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(Revision 1)

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Federal Center, Lakewood, Colorado 80225

HYDRAULIC TESTS IN HOLE UAe-3, AMCHITKA ISLAND, ALASKA

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Wilbur C. Ballance

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ABSTRACT

Inflatable straddle packers were used to isolate and test selected intervals in hole UAe-3. Packer seats were poor in the uncased part of the hole because of unstable wall conditions, and leakage around packers occurred during some tests. However, leakage generally was slight, as shown on pressure-gage charts, and had little effect on the tests. The static water levels in the intervals tested ranged from 31.6 meters (104 feet) below land surface in the upper interval tested to about 115 meters (377 feet) below land surface in the lower interval tested, indicating decreasing head with depth.

The relative specific capacities of isolated zones ranged from less than 0.001 cubic meter per day per meter (less than 0.001 gallon per minute per foot) of drawdown to 0.898 cubic meter per day per meter (0.050 gallon per minute per foot) of drawdown.

INTRODUCTION

During August through November 1967, the U.S. Geological Survey hydraulically tested hole UAe-3 on Amchitka Island, Alaska. The objectives of the tests were to obtain hydraulic information for better prediction of direction and velocity of ground-water movement, to aid in selection of an interval suitable from a hydrologic standpoint for mining a chamber thousands of feet below the water table, and to obtain samples of water for chemical and radiochemical analysis.

The scope of this report is limited to presentation of well construction, hydraulic-testing procedures, and hydraulic-testing data. A lithologic log, which was published by Lee (1969a,b) is not discussed in this report.

Drilling and Construction of Hole UAe-3

Hole UAe-3 was drilled to a depth of 698.0 m (meters) or 2,290 ft (feet) and selected zones were hydraulically tested, using inflatable straddle packers. Fresh water was used as the circulating medium during the drilling to this depth. The borehole wall was very unstable, resulting in hole wall erosion, and attempts to cement this unstable part of the hole were unsuccessful. The hole was then drilled to 1,467.9 m (4,816 ft) with mud as the circulating medium and was cased; the annulus was cemented from land surface to this depth. Drilling then was continued with water as the drilling fluid. The borehole wall continued to be unstable and, for this reason, drilling was interrupted on several occasions to hydraulically test the hole. The hole was drilled to a total depth of 2,137.0 m (7,011 ft).

Well History

Location: Universal Transverse Mercator Grid, Zone 60: N. 5,711,302.11 m; E. 637,611.31 m.

Ground elevation: 146.9 m (482.0 ft) above mean sea level.

Hole depth: Drilled to 2,137.0 m (7,011 ft).

Casing: 50.8-cm (20-in.), 0 to 8.5 m (28 ft), cemented.

34.0-cm (13$\frac{3}{8}$-in.), 0 to 87.8 m (288 ft), cemented.

24.4-cm (9$\frac{5}{8}$-in.), 0 to 1,467.9 m (4,816 ft), cemented.

Open hole: 21.9-cm (8$\frac{5}{8}$-in.) bit size, 1,467.9 to 2,137.0 m (4,816 to 7,011 ft).

Procedure for Hydraulic Tests

The hydraulic-testing schedule usually begins with geophysical logging. Rock lithology and qualitative data on hydrologic conditions in the borehole are obtained from the geophysical logs. After completion of the geophysical logging, the hole is pumped to clean suspended matter from the hole, to remove drilling fluid that may have penetrated the formations, and to measure the gross yield of water of all the rocks exposed in the well bore. Pumping generally is accomplished with a submersible pump or by lifting water from the borehole by injecting large quantities of air below the water surface, commonly termed "air jetting". During pumping, radioactive-tracer and temperature surveys are made to locate the zones of entry of water into the hole. After the pumping equipment has been removed from the hole, injection or swabbing tests are made by adding known volumes of water to, or withdrawing known volumes of water from, intervals that are isolated with straddle packers. The rate of decline or rise in water level resulting from this injection or withdrawal of water is recorded. From the rate of change in water levels with time, hydraulic characteristics of the rocks within the interval can be computed. For intervals of low permeability, the rate of decline or rise was very slow. Because of the high cost of rig time, the measurements frequently had to be discontinued before static conditions were achieved. Samples of water are collected during pumping and swabbing for chemical, radiochemical, tritium, and carbon-14 analyses. A more detailed explanation of testing procedures has been presented by Blankennagel (1967).

Analysis of Test Data

The following formula was used to compute the transmissivity (T) from recovery data obtained after jetting:

$$T = \frac{2.30Q}{4\pi s} \log_{10} \frac{t}{t'}$$

where

T = transmissivity of the formation in m^3 pd per m (cubic meters per day per meter);

s = residual drawdown (meters);

t = time since jetting began (minutes);

t'= time since jetting stopped (minutes);

Q = pumping rate, in m^3 pd (cubic meters per day).

Over one log cycle, $\log_{10} t/t'$ becomes unity; then,

$$T = \frac{2.30Q}{4\pi \Delta s}$$

and Δs is the change in head in that log cycle.

Specific capacity of a well is yield per unit of drawdown during pumping, such as gallons per minute per foot of drawdown. Relative specific capacity (RSC) is similar to specific capacity, in that the units and implications are similar. However, relative specific capacity is different, in that it is derived from a short test of a defined interval rather than from a long test of an entire well. The computation for relative specific capacity from slug injection data is as follows:

$$RSC = \frac{Q}{(h-h')}$$

where

Q = volume of water accepted by an interval isolated with packers during a 1-minute time interval (the time interval 3 to 4 minutes after the tool is opened is commonly used);

h = static water level of the hole--or interval tested--as distance below land surface;

h' = average water level in the tubing, as distance below land surface in the 1-minute interval used for determining Q. Usually, the water level at 3.5 minutes is used.

The values for relative specific capacity determined by the preceding method are reasonably accurate for relatively impermeable intervals; they are too low in highly permeable intervals. A comparison of the specific capacity values derived from injection or swabbing-test data of permeable intervals with those values from pumping tests of the same intervals show the injection or swabbing-test data to be low by a factor of as much as 50 for permeable zones.

For low-yielding zones--that is, those with relative specific capacity less than 0.083 m^3 pd per m or 0.005 gpm per ft (gallons per minute per foot) of drawdown--injection and swabbing-test data yield information which is comparable to that which could be obtained if these holes were pumped for a long period of time.

Hydraulic Tests in Hole UAe-3

During the drilling of the hole from 87.8 to 698.0 m (288 to 2,290 ft), the borehole wall was unstable, especially below 457.2 m (1,500 ft). For this reason, the hole was not pumped to remove the drilling fluid (water) for determining the transmissivity and specific capacity of the hole to this depth. However, straddle packers were used to isolate and test selected zones.

The hole was then drilled to 1,467.9 m (4,816 ft), with mud as the drilling fluid, and was cased; the annulus was cemented to this depth. Drilling then continued to 2,137.0 m (7,011 ft), using fresh water as the drilling fluid.

Water was jetted from the open hole for about 20 hours with an average discharge of about 104 m^3 pd (19 gpm). The drawdown at the end of the jetting period was 248 m (814 ft). The static water level for the interval 1,467.9 to 2,137.0 m (4,816 to 7,011 ft) was about 121 m (397 ft) below land surface. The specific capacity from jetting-test data was calculated to be 0.42 m^3 pd per m (0.023 gpm per ft) of drawdown and the transmissivity was calculated to be 0.109 m^3 pd per m (8.8 gpd per ft). After jetting and water level recovery, straddle packers were used to isolate and hydraulically test selected intervals in the hole.

Analysis of data obtained during hydraulic tests in hole UAe-3 are presented in figures 1 through 16.

