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Ground-water investigations in Yellowstone National Park, October 1960 to October 1963

By

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GROUND-WATER INVESTIGATIONS IN YELLOWSTONE NATIONAL PARK, OCTOBER 1960 TO OCTOBER 1963

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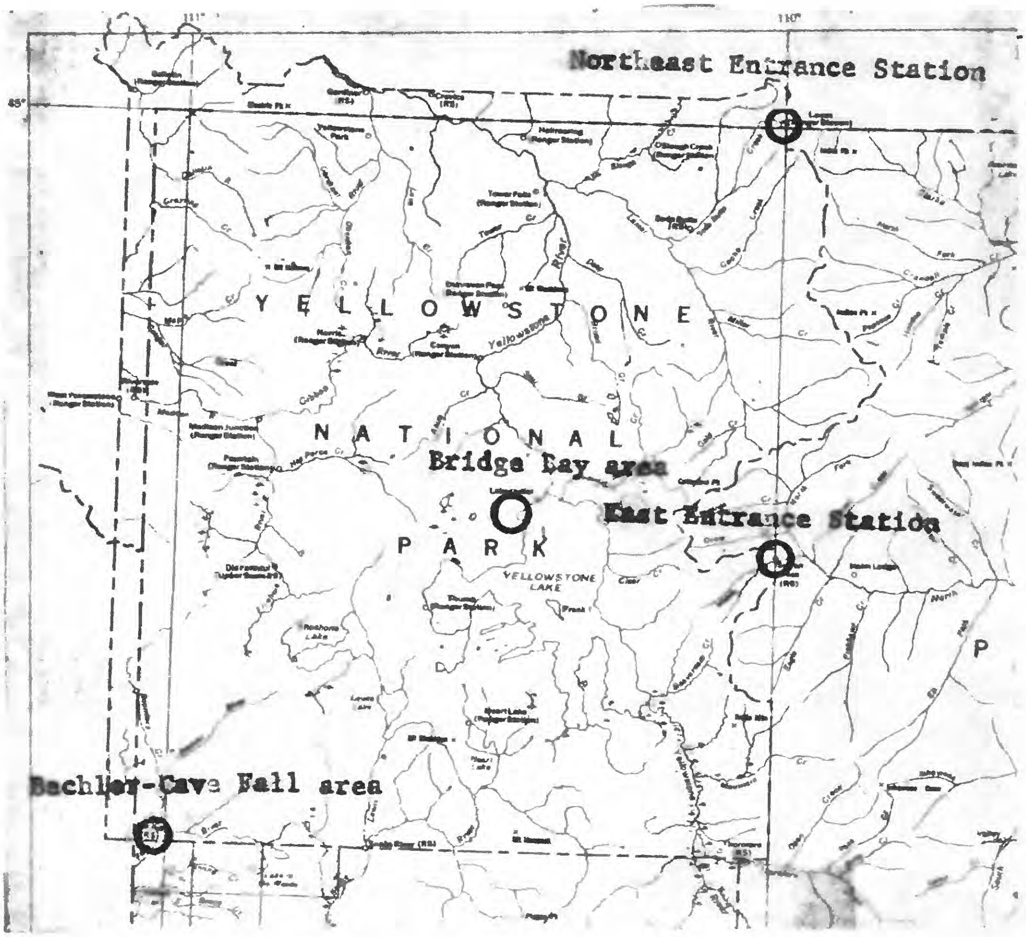
Introduction

The U.S. Geological Survey has cooperated with the National Park Service since May 1959 in ground-water investigations to develop public and domestic water supplies for National Parks, Monuments, and Historic Sites. This report describes work done in Yellowstone National Park by the Survey at intervals from October 1960 to October 1963. The areas discussed are the Northeast Entrance Station, East Entrance Station, Bridge Bay, and Bechler-Cave Fall (fig. 1). The authors were assisted at

Figure 1.--Map showing location of areas discussed in this report.

various times in the field work by L.J. McGreevy, H.A. Whitcomb, and E.P. Weeks. The work included reconnaissance studies of geology, supervision of test drilling activities, studies of drill cuttings, aquifer tests, and collection of water samples for analysis.



Scale 1:1,000,000

0 10 20 miles

Figure 1.--Map showing location of areas discussed in this report.

Geologic studies were made in Yellowstone National Park by the U.S. Geological Survey many years ago. Although many separate studies have since been made in various parts of the area, no comprehensive re-examination of the entire area has been made in recent years.

Hague (1896) prepared geologic maps of Yellowstone Park at a scale of 1:125,000, and a map of the geology about the preiphery of Yellowstone Lake (1904, pl. 27) at an approximate scale of three-fourths of an inch per mile. Hague and others (1899) described the geology of the entire Park in detail. A report by Foose and others (1961) on the structural geology of the Beartooth Mountains, Montana and Wyoming, included an area along the northern Park boundary. Brown (1961) described the geology of northeast Yellowstone Park. For detailed discussions of the geology, the references cited above and listed at the end of this report may be consulted.

Northeast Entrance Station

The geology in the vicinity of the Northeast Entrance Station, which is in the valley of Soda Butte Creek, has been mapped recently by Brown (1961). The valley walls are composed of shale and carbonate rocks of Paleozoic age, and the higher areas are capped by volcanic breccia of Tertiary age. A funnel-shaped landslide deposit extends from near the highway northward to the base of the resistant volcanic breccia. The alluvium in the valley of Soda Butte Creek is underlain by shale and sandstone of Cambrian age (fig. 2). However,

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Figure 2.--Section across the valley of Soda Butte Creek at the Northeast Entrance Station showing probable relation of the alluvium to the older formations. Nomenclature is that of Brown (1961).

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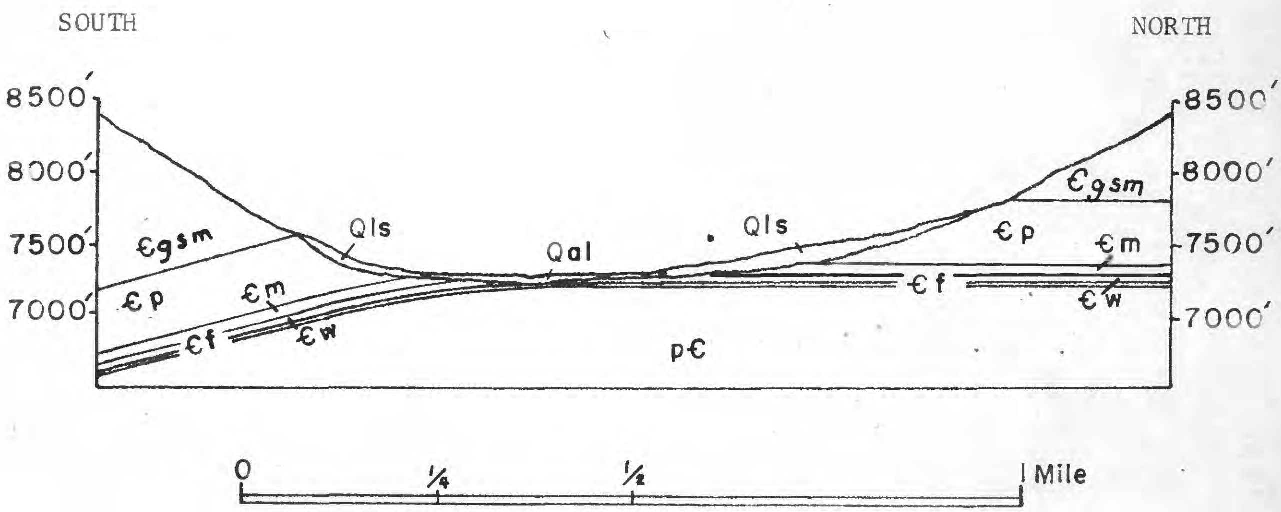
the strata may have been partly, or completely, removed by erosion in deeper parts of the old stream channel.



Explanation: Qls, landslide deposits, and Qal, alluvium of Quaternary age; €gsm, Grove Creek, Snowy Range, and Maurice Formations, €p, Park Formation, €m, Meagher Formation, €w, Wolsey Formation, and €f, Flathead Sandstone of Cambrian age; and p€r, rocks of Precambrian age.

Figure 2.--Section across the valley of Soda Butte Creek at the Northeast Entrance Station showing probable relation of the alluvium to the older formations. Nomenclature is that of Brown (1961).

The present (1963) water supply at the Northeast Entrance Station is obtained from a small unnamed stream that originates as several small springs along the margin of the landslide deposit north of the station. Water is diverted from this stream, by a slotted pipe, into an open channel. The water flows to a concrete catchment basin and from there is piped to the reservoir. The flow of the stream in the fall of 1962 was about 50 gpm (gallons per minute), of which approximately 30 gpm was being diverted into the reservoir. The entire flow of the stream could have been diverted if needed. The quantity of water probably is fairly dependable; however, water in part of the system sometimes freezes during the winter if the snow cover is light.

Water could be developed as a supply for future expansion from the alluvium along Soda Butte Creek and possibly from the Flathead Sandstone. The Flathead, which is the oldest sedimentary formation in the area, may consist of as much as 65 feet of medium-grained sandstone or quartzite, but it may be absent locally because of nondeposition, or because of erosion during Quaternary time. It is estimated that yields ranging from 30 to 40 gpm possibly could be obtained from a complete section of the sandstone in localities where it has not been altered to quartzite. Such alteration has occurred extensively and the yield therefore may be much smaller.

The best possibility of developing water in the area is from the alluvium along Soda Butte Creek. The alluvium consists of an unknown thickness of silt, sand, gravel, and boulders. The formation may differ markedly in permeability within a short distance and more than one test hole therefore may be required in order to locate a section permeable enough to furnish an adequate supply of water.

The quality of the water from the alluvium at the Northeast Entrance should be similar to that collected from a dug well 11 feet deep in the alluvium 1.5 miles east, at Silver Gate, Mont. Analyses of this water and that from the present supply at the Northeast Entrance Station are given in table 1. A water sample could not be collected from the Flathead Sandstone for analysis; the quality of the water from the Flathead, however, may be better than that from the alluvium.

It is recommended that one or two test holes be drilled in the alluvium in the area north of the creek, east of the road leading southward across the creek to the old ranger station, and south of the present entrance station (fig. 3). The exact location can be based partly on proposed

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Figure 3.--Sketch map of Northeast Entrance Station showing general area proposed for test holes (hachured). After drawing NP-YEL 2296-A.

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construction, because the more permeable areas cannot be determined from surface evidence. If the first two test holes are not successful, subsequent tests should be drilled in a line southward from the first test hole and across the valley, to gain as much geologic information as possible. In the event that a suitable water supply is not obtained from the alluvium and the Flathead Sandstone is found to be present beneath the valley, a test hole should be drilled to the base of the Flathead.

