ARTESIAN WELL EXPLORATION, COTTONWOOD C.G.

THEODORE ROOSEVELT NATIONAL PARK
MEDORA NORTH DAKOTA

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

BY
McLAUGHLIN WATER ENGINEERS
TIM L. DECKER, HYDROGEOLOGIST

JULY, 1984
83-078.00P1

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INTRODUCTION

Theodore Roosevelt National Park, located in extreme west central North Dakota with headquarters at Medora, relies on deep artesian groundwater for supplying numerous campgrounds, wildlife habitats and other facilities with potable water. Although the Little Missouri River traverses the Park from South to North, the high turbidity, (and subsequent treatment costs), organic contaminants, low flow periods, and winter freezing problems preclude its use for most domestic and municipal entities. Artesian sandstone aquifers occur at depths less than 1,200 feet and have been tapped for supply by towns, oil production companies as well as Theodore Roosevelt National Park. The pressure head is usually high enough to cause flow at ground surface of warm, moderately mineralized, very soft water in quantities of over 100 gallons per minute.

Cottonwood Campground, located 5 miles by road north of Medora, is a 100 + campsite facility capable of use by more than 300 overnight campers per day. Presently two wells, the Rassmussen (350 ± ft. deep) and what is referred to as Cottonwood #6 (1,233 ft. deep) supply water to the camping area. These old wells, although providing adequate quantity for present consumption, inherently have developed physical and water quality problems due to depth or construction/completion techniques employed when they were drilled.

As part of an existing contract to improve water transportation and distribution facilities, McLaughlin Water Engineers was asked in early April, 1984 to investigate, test drill and, if successful, complete a replacement well to service the existing and expanded campgrounds planned for the future (150 additional camp sites; 200 horses). In order to expedite the project, McLaughlin sub-contracted the services of Tim L. Decker, Hydrogeologist on 9 April, 1984, to investigate, design and supervise the construction and testing of a replacement test well.

The primary objectives, as stated in meetings and conversations between McLaughlin Water Engineers and the Denver Service Center personnel were:

- o obtain a minimum of 25 gpm flowing artesian groundwater
- o design a well which will be as trouble and maintenance free as possible
- o design a well which will have a maximum useful supply life
- o obtain the highest quality Fox Hills water practical
- o if groundwater exploration proves satisfactory, have completed facilities (well) in place to serve the campground as soon as possible, preferably before peak tourist season (June)

During late April and early May, McLaughlin Water Engineers prepared specifications and contract documents to proceed with the project. Four drilling contractors were sent documents and requested to bid the project. All four contractors responded with bids during the week of May, with Gregory Drilling Co., Dickinson, N. D. as low bidder. Final negotiations on techniques and materials were completed, and Gregory was notified by telephone of the contract award on May 16, 1984. Since the Memorial Day holiday would interfere with construction, Gregory was advised to begin construction during the week of June 4th.

Location of the well was selected by Mr. Richard Bennett, Maintenance Supervisor for Theodore Roosevelt National Park and is approximately 120 ft. north of the caretaker's cabin at the campground. Specifically the location as in the SE 1/4, Section 10, T 140N, R 102W, at a ground surface elevation of 2,254 (±) ft. above mean sea level. Permit #3680 was obtained by Mr. Bennett on March 2, 1984, from the State Engineer of North Dakota, granting a conditional right to appropriate 0.4 acre-feet per year at a maximum rate of 25 gallons per minute.

Figure 1 is a location map of the campground area and the well site.


FIGURE 1
Knutson
Spring
Eklblom Spring
Peaceful Valley
BM 2248
2350
TRAIL
LOOP
LONE TREE
Cottonwood Campground
SEE INSET
COTTONWOOD CAMPGROUND WELL
Peaceful Valley Picnic Area
SEE INSET
BM 2298
Radio Tower
Rough Rider Camping Area
15
14
10
11
BM 2508
E D O R A
BM 2557
Sheep
Creek
BM 2361
BM 2387
22
23
BM 2372
Medora Airport
2552
BM 2380
BURLINGTON
Railroad
Gaging Station
BM 2266
Sewage Disposal Ponds
Medora Cem
Medora
(Historic Medora)
Sewage Disposal Ponds
27
N
Scale 1"=2000'
LOCATION MAP
THEODORE ROOSEVELT NATIONAL PARK MEDORA, N. DAKOTA

GEOLOGY

Theodore Roosevelt National Park is situated in the southwestern quadrant of the Williston Basin, a very large structural depression extending from South Dakota northward into Saskatchewan. This Basin, noted for oil and gas resource development, is reflected locally by gentle (10 - 20 ft./mile) northeastward dips of stratigraphic units toward the Basin center. No major faulting or folding exists in the area, although minor flexures are observed due to near surface coal seam burns.

Stratigraphic units of importance in the area are Cretaceous through Quaternary in age, and are composed primarily of marine and non-marine fine grained sandstones, claystones, shales, and coals. These deposits extend over vast region with the primary aquifer target, Fox Hills Sandstone, mapped as far south as central Colorado. The Fort Union Formation, containing significant coal and lignite beds, is mined extensively in central Montana and northeastern Wyoming. It conformably overlies the Fox Hills, and is subdivided into Ludlow, Tongue River, and Sentinel Butte Members.

Table 1 below lists the geologic units significant to this project along with approximate thicknesses and character.

Table 1

Stratigraphic Units - Theodore Roosevelt National Park

Formation	Member	Description	Thickness
Quaternary (Youngest)	Alluvium	sand, silt, gravel along river on terraces	0-50 ft.
Sentinal Butte		dark gray shale, clay, sandstone, lignite in Hills above campground	250± ft.
Fort Union Formation	Tongue River	gray-tan sandstone; shale; Harmon/Hensen coal beds	450 ft.
Ludlow/ Cannonball		gray sandstone, shale, clay, lignites	200 ft.
Hell Creek Fm		siltstone; shale; dark grey, bentonite with gray-brown S.S.	480 ft.
Fox Hills Fm		white, green fine grained marine sandstones	158 ft.
Pierre Shale (Oldest)		Dark gray, brown, dense marine shale	500 + ft.

AQUIFERS

Numerous studies have been published by oil and gas concerns, coal resource companies, State Engineer, and geologic survey of North Dakota, as well as U. S. Geologic Survey describing and mapping the geology of the area. Specific studies of Theodore Roosevelt National Park were completed in the 1950's. Records of other wells in the area were obtained from Water Resources Division and local consultants in order to design and specify well drilling construction parameters.

Three aquifer systems exist below Theodore Roosevelt National Park in this area. They are (See Table 1) the Fort Union sandstones; Ludlow/Upper Hell Creek sandstones and the Lower Hell Creek/Fox Hills sandstones. Numerous coal beds, some of which (Hansen, Harmon Seams) exceed ten feet in thickness, also contain smaller quantities of recoverable, although generally poor quality water. The existing Rassmussen well taps Fort Union sandstones equivalent to those shown on electric logs at 310 to 350 ft. The Ludlow/Upper Hell Creek is at a depth of 550 to 700 ± ft., and the Lower Hell Creek sandstones begin at a depth of 940 ft. The actual top of the Fox Hills sandstone is at 1,180 ft. or an elevation of 1,074 ft. above sea level. This information indicates that Cottonwood #6 well, being 90 ft. higher in elevation and only 1,233 ft. deep (1,112 ft. elevation) probably does not tap the Fox Hills and produces from Hell Creek Sands.

Preliminary information indicated total depth of a well tapping the Fox Hills at this location would be 1,250 ft. When drilling occurred and samples were logged, the aquifer was actually found to extend to a depth of 1,340 ft. This information showed most wells in the area, (including Headquarters and Medora wells) actually only reached the lower Hell Creek sands. The only well actually fully penetrating the Fox Hills is the Painted Canyon Visitor Center well some six (6) miles east of Cottonwood.

TEST WELL DRILLING AND LOGGING

Site preparation was initiated May 30th, with mud pits, access road and drill pad in place by June 1, 1984. Drilling for installation of surface pipe was begun on June 4th, with reaming to 17" diameter completed to a depth of 62.0 ft. below ground level (b.g.l.) early afternoon of June 5th. Difficulty in drilling was encountered due to large pieces (6" diameter x 12" long) of cottonwood trees, which apparently were buried at a depth of 20 ± feet in the ancient river channel.

A total of 64.65 ft. of 13 7/8" O.D. black steel casing was installed to a depth of 61 ft. on June 5th, after which 15 sacks of Type II Portland Cement was mixed for sealing surface casing in place. A total of 180 - 120 gallons of grout was pumped into the annulus, with a 2" contractor's pump, which was sealed from 61 ft. b.g.l. up to 20 ± ft. b.g.l. to facilitate installation of below grade appurtenances upon well completion. The cement was allowed to set up overnight.

Drilling of the 6 1/4" pilot hole as begun at noon on June 6th, with a total of 755' completed that day. On June 7th, drilling continued to a depth of 1,365 ft. where it appeared the Pierre Shale had been encountered; therefore drilling was halted at 1,385' and electric logging was ordered.

Constant attention to drilling fluid weight and viscosity was necessary in order to control artesian flows. It was anticipated that drilling fluid weighing 9.5 lb./gal. would be needed to prevent the 50 p.s.i. head in the Fox Hills from flowing so that casing could be installed. This proved to be successful; however shallower flows were encountered which were not controllable. Flows at 350 ± ft. (10 - 20 g.p.m. est.) caused some concern during drilling; however they proved to present no adverse conditions when the casing was run.

During drilling of the pilot hole, driller maintained a continuous log of geologic materials encountered. Cuttings, bit penetration and drill stem response were noted, indicating rock materials being drilled. The complete driller's log is included in the Appendix.

The site geologist also logged cuttings, and this sample description is also included in the Appendix.

Once cuttings indicated the Fox Hills had been drilled, electric logging was conducted. Three survey runs were completed, which included resistance, spontaneous potential, natural gamma, density, neutron and caliper parameters. These were conducted between 2:00 and 7:00 a.m., June 8th. Copies of the electric logs are included at the end of the report. To assist the reader in interpreting the logs, a brief description of each survey type is included in the Appendix.

RESULTS

During June 8th and 11th, a detailed analysis of electric logs was conducted to determine feasibility of completing a production well at this site, and select design parameters necessary to ensure a successful well. The following Table 2 lists a summary description of geologic information obtained from the logs.

Table 2

Electric Logging Analysis and Interpretations

Depth (ft.)	Geologic Materials	Water Potential	Geologic Formation
0-23	alluvial sand, gravel	dry	Quat. alluvium
23-62	shale, clay, lignite seams	none	Sentinel Butte Member, Ft. Union
62-110	shale, clay	none	Sentinel Butte Member, Ft. Union
110-140	sandy shale	none	Sentinel Butte Member, Ft. Union
140-152	bentonitic clays	none	Tongue River
152-184	coal, lignite, shale break	minor	Tongue River Hansen/Harmon Coals Seams
184-315	shale; thin sandy zones	none	Tongue River
315-350	sand, sandstone, clayey	small flows	Tongue River
350-460	shale	none	Tongue River
460-510	carbonaceous shale; lignities	none	Tongue River
510-548	sandy clays, shale	none	Ludlow
548-574	sandstone, sandy shales/	minor, small flows	Ludlow
574-580	shale, clay	none	Ludlow
580-586	lignite	none	Ludlow
586-675	shale, sandy zones, minor lignite	none	Ludlow
675-705	sandstone, sandy shale	minor	Ludlow/Upper Hell Creek
705-780	shale, carbonaceous; 6-8 lignite beds	none	Upper Hell Creek
780-1058	shale, carb; minor lignites	none	Hell Creek
1058-1078	sandstone, clean fine grain	good	Lower Hell Creek
1078-1100	shale, clay	none	Lower Hell Creek
1100-1112	sandstone, clean fine grain	good	Lower Hell Creek
1112-1135	shale	none	Lower Hell Creek
1135-1152	sandy shale	minor, small flows	Lower Hell Creek
1152-1184	shale, dense, carb; Lignite	none	Lower Hell Creek
1184-1240	sand, sandstone, clean, fine grain	good	Fox Hills
1240-1315	sand, sandstone, clays;	fair	Fox Hills
1315-1342	sandy shale	minor	Fox Hills
1342-1385	dark brown, dense shale	none	Pierre Shale.

