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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOHYDROLOGIC DATA FOR TEST WELL UE-25p#1, YUCCA MOUNTAIN AREA, NYE COUNTY, NEVADA

by

R. W. Craig and K. A. Johnson

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1984

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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CONVERSION TABLE

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

Multiply metric unit	*by*	*To obtain inch-pound unit*
millimeter (mm)	0.03937	inch
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile
liter (L)	0.2642	gallon
liter per second (L/s)	15.85	gallon per minute
microsiemens per centimeter at 25° Celsius	1.000	micromho per centimeter at 25° Celsius
degree Celsius (°C)	[1]°F=1.8°C+32	degree Fahrenheit
microgram per liter	[1]1.0	part per billion
milligram per liter	[1]1.0	part per million

[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 DATA FOR TEST WELL UE-25p#1, YUCCA MOUNTAIN AREA, NYE COUNTY, NEVADA

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ABSTRACT

This report presents the following data for test well UE-25p#1: drilling operations, lithology, availability of borehole geophysical logs, water levels, water chemistry, pumping tests, borehole-flow survey, and packer-injection tests. The well is one of a series of test wells drilled in and near Yucca Mountain adjacent to the Nevada Test Site, Nye County, Nevada, in cooperation with the U.S. Department of Energy. These investigations are part of the Nevada Nuclear Waste Storage Investigations to identify suitable sites for underground storage of high-level radioactive wastes.

Test well UE-25p#1 was drilled to a total depth of 1,805 meters. To a depth of 1,244 meters, the rocks are predominantly ashflow tuffs of Tertiary age. From 1,244 to 1,805 meters, the rock is dolomite of Paleozoic age. The composite static water level was approximately 381 meters below land surface for the Tertiary section and 361 meters for the Paleozoic section. Hydrologic tests were performed on the well during two different periods. The Tertiary section was tested after the well was drilled to 1,301 meters, and the Paleozoic section was tested after completion of drilling. A pumping test of the Tertiary section showed a maximum drawdown of about 33.7 meters after pumping for 3,150 minutes at 22 liters per second. Pumping of the Paleozoic section showed an apparent maximum drawdown of 9.3 meters after pumping for 6,080 minutes at 31.5 liters per second. During the first 50 minutes of the pumping test, the discharge temperature increased from about 30° to 56° Celsius.

A borehole-flow survey showed that, for the Tertiary section of the hole, about 58 percent of the water withdrawn from the well came from the depth interval from 469 to 501 meters. For the Paleozoic section, 75 percent of the water withdrawn from the well came from the depth intervals from 1,340 to 1,362 meters and from 1,515 to 1,551 meters.

INTRODUCTION

The U.S. Geological Survey has been conducting investigations at Yucca Mountain, Nevada, to determine the hydrologic and geologic suitability of the area for storage of high-level nuclear waste in an underground mined repository. The investigations are part of the Nevada Nuclear Waste Storage Investigations being conducted by the U.S. Geological Survey and other agencies 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 and drill-hole data from test well UE-25p#1.

Test well UE-25p#1 is in Nye County, Nevada, approximately 140 km northwest of Las Vegas in the southern part of the State (fig. 1). The site, located at N. 756, 171 ft and E. 571, 485 ft in the Nevada State Coordinate System Central Zone, is on the valley floor about 1.5 km east of Yucca Mountain (fig. 1).

Test well UE-25p#1 was drilled primarily to obtain information about rocks of Paleozoic age that were presumed to underlie the volcanic rocks of Tertiary age penetrated in previous test wells in the Yucca Mountain area. A secondary objective was to collect additional information about the Tertiary rocks in the area. The well site was chosen primarily because gravity surveys had indicated that pre-Tertiary rocks were relatively close to the land surface at this location.

DRILLING OPERATIONS

Drilling of test well UE-25p#1 began on November 13, 1982, and was completed to a total depth of 1,805 m on May 24, 1983. Final well construction is shown in figure 2. The hole was rotary-drilled using an air-foam fluid consisting of air, detergent, and water, when possible, rather than drilling mud, to minimize infilling of pores and fractures. A polymer drilling mud was necessary during drilling of most of the Paleozoic section to clear the cuttings from the hole. Lithium chloride was added to all water used in drilling operations as well as to water used during packer-injection testing. Concentrations of lithium greater than background concentrations in fluid returns or water samples were indicative of contamination by drilling fluid. A total of 225 m was cored at selected intervals; the interval from 1,316 to 1,502 m was continuously cored.

Circulation was lost at 570 m, 710 m, 1,173 m, and 1,391 m. At 1,104 m, the hole caved in, and about 5 m of fill had to be cleared. During logging operations of the Tertiary section of the hole, the logging tools were unable to descend below about 1,200 m. The hole was finally kept open by using a high viscosity bentonite mud. No drilling difficulties for that depth were reported.

A directional survey indicated that the maximum hole deviation was 8^{o}, 45 minutes. The maximum deviation at depths shallower than 1,372 m was 1^{o}, 25 minutes. The bottom of the hole deviates 42 m from the vertical 3^{o}, 7 7 minutes in a south east direction. A detailed drilling history is contained in the files of Fenix & Scisson, Inc., Las Vegas, Nevada (consultant for U.S. Department of Energy).

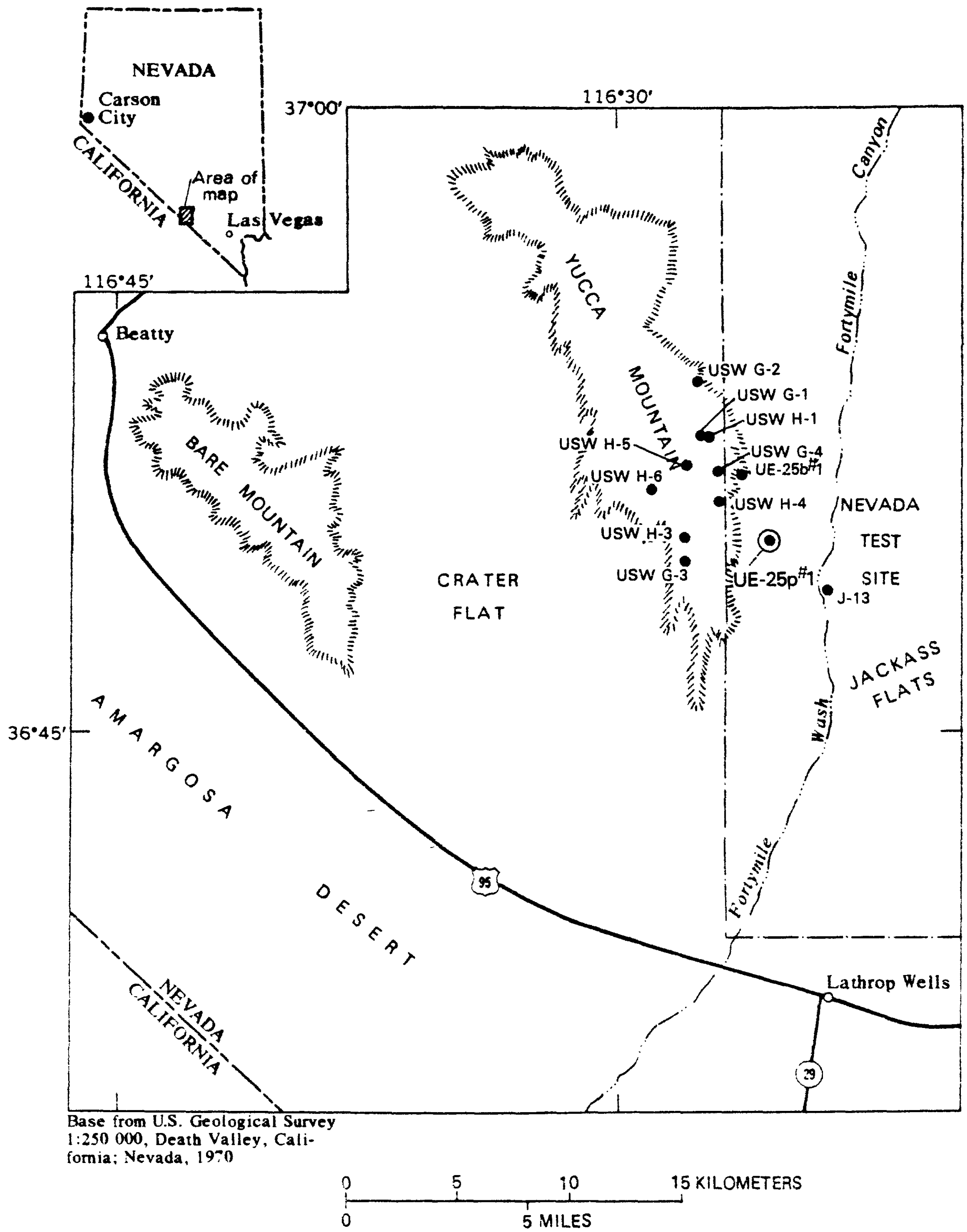

Figure 1. Location of test well UE-25p#1 and other test wells in the vicinity.

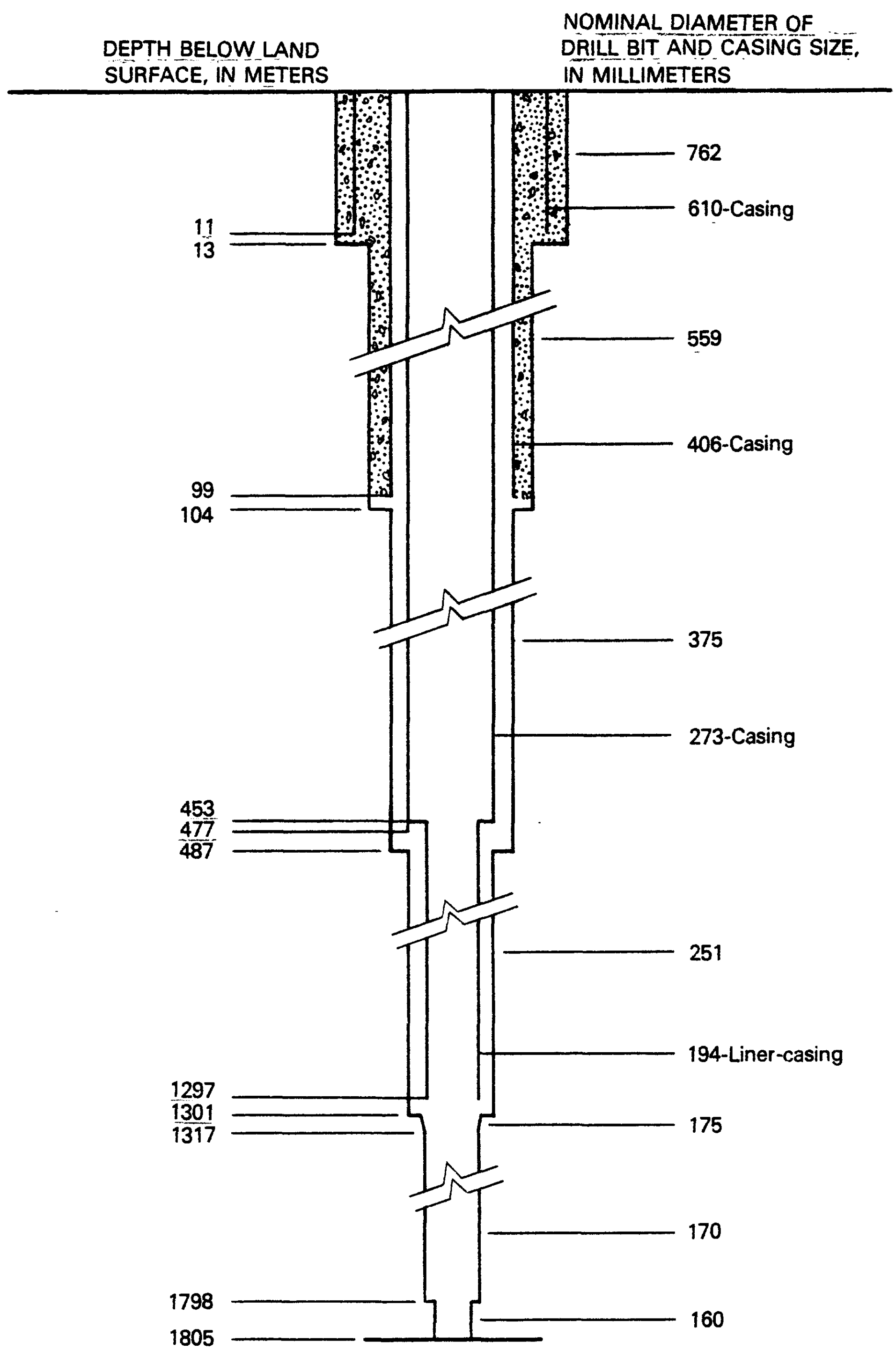

Figure 2. Well construction.

LITHOLOGIC SAMPLING AND WELL LOGGING

Lithologic Log

A summary of the major lithostratigraphic units and contacts penetrated by test well UE-25p#1 is shown in table 1. Rocks penetrated were predominantly Tertiary ashflow tuff units from the surface to approximately 1,244 m. Ashflow units generally are separated by bedded reworked tuff, tuffaceous sedimentary units, or both as much as 17 m thick. The tuffs have various degrees of welding as summarized in figure 3. A conglomerate unit 33 m thick was penetrated in the depth interval from 1,137 to 1,170 m. At least two faults within the Tertiary sequence are large enough to disrupt the normal stratigraphic succession of the tuff sequence at Yucca Mountain.

Another fault zone, at approximately 1,244 m, juxtaposes the Tertiary succession against Paleozoic carbonate rocks. Below this fault, the test hole penetrated Silurian dolomite of the Lone Mountain Dolomite and Roberts Mountain Formation. Conodonts from core and drill-bit cuttings were used to confirm the age of the dolomite sequence (A.G. Harris, U.S. Geological Survey written commun., 1984). Lone Mountain Dolomite generally is poorly bedded fine-to-medium-grained dolomite that commonly is moderately to strongly brecciated. The Roberts Mountain Formation generally consists of well-bedded, very fine-grained dolomite.

Geophysical Well Logs

An extensive suite of geophysical well logs was made in test well UE-25p#1 to guide and augment the hydrologic and geologic test programs, to confirm well construction, and to identify physical properties. Caliper logs were used to select intervals for packer-injection testing. Fluid density and neutron logs were used to confirm the depth to the saturated zone. Geophysical logs made and the depth intervals logged are shown in table 2.

Core Samples

A total of 225 m was cored in UE-25p#1. From 1,316 to 1,502 m, the hole was continuously cored to obtain samples of a part of the Paleozoic section. Above and below this interval, cores were collected at selected intervals. Total recovery was 187 m. A summary of cored intervals is shown in table 3.

Table 1.--*Summary of major lithostratigraphic units and contacts in test well UE25p#1* [M.D. Carr, U.S. Geological Survey written commun., 1983]

Age	Unit	Depth of Interval (meters)	Thickness of Interval (meters)
Quaternary	Alluvium------------------------------	0- 39	39
------	----------unconformity----------		
	Timber Mountain Tuff		
	Ranier Mesa Member------------------	39- 52	13
	----------unconformity----------		
	Paintbrush Tuff		
	Bedded tuff	52- 55	3
	Tiva Canyon Member------------------	55- 81	26
	-------------fault--------------		
	Topopah Spring Member---------------	81- 381	300
	Tuffaceous beds of Calico Hills-------	381- 422	41
	Bedded tuff---------------------------	422- 436	14
Tertiary	Crater Flat Tuff		
	Prow Pass Member--------------------	436- 546	110
	Bedded tuff-------------------------	546- 558	12
	Bullfrog Member---------------------	558- 683	125
	Bedded tuff-------------------------	683- 690	7
	Tram Member-------------------------	690- 873	183
	-------------fault-------------		
	Lithic Ridge Tuff--------------------	873-1063	190
	Bedded tuff---------------------------	1063-1067	4
	Older tuffs of USW G-1		
	Unit A------------------------------	1067-1100	33
	Unit B------------------------------	1100-1137	37
	Conglomerate-------------------------	1137-1172	35
	Older tuff		
	Calcified ash-flow tuff-------------	1172-1204	31
	Tuff of Yucca Flat------------------	1204-1244	40
------	-------------fault---------------		
Silurian	Lone Mountain Dolomite and Roberts Mountain Formation-----------------------	1244-1805	561

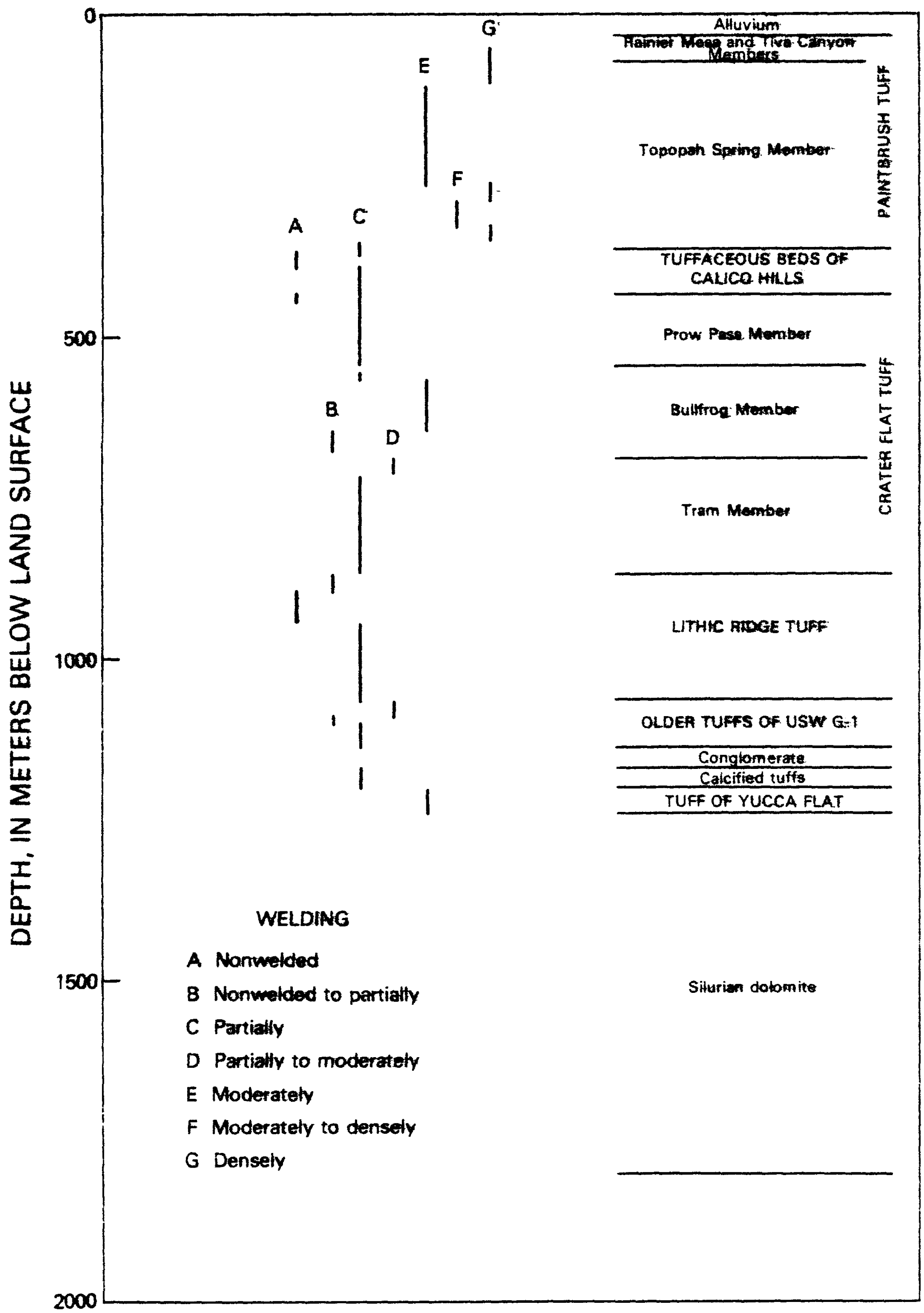

Figure 3. Generalized distribution of welding in rocks penetrated by test well UE-25p#1.

Table 2.--*Summary of geophysical well logs*

Log	Depth interval (meters)	Date
Accoustic, cement bond	363-1298	05-03-83
Accoustic fraclog, borehole compensated and gamma ray	1298-1799	05-03-83
	1297-1799	06-02-83
Accoustilog, borehole compensated and gamma ray	482-1195	01-18-83
	1219-1803	03-09-83
Caliper	2- 94	11-16-82
	2- 97	11-18-82
	83- 481	11-30-82
	84- 478	12-03-82
	457-1198	01-16-83
	1124-1205	01-22-83
	368-1195	01-24-83
	1197-1294	03-08-83
	1277-1314	03-30-83
	1274-1802	05-02-83
Casing-collar locator	423- 480	02-19-83
	610- 728	03-01-83
	1262-1315	03-30-83
Densilog, borehole compensated and gamma ray	482-1198	01-18-83
Density, borehole compensated	6- 96	11-16-82
	88- 482	11-30-82
	1204-1296	03-09-83
	1277-1804	05-03-83
Dielectric	1297-1803	05-04-83
Dual-induction, focused	482-1198	01-18-83
	1219-1299	03-09-83
	1298-1804	05-03-83
Electric	1288-1801	06-23-83
Epithermal-neutron porosity	91- 483	12-01-82
	469-1196	01-17-83
	1275-1804	05-03-83
Fluid density for water location	77- 97	11-17-82
	370- 391	11-30-82
	366- 399	12-01-82
	366- 390	01-17-83
	357- 396	02-18-83
	344- 399	03-15-83
	351- 372	05-04-83
Gamma ray	91- 482	12-01-82
	472-1197	01-17-83

Table 2.--*Summary of geophysical well logs*--Continued

Log	Depth interval (meters)	Date
Geophone survey	30- 91	11-17-82
	85- 279	12-01-83
	480-1196	01-16-83
	1219-1288	03-09-83
Induction	9- 95	11-17-82
Induction electric	99- 481	11-30-82
Magnetometer	101- 481	11-30-82
	485- 872	01-17-83
Neutron, borehole compensated	482-1195	01-18-83
	1219-1298	03-09-83
	1219-1804	05-03-83
Nuclear annulus investigation	88- 99	11-18-82
	442- 567	03-11-83
Nuclear cement-top locator	412- 519	02-22-83
	427-1293	03-14-83
Spectalog, gamma ray	0-1198	01-18-83
	884-1284	03-08-83
	762-1804	05-04-83
	1067-1804	05-04-83
Spinner survey	349-1292	03-16-83
Temperature	0- 482	12-01-82
	15-1198	01-17-83
	310-1197(while pumping)	02-08-83
	1204-1294	03-09-83
	2-1802	05-04-83
	244-1802(while pumping)	05-05-83
	1-1802	06-23-83
	1-1801	06-23-83
Television camera and video tape	0-383	11-30-82
	381-1198	02-11-83
	0-1745	05-13-83
Velocity (3-D)	380- 481	12-01-82
	1101-1295	03-14-83
	335-1105	03-14-83

Table 3.--*Summary of cored intervals*

Depth interval[1] (meters)		Length of core (meters)	Length of recovered core (meters)
1050.0-1055.2		5.2	4.9
1193.7-1198.6		4.9	4.0
1276.6-1288.9		12.3	12.3
1302.4-1312.6		10.2	8.6
1316.1-1501.8		185.7	152.6
1798.3-1805.3		7.0	4.4
	TOTAL:	225.3	186.8

[1]Depths are reported to 0.1 meter to correspond to the length of core; actual depths probably are ±0.5 meter.

HYDROLOGIC TESTING AND WATER SAMPLING

Periods of Testing and Sampling

Two separate periods of hydrologic testing and water sampling were conducted during the drilling of test well UE-25p#1. The first was after the hole had penetrated Paleozoic rocks to a depth of 1,301 m. Originally, a temporary cement plug was to have been set slightly above the area of the Tertiary-Paleozoic contact to isolate the Tertiary section from the Paleozoic section for hydrologic testing. Because it had been necessary to use a bentonite mud to keep the hole open at about 1,200 m during logging operations, it was concluded that testing the Tertiary section below 1,200 m would have been difficult. A temporary cement plug was set at 1,197 m, and the 273-mm casing was temporarily set, uncemented, at a depth of 386 m. A series of tests then was conducted on the saturated Tertiary section above 1,197 m. Well construction during testing of the Tertiary section is shown in figure 4. The second period of testing occurred after casing had been set to 1,297 m, and the well had been completed to a total depth of 1,805 m (fig. 2). The interval from 1,197 to 1,297 m was not tested during either period of testing (probable leakage past temporary cement plug may have included the interval from 1,197 - 1,301 m in pumping and recovery test 1).

