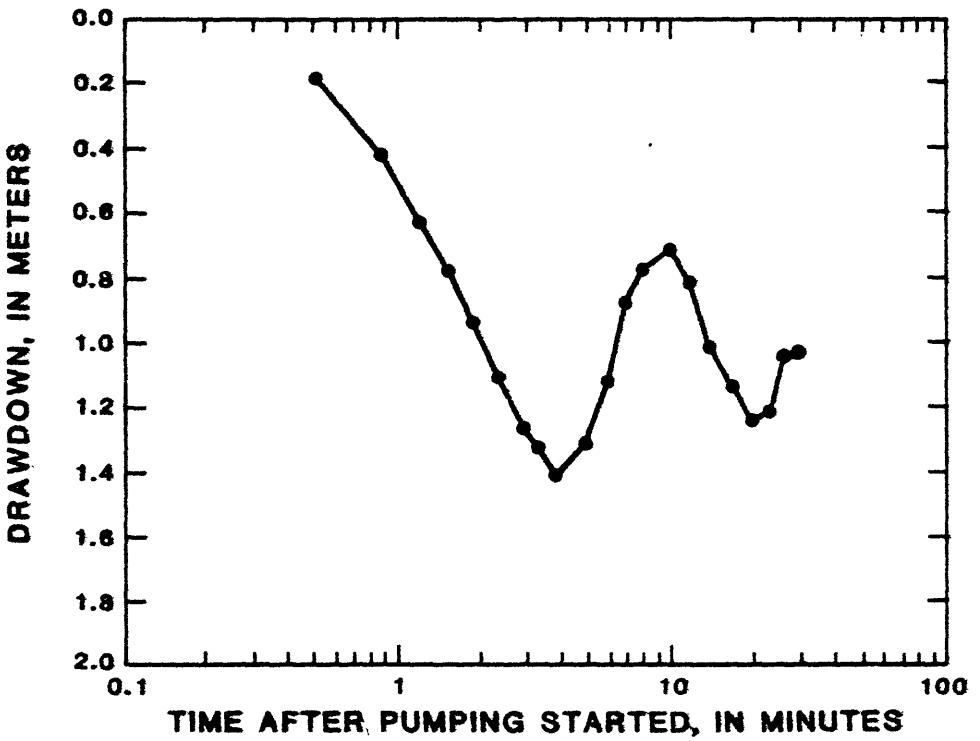


Figure 4.--Water-level drawdown versus time for pumping test 2, depth interval from 519 to 1,219 meters.

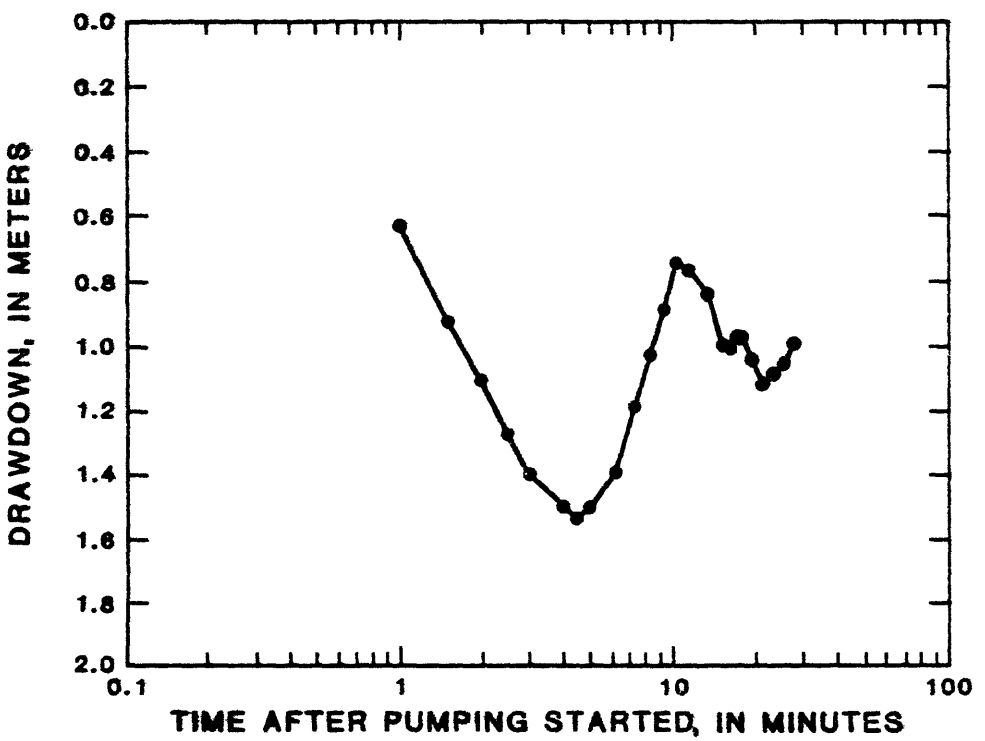


Figure 5.--Water-level drawdown versus time for pumping test 3, depth interval from 519 to 1,219 meters.

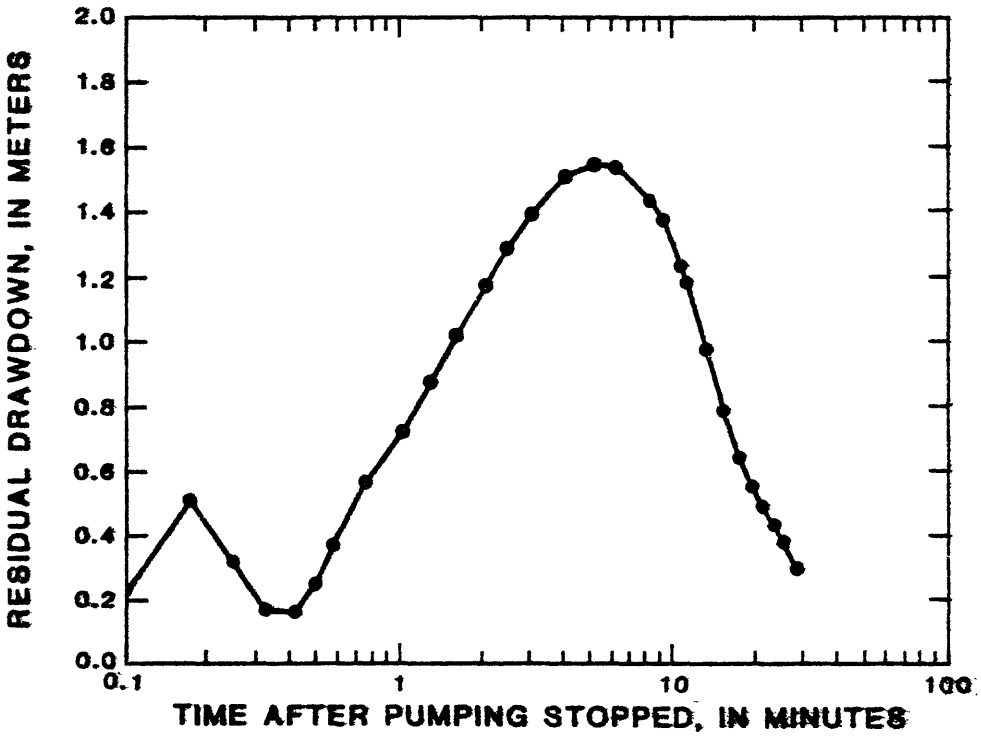


Figure 6.--Water-level recovery versus time for pumping test 2, depth interval from 519 to 1,219 meters.

