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HYDROLOGIC TESTS IN HOLE GB-1, PROJECT GASBUGGY, RIO ARRIBA COUNTY, NEW MEXICO

By

F. C. Koopman and W. C. Ballance

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This report is preliminary and has not been edited for conformity with Geological Survey format and nomenclature.

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ABSTRACT

Hole GB-1, the initial exploration hole at the proposed Gasbuggy Project site, is in the SW¼ sec. 36, T. 29 N., R. 4 W., Rio Arriba County, New Mexico. Hydrologic data collected from the Ojo Alamo Sandstone in the hole indicate a static water level of about 1,000 feet below land surface and transmissivities of 0.4 gpd (gallons per day) per foot in the depth interval 3,475 to 3,575 feet below the kelly bushing (12 feet above land surface) and 2.6 gpd per foot in the depth interval 3,575 to 3,654 feet below the kelly bushing. The heads of the upper and lower sections are about equal. The specific conductance of the water in the sandstone is about 9,000 micromhos. This indicates a dissolved-solids content of about 5,500 parts per million.

In the Kirtland Shale, Fruitland Formation, Pictured Cliffs Sandstone, and upper part of the Lewis Shale, in descending order, the section was drilled with gas as the circulating medium after the hole was cased into the upper part of the Kirtland Shale. Except for some core sections recovered in the lower part of the Pictured Cliffs Sandstone and upper part of the Lewis Shale that were reported to be moist, the yield of water to the hole is inferred to be very small. Relative specific capacity is 0.003 gpm (gallons per minute) per foot in the upper part of the zone and 0.016 gpm per foot in the lower part of the zone.

INTRODUCTION

In February 1967, the U.S. Geological Survey made hydrologic tests in the Ojo Alamo Sandstone in hole GB-1, the initial test hole drilled at the site of the Gasbuggy Project. This work is part of the program to provide background data on safety aspects and hydrologic conditions related to the technical program of the Gasbuggy Project. The primary purpose of this preliminary report is to present an analysis of the water conditions at the site. This analysis is part of the data required for the evaluation of the suitability of the site for the Gasbuggy experiment.

Gasbuggy, a Plowshare project, is a cooperative effort of the AEC (U.S. Atomic Energy Commission), USBM (U.S. Bureau of Mines), EPNG (El Paso Natural Gas), and LRL (Lawrence Radiation Laboratory). Its purpose is to determine the effect of a NE (nuclear explosion) on the yield of a low-yield, natural gas formation. The cooperators hope that the explosion will form a large, rubble-filled cavity (chimney) with fractures radiating out into the gas-producing formation. If the hopes are achieved, the permeability of an otherwise low-permeability rock should be greatly increased. The effectiveness of the NE will be determined by drilling into the chimney and evaluating the increased gas production.

The gas-producing formation selected for the experiment is the Pictured Cliffs Sandstone at a site in the San Juan Basin (SW1/4 sec. 36, T. 29 N., R. 4 W.), Rio Arriba County, New Mexico (fig. 1). EPNG owns the gas and oil lease on the property. Several test holes and gas wells have been drilled in the area of the Gasbuggy site. Geophysical logs of these test holes indicated beds of sandstone in the formations above the Pictured Cliffs Sandstone. Should these beds of sandstone in the interval of a few hundred feet above the Pictured Cliffs contain water, fractures extending upward from the shot point and intersecting these water-bearing beds could adversely affect the Gasbuggy experiment. The hydrologic testing was designed to determine how much water would flow into the chimney, if the beds of sandstone were ruptured by fractures extending upward from the chimney.

Work was done in cooperation with the U.S. Atomic Energy Commission and with the assistance of El Paso Natural Gas Company and Lawrence Radiation Laboratory personnel. J. D. Hudson, USGS, assisted the authors in the field.

A summary of USGS activities during the hydrologic testing, tabulation of data collected, and analysis of the data collected follows.

