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GEOHYDROLOGIC DATA AND TEST RESULTS FROM WELL J-13, NEVADA TEST SITE, NYE COUNTY, NEVADA

By William Thordarson

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 83-4171

Prepared in cooperation with the

U.S. DEPARTMENT OF ENERGY

Denver, Colorado

1983

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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SYMBOLS LIST

Symbol	*Description*	*Dimension*
H	Head at time t	Meters
H_0	Head immediately after injection started or after swabbing stopped	Meters
Q	Flow rate	Liters per second
r	Radial distance between wells	Meters
r_c	Radius of well casing or tubing	Meters
Δs	Drawdown for one log cycle	Meters
s	Drawdown	Meters
s'	Residual drawdown	Meters
T	Transmissivity	Meters squared per day
t	Time since discharge began	Minutes
t'	Time since discharge stopped	Minutes
α	Value of injection-test type curve	Dimensionless
Δ	Finite difference, change in	Dimensionless
Ψ	Radius divided by thickness of tested interval	Dimensionless

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*
centimeter (cm)	3.937×10^{-1}	inch
millimeter (mm)	3.937×10^{-2}	inch
kilometer (km)	6.214×10^{-1}	mile
meter (m)	3.281	foot
degree Celsius (°C)	1.8°C + 32	degree Fahrenheit
meter per day (m/d)	3.281	foot per day
meter squared per day (m^2/d)	1.076×10^{1}	foot squared per day
milligram per liter (mg/L)	[1]1.0	part per million
microgram per liter (µg/L)	[1]1.0	part per billion
liter per second (L/s)	1.585×10^{1}	gallon per minute
liter (L)	2.642×10^{-1}	gallon
gram per cubic centimeter (g/cm^3)	6.243×10^{1}	pound per cubic foot
meter per second (m/s)	3.281	foot per second
cubic meter (m^3)	3.531×10^{1}	cubic feet

[1]Approximate.

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

GEOHYDROLOGIC DATA AND TEST RESULTS FROM WELL J-13, NEVADA TEST SITE, NYE COUNTY, NEVADA

By William Thordarson

ABSTRACT

Well J-13 was drilled to a depth of 1,063.1 meters by using air-hydraulic-rotary drilling equipment. The well penetrated 135.6 meters of alluvium of Quaternary and Tertiary (?) age and 927.5 meters of tuff of Tertiary age.

The Topopah Spring Member of the Paintbrush Tuff, the principal aquifer, was penetrated from depths of 207.3 to 449.6 meters; a pumping test indicated its transmissivity is 120 meters squared per day, and its hydraulic conductivity is 1.0 meters per day. Below the Topopah Spring Member, tuff units are confining beds; transmissivities range from 0.10 to 4.5 meters squared per day, and hydraulic conductivities range from 0.0026 to 0.15 meter per day. Confining beds penetrated below a depth of 719.3 meters had the smallest transmissivities (0.10 to 0.63 meter squared per day) and hydraulic conductivities (0.0026 to 0.0056 meter per day).

A static water level of approximately 282.2 meters was measured for the various water-bearing tuff units above a depth of 645.6 meters. Below a depth of 772.7 meters, the static water level was slightly deeper, 283.3 to 283.6 meters.

Ground water sampled from well J-13 is a sodium bicarbonate water containing small concentrations of calcium, magnesium, silica, and sulfate, which is a typical analysis of water from tuff. Apparent age of the ground water, derived from carbon-14 age dating, is 9,900 years.

INTRODUCTION

Purpose and Scope

The U.S. Geological Survey is conducting investigations, funded by the U.S. Department of Energy under Interagency Agreement DE-AI08-ET44802, related to the isolation of radioactive wastes. These investigations have included test drilling and geologic, geophysical, and hydrologic studies to locate suitable environments for waste storage and to develop new techniques for site exploration and evaluation. As part of the Nevada Nuclear Waste Storage Investigations, one of the areas being evaluated as a proposed site for a nuclear-waste repository is the Yucca Mountain area in southeastern Nevada. To augment the information obtained by drilling new test wells, data from pre-existing wells and test holes are being reevaluated and re-analyzed with new techniques. This report presents the analytical results and data for well J-13.

Well J-13, drilled in 1962, was part of a test-drilling program of 10 test holes that were intended to provide an understanding of the regional flow of ground water within Paleozoic carbonate rocks of Jackass Flats, on behalf of the U.S. Atomic Energy Commission. However, in well J-13, depth to carbonate rocks of Paleozoic age was deeper than expected, and the well was completed in tuffaceous rocks of Tertiary age, with the expectation, not yet achieved, of later deepening the well into carbonate rocks of Paleozoic age. The tuffaceous rocks were studied; many swabbing, injection, and pumping tests were made; geophysical logs were obtained; and hydrochemistry of the ground water was analyzed.

Following the initial work in well J-13, a few pumping tests, static water levels, and chemical analyses of water were obtained from 1963 to the present time (1983). Some of the results of work in well J-13 were given in several reports (Young, 1972; Claassen, 1973; and Winograd and Thordarson, 1975). In 1963, well J-13 was connected by a pipeline to well J-12; later a water pipeline was constructed from well J-13 to the Nuclear Rocket Development Station.

The purpose of this report is to present all the previously collected hydrogeologic, geophysical, and hydrochemical data on well J-13, and to reanalyze these data, using newly developed methods of analysis. The U.S. Geological Survey has been drilling test wells recently in areas west of well J-13, on behalf of the U.S. Department of Energy. Tuffaceous rocks in these test wells are similar to tuffaceous rocks in well J-13, so a comparison of the geological, geophysical, and hydrogeologic studies in the test wells with similar studies in well J-13 will help locate suitable environments for waste storage and develop new techniques for site exploration and evaluation in the southwestern part of the Nevada Test Site. Data in this report will help define hydrogeology and hydrochemistry of the tuff, which will be useful in determining acceptability of the tuff for storing nuclear wastes.

Location of Study Area

Well J-13 is in the southwestern part of the Nevada Test Site, about 130 km northwest of Las Vegas, Nev., and about 19 km north of Lathrop Wells (fig. 1). The well is in western Jackass Flats near the east side of Fortymile Wash between well J-12, 4.7 km to the south, and test well USW H-1 in the Yucca Mountain area, 8.3 km to the northwest (fig. 2). The Nevada State Central Zone Coordinates of well J-13 are N 749, 209, E 579, 651. Altitude of the land surface at the well site is 1,011.3 m above sea level.

DRILLING PROCEDURES AND WELL CONSTRUCTION

Well J-13, originally designated U.S. Geological Survey test well 6, was drilled to a depth of 1,063.1 m, beginning in September 1962 and ending in January 1963. Because of drilling difficulties, such as a caving hole, a bridging hole, and a stuck drill pipe during drilling, four sizes of casing were needed to construct the well. Casing, perforation, and cementing records for well J-13 are presented in table 1. Well construction and lithologic units are presented in figure 3. Sizes of the drill bits used in drilling were:

Depth interval (meters)	Bit diameter (centimeters)
0 - 132.9	66.04
132.9 - 402.0	43.82
402.0 - 471.2	38.10
471.2 - 612.6	22.86
612.6 - 1,063.1	19.37

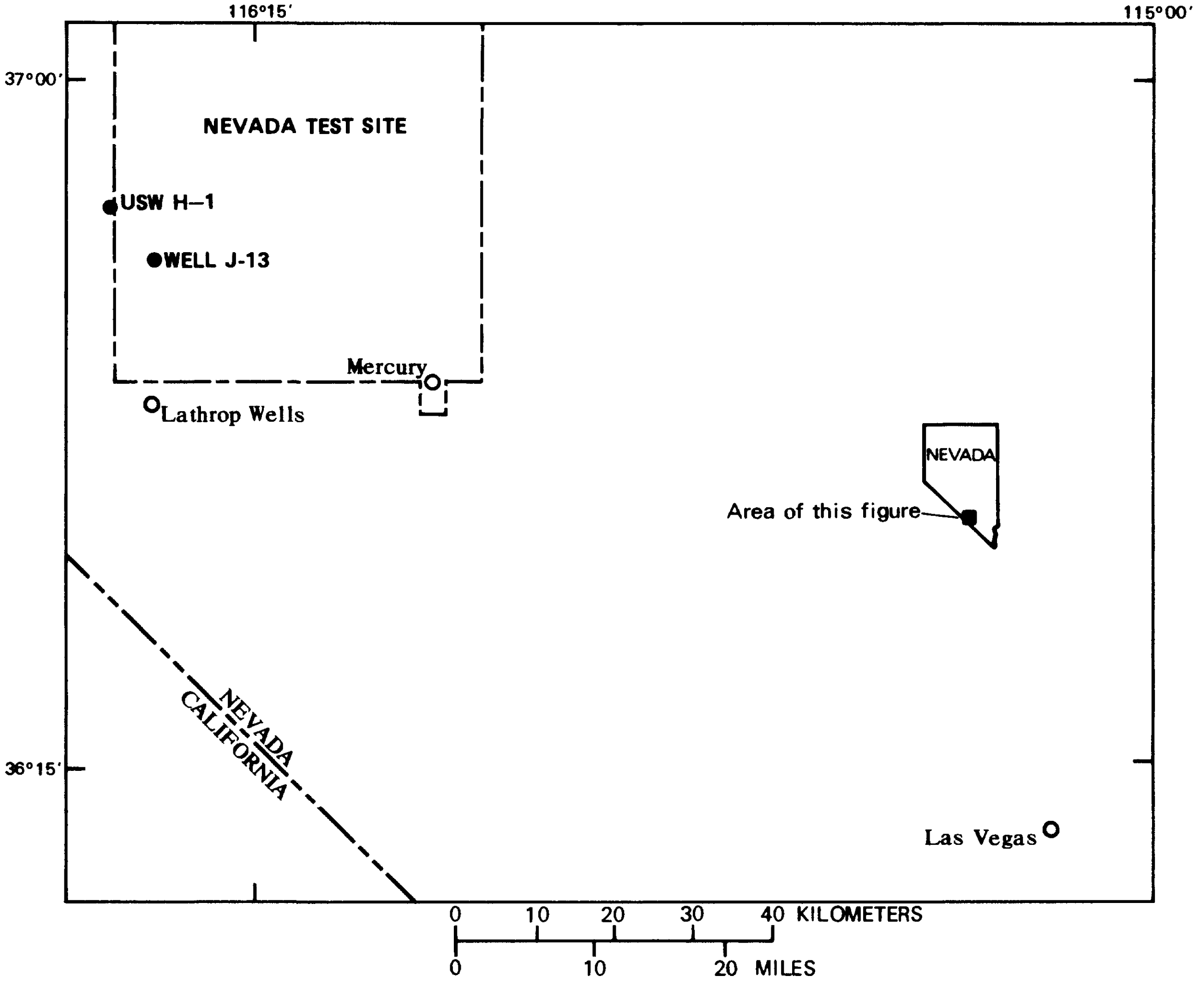


Figure 1.--Location of well J-13 in southern Nevada.

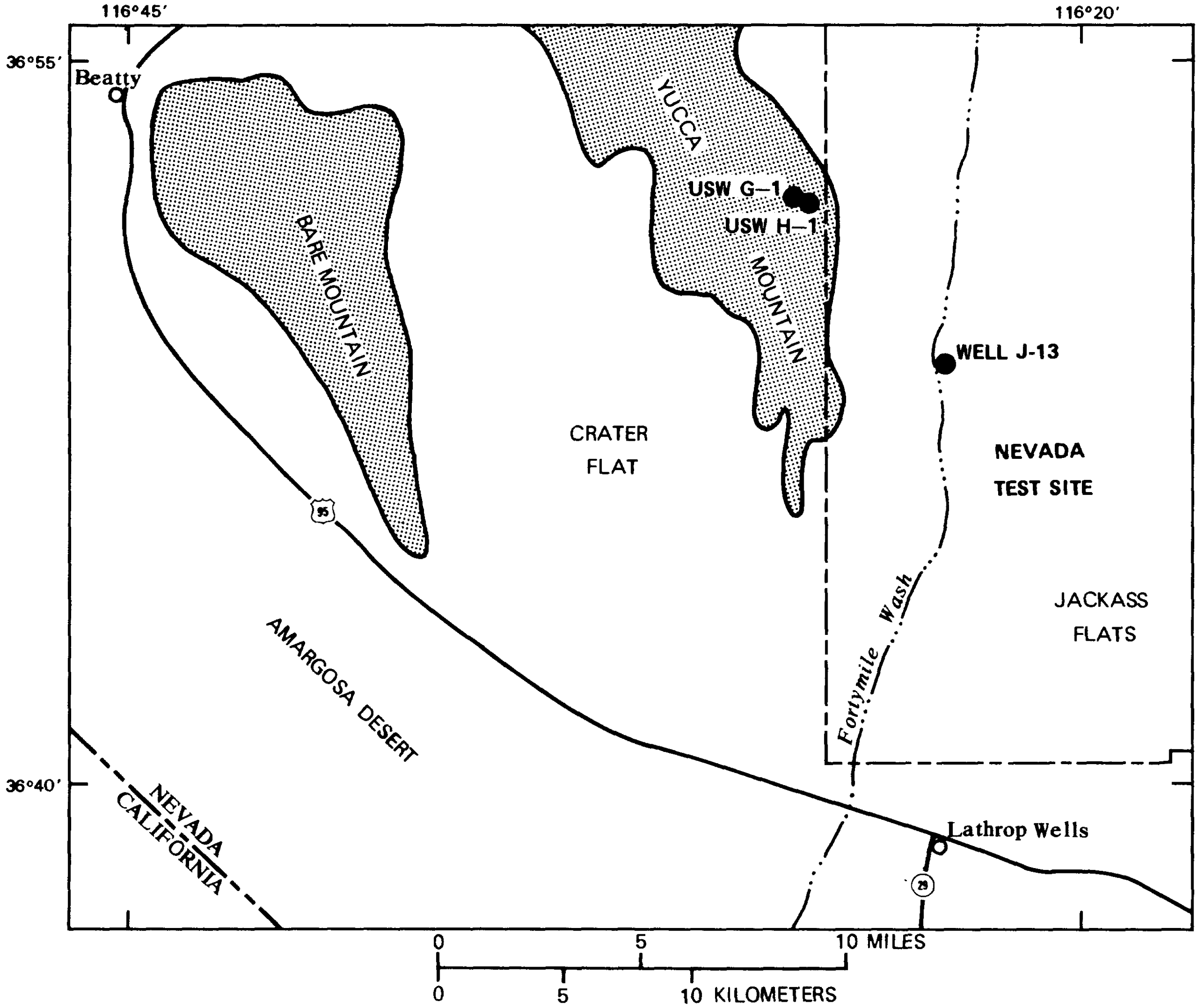


Figure 2.--Location of well J-13 and nearby geographic features.

Table 1.--*Casing, perforation, and cementing record*

[O.D., outside diameter; I.D., inside diameter; m^3, cubic meter; m, meter; cm, centimeter]

Casing O.D., I.D. in parentheses (centimeters)	Depth intervals		Remarks
	Cased (meters)	Perforated (meters)	
76.20	0 - 0.76	None	30 sacks of cement used.
45.72 (44.14)	0 - 132.6	None	Casing cemented to surface with 28.3 m^3 of cement.
33.97 (32.30)	0 - 396.6	303.6- 396.6	Jet perforated at depths from 303.6 to 396.6 m, 1 shot per each 3.05 m of depth. Gun perforated at depths from 332.2 to 396.6 m, 2 shots per each 0.61 m of depth, 1.27-cm diameter bullets; full penetration of bullets believed doubtful, because of little water entry to well.
29.84 (28.15)	396.5- 471.2	396.5- 422.4	Casing cemented by using 4.96 m^3 of cement; computed depth of cement in annulus was not above 423.7 m. Casing joined to 39.97-cm diameter casing with a 39.97- by 29.84-cm swage-nipple; top at depth of 396.6 m, 0.47 m long. Jet perforated at depths from 396.6 to 422.5 m, 1 shot per each 3.05 m of depth. Gun perforated at depths from 396.6 to 423.7 m, 2 shots per each 0.61 m of depth, 1.27-cm diameter bullets; full penetration of bullets doubtful.
13.97 (12.57)	452.3-1,031.8	819.9-1,009.5	Casing liner suspended with a slip-type liner hanger. Perforations machine cut as 0.32- by 5.1-cm openings, 16 rows on 40.6-cm centers.

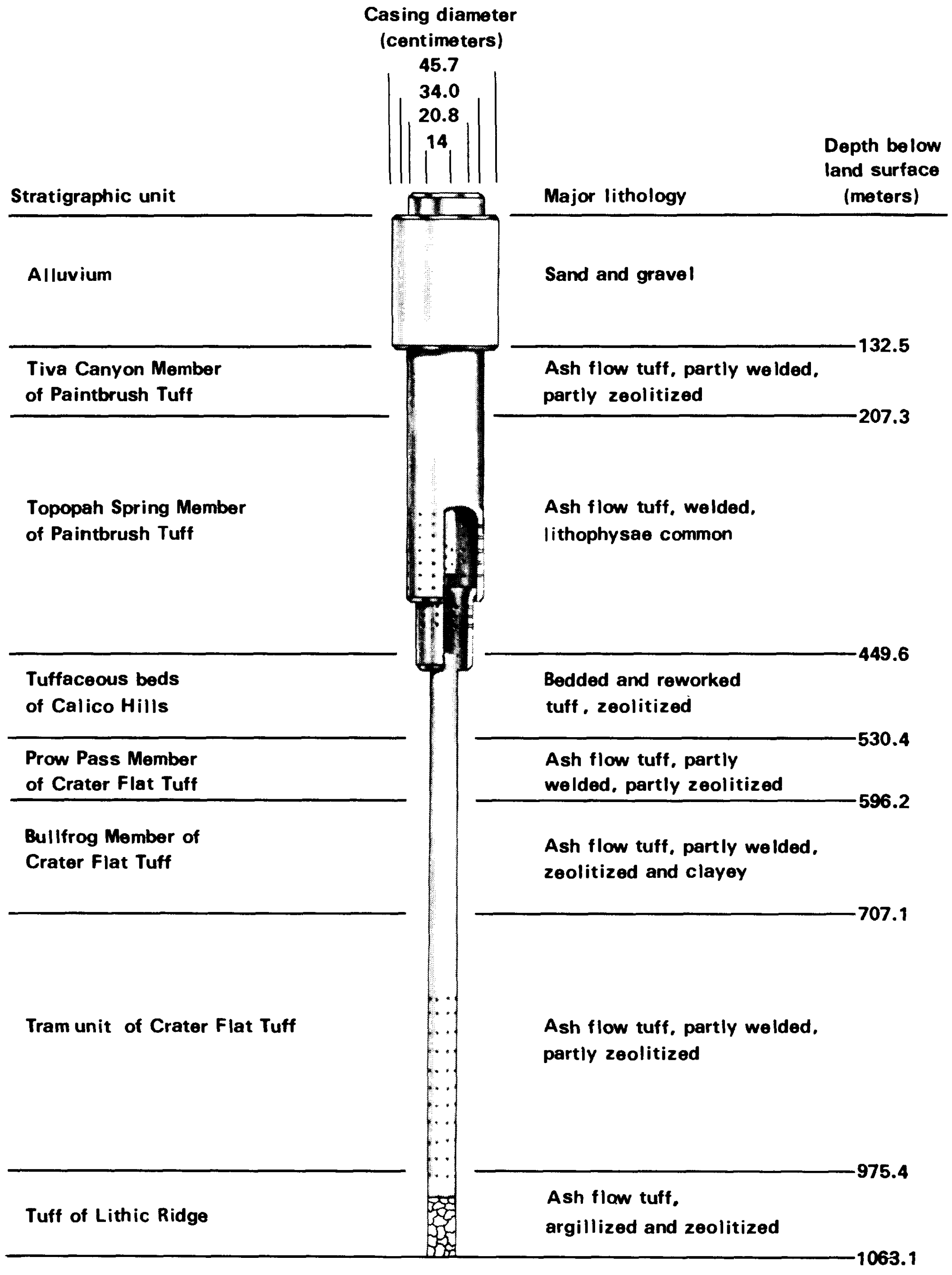


Figure 3.--Well-construction diagram and lithologic units penetrated by well J-13.