PRODUCTION WELL COMPLETION

After log interpretation was complete, it was concluded that a successful well would provide 25 - 50 g.p.m. flow at open atmosphere [50 ± p.s.i. static pressure] at surface if a well were completed at this location. Discussions ensued between Park Service personnel and the McLaughlin Water Engineers Project Engineer as to amount of water and quality desired, and completion options. Initially, the Park Service desired as much water as available. This option would require screening and completion of all sandstones in the Lower Hill Creek/Fox Hills aquifer between 1058 and 1300 feet in depth. It was noted by the geologist that the minimum requirements of 25 g.p.m. could realistically be expected even if only the Fox Hills between 1185 - 1300 feet were utilized. It also was proposed that better quality water was expected in this zone, based on electric log characteristics.

After several discussions, it was concluded that since water demand could be met by the Fox Hills zone alone, and better quality might be obtained, that only the Fox Hills zone would be completed. Materials were then ordered to construct the well. The design specified included 8 5/8" diameter steel casing cemented in place to 1185 ft., a 7 7/8" hole drilled from 1185 to 1300 ft.; and a 4 1/2" liner string, including 55 ft. of wire-wrapped stainless steel screen, be installed and sand packed between 1185 and 1300 feet. Screen design, slot selection, sand pack selection and depths of setting were specified and materials ordered.

On June 11th, reaming of the hole to 12 1/4" diameter was begun, and was completed to a depth of 1185 ft. at noon on June 13th. A total of 1169.05 ft. of 8 5/8" steel casing was installed to a depth of 1164 ft. b.g.l. The casing was equipped with a cement guide shoe at bottom, and an aluminum, drillable float shoe (one way check value) up 17 ft. in the first casing collar. All casing was assembled by hand with threads and couples as previously approved by engineer. No obstacles were encountered while running pipe and the hole was prepared for cementing.

Haliburton Services company was contracted for cementing and arrived on site at 9:00 p.m. on June 13th. A total of 510 sacks of 15.5 lb./gal. cement, with 2% calcium chloride (to speed up curing time), were pressure grouted into the annulus through the bottom of casing. After displacing cement with 16 barrels of water, a large pressure increase indicating a bridging problem occurred. Displacement continued until all cement was displaced, however, no cement returned to surface. Analysis

of the problem indicated cement had been forced into porous sands or coals, and that the annulus was cemented from total depth up to 560 ± ft. Since flows from zones above 560 ft. were not shut off (20 - 25 g.p.m. after cementing), a second cement job was necessary (as per state well construction regulations).

Haliburton crews returned at 2:00 p.m. on June 14th, and pumped 50 sacks, 17 lb./gal. cement with 4% CaCl down the annulus through 1" steel tremie provided by the driller. All procedures went well; flows were shut off, and the cement was allowed to cure. Settlement occurred with cement top at 82.5 ft., therefore additional cement was installed by hand to fill up annulus inside surface casing to approximately 15 ft. b.g.l.

On June 18th, drilling with 7 7/8" bit commenced, with cement encountered from 1141' (float shoe) to 1185' (bottom 12 1/4" hole). Once cement was penetrated, artesian flows began immediately, increasing from 5 g.p.m. to 42 ± g.p.m. at 1205 ft. By 6:00 p.m. total depth (1305') was reached, and flows exceeded 50 g.p.m. By June 19th, 9:00 a.m., flows had reduced to 30 ± g.p.m. at discharge, to atmosphere.

All screen and sand pack materials were on site as specified on June 19th. Screen consisted of 3.75" O.D., 20 slot (.020") type 304 stainless, Johnson extra strong screen; two fifteen (15) ft. lengths; two ten (10) ft. lengths and one five (5) ft. length. Each piece had one male and one female threaded fitting for assembly. In addition, three (3) stave type centralizers were obtained to facilitate sand packing, and one right and left hand coupling included for attachment to drill pipe for installation. All pieces were assembled and installed with 4" black steel casing between screens, and landed at total depth (1301') at noon on June 19th.

Figure 2 is an as-built drawing of screen and casing assembly as installed.

Sand packing was completed between 5 and 9 p.m., June 19th. Eighty five (85), 100 lb. sacks of 10 - 30 mesh silica sand were pumped down through the drill pipe, out a homemade cross-over tool attached to screen riser pipe, down around the screen assembly filling the annulus between 8 5/8" casing, or 7 7/8" drill hole, and liner string. Chlorinated water was used to assist sand placement and disinfect materials. In addition, 100 lbs. of granulated sodium hypochlorite (HTH) was added to sand pack to fully disinfect entire well production interval. This volume caused 400 + p.p.m.

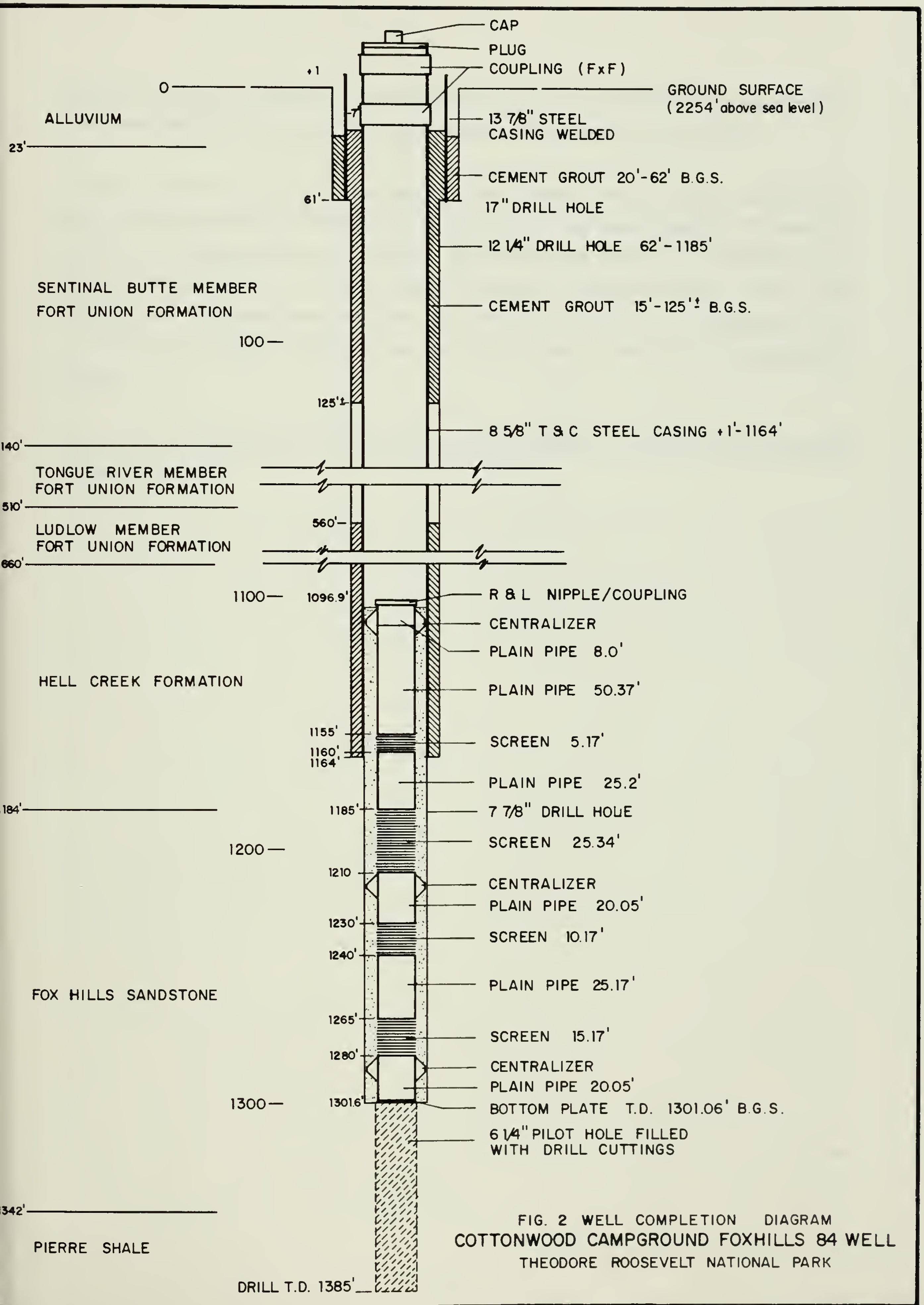


FIG. 2 WELL COMPLETION DIAGRAM
COTTONWOOD CAMPGROUND FOXHILLS 84 WELL
THEODORE ROOSEVELT NATIONAL PARK

chlorine to circulate throughout entire depth of the well, ensuring sanitary conditions. After sand packing, drill rod was disengaged and removed from the well.

On June 20th, the well was flowing 41 g.p.m., clean warm water, which had a distinct odor the driler installed 120 ft. of drill rod and began blowing 65 g.p.m. of reddish, murky (from drill rod) water. Air lifting continued and increased to 83 g.p.m. after 20 minutes. Pumping water level was calculated at 60 ft. b.g.l. Ten minutes after the compressor was shut off, the flow at surface had returned to 35 ± g.p.m. and well head equipment was installed to shut in the flow and prepare for testing.

Drilling and construction of the well was deemed complete and the rig was released on June 20, 1984.

TESTING AND ANALYSIS

During June 20th and 21st, 1984, the replacement supply well was tested for flow and head reduction in order to project short-term flowing capacity of the well. Three objectives were to be met in this initial testing: a) determine maximum flow rates which can be expected; b) determine minimum flow rate with a minimum 15 p.s.i. discharge pressure maintained; and c) what long-term capacities and/or effects on other wells in the area can be anticipated.

Initial testing consisted of a four (4) hour constant 40 g.p.m. discharge flow period, while monitoring pressure decrease (drawdown). Figure 3 shows the data obtained and resultant capacity calculations. Figure 4 is the pressure-recovery curve after terminating this flow and monitoring increasing head.

Secondary testing included opening the well head, relieving all but 15 p.s.i. residual pressure, and monitoring decreasing flow rates with time. This test was continued for a total of 15 hours in order to obtain a stabilized flow rate while maintaining 15 p.s.i. system pressure. Figure 5 represents data obtained during this phase of testing. Again, recovery was monitored when this flow was terminated to evaluate recovery responses.

Further testing (long-term/constant flow) has not been conducted to date for several reasons. First, budgetary constraints limited time available as the well required approximately one week longer to construct than originally planned. Additionally, since the well had been flowing for approximately three weeks at various times, total aquifer recovery and stabilization had not been achieved prior to testing. Accurate aquifer analysis will require that the well be shut in totally for an extended period of time (2-3 weeks), after which a constant rate flow test can be run for a 2-10 day period.

Calculation of aquifer and well capacities were made using the attached Figures 3, 4 and 5. Transmissivity of the Fox Hills aquifer is 500-640 g.p.d./ft. Measured specific capacity ranges from 0.33 to 0.47 gpm/ft. drawdown. Theoretical specific capacity is 0.32 to 0.345 gpm/ft. drawdown; therefore the well appears to be clear and efficient. No observation wells were available for monitoring, therefore, storage coefficients can not be calculated accurately. However, under such artesian conditions, storage coefficients usually range from 1×10^{-4} to 1×10^{-5}.

Should high capacities be required above the natural flow, or should artesian heads decline below ground surface, a pump could be installed in the well. Using a specific capacity of 0.25 gpm/ft. drawdown, the well should produce 80+ gpm currently from a depth of 200 ft. b.g.l., and if head is reduced to ground level, 50 gpm from the same depth.

Further observation when the system is put on-line can provide additional data to confirm/modify these calculations.

