



WATER-RIGHT DOCKET

Mesa Verde National Park

Docket No: 2

DEEP WELL, DEED 6

Supporting Hydro Data

00-00-0000: soils log of the mesa verde well

Log of the Mesa Verde well

25 ft.	.....	Sand, yellow
50 ft.	.....	Sand, yellow
60 ft.	.....	Shale, gray
75 ft.	.....	Sand, yellow
100 ft.	.....	Sand, yellow
120 ft.	.....	Shale, gray (Menefee) ?
205 ft.	.....	Sand
250 ft.	.....	Shale
325 ft.	.....	Sand
400 ft.	.....	Shale, brown
495 ft.	.....	Linn Shells (sand & shale)
530 ft.	.....	Shale, brown (water small volume)
665 ft.	.....	Sand (water)
705 ft.	.....	Shale
770 ft.	.....	Sand (water)
790 ft.	.....	Shale (brown, caving)
830 ft.	.....	Shale (water 15,500 gals. per day)
		Water standing 450' in hole;
		necessary to case.
885 ft.	.....	Sand (Point Lookout) ?
1050 ft.	.....	Shale
1060 ft.	.....	Sand
1098 ft.	.....	Shale
1120 ft.	.....	Sand
1175 ft.	.....	Mancos shale (1220' of 10" pipe)
3352 ft.	.....	Dakota sand (very hard shells & cap rock)
3432 ft.	.....	McElmo shale (green)
3553 ft.	.....	McElmo shale (green and red)

Excerpt from memorandum of January 2, 1948, for the Director
from Regional Director M. R. Tillotson.

Superintendent Rose reports the following costs for pumping water from
the well:

<u>Period</u>	<u>Gals. Water Pumped</u>	<u>Cost</u>	<u>Cost per M Gal.</u>
1940 Fiscal Year	5,009,700	\$5,716	\$1.14
1941 Fiscal Year	5,468,100	4,307	.79
1942 Fiscal Year	5,706,340	4,358	.76
1943 Fiscal Year	2,208,104	2,670	1.21
1944 Fiscal Year	468,546	1,775	3.79
1945 Fiscal Year	1,213,900	2,357	1.94
1946 Fiscal Year	2,286,900	2,845	1.24
1947 Fiscal Year	3,895,000	5,816	1.49
1948 Fiscal Year	5,200,000	8,000	1.53

Other Supporting Information



ADDRESS:
THE DIRECTOR, NATIONAL PARK SERVICE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WASHINGTON 25, D. C.

APR 29 1949

MEMORANDUM for the Regional Director, Region Three.

The memorandum of April 15 for you from Mr. Rose, concerning the deep well at Mesa Verde National Park, does not constitute the type of engineering report which we requested by memorandum of March 4. It also suggests that Mr. Rose is finding it necessary to call on the Geological Survey for instructions and suggestions as to suitable equipment for flow measurements which should be supplied by the Regional Engineering staff if such equipment is needed. Finally, Mr. Rose implies by the tone of his memorandum, that he is discouraged.

Mr. Rose advises that a pump rate of 14,000 gallons per 8-hour shift was maintained prior to February 1948, and that the average for the 15 months since that date is only 11,000 gallons per 8-hour shift. He has not supplied complete records on the rate of pumping during the last 2 months since the well was more or less reconditioned. The result is a needlessly unfavorable report which includes pump output before the trouble was corrected during the past winter and thus does not answer the question asked.

Furthermore, Mr. Livingston indicated that the well yield is no greater than the capacity of the present pump (14,000 gallons per 8-hour shift, or 29.2 gpm with new leather; and 11,000 gallons per 8-hour shift, or 23-25 gpm as parts of the pump become worn). There is no reason to expect to pump more water than this under existing conditions. The water storage at the Park should be filled before the beginning of the tourist season, and the pump should be reconditioned if possible. Thereafter, it will be necessary to pump any part of 24 hours which may be needed to keep reservoirs full or to keep the reduction in storage to a minimum.

If it becomes necessary to drill to the bottom of the aquifer, it should be a winter job and should be attempted only after a full test of operation under conditions now existing for the coming season, and as much of next winter as possible.

We shall want a complete record of pump operation from the recent resumption of operations until we are ready to use the data,

giving the amount of water pumped and the date and time of beginning and ending of each pump run. All three of these items are needed in order to see how output may vary, how yield may build up again during different periods of time, and how the yield may also vary with the season. If possible, the only other data which we would like during the next season would be the approximate water level at beginning and end of each pump run.

We recommend that Mr. Rose omit the use of meters in the well at this time. The desired information will not be obtained unless such meters are placed at proper points and the flow of a particular aquifer, either as yield or leakage, can be isolated. It is believed that the pump records will provide nearly all the desired data which can be assembled by nontechnical groups.

(SGD) CONRAD L. WIRTH

AvVD:sh.

Acting Assistant Director.

In duplicate.

cc: Mr. Vint, with copy of Mr. Rose's memo of April 15.

Mr. Kittredge, " " " " " " " " " "

Mr. Dunn, " " " " " " " " " "

C O P Y

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
MESA VERDE NATIONAL PARK, COLORADO

April 15, 1949.

MEMORANDUM for the Regional Director, Region Three.

We have received with Mr. Patraw's memorandum of March 11 a copy of Mr. Demaray's memorandum of March 4 and a copy of a report by USGS Engineers Livingston and Hale on their recent investigation of the Mesa Verde deep water well. We are asked to report further on pump operations and well behavior now existing and to supply special information that will assist in formulating comprehensive engineering recommendations for well improvement.

From pumping records of the past four years we note that prior to February 1948 the average pumping rate per 8-hour shift was maintained consistently close to 14,000 gallons. In the 15 month period since that time the production rate has gradually dropped until now it is approximately 11,000 gallons with more erratic variations appearing in the past three months. The 3,000 gallons decrease in production rate per shift is the equivalent of about 22 percent.

We doubt that any of this reduction is due to defects or deterioration in the pump. Following each major breakdown essential repairs and replacements have been made. Despite these measures, the general decrease in rate of pumping has continued. We are strongly of the opinion that the peculiar behavior of the well is due to relationships existing in the zone of the 280' liner at the bottom. This opinion is strengthened by knowledge that the nonpumping head of the well has decreased upward of 100 feet since 1933. Also, it appears that the 3 feet drawdown for each gallon a minute yield required in 1938 has now increased to about 4 feet.

My special report, dated December 23, 1948, analyzes probable pressure and waterflow relationships in the zone of the liner, including the 130' screen, at the bottom of the well. We must not ignore the fact that the recent report of Messrs. Livingston and Hale primarily concerns conditions tested above the liner except for the check they made on the specific capacity of the well after it was opened to a depth of 4133'. A plug was placed atop the liner at the 3912' level while the tests were run. It was after completion of the tests that we speared and baled finally opening the well to a depth of 4162' just 30' short of the bottom.

Additional tests now ought to be made within the liner to determine whether other formations are "robbing" the primary aquifer lying below the 4085' level. Open connections do exist making such flow possible at any time the pressure and formation permeability factors are conducive to such flow.