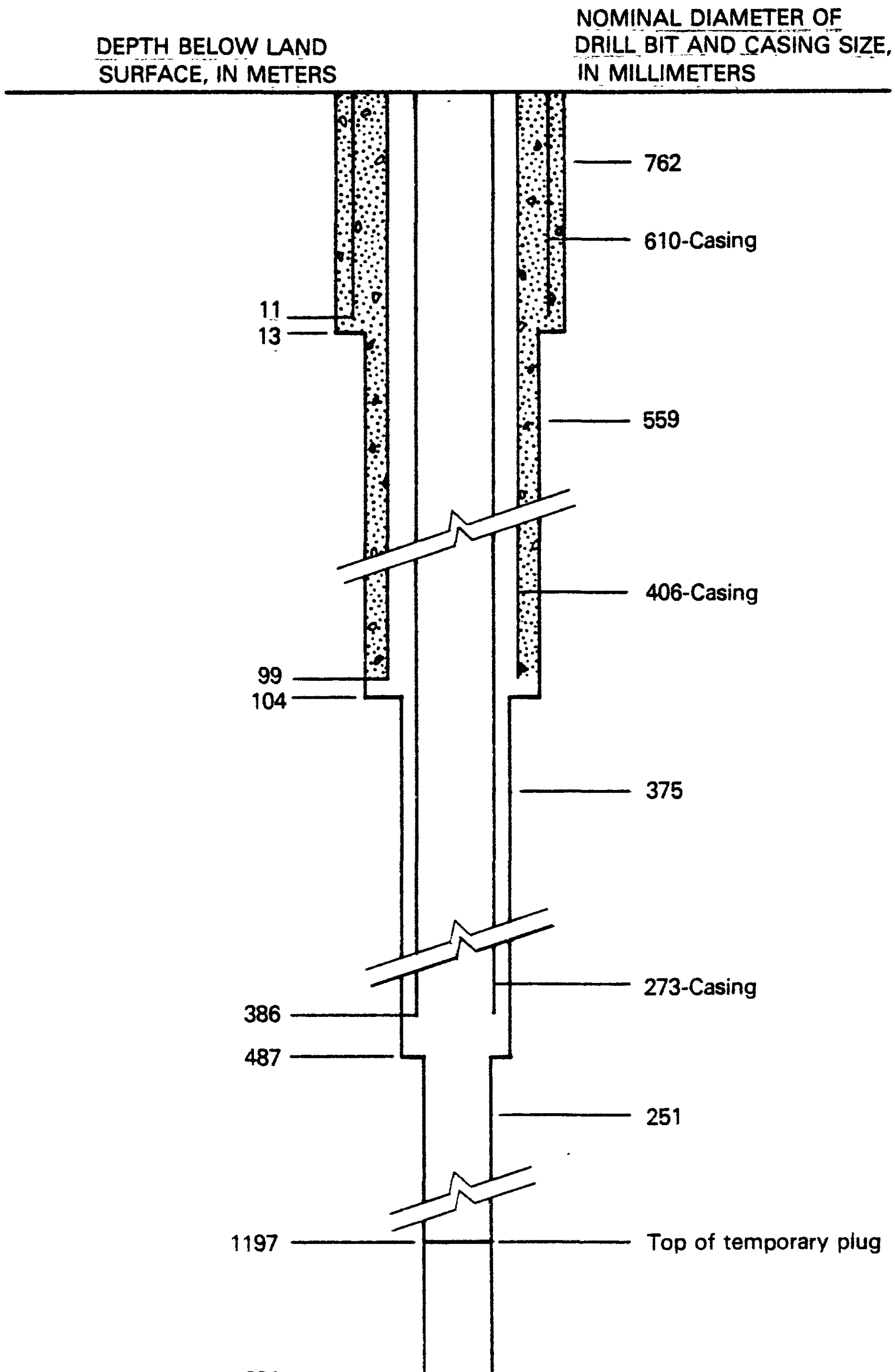

Figure 4. Well construction during testing of Tertiary section.

Water Levels

Depths to water were measured to determine the composite hydraulic head for the Tertiary and Paleozoic sections. In addition, depths to water were measured for intervals isolated during packer-injection tests. Composite water-level depths are listed in table 4. Levels measured during packer-injection testing are listed in table 5, which is in the section entitled "Packer-injection tests." The composite water level for the Tertiary section was about 381 m below land surface (731 m above sea level); composite water level for the Paleozoic section was about 361 m below land surface (751 m above sea level).

Table 4.--*Water-level measurements*

Date	Depth interval (meters)	Depth to water (meters)	Method
1-03-83	99- 913	383	Transducer
1-17-83	[1/]99-1,301	382	Fluid-density log
1-26-83	[1/]99-1,193	382	Transducer
2-06-83	[1/]99-1,193	383	Transducer
2-07-83	[1/]99-1,193	382	Transducer
2-11-83	[1/]99-1,193	380.8	Float-switch probe
5-07-83	1,297-1,805	361.5	Float-switch probe
5-13-83	1,297-1,805	361	Television camera

[1/]Probable leakage past cement plug may make the bottom of this interval 1301 meters.

Pumping and Recovery Tests

A pumping and recovery test was conducted during each period of testing in test well UE-25p#1. The first test was conducted in the interval from the top of the saturated zone to 1,197 m (or 1,301 m, based on probable leakage past plug). A second pumping and recovery test was conducted after a depth of 1,805 m had been reached; it tested Paleozoic rocks from the bottom of the 194-mm liner casing at 1,297 m to 1,805 m.

Pumping test 1 was conducted for 3,150 minutes at a rate of 22 L/s. Recovery was monitored for 1,050 minutes. Prior to pumping, the composite static water level was 381 m below land surface. The pump intake was at 425 m, and the bottom of the monitoring tube was at 408 m. Maximum drawdown was 33.7 m. Drawdown versus time data are shown in figure 5; residual drawdown (recovery) versus time data are shown in figure 6.

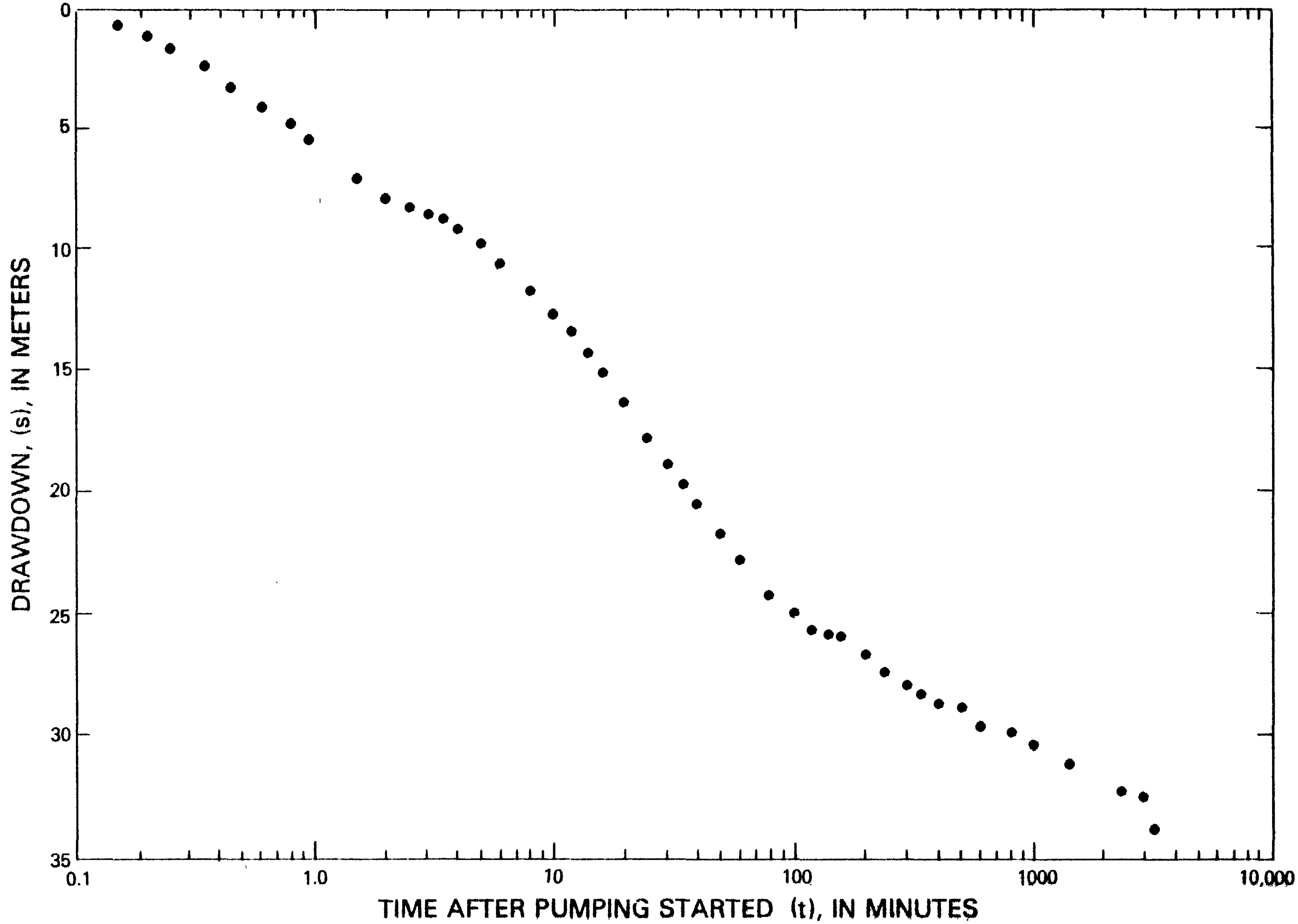

Figure 5. Water-level drawdown, pumping test 1, depth interval from 381 to 1,197 meters at a pumping rate of 22 liters per second.

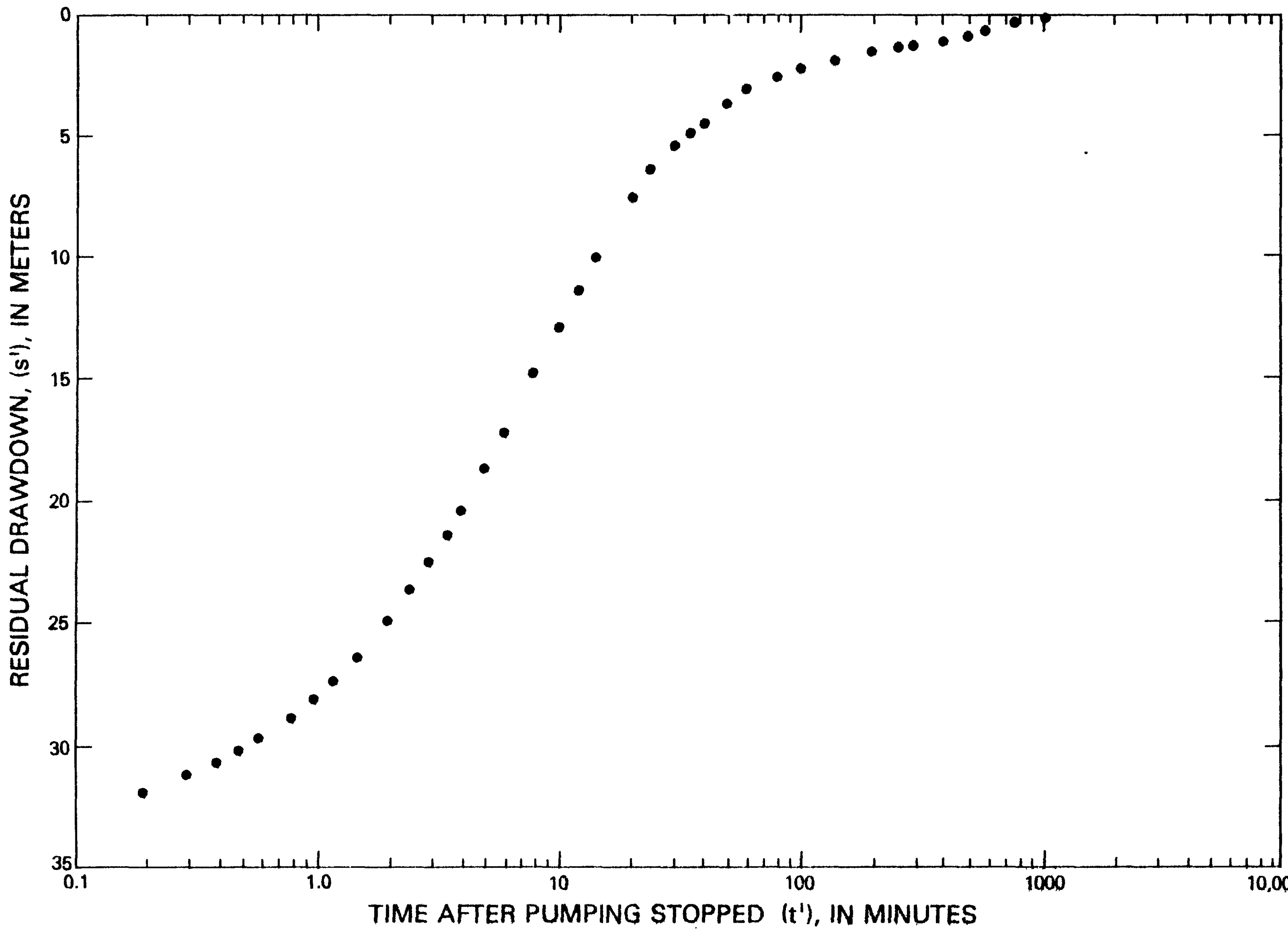

Figure 6. Residual drawdown, recovery test 1, depth interval from 381 to 1,197 meters.

Pumping and recovery test 2 was conducted after completion of drilling. The hole was open from 1,297 to 1,805 m. Composite static water level for the interval was 361 m below land surface. The pump intake was at 417 m, and the bottom of the monitoring tube was at 436 m. The well was pumped at 31.5 L/s for 6,080 minutes. Maximum drawdown was 9.3 m below the pre-pumping static water level. Drawdown versus time data for the pumping test are shown in figure 7. During the first 50 minutes of the test, discharge temperature increased from about 30° to 56° C. The temperature remained at 56° C for the remainder of the test. Recovery was monitored for 1,000 minutes and is shown in figure 8 as residual drawdown versus time. The response during recovery test 2 is similar to inertial effects described by Bredehoeft and others (1966) and van der Kamp (1976).

Borehole-flow Surveys

Three borehole-flow surveys were conducted in test well UE-25p#1. One survey was conducted during each pumping test and, one was conducted during a period of non-pumping in the Tertiary section above the temporary plug. The surveys were run to detect intervals of fluid entrance into the borehole. Small quantities of radioactive iodine-131 were injected into the water column at selected depths. Time required for the iodine-131 to move between two gamma-ray detectors, a known distance apart, was converted to a velocity. The cross-sectional area of the hole was determined by a caliper log. The product of the velocity and the cross-sectional area gave a rate of flow past a particular depth. The tool was moved through the hole as required to define the intervals of water production. A more complete description of the technique for the borehole-flow survey is in Blankennagel (1967). Depth and corresponding stratigraphy versus percentage of total flow are shown in figures 9 and 10 for the two flow surveys conducted while pumping. The quantity of flow, rather than the percentage of total flow, for the non-pumping survey is shown in figure 11.

The survey during pumping of the Tertiary section (fig. 9) showed that about 58 percent of the fluid production came from the depth interval from 469 to 501 m. About 11 percent came from the intervals from 564 to 602 m and from 1,000 to 1,119 m. Approximately 28 percent of the flow was detected near the top of the temporary plug which indicates that the plug probably was leaking. The remaining flow came from the interval from 535 to 450 m.

The non-pumping flow survey (fig. 11) in the Tertiary section showed upward movement of water within the well. Flow at the temporary plug was more than 0.4 L/s. Most of the upward movement of water entered the interval between 469 and 501 m, where 58 percent of the production during pumping was measured. The survey of the Paleozoic section between 1,297 and 1,805 m (fig. 10) showed that 75 percent of the water came from the depth intervals from 1,340 to 1,362 m and from 1,515 to 1,550 m. Below a depth of 1,550 m, flow was less than about 5 percent of total flow.

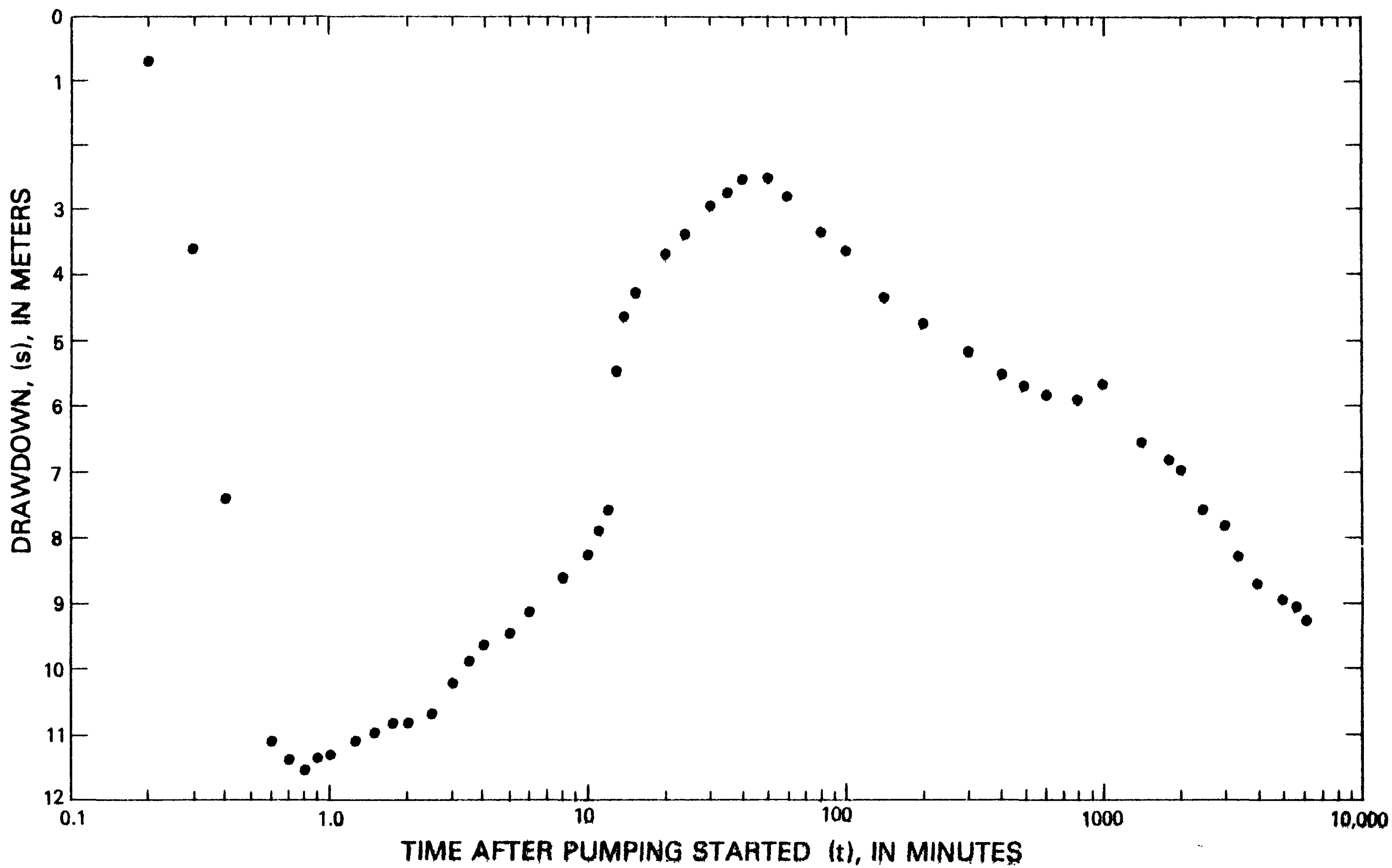

Figure 7. Water-level drawdown, pumping test 2, depth interval from 1,297 to 1,805 meters at a pumping rate of 31.5 liters per second.

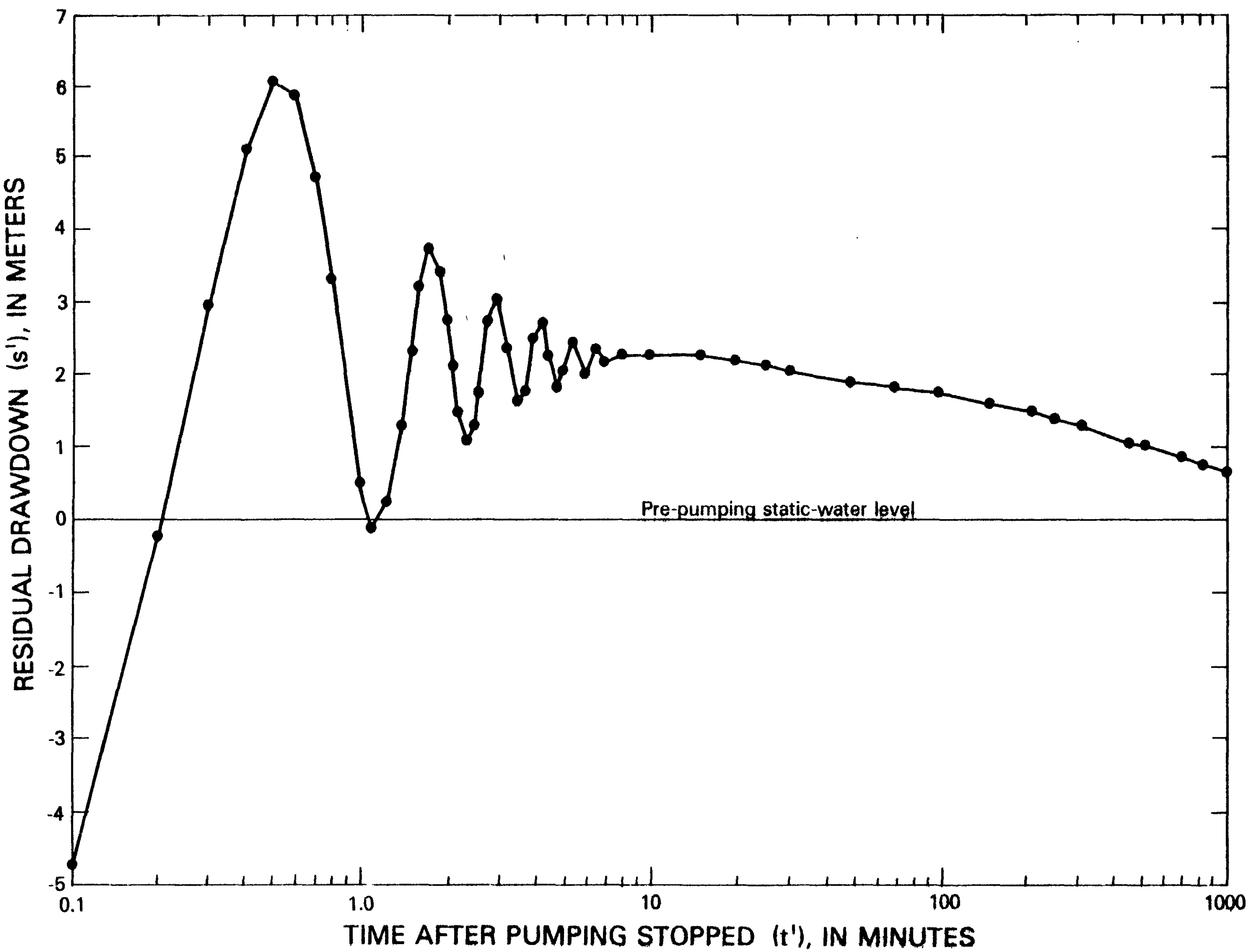

Figure 8. Residual drawdown, recovery test 2, depth interval from 1,297 to 1,805 meters.

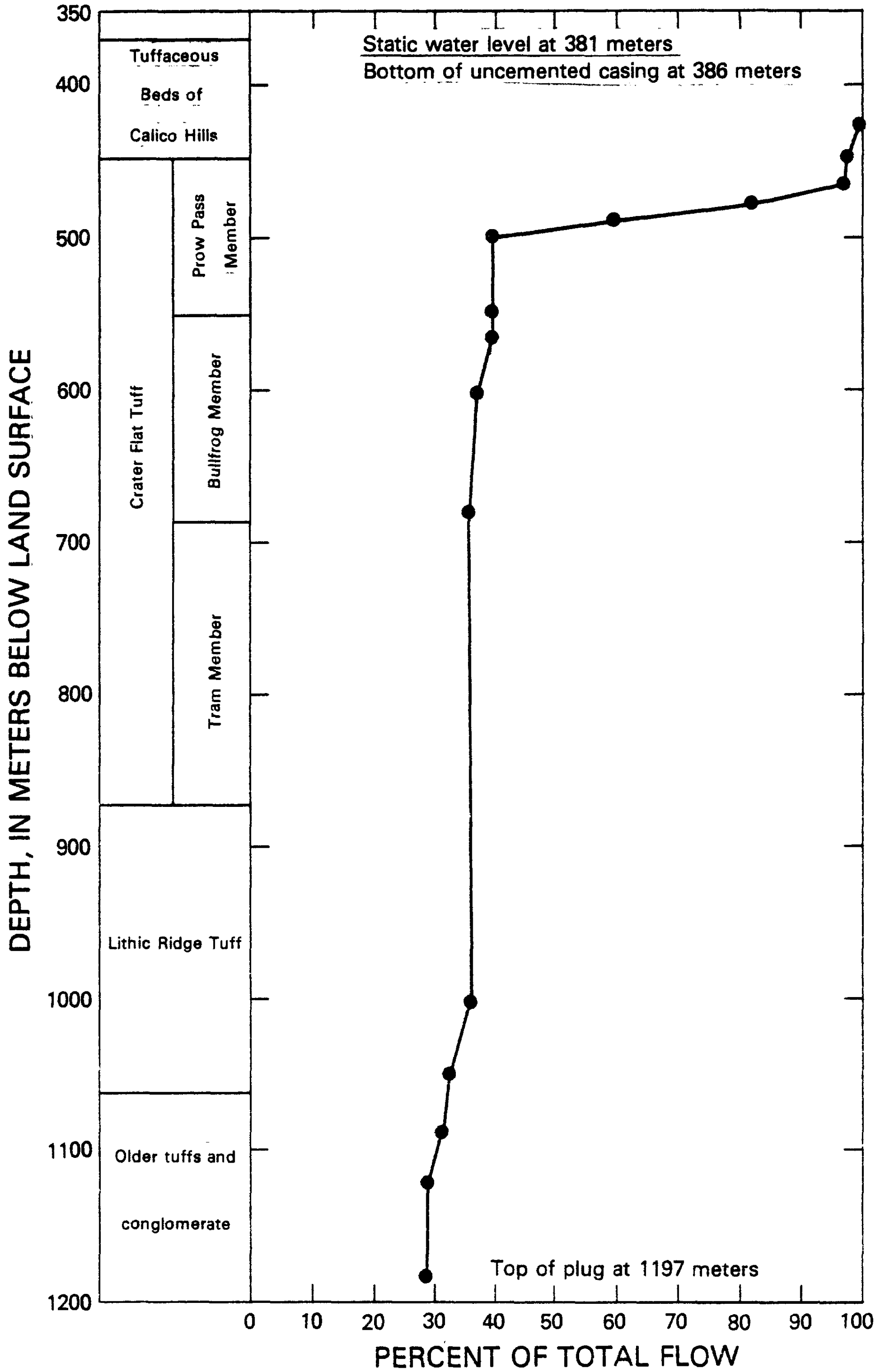

Figure 9. Borehole-flow survey of Tertiary section showing percent of pumping rate produced by intervals.