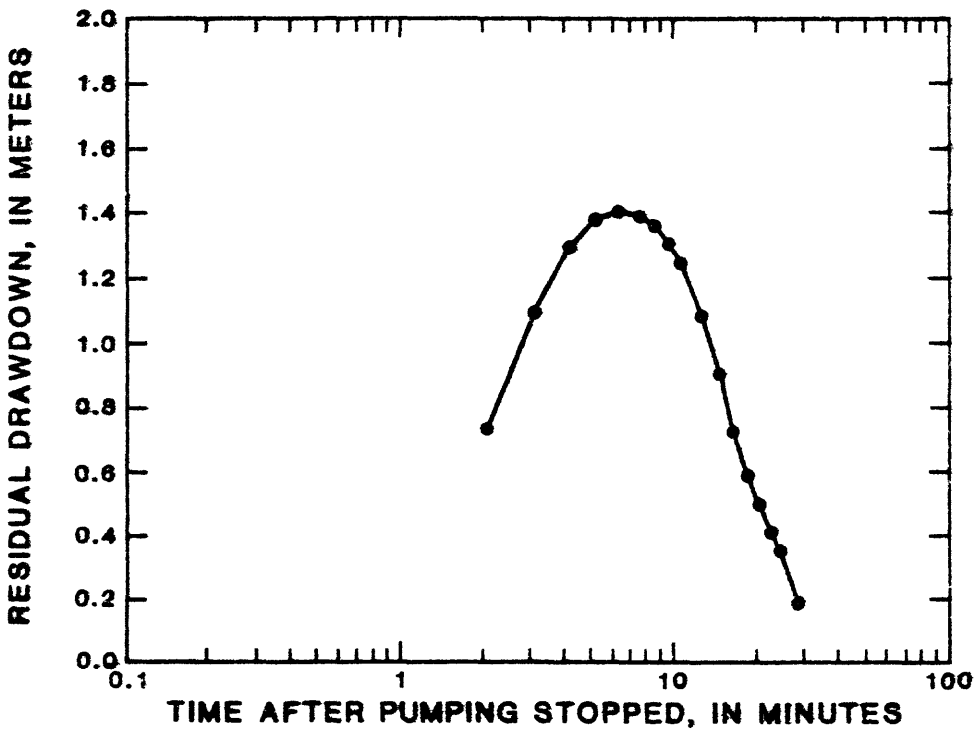


Figure 7.--Water-level recovery versus time for pumping test 3, depth interval from 519 to 1,219 meters.

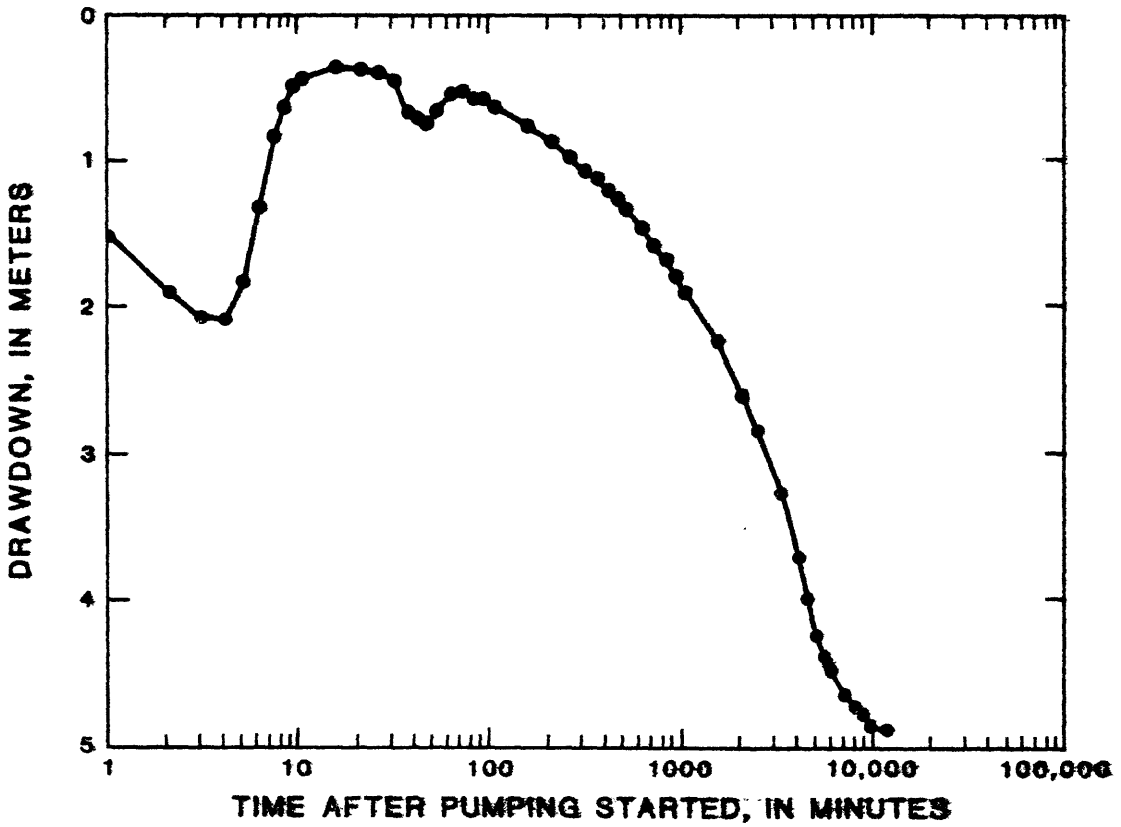


Figure 8.--Semilogarithmic graph of water-level drawdown versus time for pumping test 6, depth interval from 519 to 1,219 meters.

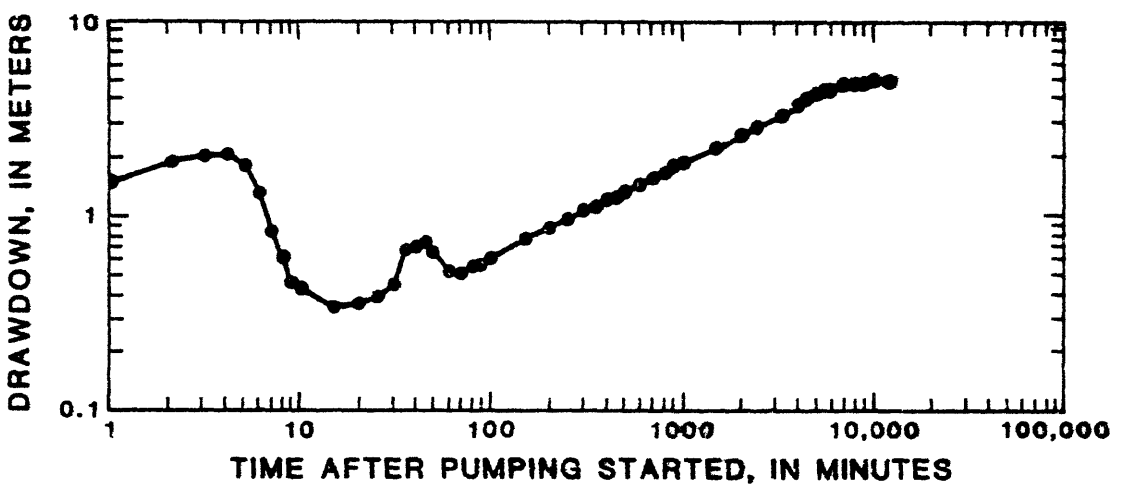


Figure 9.--Logarithmic graph of water-level drawdown versus time for pumping test 6, depth interval from 519 to 1,219 meters.