In recent conversations with Mr. L. E. Teague, driller of the well, he confirmed my information concerning the 20' and 30' of "dry" sands and shales penetrated just before the great inrush of water occurred on reaching the 4085' level. He also recalled the existence of the small amount of free space between the top of the liner and the bottom 22' portion of the 5" casing and felt that the black water and mud might easily enter the well at this point.

A new working barrel for the pump is now on order. After it is installed we will carefully observe any change in production rate. Still more important now is the need for additional tests of waterflow conditions in the liner. We intend to correspond with Mr. Livingston to determine whether a type of meter is available which would test the flow under these conditions.

Digressing somewhat, in conducting further tests and in formulating recommendations we should not forget that in the 16 years the well has been in operation only the 6" casing has prevented highly impotable water from the Dakota Sandstone and adjacent formations from entering the well. Resuming work in the interval of more than a year between the two drilling contracts, it was found that water from behind the permanently placed 8" casing had entered the well. For more than 10 years we have known also of the rupture in the 5" casing between the 1300' and 1400' levels in the well. We clearly see, therefore, that any water getting into the 6" casing from outside sources is bound to find its way eventually into the well.

Before clear-cut recommendations can be made we badly need the additional information on the nature and extent of waterflow conditions in the zone of the 280' liner. Lacking this information at present, the following new recommendations are offered which supercede all recommendations previously made:

1. Make additional waterflow tests in various levels in the 280' liner if suitable equipment for the tests is obtainable. This will prove or disprove the existence of conditions under which other formations may be "robbing" substantial amounts of water from the primary aquifer.

2. Determine accurately whether the replacement and re-conditioning of the present pumping equipment changes the rate of water production.
3. If the pumping rate per 8-hour shift can be maintained rather consistently at 10,000 gallons, or more, without too much trouble it seems the Service would be justified in the risk of deferring any major well over-haul project until late the coming fall. In these circumstances we should be able to pull through the coming months of heavy travel and increased water demand.
4. Any major overhaul project should call for removal and placement of the 280' liner. Its total length and the proportion of length given to the screen will depend on what is done about the 5" casing and the suggestion that the well be drilled deeper into the primary aquifer below the present depth of 4192'.
5. The 5" casing could be left in the well if it were found to be in reasonably good condition throughout its length. If it is left in place an extremely thorough job of cementing should be done. This cementing may require 150 to 200 sacks of cement because the cement should be forced along the outside surface of the 5" casing and for an undetermined distance upward into the space between the 5" and the 6" casings. Since a drill rig would be required to do this job, the well should be drilled deeper by an amount that depends on the conditions encountered.
6. If the 5" casing must be removed all deteriorated portions should be replaced. Consideration should be given to the extension of the 5" casing at least to the top level of the primary aquifer. At that point an absolutely tight shutoff should be obtained.
7. The new liner replacing the one now in use should extend from the bottom portion of the 5" casing down to the maximum depth of the well. In no circumstances should the screen portion extend above the top level of the primary aquifer. It would be safer to limit it entirely to the water-bearing sands well below the aquifuge that defines the upper limits of the aquifer. The total length of the liner and the length of its component parts will depend on the plan adopted with regard to the 5" casing.

I believe that a major overhaul along the lines recommended above will achieve the following encouraging results: (1) the nonpumping level of the well would probably rise at least 100 feet above the present level of 1302'; (2) the specific capacity of the well would probably increase 30 percent, or more, with a corresponding reduction in drawdown for a given rate of production; (3) surges of black water and mud would be entirely eliminated; and (4) the potability of the water might very well be improved to a degree superior to that attained at any time during the 16 years the well has been in operation.

(Sgd) Robert H. Rose

Robert H. Rose,
Superintendent.

In duplicate
w/c of well diagram
in duplicate.

cc 2 file.

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
Region Three
Santa Fe, New Mexico

April 22, 1949.

MEMORANDUM for the Superintendent, Mesa Verde.

This refers to your memorandum of April 15 regarding the behavior of the deep well pump at Mesa Verde National Park. We await with interest your report on the rate of water production after the working barrel on order has been installed.

We cannot believe that decreased inflow into the well itself has affected the pumping rate by 22 percent. The rate of inflow would not affect materially the rate of pumping unless the amount of water entering the well were less than the amount being pumped. This would result in the working barrel being uncovered. We see three causes for decreased pump production:

1. Slippage - flow of water past the cups while they are lifting the water column. This becomes progressively greater as the cups and working barrel wear.
2. Leakage from the drop pipe. A few minute thread defects allowing the water to escape would lose an appreciable percentage of 25 g.p.m.
3. Slowing down of the revolutions of the pump due to the greater head from lowering of the water surface in the well. Although the motor has excess power, we are not sure but that the variable speed motor you are using might not allow this. It may be you will have an opportunity to discuss this point with one of the power company engineers.

We suggest that you check Item 2 by installing an open tube on the line from the pump to the filtration plant, or on the end of the waste line. Any lowering of water in this tube after the pump stops would be due to leakage through the working barrel or out the drop pipe. Some increase of the wastages, due to Item 1, would occur with lowering of water level in the well. Lowering from 1,300 to 1,500 feet would increase slippage about 7 percent.

We find only one copy of your memorandum of April 15. Please send us the duplicate mentioned on the last page.

SIGNED
J. R. Lassiter,
Regional Engineer.

cc: Director.

05-06-1949: received stamp





ADDRESS:
THE DIRECTOR, NATIONAL PARK SERVICE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WASHINGTON 25, D. C.

MAR - 4 1949

MEMORANDUM for the Regional Director, Region Three.

We enclose two copies of the report on "Investigation of the Deep Well in Mesa Verde National Park, Colorado, December 6-15, 1948," by Penn Livingston and William Hale. We have also discussed the matter with Mr. Livingston during his assignment in Washington for the past two weeks, and compared the information with that in reports from Mr. Rose.

Mr. Livingston stresses the need for careful tests now that the well is cleaned and back in operation, but he holds a more optimistic opinion of the general condition of the well than is implied in past reports by Mr. Rose, except as the tests may prove otherwise. He seems to consider that, subject to such tests and observations, the well can be made to produce all the water which can be pumped with existing equipment, and that more water might be obtained with a larger pump unit. However, he pointed out that the old Lentex pump had a capacity in excess of the yield of the well at that time, and that great harm can be done to the well by attempting to pump at a rate greater than the yield.

After stressing the fact that it was impossible to determine the true condition of the well casings, Mr. Livingston expressed the tentative opinion that the casing would probably last for quite a few years to come, and that the useful life of the well could probably be maintained by cleaning out the scale from time to time, as has been done in the past few months. He also believes that little or no scale will form if the well is not pumped regularly after the Mancos water supply is made available. Therefore, he suggests that justification can probably be provided to spend enough money in reconditioning to permit full operation for a year or two, and to provide a standby supply after the West Mancos Water Supply System is placed in operation.

Mr. Livingston has also pointed out in the report and subsequent conversation that the 3-3/4" liner might be pulled to permit drilling and relining and screening to the full depth of the aquifer from which water is now obtained. The justification would depend partially on further study of the specific yield of the well, partially on the practicability of cutting off part of the 5" casing to permit installation of a pump of larger capacity, and partially on the frequency and

duration of water demand in excess of what can be supplied from the existing system of diversions and storage.