Drilling was done by air-hydraulic-rotary equipment; air and detergent foam was the preferred circulation medium. However, stuck drill pipe at depths of 304.2 and 350.2 m necessitated the use of mud or aerated mud as the circulation medium. Diesel fuel, 14,364 L, was used to free the drill pipe. A summary of the recorded use of mud and diesel fuel in the well is presented in table 2. Mud was last used at a depth of 410.6 m, with only a partial return of the mud to the surface; aerated mud was last used between depths of 410.6 and 471.2 m.

The depths at which bridges and cave-ins occurred in the hole and depths at which drill pipe stuck are shown in table 3. Hole-deviation surveys that were run as single-shot surveys using Totco[1] instruments during drilling indicate that the well is approximately vertical, as shown below:

Depth (meters)	Hole deviation (degrees)
56	1.25
91	1.0
109	1.0
123	.75
472	1.75
518	1.08

PHYSICAL SETTING

Geology

Rocks exposed in the Nevada Test Site consist of varied sedimentary rocks of Precambrian and Paleozoic age, volcanic and sedimentary rocks of Tertiary age, and alluvial and playa deposits of Quaternary age (Winograd and Thordarson, 1975; Byers and others, 1976). Sedimentary and metamorphic rocks of Precambrian and Paleozoic age have a total thickness of approximately 11,300 m; they are predominantly limestone and dolomite, but they

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

also include some marble, quartzite, argillite, shale, and conglomerate. Rocks of Paleozoic age have been intruded at a few places by granitic stocks of Mesozoic and Tertiary age, and by basalt dikes of Tertiary and Quaternary age. Overlying rocks of Tertiary age consist principally of tuffs and rhyolite flows of Miocene and Pliocene age that were extruded from the Timber Mountain-Oasis Valley caldera complex, a few miles north of the test well. The alluvium of Tertiary and Quaternary age consists principally of detritus deposited in the intermontane basins.

Table 2.--*Mud and diesel fuel used during drilling*

[cm, centimeter; m, meter; L, liter]

Depth[1] (meters)	Mud and diesel fuel used
0 - 27.1	Mud used to drill 66.04-cm diameter hole.
27.1 - 132.9	Aerated mud used to drill 66.04-cm diameter hole.
132.9 - 304.2	Mud used to drill 43.82-cm diameter hole.
144.5 - 288.0	Widened hole to 22.86-cm diameter using aerated mud. Recovered drill collars.
301.1 - 410.6	Mud used to drill 38.1-cm diameter hole; only partial return of drilling mud.
304.2	6,037 L of diesel fuel added to loosen stuck drill pipe. Shot off drill pipe. Recovered drill pipe.
350.2 - 357.5	8,327 L of diesel fuel added to loosen stuck drill pipe. Shot off drill pipe leaving drill collars and bit in hole. Pumped in mud; recovered 0.76 m of drill pipe.
410.6 - 471.2	Aerated mud, air, and air-foam used to drill 38.1-cm diameter hole.

[1]Listed by increasing depth; not necessarily in chronological order.

Table 3.--*Bridges, cave-ins, and stuck drill pipe during drilling*

Depth (meters)	Bridge in hole	Cave-in during drilling	Drill pipe stuck
93.6	---	X	---
141.7	X	---	---
160.6	---	X	---
208.8	X	---	---
304.2	---	---	X
317.0	X	---	---
317.6	X	---	---
350.2	---	---	X
405.4	X	---	---
472.1	X	---	---
542.8	---	---	X
728.5	X	---	---
893.9	X	---	---
972.3- 993.6	X	---	---
993.6	---	---	X
996.1-1,063.1	X	---	---
1,039.4	X	---	---

Lithology of Strata Penetrated

Well J-13 penetrated alluvium of Quaternary and Tertiary (?) age at depths from 0 to 132.5 m, and tuff of Tertiary age at depths from 132.5 to 1,063.1 m. The Topopah Spring Member of the Paintbrush Tuff, the predominant aquifer, was penetrated at depths from 207.3 to 449.6 m. A generalized lithologic log of the well is presented in table 4 from data provided by Byers and Warren (1983) and in written communications by personnel of the U.S. Geological Survey (A. C. Doyle and G. L. Meyer, 1963; and W. J. Carr, 1981). Units in the tuff are similar to units in the tuff penetrated by other test wells in the Yucca Mountain area. Both cores and cuttings were used to log this well; 49.3 m of cores from 30 cored intervals were

Table 4.--*Generalized lithologic log*

[Modified from W. J. Carr, U.S. Geological Survey, written communication (1981) and Byers and Warren (1983); major units are underscored]

Depth (meters)	Thickness (meters)	Stratigraphic unit	Lithology
0 -132.5	132.5	Alluvium	Sand and gravel; sand, medium to very coarse, grayish orange pink to pale red and light brown; gravel, very fine to boulder, light gray, tuffaceous, composed of tuff and basalt at depths from 48.8 to 100.6 meters.
132.5-449.6	317.1	<u>Paintbrush Tuff</u>:	
132.5-178.9	46.4	Tiva Canyon Member	Tuff, ash flow, grayish red to pale red, partly welded, devitrified; large lithophysae, fractures dip 15 to 85 degrees.
178.9-207.3	28.4	Tiva Canyon Member	Tuff, ash flow, grayish orange pink to light gray, clayey, pumiceous, and zeolitized. Fault (?), 204.2 to 205.7 meters.
207.3-399.3	192.0	Topopah Spring Member	Tuff, ash flow, pale red to light brown, moderately welded and devitrified, lithophysae common, fractures dip 10 to 90 degrees.
399.3-425.2	25.9	Topopah Spring Member	Tuff, ash flow, vitrophyre, black, cemented fractures dip 75 to 80 degrees.
425.2-449.6	24.4	Topopah Spring Member	Tuff, ash flow, partly welded to nonwelded.
449.6-530.4	80.8	<u>Tuffaceous beds of Calico Hills</u>	Tuff, bedded, reworked, and air-fall tuff, very light gray to pale red, zeolitized, some tuffaceous sandstone.

Table 4.--*Generalized lithologic log*--Continued

Depth (meters)	Thickness (meters)	Stratigraphic unit	Lithology
530.4- 975.4	445.0	Crater Flat Tuff:	
530.4- 596.2	65.8	Prow Pass Member	Tuff, ash flow, pale red to pink, partly welded and devitrified, partly zeolitized matrix, minor fractures.
596.2- 614.2	18.0	Bedded tuff	Sandstone, tuffaceous, yellowish gray to light brown, medium to coarse subrounded grains.
614.2- 707.1	92.9	Bullfrog Member	Tuff, ash flow, grayish orange pink to moderate red, partly welded, devitrified, nonwelded near top of unit, zeolitized and clayey-zeolitized; fractures dip 10 to 90 degrees, filled with calcareous cement at depths from 694.9 to 695.6 meters.
707.1- 716.3	9.2	Bedded tuff	Tuff, bedded, zeolitized.
716.3- 975.4	259.1	Tram unit	Tuff, ash flow, very light gray to grayish pink, partly welded, devitrified, commonly zeolitized, abundant lithic fragments in lower part.
975.4- 981.5	6.1	Bedded tuff	Tuff, bedded, zeolitized.
981.5-1,063.1	81.6	Tuff of Lithic Ridge	Tuff, ash flow, pale bluish to grayish green, abundant volcanic lithic fragments; matrix is argillized and zeolitized.

obtained (table 5). Core recovery in most cored intervals was 100 percent; total core recovery was 86.4 percent.

Geophysical Logs

Geophysical logs made in well J-13 were caliper, electrical, laterolog, induction, sonic, acoustic-spontaneous potential, gamma ray-neutron, density, and perforation logs (table 6). The shallowest depth logged was just above the top of the principal aquifer (132.3 m).

Physical Properties

Physical properties, including density, total porosity, water content, percent saturation, and sonic velocities from 24 core samples of tuffaceous rocks in well J-13 are presented in table 7. Total porosity is a measure, in percent, of the ratio of total void spaces in a rock to the total volume of a rock. The welded tuffs have the least total porosity, generally ranging from approximately 4 to 17 percent; total porosity of the partly welded tuffs generally ranges from 20 to 30 percent. The zeolitized tuffs have the greatest total porosity, generally ranging from 26 to 33 percent.

Laboratory values of effective porosity and hydraulic conductivity for eight core samples from the Tiva Canyon Member and Topopah Spring Member of the Paintbrush Tuff are presented in table 8. Effective porosity is a measure, in percent, of the ratio of the interconnected void spaces in the rock matrix to the total volume of a rock. This effective porosity of the rock matrix is differentiated from natural effective porosity that includes both fractures and matrix. Effective porosities in these samples of welded tuff, vitrophyre, and zeolitized clayey pumiceous tuff range from 2.7 to 8.7 percent. Hydraulic conductivities of these samples range from 3×10^{-7} to 4×10^{-3} m/d. A comparison of the effective porosity (5.2 and 3.7 percent) in the two zeolitized clayey pumiceous tuffs at depths of 205.7 and 207.3 m (table 8) with the porosities of the two zeolitized tuff units (54.4 and 31.9 percent) at nearby depths of 203.1 and 203.9 m (table 7) indicates that, although zeolitized tuff has high porosity, effective porosity and hydraulic conductivity are low.

Table 5.--*Cored intervals*

Core number	Depth interval below land surface (meters)	Recovery (percent)
1	57.9 - 59.4	100
2	93.7 - 95.0	100
3	144.3 - 145.8	100
4	160.7 - 161.9	100
5	202.7 - 204.2	100
6	229.4 - 230.9	100
7	240.3 - 241.7	100
8	263.7 - 268.2	13
9	278.5 - 279.1	100
10	310.0 - 311.5	60
11	331.7 - 334.1	100
12	359.7 - 361.5	100
13	390.6 - 392.2	100
14A	405.5 - 406.1	15
14B	406.1 - 407.3	100
15	428.5 - 430.4	100
16	438.9 - 441.3	100
17	458.1 - 460.6	100
18	476.3 - 478.7	69
19	570.9 - 571.2	100
20	607.8 - 610.2	100
21	646.2 - 648.6	100
22	691.9 - 694.3	100
23	722.4 - 724.8	100
24	768.1 - 770.5	100
25	814.4 - 816.9	100
26	862.6 - 864.4	100
27	906.5 - 908.9	6
28	910.4 - 912.9	100
29	985.7 - 988.2	100
30	1,060.7 - 1,063.1	100

Table 6.--*Geophysical logs*

Geophysical log	Depth interval below land surface (meters)
Caliper	132.3 - 536.8
Do.	471.2 - 905.9
Do.	471.2 - 1,046.7
Electrical	202.7 - 248.4
Do.	471.2 - 905.3
Do.	838.2 - 1,050.3
Laterolog	207.3 - 454.2
Induction	132.3 - 454.2
Sonic	187.1 - 535.2
Acoustic-spontaneous potential	471.2 - 904.3
Do.	471.2 - 1,046.7
Gamma ray-neutron	118.9 - 537.1
Do.	471.2 - 905.3
Do.	873.3 - 1,019.9
Density	132.3 - 537.4
Perforation	303.6 - 422.5
Magnetic perforations	303.6 - 422.5

Table 7.--*Physical-property data for lithologic units penetrated*

[Analysts, E. F. Monk and John Moreland, U.S. Geological Survey; leaders (--) indicate no data; m, meter; g/cm^3, grams per cubic centimeter; m/s, meters per second]

Lithologic unit	Depth below land surface (m)	Rock type	Laboratory No.	Dry-bulk density mercury displacement (g/cm^3)	Grain density (powder method)	Calculated porosity (percent)
Tiva Canyon Member	161.7	Welded tuff	409	2.31	2.52	8.1
Do.	203.1	Zeolitized tuff	410	1.05	2.31	54.4
Do.	203.9	do.	411	1.76	2.58	31.9
Topopah Spring Member	241.5	Welded tuff	412	2.08	2.50	16.7
Do.	263.7- 268.2	do.	413	2.13	[1]2.54	16.2
Do.	278.9	do.	414	2.31	2.60	11.0
Do.	310.9	do.	415	2.28	2.63	13.1
Do.	333.4	do.	416	1.89	2.62	27.9
Do.	360.8	do.	417	2.71	2.63	16.0
Do.	391.2	do.	418	2.31	2.64	12.3
Do.	406.0- 407.2	Vitrophyre	419	2.31	2.40	3.7
Do.	429.0	Welded tuff	420	2.12	2.40	11.6
Do.	440.6	Zeolitized tuff	421	1.60	2.38	32.7
Tuffaceous beds of Calico Hills	459.9	do.	422	1.73	2.46	29.9
Do.	476.1- 478.5	do.	423	----	2.41	----
Prow Pass (?) Member	610.0 (?)	Partly welded tuff	424	1.74	2.50	30.2
Bullfrog Member	618.0	Zeolitized tuff	425	1.92	2.63	27.1
Do.	648.6	Partly welded tuff	426	1.89	2.62	27.6
Do.	693.7	Welded tuff	427	2.07	2.64	21.4
Tram unit	724.5	Zeolitized tuff	428	1.95	2.68	27.2
Do.	815.3	Partly welded tuff	429	2.09	2.62	20.3
Do.	862.9	do.	430	2.20	2.63	16.5
Do.	911.0	Zeolitized tuff	431	1.93	2.61	26.0
Tuff of Lithic Ridge	1,062.8	Partly welded tuff	432	2.12	2.66	20.3

Table 7.--*Physical-property data for lithologic units penetrated*--Continued

Lithologic unit	Water content (percent by weight)	Water content by volume (g/cm^3)	Natural-state bulk density	Calculated saturated bulk density (g/cm^3)	Percent saturation at natural state	Longitudinal velocity (m/s)	Transverse velocity (m/s)
Tiva Canyon Member	2.5	0.058	2.37	2.39	71.6	4,169	2,800
Do.	24.6	.345	1.40	1.60	63.3	-----	-----
Do.	2.4	.256	2.01	2.07	80.2	-----	-----
Topopah Spring Member	7.1	.159	2.24	2.25	95.5	-----	-----
Do.	6.1	.139	2.27	2.29	85.9	-----	-----
Do.	3.9	.093	2.40	2.42	84.6	-----	-----
Do.	4.7	.113	2.40	2.41	86.3	-----	-----
Do.	11.9	.225	2.15	2.17	91.2	2,759	1,624
Do.	5.6	.131	2.34	2.37	81.9	3,921	2,631
Do.	4.0	.097	2.41	2.43	79.0	4,072	2,687
Do.	10	.024	2.33	2.35	64.4	4,997	2,989
Do.	4.0	.090	2.21	2.24	76.9	3,824	2,458
Do.	16.2	.310	1.91	1.93	94.6	-----	-----
Tuffaceous beds of Calico Hills	13.5	.269	2.00	2.03	90.0	2,138	1,343
Do.	23.5	-----	----	Unconsolidated		-----	-----
Prow Pass (?) Member	13.8	.280	2.02	2.04	92.5	-----	-----
Bullfrog Member	11.5	.250	2.17	2.19	92.5	3,328	1,985
Do.	11.0	.234	2.13	2.17	84.7	-----	-----
Do.	8.7	.197	2.27	2.29	91.9	3,878	2,296
Tram unit	10.8	.236	2.19	2.22	86.8	-----	-----
Do.	6.5	.144	2.23	2.29	70.9	-----	-----
Do.	6.3	.148	2.35	2.36	89.8	3,612	2,174
Do.	10.9	.236	2.16	2.19	90.9	2,689	1,721
Tuff of Lithic Ridge	7.3	.167	2.28	2.32	82.4	2,451	1,604

[1]All other data are based on powder method in water; this is based on powder method in kerosene.

Table 8.--*Laboratory analysis of effective porosity and hydraulic conductivity from the Tiva Canyon Member and the Topopah Spring Member of the Paintbrush Tuff*

[Effective porosity determined by water-saturation method; hydraulic conductivity determined using Denver, Colo., tap water. Analyses by U.S. Geological Survey, Denver, Colo.]

Formation	Depth (meters)	Lithology	Effective porosity (percent)	Hydraulic conductivity (meters per day)
Tiva Canyon				
Member----------	164.3	Welded tuff	2.8	3×10^{-7}
Do.---------------	205.7	Zeolitized tuff	5.2	4×10^{-3}
Do.---------------	207.3	do.	3.7	2×10^{-6}
Topopah Spring				
Member----------	244.1	Welded tuff	2.7	3×10^{-6}
Do.---------------	335.3	do.	8.7	2×10^{-4}
Do.---------------	363.6	do.	6.8	8×10^{-6}
Do.---------------	409.0	Vitrophyre	5.4	8×10^{-7}
Do.---------------	431.6	Partly welded tuff	3.3	3×10^{-7}

Estimates of porosity in the uncaved and little-fractured parts of the well are shown in table 9. Estimates were made from sonic logs by plotting sonic velocities for the cored intervals listed in table 7 against the porosity values determined in the laboratory, and then using relationships from these plots to derive porosity from sonic velocities on the well logs. Values of porosity are similar to those for similar lithologies shown in table 7.