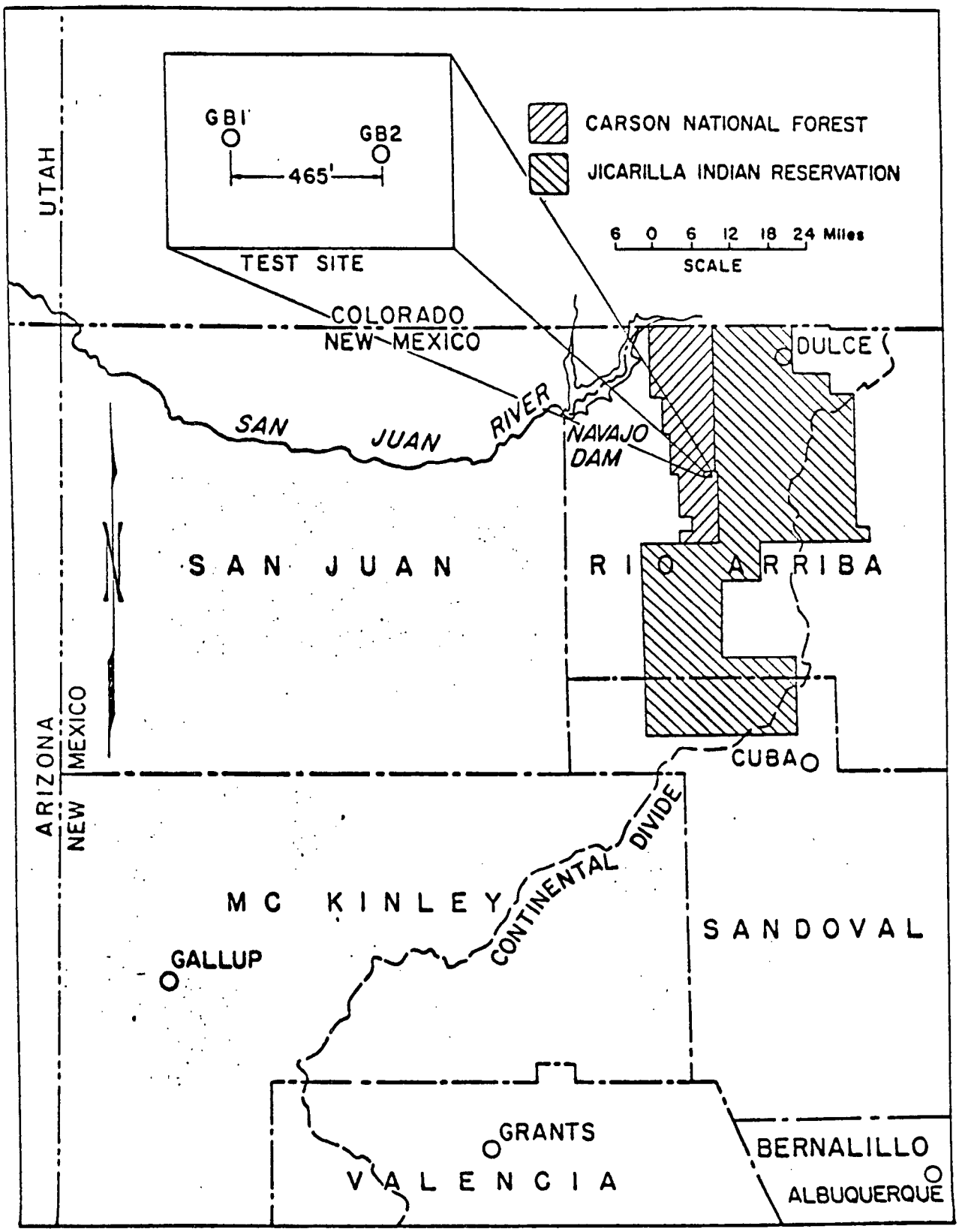


Figure 1.--Project Gasbuggy, site location of exploratory holes GB-1 and GB-2, Rio Arriba County, New Mexico.

HYDROLOGIC TESTING

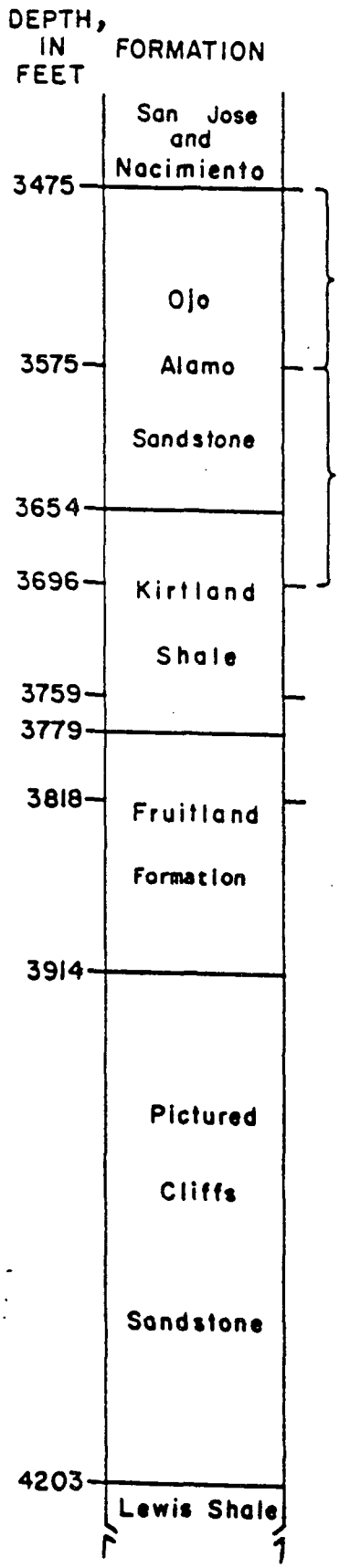
Ojo Alamo Sandstone

Hydrologic data were not scheduled for collection from the beds between the surface and the top of the Ojo Alamo Sandstone. These beds, comprising the San Jose and Nacimiento Formations, contain sandstone units and probably contain water, but these water-bearing zones are considered to be well above the probable top of the chimney and zone of contamination. Formations tested and hydrologic conditions in hole GB-1 are shown on figure 2.

Two hydrologic tests were made on the Ojo Alamo Sandstone in hole GB-1. On February 23-24, 1967, the depth interval 3,475 to 3,575 feet below the kelly bushing was tested. On February 26-27, 1967, the depth interval 3,575 to about 3,654 feet below the kelly bushing was tested.

The kelly bushing used as the reference point for all measurements during the hydrologic testing is 12 feet above land surface. The altitude of the land surface at hole GB-1 is 7,198 feet above mean sea level.

After coring to the desired depth in the sandstone had been done, the test interval was isolated from the formation above it by setting a Lynes packer on the end of the drill stem. Two recording pressure meters were attached to the string below the Lynes packer. Tubing was then inserted into the drill stem to a depth of about 3,000 feet. The hydrologic testing was done by the following procedure:



REMARKS

Transmissivity 0.4 gallons per day per foot. Static water level roughly 1,000 feet below kelly bushing.

Transmissivity 2.6 gallons per day per foot.

9 5/8-inch casing installed and cemented after hydrologic tests.

The Fruitland Formation was cored using gas as the circulating fluid. The exhaust of gas and cuttings showed no indications of water. At depth of 3,818 feet, electric probe was lowered to depth of 3,750 feet (length of line) but showed no indication of water.

Dry cuttings obtained from gas carrier. Some cores recovered from lower part of Pictured Cliffs Sandstone and from the Lewis Shale were wet.

10 feet of water in hole about 18 hours after test hole was cleaned out to total depth.

Total depth 4,320 feet.

Figure 2.--Formations tested and remarks on hydrologic conditions in hole GB-1.

1. Fluid was swabbed from the tubing to remove the drilling mud and to condition the sandstone.
2. Fluid was swabbed from the formation at a fixed rate or from a constant depth.
3. Formation fluid was collected in a tank and the rate at which the fluid was removed from the formation was determined.
4. The fluid level in the tubing was measured periodically as it rose toward a static level, after swabbing ended.

The equipment used in the hydrologic testing was as follows:

1. A swab on a wire line.
2. A calibrated 4,500 gallon storage tank.
3. An electric measur...g line.

In the first hydrologic testing of the sandstone, on February 23, 1967, the depth interval 3,475 to 3,575 feet was tested.

Swabbing through the tubing to remove the drilling mud and develop the formation began at 1640 hours. The fluids from the hole and the formation were not collected during this part of the test because the swabbed fluid was contaminated with drilling mud. Table 1 lists the data collected during the first swabbing of the hole.