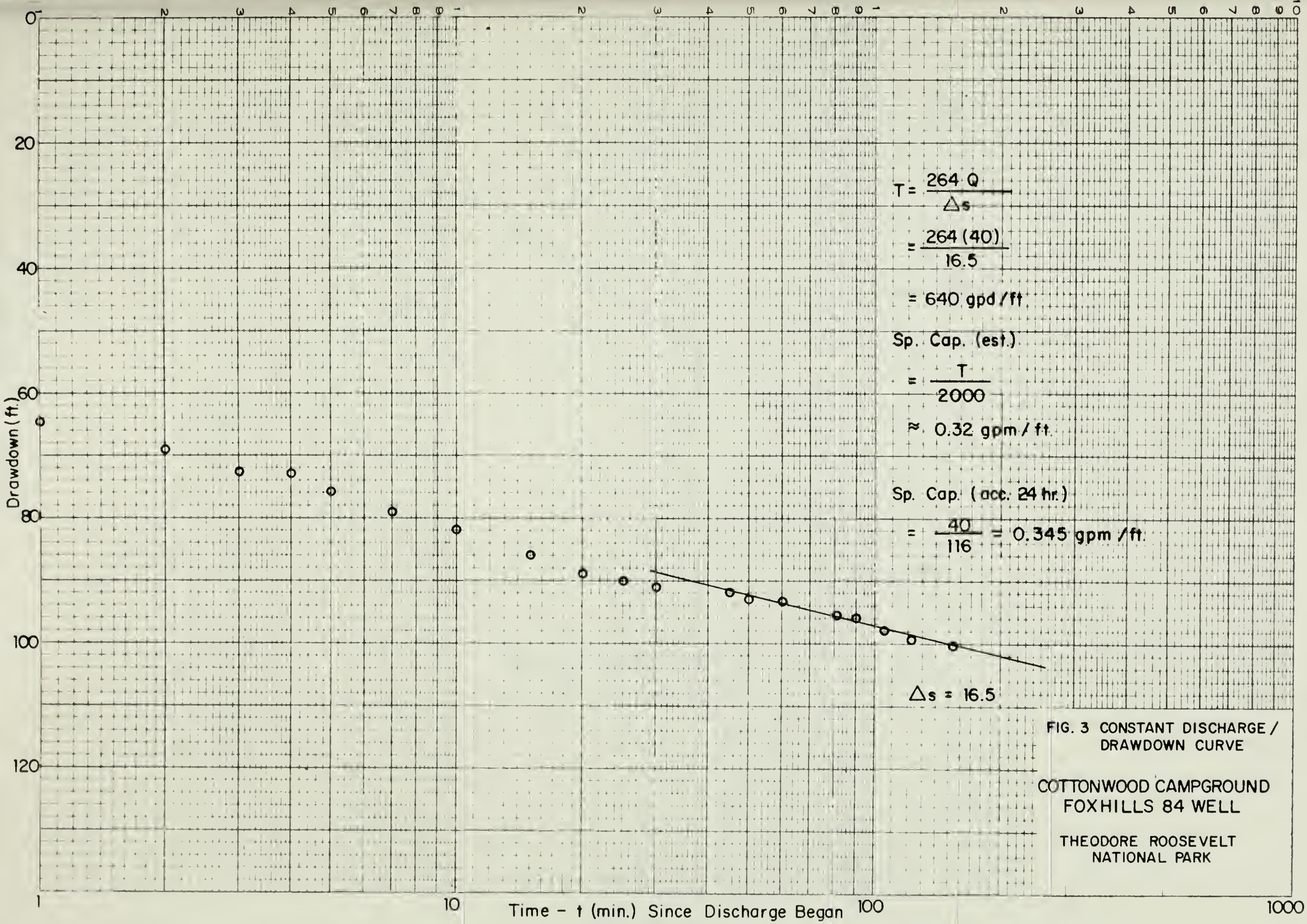


FIG. 3 CONSTANT DISCHARGE / DRAWDOWN CURVE

COTTONWOOD CAMPGROUND
FOXHILLS 84 WELL

THEODORE ROOSEVELT
NATIONAL PARK

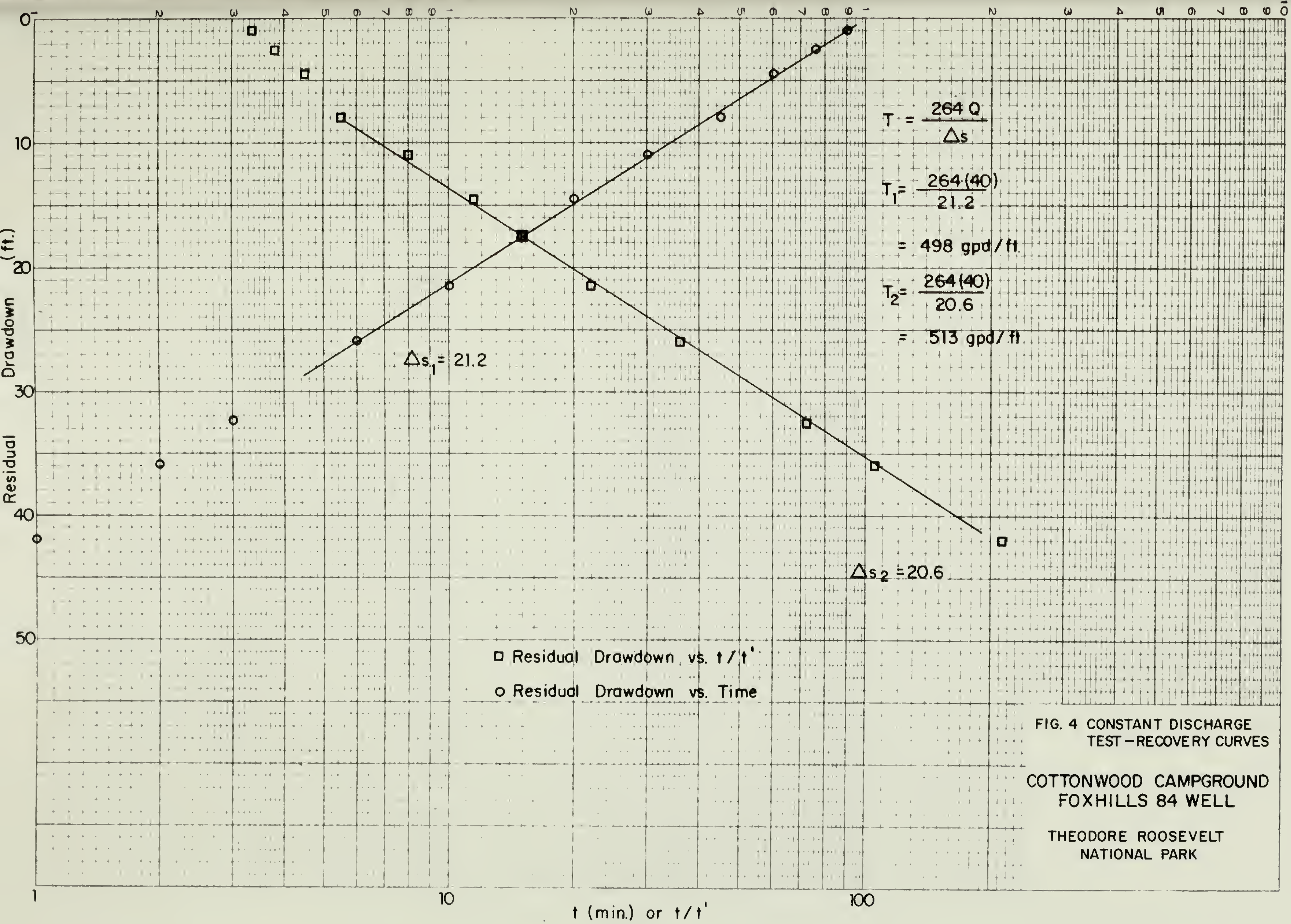


FIG. 4 CONSTANT DISCHARGE TEST-RECOVERY CURVES

COTTONWOOD CAMPGROUND
FOXHILLS 84 WELL

THEODORE ROOSEVELT NATIONAL PARK

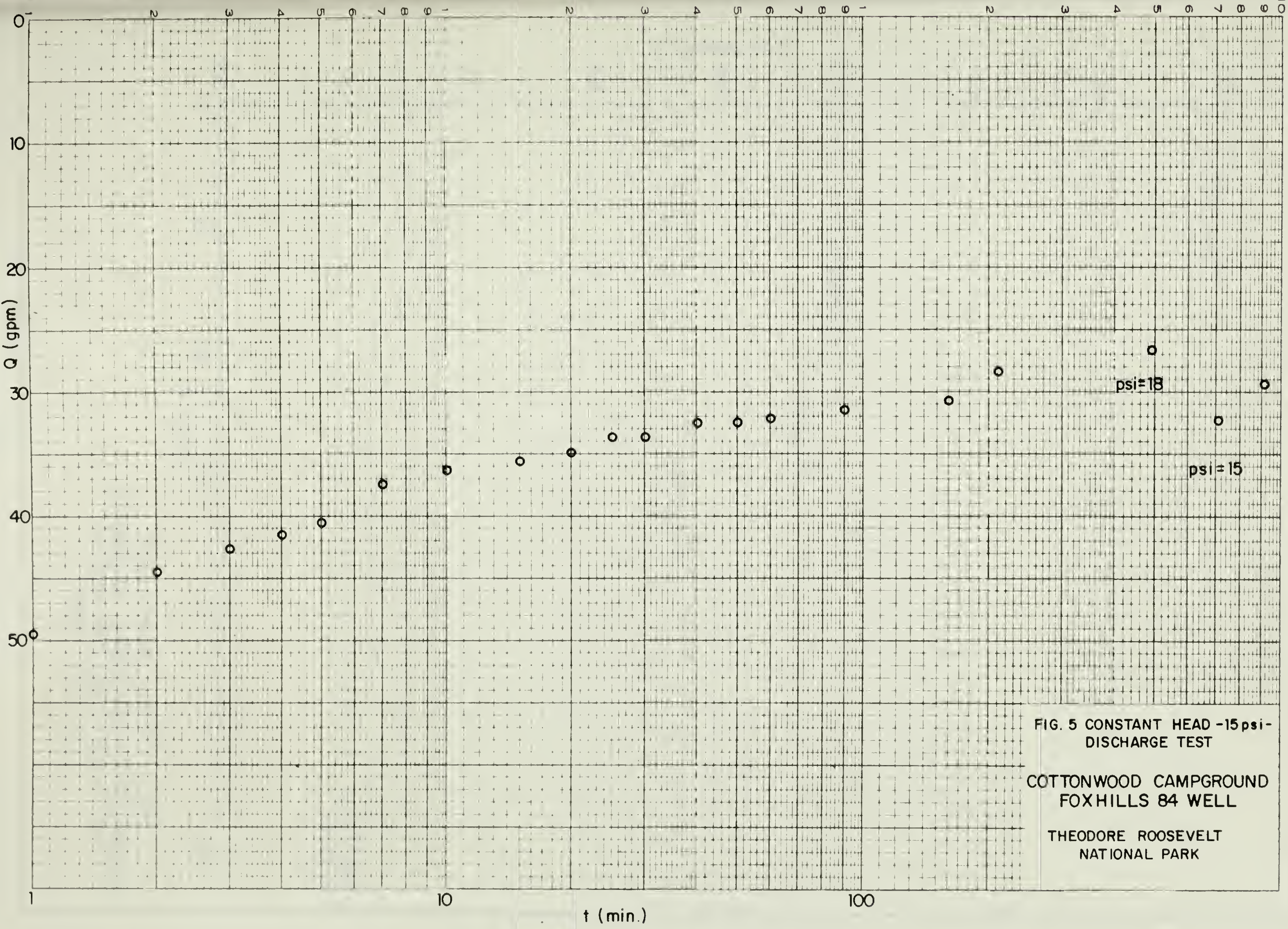


FIG. 5 CONSTANT HEAD -15psi- DISCHARGE TEST

COTTONWOOD CAMPGROUND
FOXHILLS 84 WELL

THEODORE ROOSEVELT
NATIONAL PARK

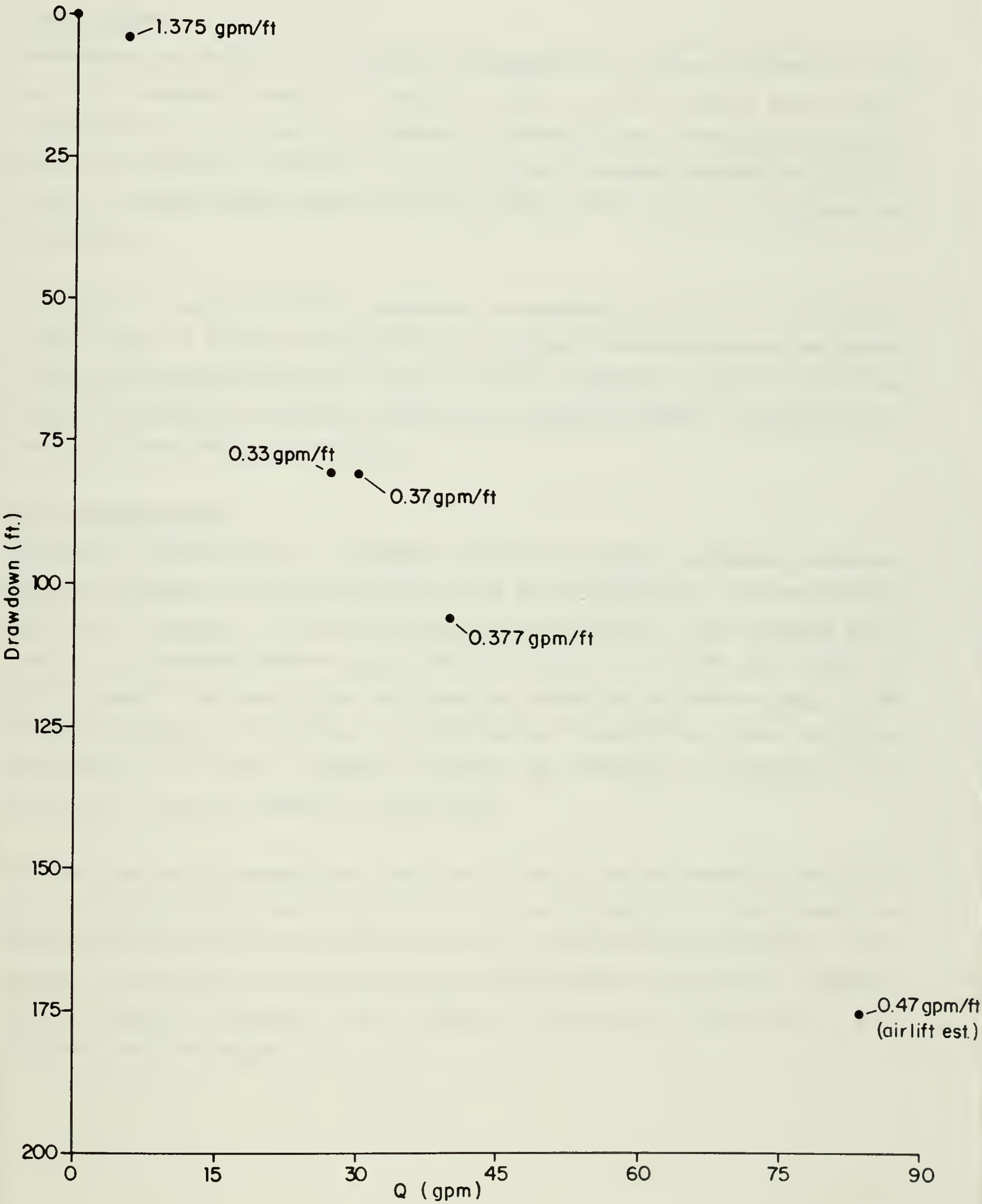


FIG. 6 SPECIFIC CAPACITY CURVE
COTTONWOOD CAMPGROUND FOXHILLS 84 WELL
THEODORE ROOSEVELT NATIONAL PARK
Medora, North Dakota

CONCLUSIONS

Groundwater exploration at Cottonwood Campground has proven successful. The Fox Hills sandstone occurs at a depth of 1184 to 1342 ft. below ground level. Pressure within the formation is adequate to cause an open discharge of 26± gpm for extended periods of time (24 + hours), and shut-in pressure currently is 116 ft. or 50 psi. At system design pressure of 15 psi, a long-term flow rate of 30-35 gpm can be expected.

The water is warm (70°-72°F), moderately mineralized 1030 mg/l total dissolved solids), and is of a sodium bicarbonate-type. Sodium concentrations are well above recommended health standards of the U.S. E.P.A., therefore, persons on restricted sodium diets should not consume quantities for extended periods. In addition, iron can also exceed recommended limits.

RECOMMENDATIONS

When well head equipment is installed (Figure 7), pressure monitoring equipment should be installed so that head readings can be taken periodically to ensure potential problems or decrease in flows can be detected and mitigated. This equipment would consist of a wellhead pressure gauge (200 psi) and a 1/4" or 3/8" nylon (2500 psi burst strength) line tapping the well head and connected to another gauge in the treatment/storage tank building. A totalizing/direct reading flow meter will allow monitoring of flow rates. Specific capacities can therefore be calculated at any given time to ensure reliability of the supply.

Concern has been expressed that if the well is shut in for any period of time, flows will not return to previous rates or may be lost altogether. Even though this apparently has occurred with other older wells, this well was constructed in such a manner that shut-in periods should not cause deterioration of the well. Production periods should be limited to those necessary to meet user demands, with flows reduced when not needed.

Water quality samples should be collected and analyzed annually, or more frequently if required by Park Service or State agencies.