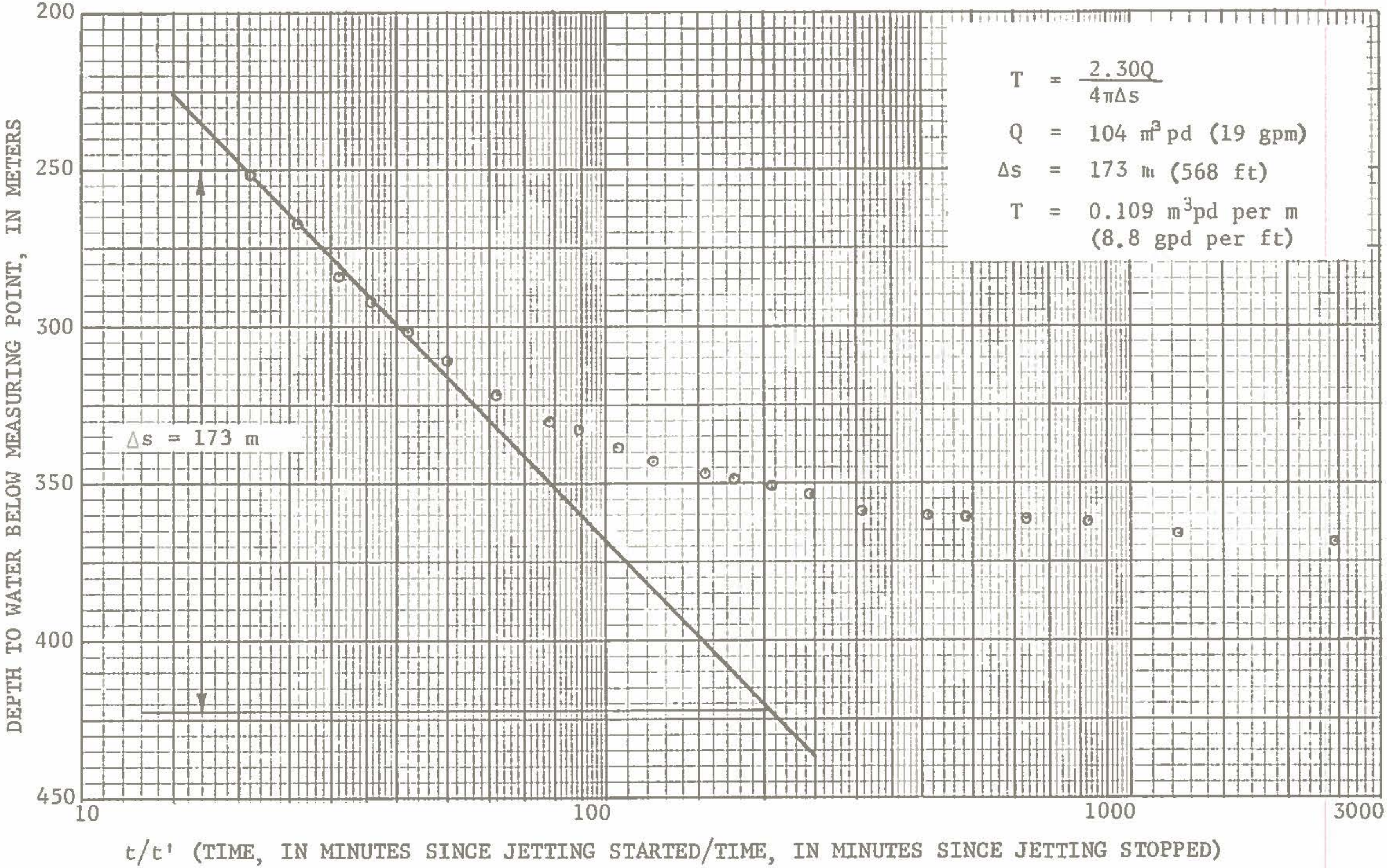

Figure 1.--Recovery of water level after jetting (air-lifting water from hole) the interval from 1,467.9 to 2,137.0 m (4,816 to 7,011 ft) in hole UAe-3, Amchitka Island, Alaska, November 20, 1967.

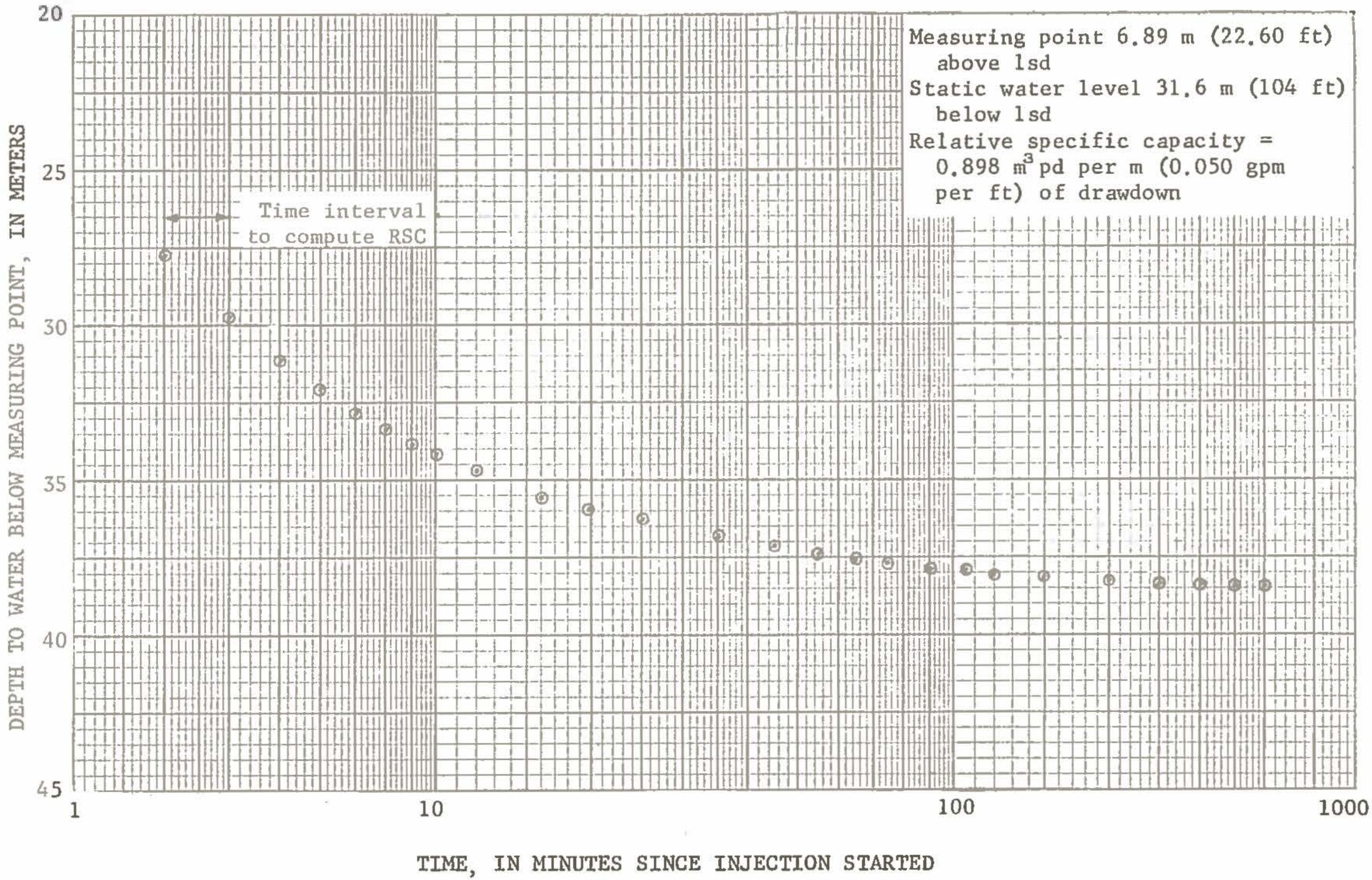

Figure 2.--Injection test of zone 216.4 to 276.8 m (710 to 908 ft), hole UAe-3, Amchitka Island, Alaska, July 28, 1967.

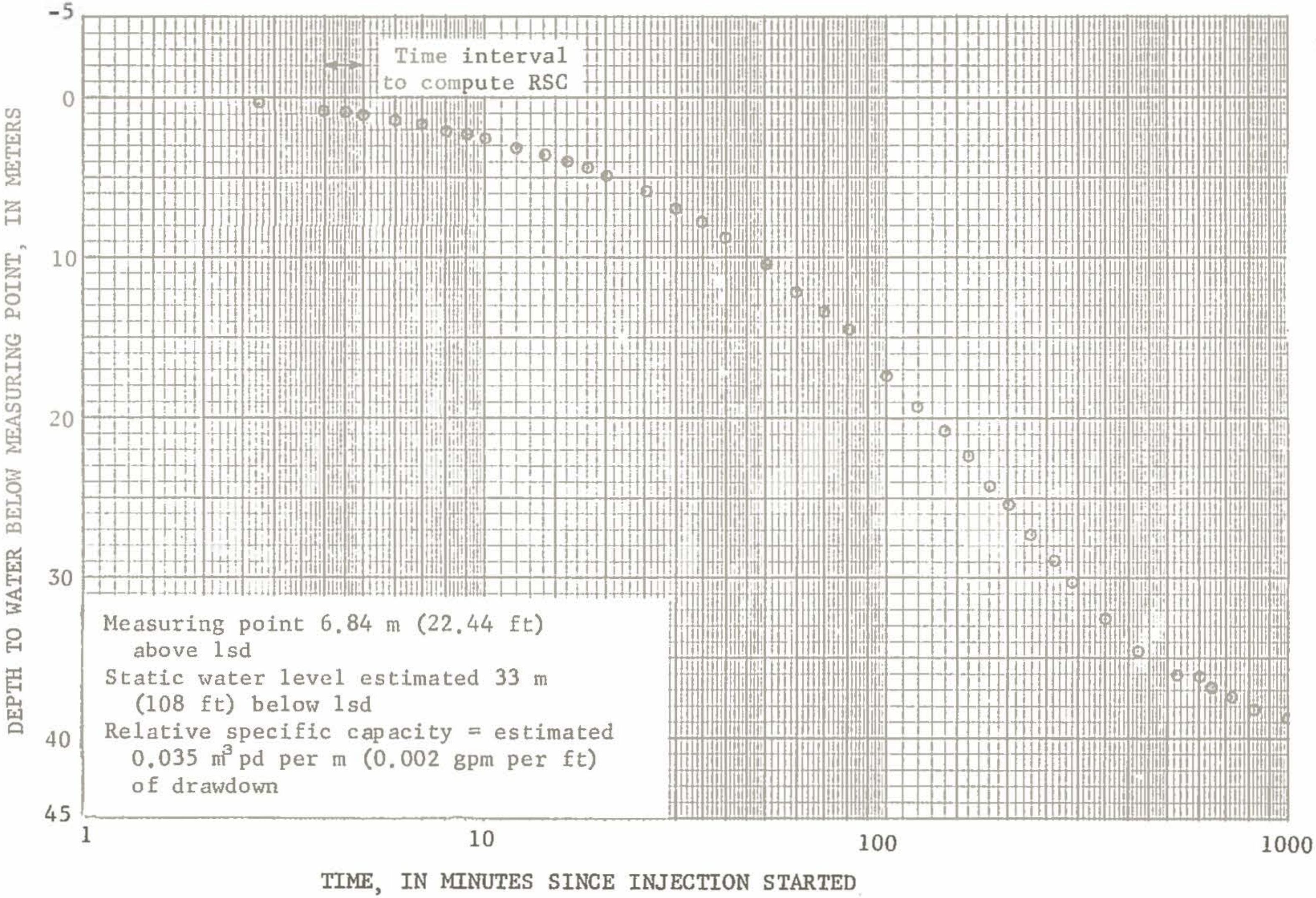

Figure 3.--Injection test of zone 354.8 to 390.8 m (1,164 to 1,282 ft), hole UAe-3, Amchitka Island, Alaska, August 2, 1967.