GROUND-WATER HYDROLOGY

Ground water in rocks penetrated by well J-13 occurs in densely to partly welded ash-flow tuffs, and in zeolitic and clayey bedded tuffs,

Table 9.--*Estimated porosities from sonic logs*

Formation	Depth interval (meters)	Lithology	Sonic velocities (microseconds per meter)	Estimated porosity (percent)
Topopah Spring Member----------	296 - 302	Welded tuff	246 - 312	12 - 25
Do.---------------	333 - 341	do.	312 - 377	25 - 30
Do.---------------	399 - 425	Vitrophyre	190 - 230	3 - 9
Tuff of Calico Hills-----------	485 - 511	Zeolitized tuff	312 - 377	24 - 28
Bullfrog Member---	640 - 652	Zeolitized partly welded tuff	262 - 328	24 - 28
Do.---------------	652 - 689	Clayey zeolitized tuff	230 - 262	23 - 27
Do.---------------	689 - 704	Zeolitized welded tuff	246 - 279	16 - 22
Tram unit---------	750 - 809	Zeolitized nonwelded to partly welded tuff	246 - 328	15 - 28
Do.---------------	809 - 869	Partly welded tuff	230 - 279	12 - 20
Do.---------------	869 - 902	Nonwelded to partly welded tuff	256 - 302	16 - 23
Do.---------------	902 - 975	do.	262 - 328	17 - 28
Bedded tuff-------	975 - 981	Bedded tuff	262 - 312	24 - 25
Tuff of Lithic Ridge-----------	981 - 1,045	Zeolitized tuff and breccia	256 - 305	24 - 25

tuffaceous sandstone, and tuffaceous breccia. The predominant aquifer is the welded tuff of the Topopah Spring Member of the Paintbrush Tuff, in which water occurs principally in fractures. The other tuff units are confining units, with hydraulic conductivities less than 0.15 m/d. Ground-water investigations associated with this well consisted of water-level monitoring, swabbing tests, injection tests, and pumping tests.

Water-Level Monitoring

During drilling, well J-13 was monitored for perched water in the unsaturated zone, and for static water levels in the saturated zone. In the unsaturated zone, little water was observed. The initial static water level was 282.2 m below land surface, after the hole had reached a depth of 334.1 m in the welded tuff of the Topopah Spring Member of the Paintbrush Tuff, the principal aquifer. Results of monitoring static water level during hydraulic testing and well construction are presented in table 10. These data indicate that static water levels to a well depth of 645.6 m are approximately that of the initial static water level of 282.2 m. However, in swabbing test 11, a lower static water level was measured in the Tram unit of the Crater Flat Tuff for the depth interval from 772.7 to 803.1 m, which had an approximate static water level of 283.6 m. In swabbing test 20, in the depth interval 819.9 to 1,063.1 m at the bottom of the well, the depth to static water level was 283.3 m. Accuracy of these static water levels depends on the seal of the packers during testing, if there was no bypassing of the packers along fractures, and if recovery of water level was complete in a relatively short time for hydraulic testing. These conditions were not evaluated. A deep-well water-level measuring device, the "iron horse" (Weir and Nelson, 1976), was used to monitor water levels in this well.

Altitude of the original static water level was 729.1 m above sea level, which is approximately the altitude of the regional water table in carbonate rocks of Paleozoic age in nearby areas.

After construction of the well, static water levels were monitored in the Topopah Spring Member and in the underlying confining beds (table 11). These static water levels probably are those in the Topopah Spring Member. Between 1962 and 1969, static water level declined from 282.5 to 283.3 m,

Table 10.--*Static water levels during hydraulic testing and construction*

Type of test and No.	Interval tested (meters)	Depth to static water level (meters)	Geologic unit tested
-------------	282.2 - 334.1	282.2	Topopah Spring Member
Pumping 1	282.5 - 451.1	282.5	Do.
Pumping 2	282.7 - 451.1	282.7	Do.
Injection 19	471.2 - 502.0	282.5	Tuffaceous beds of Calico Hills
Swabbing 19	471.2 - 502.0	282.3	Do.
Injection 16	501.1 - 562.1	282.4	Tuffaceous beds of Calico Hills and Prow Pass Member
Swabbing 18	501.1 - 562.1	282.2	Do.
Swabbing 2	471.2 - 612.6	282.0	Tuffaceous beds of Calico Hills, Prow Pass Member, and tuffaceous sandstone
Swabbing 3	471.2 - 612.6	282.4	Do.
Swabbing 6	471.2 - 661.4	282.1	Tuffaceous beds of Calico Hills, Prow Pass Member, tuffaceous sandstone, and Bullfrog Member
Injection 15	584.6 - 645.6	282.4	Prow Pass Member, tuffaceous sandstone, and Bullfrog Member
Swabbing 11	772.7 - 803.1	[1]283.6±2	Tram unit
Swabbing 20	819.9 - 1,063.1	283.3	Tram unit, bedded tuff, and Tuff of Lithic Ridge

[1]Nearly recovered to static water level after 270 minutes.

Table 11.--*Static water levels after completion*

Date	Depth to water level below land surface (meters)
12-30-62	282.5
01-01-63	282.5
02-04-63	282.8
11-27-63	282.9
12-17-63	282.8
12-19-63	283.1
02-04-64	282.7
02-07-64	282.9
03-11-67	283.1
04-21-69	283.3
08-20-80	282.4

possibly because the well was pumped nearly continuously for many years. However, by 1980, the static water level had recovered to 282.4 m, because of decreased pumping of the well.

Methods of Hydraulic Testing and Analysis

To determine the transmissivity and hydraulic conductivity of the materials penetrated by the well, 22 hydraulic tests were made at various depths. Depth intervals, types of hydraulic tests, and transmissivity and hydraulic-conductivity values developed from the test data are shown in table 12. Two pumping tests, nine swabbing tests, and seven injection tests provided usable data. Some swabbing and injection tests failed because packers failed or because, as in the case of the Topopah Spring Member, the hole was caving so much that packers could not be set securely.

Pumping tests were analyzed using both the straight-line solution and Stallman's method for unconfined anisotropic aquifers that account for vertical-flow components (Lohman, 1979; Stallman, 1965). A conceptual

Table 12.--*Transmissivity and hydraulic conductivity obtained from hydraulic tests*

[m, meter; m^2/d, square meter per day; m/d, meter per day; L/s, liter per second; min, minute]

Type of test and No.	Depth interval tested (m)	Estimated transmissivity (m^2/d)	Estimated average hydraulic conductivity (m/d)	Geologic unit tested	Water withdrawal rate (L/s)	Water withdrawal period (min)	Remarks
Pumping 1	303.6 - 422.5	120	1.0	Topopah Spring Member	18.9 to 27.1	3,155	Perforated casing. Pumped 5 million liters. Step-drawdown test. Bridge plug at 451.6 meters.
Pumping 2	303.6- 422.5	------	------	do.	27.8 to 31.5	360	Perforated casing. Pumped 645,000 liters. Step-drawdown test. Bridge plug at 451.6 meters.
Pumping 3	303.6- 422.5, 819.9-1,009.5	140	[1] -----	Topopah Spring Member, Tram unit, bedded tuff, and Tuff of Lithic Ridge	44.0	5,500	Perforated casing. Pumped 15.2 million liters. Drawdown test.
Injection 19	471.2- 502.0	4.5	.15	Tuffaceous beds of Calico Hills	-----	-----	Slug-injection test, between two straddle packers.
Swabbing 19a	471.2- 502.0	2.9	.094	do.	-----	-----	Single-swabbing test, between two straddle packers.
Swabbing 19b	471.2- 502.0	3.9	.13	do.	2.27	63	19 swab trips, 8,560 liters removed.
Injection 16	501.1- 562.1	.78	.013	Tuffaceous beds of Calico Hills and Prow Pass Member	-----	-----	Slug-injection test, between two straddle packers.
Swabbing 18	501.1- 562.1	1.6	.026	do.	2.65	58	16 swab trips, 9,240 liters removed.
Injection 21	505.4- 565.7	.34	.0057	do.	-----	-----	Slug-injection test, between two straddle packers.
Swabbing 21	505.4- 565.7	.37	.0062	do.	-----	-----	Single-swabbing test, between two straddle packers.
Swabbing 4	471.2- 612.6	1.9	.013	Tuffaceous beds of Calico Hills, Prow Pass Member, and bedded tuff	2.80	78	20 swab trips, no packers, 13,100 liters removed.

Table 12.--*Transmissivity and hydraulic conductivity obtained from hydraulic tests*--Continued

Type of test and No.	Depth interval tested (m)	Estimated transmissivity (m^2/d)	Estimated average hydraulic conductivity (m/d)	Geologic unit tested	Water withdrawal rate (L/s)	Water withdrawal period (min)	Remarks
Swabbing 6a	471.2- 661.4	1.8	0.0095	do.	3.16	40	12 swab trips, no packers, 7,590 liters removed.
Injection 15	584.6- 645.6	.55	.0090	Prow Pass Member, bedded tuff, and Bullfrog Member	-----	-----	Slug-injection test, between two straddle packers.
Injection 14	639.8- 670.3	.088	.0029	Bullfrog Member	-----	-----	Slug-injection test, between two straddle packers.
Injection 13	668.7- 699.2	.48	.016	do.	-----	-----	Slug-injection test, between two straddle packers.
Injection 12	719.3- 749.8	.10	.0033	Bedded tuff, Bullfrog Member, and Tram unit	-----	-----	Slug-injection test, between two straddle packers.
Swabbing 11	772.7- 803.1	.17	.0056	Tram unit	-----	-----	Single-swabbing test, between two straddle packers.
Swabbing 8	471.2- 912.9	3.9	.0088	Tuffaceous bed of Calico Hills, Prow Pass Member, bedded tuff, Bullfrog Member, and Tram unit	3.43	48	17 swab trips, no packers, 9,800 liters removed.
Swabbing 20	819.9-1,063.1	.63	.0026	Tram unit, bedded tuff, and Tuff of Lithic Ridge	-----	-----	Single-swabbing test, below bottom straddle packer.

[1] Hydraulic conductivity not calculated because the well yielded water from two intervals of unequal transmissivities.

model is desirable to explain the applicability of Stallman's method to the pumping tests. This conceptual model is described by an unconfined highly fractured aquifer in which both the hydraulic conductivity and the effective storage capacity are predominantly within interconnecting fractures.

The evidence that supports the conceptual model is:

1. The highly fractured aquifer tested by pumping tests is the moderate-to-densely welded tuff of the Topopah Springs Member of the Paintbrush Tuff; the high density of fractures is 42 fractures per unit meter cubed in the Yucca Mountain area (R. B. Scott, U.S. Geological Survey, written commun., 1982).
2. Fractures intersect in at least two sets of steeply dipping fractures; some fractures dip at low angles (R. B. Scott, U.S. Geological Survey, written commun., 1982).
3. The total porosity in the welded tuff aquifer averages 14.3 percent (table 7); the effective porosity averages 5.4 percent (table 8); the hydraulic conductivity averages 4.2×10^{-5} m/d; and the porosity averages 82.9 percent in water saturation (table 8).
4. Unconfined water-table conditions probably occur in the highly fractured welded tuff because the water table is 76.5 m below the top of the aquifer, indicating that there is no confining bed.

These data indicate that Stallman's method probably is applicable to the conceptual model of a highly fractured welded tuff in which fracture-hydraulic conductivity is predominant, and in which vertical fractures allow instantaneous release of water from storage as the water table is lowered. The low effective porosity and low hydraulic conductivity of the matrix indicates that only a minor part of the water is from storage in the matrix. Applicability of Stallman's method to the pumping tests results from the principal flow conditions in the conceptual model being the same as those assumed by Stallman, namely: (1) All storage comes from movement of the free surface; (2) vertical-flow components are accounted for; and (3) anisotropy is considered (Stallman, 1965).

An alternative conceptual model based on boundaries also was considered for pumping tests for this report, because of the possibility that boundaries may have been intercepted shortly after pumping began. This conceptual model considers the early-time straight-line portion of the drawdown curve during pumping test 3 as representing the aquifer conditions; the later-time steepening of the drawdown curve might then be attributed to discharge boundaries. This alternate conceptual model is considered to be less likely than the model proposed for the application of Stallman's method, although the results for both are included under results. A known but concealed fault located approximately 330 m northwest of well J-13 may or may not be a hydrologic boundary. The fault displaces other older tuffaceous beds against the aquifer, the Topopah Spring Member (Lipman and McKay, 1965).

Pumping tests 1 and 2 were run as step-drawdown tests to determine head losses in the well from turbulent flow at the wellbore and in the aquifer. These pumping tests were analyzed using both Jacob's method (1947) and the Jacob-Rorabaugh equation (Rorabaugh, 1953; Lewis Howells, U.S. Geological Survey, written commun., 1982); results provided anomalous numbers that are not presented. The effects of vertical-flow components, delayed yield, or boundaries probably prevented determination of the well-loss constants.

Swabbing tests consisted of either single-swabbing tests or multiple-swabbing tests, conducted in the open uncased hole, or in intervals that were between two straddle packers or below the straddle packers. Swabbing tests consisted of lowering two swabs on the end of steel rods below the water level in the drill stem, and then raising the swabs that expand to fit the drill stem, resulting in raising the column of water above the swabs out of the hole. Single-swabbing tests were analyzed as slug tests using a method of Cooper and others (1967), and Papadopulos and others (1973). However, in these single-swabbing tests, maximum drawdown had to be estimated from the first measured rate of rise of water level, because 4 or 5 minutes elapsed between swab removal and water-level measurements; therefore, the first water levels during swabbing indicate less than maximum drawdown. Multiple-swabbing tests were analyzed using the Theis recovery method (Ferris and others, 1962). Discharges during the multiple-swabbing tests were measured accurately; discharges during the single-swabbing tests were not measured accurately.

Injection tests consisted of slug tests of a full column of water within a tubing with 8.890-cm outside diameter and 7.793-cm inside diameter; water was injected as a slug into depth intervals between or below two straddle packers or below a single packer. These injection tests were analyzed as slug tests (Cooper and others, 1967; Papadopulos and others, 1973).

The effects of wellbore storage that were prominent during early parts of the swabbing and injection tests were minimized by drawing a unit-slope straight line on a log-log plot of Δp and Δt (Earlougher, 1977). This plot showed the dominance of wellbore-storage effects during early parts of the swabbing and injection tests. The first point to depart from the unit-slope straight line is marked on the analyses of the swabbing and injection tests; only data after this point are analyzable for transmissivity and hydraulic conductivity. Using late-time recovery data is effective in eliminating wellbore storage and skin effects that are less pronounced near the ends of the tests.

Results of Hydraulic Testing

Values of transmissivity and hydraulic conductivity for each of the two pumping tests, seven injection tests, and nine swabbing tests are given in table 12. Graphical data plots and analysis of pumping, slug injection, and swabbing tests are shown in figures 4 through 24. In general, pumping tests indicate that the predominant aquifer, the Topopah Spring Member of the Paintbrush Tuff, has an estimated transmissivity of 120 m^2/d and an estimated hydraulic conductivity of 1.0 m/d. Swabbing and injection tests indicate that the welded tuffs and bedded or reworked tuffs beneath the Topopah Spring Member are confining beds with transmissivities of 0.088 to 4.5 m^2/d, and hydraulic conductivities of 0.0026 to 0.15 m/d. Although these values are small for the confining beds, the values obtained for any given depth interval contain some uncertainty because the analysis was not fully diagnostic. For this reason, and because the packers may have leaked in some tests and because of possible leakage to or from the annulus at the base of the casing, the transmissivities and hydraulic conductivities are given as estimated values in table 12.

Results of pumping test 1 using Stallman's method indicate that the aquifer in the Topopah Spring Member of the Paintbrush Tuff in the depth interval from 303.6 to 422.5 m has a transmissivity of 120 m^2/d and an average hydraulic conductivity of 1.0 m/d (fig. 5, table 2). Using the

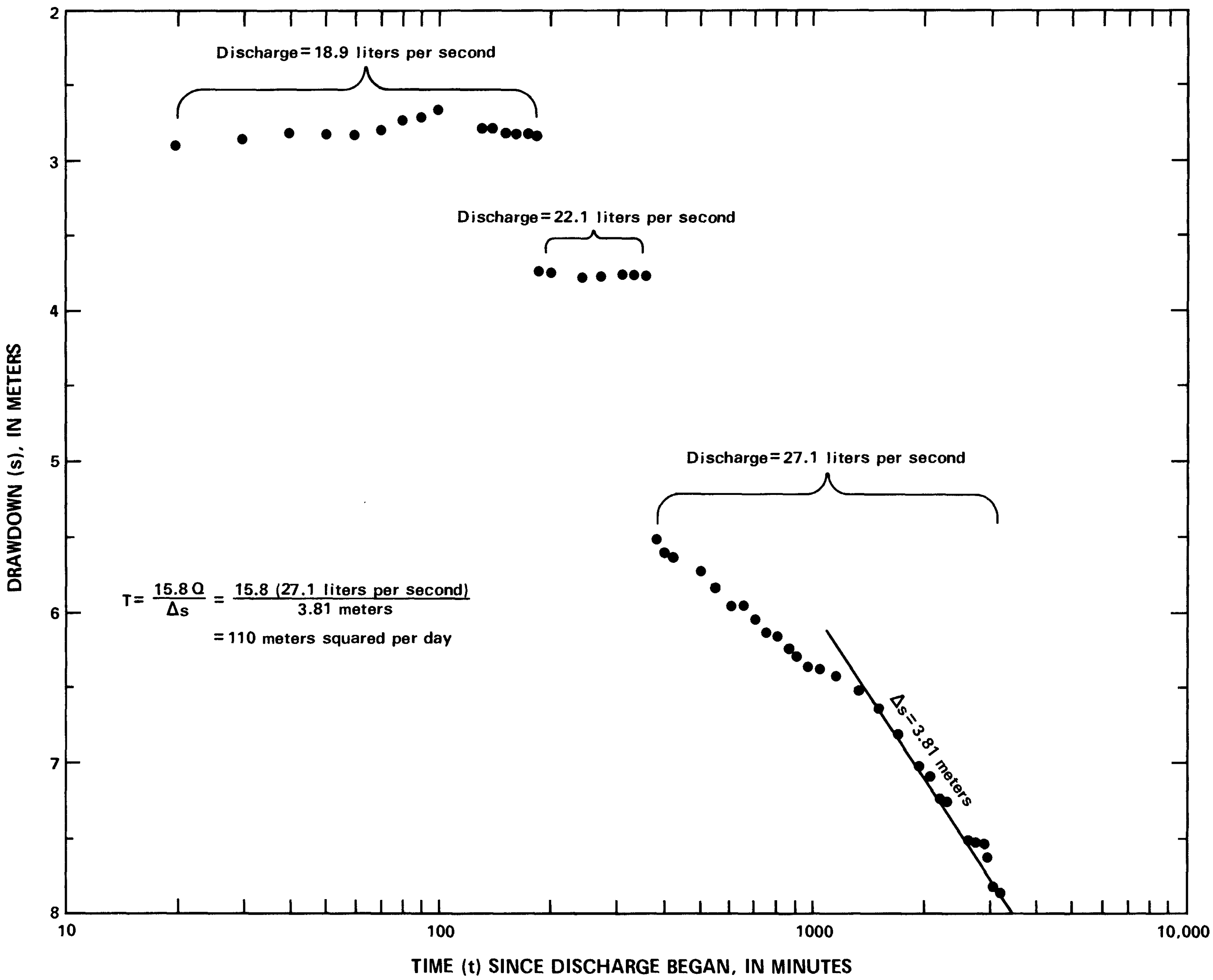


Figure 4.--Drawdown and analysis of drawdown during step-drawdown tests of pumping test 1, straight-line method.