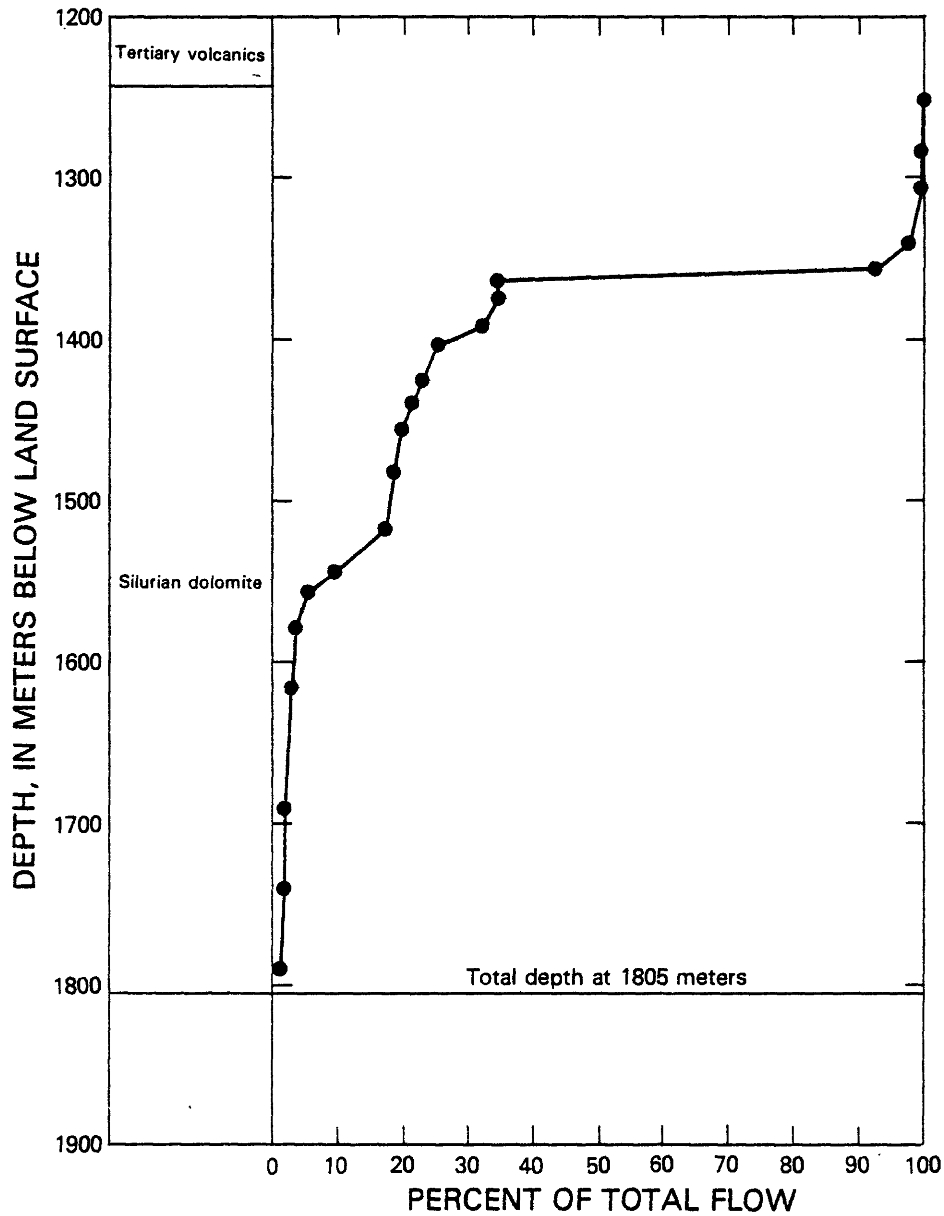

Figure 10. Borehole-flow survey of Paleozoic section showing percent of pumping rate produced by intervals.

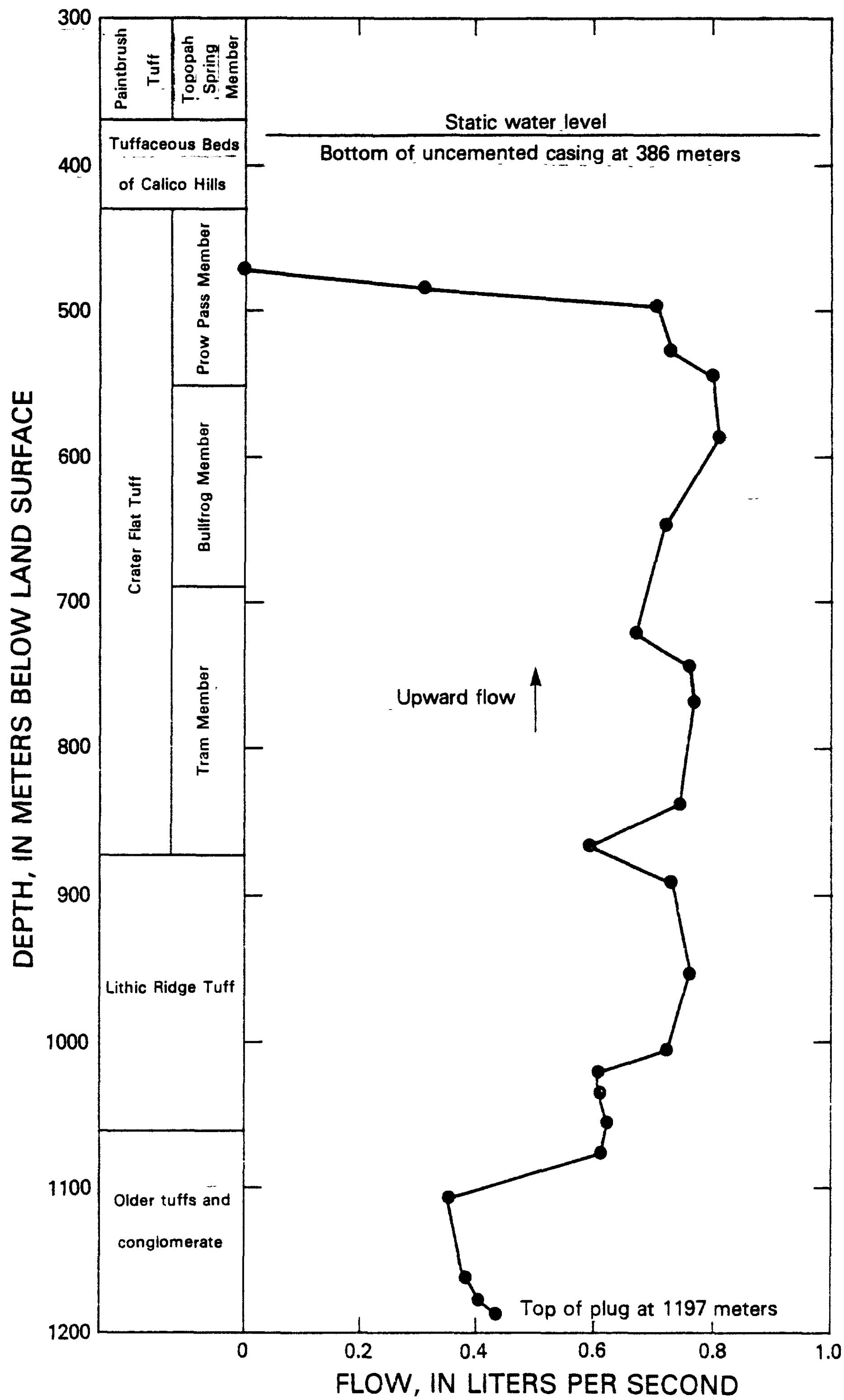

Figure 11. Borehole-flow survey showing flow in Tertiary section during non-pumping period.

Packer-injection Tests

Packer-injection tests were conducted in various intervals of the well to: (1) Obtain data on the distribution of hydraulic head in the well; and (2) obtain data for future determination of the distribution of transmissivity in the well. The intervals to be tested were isolated from the remainder of the bore-hole by inflatable straddle-packers. Tests were conducted either on the interval between the packers or on the interval from the bottom packer to the bottom of the well. Water was injected by filling tubing that was connected to the packer tool and then opening the tool to either the between-packer interval or below-packer interval, as appropriate.

Data for these tests are summarized in table 5. Tests 1-14 are for the Tertiary section; tests 15-29 are for the Paleozoic section. Tests 1 and 14 measured water levels only. The decline of water level during the remaining tests, presented as the ratio of the hydraulic head above the static water level at a given time (H) to the hydraulic head above the static water level at time of injection (H_0) versus time since injections began, is shown in figures 12 to 38. Height of the water column is shown on the right side of the graphs as meters above static water level. Most tests were started with a full tube of water with the hydraulic head about 5 m above land surface. The hydraulic head above static-water level at time of injection for each test is shown in figures 12 to 38 as the value equal to H_0.

Table 5.--*Summary of packer-injection tests*

Test Number	Depth interval (meters)	Length of interval (meters)	Depth to static-water level (meters)	Average hole diameter[1/] (millimeters)	Approximate time required to reach static-water level[2/] (minutes)
1	static-500	116	383.9	---	W.L.[3/]
2	500-550	50	383.5	310	150
3	550-600	50	383.9	340	40
4	600-650	50	-----	290	30
5	640-690	50	-----	320	110
6	690-740	50	-----	300	[4/]
7	739-789	50	383.3	300	110
8	764-834	70	383.1	300	170
9	834-904	70	381.1	310	150
10	904-974	70	382.2	300	120
11	974-1,044	70	380.9	280	30
12	1,044-1,114	70	379.4	280	5
13	1,110-1,180	70	-----	290	120
14	[5/]1,180-1,197	7	355.0+	290	W.L.[3/]
15	1,297-1,308	11	361.1	240	150
16	1,297-1,338	41	360.2	190	80(?)
17	1,341-1,381	40	362.3	210	[6/]5
18	1,381-1,421	40	362.4	220	[6/]5

Table 5.--*Summary of packer-injection tests*--Continued

Test Number	Depth interval (meters)	Length of interval (meters)	Depth to static-water level (meters)	Average hole diameter[1/] (millimeters)	Approximate time required to reach static-water level[2/] (minutes)
19	1,423-1,463	40	362.5	210	[6/]6
[7/]20	1,463-1,509	46	362.6	220	[6/]5
[7/]21	1,509-1,555	46	362.6	210	[6/]5
22	1,558-1,805	247	362.4	180	[6/]5
[7/]23	1,554-1,600	46	362.5	180	[6/]5
[7/]24	1,597-1,643	46	362.7	180	[6/]5
25	1,646-1,805	159	362.9	180	[6/]6
[7/]26	1,643-1,689	46	363.0	180	[6/]5
[7/]27	1,689-1,735	46	363.4	180	[6/]5
[7/]28	1,734-1,780	46	363.3	180	[6/]5
29	1,783-1,805	22	363.0	170	20

1/Bit diameter was 251 millimeters (mm) from 487 to 1,301 meters (m), 175 mm from 1,301 to 1,317 m, 171 mm from 1,317 to 1,798 m, and 56 mm from 1,798 to 1,805 m.

2/Time after injection started when water in tubing has reached an approximate static-water level.

3/Water-level measurement only; borehole-flow survey showed permeability greater than could be tested with the packer-injection tool.

4/Test stopped after 120 minutes with about 73 percent of the water column dissipated.

5/Probable leakage past cement plug may have made effective interval 1,180 to 1,301 m.

6/Approximate minimum time to dissipate water column through tool.

7/Results not necessarily valid (see text).

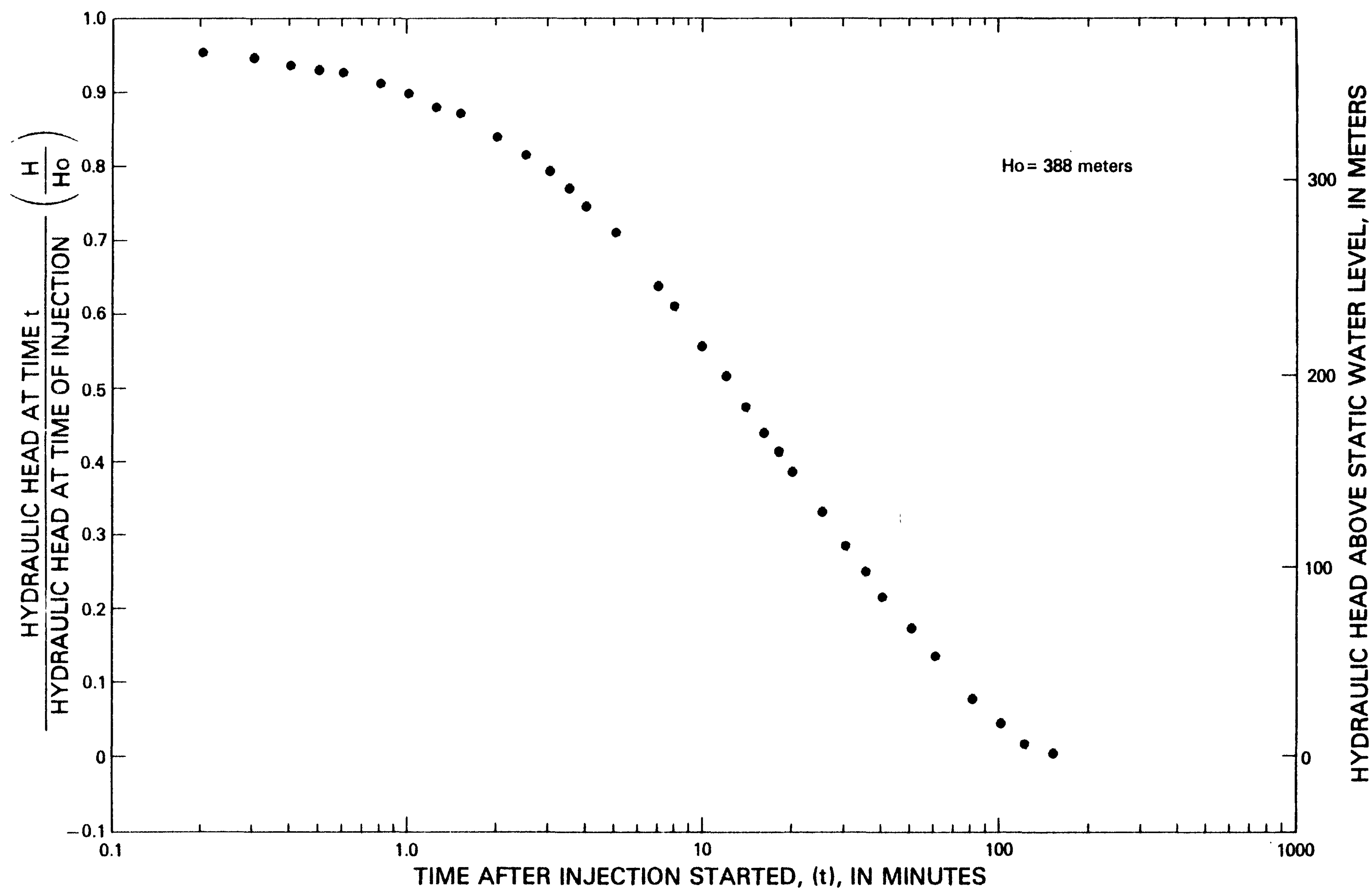

Figure 12. Packer-injection test 2, depth interval from 500 to 550 meters.

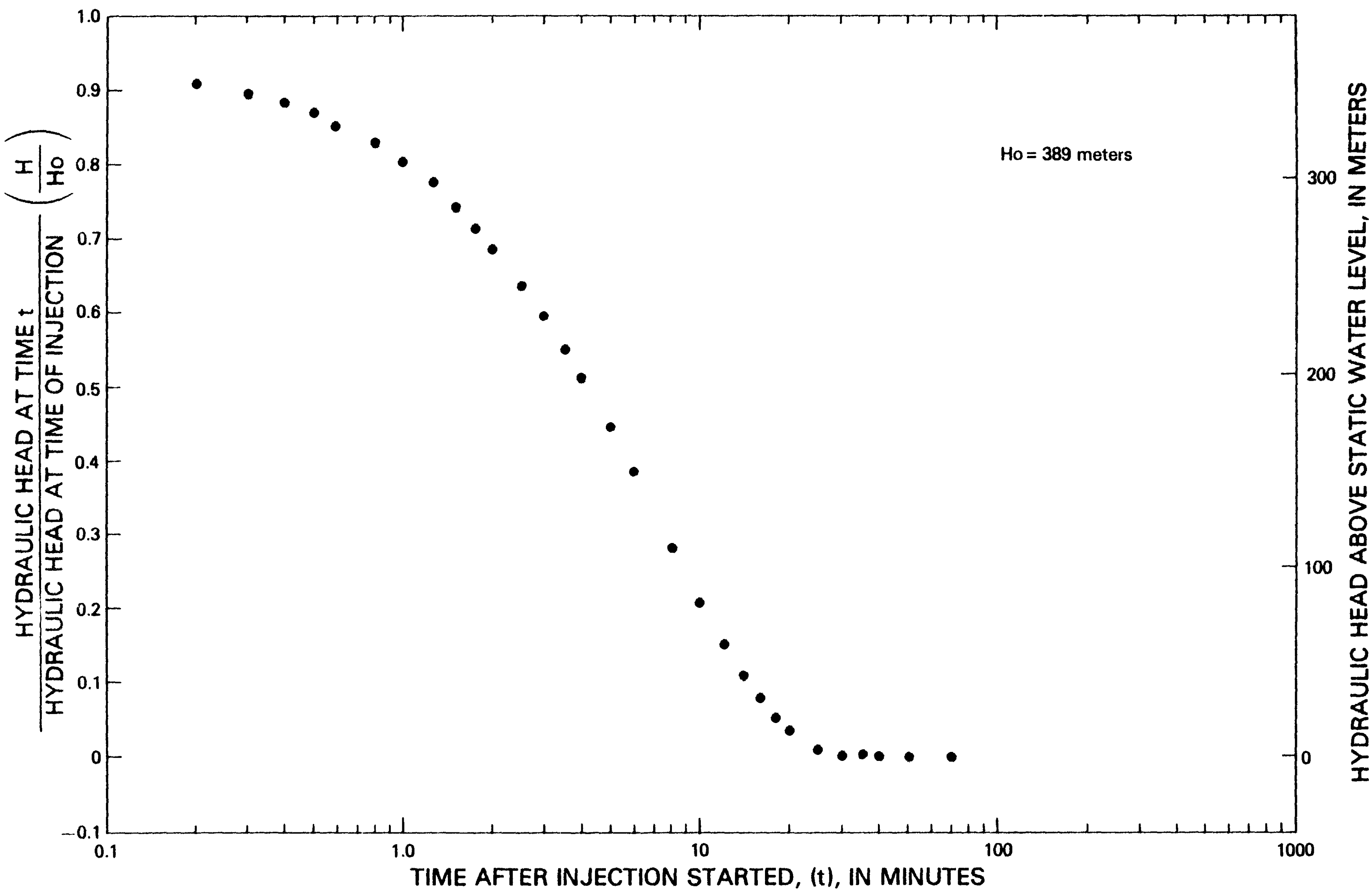

Figure 13. Packer-injection test 3, depth interval from 550 to 600 meters.

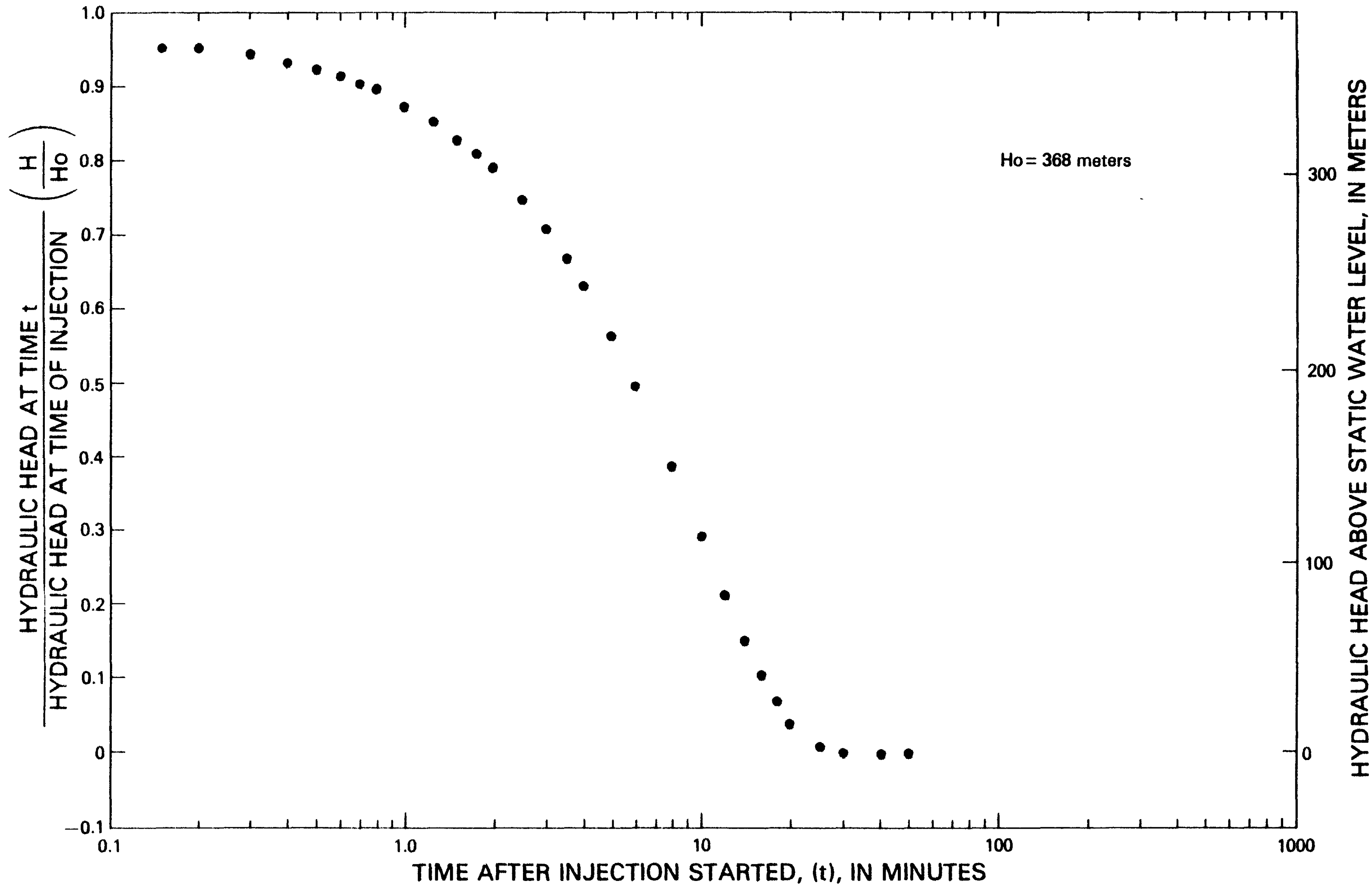

Figure 14. Packer-injection test 4, depth interval from 600 to 650 meters.

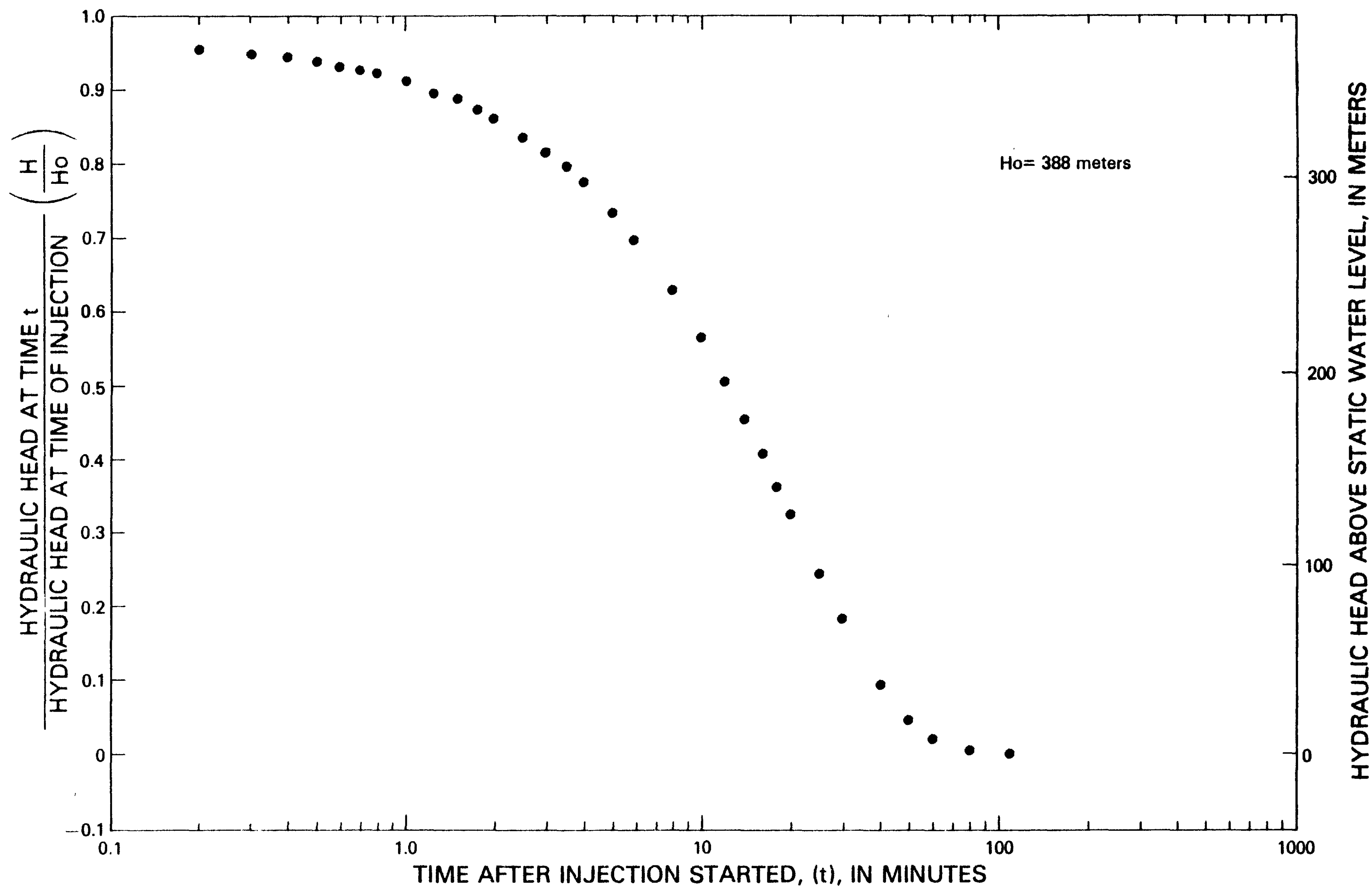

Figure 15. Packer-injection test 5, depth interval from 640 to 690 meters.