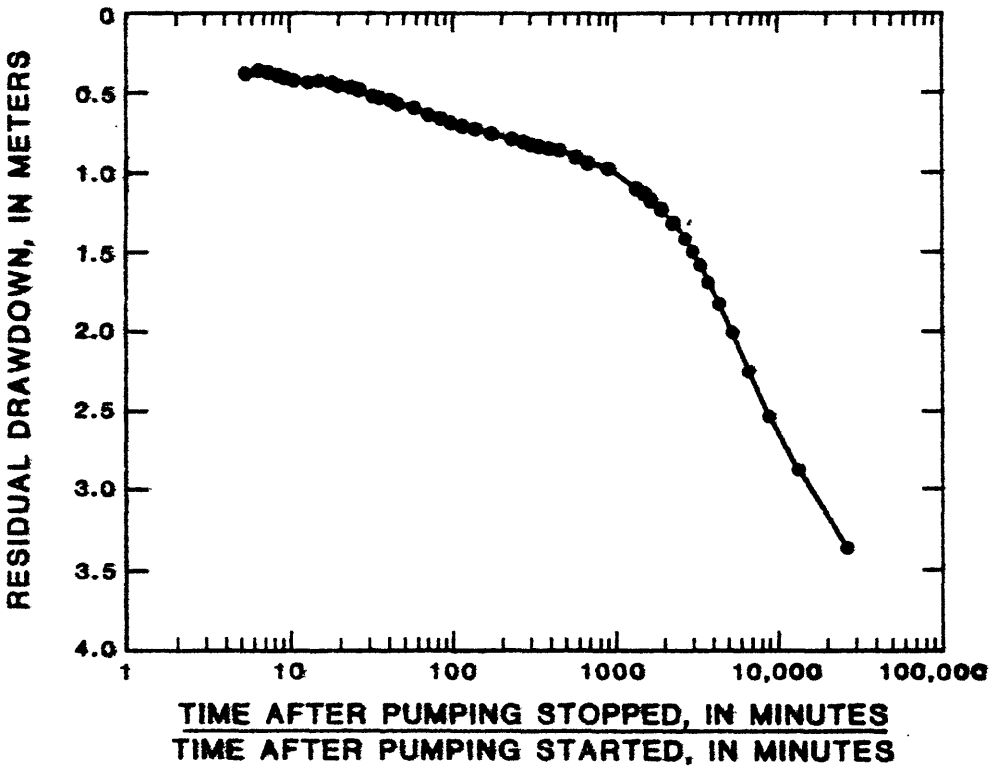


Figure 10.--Water-level recovery versus time for pumping test 6, depth interval from 519 to 1,219 meters.

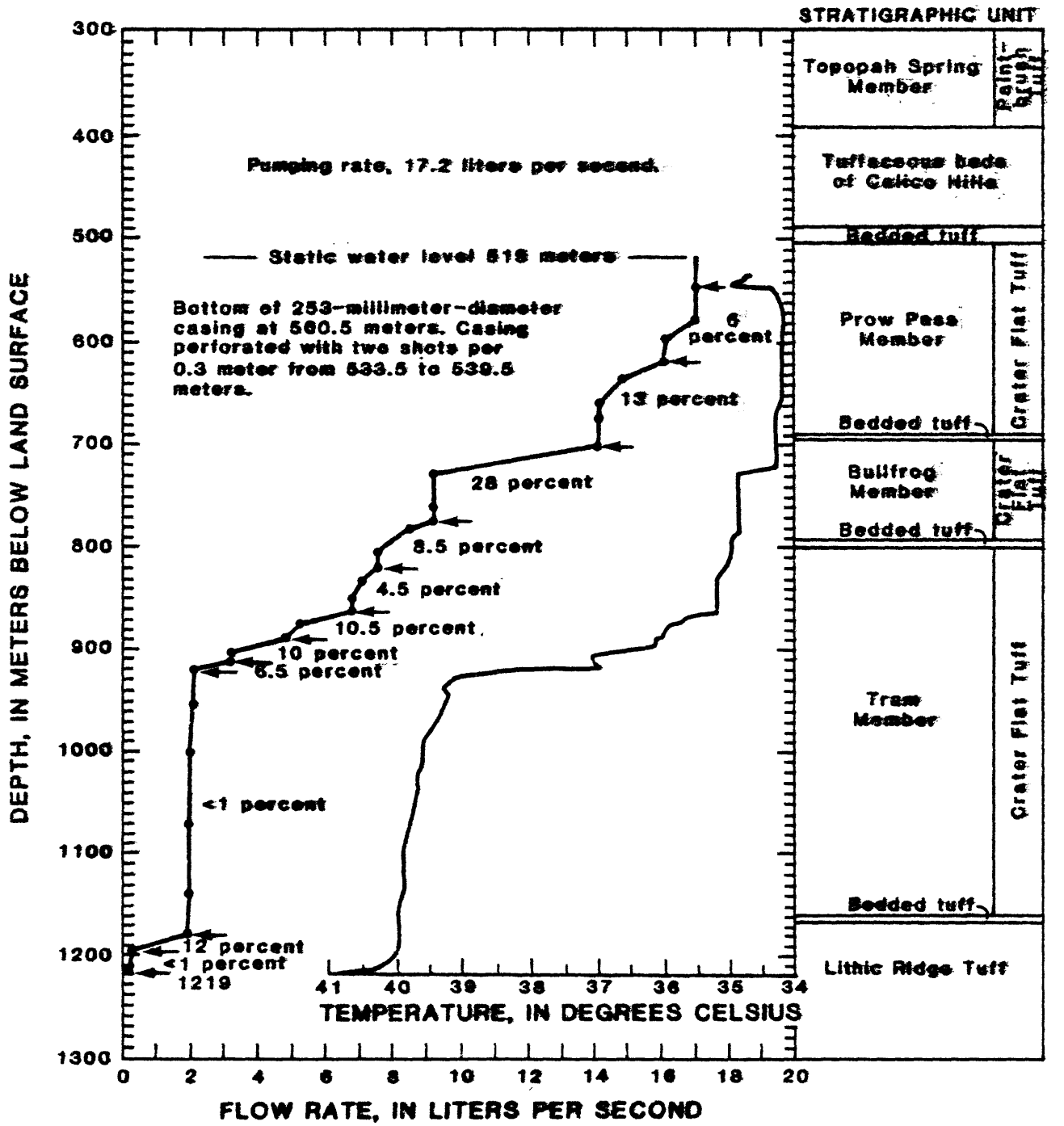


Figure 11.--Borehole-flow and temperature survey for test well USW H-4, showing percent of pumping rate produced for intervals from 555 to 1,219 meters.

## Injection Tests

Inflatable packers were used to isolate individual zones for injection tests. Intervals tested are shown in table 8. Data for 15 injection tests for intervals between 555 and 1,219 m (total depth) are shown in figures 12 through 26. The decline of water level to static is shown versus time since injection began.

## Chemical Analysis of Water

A water sample was collected on May 17, 1982, for chemical analysis of major constituents. The sample was taken near the end of pumping test 6 after approximately 14,700,000 L of water were pumped. This sample represents water produced from the zone that extends from the water table (519 m) to the total depth of the well (1,219 m). Chemical constituents in this water sample are shown in table 9.

Table 8.--*Intervals tested by injection tests*

| Date | Interval tested (meters) | Geologic unit | Static water level (meters below land surface) | Test duration (minutes) | Remarks |
|---|---|---|---|---|---|
| 6/01/82 | 555- 604 | Prow Pass Member of Crater Flat Tuff | 517.75 | 200 | Not a static water level; water level still declining. |
| 6/03/82 | 604- 652 | ---do.------- | 519.71 | 124.0 | ---------- |
| 6/03/82 | 604- 652 | ---do.------- | 519.37 | 60.0 | Reduced head by two-thirds. |
| 6/03/82 | 652- 701 | Prow Pass and Bullfrog Members of Crater Flat Tuff. | 519.53 | 60.0 | ---------- |
| 5/29/82 | 703- 735 | Bullfrog Member of Crater Flat Tuff. | 519.04 | 60.0 | ---------- |
| 5/30/82 | 735- 767 | ---do.-------- | 518.78 | 60.0 | ---------- |
| 6/04/82 | 783- 832 | Bullfrog and Tram Members of Crater Flat Tuff. | 519.47 | 5.0 | ---------- |
| 6/04/82 | 832- 850 | Tram Member of Crater Flat Tuff. | ------ | 58.0 | ---------- |
| 5/27/82 | 855- 873 | ---do.-------- | 519.47 | 10.0 | ---------- |
| 5/26/82 | 873- 892 | ---do.-------- | 519.42 | 20.0 | ---------- |
| 5/26/82 | 892- 910 | ---do.-------- | 518.88 | 60.0 | ---------- |
| 5/24/82 | 910- 928 | ---do.-------- | 519.31 | 10.0 | Water level after 28 hours of monitoring. |
| 5/26/82 | 928-1,219 | Tram Member of Crater Flat Tuff and Lithic Ridge Tuff. | 519.42 | 20.0 | Open below test. |
| 5/23/82 | 1,173-1,192 | Lithic Ridge Tuff | 519.31 | 4.5 | ---------- |
| 5/24/82 | 1,195-1,219 | Lithic Ridge Tuff | None | 11.0 | ---------- |

