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Investigation of the deep well in Mesa Verde National Park, Colorado

December 6-15, 1948

By Penn Livingston and William Hale

Purpose and scope of the investigation

On November 4, 1948, the pump on the 4,192-foot well at the Mesa Verde National Park failed during pumping operations. Several failures had been caused in the past by sediment gradually accumulating in the standing valve of the cylinder pump. However, after cleaning the pump and installing it in the well on November 8, no water could be pumped. There was apparently so much sediment in the water that the pump could not be put back into operation. As the well is the only present source of water for the Park, it was imperative that pumping be resumed as soon as possible.

Mr. Robert H. Rose, Superintendent of the Park, requested the assistance of the U. S. Geological Survey in making an investigation to determine the cause of the trouble and to ascertain the general condition of the well. In addition, it was requested that suggestions be made in regard to rehabilitating the well. The writers were assigned to make the investigation and were at the Park from December 6 to December 15, 1948.

Brief history of deep well at Mesa Verde National Park, 1938-48

The Park well was completed in sandstone at a depth of 4,192 feet in 1932. According to the well log, the well is cased with 12½-inch pipe from the surface to 880 feet; 10-inch pipe from surface to 1,220 feet (cemented at bottom); 8-inch pipe from surface to 3,553 feet; 6-inch pipe from surface to 3,896 feet (cemented at bottom); 5-inch pipe from surface to 3,934 feet; 3-3/4-inch liner from 3,912 to 4,062 feet; and 130 feet of 3½-inch McEvoy button screen pipe from 4,062 to 4,192 feet.

Following the tests by Livingston[1] on the deep well, which were com-

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1/ Livingston, Penn, Report on the condition of the deep-well in Mesa Verde National Park, Colorado, with suggestions for repairing. Typewritten report in files of National Park Service and U. S. Geological Survey, November 1938.

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pleted on November 8, 1938, the Lamtex casing pump was set aside and the old 3-inch cylinder pump was reinstalled in the well. The pump cylinder was set at a depth of about 1,600 feet below the land surface and operated with a stroke of 4 feet, 8 inches at a rate of 22 strokes a minute. The barrel was 10 feet long and 2 25/32 inches in inside diameter. The discharge column was 2-7/8 inches in inside diameter and the sucker rods were 7/8-inch round iron. When the pump was in good condition it would discharge about 30 gallons a minute; as the leathers wore, the discharge would decline to 25 gallons a minute. New leathers were required about once a month and about once each year the cylinder was removed and a new standing valve was installed. On several occasions during the period 1938-48 the pump stopped discharging water and when the cylinder was removed it was found to be clogged with "mud and scale." No new tubing or sucker rods have been installed since about 1942. The rods are in good condition but some of the tubing is worn. No repairs or changes were made in the well casing since the inspection was completed in November 1938.

On September 3, 1948, the pump stopped discharging water and when the cylinder was removed the standing valve was clogged with "black mud". After the cylinder was cleaned out considerable trouble was experienced in getting the pump back into operation on September 16. The same trouble developed on

October 1 but by October 7 the pump was back in operation. On November 4 the cylinder clogged again. Several attempts to pump water were unsuccessful, even with as much as 1½ hours of pump operation.

The Florence Drilling Company, Aztec, New Mexico, was employed to clean out the well and they moved in a Cordwell cable tool rig on November 22. Bailing operations began on November 26 and an obstruction was found at a depth of 3,910 feet. A 4-inch impression block was placed on the obstruction and it was believed that a good impression was obtained of a metal slip (a tubing-catcher dog was believed to have been lost in the well several years ago, see Mesa Verde Park office files) about 6 inches long, 3 inches wide, and 3/4-inch thick. The obstruction was dislodged by a few light blows with the bit. Other temporary obstructions were found at 4,002 and 4,022 feet, and the bit was lowered to 4,057 feet without further trouble. A 30-foot length of 2-7/8-inch tubing was lowered to 4,114 feet. Evidently the top of the 3-3/4-inch liner was encountered at 3,910 feet and the top of the 3½-inch screen at 4,057 feet (compared with 3,912 and 4,062 according to the log).