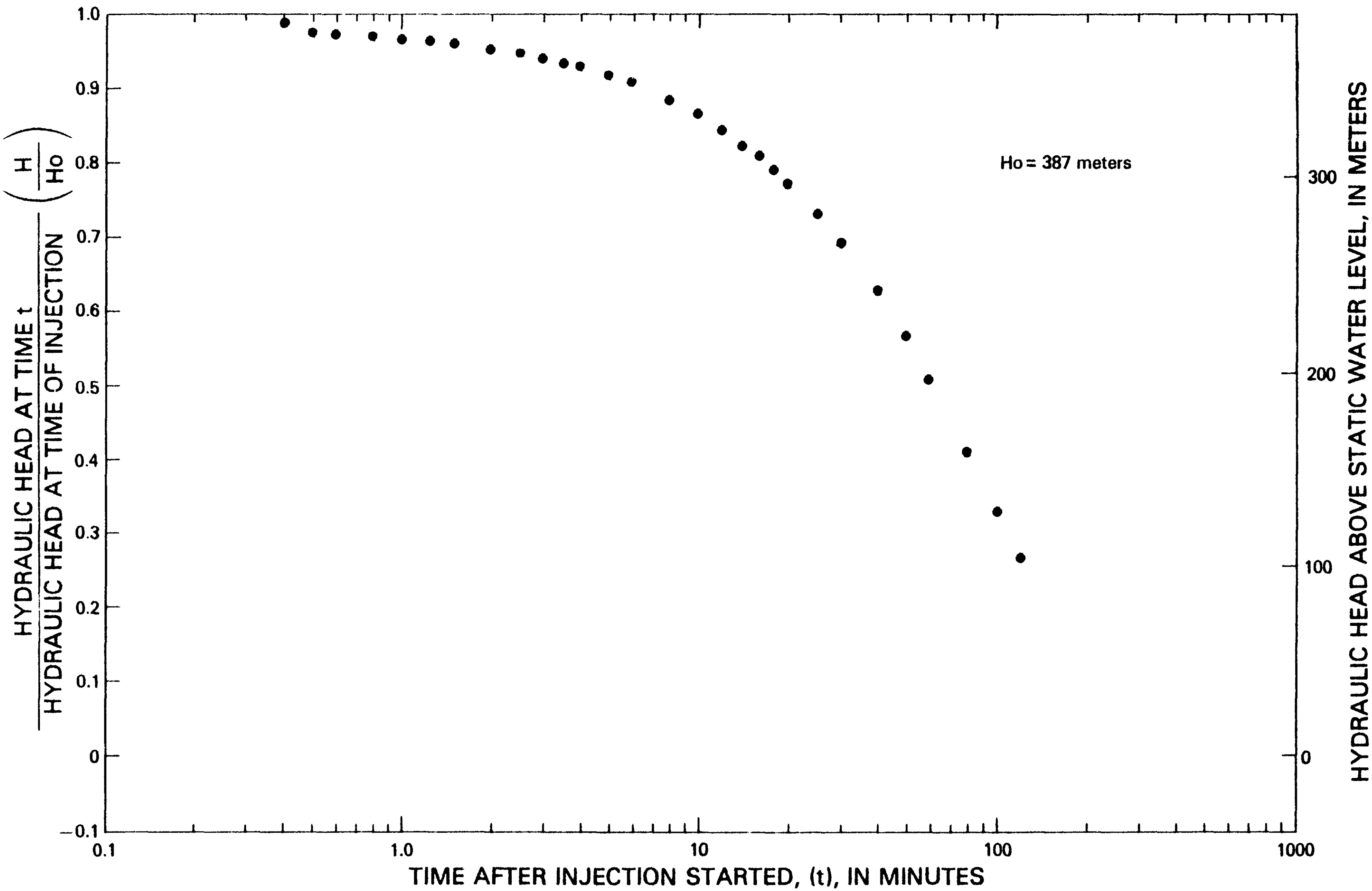

Figure 16. Packer-injection test 6, depth interval from 690 to 740 meters.

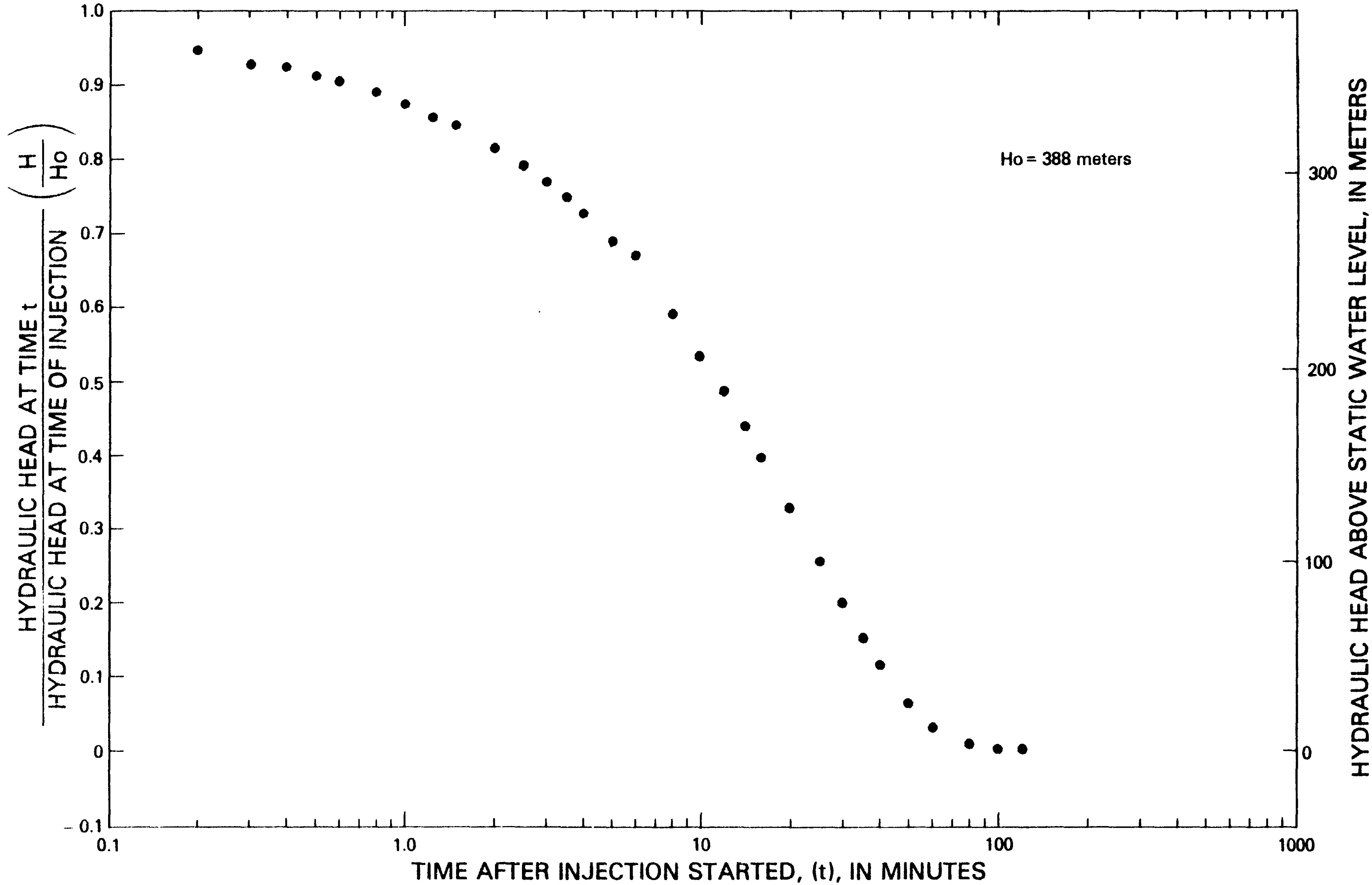

Figure 17. Packer-injection test 7, depth interval from 739 to 789 meters.

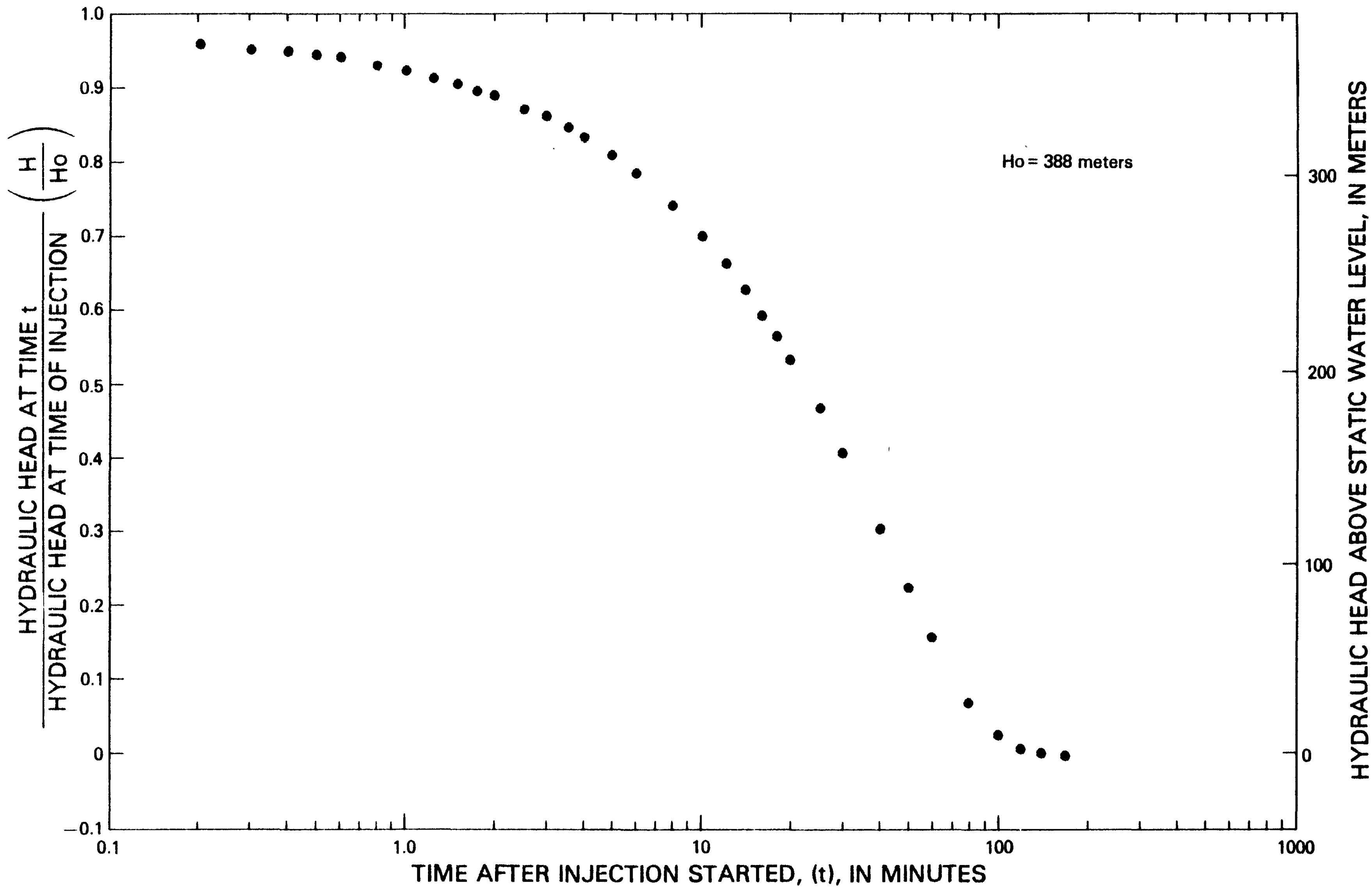

Figure 18. Packer-injection test 8, depth interval from 764 to 834 meters.

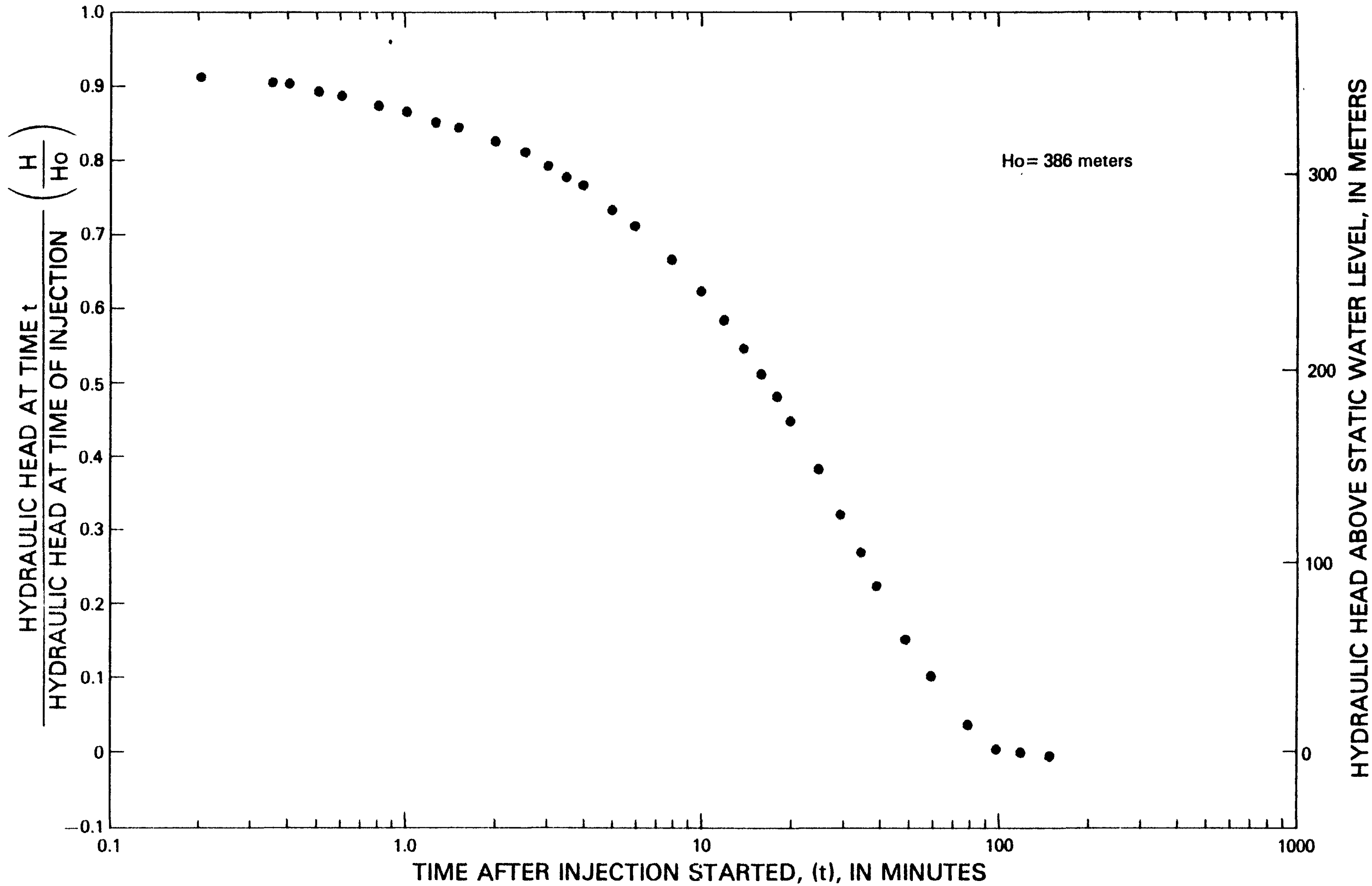

Figure 19. Packer-injection test 9, depth interval from 834 to 904 meters.

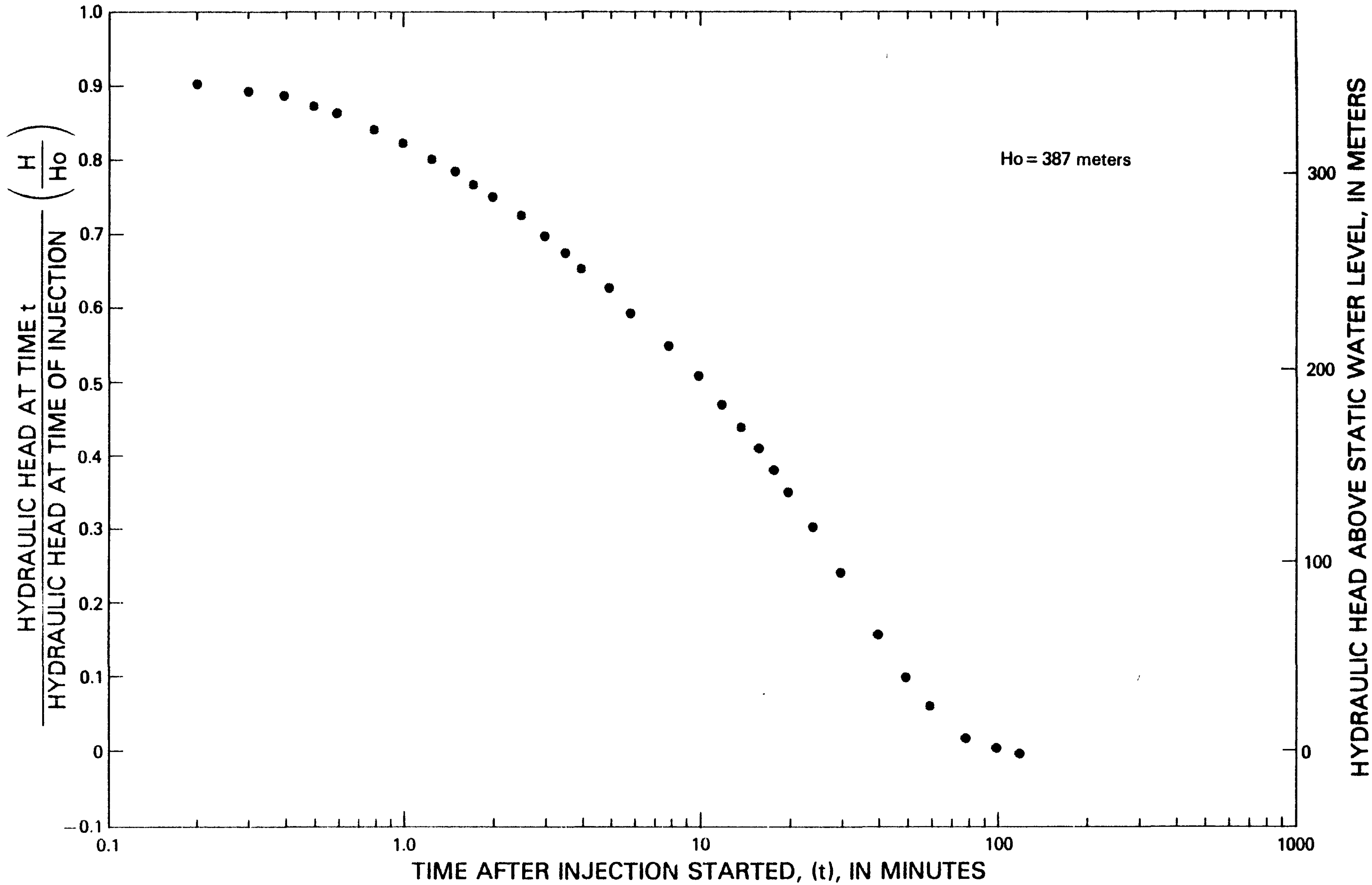

Figure 20. Packer-injection test 10, depth interval from 904 to 974 meters.

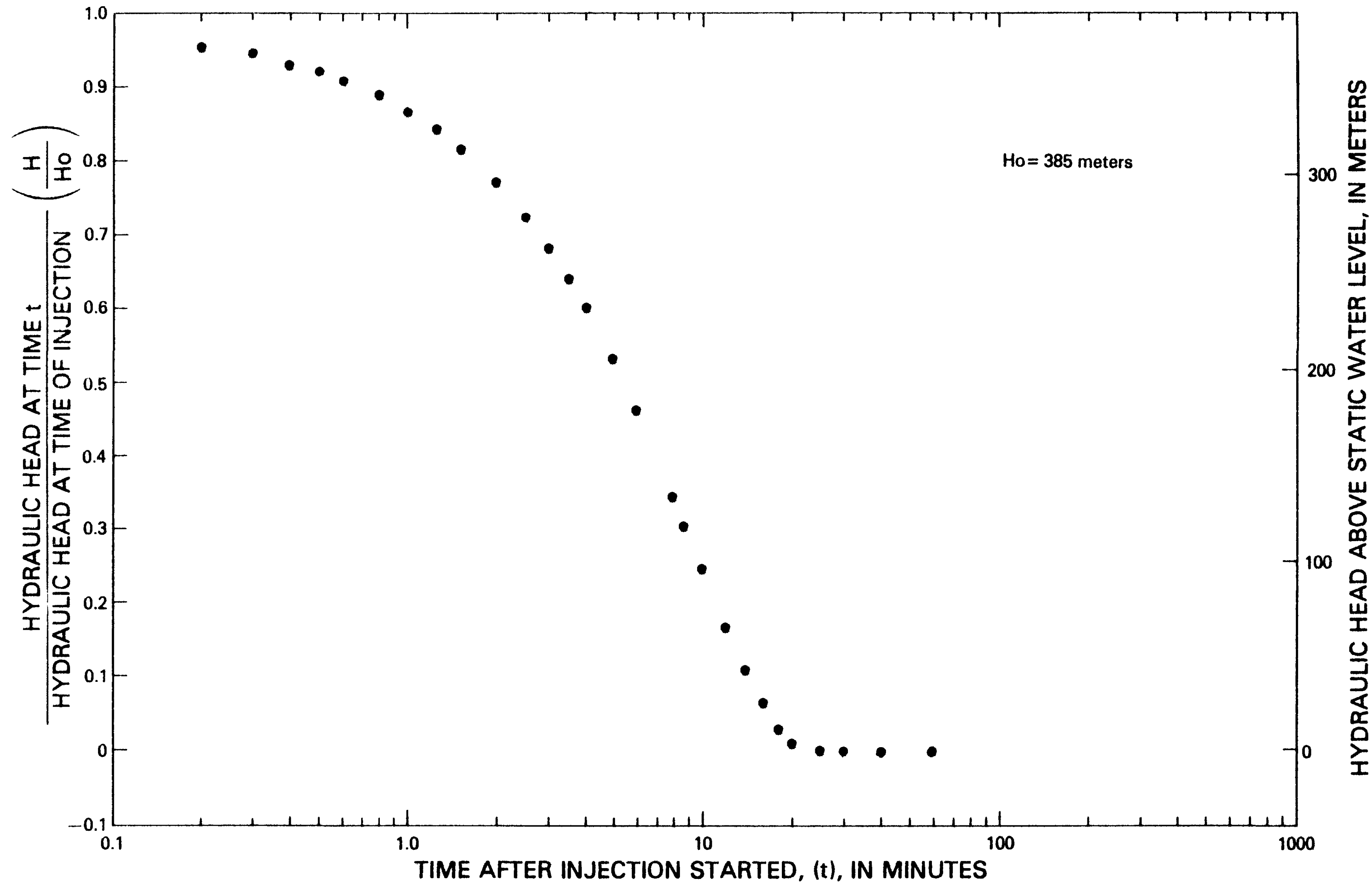

Figure 21. Packer-injection test 11, depth interval from 974 to 1,044 meters.

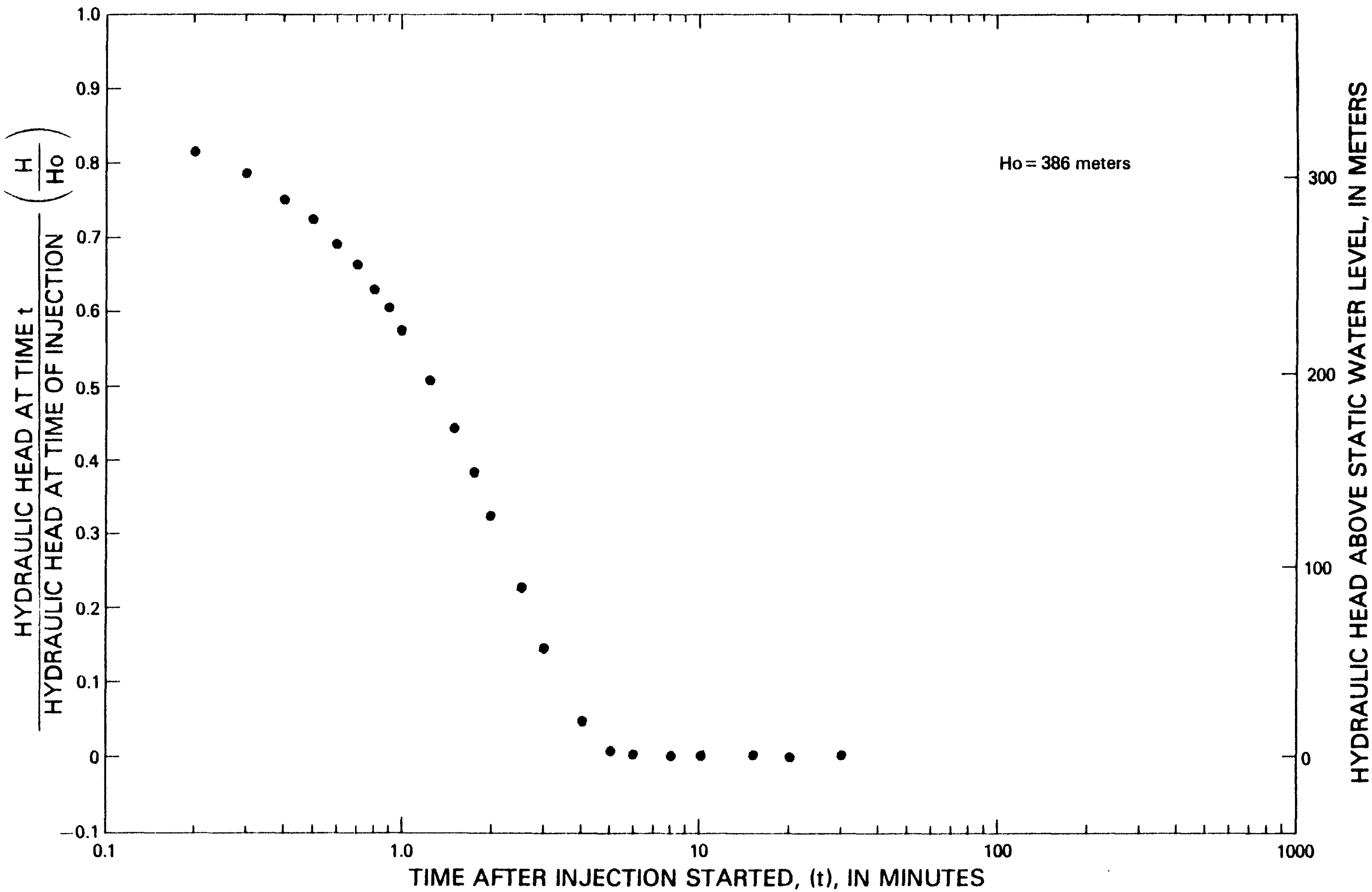

Figure 22. Packer-injection test 12, depth interval from 1,044 to 1,114 meters.