Please supply us with a complete report on the pump operation and behavior of the well under conditions now existing. Also please supply us with comprehensive engineering recommendations pertaining to the possible improvement of the well, and its relation to apparent water demand of the next few years as a temporary substitute for, and ultimate auxiliary supply to, the West Mancos Water Supply System.

(SGD) A. E. DEMARAY

Associate Director.

AvVD:sh.

Enclosure 126.

In duplicate.

cc: Mr. Dunn.

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

WR Copy
Dwight

December 23, 1948.

MESA VERDE NATIONAL PARK, COLORADO

MEMORANDUM for the Regional Director, Region Three.

I am transmitting herewith a report in memorandum form giving a more or less technical explanation for the mysterious behavior observed and pumping conditions experienced at the deep water well during the past 10 to 15 years. A study of USGS Engineer Livingston's 1938 report on well tests, and general observation of the tests completed more recently by Messrs. Livingston and Hale, convince me that the explanation of well behavior and operation are to be found in relationships that exist between the Navajo Sands and the lower members of the McElmo Formation down in the zone where these two aquifers are connected by the 130' screen and the top portion of the 280' liner.

Pumping drawdown under existing well construction and formation relationships in the well causes a sudden gush of water from the McElmo Formation into the well. These surges account for the slugs of mud and the masses of black water that enter the well from time to time. During idle hours a more or less continuous flow of water occurs out of the Navajo Sands and into the McElmo Formation through the screen and also through and around the top of the liner. The higher pressure in the McElmo Formation causing the sudden reversal of water-flow back into the well, at the start of pumping drawdown, originates through the pressure build-up that occurs in a zone of undetermined extent within the formation itself during times of no drawdown.

Based on technical principles understood by ground water geologists that I have used in the attached report it now seems highly improbable that pumping can ever be resumed after the current breakdown without a major overhaul of the well. Should an overhauling project be decided upon the report contains a number of recommendations that should be carefully considered.

(SGD) ROBERT H. ROSE
Robert H. Rose,
Superintendent.

In triplicate.

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

December 23, 1948.

MESA VERDE NATIONAL PARK, COLORADO

MEMORANDUM for the Regional Director, Region Three.

SPECIAL REPORT ON MESA VERDE DEEP WATER WELL

U. S. Geological Survey Engineers Livingston and Hale left the park December 15. Their recent tests, generally speaking, do not disclose radical changes in leakage between the 5" and the 6" casings since Mr. Livingston's tests in 1938. Their report will doubtless be received through proper channels at an early date.

It is my considered opinion, therefore, that the explanation for the mysterious behavior of the well and related pumping difficulties is not to be found in leakage relationships between the 5" and the 6" casings. The key to the mystery is to be found in the conditions at more extreme depths - down in the lower portions of the McElmo Formation - particularly between the lower end of the 5" casing at 3934' depth and the very bottom of the well at 4192'. Every unusual aspect of deep well behavior since the well's completion in 1933 can be accounted for on the basis of the analysis to follow.

The liner at the bottom of the well consists of 130' of screened pipe coupled to 150' of solid joint casing, totaling 280'. Only 107' of the screen are in the high pressure water-bearing sands designated as Navajo Sands on the well log. The remaining 23' at the screen top above the 4,085' level are in soft sands, limy shell layers and red shales of the McElmo Formation. Records especially mention 20' of soft sand with some lime and shale content between 4,065' and 4,085' with thin, interspersed layers of shale, limy shells and sand predominating immediately above the 4,065' level. Therefore, the 23' top portion of the screen passes clear through the 20' of soft limy and sandy shale and extends at least 3' higher into the more or less thinly laminated layers mentioned.

The sand, lime and red shale layers caved badly while drilling the well particularly in the zone at 4,065' and above. Caving indicates their high water bearing content though their permeability was relatively low making the layers incapable of any large rate of water production. Unfortunately no detailed records are available on water yield in this critical zone. It is unmistakably clear, however, that water seepages were present which were the primary causes of the caving difficulties. In a word, even the caving formations possess some degree of permeability permitting passage of water through them.

Obviously, then, the 130' of screen liner forms an open connection between Navajo Sands below 4,085' and layers of the McElmo immediately above. There is absolutely nothing to prevent free flow of water between the two formations at any time pressure conditions exist that would produce such a flow. I shall demonstrate in subsequent paragraphs how pressure conditions conducive to such inter-formation flow do exist. This water flow is inevitable. In all probability, still another Navajo-McElmo connection occurs in the small amount of free space between the top portion of the 280' liner and the lower portion of the 5" casing. The liner was merely inserted in the lower end of the 5" casing. Space between the liner and the 5" casing is very small. However, since they were not joined by an absolutely water-tight connection, a flow of water through this space can also occur.

Experienced ground water and petroleum geologists know that flow of water must occur between connected semi-artesian types of aquifers with differing maximum levels attained by the static heads of each as determined in the same well; that the top level of static head in a common well bore connection between the two is less than that of the aquifer of initially higher level of static head; and that when the connecting well is not subject to reduction of head level by pumping drawdown or other causes the flow of water is out of the aquifer of higher top level of normal static head and into the aquifer of lower top level of normal static head. Furthermore, this flow will either continue indefinitely with a gradual build-up of a zone of increasingly higher back pressure in the weaker aquifer, or will virtually cease in time as hydrostatic equilibrium of top level of pressure head is attained between the two aquifers. In the Mesa Verde well the strong aquifer of higher top level of static head is the Navajo Sands. The weaker aquifer is the McElmo Series. Unquestionably these layers of the McElmo between the Navajo Sands at 4,085' and the lower end of the 5" casing at 3,934' are fair aquifers for enough water entered the hole while drilling in this zone to make unnecessary the adding of water as was done at some of the levels much higher in the well.

The McElmo Formation and the Navajo Sands are, therefore, connected between the upper and lower portions of the 130' screen. A second connection, as explained, probably also exists in the free space between the liner and the lower end of the 5" casing. Referring to the ground water principles stated above, a positive flow of water has been passing from Navajo Sands, through the liner and into the McElmo Formation during idle hours of well drawdown from the very moment the great inrush of Navajo Sands water attained a high level on April 3, 1933! This is in accordance with principles as firmly established as night following day.

Astonishing phenomena occur from the moment well pressure is reduced by pumping drawdown. As pumping drawdown begins the water flow from the stronger Navajo aquifer into the weaker McElmo aquifer is reversed! Water from the McElmo at the moment of reversal begins to enter the well. The

actual or near-equilibrium of hydrostatic head level due to idle hour back-pressure build-up in the McElmo is disturbed at the start of pumping drawdown. For an undetermined length of time McElmo level of pressure head augmented by idle-hour inflow is higher than the now reduced pressure head level of the well. As long as this relationship exists water must leave the McElmo Formation and flow into the well.

It is comparatively easy to determine the approximate pressure under which this McElmo water is pushed into the well. It is roughly equivalent to the difference between the static head level of the well when idle and the lower head level attained during pumping. In his 1938 report on well tests Mr. Livingston computed that the Mesa Verde well then experienced about 3' of drawdown for each gallon per minute pumped. At our approximate production rate of 12,000 gallons per 8-hour shift, equal to 25 gallons per minute, our drawdown is around 75'. This drawdown of 75' is roughly the equivalent of 35 pounds per square inch. In other words, back pressure in the McElmo approximates 35 pounds per square inch in the direction of the well bore simply because of idle-hour back-pressure build-up.