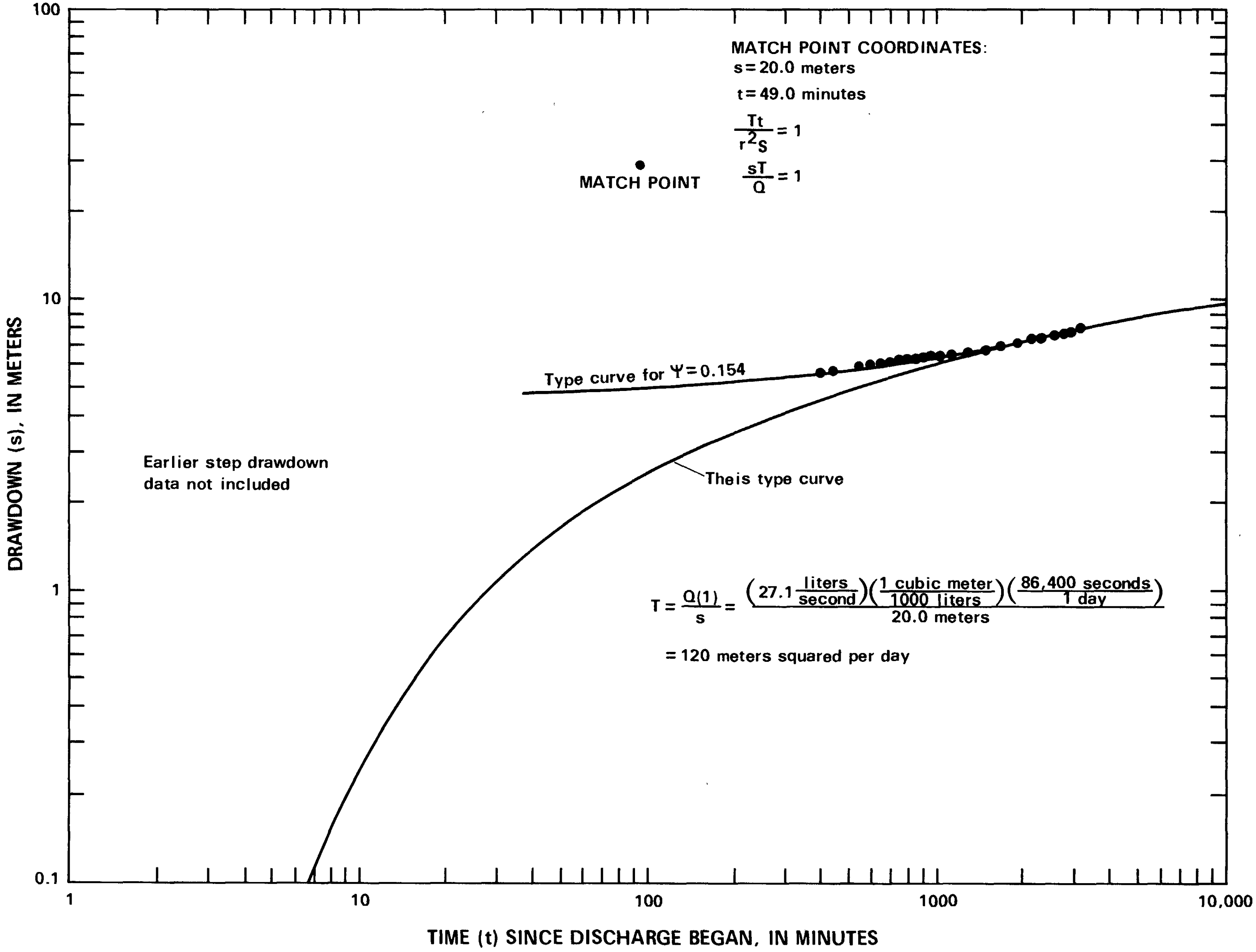


Figure 5.--Drawdown and analysis of drawdown during step-drawdown test of pumping test 1, Stallman's method.

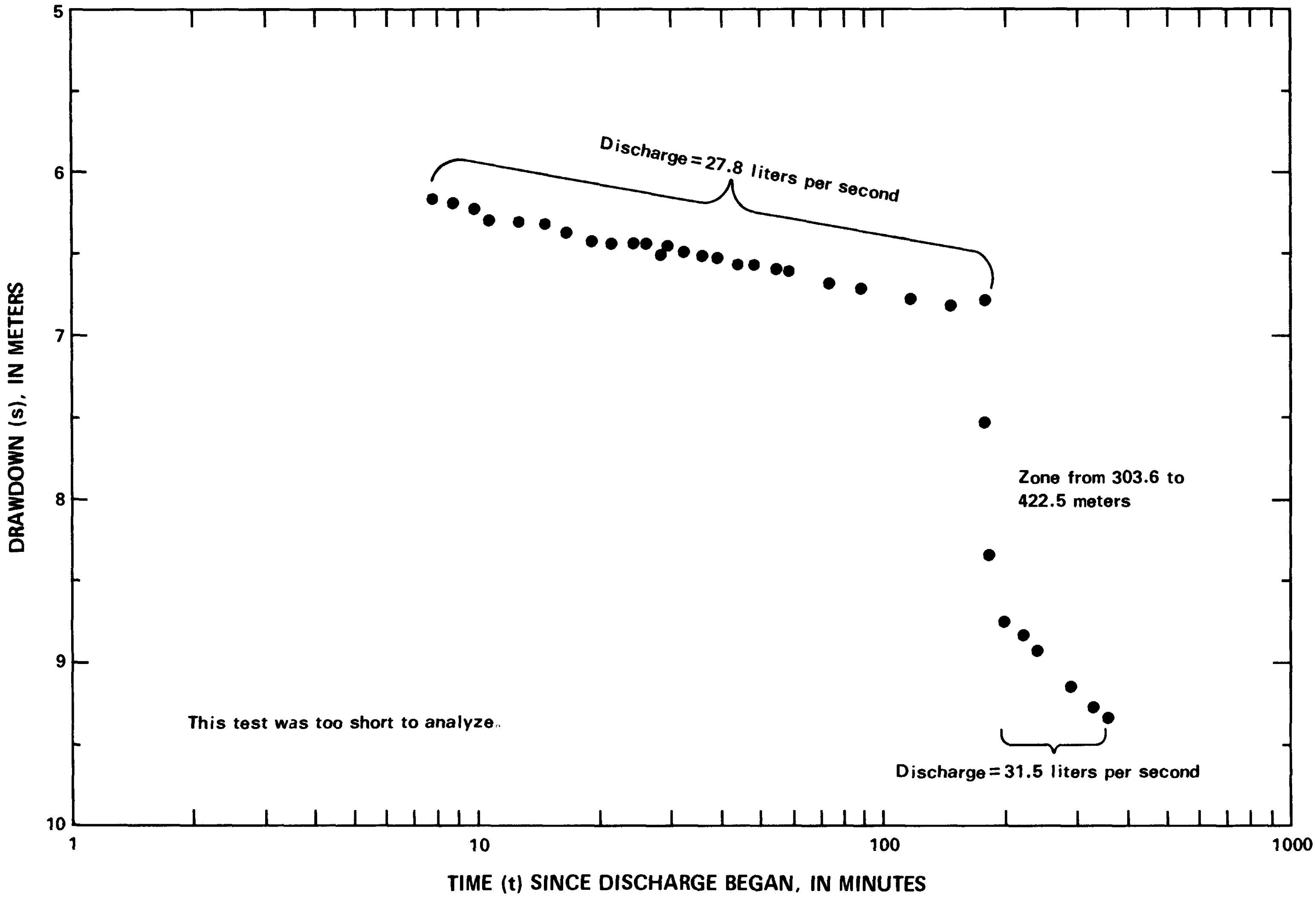


Figure 6.--Drawdown during step-drawdown test of pumping test 2.

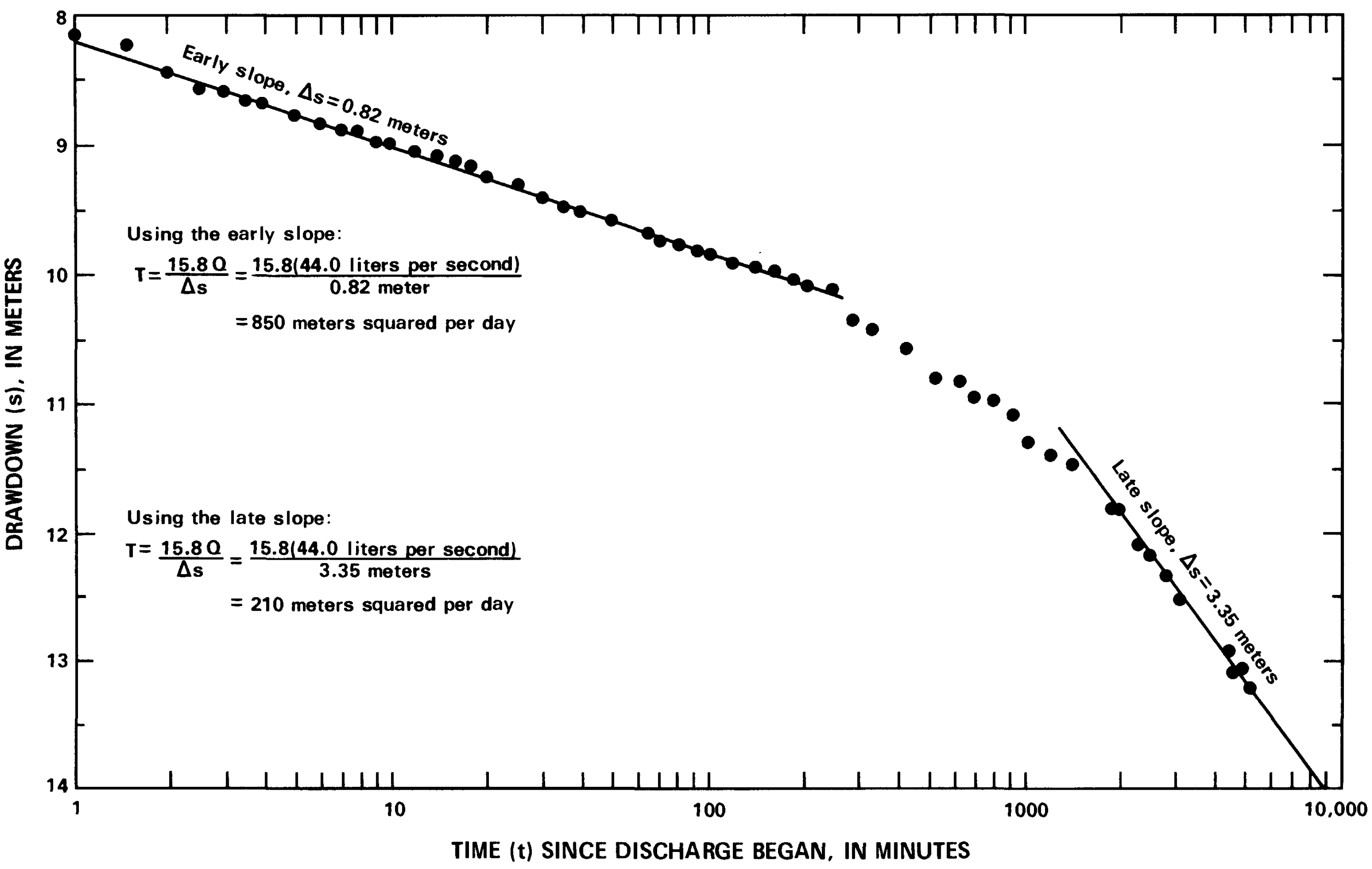


Figure 7.--Drawdown and analysis of drawdown during pumping test 3, straight-line method.

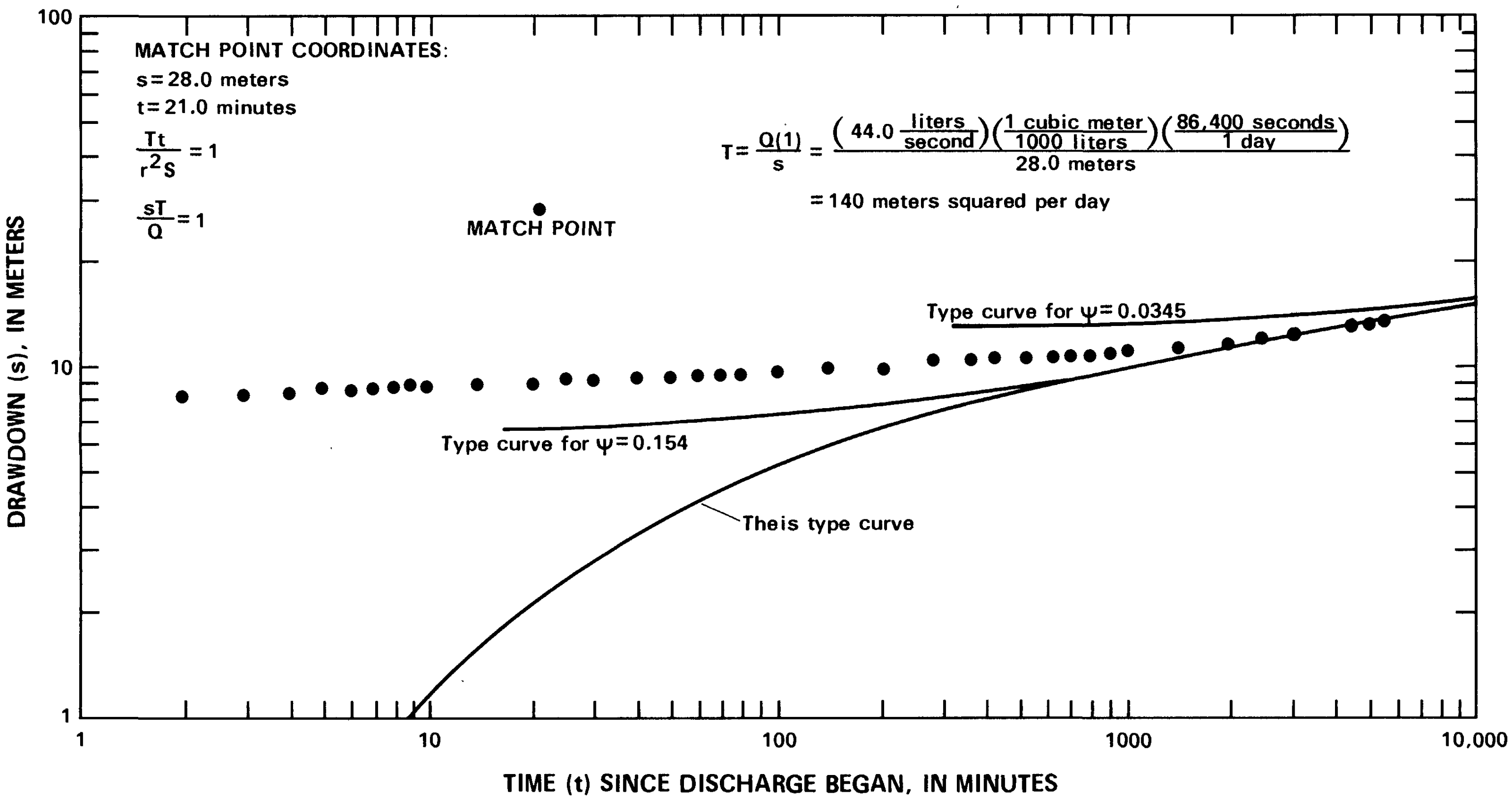
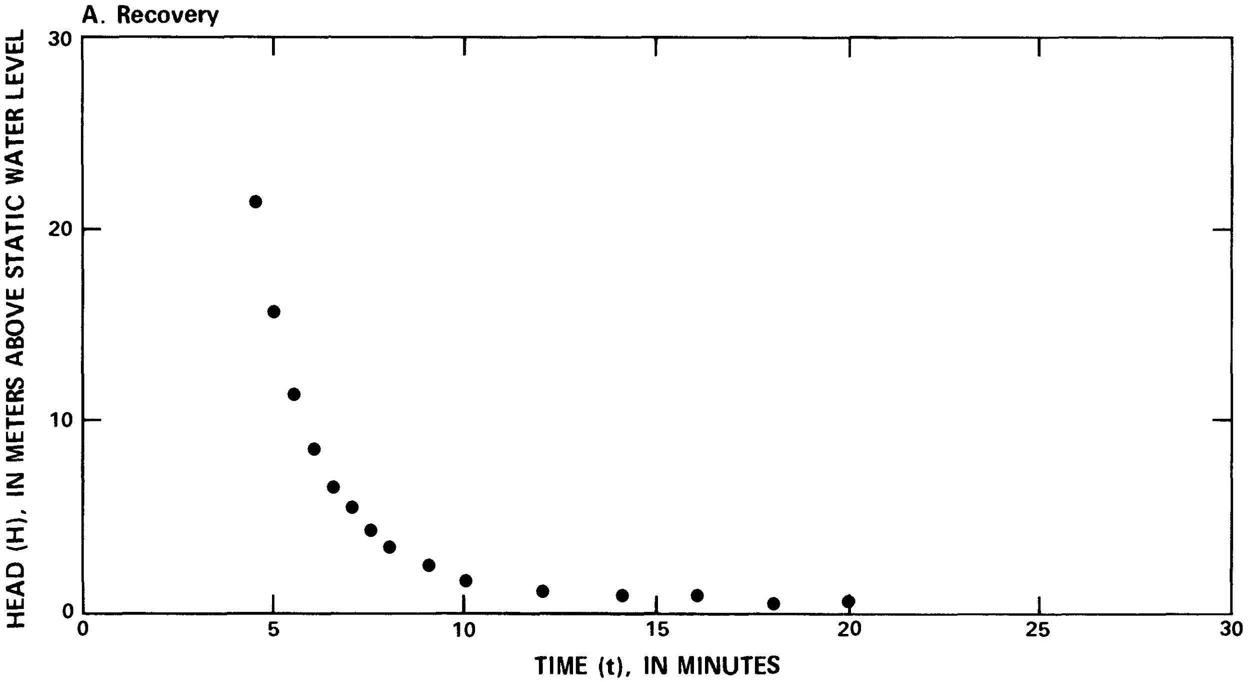


Figure 8.--Drawdown and analysis of drawdown during pumping test 3, Stallman's method.