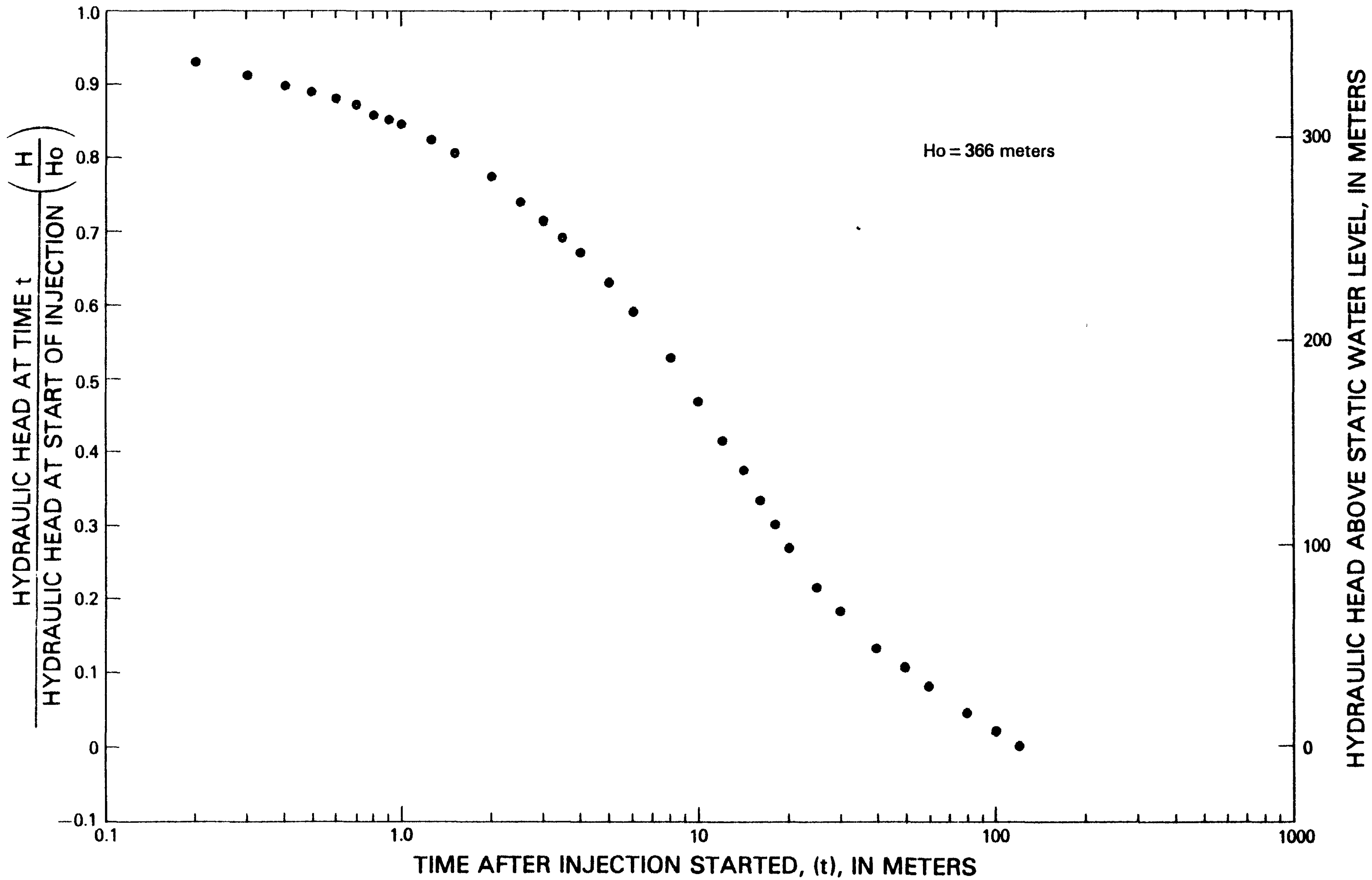

Figure 23. Packer-injection test 13, depth interval from 1,110 to 1,180 meters.

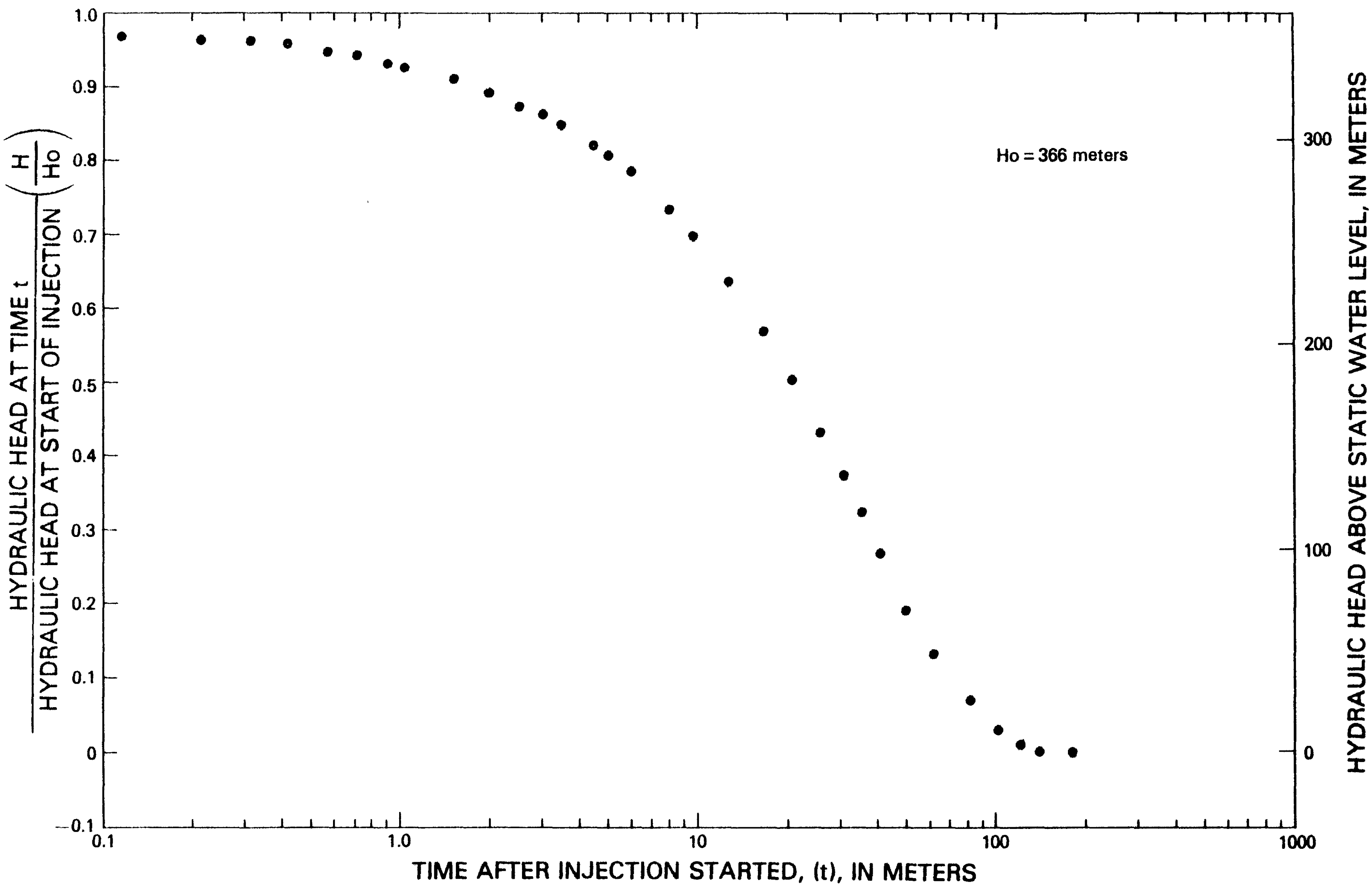

Figure 24. Packer-injection test 15, depth interval from 1,297 to 1,308 meters.

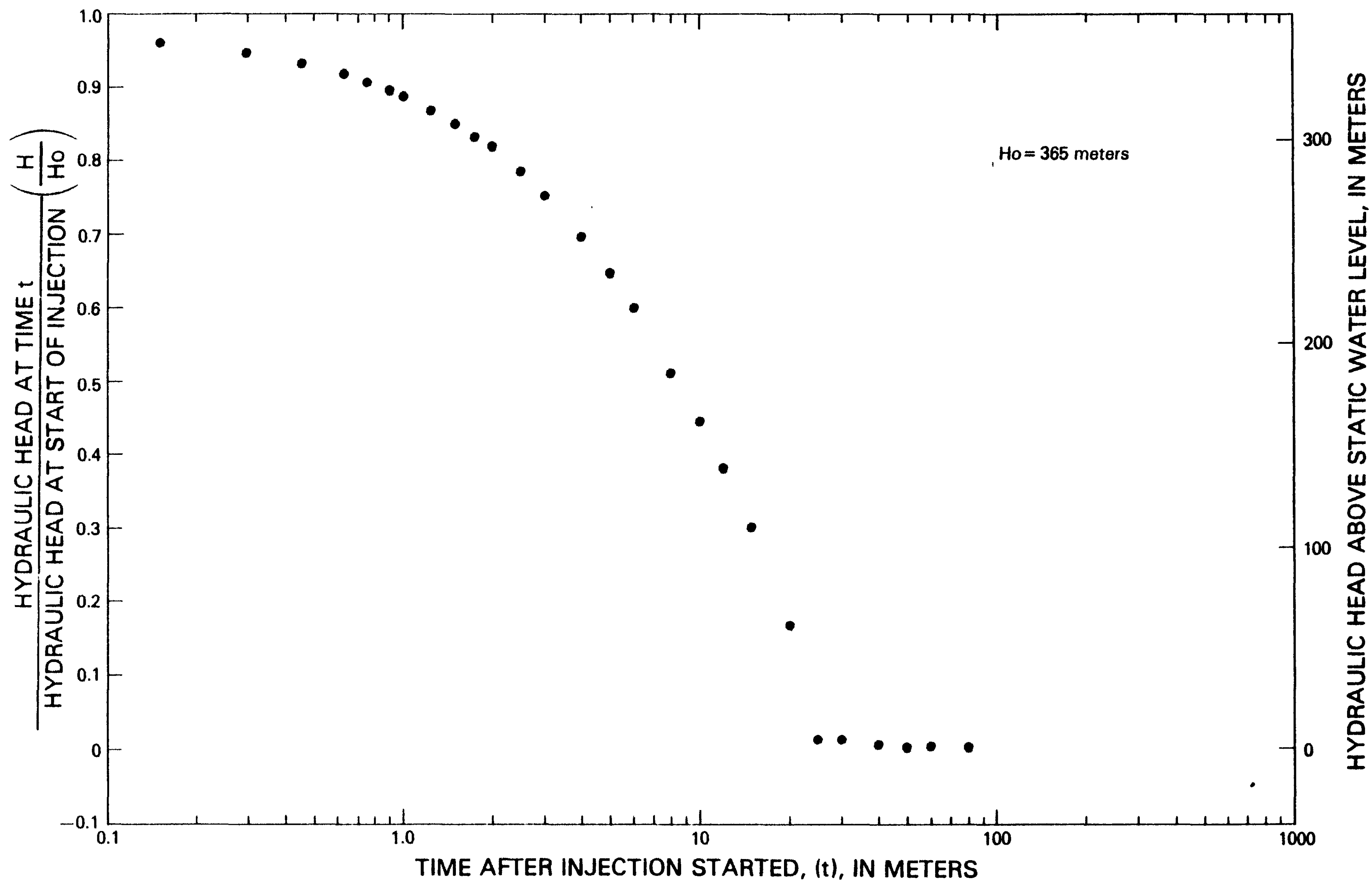

Figure 25. Packer-injection test 16, depth interval from 1,297 to 1,337 meters.

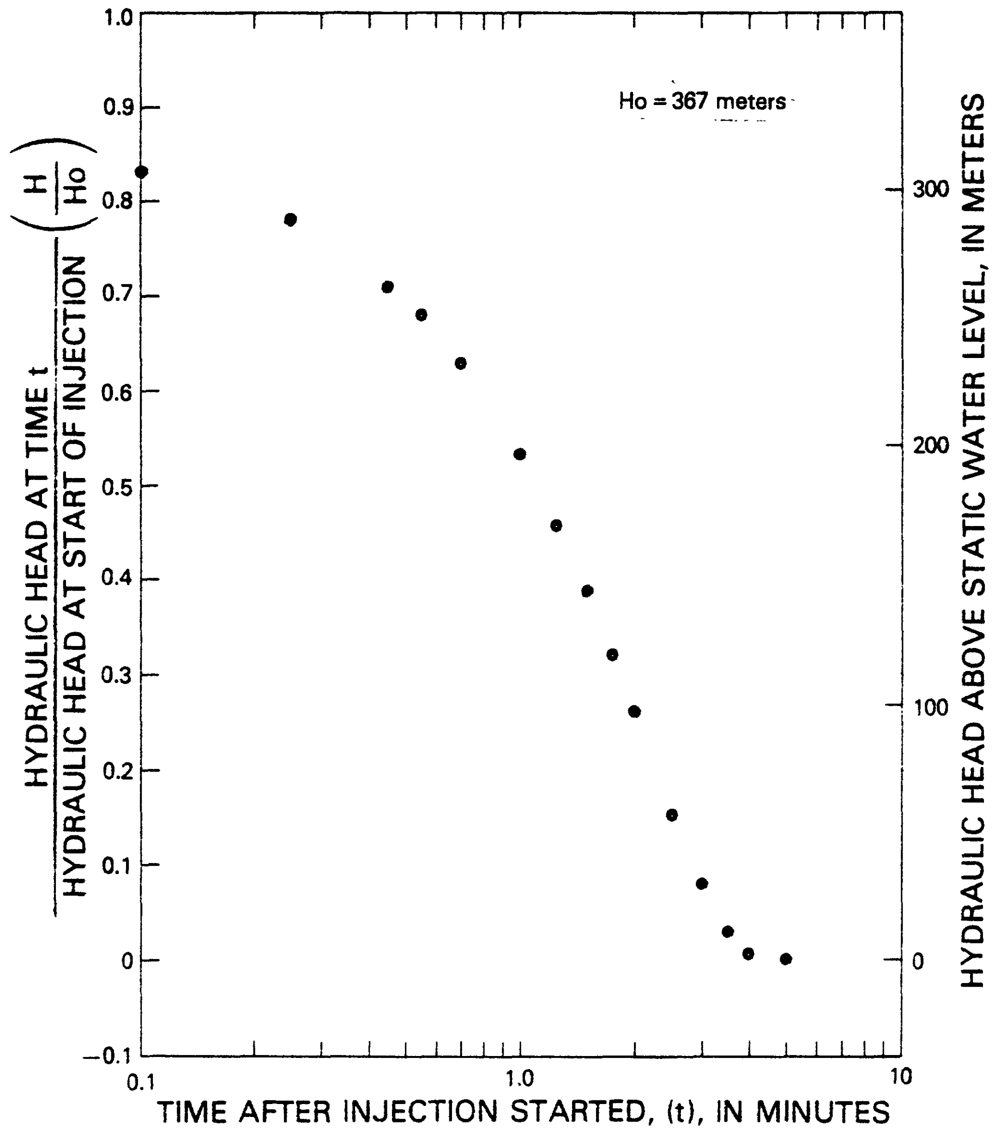

Figure 26. Packer-injection test 17, depth interval from 1,341 to 1,381 meters.

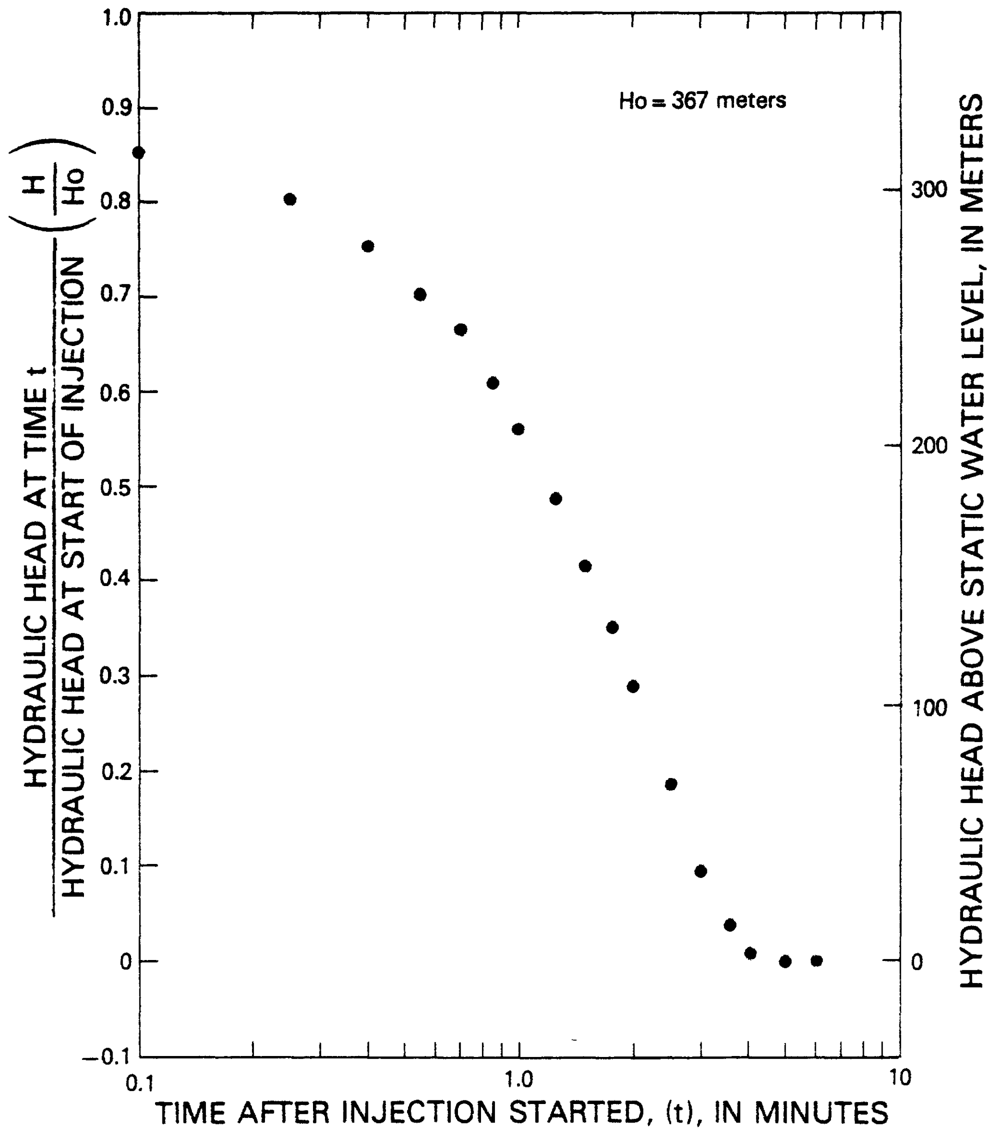

Figure 27. Packer-injection test 18, depth interval from 1,381 to 1,421 meters.

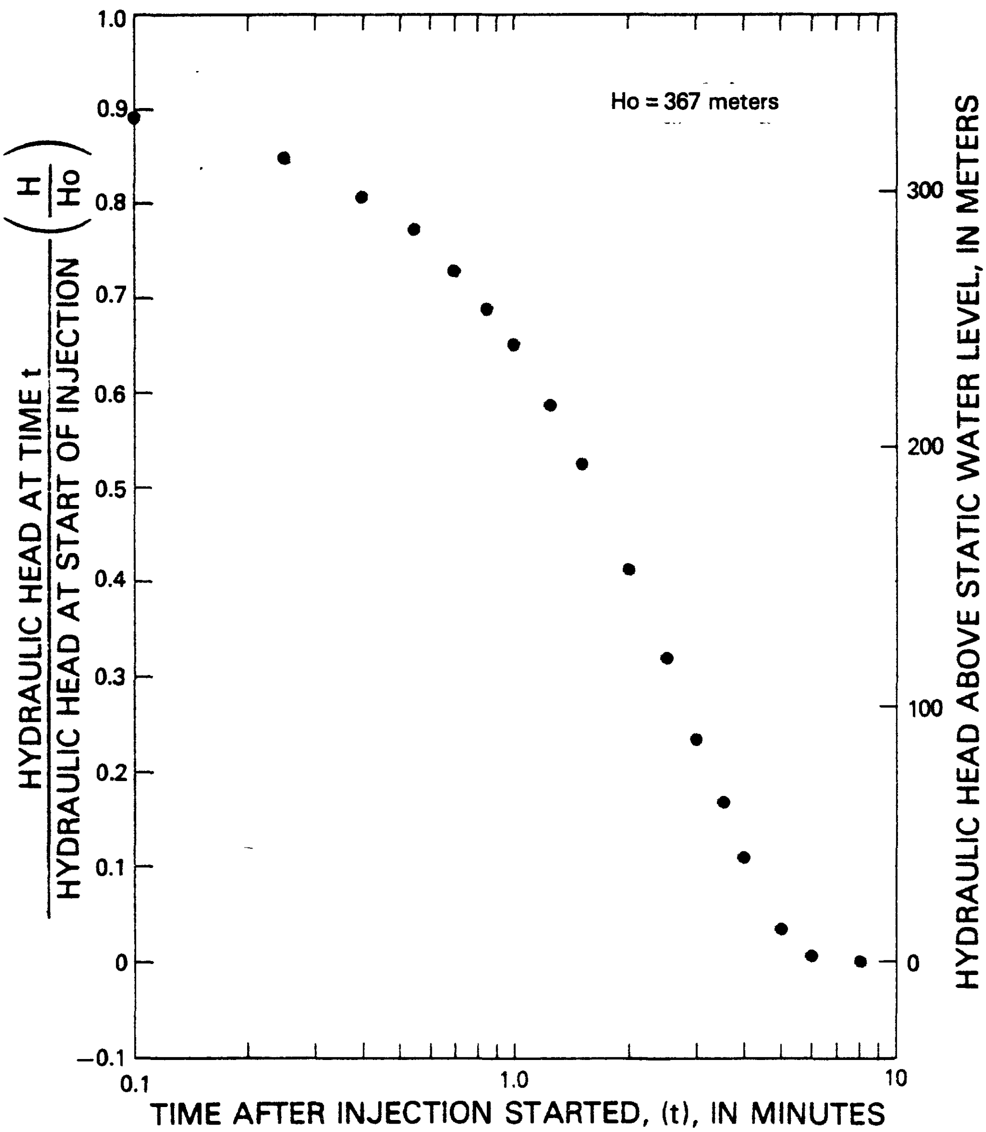

Figure 28. Packer-injection test 19, depth interval from 1,423 to 1,463 meters.

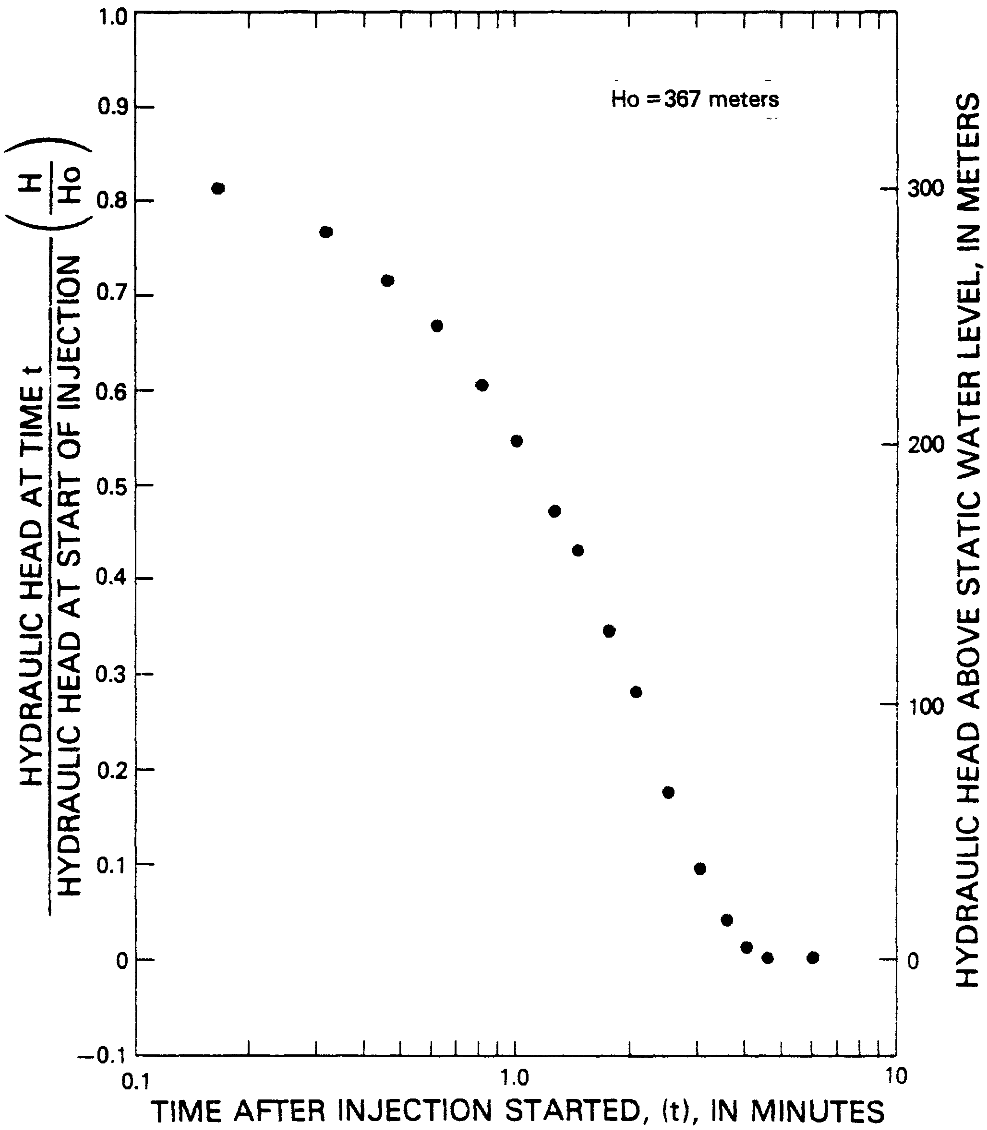

Figure 29. Packer-injection test 20, depth interval from 1,463 to 1,509 meters.