Doubtless this McElmo outflow into the well begins with a powerful surge. How long it continues hinges on several key factors. It may continue throughout the period of pumping. On the other hand it can gradually dissipate itself within a relatively short time. In fact as long as the reduced head level in the well is a little higher than the normal static head level of the weaker aquifer, it is possible for the reversed McElmo flow into the well to be completely checked and again resumed in the normal idle-hour direction but at somewhat reduced pressure relationships. If, however, the reduced head level of the well under pumping drawdown maintains itself at less than the normal static head level of the weaker aquifer, such as the McElmo, then the flow from McElmo into the well occurs during every moment of pumping operations!

It is highly important to inject here parenthetically the thought that conditions in Mesa Verde seem very favorable for an extensive high pressure build-up zone in the McElmo during idle hours because (1) the steeply inclined igneous dyke just south of the well is believed to close off all aquifers in the well preventing escape of water down-dip with formation and causing an increase in the semi-artesian pressure heads within the aquifers, and (2) there is probably an indefinitely large zone in an up-dip northward direction wherein an extensive pressure-buildup can be established.

Like a "bolt out of the blue", we now see why the slugs of black and red muds mixed with gritty and limy shell particles enter the well. We also understand why the gushes of jet-black water can appear seemingly without any advance warning. I have checked the operating history of the well and discover that the well yielded surges of black water and slugs of mud during the first stages of pumping operations. On numerous occasions

the deposits had to be removed from the pumping mechanism. Surges of water from the McElmo into the well must occur as well drawdown begins. It is not too important to this discussion to determine whether or not these surges are soon dissipated or whether the flow continues indefinitely at a gradually diminishing rate. If black water and mud were to appear suddenly after some 24 to 36 hours of uninterrupted pumping we would have a sure indication that the McElmo surge into the well is not momentary in duration. As a general rule we can state that mud and black water are more likely to appear shortly after pumping starts following a period of idleness and that the longer the periods of idleness between pumping drawdowns the more likely it is that the black water and mud will appear.

This analysis also helps account for great masses of sand drawn into the well in 1938 when efforts were made to increase the rate of water production by the installation of a larger capacity-per minute pump. When yield was stepped up to 35 gallons per minute and conditions became intolerable. Based on 75' of drawdown for 25 gallons per minute yield, this larger pump produced a drawdown of around 105' equivalent to about 45 pounds per square inch. While this drawdown doubtless resulted in more sand coming into the well from the Navajo aquifer, it is also highly probable that an increased amount of sand was drawn from the softer basal sands of the McElmo around the upper portion of the screen. Its softness and fine texture would facilitate such action. It should also not be forgotten that with the decreased pressure in the well due to still further drawdown, the previously explained back pressure in the McElmo was correspondingly stepped up from 35 pounds per square inch to about 45 pounds per square inch.

As these processes continue, progressive deterioration of McElmo formations takes place around the top of the screen and also adjacent to the liner at the lower end of the 5" casing. The uncemented formation shut-off at the very bottom of the 5" casing would be highly vulnerable to deterioration by the frequent passage of water into and out of McElmo strata in the immediate zone. This analysis now leads me to suggest that this deteriorating action has to some extent pierced the formation shut-off at the bottom of the 5" casing exposing additional McElmo strata in an upward direction outside the 5" casing toward the cemented lower end of the 6" casing at 3,896'. The thin layers of McElmo strata in this zone between the bottoms of the 5" and the 6" casings are rather heavily water-bearing which would accelerate, rather than retard, this deteriorating action in an upward direction.

As thickness of McElmo members subject to this action increase we must expect (a) continued loss of static pressure head of the well; (b) continued, and possibly more frequent, appearances of slugs of mud and surges of black water; and (c) gradually increasing percentages of contamination of the well yield by the more mineralized water of the McElmo. Mr. Livingston found that an apparent loss in static pressure head had occurred between 1933 and 1938 and I believe a check will disclose additional slight losses have occurred from 1938 to the present date.

A thorough job of scaling the inside of the 5" casing has been completed with removal of more than a cubic yard of scale. Contamination of the well by McElmo waters containing H₂S in some of its layers could be the primary reason for the thick incrustment. Since scale fragments seem to have contributed materially to the debris collected in the standing valve in recent pumping failures, we hope removal of the scale deposits will tend to increase the intervals between breakdowns. Without the scale aggravating the situation possibly the smaller masses of gritty muds and surges of black water will pass through the pumping mechanism and out of the well without invariably causing pumping failure.

All difficulties experienced with the well since its completion seem to stem from relationships existing from the very beginning between the Navajo Formation and the McElmo Formation after they were connected by the 130' of screen and the additional 150' of unperforated liner. If the well should utterly fail to operate following our present breakdown then we must determine whether to give the well a major overhaul or to transport water in trucks from points outside the park. Should the final determination be in favor of an overhaul job, the following recommendations should receive serious consideration:

1. The 5" casing should be run deeper into the well, probably to the top of the aquifuge layer that must separate the Navajo and the McElmo Formations near the 4,085' level. An absolutely water-tight shutoff should be achieved at this point. All deteriorated sections should be replaced.

2. Drilling to an undetermined depth below the present level of 4,192' should be considered. Geologists seriously doubt whether our water-yielding sands below 4,085' are Navajo Sands; they might very well be a portion of the Entrada Sandstone. In any event it would be worthwhile to determine whether better water with potentially higher rate of yield exists at levels a little below the present well depth. The increased depth of drilling would not run excessively high in cost. If improved conditions of water production are not found it would be a simple matter to tightly plug the hole and use the well at its present depth.

3. The 280' liner should be pulled, of course, and completely replaced. The length of the screen should be reduced such as to prevent any water passage whatsoever between the Navajo Sands and the McElmo Series. An absolutely water-tight connection should be made between the outer surface of the liner and the inner circumference of the 5" casing.

It would prove more economical in the long run to overhaul the well than to haul water through even one travel season. Mancos would be our most convenient source of water but that source would probably not be

available to us in the warmer months of the summer. Serious water shortages have been occurring regularly for the past several years. During those times it would be necessary to go even farther with our transport units. It seems probable, therefore, that the deep water well could be given a major overhaul for the cost of hauling our water for one season. An overhaul would give us the advantages of having a workable well in standby condition during the earlier years of the West Mancos River water supply line. By the time the well again deteriorated beyond usefulness all of the "bugs" would be eliminated from the new water-line installation.

This analysis based on technical principles of ground water geology contains the key to the mysterious behavior of the well observed since drilling was completed in April, 1933 and the pumping difficulties experienced since water production began a little later. The analysis further demonstrates without reasonable fear of contradiction that pumping difficulties over a period of time will increase rather than diminish. Should repeated efforts to resume water production after the current breakdown fail, we had as well reconcile ourselves to the fact that, in its present condition, the 'finis' to the well is already written. Certainly the study presented in this report would strongly confirm such a conclusion.

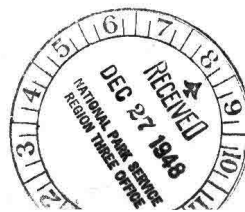
(S&D) ROBERT H. ROSE

Robert H. Rose,
Superintendent.