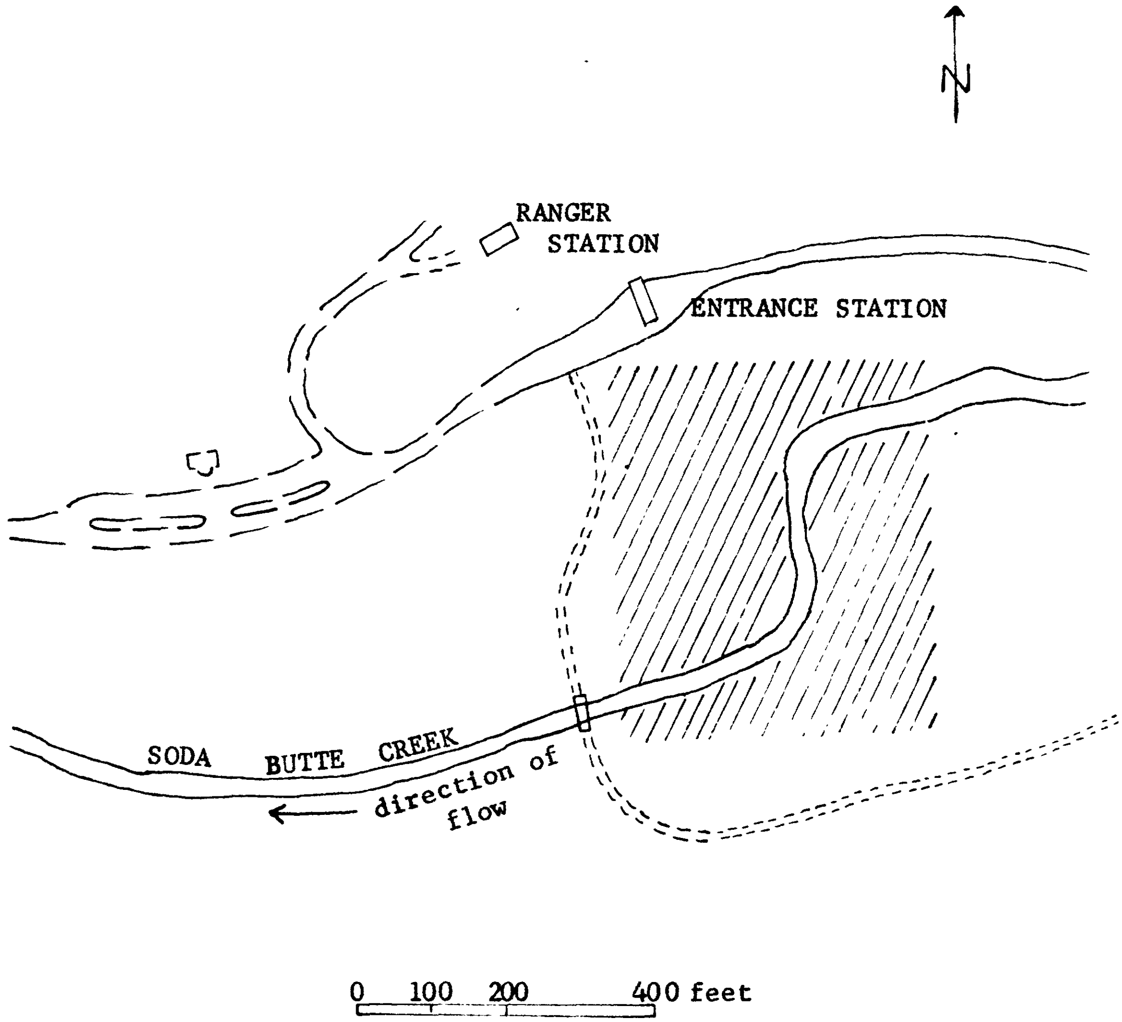

Figure 3.--Sketch map of Northeast Entrance Station showing general area proposed for test holes (hachured). After drawing NP-YEL 2296-A.

Table 1.--Analyses of ground water and surface water in areas of investigation, Yellowstone National Park.

[Results in parts per million except as indicated. Analyses by U.S. Geological Survey.]

Location	Date of collection	Source	Depth of well (feet)	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Arsenic (As_2O_3)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (N)	Boron (B)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Noncarbonate	Percent sodium	Sodium-adsorption ratio	Specific conductance (micromhos at 25°C)	pH	Color
GROUND WATER																														
Silver Gate, Mont.	9-14-62	Dug well	11	--	14	0.00	----	----	----	----	----	52	11	4.4	0.6	199	0	23	0.0	0.1	0.2	0.03	200	176	13	5	0.1	340	7.5	1
Pahaska Campground, Wyo.	9-17-62	Drilled well	20	48	22	.03	----	----	----	----	----	5.4	2.1	13	.5	52	0	10	.0	.2	.2	.04	77	22	0	56	1.2	104	7.2	4
Bridge Bay well 1, Yellowstone National Park	10-19-60	Drilled well	95	57	75	.28	----	----	----	----	----	10	7.6	8.2	2.5	84	0	.8	1.4	1.4	.2	.02	161	56	0	23	.5	150	7.1	45
--------do----------------	8- 3-63			60	73	.03	----	0.00	0.03	0.01	0.03	13	6.5	9.0	2.7	88	0	3.4	.5	2.2	.1	---	144	59	0	24	.5	163	6.8	--
Bridge Bay well 2, Yellowstone National Park	9- 5-63	Drilled well	59.5	55	80	.02		.00	.01	.01	.02	5.8	6.2	11	2.5	64	0	1.4	.4	4.7	.1	---	139	40	0	36	.8	131	7.0	--
Cave Fall well 1, Yellowstone National Park	10- 5-63	Drilled well	153	48	42	.13	0.04	----	----	----	----	14	5.8	26	3.5	110	0	3.0	16	2.8	.01	.48	183	59	0	47	1.5	253	7.3	--
SURFACE WATER																														
Northeast Entrance Station Yellowstone National Park	7-26-63	Domestic supply	Unnamed stream	--	15	1/ .17	----	----	----	----	----	34	13	4.5	.6	170	0	7.8	.4	.1	.0	.09	156	138	0	7	.2	271	7.8	3
East Entrance Station Yellowstone National Park	7-23-63	Domestic supply	Unnamed stream	--	29	1/ .09	----	----	----	----	----	2.0	.2	38	.2	79	7	10	.4	.8	.1	.19	130	6	0	93	6.7	172	8.8	6

1/ In solution when collected.

East Entrance Station

The East Entrance Station of Yellowstone National Park is in the canyon of Middle Creek, which has been deeply eroded into the volcanic breccia of Tertiary age. Flanking the walls of the canyon are talus slopes and small alluvial fans. The valley is underlain by volcanic breccia, which is covered to an unknown depth of alluvium deposited by Middle Creek.

The present water supply at the East Entrance Station is from a small stream that heads as contact springs near the top of the ridge, about 1 mile north of the highway. The springs issue from the base of landslide and talus deposits at the contact with the underlying breccia. The stream flows into Middle Creek about half a mile west of the entrance station. The water is diverted into a reservoir by a collector pipe buried in the alluvial fan deposited by the stream. The flow into the reservoir was 20 gpm on September 12, 1962.

It is doubtful that a successful well could be developed in the volcanic breccia or the talus material. The breccia would yield water only from fractures; the talus material is poorly sorted and, therefore, may not yield adequate supplies.

A water supply for expansion of Park facilities could be developed from the alluvium. Water has been developed from the alluvium along Middle Creek at the Pahaska Campground, 2 miles downstream from the entrance station, and the occurrence of the water in the alluvium at the entrance station would be similar. The driller reported that the wells are from 20 to 30 feet deep and that the formation consists of "rocks and gravel." The yield of the wells was not reported, but they probably will yield about 30 gpm. Larger yields could be obtained if the complete section of the alluvium is thicker than that penetrated by these wells.

The quality of water from the alluvium at the East Entrance should be similar to that of the water from the well at Pahaska Campground. An analysis of this water and the analysis of the water from the present supply at the East Entrance Station are given in table 1.

The test well or wells should be drilled in the alluvium in the area shown on figure 4, and upstream from the location of existing sewage systems.

Figure 4.--Sketch map of East Entrance Station showing area proposed for test holes (hachured). After drawing NP-YEL 2283-C.

If it is desirable to have a well at the proposed maintenance building at the north edge of the valley flat, an adequate supply possibly could be obtained at this location. The alluvium at this location, however, will have a larger proportion of less permeable slope wash, because it is closer to the edge of the talus. Therefore, a well at the edge of the flat may have a smaller yield than one nearer the center of the valley.

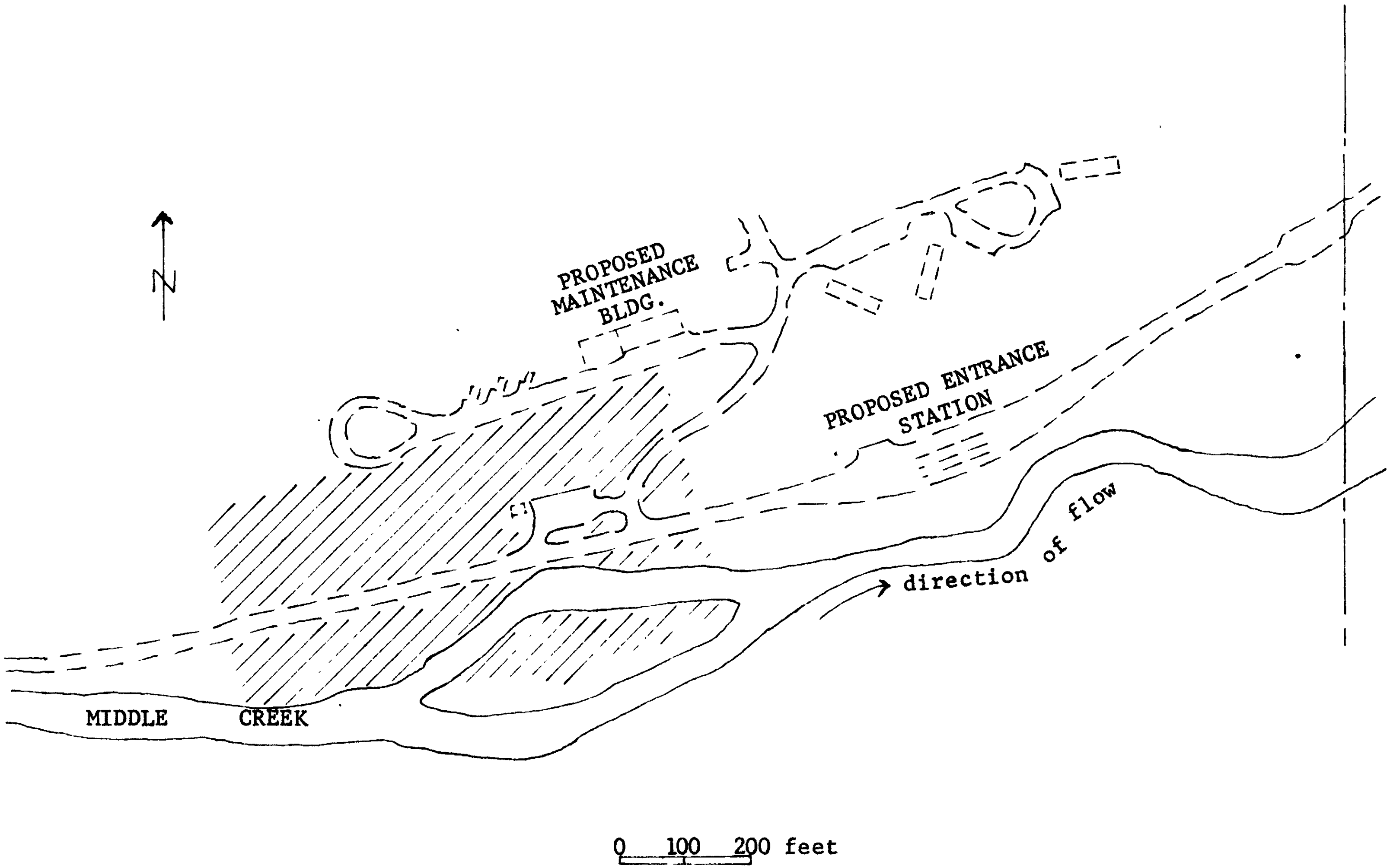

Figure 4.--Sketch map of East Entrance Station showing area proposed for test holes (hachured).