Description of investigation

The writers arrived at the Park on December 6, and spent the afternoon in conference with Messrs. Rose, Brown, Nelson, and Boyland of the Park Service; and Mr. Cooper, an employee of the Aztec Drilling Company. It seemed to be the consensus that the slip or slips that had been lost in the well several years ago had been dislodged with the bit on November 27, and had fallen to 4,114 feet where they had either bridged the hole or rested on debris in the bottom of the well. On December 7, two impression blocks were run to a depth of 4,114 feet, but no recognizable impression of the slips was found. Bailing operations began with a sand pump in order to uncover the slips or work them down. About 0.7 cubic foot of black scale was recovered during the day, including many large pieces(as large as 2 square inches) between 1/16 and 3/16 inch thick that fitted the inside of the 5-inch pipe. A sample of the scale was collected for chemical analysis. The sand pump finally reached a depth of 4,133 feet at the close of the day. On December 8 bailing with a small dart-valve bailer gave poor results, so bailing was resumed with the sand pump, on which repairs had been attempted. On December 9 the Geological Survey's deep-well current meter was lowered to a depth of 2,500 feet, but no movement of water inside the 5-inch casing was found. The meter was equipped with a rubber ring so that all the water would move through the meter. Any flow of water greater than a gallon a minute could have been detected easily. The nonpumping water level was about 1,302 feet below land surface.

With the well open to a depth of about 4,133 feet, exposing between 60 and 70 feet of screen, a test was made to determine the present specific capacity of the well. This test was made to determine if the screen were open above 4,133 feet and if it were imperative to open the screen below that depth to obtain a supply of 30 gallons a minute. Water was introduced into the well at the surface at a rate of 5 gallons a minute starting at 4:45 p.m. on December 9 and ending at 6:07 p.m. The water level rose about 17 feet during the test and had an estimated ultimate rise of 18 feet or more, indicating a rise of about 3.5 feet for each gallon a minute of recharge (fig. 1). Conversely, if the well were pumped it would yield water at approximately the same rate per foot of drawdown. At a pumping rate of 30 gallons a minute, the drawdown would be about 120 feet.

When bailing was discontinued on December 8, it seemed evident that pipe scale was being loosened from the 5-inch casing about as fast as it was being recovered with the sand pump, resulting in little progress toward opening more screen at the bottom of the well. It was believed that better progress could be made by setting a plug at the top of the liner at 3,910 feet, scaling the pipe from the top down to 3,910 feet, and recovering the scale with a larger sized bailer that would pass into the 5-inch casing. If the plug were water tight, the 5-inch casing could also be tested for leaks. An opening in the 5-inch casing at 1,325-1,336 feet was found in 1938 (see 1938 manuscript report), but it was not known whether circulation of water between the 5- and 6-inch pipes had developed through this opening. On December 10, 1948, an attempt was made to bridge the casing at 3,910 feet with a bag of beans. The bag was held in place for several hours, but when the tools were brought out it was learned that the bag had been worn through by friction on the pipe while being forced down. On December 11 another plug was made of sand bags wrapped in canvas. It was lowered to the water surface, where it was released and allowed to settle by its own weight. The plug was then followed to a depth of 2,400 feet with the deep-well meter and with the sand pump to 3,800 feet without trouble. It was assumed that the plug stopped at the top of the liner at a depth of 3,910 feet. About 0.1 cubic foot of gravel followed by 1.6 cubic feet of sand was poured into the well and allowed to settle overnight to the top of the plug. The next morning December 12, the bailer was lowered into the well and stopped on an obstruction, presumably the top of the sand, at 3,898 feet. About 15 gallons of Aquagel was lowered in the dart-valve bailer and dumped at a depth of 3,898 feet by means of dump-stick. The only known water-bearing beds exposed to the wells were thus apparently shut off, and the casing was ready to test for leaks by raising the water level above the normal nonpumping level and observing any decline of water level.

Starting at 3:22 P. M. on December 12, five gallons a minute of water was discharged into the well at the surface for 10 minutes, which raised the water level about 35 feet above a starting level of about 1,303 feet. The rise amounted to about 1 foot for each 1.3 gallons of water added. This volume checked closely with the volume of the 5-inch casing plus the annular space between the 5- and 6-inch casings. The water level lowered about 2½ feet during the hour after the peak had been reached, indicating a leakage of about 3 gallons an hour. Again water was added for 10 minutes at the rate of 5 gallons a minute, starting at 5:05 p. m., and the water level rose an additional 35 feet, making a total rise of about 70 feet above the initial level. After reaching the peak, the water level declined about 19 feet during a period of about 5½ hours, indicating leakage of about 4 or 5 gallons an hour. More water was added at 11:00 p. m. to raise the differential water pressure on the plug to about 151 feet. The decline of the water level was observed until 3:45 a. m. and again at 8:00 a. m. on December 13. The rate of decline was 33.5 feet during 8 hours, indicating a rate of leakage of 5 or 6 gallons an hour. Further observations were made on the decline of the water level during the evening and into the morning of December 14, after a brushing tool for dislodging scale from the 5-inch pipe, devised in the Park machine shop, had been used in the well during the working hours on December 13. The water level was lowered by bailing during two periods on December 14, and observations made of the water level in the well while it stood below the normal nonpumping level until 9:00 a. m. on December 15.