In triplicate.



12-27-1948: received stamp



Two "charts" attached at end of this report have been detached by Mr. Dunn and are being photostated. It is expected they will be returned to Mr. Dunn with the photostats in about a week.

This is Mr. Dunn's copy of report, and it will be appreciated if it is returned to him.

Mr. Kittredge.

March 23, 1949.

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

Very helpful
K
To Mr Hunt
K 3/28

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 12 $\frac{1}{2}$ -inch pipe from the surface to 850 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 3 $\frac{1}{2}$ -inch McEvoy

2.

button screen pipe from 4,062 to 4,192 feet.

Following the tests by Livingston ^{1/} on the deep well, which were com-

^{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.

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 1,500 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 8, 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

3.

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 $1\frac{1}{2}$ 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 $3\frac{1}{2}$ -inch screen at 4,057 feet (compared with 3,912 and 4,062 according to the log).

24 in. max.

Does this mean pushed up by much?

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

*4192
4114
878*
*Depth of
possible
debris*

4.

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 $2\frac{1}{2}$ 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 $5\frac{1}{2}$ 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} ~~referred~~ 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:	1,100
Magnesium (Mg)	11	Sum-/	
Sodium (Na)	} ----- 326	Hardness as CaCO ₃ :	
Potassium (K)		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 $\frac{4}{7}$
Black mud taken with bailer (4,113')	45	.29	8.9	2.3 $\frac{4}{7}$

^aThe 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
4,085 - 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 ~~rock~~ 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 $4\frac{1}{2}$ 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.

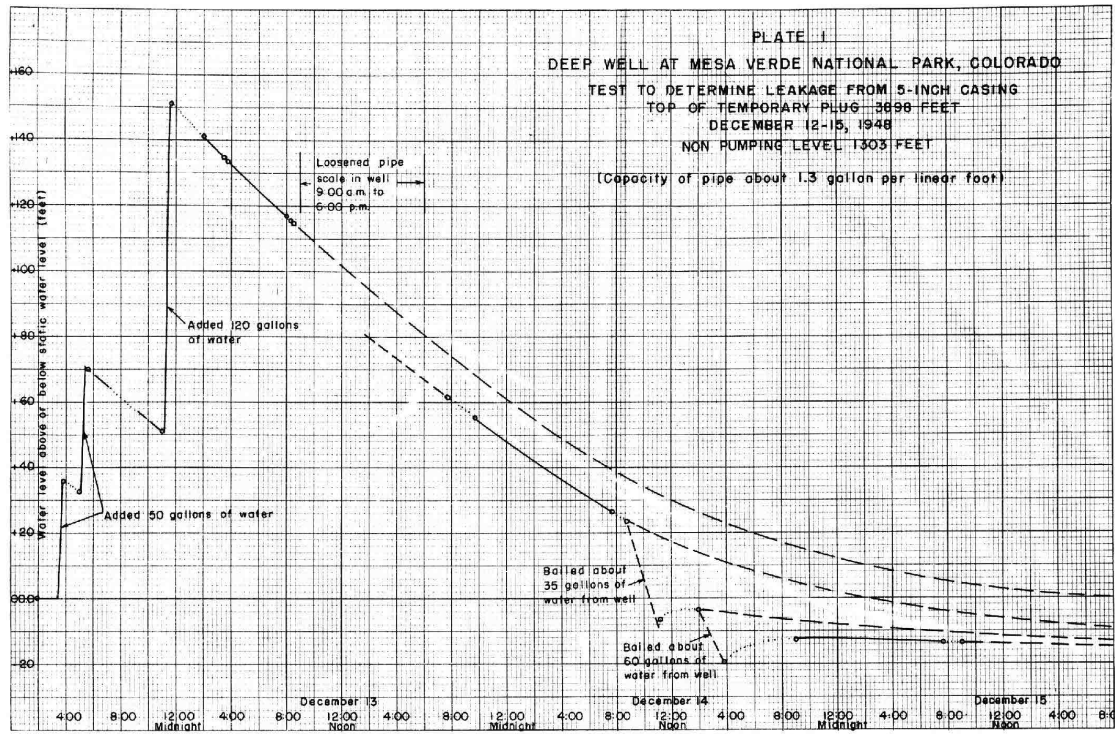
Suggestions for Reconditioning and Operating the Well

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.

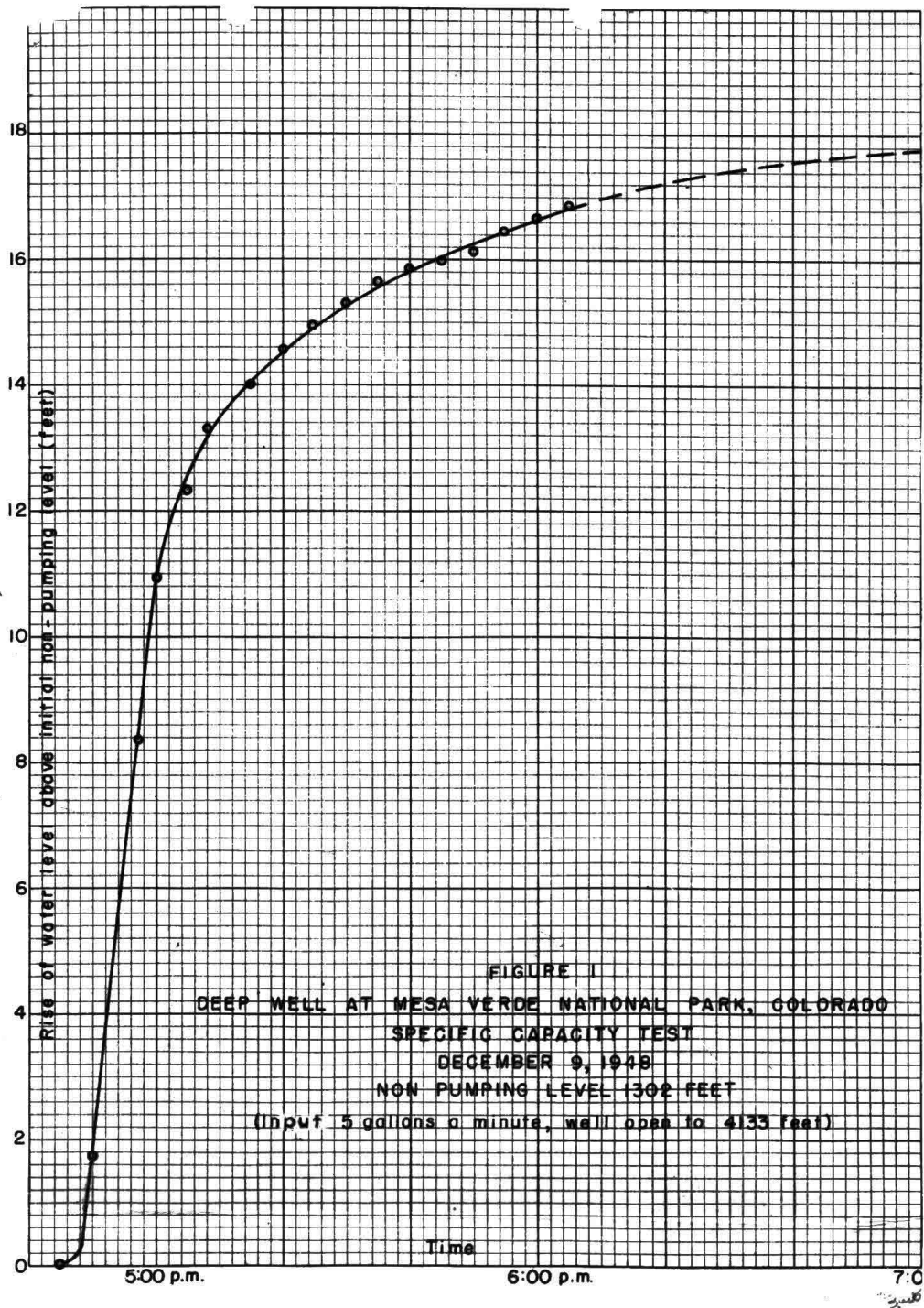
1. Scrape and brush the inside of the 5-inch casing from the top to a depth of 3,898 feet to dislodge the loose scale. Bail out the scale and remove the temporary plug at 3,898-3,910 feet. Clean out the screen to a depth of 4,133 feet and as much deeper as satisfactory progress can be made. Make no attempt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