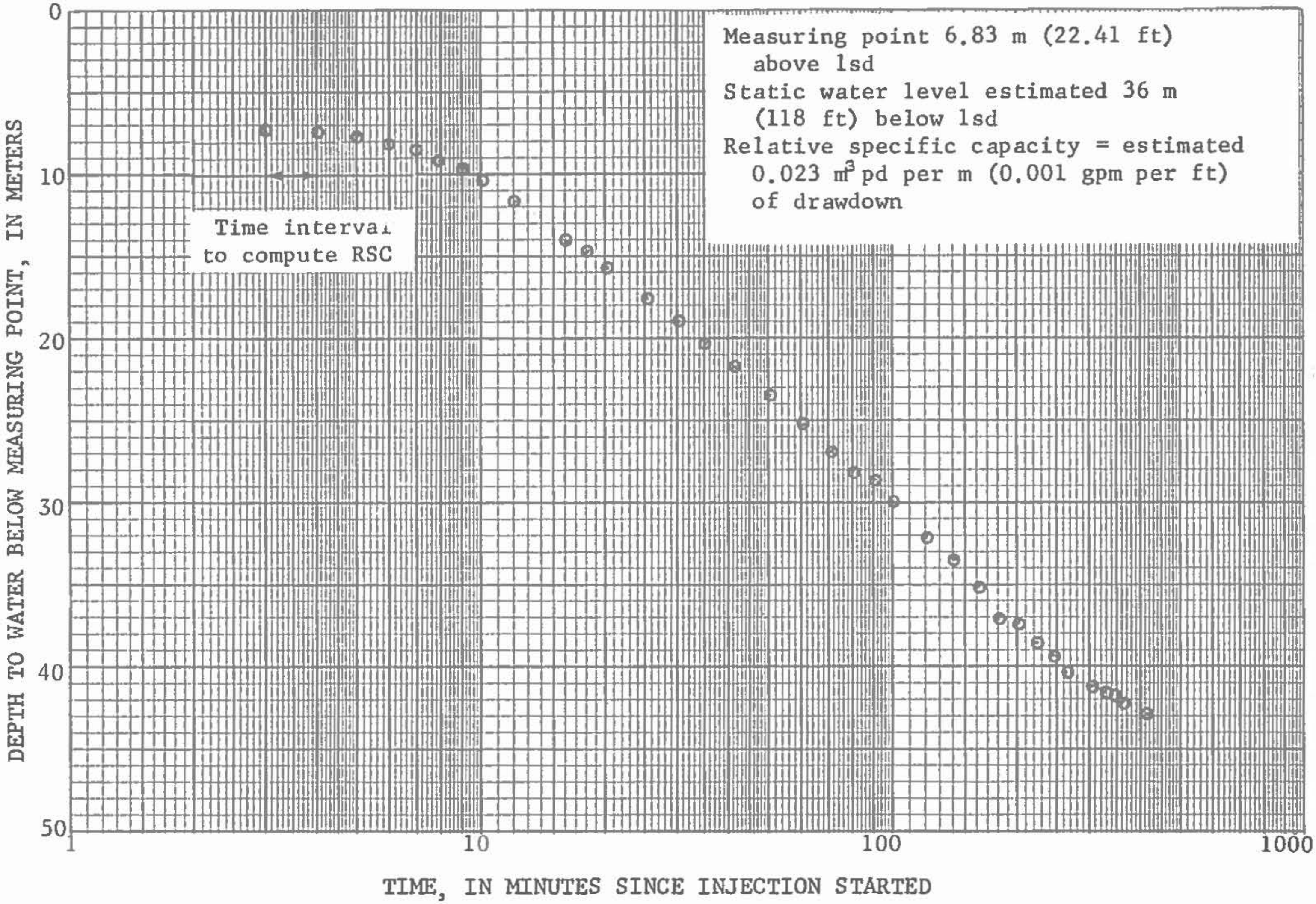

Figure 4.--Injection test of zone 399.3 to 459.6 m (1,310 to 1,508 ft), hole UAe-3, Amchitka Island, Alaska, July 31, 1967.

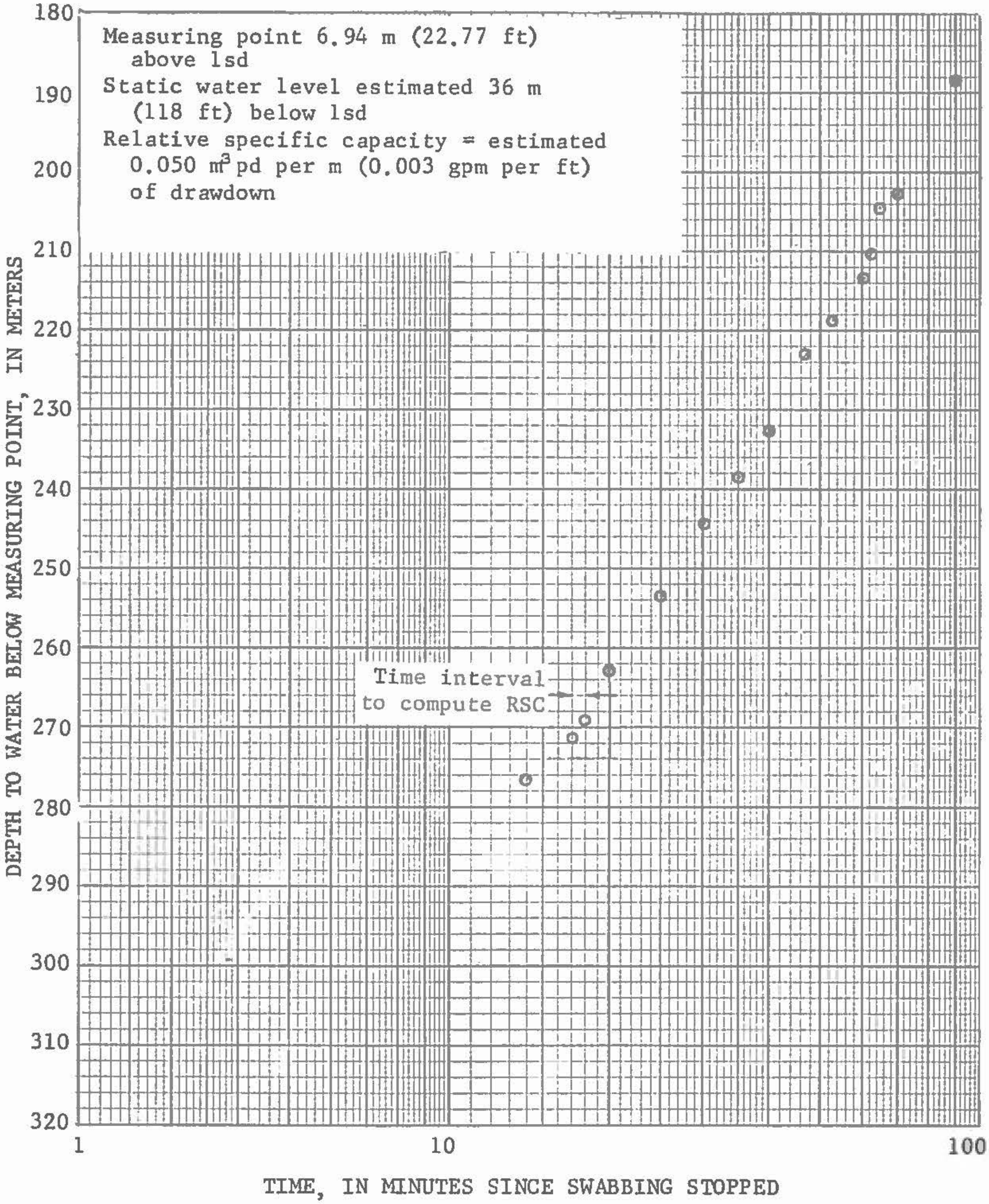

Figure 5.--Swabbing recovery test of zone 460.9 to 631.9 m (1,512 to 2,073 ft), hole UAe-3, Amchitka Island, Alaska, August 1, 1967.

