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FINAL REPORT

SHELL VALLEY DEEP WELL PROJECT
WITH
RESULTS OF AQUIFER TESTS
FOR
SHELL VALLEY WATERSHED SUPPLY PROJECT

PREPARED FOR:

WYOMING WATER DEVELOPMENT COMMISSION
THIRD FLOOR, EAST WING
HERSCHLER BUILDING
CHEYENNE, WYOMING 82002

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Prepared for:
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FEBRUARY 1986

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EXECUTIVE SUMMARY

The Shell Valley Deep Well Project consisted of a Level II Feasibility Study to determine the feasibility of developing groundwater sources for agricultural irrigation water supply to supplement surface water sources utilized by the Shell Valley Watershed Improvement District. Satellite imagery interpretation performed by the U.S. Bureau of Land Management was used by the Wyoming Water Development Commission geohydrology staff to identify potential drilling sites within the irrigation District service area suitable for constructing exploration wells into the Paleozoic aquifer system including the Madison, Bighorn, and Flathead strata.

The groundwater exploration and development feasibility study resulted in the construction of two wells. The first well, the Shell Valley Well No. 1, penetrated to a depth of 3,041 feet. The initial artesian flow of the well was 176.5 gpm from the Madison aquifer. The Madison aquifer was subjected to high pressure hydrofracture stimulation with gelled sand with a resultant increase in the artesian flow of the well to 367 gpm. Subsequently, the well was deepened through the entire thickness of the Bighorn Dolomite; however, the Bighorn strata did not yield groundwater and the well was plugged back to 2,421 feet near the base of the Madison aquifer. The Shell Valley Well No. 1 shut-in pressure at the end of construction and testing was 143 psi with the initial artesian flow rate of 367 gpm decreasing to 224 gpm over a 10-day flow test.

The second well, Shell Valley Well No. 2, was drilled to a total depth of 3,379 feet and penetrates both the Madison and Bighorn aquifers. The Bighorn aquifer, which is deeper than the Madison aquifer, yielded an artesian flow of 796.8 gpm after several months of unrestricted flow. The Madison aquifer yielded 292.2 gpm of artesian flow providing a total artesian flow from the well of 1,090 gpm at the time of geophysical logging of the well during the final stages of construction. Subsequent testing after completion of the well revealed a shut-in pressure of 161 psi and an initial artesian flow of 1,280 gpm declining to 1,091 gpm during the period of a 20-day flow test. The long-term artesian discharge rate of the well is projected to decline to 879 gpm after 20 years of continuously uninterrupted maximum artesian discharge. Intermittent operation of the well or sustained operation at less than maximum flow will result in a lesser decline of maximum artesian flow yields with time.

The chemical quality of the groundwater from the Madison and Bighorn aquifers is excellent for use as agricultural irrigation water with total dissolved solids concentrations of 234 mg/l and 264 mg/l for the Madison and Bighorn, respectively. The groundwater is hard water exhibiting about 225 mg/l total hardness as $CaCO_3$. The chemical quality is well suited for use as a municipal water supply source as well as being suited for agricultural irrigation.

1. INTRODUCTION

The Shell Valley Deep Well Project consisted of a Level II Feasibility Study as described in Enrolled Act No. 44 of the 1982 Session of the 46th Wyoming Legislature. The purpose of the Level II Feasibility Study was twofold. One objective was to obtain information on the productivity of the Paleozoic aquifer system in the vicinity of Shell, Wyoming by constructing an exploration/observation well and a test/production well into the Paleozoic formations and conducting an aquifer test of selected Paleozoic aquifers. The results obtained from the aquifer test program were to be evaluated to determine the potential long-term yield available from the aquifer system and to develop data required for predicting the aquifer response to long-term ground-water withdrawal. The second objective of the study was to provide a production well that could produce a minimum sustained yield of about 1,000 gallons per minute for use by the Shell Valley Watershed Improvement District to augment their existing irrigation water supply. Greater sustained yield would also make it possible to supply additional water to the Town of Greybull, Wyoming, if the necessary irrigation requirements were satisfied.

Implementation of the Level II Feasibility Study resulted in the construction of two wells as planned. However, drilling technology was selected and applied that permitted construction of both of the wells as aquifer testing and production wells rather than as one small diameter exploration/observation well and one test/production well. Project objectives were satisfied in that (1) the two wells constructed for the project have provided the required hydrologic and hydraulic characterizations of the long-term yield capabilities of the Paleozoic aquifer system and (2) the combined instantaneous yield of the two wells available for use as supplemental irrigation water supplies and other uses exceeds 1300 gpm. Total footage drilled for the project is 6,429 feet which is well in excess of the approximately 5,000 feet of drilling anticipated by the modified project scope after receipt of the initial competitive cost proposals from short-listed consultants. Moreover, the provision of two production wells instead of the originally planned one exploration well and one production well is a substantial increase in the benefits of the Level II Feasibility Study as implemented.

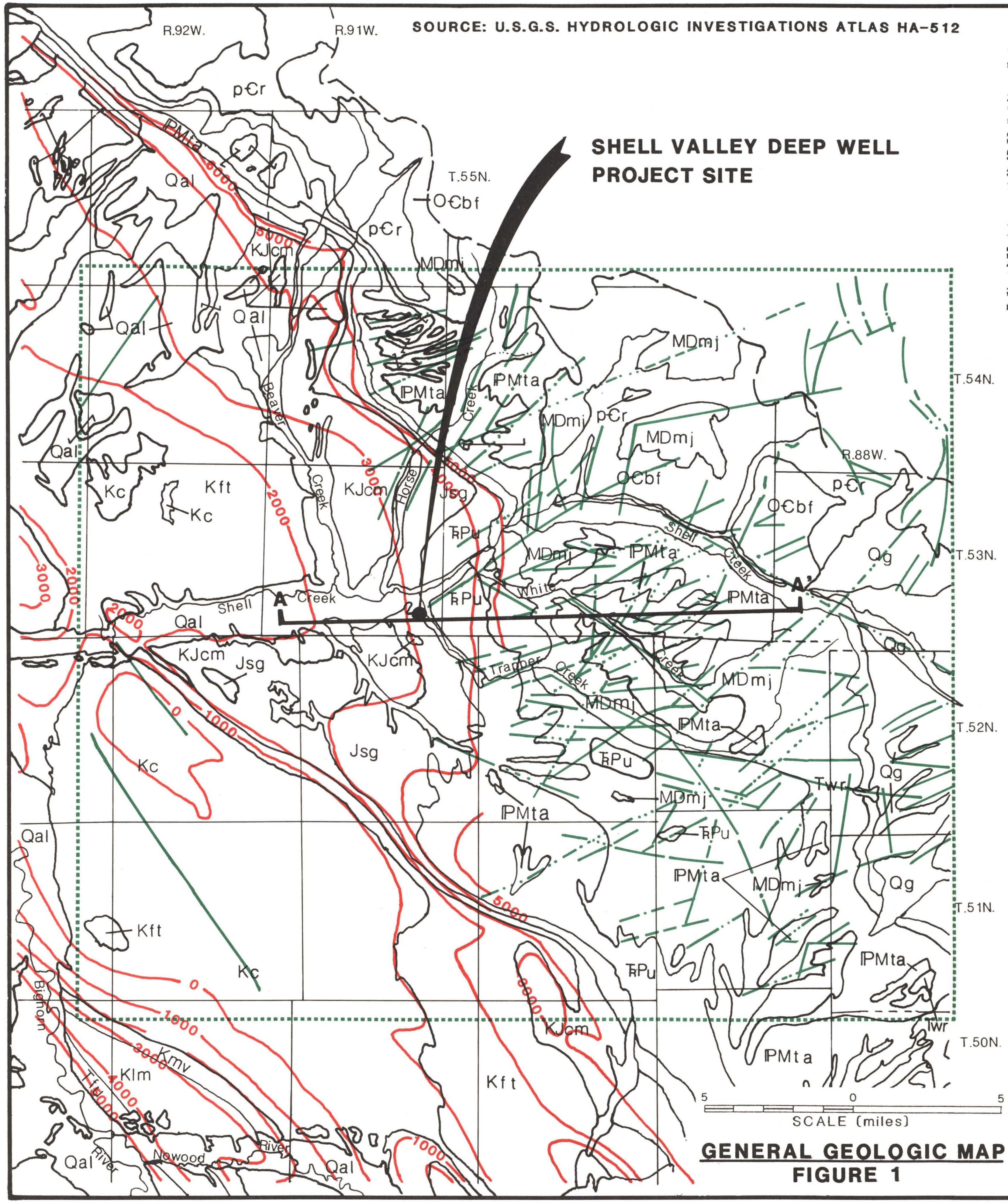
2. ACKNOWLEDGEMENTS

The kindly cooperation and assistance of K. L. Reid for providing access to his property for placement of the discharge pipeline to Trapper Creek is greatly appreciated. Likewise, the cooperation of Jack Klucas and other members of the Shell Valley Watershed Improvement District was very helpful. Mr. Jon Wade, geohydrologist for the Wyoming Water Development Commission, rendered invaluable assistance in obtaining the necessary State and Federal permits and in providing continued participation in decisions pertaining to all aspects of the well construction activities. Special recognition is given to the drilling crews of the Sargent Irrigation Company of Casper, Wyoming who persevered through adverse weather conditions, numerous technical difficulties, and extended periods of 24-hour per day operations. Mr. Mike Purcell, Administrator of the Wyoming Water Development Commission, and the members of the Wyoming Water Development Commission merit special commendation for their support of the exploration project and perseverance in the face of numerous difficulties in the accomplishment of the project.

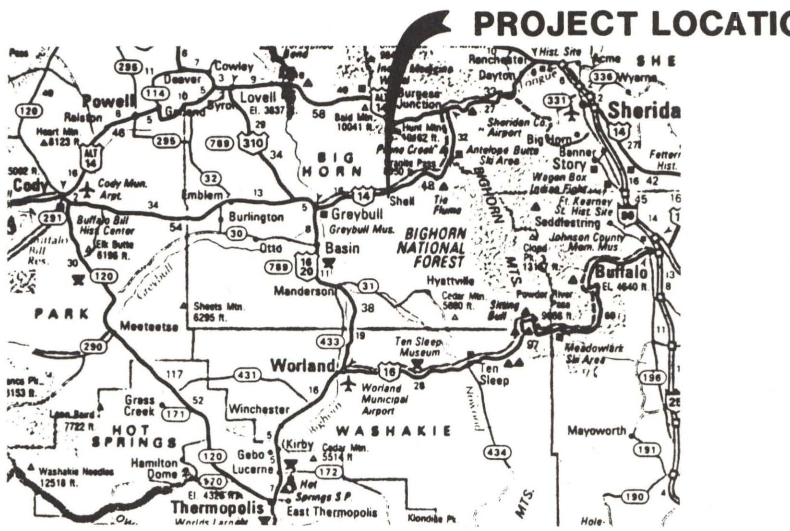
3. GEOLOGY AND GEOHYDROLOGY

A general location map for the Shell Valley Deep Well Project is shown on Figure 1 with a generalized geologic map and geologic cross section of the local area of the Shell Valley Deep Well Project. The site is located adjacent to the Trapper Creek Road in the NE 1/4, NE 1/4, Section 35, T53N, R91W, approxmately 9,500 feet from the synclinal axis of the Bighorn Mountains monocline. The project location is structurally down dip from a major recharge area for the Madison Group strata and for other water-bearing strata such as the Tensleep, Bighorn, and Flathead formations. The dip of the strata east of the axial trace of the lower limb of the monocline ranges from 12 to 17 degrees whereas the dip of the strata west of the monocline and in the vicinity of the well sites for the project ranges from about 4 to 7 degrees. The hydraulic gradient in the Madison Group strata is from the recharge area on the west flank of the Bighorn Mountains in a westward direction into the Bighorn Basin. The potentiometric surface of the groundwater levels at the Shell Valley Deep Well project site is 330 feet above the land surface at Well No. 1.

The location of the exploratory well site was selected largely on the basis of satellite imagery interpretation performed for the WWDC by the U.S. Bureau of Land Management. The second major consideration in selecting the drilling site was the relationship between the drilling site and the existing irrigation project conveyance system and plans to improve the irrigation project water supply. Other factors taken into consideration in siting the well included field inspection of the local surface geology, topography, and local land ownership and access conditions. As shown on Figure 1, the drilling site is located near the end of a lineament trace identified by the satellite imagery interpretation.



GENERAL GEOLOGIC MAP
FIGURE 1



VICINITY MAP

LEGEND

1000 — STRUCTURAL CONTOURS*

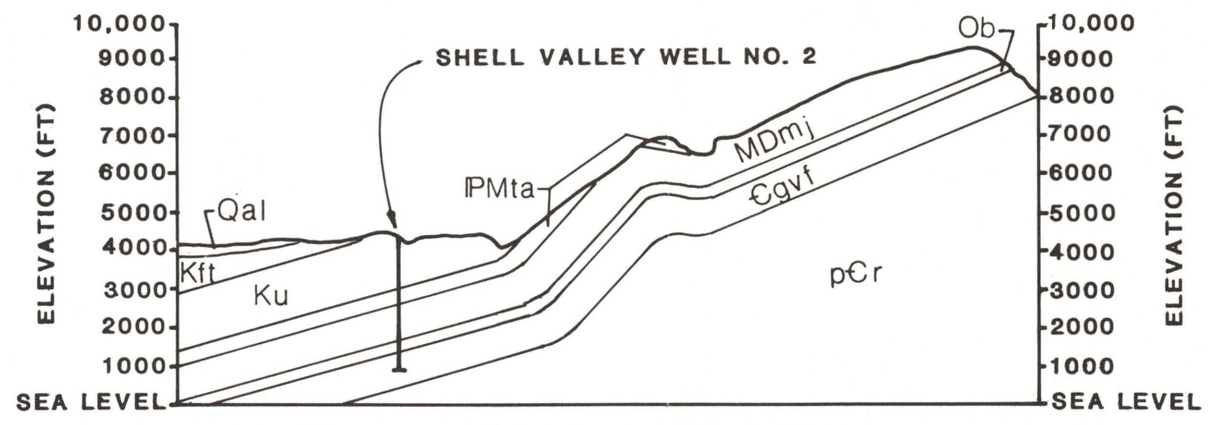
— · — LINEAMENT

▨ SATELLITE IMAGERY INTERPRETATION AREA

*Structural contours on top of Tensleep Formation

DESCRIPTION OF MAP UNITS

Qal	FLOOD PLAIN (Qfp) AND TERRACE (Qt) DEPOSITS, UNDIVIDED
Tfu	FORT UNION FORMATION (Paleocene)
Klm	LANCE (Kl) AND MEETEETSE (Kme) FORMATIONS, UNDIVIDED
Kmv	MESAVERDE FORMATION
Kc	CODY SHALE
Kft	FRONTIER FORMATION (Kf), MOWRY (Km), AND THERMOPOLIS (Kt) SHALES, UNDIVIDED - (Kmu), Muddy Sandstone Member of Thermopolis Shale
KJcm	CLOVERLY (Kcv) AND MORRISON (Jm) FORMATIONS, UNDIVIDED
Jsg	SUNDANCE (Jsd) AND GYPSUM SPRING (Jsg) FORMATIONS, UNDIVIDED
ŦPu	CHUGWATER (Ŧc) AND GOOSE EGG (Pge) FORMATIONS, UNDIVIDED
ℙMta	TENSLEEP (ℙt) AND AMSDEN (ℙma) FORMATIONS, UNDIVIDED
MDmj	MADISON LIMESTONE (MDm), JEFFERSON (Dj), AND THREE FORKS (Dt) FORMATIONS, UNDIVIDED
OꞒbf	BIGHORN DOLOMITE (Ob), GALLATIN (Ꞓg), AND GROS VENTRE (Ꞓgv) FORMATIONS, AND FLATHEAD SANDSTONE (Ꞓf), UNDIVIDED
pꞒr	IGNEOUS AND METAMORPHIC ROCKS



GENERALIZED GEOLOGIC CROSS SECTION A-A'

The significance of lineations and curvilinear traces identified by imagery interpretation is that the traces may delineate zones of structural deformation such as faults or master joints in the earth's strata. The presence of fractured rock along faults or joints provides so called secondary permeability in the rocks in addition to the intrinsic permeability provided by the intergranular or intercrystalline interstices of the rocks. The presence of secondary permeability in bedrocks tends to enhance the availability of groundwater to water wells penetrating the zones of secondary permeability. The enhanced groundwater yields are the result of the relatively greater potential for groundwater to be stored and transmitted along the zones of fractured rock.

The lineament trace upon which the Shell Valley Wells Nos. 1 and 2 were drilled is not evident to visual examination of the terrain or geology at the land surface. Field inspection of the lineament location does not reveal an indication of faulting or other structural deformation in the strata exposed at the land surface. This is a typical characteristic of lineaments which extend from terrain on relatively brittle rock such as the Madison Group into terrain on relatively plastic rock such as the siltstones and shales of the Amsden, Chugwater, Gypsum Springs, and Sundance Formations underlaying the drilling site. The plastic shales tend to absorb most of the deformation that finds expression in the brittle rocks; however, satellite imagery may detect the trace of the structural feature in the plastic rocks even where the structural deformation in the subsurface does not extend to the strata exposed at the land surface.

Consequently, the absence of evidence of structural deformation in the surface exposures of strata at the drilling site is not necessarily a discouraging sign. Evaluation of the results of the two exploration/production wells drilled at the site provides some strong indications that secondary fracture enhancement of permeability in the carbonate rocks of the Madison Group and Bighorn Dolomite was a major factor influencing the well yields. The rational for this conclusion is provided by a comparison of the results of the two wells drilled at the site. Well No. 1 yielded an artesian flow of 176 gpm from the Madison Group and did not yield any groundwater from the Bighorn Dolomite which did not display any particular evidence of either intrinsic or secondary permeability. In comparison, Well No. 2, a scant 567 feet distant from Well No. 1, yielded 364 gpm from the Madison (as measured with a packer isolating the Madison from the lower strata) and 916 gpm from the Bighorn Dolomite.

Obviously, there is a drastic difference in the permeabilities of the carbonate rocks at the two well sites, only 567 feet apart, particularly in the Bighorn Dolomite. Circumstantial evidence suggests the main difference between the two sites may be secondary fracture openings in the carbonate strata penetrated by Well No. 2 that are not present at Well No. 1. Secondary fracture fillings were recovered in the drill cuttings from the Madison Group strata penetrated by Well No. 1 but were not particularly prevelant in the cuttings from Well No. 2. This suggests that the refilled fractures penetrated by Well No. 1 are probably of a different age than the open fractures presumably penetrated by Well No. 2 and were the result of a different tectonic event. Well No. 1 penetrated two caverns or voids in the Madison Group yet Well No. 2, which did not penetrate cavernous zones, yields more water from the Madison. This fact again implies that intrinsic permeability and secondary porosity and solution openings played a subordinate role to secondary fracture permeability. Examination of the geophysical borehole logs shows a number of zones of increased porosity in the carbonate rocks. However, comparison the the zones of porosity to the zones of greatest groundwater inflow indicated by temperature differential logs of the borehole at Well No. 2 shows that the greatest groundwater inflow zones do not always correspond to the zones of greatest porosity. This again suggests that fracture permeability played a significant role in providing the water-bearing zones in Well No. 2.

Although the evidence is circumstancial, it is probable that the relatively large yields of flowing artesian groundwater obtained at Well No. 2 are the result of secondary fracture enhancement of permeability. If this conclusion is correct, it points out another aspect of utilizing satellite imagery interpretation and lineaments as a groundwater exploration tool. Namely, the lineament trace observed on the imagery is a general trend, often interpreted from landform shapes and other indirect information, and which may have considerable width as an interpretive feature. The width and exact line of the lineament are not defined by the imagery interpretation. In the absence of observable structural phenomena in the strata exposed at the land surface, there is considerable question as to the exact location of the lineament and the structural feature in the subsurface which the lineament is supposedly related to.

This problem is succinctly demonstrated by the experience at the Shell Valley wells where a difference of 567 feet in the well site locations resulted in a substantial difference in the well yields. The conclusion that must be drawn from this experience is that in areas where substantial thicknesses of shale and other soft rocks conceal the precise location of a lineament related structure in the subsurface, it is highly desirable that additional subsurface investigations be conducted by geophysical means if at all possible. Intensive deep earth resistivity profiles combined with detailed seismic investigations of a site like the Shell Valley wells site may provide the resolution necessary to identify the precise location of a target zone for drilling in the absence of surface indications of the structure.

4. PROJECT IMPLEMENTATION

Although the overall objectives of the Shell Valley Deep Well Project remained unchanged throughout the duration of the program, the implementation of the groundwater exploration and aquifer testing studies was subjected to a number of modifications during accomplishment of the program.

4.1. Program Philosophy

The initial scope of the Shell Valley Deep Well Project was to consist of drilling and completion of one small diameter exploration/observation well and one large diameter test/production well, both fully penetrating the entire Paleozoic aquifer system with a maximum estimated depth of 3,500 feet per well. The philosophy of the initial program concepts was governed by two considerations. One consideration was that the relatively inexpensive small diameter exploration well would be used to verify the presence of aquifer production zones suitable for development and testing. If the small diameter exploration well did not reveal the presence of suitable aquifers, the site could be abandoned and an alternate location selected for implementation of the exploration program. The second consideration was that reliable measurement of aquifer storage coeficients requires the use of an observation well. If suitable aquifers were penetrated by the exploration well, it would be completed as an observation well to provide test data necessary for calculating the aquifer storativity. Aquifer testing was anticipated to consist of a seven-day constant rate test, followed by a recovery test, in the case of a flowing well; and a stepped rate test followed by a constant rate test (with associated recovery tests) in the case of a non-flowing well.

4.2. First Program Revision

Preliminary competitive cost proposals received by the Wyoming water Development Commission (WWDC) for the originally requested scope of work revealed that the original scope of work required a budget considerably in excess of the funding approved by the Wyoming State Legislature for this project. Subsequently, a revised scope of work was developed which reduced the Level II Feasibility efforts to drilling, completion, and testing of one small diameter exploration/observation well and one large diameter test/production well, both to fully penetrate the Madison Group, with an estimated maximum depth of 2,500 feet per well.

4.3. Second Program Revision

Investigation of the types of drilling technology available for construction of the relatively deep water wells required for implementation of the exploration program indicated that application of air-reverse circulation rotary drilling methods would permit the construction of a relatively large diameter exploration/observation well, which would be suitable for later utilization as a production well, for construction costs comparable to the costs for a smaller diameter exploration/observation well constructed by other conventional rotary drilling techniques. Consequently, the second change to the scope of work was made in which the WWDC directed that the first well be constructed to specifications which would render the well suitable for use as a production well after completion of the exploration and testing program. This change was motivated by the philosophy that if suitable conditions were encountered, the program implementation would not only provide the observation well required for aquifer testing, but would also result in provision of two production wells upon project completion. It was hoped that the provision of a two-well field would provide more groundwater to supplement irrigation water supplies than would be provided by a single test/production well paired with a small diameter exploration/observation well.

Accordingly, air-reverse circulation rotary drilling methods were used to construct the initial exploration well through the Madison Group aquifer system to a total depth of 2,440 feet. The exploration well minimum diameter of 8-3/4 inches was large enough to permit the well to function as a high capacity production well. In addition, the upper 600 feet of 14-inch diameter well casing was large enough in diameter to accommodate high capacity pump bowls in the event that the water users elected to supplement the natural artesian flow by pumping the well. However, the natural artesian flow of 176 gpm from the well was disappointing and did not satisfy the project requirements for a minimum flow of 1,000 gpm. Moreover, flow tests of the well indicated that even if the water users elected to install a pump (an objectionable cost of service from their standpoint) the well would only yield about 600 gpm when pumped.

4.4. Stimulation by Hydrofracturing

Consequently, the well was evaluated to determine if application of high pressure hydrofracturing techniques might reasonably be expected to increase the natural artesian flow yield.

The evaluation indicated that the Madison Group aquifers would respond to hydrofracture stimulation; however, the presence an eight inch high cavern penetrated at 2,110 feet and another 1.5 foot high cavern from 2,126 to 2,127.5 feet in the lower third of the Madison Group presented zones that might consume the pressure needed to propagate fractures. Further evaluation indicated that relatively high rates of downhole flow would be necessary to create the volume needed to sustain the pressure gradient necessary for hydrofracturing. In addition, it was determined that utilization of acid to etch the fracture faces, a conventional and highly effective fracturing technique, was undesirable due to the problems associated with disposal of any unneutralized acid and due to the potential to contaminate Trapper Creek. Accordingly, a gelled sand hydrofracturing application was recommended as most suitable for the specific site conditions.

After careful consideration of the alternatives, the WWDC staff decided to proceed with the gelled sand hydrofracture treatment in an attempt to stimulate an increase in the artesian flow from the exploration well. Accordingly, a casing packer was installed at a depth of 1,396 feet and a hydrofracture stimulation treatment was conducted at the average flow rates and average pressures depicted on Table 1.

Table 1: Summary of rates and pressures for hydrofracturing.

Treatment	Volume	Rate	Pressure
Clear water injection:	476 BBL	37 BPM	2,200 psi
Gelled water and sand:	815 BBL	45 BPM	2,300 psi
Clear water flush:	83 BBL	50 BPM	2,800 psi

In summary, a total of 1,374 barrels (BBL), i.e. 57,708 gallons, of fluid was injected into the well at an average tubing pressure of 2,400 psi, at rates ranging from 37 barrels per minute (BPM) to a peak of 56 BPM (1,554 to 2,352 gpm), including 35,000 pounds of 20/40 "frac" sand in 815 BBL (34,230 gallons) of gelled water. Peak tubing pressure during the treatment was 2,600 psi and instantaneous shut-in pressure was 1,500 psi indicating friction flow losses in the tubing and packer of 1,100 psi for an effective pressure against the formation of 1,300 psi average and 1,500 psi peak pressure. A summary of post-fracturing shut-in pressures is shown on Table 2.

Table 2: Post-hydrofracture treatment shut-in pressures.

0 minutes shut-in	1,500 psi at well head
5 minutes shut-in	850 psi at well head
10 minutes shut-in	700 psi at well head
15 minutes shut-in	600 psi at well head

The slow dissipation of the differential pressure between the formation pressure of 143 psi and the post treatment pressures demonstrates that the hydrofracturing treatment was successful in building up significant pressure in the Madison Group aquifers and in overcoming the effects of the cavernous limestone zones between about 2,110 and 2,128 feet. Following development by reverse-circulation conditioning and removal of a considerable amount of "frac" sand, the natural artesian flow of the well increased to 367 gpm, or more than twice the pre-fracturing yield.

4.5. Deepening the Exploration Well

The fact that the gelled sand fracture stimulation of the exploration well did not increase the yield to the desired minimum artesian flow of 1,000 gpm resulted in further evaluation and redirection of the program. Geophysical logs of the borehole completed prior to the hydrofracture treatment indicated that with the exception of the cavernous zone just below 2,100 feet, the primary or intrinsic porosity of the Madison Group carbonates was the principal source of groundwater storage and movement and that little or no evidence of secondary fracture enhancement of permeability was present. Therefore, there was no reason to believe that drilling a second exploration well at any location along the lineament identified in the satellite imagery interpretation would lead to discovery of a highly productive zone by virtue of secondary fracture enhancement of the rock permeabilities in the Madison Group strata.

Moreover, one of the initial objectives of the program had been to explore the availability of groundwater from other Paleozoic strata below the Madison Group strata. This objective had not been accomplished by the initial exploration well which penetrated only a short distance into the strata below the Madison. Considerable local interest was expressed on the part of the local water users' association to determine the availability of groundwater from strata deeper than the Madison Group. Thus, there was considerable motivation to deepen the existing exploration well to investigate the aquifer potential of the deeper strata. However, concomitant with a decision to investigate the deeper strata was the consideration that such an effort would utilize most of the remaining project funds and therefore would rule out any possibility of constructing an observation well to the same depth for use in aquifer testing.

After considerable deliberation over the alternatives of constructing another exploration well at a new location versus deepening the existing exploration well, the WWDC opted to stay with the original program philosophy of exploring the entire

Paleozoic sequence of strata from the Madison Group on down to the basement complex. Considerations contributing to this decision included (1) the lack of any evidence of secondary fracturing to be exploited for greater yields by a new well on the lineament being explored, (2) the undesirable location with respect to the agricultural irrigation project of other sites favorable to large groundwater yields, and (3) strong interest in determining the availability of groundwater from strata deeper than the Madison Group.

Accordingly, work began to re-enter the exploration well and deepen it. Plan formulation for this phase of the project included three potential types of well completion, depending on the results of tests in the exploration borehole. State Engineer's Office regulations prohibit multiple completion of a water well in the State of Wyoming, that is, water wells penetrating more than one major aquifer system must be completed in a manner such that the groundwaters from the different aquifer systems are isolated and cannot comingle. Thus, if the exploration well were to encounter aquifer production zones in the Bighorn Dolomite and Flathead Sandstone in addition to the Madison Group aquifers, the final well construction would have to prevent hydraulic communication between any of the three aquifer systems. The three options for final well completion were designed to comply with the State Engineer's Office regulations.

The requirements of the State Engineer's Office were one element contributing to the level of technical difficulty and the risks inherent in re-entering the exploration well. A second source of risk was the fact that the well had been hydrofractured. An extensive survey of qualified water well and oil and gas well drillers in the State of Wyoming did not identify a single drilling company who had experience in re-entering a well that had been subjected to fracture stimulation treatment or who had even heard of re-entering such a well. Moreover, the survey did not identify a drilling company willing to take on the job of re-entering the well, other than the drilling subcontractor who drilled the well prior to the hydrofracture treatment.

The original drilling subcontractor agreed to re-enter the well and the first step in deepening the well was initiated. The first step consisted of reaming the 8-inch nominal borehole below the end of the casing at 1,855 feet to a new diameter of 9-7/8 inches so that adequate borehole diameter would exist to install 8-5/8 inch diameter casing necessary to obtain high capacity yields from the anticipated depth range of 2,500 to 3,500 feet. Smaller diameter casing would have severely limited potential production from any high capacity aquifers encountered in that depth range. Thus, the deepening efforts continued to be consistent with the philosophy of providing an exploration well that would be suited to use as a production well after completion of the exploration and testing program. The reaming operations to the total depth of 2,440 feet were completed without serious difficulty and deepening of the exploration well began.

The first step in the deepening process was to drill through the combined thickness of the Bighorn Dolomite and the Gallatin Limestone. These strata act as an aquifer system in some areas and would be the first target of ongoing testing as the exploration well was deepened. When the basal contact of the Gallatin Limestone was encountered at a total depth of 3,041 feet, drilling activities were suspended to conduct a pressure and flow test of the Bighorn-Gallatin interval. A Halliburton Well Services mechanical packer was installed near the top of the Bighorn

Dolomite and used to isolate the Bighorn-Gallatin interval from the overlying strata penetrated by the well. The test of the Bighorn-Gallatin interval did not show any flow or presure and indicated that the carbonate strata in this interval did not yield groundwater.

The Halliburton packer and appurtanent tools were installed with approximately 380 feet of tools hanging below the packer including 60 feet of Halliburton perforated tubing and 320 feet of 7-1/2 inch diameter drill collars. As the packer assembly was being removed from the well, the perforated tubing below the packer became unscrewed and about 360 feet of tubing and drill collar fell to the bottom of the well at 3,041 feet from an estimated depth of about 500 feet. Substantial and extensive fishing efforts to recover the lost tools ensued. The fishing efforts were successful in recovering all of the tools except the last five feet of perforated tubing that had been on the bottom of the tool string. Fishing and milling operations had deepened the well to 3,050 feet by this time where the last five feet of tubing remained lodged in the bottom of the hole, at a diagonal from top to bottom, similar to a whipstock that would be placed into a borehole to change the direction of the drilling from vertical to an angle.

When extensive efforts with various fishing tools, sidewall hooks, and milling tools failed to dislodge or destroy the tubing at the bottom of the well, it was clear that the remaining alternatives were to (1) abandon further efforts on the project, (2) move to a new location and start a new well, or (3) plug back from the lost tubing and then use directional drilling to go around the lost tool and continue to deepen the well.

Directional drilling was feasible but presented a number of uncertainties regarding the ability to control the direction of the borehole, the capability to install casing into the directional borehole, and the ability to accomplish directional drilling efforts within the remaining project funds. However; reevaluation of the project objectives and remaining budget indicated that it was still possible to construct a new well, including provision for completion of the well as a production well, to the base of the Paleozoic strata with the remaining project funding. This fact was made possible in large part by a significant financial contribution to the project by the drilling contractor who remained committed to successful completion of the project.

The possibility of starting a new exploration well nearby on the same lineament was attractive from two standpoints. The first exploration well had shown that there was not a yield of groundwater from the Bighorn-Gallatin interval below the Madison Group. The only remaining target for the exploration well was the Flathead Sandstone, which from a purely interpretive standpoint did not present a high probability of success in completing a high yield artesian well although local interest in exploring the Flathead remained high. Therefore, it was clear that if a second exploration well failed to discover substantial yields of groundwater in the deeper strata, there was at least the probability of completing it in the Madison Group to equal the artesian flow yield of the first exploration well and therefore double the availability of groundwater to the agricultural irrigation project.

Moreover, the local water users indicated that even a reduced groundwater source of supply yielding flows in the 500 to 700 gpm range would be of use in mitigating the impacts of the droughty conditions prevailing at the time. Accordingly, the WWDC concluded that the most reasonable alternative was to plug the existing exploration well back to the base of the Madison Group and complete it as a Madison production well while pursuing construction of a second Paleozoic strata exploration well at a nearby location with the thought that if deeper strata, namely the Flathead Sandstone, did not provide the desired groundwater yields, the second exploration well would also be plugged back to the base of the Madison and completed as a Madison production well.

4.6. Second Exploration Well Construction

Preliminary flow test data from the first exploration well, referred to herein as the Shell Valley Well No. 1 or simply Well No. 1, were evaluated to estimate aquifer hydraulic parameters and to determine a minimum reasonable distance that should exist between two production wells in the Madison aquifer at the exploration drilling site so that the two wells could be utilized concurrently without excessive drawdown interference and resultant adverse reduction of well yields. A minimum desirable well separation of 500 to 600 feet was established and used in conjunction with land access considerations to select a drilling site for the second well on private land where an easement was available. The second well is referred to herein as the Shell Valley Well Number 2 or simply Well No. 2 and is located a distance of 567 feet from Well No. 1 in the SE 1/4, SE 1/4, Section 26, T53N, R91W.

Air-reverse circulation rotary drilling methods were utilized to construct Well No. 2, which like Well No. 1 was also designed to be a production well. Well No. 2 proved to be more productive than Well No. 1 with an artesian flow of about 364 gpm from the Madison aquifers compared to a pre-hydrofracture flow of about 176 gpm from the Madison in Well No. 1 and an artesian flow of 916 gpm encountered from an aquifer in the Bighorn Dolomite, where Well No. 1 did not yield groundwater. Both wells exhibited artesian flows of about 30 gpm from the Tensleep Formation above the Madison.

4.6.1. Borehole Caving Problems

Despite the presence of strong artesian flows from the Madison and Bighorn aquifers, drilling of Well No. 1 continued with the objective of penetrating the Flathead Sandstone and testing the potential of the formation as an aquifer. Drilling of the entire well, below the 179 feet of 16-inch diameter surface casing, was conducted as open hole drilling using clear water as a drilling fluid once the Tensleep Formation was penetrated and artesian flows began. At a depth of 3,324 feet, borehole caving problems began in the Gros Ventre Formation shales. Intermittent caving problems continued to a depth of 3,379 feet where caving was so severe that further progress could not be made with clear water as a drilling fluid.

The artesian flow from the Bighorn and Madison aquifers, with the drilling tools in the hole, was about 700 to 800 gpm at this time, a fact which precluded the circulation of conventional bentonite gel drilling fluid in the borehole to stabilize the caving interval. The use of a drilling fluid with adequate density and viscosity to supress the artesian flows would also result in invasion of the artesian aquifers by the drilling fluid and would possibly prevent full development of the artesian aquifers if it was later decided to complete the well in those aquifers. Therefore, heavy drilling fluid could not be circulated into the borehole to stabilize the Gros Ventre Formation.

Consequently, it was necessary to install casing down to the caving zone so that bentonite gel drilling fluid could be circulated inside the casing where dilution by artesian flows and plugging of the artesian flow zones would not occur. If the Flathead Sandstone did not prove to be a productive aquifer, the casing would be pulled back above the artesian zones to be developed in the Bighorn or the Madison. Drilling operations were suspended for approximately 72 hours while 3,500 feet of 9-5/8 inch diameter threaded well casing was delivered to the site.

Geophysical logs of the borehole were to be completed before the casing was installed because electrical logging devices will not log borehole through casing. Operation of the geophysical logging tools revealed that the borehole had caved and bridged in the Amsden Formation at a depth of about 1,751 feet with minor bridges present in the Amsden at 1,695 feet and 1,714 feet. Attempts to drill out the bridges of caved material resulted in further caving and after several days of effort to clear the caved area the top of the caved material was at about 1,681 feet. Artesian flows ranging from 600 to 750 gpm continued to discharge from the well during the entire effort to clear the caved material from the borehole.

4.6.2. Casing Installation

When it became evident that the caved zone in the Amsden would continue to cave and enlarge the borehole if further efforts were made to drill out the caved materials, it was decided to pressure cement the caved zone in an attempt to stabilize it so that a new borehole could be drilled back through the cemented materials. A formation packer was installed in the open borehole at a depth of 1,465 feet and a total of 145 sacks of cement were injected into the caved materials at a final pressure of 700 psi.