After drawing NP-YEL 2283-C.

Bridge Bay area

Bridge Bay well 1.--Bridge Bay well 1 was drilled during October 1960 in the lacustrine deposits north of Bridge Bay Lagoon (fig. 5).

Figure 5.--Map showing locations of wells and auger holes, Bridge Bay, Yellowstone National Park, Wyo.

The well is 95 feet deep and is screened from about 87 feet to the bottom with a 0.040 slot screen. Although the driller reported a yield of 50 gpm, the well yielded only 30 gpm if operated continuously for several hours. In July 1963 a contract was awarded for work including reconditioning the well in an attempt to increase the yield.

Reconditioning was started on July 24, 1963. The well was alternately swabbed and bailed in an attempt to induce the fine sand to enter the screen and thereby increase the permeability of the material surrounding the screen, but the quantity of sand that entered the screen was less than 1 foot each time the well was swabbed. The amount of sand that entered the screen during the reconditioning and the amount that was present in the well when the pump was pulled was so small that it was not considered necessary to pull the screen for inspection. This conclusion was substantiated during the aquifer test, following reconditioning, when less than 0.05 milliliter of sand per liter of water was pumped. This is within the limit of less than 1 ounce of sand per 100 gallons of water commonly used by some government agencies.

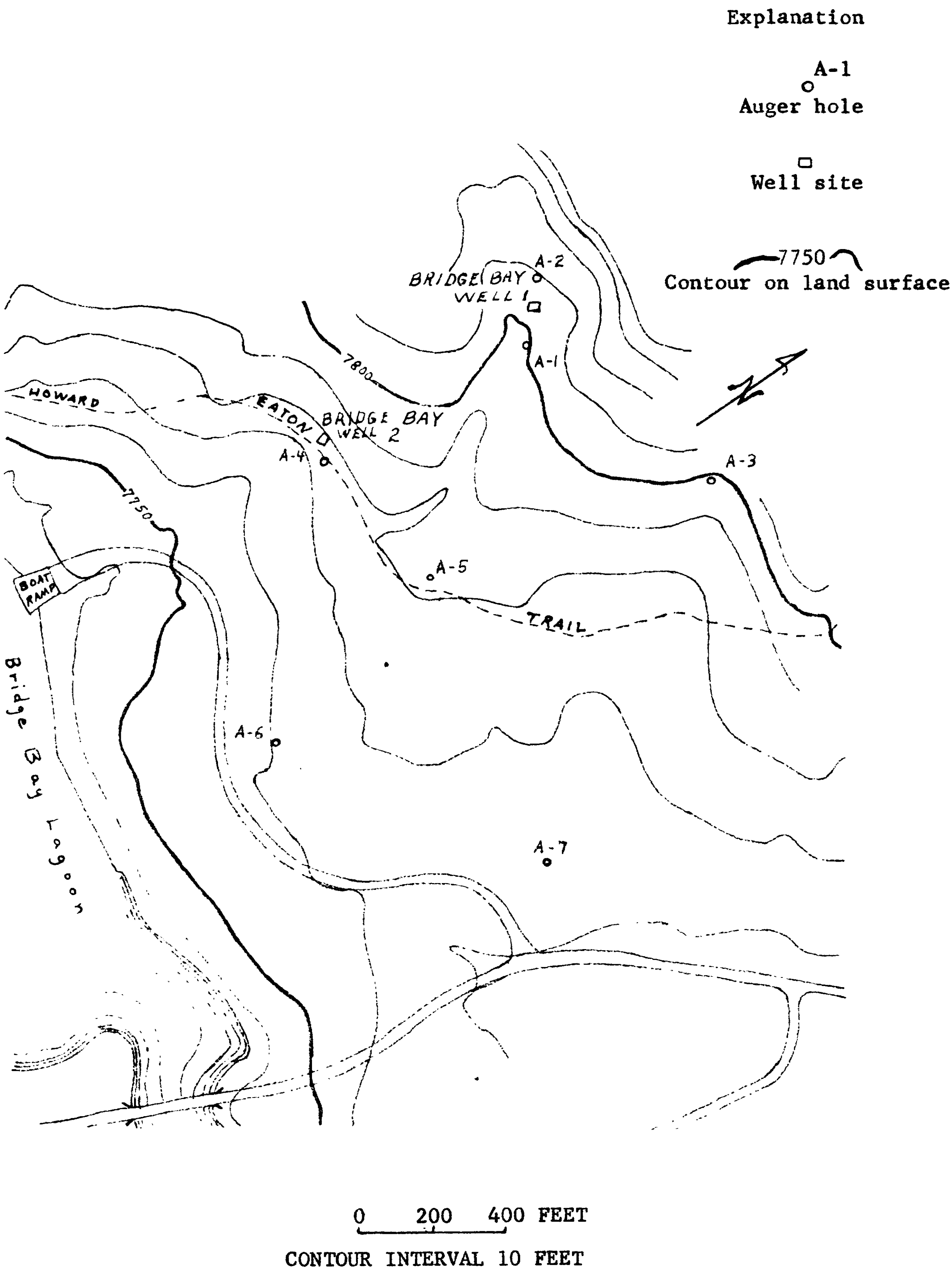

Figure 5.--Map showing locations of wells and auger holes, Bridge Bay, Yellowstone National Park, Wyo.

Aquifer tests were made at Bridge Bay well 1, and other wells in the project area, to determine the coefficient of transmissibility and also coefficient of storage where possible. The methods used in the tests are those described by Ferris and others (1962).

The coefficient of transmissibility is a measure of the rate of flow of water through a vertical strip of aquifer one foot wide extending the full saturated thickness of the aquifer under a hydraulic gradient of 100 percent. The coefficient of storage of an aquifer is defined as the volume of water it releases or takes into storage per unit surface area of the aquifer per unit change in head normal to that surface.

Aquifer tests were made at Bridge Bay well 1 in 1961 and 1963. It is believed that the values determined are representative of the conditions existing in the aquifer. Data from two recovery tests for the well give a transmissibility of 1,100 gpd/ft (gallons per day per foot) and the drawdown data from an observation well 100 feet northwest of the pumped test well give a transmissibility of 1,400 gpd/ft and a storage coefficient of 7.3×10^{-4}. (See figs. 6, 7, and 8, and table 2.)

Figure 6.--Semilogarithmic graph of water-level recovery in Bridge Bay well 1, July 10-11, 1961.

Figure 7.-- Semilogarithmic graph of water-level recovery in Bridge Bay well 1, Aug. 2-3, 1963.

Figure 8.--Logarithmic graph of drawdown in observation well A-2 during the pumping of Bridge Bay well 1, Aug. 2-3, 1963.

The values of transmissibility obtained from aquifer tests indicate that the specific capacity of the well should be about 0.55 gpm per foot of drawdown. This compares favorably with the observed specific capacities of 0.44 gpm per foot of drawdown at the end of the 24-hour pumping test and 0.48 gpm per foot of drawdown at the end of the 13-hour pumping test. These data indicate that the yield of the well would not be substantially increased by additional development.

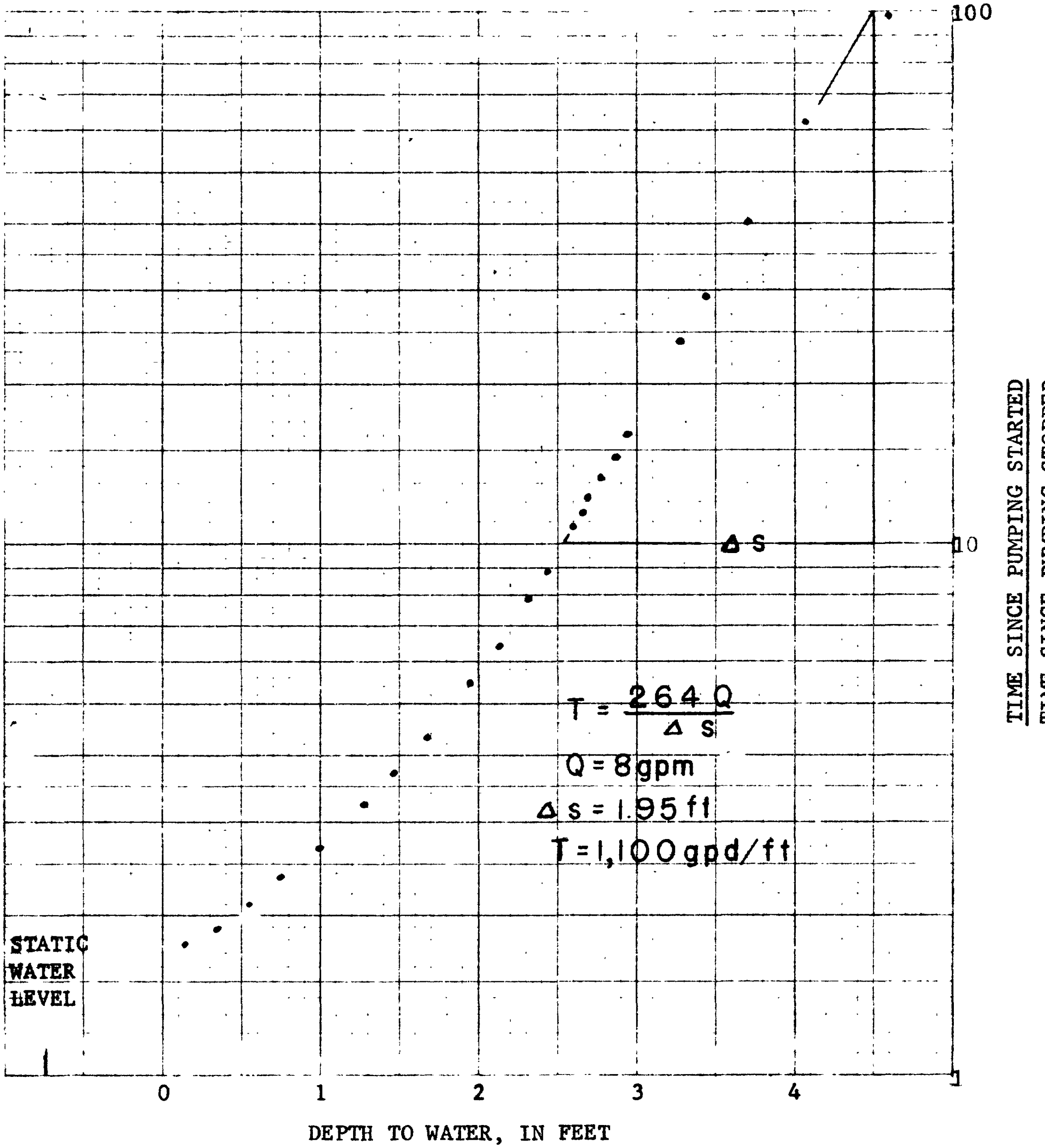

Figure 6.--Semilogarithmic graph of water-level recovery in Bridge Bay well 1, July 10-11, 1961.