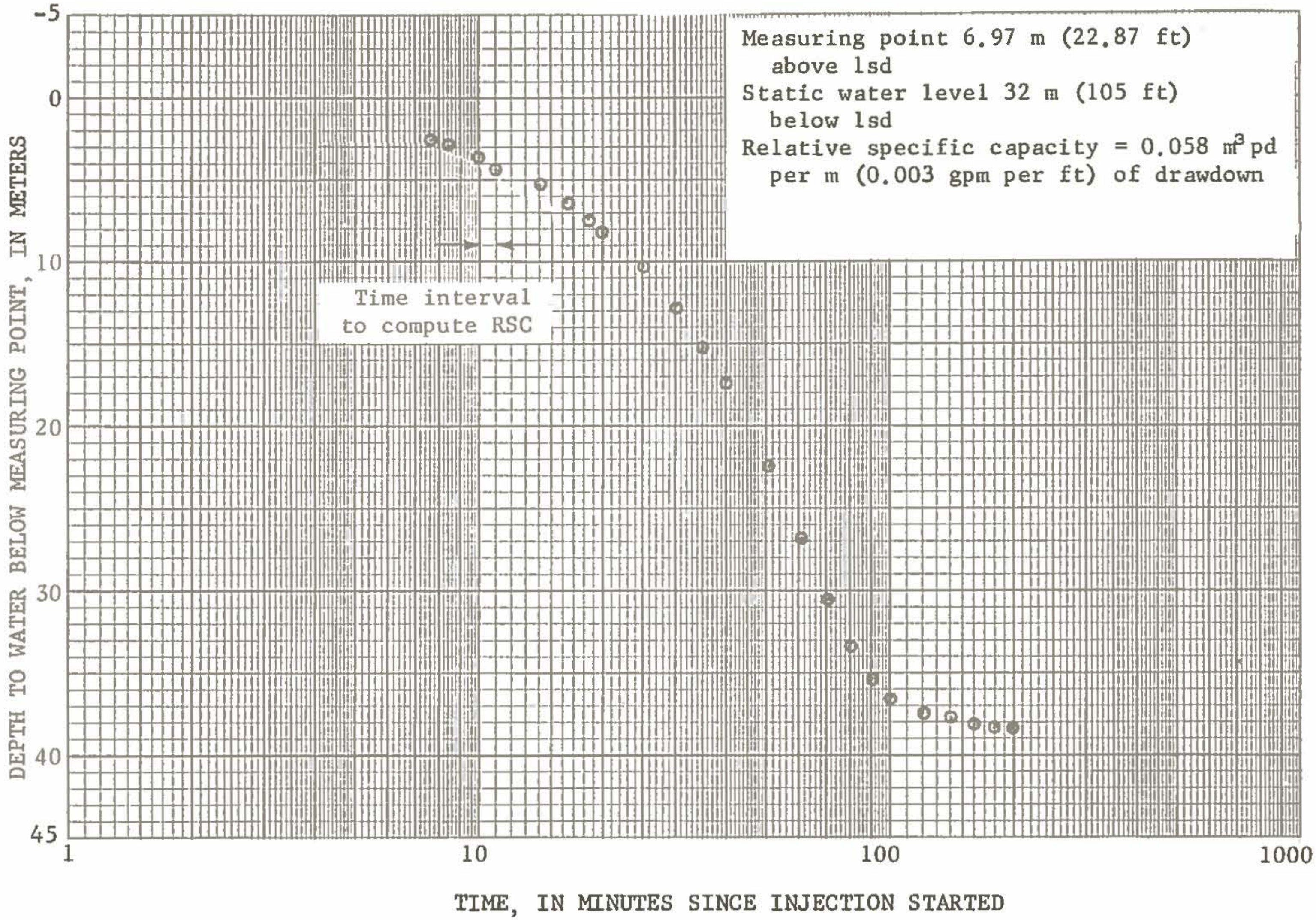

Figure 6.--Injection test of zone 527.3 to 587.7 m (1,730 to 1,928 ft), hole UAe-3, Amchitka Island, Alaska, August 2, 1967.

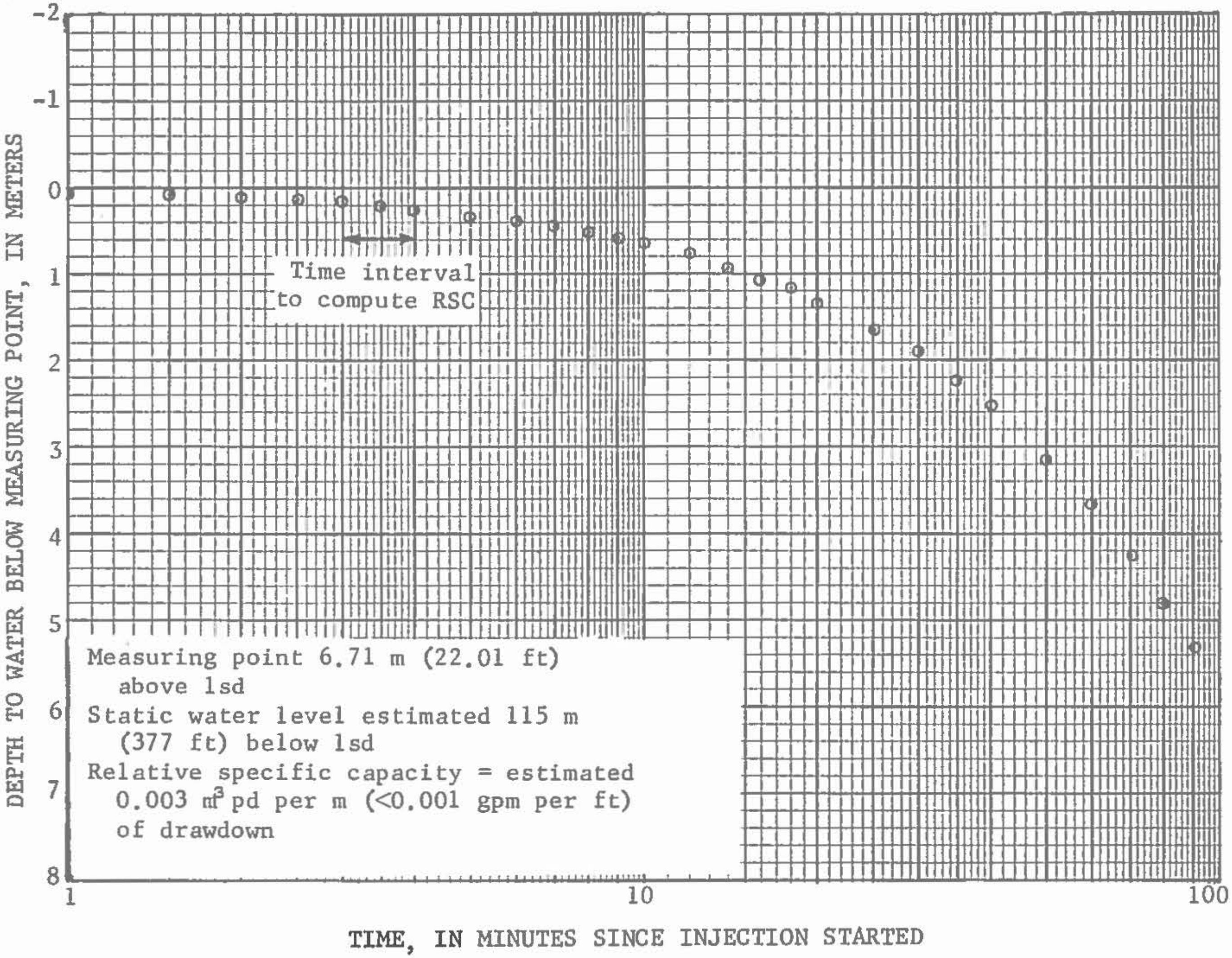

Figure 7.--Injection test of zone 1,467.9 to 1,528.3 m (4,816 to 5,014 ft), hole UAe-3, Amchitka Island, Alaska, October 19, 1967.

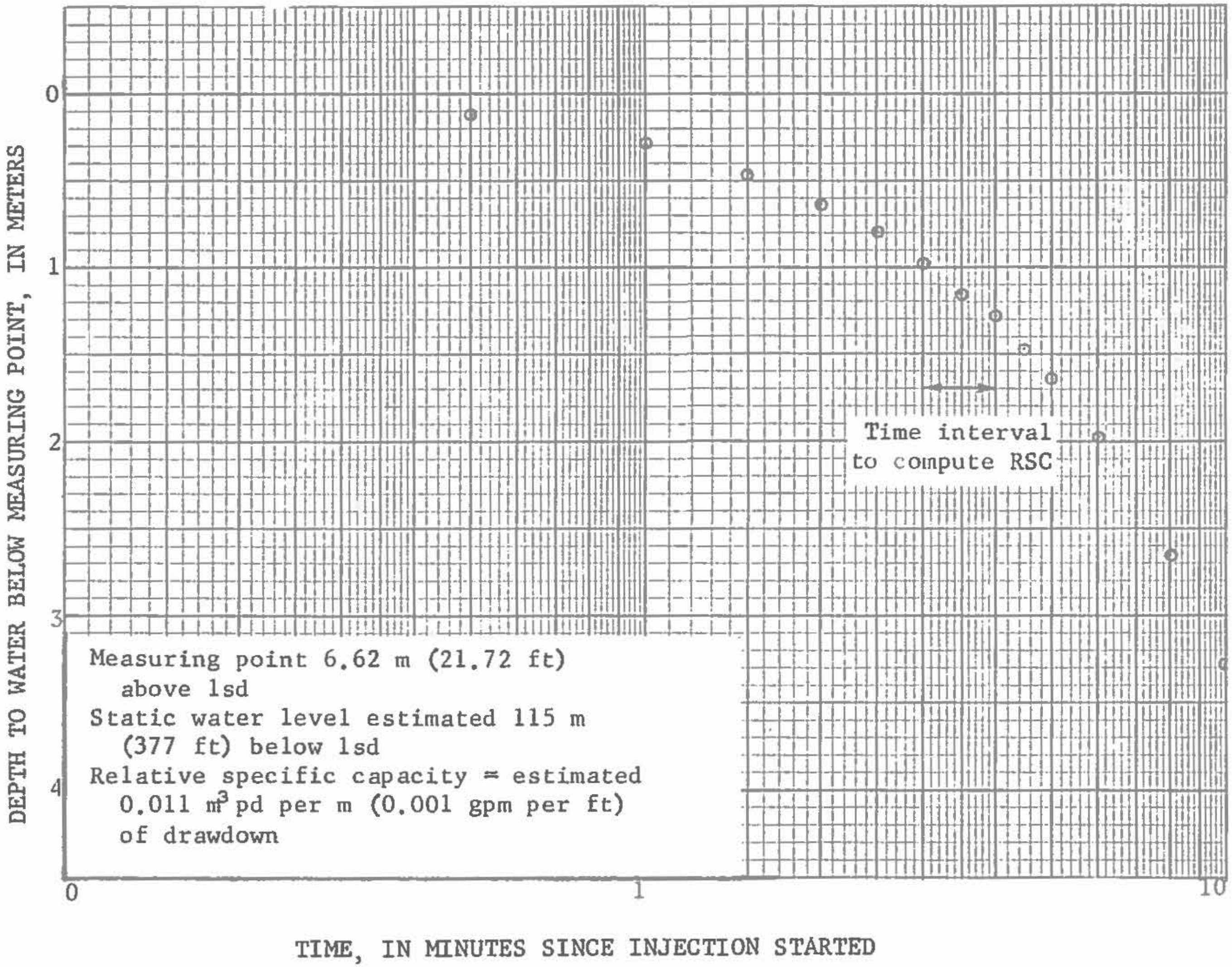

Figure 8.--Injection test of zone 1,612.4 to 1,657.5 m (5,290 to 5,438 ft), hole UAe-3, Amchitka Island, Alaska, October 18, 1967.