The cement failed to stabilize the caved material and when the drill bit reached a depth of 1,598 feet while clearing the cement a full artesian discharge of 600 to 700 gpm resumed. Moreover, borehole caving continued in the same interval. Borehole logging with a special oversized caliper logger revealed that the top of the caved material was at 1,680 feet.

The conditions in the borehole at this time necessitated several decisions that resulted in modification of the final scope of the project. A major consideration was the fact that the budget remaining after the attempts to drill out and stabilize the caved zone in the Amsden Formation was not adequate to pursue installation of the casing into the Gros Ventre and continued drilling of the well into the Flathead Sandstone. A second major consideration was that the strong flows from the Bighorn and Madison aquifers provided a good indication that the combined flows from Well No. 1 and Well No. 2 would satisfy the water users' requirements for an artesian flow of 1,000 gpm. It was clear from a pragmatic standpoint that the ultimate goal of providing the required water supply from artesian flow could possibly be realized within the remaining project funds if the casing could be installed to the top of the Madison Group strata without too much additional cost.

The main problem, both technical and financial, was how to install the well casing past the caved interval beginning at 1,680 feet. Data provided by a specially modified caliper tool indicated that much of the borehole was enlarged to 14 inches in diameter or more. The 48-inch caliper tool also indicated a substantial void, projected to be in excess of 60 inches in diameter, in the borehole just above the caved material at 1,680 feet. Based on this information and on the presence of a strong artesian flow through the caved material, it was concluded that it would be possible to wash the well casing down through the caved material by pumping water down through the casing to use the casing as a large jetting tool.

Two centrifugal pumps intregal to the drilling rig, rated at 1,200 gpm each under the estimated operating heads in the well, were connected to the casing through the kelley swivel on the rig so that the casing could be rotated and moved up and down during the jetting process. Washing and jetting operations began with pump pressures ranging from 108 to 110 psi at a circulation rate of 2,400 gpm and casing weights placed on the caved material generally ranging between 500 and 5,000 pounds and being carefully increased to ranges between 10,000 and 32,000 pounds where exceptionally hard spots were encountered in the bridged materials. A conical washing shoe placed on the end of the casing caused casing rotation as the casing advanced. Strong returns of water and Amsden Formation cuttings up to 3 inches in mean dimension were received from the annulus at the surface. The casing was washed down from 1,680 feet to 1,760.5 feet where the bottom of the bridged interval was passed and the casing could then be lowered to its final installation depth of 1,813 feet just into the top of the Madison Group strata.

4.6.3. Casing Cementing Operations

The next technical difficulty was that of cementing 1,813 feet of casing into more than 3,000 feet of open borehole with artesian flows now in excess of 754 gpm coming up both the casing and the annulus. An additional complication was provided by the fact that a layer of stream rounded gravels on the eroded surface of the Madison strata in the 1,750 to 1,800 foot interval was caving behind the casing and the artesian flows were carrying the gravels up the casing. The presence of gravel ranging in size from 1 to 4 inches floating up the inside of the casing meant that drilling tools and logging tools could not be run into the casing for fear of getting them stuck inside the casing. Consequently, operations were suspended to wait until the material caved to a stable condition and gravels ceased to be discharged from the well, a condition which was obtained after about three days.

Borehole logging below the end of the casing at 1,813 feet indicated that the borehole was obstructed at 1,834 feet by a gravel bridge. The presence of the gravel bridge made the use of an open borehole formation packer for cementing risky since the packer could not be chased to the bottom of the hole if it could not be retrieved following the cementing operations. If an open hole packer was stopped on top of the gravel bridge at 1,834 feet, the packer would restrict the flow of water from the well and would have to be ground up with a milling bit, a risky business at best. Consequently, an attempt was made to set a cement plug just below the end of the casing. The attempt failed and revealed the presence of a pressure gradient of at least 210 psi in the annulus which displaced the cement plug leaving the borehole open. As later events revealed, the pressure gradient was to a zone of water loss in the Chugwater Formation only about 307 feet down in the annulus.

In view of the pressure differential between the bottom of the casing and an unidentified (at that time) zone in the annulus, the risk of using a retrievable open hole packer was accepted and an inflatable borehole packer was set below the end of the casing, released from the tool string, and covered with about 20 feet of sand to protect it from being cemented into the borehole. A total of 2,167 cubic feet of cement was displaced up the annulus including 1,145 cubic feet of 50:50:2 light weight fly ash cement on top of 1,022 cubic feet of Type G cement. The cement filled the annulus from 1,813 feet back up to 307 feet where the cement was displaced into a fracture in the Chugwater Formation as evidenced by the loss of returns from the annulus during displacement of about the last 300 cubic feet of cement and 8 barrels of additional displacement water.

The zone where the cement was lost shows clearly on the electrical geophysical logs of the borehole. After the cement was provided with time to gain shear strength, introduction of water into the borehole revealed that the lost zone was still taking several hundred gallons per minute of flow. Subsequently, the annulus was backfilled with sand from 162 feet to 307 feet to prevent additional cement from flowing out into the loss zone and then cemented from the top with Portland Cement (Type A) back up to the discharge pipe on the surface casing.

4.7. Completion

Upon completion of the casing cementing operations, Well No. 2 was re-entered with a drill bit and cleared to a total depth of 3,108 feet, below which caved material from the Gros Ventre Formation was present and would continue to cave back into the borehole. Geophysical logging of the interval below 1,834 feet was completed and the well was shut in. Shut-in pressure recovered to 161 psi and initial artesian flow discharge upon opening the recovered well was 1,280 gpm from the combined Madison-Bighorn aquifer systems. Stabilized artesian flow at the end of 30 days, including 10 days with Well No. 1 flowing at a stabilized rate of 224 gpm, was 1,090 gpm from Well No. 2.

4.8. Summary of Operations

A summary of daily construction activities for the drilling and completion of Well No. 1 to its initial depth of 2,440 feet is shown on Table 3.

Table 3: Abbrviated Summary of Well No. 1 Construction Progress

Date	Construction Progress
January 10, 1984	Move drilling rig onto site and begin set-up. Excavate mud pit under supervision of BLM archeologist. Determine route for pipeline and location of discharge point with representative of WWDC.
January 11, 1984	Begin drilling 22 inch hole for surface conduit at 8:00 a.m. Drill direct rotary to 50 feet depth, then switch to air-reverse rotary with mud to seal fluid loss zone in 15-30 foot interval. Drill to 118 feet by midnight.
January 12, 1984	Drill to 130 feet by 3:15 a.m., 18 inch casing set and grouted by 8:20 a.m.
January 13, 1984	Begin drilling 17 inch hole at 130 feet at 2:45 p.m. 318 feet depth at 12:00 midnight.
January 14, 1984	Drill to 366 feet at 11:00 a.m. Pump used to mix mud breaks down. Shut down at 11:00 a.m. and send for replacement pump.
January 15, 1984	No drilling performed this day. Wait for pump being trucked in from Nebraska.
January 16, 1984	Begin drilling at 366 feet at 2:35 p.m. 478 feet depth at 12:00 midnight.
January 17, 1984	612 feet depth at 6:30 p.m. Unable to keep fluid in mud pit from freezing in -20 to -30 degree temperatures. Shut operations down until weather moderates.
January 24, 1984	Begin drilling 12-1/4 inch hole at 612 feet at 7:50 p.m. 702 feet depth at midnight.
January 25, 1984	939 feet depth at 12:00 midnight.
January 26, 1984	1177 feet depth at 12:00 midnight.
January 27, 1984	1186.5 feet depth at 12:00 midnight.
January 28, 1984	1198.5 feet depth at 12:00 midnight.
January 29, 1984	1254 feet depth at 12:00 midnight.
January 30, 1984	1290 feet depth at 12:00 midnight.

Table 3: (continued)

Date	Construction Progress
January 31, 1984	1443 feet depth at 12:00 midnight.
February 1, 1984	1648.7 feet depth at 12:00 midnight.
February 2, 1984	1737 feet depth at 11:10 a.m. Chemical con-constituents in formation water cause drilling mud to flocculate, cuttings drop out of circulating fluid and settle to bottom of hole. Drill tool string breaks off in hole at 6:10 p.m. while tripping out.
February 3-6	Fishing operations to recover stuck tools.
February 7, 1984	Clean and condition borehole to 1732 feet.
February 8, 1984	Finish cleaning hole and resume drilling at 1737 feet at 8:00 p.m. 1751.8 feet depth at 9:14 p.m. Stabilizer in tool string hanging up in borehole at 1715 feet, ream interval to clear obstruction.
February 9, 1984	Continue reaming interval from 1715 - 1751.8 feet. Tool joint rod breaks while reaming at 2:36 p.m.
February 10 - March 4, 1984	Fishing operations to recover stuck tools. Hole depth increased to 1780 feet as a result of fishing operations.
March 5, 1984	Begin drilling at 1780 feet at 5:26 p.m. Bit catching on piece of broken air pipe at 1781 feet.
March 6, 1984	Fishing operations to recover broken air pipe
March 7, 1984	Begin drilling with coring bit at 1781 feet at 2:30 p.m. 1784 feet depth at 9:00 p.m.
March 8, 1984	Begin coring at 1784 feet at 11:00 a.m. 1789 feet depth at 10:00 p.m. Trip out of hole, crew takes time off from March 9 - 11.
March 12, 1984	Begin drilling with 12-1/4 inch bit at 1789 feet at 10:00 p.m. 1798 feet at midnight.
March 13, 1984	Reach top of Madison Formation at 1834 feet at 1:00 p.m. 1836 feet depth at midnight.
March 14, 1984	1855 feet depth at 10:35 a.m. Trip out, and begin geophysical logging of borehole at 8:15 p.m.
March 15, 1984	Complete geophysical logging at 2:33 a.m.

Table 3: (continued)

Date	Construction Progress
	Begin running 14 inch casing to 597.7 feet and 10-3/4 inch casing from 597.7 - 1850 feet Halliburton Services Company begins grouting operations at 3:15 p.m. and casing grouting complete at 5:00 p.m.
March 16 -21	Allow grout to set. Drilling crew cleans out mud pit and disposes of barite drilling mud.
March 22, 1984	Begin drilling 8-3/4 inch hole at 1855 feet at 3:00 p.m. 1924 feet at 12:00 midnight.
March 23, 1984	2280 feet depth at 12:00 midnight.
March 24, 1984	Drill through basal contact of Madison Formation at 2421 feet. Terminate drilling operations at 2440 feet depth at 9:50 p.m.
March 25, 1984	Trip out and begin geophysical logging at 6:40 a.m. Unable to get some logging tools past casing separation discovered at 1810 - 1815 feet depth. Geophysical logging completed at 12:15 p.m. Cap well and shut-in.

A summary of the hydrofracturing activities conducted in Well No. 1 with the well depth at 2,440 feet is provided on Table 4.

Table 4: Abbreviated Summary of Fracture Stimulation Operations

Date	Construction Progress
April 12, 1984	Halliburton crew fills frac tanks with water in preparation for fracture stimulation of of Madison Formation.
April 13, 1984	Halliburton crew arrives at well site at 7:00 a.m. and begins set-up for gelled-sand fracture stimulation. Start mixing gel at 8:00 a.m. Attempt to thread nipple into well casing collar from 9:30 - 11:55 a.m. Begin stimulation operations at 12:30 p.m. Nipple threaded into well casing blows out when casing pressure reaches 920 psi. Shut-down operations for this day at 1:00 p.m.
April 14, 1984	Ron's Anchor Service arrives on site at 7:45 a.m. and begins setting anchors for work-over

Table 4: (continued)

Date	Construction Progress
	rig. Anchor installation completed at 9:00 a.m. Corbin Well Service workover rig on site at 9:15 a.m. Halliburton casing packer arrives at site at 12:15 p.m. Rented 3-1/2 inch tubing arrives at site at 1:11 p.m. Finishing tripping into hole with packer at 3:10 p.m. Fracture stimulation operation commences at 3:32 p.m. and is completed at 4:04 p.m. Well shut-in at 4:05 p.m.
April 15, 1984	Begin post-fracture stimulation flow-back at 8:47 a.m. Begin getting frac sand in flow at 10:30 a.m. No frac sand in flow after 1:15 p.m. Control valve opened fully at 9:05 p.m.
April 16, 1984	Truck arrives at site to pick-up rental tubing at 8:20 a.m. Corbin Well Service crew on site to trip out packer at 8:40 a.m. Finish tripping out tubing and packer at 10:19 a.m. Corbin Well Service work-over rig leaves well site at 11:45 a.m.

A summary of activities related to re-entering Well No. 1 to deepen the well is provided on Table 5.

Table 5: Abbreviated Summary of Deepening Activities Well No. 1.

Date	Construction Progress
November 16 - November 30, 1984	Move drilling rig back over hole, begin reaming operations.
December 1, 1984	Reaming operations in progress to enlarge 8-3/4 inch diameter borehole to 9-7/8 inch diameter. Mechanical problems with hydraulic system on drilling rig cause delays.
December 2, 1984	Complete reaming hole to 2440 feet depth at 5:15 p.m., and begin drilling new hole. Drill to 2507.5 feet depth at 12:00 midnight.
December 3, 1984	2633.9 feet depth at 1:15 p.m. when drill rods twist off. Trip out of hole. Part of crew goes to Casper for fishing tools.

Table 5: (continued)

Date	Construction Progress
December 4 - December 6, 1984	Recover drill stem left in borehole when rods twisted off, and make repairs to kelly which was damaged during fishing operations.
December 7, 1984	Resume drilling new hole at 3:45 a.m. 2716 feet depth at 12:00 midnight.
December 8, 1984	2977 feet depth at 12:00 midnight.
December 9, 1984	Terminate drilling operations at 3041 feet depth at 3:00 p.m. and trip out of hole to set-up for flow test of Big Horn and Gallatin Formations.
December 10, 1984	Trip packer and sidewall anchor assembly into borehole. Unable to get anchor to operate. Trip out sidewall anchor and replace it with perforated pipe run to bottom of borehole. Set packer at 8:45 p.m. but unable to determine whether a tight seal has been attained. Monitor water levels inside tubing until 11:10 p.m.
December 11, 1984	Begin tripping packer out of borehole at 8:40 a.m. after measuring water level inside tubing. Continue to monitor water level until packer is inside casing at 1,855 feet depth. At 12:17 p.m., driller reports that packer is out of hole but that drill collars and some of perforated pipe below packer have separated and fallen to bottom of hole.
December 12, 1984 to February 8, 1985	Fishing operations to recover perforated pipe and drill collars; and to mill out pipe to mill out pipe embedded in bedrock at bottom of borehole.
February 9, 1984	Fishing and milling operations suspended. Decide to plug well back to base of Madison Group strata and complete in Madison aquifer.

A summary of the construction activities for Well No. 2 is provided on Table 6.

Table 6: Abbreviated Summary of Well No. 2 Construction Progress

Date	Construction Progress
June 18,1985	Drilling contractor's crew completes rig set-up on site for Shell Well No. 2.
June 19, 1985	Begin drilling 22 inch borehole for surface conduit using direct (mud) rotary method. Morrison-Maierle, Inc. geologist arrives on well site at 11:03 a.m. Drilling progress slow due to lack of weight on bit. Switch from 22 inch bit to 17 inch pilot bit at 51 feet depth. 64 feet depth at 12:00 midnight.
June 20, 1985	66 feet depth at 1:15 a.m. Unable to keep 17 inch diameter borehole clear when adding small diameter drill collar to pipe string. Shut-down at 3:20 p.m. and send part of crew to Casper for large drill collars. Collars arrive at 10:00 p.m. Begin reaming 17 inch pilot hole to 22 inch diameter at 12:00 midnight.
June 21, 1985	159 feet depth at 12:00 midnight. Quit for day.
June 22, 1985	At 6:15 a.m., resume drilling at 159 feet depth. 183 feet depth at 7:00 a.m. Begin tripping out of hole at 7:25 a.m., and prepare to run 16 inch diameter surface casing to 179 feet. Morrison-Maierle, Inc. geologist leaves site at 8:20 a.m.
June 23 to July 19, 1985	Contractor drills 12 1/4 inch diameter borehole to a depth of 2971 feet. Morrison-Maierle, Inc. geologists arrive on site at 10:20 p.m. on July 19 to resume logging well.
July 20, 1985	3132.5 feet depth at 9:51 p.m. Shut-down to repair compressor pressure gauges at 10:01 p.m. Begin tripping out of hole to change bit at 11:00 p.m. Flow from Madison and Big Horn Formations is about 714 gpm.
July 21, 1985	Contractor must ream tight spot in Amsden Formation while tripping back into hole with new bit. Back on bottom at 8:36 a.m. 3242 feet depth at 12:00 midnight.
July 22, 1985	3324.6 feet depth at 11:34 a.m. Gros Ventre Formation begins sloughing into borehole while adding next piece of drill pipe and while trying to get back to bottom of borehole. Resume drilling new hole at 2:17 p.m. 3352.5 feet depth at 12:00 midnight. Gros Ventre Formation continuing to slough into

Table 6: (continued)

Date	Construction Progress
	borehole causing intermittent loss of circulation and binding of drill rods.
July 23, 1985	3370 feet depth at 6:05 a.m. Continued sloughing of Gros Ventre Formation and worn out drill bit slow progress. Begin tripping out of hole to change bit at 6:31 a.m. Must ream tight spot in Amsden Formation once again while tripping back into borehole. Back in hole to 3350 feet depth at 4:47 p.m. when Gros Ventre Formation sloughs causing circulation loss. Unable to regain circulation. Begin tripping out to clean plugged drill rods at 7:17 p.m. Finish cleaning rods and start tripping back into hole at 12:00 midnight. Flow from Madison and Big Horn Formations is still about 714 gpm.
July 24, 1985	Back in hole to 3330 feet depth at 3:45 a.m. when Gros Ventre Formation sloughs again causing circulation loss. Unable to clear plugged drill rods. Begin tripping out of hole at 5:20 a.m. At 12:00 noon, rods appear to be clear after tripping out to 1600 feet depth. Start back down hole. About 112 feet of caved material at bottom of borehole. Borehole clean to 3325 feet at 12:00 midnight.
July 25, 1985	Back on bottom (3370) at 7:40 a.m. 3379 feet depth at 12:00 noon. Gros Ventre Formation continues to cave into open hole throughout the afternoon and evening. Contractor unable of advance hole past 3379 feet depth. Decide to trip out of hole and remove stabilizer. Still tripping out at 12:00 midnight when crew quits for day.
July 26, 1985	Crew on site at 6:50 a.m. Finish tripping out of hole. Remove lowest stabilizer and trip back into hole. Must ream tight spot in Amsden Formation at 1753 feet depth while tripping in. About 50 feet of caved material in bottom of hole. At 11:00 p.m., rod become plugged while cleaning hole when Gros Ventre Formation caves causing circulation loss. Unable to clear plugged drill pipe so crew starts tripping out of hole.
July 27, 1985	Decision is made to terminate further attempts to deepen well until caving problem in Gros Ventre Formation can be eliminated by casing off caved interval. At 1:45 a.m.,

Table 6: (continued)

Date	Construction Progress
	arrange for Strata Data to run borehole logs later today. Strata Data arrives on site at 7:30 a.m. Unable to get logging tools past obstruction in borehole at 1751 feet depth in Amsden Formation. Run caliper and natural gamma logs on hole above 1751 feet depth. Most of borehole exceeds the 13 inch maximum diameter of caliper tool. Tight spots are also present at 1696, 1698, and 1714 feet depths. At 1:10 p.m., try running drill pipe down hole to clear obstruction. At 5:00 p.m., attempt to log borehole is terminated when contractor is unable to get drill rods past 1751 feet. Work is suspended and crew is sent back to Casper until casing can be delivered to the well site.
July 28 to August 7, 1985	Crew resumes work on morning of July 31, but attempts to drill out caved interval in Amsden Formation are unsuccessful and borehole continues to cave in as fast as the fill material is drilled out. Attempts to drill out caved interval which now extends back to 1690 feet are suspended at about 10:00 p.m. on August 1. On August 6, the WWDC instructs Morrison-Maierle, Inc. to terminate efforts to drill into the Flathead Formation and to complete the well by running casing to the top of the Madison Formation. Decision is made to attempt to stabilize Amsden Formation by pressure grouting caved zone.
August 8, 1985	At 7:00 a.m., crew prepares to run inflatable packer down hole for cementing operations. Flow from Madison and Big Horn Formations is still about 714 gpm. BJ-Titan cementing crew and equipment arrive on site at 8:05 a.m. Packer set at depth of 1465 feet at 10:00 a.m. 118.2 barrels of 50:50:2 pozzolan (Type G) cement and 26.7 barrels of displacement water pumped down well by 10:51 a.m. 750 psi squeeze developed during displacement operations. Shut-down for remainder of day while cement cures overnight.
August 9, 1985	Packer released at 12:15 p.m., but crew is unable to free packer until 2:47 p.m. After tripping out packer, trip back into hole with bit to drill out cement. At 9:41 p.m., begin drilling hard cement at 1503 feet depth.
August 10, 1985	At 1:00 a.m., drill out of cement at 1598 feet depth. Full flow of water from Madison

Table 6: (continued)

Date	Construction Progress
	and Big Horn Formations returns. At 2:00 a.m., hit to of caved zone in Amsden Formation at about 1681 feet depth. Hit cement again at 1687 feet. At 4:50 a.m., formation caves into hole while cleaning at 1695 feet depth causing loss of circulation. Unable to clear plugged drill rods. Start tripping out of hole at 5:40 a.m. Back in hole to 1669 feet at 11:30 a.m. Hit top of caved zone at 1683 feet. Clean caved zone down to 1696 feet throughout afternoon. Amsden Formation continues to slough into hole each time rods are pulled back. At 6:00 p.m., formation caves while cleaning at 1696 feet causing circulation loss and plugging of drill rods. Start tripping out of hole.
August 11 to August 12, 1985	Operations are suspended while solutions to caving problem are evaluated. Decision is made to try washing casing down through caved zone in Amsden Formation.
August 13, 1985	Crew on site at 9:10 a.m. to complete equipment change-over for running casing. Strata Data arrives on site at 11:27 a.m. to log borehole above caved zone. Logging tools include a specially fabricated three-arm caliper with a maximum expansion capacity of 47 inches. Top of caved zone is now at 1680 feet depth. Logging of borehole indicates that several large cavities have formed above the caved zone, one of which is in excess of 5 feet diameter.
August 14, 1985	Begin running casing down well at 8:00 a.m. At 1:21 p.m., casing down to top of caved zone at 1680 feet. Start washing casing through caved interval. At 6:52 p.m., casing washes out through bottom of caved zone at 1760.5 feet depth. Run casing down to 1813 feet. Begin tripping into casing with milling bit at 11:32 p.m.
August 15, 1985	Start milling backflow valve and casing drag bit at 4:09 a.m. Strata Data on site at 10:20 a.m. Complete milling operations at 1:46 p.m., start tripping out of hole. Strata Data starts logging open hole below casing at 3:15 p.m., but logging tool hits an obstruction in the borehole at 1848 feet depth. Repeated attempts to jar obstruction loose by hitting it with a hoisting plug

Table 6: (continued)

Date	Construction Progress
	lowered on the sand line are unsuccessful. At 7:15 p.m., sand to +3 inch diameter stream rounded cobbles are observed coming up through the open casing. Flow from Madison and Big Horn Formations is now about 745 gpm.
August 16, 1985	Decision is made to place cement plug in annulus at bottom of casing to seal off the Amsden-Madison contact, the interval where the gravel is though to be coming. With the annulus between the 16 inch surface casing and the 9 5/8 inch well casing sealed at the surface, BJ-Titan pumps a cement plug, consisting of 9 sacks of bentonite gel, followed by 10 sacks of cement with 10% gypseal and 2% calcium chloride, and 23 sacks of Type G cement with 10% calcium chloride, into the annulus at the bottom of the casing. The casing was then shut-in and the cement is allowed to cure overnight.
August 17, 1985	When valve on cementing cap is opened in morning, water under high pressure is discharged. Flow up the annulus is also observed when the trench pipe valve is opened. Cement plug did not seal the annulus. When pressure gauge is installed on the wellhead and the well is shut-in, the pressure recovers to only about 80 psi. Based upon the pressure gauge reading of Well No. 1, corrected for elevation differences, the gauge on Well No. 2 should read about 136 psi. The pressure differential observed is probably due to recharge of the Tensleep Formation by water flowing up the uncemented annulus. This flow in annulus caused dispersion of the cement plug before it could set-up.
August 18 to August 20, 1985	Well completion operations are suspended until a satisfactory cementing plan can be devised.
August 21, 1985	Set-up to run inflatable packer into borehole below casing. Start running packer into well at 5:15 p.m. Packer hits obstruction in borehole below casing at 1860.9 feet depth. Packer inflated at 9:35 p.m. Finish pumping sand backfill into borehole at 12:00 midnight.
August 22, 1985	Top of sand backfill covering packer tagged at 1835.5 feet. Begin circulating water up

Table 6: (continued)

Date	Construction Progress
	annulus at 2:00 a.m. Pump 204 bbls. of 50:50:2 pozzolan (flyash) cement and 182 bbls. of Type G cement into borehole between 3:10 a.m. and 5:00 a.m. Displace cement with 131 barrels of +9 lb./gal. gel and 7 barrels of water. Cementing operations completed at 5:45 a.m. At 10:00 a.m., top of cement is tagged at 307 feet depth. Contractor backfills annulus above cement with sand to a depth of 162 feet.
August 23, 1985	Contractor completes backfilling of annulus with sand to 144 feet depth. Annulus is then backfilled with cement to a depth of about 4 feet. Trip into casing, drill out cement, and clean out sand above packer. Packer released at 11:35 p.m.
August 24, 1985	With packer out of hole at 2:40 a.m., flow form Madison and Big Horn Formations is 1068 gpm. At 2:50 a.m., start tripping into hole to drill out obstruction in borehole below casing. Tools out of hole at 12:30 p.m. Only obstruction was bridge at 1847 feet. Flow from Madison and Big Horn Formations is 1090 gpm at 1:00 p.m. Strata Data on site at 2:50 p.m. Begin logging hole at 4:00 p.m.
August 25, 1985	Borehole logging completed at 4:00 a.m. Total depth of borehole is now 3101 feet. Well construction operations completed. Set-up for aquifer testing of Madison and Big Horn Formations.

5. GENERAL AS-BUILT CONDITIONS OF WELLS

The following paragraphs provide a general description of the two exploration/production wells as completed. This information is provided for future reference in the event that the water users decide to install a pump on either of the wells or if plans are made to deepen Well No. 2 at some time in the future in an attempt to evaluate the groundwater yield of the Flathead Formation. It should be noted that the completion of Well No. 2 anticipated the possibility that the well might be re-entered and every attempt was made to leave Well No. 2 in a condition in which it could be deepened.

5.1. Well No. 1

Surface casing for Well No. 1 consisted of 18-inch diameter steel casing installed to a depth of 125 feet into a 22-inch diameter borehole which was drilled to a depth of 130 feet. The surface casing was pressure grouted into the borehole by positive displacement from the bottom up. Circulation was lost several times to the 19 feet of gravel from 15 to 34 feet in depth during drilling of the surface casing hole and cement failed to reach the surface when the surface casing was cemented in, presumably because cement rising up the annulus was lost into the gravel zone between 15 and 34 feet.

Open borehole 17 inches in diameter was bored from the bottom of the surface casing at 125 feet to a total depth of 612 feet. At 612 feet, the bit diameter was reduced to 12-1/4 inch and 12-1/4 inch diameter open hole was drilled from 612 feet to 1,855 feet. A casing string consisting of 14-inch OD steel water well casing to 600 feet over 10-3/4-inch OD steel API line pipe from 600 to 1,850 feet was floated into the borehole in one piece. The bottom of the casing was equipped with a cement guide shoe and the first joint 40 feet up from the bottom end of the casing was equipped with an aluminum backflow baffle into which a 3/8-inch diameter hole had been drilled to permit controlled sinking of the casing string. The 14-inch OD casing was connected to the 10-3/4 inch OD casing by means of a bell reducer which was welded to both casings. All other joints in the 14-inch OD casing were beveled, butt-welded joints and joints in the 1-3/4 inch OD casing were connected with weld collars. Centralizers were installed on the casing string about every 200 feet with several closely spaced centralizers placed near the guide shoe.

The casing string was cemented by means of single wiper plug displacement of the cement out through the guide shoe at the bottom of the casing and cement was returned to the surface up the annulus. The wiper plug was landed on the backflow baffel 40 feet up from the bottom of the casing string and evidently caused a casing separation forcing the bottom 40-foot long joint of casing down to the bottom of the borehole at 1,855 feet. The casing separation left an uncased interval in the borehole from 1,810 feet to 1,815 feet which shows clearly on the electric logs. The displacement fluid used inside the casing was barite weighted bentonite gel weighted to overcome the buoyancy effects on the casing. The cementing head was left shut-in until the cement had time to set. The combination of weighted fluid and the shut-in cement head prevented the cement in the annulus from backflowing up into the casing when the casing separated.

Following casing installation, milling out of the backflow baffle, and drilling out of the cement and guideshoe, 8-3/4 inch diameter borehole was drilled from 1,855 feet to the final depth of the first phase of the drilling at 2,440 feet. After the well was subjected to high-pressure hydrofracture treatment, the interval from 1,855 feet to 2,440 feet was reamed out to 9-7/8 diameter and the open borehole was deepened to 3,041 feet with a 9-7/8 diameter bit. Subsequent milling and washing operations associated with fishing for lost tools further deepened the open borehole to a final depth of 3,050 feet. Approximately five feet of 4-inch perforated tubing remained unaccounted for after the fishing and milling operations and were jammed into the bottom of the borehole, preventing further drilling progress. Consequently, the well was completed by setting a 200-foot long cement plug in the 2,421 to 2,621 foot depth interval. The well cap is attached to the 18-inch OD surface casing with a bolted flange and the surface casing is equipped with an 18-inch diameter horizontal discharge pipe and gear operated butterfly valve.

The purpose of the design of the foregoing well was twofold. First, provision of the 14-inch OD casing to a depth of 600 feet was intended to provide the opportunity to supplement the natural aretesian flow that was anticipated from the well by virtue of installing a high capacity pump. The 14-inch OD casing is large enough to accept a reasonably large pump bowl if the water users ever elect to exercise this option. Secondly, the 10-3/3 inch OD casing and the 8-7/8 open borehole below the casing were the minimum diameters necessary to prevent the possibility of excessive friction losses from flow up the well. Reduction of the borehole to a 6-inch nominal diameter would have substantially increased the potential head loss due to friction and the well design was intended to prevent such a head loss from becoming a significant factor in reducing the natural artesian flow of water from the well.

5.2. Well No. 2

Surface casing for Well No. 2 consisted of 16-inch OD diameter steel water well casing installed to a depth of 179 feet into a 22-inch diameter borehole 183 feet deep and cemented by positive displacement from the bottom up with cement returning to the surface. Open borehole was drilled with a 12-1/4 inch diameter bit size from 183 to 3,379 feet. Subsequently, 9-5/8 inch OD casing was installed from the invert of the trench pipe (present discharge pipe at the well head) to a depth of 1,813 feet. The top of the 9-5/8 inch OD casing is equipped with a threaded coupler and the 9-5/8 casing is assembled with threaded couplers on 40-foot joints. Cement was forced up the annulus on the outside of the casing from 1,813 feet back to 307 feet where the cement flowed into a fracture zone in the formation. Subsequently, the annulus was backfilled by washing down sand from the surface without a tremie pipe to a measured depth of 144 feet, followed by neat cement grout (Type A Portland Cement) poured from a Readi-Mix truck from 144 feet back to the invert on the trench pipe. The well cap is attached to the 16-inch diameter surface casing with a bolted flange and the surface casing is equipped with a 16-inch diameter horizontal discharge pipe with a gear operated butterfly valve.

The foregoing well design was intended to provide an opportunity to drill the exploration well as deep as the Flathead Sandstone while still staying within the remaining project budget. Threaded casing was used so that if the Flathead Sandstone was not productive or yielded water with unacceptable chemical quality, the threaded casing could be pulled back for a completion in either the Bighorn or the Madison. If the casing had become stuck, it would have been shot off with wireline explosives and pulled back. The design also allowed for isolation of the Bighorn and Madison aquifers by running a liner to the deeper Bighorn and producing from the Madison up the annulus between the liner and the outside casing. The outside casing was originally intended to be 10-3/4 inch OD but was reduced to 9-5/8 as a cost saving step when it was apparent that the project budget would not encompass drilling to the Flathead after caving problems began in the Amsden and Gros Ventre Formations.

Although tolerences are tight, it would still be possible to run a welded liner through the existing well, drill the liner down into the caved part of the Gros Ventre, and continue drilling down to the Flathead Sandstone. The resultant well could possibly be completed as a production well but would preclude the very favorable production presently obtained from the Bighorn and Madison aquifers. The only purpose of such a scheme would be to drill the estimated 400 to 600 feet remaining to test the yield of the Flathead Sandstone. The test bore could then be plugged back, the casing withdrawn, and production from the Bighorn and Madison aquifers resumed.

It should be noted, however, that the metal shoe used in washing the existing casing through the caved zone in the Amsden was milled off and is still somewhere in the bottom of the well. The washing shoe consisted of three 1/4 inch by 2-inch straps welded into a conical spider and coated with Cut-Rite tungsten-carbide hardfacing. The shoe was milled off of the casing from the backside with a flat-bottomed milling bit once the casing was in place and fell or was chased by the bit back down to the final depth tagged by the geophysical logger at 3,128 feet. The remains of the washing shoe probably do not pose a serious problem to deepening the hole, in view of the enlarged nature of the borehole in the Gros Ventre; however, any driller reentering the well should be aware of the presence of metal somewhere at the bottom of the open borehole.

6. BOREHOLE LOGS

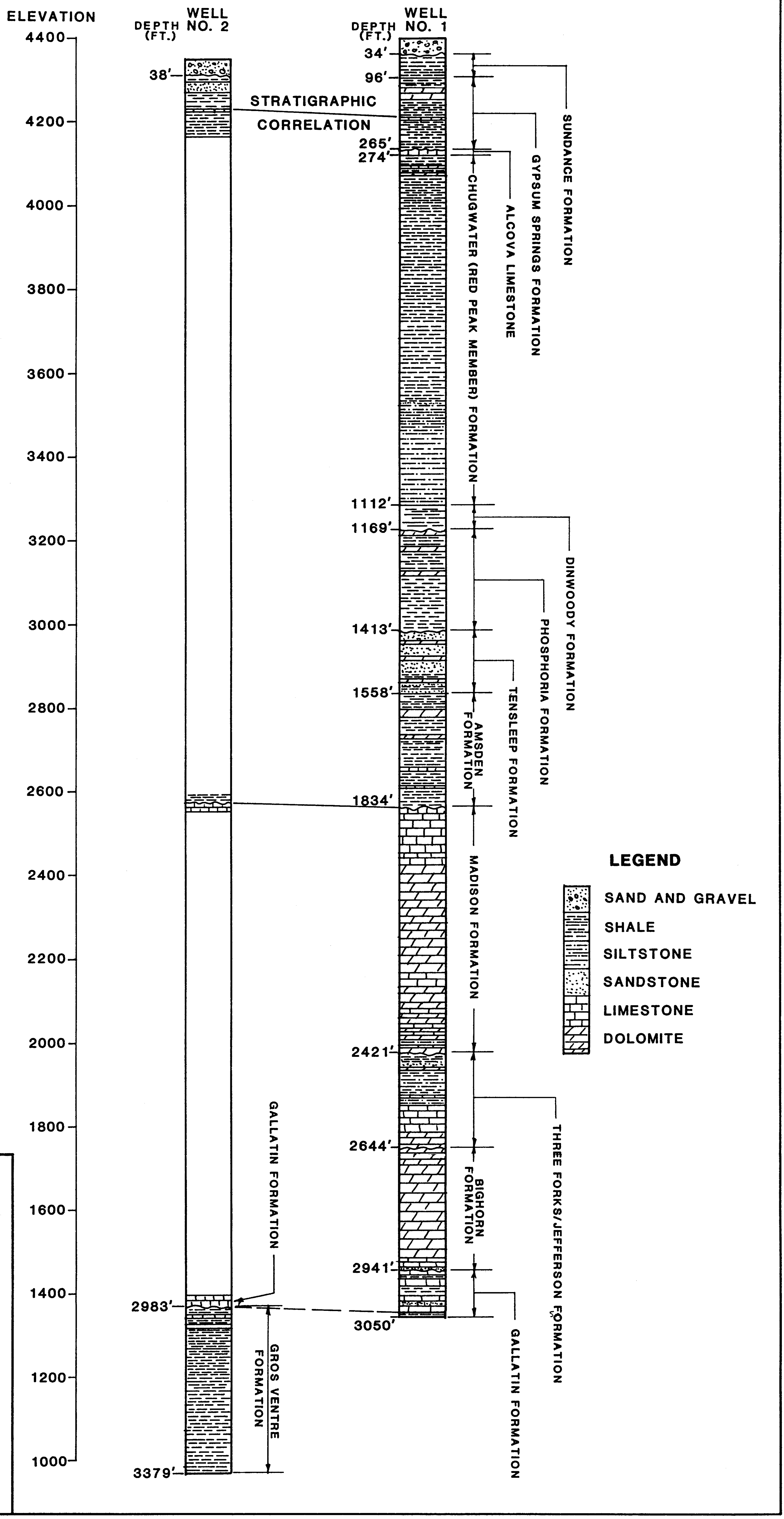
In addition to logs of construction activities and construction details of the completed well, full-time, 24-hour per day logging of the drill cutting returns and identification of formation tops by a qualified geologist was provided for Well No. 1. On Well No. 2, logging was provided for the surface casing drilling to make sure the surface casing was below a carbonate zone that caused lost circulation in Well No. 1. However, geologic logging on Well No. 2 ceased until the well was near the same stratigraphic depth as nearby Well No. 1, when geologic logging of the remainder of the well depth was provided. In addition, geophysical borehole logging was performed on both of the wells.