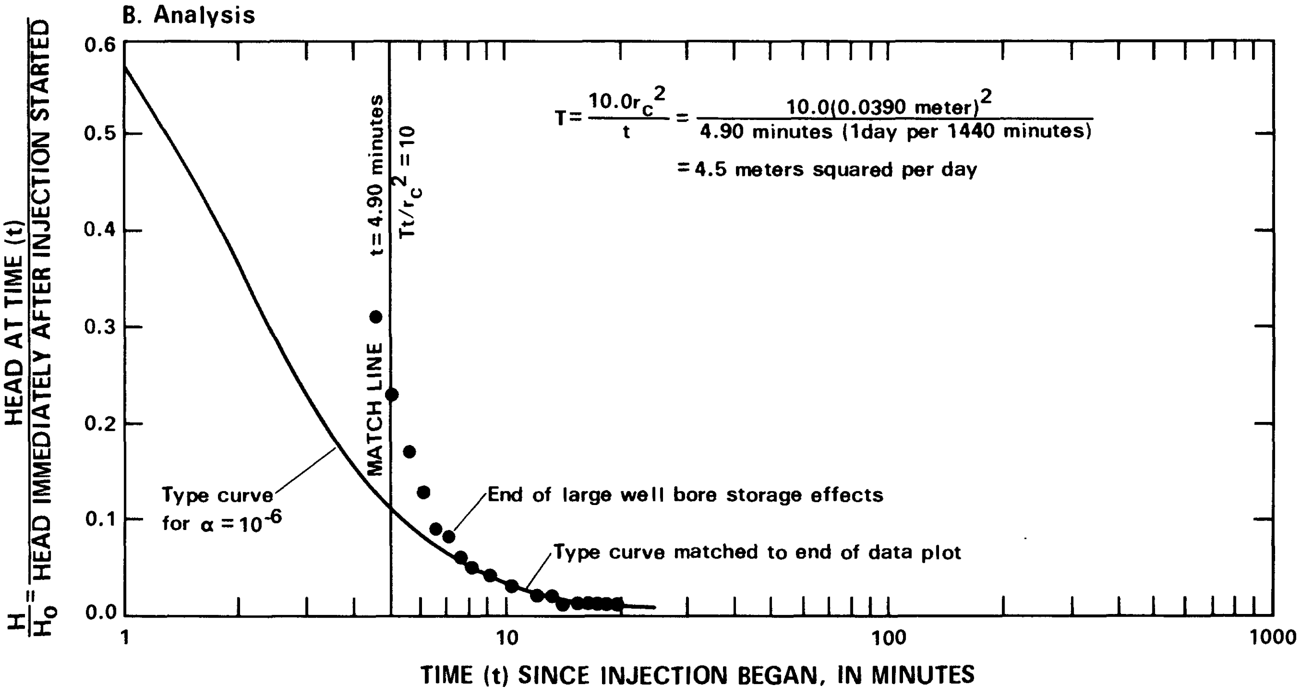


Figure 9.--Recovery and analysis of water-level recovery during slug-injection test 19.

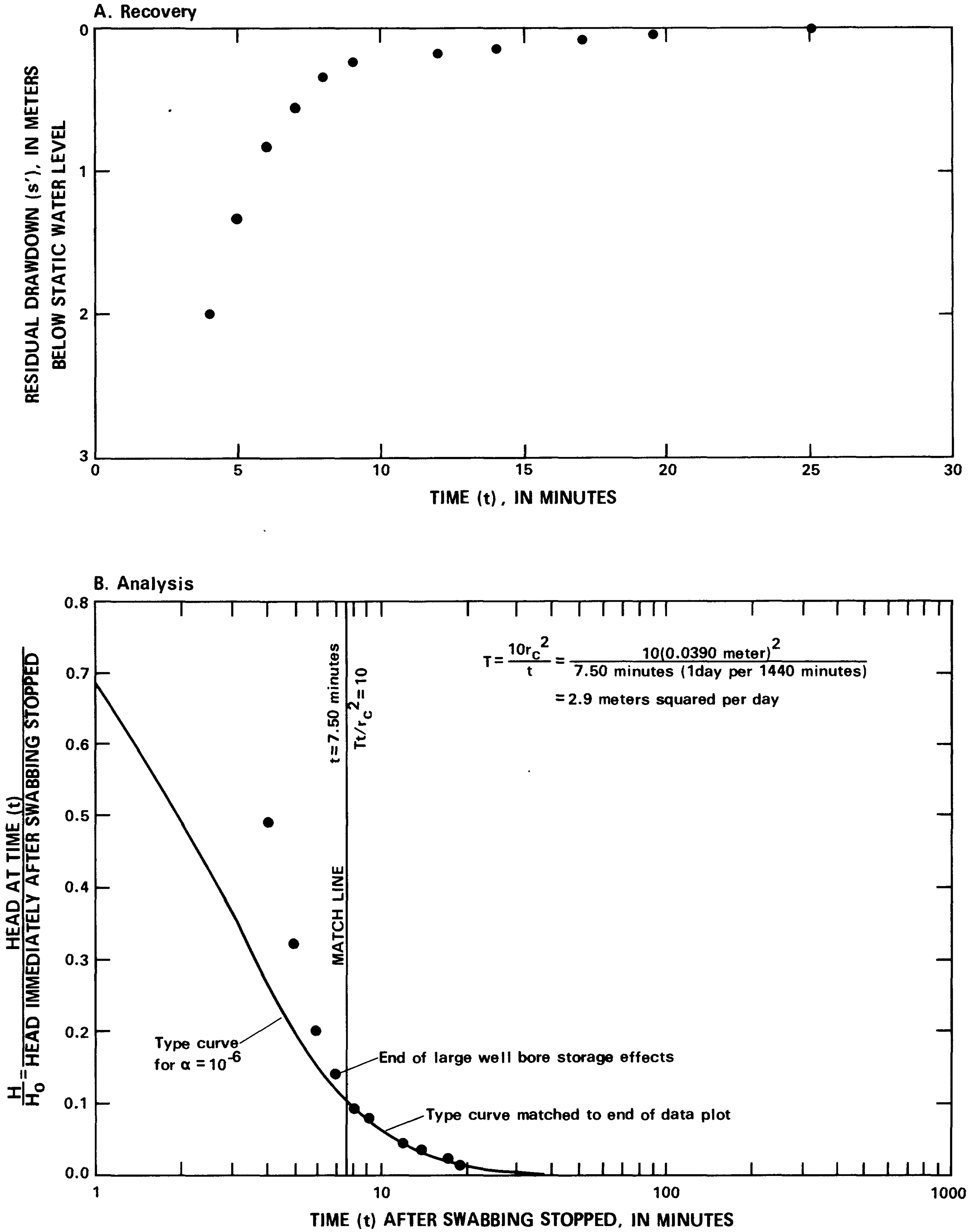
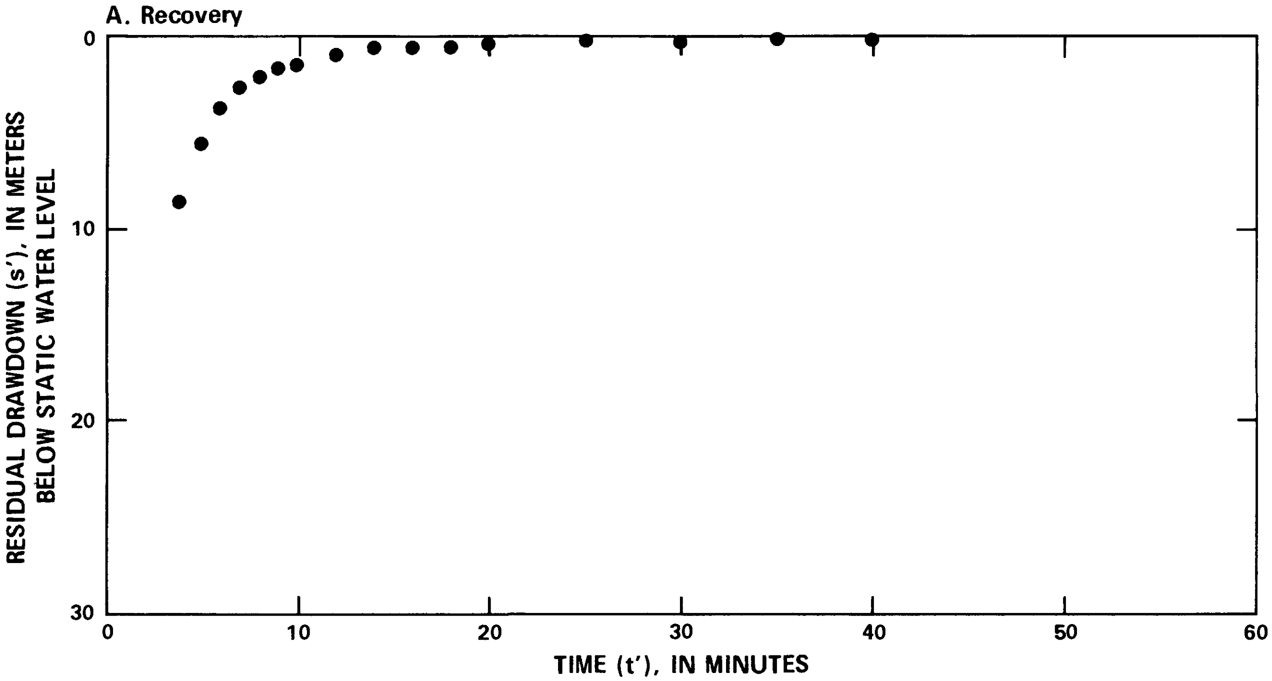


Figure 10.--Recovery and analysis of water-level recovery during single-swabbing test 19a.



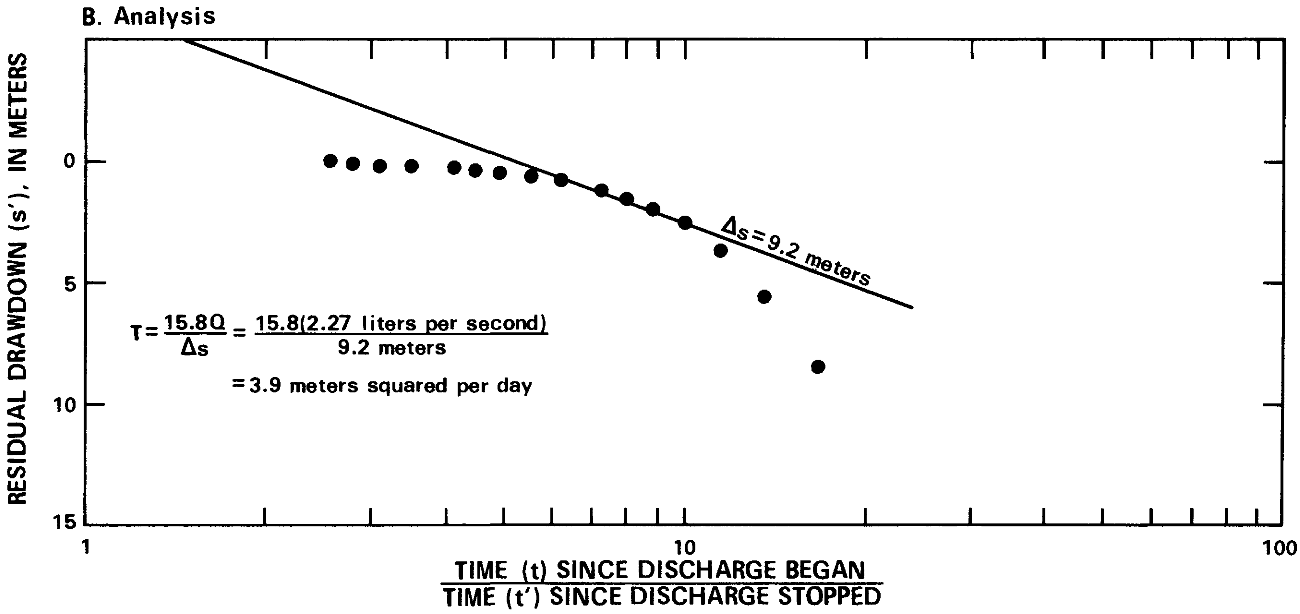


Figure 11.--Recovery and analysis of water-level recovery during multiple-swabbing test 19b.

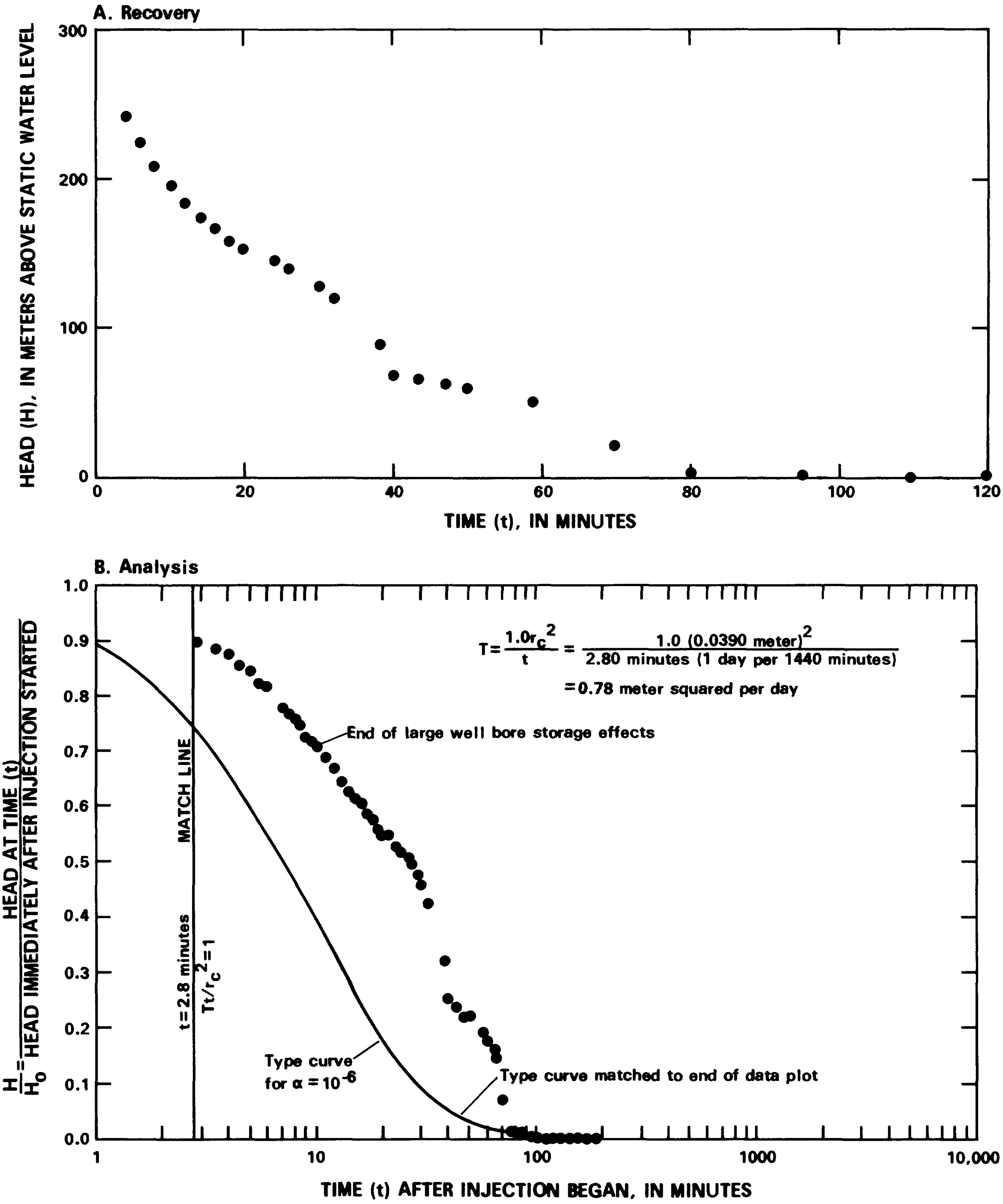
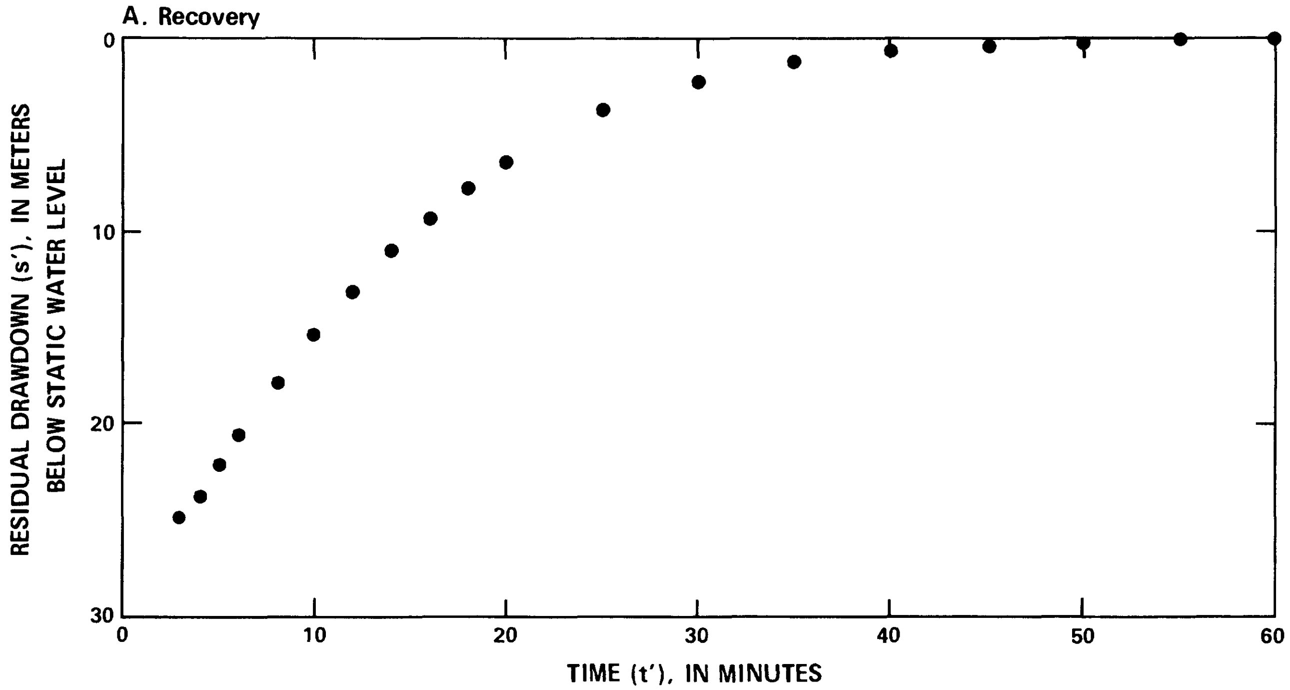


Figure 12.--Recovery and analysis of water-level recovery during slug-injection test 16.