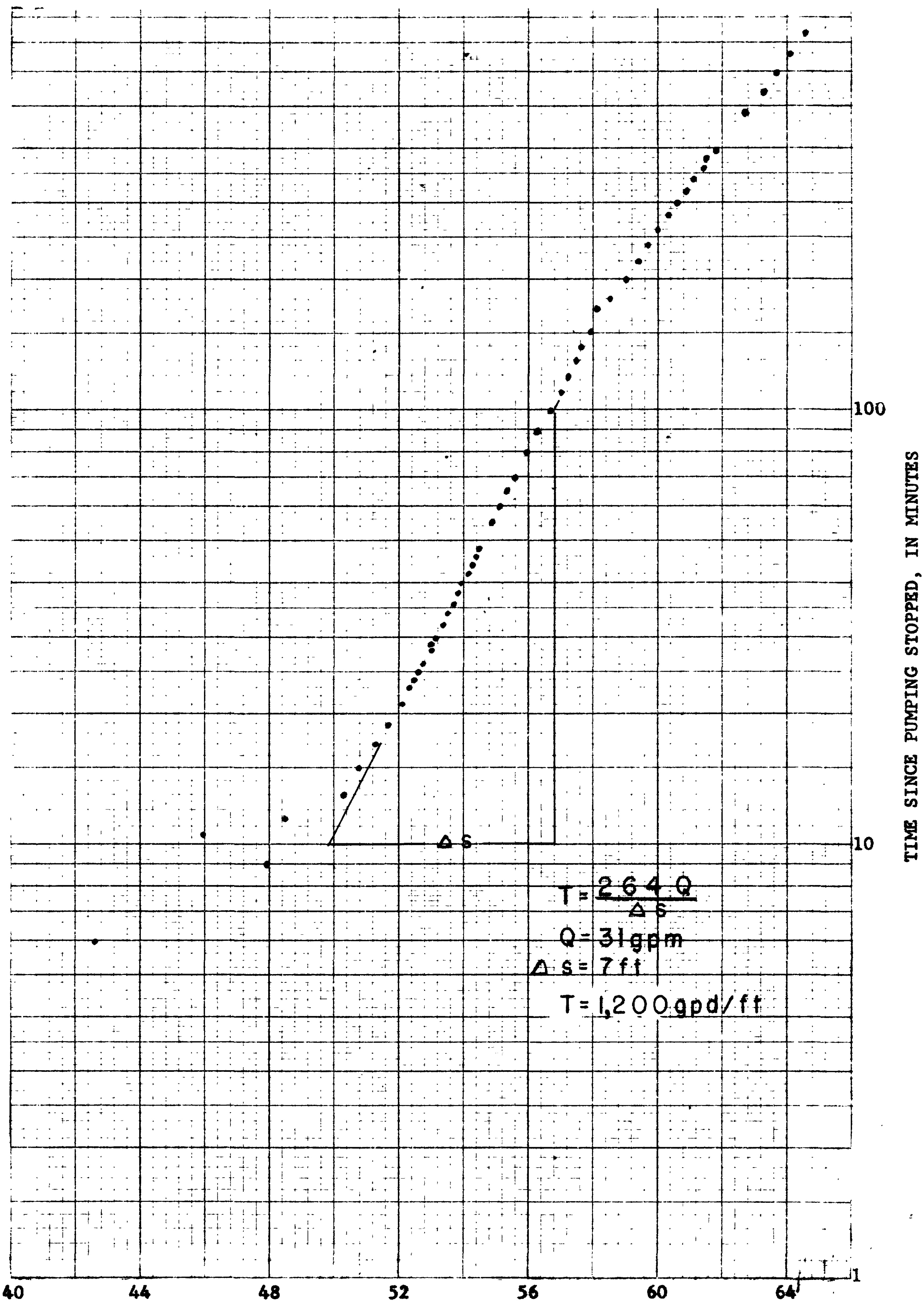

Figure 7.--Semilogarithmic graph of water-level recovery in Bridge Bay well 1, Aug. 2-3, 1963.

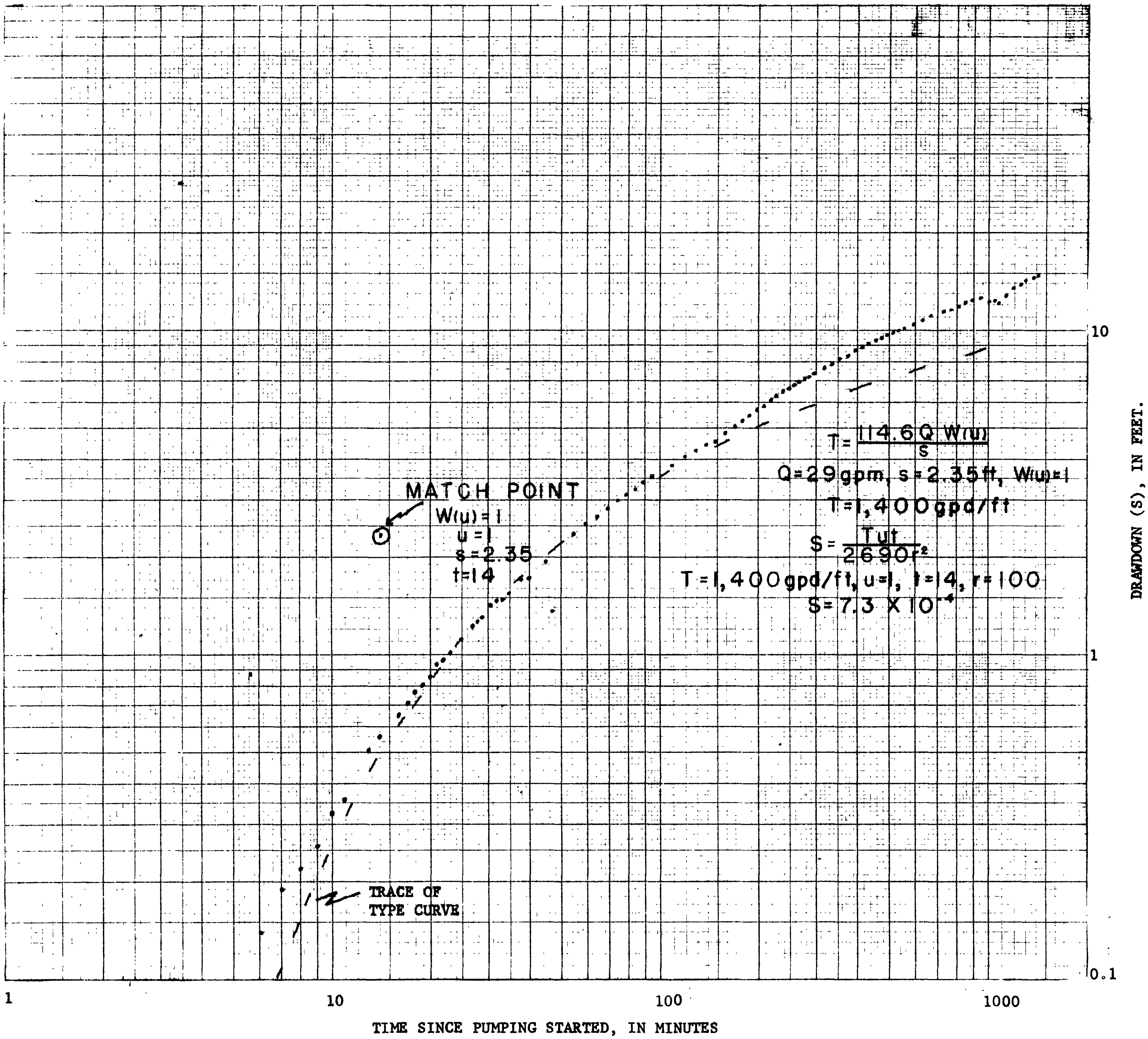

Figure 8.--Logarithmic graph of drawdown in observation well A-2 during the pumping of Bridge Bay well 1, Aug. 2-3, 1963.

Table 2.--Aquifer-test data.

Date	Time	Depth to water (feet)	Discharge (gpm)	Remarks	Date	Time	Depth to water (feet)	Discharge (gpm)	Remarks
1961					1961				
Bridge Bay well 1, July 10-11, 1961									
7/10	0850	+0.73	0	Static	7/10	0945	13.57		
				level		0950	13.48		
	0900	Began pumping test well				0955	13.77	9.5	
	0904	14.35				1000	14.52	9.1	
	0905	13.84				1001	14.43		
	0906	13.56				1005	14.47		
	0907	13.16				1010	14.78	9.1	
	0908	13.86				1015	14.66	9.2	
	0909	14.05				1020	13.89	8.6	
	0910	13.24				1025	13.69		
	0911	12.58				1030	13.85	8.6	
	0912	12.08				1035	13.94		
	0913	13.33				1040	14.11	8.6	
	0914	13.45				1050	14.24	8.8	
	0915	13.59				1100	14.36	8.8	
	0916	13.59				1110	14.25		
	0917	13.52				1120	14.28		
	0918	13.62				1130	14.40	8.6	
	0919	13.49				1140	14.34		
	0920	13.56				1150	14.29		
	0921	13.51				1200	14.51	8.6	
	0922	13.46				1210	14.47	8.1	
	0923	13.41				1220	14.41	8.1	
	0924	13.42				1230	14.34	8.1	
	0925	13.39				1245	14.40		
	0926	13.32				1300	14.78	8.3	
	0927	12.95				1315	14.62		
	0928	13.19				1330	14.43	7.7	
	0929	13.55				1335		7.9	
	0930	12.86				1345	14.39	7.9	
	0935	13.67				1400	14.46	7.9	
	0940	13.28							