6.1. Geologic Logs

Geologic and lithologic logs for Wells Nos. 1 and 2, are displayed in Appendices A and B, respectively. The logs are self explanatory and show the depths to formation tops and provide lithologic descriptions of the strata penetrated. The scientific color nomenclature used on the logs is based on the application of Munsell soil color charts. The logs also provide information on the hole diameter, casing sizes, drilling methods, bit types, drilling fluid, fluid losses and gains, and character of drilling.

The geologic log for Well No. 2 (Appendix B) is blank from 183 feet to 2,970 feet due to the fact that a geologist was not present during the drilling of this interval on the second well as a cost saving measure. The strata penetrated in the interval not logged by a geologist are the same strata penetrated by Well No. 1, some 567 feet distant, for which a geologic log is provided (Appendix A). Composite five-foot interval samples were collected by the drillers for the last 200 feet of the Madison Group strata and were examined later by the field geologists on the site to pick the top of the Madison aquifer.

The relationship between strata penetrated by Wells Nos. 1 and 2 is shown on Figure 2 which compares generalized geologic logs of the two wells and shows the relative elevations of the formation tops. The elevation difference between the two wells, as measured from flange to flange on the top of the flanges



GENERALIZED GEOLOGIC LOGS
SHELL WELLS NOS. 1 & 2
FIGURE 2

MORRISON-MAIERLE, INC.
CONSULTING ENGINEERS

welded onto the surface casings, is 50.91 feet with Well No. 2 being at a lower elevation than Well No. 1. Stratigraphic correlation between the two wells is based on a limestone unit in the Gypsum Springs Formation that was used as a marker horizon and on the location of the top of the Madison Group.

Table 7: Formation top elevations and depths.

	Well No. 1		Well No. 2	
	Elevation	Depth	Elevation	Depth
Sundance	Land surface	0		
Gypsum Springs	4,304	96	Land surface	0
Alcova	4,135	265		
Chugwater	4,126	274		
Dinwoody	3,288	1,112		
Phosphoria	3,231	1,169		
Tensleep	2,987	1,413		
Amsden	2,839	1,561		
Madison	2,566	1,834	2,574	1,775
Three Forks/Jefferson	1,979	2,421		
Bighorn	1,754	2,646		
Gallatin	1,461	2,941		
Gros Ventre	1,359	3,041	1,366	2,983

Formation top elevations and the depth from the land surface to the top of each formation are summarized for both wells on Table 7. The thicknesses of the strata may be determined by the differences between either the elevations or depths to the

Table 8: Formation top elevations and thicknesses.

	Elevation	Depth	Thickness
Sundance	Land surface	0	Unknown
Gypsum Springs	4,304	96	169
Alcova	4,135	265	9
Chugwater	4,126	274	838
Dinwoody	3,288	1,112	57
Phosphoria	3,231	1,169	244
Tensleep	2,987	1,413	148
Amsden	2,839	1,561	273
Madison	2,566	1,834	587
Three Forks/Jefferson	1,979	2,421	225
Bighorn	1,754	2,646	293
Gallatin	1,461	2,939	105
Gros Ventre	1,359	3,041	Unknown

formation tops shown on Table 7. Examination of the data presented on Table 7 shows that the elevations of the formation tops penetrated in Well No. 2 are seven to eight feet higher than the formation top elevations in Well No. 1. Table 8 is the same data shown on Table 7 for Wells Nos. 1 and 2 compiled to show the thicknesses of the strata penetrated.

6.2. Geophysical Borehole Logs

Electrical resistivity logs (Dual Normal Electric Log with S.P.), formation density logs (Compensated Density Log), caliper, and natural gamma (Gamma Ray) logs were completed for both Well No. 1 and Well No. 2. Camera copies of the geophysical logs for Wells Nos. 1 and 2 are presented in Appendices C and D, respectively.

In addition to the conventional logs listed above, a special 49-inch diameter three-arm caliper tool was fabricated by Strata Data, Inc. and used to log Well No. 2 where considerable enlargement of the borehole had occurred in some intervals due to borehole caving. A copy of the 49-inch caliper log operated in conjunction with the Gamma Ray tool is included in Appendix H. Also included in Appendix D are copies of a Spinner Flowmeter Log, Temperature Log (absolute temperature), and Differential Temperature Log (rate of temperature change). The spinner and temperature logs were used to identify water-bearing intervals within the artesian aquifers in the Madison and Bighorn units and to identify the separate rates of yield from the two aquifer systems.

6.2.1. Resistivity Logs

In water well applications, the most important use of the resistivity logs is to identify zones of porosity which may be indicative of permeability. Resistivity logs cannot be run in a cased borehole nor can they by conducted above the fluid level in the borehole. Resistivity logging must be conducted in an uncased, open borehole filled with fluid.

The mere presence of porosity does not mean that the formation is permeable unless the voids creating the porosity are interconnected and large enough in size so that they may transmit fluid through the formation at the prevailing viscosity of the formation fluid. Thus, a high resistivity reading associated with high porosity may or may not be indicative of a zone of permeability and other factors must be considered in addition to and in conjunction with the resistivity logs to identify water-bearing zones.

The Dual Normal electric logs consist of a short normal tool with a 16-inch electrode spacing and a long normal tool with a 64-inch electrode spacing. The short normal tool measures resistivity at a shallow depth of investigation out from the borehole wall which is the resistivity of the zone invaded by the drilling fluid during boreing of the hole. The long normal tool measures the resistivity further out from the borehole which is the resistivity of the formation outside of the zone of invasion by drilling fluid near the borehole. The presence of invasion is important in interpreting the logs because it indicates that the formation is permeable. The separation between the curves for the short and long normal tools is indicative of the invasion of the formation by the borehole fluids. In the case of Wells Nos. 1 and 2, interpretation of the resistivity logs from the top of the Madison aquifer on down must take into consideration the fact that the well was flowing 500 gpm or more and little or no invasion of the formation by drilling fluid was occuring, thus the short and long normal tools show congruent resistivities.

The short normal tool will provide reliable resistivities for bed thicknesses as small as four feet whereas the long normal tool requires thicker beds. Alternating beds of materials less than four feet thick per bed will often result in an inversion of the resistivity log results where one tool shows increasing resistivity and the other tool shows decreasing resistivity for the same zone. Other considerations in interpreting the resistivity logs are responses to factors other than porosity. For example, on the log of Well No. 1, high resistivity occurs from about 340 to 390 feet (Appendix C). Examination of the geologic log (Appendix A) indicates that the high resistivity corresponds to an interval of the Chugwater Formation containing a considerable amount of anhydrite and gypsum which are poor electrical conductors. Similar responses of the electric log are seen in the Phosphoria Formation and other intervals.

Examination of the resistivity logs for Wells Nos. 1 and 2 indicates that both the Madison and Bighorn aquifers exhibit considerable porosity throughout their thicknesses. A relatively constant separation exists between the short normal and long normal curves as is best observed on the logs for Well No. 2. The relatively constant separation of the short and long normal curves, combined with the fact that the fluid in the well bore during logging was formation water because the well was flowing more than 750 gpm during the geophysical logging, indicates that the congruent curves of the short and long normal tools are simply parallel measurements of the formation resistivity and that little or no invasion of the carbonate aquifer rocks was present during logging.

However; distinct zones of increased formation resistivity are present in the carbonate aquifer rocks of the Madison and

Bighorn. For example, the Dual Normal log of Well No. 2 (which is easier to read than the logs of Well No. 1) shows increased resistivity in the Madison Group at intervals from 1,822 to 1,880 feet; 1,906 to 1,990 feet; and 2,206 to 2,278 feet. Conventional interpretation of the resistivity logs in which an invaded zone is present in the formation around the borehole would erroneously indicate that the zones of increased resistivity represent permeable zones which have been invaded by drilling fluids. However; in view of the reverse circulation drilling method used and the artesian flows from the formation to the borehole, the correct interpretation of the resistivity logs is that the zones of high resistivity are intervals that do not yield significant groundwater and the remainder of the carbonate rocks in the Madison aquifer are permeable and yield groundwater.

The Compensated Density logs are a resistivity derived porosity log based in part on the short normal tool which provides resistivity measurements close to the borehole (normally in the flushed or invaded zone). Comparison of the Compensated Density log for the Madison interval in Well No. 2 to the resistivity logs of the same interval shows that the three cited zones of high resistivity correspond closely to zones of relatively low porosity whereas the remainder of the carbonate interval in the Madison exhibits good carbonate porosity. This correlation suggests that although aquifer permeability may have been enhanced by secondary fracture opennings in the rocks as suggested by other data, there is a good component of intrinsic porosity in the carbonate rocks of the aquifer. However, the logs described so far do not indicate the degree of interconnection of the porosity or the resultant permeability and it must be assumed that porosity is equivalent to permeability. The spinner flowmeter and temperature logs described in following parts of this report further identify the actual water-bearing zones in the aquifers.

Spontaneous potential (S.P.) logs are used in water wells primarily to identify impermeable zones such as shale and permeable zones such as sandstone. The SP response of shales is relatively constant and follows a straight line called a shale baseline. SP curve deflections are measured from the shale baseline and a deflection of the SP curve to either side of the shale baseline indicates the presence of a permeable zone. The factor determining whether the curve deflects to the right or the left of the shale baseline is the relative difference between the resistivity of the borehole fluid and the formation fluid. If the borehole fluid is more resistant than the formation fluid, the curve will deflect or "kick" to the left of the shale baseline. If the borehole fluid has lower resistivity than the formation fluid (a typical condition next to a permeable fresh water aquifer), the SP curve will kick to the right.

The permeable bed boundaries are detected by the point of inflection from the shale baseline. However, where the resistivity of the borehole fluid is equal to the resistivity of the formation fluid (a strong probability in the borehole of a strongly flowing artesian well such as Wells Nos. 1 and 2), the SP curve will not deflect from the shale baseline even though intervals of different permeability are being logged. This is exactly the response exhibited in the carbonate aquifer intervals in Wells Nos. 1 and 2. In the example intervals described for the Dual Normal and Compensated Density logs, the SP curve remains relatively close to the shale baseline through the intervals of relatively low resistivity and high porosity. However;

in the three intervals of relatively high resistivity and low porosity, the SP curve kicks to the left indicating that the resistivity of the water flowing up the borehole is greater than the resistivity of the formation water in those three intervals. The fact that the formation water in the three intervals of higher resistivity and lower porosity has lower resistivity than the water flowing up the borehole from the water-bearing zones in the well indicates the three intervals are zones of restricted permeability and poor circulation with relatively higher mineralization of the pore waters as compared to permeable water-bearing zones.

6.2.2. Gamma Ray Log and Caliper

Gamma ray logs measure the natural radioactivity in formations. Gamma ray logs can be conducted through steel well casing and can be obtained in the interval above the fluid level in the borehole. In general, shale-free sandstones and carbonates have low concentrations of radioactive material and give low gamma ray readings whereas shales contain relatively greater amounts of radioactive materials and give high gamma ray readings. Therefore, increasing shale content in a formation causes increased gamma ray response on the logs. Other formation conditions that may give a high gamma ray response include feldspathic and glauconitic sandstones or sandstones containing uranium water. Quantitative application of gamma ray logs is for calculation of the volume of shale in a porous reservoir or aquifer. Application of the gamma ray logs on the Shell Valley Deep Well Project is limited to identification of lithologies (shale versus sandstone and carbonate rocks) and correlation.

Caliper logging tools measure and record the average diameter of the drill hole. Caliper logs have a number of applications both in the construction of the well and the interpretation of other logs. A primary construction application of caliper logs is the calculation of the volume of cement required to fill the annulus between the borehole wall and the outside of the well casing. A primary application of caliper logs in interpreting other logs is provision of correction factors for borehole diameter effects on porosity logs such as the Compensated Density log. Caliper logs are required for compensation (correction) of all geophysical logs subject to effects from changes in borehole diameter.

Caliper tools use either pads (referred to as arms) or bowsprings to ride against the borehole wall and measure the borehole diameter. The graphic record produced by the sonde is conventionally the average hole diameter. Average diameter is used so that an increase in hole radius in one direction will not cause the recorded increase in diameter to be as great as an equal radial increase that is symmetrical around the axis of the hole. None of the tool configurations necessarily give correct measurement in eliptical holes where special tools with independently recording arms are needed. The caliper tools used for logging Wells Nos. 1 and 2 were three-arm tools. A specially modified three-arm caliper tool with a 49-inch diameter capability was fabricated to log Well No. 2 in order to provide a reasonable caliper log of the borehole intervals enlarged by caving. The 49-inch diameter caliper was required to provide an accurate enough log to reasonably calulate the volume of cement required to cement the casing on Well No. 2.

6.2.3. Flowmeter Logs

Shell Valley Well No. 2 is completed in two flowing aquifers, the Madison aquifer and the Bighorn aquifer, and the flowing artesian discharge of water from the well is the sum total of flows from both aquifers. A spinner flowmeter log was made in Well No. 2 for the purpose of identifying major water-bearing zones in each aquifer and to determine how much flow was coming from the Madison aquifer versus the Bighorn aquifer. The spinner flowmeter tool consists of a helictical gear or "spinner" rotating on a vertical axis. The spinner is lowered to the bottom of the well and then raised up the borehole at a known and constant rate. The revolutions per minute of the spinner (corrected for the rate of movement of the tool) are converted to the velocity of fluid or gas flow in the borehole.

In order to calculate the rate of flow for any specific location in the borehole, the spinner flow velocity must be used in conjunction with the caliper log of the borehole diameter. The borehole diameter determined by the caliper log is used to calculate the cross-sectional area of the borehole. The cross-sectional area multiplied times the flow velocity provides the rate of flow at the specific cross-sectional area being examined. Changes in the rate of flow at different locations in the borehole reveal the presence of water-bearing zones as well as "theft zones" where water is being lost to the formation.

In practice, it is necessary to select segments of the borehole which have relatively consistent diameter over a reasonable length and then average the caliper diameter for the selected interval. Cross-sectional borehole diameters measured in areas of rapidly changing borehole diameter do not give good results when used with the spinner flow velocities. The flowing artesian discharge of Well No. 2 at the time the spinner log was made was 1,090 gpm as measured in a Parshall flume. A summary of flow rates calculated from the spinner and caliper logs at different depth intervals with borehole wall conditions suitable for application of the method is shown on Table 9. The sum of the flows from the different depths shown on Table 9 is 1,089 gpm which is in good agreement with the measured surface discharge of 1,090 gpm.

Table 9: Borehole flows calculated from spinner and caliper logs for Shell Valley Well No. 2.

Cross Section Depth	Flow Rate (gpm)	Incremental Flow Increase (gpm)	Aquifer
2,860	0		Bighorn
2,842	480.7	480.7	Bighorn
2,810	599.7	119.0	Bighorn
2,780	755.5	155.8	Bighorn
2,770	796.8	41.3	Bighorn
		796.8	
2,400	822.3	25.5	Madison
2,050	824.3	2.0	Madison
2,150	857.9	33.6	Madison
2,070	874.6	16.7	Madison
2,020	874.6	0	Madison
1,990	965.0	90.4	Madison
1,942	1,057.9	92.9	Madison
1,920	1,057.9	0	Madison
1,846	1,089.0	31.1	Madison
		292.2	

Calculated well flow	1,089.0 gpm
Measured well flow	1,090 gpm

The information shown on Table 9 indicates that 797 gpm or about 73 percent of the artesian flow from Well No. 2 comes from the Bighorn aquifer and 293 gpm or 27 percent of the flow comes from the Madison aquifer. The end of the well casing is at 1,813 feet or 33 feet above the last cross section used to calculate the flow rate in the borehole. The concentrated yield of 480.7 gpm from the lowermost 18 feet or less of the Bighorn suggests that enhancement of the rock permeability by secondary fracture opennings may be a factor in the groundwater yield in this interval. The overall high rate of groundwater yield from the Bighorn in Well No. 2 as compared to no yield from the Bighorn in Well No. 1 also suggests that secondary fractures played a role in the permeability of the Bighorn aquifer at Well No. 2. By comparison, yields from the Madison are somewhat more evenly distributed over long intervals of borehole and appear to be more likely the function of intrinsic permeability or well distributed secondary solution enlargement of natural porosity enhancing permeability with at least three zones present that do not yield groundwater.

6.2.4. Temperature Logs

Temperature and Differential Temperature logs were obtained in Well No. 2 and are shown on the Spinner Flowmeter Log in Appendix D. The temperature log is calibrated in terms of absolute temperature and therefore provides a measure of the ambient temperatures of the flowing water in the borehole. The temperature log is conventionally referred to as the gradient temperature log and shows the change in temperature from the top to the bottom of the borehole. The differential temperature log shows the relative rate of change of the gradient temperature and is very sensitive.

The gradient temperature in Well No. 2 remains constant at about 64.9° F from the bottom of the well casing at 1,813 feet to a depth of 1,958 feet where the gradient begins to increase and the differential temperature shows an abrupt and strong increase in the rate of temperature increase. The gradient temperature increases steadily from 1,958 feet to the bottom of the Madison at about 2,420 feet where the temperature is 66° F. The differential temperature log indicates inflows of groundwater from 1,958 to about 2,100 feet in depth with some interspersed impermeable zones. This information is consistent with the spinner flowmeter data shown on Table 9, however, neither the gradient temperature nor the differential temperature indicate all of the water-bearing zones detected by the spinner, a fact which reflects greater yields per foot of borehole in some water-bearing zones than in others.

The gradient temperature rises only about one-quarter of a degree Fahrenheit from the base of the Madison to a depth of 2,900 feet about 40 to 50 feet above the base of the Bighorn. The gradient abruptly increases from about 66.25° F at 2,900 feet to 67.75° F at the base of the Gallatin Formation at 3,038 feet. The differential temperature indicates a small inflow of groundwater from the Bighorn in the 2,840 to 2,880 foot interval and a strong inflow from about 2,900 feet to the base of the Bighorn around 2,950 to 2,960 feet. The gradient temperature in the Gros Ventre, below the water-bearing zones, is very eratic and the differential temperature from the top of the Gallatin (base of the Bighorn) on down is extremely eratic showing large increases and decreases in the rate of the gradient in short distances. These phenomena occur to some extent where borehole caving was experience, especially in the Gros Ventre, and may be some type of borehole effect that is masked in flowing portions of the borehole but show up where there is no flow in the borehole.

The temperature logs indicate a water temperature of about 67° F to 68° F in the Bighorn and 66° F in the Madison with the gradient temperature decreasing to about 65° F at the lower end of the well casing at 1,813 feet depth. Water temperatures measured at the surface during aquifer flow tests with a packer isolating the Bighorn from the Madison were 57.2° F for the Madison and 59° F for the Bighorn (as converted from field measurements of 14° C and 15° C, respectively. This information indicates about a 9° F temperature differental for water flowing up from both the Bighorn and the Madison.

7. AQUIFER TESTS

Aquifer and well tests were conducted at Wells Nos. 1 and 2 at four different times during the project implementation. A summary of information pertinent to the various tests is presented on Table 10.

Table 10: Summary of aquifer test rates and durations.

Test Date	Well No.	Aquifer System	Flow Rates (gpm)	Test Duration (minutes)
4/ 3/84	1	Madison	176.5(1)	1,470
4/20/84	1	Madison	104- 95 (2)	14,280
8/26/85	2	Madison(3)	359	40
8/26/85 to 8/27/85 step tests with packer at 2,390 feet(4):				
Step 1:	2	Madison	318.7	99
	2	Bighorn	16.5	98
Step 2:	2	Madison	94	80
	2	Bighorn	26.9	80
Step 3:	2	Madison	332	100
	2	Bighorn	67.3	100
Step 4:	2	Madison	363.6	880
	2	Bighorn	170.6	880
Step 5:	2	Madison	363.6-345.6	440
	2	Bighorn	170.6	440
	1	Madison(5)	367-309	440
9/ 9/85 to 10/11/85 long-term flow tests:				
Step 1:	2	Madison/Bighorn(6)	1280-1090	29,500
Step 2:	2	Madison/Bighorn(6)	1090-1023	15,500
	1	Madison(5)	293- 224	15,500

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(1) Pre-hydrofracture flow.

(2) Post-hydrofracture flow; initially 104 gpm decreasing to 95 gpm over test duration of 9.9 days.

(3) Test to insure that packer between Madison and Bighorn at 2,390 feet is isolating pressure between the two aquifers.

(4) Flow from Bighorn severely restricted throughout step tests due to friction losses in 2,390 feet of tubing from packer to surface.

(5) Flow started from Madison at Well No. 1 without interrupting flow from previous step at Well No. 2.

(6) Combined flow from both aquifers.

7.1. Tests of Well No. 1

The first test conducted to determine the hydraulic parameters of the aquifers penetrated by the Shell Valley Wells was a flow test of the Madison aquifer at Well No. 1 on April 3, 1984 (Table 10), prior to the hydrofracture stimulation of the well. As shown on Table 10, the test was conducted for 24.5 hours at a flow rate of 176.5 gpm which was essentially the total artesian flow available from the well with just enough backpressure to enable readings of the flowing well pressure to be conducted. Initial measurements of well pressure were made with a pressure gage until the pressure dropped below the range of sensitivity of the gage. A manometer tube was used to replace the gage and sight readings of the head above the port on the well were made with a 25-foot glass surveyor's rod for pressures below the gage sensitivity. Discharge measurements were conducted by application of the Manning equation to partial pipe flow through a discharge pipe of measured gradient and were verified frequently with timed volumetric measurements in a container of known volume. The discharge rate remained constant throughout the test. An observation well was not available for this single well test as no other wells penetrated to the Madison aquifer in this area at the time of the test.

Time-drawdown data for the pre-hydrofracture test of the Madison in Well No. 1 are shown on Table 11 and logarithmic plots of the time-drawdown curve are shown on Figure 3. Drawdown due to formation losses and friction losses of the flow up the well bore are in the range of 281 to 292 feet, depending upon where the point of inflection on the early flow test data is selected. Curve 1 on Figure 3 is based on assumed formation and well losses of 281.29 feet (drawdown observed at 0.25 minutes elapsed time

Table 11. Time-Drawdown Data, April 3, 1984 Test of Well No. 1

Elapsed Time (min.)	Pressure Head (feet)	Drawdown (feet)	Head Loss Correction (feet)	Corrected Drawdown (feet)	Elapsed Time (min.)	Pressure Head (feet)	Drawdown (feet)	Head Loss Correction (feet)	Corrected Drawdown (feet)
0	302.54	0	281.29	----	0	302.54	0	292.15	----
.25	21.25	281.29	281.29	0	.25	21.25	281.29	292.15	----
.50	17.32	285.22	281.29	3.93	.50	17.32	285.22	292.15	----
.75	15.25	287.29	281.29	6.00	.75	15.25	287.29	292.15	----
1.00	13.86	288.68	281.29	7.39	1.00	13.86	288.68	292.15	----
1.25	13.17	289.37	281.29	8.08	1.25	13.17	289.37	292.15	----
2	12.70	289.84	281.29	8.55	2	12.70	289.84	292.15	----
3	11.55	290.99	281.29	9.70	3	11.55	290.99	292.15	----
4	10.39	292.15	281.29	10.86	4	10.39	292.15	292.15	0
5	10.13	292.41	281.29	11.12	5	10.13	292.41	292.15	.26
6	9.86	292.68	281.29	11.39	6	9.86	292.68	292.15	.53
7	9.75	292.79	281.29	11.50	7	9.75	292.79	292.15	.64
8	9.58	292.96	281.29	11.67	8	9.58	292.96	292.15	.81
9	9.43	293.11	281.29	11.82	9	9.43	293.11	292.15	.96
10	9.28	293.26	281.29	11.97	10	9.28	293.26	292.15	1.11
15	8.89	293.65	281.29	12.36	15	8.89	293.65	292.15	1.50
20	8.54	294.00	281.29	12.71	20	8.54	294.00	292.15	1.85
25	8.43	294.11	281.29	12.82	25	8.43	294.11	292.15	1.96
30	8.27	294.27	281.29	12.98	30	8.27	294.27	292.15	2.12
35	8.19	294.35	281.29	13.06	35	8.19	294.35	292.15	2.20
40	8.11	294.43	281.29	13.14	40	8.11	294.43	292.15	2.28
45	8.07	294.47	281.29	13.18	45	8.07	294.47	292.15	2.32
50	7.99	294.55	281.29	13.26	50	7.99	294.55	292.15	2.40
55	7.89	294.65	281.29	13.36	55	7.89	294.65	292.15	2.50
60	7.81	294.73	281.29	13.44	60	7.81	294.73	292.15	2.58
70	7.81	294.73	281.29	13.44	70	7.81	294.73	292.15	2.58
80	7.72	294.82	281.29	13.53	80	7.72	294.82	292.15	2.67
90	7.67	294.87	281.29	13.58	90	7.67	294.87	292.15	2.72
100	7.61	294.93	281.29	13.64	100	7.61	294.93	292.15	2.78
150	7.54	295.00	281.29	13.71	150	7.54	295.00	292.15	2.85
200	7.51	295.03	281.29	13.74	200	7.51	295.03	292.15	2.88
250	7.40	295.14	281.29	13.85	250	7.40	295.14	292.15	2.99
300	7.36	295.18	281.29	13.89	300	7.36	295.18	292.15	3.03
350	7.27	295.27	281.29	13.98	350	7.27	295.27	292.15	3.12
400	7.20	295.34	281.29	14.05	400	7.20	295.34	292.15	3.19
450	7.17	295.37	281.29	14.08	450	7.17	295.37	292.15	3.22
500	7.14	295.40	281.29	14.11	500	7.14	295.40	292.15	3.25
600	7.09	295.45	281.29	14.16	600	7.09	295.45	292.15	3.30
700	7.02	295.52	281.29	14.23	700	7.02	295.52	292.15	3.37
800	6.98	295.56	281.29	14.27	800	6.98	295.56	292.15	3.41
900	6.95	295.59	281.29	14.30	900	6.95	295.59	292.15	3.44
1000	6.92	295.62	281.29	14.33	1000	6.92	295.62	292.15	3.47
1100	6.89	295.65	281.29	14.36	1100	6.89	295.65	292.15	3.50
1200	6.86	295.68	281.29	14.39	1200	6.86	295.68	292.15	3.53
1300	6.84	295.70	281.29	14.41	1300	6.84	295.70	292.15	3.55
1400	6.81	295.73	281.29	14.44	1400	6.81	295.73	292.15	3.58
1470	6.80	295.74	281.29	14.45	1470	6.80	295.74	292.15	3.59

Table 11. (continued)

Total Elapsed Time (min.)	Elapsed Time Since Well was Shut-in (min.)	Pressure Head (feet)	Residual Drawdown (feet)
1470	0	6.80	295.74
1470.25	.25	138.57	163.97
1470.50	.50	170.90	131.64
1470.75	.75	184.76	117.78
1471.00	1.00	196.30	106.24
1471.25	1.25	205.54	97.00
1471.50	1.50	214.78	87.76
1471.75	1.75	219.40	83.14
1472	2	224.02	78.52
1473.5	3.5	244.80	57.74
1474	4	250.58	51.96
1475	5	251.73	50.81
1476	6	255.20	47.34
1477	7	258.66	43.88
1478	8	262.12	40.42
1479	9	264.43	38.11
1480	10	266.74	35.80
1485	15	272.52	30.02
1490	20	277.14	25.40
1500	30	282.91	19.63
1505	35	284.06	18.48
1510	40	286.37	16.17
1515	45	286.37	16.17
1520	50	287.53	15.01
1525	55	288.68	13.86
1530	60	288.68	13.86
1540	70	289.84	12.70
1550	80	290.99	11.55
1560	90	290.99	11.55
1570	100	292.15	10.39
1620	150	294.46	8.08
1670	200	295.61	6.93
2898	1428	302.54	0

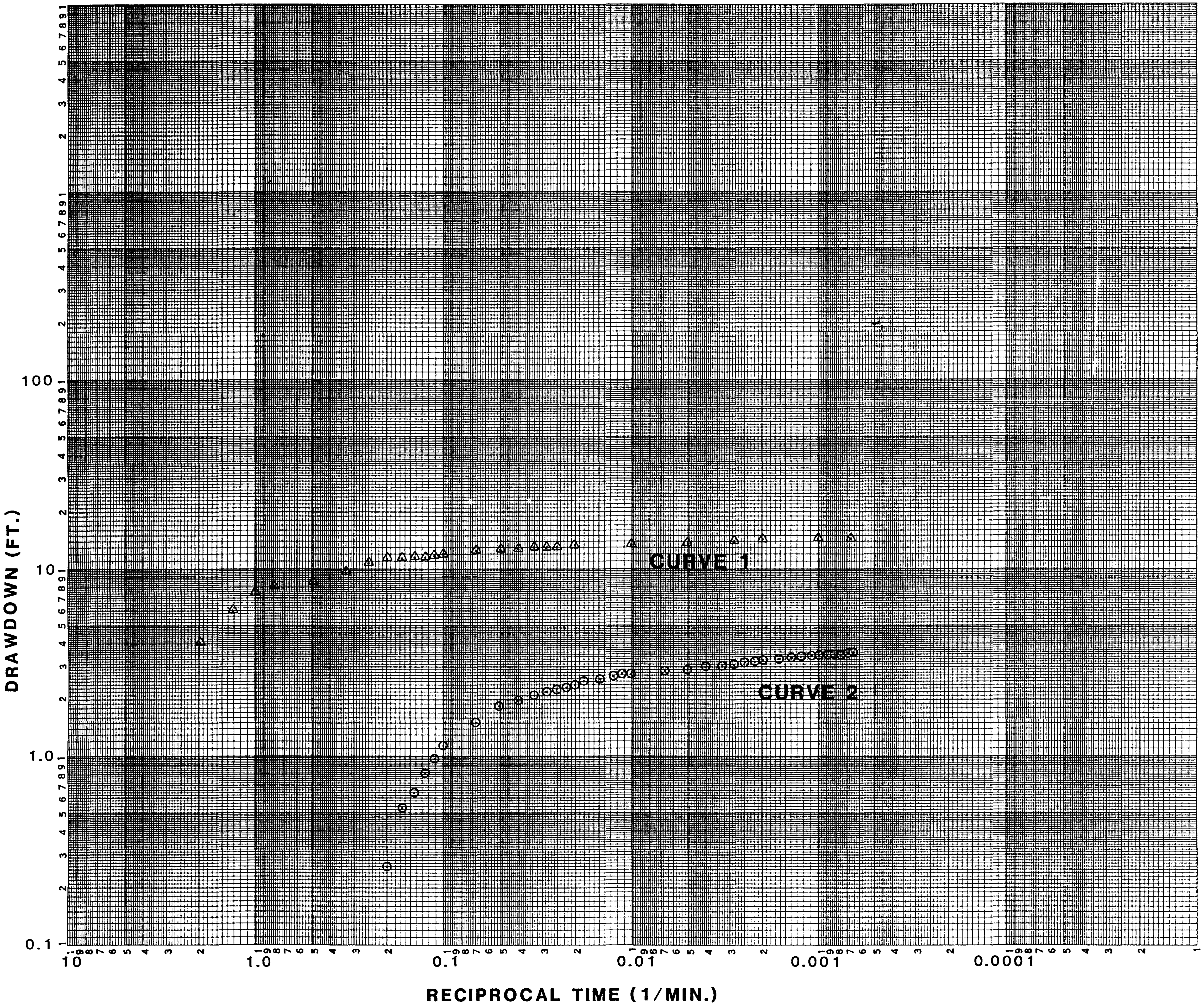


FIGURE 3:

RANGE OF LIMITS FOR TIME-DRAWDOWN CURVE APRIL 3, 1984

TEST WELL NO. 1 FLOWING
DATA FROM WELL NO. 1

CURVE 1 = UPPER LIMIT OF DRAWDOWN
CURVE 2 = LOWER LIMIT OF DRAWDOWN

into the test) and Curve 2 is based on assumed formation and well losses of 292.15 feet (observed at 4 minutes elapsed time into the test). The time-drawdown data for the two curves have been corrected by subtracting the assumed formation and well losses from the total observed drawdown. The drawdown remaining after the correction factor is subtracted from the observed drawdown is the drawdown attributed to a change in storage in the aquifer due to the groundwater abstraction rate of the well.

The correction factors applied to subtract the formation and well losses from the observed total drawdown in order to estimate aquifer drawdown cover a wide range which includes the true values of drawdown for the test. Thus, the two curves shown on Figure 3 depict the limits of aquifer drawdown within which the true values of aquifer drawdown are contained. The true values of aquifer drawdown will proscribe a time-drawdown curve that is congruent with the curves on Figure 3 and which will plot somewhere between the curves on Figure 3.

Examination of the range shown on Figure 3 for the time-drawdown curve for the Madison aquifer in Well No. 1 reveals that the curve is not suitable for conventional analysis by curve-matching methodology utilizing the Theis nonequilibrium type curve or other type curves. The problem is in the shape of the curve. The curve shows rapidly increasing drawdown to 4 minutes where an abrupt inflection point is present in the data. The drawdown response prior to the inflection point at 4 minutes is attributed mostly to the initial drawdown due to friction losses in the formation around the well bore (formation losses) and in the flow up the well bore and casing (well losses) and probably contains only a very small component of drawdown due to change in storage in the aquifer.

From 4 minutes to 10 minutes, the logarithmic curve is essentially a straight line, possibly due to adjustments occuring in the flowing discharge rate in the first 10 minutes as the well discharge adjusted to the initial large changes in the differential head causing the well to flow. The data points for the first 10 minutes of the test can be fitted to type curves for leaky aquifer conditions, however, there is no reason to anticipate that the Madison aquifer is a leaky aquifer and use of leaky aquifer type curves is not appropriate. After 100 minutes of elapsed time, the time-drawdown data diverge from the trend of the curve established in the first 100 minutes and turn upward in the direction of an increasing rate of drawdown. The upward inflection of the curve after 100 minutes of flow is characteristic of a negative boundary in the test and suggests that the cone of depression expanding out from the flowing well encountered some type of decrease in the transmissivity of the aquifer materials or encountered a barrier to groundwater flow.

The net conclusion drawn from evaluation of the time-drawdown data for the 24.5-hour flow test of the Madison aquifer system at Well No. 1 prior to the hydrofracture treatment of the well is that the data cannot be used reliably to calculate the hydraulic parameters of the aquifer. The test data does indicate that the 24-hour specific capacity of Well No. 1, prior to hydrofracture stimulation, was about 0.6 gallons per minute per foot of drawdown.

After the April 3, 1984 test of Well No. 1 was completed, the well was subjected to hydrofracture treatment. On April 20, 1984, a second flow test of the well was initiated to determine the effectiveness of the hydrofracture stimulation. However; initial flowing discharge from the well was only 104 gpm, some 72 gpm less than the natural artesian discharge prior to the hydrofracture treatment. The discharge of copious amounts of frac sand from the well indicated that flow from the well was impeded by sand plugging the formation and perhaps by sand bridges in the well bore. Accordingly, it was decided to continue to flow the well without interruption for a period of time in an attempt to let the sand clean out of the well and to develop unrestricted flow out of the aquifer formation and up the well bore. This effort was not successful and, as shown on Table 10, after nearly 10 days of continuous flow the discharge had decreased to 95 gpm as the result of drawdown effects.

After completion of the April 20, 1984 test of Well No. 1, there were plans being considered to reenter the well and deepen it in order to explore the availability of groundwater from deeper aquifers. Because of these tentative plans, development of the well to further remove the frac sand and improve flows was deferred with the thought that reentry and deepening of the well with reverse circulation drilling techniques would also develop and clean the hydrofractured Madison aquifer during the well drilling activities. Subsequently, the WWDC decided to reenter the well and cleaning and development of the Madison aquifer was accomplished by reverse circulation reaming and drilling operations. Following completion of the well deepening activities, flows from the well measured during packer test isolation of the Madison from the Bighorn showed that the Madison flow had increased from the 104 to 95 gpm measured prior to development to about 380 gpm initial flow rate. This was an increase of 203.5 gpm over the pre-hydrofracture flow or an improvement of the short-term well yield of about 115 percent.

7.2. Tests of Well No. 2

The first tests of Well No. 2 were conducted on August 26 and 27, 1985. Well No. 2 is completed in both the Madison and Bighorn aquifers and flows water from both aquifers. By August 26, 1985, an inflatable open-hole packer had been installed at a depth of 2,390 feet (top of packer element) with tubing connecting the interval below the packer back to the atmosphere at the land surface. Thus, the packer isolated the Bighorn aquifer below the packer from the Madison aquifer above the packer. Artesian flow from the Bighorn aquifer was conveyed to the surface through the tubing connected to the packer and artesian flow from the Madison aquider was conveyed to the surface separately up the annulus between the packer tubing and the exterior circumference of the well bore and well casing.

The initial test with the packer in the hole was conducted to test the effectiveness of the packer in isolating the two aquifers. Shut-in pressures at the surface were 161 psi for the Bighorn aquifer and 143 psi for the Madison aquifer. As shown on Table 10, the Madison side of the packer was allowed to flow "wide open" at 359 gpm while the Bighorn side of the packer remained shut-in. If the packer was not separating the two aquifers, the shut-in pressures would not have been different on each side of the packer. Moreover, the Bighorn side of the packer would have responded to the flow test of the Madison. However, the Bighorn aquifer pressure remained constant at 161 psi throughout the 40-minute flow test of the Madison thus demonstrating that the inflatable packer element was effectively sealing the borehole between the two aquifers and demonstrating that the Madison and Bighorn aquifers are geologically and hydraulically isolated by intervening strata.