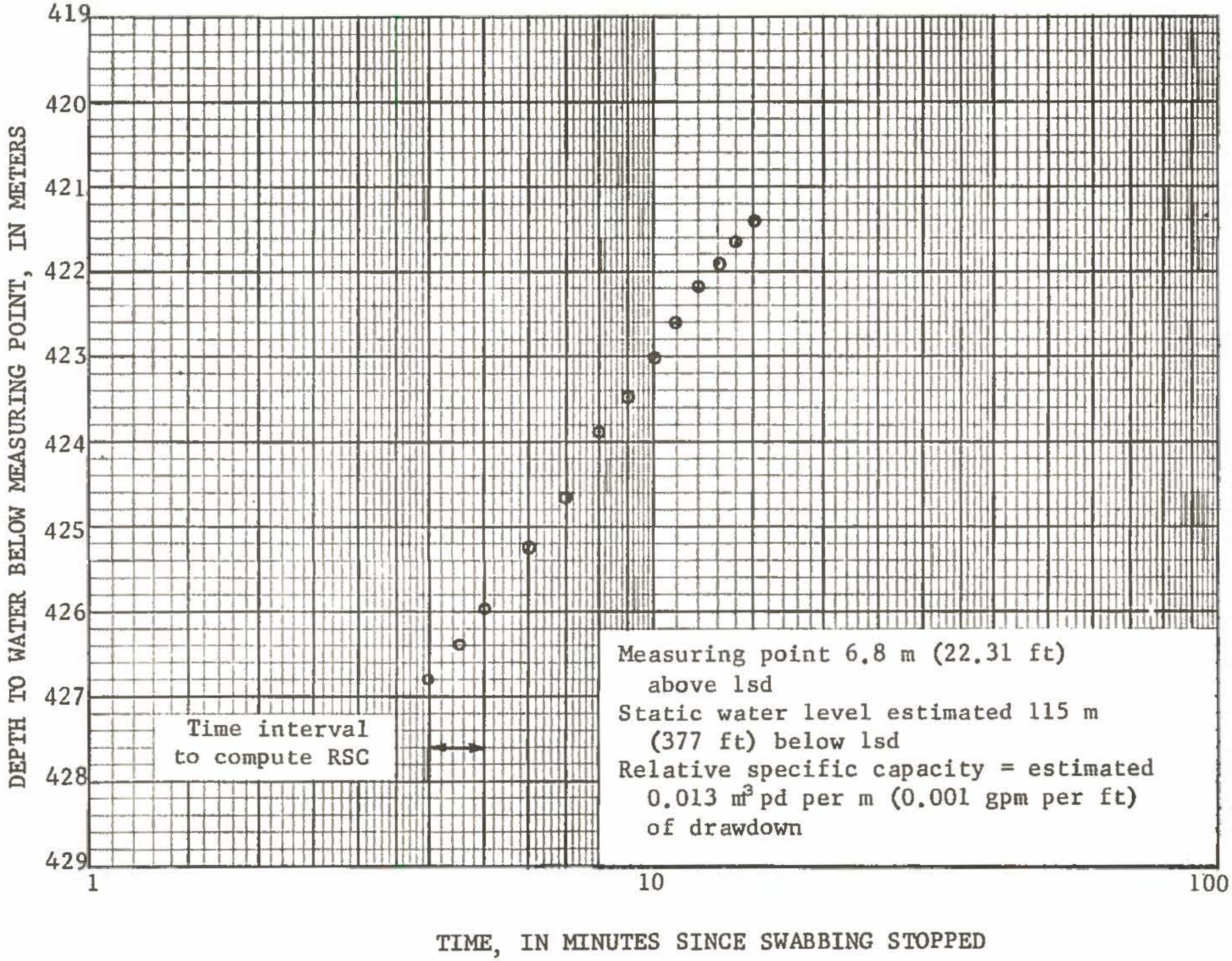

Figure 9.--Swabbing recovery test of zone 1,660.6 to 1,705.7 m (5,448 to 5,596 ft), hole UAe-3, Amchitka Island, Alaska, October 18, 1967.

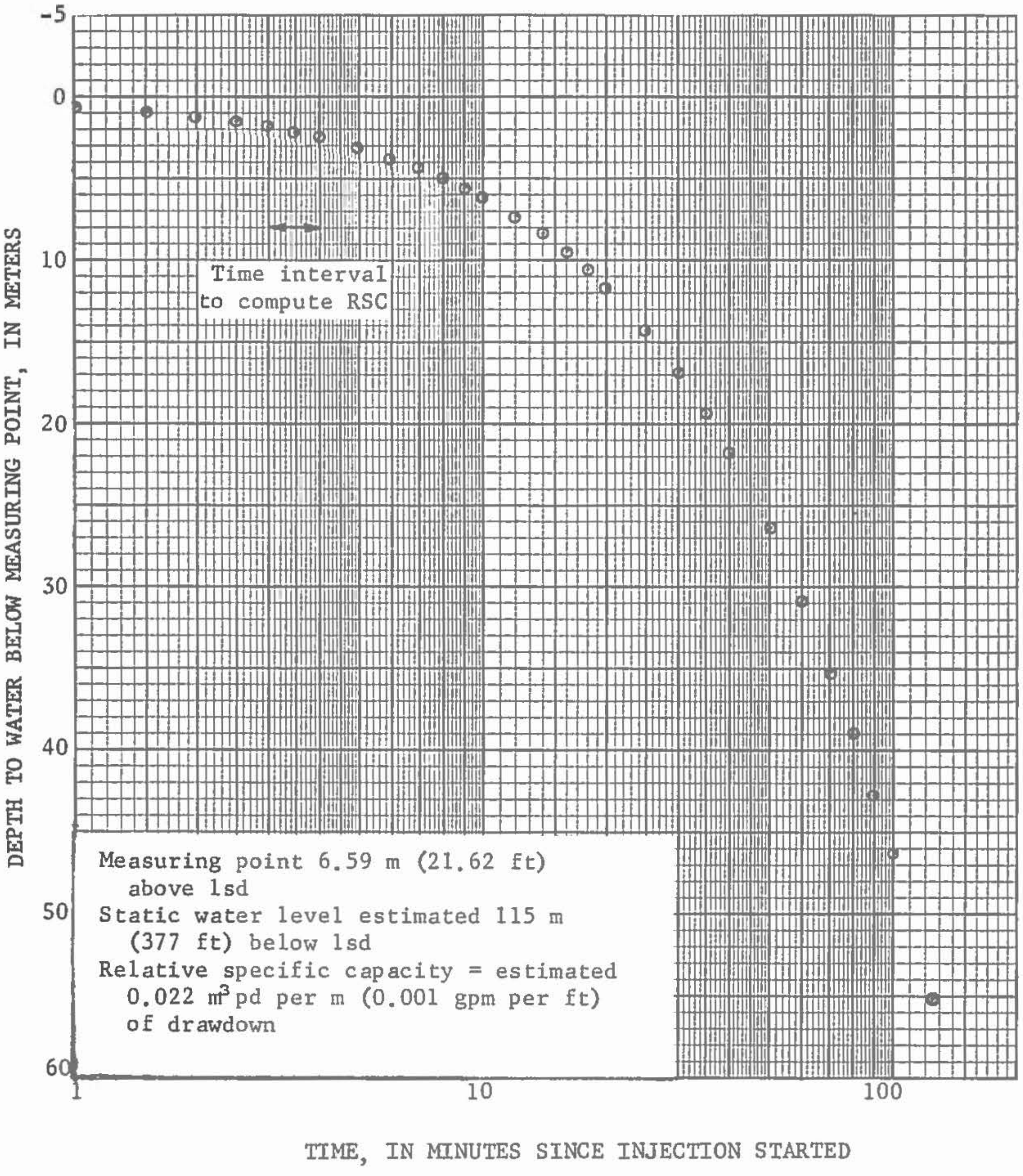

Figure 10.--Injection test of zone 1,744.1 to 1,789.2 m (5,722 to 5,870 ft), hole UAe-3, Amchitka Island, Alaska, October 17, 1967.