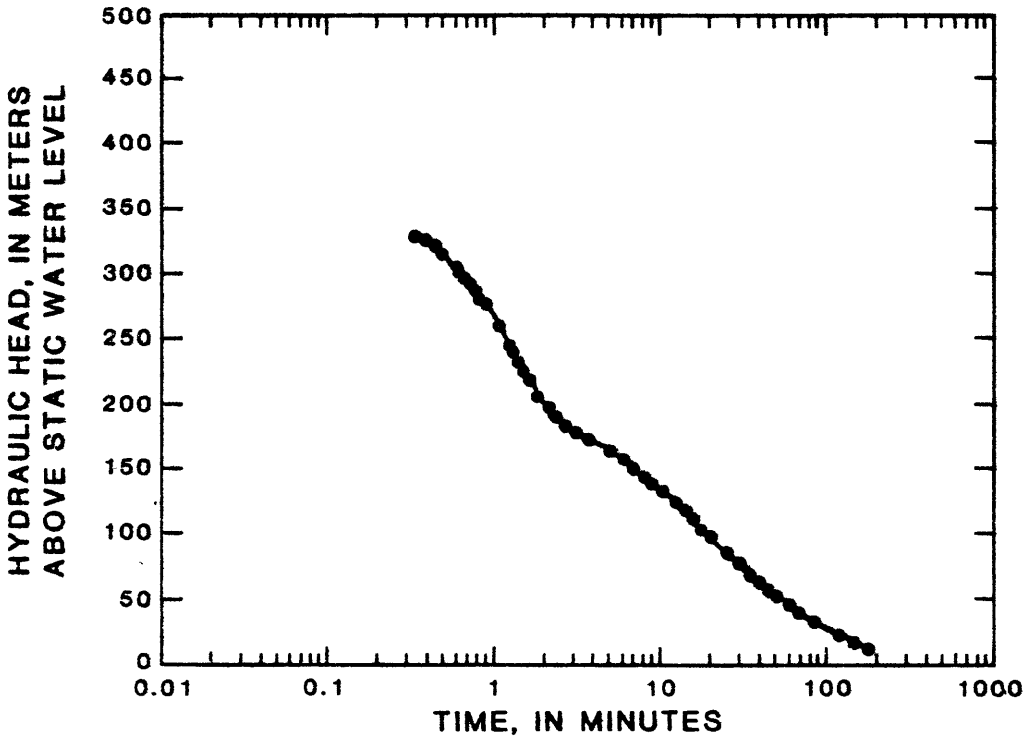


Figure 12.--Water-level recovery versus time during injection test for depth interval from 555 to 604 meters.

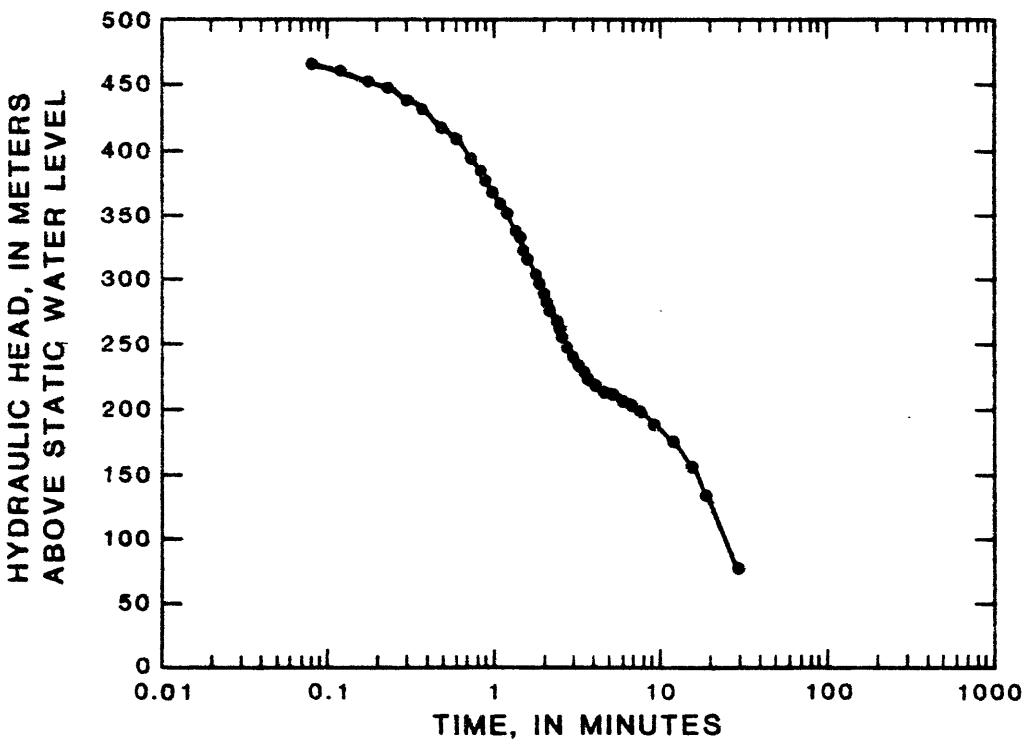


Figure 13.--Water-level recovery versus time during injection test for depth interval from 604 to 652 meters. (Full column of water.)

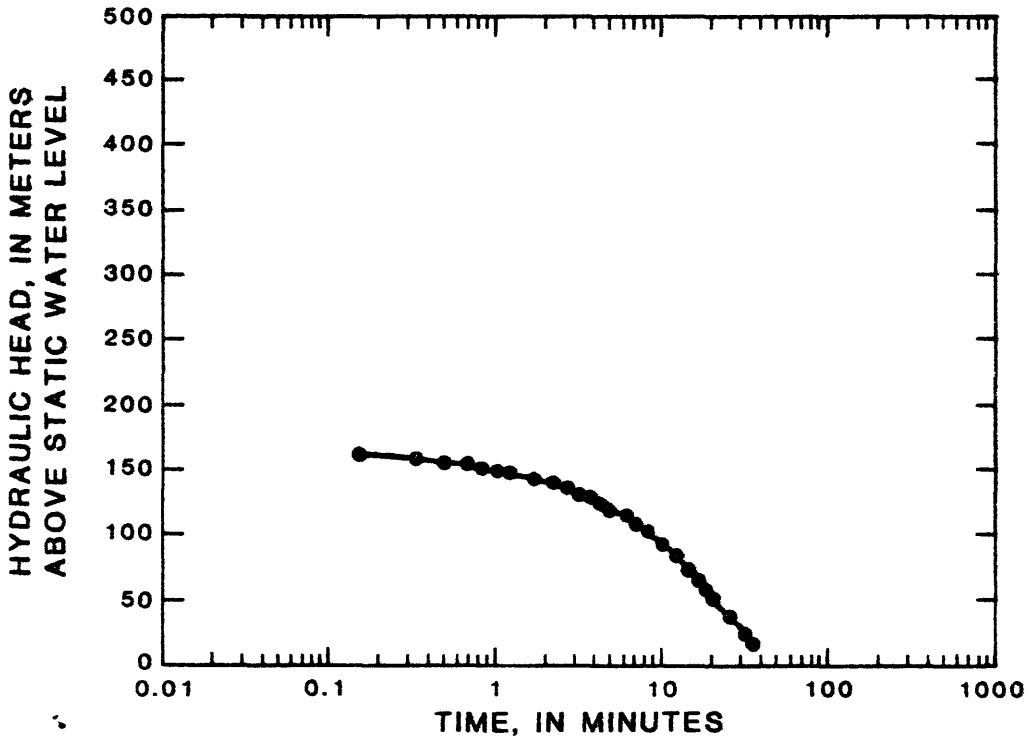


Figure 14.--Water-level recovery versus time during injection test for depth interval from 604 to 652 meters. (One-third column of water.)