The data collected in connection with this bailing operation appeared to give results that were inconsistent with observed conditions. (see p. 11,) however, as the cost of following this point to a conclusion did not appear to be justified, testing of the well was discontinued, and brushing-down operations on the well were resumed.

The well was cleaned out to a depth of 4,162 feet, and on December 30, at 10:30 a. m., pumping was begun. The water at the beginning of the pumping period was black but cleared by 7 p. m. Pumping continued without interruption until January 1, 1949, after which a normal pumping schedule of two 8-hour shifts was resumed.

A water sample was collected from the well on January 5, 1949, after the well had been pumped for several hours at the rate of about 25 gallons per minute. The analysis of this sample, shown below, was by J. D. Hem, U. S. Geological Survey, Albuquerque, New Mexico.

Chemical analysis of water from Mesa Verde Park well, January 5, 1949

	Parts per million		Parts per million
Silica (SiO_2)	23	Temperature 112° F.	
Iron (Fe)	.40*	Boron (B)	0.1
Manganese	0.03		
Calcium (Ca)	35	Dissolved solids: Sum-/	1,100
Magnesium (Mg)	11		
Sodium (Na), Potassium (K)	326	Hardness as $CaCO_3$:	
		Total	132
		Noncarbonate	0
Bicarbonate (HCO_3)	352	Specific conductance	
Sulfate (SO_4)	525	(Micromhos, 25° C.)	1,590
Chloride (Cl)	1.8	pH	7.6
Fluoride (F)	1.7		
Nitrate (NO_3)	0.1		

* In solution. Total iron 7.5 ppm, mostly in sediment.

Analyses were also made by J. D. Hem of the pipe scale recovered with the bailer and of the "mud" taken from the pump cylinder, as shown below.

Analysis of pipe scale and deposit in the pump cylinder

	Percent			
	Iron	Manganese	Insoluble	Sulfur
Deposit on traveling valve	57	0.40	4.0	—
Do.	57	.38	2.8	Absent
Deposit on standing valve	50	.18	6.7	—
Black scale in chunks taken with bailer (4,113')	48	.14	9.6	4.7 ±
Black mud taken with bailer (4,113')	45	.29	8.9	2.3 ±

The small amount of hydrogen sulfide was liberated when the deposit obtained from the cylinder was dissolved in aqua regia. The iron that was present as sulfide was estimated as less than 10 percent. The scale recovered from deep in the well contained considerable amounts of sulfur, probably in the form of ferrous sulfide.

Conclusion

The specific capacity of the well on December 9, 1948, when the well was open to 4,133 feet, was somewhat less than, although comparable with, the specific capacity that was found during November 1938. It was very encouraging to observe that the nonpumping water level is now the same as it was during 1938.

The maximum leakage from the 5-inch casing was about 5 to 6 gallons an hour with a differential water pressure amounting to about 150 feet. Of this amount of leakage, some of all could have been through the temporary plug.

Consequently, it is believed that the leakage that passes between the 5- and 6-inch casings into or out of the well is very small and is of negligible importance at this time.

During the tests following the bailing operations the water level in the well rose and fell, although it remained below the normal static level. (See pl. 1.) The water level could have been affected by one of several different conditions or a combination of conditions, such as a change in the weight of the water column, caused by the addition of scale or the subsequent settling out of the suspended matter; changes in barometric pressure; changes in the rate of leakage through the plug; leakage between the 5- and 6-inch casings; and water seeping down the inside of the casing, which had become wet during bailing operations. The fluctuations of the water level, however, represented a gain or loss of less than a gallon an hour, which was considered too minute for exact interpretation. The writers would have enjoyed making additional tests to work out seemingly inconsistent fluctuations at the low levels, but the collection of additional data could not be justified, considering the cost involved.