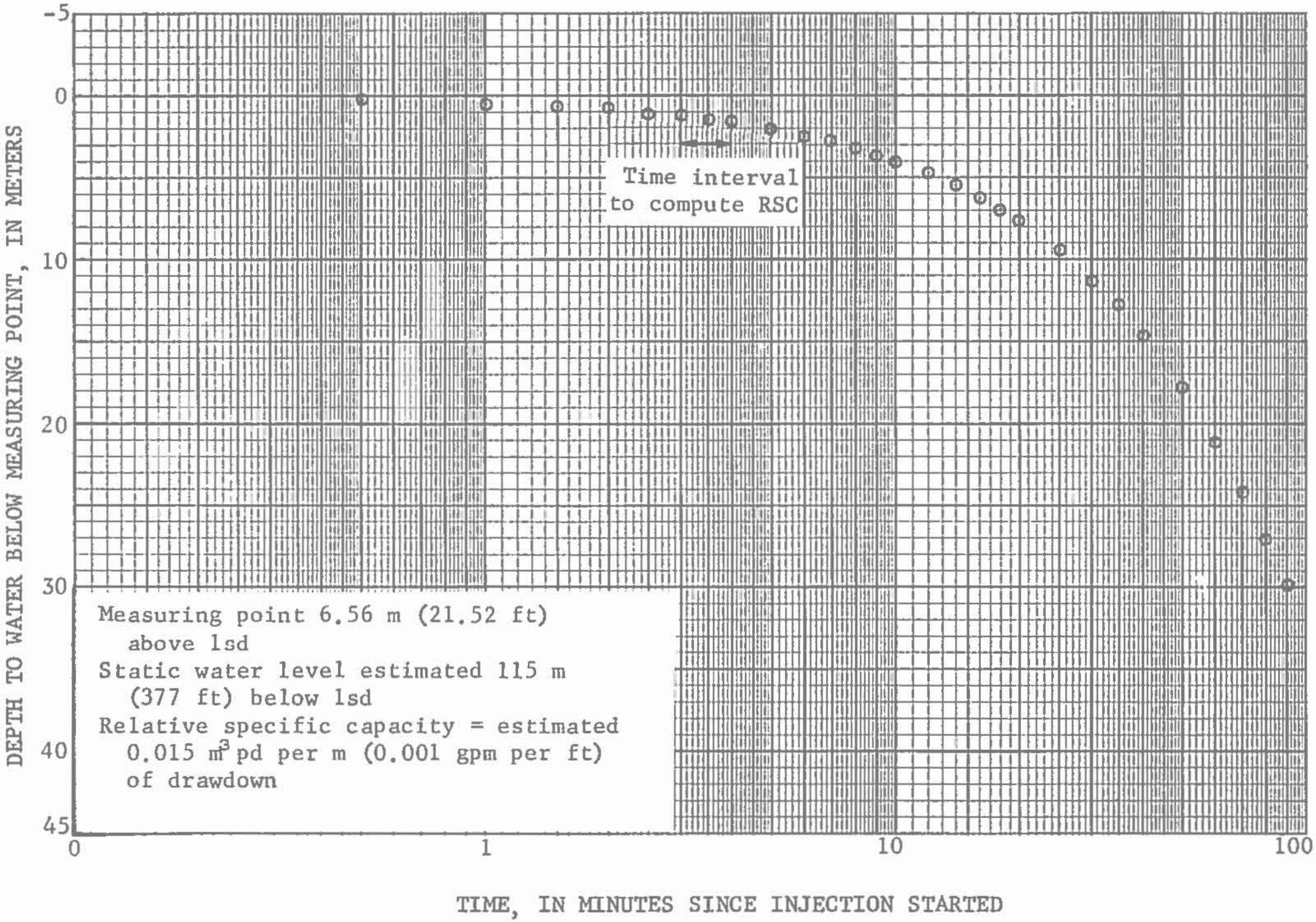

Figure 11.--Injection test of zone 1,790.4 to 1,825.8 m (5,874 to 5,990 ft), hole UAe-3, Amchitka Island, Alaska, October 17, 1967.

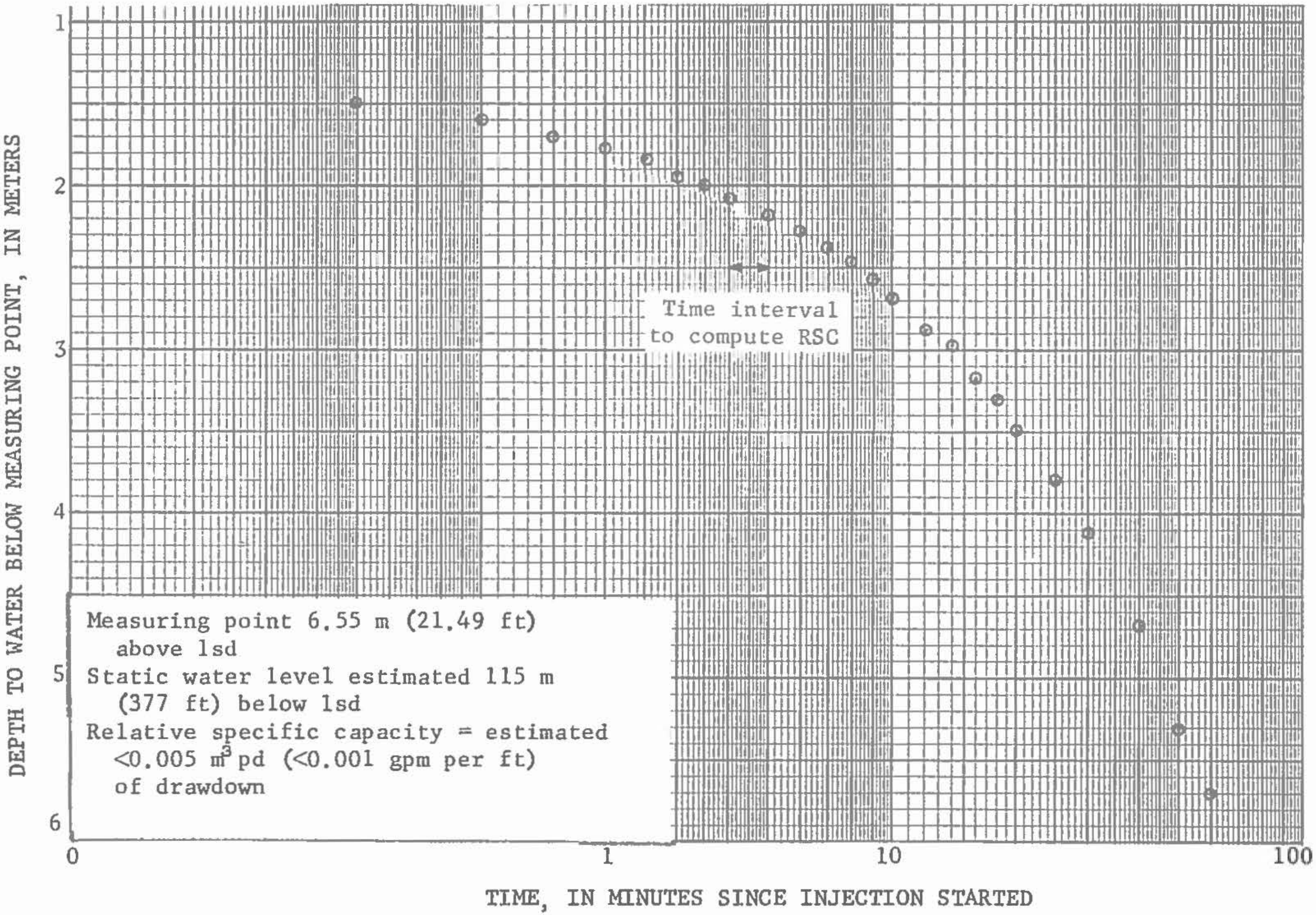

Figure 12.--Injection test of zone 1,816.0 to 1,858.1 m (5,958 to 6,096 ft), hole UAe-3, Amchitka Island, Alaska, November 12, 1967.

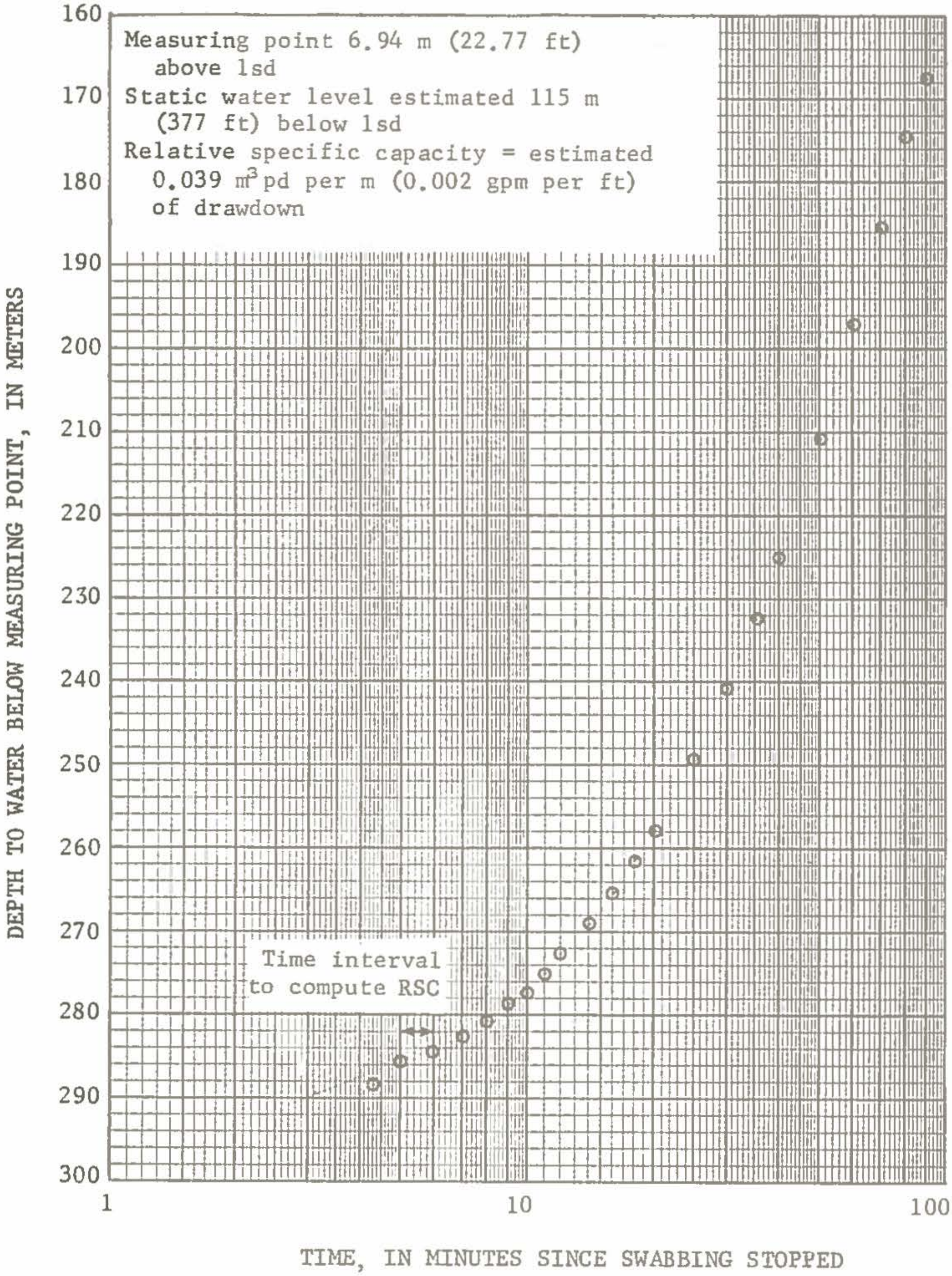

Figure 13.--Swabbing recovery test of zone 1,859.3 to 1,968.7 m (6,100 to 6,459 ft), hole UAe-3, Amchitka Island, Alaska, November 11, 1967.