Table 2.--Aquifer-test data.--continued

Date	Time	Depth to water (feet)	Dis-charge (gpm)	Remarks	Date	Time	Depth to water (feet)	Dis-charge (gpm)	Remarks
1961					1961				
Bridge Bay well 1, July 10-11, 1961--continued									
7/10	1415	14.50	8.1		7/10	2335	2.51		
	1500	14.60	8.1			2340	2.47		
	1530	14.67	7.9			2345	2.43		
	1600	14.78	8.1			2350	2.43		
	1630	14.95	7.9			2355	2.35		
	1700	14.93	7.9			2400	2.31		
	1730	15.01	7.9		7/11	2410	2.25		
	1800	15.13	7.9			2420	2.19		
	1830	15.17				2430	2.13		
	1900	15.08	7.5			2440	2.07		
	1930	14.63	7.1			2450	2.00		
	2000	14.47	7.1			0100	1.95		
	2015	15.12	7.9			0130	1.82		
	2030	15.05	7.5			0200	1.69		
	2110	16.10	8.1			0230	1.58		
	2135	15.73	7.9			0300	1.47		
	2205	-----	7.5	Pump stopped		0330	1.36		
		Began recovery test				0400	1.27		
	2213	4.60				0430	1.19		
	2218	4.07				0500	1.10		
	2225	3.70				0530	1.04		
	2233	3.43				0600	0.98		
	2239	3.28				0630	0.90		
	2244	3.00				0700	0.84		
	2256	2.94				0730	0.79		
	2303	2.86				0800	0.74		
	2309	2.77				0830	0.68		
	2315	2.69				0900	0.63		
	2320	2.65				0930	0.60		
	2325	2.60				1000	0.56		
	2330	2.55				1030	0.52		

Table 2.--Aquifer-test data.--continued

Date	Time	Depth to water (feet)	Dis-charge (gpm)	Remarks	Date	Time	Depth to water (feet)	Dis-charge (gpm)	Remarks
1961					1961				
Bridge Bay well 1, July 10-11, 1961--continued									
7/11	1100	0.48			7/11	1400	0.27		
	1200	0.41				1500	0.21		
	1300	0.34				1600	0.16		
1963					1963				
Bridge Bay well 1, August 2-3, 1963									
8/2	0645			Flowing 2 gpm	8/3	Began recovery test			
	0700	Began pumping test well				0706	27.4		
	0750	55.20	32.5			0709	22.11		
	0805	55.61				0710.5	24.05		
	0823	55.52	31			0711.5	21.50		
	0845	54.58	30			0713	19.73		
	0913	52.74	28.3			0715	19.24		
	0943	55.83	28.3			0717	18.74		
	0945	-----	34.8			0719	18.34		
	1000	-----	32			0721	17.96		
	1013	62.14	33			0723	17.69		
	1100	60.80	31			0724	17.55		
	1130	could not measure	31			0725	17.41		
	1315	62.75	31			0726	17.29		
	1410	62.37	31			0728	17.05		
	1700	63.54				0729	16.97		
	1745	63.20	31			0730	16.85		
	1945	63.46	31			0732	16.66		
8/3	0200	70+	34.5	poor measure-ments (0200-0400)		0734	16.48		
	0300	70+	34.5			0736	16.33		
	0400	70.0	31			0738	16.16		
	0600	68.82	31			0740	16.04		
	0645	70.48	31			0742	15.89		
	0700	-----		Pump stopped		0744	15.76		
						0746	15.62		
						0748	15.52		

Table 2.--Aquifer-test data.--continued

Date	Time	Depth to water (feet)	Dis-charge (feet)	Remarks	Date	Time	Depth to water	Dis-charge	Remarks
1963					1963				
Bridge Bay well 1, August 2-3, 1963--recovery, continued									
8/3	0750	15.49			8/3	1100	10.31		
	0755	15.12				1120	9.95		
	0800	14.85				1140	9.65		
	0805	14.65				1200	9.37		
	0810	14.42				1220	9.10		
	0820	14.03				1240	8.84		
	0830	13.69				1300	8.60		
	0840	13.30				1320	8.37		
	0850	13.03				1335	8.19		
	0900	12.78				1500	7.31		
	0910	12.53				1600	6.71		
	0920	12.38				1700	6.32		
	0932	12.05				1800	5.90		
	0953	11.91				1920	5.40		
	1000	11.47				2120			Flowing
	1020	11.02							
	1040	10.65							
Observation Well A-2, measured during pumping of Bridge Bay well 1 August 2-3, 1963									
8/2	0700	5.69			8/2	0711	6.05		
	0701	5.70				0712	6.11		
	0702	5.71				0713	6.20		
	0703	5.73				0714	6.25		
	0704	5.75				0716	6.34		
	0705	5.78				0717	6.40		
	0706	5.83				0718	6.46		
	0707	5.88				0719	6.50		
	0708	5.91				0720	6.55		
	0709	5.45				0721	6.63		
	0710	6.02				0722	6.66		
						0723	6.70		

Table 2.--Aquifer-test data.--continued

Data	Time	Depth to water (feet)	Dis-charge (gpm)	Remarks	Date	Time	Depth to water (feet)	Dis-charge (gom)	Remarks
1963				.	1963				
Observation Well A-2, measured during pumping of Bridge Bay well 1 August 2-3, 1963--continued									
8/2	0725	6.81			8/2	1010	11.21		
	0727	6.91				1020	11.42		
	0728	6.95				1030	11.62		
	0729	7.00				1040	11.79		
	0731	7.12				1050	11.98		
	0732	7.15				1100	12.14		
	0733	7.16				1110	12.31		
	0735	7.25				1120	12.47		
	0738	7.40				1130	12.62		
	0740	7.42				1140	12.79		
	0745	7.64				1150	12.91		
	0750	7.85				1200	13.09		
	0755	8.05				1220	13.35		
	0800	8.22				1240	13.61		
	0805	8.35				1300	13.87		
	0810	8.51				1320	14.11		
	0815	8.68				1340	14.34		
	0820	8.81				1400	14.56		
	0825	8.92				1420	14.76		
	0830	9.08				1440	14.97		
	0835	9.21				1500	15.15		
	0840	9.33				1520	15.35		
	0850	9.55				1540	15.50		
	0900	9.77				1600	15.66		
	0910	9.96				1620	15.83		
	0920	10.14				1700	16.14		
	0930	10.35				1740	16.42		
	0940	10.55				1820	16.70		
	0950	10.75				1920	17.14		
	1000	10.97				2000	17.34		

Table 2.--Aquifer-test data.--continued

Date	Time	Depth to water (feet)	Dis-charge (gpm)	Remarks	Date	Time	Depth to water (feet)	Dis-charge (gpm)	Remarks
1963					1963				
Observation Well A-2, measured during pumping of Bridge Bay well 1 August 2-3, 1963--continued									
8/2	2040	17.57			8/3	0100	17.89		
	2120	17.82				0200	18.58		
	2200	18.02				0300	19.18		
	2300	18.25				0400	19.60		
	2400	17.99				0500	19.85		
	2430	17.96				0600	20.12		
						0655	20.39		
Bridge Bay well 2									
9/3	1930	12.45			9/4	1500	38.60	46	
	2110	12.44				1600	38.93	47	
9/4	0755	12.43				1700	38.80	47.5	
	0800	Began pumping well				1800	39.37	44.5	
	0802	30.18	35			1925	39.20	45.5	
	0805	-----	46			2100	39.21	45.5	
	0807	36.30				2300	40.44	47	
	0813	36.99	46		9/5	0100	39.66	45.5	
	0825	38.20	48.5			0300	40.61	48.5	
	0845	38.18	46			0600	39.77	46	
	0900	38.82	48.5			0745	39.88	46	
	0915	38.99	50			0748	39.23	47.5	
	0925	38.04	46			0800	-----		Pump stopped
	0930	38.63	46			0800.5	24.6		measured with electric tape
	0945	38.60	46			0801	19.73		
	1000	37.43	44			0802	15.42		
	1030	38.55	46			0802.5	14.51		
	1110	38.60	46			0803	14.04		
	1125	38.88	47.5			0803.5	13.73		
	1145	37.55				0804	13.53		
	1230	40.04	56			0804.5	13.42		
	1255	38.37	46			0805	13.36		
	1400	39.66	46			0806	13.25		

Table 2.--Aquifer-test data.--continued

Date	Time	Depth to water (feet)	Dis-charge (gpm)	Remarks	Date	Time	Depth to water (feet)	Dis-charge (gpm)	Remarks
1963					1963				
Bridge Bay well 2--recovery, continued									
9/5	0807	13.21		measured with electric tape	9/5	0836	12.88		measured with steel tape
	0808	13.16				0840	12.88		
	0809	13.14				0850	12.85		
	0810	13.12				0900	12.84		
	0812	13.11				0920	12.84		
	0814	13.07				0940	12.83		
	0816	13.07				1000	12.81		
	0818	13.04				1100	12.75		
	0818	12.89		measured with steel tape		1200	12.74		
	0820	13.01		measured with electric tape		1330	12.71		
	0820	12.87		measured with steel tape		1630	12.68		
	0824	12.86				1930	12.67		
	0826	12.86			9/6	0715	12.63		
	0827	12.85				0830	12.62		
	0832	12.84							
Cave Fall well 1, October 3-4, 1963									
10/3	2400	32.75			10/4	2200	71.73	10	
10/4	0945	32.35				2330	76.15	11.5	
	1000	Began pumping well				2400	72.50	10.6	
	1005	41.57		K-210 T 46°F	10/5	0100	74.40	10	
	1020	56.00	8.1			0200	73.00	10	
	1030	59.8	10			0400	71.11	10	
	1050	60.9	8.8			0600	71.28	9.8	
	1130	64.92	10	K-220 T48°F		0800	71.38	10	
	1200	62.70	8.8			0900	71.3	10	
	1300	66.27	9.7			0950	70.61	8.1	
	1400	65.26	9.2			1000			Pump stopped
	1500	67.92	10				Began recovery test		
	1630	68.48	9.4			1000.5	57		
	1800	68.35	9.7			1001	55.71		
	2000	69.22	10			1001.5	54.62		

Table 2.--Aquifer-test data.--continued

Date	Time	Depth to water (feet)	Dis- charge (gpm)	Remarks	Date	Time	Depth to water (feet)	Dis- charge (gpm)	Remarks
1963					1963				
Cave Fall well 1, October 3-4, 1963--recovery, continued									
10/5	1002	53.65			10/5	1040	39.63		
	1002.5	52.79				1045	39.29		
	1003	51.85				1050	39.02		
	1003.5	51.04				1055	38.78		
	1004	50.38				1100	38.59		
	1004.5	49.74				1110	38.26		
	1005	49.22				1120	38.00		
	1006	48.33				1130	37.78		
	1007	47.93				1148	37.76		
	1008	47.37				1200	37.54		
	1009	46.80				1220	37.25		
	1010	46.10				1240	37		
	1011	45.45				1300	36.78		
	1012	45.00				1330	36.59		
	1013	44.62				1415	36.30		
	1014	44.35				1500	36.12		
	1016	43.70				1600	35.98		
	1018	43.22				1700	35.62		
	1020	42.56				1830	35.28		
	1022	41.66				2130	34.79		
	1024	41.25				2400	33.97		
	1026	40.89			10/6	0300	33.69		
	1028	40.62				0600	33.89		
	1030	40.40				1000	33.60		
	1035	39.97							

The plot of data obtained from observation well A-2 indicates the presence of an impermeable boundary about 300 feet from the observation well. Other boundaries probably are present but were not detected because of the short duration of the test. The exact location of the observed boundary, with respect to Bridge Bay well 1, could not be determined with the data available and, therefore, its effect on the well can not be determined precisely. However, if the well were pumped continuously for 60 days at a rate of 30 gpm, the effect of the boundary would be to increase the drawdown an additional 10 to 15 feet. This additional drawdown would result in a pumping level below 80 feet, which is the present pump setting. Therefore, a discharge of not more than 25 gpm is advisable for Bridge Bay well 1 if it is anticipated that it will be pumped continuously. A discharge of 30 gpm, however, should be satisfactory for periodic use.