Water samples were collected for chemical analysis just prior to 1906 hours, the end of the swab test. The approximate fluid level at the end of the swab test was 2,700 feet. During the latter part of the test, the swabbing depth was 3,000 feet. During the initial part of the test the specific conductance of the fluid removed from the hole was about 650 micromhos; during the latter part of the test, it was 9,000 micromhos. The thermometer in the pressure bomb showed that the temperature of the formation fluid was about 101°F. The temperatures indicated in the tables are low owing to heat exchange from the swabbing equipment and should not be used in the analysis of the data.

Measurement of water-level recovery began at 1955 hours, 49 minutes after the last swab run. The delay in measuring the water level was due to removing the swabbing equipment and installing the water-level measuring equipment.

Table 2 lists the clock time of each water-level measurement, the elapsed time since swabbing began, the elapsed time since swabbing stopped, and the fluid level, in feet, below the kelly bushing. Measurement of water level continued until 2206 hours. The tubing originally placed at a depth of about 3,000 feet was lowered to about 3,500 feet. This was done so that the swabbing during the next test could be done at a greater depth.

Measurement of water levels continued at 2353 hours, February 23, 1967, and ended at 0055 hours, February 24, 1967. The fluid level had recovered from 2,454.5 feet at the beginning of the recovery test to 1,697.2 feet at the last measurement.

The second swab test (table 3) of the upper part of the sandstone began at 0215 hours February 24 and continued until 0552 hours February 24, 1967. Swabbing was done from a depth of about 3,300 feet throughout most of this test. The specific conductance of the formation fluid was about 9,000 micromhos.

The water-level measurements that followed the second swabbing test began at 0625 hours February 24 and were discontinued at 1308 hours February 24, 1967 (table 4). To expedite the recovery of the fluid to a static level, water was injected into the tubing at a rate of 2.5 gpm for 1 hour beginning at 1139 hours February 24. Water injection was discontinued at 1239 hours February 24 after about 150 gallons of water had been injected into the system. The results of the water injection are indicated in table 4 and will be discussed under "Analysis of pump test data." This concluded the hydrologic testing of the upper part of the sandstone.

The Lynes packer was removed and the remainder, about 80 feet, of the Ojo Alamo Sandstone. and about 42 feet of underlying Kirtland Shale were cored. Only a small sample of the shale was available for examination by the U.S. Geological Survey personnel. The examination indicated that the fluid-yield of the shale, if any, under a large head differential would be quite small and that any influence this yield might have on the testing of the lower part of the Ojo Alamo Sandstone would be negligible.

The first swab test (table 5) of the lower portion of the sandstone (interval 3,575 to about 3,654 feet) was begun at 2011 hours February 26, 1967, and was completed at 2310 hours February 26. The fluid produced by the first two runs of the swab was estimated to be about 300 gallons. This fluid was not collected because of the drilling-fluid content. Water samples for chemical analyses were taken prior to the end of the swab test.

Water-level-recovery measurements that followed the first swabbing period in the lower zone (table 6) began at 2341 hours February 26 and ended at 0700 hours February 27. The water level rose from 1,888.0 feet near the beginning of the recovery period to 1,044.2 feet at the end of the monitoring period.

Table 7 shows the data for the second swab test of the lower part of the sandstone. The swab test began at 0816 hours February 27 and ended at 1149 hours February 27. This concluded the testing of the Ojo Alamo Sandstone.

Kirtland Shale and Fruitland Formation

After the testing of the Ojo Alamo Sandstone, the test hole was reamed to a depth of 3,759 feet. The hole was then cased to this depth with 9 5/8-inch pipe and cemented.

Coring with gas as the circulating medium began at 3,757 feet and continued through the Kirtland Shale and Fruitland Formation. Free water was not observed during the drilling of these formations. The water detection probe was run into the hole to a depth of 3,750 feet (effective length of line) after coring to a depth of 3,818 feet. There was no indication of water.

Pictured Cliffs Sandstone and Lewis Shale

Dry cuttings are reported to have been obtained by the use of gas as the circulating fluid in the drilling of the Pictured Cliffs Sandstone and upper part of the Lewis Shale. Some cores recovered from the lower part of the sandstone and upper part of the shale were reported to be wet, but the yield of water to the hole was small and did not interfere with drilling.

CHEMICAL QUALITY OF WATER SAMPLES FROM OJO ALAMO SANDSTONE

Water samples were collected from the upper and lower parts of the Ojo Alamo Sandstone for chemical, spectrographic, radiochemical (beta/gamma and gross alpha), and tritium analyses.

On-site specific conductance measurements of the water removed from the Ojo Alamo Sandstone near the end of the swab tests indicated a conductance of about 9,000 micromhos per cm. This conductance suggests that the dissolved-solids content of the water is about 5,500 milligrams per liter.

ANALYSIS OF PUMP TEST DATA

The following formula for computing the transmissivity (T) was used for analyzing the recovery portions of the hydrologic tests.

T in gallons per day per foot = $\frac{2640}{s} \log_{10} \frac{t}{t'}$ where:

s = Residual drawdown

t = Time since pumping began

t' = Time since pumping stopped

Q = Pumpage in gallons per minute

Time may be in any unit, as the term t/t' becomes dimensionless by cancellation of units. However, time in minutes is recorded in the data tables. Over one log cycle, $\log_{10} t/t'$ becomes unity; s equals Δs or change in s; and then $T = \frac{2640}{\Delta s}$.

The recovery data were used also to compute the relative specific capacity of the interval tested, a common practice for estimating water inflow to mined chambers at the Nevada Test Site. The equation for computation of specific capacity is as follows:

$$\text{Relative specific capacity} = \frac{Q}{(h' - h)}$$

where: Q = gallons of water accepted by an interval isolated with straddle packers during 1-minute time span. The time span 3-4 minutes after the tool is opened is commonly used.

h = static water level of the hole, or interval tested, in feet below land surface.

h' = average water level in the tubing, in feet below land surface, in 1-minute time span used for determining Q. The water level at 3.5 minutes is used.

The relative specific capacity figures determined by the preceding method are reasonably accurate for relatively impermeable zones; they are too low in highly permeable zones.