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C O P Y

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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 $4\frac{1}{2}$ 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 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.



ADDRESS:
THE DIRECTOR, NATIONAL PARK SERVICE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WASHINGTON 25, D. C.

OCT 29 1948

Mr. Ansel F. Hall,
General Manager,
Mesa Verde Company,
Mesa Verde National Park, Colorado.

My dear Mr. Hall:

We all appreciate your letter of September 20 concerning the recent nine-day shutdown of the well at Mesa Verde National Park. We realize, only too well, how serious the water situation will remain until we complete a new water system to use the West Mancos River as a source of supply.

Having failed to obtain the necessary appropriations to date, the funds are included in the budget for the 1950 fiscal year, with priority No. 1. The estimated cost of at least a third of a million dollars, however, has not previously received appreciable support by the economy-minded Congress. Such letters as yours may be helpful when the hearings begin.

Sincerely yours,

(SIGNED) NEWTON B. DRURY

AvVD:sh.

Newton B. Drury,
Director.

cc: Regional Director, Region Three (2).
Mr. Dunn. ✓

C O P Y

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
Region Three
Santa Fe, New Mexico

October 6, 1948.

MEMORANDUM for the Director.

Reference is made to Mr. Miller's memorandum of September 24, relative to a supplemental estimate for the construction of the Mancos River Pipe Line at Mesa Verde National Park.

In connection with this subject, there is enclosed Ansel Hall's letter of September 20, addressed to Mr. Drury, and copy of Mr. Rose's memorandum of September 27. Mr. Hall's letter cites very clearly the difficulties which would beset him and his company if the well does fail completely, or for a period of two weeks or more.

As justification for this project, either as a supplemental item or for its inclusion in the 1950 Physical Improvement Appropriation, the following is submitted:

In 1931-1933 a water well was drilled in Mesa Verde National Park, to provide water for domestic and industrial purposes and for fire protection. This well was drilled to a depth of 4200 feet, where a supply of water was encountered. This water is warm, 112°, and very highly mineralized. To make it potable, it is necessary to cool it, and to treat it chemically and to filter it. Even with this treatment, the water is hard, and has a slightly objectionable taste.

Water is obtained from the well by means of a deep well cylinder type pump. This pump delivers 25 gallons per minute. This well provides about 90% of water used in the Park, the other 10% coming from the catchment of rain water, and from the Spruce Tree Spring.

The well water, due to its chemical content and temperature, has a corrosive effect on the well casing, pump cylinder, pump rods, drop pipe, and other metal parts with which it is in contact. As a result, this well, which has been in service for 15 years, has deteriorated to such a degree that complete failure may occur at any time.

The last breakdown of the well on September 8, when the pump was shut down for nine days, was by far the most serious development since the well was put in operation 15 years ago. The great amount of mud pumped from the well on this occasion indicates that the lower portion of the well casing must be failing from the corrosive effects of the water, and that, at best, the well can have but a short life remaining.

Travel to Mesa Verde National Park has shown a steady increase, with the exception of the war years. Visitation for the travel year ending September 30, 1948 was three times the annual travel of 1933, when the well was put in service. This increase in travel is much greater than was anticipated, and if the trend continues, additional water must be procured in the near future. To provide this additional water, we have prepared plans for a gravity pipe line from the West Fork of the Mancos River to the Park, to deliver 75 gallons per minute. This project is covered by PCP MV-U-12-2 and is estimated to cost \$324,000.

The Park is placed in such a precarious position with respect to water due to relying upon a fast failing well, that we feel that work should be undertaken on the Mancos River Pipe Line at once. At best, it will take a year to obtain materials and install the pipe line. Therefore no time should be lost in getting this project under way.

(Sgd) H. H. Cornell.

Harvey H. Cornell,
Acting Regional Director.

Enclosure 862.

cc: Superintendent, Mesa Verde.

C O P Y

MESA VERDE COMPANY
Operating
Spruce Tree Lodge
and Other Tourist Facilities
Ansel F. Hall, General Manager

September 20, 1948

Mr. Newton B. Drury, Director
National Park Service
Washington, D. C.

Dear Mr. Drury: Submitted Through The Superintendent,
Mesa Verde National Park, Colorado

Doubtless you have been appraised of the near-catastrophe which recently almost resulted in the closing of Mesa Verde National Park to tourist travel. I refer to the nine-day shutdown of our one and only water well which serves the whole of Mesa Verde National Park--the result, I understand, of a serious condition several hundred feet beneath the surface.

Having played the part of a vitally interested bystander during the nine days that your Park Service personnel worked so energetically and tirelessly to make repairs I want this letter to go on record as evidence of our appreciation of their skill in meeting the emergency. Mr. Rose and all of the members of his staff recognized the seriousness of the situation and threw every ounce of energy into making repairs that reestablished our water service. Fortunately, the fight was won when we had only two days supply of water left in the emergency storage tanks. Perhaps this incident was not as spectacular as a forest fire but I can assure you that the emergency was every bit as important to the operation of the Park as we, whose duty it is to provide accommodations to the visiting public, so thoroughly realize.

I understand that geologists and geophysicists claim that the life expectancy of a well 4200 feet deep (as is our water well) is about ten years. Having now exceeded this time by five years we local residents are fully aware of the serious situation under which we live and operate our business. It is quite conceivable that the next small subterranean earth movement may completely shut off our water supply which, of course, would mean closing the Park to the public.

To a concessioner who is currently having a serious struggle to keep his operation on the black side of the ledger and, at the same time, recoup war losses, this situation is very serious indeed. A shutdown which would force us to stop serving the public for a period of two weeks or less would completely ruin our whole year's operation--and a longer shutdown would mean economic disaster.

Mr. Newton B. Drury, Director

- 2 -

September 20, 1948

In view of the fact that our water situation in Mesa Verde National Park is very evidently a sword of Damocles which may at any moment sever the thread of tourist travel we urge that you make every effort to meet the emergency by securing an immediate priority for completion of the project which will bring us a permanent and unlimited water supply from the nearby La Plata Mountains.