After the well has been shut-in (i.e. during construction) for an extended period, a flow test should be conducted in a similar fashion to the one reported herein. It is recommended that the well be opened to 25 gpm flow rate, and pressure head data obtained for a period of 2-4 days, with recovery data obtained after final shut-in.

WATER QUALITY TESTING RESULTS

CHEMICAL ANALYSIS OF WATER
COLORADO DEPARTMENT OF HEALTH
DIVISION OF LABORATORIES
CHEMISTRY SECTION

Lab No. 846381

Name :	McLaughlin Water Engineers	Date Sampled:	6/21/84
Address:	2420 Alcott Street	Date Received:	6/22/84
City:	Denver, Colorado 80211	Date Reported:	7/20/84
Where Collected:	Theodore Roosevelt National Park ~~New Cottonwood well, Medora, North~~ Dakota		
Collected by:	Tim Decker		

Mandatory Parameters	MCL*	Results
Arsenic	0.05 mg/l	K.010
Barium	1. mg/l	K.5
Cadmium	0.010 mg/l	0.0025
Chromium	0.05 mg/l	K.005
Fluoride	2.4 mg/l	2.8
Lead	0.05 mg/l	0.006
Mercury	0.002 mg/l	K.0005
Nitrate plus Nitrite as Nitrogen	10 mg/l	K0.5
Selenium	0.01 mg/l	K.002
Sodium (recommended)	20 mg/l	400
Silver	0.05 mg/l	K.05
Radioactivity		
Gross Alpha	15 pCi/l	K8
Gross Beta	50 pCi/l	K8
Radium 226	3 pCi/l	
Radium 228 + 226	5 pCi/l	
Uranium	pCi/l	
Monthly composite ☐		
Plutonium	pCi/l	
Monthly composite ☐		

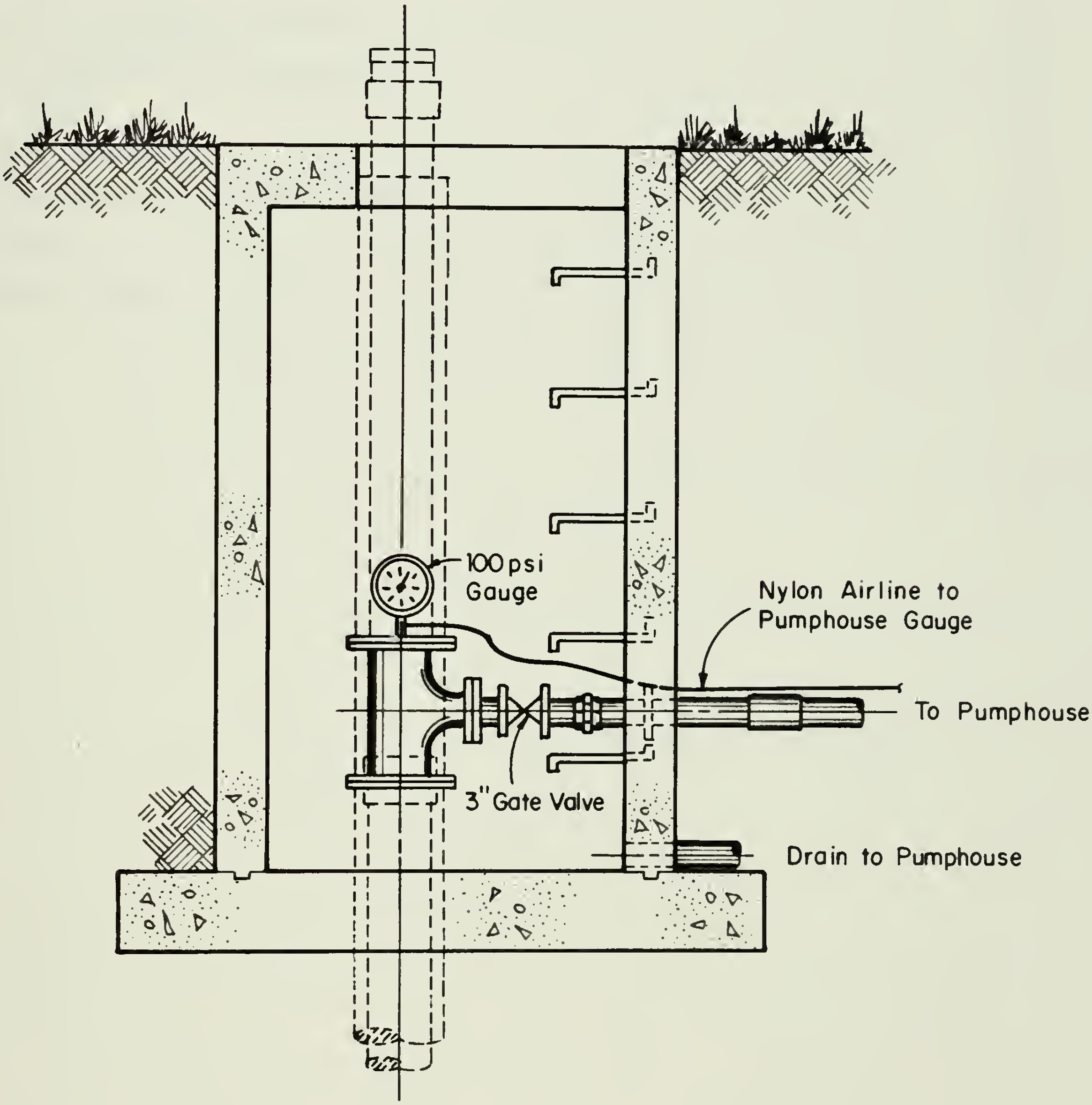
Non-Mandatory Parameters	MSL**	Results
Total Alkalinity	mg/l	680
Dissolved Solids	500 mg/l	1030
Specific Conductance	Micromhos	1850
Iron	0.3 mg/l	0.650
Manganese	0.05 mg/l	K.05
Copper	1.0 mg/l	K.005
Zinc	5.0 mg/l	K.01
Molybdenum	mg/l	K.01
Total Hardness as $CaCO_3$	mg/l	K10
Calcium as $CaCO_3$	mg/l	K10
Magnesium	125 mg/l	K1
Chloride	250 mg/l	71
Sulfate	250 mg/l	110
Turbidity		1.25
pH		
Water Temperature		
Langelier Index		
Chlorine - Residual		K.05

K = Less than

* Maximum contaminate Level

** Maximum suggested Level

FIG. 7 WELLHEAD DETAIL
COTTONWOOD CAMPGROUND FOXHILLS 84 WELL



THEODORE ROOSEVELT NATIONAL PARK
MEDORA, NORTH DAKOTA

APPENDIX

Permit No. 3680

STATE OF NORTH DAKOTA
CONDITIONAL WATER PERMIT

This conditional water permit authorizes permittee to construct the necessary diversion facilities and to appropriate the water specified below.

1. Name of Applicant U. S. National Park Service

   Mailing Address Theodore Roosevelt National Park

   City Medora State North Dakota Zip 58645

2. Source of Water Supply: Ground Water [X] Surface Water [ ]

   If Surface Water: 1) Stream ______ A Tributary of ______

3. (a) Point of Diversion:

   (1) SE ¼ of Section 10 Township 140 N., Range 102 W., Billings County

   Additional Points of Diversion, if any:

   (2) ____ ¼ of Section ____ Township ____ N., Range ____ W., ____ County

   (3) ____ ¼ of Section ____ Township ____ N., Range ____ W., ____ County

   (b) If water is not consumed, estimated quantity of water returned ______,

   name of receiving body of water Little Missouri River,

   and location of discharge point: SW ¼ SE ¼ Sec. 10, TWP. 140N., Rge. 102W.