Bridge Bay well 2.--This well was drilled to supplement Bridge Bay well 1 as a source of water for the Bridge Bay campground and marina. Bridge Bay well 2 is located 880 feet north of the boat ramp and 620 feet south of Bridge Bay well 1, at a site based on data obtained from auger holes drilled by the U.S. Geological Survey (table 3). The well was drilled to a total depth of 96 feet but was plugged back to 59.5 feet to include sands that could be developed to form a natural gravel pack. The casing record is shown on figure 9. Analysis of a 24-hour pumping test at

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Figure 9.--Diagram showing screen and casing settings, Bridge Bay well 2.

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the well indicates the transmissibility of the aquifer is 60,000 gpd/ft. (See figure 10 and table 2.) Although this figure probably is larger than

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Figure 10.--Semilogarithmic graph of the water-level recovery in Bridge Bay well 2, Sept. 5-6, 1963.

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that which would result from a longer test, it does indicate that the aquifer has a high permeability.

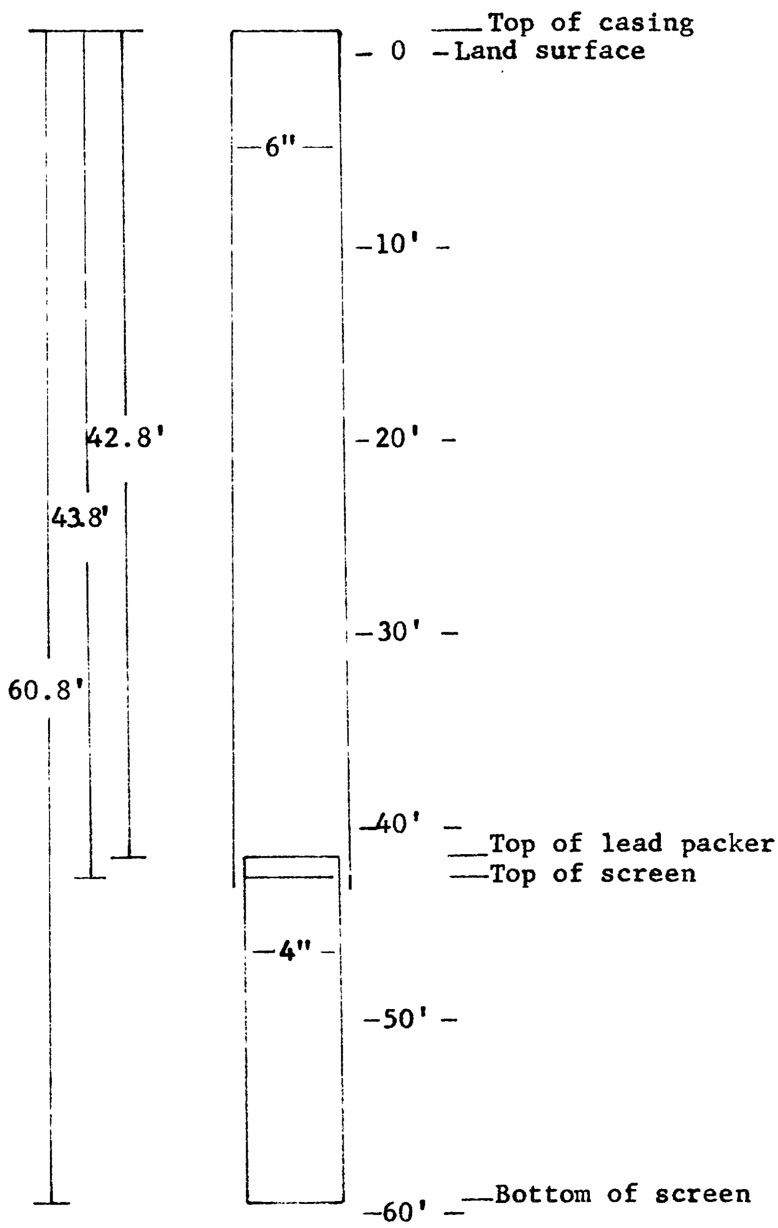

Figure 9.--Diagram showing screen and casing settings,

Bridge Bay well 2.

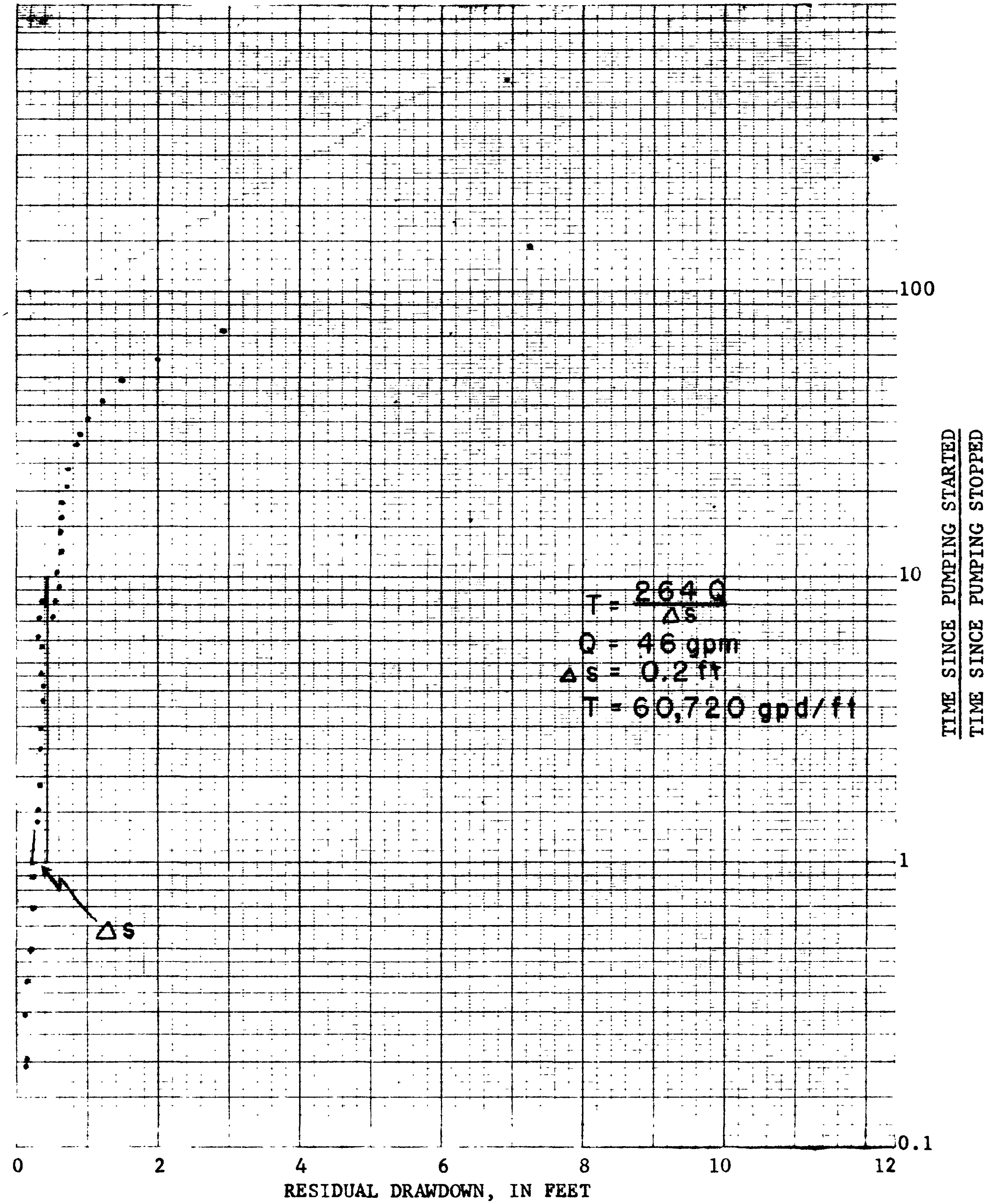

Figure 10.--Semilogarithmic graph of the water-level recovery in Bridge Bay well 2, Sept. 5-6, 1963.

Table 3.--Logs of auger holes and wells, Yellowstone National Park.

Description	Thickness (feet)	Depth (feet)
A-1, Bridge Bay		
Soil, dark-brown	3	3
Sand, very fine to medium, silt and clay, containing some coarse material, light-brown, drilled hard at 9 feet	11	14
Sand, very fine, to very fine gravel, containing some silt, clay, and fine and medium gravel, dark gray	11	25
Sand, very fine, to very fine gravel and clay and silt, light-brown	5	30
Clay and very fine sand to fine gravel, grayish-brown, hard drilling	3	33
Clay, grayish-brown, containing very fine sand to very fine gravel	10	43
Clay, soft, tan, containing a little very fine sand to very fine gravel	2	45
Clay, grayish-brown, containing very fine sand to very fine gravel	22	67
Clay, soft, tan, containing some very fine sand to very fine gravel	8	75
Clay, very soft, tan, containing a little very fine sand to very fine gravel	17	92

Table 3.--Logs of auger holes and wells, Yellowstone National Park.--continued

Description	Thickness (feet)	Depth (feet)
A-2, Bridge Bay		
Clay, silt and fine to coarse sand, dark gray	5	5
Clay, brownish-gray, slightly sandy, hard zones at 23 to 27 feet and 32 to 35 feet	30	35
Clay, brownish-gray, sandy	5	40
Clay and silt, slightly sandy, brownish-gray	5	45
Clay and silt, sandy, brownish-gray, hard zone 66 to 69 feet, more sand last 12 feet	47	92
A-3, Bridge Bay		
Soil	3	3
Sand, fine, clayey, dark brownish-gray	5	8
Sand, fine to coarse, few grains of gravel size, clayey more brownish	6	14
Sand, very fine to fine, very clayey, brownish-gray	3	17
Clay, sandy, dark-gray	8	25
Clay, contains a little sand, dark-gray	25	50
Clay, slightly sandy, light-gray	5	55
Clay, more sandy, some coarse sand and fine gravel	5	60
Clay, slightly sandy, some coarse sand and fine gravel	32	92

Table 3.--Logs of auger holes and wells, Yellowstone National Park.--continued

Description	Thickness (feet)	Depth (feet)
A-4, Bridge Bay		
Sand, very fine, to very coarse, grayish-brown	5	5
Sand, very fine, to very fine gravel, contains clay and silt, grayish-brown	5	10
Sand, very fine, to very fine gravel, contains a little clay and silt, grayish-brown, more very fine gravel and coarse sand 35 to 45 feet	35	45
Sand, coarse to very fine gravel, contains finer sand and a little silt and clay, grayish-brown	5	50
Sand, very fine, to very fine gravel, contains a little silt and clay, grayish-brown, finer sand 65 to 75 feet	25	75
No returns. Sand, medium to coarse, contains some finer sand and very fine gravel, silty and clay streaks collected from auger stem	17	92
A-5, Bridge Bay		
Soil, gravelly	2	2
Sand, medium to coarse gravel, contains finer sand, silty, clayey, brown	3	5
Clay, tan and very fine sand to fine gravel	1	6
Sand, very fine, to fine gravel, silty, clayey, grayish-brown	4	10