Additional testing of Well No. 2 on August 26 and 27, 1985 consisted of stepped rate tests of both the Madison and Bighorn aquifers. The various rates and durations of the tests are shown on Table 10. As anticipated, the 2,400 feet of 4-1/2 inch diameter oil field drill tubing conveying water from the Bighorn aquifer to the surface placed a severe restriction on the rate of flow from the Bighorn aquifer. The maximum rate of flow obtained through the drill tubing from the Bighorn aquifer was 170.6 gpm as compared to the 796 gpm measured in the 9-5/8 well casing with the spinner log. Thus, the principal result of testing the Bighorn aquifer was determining the shut-in pressure and obtaining separate water quality samples from the aquifer.

Discharge from the Bighorn aquifer was measured in a 6-inch portable Parshall flume. Discharge from the Madison aquifer was measured in a 12-inch Parshall flume which was installed on the mud pit used for drilling the well. The storage capacity of the mud pit was considerable with the consequence that 15 to 20 minutes were required for the mud pit fluid level to stabilize after each change of flow from the Madison aquifer before a reliable measurement of the new discharge rate could be obtained. The effects of the mud pit on obtaining discharge measurements coupled with the operation of the gear operated butterfly valve on the well head made it very difficult to set the well discharge to proper increments for the stepped test.

The foregoing details of the stepped rate tests are provided in regards to their influence in regards to subsequent events of the stepped rate tests. Pressure in the two aquifers being tested was monitored and recorded by means of In-Situ, Inc. SE1000B microchip data loggers connected to pressure transducers. After completion of the stepped rate testing, both aquifers were shut-in and recovery data collection was initiated. Unfortunately, some time during the recovery period, the pressure transducer connected to the tubing to the Bighorn aquifer failed. The failed transducer permitted artesian pressure in the aquifer to force water up the temperature compensation vent in the transducer cable with the result that the SE1000B instrument was filled with water. All of the time-drawdown data from the stepped rate tests were lost and the electronics in the SE1000B were destroyed.

The only data remaining from the test were the field notebook entries regarding discharge rates which are shown on Table 10. It is worth noting that the discharge from the Madison aquifer during the final step of the test was 363 gpm. The Madison discharge declined to 345 gpm (Table 10) over the 440-minute duration of the test due to the effect of beginning to flow Well No. 1 wide open at the beginning of the final step. The only difference between Step 4 and Step 5 (Table 10) is that Well No. 1 was started flowing with the result that the flow from the Madison in Well No. 2 decreased by 18 gpm.

The 363 gpm discharge rate is a higher discharge rate than the 293 gpm measured from the Madison aquifer by the spinner log; however, the spinner log was conducted after the well had been flowing for several months during the various problems with the casing installation and the water levels were drawn down. The well discharge at the time of the spinner logging was 1,090 gpm which is exactly the discharge at the end of 20 days of flow testing (Step 1, Table 10). This indicates that after 20 days of flow, the discharge from the Madison in Well No. 2 stabilizes at about 293 gpm as compared to the 363 gpm observed in the less than 24 hours of stepped rate testing.

In view of the costs being placed against the project budget for drilling rig standby, packer rental, and other costs associated with repeating the stepped rate tests, it was decided that stepped rate retesting would not provide information of comensurate value to the costs. Considerations in this conclusion included the fact that the tests had been successful in determining the independent shut-in pressure of each aquifer and individual water quality samples had been collected from each aquifer. An additional consideration was that the tubing to the packer prevented meaningful testing of the Bighorn aquifer and the differences in flow from the Bighorn versus the Madison aquifers were already established by the spinner flowmeter log. Accordingly, Well No. 2 was shut-in to recover for a long-term test.

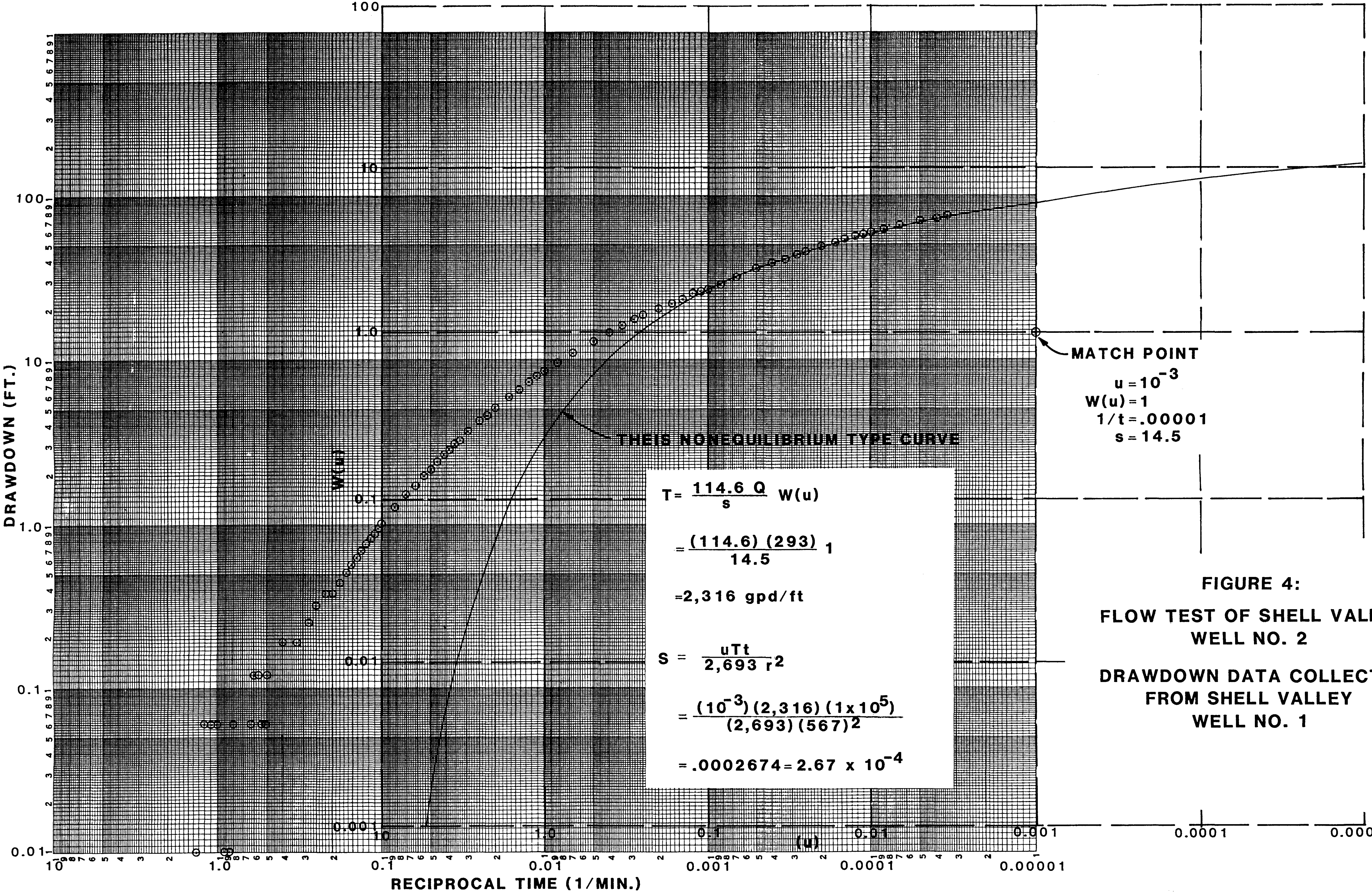
The long-term test was started on September 9, 1985 and included more than 31 days of "wide open" flow from both aquifers followed by shut-in of the well and observation of the recovery of the artesian pressure in the well for an additional nine days. The 31 days of flow testing in Well No. 2 consisted of two phases; 20 days of testing with Well No. 1 shut-in and an additional 11 days of testing with Well No. 1 also flowing wide open. Well No. 1 was used as an observation well for the Madison aquifer during the first 20 days of testing and then was flowed for the final 11 days of testing in order to evaluate the effects on discharge due to flowing both wells simultaneously. The discharge from Well No. 2 started at 1,280 gpm and declined to 1,090 gpm over the first 20 days of flow. When Well No. 1 was opened up at the end of 20 days, the discharge rate from Well No. 2 declined from 1,090 gpm to 1,023 gpm over 11 days and the discharge rate from Well No. 1 declined from 293 gpm to 224 gpm over the same 11 day period.

7.3. Calculation of Aquifer Parameters

Loss of the stepped rate test data due to the pressure transducer failure and destruction of the monitoring electronics ruled out the use of the stepped rate test data for calculating separate aquifer parameters from the test with a packer in Well No. 2. As previously described, the data from the single well test in the Madison aquifer in April of 1984 do not support reliable calculation of transmissivity or storativity for the aquifer. However; data from the long-term flow test of Well No. 2, using Well No. 1 as an observation well, do support calculation of transmissivity and storativity for the Madison aquifer.

Time-drawdown data for the Madison aquifer as observed in Well No. 1 are shown in Appendix E for the first 20 days of the test. The data shown in Appendix E reflect only the drawdown associated with artesian flow from the Madison aquifer because Well No. 1 only penetrates water-bearing strata in the Madison aquifer. Conventional analysis of the time-drawdown data by curve matching to the Theis nonequilibrium equation is shown on Figure 4. The discharge rate from the Madison aquifer in Well No. 2 is assumed to be equal to the spinner log flow rate of 293 gpm. This is a conservative assumption of the discharge rate and the actual average discharge rate for the test is somewhat greater than 293 gpm; however, it is somewhat speculative to apportion flow from the Bighorn from flow from the Madison at discharge rates greater than 1,090 gpm so the conservative discharge rate is used in this analysis. The measured distance between Well No. 1 and Well No. 2 of 567 feet is also used in the analysis.

As shown on Figure 4, the time-drawdown data from the observation well in the Madison aquifer (Well No. 1) for the first



MATCH POINT

$u = 10^{-3}$

$W(u) = 1$

$1/t = .00001$

$s = 14.5$

$$T = \frac{114.6\ Q}{s}\ W(u)$$

$$= \frac{(114.6)\ (293)}{14.5}\ 1$$

$$= 2{,}316 \text{ gpd/ft}$$

$$S = \frac{uTt}{2{,}693\ r^2}$$

$$= \frac{(10^{-3})\ (2{,}316)\ (1 \times 10^5)}{(2{,}693)\ (567)^2}$$

$$= .0002674 = 2.67 \times 10^{-4}$$

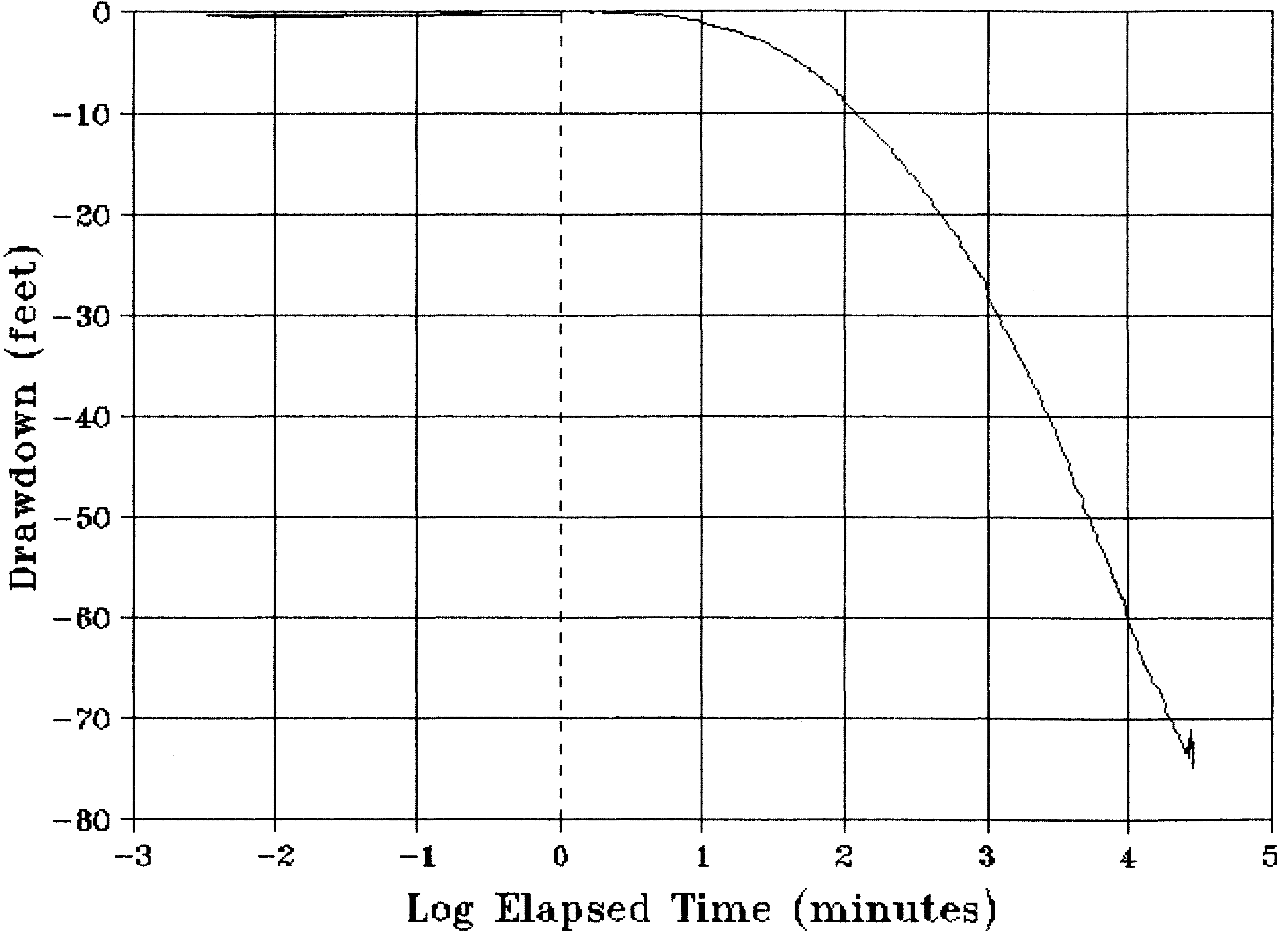
FIGURE 4:

FLOW TEST OF SHELL VALLEY WELL NO. 2

DRAWDOWN DATA COLLECTED FROM SHELL VALLEY WELL NO. 1

FIG. 5: TIME-DRAWDOWN PLOT

Well No. 2 Flowing - Well No. 1 Obs. Data



1,000 minutes of the 29,500 minute (20-day) flow test do not conform to typical drawdown curve for a constant discharge test. The shape of the time-drawdown curve shown on Figure 4 is due to the fact that discharge from the flowing artesian well was not constant during the test. In a pumped well, the water over the pump inlet available for drawdown in the well provides the pump an opportunity to create as much differential head between the inside and the outside of the well as is necessary to obtain the desired constant discharge rate (within the operational range of the well) and the drawdown at any given time is a function of the discharge rate. However; in a naturally flowing artesian well, the discharge rate is a function of the head above the land surface at the well (the differential head between the aquifer head elevation and the well head elevation at any given time). This means that as drawdown occurs in association with the flow of water from the well, the differential head causing the flow is reduced in direct proportion to the drawdown and the rate of flowing discharge from the well is reduced accordingly. The result is that the flowing discharge from wells such as Wells Nos. 1 and 2 decreases with increasing flow duration and associated drawdown.

The discharge rate from Well No. 2 for the combined production of the Madison and Bighorn aquifers is shown on Figure 6 plotted versus elapsed time. Regression analysis of the discharge versus time curve for Well No. 2 shows that the data define a power curve which is mathematically described as follows:

$$Q = 1,592.0882 \times t^{-.036756} \qquad \text{Equation 1}$$

where Q = discharge, gpm
t = elapsed time of "wide open" flow, minutes

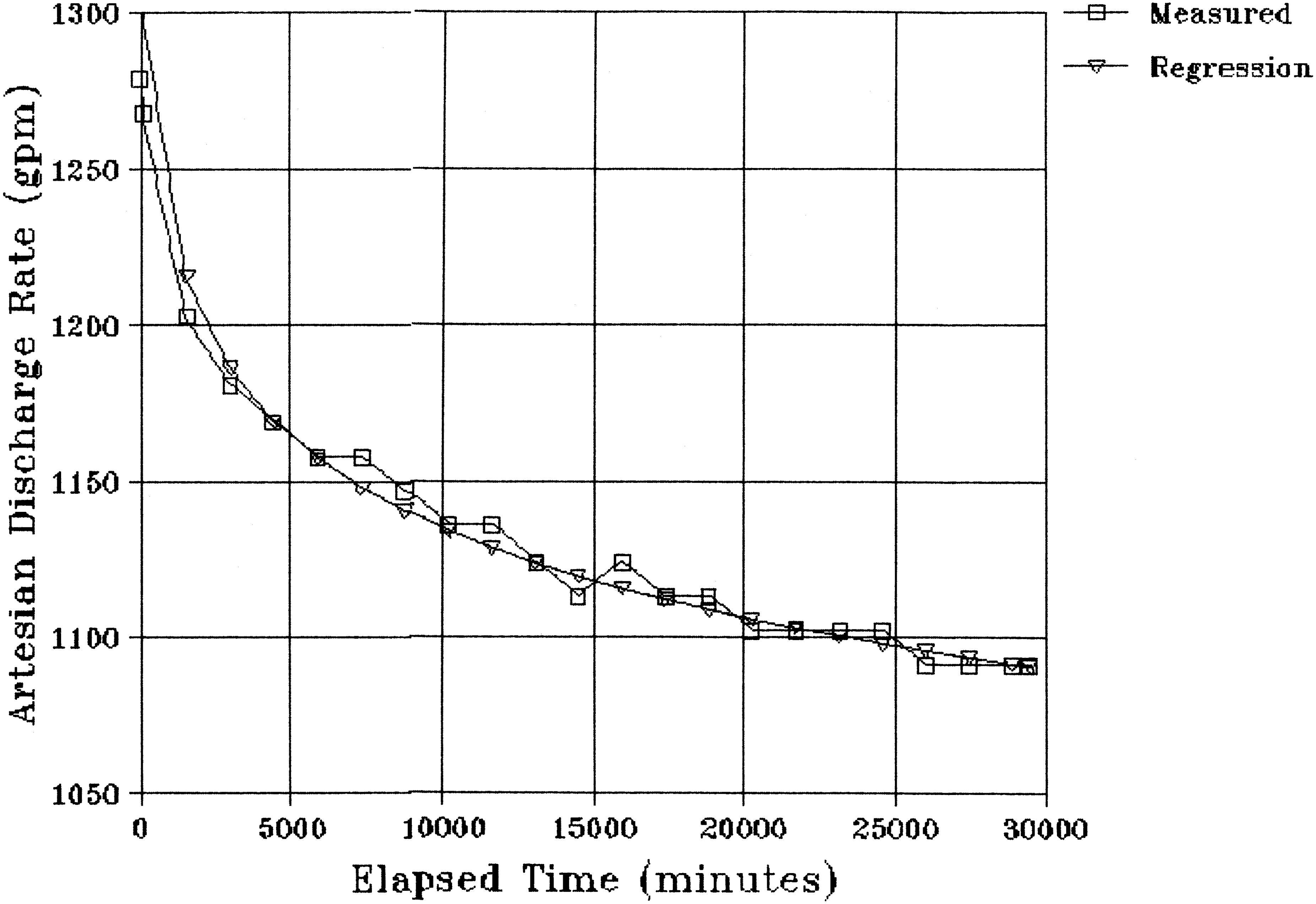


FIG. 6: DISCHARGE VERSUS TIME

Shell Well No. 2

Table 12: Projected maximum artesian flow for Well No. 2.

	Elapsed Time			Maximum Discharge Rate (gpm)
	Minutes	Days	Years	
Field Data:				
	3,000	2.08	--	1,186
	4,000	2.78	--	1,174
	5,000	3.47	--	1,164
	6,000	4.17	--	1,156
	7,000	4.86	--	1,150
	8,000	5.56	--	1,144
	9,000	6.25	--	1,139
	10,000	6.94	--	1,135
	12,000	8.33	--	1,127
	14,000	9.72	--	1,121
	16,000	11.11	--	1,115
	18,000	12.50	--	1,111
	20,000	13.89	--	1,106
	22,000	15.28	--	1,102
	24,000	16.67	--	1,099
	26,000	18.06	--	1,096
	29,500	20.49	--	1,091
Projected data:				
	43,200	30	--	1,075
	86,400	60	--	1,048
	129,600	90	--	1,033
	172,800	120	0.3	1,022
	216,000	150	0.4	1,014
	259,200	180	0.5	1,007
	302,400	210	0.6	1,001
	345,600	240	0.66	996
	388,800	270	0.7	992
	432,000	300	0.8	988
	475,200	330	0.9	985
	525,600	365	1	981
	1,051,200	730	2	956
	1,576,800	1,095	3	942
	2,102,400	1,460	4	932
	2,628,000	1,825	5	925
	3,153,600	2,190	6	919
	3,679,200	2,555	7	913
	4,204,800	2,920	8	909
	4,730,400	3,285	9	905
	5,256,000	3,650	10	901
	6,307,200	4,380	12	895
	7,358,400	5,110	14	890
	8,409,600	5,840	16	886
	9,460,800	6,570	18	882
	10,512,000	7,300	20	879

Equation 1 may be used to predict the discharge rate of Well

No. 2 for any given duration of "wide open" flow. Table 12 shows the maximum anticipated flows from Well No. 2 projected out to 20 years of continuously uninterrupted artesian discharge from the well, based on Equation 1. If the well is not left flowing at maximum uninterrupted discharge for 20 years, the artesian discharge rates between periods of recovery will be greater than the discharge rates predicted on Table 12.

It is important to examine the observed and predicted flowing discharge rates for Well No. 2 in order to evaluate the validity of the curve matching analysis shown on Figures 4 and 5. For example, if the relationship between discharge and drawdown in the well were known and could be described and predicted mathematically, the predicted discharge rates shown on Table 12 could be used to predict the drawdown at any given time. The relationship between discharge and drawdown is conventionally expressed as the discharge rate divided by the drawdown and is referred to as the specific capacity of a well. Specific capacity is a concept that is used to express well capacity in relation to an arbitrary, but constant, standard so that the relative productivity of different wells may be compared. Theis and others[1] demonstrated that the specific capacity of a well (ignoring well losses) can be determined from the Theis nonequilibrium equation or an abbreviated form thereof as follows:

$$\frac{Q}{s} = \frac{T}{264 \log(Tt/1.87\ r^2 S) - 65.5} \qquad \text{Equation 2}$$

Thus, the specific capacity of a well is directly proportional to T, and inversely proportional to log t, log $1/r^2$, and log 1/S.

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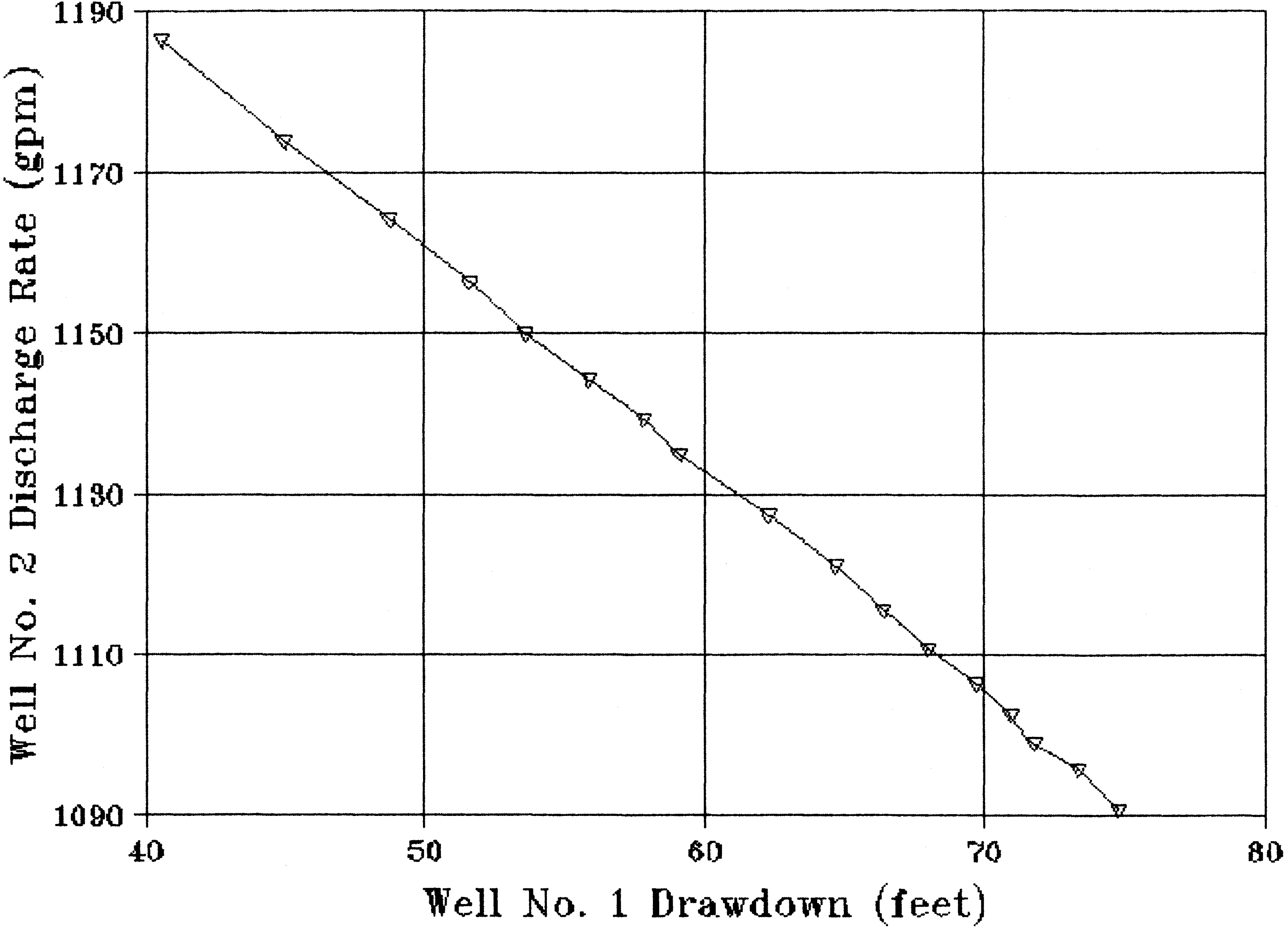
[1] Theis, C.V., R.H. Brown, and R.R. Meyer: Estimating the transmissibility of aquifers from the specific capacity of wells, in Methods of determining permeability, transmissibility, and drawdown, *U.S. Geol. Surv., Water Supply Papers, 1536-I, pp. 331-340, 1963.*

FIG. 7: DRAWDOWN VERSUS DISCHARGE

Shell Valley Wells Nos. 1 and 2



This means that specific capacity is not particularly sensitive to changes in t, r, or S; however, changes in T (transmissivity) cause corresponding changes in $\frac{Q}{s}$ (specific capacity).

The relationship between discharge from Well No. 2 and the drawdown observed in the Madison aquifer at Well No. 1 is shown on Figure 7. It is necessary to use the drawdown data from the observation well (Well No. 1) due to the fact that the well head configuration on Well No. 2 resulted in a vacuum in the pressure transducer port during flowing conditions and drawdown data were not obtained from Well No. 2 during the flowing part of the test. Drawdown in the Madison aquifer at Well No. 1 is less than the drawdown in the Madison at Well No. 2; however, it is impossible to separate Madison drawdown from Bighorn drawdown in Well No. 2 even if data were available and it may safely be assumed that the drawdown in Well No. 1 responds to the Madison flow from Well No. 2 in a similar manner as would be observed in Well No. 2 had there been a way to measure the Madison drawdown in Well No. 2.

Accordingly, the discharge versus drawdown curve shown on Figure 7 is not a true specific capacity curve. However, it is an accurate reflection of the trend of the relationship between drawdown and discharge in the Madison aquifer. The curve on Figure 7 shows a straight-line relationship between discharge and drawdown, or in other words, the specific capacity of Well No. 2 in regards to the flows from the Madison aquifer is a constant relationship. Since it has been demonstrated that specific capacity is directly proportional to transmissivity (Equation 2), the constant specific capacity for the Madison aquifer flow in Well No. 2 indicates that the transmissivity of the Madison aquifer penetrated by Well No. 2 is constant <u>even though the rate of discharge declines as drawdown increases.</u> The analysis thus presented demonstrates that the decreasing discharge observed in Well No. 2 is strictly a function of the drawdown decreases in the differential head driving the discharge and that the transmissivity of the artesian Madison aquifer remained constant during the test.

Accordingly, the time-drawdown curve shown on Figure 4 is simply a function of the rate of change in storage in the aquifer due to abstraction of groundwater and fullfills the assumptions and requirements of conventional non-steady state flow to a point sink as required by the Theis nonequilibrium equation. After 1,000 minutes of flow, the rate of the change of the discharge rate is small enough that the data converges on the Theis type curve and curve matching methodology is appropriate for evaluation of the time-drawdown curve. The discharge rate controlling the change in groundwater storage resulting in the time-drawdown curve is the average discharge rate from the Madison for the test period. As is previously describe, the 20-day discharge rate of 293 gpm is used in the analysis as a conservatively low value of average discharge.

The match point derived from curve fitting to the Theis nonequilibrium curve provides values of transmissivity and storativity for the Madison aquifer as follows:

$W(u) = 1$
$u = 10^{-3}$
$1/t = 10^{-5}$; $t = 100,000$ min
$s = 14.5$ feet

for $T = \frac{114.6\ Q}{s} W(u)$ Equation 3,

and $S = \frac{uTt}{2,693\ r^2}$ Equation 4,

where T = transmissivity (gallons per day per foot, gpd/ft)
S = storativity (dimensionless)
Q = well discharge (gallons per minute, gpm)
s = drawdown (feet, ft)

t = elapsed time since pumping started (minutes)
r = distance from flowing well to observation well or effective radius in single well test (feet, ft)

so $T = \frac{(114.6)(293)}{14.5}(1) = 2,316$ gpd/ft

and $S = \frac{(.001)(100,000)(2316)}{(2,693)(567)^2} = 2.67 \times 10^{-4}$

The foregoing analysis indicates that application of conventional straight-line solutions to a semilogarithmic plot of the time-drawdown data for the observation well in the Madison aquifer (Figure 5) is also appropriate. Application of the straight-line solution (Figure 5) provides a value of transmissivity of 2,209 gpd/ft and a storativity of 2.91 X 10^{-4} for the Madison aquifer. The slope of the straight line across one log cycle and the zero drawdown time intercept were determined by linear regression analysis of the data and the aquifer parameters calculated by a sofeware program developed by Morrison-Maierle, Inc. specifically for that purpose.These values are in good agreement with those derived from the nonequilibrium solution. Transmissivity and storativity values for the Madison aquifer are summarized on Table 13.

Table 13: Madison aquifer transmissivity and storativity.

Aquifer Parameter	Theis nonequilibrium solution	straight-line solution
Transmissivity (gpd/ft)	2,316 gpd/ft	2,209 gpd/ft
Storativity (dimensionless)	2.67 X 10^{-4}	2.91 X 10^{-4}

7.4. Inter-aquifer Flow in Well No. 2

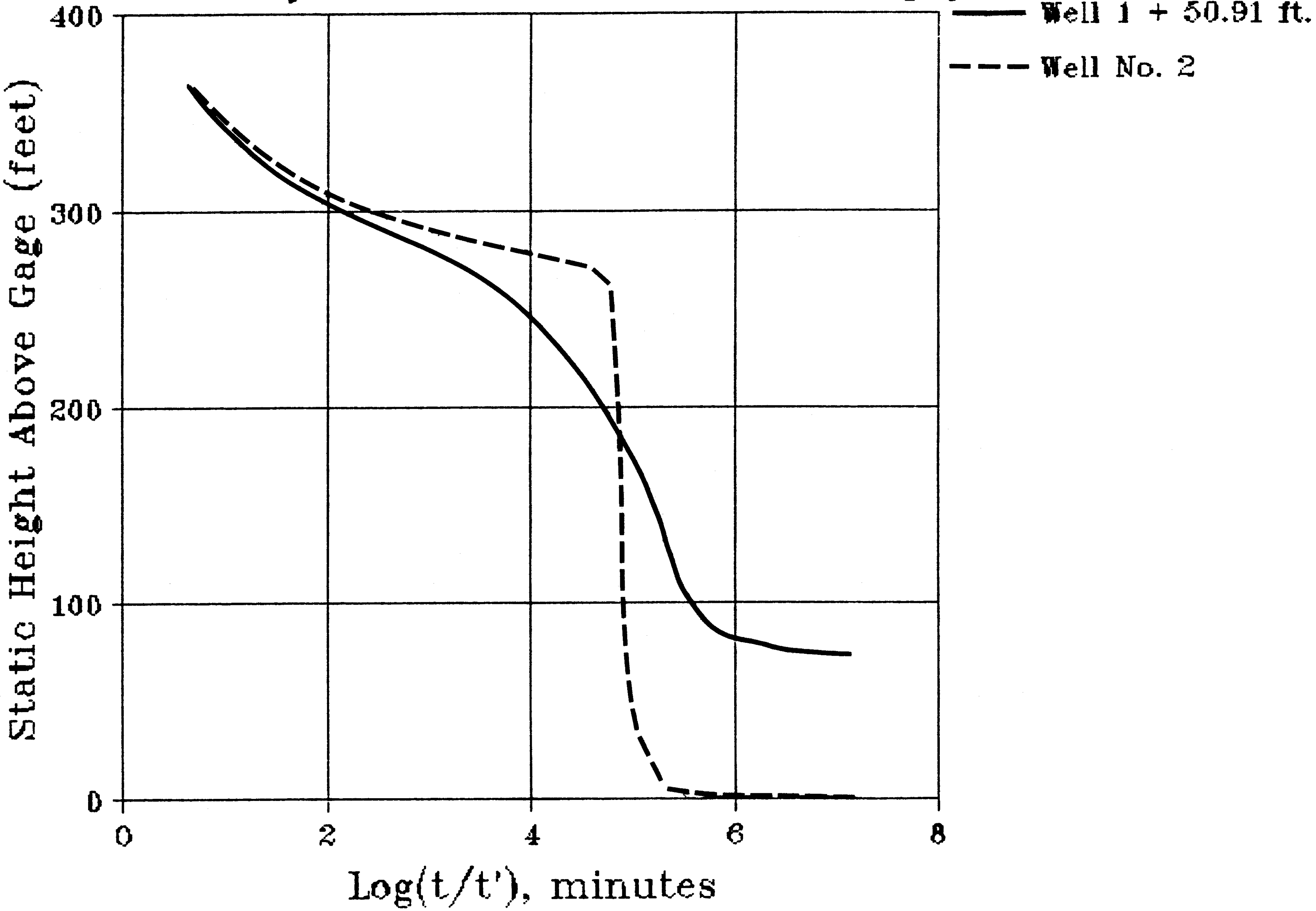
As previously described, the well head configuration prevented the collection of time-drawdown data from the flowing well (Well No. 2) during the long-term test. It was possible to valve the flow of Well No. 2 back until pressure could be recorded in the well head; however, determination of the maximum discharge rate of the well and its interaction with Well No. 1 was deemed more important than obtaining time-drawdown data, particularly in view of the difficulties that would prevail in interpreting the data from the multiple aquifer well. Review and analysis of the residual drawdown data collected from Well No. 2 during a nine-day recovery period following 31 days of flow testing of Well No. 2 provides some insight into the difficulties of interpreting the data from the multiple aquifer well.

Residual drawdown data for Well No. 1 are presented in Appendix G and for Well No. 2 in Appendix H. Both wells were shut-in within a minute of each other. Residual drawdown curves for the two wells are shown on Figure 8 based on the data compiled in Appendices G and H. The residual drawdown curves are plotted in terms of actual feet of head with respect to the gage elevation rather than as drawdown. The pressure gage port for Well No. 1 was 50.91 feet higher in elevation than the port on Well No. 2, therefore 50.91 feet of head was added to the water level elevations calculated for Well No. 1 from the residual drawdown data in order to bring the Well No. 1 data to a common reference datum with Well No. 2. In other words, if the Well No. 1 pressure gage had been at the same elevation as that at Well No. 2, it would have read an additional 50.91 feet (22.06 psi) greater.

It is readily evident from the residual drawdown curves on Figure 8, as corrected to a common datum, that the residual pressure in both wells converged to the same static water level during the nine days of recovery in the shut-in wells. Well No. 1 is completed in only the Madison aquifer whereas Well No. 2 is

FIG. 8: RESIDUAL DRAWDOWN

Recovery data corrected to common gage elevation



completed both the Bighorn and Madison aquifers. Unless the pressures were the same in both aquifers, it would be anticipated that the water level in Well No. 1 would recover to a different elevation than that in Well No. 2. The tests conducted with the inflatable open hole packer showed that there was about 20 psi more pressure in the Bighorn aquifer than in the Madison aquifer. Therefore, it would not be anticipated that the pressure in Well No. 2, penetrating both the Bighorn aquifer and the Madison aquifer, would be the same (corrected for elevation difference) as the pressure in Well No. 1 which penetrates only the Madison aquifer. The fact that the two wells show the same shut-in pressures, when corrected to a common gage datum, indicates that water from one aquifer is recharging the other with the result that the shut-in pressure is reflective of only the formation pressure of the lower pressure aquifer.