4. Amount of water authorized, rate at which it may be diverted at the points listed and period of use:

   (1) 0.4 (AMOUNT) Acre-feet at 25 (RATE) ~~cfs~~ gpm from May 1 (MONTH DAY) to October 1 (MONTH DAY) inclusive

   (2) ____ (AMOUNT) Acre-feet at ____ (RATE) cfs gpm from ____ (MONTH DAY) to ____ (MONTH DAY) inclusive

   (3) ____ (AMOUNT) Acre-feet at ____ (RATE) cfs gpm from ____ (MONTH DAY) to ____ (MONTH DAY) inclusive

   Total amount authorized: 0.4 acre-feet at a maximum rate of 25 ~~cfs~~ gpm

5. Priority date: December 22, 1983

6. Nature of use:

   Municipal ______

   Rural-Domestic ______

   Industrial ______

   Irrigation ______

   Recreation X Campground

   Fish and Wildlife ______

   Other, Please Specify ______

7. If applicable, description of land to be irrigated (show lot numbers when possible):

Sec	Two	Rge	NE¼				NW¼				SW¼				SE¼				Total
			NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	
			N/A																
										Total number of acres to be irrigated									

8. Conditions, limitations, restrictions, and terms of permit:

1) The well(s) shall be placed in such a location, constructed to such a depth, have such an efficiency, and pumped at such a rate that will not unreasonably restrict further development of the aquifer system;

2) The pumping rate shall be subject to the results of an aquifer test;

3) Prior to the beneficial use of water, instrumentation shall be installed from which the quantity of water pumped can be determined. The instruments are subject to approval by the State Engineer and shall be available for inspection by representatives of the State Engineer; and

4) Failure to comply with any order of the State Engineer may result in forfeiture of water permit.

9. Water shall be beneficially used on or before: April 1, 1987.

10. Date application reviewed by State Engineer: March 2, 1984.

A perfected permit will be issued after the facilities have been properly constructed and inspected. A water right accrues upon placing the water to beneficial use, as authorized herein.

Dated this 2nd day of March, 19 84.

Vernon Fahy
VERNON FAHY
State Engineer

STATE OF NORTH DAKOTA
COUNTY OF BURLEIGH

Subscribed and sworn before me this 2 day of March, 19 84.

M. C. EMERSON
Notary Public, BURLEIGH CO., N. DAK.
My Commission Expires MAR. 1, 1987

M. C. Emerson
NOTARY PUBLIC

(Seal)

DESCRIPTION - GEOPHYSICAL LOGGING

A total of seven (7) different geophysical logs were run in the Cottonwood Campground Test Well, prior to completion to production status. These consisted of single point resistance, induction resistivity, spontaneous potential, caliper, natural gamma, newtron and density logs. Copies of all surveys are included at the back of this report. The following are general descriptions of each type of log, to assist the reader interpretations.

Resistance Log

Resistance-logging devices measure the resistance, in ohms, of the earth materials lying between an inhole electrode and a surface electrode, or between two inhole electrodes. A potential difference in volts or millivolts is measured between the electrodes, and this is converted to resistance by Ohm's law because a constant current is maintained. These qualitative-logging methods are known as single-point, point-resistance, electrode systems. The main uses of point-resistance logs is for geologic correlation, such as determining bed boundaries and changes in lithology and identifying fractures in resistive rocks.

The resistivity measured when using a single-point electrode is that of a limited volume of material surrounding the electrode at any particular depth. This volume, which may be thought of as being spherical, includes a short section of the mud column in the borehole plus a small volume of the formation materials surrounding the borehole. The resistivities of the mud and the formation materials differ, so the measurement that is recorded is a composite value of the two.

Interpretation is affected by many conditions, including borehole diameter, type of fluid in the hole, chemical quality of the formation water, porosity of the formation, degree of mud invasion into the formation, and type of electrode arrangement used in the operation. One of the most important variables in electric logging is the chemical quality of the formation water. To a first approximation, the formation resistivity varies inversely with the dissolved solids content of the formation water. A clean sand saturated with water having 600 ppm dissolved solids will show a formation resistivity about half that of the same sand containing water with 300 ppm dissolved solids.

Resistivity Log

Resistivity-logging devices measure the electrical resistivity of a known or assumed volume of earth materials under the direct application of an electric current or an induced electric current. Resistivity devices are generally used to determine the formation resistivity, formation porosity, mud cake resistivity, invaded zone resistivity and porosity, hydrocarbon and water saturation, fluid resistivity, and formation factor.

Multiple-electrode resistivity measurements include such curves as the short and long normal, lateral, micrology, and focused logs. The normal curves are derived from a four-electrode system, using two current electrodes, A and B, and two potential electrodes, M and N. Because only two electrodes, A and M, are effective in measuring apparent resistivity, the normals are sometimes called the two-electrode method. Two outer electrodes, A and B, supply current to the sample under study, and two inner electrodes, M and N, measure the potential drop across a known section and length of the sample. The current flows from electrode A of higher potential to electrode B of lower potential. Ordinarily, the potential drop, in volts or millivolts, between electrodes M and N is measured, and the current between electrodes A and B is held constant by suitable circuits. The more resistant the sample, the greater the voltage drop between electrodes M and N.

Except for conductive minerals like graphite, metallic sulfides like pyrite and galena, and native metals, such as silver, most minerals are good insulators when they are dry. Completely dry rocks rarely occur in boreholes, and subsurface formations have measurable resistivities due to formation water in rock pores, solution channels, and adsorbed water on clay particles. The resistivity of a rock therefore depends on the composition of the contained water, on the amount of water, and on the shape and length of the interconnected pores.

Spontaneous Potential Log

Spontaneous-potential logs are records of the natural potentials developed between the borehole fluid and the surrounding rock materials. The spontaneous potential is used chiefly for geologic correlation, determination of bed thickness, and separating nonporous from porous rocks in shale-sandstone and shale-carbonate sequences. The spontaneous-potential log is a graphic plot of the small differences in voltage, measured in millivolts, that develop at the contacts between the borehole fluid, the shale or clay, and the water in the aquifer. Two sources of potential are recognized.

The first source, and least important to the magnitude of SP, is the streaming potential caused by electrokinetic phenomena.

The second and most important source of SP arises in the electrochemical emf produced at the junction of dissimilar materials in the borehole. The junctions are between the following materials: Mud-mud filtrate, mud filtrate-formation water, formation water-shale, and shale-mud. The potential arising from these junctions cause a current to flow near shale-aquifer boundaries in the mud column in the borehole. When the formation water is much more saline than the mud, the current follows the paths shown by the arrows, entering the mud column from the shale and moving into the sandstone. At the bed boundary the current density is maximum, and the SP curve exhibits an inflection at this level. If the formation water is fresh compared with the mud, the polarity of the SP curve is reversed, and the reciprocal of the log is produced. The SP is, therefore, more positive opposite the sands and is more negative opposite the shales. This condition occurs in hydrologic regimes where ground water contains very few dissolved solids and results in an electric log on which both the SP and the resistivity deflect in the same direction, opposite the sand and shale beds.

Caliper Log

The caliper log is a record of the average diameter of a drill hole. Its major use is to evaluate the environment in which other logs are made in order to correct them for hole-diameter effects and to provide information on lithology. Continuous logging of the average diameter of drill holes is one of the most useful and simplest techniques in borehole geophysics. Most caliper sondes consist of one to four pads, or bow springs, or feelers which follow the wall of the hole. The graphic record, calibrated in inches, is the average hole diameter.

Caliper logs are utilized for the identification of lithology and stratigraphic correlation, for the location of fractures and other openings, as a guide to well construction, and to correct the interpretation of other logs for hole-diameter effects. Most changes in hole size are caused by a combination of drilling techniques and lithology. Drilling factors which can cause changes in hole diameter include: Drilling technique; weight and straightness of the drill stem; volume, pressure, and type of fluid circulated; and length of time the drilling equipment is in the hole. Lithologic factors which will affect the hole diameter include: Type and degree of cementation

or compaction; porosity and permeability; bed thickness and vertical distance to adjacent hard beds; size, spacing, and orientation of fractures and vugs; and the swelling or hydration of clay.

Natural Gamma Log

Natural-gamma logs are records of the amount of natural-gamma radiation that is emitted by all rocks. The chief use of natural-gamma logs is for the identification of lithology and stratigraphic correlation in open or cased, liquid- or air-filled holes. The gamma-emitting radioisotopes normally found in rocks are potassium-40 and daughter products of the uranium- and thorium-decay series. The natural-gamma log does not distinguish the various radioisotpes, and only gross gamma activity above a detection threshold is recorded. Even though the common gamma probe detects the several radioactive elements without distinguishing them, it does provide diagnostic lithologic information. Clays concentrate the heavy radioelements through the processes of ion-exchange and adsorption. In general, the natural gamma activity of clay-bearing sediments is much higher than that of quartz sands and carbonates.

Probably the most important application in ground-water hydrology is in identification of clay- or shale-bearing sediments. Clay tends to reduce the effective porosity and permeability of aquifers, and the gamma log can be used to empirically determine the shale or clay content in some sediments. The widest use of gamma logs is for the identification of lithology, chiefly in detrital sediments, where the fine-grained units have the highest gamma intensity.

Neutron and Density Logs

Gamma-gamma logs are records of the intensity of gamma radiation from a source in the probe after it is backscattered and attenuated within the borehole and surrounding rocks. The main uses of gamma-gamma logs are for identification of lithology and the measurement of the bulk density and porosity of rocks.

The gamma-gamma probe contains a source of gamma photons, generally cobalt-60 or cesium-137, shielded from a sodium iodide detector. Gamma photons from the source penetrate and are scattered and absorbed by the fluid, casing, and formation surrounding the probe. Gamma radiation is absorbed and (or) scattered by all material through which it travels. Bulk density may be read directly from a calibrated and corrected log or derived from a chart providing correction factors.

A neutron source and a detector are arranged in a probe so that the output is primarily a function of the hydrogen content of the borehole environment. Neutron logs are used chiefly for the measurement of moisture content above the water table and of total porosity below the water table. The various types of neutron logs are potentially the most useful techniques in borehole geophysics, as applied to ground-water investigations, because most of the probe response is due to hydrogen and, therefore, also to water. Neutron logs also have advantages peculiar to other radiation logs; they can be used in liquid-filled or dry holes or in cased or open holes, and they have a relatively large volume of influence.

In well-logging, neutrons are artificially introduced into the rock-fluid system, and the effect of the environment on the neutrons is measured (fig. 4).

Neutrons from the source pass through the walls of the source and source sub, fluid column, casing, and rock and are slowed down by collisions with atomic nuclei. The most effective element in moderating neutrons is hydrogen because the nucleus of a hydrogen atom has approximately the same mass as a neutron.

In most rocks the hydrogen content is directly proportional to the interstitial-water content; however, hydrocarbons, chemically or physically bound water, and (or) any other hydrogenous materials can give anomalous values.

Gregory Drilling Co.
1059 2nd AVENUE EAST · DICKINSON, NORTH DAKOTA 58601 · (701) 227-0320

U.S. National Park Service
Theodore Roosevelt National Park
Medora, North Dakota 58645

Cottonwood Park
Water Well No. 2
Water Permit No. 3680
SW¼ SE¼ Sec. 10, TWP. 140N, Rge. 102W Billings County, N.D.

0	15	Brown sand (loose)
15	18	Shale
18	35	Sandy shale (Old River Bed, pieces of wood logs)
35	37	Coal
37	40	Shale, sandy
40	61	Gray shale
61	90	Gray shale
90	120	Sand, soft
120	150	Shale
150	180	Coal
180	212	Shale
212	225	Sand
225	415	Shale
415	416	Sandstone
416	443	Shale
443	444	Sandstone
444	462	Shale
462	464	Sandstone
464	515	Shale
515	525	Soft, shale
525	551	Shale
551	552	Sandstone
552	574	Shale
574	575	Sandstone
575	592	Shale
592	605	Soft shale, sandy
605	650	Shale
650	651	Sandstone
651	675	Shale w/coal layers
675	702	Shale sandy, soft
702	703	Sandstone
703	730	Shale
730	731	Sandstone
731	755	Shale
755	762	Coal w/shale layers
762	795	Shale
795	796	Sandstone
796	840	Shale
840	841	Sandstone
841	890	Shale
890	907	Shale, sandy
907	910	Sandstone
910	938	Shale
938	953	Sandy shale

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953	978	Shale
978	987	Sandy shale
987	989	Sandstone
989	995	Shale
995	1005	Sandy shale
1005	1065	Shale
1065	1080	Sandy clay, lt. green
1080	1096	Shale
1096	1121	Sandy shale
1121	1125	Sandstone
1125	1130	Shale, lt. gray
1130	1131	Sandstone
1131	1151	Sandy shale
1151	1165	Shale, gray
1165	1173	Shale, brown
1173	1186	Coal
1186	1268	Sandy shale
1268	1269	Sandstone
1269	1274	Sandy shale
1274	1275	Limestone
1275	1284	Shale, sandy
1284	1286	Coal
1286	1292	Dark brown shale
1292	1293	Rock
1293	1304	Sandy shale
1304	1305	Limestone
1305	1333	Sandy shale
1333	1334	Sandstone
1334	1341	Shale, gray
1341	1385	Shale, dk. brown

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD · BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

Name: U.S. National Park Service

Address: Theodore Roosevelt National Park
Medora, N. D. 58645

2. WELL LOCATION

Sketch map location must agree with written location.