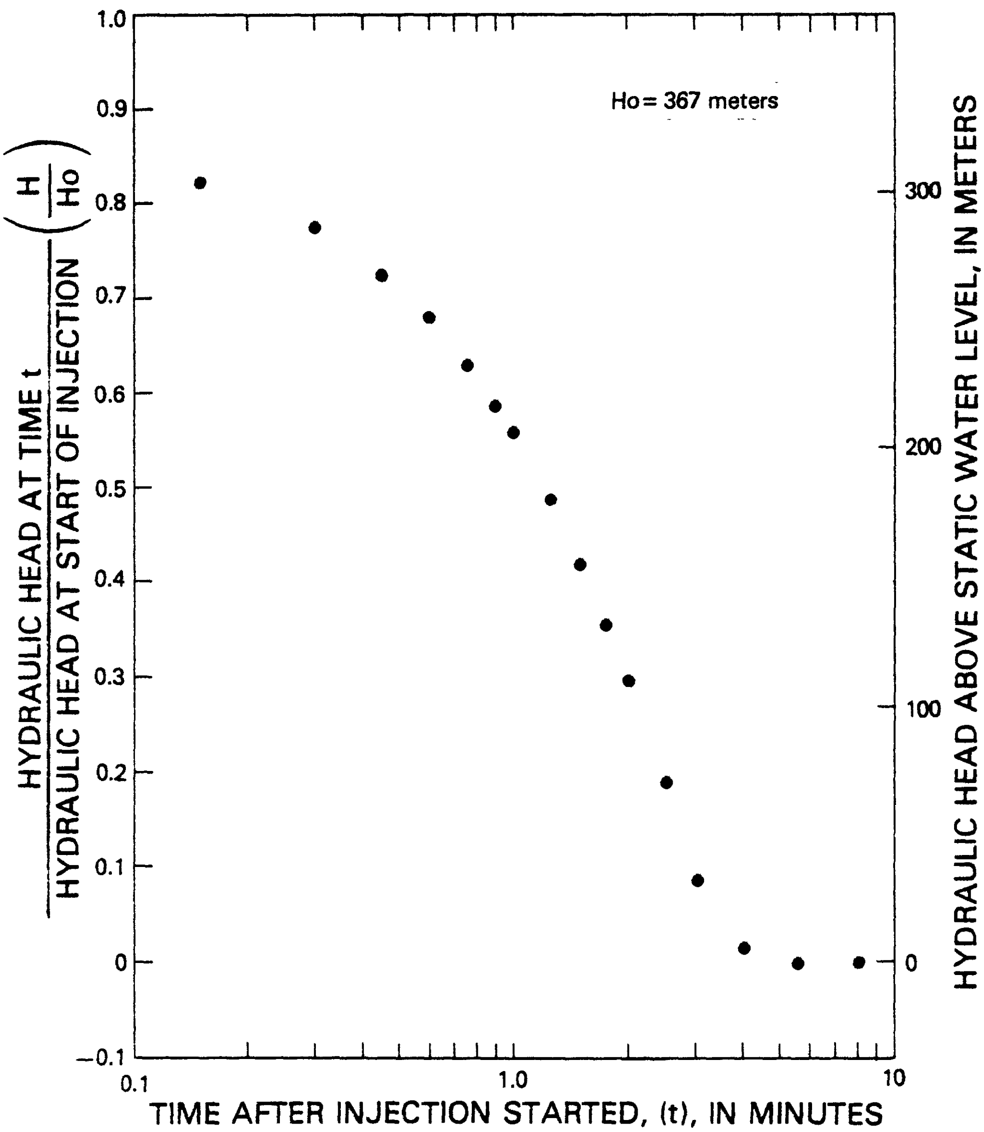

Figure 30. Packer-injection test 21, depth interval from 1,509 to 1,555 meters.

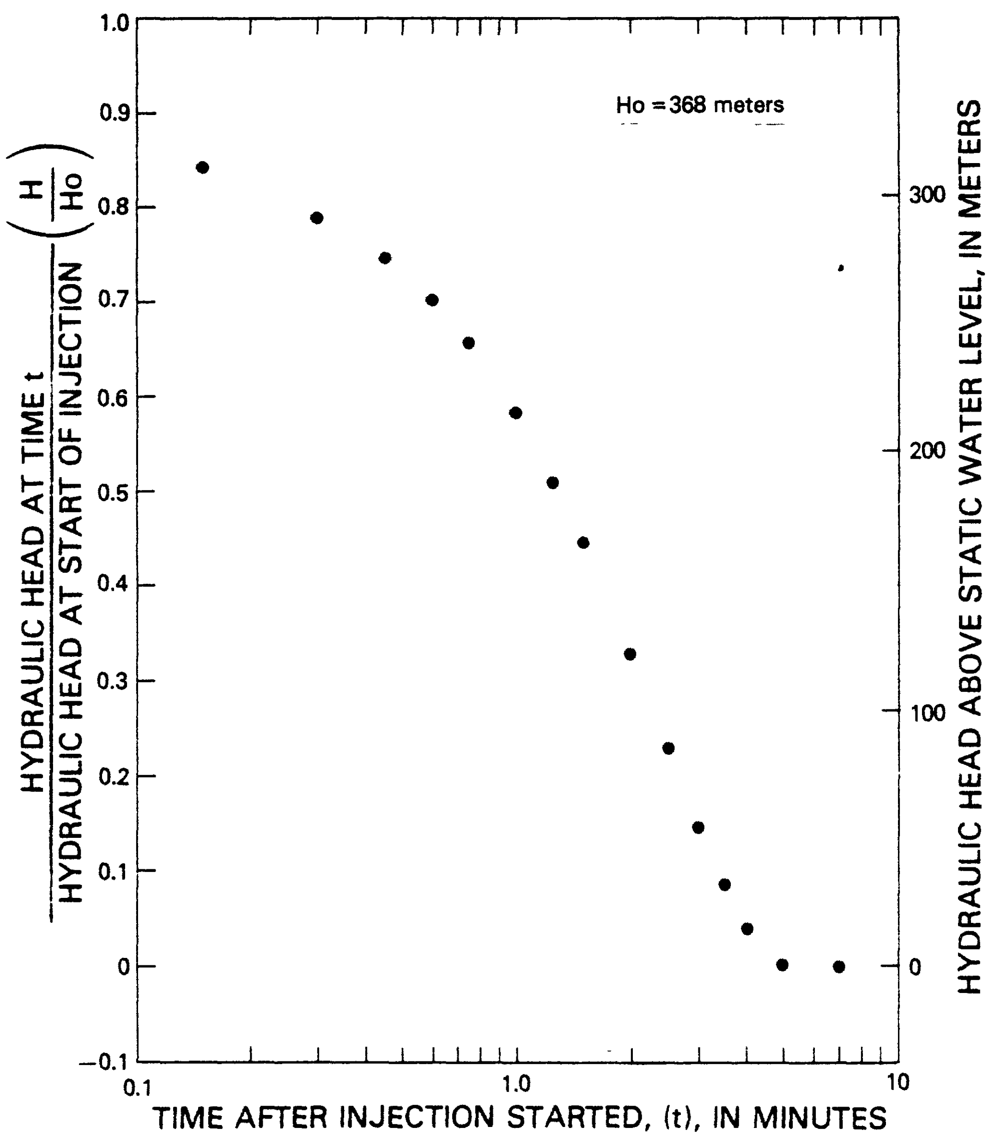

Figure 31. Packer-injection test 22, depth interval from 1,558 to 1,805 meters.

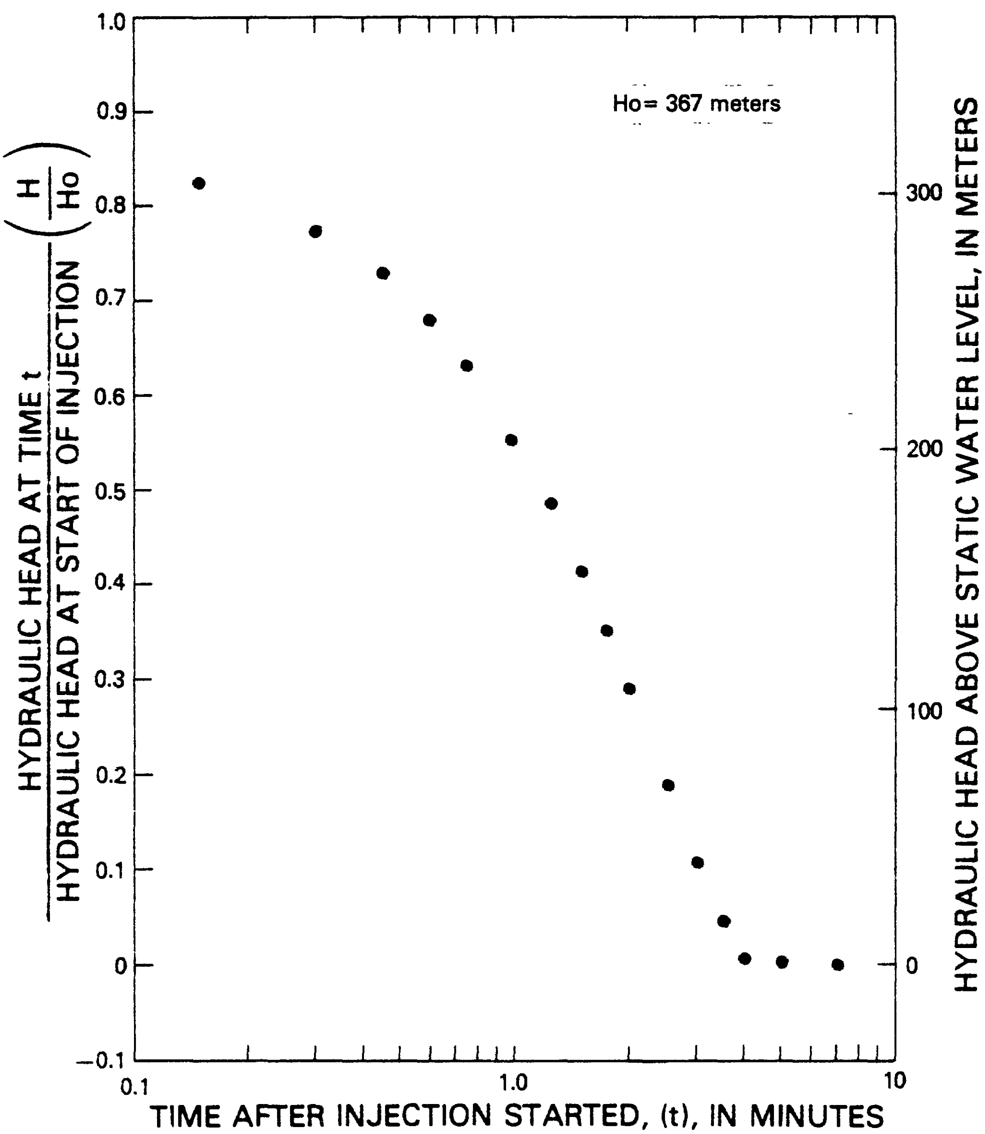

Figure 32. Packer-injection test 23, depth interval from 1,554 to 1,600 meters.

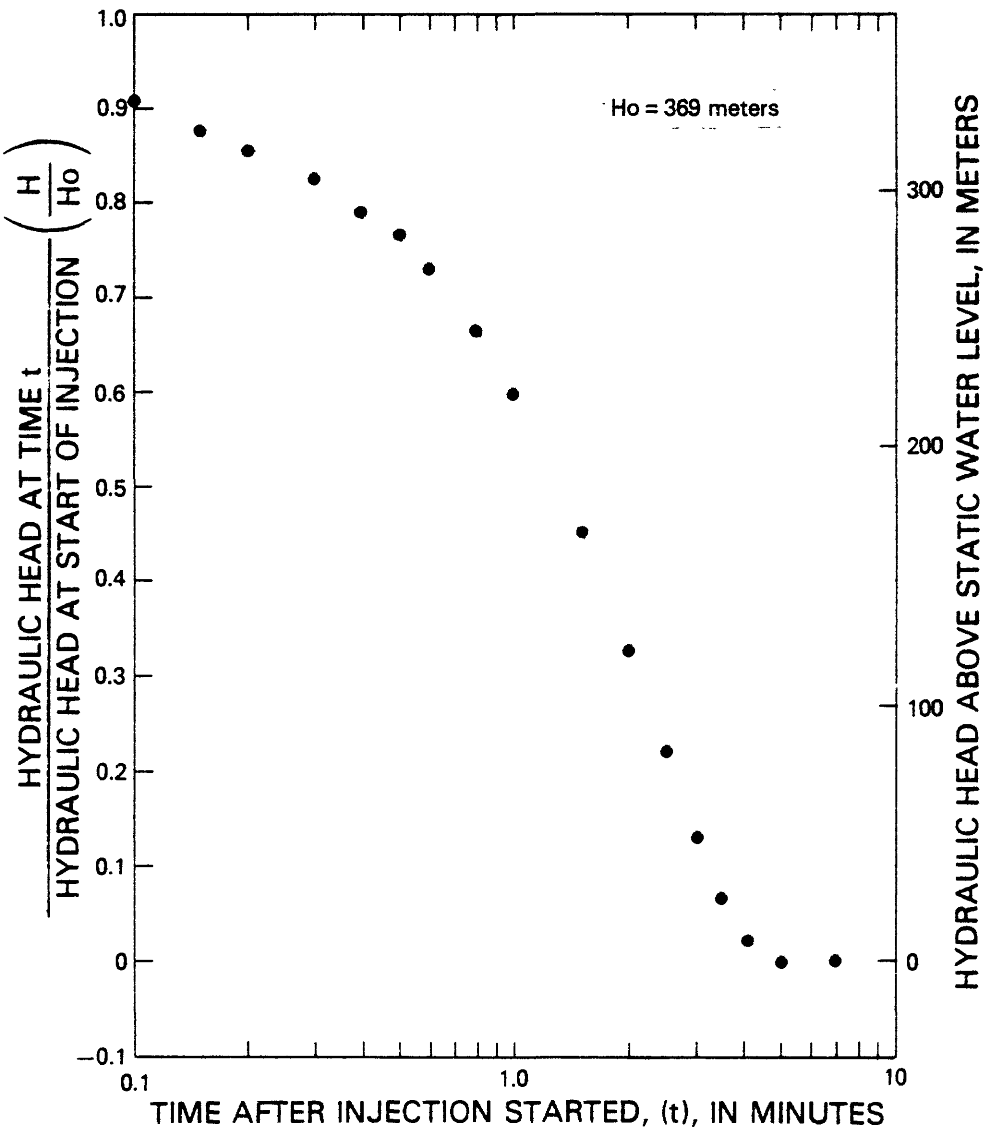

Figure 33. Packer-injection test 24, depth interval from 1,597 to 1,643 meters.

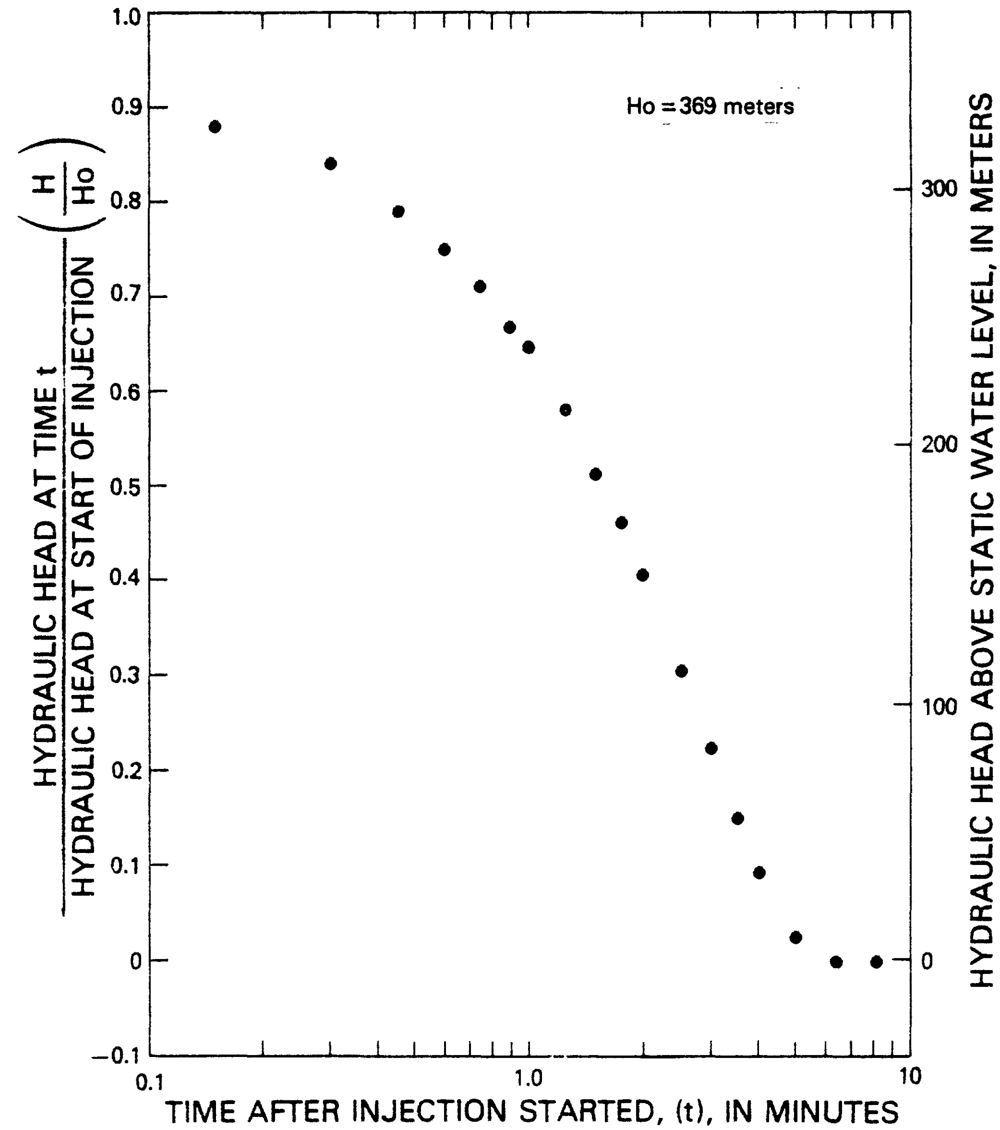

Figure 34. Packer-injection test 25, depth interval from 1,646 to 1,805 meters.

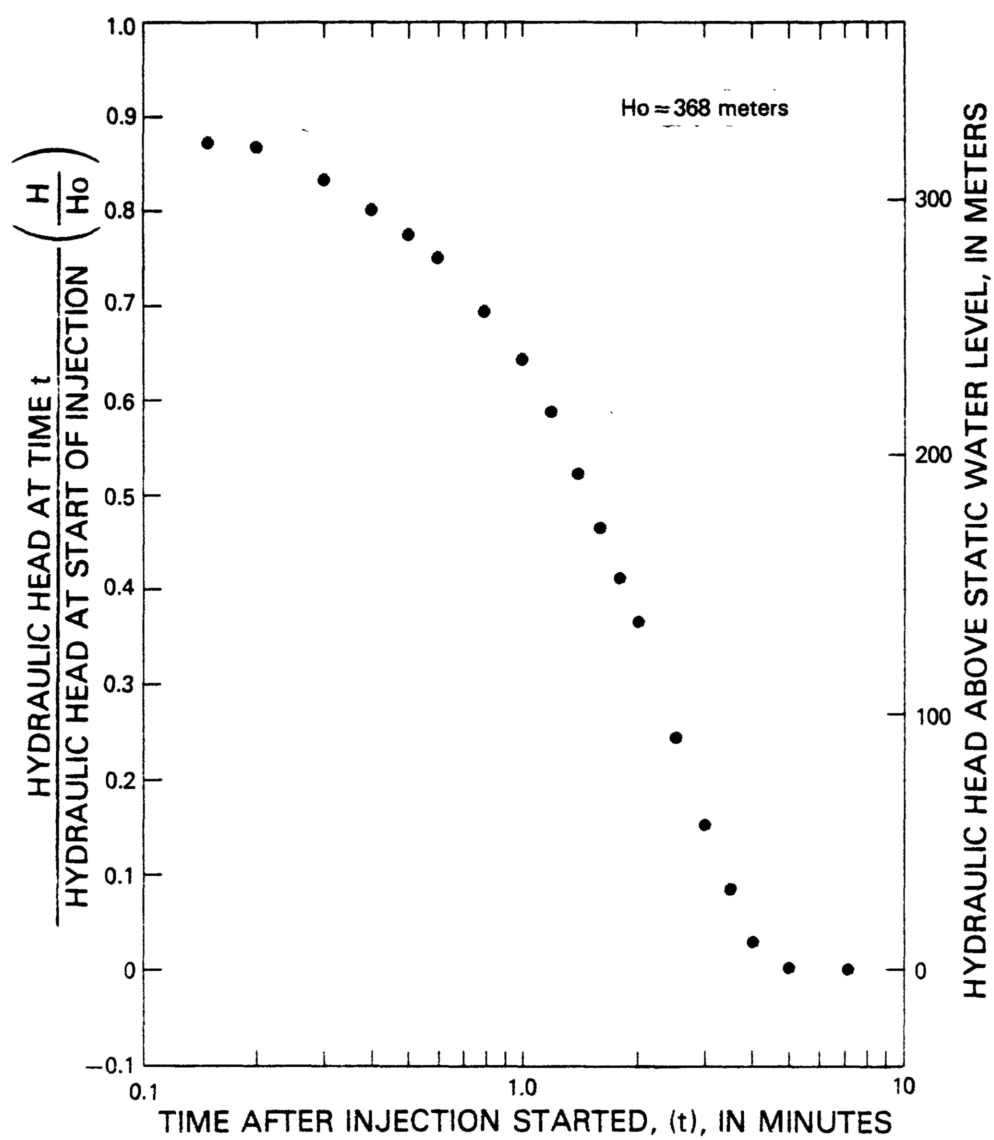

Figure 35. Packer-injection test 26, depth interval from 1,643 to 1,689 meters.

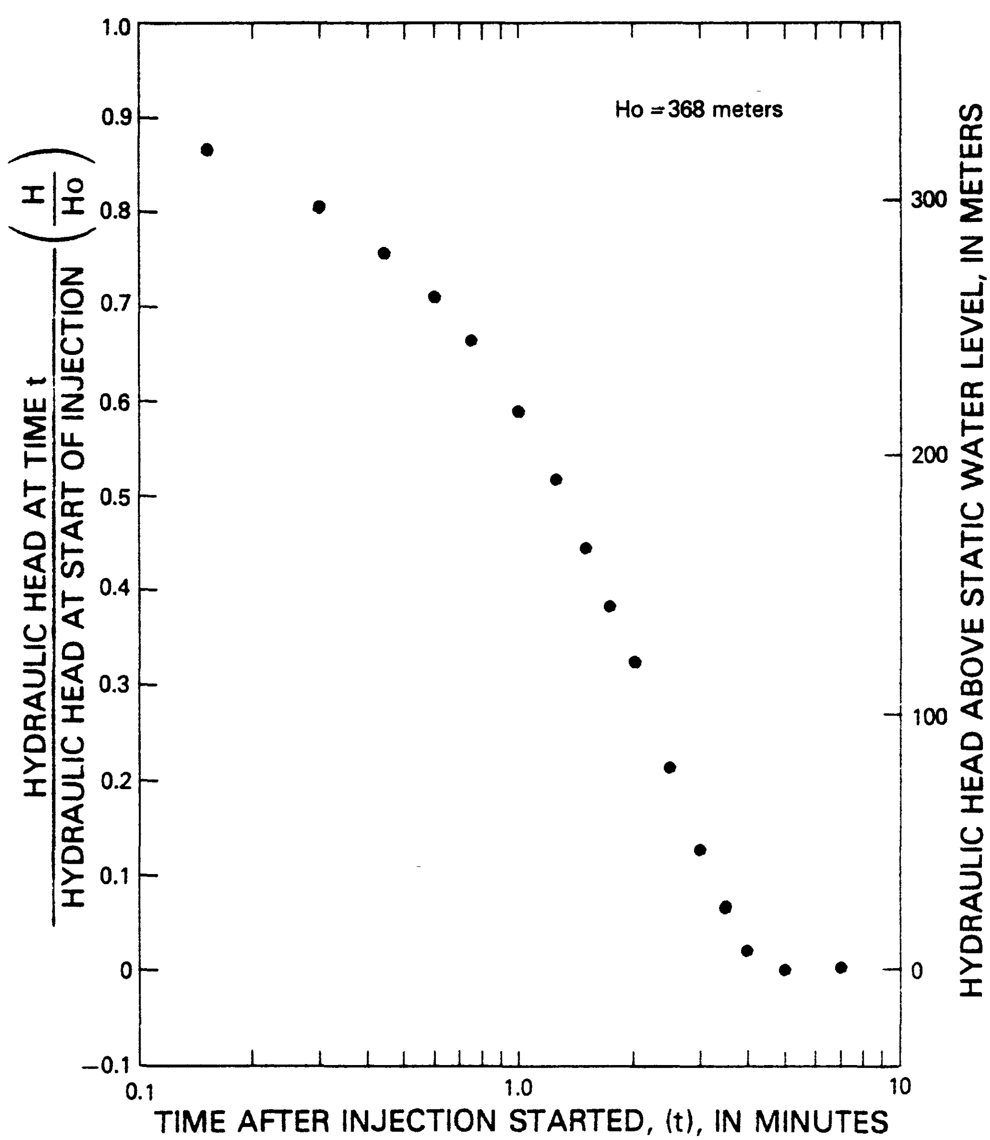

Figure 36. Packer-injection test 27, depth interval from 1,689 to 1,735 meters.