About 100 feet of the upper part of the Ojo Alamo Sandstone was cored and isolated from the upper formations with a Lynes packer. Drilling mud was swabbed from the hole, the sandstone was developed by swabbing, and then it was swabbed again to produce formation fluid. The total swabbing time amounted to 146 minutes. Because the fluid was not collected during this swabbing period, the rate at which the fluid was withdrawn could not be calculated. However, during the second swabbing test the fluid was collected and the withdrawal rate amounted to an average of about 5.3 gpm; this figure was used for all computations involving the upper 100 feet of sandstone.

The values of t/t' were computed from data in table 2. These values were plotted against s on semilogarithmic graph paper using the logarithmic scale for t/t' and the arithmetic scale for s (fig. 3). From the slope of the straight line drawn through several points on the latter part of the recovery curve Δs is determined. For one log cycle Δs was determined to be 3,400 feet. Q was estimated to be 5.3 gpm. Therefore,

$$T = \frac{264Q}{\Delta s} = \frac{(264)(5.3)}{3,400}$$

T = 0.412 gpd per ft at prevailing field conditions or 0.0226 Darcy ft.

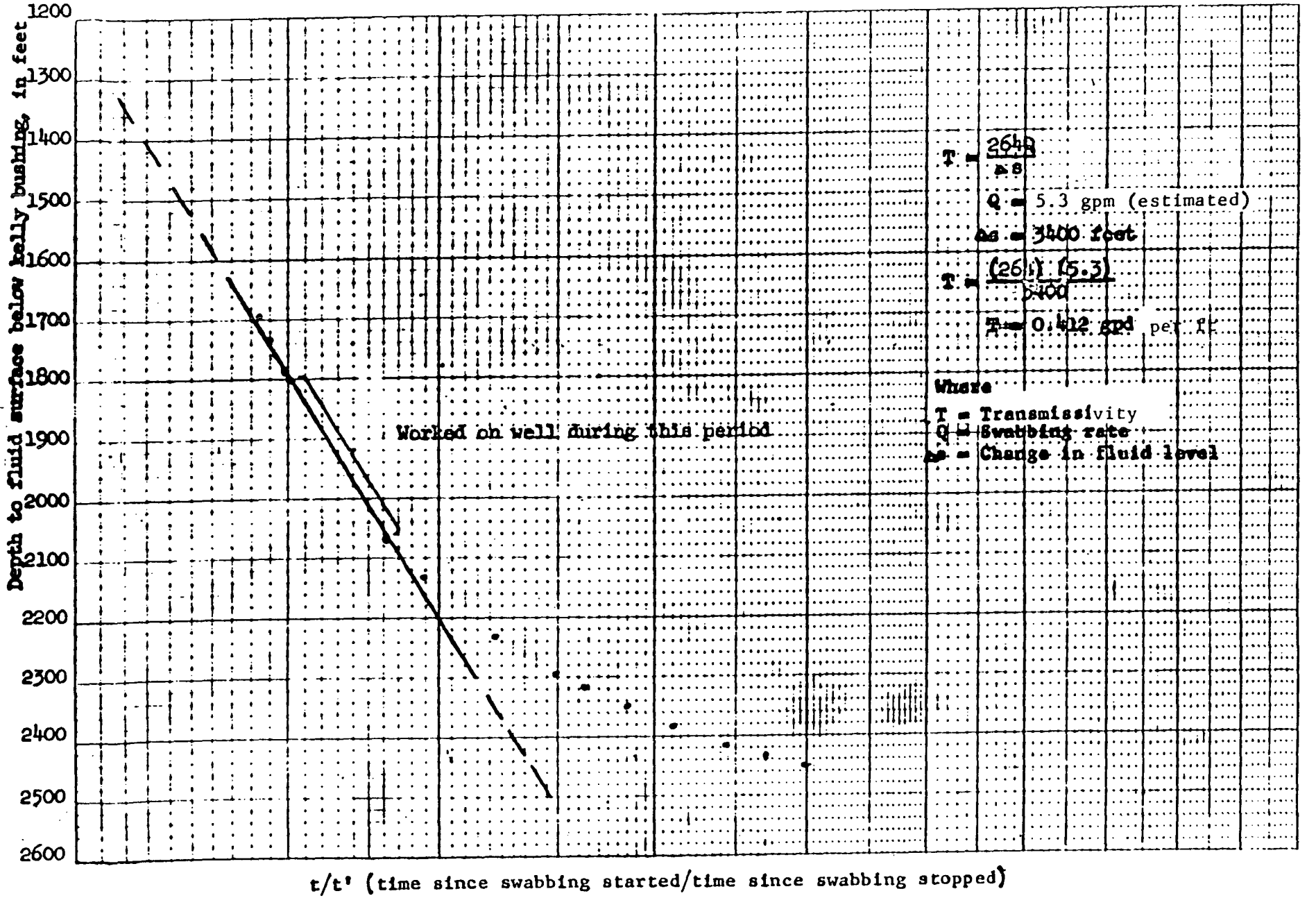


Figure 3.--Recovery of water level in hole GB-1 after first swabbing test of upper zone of Ojo Alamo Sandstone.

Calculation of the relative specific capacity in 100 feet of the upper Ojo Alamo Sandstone follows:

$$\text{Relative specific capacity} = \frac{Q}{(h'-h)}$$

$$= \frac{5.3}{2,445-1,000}$$

$$= 0.003 \text{ gpm per ft}$$

For comparison, this value is much lower than necessary for safe mining of a chamber in zeolitized tuff at depths of a few thousand feet below the water table at the Nevada Test Site.

The data in table 4 are from the second test of the upper 100 feet of the Ojo Alamo Sandstone. Data from table 4 were used to construct the plot on figure 4.

Hydrologic testing of the lower part of the sandstone began on February 26, 1967. The section tested consisted of about 80 feet of the Ojo Alamo Sandstone (interval 3,575 to about 3,654 feet) and about 42 feet (interval 3,654 to 3,696 feet) of the Kirtland Shale.

Laboratory tests of core from the Kirtland Shale were made by Core Laboratories, Inc. These tests showed a horizontal permeability of 0.02 millidarcies and a vertical permeability of 0.01 millidarcies. About 42 feet of the Kirtland Shale was exposed in the well when the tests were conducted on the lower Ojo Alamo Sandstone. If water was available from the Kirtland Shale, it was probably insufficient to have any noticeable effect on the hydrologic testing of the lower part of the Ojo Alamo Sandstone.