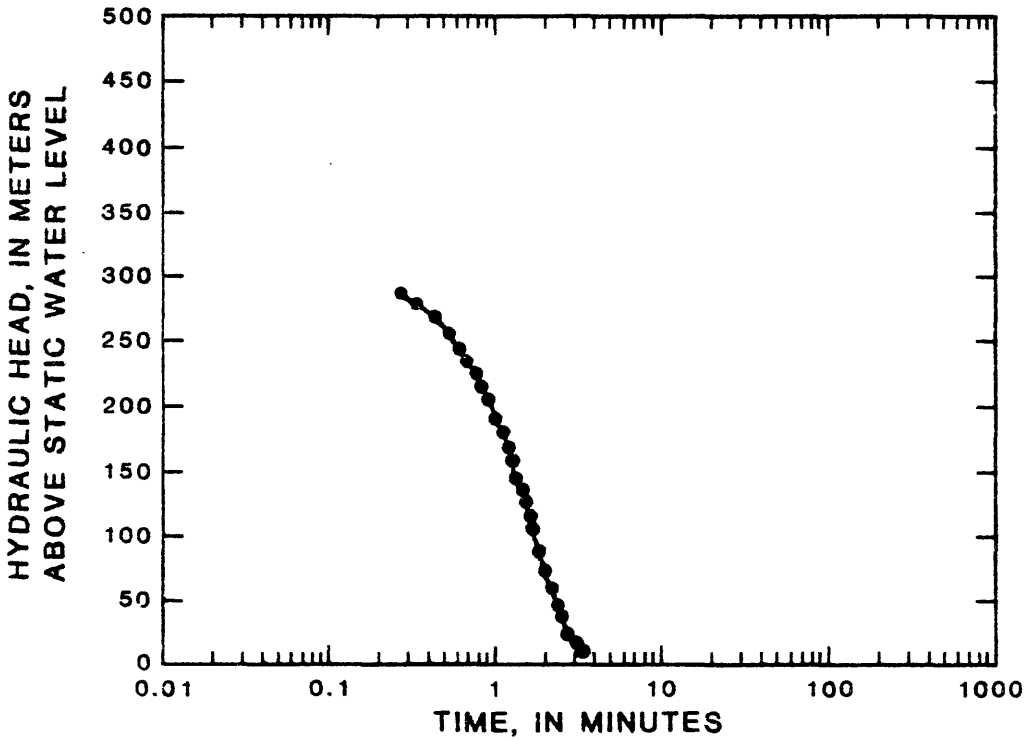


Figure 15.--Water-level recovery versus time during injection test for depth interval from 652 to 701 meters.

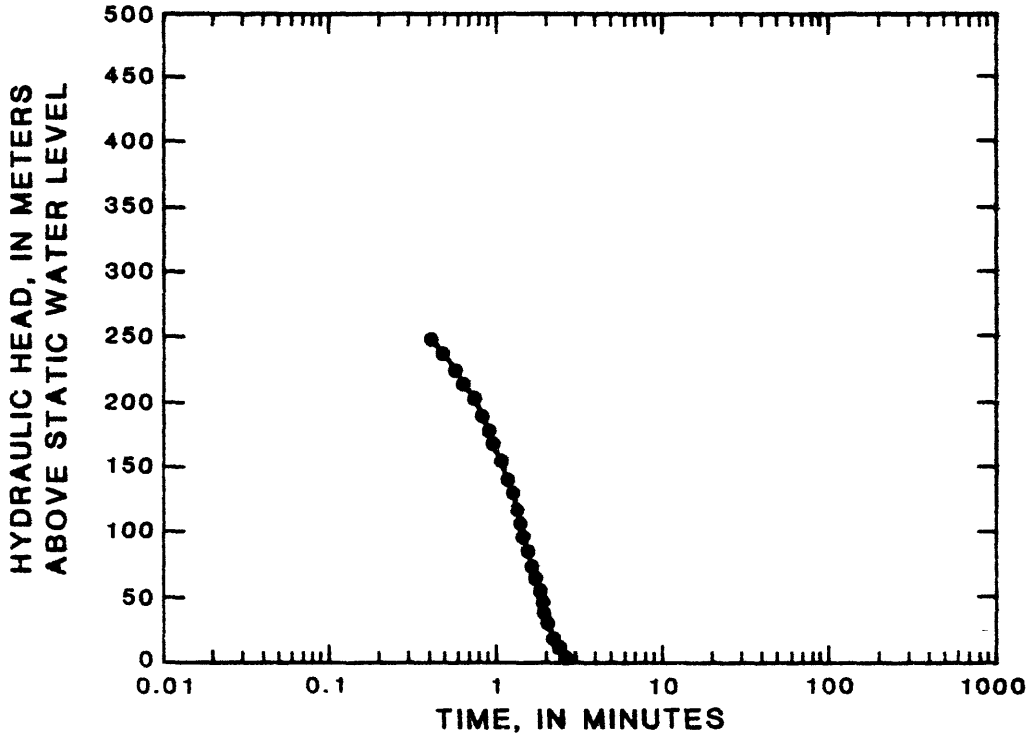


Figure 16.--Water-level recovery versus time during injection test for depth interval from 703 to 735 meters.

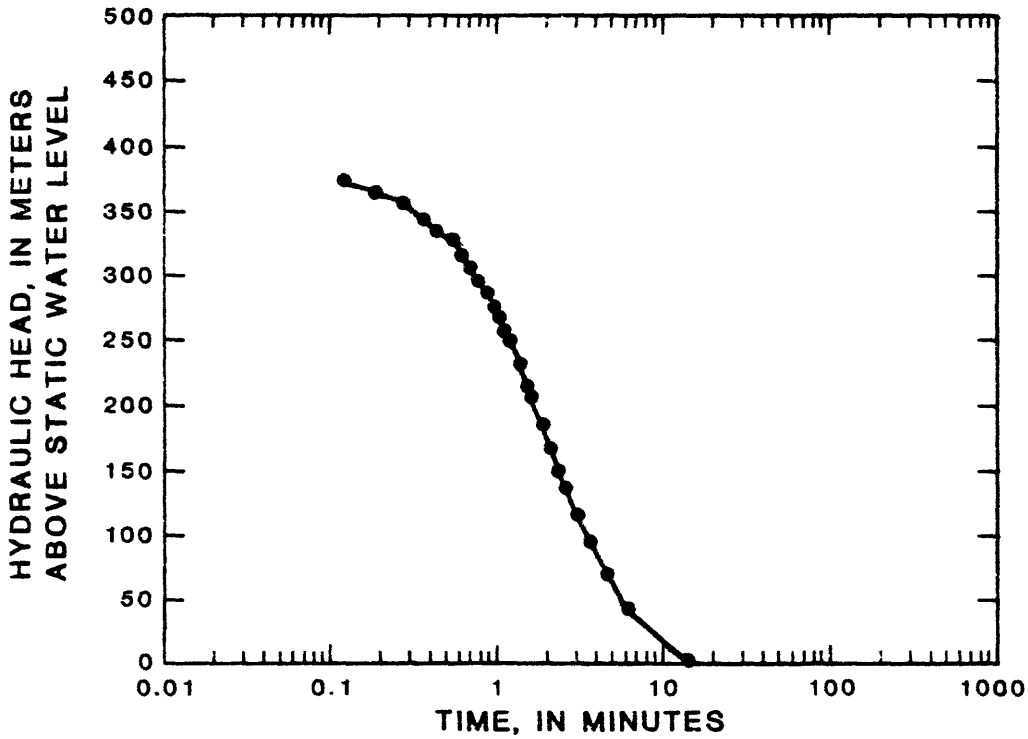


Figure 17.--Water-level recovery versus time during injection test for depth interval from 735 to 767 meters.