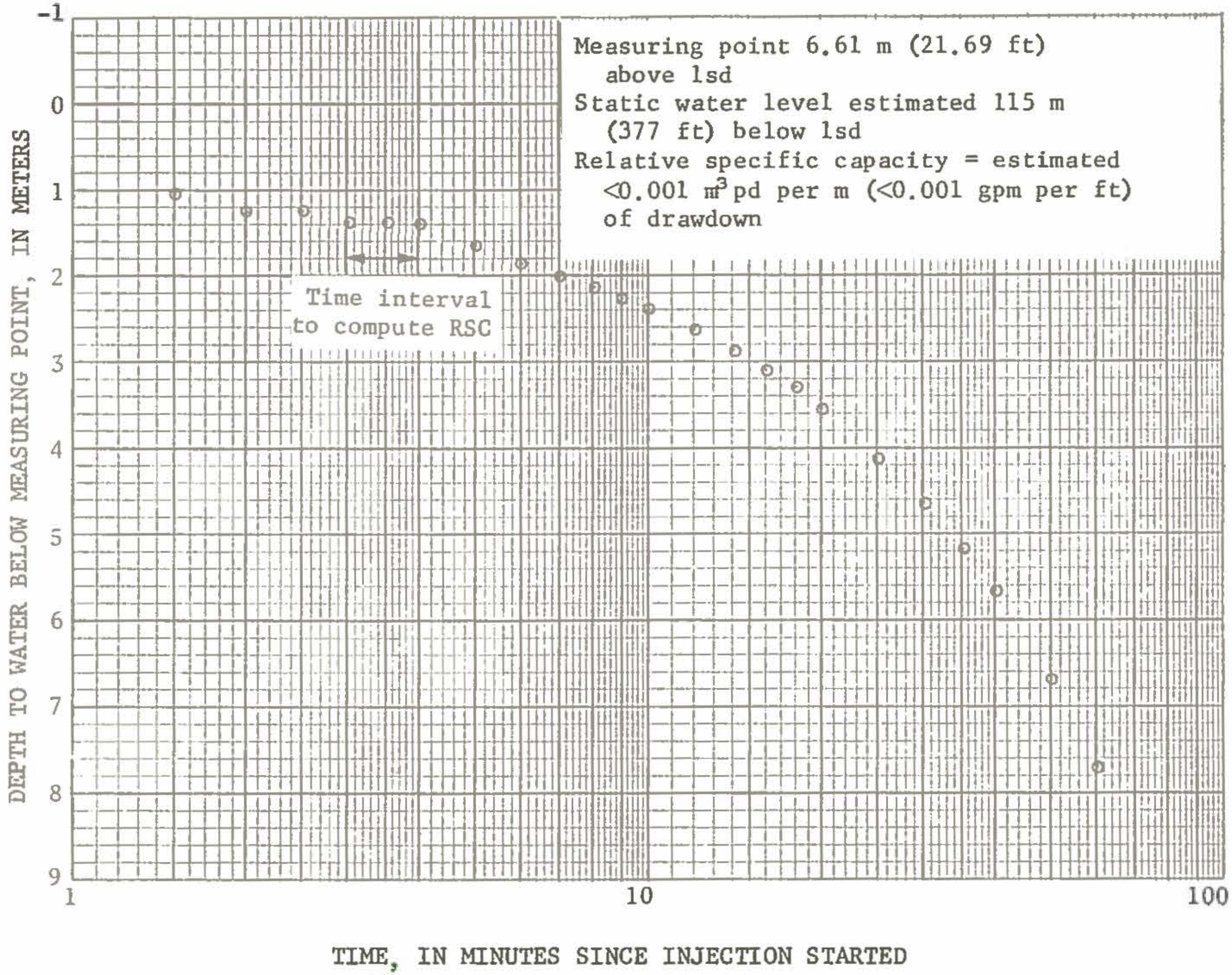

Figure 14.--Injection test of zone 1,860.5 to 1,899.5 m (6,104 to 6,232 ft), hole UAe-3, Amchitka Island, Alaska, November 12, 1967.

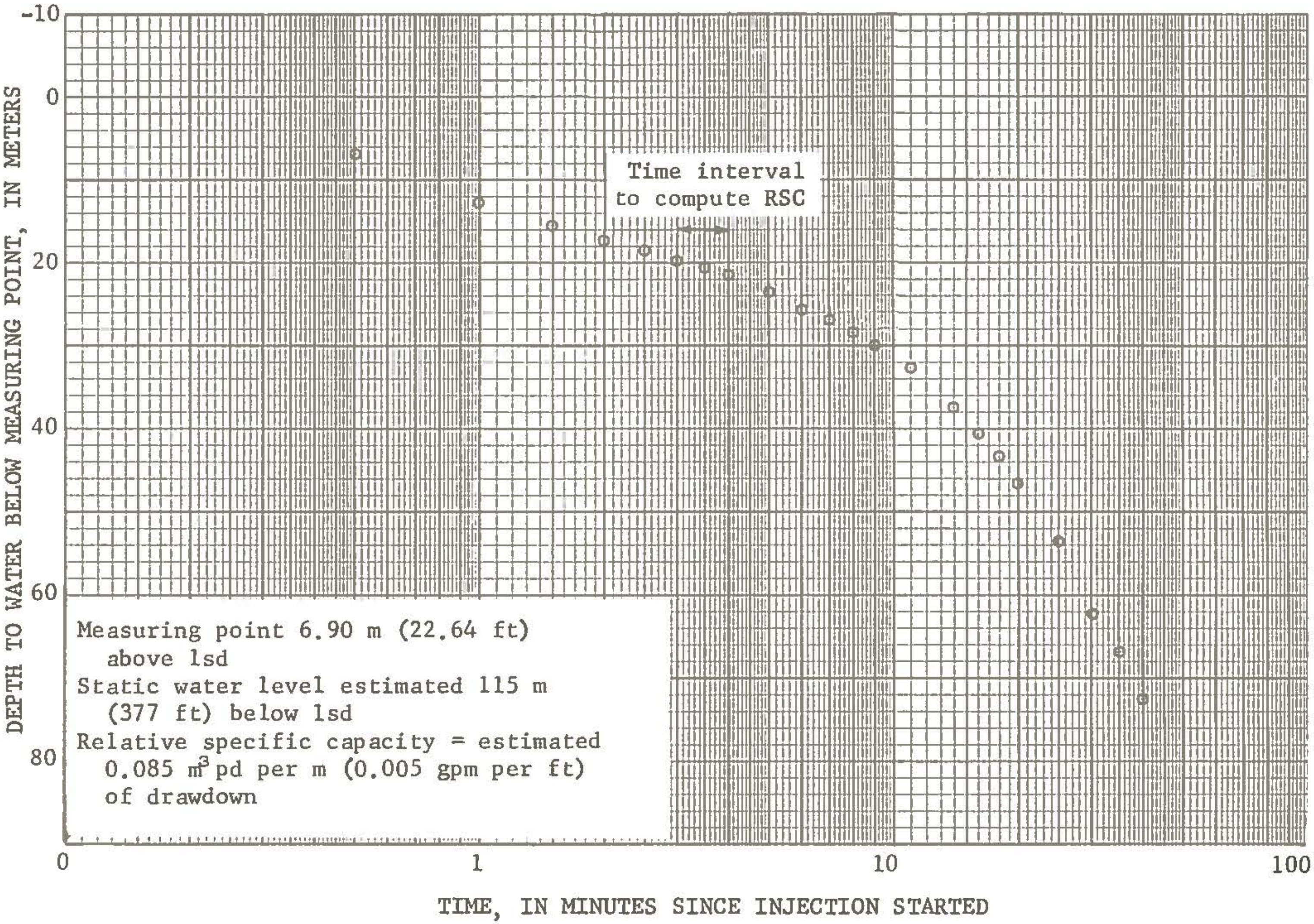

Figure 15.--Injection test of zone 1,984.3 to 2,029.4 m (6,510 to 6,658 ft), hole UAe-3, Amchitka Island, Alaska, November 21, 1967.