Permit #3680

NORTH

1 Mile

County: Billings

SW ¼ SE ¼ ___ ¼ Sec. 10 Twp. 140 N. Rg. 102 W.

3. PROPOSED USE

☐ Domestic ☐ Irrigation ☐ Industrial
☐ Stock ☒ Municipal ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Reverse Rotary ☐ Bored
☒ Forward Rotary ☐ Jetted ☐ Other
If other, specify ______

5. WATER QUALITY

Was a water sample collected for chemical analysis?
☒ Yes ☐ No
If so, to what laboratory was it sent: State

6. WELL CONSTRUCTION

Diameter of hole 12¼ inches. Depth 1165 feet.

Casing: ☒ Steel ☐ Plastic ☐ Concrete
☒ Threaded ☐ Welded ☐ Other
If other, specify ______

Pipe Weight:	Diameter:	From:	To:
28 lb/ft.	8 inches	0 feet	1165 feet
lb/ft.	inches	feet	feet
lb/ft.	inches	feet	feet
lb/ft.	inches	feet	feet

Was perforated pipe used? ☐ Yes ☒ No

Length of pipe perforated ______ feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material Stainless Diameter 4 inches
(stainless steel, bronze, etc.)

Slot size 20 set from 1155 feet to 1160 feet
Slot size 20 set from 1185 feet to 1210 feet
Slot size 20 set from 1230 feet to 1240 feet
Slot size 20 set from 1265 feet to 1280 feet

Was a packer or seal used? ☐ Yes ☒ No

If so, what material ______

Type of well: ~~Straight~~ Sand Pack -10mesh. screen ☒ Gravel packed ☐

Was the well grouted? Yes ☒ No ☐

To what depth? 1165 feet

Material used in grouting: Halliburton Cement

Well head completion: Pitless adapter No

12" above grade Yes Other ______

If other, specify ______

Was well disinfected upon completion? ☒ Yes ☐ No

7. WATER LEVEL

Static water level flowing feet below land surface

If flowing: closed-in pressure 50 psi

GPM flow 42 through 2½ inch pipe

Controlled by: ☒ Valve ☐ Reducers ☐ Other

If other, specify ______

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm
___ ft. after ___ hrs. pumping ___ gpm

9. WELL LOG

Formation	Depth (ft.) From	To
See attached log.		

(Use separate sheet if necessary.)

10. DATE COMPLETED June 21, 1984

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how ______

12. REMARKS:

61' of 14" steel surface casing set and cemented

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Gregory Drilling, Inc. — 144
Driller's or Firm's Name — Certificate No.

1059 2nd Ave E. Dickinson, ND
Address

[signature] — 6/21/84
Signed by — Date

WHITE—DRILLER'S COPY YELLOW—BOARD'S COPY PINK—CUSTOMER'S COPY

DRILL CUTTINGS DESCRIPTION

Depth	Description
95-105	gray shale/clay-mix with clinker and sand (above)
105-125	gray shale/clay-minor clinker and sand (above)
125-135	light gray/white bentonitic clay, gray shale
135-145	As 105-125 above
145-155	light gray/white bentonite clay
155-165	coal, fine grain, no cleating
165-175	gray-black carbonaceous shale/fissile
175-195	coal, fine-medium texture, some cleating
195-200	gray clay with minor black shale
200-210	gray clay with shale balls with clinker fragments
210-240	gray-white clay with very fine sand
240-249	gray clay with blackshale/coal fragment and fine sand
249-251	calcareous siltstone - hard
251-260	gray clay, A.A.
260-270	coal, thin (2'-3') and carb. shale/gray clay
270-280	fine carb. black shale/gray clay - 20%
280-320	fine gumbo gray clay with minor black shale
320-340	gray clay with 50% fine lignite
340-350	gray clay with black, carb - shale frags.
350-370	gray clay with black, carb - shale frags. - fewer
370-410	gray clay with minor S.S. frags. - fine
410-440	gray clay - dense/gumbo - minor S.S. frags.
440-450	gray clay with 25% white, V. fine S.S., minor limestone
450-460	gray clay with minor dense siltstone frags.
460-470	white, V. fine S.S. (50%) with carb shale frags, gray clay
470-480	gray clay with minor l.s. frags.
480-490	gray clay with minor black shale frags - fine
490-500	lignite, fine coal with gray clay
500-510	light gray-white clay with V. fine white sand; 10% lignite
510-530	dary gray clay with minor coal flakes
530-570	gray clay with dense brown claystone chips
570-580	gray clay with l.s. chips
580-620	dark to light gray carb. clay, lignite to 15%
620-630	fossiliferous gray clay with 30% lignite
630-640	lignite
640-650	gray carb. clay/shale with lignite
650-665	gray clay/shale with minor lignite
665-680	lignite in gray clay
680-700	gray/white clay; minor dense claystone
700-710	carb. dense black shale
710-720	gray clay
720-725	gray clay with lignite
725-755	gray/white clay and gummy shale
755-760	lignite with gray clay
760-795	gray/white clays
795-810	brown/gray clays with soft lignites

DRILL CUTTINGS DESCRIPTION
(Continued)

Depth	Description
810-880	gray/brown clay and shale
880-885	gray clay with lignite
885-920	gray clays
920-925	gray clay/green-gray siltstones - V. fine sand included
925-950	gray/brown clays
950-955	gray/brown clay with lignite
955-965	gray/brown clay
915-985	gray/brown clays with sandy/V. fine - green/gray S.S.
985-995	gray/brown clays with white bent mix.
995-1025	gray/brown clays with minor lignite
1025-1040	gray clay with dense brown siltstone included
1040/1090	gray/white/green clays; minor shell frags.
1090-1105	gray clay with dense green shale frags.
1105-1125	gray clay with green shale pieces
1125-1165	A.A. - mix bag.
1165-1170	lignite - fine grain
1170-1180	gray/brown clays
1180-1320	light green/white, V. fine friable, clayey S.S.
1320-1340	gray/green clays
1340-1360	hash; l.s. frags, clays, minor siltstone, green shale
1360-1380	gray/green clays; brown clay/shale included

TEAR ORIGINAL HERE FOR CUSTOMER

Phone 314: 231-2160

Date 10/7/94

VALLEY STEEL PRODUCTS COMPANY

A Division of Valley Industries, Inc

P.O. Box 503 / St. Louis, Missouri 63166

Car No. ____

Size: 8 5/8" O.D. TXC

CUSTOMER Gregory Drilling

CITY & STATE ____

No.	Feet	10THS	No.	Feet	10THS	No.	Feet	10THS	No.	Feet	10THS	No.	Feet	10THS
1	21	2	21	21	1	41	20	6	61			81		
2	21	2	22	20	1	42	20	9	62			82		
3	21	0	23	21	—	43	19	1	63			83		
4	21	2	24	16	0	44	20	5	64			84		
5	21	2	25	21	2	45	21	3	65			85		
6	[illegible]	[illegible]	26	21	—	46	17	7	66			86		
7	21	3	27	21	2	47	25	3	67			87		
8	20	6	28	21	1	48	[illegible]	3	68			88		
9	19	—	29	21	5	49	[illegible]	2	69			89		
10	21	[illegible]	30	21		50	[illegible]	[illegible]	70			90		
11	21	[illegible]	31	25	9	51	[illegible]	[illegible]	71			91		
12	19	2	32	21	5	52	17	—	72			92		
13	[illegible]	[illegible]	33	[illegible]	8	53	21	[illegible]	73			93		
14	[illegible]	[illegible]	34	[illegible]	[illegible]	54	20	9	74			94		
15	[illegible]	[illegible]	35	[illegible]	[illegible]	55	[illegible]	[illegible]	75			95		
16	[illegible]		36	[illegible]	[illegible]	56	[illegible]	[illegible]	76			96		
17	[illegible]	[illegible]	37	[illegible]	[illegible]	57	21	[illegible]	77			97		
18	17	2	38	[illegible]	—	58	[illegible]	[illegible]	78			98		
19	18	6	39	21	6	59	2	—	79			99		
20	17	5	40	11	[illegible]	60	2	—	80			100		
COL TOT	407	9		406	9		340	2						

Total This Sheet	.	PCS	Tallied By [illegible]
Total Forwarded	.	PCS	Addition Checked By [illegible]
Total Above	.	PCS	Sheet No. ____
Grand Total	1155.0	59 PCS	

DETAILED TALLY

CONTEMPORARY SALES

Cotton-wood Camp Ground
Well #2

8 5/8 Casing Tally

#			
1	17.70 ✓ w/Shoe	27	2113 ✓
2	20.90 ✓	28	2112 ✓
3	21.15	29	2030 ✓
4	20.76 ✓	30	2081 ✓
5	16.75 ✓	31	.1705 — 604.66 (5753
6	20.05 ✓	32	2125 ✓
7	16.60 ✓	33	2068 ✓
8	20.83 ✓	34	1740 ✓
10	1885 ✓	35	2110 ✓
9	1860 ✓	36	2025 ✓
13	1887 ✓	37	2103 ✓
12	2106 ✓	38	2080 ✓
11	1830 — 250.35 ([illegible])	39	2011 ✓
14	[illegible] ✓	40	2115 ✓ — 785.33 (591.7
15	1735 ✓	41	2081 ✓
16	2104 ✓	42	1980
17	2110 ✓	43	2123
18	2198 ✓	44	2070
19	1712 ✓	45	2075
20	21[illegible] ✓	46	2110
21	1707 ✓	47	2077
22	2078 — 423.92 ✓ (75606)	48	1700
23	1998 ✓	49	2083
24	2110 ✓	50	2066
25	2060 ✓	51	2100 — 1014.94 (165[illegible])
26	1865 ✓		

52	2108
53	2094
54	1744
55	1982
56	2060
57	2072
58	2010
59	12[illegible]

(10.95) Total 1[illegible]05

HALLIBURTON SERVICES

Re: Federal #36-80

Sec.-10, T140N, R102W

Billings County, North Dakota

To Whom it May Concern;

In reference to the above mentioned water well, Halliburton Services were contracted to perform the cementing of the casing of this well by Lawrence Gregory of Gregory Drilling. Our cement crew arrived on said location at 10:00 PM MST on 6-13-84. At that time the hole was already cased and the drilling contractor was circulating with their rig. Our crew set up to do the job which took approximately 50 minutes. At 10:53 PM Halliburton Services proceeded with our treatment of cementing casing(see attached copy of job log). At approximately 16 barrels into displacement of the casing we experienced an instant rise in pressure(see attached copy of pressure recorder chart). At this time we had also lost circulation on the hole. We proceeded with displacing the casing with fresh water at 4 bpm, and landed the rubber plug between cement and displacement fluid. We released wellhead pressure and the insert float valve held with 1 barrel of fluid returned. It is calculated that the cement was circulated approximately 624 ft off bottom of hole before the loss of circulation occured. Based on information provided to me and through my past experience with problems of this nature. It is my opinion that a bridge had formed in the annulus very near a known water flow. This could have happened because of a possible sand bridge from the water area. Considering the location of the possible bridge and the number of known water flows throughout the hole it was difficult for Gregory Drilling to control all water flows in this particular well. At 12:30 AM on 6-14-84 Halliburton Services was released pending further orders on 6-14-84 morning.