This whole water situation represents an extreme emergency upon which we are entirely dependent for our existence as an operating National Park. Please give this problem your earnest consideration and if there is anything you can do to facilitate the securing of the new water supply for Mesa Verde we hope you will use all of your influence on behalf of the project.

Sincerely yours

(Sgd) Ansel F. Hall

Ansel F. Hall
General Manager

AFH:mk

Excerpt from

"Report on the Condition of the Deep Well in Mesa Verde
National Park, Colorado, with Suggestions for Repairing"

November 1938

by

Penn Livingston

The Deep Well

During drilling operations a small amount of water was found at a depth of 765 feet and a little later when the well was 850 feet deep a bailing test showed that the well would yield about 10 gallons a minute. It has been reported that this was the maximum rate of bailing and not necessarily the maximum capacity of the well. The water level when at this depth was reported as 370 feet below the ground. 850 feet of 12½-inch casing were set and drilling was continued. The Mancos Shale was encountered at 1220 feet, at which point 10-inch casing was set and cemented. The drill passed out of the Mancos Shale into the Dakota sand at 3352 feet, and water from the Dakota sand rose to within about 1560 feet of the ground surface. The 8-inch casing was carried down to 3553 feet and a good formation shutoff was reported. On June 6, 1931 work at this depth was discontinued under the first contract and was not continued under the second contract until the first part of August of the same year. During the intervening time the water from the Dakota sand filled the hole up to a point about 1560 feet from the surface. This water was bailed out and drilling continued, 6-inch casing being set at a depth of 3896 feet and cemented with 30 sacks of cement. Five-inch, 13.08-pound casing was set at 3934 feet and not cemented. Water in the Navajo sand was encountered at 4085 feet and it rose to about 1200 feet from the surface. The depth of the well was carried to 4192 feet or 107 feet into the Navajo sand but the bottom of the sand was not reached. The well yielded 24,000 gallons a day when completed in June 1932. Following is the log of the material penetrated by the drill and a graph of the formations and the positions of the well casings.

Log of Mesa Verde Deep Well
June 1932

	Thickness	Depth
Surface	25	25
Sand, yellow	25	50
Sand, yellow	10	60
Shale, gray	15	75
Sand, yellow	25	100
Sand, yellow	20	120
Shale, gray	85	205
Sand	45	250
Shale	75	325
Sand	75	400
Shale, brown	95	495
Lime shells, (sand and shale)	35	530
Shale, brown, (small volume of water)	135	665
Sand, water	40	705
Shale	65	770
Sand, water	20	790
Shale, brown, caving	40	830
Shale, 13,500 gallons of water per day	55	885
Sand	165	1050
Shale	10	1060
Sand	38	1098
Shale	22	1120
Sand	55	1175
Shale	2177	3352
Sand, hard shells	80	3432
Shale, green	121	3553
Shale, green and red	207	3760
Sand	9	3769
Shale	41	3810
Sand	32	3842
Shale	23	3865
Sand	31	3896
Hard lime shell, with soft shale	189	4085
Sands, buff to white, large volume of water	107	4192

Note: The graph mentioned on the first page of the foregoing excerpt is not reproduced here, since it is identical with the one in the Final Report, listed as item 2 of this assembly.

February 5, 1937

Mr. J. L. Nusbaum,
Superintendent,
Mesa Verde National Park,
Mancos, Colorado.

Attention: Mr. Paul R. Franke

Gentlemen:

MESA VERDE WELL

During our recent visit on the train, you asked regarding our latest findings and recommendations with respect to the Mesa Verde well. Since that conference, Mr. Webber and I have checked up the Pomona pump which you mentioned. We find that the company are very enthusiastic about their pump for lesser depths, but they are very hesitant about recommending it for a well as deep as yours. They say it has never been tried and that they wish to make further studies. We have been expecting word from them again since they took this matter under study for the last three weeks; however from their own statements I am afraid that they are not going to report favorably.

We have reviewed the various problems for improving the service of this well and we feel confident that our recommendations as contained in our letter to you of October 21, 1936 which were prepared after a very detailed study, is the most practical. Please refer to the letter of October 21, but in brief, the rudiments of the proposal are as follows:

"First, cut the 4-3/4-inch casing at some level not less than 50 ft. above the bottom of the 6-5/8", and at about the 3700 ft. depth.

"Pull the 4-3/4-inch casing--that extending above the 3700 ft. level--attach a 3-3/4-inch pumping cylinder and reinsert in the well approximately 1500 feet of the 4-3/4-inch casing with the cylinder at the bottom. Thus, the size of the proposed pumping cylinder will be increased from its present diameter of 2-3/4 to 3-3/4 inches and the water will be lifted through a 4-3/4-inch casing instead of the present 3 inch pipe. This should lessen the water friction in lifting the water and what is of much more importance, should reduce the friction of the suction rods against the sides of the pipe, thus greatly reducing the wear on the suction rods and the power required to lift them."

UNITED STATES
DEPARTMENT OF THE INTERIOR

GENERAL OFFICE BUILDING
SAN FRANCISCO, CALIFORNIA

NATIONAL PARK SERVICE
BRANCH OF ENGINEERING

note from Ltr. Mustang Jan 8, 1937
December record
513,800 gal pump in 348 pump hours
av. 1476.4 g/h
Rated Cap. 1500 g/h
By installing pump in new downed house
this implies pump was 13,500 gph

Our estimate for making these improvements is approximately \$2,000. Inasmuch as money has been allotted for this project, if I understand correctly, my suggestion would be to make this change at whatever time is most convenient to the park.

Without doubt, your present sucker rods being new could be used in the larger 4-3/4 inch pipe, but it would be a good plan, it seems to me, to have the larger sucker rods available for insertion whenever these gave out.

Taking all things together, it seems to me that our suggestion for pumping through the larger barrel, etc., is so full of possibilities for greatly improving the pumping service that we have no hesitation in recommending it.

Sincerely yours,

F. A. Kittredge,
Chief Engineer.

FAK:JTB

cc The Director

UNITED STATES
DEPARTMENT OF THE INTERIOR

NATIONAL PARK SERVICE

SEP 29 1931
MESA VERDE NATIONAL PARK
MANCOS, COLO.

OFFICE OF THE SUPERINTENDENT

MAILS AND FILES

September 25, 1931.

The Director,
National Park Service,
Washington, D. C.

Dear Mr. Director:

In accordance with the understanding had with the appropriations committee and Mr. Bailey of the Bureau of the Budget, I am submitting a deficiency item intended for completion of the water well at Mesa Verde.

As requested in your recent undated letter I submit the following brief report of the project to date:

The well is located $1\frac{1}{4}$ miles north of the headquarters area on Chapin Mesa and is equi-distant between Navajo and Soda Canyons. There were two factors which determined this location: the first, a volcanic dike which upthrusts through the mesa cutting sandstone strata in a northeasterly direction. Since the subterranean flow of water is from the mountainous regions to the north it was necessary to locate the well north of the dike since this igneous material, which geologists estimate rises from infinity, may have acted as a barrier to the flowing water. Second, the equal distance between the two major canyons was desirable so that if water had been encountered in the top-most strata the volume would not have been impaired by seepage in the canyon walls.