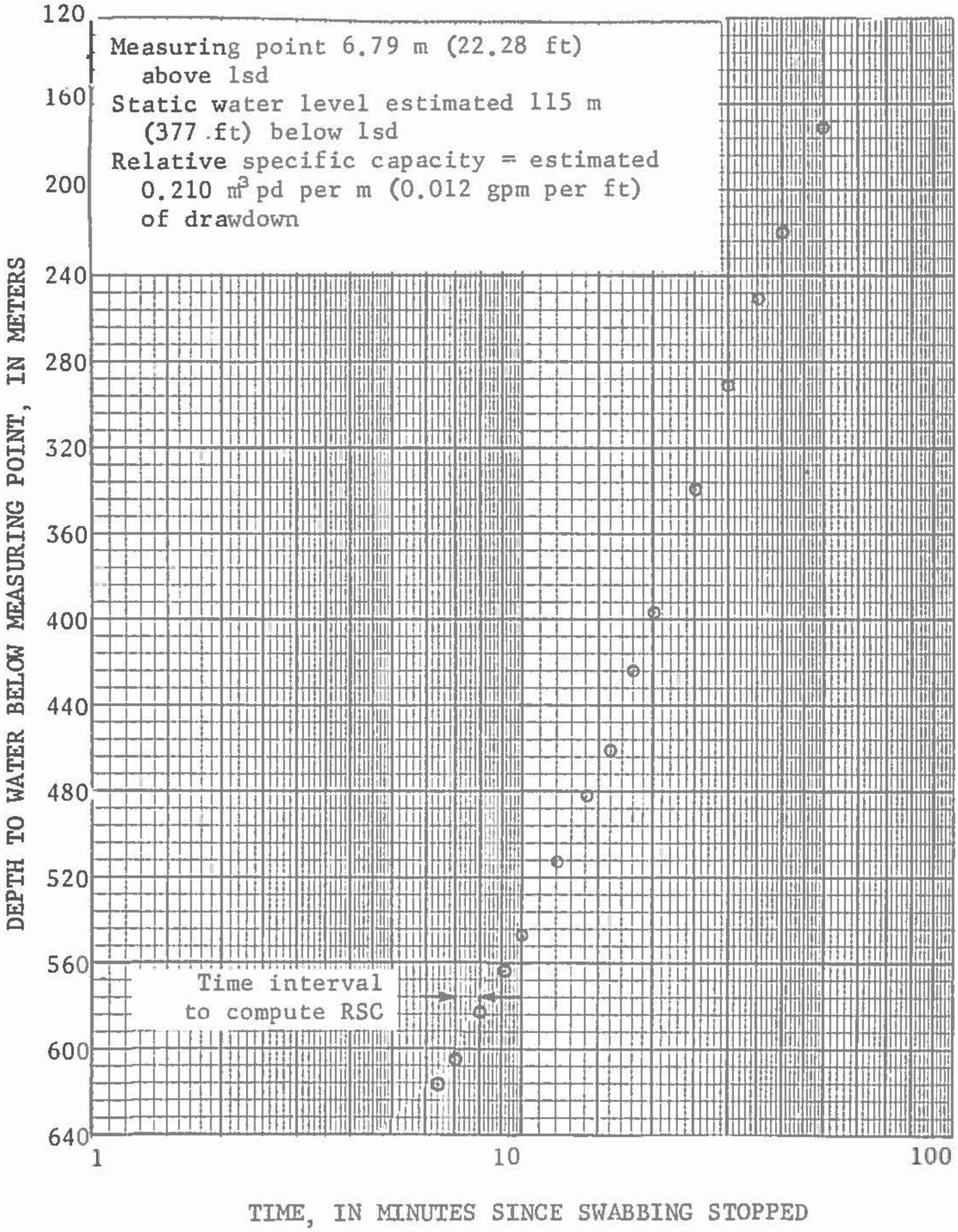

Figure 16.--Swabbing recovery test of zone 2,032.4 to 2,098.0 m (6,668 to 6,883 ft), hole UAe-3, Amchitka Island, Alaska, November 21, 1967.

SUMMARY AND CONCLUSIONS

The static water level for each zone was determined after the injection test or swabbing test. Because the rocks have low permeability, the rate of recovery was very slow thus very costly because of the high cost of rig time. The measurement of water levels frequently had to be discontinued before static conditions were achieved. Therefore, the static water level was often estimated.

Results of testing the hole indicate the composite static water level for the interval 87.8 to 698.0 m (288 to 2,290 ft) is about 32 m (118 ft) below land surface. The composite static water level for the interval 1,467.9 to 2,137.0 m (4,816 to 7,011 ft) was about 121 m (397 ft) below land surface. The specific capacity of the interval 1,467.9 to 2,137.0 m (4,816 to 7,011 ft) was 0.42 m^3pd per m (0.023 gpm per ft) of drawdown and the transmissivity of this interval was 0.109 m^3pd per m (8.8 gpd per ft).

The data obtained from hydraulic tests indicate the most permeable part of the hole is above 276.8 m (908 ft). Figure 17 and table 1 summarize the injection and swabbing tests of all zones tested.

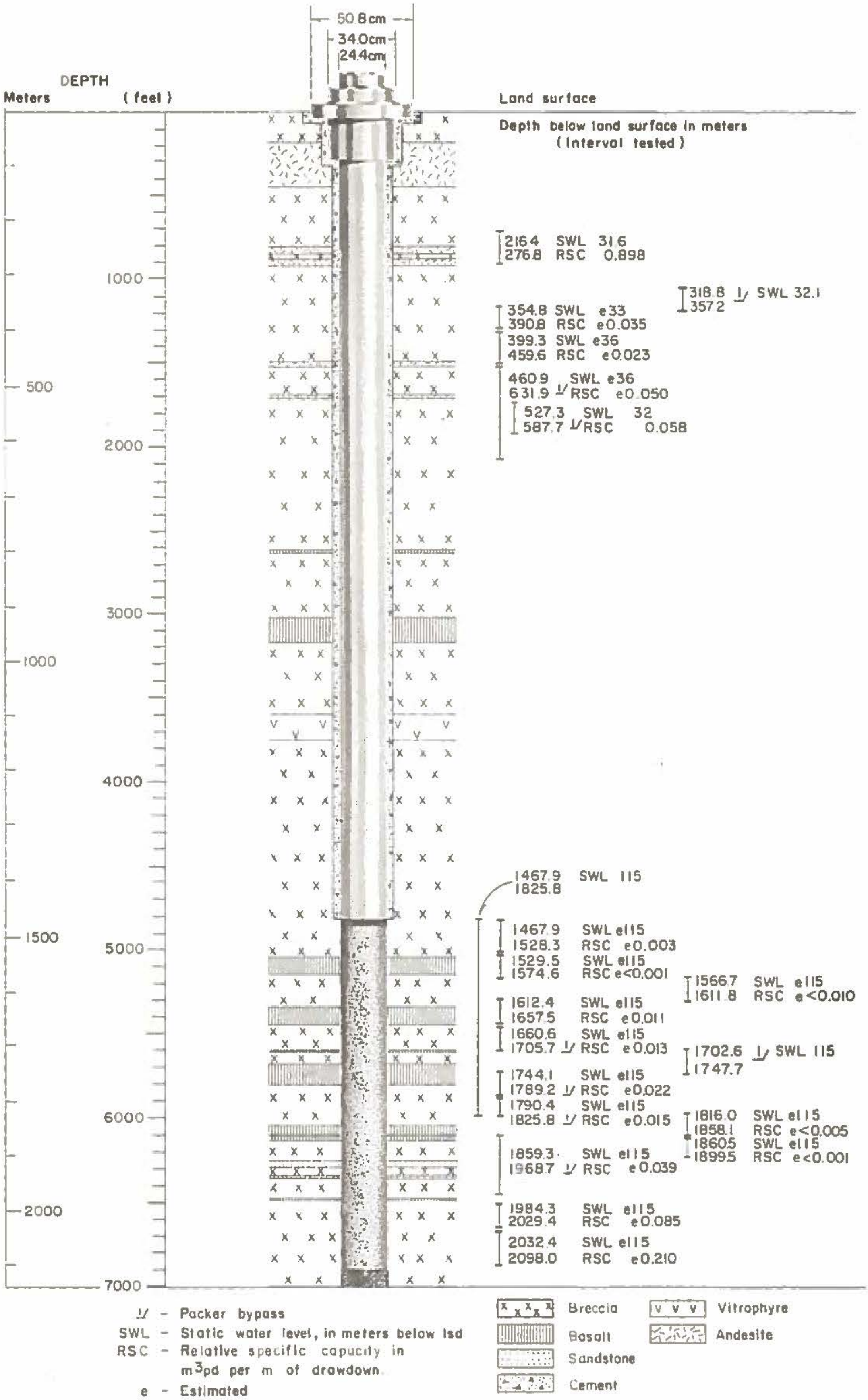

Figure 17.--Construction diagram, lithologic log, and summary of hydrologic tests, hole UAe-3, Amchitka Island, Alaska.

Table 1.--Summary of hydraulic testing in hole UAe-3, Amchitka Island, Alaska

Interval tested (depth below lsd)		Method of testing	Packer bypass	Static water level (depth below lsd)		Relative specific capacity	
m	ft			m	ft	m^3pd per m of dd	gpm per ft of dd
216.4-276.8	710-908	Injection	No	31.6	104	0.898	0.050
318.8-357.2	1,046-1,172	Injection	Yes	32.1	105.3	--	--
354.8-390.8	1,164-1,282	Injection	No	e33	e108	e.035	e.002
399.3-459.6	1,310-1,508	Injection	No	e36	e118	e.023	e.001
460.9-631.9	1,512-2,073	Swabbing	Yes	e36	e118	e.050	e.003
527.3-587.7	1,730-1,928	Injection	Yes	32	105	.058	.003
1,467.9-1,528.3	4,816-5,014	Injection	No	e115	e377	e.003	e<.001
1,467.9-1,825.8	4,816-5,990	Injection	No	115	377	--	--
1,529.5-1,574.6	5,018-5,166	Injection	No	e115	e377	e<.001	e<.001
1,566.7-1,611.8	5,140-5,288	Injection	No	e115	e377	e<.010	e<.001
1,612.4-1,657.5	5,290-5,438	Injection	No	e115	e377	e.011	e.001
1,660.6-1,705.7	5,448-5,596	Swabbing	Yes	e115	e377	e.013	e.001
1,702.6-1,747.7	5,586-5,734	Injection	Yes	115	377	--	--
1,744.1-1,789.2	5,722-5,870	Injection	Yes	e115	e377	e.022	e.001
1,790.4-1,825.8	5,874-5,990	Injection	Yes	e115	e377	e.015	e.001
1,816.0-1,858.1	5,958-6,096	Injection	No	e115	e377	e.005	e<.001
1,859.3-1,968.7	6,100-6,459	Swabbing	Yes	e115	e377	e.039	e.002
1,860.5-1,899.5	6,104-6,232	Injection	No	e115	e377	e.001	e<.001
1,984.3-2,029.4	6,510-6,658	Injection	No	e115	e377	e.085	e.005
2,032.4-2,098.0	6,668-6,883	Swabbing	No	e115	e377	e.210	e.012

EXPLANATION

lsd - land-surface datum
m - meters
ft - feet
m^3pd - cubic meters per day
dd - drawdown
gpm - gallons per minute
e - estimated

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