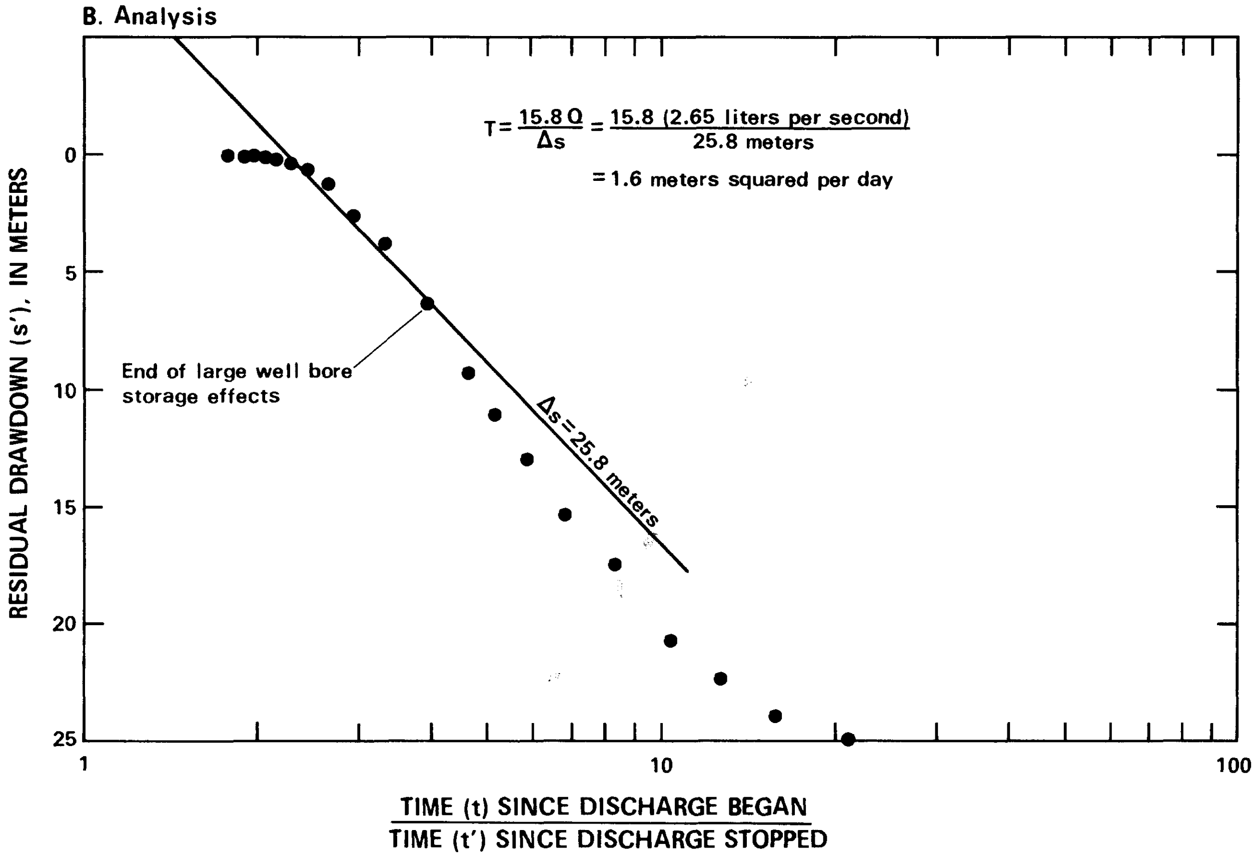


Figure 13.--Recovery and analysis of water-level recovery during multiple-swabbing test 18.

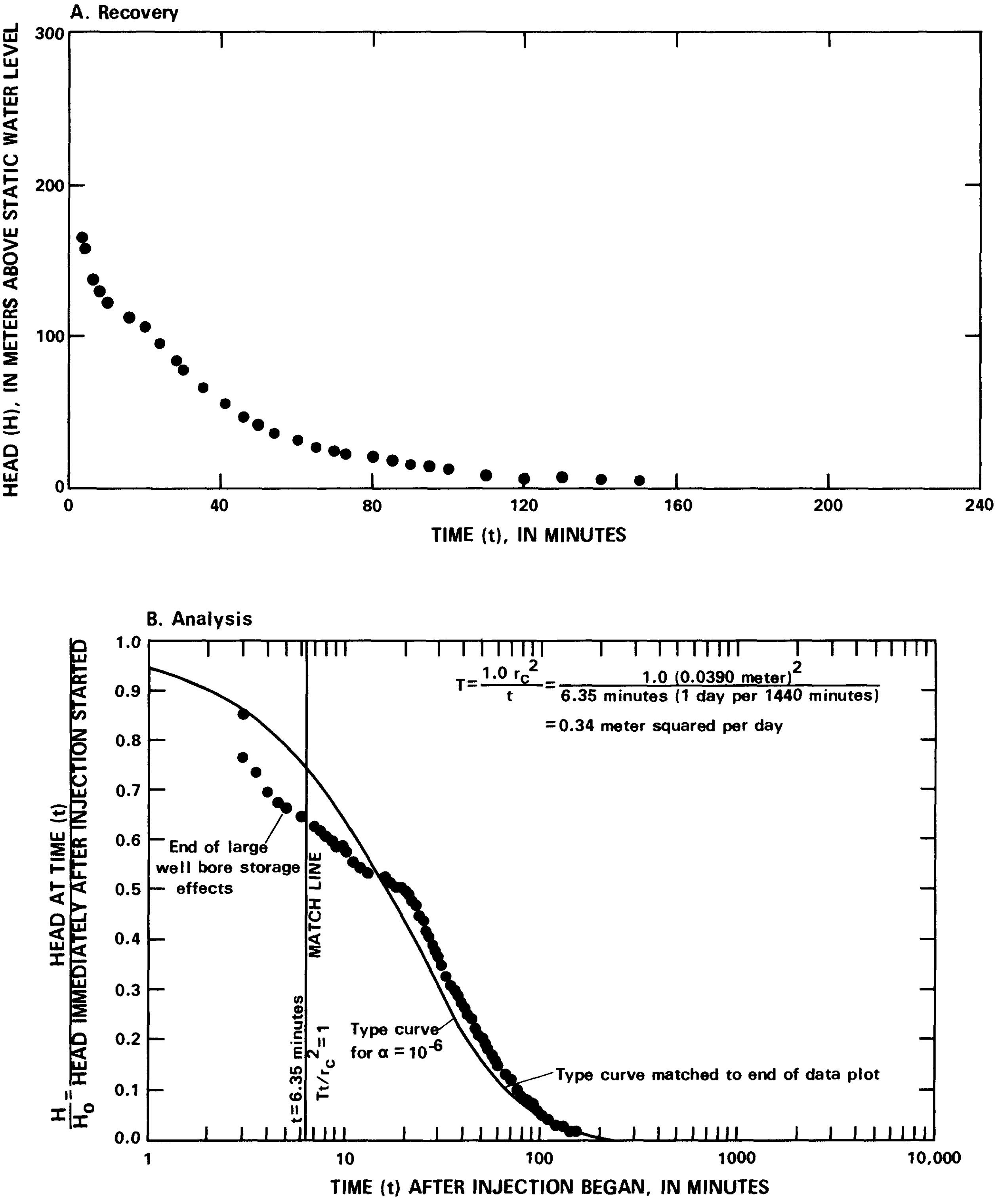


Figure 14.--Recovery and analysis of water-level recovery during slug-injection test 21.

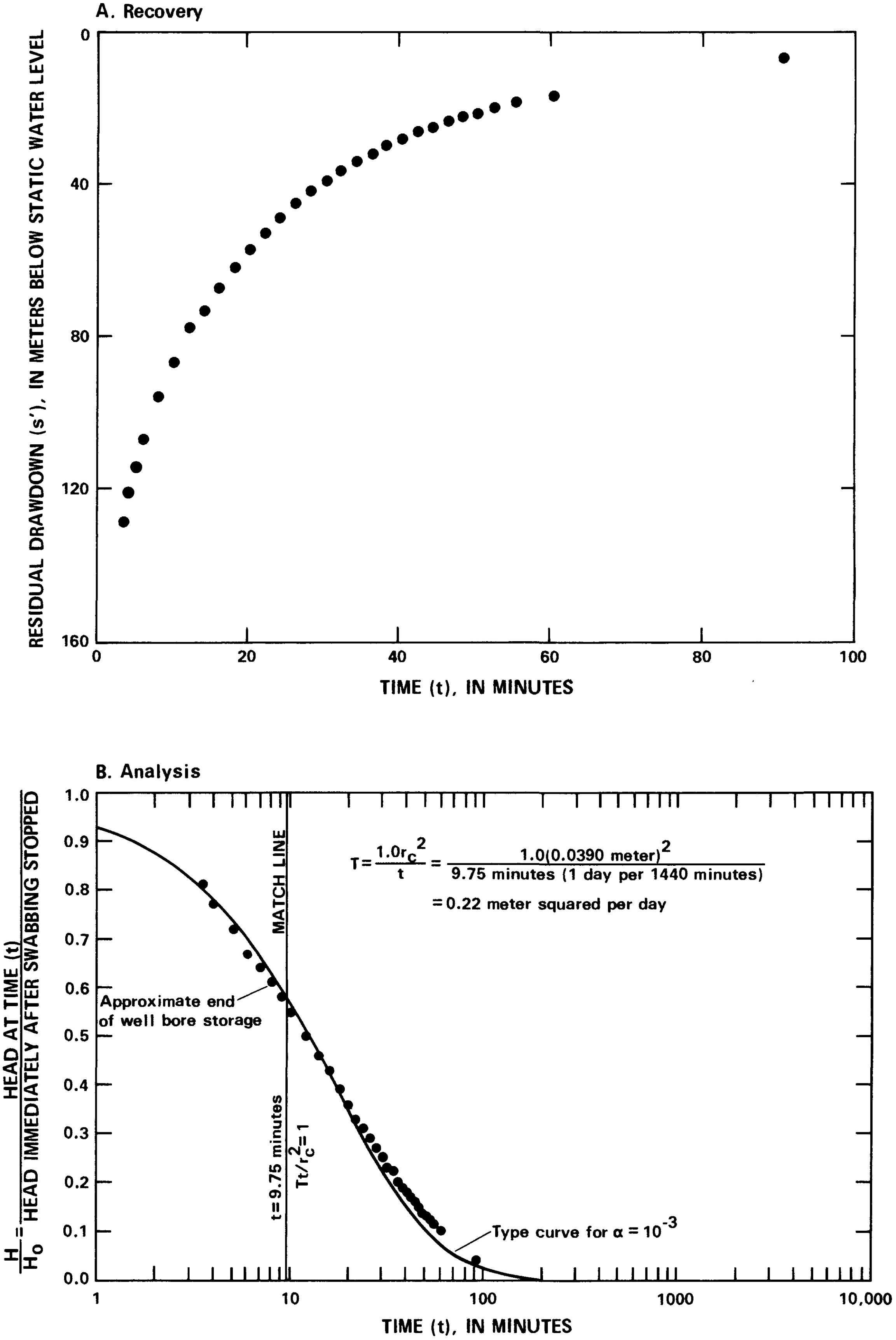


Figure 15.--Recovery and analysis of water-level recovery during single-swabbing test 21.

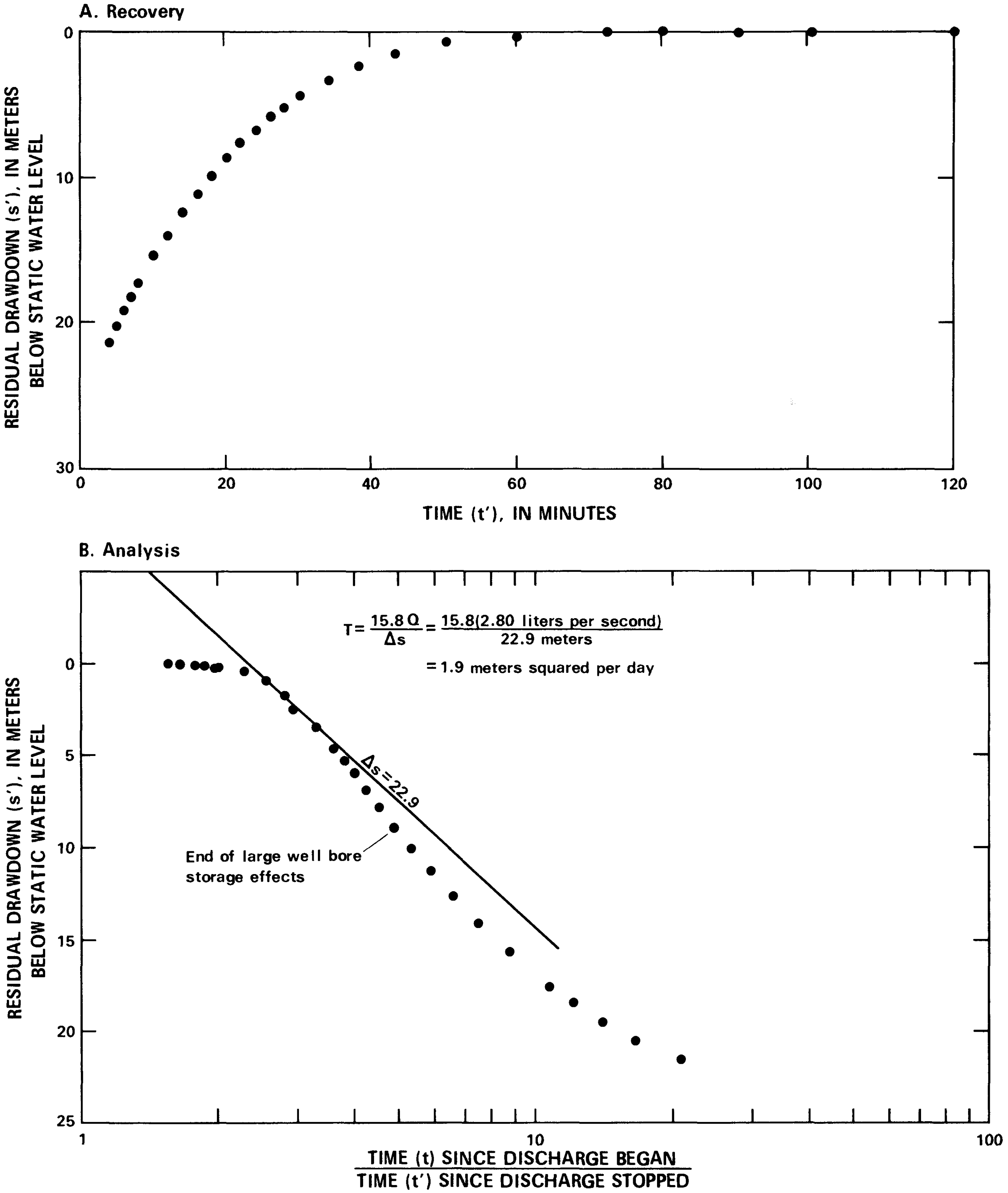


Figure 16.--Recovery and analysis of water-level recovery during multiple-swabbing test 4.

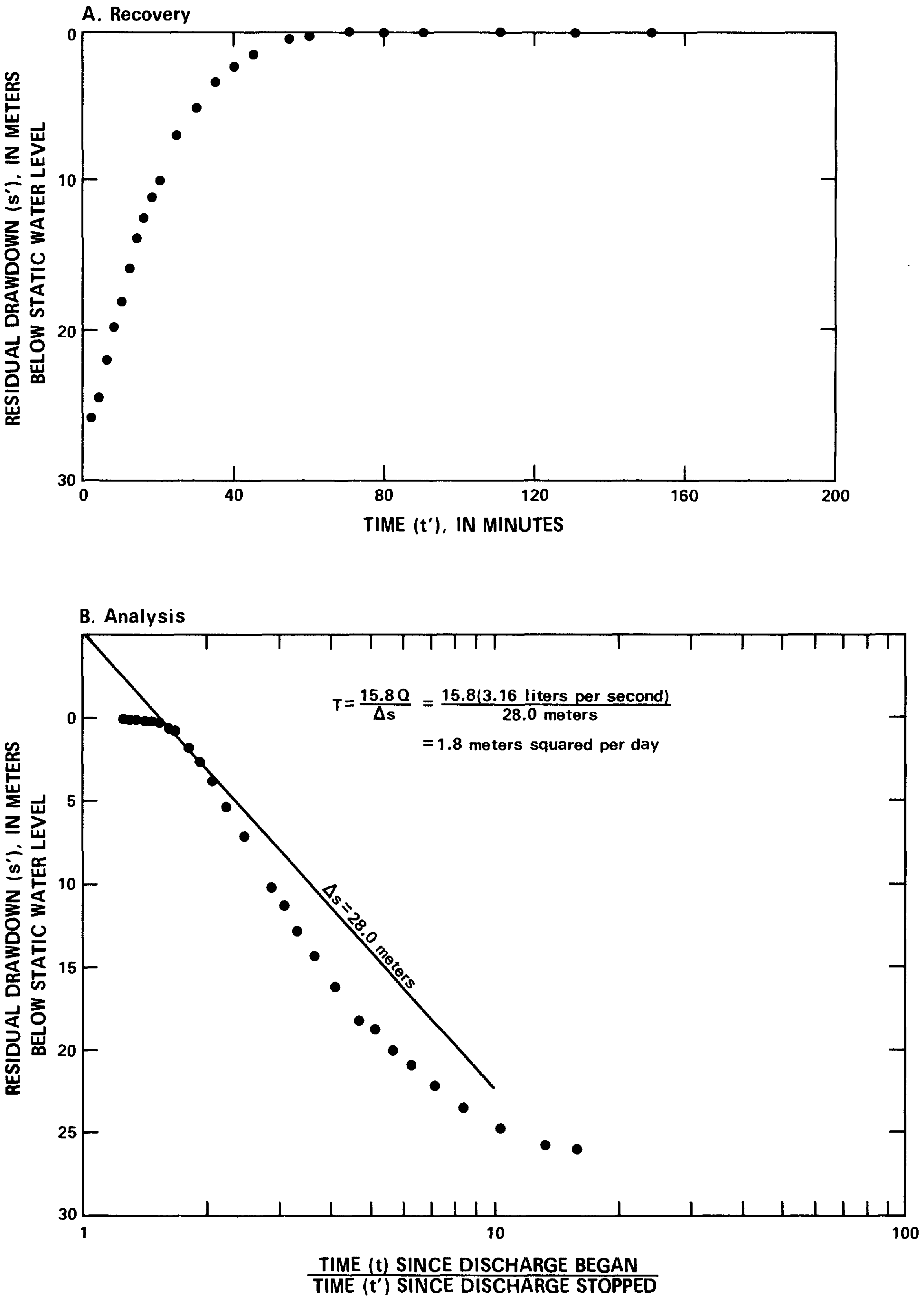


Figure 17.--Recovery and analysis of water-level recovery during multiple-swabbing test 6a.