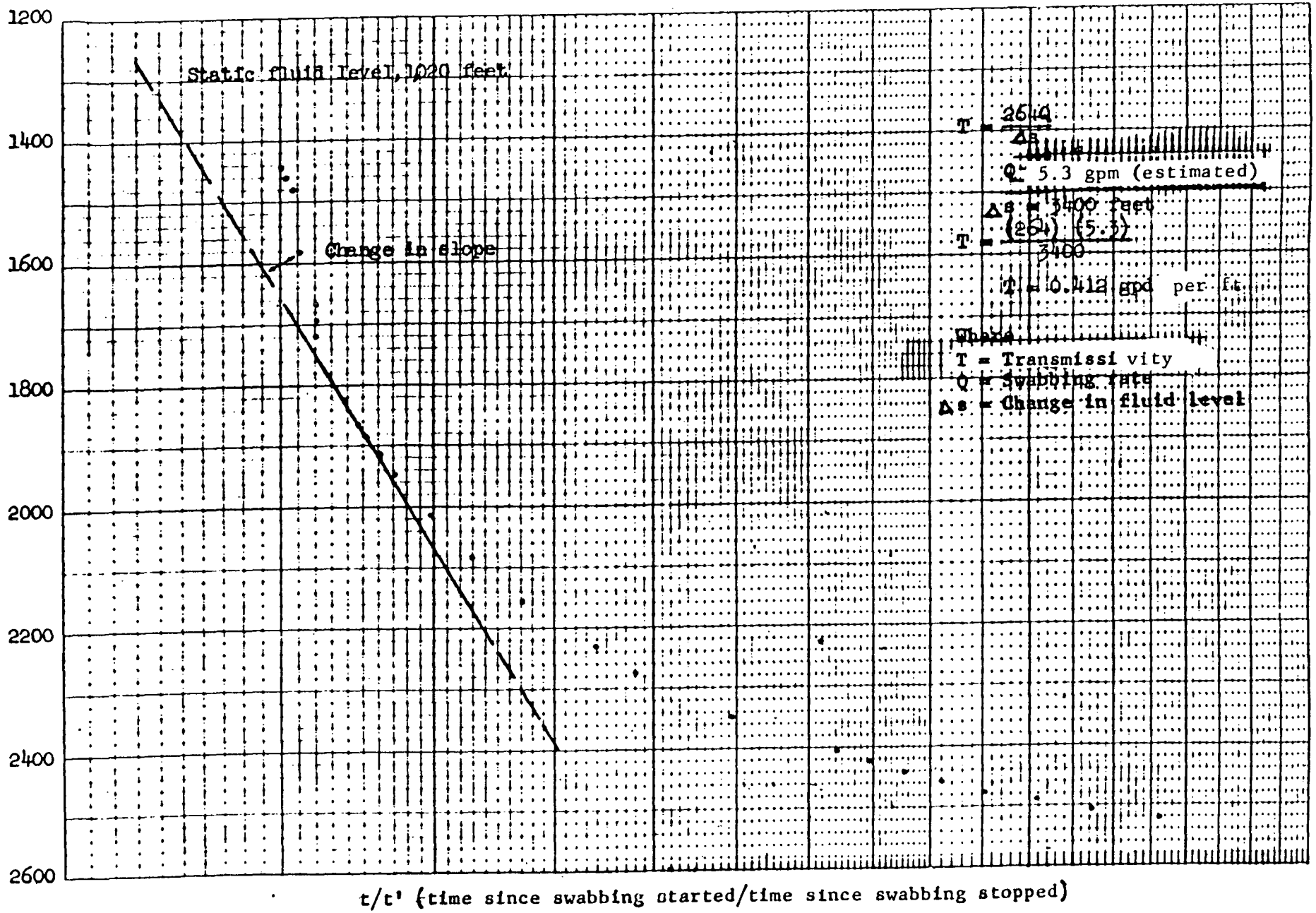


Figure 4.--Recovery of water level in hole GB-1 after second swabbing test of upper zone of Ojo Alamo Sandstone.

Production of fluid during the first swab test of the lower part of the Ojo Alamo Sandstone was about 14 gpm with nearly 2,000 feet of drawdown. The data on water-level recovery in table 6 are plotted on figure 5. The change in drawdown (s) over one cycle is about 1,400 feet.

$$T = \frac{264Q}{\Delta s} = \frac{264(14)}{1,400}$$

$T = 2.64$ gpd per ft or 0.144 Darcy ft.

The relative specific capacity for this zone is:

$$\text{Specific capacity} = \frac{14}{(1884-1000)} = 0.016 \text{ gpm per ft}$$

For comparison, this value is slightly lower than necessary for safe mining of a chamber in zeolitized tuff at depths of as much as 2,000 feet below the water table at the Nevada Test Site.