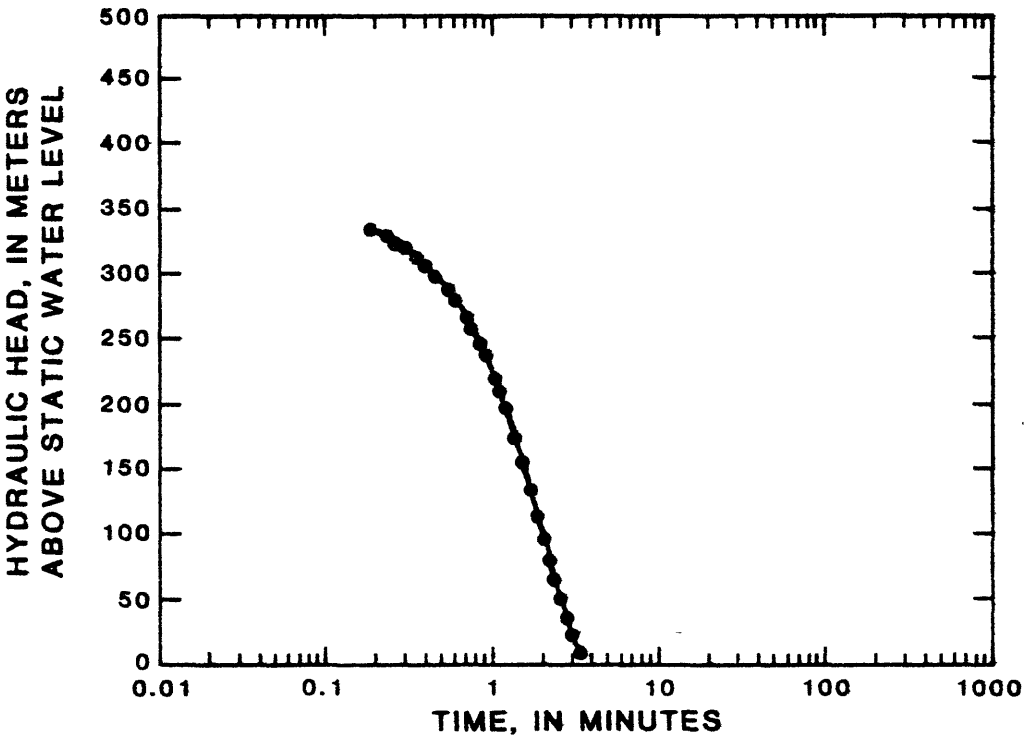


Figure 18.--Water-level recovery versus time during injection test for depth interval from 783 to 832 meters.

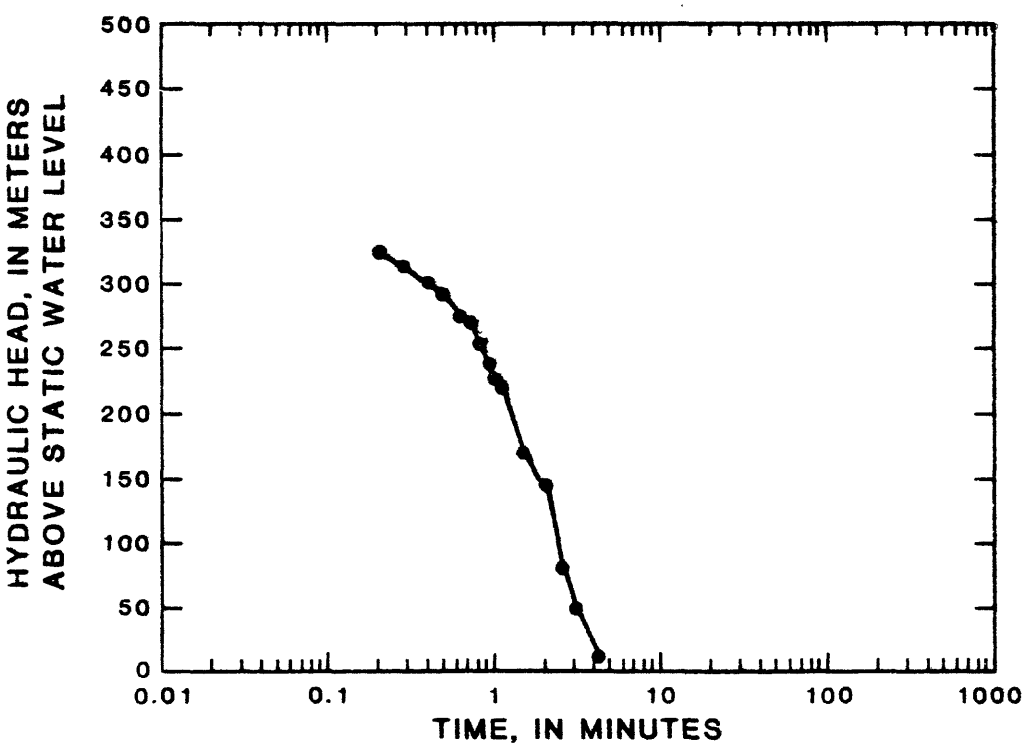


Figure 19.--Water-level recovery versus time during injection test for depth interval from 832 to 850 meters.

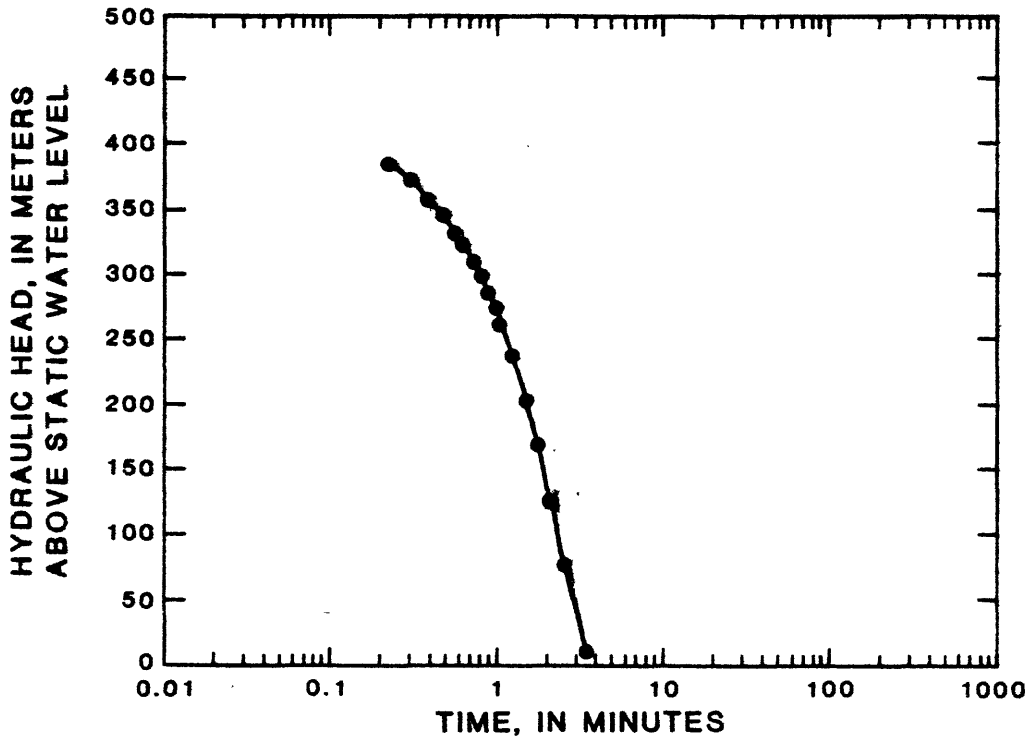


Figure 20.--Water-level recovery versus time during injection test for depth interval from 855 to 873 meters.

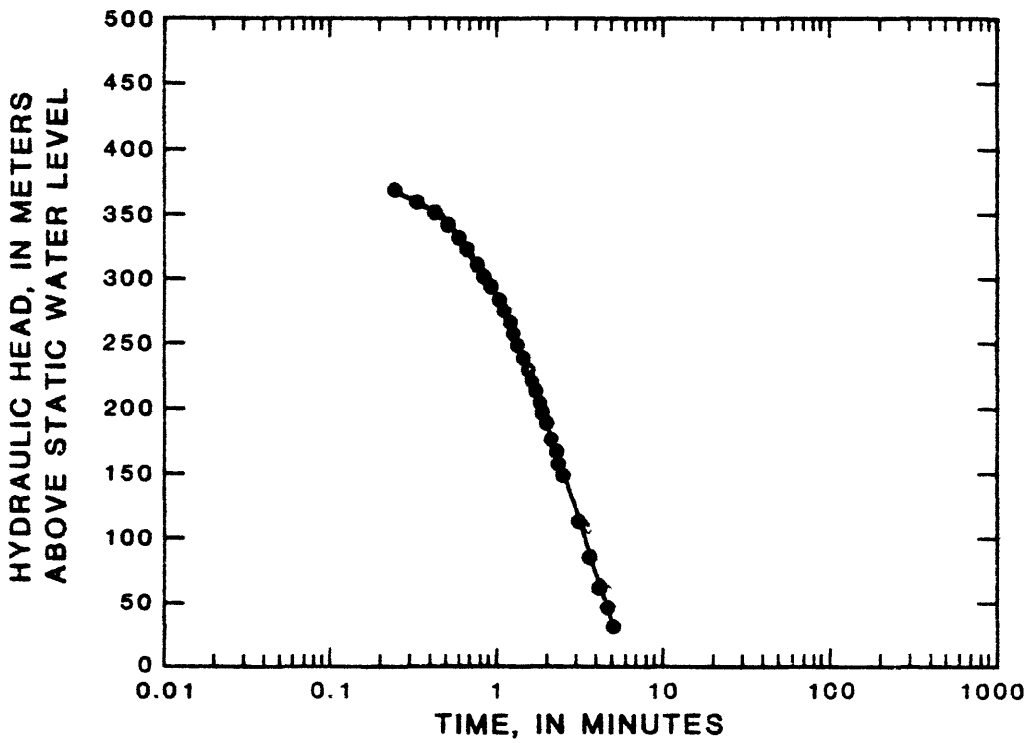


Figure 21.--Water-level recovery versus time during injection test for depth interval from 873 to 892 meters.