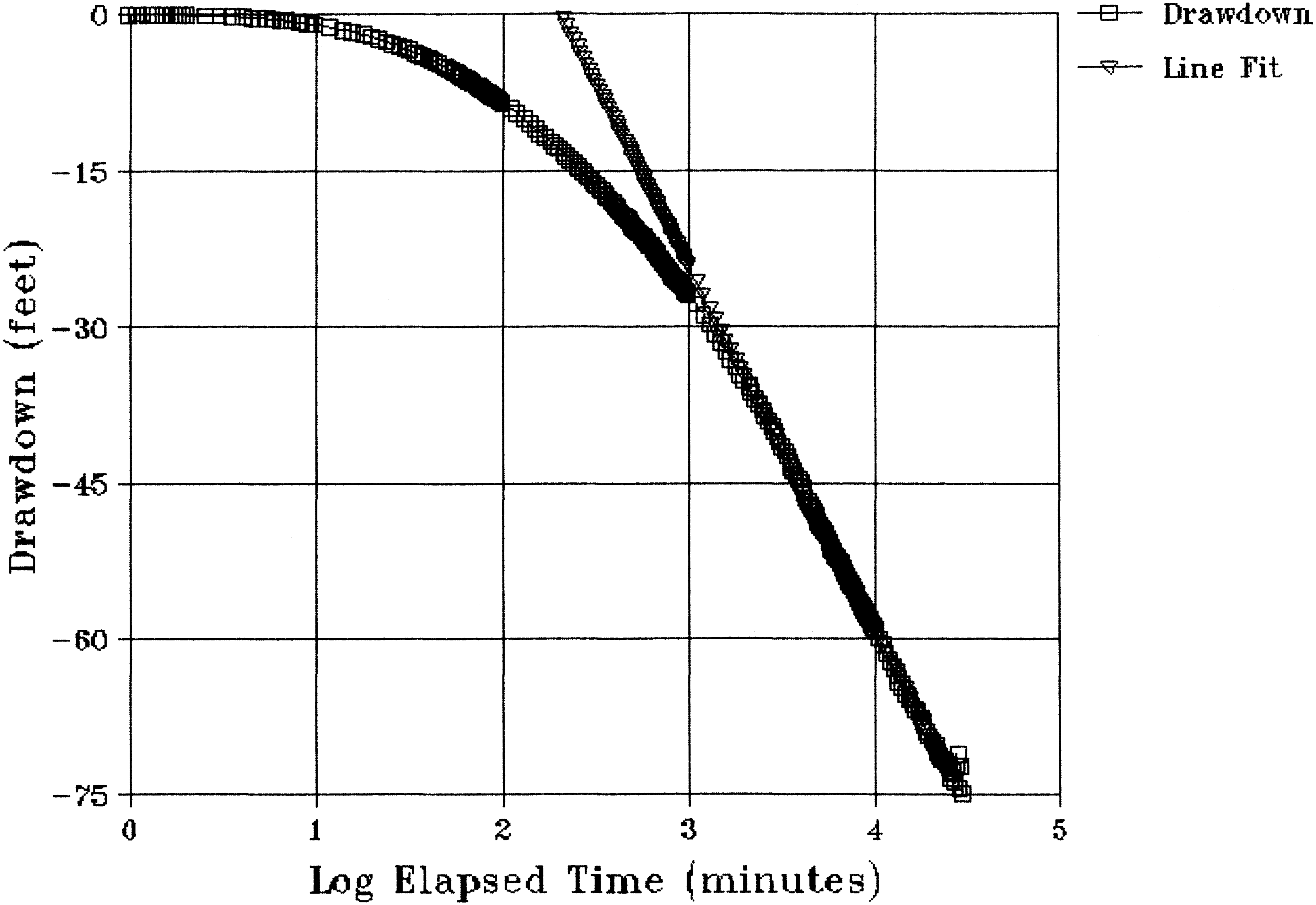
Further evidence indicates that the shut-in pressure of Well No. 2 is essentially the shut-in pressure of the Madison aquifer and that the water from the Bighorn aquifer is flowing up the borehole of Well No. 2 and recharging the Madison aquifer when the well is shut-in. The shut-in pressure in Well No. 1 at the start of the long-term flow test was 143 psi or 18 psi lower than the 161 psi at Well No. 2. When the 50.91 foot (22.06 psi) elevation difference between the two wells is taken into account, Well No. 1 exhibited a pressure about 4 psi greater than Well No. 2 despite the fact that the Bighorn aquifer penetrated by Well No. 2 exhibited 20 psi more pressure than the Madison aquifer when the inflatable packer was used to isolate the two aquifers on August 25 through 27, 1986. The slight difference of 4 psi between the two wells is within the potential error of the pressure gages used to measure the shut-in pressures and it is probable that the shut-in pressures of the two wells prior to the long-term flow test were essentially identical. Again, the similar pressures in the two wells when shut-in is contradictory to the difference in aquifer pressure measured between the Bighorn and the Madison with the inflatable packer isolating the two formations.

The forgoing observations indicate that one aquifer is stealing pressure from the other in the borehole of Well No. 2. Since the pressure differential will go from the higher pressure aquifer to the lowere pressure aquifer, the observations indicate that the Madison aquifer is receiving recharge from the Bighorn aquifer and the pressure differential between the Bighorn and the Madison is absorbed by the Madison when Well No. 2 is shut-in. Accordingly, the shut-in pressure in Well No. 2 represents only the pressure of the Madison aquifer. Two lines of analysis can be pursued to demonstrate the basis for this conclusion.

The first line of evidence showing the recharge of the Madison by the Bighorn due to interformational differential under static conditions in the borehole of Well No. 2 is the residual drawdown curves shown on Figure 8. Application of a conventional straight-line solution for transmissivity and storativity to the late residual drawdown data is shown on Figure 9 and provides values of 5,783 gpd/ft for transmissivity and 11.59 for storativity. The value of transmissivity of 5,783 gpd/ft is considerably greater than the transmissivity of 2,316 gpd/ft derived for the Madison from the observation well data. The storativity value of 11.59 is patently in error since it would require the aquifer to yield 11.59 cubic feet of water for each cubic foot of aquifer material. Assumption of a wide range of effective radii for the flowing well does not reduce the calculated storativity

FIG. 9: STRAIGHT-LINE SOLUTION

Well No. 1 as Madison Observation Well



value to a physically possible value, based on the recovery data measured in the flowing well. The excessively high values of transmissivity and storativity provided by the residual drawdown data are reflective of the recharge of the Madison aquifer by the Bighorn aquifer. The flow of water from the Bighorn aquifer to the Madison results in an apparently impossible value of storativity and distorts the transmissivity value as well. Moreover, examination of Figure 9 indicates that the residual drawdown recovery rate never does reach a true straight line but that the recovery rate accelerates throughout the recovery period, presumably due to the effects of recharge from the Bighorn aquifer.

A second line of evidence supporting the conclusions regarding flow from the Bighorn to the Madison in the borehole of Well No. 2 under shut-in or static conditions is that of the pressure differentials for the two aquifers. The surface shut-in pressure of the Madison aquifer of 143 psi is equivalent to a downhole pressure (formation pressure) of 1,131 psi at a depth of 2,280 feet which the geophysical logs (Appendix D) show to be the base of the lowermost major water-bearing zone in the Madison aquifer. Similarly, the downhole pressure (formation pressure) at the top of the major water-bearing zone in the Bighorn aquifer at a depth of about 2,900 feet is 1,418 psi. The separation of 620 vetical feet between the two water-bearing zones requires about 269 psi to cause water to rise from the top of the Bighorn zone to the base of the Madison zone. The downhole pressure of 1,418 psi minus the pressure of 269 psi required to cause water to rise to the elevation of the base of the first major water-bearing zone in the Madison leaves a downhole pressure from the Bighorn at 2,280 feet of 1,149 psi. Since the formation pressure in the Madison aquifer at the same elevation is only 1,131 psi, the pressure of 1,149 psi remaining from the Bighorn exceeds the Madison formation pressure by 18 psi and water can flow from the Bighorn into the Madison formation when the well is shut-in to static conditions. The 18 psi is very close to the pressure differential of 20 psi measured across the inflatable packer and is essentially the same differential when the accuracy of the pressure gages is taken into consideration along with the accuracy of the locations of the water-bearing zones identified from the geophysical logs.

An estimate of the rate of flow from the Bighorn to the Madison when Well No. 2 is shut-in and is under "static" conditions may be obtained from the specific capacity values for Well No. 2. The shut-in pressure of the well has been demonstrated to be equal to the Madison aquifer pressure and is 161 psi. The packer test demonstated that the pressure of the Bighorn aquifer is about 20 psi greater than that of the Madison, so the Bighorn aquifer shut-in pressure may be estimated to be about 181 psi which is equivalent to a static water level 417.7 feet above the gage elevation at the land surface. The spinner flowmeter log of Well No. 2 demonstrated a flow of 796.8 gpm from the Bighorn aquifer. If it is assumed that the yield of 796.8 gpm from the Bighorn used essentially all of the 417.7 feet of differential head available to artesian flow, then the specific capacity of the Bighorn aquifer can be calculated by dividing 796.8 gpm by 417.7 feet to derive a value of 1.91 gallons per minute per foot of drawdown (gpm/ft-dd). In turn, the 18 to 20 psi differential between the two formations is equivalent to 41.5 to 46.2 feet of differential head which when multiplied by the specific capacity of 1.91 gpm/ft-dd indicates a potential flow from the Bighorn to the Madison of 79 to 88 gpm.

7.5. Long-term Well Yields

It was recognized from the onset of testing of Well No. 2 that derivation of separate values of transmissivity for the Bighorn aquifer versus the Madison aquifer would require a certain number of assumptions; however, there appeared to be a reasonable chance of estimating a value of transmissivity for the Bighorn aquifer because the spinner logs were available to use in conjunction with the time-drawdown data from the flowing well. This approach changed when it was discovered that flowing Well No. 2 at maximum artesian discharge did not leave enough pressure in the well to cause the water to rise above the discharge pipe and create pressure at the well cap. In fact, the flow of water out of the discharge pipe created a negative pressure (vacuum) at the well cap.

When this condition was discovered, there were two alternatives to be selected between as a scheme for the aquifer test. One scheme would be to valve back the well until the well head was still pressurized under flow so that continuous drawdown and recovery data could be collected during the test. This alternative would mean that the discharge from the well would be reduced from the maximum potential yield but there would be an opportunity to estimate the aquifer constants. The alternative scheme would be to allow the well to flow at maximum discharge at the sacrifice of time-drawdown data needed to determine aquifer constants. Consideration of the alternatives produced the conclusion that the ultimate objective of the groundwater exploration program and of testing the well was to determine the maximum yield. The second alternative was selected and the well was tested at maximum discharge.

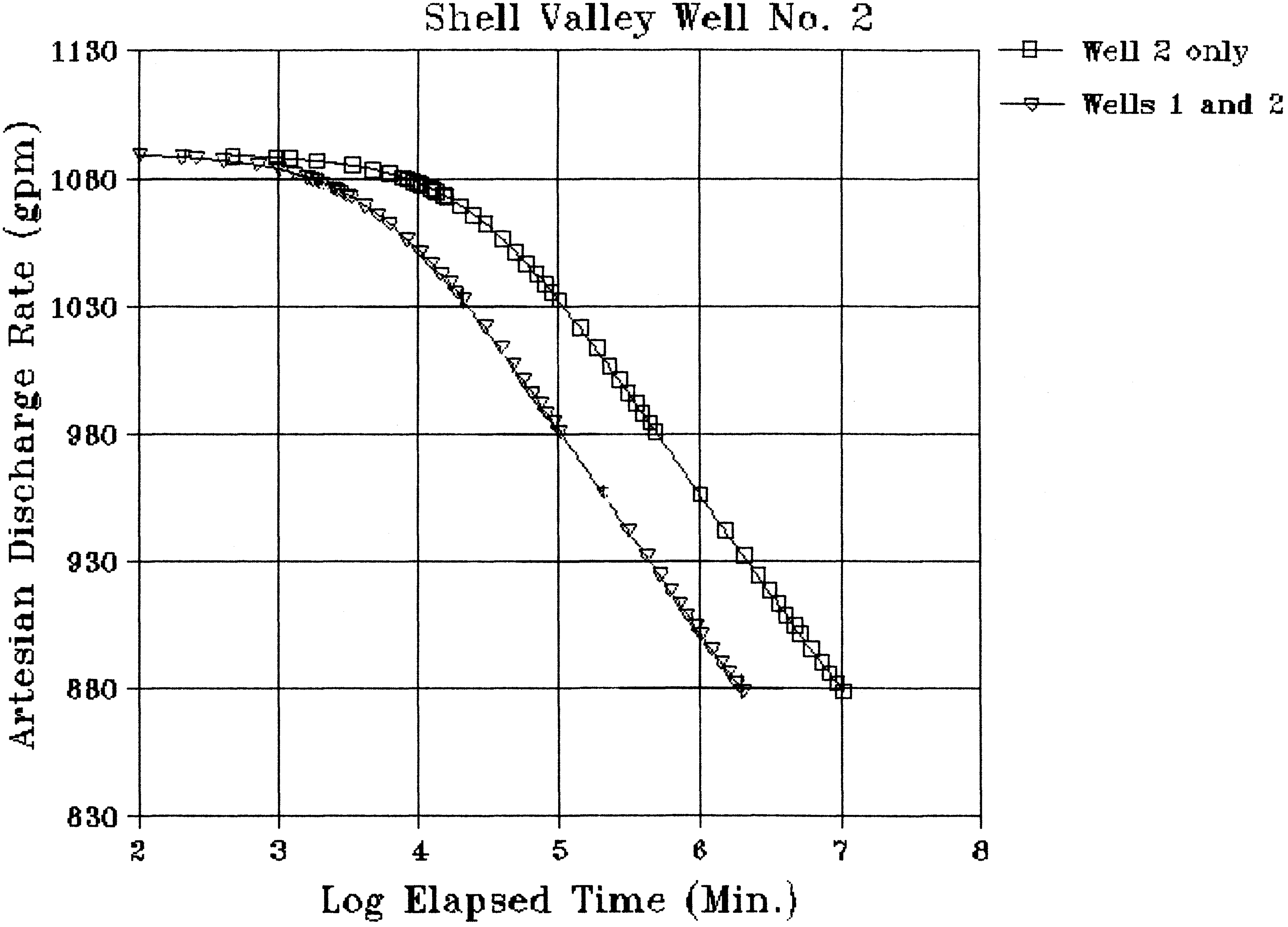
Consequently, the aquifer constants of transmissivity and storativity, which are normally used in projections of long-term declines in groundwater levels around a well and in predicting long-term safe well yield, were not determined for the Bighorn aquifer. However, the aquifer test yielded other data which is just as useful in determining the long-term potential yield of Well No. 2 at maximum flow. The data referred to is the relationship determined between the maximum rate of artesian discharge and elapsed time of flow (Equation 1) as shown on Table 12. The values presented on Table 12 are for the discharge from Well No. 2 if Well No. 1 is not flowing.

Table 14 shows the effects of maximum discharge from Well No. 1 on the discharge rate of Well No. 2 after Well No. 2 has been flowing at maximum discharge for 20 days. The discharge rate of Well No. 2 declined from 1090 gpm to about 1,046 gpm over the approximately 11 day period following the start of flow from Well No. 1. The interference effect of Well No. 1 on the maximum predicted yield for Well No. 2 is shown on Figure 10. The

Table 14: Well No. 2 Discharge as affected by Well No. 1.

Time Elapsed Since Well No. 1 Opened	Well No. 2 Maximum Discharge (gallons per minute)
1.00 minute	1,090.7
7.92 hours	1,085.1
15.92 hours	1,079.5
19.92 hours	1,073.9
2.33 days	1,068.3
3.33 days	1,068.3
4.33 days	1,068.3
5.33 days	1,068.3
5.83 days	1,068.3
6.33 days	1,062.7
6.83 days	1,057.1
7.33 days	1,052.6
8.33 days	1,051.5
8.83 days	1,045.8
9.33 days	1,045.8
10.33 days	1,045.8
11.00 days	1,045.8

FIG. 10: MAXIMUM YIELD PROJECTION



uppermost curve on Figure 10 is the predicted yield of Well No. 2 from Table 12 without interference from Well No. 1. The lowermost curve on Figure 10 is the predicted yield of Well No. 2 with Well No. 1 in simultaneous and continuous operation with Well No. 2.

It must be recognized that the predicted decline in well yield shown on Figure 10 is based on continuously uninterrupted discharge from Wells Nos. 1 and 2 for the 20-year period shown. The predicted yield does not take into account a number of factors that may influence the yield of the well over the long-term. For example, if the wells are not operated continuously without ceasing for 20 years, the maximum yield of Well No. 2 (and Well No. 1) will remain greater than that predicted on Figure 10. The analysis shown on Figure 10 also assumes that there is no recharge of the aquifer system. It is not known to what extent long-term fluctuations in the recharge and groundwater levels will affect the maximum yield of Well No. 1 or Well No. 2. However, the data presented in this analysis indicates that the flowing artesian discharge of groundwater from Well No. 2, with or without interference from Well No. 1 should remain in excess of 800 gpm for the next twenty years.

In order that the logarithmic time frequency used on Figure 10 might be easier to read, the following table is provided to show the relationship between logarithmic values and real time.

Table 15: Logarithmic values of time.

Time			
Minutes	Days	Years	Log of Time in Minutes
1	--	--	0
10	--	--	1
100	--	--	2
1,000	--	--	3
10,000	6.9	--	4
100,000	69.4	--	5
1,000,000	694.4	1.9	6
10,000,000	6,944.4	19.0	7

8. WATER QUALITY

Water quality samples were collected from Well No. 1 at two different times. The first sample was collected on April 30, 1984 at the end of a 10-day flow test of the Madison aquifer following the hydrofracture stimulation of the well. The total depth of the well at the time of the sampling was 2,440 feet and the deepest potential aquifer formation penetrated was the Madison Group. Measurements conducted at the well head on April 30, 1984 indicated the following water quality parameters for groundwater from the Madison aquifer:

pH = 6.5 Temperature = 14° C

Specific Conductance = 430 umhos/cm @ 25° C

Bicarbonate Alkalinity as HCO_3 = 303 mg/l

Total Alkalinity as $CaCO_3$ = 248 mg/l

The results of laboratory analysis of the April 30, 1984 water quality sample of the Madison aquifer groundwater are shown on Table 15.

The second water quality sample collected from Well No. 1 was collected on December 11, 1984 after the well was deepened to 3,041 feet and penetrated both the Madison and Bighorn strata; however, packer testing of the well indicated that the Bighorn formation was not permeable and was not yielding groundwater. Therefore, the December 11, 1984 groundwater sample is regarded to be a sample of Madison aquifer groundwater. Well head water quality parameters were as follows:

pH = 6.7 Temperature 14° C

Specific Conductance = 434 umhos/cm @ 25° C

Bicarbonate Alkalinity as HCO_3 = 307 mg/l

Total Alkalinity as $CaCO_3$ = 251 mg/l

The results of laboratory analysis of the December 11, 1984 sample of Madison aquifer groundwater are shown on Table 15.

Well No. 2 was sampled for groundwater quality on August 27,

Table 16: Water quality parameters, Madison aquifer, Well No. 1.

	04/30/84	12/11/84
Total Coliform Bacteria	Greater than 16 colonies/100 ml.	
pH, Standard Units	7.3	7.3
Specific Conductance, umhos/cm	342	388
Total Dissolved Solids, mg/l	253	242
CATIONS	mg/l	mg/l
Total Hardness as $CaCO_3$	240	237
Calcium	50	52
Magnesium	28	26
Sodium	11	5
Potassium	-1	1
ANIONS		
Total Alkalinity as $CaCO_3$	205	206
Bicarbonate Alkalinity as HCO_3	250	251
Carbonate Alkalinity as CO_3	0	0
Hydroxide Alkalinity as OH	0	0
Acidity as $CaCO_3$	0	0
Chloride	19	32
Fluoride	0.50	0.28
Nitrate + Nitrite as N	0.39	0.05
Sulfate	17	12
TRACE ELEMENTS		
Arsenic	-0.005	--
Barium	-0.1	--
Boron	-0.1	--
Cadmium	-0.005	--
Chromium	-0.02	--
Copper	-0.02	--
Iron	-0.05	--
Lead	-0.02	--
Manganese	-0.02	--
Mercury	-0.001	--
Selenium	-0.005	--
Silver	-0.02	--
Zinc	-0.02	--
Silica as SiO_2	1.4	--
RADIONUCLIDES		
Gross Alpha	0 ± 2 pCi/l	--
Gross Beta	2 ± 3 pCi/l	--
Radium 226	0.7 ± 0.6 pCi/l	--
Uranium as U	0.003 mg/l	--

A minus sign (-) means less than the reported value was present.
A dash (--) means the parameter was not analysed.

1985. The water quality samples were collected while an inflatable packer was seated in the borehole separating the Bighorn aquifer water from the Madison aquifer water. The first suite of water quality samples from the respective aquifers were collected after 819 minutes of stepped rate testing of the two aquifers. The second suite of water quality samples from the two aquifers was collected at the end of the 1,509 minute test. The inflatable packer remained properly sealed throughout the testing procedures and there was no evidence of hydraulic communication or comingling of waters of the two aquifers during the tests. The results of field measurements of pH, temperature, and specific conductance at the well head are shown on Table 16.

Table 17: Well No. 2 field measurements of water quality parameters.

	Madison				Bighorn			
Elapsed Time (minutes)	Flow Rate (gpm)	pH	S.C.	Temp. (° C)	Flow Rate (gpm)	pH	S.C.	Temp. (° C)
90	318.7	6.2	470	14.5	16.5	6.2	450	15.0
159	94	6.3	455	14.0	26.9	6.4	448	15.0
219	332.2	6.2	465	14.0	67.3	6.2	450	15.0
289	363.6	6.3	460	14.0	170.6	6.2	450	15.0
819	363.6	6.2	460	15.5	170.6	6.3	445	16.0
1,184	363.6	6.2	468	16.0	170.6	6.1	468	16.0
1,509	345.6	6.2	454	16.0	170.6	6.2	454	16.0

The results of laboratory analysis of water quality samples collected from the Bighorn and Madison aquifers at approximately the midpoint of the 24-hour stepped rate test with a packer in the borehole separating the two aquifers are shown on Table 17. The results of laboratory analysis of water quality samples similarly collected from the Bighorn and Madison aquifers at the end of the 24-hour stepped rate test are shown on Table 18.

The results of the tests as shown on Tables 15 through 18 indicate that the quality of the groundwater from the Madison and

Table 18: Interim Water Quality Analysis from Well No. 2.

	Madison	Bighorn
pH, Standard Units	7.4	7.4
Specific Conductance, umhos/cm	433	416
Total Dissolved Solids, mg/l	266	286
CATIONS		
	mg/l	mg/l
Total Hardness as $CaCO_3$	218	218
Calcium	46	46
Magnesium	25	25
Sodium	-1	1
Potassium	-5	-5
ANIONS		
Total Alkalinity as $CaCO_3$	197	194
Bicarbonate Alkalinity as HCO_3	240	237
Carbonate Alkalinity as CO_3	0	0
Hydroxide Alkalinity as OH	0	0
Acidity as $CaCO_3$	0	0
Chloride	1	-1
Fluoride	0.4	0.4
Nitrate + Nitrite as N	0.69	0.21
Sulfate	11	8

A minus sign (-) means less than the reported value was present.
A dash (--) means the parameter was not analysed.

Bighorn aquifers is of excellent quality for use as a municipal water supply as well as for agricultural irrigation. The concentrations of minerals present as dissolved solids in the groundwater from the two aquifers does not even approach recommended limits for concentrations of dissolved solids in drinking water let alone the maximum permissible concentrations permissible under the U.S. Environmental Protection Agency (EPA) Interim Primary Drinking Water Standards. In addition, the data shown on Tables 17 and 18 reveal that the chemical quality of the Madison and Bighorn groundwater is essentially identical, a fact which is not surprising in view of the geological/mineralogical similarity of the two aqufers and their common recharge area.

Table 19: Final water quality analysis from Well No. 2.

	Madison	Bighorn
Total Coliform Bacteria	TNTC	TNTC
pH, Standard Units	7.5	7.4
Specific Conductance, umhos/cm	428	433
Total Dissolved Solids, mg/l	234	264
CATIONS		
	mg/l	mg/l
Total Hardness as $CaCO_3$	225	222
Calcium	47	46
Magnesium	26	26
Sodium	3	3
Potassium	-5	-5
ANIONS		
Total Alkalinity as $CaCO_3$	194	197
Bicarbonate Alkalinity as HCO_3	237	240
Carbonate Alkalinity as CO_3	0	0
Hydroxide Alkalinity as OH	0	0
Acidity as $CaCO_3$	0	0
Chloride	-1	-1
Fluoride	0.5	0.4
Nitrate + Nitrite as N	0.61	0.54
Sulfate	16	12
Cyanide	-0.02	--
Phenol	0.012	--
TRACE ELEMENTS		
Aluminum	-0.1	-.01
Arsenic	-0.010	-0.010
Barium	-0.1	-0.1
Boron	-0.1	-0.1
Cadmium	-0.005	-0.005
Chromium	-0.02	-0.02
Copper	0.04	0.03
Iron	0.07	0.13
Lead	-0.02	-0.02
Manganese	-0.02	-0.02
Mercury	-0.001	-0.001
Molybdenum	-0.05	-0.05
Nickel	0.04	0.03
Selenium	-0.005	-0.005
Silver	-0.02	-0.02
Vanadium	0.07	0.05
Zinc	0.11	0.02
Silica as SiO_2	4.58	0.02
RADIONUCLIDES		
	pCi/l	pCi/l
Gross Alpha	0.0 ± 1.0	0.0 ± 0.8
Gross Beta	0.7 ± 1.4	1.0 ± 1.4

TNTC means the coliform colonies were too numerous to count.
A minus sign (-) means less than the reported value was present.
A dash (--) means the parameter was not analysed.

Similarly, analysis of the radionuclide concentrations in the groundwater of the two aquifers shows the radionuclide concentrations to be well below threshold concentrations that may affect suitability of the water for public supplies and require additional analysis. For example, gross alpha concentrations, including radium 226, may be as high as 15 pCi/l before it is necessary to conduct separate analysis for uranium and subtract the uranium concentration from the gross alpha concentrations. Gross beta concentrations must be 50 pCi/l or more before it is necessary to do analysis to determine the major radioactive constituents in the water. The threshold value for combined radium 226 and radium 228 concentrations is 5.0 pCi/l. The concentrations of radionuclides in the Madison and Bighorn groundwaters are substantially less than the threshold values of concern to use of the water for drinking water supplies.

Only two chemical characteristics of the groundwater are present in concentrations that should be considered if the groundwater is to be used as a public drinking water supply. One chemical characteristic is the hardness which is in excess of 200 mg/l for both aquifers thus classifying the groundwater as very hard groundwater. The hardness is not a hazard to health and is an acceptable condition for many water users in the western United States. The second chemical constituent meriting further consideration is the presence of 0.012 mg/l of phenol detected in the flow from the Madison aquifer in Well No. 2.

Phenol is an organic hydrocarbon compound which is present in natural petroleum as well as in many refined oils and greases. Federal and State regulatory agencies have not established a drinking water standard for the presence of phenol in drinking water; however, the Wyoming State Department of Environmental

Quality requires that where groundwater becomes contaminated by an oil spill, the aquifer must be restored so that only 0.001 mg/l of phenol concentration or less remains in the contaminated aquifer. The nondegradation standard does not stem from a health hazard presented by the phenol but is simply a nondegradation policy.

There are two potential sources of the phenol detected in the Madison groundwater flow from Well No. 2. One potential source is a tar sand which was drilled through in a zone above the Madison aquifer. Although the tar sand is cemented off behind the well casing, it is possible that some of the petroleum residue continued to circulate into the well from the mud pit as the well was drilled. If this was the case, the concentration of phenol should become less as the well is used over a period of time. A second, and more likely source of the phenol may be the lubricant used on the tubing joints used with the packer placed in the well for the testing and water quality sampling. If the tool joint lubrication was the source of the phenol, the phenol should not be present in tests in the future. A third, but unlikely, source of phenol that might be possible is petroleum residue that could be present in the Madison formation. However, natural hydrocarbon residue was not observed in the drill cuttings of the Madison aquifer rocks.

A final possibility, which is the probable source of the phenol in the Madison aquifer water quality sample, is a zone of oil-bearing sand at the base of the Bighorn Dolomite in the depth interval equivalent to the 2,939 to 2,941 foot zone in Well No. 1 (see lithologic log, Appendix A). Although the phenol appeared in the Madison water sample, it is quite possible that the entire borehole was contaminated with phenol from the water flowing up the well prior to installation of the packer. A separate phenol sample was not taken from the Bighorn aquifer water. Consequently, it is recommended that Well No. 2 be retested for phenol if the well is to be utilized as a public drinking water supply source.

The phenol is not present in concentrations great enough to be detectable to humans drinking the water and standards and criteria for public drinking water supplies do not list phenol as a health hazard. If the phenol were present at concentrations significant to public health, the water would probably be unpalatable. The best way to deal with the phenol concentration measured in the Madison aquifer water at Well No. 2 is to resample for phenol if the well is to be used for a public water supply. Retesting for phenol may reveal that the phenol concentrations were a transient condition somehow related to the well construction activites.

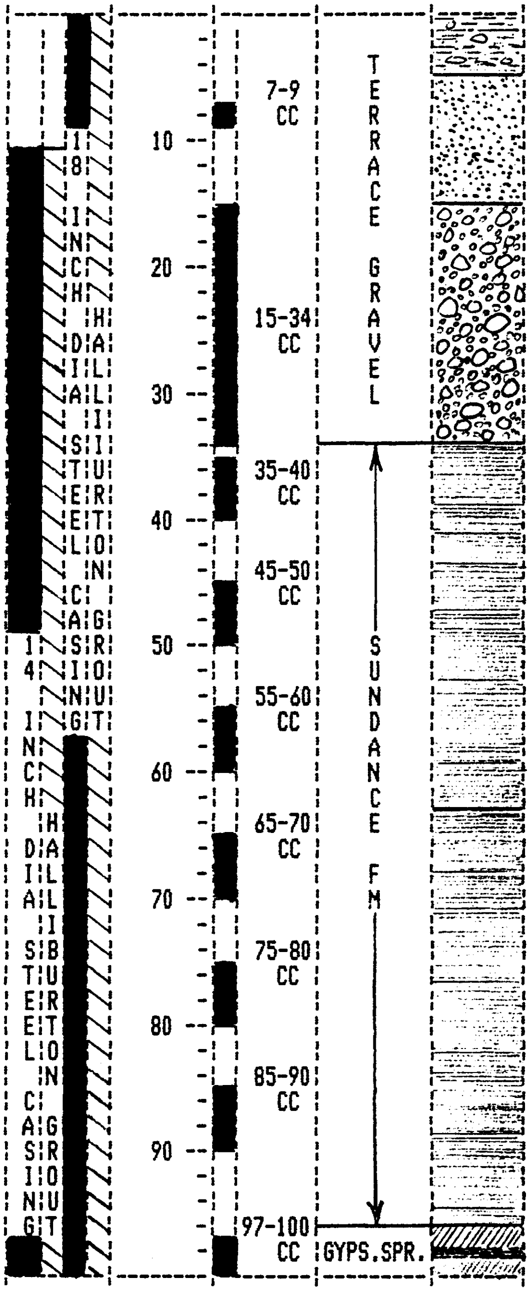
A final consideration in the use of the two wells for public drinking water supply sources, is the high concentrations of coliform bacteria detected in every bateriologic sample collected from the two wells. This should particularly be a concern in Well No. 1 which was subjected to a gelled sand hydrofracture treatment. The gelled fluid used in the hydrofracture treatment is an organic base and may provide a media for microbiologic growth. Although the well was flowed for 10 days prior to collection of the first coliform sample, it is possible that residual decomposition of the gelled fluid was still occuring somewhere in the formation. The coliform samples collected from Well No. 2 were subject to several potential sources of sample contamination during the collection process, namely the oilfield tubing used to install the packer, the packer assembly, and the discharge pipes from which the samples were collected. If the wells are to be used for a source of public drinking water, additional coliform sampling should be performed to determine whether or not microbiologic contamination remains in the wells requiring disinfection of the wells prior to their use as a public water supply.

APPENDIX A

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 1 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY | DEPTH (FEET) | SAMPLE DEPTHS | GEOLOGIC UNIT | GRAPHIC LOG



CLASSIFICATION AND PHYSICAL DESCRIPTION

0-5 TOPSOIL,SPARSE GRAVELS

5-15 SAND, Weathered dolomite grit, somewhat gypsiferous.

15-34 GRAVEL, Light gray (10YR-7/2) to white (10YR-8/2), rounded 1-3 inch gravel with scattered cobbles, mostly dolomite with some limestone.

34-63 SHALE, Olive gray (5Y-5/2) to olive (5Y-5/3), silty,gypsiferous. Some brownish-yellow (10yr-6/8) mottles. Occassional bellemnite fossils.

63-96 SHALE, Gray (5Y-5/1) to dark gray (N5/), gypsiferous, blocky to fissile, moderately indurated. Scattered bellemnite fossils to 76 ft.

96-102 GYPSUM, light brown (7.5YR-6/4) with interbedded pale yellow (2.5Y-7/4) claystone.

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig

DRILLING METHOD

0-50, MR.
50-100, ARR.

BIT TYPE

0-10 22 inch drag bit
10-50 22 inch soft roller bit
50-100 22 inch medium roller bit

DRILLING FLUID

0-50 Clear water
50-100 CMS Gel

DRILL FLUID LOSS

15-34 Moderate

CASED INTERVAL

0-127 18" Dia.
0-597.7 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet
Casing separation from 1810-1815

CHARACTER OF DRILLING

0-34 Some caving of gravel into open hole

34-100 Drilled smoothly penetration rate is about 16 ft./hr.

EXPLANATION

¦ ¦	NO SAMPLE
■	SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

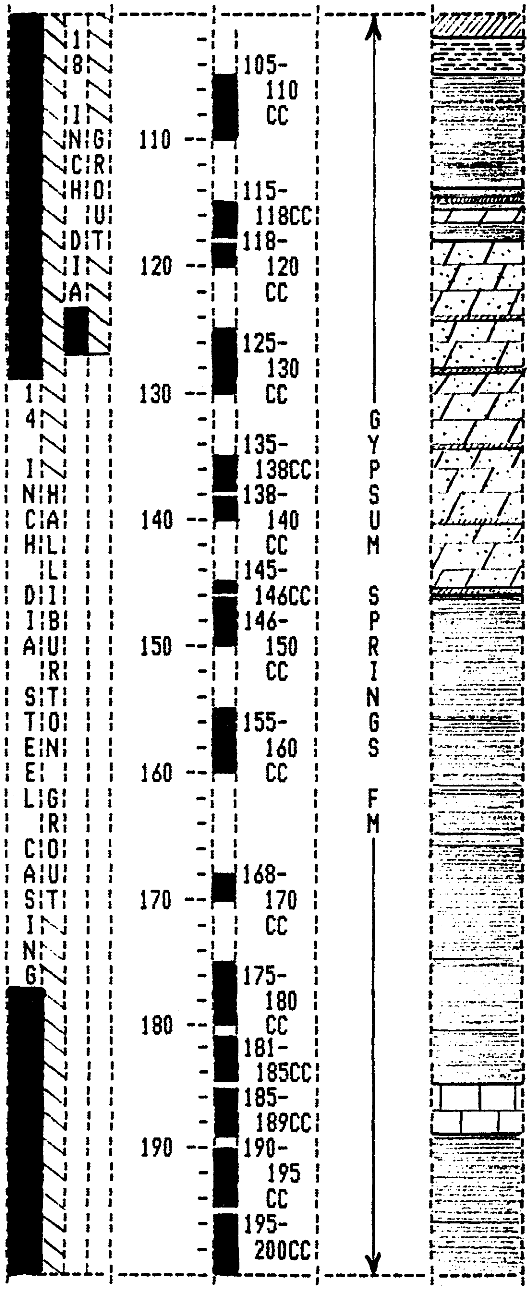
TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 2 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION



96-102 GYPSUM

102-105 CLAYSTONE, Pale yellow (2.5Y-7/4), gypsiferous.

105-114 SHALE, Light olive gray (5Y-6/2), gypsiferous.

114-118 SHALE, Dark gray (5N/), intercalated with light gray dolomite and light brown to reddish brown vuggy gypsum. Hard fissile shale.

118-146 DOLOMITE, Light gray (2.5Y-7/0) to pale yellow ((2.5Y-7/4), laminated, very fine sandy dolomite. Intercalated with strong brown (7.5YR-4/6) gypsum. Vuggy. Some light brownish gray (10YR-6/2) sucrose anhydrite also present. Dolomite becomes alternating light gray (2.5Y-6/0) and brown (10YR-5/3) beds from 137-141 ft. Sparry gypsum at base of unit.

146-185 SHALE, Light olive (5Y-6/2), fissile, gypsiferous shale.

Becomes gray (2.5Y-5/0), with belemnite and brachiopod fossils from 168-185.

185-189 LIMESTONE, Gray (2.5Y-5/0), gypsiferous, pyritic limestone.

189-261 SHALE, Light brownish gray (2.5Y-6/4) to to strong brown (7.5YR-4/6) shale.

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

100-200, ARR.

BIT TYPE

100-200 17 inch medium roller bit.