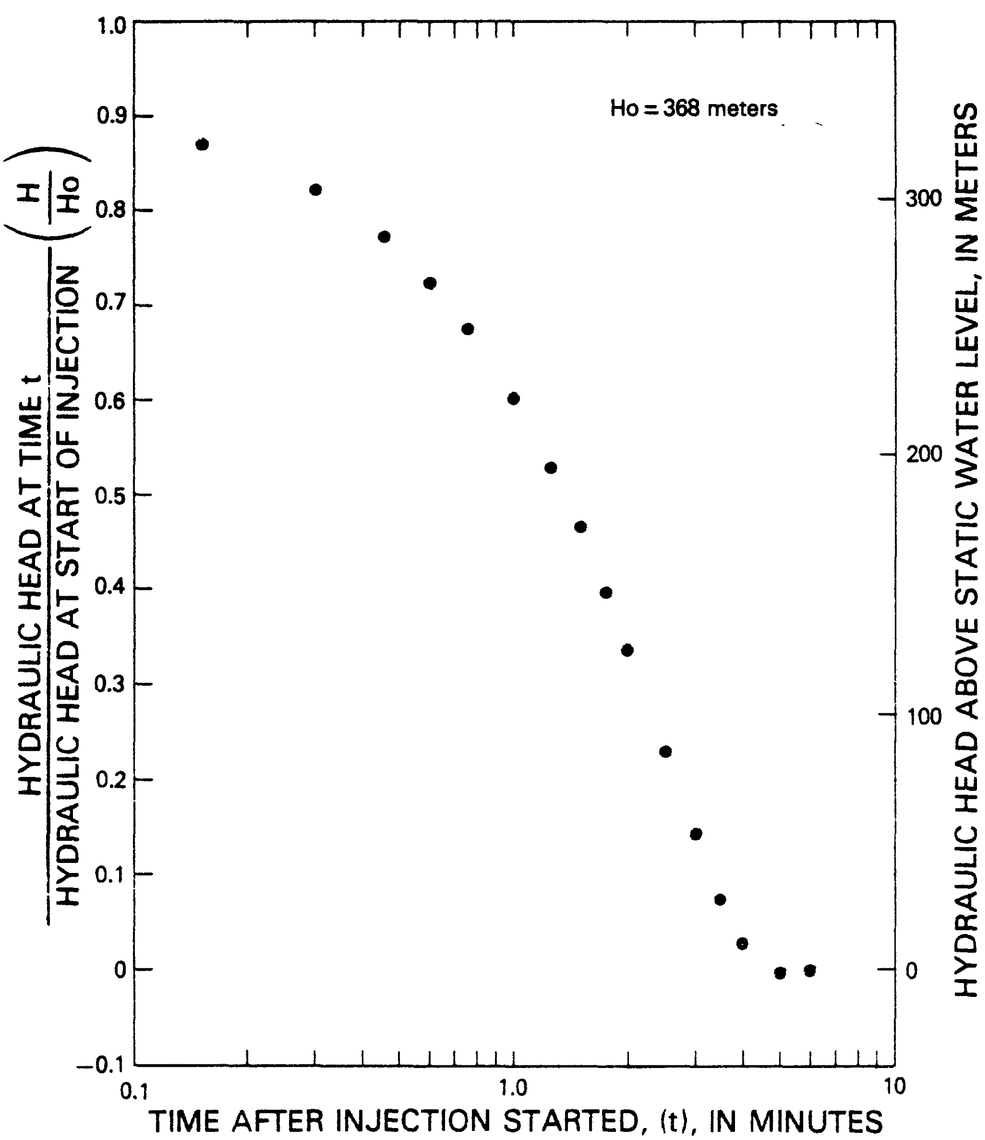

Figure 37. Packer-injection test 28, depth interval from 1,735 to 1,781 meters.

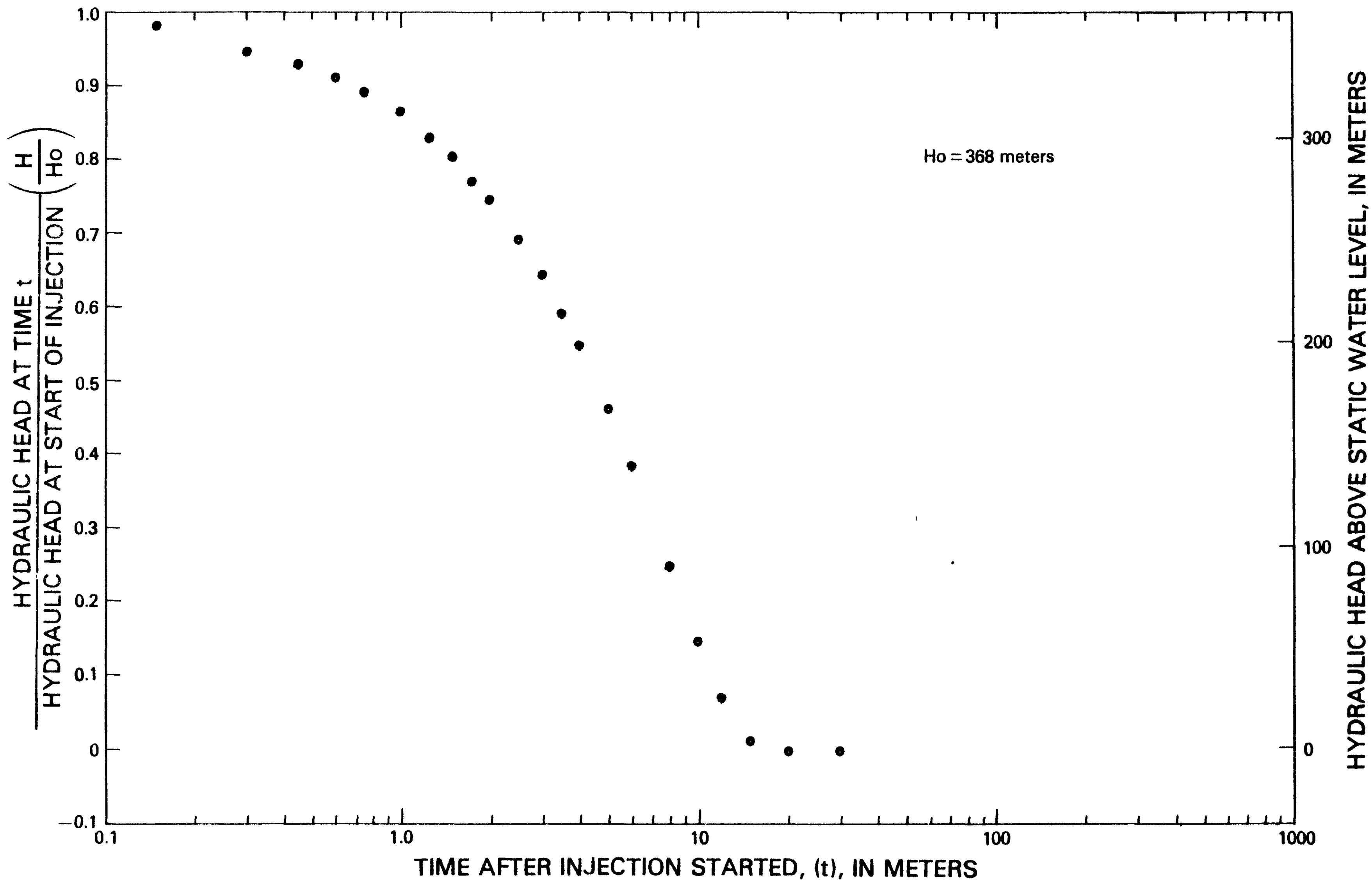

Figure 38. Packer-injection test 29, depth interval from 1,783 to 1,805 meters.

Packers used for injection tests in UE-25#1 were later used in another test hole where it was observed that a tool malfunction allowed the upper packer to deflate slowly, thereby allowing water to bypass the packer. This condition resulted in water-level changes occurring more quickly than the tested interval alone would have allowed and might have resulted in erroneously high interpretations of permeability. At UE-25p#1, no tool malfunction was observed, and only indirect evidence can be used to determine when the upper packer may have begun to deflate during testing. Based on rates of water-level changes during the tests and records of pressure obtained from beyond the tested intervals, those tests for which leakage could have occurred and for which results are not necessarily valid are noted in table 5.

All but three of the tests in the Paleozoic section had a response after reaching static-water level that was similar to the sine-wave appearance of recovery test 2. Only tests 15, 16, and 29 in the Paleozoic section did not have the sine-wave response. The sine-wave response of tests 7-28, with the exception of tests 22 and 25, is shown in figures 39 and 48. Data collected for tests 22 and 25 indicate a cyclic water-level fluctuation but not in enough detail to be useful; therefore, these data are not shown. A temperature log made June 23, 1983, is shown in figure 49. The temperature log is useful to estimate viscosity of water in the well if van der Kamp's solution (1976) for the sine-wave response is used.

Chemical Analysis of Water

Composite water samples were collected near the end of each period of pumping. At the time of sampling the Tertiary section, approximately 2.5×10^7 L of fluid had been pumped. Prior to sampling the Paleozoic section, about 1.5×10^7 L had been pumped. Results of analyses of the water samples are shown in table 6.

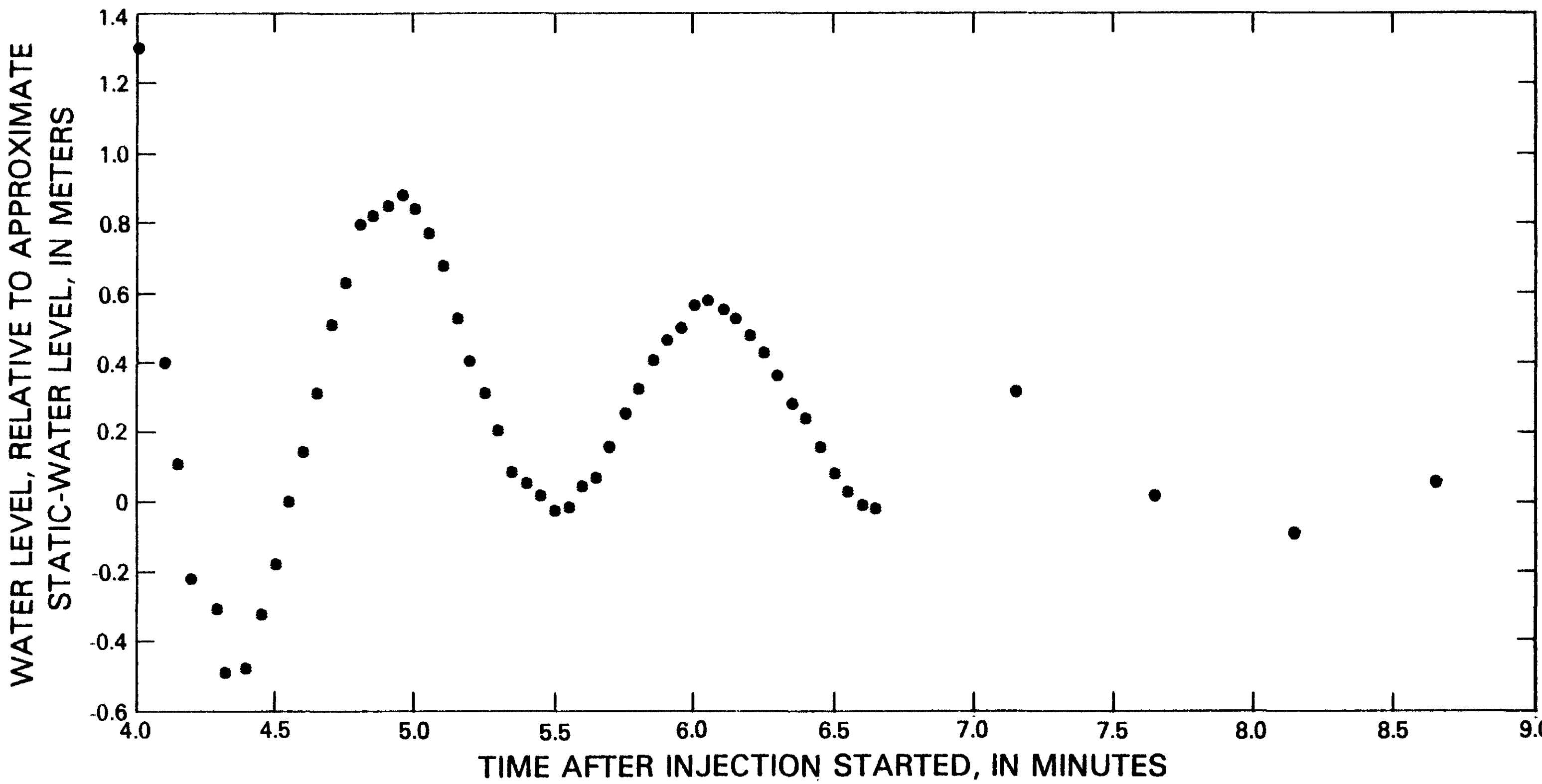

Figure 39. Damped sine-wave response during packer-injection test 17, depth interval from 1,341 to 1,381 meters.

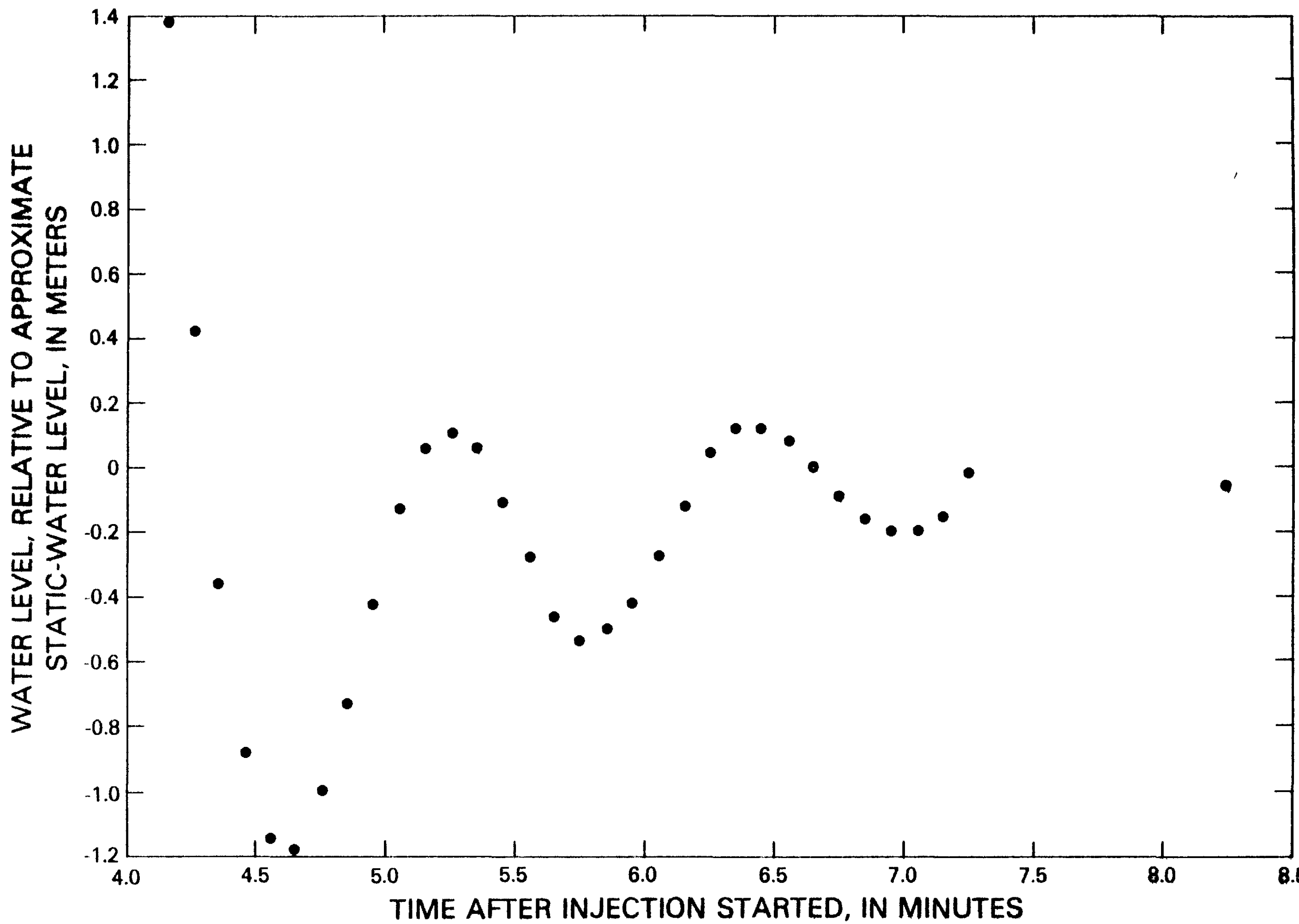

Figure 40. Damped sine-wave response during packer-injection test 18, depth interval from 1,381 to 1,421 meters.

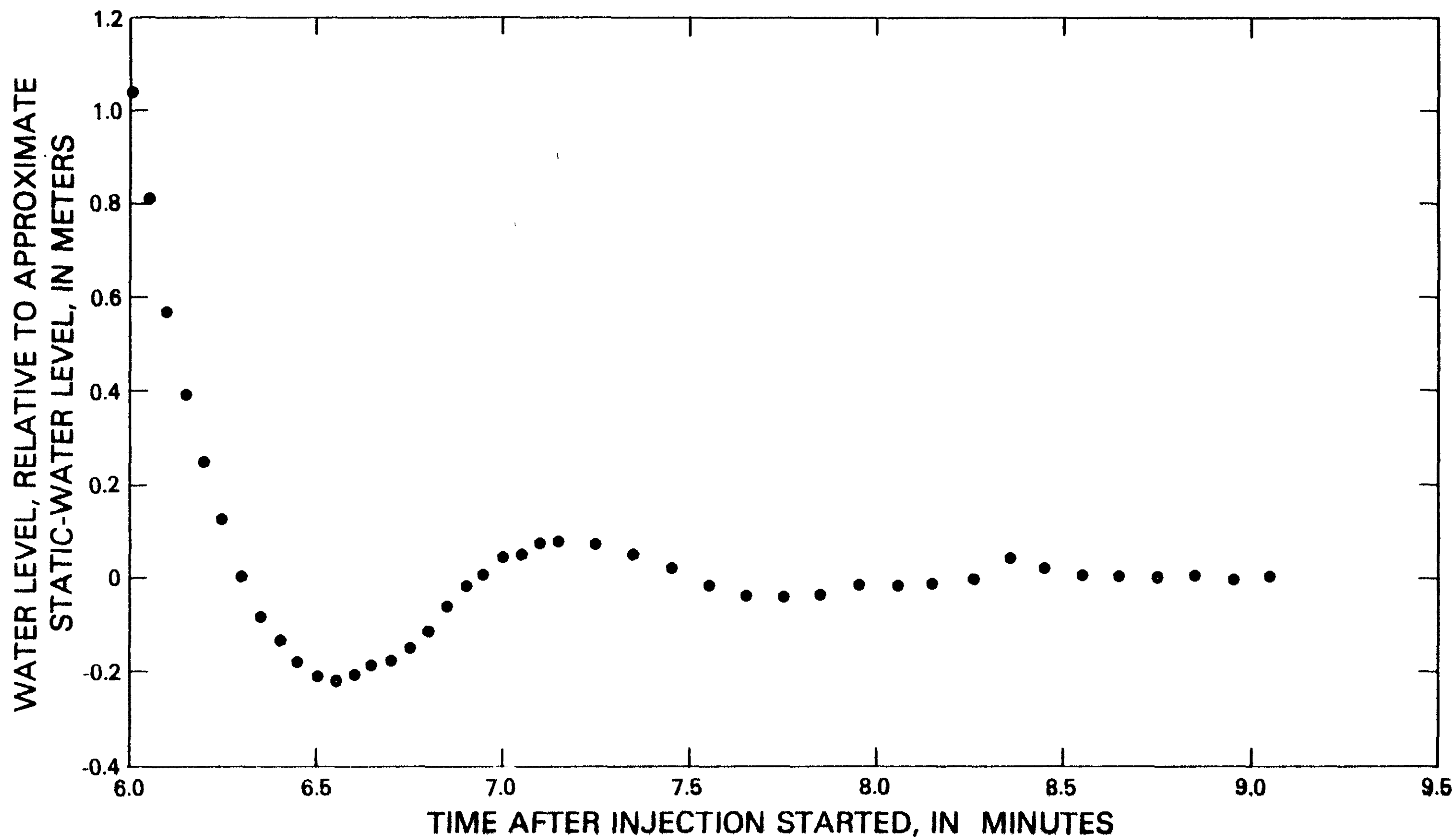

Figure 41. Damped sine-wave response during packer-injection test 19, depth interval from 1,423 to 1,463 meters.

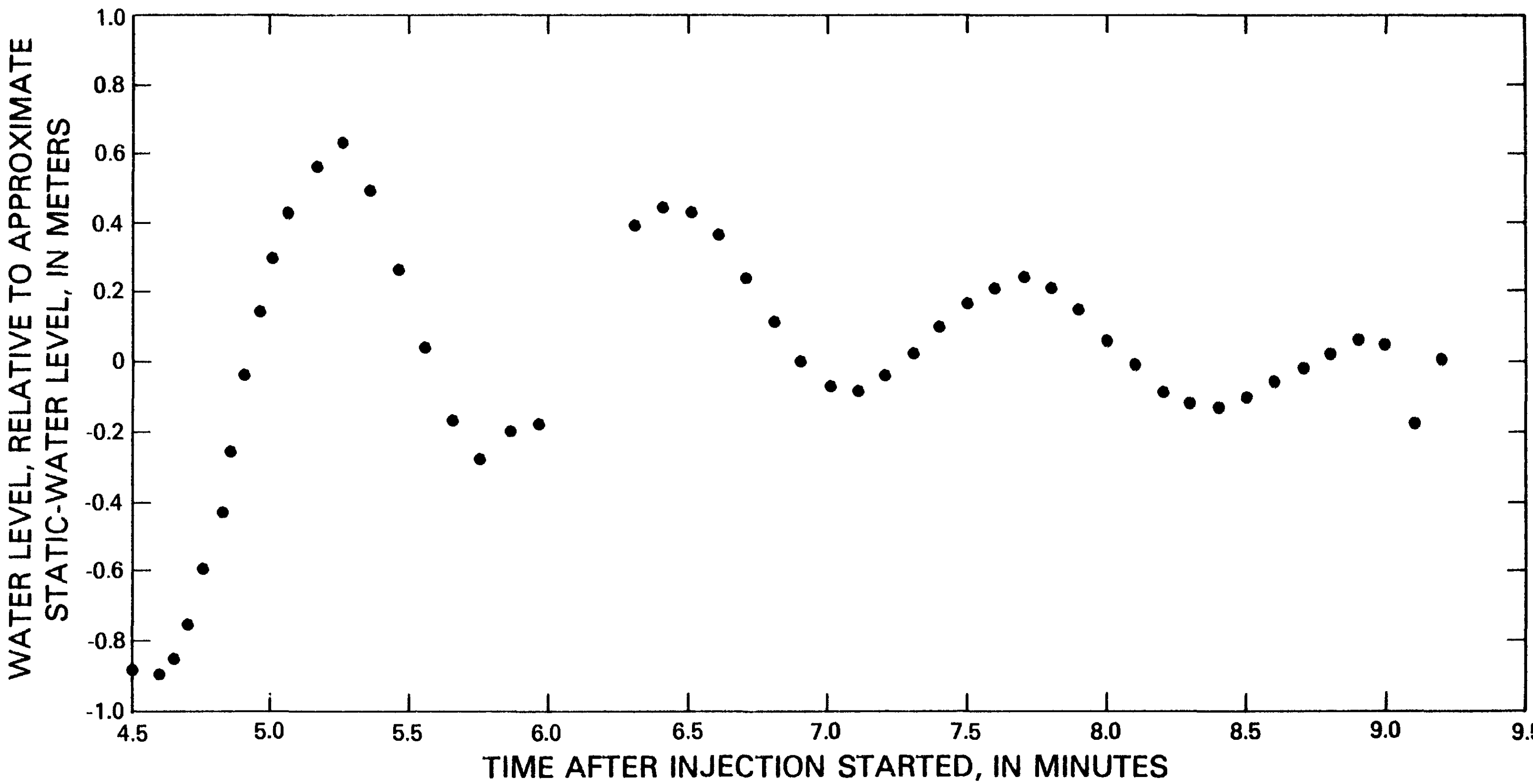

Figure 42. Damped sine-wave response during packer-injection test 20, depth interval from 1,463 to 1,509 meters.