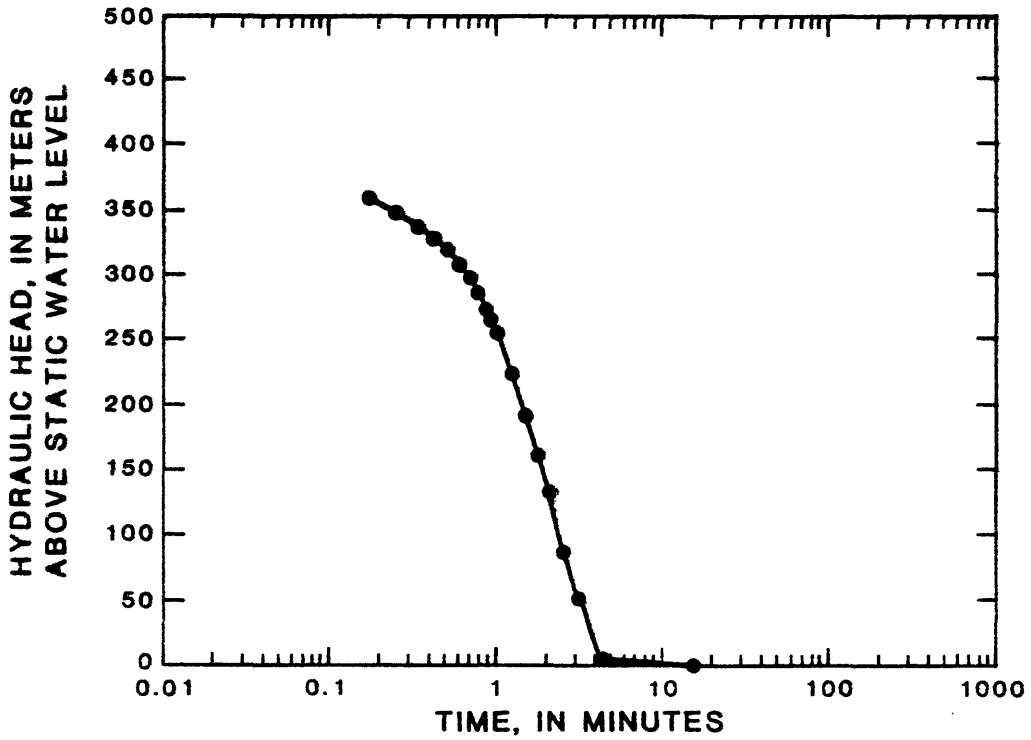


Figure 22.--Water-level recovery versus time during injection test for depth interval from 892 to 910 meters.

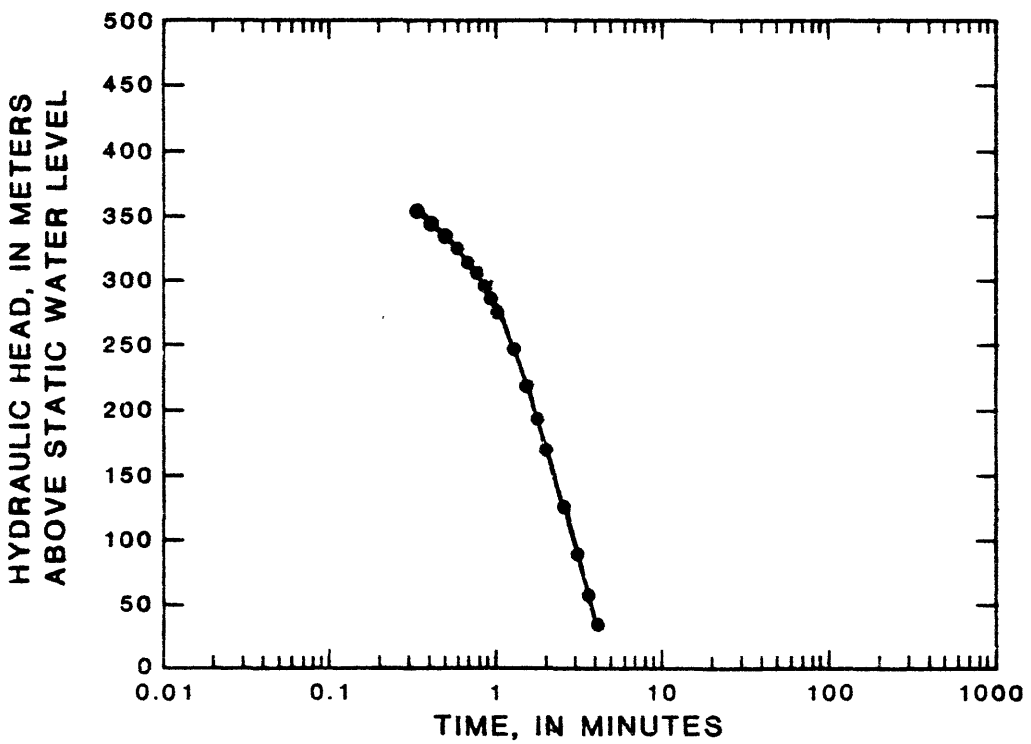


Figure 23.--Water-level recovery versus time during injection test for depth interval from 910 to 928 meters.

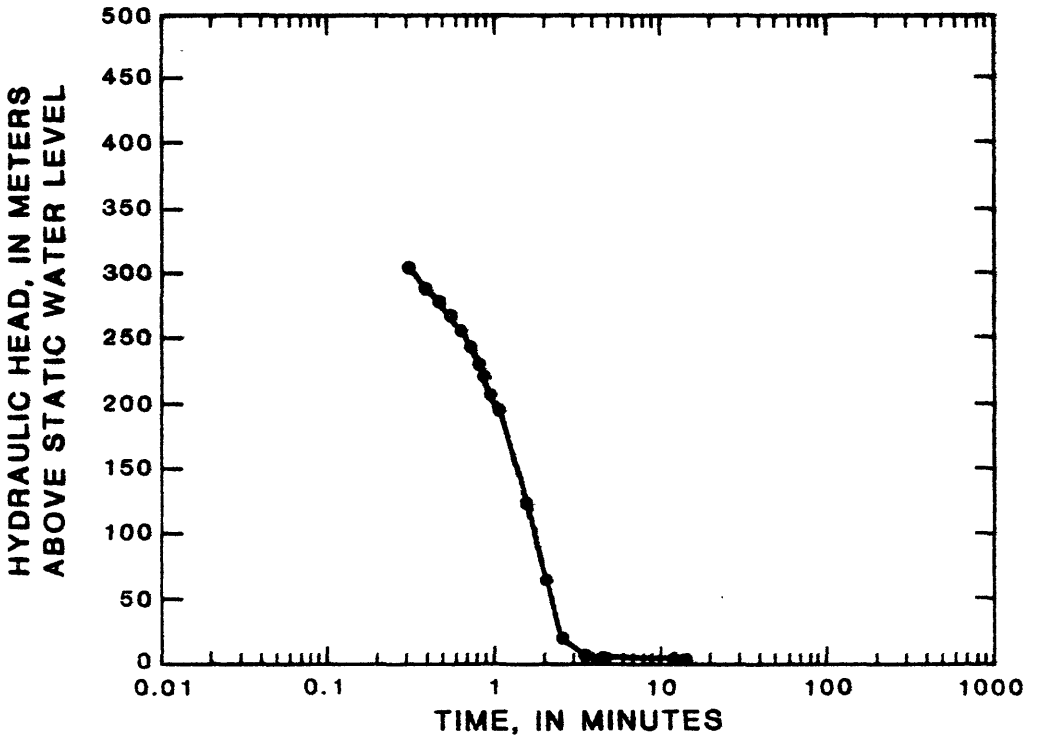


Figure 24.--Water-level recovery versus time during injection test for depth interval from 928 to 1,219 meters.