The hole was spudded-in with an 18-inch bit December 22, 1930, and drilling continued to 80 feet at which depth the bit was reduced to 15 inches. Work then progressed satisfactorily through a series of lenses of shales and sandstones to a depth of 765 feet when a slight flow of water was encountered. As drilling continued this flow of water in running over the soft, brown shale caused considerable caving. At 820 feet a real water-bearing sand carrying 13,500 gallons per day was opened. By careful operations this sand was penetrated and at a depth of 850 feet the $12\frac{1}{2}$ -inch casing was run to shut off the flow of water. Baling tests were used to determine this 13,500-gallon flow. After the baling test had been accomplished the water level in the hole had not been lowered which, of course, was indicative of a good, substantial flow. Hydrostatic head or pressure in this particular stratum was sufficient to raise the water 450 feet in the hole. It would be practical to produce this water, but since the flow is limited to 13,500 gallons a day and the seepage producing this quantity is only from the drainage of the Mesa

Verde proper, this source is neither adequate nor reliable. For the aforementioned reasons, then, drilling continued and no more water-bearing sands were penetrated until a depth of 3352 feet had been reached and the Dakota sands yielded a very minute quantity of sulphur water. The Dakota formation was but 71 feet in thickness so the 8-inch casing was underreamed, carried through the sands and placed safely on top of the McElmo formation. The water-bearing sands of the McElmo were the original objective of this project but owing to the fact that the strata lying above this formation were much thicker than anticipated a depth of 3432 feet was reached before we encountered the McElmo formation.

In the water wells at Shiprock, Farmington, and in other areas adjacent to the park the third sandstone lens in the McElmo formation usually carries the major water supply. This lens is approximately 300 or 400 feet below the top of the formation, consequently it will be necessary to drill approximately 400 feet additional before tapping the water sands.

Information recently received is of vital importance to this project. In the well at the Indian school at Towaoc, just a few miles west of park headquarters, the McElmo sands were almost dry, but an excellent flow of water was encountered just at the base of the McElmos in what is known as the Navajo formation. In a new deep test well at Shiprock the same thing occurred and the Navajo sands are producing an exceptionally fine supply of water. It is the purpose, then, of the estimate submitted, in which we allow for 700 feet of additional drilling, to enable us to drill through the McElmos, if necessary, and open the top of the Navajo formation.

At the present time the Mesa Verde well is drilled to a depth of 3553 feet; the 8-inch casing safely landed on the shoulder of the McElmo formation, and the hole is in such condition that we are ready to begin operations without any delay or difficulty.

I am also enclosing with this report a log of the well showing the different water-bearing strata and the present depth of the hole. In the enclosed estimate it will be seen that the estimated bid price per foot is in excess of the cost per foot for the first 3500 feet of drilling. However, it should be remembered that the greater the depth the greater the hazard, and progress must necessarily be much slower because of the time lost in putting the bits and bailers in and out of the hole. The item of \$2,000 submitted for extra work is important because we must have sufficient funds to accomplish the necessary finishing in order to place the well in readiness for production. This work will include such miscellaneous items as back-filling in back of the 12 $\frac{3}{4}$ -inch casing, the setting of casing head, and numerous other minor items. The original allotment was \$42,500; the total expenditures \$41,235.18, leaving an unencumbered balance of \$1264.82.

I trust that this resume of the project, as well as the items estimated for the continuation of drilling, will be sufficient information for working up the deficiency item. May I refer you for more detailed statements to my letters of May 21 and 22?

Yours very truly,

Marshall Sumner
Superintendent.

Encs.

ESTIMATE FOR WATER WELLLabor:

Drilling (700 ft. estimated @ \$12.00 per ft.)	\$8,400.00	
Underreaming (estimated 150 ft. @ \$10.00 per ft.)..	1,500.00	
Extra work (cementing casing; placing casing head; backfilling, and other necessary work to leave hole in satisfactory condition for production) estimated @ \$125.00 per day for 16 days	2,000.00	
Force account by park forces (hauling casing from Mancos to park, 160,000 lbs. @ 25¢ per cwt., \$400; msc. items, \$200.	600.00	
Total all labor	\$12,500.00	\$12,500.00

Casing and supplies:

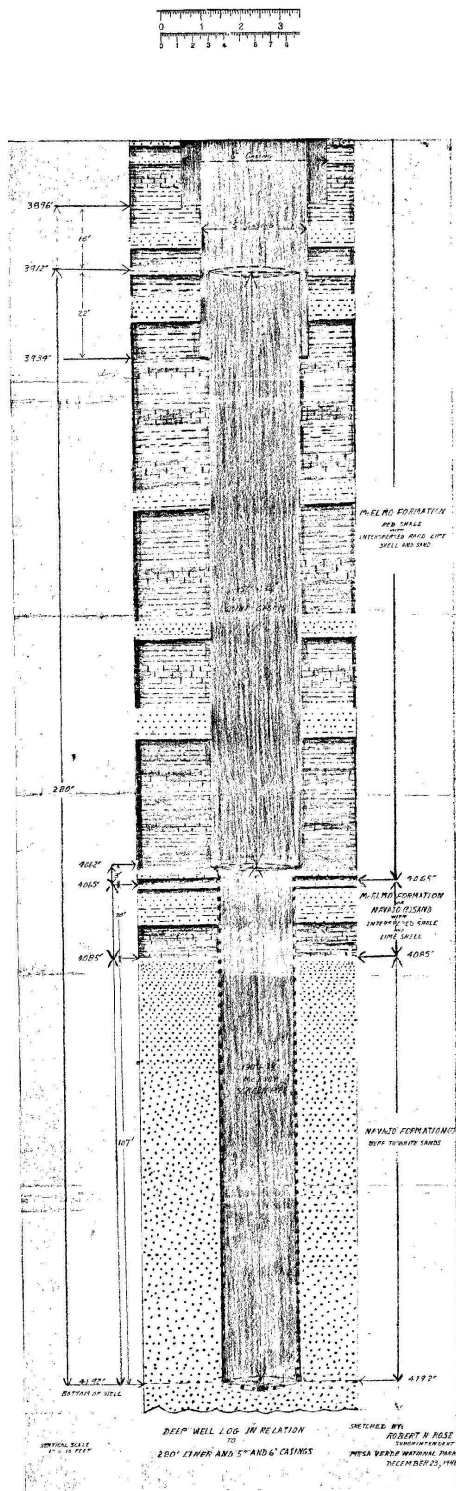
3700 ft. 6-5/8" 26-lb. Lapweld (purchased from 1930-31 appropriation and now in storage Chester, Pa.)	.00	
4200 ft. 4 3/4" 15-lb. seamless casing @ 90¢ per ft. .	3,780.00	
Cement, 100 sacks @ \$1.20 per sack	120.00	
Cement hardener, 20 gals. @ \$10.00 per gal.	200.00	
Freight on all supplies @ \$1.38¢ per cwt.	2,300.00	
Total supplies & freight	\$6,400.00	6,400.00

Contingencies:

Includes purchase of additional casing, cement, etc., if necessary, and to meet other exigencies of drilling	1,100.00	1,100.00
<i>Engineering and supervision</i>		~~2,000.00~~
TOTAL ESTIMATED COST		<u><u>\$22,000.00</u></u>

9-25-31

Maps and Miscellaneous Information



Docket Compiled: 5/26/2011