Sincerely;

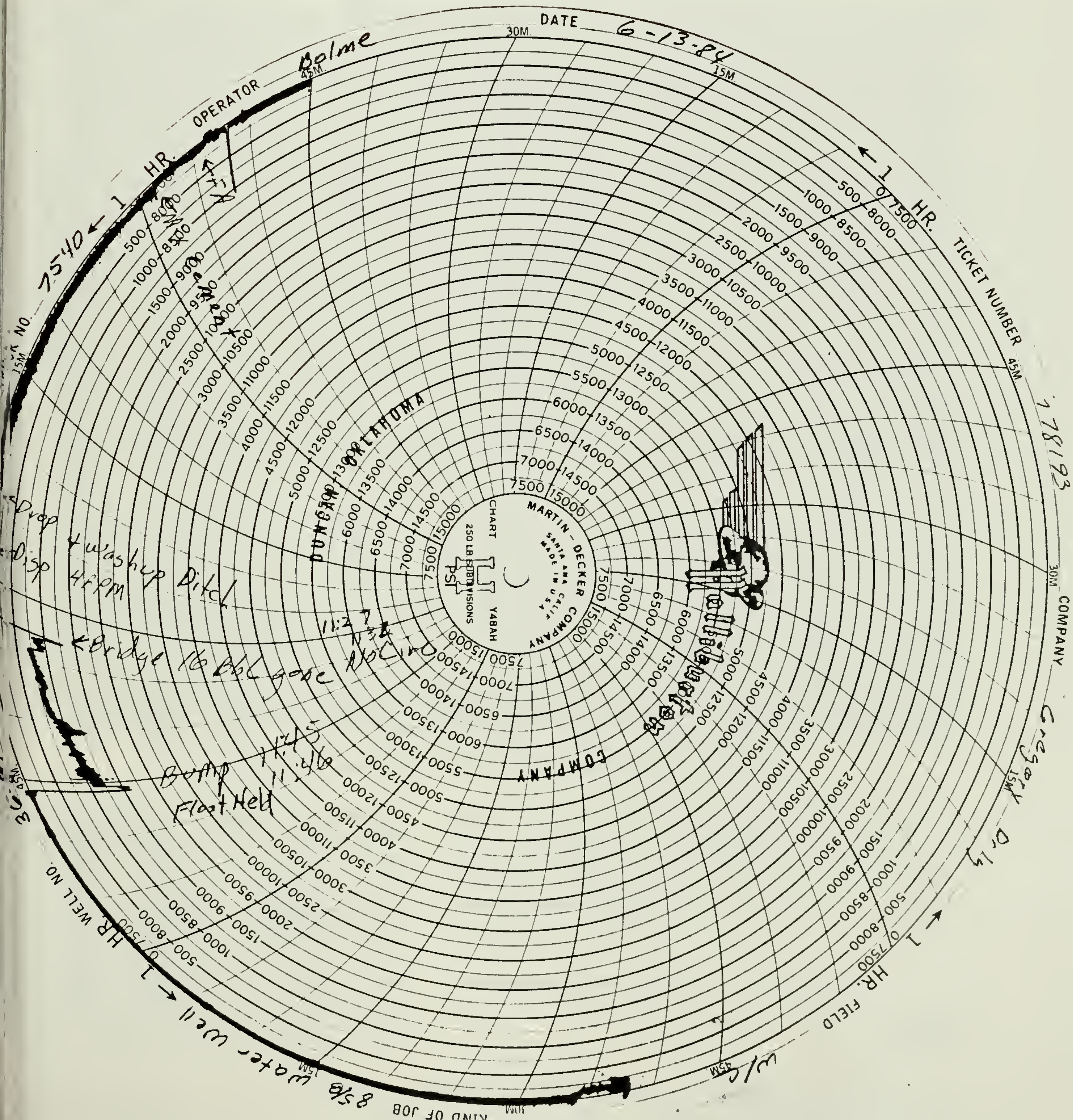
Mike Bolme

Mike Bolme

Halliburton Cementer on location

cc: File

R. G. Parker



DATE
6-13-84
OPERATOR
Bolme
TICKET NUMBER
778193
COMPANY
Gregory Drlg
FIELD
WELL NO
Water Well
KIND OF JOB
8 5/8
MARTIN-DECKER COMPANY
SANTA ANA CALIF
MADE IN U.S.A.
CHART Y48AH
250 LB SUBDIVISIONS
PSI
DUNCAN, OKLAHOMA
COMPANY
Drop + Washup Ditch
Disp 4 BPM
Bridge 16 bbl gone No Circ
Bump 11:45
Float Held

Johnson Division
P.O. Box 43118 · St. Paul, Minnesota 55164
Telephone 612-636-3900 · Telex 29-7451
UOP Inc.

SAND ANALYSIS
(FINE)

MAILING ADDRESS: P.O. BOX 43118
ST. PAUL, MINNESOTA • 55164

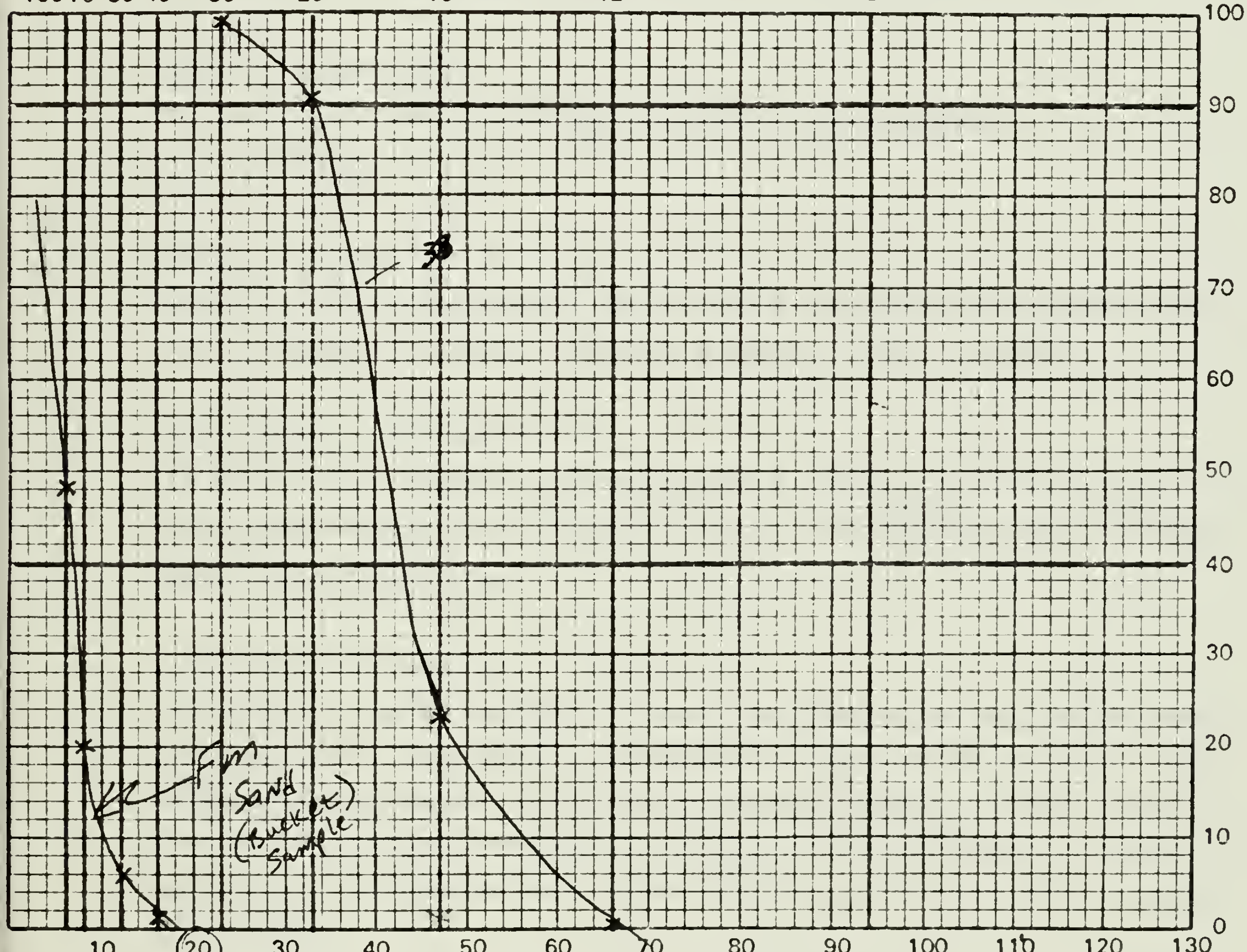
Sample sent in by Larry Gregory

Town Dickinson State N. D Zip ______ Date 6/15/84

~~From well of~~ G.P. for TRNP – Cottonwood #2

Remarks:

U.S. STANDARD SIEVE NUMBERS



SLOT OPENING AND GRAIN SIZE, IN THOUSANDTHS OF AN INCH

SIEVE NO	SIEVE OPENING INCHES	SIEVE OPENING MM	CUMULATIVE % RETAINED		
6	.132	3.36			
8	.094	2.38			
12	.066	1.68	1	0.67	
16	.047	1.19	35	23.3	
20	.033	0.84	136	90.67	
30	.023	0.60	149	99.3	
40	.016	0.42	150		
50	.012	0.30	—		
70	.008	0.21	—		
100	.006	0.15	—		

Notes: S.C ≈ 0.033 ÷ 0.056 ≈ 1.7

Recommended Slot Opening ______

Recommended Screen: Dia. ______ in. Length ______ Ft.

By TLP

SO MANY CONSIDERATIONS ENTER INTO THE MAKING OF A GOOD WELL THAT WHILE WE BELIEVE SLOT SIZES FURNISHED OR RECOMMENDED

TERMS USED

- Aquifer

  A stratum or zone below ground level that contains sufficient saturated permeable material to yield significant quantities of water to wells or springs.

- Drawdown(s)

  The lowering of the water level of the aquifer due to pumping (ft.)

- Specific Capacity (SC)

  The discharge from the well (gpm) divided by the drawdown.

  (s) = gpm/ft.d.d.

- Hydraulic Conductivity (K)

  The rate of flow in gallons per day through a one square foot cross-sectional area of the aquifer under a hydraulic gradient of one. (gpd/ft.^{2}).

- Coefficient of Transmissivity (T)

  The rate of flow in gallons per day through a vertical strip of the aquifer one foot wide extending the full saturated thickness of the aquifer; under a hydraulic gradient of one (gpd/ft.).

- Coefficient of Storage (S)

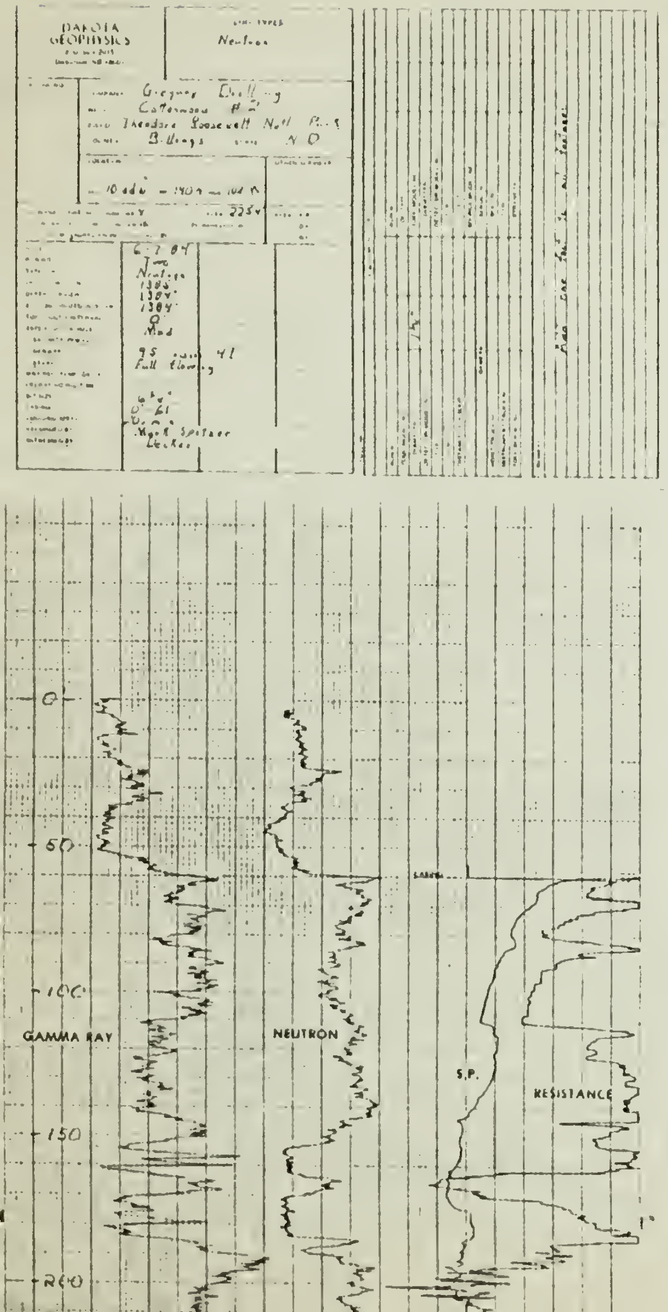
  The volume of water released or taken into storage, per unit surface area, when the head on the aquifer is changed by one unit; or the amount of water released from one square foot column of saturated aquifer, in place, when the head on this column is reduced by one foot. the coefficient of storage is referred to as the specific yield or drainable porosity for water table conditions in an aquifer.