It was concluded that the "red and black mud" that clogged the working barrel was pulverized pipe scale and rust that accumulated on the tubing and on the inside of the 5-inch casing. The "red mud" probably came from the area above the pumping level where the pipe was exposed to the air, resulting in a greater percentage of iron oxide. The heavy black pipe scale may have accumulated at any depth, but most likely near the pumping level as the result of the gradual release of pressure amounting to more than 1,000 pounds per square inch as the water moved upward in the well. During periods of pumping the temperature of the water discharged increased from about 85° to 112-117° F., depending upon the rate and duration of pumping. During idle periods the temperature of the water in the upper part of the well declined again to about 85°. This temperature change might result in some deposition of iron or calcium carbonate from the water.

It is not possible to decide from the information at hand whether the iron in the pipe scale was in solution as the water came from the formation or was dissolved from the well casing. The second condition would be the more unfavorable, namely, that the iron was dissolved from the casing in the lower part of the well and was carried upward and deposited as part of the scale in the upper part of the well. Water samples would have to be collected from the bottom of the well during pumping operations to make certain of the true composition of the water in the sandstone aquifer, and this, of course, is impossible.

Several wells have been drilled and considerable work has been done on the correlation of geological formations near the southwestern corner of the State of Colorado since the Mesa Verde well was completed during 1932. It now appears that the well may not have reached the Navajo sandstone. Below is a quotation from a letter received from Alfred D. Zapp, geologist, U. S. Geological Survey, Albuquerque, New Mexico:

"Our stratigraphic interpretation of the log of the deep well in Mesa Verde National Park, Colorado, follows:

0 - 400 feet	Cliff House sandstone
400 - 885 "	Menefee formation
885 - 1,175 "	Point Lookout sandstone
1,175 - 3,352 "	Mancos shale
3,352 - 3,423 "	Dakota sandstone
3,423 - 3,896 "	Morrison formation
3,896 - 4,085 "	Wanakah formation
4,985 - 4,192 "	Entrada sandstone

"The regional stratigraphy of the area, as interpreted from published and unpublished material in the files of the Fuels Branch, indicates that the present producing aquifer, the Entrada sandstone, is probably the best one, and deepening the well, except perhaps for completing penetration of the Entrada sandstone, is not recommended. In the sequence below the Entrada, the sandstones of the Jurassic Glen Canyon group are probably relatively thin and silty, and the

Triassic and Permian redbeds are not likely to include good aquifers."

It should be kept in mind, however, that if the well is deepened and the static water level stays at its present altitude, the means of extraction would still be confined to a small pump, the upper discharge limit of which probably would be less than 100 gallons a minute. In other words, regardless of the capacity of the well to yield water, the actual yield that could be pumped with a pump 4½ inches in diameter would be less than 100 gallons a minute.

The well, even in its present condition, has considerable value as a stand-by unit that might be used during an emergency if trouble were experienced with the surface pipe line that is expected to be installed soon. Appreciable scale probably would not form on the casing while the well stood idle. Thus the well might remain unused and still serve a useful purpose.

Suggestions for Reconditioning and Operating the Well

The following suggestions are made for reconditioning the well with the thought in mind of getting the well back into production as soon as possible to replenish the storage tanks. Item 1 was carried out during the latter part of December when the well was opened to 4,162 feet; the yield is about 25 gallons a minute. Later, more extensive repairs (items 2-4) can be made if and when a greater expenditure of funds can be justified.

1. Scrape and brush the inside of the 5-inch casing from the top to a depth of 3,898 feet to dislodge the loose scale. Bail out the scale and remove the temporary plug at 3,898-3,910 feet. Clean out the screen to a depth of 4,133 feet and as much deeper as satisfactory progress can be made. Make no attempt to retrieve the slips that are ~~alleged~~ believed to be in the well. Replace the 3-inch

pump and, while lowering it, add enough water to the tubing before the cylinder reaches the water level to keep water from entering the tubing through the standing valve. Operate the pump in periods as long as possible and avoid short shut-down periods.

2. In case the well does not yield enough water to supply the 3-inch pump (30 gallons a minute), then pull the liner and screen; clean out the hole to 4,192 feet and replace the liner and screen.

3. If the specific capacity of the well is increased substantially by cleaning out the screen to full depth, about 1,500 feet of the 5-inch casing could be removed so that a larger sized pump could be installed.