DRILLING FLUID

100-200 CMS Gel with 0.5lb/bbl Driscose

180-200 LCM added to mud

DRILL FLUID LOSS

180-200 Losing about 2800 gal./hr. through dolomite unit at 127-146 feet.

CASED INTERVAL

0-127 18" Dia.
0-597.7 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet.
Casing separation from 1810-1815 feet.

CHARACTER OF DRILLING

Drilling smoothly, penetration rate is about 20 ft./hr.

EXPLANATION

¦--¦ NO SAMPLE

█ SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

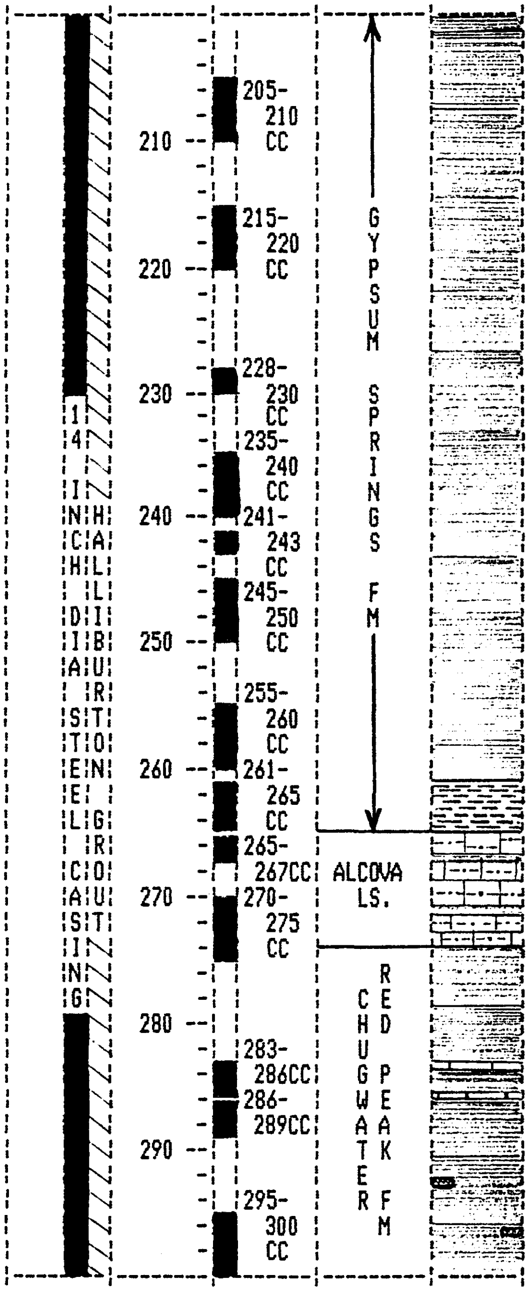
TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 3 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY | DEPTH (FEET) | SAMPLE DEPTHS | GEOLOGIC UNIT | GRAPHIC LOG



CLASSIFICATION AND PHYSICAL DESCRIPTION

189-261 SHALE, Reddish-brown (5YR-4/6), fissile shale.

Becomes alternating red (2.5YR-4/8 to 5/8) and gray (2.5YR-6/0) beds from 221-261

261-265 CLAYSTONE, White (5YR-8/1), soft, claystone.

265-274 LIMESTONE, Grayish-brown (2.5Y-6/2), pale red (2.5YR-6/2), red (10R-4/8), weak red (10R-4/4), and grayish brown (2.5Y-6/2) silty micrite and micrite, interbedded with red, hard, fissile shale.

274-311 SHALE, Red (2.5YR-5/8), soft, fissile shale. Pinkish-gray (7.5YR-6/2) limestone intercalated with the shale from 283-286.

Becomes light olive-gray (5Y-5/8) from 286-289.

Yellowish-red (5YR-5/8), soft, gypsiferous shale containing white anhydrite nodules from 289-300.

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

200-300, ARR.

BIT TYPE

200-300 17 inch medium roller bit.

DRILLING FLUID

200-300 CMS Gel with 0.5lb/bbl Driscose and LCM.

DRILL FLUID LOSS

200-300 Losing about 2800 gal./hr. through dolomite unit at 127-146 feet.

CASED INTERVAL

0-127 18" Dia.
0-597.9 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet.
Casing separation from 1810-1815 feet.

CHARACTER OF DRILLING

Drilled smoothly, penetration rate is about 20 ft./hr.

EXPLANATION

¦--¦ NO SAMPLE
█ SAMPLED INTERVAL

TYPE OF HOLE

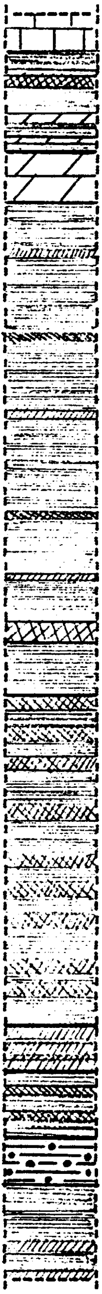
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 4 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
14 INCH DIA STEEL CASING HALLIBURTON GROUTING	310 320 330 340 350 360 370 380 390	300-303 CC 310-315 CC 320-325 CC 335-340 CC 345-348 CC 354-356 CC 360-365 CC 370-375 CC 380-383.5 CC 389-392.5 CC 392.5-395 CC	CHUGWATER RED PEAK FM		274-311 SHALE, Red to green, intercalated with anhydrite. Gray limestone unit from 300-303. Interbedded shale and dolomite from 308-311. 311-315 DOLOMITE, Light gray (2.5Y-7/2), hard dolomicrite. Conchoidal. 315-354 SHALE, Red (2.5YR-4/8) to light red (2.5YR-6/8), well indurated shale with soft, white, sucrose gypsum and hard, translucent anhydrite in 1-2 inch beds. Massive anhydrite present from 348-349.5 . 354-380 ANHYDRITE AND SHALE, Red to light red shale interbedded with bluish-white, massive, crystalline anhydrite in 1-1.5 foot thick beds. 380-383.5 GYPSUM, White, soft, sucrose gypsum containing thin red shale and translucent anhydrite. 383.5-389 SHALE, Red (2.5YR-5/6), soft shale with white, translucent anhydrite. 389-392.5 SILTSTONE, Weak red (10R-6/2), hard, blocky siltstone. 392.5-444 SHALE, Light brownish-gray (2.5Y-6/2) to pale red (10R-6/4), soft, gypsiferous shale.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 300-400, ARR. BIT TYPE 300-400 17 inch medium roller bit. DRILLING FLUID 300-400 CMS Gel with Driscose and LCM 351-400 Add Quik Seal to gel. DRILL FLUID LOSS 300-400 Losing about 3000 gal./hr. through dolomite unit at 127-146 feet. CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet. CHARACTER OF DRILLING Drilled smoothly. 300-366 Penetration rate is about 6 ft./hr. 366-400 Penetration rate is about 10 ft./hr.

EXPLANATION

¦--¦	NO SAMPLE
█	SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

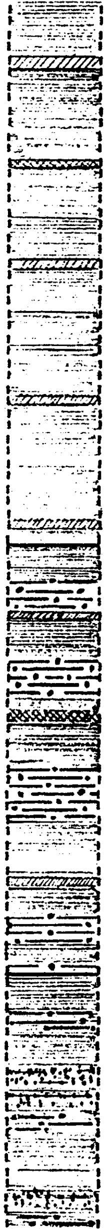
TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 5 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT
14 INCH DIA STEEL CASING / HALLIBURTON GROUT (430-479)		400-405 CC	CHUGWATER / RED PEAK FM (400-500)
	410	410-415 CC	
	420	420-425 CC	
	430	430-435 CC	
	440	440-445 CC	
	450	450-455 CC	
	460	460-465 CC	
	470	470-475 CC	
	480	480-485 CC	
	490	490-495 CC	

GRAPHIC LOG



CLASSIFICATION AND PHYSICAL DESCRIPTION

392.5-444 SHALE, Red (2.5YR-5/8) and dark reddish-brown (2.5YR-3/4), soft, gypsiferous shale with traces of anhydrite.

444-478 SHALE AND SILTSTONE, Red (5YR-5/8), soft, clay shale interbedded with red (2.5 YR-3/6) siltstone. Scattered very thin gypsum and anhydrite stringers.
Red (2.5YR-3/6), hard, blocky, silty shale at 461-462.
Shale becomes red to orange from 462-478.

478-626 SHALE, SILTSTONE, AND SANDSTONE, Red (2.5YR-3/6 to 5YR-5/8), soft shale and siltstone interbedded with harder beds of very fine grained sandy shale and shaly very fine grained sandstone. Gypsum and anhydrite stringers are almost entirely absent in this interval.
Light greenish-gray (5BG-7/1) mottles surround <1mm pyrite cubes from 481.5-509.

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

400-500, ARR.

BIT TYPE

400-500 17 inch medium roller b it.

DRILLING FLUID

400-500 CMS Gel with Driscose and LCM.

DRILL FLUID LOSS

NONE

CASED INTERVAL

0-127 18" Dia.
0-597.9 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet.
Casing separation from 1810-1815 feet.

CHARACTER OF DRILLING

Drilling smoothly, penetration rate is 10-16 ft./hr.

EXPLANATION

¦--¦	NO SAMPLE
█	SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL	ARR -- AIR REVERSE ROTARY
MR -- MUD ROTARY	CA --- CONTINUOUS AUGER
AR -- AIR ROTARY	WB --- WASH BORE

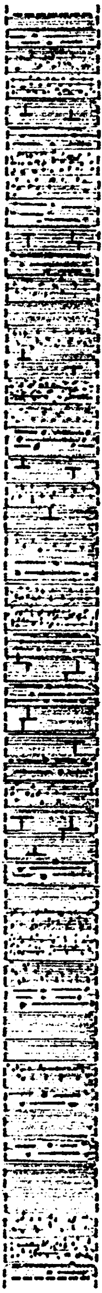
TYPE OF SAMPLE

DS -- DRIVE SAMPLE	SC -- STATIC BORE WASH SAMPLE
CC -- CONTINUOUS WASH SAMPLE	BS -- BAILER SAMPLE

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 6 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT
		500-505 CC	
	510	510-515 CC	
	520	520-525 CC	
	530	530-535 CC	
14 INCH DIA STEEL CASING	540	540-545 CC	CHUGWATER
HALLIBURTON GROUT	550	550-555 CC	RED PEAK FM
	560	560-565 CC	
	570	570-575 CC	
	580	580-585 CC	
	590	590-595 CC	

GRAPHIC LOG



CLASSIFICATION AND PHYSICAL DESCRIPTION

478-626 SHALE, SILTSTONE, SANDSTONE, Red (5YR-5/6 to 4/6) alternating 1-3 inch beds of soft, silty to clay shale, and sandy shale and shaly very fine grained sandstone.

Shale beds are moderately calcareous from 506-568.

Scattered very thin bluish-gray (5B-6/1) shale stringers from 510-546.

Hard, sandy shale beds become dark reddish-brown (5YR-3/3) at 546.

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

500-600, ARR.

BIT TYPE

500-600 17 inch medium roller bit.

DRILLING FLUID

500-600 CMS Gel with Driscose and LCM.

DRILL FLUID LOSS

NONE

CASED INTERVAL

0-127 18" Dia.
0-597.9 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet.
Casing separation from 1810-1815 feet.

CHARACTER OF DRILLING

Drilling smoothly, penetration rate is about 14 ft./hr.

EXPLANATION

¦--¦	NO SAMPLE
■	SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

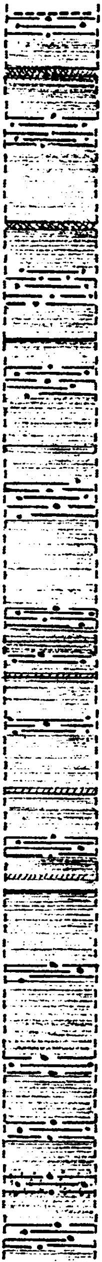
DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 7 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT
10.75 INCH DIA STEEL CASING HALLIBURTON GROUT	600	600-605 CC	CHUGWATER RED PEAK FM
	610	610-615 CC	
	620	620-625 CC	
	630	630-635 CC	
	640	640-645 CC	
	650	650-655 CC	
	660	660-665 CC	
	670	670-675 CC	
	680	680-685 CC	
	690	690-695 CC	

GRAPHIC LOG



CLASSIFICATION AND PHYSICAL DESCRIPTION

426-626 SHALE, SILTSTONE, AND SANDSTONE, A few very thin (1mm) anhydrite stringers present from 600-626.

626-669.5 SHALE AND SILTSTONE, Light red (2.5YR-6/6) clay shale alternating with siltstone, in 1-12 inch beds that thicken toward base of unit. Beds are gypsiferous and anhydritic.

Gray (10YR-5/1) shale beds at 650-651 and 669-669.5

White sucrose gypsum beds 1/2-1 inch thick scattered throughout interval from 651-669.

669.5-701 SHALE AND SILTSTONE, Red (5YR-5/8), alternating 1-4 inch beds of shale and siltstone. Shale beds are prominent from 669.5-688. Siltstone beds become more numerous from 688-701, and they consist of hard siltstone and sandy siltstone units.

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

600-700, ARR.

BIT TYPE

600-612 17 inch medium roller bit.
612-700 12.25 inch med. roller bit.

DRILLING FLUID

600-700 CMS Gel with Driscose and LCM.
668 Add 5 gal. Easy Mud.

DRILL FLUID LOSS

600-700 Slight loss through dolomite unit at 127-146 feet.

CASED INTERVAL

0-127 18" Dia.
0-597.9 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet.
Casing separation from 1810-1815 feet.

CHARACTER OF DRILLING

Drilled smoothly and without difficulty.
600-648 penetration rate is about 20 ft./hr.
648-700 penetration rate is about 25 ft./hr.

EXPLANATION

|--| NO SAMPLE

█ SAMPLED INTERVAL

TYPE OF HOLE

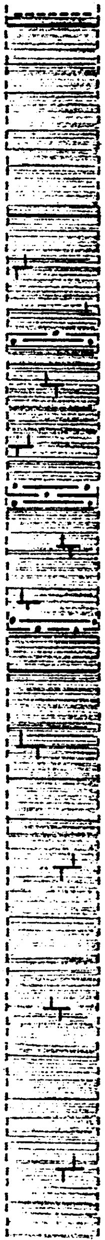
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 8 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
		700-705 CC			701-716 SHALE, Red (5YR-5/8), soft shale intercalated with some hard shale beds. Trace of anhydrite.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 700-800, ARR. BIT TYPE 700-800 12.25 inch med. roller bit. DRILLING FLUID 700-800 CMS Gel with Driscose and LCM. DRILL FLUID LOSS 700-800 Losing about 2800 gal./hr. through dolomite unit at 127-146 feet. CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet. CHARACTER OF DRILLING Drilled smoothly and without difficulty. 700-716 Penetration rate is about 30 ft./hr. 716-800 Penetration rate is about 15 ft./hr.
	710	710-715 CC			716-752 SHALE, Very dusky red (7.5R-2.5/2), very well indurated shale. Trace of anhydrite. Some yellowish-red (5YR-5/8), weakly calcareous, soft siltstone intercalated intermittently.	
	720	720-725 CC				
10.75 INCH DIA STEEL CASING	730	730-735 CC				
HALLIBURTON GROUT	740	740-745 CC	CHUGWATER RED PEAK FM			
	750	750-755 CC			752-861 SHALE, Weak red (2.5YR-4/2) to dark reddish-brown (2.5YR-3/4), hard shale. Weakly calcareous. Occassional gray (2.5YR-2/0) mottles and 1-4 inch interbeds.	
	760	760-764 CC				
	770	770-774 CC				
	780	782-785 CC				
	790	790-795 CC				

EXPLANATION

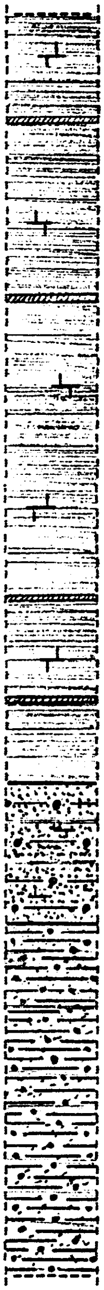
¦--¦	NO SAMPLE
■	SAMPLED INTERVAL

TYPE OF HOLE
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE
DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 9 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
		800-805 CC	CHUGWATER RED PEAK FM		752-861 SHALE, Weak red (2.5YR-4/2), hard, sandy, slightly calcareous shale. Occassional gray (2.5YR-2/0) mottles. Sucrose gypsum stringers scattered throughout interval from 800-861.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.
	810	810-815 CC				DRILLING METHOD 800-900, ARR.
	820	820-825 CC			Becomes weak red (2.5YR-4/2) to red (5YR-5/5) to dusky red (7.5R-2/2) beds with occassional gray mottles from about 820-861.	BIT TYPE 800-900 12.25 inch med. roller bit.
10.75 INCH DIA STEEL CASING HALLIBURTON GROUT	830	830-835 CC				
	840	840-845 CC				DRILLING FLUID 800-900 CMS Gel with Driscose and LCM.
	850	850-855 CC				DRILL FLUID LOSS NONE
	860	861-865 CC			861-872 SANDSTONE, Reddish-brown (5YR-4/4), very fine grained, silty, slightly calcareous quartz sandstone. Trace of biotite. Light brown (7.5YR-7/6) clay shale stringers scattered throughtout interval.	CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet.
	870	870-875 CC			872-1112 SILTSTONE, Dark reddish-brown (5YR-3/4) with reddish-yellow (7.5YR-7/6) mottles, sandy to shaley, calcareous siltstone.	CHARACTER OF DRILLING
	880	880-885 CC				Drilling smoothly and without difficulty. 800-882 penetration rate is about 15 ft./hr. 882-900 penetration rate is about 26 ft./hr.
	890	890-895 CC				

EXPLANATION

TYPE OF HOLE

¦--¦	NO SAMPLE
■	SAMPLED INTERVAL

CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

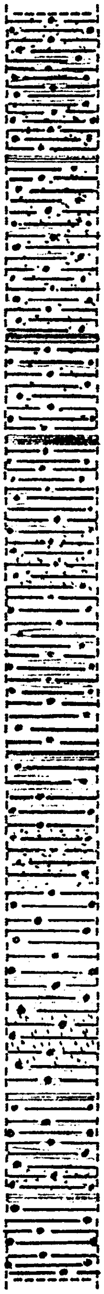
TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 10 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG
10.75 INCH DIA STEEL CASING HALLIBURTON GROUT		900-905 CC	CHUGWATER RED PEAK FM	
	910	910-915 CC		
	920	920-925 CC		
	930	930-935 CC		
	940	940-945 CC		
	950	950-955 CC		
	960	960-965 CC		
	970	970-975 CC		
	980	980-985 CC		
	990	990-995 CC		



CLASSIFICATION AND PHYSICAL DESCRIPTION

872-1112 SILTSTONE, Dark reddish-brown (5YR-3/4), sandy to shaley, calcareous siltstone. Traces of mica and gypsum. Scattered light red (2.5YR-6/6) clay shale stringers. Occassional gray mottles.

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

900-1000, ARR.

BIT TYPE

900-1000 12.25 inch med. roller bit.

DRILLING FLUID

900-1000 CMS Gel with Driscose and LCM.

DRILL FLUID LOSS

900-915 Slight loss through dolomite unit at 127-146 feet.
915-1000 NONE

CASED INTERVAL

0-127 18" Dia.
0-597.9 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet.
Casing separation from 1810-1815 feet.

CHARACTER OF DRILLING

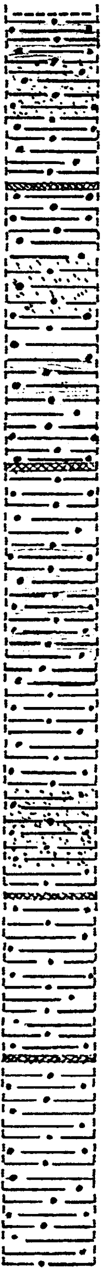
Drilled smoothly and without difficulty.
900-910 penetration rate is about 26 ft./hr.
910-1000 penetration rate is about 15 ft./hr.

EXPLANATION

NO SAMPLE	**TYPE OF HOLE**	
SAMPLED INTERVAL	CT -- CABLE TOOL	ARR -- AIR REVERSE ROTARY
	MR -- MUD ROTARY	CA --- CONTINUOUS AUGER
	AR -- AIR ROTARY	WB --- WASH BORE
	TYPE OF SAMPLE	
	DS -- DRIVE SAMPLE	SC -- STATIC BORE WASH SAMPLE
	CC -- CONTINUOUS WASH SAMPLE	BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 11 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION
		1000-1005 CC	CHUGWATER RED PEAK FM		872-1112 SILTSTONE, Becomes slightly gypsiferous below 1012 feet, with a few scattered anhydrite stringers.
	1010	1010-1015 CC			
	1020	1020-1025 CC			
10.75 INCH DIAMETER STEEL CASING	1030	1030-1035 CC			
HALLIBURTON GROUT	1040	1040-1045 CC			
	1050	1050-1055 CC			
	1060	1060-1065 CC			
	1070	1070-1075 CC			
	1080	1080-1085 CC			
	1090	1090-1095 CC			

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

1000-1100, ARR.

BIT TYPE

1000-1100 12.25 inch medium roller bit.

DRILLING FLUID

1000-1100 CMS Gel with Driscose and LCM.

DRILL FLUID LOSS

NONE

CASED INTERVAL

0-127 18" Dia.
0-597.9 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet.
Casing separation from 1810-1815 feet.

CHARACTER OF DRILLING

Drilled smoothly and without difficulty. Penetration rate is about 15 ft./hr.

EXPLANATION

¦--¦	NO SAMPLE
█	SAMPLED INTERVAL

TYPE OF HOLE

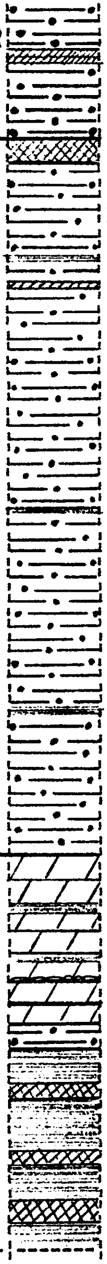
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1   PROJECT: WWDC - Shell Valley Deep Well Project   SHEET 12 OF 31
HOLE NO.: 1   LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W.   STATE: Wyoming
TOTAL DEPTH: 3041   GROUND ELEVATION: 4400   ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84   FINISHED: 9 Dec. 84   DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00   ELEVATION OF WATER LEVEL: 4730   DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand   LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
/	-	1100-			872-1112 SILTSTONE, Same as above. White, marly,	DRILLING EQUIPMENT
/	-	1105CC	CHUGWATER		soft, shaley gypsum bed with bluish-	
/	-	1105-	RED PEAK		gray (5B-5/1) to dark greenish-gray	Sargent Irrigation Co.
/	-	1106	FM		(5G-4/1) shale partings from 1105-	proprietary air-reverse
/	1110 --	CC			1106.	circulation rotary rig.
/	-				1112-1114 ANHYDRITE, White to weak red (7.5R-4/4),	DRILLING METHOD
/	-	1113-			massive anhydrite with some gypsum	
/	-	1114			marl.	1100-1200, ARR.
/	-	CC			1114-1169 SILTSTONE, Dark reddish-brown (5YR-5/1),	
/	1120 --	1120-			well indurated siltstone with soft,	
/	-	1125			reddish-yellow (5YR-6/6) shale part-	BIT TYPE
/	-	CC			ings and a trace of gypsum marl.	
1 /	-					1100-1200 12.25 inch
0 /	-					medium roller bit.
. /	1130 --	1130-	D			
7 /	-	1135	I			
5 /	-	CC	N			
/	-		W			DRILLING FLUID
I /	-		O			
N H	1140 --	1140-	O			1100-1200 CMS Gel with
C A	-	1145	D			Driscose and LCM.
H L	-	CC	Y			1155 Add 5 gal. Easy Mud
L	-					1198.5 Add 3 quarts of
D I	-		F		Becomes a greenish-gray (5G-5/1),	detergent.
I B	1150 --	1149-	M		hard, blocky siltstone with shale	DRILL FLUID LOSS
A U	-	1155			partings at 1149-1169. Traces of	
R	-	CC			light bluish-gray (5b-7/1) gypsum	NONE
S T	-				and micropyrite cubes also present.	
T O	-					
E N	1160 --	1160-				
E	-	1165				CASED INTERVAL
L G	-	CC				
R	-					0-127 18" Dia.
C O	-				1169-1182 DOLOMITE, Pinkish-gray (7.5YR-6/2), hard	0-597.9 14" Dia.
A U	1170 --	1169-			dolomite with pinkish-white (7.5YR-	597.7-1855 10.75" Dia.
S T	-	1175	P		8/2) clay shale interbeds. Thin	Grout to 1850 feet.
I /	-	CC	H		(<1cm) red chert beds. Traces of	Casing separation from
N /	-		O		bluish anhydrite and white gypsum.	1810-1815 feet.
G /	-		S		Interval is oil stained and odorous.	CHARACTER OF DRILLING
/	1180 --	1180-	P			
/	-	1183	H		1182-1184 SILTSTONE, Pinkish-gray (7.5YR-7/2), hard	Drilling smoothly.
/	-	CC	O		siltstone with pinkish-gray dolomite	1100-1155 penetration
/	-		R		and pinkish-white shale stringers.	rate is about 12 ft./hr.
/	-		I		Traces of anhydrite.	1155-1177 penetration
/	1190 --	1190-	A		1184-1209 SHALE AND ANHYDRITE, Dark greenish-gray	rate is about 6 ft./hr.
/	-	1195			(5BG-4/1) to light gray (N7/) and	1177-1200 penetration
/	-	CC	F		white (N8/), hard, fissile, clay	rate is about 1-3 ft./hr.
/	-		M		shale, becoming interbedded shale	Clay and anhydrite plug-
/	-				and shaley anhydrite at 1187.	ging bit.

EXPLANATION

|--| NO SAMPLE

■ SAMPLED INTERVAL

TYPE OF HOLE

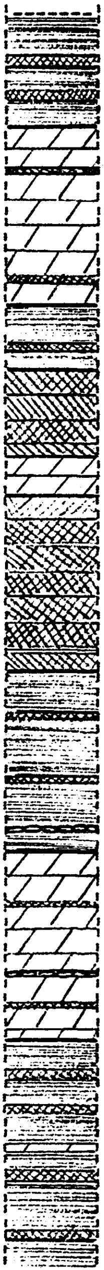
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 13 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
10.75 INCH DIA STEEL CASING HALLIBURTON GROUT	1210 1220 1230 1240 1250 1260 1270 1280 1290	1200-1205 CC 1209-1215 CC 1220-1223CC 1223-1227 CC 1230-1235 CC 1240-1245 CC 1252-1260 CC 1261-1266 CC 1270-1275 CC 1281-1285 CC 1290-1295 CC	PHOSPHORIA FM		1184-1209 SHALE AND ANHYDRITE, Dark reddish-brown (2.5YR-3/4) and dark greenish-gray (5G-4/1) shale interbedded with bluish to white massive anhydrite. 1209-1223 DOLOMITE, Very pale brown (10YR-7/3) to pinkish-gray (5YR-7/2) dolomicrite with white to bluish anhydrite stringers. Oil stained and odorous. 1223-1228 SHALE, Greenish-gray (5G-5/1) shale containing soft, thin laminae of reddish-brown shale and stringers of white to bluish anhydrite. Becomes dark reddish-brown shale at 1227. 1228-1235 ANHYDRITE, White to pinkish-gray(5YR-7/2) massive anhydrite with <1 inch dolomicrite stringers. 1235-1238 DOLOMITE, Light gray (5YR-7/1), hard dolomicrite with thin stringers of anhydrite. 1238-1252 ANHYDRITE, Same as above; with very thin dark red shale laminae. 1252-1266 SHALE, Dark red (2.5YR-3/6), hard, fissile shale. Shale becomes dusky red (2.5YR-3/2) to weak red (2.5YR-4/2) at 1262. White to pink (5YR-7/4) anhydrite stringers and very thin red (10R-5/8) chert stringers. 1266-1281 DOLOMITE, Pinkish-gray (7.5YR-6/2), hard, dolomite, with thin white to bluish anhydrite and red chert stringers. 1281-1318 SHALE AND ANHYDRITE, Dark reddish-brown (2.5YR-3/4) and dark greenish-gray (5G-4/1) shale interbedded with white to bluish massive anhydrite. Beds are 1-4 inches thick. A few .5-1 inch stringers of dolomite and a trace of chert also present in this interval.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 1200-1300, ARR. BIT TYPE 1200-1290 12.25 inch medium roller bit. 1290-1300 12.25 inch button bit. DRILLING FLUID 1200-1300 CMS Gel with Driscose and LCM. DRILL FLUID LOSS NONE CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet. CHARACTER OF DRILLING Drilled smoothly. 1200-1205 penetration rate is about 18 ft./hr. 1205-1254 penetration rate is about 9 ft./hr. 1254-1290 penetration rate declines from 5 to 2 ft./hr. due to bit wear. 1290-1300 10 ft./hr.

EXPLANATION

|--| NO SAMPLE

■ SAMPLED INTERVAL

TYPE OF HOLE

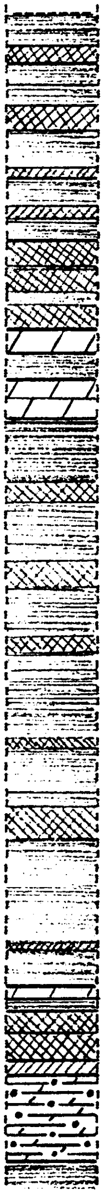
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 14 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
/	-	1300-	↑		1281-1318 SHALE AND ANHYDRITE, Red (5YR-4/8) shale	DRILLING EQUIPMENT
/	-	1305			interbedded with white anhydrite.	------------------
/	-	CC			Beds are .5-4 feet thick.	Sargent Irrigation Co.
/	-					proprietary air-reverse
/	1310 --	1310-				circulation rotary rig.
/	-	1315				DRILLING METHOD
/	-	CC				--------------
/	-					1300-1400, ARR.
/	-	1318-			1318-1325 ANHYDRITE, White anhydrite with thin red	
/	1320 --	1325			(2.5YR-4/8) shale laminae.	
/	-	CC				BIT TYPE
/	-	1325-			1325-1327 DOLOMITE, Reddish-gray (5YR-5/2) dolo-	--------
1 /	-	1327CC			sparite with white anhydrite string-	1300-1400 12.25 inch
0 /	-	1327-			ers and calcite nodules.	button bit.
. /	1330 --	1329CC			1327-1329 SHALE, Weak red (7.5R-5/2), soft, fissile	
7 /	-	1329-			shale.	
5 /	-	1332CC			1329-1332 DOLOMITE, Light brownish-gray (10YR-6/2)	
/	-	1332-			dolomicrite with traces of anhydrite	DRILLING FLUID
I /	-	1340CC				--------------
N H	1340 --	1340-	P		1332-1377 SHALE AND ANHYDRITE, Red (2.5YR-4/8),	1300-1400 CMS Gel with
C A	-	1344	H		fissile shale interbedded with white	Driscose and LCM.
H L	-	CC	O		to pink (5YR-7/3), hard, massive	
L	-		S		anhydrite.	
D I	-		P			
I B	1350 --	1350-	H			DRILL FLUID LOSS
A U	-	1355	O			----------------
R	-	CC	R			NONE
S T	-		I			
T O	-		A			
E N	1360 --	1360-				
E	-	1365	F			CASED INTERVAL
L G	-	CC	M			--------------
R	-					0-127 18" Dia.
C O	-					0-597.9 14" Dia.
A U	1370 --					597.7-1855 10.75" Dia.
S T	-	1373-				Grout to 1850 feet.
I /	-	1377				Casing separation from
N /	-	CC			1377-1378 DOLOMITE, Pinkish-gray (7.5YR-7/2), hard	1810-1815 feet.
G /	-	1377-			dolomicrite. Conchoidal fractures.	CHARACTER OF DRILLING
/	1380 --	1378CC			1378-1379 SHALE, Red (2.5YR-4/8), same as above.	---------------------
/	-				1379-1383 ANHYDRITE, white to pink (5YR-7/3),	Drilled smoothly and
/	-	1383-			massive anhydrite. Gypsiferous.	without difficulty.
/	-	1384CC			1383-1384 GYPSUM, White, sucrose gypsum with	1300-1327 penetration
/	-	1385-			anhydrite stringers.	rate is about 10 ft./hr.
/	1390 --	1390			1384-1391 SILTSTONE, Pink (5YR-7/3), laminated,	1327-1400 penetration
/	-	CC			dolomitic siltstone. Traces of	rate is about 15 ft./hr.
/	-				anhydrite.	
/	-				1391-1413 SHALE, Red (2.5YR-4/8), fissile shale.	
/	-		↓		Traces of anhydrite.	

EXPLANATION

|--|	NO SAMPLE
■	SAMPLED INTERVAL

TYPE OF HOLE

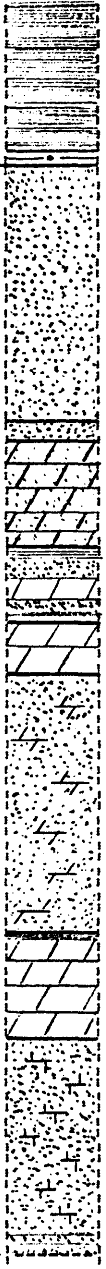
CT -- CABLE TOOL	ARR -- AIR REVERSE ROTARY
MR -- MUD ROTARY	CA --- CONTINUOUS AUGER
AR -- AIR ROTARY	WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE	SC -- STATIC BORE WASH SAMPLE
CC -- CONTINUOUS WASH SAMPLE	BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 15 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
10.75 INCH DIA STEEL CASING HALLIBURTON GROUT	1410	1400-1405 CC	PHOSPHORIA FM		1391-1413 SHALE, Red (2.5YR-4/8), same as above.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.
		1413-1414CC			1413-1414 SILTSTONE, Greenish-gray (5G-5/1), soft, fissile siltstone.	DRILLING METHOD 1400-1500, ARR.
	1420 1430	1414-1420 CC 1425-1430 CC	TENSLEEP FM		1414-1434 SANDSTONE, White to light gray (5YR-7/1), medium grained, well sorted quartz sandstone. Soft.	BIT TYPE 1400-1500 12.25 inch button bit.
		1434-1436CC			1434-1435.5 SANDSTONE, gray (5YR-6/1), fine grained arkosic sandstone.	DRILLING FLUID
	1440	1438-1442 CC			1435.5-1444 DOLOMITE, Gray (5Y-6/1), very fine grained sandy, fine dolosparite. Becomes very dark gray (5YR-3/1) at 1443.	1400-1500 CMS Gel with Driscose and LCM.
		1446-1450 CC			1444-1450 SHALE, SANDSTONE, AND DOLOMITE; Pink, gray, and brown interbedded shale, quartz sandstone, and dolomite in 3-4 inch beds.	
	1450	1451-1454 CC			1450-1454 DOLOMITE, Gray (5Y-6/1), very fine dolosparite.	DRILL FLUID LOSS None. Making about 20 gal./min. from Tensleep Formation beginning at 1414 feet.
	1460 1470	1460-1465 CC 1470-1474 CC			1454-1474.5 SANDSTONE, Very pale brown (10YR-7/3) to pink (5YR-7/3 to 7/4), very fine to fine grained, subangular to subrounded, well sorted, quartz sandstone. Dolomitic. Very soft and friable from 1462-1471. Cuttings are primarily individual grains.	CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet.
	1480	1478-1483 CC			1474.5-1483 DOLOMITE, Gray (7.5YR-6/0), very fine dolosparite. Red to green mottled, thin shale stringer at upper contact	CHARACTER OF DRILLING Drilled smoothly and easily. 1400-1414 penetration rate is about 15 ft./hr. 1414-1500 penetration rate is about 23 ft./hr.
	1490	1490-1495 CC			1483-1500.5 SANDSTONE, Light gray (5YR-7/1) to pinkish-gray (5YR-7/2), very fine to fine grained, subangular, moderately well sorted, quartz sandstone. Calcareous cement. Gray shale stringers at 1498.5-1499.5 .	

EXPLANATION

|--| NO SAMPLE

▮ SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 16 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG
10.75 INCH DIA STEEL CASING HALLIBURTON GROUT	1510 1520 1530 1540 1550 1560 1570 1580 1590	1500-1505 CC 1510-1515 CC 1520-1525 CC 1526-1530 CC 1535-1540 CC 1545-1550 CC 1555-1560 CC 1562-1568 CC 1575-1580 CC 1585-1590 CC 1592-1598 CC	TENSLEEP FM AMSDEN FM	

CLASSIFICATION AND PHYSICAL DESCRIPTION

1483-1500.5 SANDSTONE

1500.5-1506 DOLOMITE, Dark reddish-gray (10R-3/1) from 1500.5-1501.5, pinkish-gray (5YR-7/2) from 1501.5-1506, sandy, very fine dolosparite. Basal contact is gradational with sandstone unit below.

1506-1518 SANDSTONE, Pinkish-gray (5YR-7/2) to light gray (10YR-7/1), very fine grained, subangular, well sorted, clean, quartz sandstone. Dolomitic.

1518-1523 SHALE, Light red (2.5YR-6/6) to light reddish-brown (2.5YR-6/4), soft, laminated shale. Very calcareous, with numerous calcite partings.

1523-1526 DOLOMITE, Same as above except this interval contains numerous small solution cavities.

1526-1527 SHALE, White (5Y-8/1) to light gray (5Y-7/1) shale.

1527-1530 SANDSTONE, Same as above.