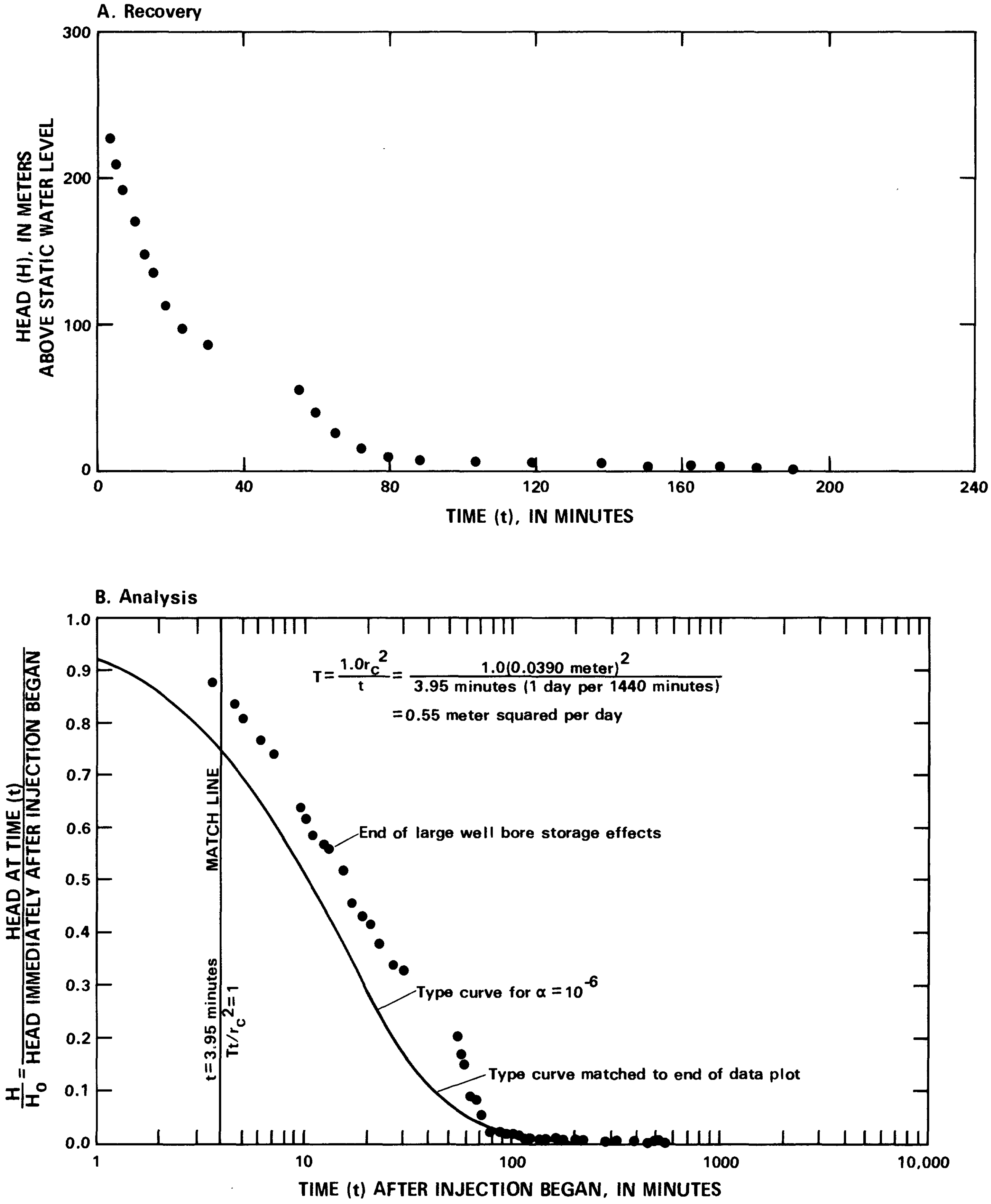


Figure 18.--Recovery and analysis of water-level recovery during slug-injection test 15.

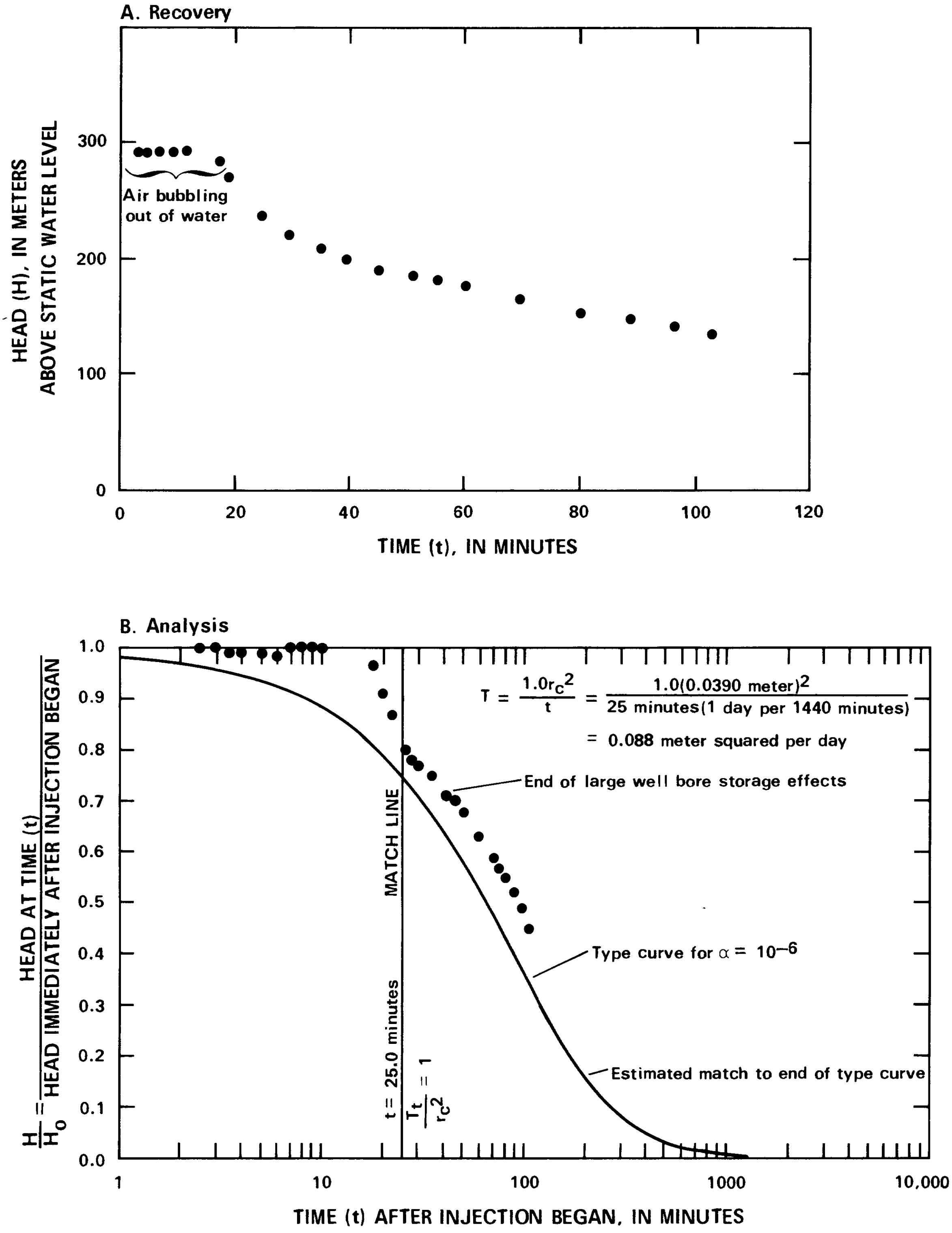


Figure 19.--Recovery and analysis of water-level recovery during slug-injection test 14.

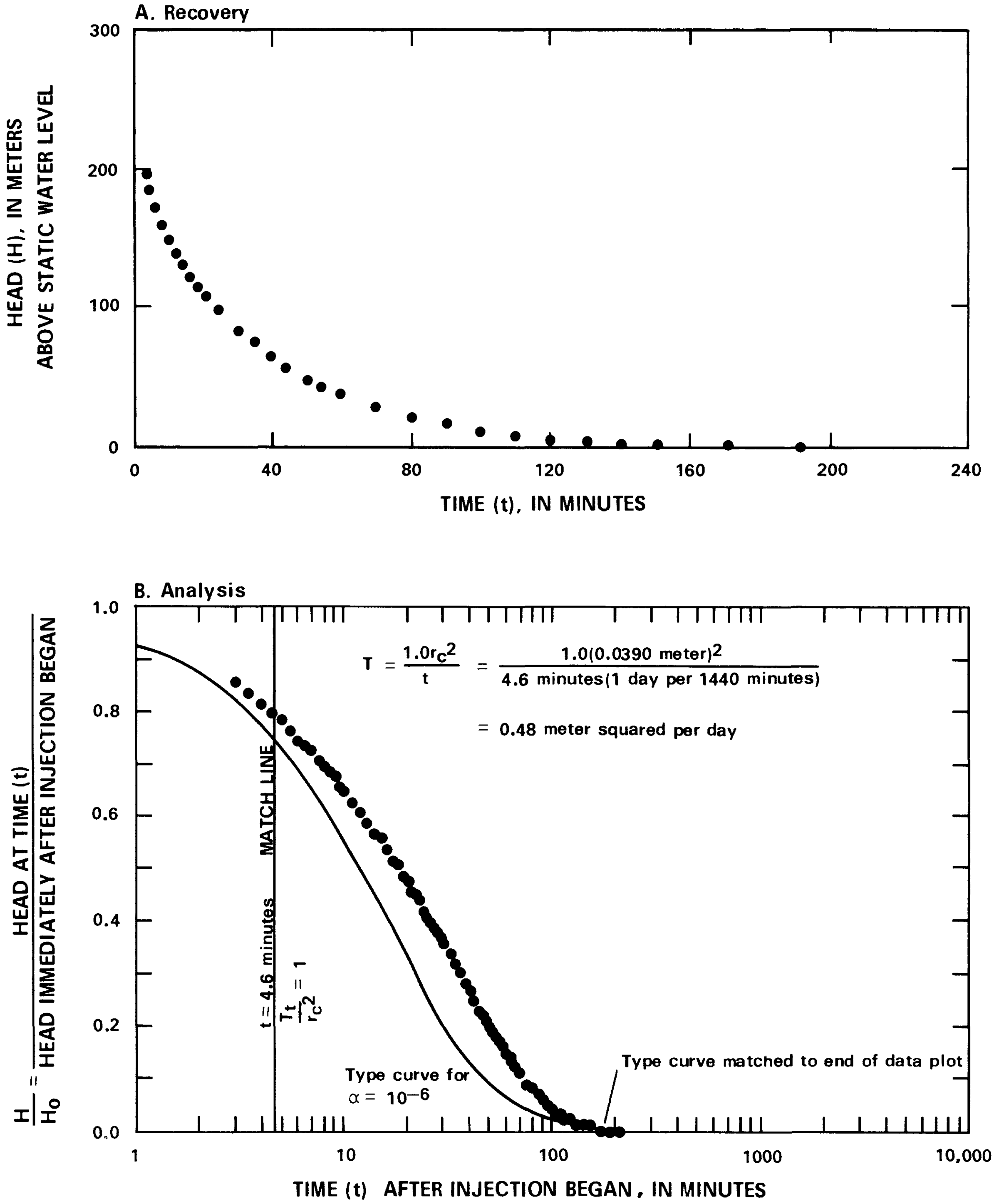


Figure 20.--Recovery and analysis of water-level recovery during slug-injection test 13.

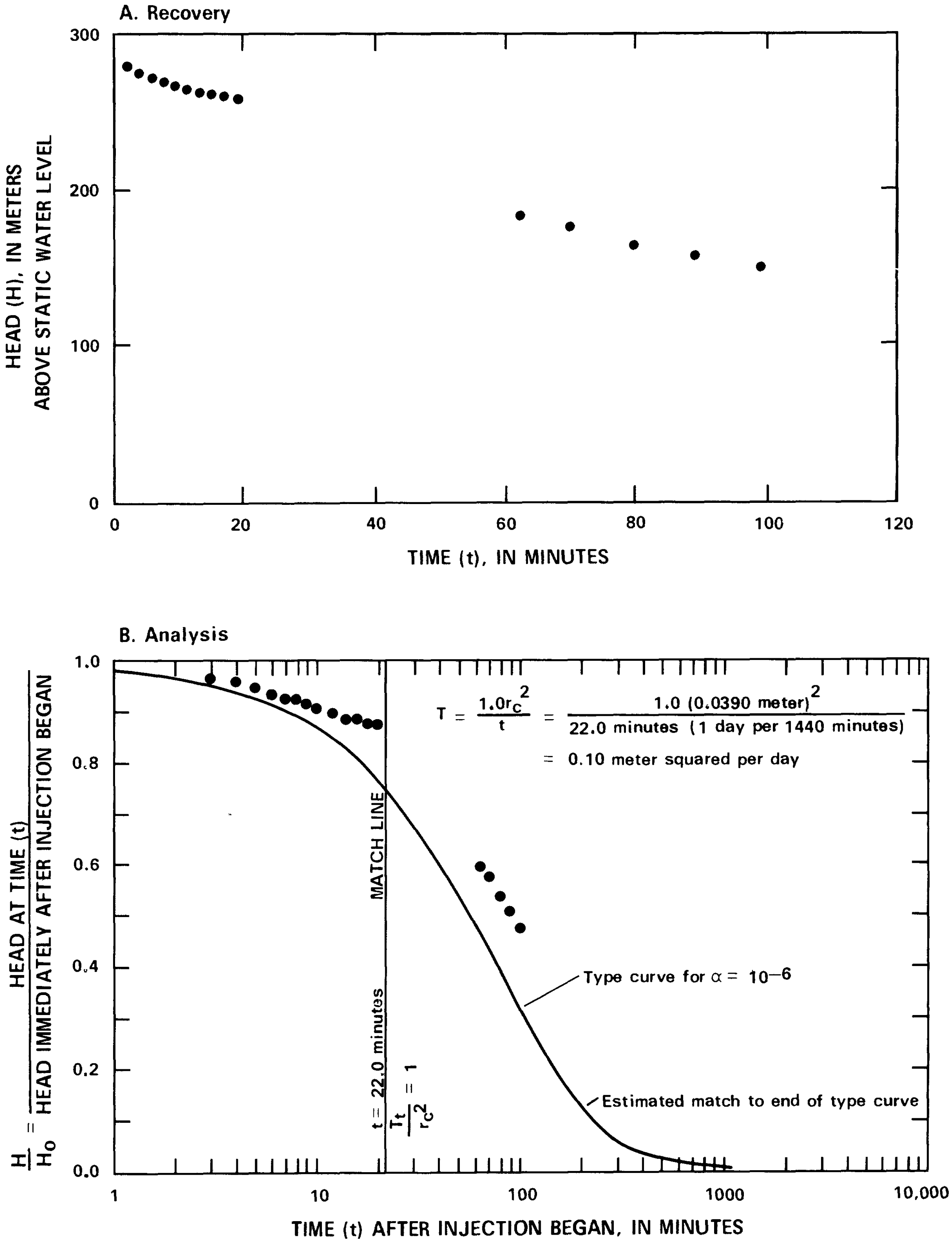


Figure 21.--Recovery and analysis of water-level recovery during slug-injection test 12.

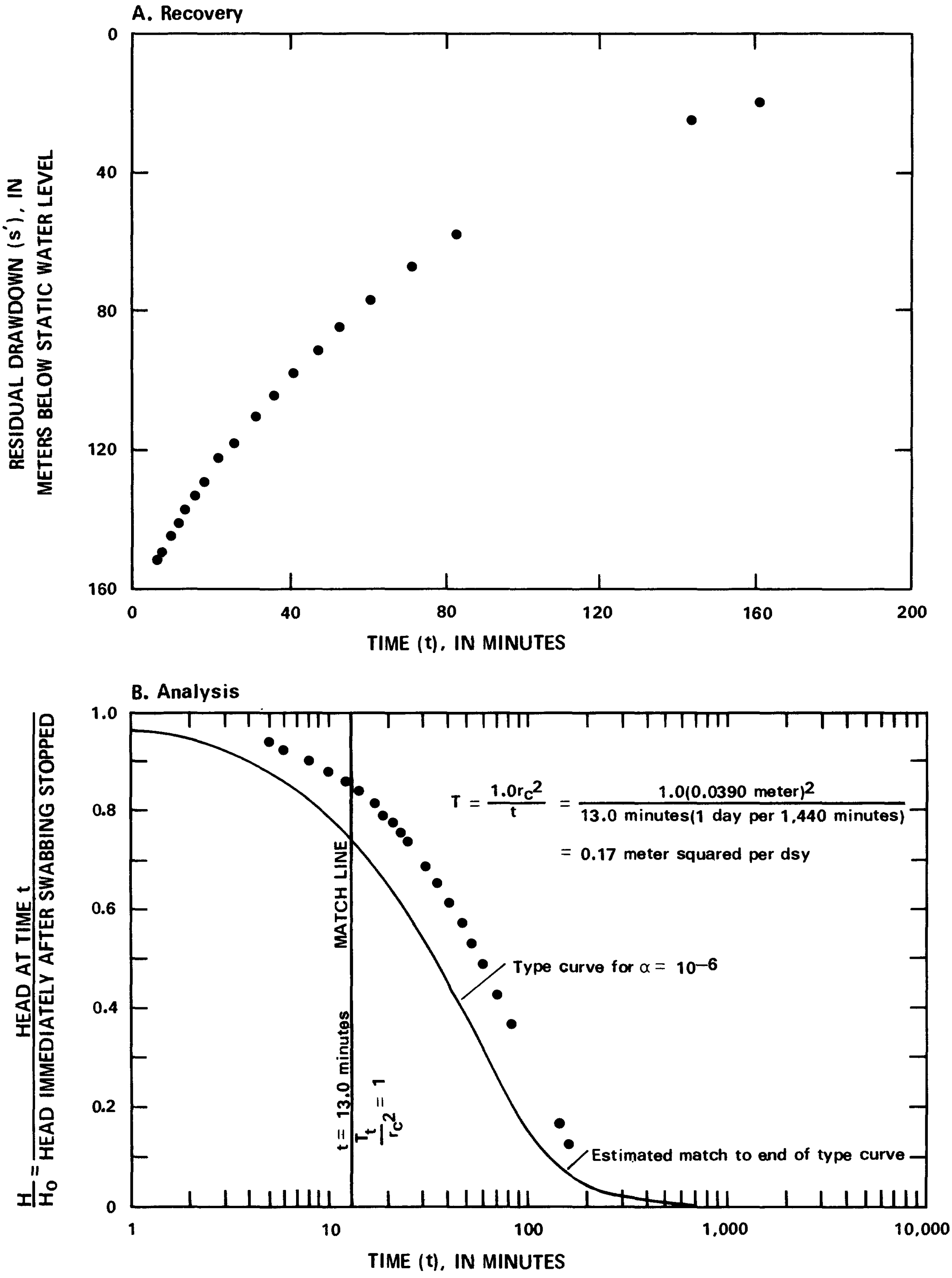


Figure 22.--Recovery and analysis of water-level recovery during single-swabbing test 11.