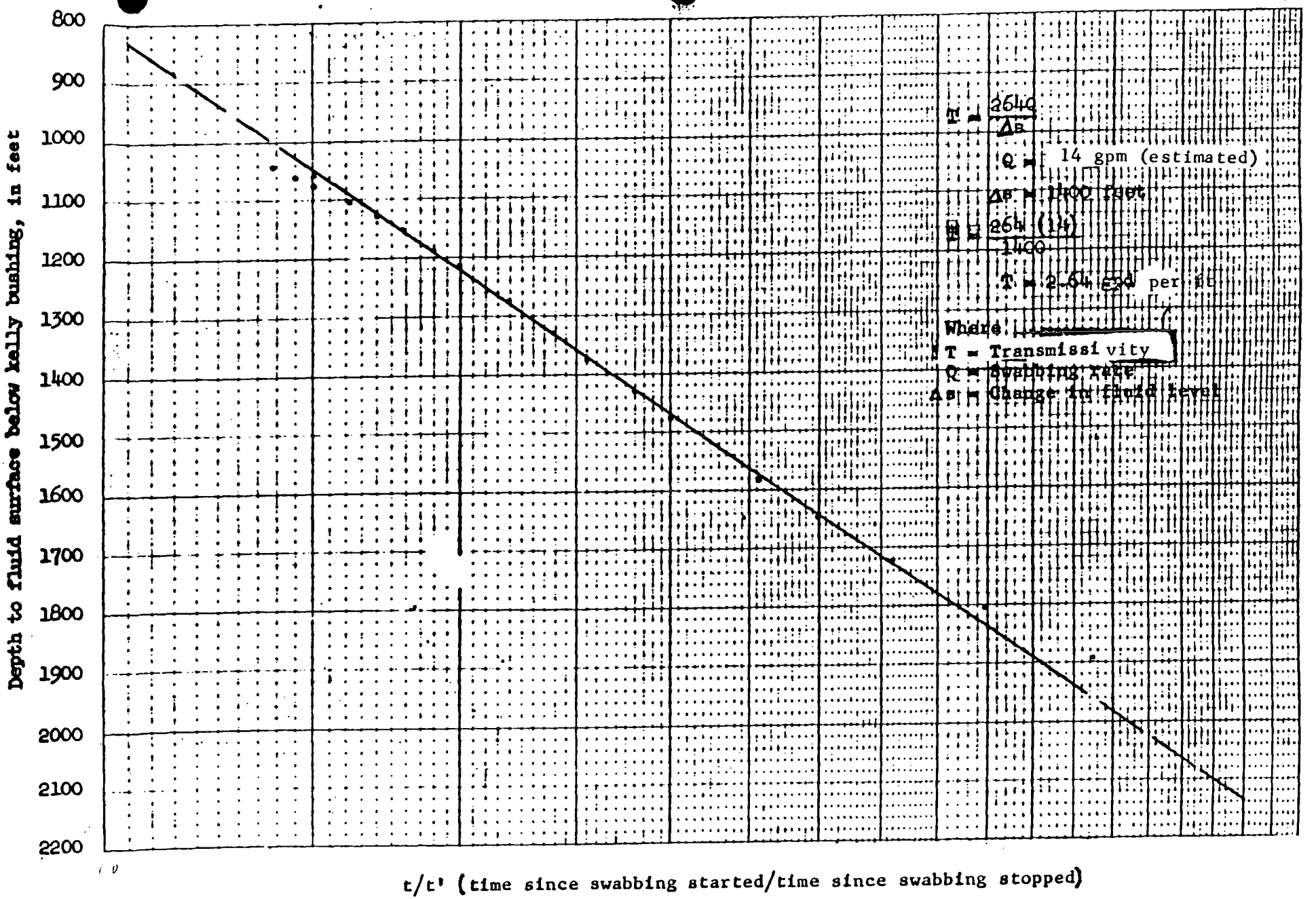


Figure 5.--Recovery of water level in hole GB-1 after first swabbing test of the lower zone of Ojo Alamo Sandstone.

SUMMARY

In February 1967, the U.S. Geological Survey made hydrologic tests in the Ojo Alamo Sandstone in hole GB-1, the initial test hole drilled at the site of the Gasbuggy Project. This work is part of the program to provide background data on safety aspects and hydrologic conditions related to the technical program of the Gasbuggy Project.

No water was detected during drilling and testing of the Kirtland Shale, Fruitland Formation, Pictured Cliffs Sandstone, and Lewis Shale.

The transmissivity of the Ojo Alamo Sandstone was found to be 0.412 gpd per ft in the upper 100 feet and 2.64 gpd per ft in the lower 70 feet.

The separation between the bottom of the Ojo Alamo Sandstone (approximate depth 3,654 feet) and the bottom of the Pictured Cliffs Sandstone (approximate depth 4,203 feet) is about 545 feet thick.

Table 1.--First swabbing test of upper zone of Ojo Alamo Sandstone in the depth interval 3,475 to 3,575 feet of hole GB-1, February 23, 1967

Swab run no.	Clock time	Approximate depth to top of fluid (feet)[1]	Swab depth (feet)[1]	Specific conductance of fluid (micromhos per cm at 25°C)	Fluid temp (°F) (at surface)
1	1640				
2	1649				
3	1656	700			
4	1716		1500		
5	1724	1100	2000		
6	1731	1300	2500		
7	1743	1600	2984		
8	1756	1750	3000		
9	1810	2150	3000		
10	1820	2250	3000	600	81
11	1829	2500	3000	640	81
12	1837	2600	3000	645	81
13	1846	2700	3000	645	82
14	1854	2700	3000		
15	1900	2700	3000		
16	1906	2700	3000	9000	82

[1] All depth measurements from top of kelly bushing.

Table 2.--Recovery of water level in hole GB-1 after first swabbing test of upper zone of Ojo Alamo Sandstone in the depth interval 3,475 to 3,575 feet, February 23-24, 1967

Clock time	Elapsed time (minutes)		Depth to fluid level (feet)[1/]
	Since swabbing started (t)	Since swabbing stopped (t')	
	February 23, 1967		
1906	146	0	2700 ±
1955	195	49	2454.5
2000	200	54	2437.2
2002	202	56	2430.0
2004	204	58	2423.1
2006	206	60	2416.1
2008	208	62	2410.0
2010	210	64	2403.0
2012	212	66	2396.0
2014	214	68	2389.0
2016	216	70	2382.5
2018	218	72	2376.0
2020	220	74	2369.5
2022	222	76	2363.0
2024	224	78	2356.0
2026	226	80	2350.0
2028	228	82	2343.2
2030	230	84	2337.5
2032	232	86	2330.5
2034	234	88	2324.5
2036	236	90	2319.0
2038	238	92	2313.0

Table 2.--Recovery of water level in hole GB-1 after first swabbing test--Continued

Clock time	Elapsed time (minutes)		Depth to fluid level (feet)[1/]
	Since swabbing started (t)	Since swabbing stopped (t')	
February 23, 1967 (Continued)			
2040	240	94	2307.0
2042	242	96	2300.3
2044	244	98	2294.2
2050	250	104	2277.0
2055	255	109	2261.5
2100	260	114	2247.2
2105	265	119	2232.8
2110	270	124	2219.0
2115	275	129	2204.5
2120	280	134	2191.0
2125	285	139	2177.0
2130	290	144	2164.0
2135	295	149	2151.0
2141	301	155	2134.7
2145	305	159	2124.5
2150	310	164	2111.0
2155	315	169	2098.0
2200	320	174	2085.5

Table 2.--Recovery of water level in hole GB-1 after first swabbing test--Concluded

Clock time	Elapsed time (minutes) Since swabbing started (t)	Elapsed time (minutes) Since swabbing stopped (t')	Depth to fluid level (feet)[1]
February 23, 1967 (Continued)			
2205	325	179	2073.0
2206	326	180	2070.5
2353	433	287	1803.0
2355	435	289	1799.0
2400	440	294	1790.0
February 24, 1967			
0005	445	299	1780.0
0010	450	304	1771.0
0015	455	309	1762.5
0020	460	314	1754.5
0030	470	324	1737.2
0035	475	329	1729.0
0040	480	334	1721.0
0045	485	339	1713.0
0050	490	344	1704.9
0055	495	349	1697.2

[1] All depth measurements from top of kelly bushing.