Table 3.--Logs of auger holes and wells, Yellowstone National Park.--continued

Description	Thickness (feet)	Depth (feet)
A-5, Bridge Bay--continued		
Sand, very fine, to medium gravel, silty, clayey, grayish-brown--	5	15
Sand, very fine, to medium gravel, silty, grayish-brown---------	5	20
Sand, very fine, to medium gravel, contains some coarse gravel, silty, grayish-brown--	10	30
Sand, very fine, to very fine gravel, silty, clayey, grayish-brown---	10	40
Sand, medium, to very fine gravel, contains some finer sand, clayey, grayish-brown--	5	45
Sand, coarse, to very fine gravel, contains some finer sand, clayey, grayish-brown--	5	50
Sand, coarse, to very fine gravel, contains some finer sand, dark gray--	10	60
Sand, medium, to very fine gravel, contains some finer sand, dark gray--	5	65
No returns, probably the same as above-------------------------	27	92

Table 3.--Logs of auger holes and wells, Yellowstone National Park.--continued

Description	Thickness (feet)	Depth (feet)
A-6, Bridge Bay		
Sand, very fine to fine, clayey, dark grayish-brown	5	5
Sand, very fine, clayey, grayish-brown	15	20
Sand, very fine, and clay, grayish-brown	5	25
Sand, very fine, and clay, contains some coarse sand, grayish-brown	10	35
Sand, and clay, few grains of coarse sand, brownish-gray	15	50
Sand and clay, dark-gray, hard; very fine sand 55 to 67 feet and 84 to 85 feet	42	92
A-7, Bridge Bay		
Clay, gray, and very fine to very coarse sand, contains some very fine gravel	5	5
Sand, very fine to coarse, contains some very coarse sand and clay	5	10
Sand, fine to coarse, and some very fine and very coarse sand, and clay	10	20
Sand, fine, to fine gravel, contains some very fine sand and clay	5	25
No sample	5	30
Sand, very fine to very coarse, and clay, contains some very fine gravel	5	35

Table 3.--Logs of auger holes and wells, Yellowstone National Park.--continued

Description	Thick-ness (feet)	Depth (feet)
A-7, Bridge Bay--continued		
No sample--	25	60
Sand, very fine to very coarse, and clay, contains some coarse gravel--	5	65
Sand, very fine to very coarse, and clay----------------------	5	70
Sand, very fine to very coarse, and some clay-----------------	5	75
Bridge Bay well 2		
Soil, tan, sandy, contains some gravel------------------------	1	1
Obsidian and quarts sand, fine to medium and some coarse to very coarse sand and very fine gravel, angular; loosely cemented streaks---	4	5
Obsidian and quartz sand, fine to very coarse, angular, and fine to very fine gravel and silt----------------------------	3	8
Obsidian and quartz sand, fine to medium, some coarse sand to very fine gravel, angular to subangular, and very fine sand	3	11
Obsidian and quartz sand, very fine to medium, angular; some coarse to very coarse sand and very fine gravel--------------	5	16
Obsidian and quartz sand, fine to coarse, angular, some fine to very fine obsidian gravel; well-cemented at 18 ft.---------	4	20
Predominantly obsidian sand with some quartz, coarse to very coarse, subangular; contains some fine gravel and fine to medium sand---	3	23

Table 3.--Logs of auger holes and wells, Yellowstone National Park.--continued

Description	Thickness (feet)	Depth (feet)
Bridge Bay well 2--continued		
Predominantly obsidian sand with some quartz, medium to very coarse, subangular; contains some very fine gravel, very fine to fine sand and silt	5	28
Predominantly obsidian sand, medium to coarse, subangular to rounded; some very fine gravel, very fine to fine sand and silt	5	33
Obsidian and quartz sand, fine to medium, angular; some coarse to very coarse sand	5	38
Obsidian and quartz sand, medium to very coarse, angular; with some very coarse and very fine to fine sand	5	43
Obsidian and quartz sand, medium to coarse, angular; with some very coarse and very fine to fine sand	5	48
Quartz and obsidian sand, fine to medium and some very fine and coarse sand, angular; interbedded with bentonitic clay	7	55
Obsidian and quartz sand, medium to coarse, angular; some very coarse and very fine to fine sand	3½	58½
Obsidian and quartz sand, fine to coarse, with some very coarse and very fine sand, angular	4½	63
Quartz and obsidian sand, very fine to medium, with some coarse sand, angular; interbedded with bentonitic clay	13	76
Clay, gray, sandy	10	86
Clay, gray, sandy, contains a few pieces of angular obsidian fragments	10	96

Table 3.--Logs of auger holes and wells, Yellowstone National Park.--continued

Description	Thickness (feet)	Depth (feet)
Cave Fall well 1		
Soil, reddish-brown, sandy	2	2
Rhyolite, gray, contains phenocrysts of quartz up to .5 mm., some clay; probably a terrace deposit	4	6
Rhyolite, gray, contains small phenocrysts of quartz and magnetic accessory minerals	25	31
Predominately quartz and sanidine; angular, many fragments show crystal faces or fresh fractures	10	41
Rhyolite, gray, contains small phenocrysts of quartz and magnetic accessory minerals	48	89
Similar to 41-89 only darker; contains less quartz	6	95
Glass, dark-gray	8	103
Obsidian sand and gravel, angular; poorly sorted; contains large amount of silt and clay	4	107
Obsidian gravel, very fine, and coarse sand, angular; some medium to very fine sand, silt, and interbedded clay	4	111
Obsidian sand, coarse to medium, angular; some fine to very fine sand; more silt and clay than previous sample	9	120
Obsidian gravel, very fine, and coarse to medium sand, angular; some very fine to fine sand, silt, and clay	10	130
Obsidian and quartz sand, coarse to medium, some very fine gravel and fine to very fine sand, angular; contains some silt and clay	5	135

Table 3.--Logs of auger holes and wells, Yellowstone National Park.--continued

Description	Thickness (feet)	Depth (feet)
Cave Fall well 1--continued		
Poorly sorted sand, silt, and clay	5	140
Obsidian and quartz sand, coarse to medium, angular; some very fine gravel, fine to very fine sand, silt, and clay	5	145
Poorly sorted sand and silt	8	153

Figure 11 shows successive specific capacities of Bridge Bay well 2,

Figure 11.--Specific capacities of Bridge Bay well 2 at different stages of development. The discharge, Q, is in gallons per minute; the drawdown, dd, is in feet.

as determined during short tests, which shows that the well was not improved until after it was treated with sodium hexamataphosphate to break down and remove some of the clay from the formation. The decrease in specific capacity during the first stage of development was caused by an increased pumping rate. The yield will not approximate the potential yield indicated by the transmissibility, because of high entrance losses which are the result of partial blinding of the screen by the angular sand of the aquifer, and of the small diameter of the well. The slow recovery of the water level in the well the first few minutes after pumping stops may be caused by these entrance losses. The progressive increase in the specific capacity during the development, however, indicates that the well could be further improved with additional development.

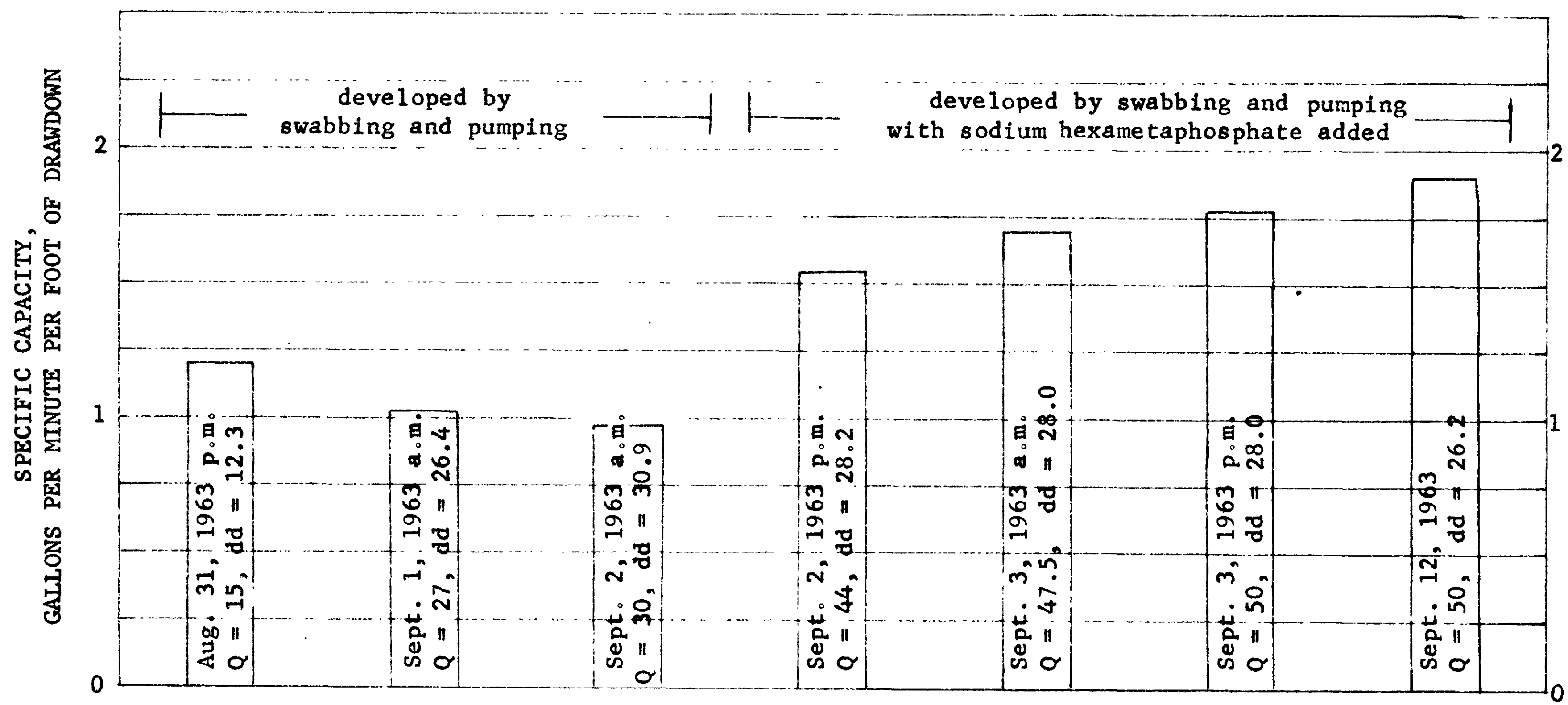

Figure 11.--Specific capacities of Bridge Bay well 2 at different stages of development.