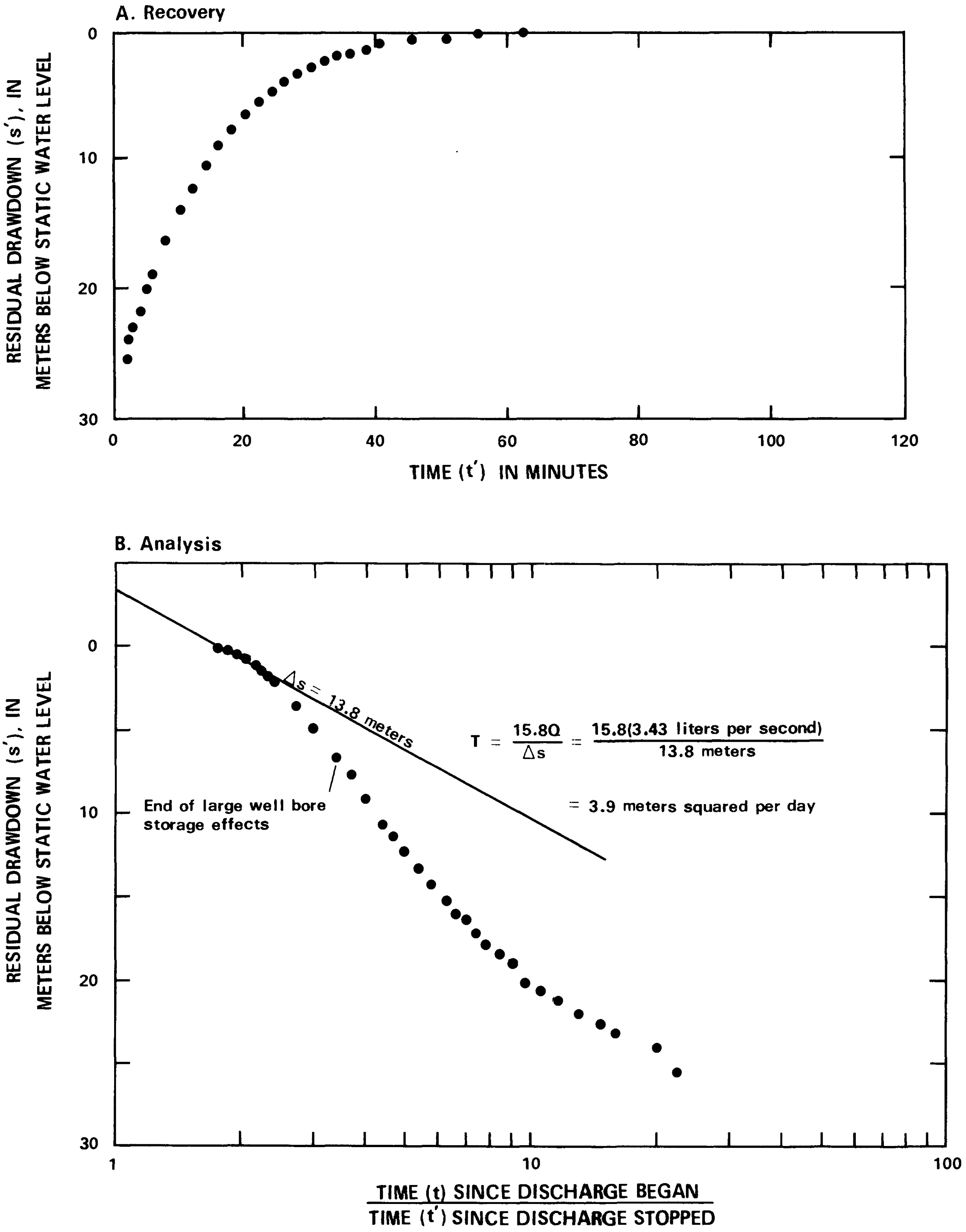


Figure 23.--Recovery and analysis of water-level recovery during multiple-swabbing test 8.

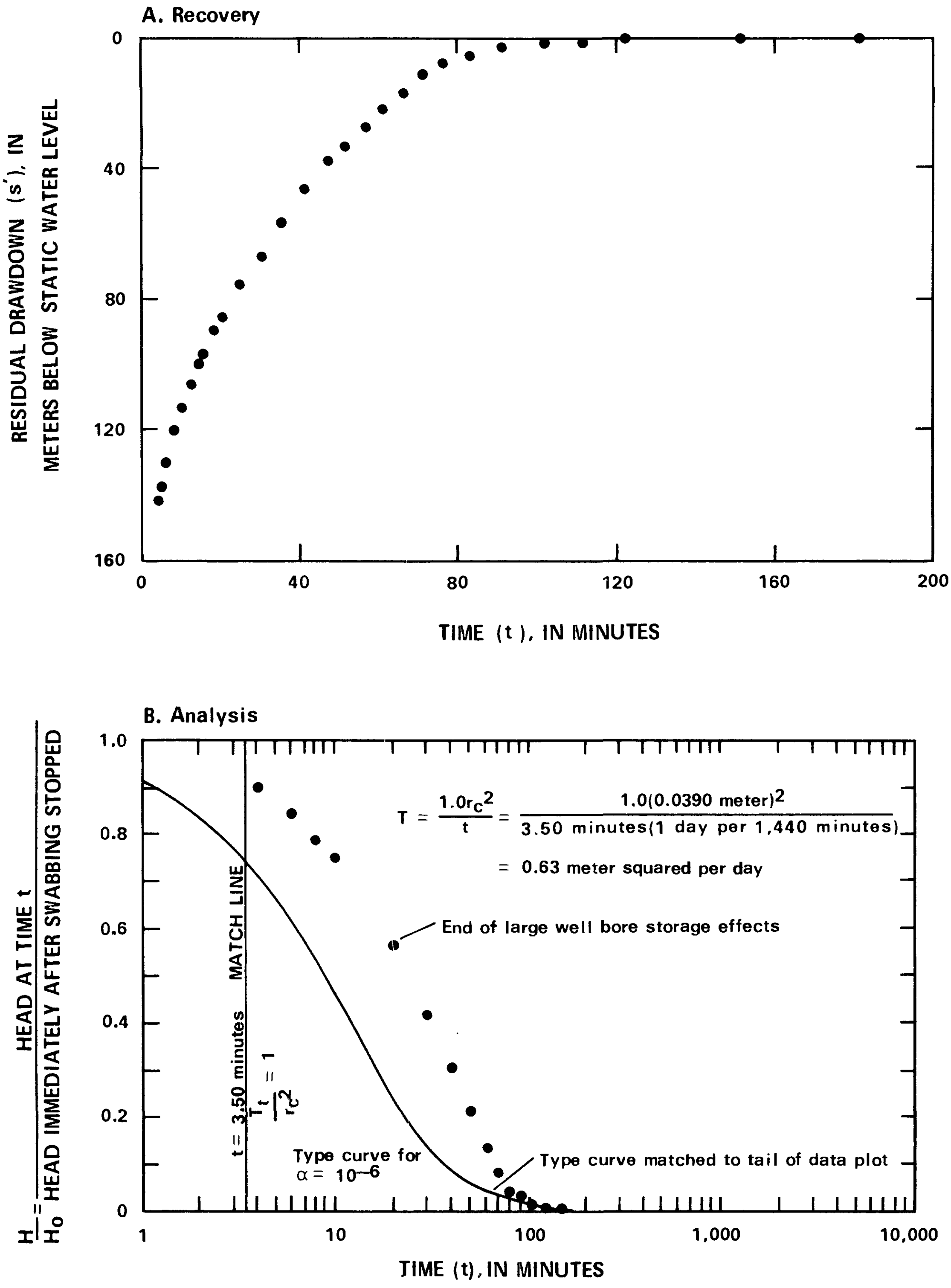


Figure 24.--Recovery and analysis of water-level recovery during single-swabbing test 20.

straight-line method in pumping test 1, transmissivity is 110 m^2/d, and average hydraulic conductivity is 0.9 m/d (fig. 4). Pumping test 2 was not analyzed because the test was too short to use with Stallman's method or the straight-line method; only the drawdown is presented (fig. 6).

Results of pumping test 3 using Stallman's method indicate that the unconfined aquifer in the depth interval from 303.6 to 422.5 m plus the confined depth interval from 819.9 to 1,009.5 m has a transmissivity of 140 m^2/d (fig. 8, table 12). Using the straight-line method in pumping test 3 and using the late slope, transmissivity is 210 m^2/d (fig. 7). Hydraulic conductivity was not calculated from this test because there were two diverse depth intervals of unequal transmissivities that yielded water to the well. However, hydraulic conductivity of the lower zone is much lower than hydraulic conductivity of the upper zone, so transmissivities calculated from pumping tests 1 and 3 are similar.

Results of pumping test 3, using the alternate conceptual model of boundaries and the early slope for the straight-line method, indicate that transmissivity of the Topopah Spring Member is 850 m^2/d (Young, 1972; fig. 7). In this report, the transmissivity of 120 m^2/d, based on later-time data, is considered more representative of actual aquifer conditions; 850 m^2/d probably is a reasonable maximum value for transmissivity.

Results of the swabbing and injection tests indicate that the tuffaceous beds penetrated in the lower part of the well, from depths of 719.3 to 1,063 m, have estimated values of hydraulic conductivity from 0.0026 to 0.0056 m/d and estimated values of transmissivity from 0.10 to 0.63 m^2/d. Beds between the Topopah Spring Member and the beds penetrated in the lower part of the well, from depths of 471.2 to 699.2 m, have estimated values of hydraulic conductivity from 0.0029 to 0.15 m/d, and estimated values of transmissivity from 0.088 to 4.5 m^2/d. H_0 was obtained by difference of head between static water level and water level at time t_0, either immediately after injection started or after swabbing stopped. Recovery and analysis of recovery of water level during each test are presented in figures 9 through 24.

TESTS FOR HYDRAULIC CONNECTION BETWEEN WELL J-12 AND WELL J-13

Two attempts were made to determine the hydraulic connection between well J-12 (which was pumped) and well J-13 (which was used as an observation well). Well J-12 is 4.7 km south of well J-13 (fig. 1). The purposes of these pumping tests were to determine interference between the wells and to reevaluate aquifer characteristics. The first pumping test was conducted on February 15-18, 1964, by continously pumping well J-12 for 3 days at an average discharge rate of 22.7 L/s. Apparent drawdown in well J-13, due to pumping well J-12, was 0.37 m even after correction for barometric-pressure effects was made. At the time of this test, well J-12 was 270.4 m deep and only partly penetrated the aquifer, the Topopah Spring Member of the Paintbrush Tuff. Before the second pumping test, the well was deepened in August 1968 to a depth of 347.2 m to the bottom of the Topopah Spring Member, in order to screen the full thickness of the aquifer.

During the second pumping test, made on June 6, 1970, well J-12 was pumped for 420 minutes at an average discharge rate of 5.68 L/s. No apparent drawdown of water level occurred in well J-13, possibly because the test was too short for the effects of well interference to reach well J-13.

CHEMICAL QUALITY OF THE WATER

Water samples were collected during pumping or pumping tests (Claassen, 1973); the chemical analyses generally represent the chemical character of water in the aquifer, the Topopah Spring Member (table 13). The water sample collected on January 1, 1963, during pumping test 2 represents water from the Topopah Spring Member, between depths of 282.7 and 422.5 m, because a bridge plug at a depth of 451.6 m in the casing blocked out water from below. The remainder of the water samples represent water in both the Topopah Spring Member, from depths of 282.7 to 422.5 m, and in the tuff beds, from depths of 819.9 to 1,009.5 m; probably less than 5 percent of the water is derived from the lower tuff beds.

Water sampled from well J-13 is typical of water derived from tuffaceous rocks. The water is predominantly a sodium bicarbonate water containing small concentrations of silica, calcium, magnesium, and sulfate (Winograd and Thordarson, 1975). Chemical analyses of the water samples are

Table 13.--*Chemical, spectrographic, and radiochemical analyses of water*

[cm, centimeter; °C, degrees Celsius; μg/L, micrograms per liter; pCi/L, picocuries per liter; <, less than]

Chemical analyses

[Constituents in milligrams per liter]

Date of sample collection	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Magnesium (Mg)	Calcium (Ca)	Strontium (Sr)	Lithium (Li)	Sodium (Na)
01-01-63	57	0.03	0.16	0.24	2.4	14	0.10	0.04	46
05-25-64	58	.03	.04	.11	1.8	14	----	----	48
11- -66	61	.06	<.01	.03	2.1	13	.09	.04	44
04-21-69	57	<.1	<.01	<.01	2.5	14	.09	.04	44
03-26-71	57	<.1	<.01	<.01	2.1	12	.02	.04	42

Spectrographic analyses

[Constituents in micrograms per liter]

Date of sample collection	Aluminum (Al)	Barium (Ba)	Beryllium (Be)	Bismuth (Bi)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Gallium (Ga)
05-25-64	62	20	<0.8	--	140	--	<4	<4	5	--
04-21-69	8	8	<.2	<3	130	<15	<2	<2	3	--

Table 13.--*Chemical, spectrographic, and radiochemical analyses of water*--Continued

Chemical analyses--Continued

Date of sample collection	Potassium (K)	Arsenic (As)	Copper (Cu)	Selenium (Se)	Zinc (Zn)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Fluoride (Fl)	Chloride (Cl)
01-01-63	6.6	<0.01	----	0.03	----	0	124	2.0	8.4
05-25-64	5.0	----	----	----	----	0	136	2.4	7.4
11- -66	4.8	----	0.01	.02	0.02	0	126	2.7	7.2
04-21-69	5.4	----	<.01	<.01	.01	0	124	2.4	5.4
03-26-71	5.0	----	----	----	----	0	124	2.4	7.1

Spectrographic analyses--Continued

Date of sample collection	Germanium (Ge)	Iron (Fe)	Lead (Pb)	Lithium (Li)	Manganese (Mn)	Molybdenum (Mo)	Nickel (Ni)	Rubidium (Rb)	Silver (Ag)
05-25-64	--	22	3	46	28	15	5	13	<0.2
04-21-69	<3	11	<2	--	12	7	<5	--	<.2

Table 13.--*Chemical, spectrographic, and radiochemical analyses of water*--Continued

Chemical analyses--Continued

Date of sample collection	Sulfate (SO_4)	Nitrate (NO_3)	Phosphate (PO_4)	Boron (B)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Dissolved solids (residue at 180°C)	Specific conductance (micromhos per cm at 25°C)	pH (units)
01-01-63	25	5.6	0.12	----	45	0	242	285	7.0
05-25-64	23	4.5	<.01	----	43	0	230	303	6.8
11- -66	18	6.8	<.01	0.12	41	0	213	284	7.6
04-21-69	18	9.0	<.01	.07	46	0	213	280	7.3
03-26-71	17	7.2	<.01	----	39	0	202	252	7.4

Spectrographic analyses--Continued

Date of sample collection	Strontium (Sr)	Tin (Sn)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)	Zirconium (Zr)
05-25-64	60	<4	<3	9	<100	<4
04-21-69	45	<3	<5	7	<15	--

Table 13.--*Chemical, spectrographic, and radiochemical analyses of water*--Continued

Chemical analyses--Continued

Date of sample collection	Percent sodium	Sodium adsorption ratio	Temperature (°C)
01-01-63	65	3.0	30.5
05-25-64	68	3.2	31.0
11- -66	67	3.0	----
04-21-69	64	2.8	31.0
03-26-71	67	2.9	31.0

Radiochemical analyses

Date of sample collection	Gross beta as 90Sr-90Y (pCi/L)	Gross alpha as U equivalent (µg/L)	Radium as 226 Ra (pCi/L)	Strontium 90 (pCi/L)	Uranium (µg/L)	Tritium (T.U.)
01-01-63	7.2	<6.7	0.1	0.4	0.7	----
05-25-64	9.2	<2.8	.2	---	.7	21
04-21-69	4.9	5.0	---	---	---	<220
03-26-71	8.2	6.1	---	---	---	<220

similar to each other and similar to water samples obtained from tuffs penetrated by well USW H-1, 8.3 km to the northwest on Yucca Mountain (fig. 1). The uniformly low and invariant concentrations of calcium and magnesium between 1963 and 1971 indicate that the mud and diesel fuel, added briefly during drilling operations, have been flushed out of the aquifer.

Radiochemical analyses of dissolved gross alpha activity reported as natural uranium equivalent in micrograms per liter (μg/L) ranges from less than 2.8 to 6.1 μg/L. Dissolved gross beta activity reported as strontium-90-yttrium-90 ranges from 4.9 to 9.2 pCi/L (picocuries per liter). Tritium values range from 21 to less than 220 pCi/L.

Ratios of the chief isotopes in water $^{18}O/^{16}O$, -13.0 parts per thousand referred to Standard Mean Ocean Water ($^{o}/oo$ SMOW), $^{2}H/^{1}H$, -97.5 $^{o}/oo$ SMOW, and the apparent age of the ground water derived from carbon-14 age dating, 9,900 years before present, were provided by H. C. Claassen (U.S. Geological Survey, written commun., 1982). These isotopic data indicate that the ground water was derived originally from precipitation.

SUMMARY

Well J-13 yields water from tuffs of Tertiary age. The Topopah Spring Member of the Paintbrush Tuff, the predominant aquifer, is underlain by confining beds with hydraulic conductivities less than 0.15 m/d. The transmissivity of the Topopah Spring Member, as estimated from pumping tests, is 120 m^2/d, and the hydraulic conductivity is 1.0 m/d. Results of nine swabbing tests and seven injection tests indicate that the tuff units beneath the Topopah Spring Member from depths of 471.2 to 1,063.1 m are confining beds with estimated transmissivities ranging from 0.088 to 4.5 m^2/d, and hydraulic conductivities ranging from 0.0026 to 0.15 m/d. Confining beds penetrated in the lower part of the well, below a depth of 719.3 m, have estimated transmissivities that range from 0.10 to 0.63 m^2/d, and hydraulic conductivities that range from 0.0026 to 0.0056 m/d.

Static water level was at a depth of approximately 282.2 m in all units down to a depth of 645.6 m. Below a depth of 772.7 m, static water level, based on short periods of measurement, was slightly deeper, 283.3 to 283.6 m.

Ground water sampled from well J-13 is typical of tuff; it is a sodium bicarbonate water containing small concentrations of silica, calcium, magnesium, and sulfate. Apparent age of the ground water, derived from carbon-14 age dating, is 9,900 years.

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GPO 841-394