Table 3.--Second swabbing test of upper zone of Ojo Alamo Sandstone in the depth interval 3,475 to 3,575 feet of hole GB-1, February 24, 1967

Swab run no.	Clock time	Staff gage (feet)	Gallons each swab	Approximate depth to top of fluid (feet)[1]	Swab depth (feet)[1]	Specific conductance of fluid (micromhos per cm at 25°C)	Fluid temp (°F)
1	0215	0.34	128.18		2900	9000	78
2	0225	0.71	139.49		3000		
3	0237	1.08	139.49		3300		
4	0252	1.36	105.56	2200	3300		
5	0320	1.61	94.25		3300		
6	0330	1.80	71.63	2500	3300		
7	0344	2.00	75.40		3300		
8	0359	2.23	86.71		3300		
9	0414	2.43	75.40	2600	3300		
10	0428	2.59	60.32		3300		
11	0445	2.73	52.78	2900	3300		
12	0458	2.84	41.47		3300		
13	0515	2.93	33.93		3300		
14	0530	2.95	[2]14.54	3000	3300		
15	0545	3.00	18.85		3300		
16	0552	3.06	22.62	3000	3300	9000	78

[1] All depth measurements from top of kelly bushing.

[2] Seven gallons removed for chemical analyses.

Table 4.--Recovery of water level in hole GB-1 after second swabbing test of upper zone of Ojo Alamo Sandstone in the depth interval 3,475 to 3,575 feet, February 24, 1967

Clock time	Elapsed time (minutes)		Fluid level (feet)[1/]	Water added to well	
	Since swabbing started (t)	Since swabbing stopped (t')		Gallons per minute	Elapsed time (minutes)
0625	250	33	2520.5	--	--
0630	255	38	2505.5	--	--
0635	260	43	2488.0	--	--
0640	265	48	2472.5	--	--
0645	270	53	2456.2	--	--
0650	275	58	2440.2	--	--
0655	280	63	2424.0	--	--
0700	285	68	2407.8	--	--
0710	295	78	2376.7	--	--
0720	305	88	2346.8	--	--
0730	315	98	2318.0	--	--
0745	330	113	2275.2	--	--
0800	345	128	2234.2	--	--
0815	360	143	2195.0	--	--
0830	375	158	2155.8	--	--
0845	390	173	2118.8	--	--
0900	405	188	2082.2	--	--
0915	420	203	2048.0	--	--
0930	435	218	2013.3	--	--
0945	450	233	1981.2	--	--
1000	465	248	1949.2	--	--
1015	480	263	1919.0	--	--
1030	495	278	1890.0	--	--
1045	510	293	1861.0	--	--

Table 4.--Recovery of water level in hole GB-1 after second swabbing test--Continued

Clock time	Elapsed time (minutes) Since swabbing started (t)	Since swabbing stopped (t')	Fluid level (feet)[1/]	Water added to well: Gallons per minute	Water added to well: Elapsed time (minutes)
1100	525	308	1833.8		
1115	540	323	1806.8		
1130	555	338	1780.7		
1139	564	347	1766.2	Began adding water at 1139 hours at 2.5 gpm	0
1142	567	350	1762.0		3
1144	569	352	1748.0		5
1145	570	353	1742.5		6
1146	571	354	1738.5		7
1147	572	355	1734.1		8
1148	573	356	1728.5		9
1149	574	357	1724.0		10
1150	575	358	1719.0		11
1151	576	359	1714.0		12
1152	577	360	1709.0		13
1153	578	361	1704.0		14
1154	579	362	1698.2		15
1155	580	363	1693.5		16
1156	581	364	1688.8		17
1157	582	365	1684.0		18
1158	583	366	1678.5		19
1159	584	367	1674.0		20

Table 4.--Recovery of water level in hole GB-1 after second swabbing test--Continued

Clock time	Elapsed time (minutes) Since swabbing started (t)	Since swabbing stopped (t')	Fluid level (feet)[1]	Water added to well: Gallons per minute	Water added to well: Elapsed time (minutes)
1200	585	368	1669.5		21
1202	587	370	1659.2		23
1204	589	372	1648.8		25
1206	591	374	1639.0		27
1208	593	376	1629.2		29
1210	595	378	1619.0		31
1212	597	380	1610.0		33
1214	599	382	1600.2		35
1216	601	384	1591.0		37
1218	603	386	1580.7		39
1220	605	388	1571.0		41
1222	607	390	1561.5		43
1224	609	392	1552.0		45
1228	613	396	1533.0		49
1230	615	398	1528.0		51
1232	617	400	1518.0		53
1234	619	402	1508.0		55
1236	621	404	1496.0		57
1237	622	405	1490.5		58
1238	623	406	1485.5		59
1239	624	407	1481.0	Stopped addition of water at 1239 hours	60

Table 4.--Recovery of water level in hole GB-1 after second swabbing test--Concluded

Clock time	Elapsed time (minutes) Since swabbing started (t)	Since swabbing stopped (t')	Fluid level (feet)[1]	Water added to well: Gallons per minute	Water added to well: Elapsed time (minutes)
1240	625	408	1478.0		61
1241	626	409	1475.5		62
1242	627	410	1473.0		63
1243	628	411	1472.5		64
1244	629	412	1471.2		65
1245	630	413	1470.6		66
1246	631	414	1470.0		67
1247	632	415	1469.0		68
1248	633	416	1467.5		69
1249	634	417	1466.8		70
1250	635	418	1466.0		71
1251	636	419	1464.8		72
1252	637	420	1463.2		73
1254	639	422	1461.0		75
1256	641	424	1458.5		77
1258	643	426	1456.8		79
1300	645	428	1454.3		81
1302	647	430	1452.0		83
1304	649	432	1450.0		85
1306	651	434	1448.5		87
1308	653	436	1446.5		89

[1] All depth measurements from top of kelly bushing.