4. If the specific capacity is not increased by removing and cleaning the screen, all the 5-inch casing, the liner, and the screen could be removed and the well drilled through the Entrada sandstone with a rotary rig. Five-inch casing and screen could be set in the water-bearing formation, leaving the 6-inch casing in the upper part of the well so that a larger-sized pump could be installed.

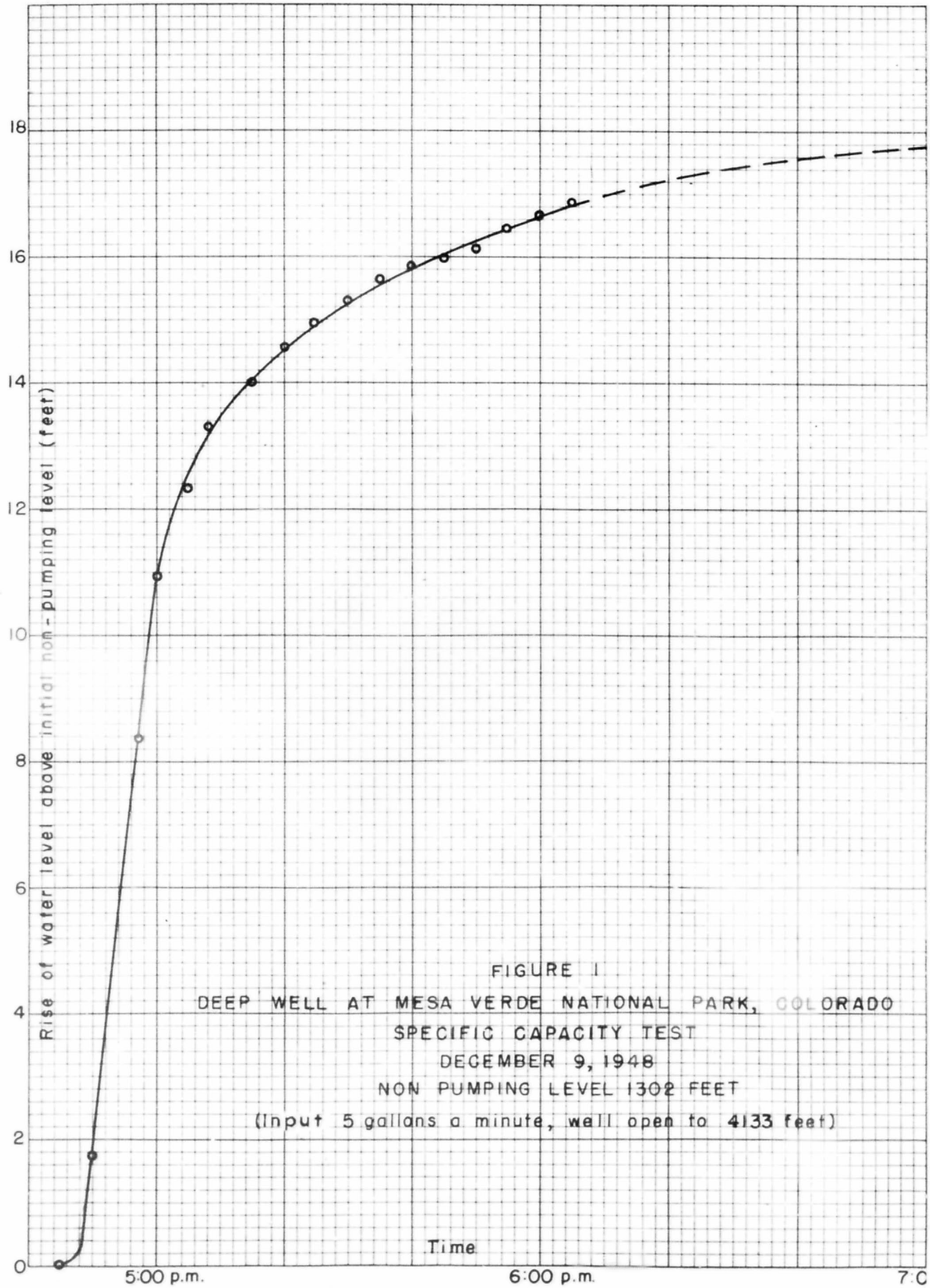

FIGURE 1
DEEP WELL AT MESA VERDE NATIONAL PARK, COLORADO
SPECIFIC CAPACITY TEST
DECEMBER 9, 1948
NON PUMPING LEVEL 1302 FEET
(Input 5 gallons a minute, well open to 4133 feet)