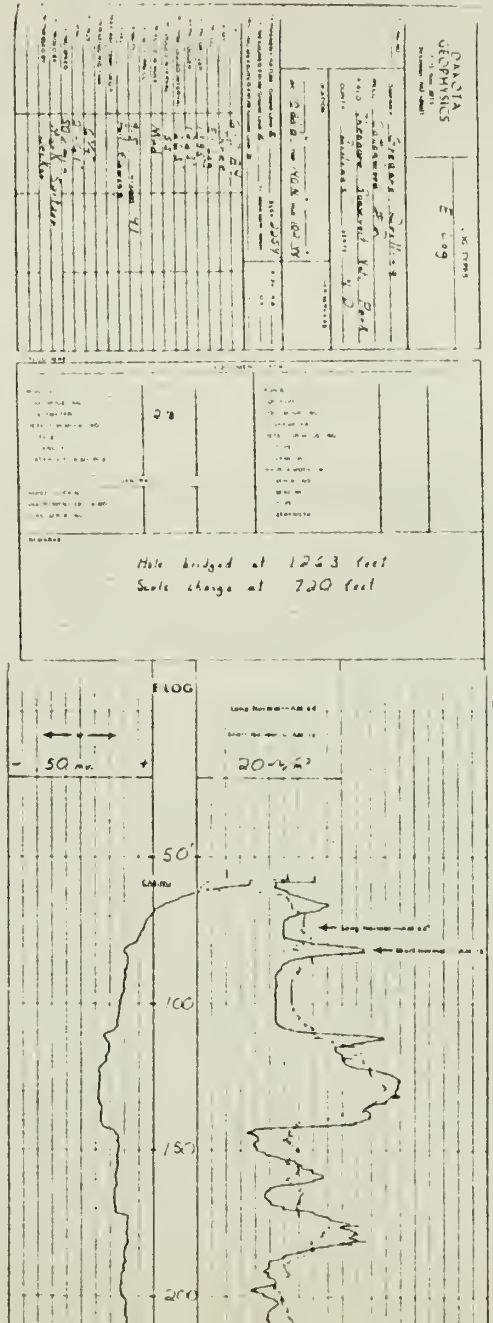
- Artesian Condition

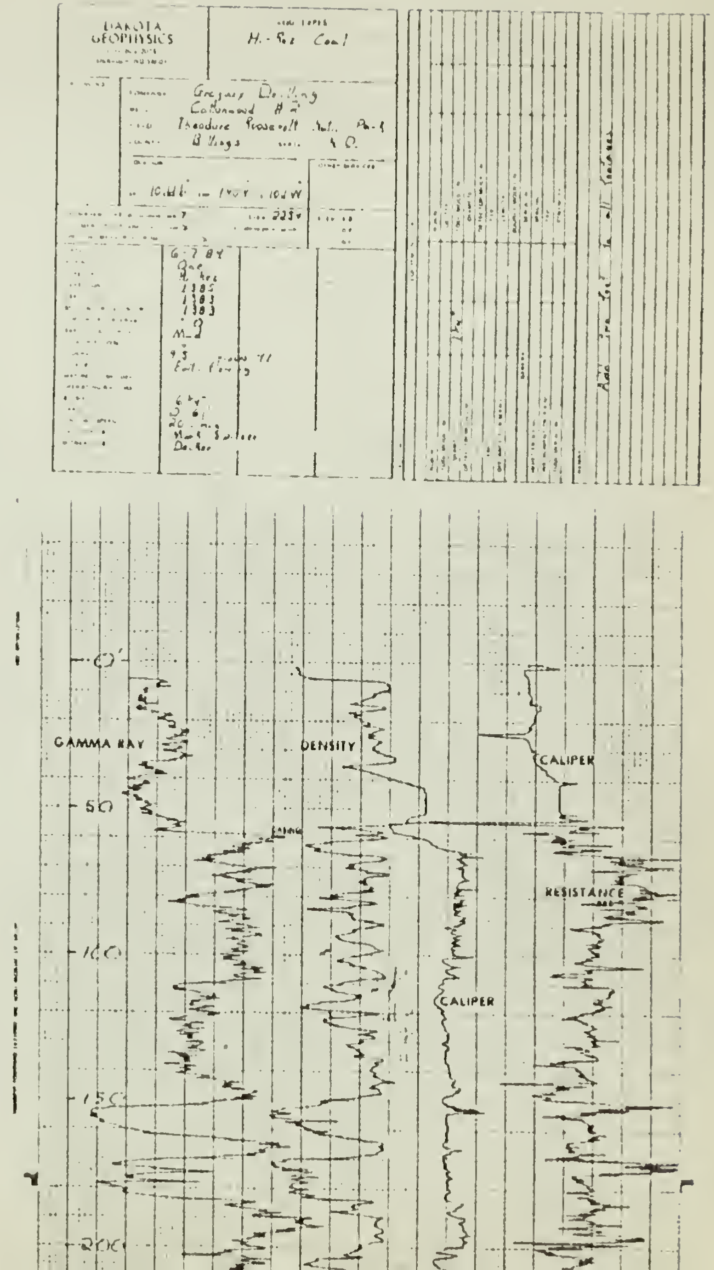
  The hydraulic condition under which piezometric water level (static water level) rises above the top of the aquifer, i.e., water pressure below a confining layer causes water to rise, in a well, above the top of the aquifer.

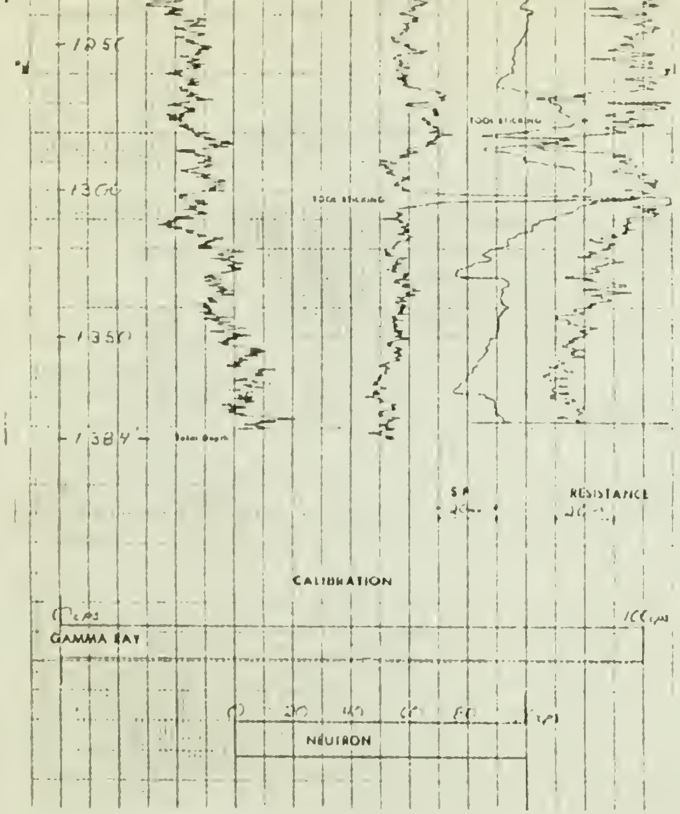
- Water Table Conditions

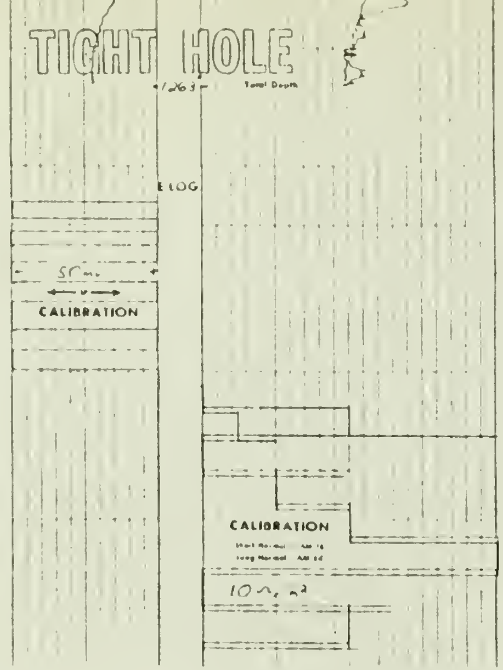
The hydraulic case where the water level is equal to or lower than the top of the aquifer; i.e. under static (non-pumping) conditions is at the level of saturation within the aquifer and is indirect contact with atmospheric pressure.

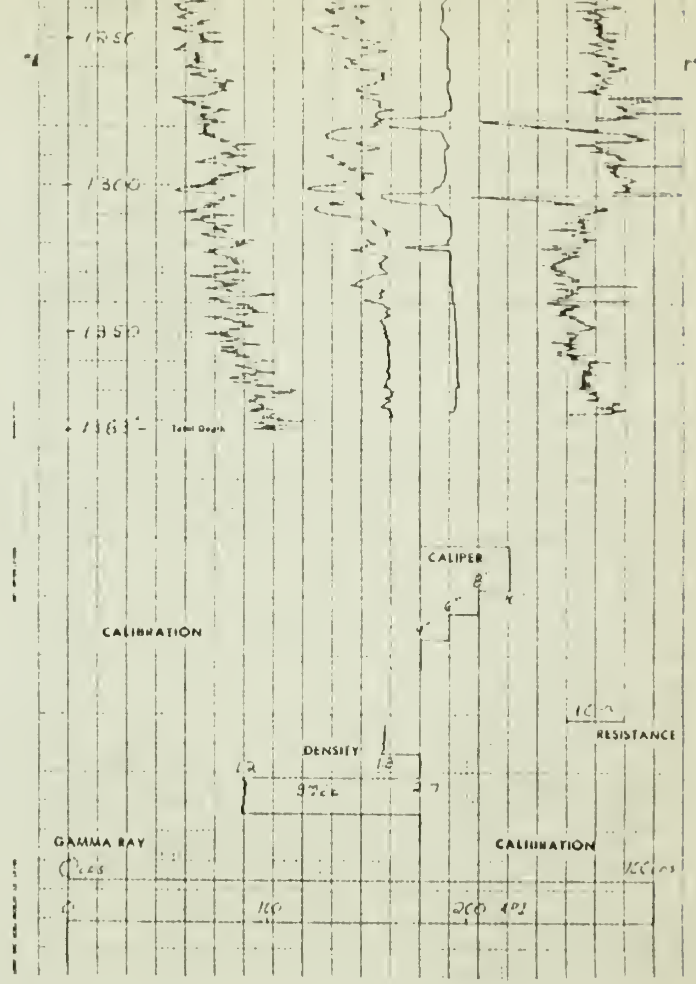

DAKOTA GEOPHYSICS
Neutron
Gregory Drilling
Cottonwood # 2
Theodore Roosevelt Nat'l Park
Billings N. D.
GAMMA RAY
NEUTRON
S.P.
RESISTANCE
0
50
100
150
200


DAKOTA GEOPHYSICS
E Log
Gregory Drilling
Theodore Roosevelt Nat. Park
Hole bridged at 1263 feet
Scale change at 720 feet
E LOG
50 mv.
50'
100
150
200


DAKOTA GEOPHYSICS
H.-Res. Coal
Gregory Drilling
Cottonwood # 2
Theodore Roosevelt Nat. Park
Billings N. D.
GAMMA RAY
DENSITY
CALIPER
RESISTANCE
0'
50
100
150
200


1250
1300
1350
1384
Total Depth
TOOL STICKING
TOOL STICKING
SP
RESISTANCE
CALIBRATION
GAMMA RAY
NEUTRON


TIGHT HOLE
1263
Total Depth
E LOG
CALIBRATION
CALIBRATION


1250
1300
1350
1363
Total Depth
CALIPER
CALIBRATION
RESISTANCE
DENSITY
GAMMA RAY
CALIBRATION

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