The discharge, Q, is in gallons per minute; the drawdown, dd, is in feet.

The rate at which water can be pumped from the well is limited by the difference between the static water level in the well and the setting of the pump intake. The static water level had declined to 13.1 feet below the top of the casing when measured in October 1963, and the water level should not be lowered below the top of the screen, which is 43.8 feet below the top of the casing; thus, the maximum drawdown is about 30 feet. Allowance also should be made for lowering of the water level that might result from seasonal change or prolonged pumping. Therefore, the well, in its present condition, should not be pumped at a rate in excess of about 45 gpm. If this yield is not sufficient, additional development of the well will be necessary.

The analyses of water from the Bridge Bay wells are given in table 1. The samples collected in 1963 do not meet the allowable quality standards of the Public Health Service because of the high fluoride content. However, the water sample collected in 1960 from Bridge Bay well 1 was within the limits set for fluoride. The arsenic content of the samples collected in 1963 was greater than the recommended limit but within the allowable limits set by the Public Health Service.

Bechler-Cave Fall area

A test well was drilled during September 1963 at the location for the new Bechler ranger station, near the southwest corner of Yellowstone National Park. The well is approximately 1,100 feet north of the south boundary of the Park, about 1,100 feet west of Falls River, and 950 feet west of the Cave Fall road (fig. 12). It penetrated a veneer of soil and

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Figure 12.--Sketch map of Bechler-Cave Fall area.

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terrace deposits, then a thick section of rhyolite, and then sand and gravel beneath the rhyolite. The main water-bearing zone is the sand and gravel from 107 to 153 feet. The sample log of the well is given in table 3. A transmissibility of 240 gpd/ft was computed for the aquifer from a 24-hour pumping test on October 4-6, 1963 (fig. 13 and table 2). The well was pumped

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Figure 13.--Semilogarithmic graph of water-level recovery in Cave Fall well 1, Oct. 5-6, 1963.

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at 10 gpm and the drawdown at the end of the test was 38 feet, giving a specific capacity of 0.26 gpm per foot of drawdown. A yield of 15 gpm should be possible with a pump setting of 110 feet; however, an increase in the discharge will result in a lower specific capacity. A pump setting lower than 107 feet would be undesirable, as it might result in partial dewatering of the aquifer during pumping, which would allow air to enter the aquifer. The high specific capacity in relation to the transmissibility may be caused by a recharge boundary that is expressed in the recovery graph as a deflection in the straight-line plot.

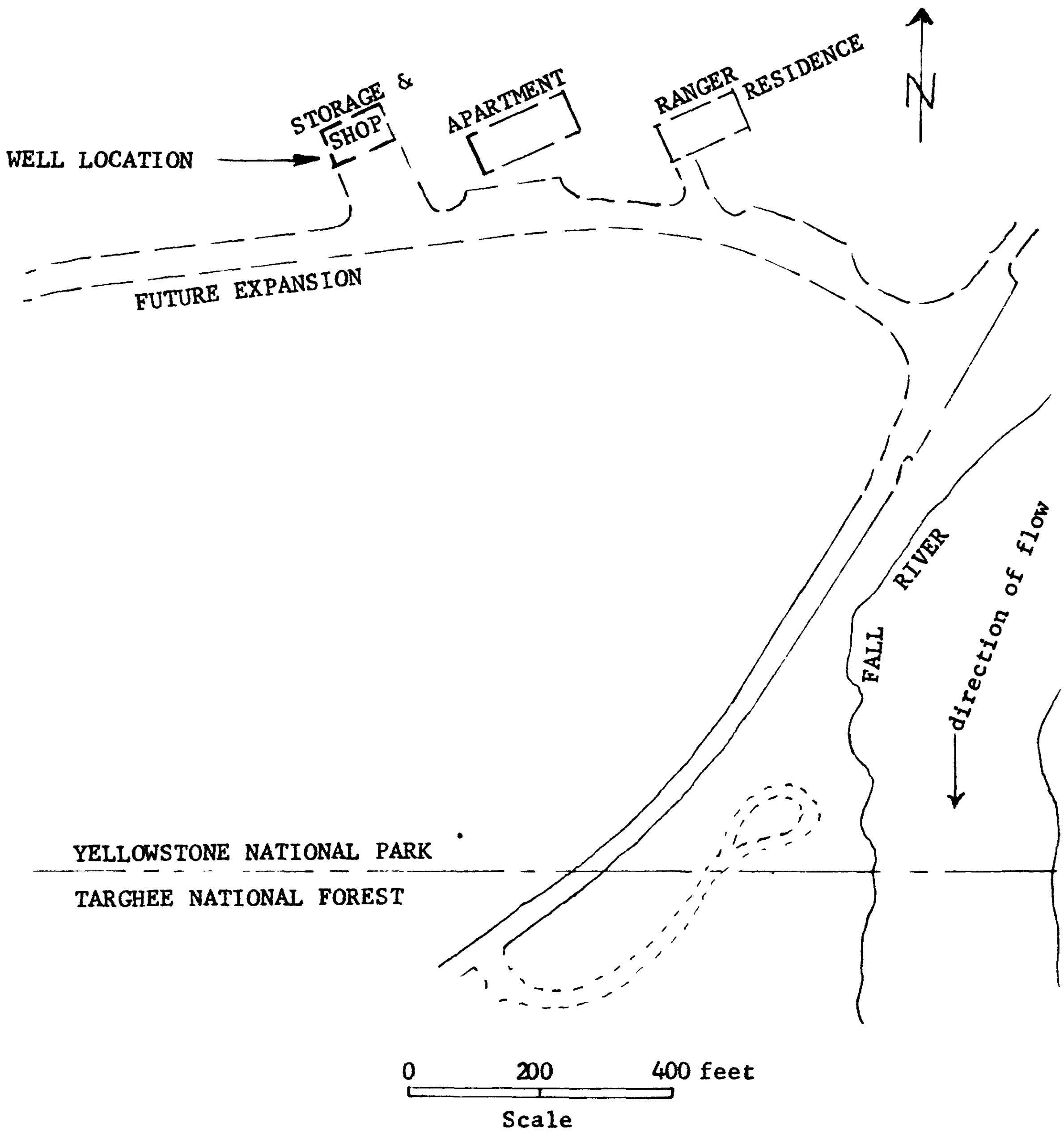

Figure 12.--Sketch map of Bechler-Cave Fall area.

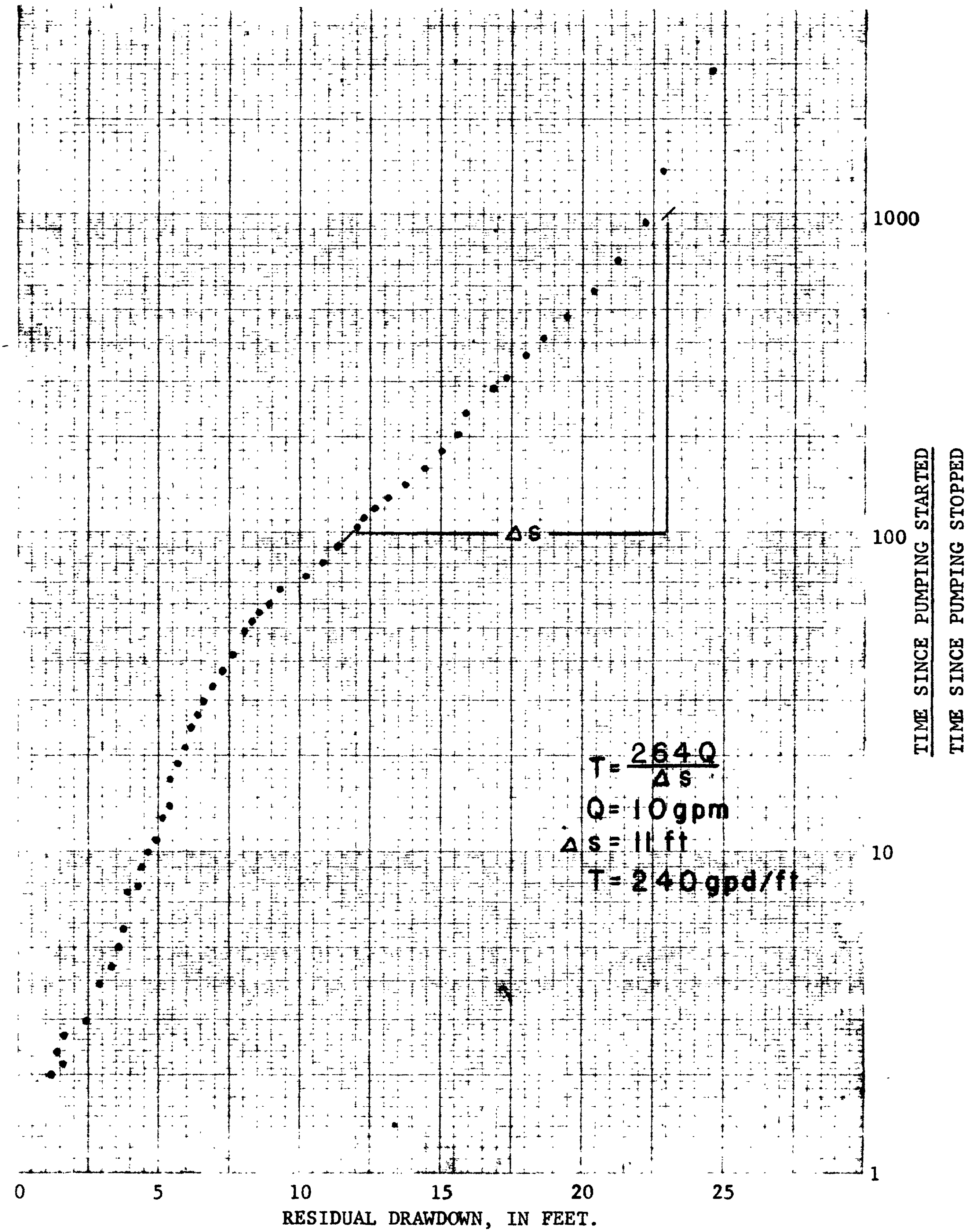

Figure 13.--Semilogarithmic graph of water-level recovery in Cave Fall well 1, Oct. 5-6, 1963.

This recharge boundary may be the result of a hydraulic connection, through fractures or crevices, between the well and Falls River. The location of the boundary, however, cannot be determined from the pumping test. The static water level in the well is about 20 feet higher than the water level in the river opposite the well. Therefore, the point of recharge from the river, if such recharge occurs, must be a considerable distance upstream from the well.

Field measurements of specific conductance of water from Falls River, from Cave Fall well 1, and from the spring in the Forest Service campground just south of the Park were 180, 220, and 80 micromhos, respectively. The similarity between the conductance of the water from the river and the well suggests a possible correlation between the two. The difference between the specific conductance of the water from the spring and from the well shows that the waters are from different aquifers, and, therefore, that the well should not affect the flow of the spring.

The analyses of water from Cave Fall well 1 is given in table 1. Although the water has a low total dissolved-solids content, it does not meet the standards of the Public Health Service because of high fluoride content.

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