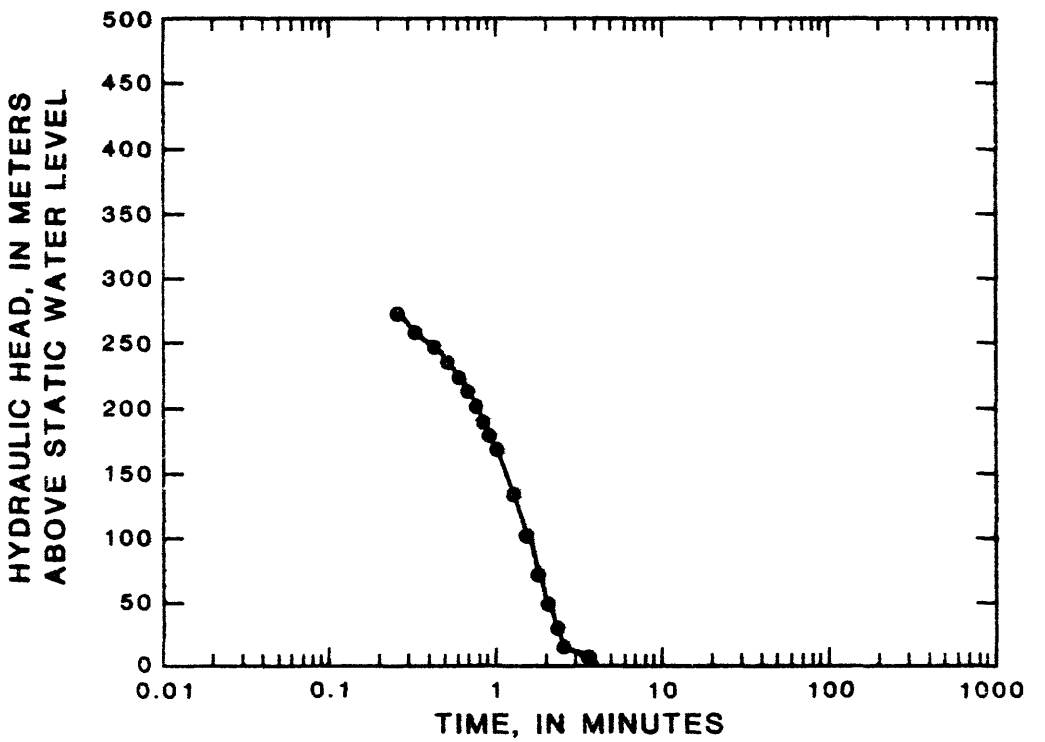


Figure 25.--Water-level recovery versus time during injection test for depth interval from 1,173 to 1,192 meters.

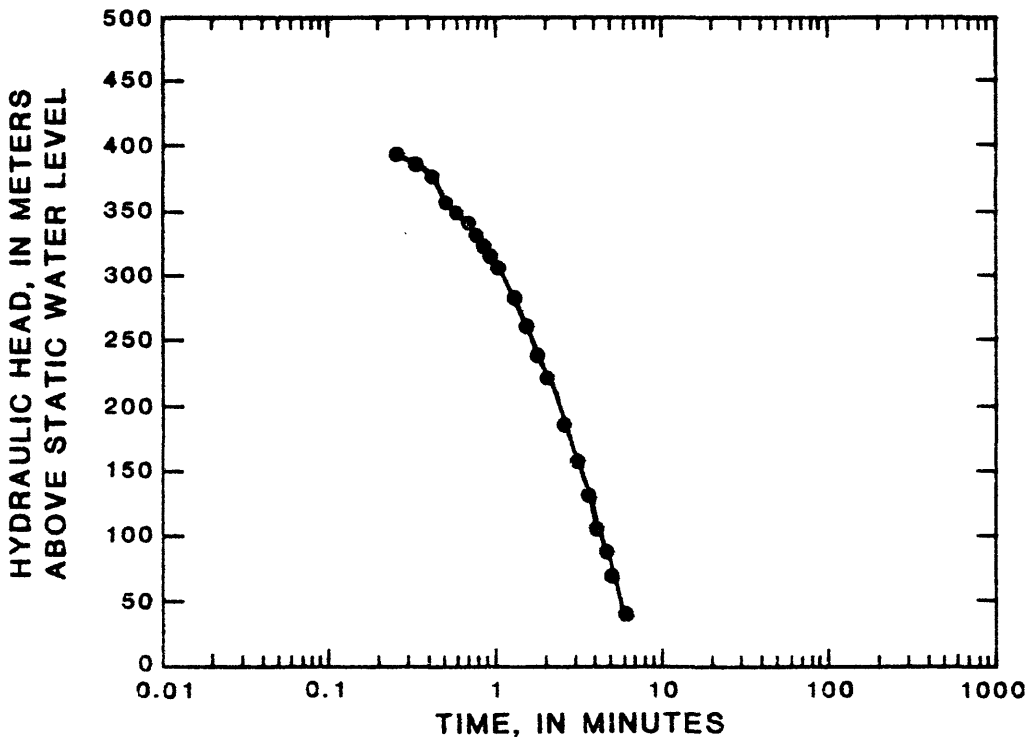


Figure 26.--Water-level recovery versus time during injection test for depth interval from 1,195 to 1,219 meters.

Table 9.--*Chemical analysis of water sample*[1]

[All units are milligram per liter unless otherwise indicated; sample collected 05/17/82 during pumping of depth interval from 519 m to 1,219 m]

| Chemical constituents or physical property | Value |
|---|---|
| Bicarbonate ($HCO_3$) (onsite) | 173 |
| Alkalinity ($CaCO_3$) (laboratory) | 140 |
| Calcium (Ca) | 17 |
| Carbon-13/Carbon-12 ratio ($\delta^{13}C$)[2] | -7.4 |
| Carbon-14 ($H_2O$)AGE | 17,200 |
| Chloride (Cl) | 6.9 |
| Deuterium/hydrogen ratio ($\delta^{2}H$)[3] | -104.0 |
| Fluoride (F) | 4.6 |
| Lithium (Li, micrograms per liter) | 130 |
| Magnesium (Mg) | 0.29 |
| Oxygen-18/oxygen-16 ratio ($\delta^{18}0$)[4] | -14.0 |
| pH, laboratory (units) | 7.9 |
| pH, field (units) | 7.4 |
| Potassium (K) | 2.6 |
| Residue on evaporation | 248 |
| Silica($SiO_2$) | 46 |
| Sodium (Na) | 73 |
| Specific conductance, field (microsiemens)[5] | 340 |
| Specific conductance, laboratory (microsiemens) | 381 |
| Strontium (Sr, micrograms per liter) | 27 |
| Sulfate ($SO_4$) | 26 |
| Temperature (degrees Celsius) | 34.8 |
| Tritium (picocuries per liter) | 10 |
| Cations (milliequivalents per liter) | 4.114 |
| Anions (milliequivalents per liter) | 3.785 |
| Difference (percent) | 4.16 |

[1]Chemical analysis made by U.S. Geological Survey laboratory, Denver, Colo.

[2]Deviation of carbon-13/carbon-12 ratio of sample from PeeDee Belemnite standard (PDB) relative to PDB, in parts per thousand.

[3]Deviation of deuterium/hydrogen ratio of sample from standard mean ocean water (SMOW) relative to SMOW, in parts per thousand.

[4]Deviation of oxygen-18/oxygen-16 ratio of sample from standard mean ocean water (SMOW) relative to SMOW, in parts per thousand.

[5]Equivalent to micromhos per centimeter at 25°C.

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