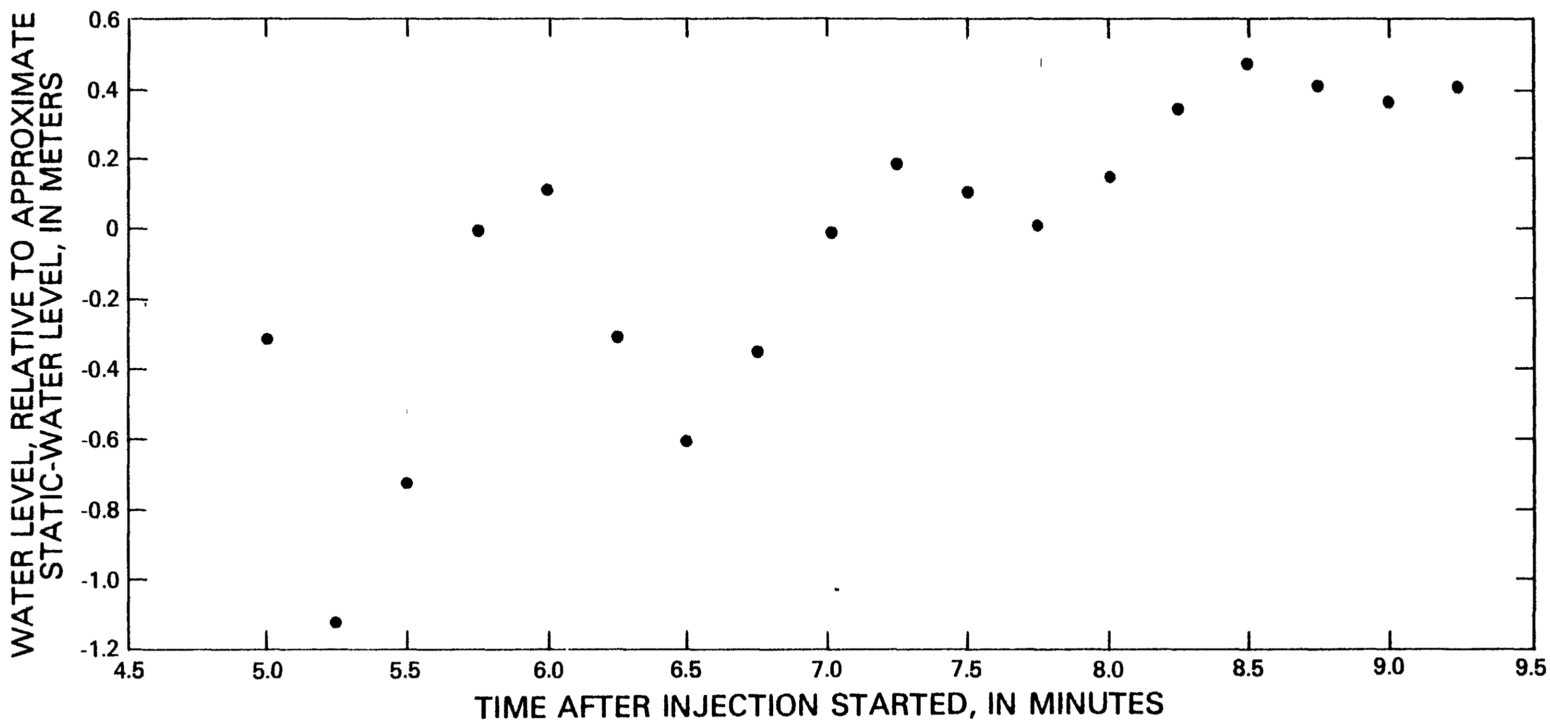

Figure 43. Damped sine-wave response during packer-injection test 21, depth interval from 1,509 to 1,555 meters.

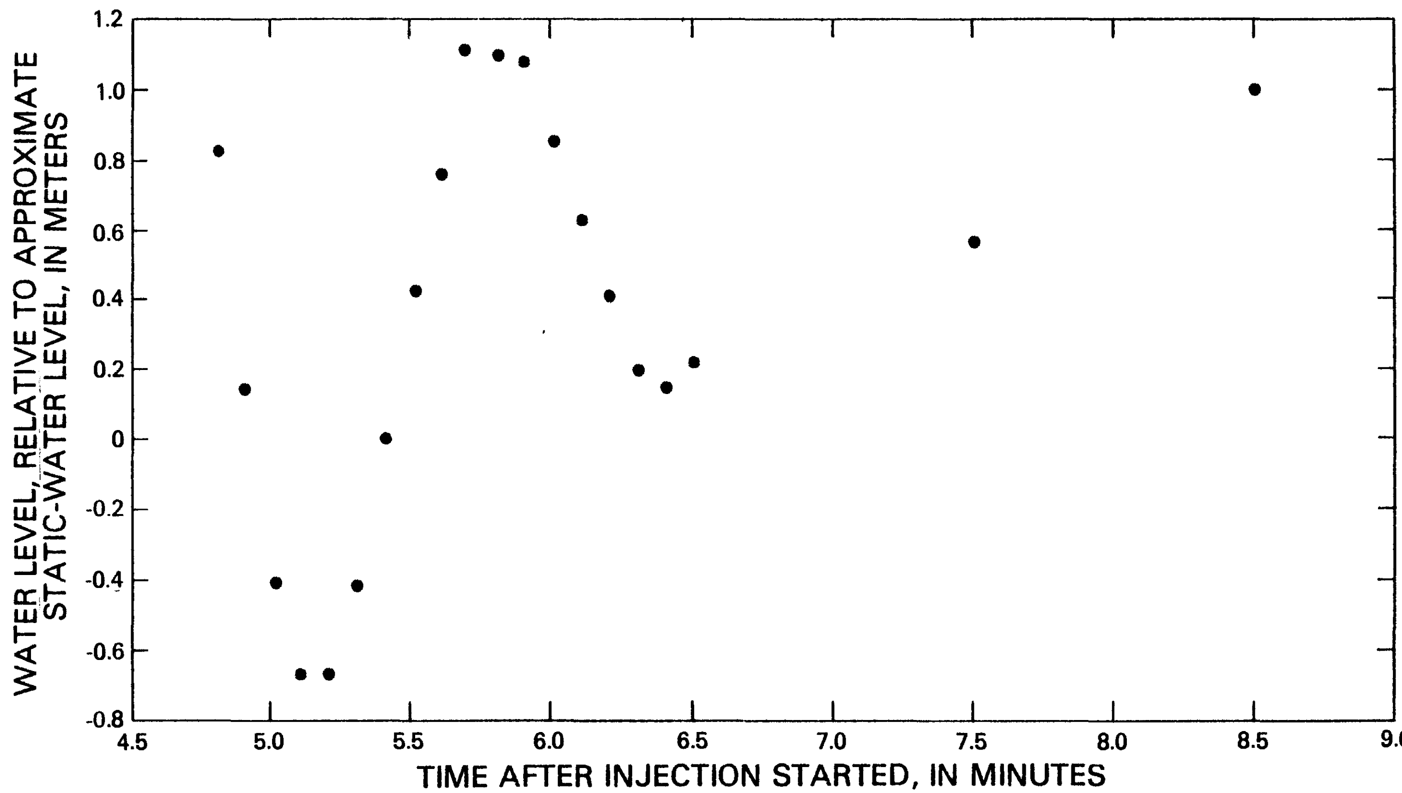

Figure 44. Damped sine-wave response during packer-injection test 23, depth interval from 1,554 to 1,600 meters.

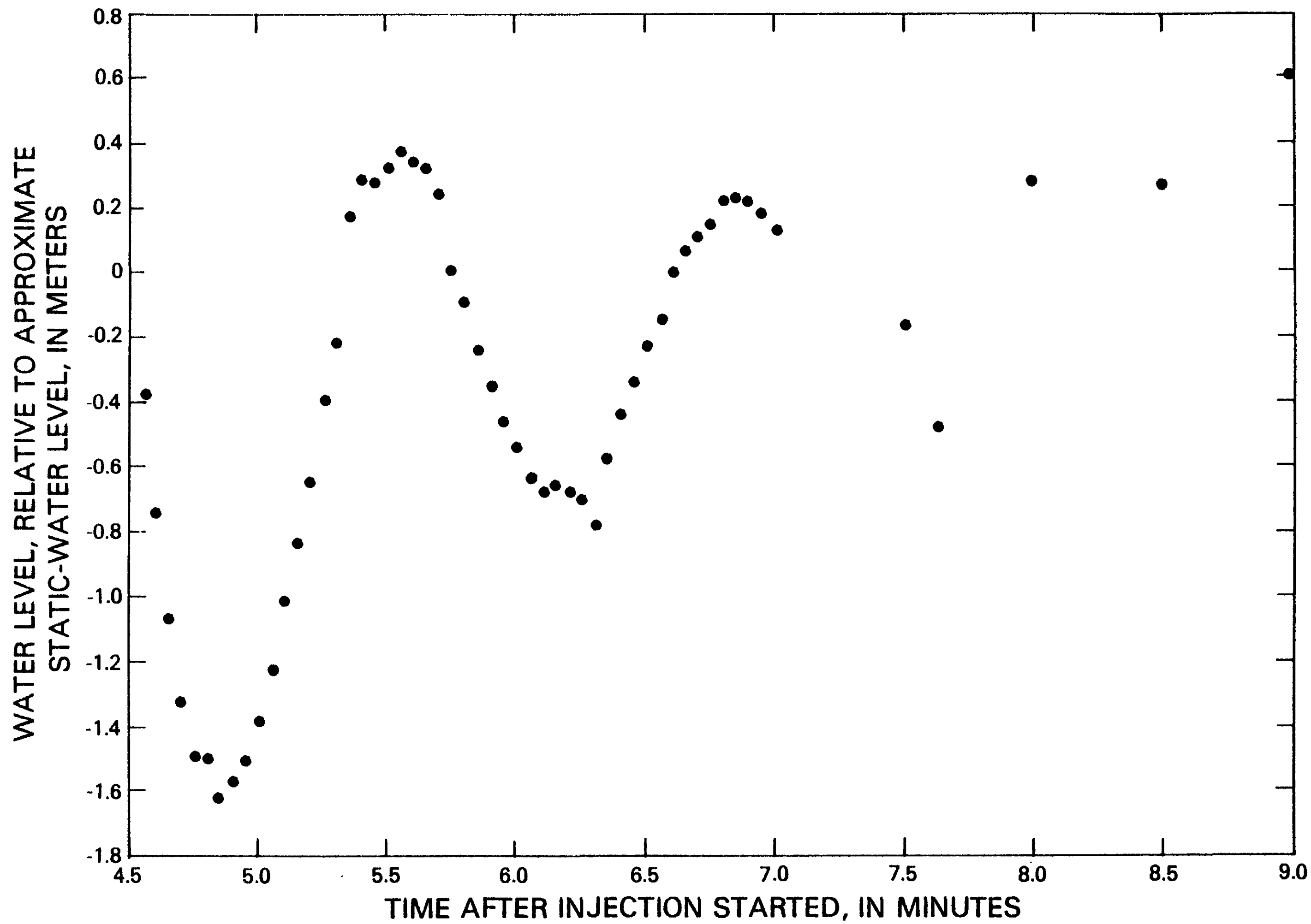

Figure 45. Damped sine-wave response during packer-injection test 24, depth interval from 1,597 to 1,643 meters.

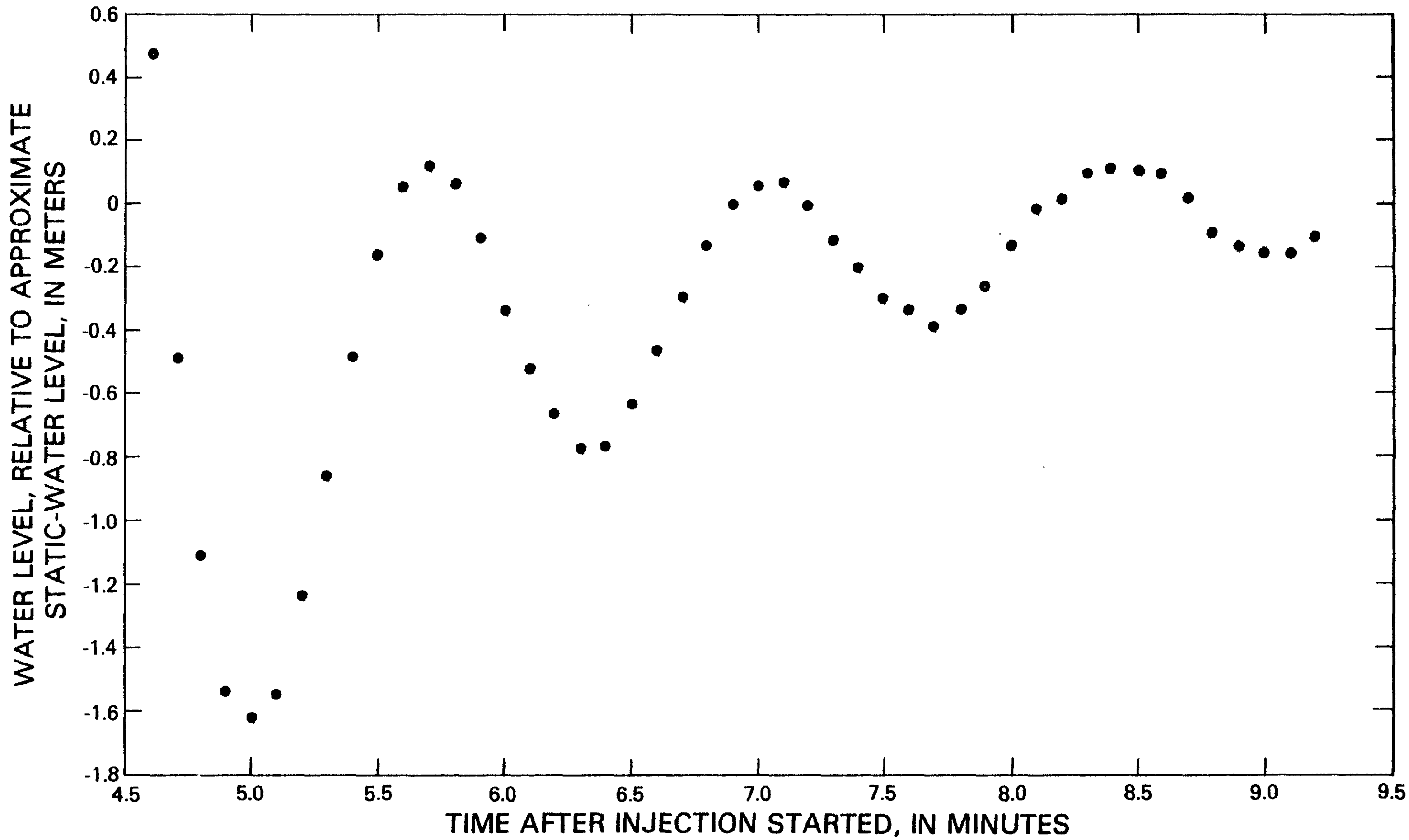

Figure 46. Damped sine-wave response during packer-injection test 26, depth interval from 1,643 to 1,689 meters.

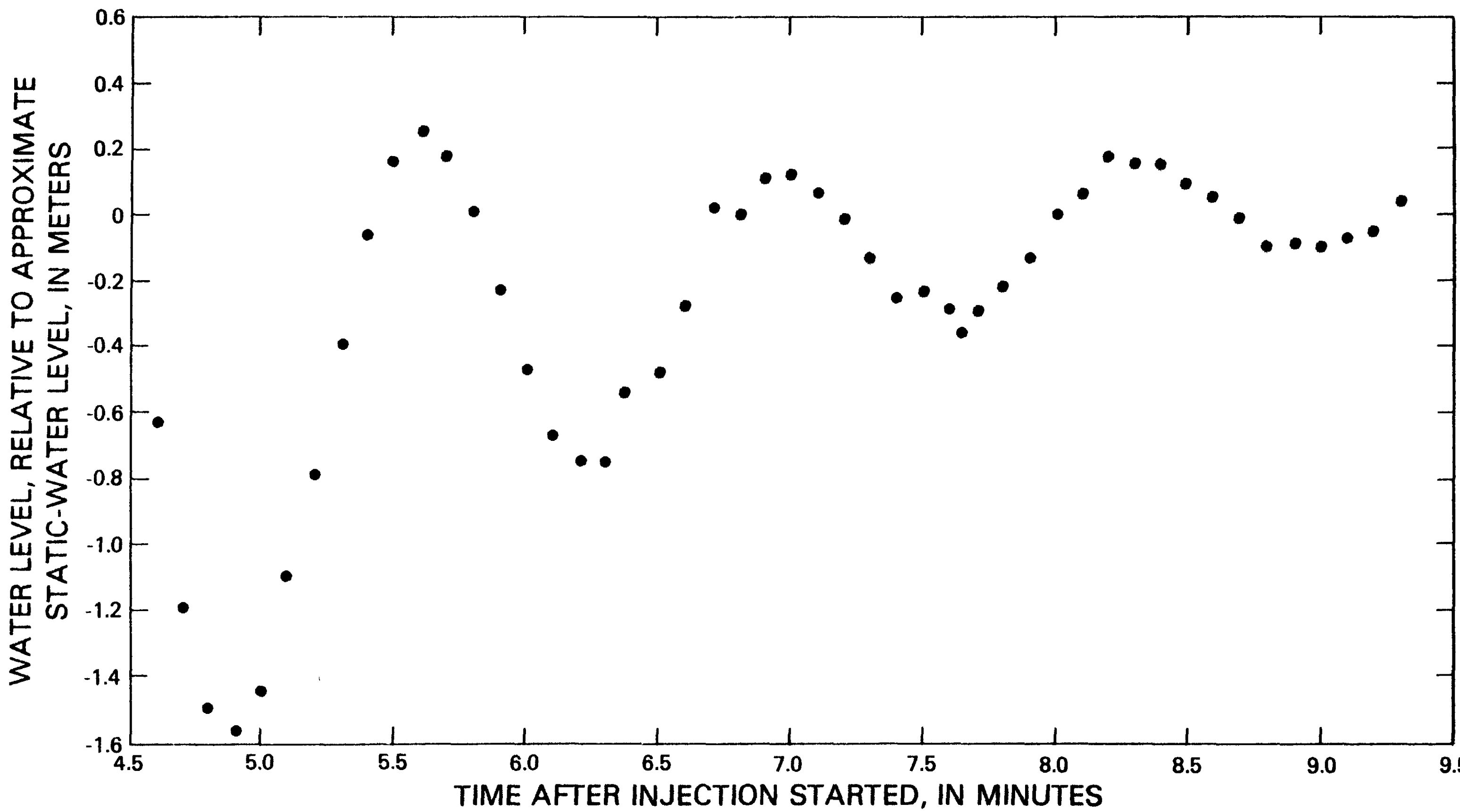

Figure 47. Damped sine-wave response during packer-injection test 27, depth interval from 1,689 to 1,735 meters.

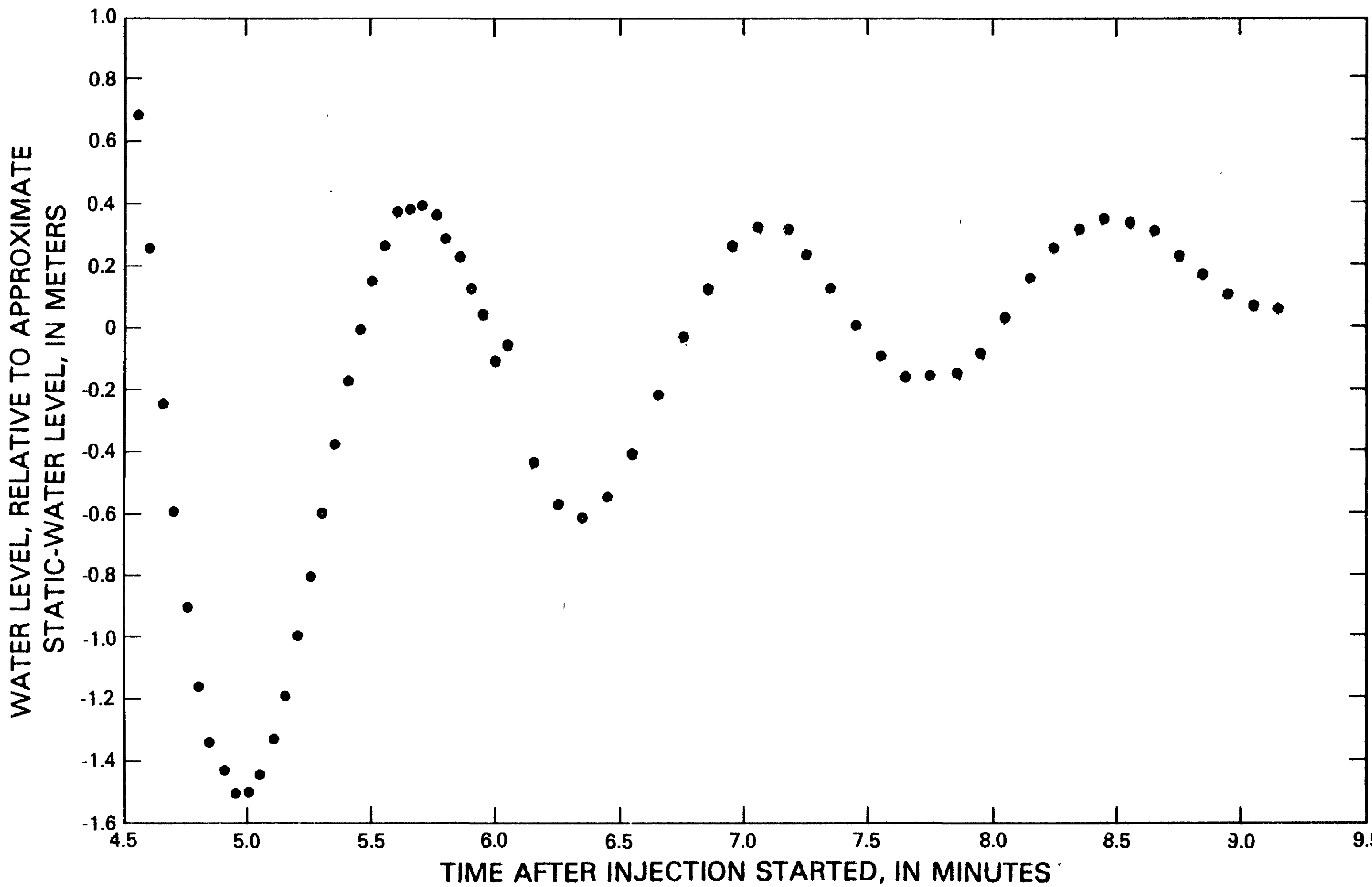

Figure 48. Damped sine-wave response during packer-injection test 28, depth interval from 1,735 to 1,781 meters.

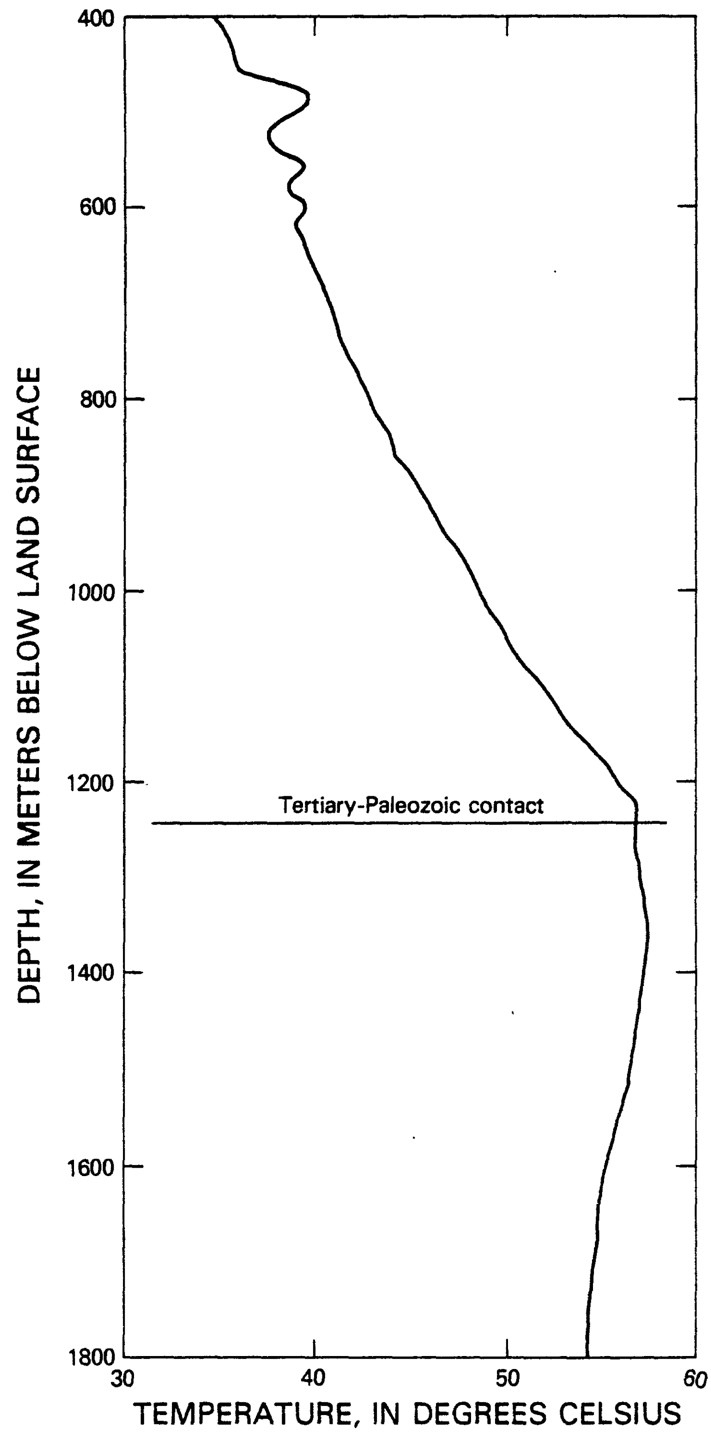

Figure 49. Temperature survey made June 23, 1983.

Table 6.--*Chemical analyses of water samples by U.S. Geological Survey laboratory, Denver, Colorado*

[All units are milligrams per liter unless otherwise indicated]

Date of collection	02/09/83	05/12/83
Depth interval (meters)	1/381-1,197	1,297-1,805
Temperature (degrees Celsius)	44	56
pH, field (units)	6.8	6.6
pH, laboratory (units)	7.7	7.2
Potassium (K)	5.6	12
Calcium (Ca)	37	100
Magnesium (Mg)	10	39
Sodium (Na)	92	150
Strontium (Sr, micrograms per liter)	180	450
Lithium (Li, micrograms per liter)	230	590
Chloride (Cl)	13	28
Bicarbonate (HCO_3), field	330	710
Fluoride (F)	3.4	4.7
Sulfate (SO_4)	38	160
Silica (SiO_2)	49	41
Specific conductance, laboratory (microsiemens per centimeter at 25^{o} Celsius)	639	1,330
Dissolved solids (sum)	418	878
Tritium (picocuries per liter)	0±10	0±10
Oxygen-18/oxygen-16 ($\delta^{18}O$)2/	-13.5	-13.8
Deuterium/hydrogen ($\delta^{2}H$)3/	-106.0	-106.0
Carbon-13/carbon-12 ($\delta^{13}C$)4/	-4.2	-2.2
Carbon-14 (percent of modern standard)	3.40	2.31

1/Borehole-flow survey indicated that about 28 percent of pumping production was from below 1,197 meters; see borehole-flow survey section for explanation.

2/Deviation of oxygen-18/oxygen-16 ratio of sample from standard mean ocean water (SMOW) relative to SMOW, 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 carbon-13/carbon-12 ratio of sample from Peedee belemnite standard (PDB) relative to PDB, in parts per thousand.

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