1530-1558 SHALE AND DOLOMITE, Red (2.5YR-4/8) to dark reddish-brown (2.5YR-3/4) shale interbedded with pinkish-gray (5YR-6/2 to 7/2) to pink (5YR-7/3) very fine dolosparite. Beds are generally 1-2 feet thick. Some are sandy. Dolomites contain very small solution cavities.

1558-1561 SANDSTONE, Light gray (10YR-7/2), very fine grained, subangular to subrounded, well sorted quartz sandstone. Dolomitic. Red clay stringers present from 1558-1559.

1561-1607 SHALE, DOLOMITIC SHALE, AND DOLOMITE, Reddish-gray (5YR-5/2) to reddish-brown (5YR-5/4 and 2.5YR-4/4) to red (2.5YR-5/8) shale interbedded with brown (10YR-5/3) to light gray (10YR-7/1 to 7/2) dolomitic shale and light gray (5Y-7/2) to light olive-gray (5Y-6/2) dolomite. Cherty dolomite bed at 1574-1575.

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

1500-1600, ARR.

BIT TYPE

1500-1600 12.25 inch button bit.

DRILLING FLUID

1500-1600 CMS Gel with Driscose and LCM.

DRILL FLUID LOSS

None. Making about 30 gal./min. from Tensleep Fm. at 1500 feet, declining to 5 gal/min. at 1600

CASED INTERVAL

0-127 18" Dia.
0-597.9 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet.
Casing separation from 1810-1815 feet.

CHARACTER OF DRILLING

Drilled smoothly and and easily.
1500-1561 penetration rate is about 25 ft./hr.
1561-1600 penetration rate is about 15 ft./hr.

EXPLANATION

¦--¦ NO SAMPLE

█ SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

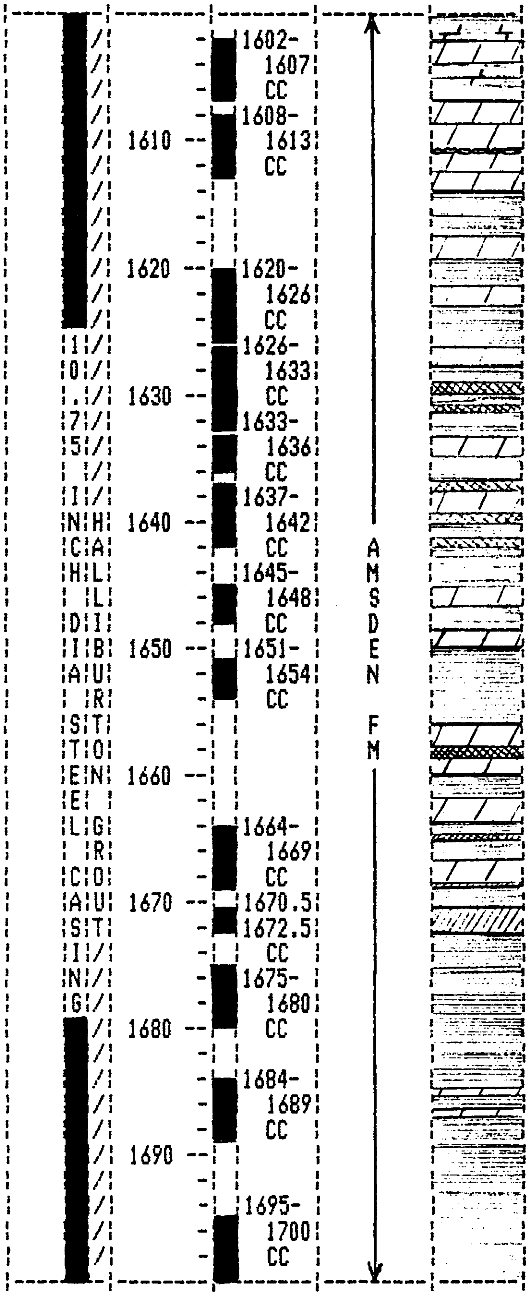
TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 17 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY | DEPTH (FEET) | SAMPLE DEPTHS | GEOLOGIC UNIT | GRAPHIC LOG | CLASSIFICATION AND PHYSICAL DESCRIPTION | DRILLING INFORMATION



1561-1607 SHALE, DOLOMITIC SHALE, AND DOLOMITE

1607-1614 DOLOMITE, Light gray (5Y-7/1 and 7/2) to (10YR-7/1 to 7/2), very fine dolosparite. Very thin, pink (7.5YR-7/4) to yellowish-red (7.5YR-6/8) chert stringers at 1610-1611. A 4 inch chert bed is present at 1611. Dolomite becomes very vuggy, with numerous solution cavities at 1611.5

1614-1650 SHALE, DOLOMITE, AND ANHYDRITE; Variegated red (2.5YR-4/6 and 4/8) to weak red (10R-4/2 and 4/3) and greenish-gray (5G-6/1) shales interbedded with pinkish-gray (7.5YR-7/2) dolomite and white to bluish anhydrite. Beds are about 1 foot thick. Anhydrite beds are present from 1629-1631 and 1637-1642.

1650-1656 SHALE, Red (10R-4/8), soft, clay shale with scattered anhydrite partings.

1656-1660 DOLOMITE, Red (10R-4/6), hard dolosparite with interbedded massive blue anhydrite.

1660-1670.5 SHALE AND DOLOMITE, Red (10R-4/6 to 4/8) clay shale and dolosparite interbedded with shaley anhydrite and gypsum.

1670.5-1672.5 GYPSUM, White (5YR-8/1), soft gypsum with very thin red shale partings.

1672.5-1741.5 SHALE, Red (10R-4/6), clay shale. Becomes gray (2.5YR-6/0) from 1684-1685, then red again. Beds are 0.5-5.0 feet thick. Numerous 1-3 mm gypsum stringers from 1672.5-1684. Gypsum stringers are almost entirely absent below 1684. Very thin (1-4 mm) anhydrite partings from 1682-1683. Gray dolomite beds at 1685-1685.5 and 1686.5-1687.

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

1600-1700, ARR.

BIT TYPE

1600-1700 12.25 inch button bit.

DRILLING FLUID

1600-1700 CMS Gel with Driscose and LCM.

DRILL FLUID LOSS

None. Making about 4-6 gal./min. from Tensleep Formation.

CASED INTERVAL

0-127 18" Dia.
0-597.9 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet.
Casing separation from 1810-1815 feet.

CHARACTER OF DRILLING

Drilled smoothly and without difficulty. Penetration rate is about 10 ft./hr.

EXPLANATION

|--| NO SAMPLE
█ SAMPLED INTERVAL

TYPE OF HOLE

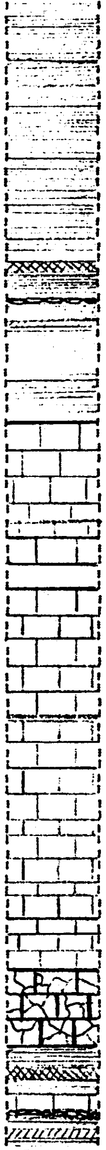
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 18 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
10.75 INCH DIA STEEL CASING HALLIBURTON GROUT	1710 1720 1730 1740	1705-1710 CC 1715-1720 CC 1725-1730 CC 1730-1737 CC	AMSDEN FM		1672.5-1741.5 SHALE Carbonated formation water at 1729-1730 and at 1737. Cuttings are poor or absent in interval from 1729-1737 when initially drilled. Cuttings obtained while subsequently cleaning hole in this interval indicate that there were probably thin chert and anhydrite or gypsum stringers scattered throughout this interval.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 1700-1800, ARR. BIT TYPE 1700-1781 12.25 inch button bit. 1781-1790 12.25 inch coring bit. 1790-1800 12.25 inch medium roller bit. DRILLING FLUID 1700-1781 CMS Gel with Driscose and LCM. 1781-1800 CMS Gel, bentonite, and barite. DRILL FLUID LOSS None. Making about 4-6 gal./min. from Tensleep Formation while drilling interval from 1700-1751. CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet. CHARACTER OF DRILLING 1700-1751 Drilled smoothly. Penetration rate is about 10-12 ft./hr. Rods binding on broken air pipe when pulling back below 1737 feet. 1781-1790 Coring bit bouncing on air pipe. 1790-1800 Rate: 5 ft/hr.
	1750 1760 1770 1780	1743-1750 CC NO SAMPLES			1741.5-1785 LIMESTONE, Light olive-brown (2.5Y-5/4) to light gray (2.5Y-7/2) limestone with red (2.5YR-5/8) shale partings. Sparse, very thin gypsum stringers. Interval from 1751-1781 was drilled while trying to retrieve section of air pipe which broke off during drilling and fell to the bottom of the hole. No cuttings were recovered from this interval.	
	1790	1785-1791 CC			1785-1791 LIMESTONE SOLUTION BRECCIA, Purple, tan, and yellow, fractured and recemented limestone.	
		1791-1801 CC			1791-1801 INTERBEDDED SHALE, ANHYDRITE, GYPSUM, AND LIMESTONE. Some amber chert stringers.	

EXPLANATION

┆--┆	NO SAMPLE
█	SAMPLED INTERVAL

TYPE OF HOLE

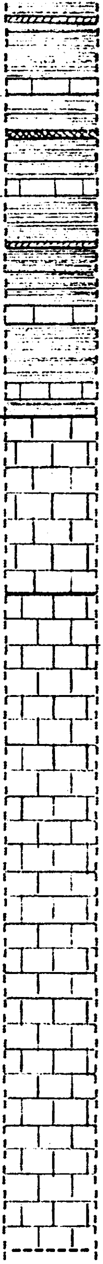
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 19 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
10.75 INCH DIA CASING HALLIBURTON GROUT	1810 1820 1830	1801-1810 CC 1820-1830 CC	AMSDEN FM		1801-1834 INTERBEDDED SHALE, ANHYDRITE, GYPSUM, AND LIMESTONE, Same as above except limestone beds have small hairline fractures filled with red silica.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 1800-1900, ARR. BIT TYPE 1800-1836 12.25 inch medium roller bit. 1836-1855 12.25 inch button bit. 1855-1900 8.75 inch button bit. DRILLING FLUID 1800-1855 CMS Gel, bentonite, and barite. 1855-1900 Clear water. DRILL FLUID LOSS NONE CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet. CHARACTER OF DRILLING 1800-1855 Drilled smoothly, penetration rate is about 3-5 ft./hr. to 1836 and about 8 ft/hr to 1855 1855-1900 Drilled smoothly, penetration rate is about 23 ft./hr. Rubber wiper plug fragments plug bit openings down to 1892
	1840	1840-1848 CC	MADISON FM		1834-1848 LIMESTONE, Light gray (5Y-7/2) to white (10YR-8/2), very hard limestone. Rock is weathered and broken, with thin white to brownish-yellow (10YR-6/8) clay stringers or fracture fillings.	
OPEN HOLE	1850 1860 1870 1880 1890	1850-1855CC NO SAMPLES 1890-1895 CC			1848-1900 LIMESTONE, White (10YR-8/2) to light brownish-gray (2.5Y-6/2), hard sparite. Fresh rock. Soft, sucrose gypsum present in 0.5-1.0 inch beds.	

EXPLANATION

Symbol	Meaning
¦--¦	NO SAMPLE
█	SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL	ARR -- AIR REVERSE ROTARY
MR -- MUD ROTARY	CA --- CONTINUOUS AUGER
AR -- AIR ROTARY	WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE	SC -- STATIC BORE WASH SAMPLE
CC -- CONTINUOUS WASH SAMPLE	BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 20 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

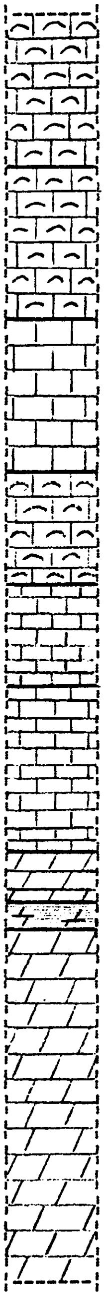
CASING TALLEY: OPEN HOLE

DEPTH (FEET): 1910, 1920, 1930, 1940, 1950, 1960, 1970, 1980, 1990

SAMPLE DEPTHS:
- 1900-1905 CC
- 1912-1915 CC
- 1920-1924 CC
- 1924-1930 CC
- 1936-1940 CC
- 1941-1945 CC
- 1955-1960 CC
- 1962-1964CC
- 1966-1970CC
- 1970-1972 CC
- 1975-1978CC
- 1982-1987 CC
- 1990-1995 CC

GEOLOGIC UNIT: MADISON FM

GRAPHIC LOG



CLASSIFICATION AND PHYSICAL DESCRIPTION

1900-1912 LIMESTONE, White to pinkish-gray (5YR-7/2) to brownish-gray (2.5Y-6/2), hard, biosparite. Fossils are brachiopods. Interval contains pyrite cubes surrounded by iron stain halos, and stained fracture surfaces. Traces of gypsum.

1912-1924 LIMESTONE, Pinkish-gray (5YR-7/2) to pinkish-white (7.5YR-7/2) biosparite. Fossils are brachiopods. Trace of pyrite.

1924-1936 LIMESTONE, Pinkish-gray (7.5YR-6/2), clean, dismicrite. Sparry calcite fracture filling. Thin (<1 cm) gypsum stringers scattered throughout interval.

1936-1945 LIMESTONE, Pinkish-gray (7.5YR-6/2) biosparite. Fossils are brachiopods. Becomes gray (10YR-6/1) and pinkish-gray from 1941-1945 . Thin (<1-5cm) soft, sucrose gypsum stringers scattered throughout interval. Pyritic.

1945-1953 LIMESTONE, Gray (10YR-6/1) to pinkish-white (7.5YR-7/2) to green sparite. Beds are about 1-2 inches thick. Soft, white, sucrose gypsum stringers scattered throughout interval.

1953-1966 LIMESTONE, Light gray (10YR-7/2) to white (5Y-8/1), thin bedded micrite. Pyritic, with numerous pyrite microcubes. Very thin (<1-1 cm) gypsum and white clay stringers. Some limonitic staining. Grades to a dolomitic very fine sparite from 1962-1966.

1966-1970 DOLOMITE, Gray (5Y-5/1) to light gray (10YR-7/2) dolomicrite. Scattered, very thin white to light gray clay stringers.

1970-1972 SHALE, Very pale brown (10YR-8/4) to white (5Y-8/2), soft, sticky, dolomitic clay shale. Limonitic stained.

1972-2186 DOLOMITE, Very pale brown (10YR-7/4), white (10YR-8/2), and light gray (10YR-7/2), very fine dolosparite. A few dolomicrite interbeds also present in this interval. Very vuggy. Some vugs are filled with sparry dolomite or calcite.

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

1900-2000, ARR.

BIT TYPE

1900-2000 8.75 inch button bit.

DRILLING FLUID

Clear Water

DRILL FLUID LOSS

None. Making a small amount of water from the Madison Formation.

CASED INTERVAL

0-127 18" Dia.
0-597.9 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet.
Casing separation from 1810-1815 feet.

CHARACTER OF DRILLING

Drilled smoothly and easily. Penetration rate is about 17-23 ft./hr.

EXPLANATION

¦--¦	NO SAMPLE
█	SAMPLED INTERVAL

TYPE OF HOLE

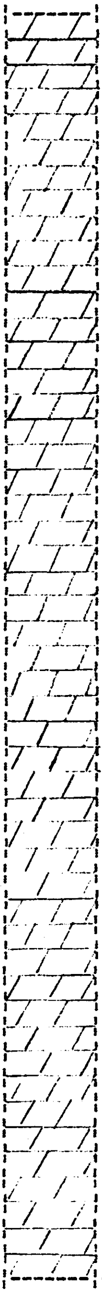
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1   PROJECT: WWDC - Shell Valley Deep Well Project   SHEET 21 OF 31
HOLE NO.: 1   LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W.   STATE: Wyoming
TOTAL DEPTH: 3041   GROUND ELEVATION: 4400   ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84   FINISHED: 9 Dec. 84   DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00   ELEVATION OF WATER LEVEL: 4730   DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand   LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG
OPEN HOLE	2010 2020 2030 2040 2050 2060 2070 2080 2090	2000-2005 CC 2012-2017 CC 2025-2030 CC 2035-2040 CC 2044-2048 CC 2055-2060 CC 2065-2070 CC 2075-2080 CC 2083-2088 CC 2095-2100 CC	MADISON FM	

CLASSIFICATION AND PHYSICAL DESCRIPTION

1972-2186 DOLOMITE.

White sucrose gypsum stringers (1-1 cm thick scattered throughout interval.

Dolomite becomes entirely light gray (10YR-7/2), very fine dolosparite from 2020-2061.

Very thin (1-3 mm), white (2.5Y-8/0) calcareous clay stringers from 2028-2047.
Light yellowish-brown (10YR-6/4) to pale yellow (2.5Y-7/4) chert in (1-1 cm stringers from 2034-2048.

Limonitic staining present on a few fracture surfaces.

Vugs are almost entirely absent from 2045-2070.

Very thin chert stringers present from 2058-2073.
Dolomite becomes entirely white (2.5 Y-8/2) from 2061-2105.

Sparry calcite filled fractures 0.2-1 cm thick scattered throughout interval from 2069-2105.

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

2000-2100, ARR.

BIT TYPE

2000-2100 8.75 inch button bit.

DRILLING FLUID

Clear Water

DRILL FLUID LOSS

None. Making about 50 gal./min. from Madison Formation.

CASED INTERVAL

0-127 18" Dia.
0-597.9 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet.
Casing separation from 1810-1815 feet.

CHARACTER OF DRILLING

Drilled smoothly and easily except for irregular cuttings return between 2032-2047 feet. Penetration rate is about 26-30 ft./hr.

EXPLANATION

| --- NO SAMPLE
█ SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

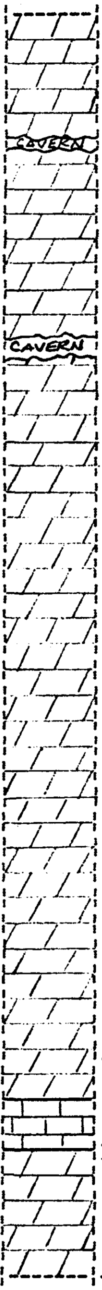
DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 22 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT
OPEN HOLE		2105-2110 CC	MADISON FM
	2110		
		2115-2120 CC	
	2120		
		2125-2130 CC	
	2130		
		2135-2140 CC	
	2140		
		2145-2150 CC	
	2150		
		2155-2160 CC	
	2160		
		2165-2170 CC	
	2170		
		2175-2180 CC	
	2180		
		2186-2190 CC	
	2190		
		2195-2200 CC	

GRAPHIC LOG



CLASSIFICATION AND PHYSICAL DESCRIPTION

1972-2186 DOLOMITE.

Dolomite is very pale brown (10YR-7/3) from 2105-2125. Fracture surfaces are limonitic stained. An 8 inch high cavern is present at 2110.

A 1.5 foot high cavern is present from 2126-2127.5 . Dolomite is brown (10YR-5/3) from 2125-2172, and has a granular texture from 2132-2172. There is very little limonitic staining on the fracture surfaces, and gypsum is absent from 2125-2132. From 2132-2172, many of the fractures are again limonitic stained. Some fractures are also filled with dark brown calcite. Thin (1 cm) sucrose gypsum stringers, and pyrite micro-cubes, are scattered throughout interval from 2132-2172.

Dolomite becomes white (10YR-8/2) dolosparite from 2172-2179. Fracture surfaces are limonitic stained. Thin gypsum stringers are scattered throughout this interval. Dolomite is brown (10YR-5/3) from 2179-2186.

2186-2190 LIMESTONE, White to very pale brown (10YR-7/3) sparite. Some fractures are filled with sparry calcite. Thin, sucrose gypsum stringers present.

2190-2229 DOLOMITE, White and very pale brown (10YR-7/3) to brown (10YR-5/3) dolosparite. Thin, sucrose gypsum stringers scattered throughout interval. Fracture surfaces are limonitic stained.

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

2100-2200, ARR.

BIT TYPE

2100-2200 8.75 inch button bit.

DRILLING FLUID

Clear Water

DRILL FLUID LOSS

None. Making about 50 gal./min. from Madison to 2110, increasing to about 150 gal./min. by 2200.

CASED INTERVAL

0-127 18" Dia.
0-597.9 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet.
Casing separation from 1810-1815 feet.

CHARACTER OF DRILLING

Drilled smoothly and easily. Penetration rate is about 30 ft./hr. at 2100, increasing to about 40 ft./hr. at 2200.

EXPLANATION

☐ NO SAMPLE
■ SAMPLED INTERVAL

TYPE OF HOLE

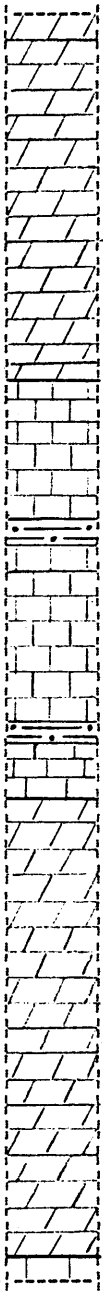
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1   PROJECT: WWDC - Shell Valley Deep Well Project   SHEET 23 OF 31
HOLE NO.: 1   LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W.   STATE: Wyoming
TOTAL DEPTH: 3041   GROUND ELEVATION: 4400   ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84   FINISHED: 9 Dec. 84   DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00   ELEVATION OF WATER LEVEL: 4730   DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand   LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
OPEN HOLE	2210 2220 2230 2240 2250 2260 2270 2280 2290	2205-2210 CC 2215-2220 CC 2235-2240 CC 2245-2250 CC 2255-2260 CC 2265-2270 CC 2274-2280 CC 2285-2290 CC 2298-2302CC	MADISON FM		2190-2229 DOLOMITE, Brown (10YR-5/2) dolosparite with gypsum stringers from 2202-2206. Becomes light reddish-brown (5YR-6/3) from 2206-2211. Dolomite becomes alternating brown (10YR-5/2) and very pale brown (10YR-7/3) from 2211-2229. 2229-2262 LIMESTONE, Alternating white, light brown (7.5YR-6/4), and weak red (5R-4/2) limestone beds. 1-3 cm sucrose gypsum stringers. Occassional yellow (10YR-7/8) siltstone stringers. Yellow siltstone interbeds with sucrose gypsum stringers at 2240-2242 and 2256-2257.5 . Becomes entirely weak red (5R-4/2) limestone with gypsum and siltstone stringers from 2242-2262. 2262-2298 DOLOMITE, Varicolored, weak red (10R-5/2) reddish-gray (10R-5/1), light brownish-gray (10YR-6/2), pinkish-gray (5YR-6/2), and white dolosparite in 0.5-3 foot beds. A few white to gray limestone interbeds scattered throughout interval. Gypsum stringers. Limonitic stains on fracture surfaces. 2298-2302 LIMESTONE, White, clean, sparite. White gypsum stringers present in this interval.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 2200-2300, ARR. BIT TYPE 2200-2300 8.75 inch button bit. DRILLING FLUID Clear Water DRILL FLUID LOSS None. Making about 150 gal./min. from Madison Formation. CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet. CHARACTER OF DRILLING Drilled smoothly and easily. 2200-2228 penetration rate is about 37 ft./hr. 2228-2300 penetration rate is about 23-29 ft/hr

EXPLANATION

¦--¦	NO SAMPLE
█	SAMPLED INTERVAL

TYPE OF HOLE

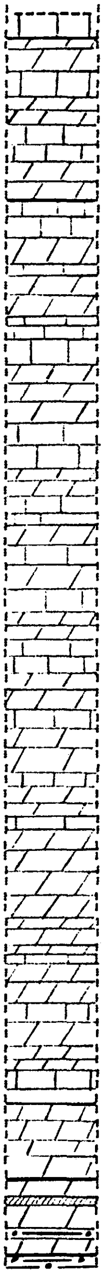
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 24 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
	2310 2320	2298-2302CC 2305-2310CC NO SAMPLES	MADISON FM		2298-2302 LIMESTONE. 2302-2325 DOLOMITE AND LIMESTONE, Varicolored (same as 2262-2298 interval), fine to medium dolosparite interbedded with white, fine sparite in 0.5-3 foot beds. Very vuggy (primary porosity) with secondary sparry calcite filling some vugs. Gypsum stringers.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 2300-2400, ARR.
OPEN HOLE	2330 2340 2350 2360 2370 2380 2390	2325-2330 CC 2335-2340 CC 2345-2350 CC 2355-2360 CC 2365-2370 CC 2375-2380 CC 2385-2390 CC			2325-2392 DOLOMITE AND LIMESTONE, Brown (7.5YR-5/2) to pinkish-gray (7.5YR-6/2) dolosparite interbedded with white sparite in 0.5-2 foot beds. Vuggy, with secondary sparry calcite filling some vugs. Scattered thin stringers of white gypsum. Limestone beds decrease in frequency and thickness below 2355.	BIT TYPE 2300-2400 8.75 inch button bit. DRILLING FLUID Clear Water DRILL FLUID LOSS None. Making about 150 gal./min. at 2300 feet, increasing to about 175 gal./min. at 2400 feet. CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet.
		2392-2398CC			2392-2398 DOLOMITE, Reddish-brown (2.5YR-5/8) dolosparite. Several thin interbeds of gypsum and yellow siltstone. Secondary sparry calcite.	CHARACTER OF DRILLING 2310-2325 Pieces of rubber wiper plug block bit openings preventing circulation of cuttings. Bit binding in hole.
		2398-2402CC			2398-2402 SILTSTONE AND GYPSUM, Red (10R-4/6) to yellow (10YR-7/8) siltstone interbedded with white gypsum. A few thin, sandy dolomite interbeds also present in this interval.	2300-2310 and 2325-2400, drilled smoothly and easily. Penetration rate is about 25-32 ft./hr.

EXPLANATION

¦--¦ NO SAMPLE

█ SAMPLED INTERVAL

TYPE OF HOLE

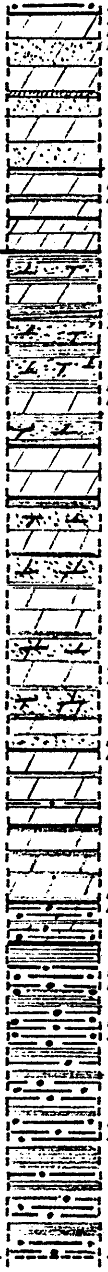
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 25 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
O	-	2398-	M		2398-2402 SILTSTONE AND GYPSUM.	DRILLING EQUIPMENT
P	-	2402CC	A		2402-2414 DOLOMITE, Weak red (10R-5/3), hard dolo-	------------------
E	-	2405-	D		sparite. Some beds are sandy dolo-	Sargent Irrigation Co.
N	-	2410	I		sparite. Not as vuggy as carbonate	proprietary air-reverse
	2410 --	CC	S		units higher in the formation.	circulation rotary rig.
H	-		O		Sparry calcite filling some frac-	DRILLING METHOD
O	-	2414-	N		tures. Thin gypsum stringers.	---------------
L	-	2418CC			2414-2418 DOLOMITE AND SHALE, Weak red (10R-5/3)	2400-2500, ARR.
E	-	2418-	F		dolosparite interbedded with red	
_	2420 --	2421CC	M		(10R-4/6), silty shale. Beds are	
	-	2421-			about 2-3 inches thick. Scattered,	BIT TYPE
	-	2430			thin, white gypsum stringers.	--------
	-	CC			2418-2421 DOLOMITE, White, hard dolomicrite. Limo-	2400-2440 8.75 inch
	-		T		nitic stains on some fracture sur-	button bit.
	2430 --	2430-	H		faces.	2400-2440 Hole reamed
	-	2436	R		2421-2436 SHALE, DOLOMITE, AND DOLOMITIC SANDSTONE;	with 9.875 inch
	-	CC	E		Red (2.5YR-5/8) to reddish-brown	button bit.
	-	2436-	E		(2.5YR-5/4) shale interbedded with	2440-2500 9.875 inch
	-	2440CC			white to pinkish-gray dolomite and	button bit.
	2440 --	2440-	F		white dolomitic quartz sandstone.	
	-	2445	O		Beds are 1-4 inches thick. A few	DRILLING FLUID
	-	CC	R		very thin, yellow, quartz sandstone	-------------
	-	2446-	K		beds are present at 2425. Sucrose	Clear Water
	-	2450	S		gypsum stringers present throughout	
C	2450 --	CC	/		interval. Fracture surfaces in	DRILL FLUID LOSS
E	-		J		dolomite beds are limonitic stained.	----------------
M	-		E		2436-2440 DOLOMITE, Dark brown (7.5YR-3/4), very	None. Making about 175
E	-	2455-	F		hard , clean, granular (recrystal-	gal./min. from Madison
N	-	2460	F		lized) dolosparite.	Formation. After frac.
T	2460 --	CC	E		2440-2460 DOLOMITE, SHALE, DOLOMITIC SANDSTONE;	job, flow dropped to 113
	-		R		Pinkish-gray (5YR-7/2) to light red-	gal./min. Flow increased
P	-		S		dish brown (2.5YR-6/4) dolosparite	to 144 gal./min. while
L	-	2465-	O		and dolomitic sandstone interbedded	reaming hole to 2440 feet
U	-	2470	N		with red (2.5YR-5/8) shale in 1-4	CASED INTERVAL
G	2470 --	CC			inch thick beds. Limonitic stained.	--------------
	-		F		2460-2466 DOLOMITE, Pinkish-gray (5YR-6/2) dolo-	0-127 18" Dia.
	-		M		sparite with very thin ((1 inch) red	0-597.9 14" Dia.
	-	2475-	S		(10R-5/6) shale and siltstone beds.	597.7-1855 10.75" Dia.
	-	2480			2466-2472 DOLOMITE AND SHALE, Same as 2440-2460	Grout to 1850 feet.
	2480 --	CC	U		foot interval.	Casing separation from
	-		N		2472-2475 SILTSTONE, Brown (10YR-5/3) to dark gray	1810-1815 feet.
	-		D		(10YR-4/1) dolomitic siltstone. A	CHARACTER OF DRILLING
	-	2485-	I		few thin reddish shale stringers	--------------------
	-	2490	F		scattered throughout interval.	Drilled smoothly and
	2490 --	CC	F		2475-2509 SILTSTONE AND SHALE, Gray (10YR-6/1 to	easily.
	-		.		2.5Y-5/0) to pinkish-gray (5YR-6/2)	2400-2440 penetration
	-	2495-			hard siltstone and dolomitic silt-	rate is about 23-26 ft/hr
	-	2500			stone interbedded with soft, white	2440-2500 penetration
	-	CC			(2.5Y-8/0) to reddish shale.	rate is about 8-14 ft./hr

EXPLANATION

|--| NO SAMPLE

■ SAMPLED INTERVAL

TYPE OF HOLE

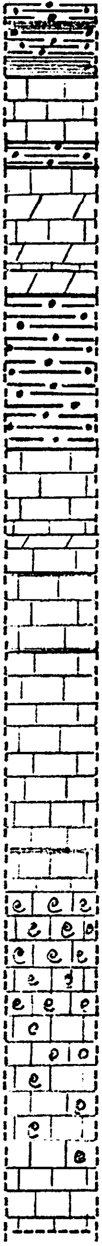
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 26 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek



CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
CEMENT PLUG	2510 2520 2530 2540 2550 2560 2570 2580 2590	2505-2509 CC 2509-2514 CC 2521-2526 CC 2533-2538 CC 2540-2545 CC 2550-2555 CC 2560-2565 CC 2575-2580 CC 2585-2590 CC 2595-2600 CC	THREE FORKS/JEFFERSON FM UNDIFF.		2475-2509 SILTSTONE AND SHALE Siltstone beds are 1-5 feet thick. Shale beds are 1-4 inches thick. Scattered 5-10 mm gypsum stringers. 2509-2514 LIMESTONE, White (5YR-8/1) very fine dolomitic sparite. 2514-2516 SILTSTONE, Same as interval from 2475-2509. Siltstone is laminated, and calcareous to dolomitic. 2516-2526 LIMESTONE AND DOLOMITE, Light gray (10YR-7/1 to 5Y-7/1) and white (10YR-8/1 to 5Y-8/1) very fine sparite, dolomitic sparite, and dolosparite. Thin bedded. Slightly vuggy. Red to dusky red shale stringers from 2523.5-2525. 2526-2538 SILTSTONE, Gray (10YR-6/1 to 5/1), calcareous to dolomitic siltstone. Becomes brown (7.5YR-5/2) siltstone from 2536-2538. 2538-2614 LIMESTONE, Pale red (7.5R-6/2), weak red (7.5R-5/4), and dusky red (7.5R-3/4) very fine to fine sparite and dolomitic sparite and micrite. Thin bedded. Dolosparite interbed at 2545-2546. White to red shale stringers scattered throughout interval. Becomes pinkish-gray (5YR-6/2) at 2547, and alternating pinkish-gray and reddish-gray (5YR-5/2) beds at 2553. Becomes entirely sparite from 2558-2573. Very small solution cavities scattered throughout this interval. Hairline fractures also present, but all are tight and many are cemented with calcite. Becomes variegated grayish-brown (2.5Y-5/2), dark gray (2.5Y-4/0), and very dark gray (2.5Y-3/0) dolomitic biosparite at 2573, with light gray (5Y-7/1) shale stringers at 2577.5-2594. Fossil content decreases with depth, and fossils are absent at 2595 where unit becomes a pale brown (10YR-6/3) and light gray (10YR-7/2) very fine sparite.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 2500-2600, ARR. BIT TYPE 2500-2600 9.875 inch button bit. DRILLING FLUID Clear Water DRILL FLUID LOSS None. Making about 144 gal./min. from Madison at 2500 feet depth, increasing to about 166 gal./min from Madison Fm. at 2600 feet depth. Frac sand coming out of Madison Fm. CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet. CHARACTER OF DRILLING Drilled smoothly and without difficulty. Penetration rate is about 9-13 ft./hr.

EXPLANATION

☐	NO SAMPLE
■	SAMPLED INTERVAL

TYPE OF HOLE

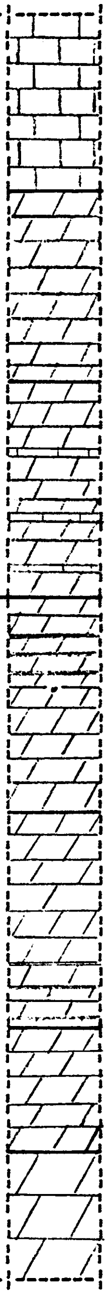
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1   PROJECT: WWDC - Shell Valley Deep Well Project   SHEET 27 OF 31
HOLE NO.: 1   LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W.   STATE: Wyoming
TOTAL DEPTH: 3041   GROUND ELEVATION: 4400   ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84   FINISHED: 9 Dec. 84   DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00   ELEVATION OF WATER LEVEL: 4730   DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand   LOG REVIEWED BY: M. Kaczmarek



CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	CLASSIFICATION AND PHYSICAL DESCRIPTION
CEM. PLUG_	2610	2605-2610 CC	THREE FORKS/JEFFERSON	2538-2614 LIMESTONE, becomes pale brown (10YR-6/3) to light yellowish-brown (10YR-6/4), very fine sparite to micrite at 2604.5. Sparry calcite filled fractures become more numerous at 2608.
	2620	2615-2620 CC 2625-2630 CC		2614-2629 DOLOMITE, light brownish-gray (2.5Y-6/2) to grayish-brown (2.5Y-5/2) very fine dolosparite.
OPEN	2630 2640	2631-2634 CC NO RECY		2629-2646 DOLOMITE, pale brown (10YR-6/3) to reddish-gray (5YR-5/3) very fine dolosparite. Very vuggy. Some limonitic fracture filling. A few thin (0.5-1.0 foot thick) limestone beds scattered throughout interval. NO SAMPLE RECOVERY FROM 2634-2644 FEET DUE TO FAULTY FLOWCHECK VALVE IN DRILL STRING.
HOLE	2650 2660 2670	2546-2650 CC 2654-2658 CC 2663-2670 CC	BIGHORN FORMATION	2646-2663 DOLOMITE, pinkish-gray (7.5YR-7/2 to 7/1) at 2646-2652, becoming light-gray (10YR-7/1) to white (7.5YR-8/0) at 2652, very fine dolosparite to dolomicrite. Very thin (1-3 mm) red shale stringers from 2649-2652. Scattered thin, light gray (10YR-7/1) siltstone stringers at 2653. Becomes a moderately vuggy, very fine to fine dolosparite at 2654.5. Unit appears to be tight above 2654, but has moderate porosity below 2654
	2680	2675-2680 CC		2663-2680 DOLOMITE, same as above but now includes some gray (5Y-5/1) dolosparite beds. A few thin red shale stringers are also present from 2675-2680. Some limonitic staining.
		2685-2690 CC		2680-2690 DOLOMITE, light gray to white very fine dolosparite to dolomicrite. Vuggy. Recrystallized calcite filling some fractures.
	2690	2695-2700 CC		2690-2712 DOLOMITE, white (5YR-8/1), massive, dolosparite. Tight, little porosity.

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

2600-2700, ARR.

BIT TYPE

2600-2700 9.875 inch button bit.

DRILLING FLUID

Clear Water

DRILL FLUID LOSS

None. Making about 166 gal./min. from Madision Fm at 2600 feet, increasing to about 240 gal./min from Madison Fm. at about 2685 feet. Frac sand coming out of Madison Fm.

CASED INTERVAL

0-127 18" Dia.
0-597.9 14" Dia.
597.7-1855 10.75" Dia.
Grout to 1850 feet.
Casing separation from 1810-1815 feet.