Table 5.--First swabbing test of lower zone of Ojo Alamo Sandstone in the depth interval 3,575 to about 3,654 feet and Kirtland Shale from about 3,654 to 3,696 feet of hole GB-1, February 26, 1967

Swab run no.	Clock time	Staff gage (feet)	Gallons each swab	Approximate depth to top of fluid (feet)[1]	Swab depth (feet)[1]	Specific conductance of fluid (micromhos per cm at 25°C)	Fluid temp. (°F) (at surface)
1	2011		300[2]		1,000		
2	2017		300[2]		1,500		
3	2025	0.37	139.50		1,900		
4	2032	.85	180.96		2,000		
5	2042	1.35	188.50	1,000	2,400		
6	2051	1.77	158.34	1,000	2,500		
7	2111	2.31	203.58	1,300	3,000		
8	2122	2.78	177.19	1,600	3,000	750	75
9	2133	3.23	169.65	2,000	3,000		
10	2148	3.67	165.88	2,100	3,000	2,000	78
11	2202	4.04	139.49	2,100	3,000	5,550	78
12	2219	4.39	131.95	2,100	3,000	7,000	76
13	2237	4.84	168.65	2,200	3,400	8,100	78
14	2247	5.20	135.72	2,300	3,900	8,700	78
15	2202	5.57	139.49	2,300	3,000	9,000	78
16	2310	5.86	119.33	2,300	3,000	9,000	78

[1] All depth measurements from top of kelly bushing.

[2] Approximately 300 gallons.

Table 6.--Recovery of water level in hole GB-1 after first swabbing test of lower zone of Ojo Alamo Sandstone in the depth interval 3,575 to about 3,654 feet and Kirtland Shale from about 3,654 to 3,696 feet, February 26-27, 1967

Clock time	Elapsed time (minutes)		Depth to fluid level (feet)[1/]
	Since swabbing started (t)	Since swabbing stopped (t')	
February 26, 1967			
2341	210	31	1,888.0
2342	211	32	1,879.0
2343	212	33	1,867.0
2344	213	34	1,857.0
2345	214	35	1,847.0
2346	215	36	1,839.0
2347	216	37	1,830.0
2348	217	38	1,822.0
2349	218	39	1,813.0
2350	219	40	1,803.3
2352	221	42	1,786.5
2354	223	44	1,769.8
2356	225	46	1,752.6
2358	227	48	1,737.0
2400	229	50	1,721.0
February 27, 1967			
0002	231	52	1,705.8
0004	233	54	1,689.5
0006	235	56	1,676.3

Table 6.--Recovery of water level in hole GB-1 after first swabbing test--Continued

Clock time	Elapsed time (minutes)		Depth to fluid level (feet)[1/]
	Since swabbing started (t)	Since swabbing stopped (t')	
February 27, 1967 - Continued			
0008	237	58	1,662.0
0010	239	60	1,648.0
0012	241	62	1,635.0
0014	243	64	1,621.3
0016	245	66	1,609.8
0018	247	68	1,595.5
0020	249	70	1,584.8
0025	254	75	1,555.0
0035	264	85	1,501.3
0040	269	90	1,478.0
0045	274	95	1,455.8
0050	279	100	1,434.8
0055	284	105	1,415.0
0100	289	110	1,395.0
0105	294	115	1,376.5
0110	299	120	1,360.8
0115	304	125	1,344.2
0120	309	130	1,329.8
0130	319	140	1,302.5
0140	329	150	1,277.5
0150	339	160	1,256.2
0200	349	170	1,236.3
0210	359	180	1,218.5

Table 6.--Recovery of water level in hole GB-1 after first swabbing test--Concluded

Clock time	Elapsed time (minutes)		Depth to fluid level (feet) [1]
	Since swabbing started (t)	Since swabbing stopped (t')	
February 27, 1967 - Concluded			
0220	369	190	1,202.5
0230	379	200	1,188.2
0240	389	210	1,176.0
0250	399	220	1,164.2
0300	409	230	1,153.0
0315	424	245	1,139.2
0330	439	260	1,127.0
0345	454	275	1,116.0
0400	469	290	1,107.0
0415	484	305	1,098.0
0430	499	320	1,090.5
0445	514	335	1,084.0
0500	529	350	1,078.0
0515	544	365	1,072.5
0530	559	380	1,067.0
0545	574	395	1,062.5
0600	589	410	1,057.0
0615	604	425	1,054.0
0630	619	440	1,050.7
0645	634	455	1,047.5
0700	649	470	1,044.2

[1] All measurements from top of kelly bushing.

Table 7.--Second swabbing test of lower zone of Ojo Alamo Sandstone in the depth interval 3,575 to about 3,654 feet and Kirtland Shale from about 3,654 to 3,696 feet of hole GB-1, February 27, 1967

Swab run no.	Clock time	Staff gage (feet)	Gallons each swab	Approximate depth to top of fluid (feet)[1]	Swab depth (feet)[1]
1	0816	0.46	172		2,300
2	0827	.93	177		2,400
3	0835	1.35	158	1,400	2,600
4	0844	1.74	147		2,800
5	0853	2.14	151	1,600	3,000
6	0902	2.48	128		3,000
7	0911	2.81	124	1,950	3,000
8	0931	3.27	173		3,000
9	0941	3.67	151	2,250	3,000
10	0950	3.98	117		3,000
11	0959	4.28	113		3,000
12	1007	4.54	98		3,000
13	1024	4.81	102	2,125	3,000
14	1034	5.13	121		3,000
15	1042	5.38	94	2,100	3,000
16	1058	5.75	140	2,175	3,000
17	1106	6.07	121		3,000
18	1112	6.35	105	2,200	3,000
19	1121	6.63	105	2,300	3,000
20	1128	6.90	102		3,000
21	1135	7.13	87		3,000
22	1141	7.34	79	2,358	3,000
23	1149	7.57	87		3,000

[1] All measurements from top of kelly bushing.