CHARACTER OF DRILLING

2600-2631 Drilled smoothly and without difficulty. Penetration rate is about 18 ft./hr.
Twist-off at 2634 feet.
2631-2700 Irregular circulation to 2675 feet. Drilled smoothly, penetration rate: 5-11 ft/hr.

EXPLANATION

¦--¦ NO SAMPLE
█ SAMPLED INTERVAL

TYPE OF HOLE

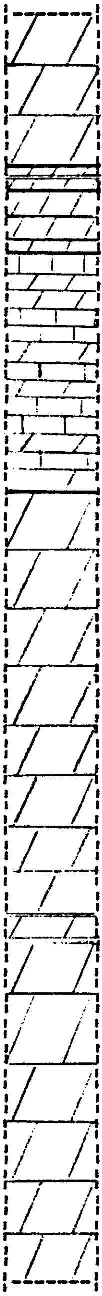
CT -- CABLE TOOL	ARR -- AIR REVERSE ROTARY
MR -- MUD ROTARY	CA --- CONTINUOUS AUGER
AR -- AIR ROTARY	WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE	SC -- STATIC BORE WASH SAMPLE
CC -- CONTINUOUS WASH SAMPLE	BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 28 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
OPEN HOLE	2710 2720 2730 2740 2750 2760 2770 2780 2790	2705-2710 CC 2714-2719 CC 2725-2730 CC 2737-2740 CC 2745-2750 CC 2755-2760 CC 2765-2770 CC 2775-2780 CC 2785-2790 CC 2795-2800 CC	BIG HORN FORMATION		2690-2712 DOLOMITE, white (5YR-8/1), massive, dolomicrite. Clean. Tight, little primary porosity. Limonitic staining. 2712-2714 INTERBEDDED DOLOMITE AND SHALE, white (5YR-8/1) dolomicrite interbedded with dark red (10R-3/6) shale. Beds are about 1 cm thick. 2714-2719 DOLOMITE, white (5YR-8/1) to light gray (5YR-7/1) dolomicrite. 2719-2737.5 INTERBEDDED DOLOMITE AND LIMESTONE, very dark gray (2.5Y-3/0), black (2.5Y-2/0), light gray (10YR-7/1), light brownish gray (10YR-6/2), and gray (10YR-5/1 to 7.5YR-6/0), thin bedded dolomicrite, very fine dolosparite, and very fine dolomitic sparite and micrite. Some banding evident. Dark brown to black staining on fractures and bedding plane surfaces. Fairly tight interval, with only scattered small solution cavities. 2737.5-2908 DOLOMITE, pinkish-gray (5YR-7/2) from 2737.5-2740.5, becoming pinkish-gray (5YR-6/2) to brown (10YR-5/3) at 2740.5, very fine to fine dolosparite. Slightly to very vuggy. Massive. Thin (5-10 cm) dark brown to black shale stringers at 2671-2673. Becomes light gray (2.5Y-7/2) at 2772. Limonitic stains present on some fracture surfaces.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 2700-2800, ARR. BIT TYPE 2700-2800 9.875 inch button bit. DRILLING FLUID Clear Water DRILL FLUID LOSS None. Making about 240 gal./min. from Madison Fm at 2700 feet, increasing to about 260 gal./min. from Madison Fm. at 2800 feet. Frac sand still coming out of Madison Fm. CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet. CHARACTER OF DRILLING 2700-2800 Drilled smoothly and with difficulty. Penetration rate is about 9 ft./hr. from 2700-2751 and about 16-20 ft./hr. from 2751-2800.

EXPLANATION

¦--¦	NO SAMPLE
█	SAMPLED INTERVAL

TYPE OF HOLE

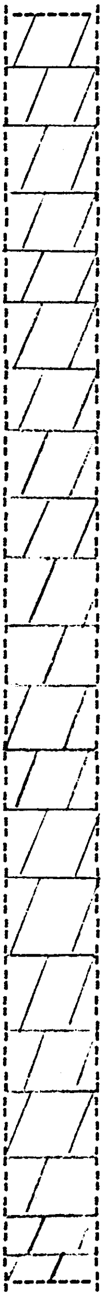
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 29 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
OPEN HOLE	2810 2820 2830 2840 2850 2860 2870 2880 2890	2805-2810 CC 2815-2820 CC 2823-2828 CC 2834-2839 CC 2845-2850 CC 2855-2860 CC 2865-2870 CC 2875-2880 CC 2885-2890 CC 2895-2900 CC	BIG HORN FORMATION		2737.5-2908 DOLOMITE, light gray (2.5Y-7/2), very fine to fine dolosparite. Massive. Slightly to very vuggy. Limonitic stains on many fracture surfaces. Some fractures are filled with white dolomicrite.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 2800-2900, ARR. BIT TYPE 2800-2900 9.875 inch button bit. DRILLING FLUID Clear Water DRILL FLUID LOSS None. Making about 260 gal./min. from Madison Fm at 2800 feet, increasing to about 270 gal./min. from Madison Fm. at 2900 feet. Frac sand still coming out of Madison Fm. CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet. CHARACTER OF DRILLING Drilled smoothly and without difficulty. Penetration rate is about 20 ft./hr. from 2800-2814 and 16 ft./hr. from 2814-2900 feet depth.

EXPLANATION

¦--¦	NO SAMPLE
█	SAMPLED INTERVAL

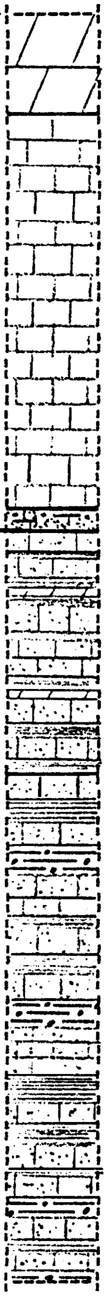
TYPE OF HOLE

CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 30 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
OPEN HOLE	2910 2920 2930 2940 2950 2960 2970 2980 2990	2908-2913 CC 2917-2922 CC 2928-2933 CC 2939-2941 CC 2945-2950 CC 2955-2960 CC 2965-2970 CC 2975-2980 CC 2985-2990 CC 2995-3000 CC	BIG HORN FORMATION GALLATIN FORMATION		2737.5-2908 DOLOMITE, light gray, very fine to fine dolosparite. Massive. 2908-2939 LIMESTONE, reddish-brown (5YR-5/3) to pinkish-gray (7.5YR-7/2), medium grained dolomitic sparite. Becomes vuggy at 2930. Scattered very small pyrite crystals. Recrystallized calcite filling some fractures. 2939-2941 SANDSTONE, dark greenish-gray (5BG-4/1), fine-grained, subrounded to rounded, well sorted, quartz sandstone. Calcareous. Scattered, thin (1-3 cm.) pinkish-gray (7.5YR-7/2) limestone interbeds. Interval is heavily oil stained and odorous. 2941-2960 INTERBEDDED LIMESTONE AND SHALE, dark greenish-gray (5G-4/1) sandy limestone interbedded with dark greenish gray (5BG-4/1) shale. Scattered pyrite cubes in 2941-2960 foot interval. A few thin beds of pinkish gray dolomite also present from 2941-2960. 2960-3018 INTERBEDDED LIMESTONE, SHALE, AND SILTSTONE, gray (7.5YR-6/0) limestone interbedded with greenish-gray shale and siltstone. Limestone is sandy, fine sparite. Shale and siltstone beds are more numerous than in overlying interval. Beds are 1-5 cm. thick. Thin, pinkish-gray (7.5YR-7/2) dolomite beds scattered throughout interval. Becomes dark blue-gray (5B-4/1) from 2975-2989.5 and 2992-2995. A thin (7-12 cm) bed of flat pebble conglomeratic limestone is present at 2979 feet. Glauconitic (?) throughout entire interval.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 2900-3000, ARR. BIT TYPE 2900-3000 9.875 inch button bit. DRILLING FLUID Clear Water DRILL FLUID LOSS None. Making about 270 gal./min. from Madison Fm at 2900 feet, increasing to about 280 gal./min. from Madison Fm. at 3000 feet. Frac sand still coming out of Madison Fm. CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet. CHARACTER OF DRILLING Drilled smoothly and without difficulty. Penetration rate is about 12-15 ft./hr. from 2900-2969 and about 8 ft./hr. from 2969-3000.

EXPLANATION

¦--¦ NO SAMPLE
■ SAMPLED INTERVAL

TYPE OF HOLE

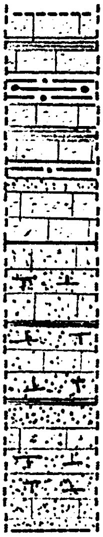
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 1 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 31 OF 31
HOLE NO.: 1 LOCATION: NE1/4, NE1/4, Sec. 35, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3041 GROUND ELEVATION: 4400 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 11 Jan. 84 FINISHED: 9 Dec. 84 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +330.00 ELEVATION OF WATER LEVEL: 4730 DATE WATER LEVEL MEASURED: 16 APR. 84
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 143 psi = +330.00 feet of head.
LOGGED BY: M. Kaczmarek, P. Dunlavy, P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
OPEN HOLE T.D. (3040)	3010 3020 3030 3040 3050 3060 3070 3080 3090	3005-3010 CC 3012-3017 CC 3018-3023 CC 3035-3040 CC	GALLATIN FORMATION		2960-3018 INTERBEDDED LIMESTONE, SHALE, AND SILTSTONE, gray limestone interbedded with greenish-gray shale and siltstone. Limestone becomes a micrite at 3001, and the shale content increases to about 30 percent. Beds are very thin (.75-2.5 cm.). Very thin (5mm) fine-grained, subrounded light brown sandstone stringers at 3013. Limestone becomes a very fine sparite and shale is almost entirely absent from 3014-3018. 3018-3041 INTERBEDDED LIMESTONE AND SANDSTONE, light greenish-gray (5GY-7/1) and greenish-gray (5G-5/1 and 5BG-5/1) to dark greenish-gray (5G-4/1) very fine-grained sandy sparite and micrite interbedded with very fine-grained, rounded, well sorted, calcareous quartz sandstone. Bedding contacts are gradational. Scattered dark greenish-gray shale stringers throughout, become prevalent at 3038. Limestone and sandstone beds appear to be glauconitic (?). Salt and pepper.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 3000-3041, ARR. BIT TYPE 3000-3041 9.875 inch button bit. DRILLING FLUID Clear Water DRILL FLUID LOSS None. Making about 280 gpm at 3000, same at 3041 feet. All of water coming out of Madison Fm., which is still washing out considerable sand from Frac job of April 14 CASED INTERVAL 0-127 18" Dia. 0-597.9 14" Dia. 597.7-1855 10.75" Dia. Grout to 1850 feet. Casing separation from 1810-1815 feet. CHARACTER OF DRILLING Drilled smoothly and without difficulty. Penetration rate is about 14 ft./hr. from 3000-3031 and about 10 ft./hr. from 3031-3041 feet depth.

EXPLANATION

¦--¦	NO SAMPLE
█	SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

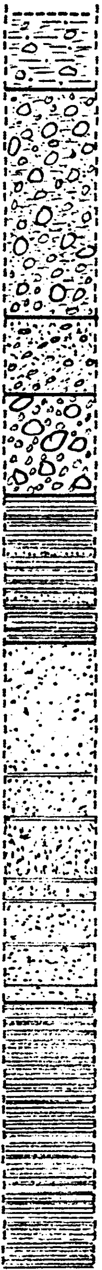
TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

APPENDIX B

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 2   PROJECT: WWDC - Shell Valley Deep Well Project   SHEET 1 OF 7
HOLE NO.: 1   LOCATION: SE1/4, SE1/4, Sec. 26, T.53N., R.91W.   STATE: Wyoming
TOTAL DEPTH: 3379   GROUND ELEVATION: 4349   ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 19 June 85   FINISHED: 24 Aug. 85   DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +371.54   ELEVATION OF WATER LEVEL: 4720.54   DATE WATER LEVEL MEASURED: 9 Sept. 85
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 161 psi = +371.54 feet of head.
LOGGED BY: P. Wiegand   LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
CEMENT GROUT 16 INCH DIA STEEL CASING CEMENT GROUT 9 5/8 INCH DIA THREADED STEEL CASING	10 20 30 40 50 60 70 80 90		TERRACE GRAVEL GYPSUM SPRINGS FM		(Geologist not on site when interval from 0-38 feet was drilled. Log based upon samples collected by driller, and upon driller's log for that interval) 0 - 6 TOPSOIL, silty, with sparse gravels. 6 -24 GRAVEL, rounded 1-3 inch gravel with scattered cobbles in a sandy silty to silty clay matrix. 24 - 30 SAND AND GRAVEL, clayey sand with fine gravel. 30 - 38 GRAVEL AND COBBLES, rounded 1-3 inch gravel with numerous cobbles, some larger than 6 inches diameter. 38 - 49.5 SHALE, light olive-gray (5Y-6/2) to pale olive (5Y-6/3), silty to very silty shale. Calcareous to very calcareous. Laminated. Limonitic stains. Scattered 0.1-.25 foot thick very fine grained sandstone stringers. 49.5 - 78 SANDSTONE, brown (10YR-5/3), very fine grained, very calcareous, well cemented, thin bedded sandstone. Limonitic stains. Becomes very thin bedded to laminated (0.05-0.1 foot) brown sandstone alternating with dark greenish-gray (5G-4/1) to greenish-gray (5G-5/1) sandstone. Very thin white dolomite stringers scattered throughout interval. White, sandy clay stringers at 60-77 feet. Soft, poorly cemented sandstone at 73-77 feet. 78 - 115 SHALE, olive gray (5Y-5/2) to light olive gray (5Y-6/2), fissile shale. Shale is clayey. Drill cuttings are mostly sticky and plastic. Shale is dissolving in drilling fluid. Becomes gray (N-5/0) shale at 99 ft.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 0-100, MR BIT TYPE 0-100 22 inch roller bit with reamers. DRILLING FLUID 0-100 CMS gel with Driscose. DRILL FLUID LOSS NONE CASED INTERVAL 0-179 16 inch Diameter 0-1813 9 5/8 inch Diameter, threaded. CHARACTER OF DRILLING Drilling smoothly but slowly due to large bit size and low bit weight. Penetration rate is about 1-5 ft./hr. Shale dissolving in drilling fluid causes circulation problems and bit to float, also slowing penetration.

EXPLANATION

▯ NO SAMPLE

■ SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL	ARR -- AIR REVERSE ROTARY
MR -- MUD ROTARY	CA --- CONTINUOUS AUGER
AR -- AIR ROTARY	WB --- WASH BORE

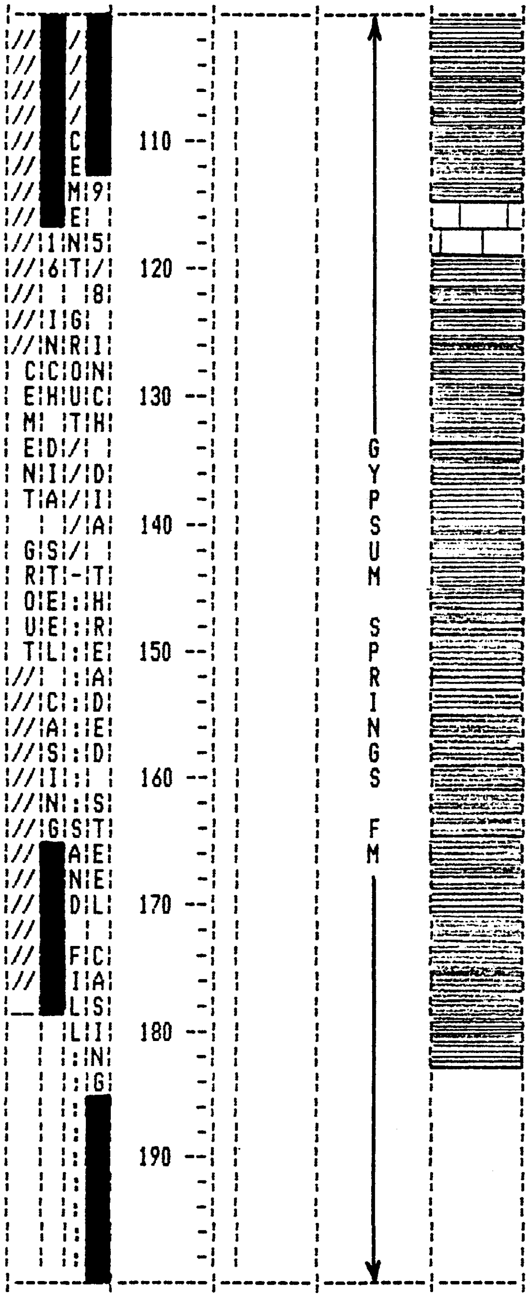
TYPE OF SAMPLE

DS -- DRIVE SAMPLE	SC -- STATIC BORE WASH SAMPLE
CC -- CONTINUOUS WASH SAMPLE	BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 2 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 2 OF 7
HOLE NO.: 1 LOCATION: SE1/4, SE1/4, Sec. 26, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3379 GROUND ELEVATION: 4349 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 19 June 85 FINISHED: 24 Aug. 85 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +371.54 ELEVATION OF WATER LEVEL: 4720.54 DATE WATER LEVEL MEASURED: 9 Sept. 85
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 161 psi = +371.54 feet of head.
LOGGED BY: P. Wiegand LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION



78 - 115 SHALE, gray (N-5/0), fissile shale.

115 - 119 LIMESTONE, dark gray (5Y-4/1) to very dark gray (5Y-3/1), fine sparite. Becomes gray (2.5Y-5/0 to 5Y-6/1) at 117 feet. Pyritic.

119 - 183 SHALE, light brownish-gray (2.5Y-6/2), pale brown (10YR-6/3), and brown (7.5YR-4/4) fissile shale.

Becomes reddish-brown (2.5YR-4/4) with olive-gray (5Y-5/2) mottling from 159 - 183 feet.

Geologist stopped logging upper part of well at 183 feet, where drilling of 22 inch diameter borehole for surface casing was terminated. Interval from 0 - 183 feet used to correlate stratigraphy of Well No. 2 with that of Well No. 1.

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

100-183, MR
183-200, ARR

BIT TYPE

100-183	22 inch roller bit with reamers
183-200	12 1/4 inch med. button bit.

DRILLING FLUID

100-183	CMS gel with Driscose.
183-200	Clear water.

DRILL FLUID LOSS

NONE

CASED INTERVAL

0-179	16 inch Diameter
0-1813	9 5/8 inch Dia.

CHARACTER OF DRILLING

Drilled smoothly and without difficulty. Average penetration rate was about 5 ft./hr. at 100 feet, increasing to about 30 ft./hr. at 183 feet as bit weight increased.

EXPLANATION

☐	NO SAMPLE
■	SAMPLED INTERVAL

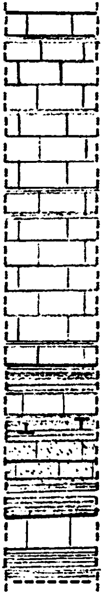
TYPE OF HOLE

CT -- CABLE TOOL	ARR -- AIR REVERSE ROTARY
MR -- MUD ROTARY	CA --- CONTINUOUS AUGER
AR -- AIR ROTARY	WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE	SC -- STATIC BORE WASH SAMPLE
CC -- CONTINUOUS WASH SAMPLE	BS -- BAILER SAMPLE

FEATURE: Shell Valley Well No. 2 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 3 OF 7
HOLE NO.: 1 LOCATION: SE1/4, SE1/4, Sec. 26, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3379 GROUND ELEVATION: 4349 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 19 June 85 FINISHED: 24 Aug. 85 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +371.54 ELEVATION OF WATER LEVEL: 4720.54 DATE WATER LEVEL MEASURED: 9 Sept. 85
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 161 psi = +371.54 feet of head.
LOGGED BY: P. Wiegand and J. Eifealdt LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
OPEN HOLE	2910 2920 2930 2940 2950 2960 2970 2980 2990	2975-2980 CC 2985-2990 CC 2995-3000 CC	GALLATIN FM GROS VENTRE		NOTE: Based upon samples collected by the drilling contractor and examined by Morrison-Maierle, Inc. geologists, the Amsden Fm.-Madison Fm. contact in this well is at a depth of about 1775 feet. Geologists began logging well at 2970 feet, and examined drill cuttings collected by drilling contractor from 2950 - 2970 feet depth. -2983 LIMESTONE, greenish-gray (5G-5/1 to 5BG-5/1) to dark greenish-gray (5G-4/1) fine sparite. Very thin gray to greenish-gray shale stringers scattered throughout interval. 2983-3034 INTERBEDDED SHALE AND LIMESTONE, greenish gray to gray, slightly to moderately calcareous, laminated, fissile shale interbedded with greenish-gray to gray, very thin to thin bedded, fine sparite. Beds are about 0.5-4 feet thick. Some limestone beds are very fine sandy limestone. Shales are fairly hard.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 2900-3000, ARR BIT TYPE 2900-3000 12 1/4 inch medium button DRILLING FLUID Clear Water DRILL FLUID LOSS None. Making about 714 gpm from Madison and Big Horn Formations. CASED INTERVAL 0-179 16 inch Diameter 0-1813 9 5/8 inch Diameter, threaded. CHARACTER OF DRILLING Drilled smoothly and without difficulty. Penetration rate is about 7-8 ft./hr.

EXPLANATION

☐ NO SAMPLE
■ SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

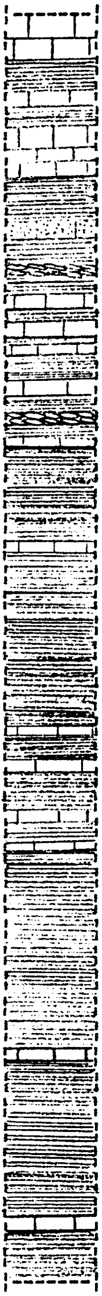
DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 2 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 4 OF 7
HOLE NO.: 1 LOCATION: SE1/4, SE1/4, Sec. 26, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3379 GROUND ELEVATION: 4349 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 19 June 85 FINISHED: 24 Aug. 85 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +371.54 ELEVATION OF WATER LEVEL: 4720.54 DATE WATER LEVEL MEASURED: 9 Sept. 85
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 161 psi = +371.54 feet of head.
LOGGED BY: P. Wiegand and J. Eifealdt LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT
OPEN HOLE	3010	3005-3010 CC	GROS VENTRE FM
	3020	3015-3020 CC	
	3030	3025-3030 CC	
	3040	3035-3040 CC	
	3050	3045-3050 CC	
	3060	3055-3060 CC	
	3070	3065-3070 CC	
	3080	3075-3080 CC	
	3090	3085-3090 CC	
		3095-3100 CC	

GRAPHIC LOG



CLASSIFICATION AND PHYSICAL DESCRIPTION

2983-3034 INTERBEDDED SHALE AND LIMESTONE, greenish gray to gray shale and limestone. Shales are slightly to moderately calcareous, laminated, and most are fissile. Limestones are laminated, and very thin to thin bedded fine sparites. Alternating shale and limestone units are about 0.5-4 feet thick from 2983-3024, then become about 0.1-1 foot thick from 3024-3034. Some limestone beds are sandy. Shales are fairly hard, and the interval is tight. Several thin flat pebble limestone conglomerate beds are also present in this interval. Very thin (<0.1 ft.), olive-brown (2.5Y-4/4) to dark grayish-brown (2.5Y-4/2), siliceous limestone beds are present from 3014-3030 feet. A few very thin red shale stringers are present at 3025-3026 feet.

3034-3275 SHALE, same as above, with scattered very thin to thin (0.1-.5 ft.), very fine to fine sparry limestone beds. A 0.3 foot thick red (10R-5/8) limestone bed is present at 3048 feet. 0.1-0.5 foot thick, dark greenish-gray (5GY-4/1) to dark gray (5Y-4/1) very fine sparry limestone beds present in interval from 3056-3066.

Shales become more fissile at 3071 and are greenish-gray (5BG-6/1).

Shales are fairly hard.

Limonitic staining present in some limestone units.

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

3000-3100, ARR

BIT TYPE

3000-3100 12 1/4 inch medium button

DRILLING FLUID

Clear Water

DRILL FLUID LOSS

None. Making about 714 gpm from Madison and Big Horn Formations.

CASED INTERVAL

0-179 16 inch Diameter
0-1813 9 5/8 inch Diameter, threaded.

CHARACTER OF DRILLING

Drilled smoothly and without difficulty. Penetration rate is about 7.0-9.8 ft./hr.

EXPLANATION

☐ NO SAMPLE
■ SAMPLED INTERVAL

TYPE OF HOLE

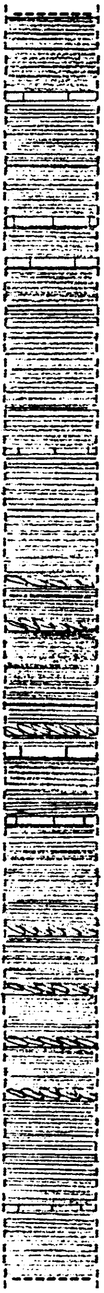
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 2 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 5 OF 7
HOLE NO.: 1 LOCATION: SE1/4, SE1/4, Sec. 26, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3379 GROUND ELEVATION: 4349 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 19 June 85 FINISHED: 24 Aug. 85 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +371.54 ELEVATION OF WATER LEVEL: 4720.54 DATE WATER LEVEL MEASURED: 9 Sept. 85
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 161 psi = +371.54 feet of head.
LOGGED BY: P. Wiegand and J. Eifealdt LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION
	3110	3105-3110 CC	GROS VENTRE FM		3034-3275 SHALE Light olive-brown (2.5Y-5/6), 0.4 foot thick limestone bed at 3107.
	3120	3115-3120 CC			
	3130	3125-3130 CC			
	3140	3135-3140 CC			
OPEN HOLE	3150	3145-3150 CC			Very thin, flat pebble limestone conglomerate beds scattered through interval from 3144-3157 feet.
	3160	3155-3160 CC			Light gray (5Y-6/1) to white (5Y-8/1), 0.3-0.5 foot thick limestone and dolomitic limestone beds present below 3155 feet.
	3170	3165-3170 CC			Shales become dark greenish-gray (5G-4/1), very thinly laminated, and pyritic from 3160-3188 feet.
	3180	3175-3180 CC			Very thin, flat pebble limestone conglomerate beds scattered throughout interval from 3172-3184 feet.
	3190	3185-3190 CC			Sparry limestone and flat pebble limestone conglomerate beds become thinner and less numerous below 3188 feet.
		3195-3200 CC			Pyrite content is shale decreases noticeably below 3188 feet.

DRILLING INFORMATION

DRILLING EQUIPMENT

Sargent Irrigation Co. proprietary air-reverse circulation rotary rig.

DRILLING METHOD

3100-3200, ARR

BIT TYPE

3100-3200 12 1/4 inch medium button

DRILLING FLUID

Clear Water

DRILL FLUID LOSS

None. Making about 714 gpm from Madison and Big Horn Formations.

CASED INTERVAL

0-179 16 inch Diameter
0-1813 9 5/8 inch Diameter, threaded.

CHARACTER OF DRILLING

Drilled smoothly and without difficulty. Penetration rate is about 9.8-12.5 ft./hr. from 3100-3132 feet depth, and about 6.7-8.1 ft./hr. from 3132-3200 feet.

EXPLANATION

☐	NO SAMPLE
■	SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL	ARR -- AIR REVERSE ROTARY
MR -- MUD ROTARY	CA --- CONTINUOUS AUGER
AR -- AIR ROTARY	WB --- WASH BORE

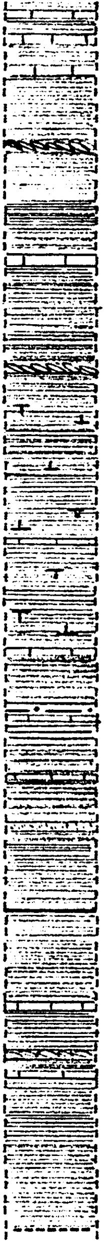
TYPE OF SAMPLE

DS -- DRIVE SAMPLE	SC -- STATIC BORE WASH SAMPLE
CC -- CONTINUOUS WASH SAMPLE	BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 2	PROJECT: WWDC - Shell Valley Deep Well Project	SHEET 6 OF 7
HOLE NO.: 1	LOCATION: SE1/4, SE1/4, Sec. 26, T.53N., R.91W.	STATE: Wyoming
TOTAL DEPTH: 3379 GROUND ELEVATION: 4349	ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.	
BEGUN: 19 June 85	FINISHED: 24 Aug. 85	DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +371.54	ELEVATION OF WATER LEVEL: 4720.54	DATE WATER LEVEL MEASURED: 9 Sept. 85

METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 161 psi = +371.54 feet of head.
LOGGED BY: P. Wiegand and J. Eifealdt LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
OPEN HOLE	3210 3220 3230 3240 3250 3260 3270 3280 3290	3205-3210 CC 3215-3220 CC 3225-3230 CC 3235-3240 CC 3245-3250 CC 3255-3260 CC 3265-3270 CC 3275-3280 CC 3285-3290 CC 3295-3300 CC	GROS VENTRE FM		3034-3275 SHALE Very thin, micritic limestone beds present from 3203-3209 feet. Shales are very fissile and pyritic from 3210-3232 feet; and contain scattered 0.1-0.4 foot thick sparry limestone and flat pebble conglomerate beds. Unit becomes a softer, calcareous, fissile, clay shale at 3233 feet. Very fine sparite and micrite limestone stringers 0.05-0.1 feet thick present from 3245-3260 Light greenish-gray (5G-7/1) siltstone stringers present from 3259-3259.5 feet. Light olive-brown (2.5Y-5/4) very fine sparite bed 0.1 foot thick at 3263 feet. Gray, very fine grained, calcareous, quartz sandstone stringer at 3268 feet. 3275-3379 SHALE, alternating dark greenish-gray (5G-4/1), dark blueish-gray (5B-4/1), and very dark gray (2.5Y-3/0), laminated, very fissile, non-calcareous to slightly calcareous shale. Moderately hard. Very thin sparite, micrite, and conglomeratic limestone stringers present from 3282-3288. 0.05 foot thick limestone stringer at 3292 feet.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 3200-3300, ARR BIT TYPE 3200-3300 12 1/4 inch medium button DRILLING FLUID Clear Water DRILL FLUID LOSS None. Making about 714 gpm from Madison and Big Horn Formations. CASED INTERVAL 0-179 16 inch Diameter 0-1813 9 5/8 inch Diameter, threaded. CHARACTER OF DRILLING Drilled smoothly and without difficulty. Penetration rate is about 10.1 ft./hr. from 3200-3231 feet, and about 8 ft/hr. from 3231-3300 feet.

EXPLANATION

☐	NO SAMPLE
■	SAMPLED INTERVAL

TYPE OF HOLE

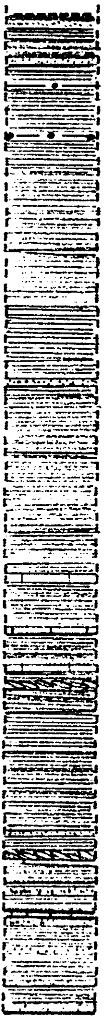
CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

MORRISON-MAIERLE, INC.
GEOLOGIC LOG

FEATURE: Shell Valley Well No. 2 PROJECT: WWDC - Shell Valley Deep Well Project SHEET 7 OF 7
HOLE NO.: 1 LOCATION: SE1/4, SE1/4, Sec. 26, T.53N., R.91W. STATE: Wyoming
TOTAL DEPTH: 3379 GROUND ELEVATION: 4349 ELEVATION SOURCE: 7.5 Min. Topo Quad. with 20 Ft. Contours.
BEGUN: 19 June 85 FINISHED: 24 Aug. 85 DIP(ANGLE FROM HORIZ.): 90
DEPTH OF WATER LEVEL: +371.54 ELEVATION OF WATER LEVEL: 4720.54 DATE WATER LEVEL MEASURED: 9 Sept. 85
METHOD MEASURED WATER LEVEL: Pressure Gage, shut-in pressure = 161 psi = +371.54 feet of head.
LOGGED BY: P. Wiegand and J. Eifealdt LOG REVIEWED BY: M. Kaczmarek

CASING TALLEY	DEPTH (FEET)	SAMPLE DEPTHS	GEOLOGIC UNIT	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL DESCRIPTION	DRILLING INFORMATION
OPEN HOLE TD	3310 3320 3330 3340 3350 3360 3370 3380 3390	■ 3303-3308 CC ■ 3314-3319 CC ■ 3326-3330 CC ■ 3335-3340 CC ■ 3345-3350 CC ■ 3355-3360 CC ■ 3365-3370 CC	GROS VENTRE FM		3275-3379 SHALE 0.05 foot thick very fine grained sandstone stringer at 3301 feet. Gray (2.5Y-5/0) to black (2.5Y-2/0), subangular to rounded, well sorted, quartz sandstone stringers 0.02-0.05 feet thick from 3303-3304 feet. Quartz grains are frosted. Scattered, very thin siltstone stringers present in shales below 3304 feet. Gray to black, subangular to rounded well sorted, calcareous quartz sandstone stringer at 3329. Slight oil staining in shales from 3345-3348 feet. Shale is pyritic below 3345 feet. White (2.5Y-8/0) to gray (N-6/0), very thin, micrite to very fine sparry limestone stringers in shale from 3344-3352. Flat pebble limestone conglomerate at 3352 feet. Limestone pebbles are vuggy sparite. Very hard, gray, calcareous quartz sandstone stringer at 3364.5 feet. Flat limestone pebbles present in shale at 3366 feet. Very hard, non-calcareous sandstone stringers at 3369 and scattered throughout interval from 3370-3379 feet. Light greenish-gray limestone stringer at 3371.5 feet. Siltstone laminae in shale at 3371.5 feet. Drilling terminated at 3379 feet depth due to unstable borehole conditions.	DRILLING EQUIPMENT Sargent Irrigation Co. proprietary air-reverse circulation rotary rig. DRILLING METHOD 3300-3379, ARR BIT TYPE 3300-3370 12 1/4 inch medium button 3370-3379 12 1/4 inch short tooth button bit. DRILLING FLUID Clear Water DRILL FLUID LOSS None. Making about 714 gpm from Madison and Big Horn Formations. CASED INTERVAL 0-179 16 inch Diameter 0-1813 9 5/8 inch Diameter, threaded. CHARACTER OF DRILLING Drilled smoothly and without difficulty from 3300-3325 feet. Caving of formation caused rods to bind in borehole from 3325-3379 feet. Unable to keep borehole open below 3325 feet. Penetration rate is 2.5-4 ft/hr.

EXPLANATION

☐ NO SAMPLE

■ SAMPLED INTERVAL

TYPE OF HOLE

CT -- CABLE TOOL
MR -- MUD ROTARY
AR -- AIR ROTARY
ARR -- AIR REVERSE ROTARY
CA --- CONTINUOUS AUGER
WB --- WASH BORE

TYPE OF SAMPLE

DS -- DRIVE SAMPLE
CC -- CONTINUOUS WASH SAMPLE
SC -- STATIC BORE WASH SAMPLE
BS -- BAILER SAMPLE

APPENDIX C

STRATA DATA INC

DUAL NORMAL ELECTRIC LOG
WITH S. P.

FILE NO 3032

COMPANY WYOMING WATER DEVELOPMENT COMMISSION
WELL SHELL VALLEY NO.1
FIELD
COUNTY BIG HORN STATE WYOMING
LOCATION: NE/NE
SEC 35 TWP 53N. RGE 91W.
Other Services GR/CDL

Permanent Datum Ground Level Elev. 4400
Log Measured from K.B. 5 Ft. Above Permanent Datum
Drilling Measured from K.B.
Elevations KB 4405 DF GL 4400

Date	03/15/84	03/25/84		
Run No.	ONE	TWO		
Depth—Driller	1855	2440		
Depth—Logger	1855	2418		
Bottom Logged Interval	1854	2417		
Top Logged Interval	132	1809		
Casing—Driller	18" @ 126	10" @ 1850	@	@
Casing—Logger	132	1857		
Bit Size	16" - 12 1/4"	8 3/4"		
Type Fluid in Hole	CHEM. GEL	FORMATION WATER		
Density and Viscosity	10.2 60	N/A N/A		
pH and Fluid Loss	N/A N/A cc	N/A N/A cc	cc	cc
Source of Sample	PIT	FLOWLINE		
Rm @ Meas. Temp.	2.74 @ 70 °F	28.10 @ 65 °F	@ °F	@ °F
Rmf @ Meas. Temp.	2.45 @ 69 °F	N/A @ °F	@ °F	@ °F
Rmc @ Meas. Temp.	2.62 @ 73 °F	N/A @ °F	@ °F	@ °F
Source of Rmf and Rmc	MEAS. MEAS.	N/A N/A		
Rm @ BHT	3.04 @ 63 °F	28.99 @ 63 °F	@ °F	@ °F
Time Since Circ.	5 HRS.	7 HRS.		
Max. Rec. Temp. Deg. F.	63 °F	63 °F	°F	°F
Equip. No. and Location	101 CASPER	101 CASPER		
Recorded By	R. McDONALD	R. McDONALD		
Witnessed By	MR. DUNLAVY	MR. WIEGAND,	MR. DUNLAVY,	MR. STRUEMPLER

FOLD HERE

REMARKS BIT SIZE 16" FROM SURF. CASING TO 612' AND 12 1/4" FROM 612' TO T.D.
RUN #2: WELL FLOWING WATER AT APPROX. 500 G.P.M. WHILE LOGGING.

CASING APPEARS TO BE PARTED AT 1809 FT.

UNABLE TO RUN EITHER CDL OR GAMMA RAY - CALIPER BECAUSE OF OBSTRUCTION AT 1814 FT.

Changes in Mud Type or Additional Samples

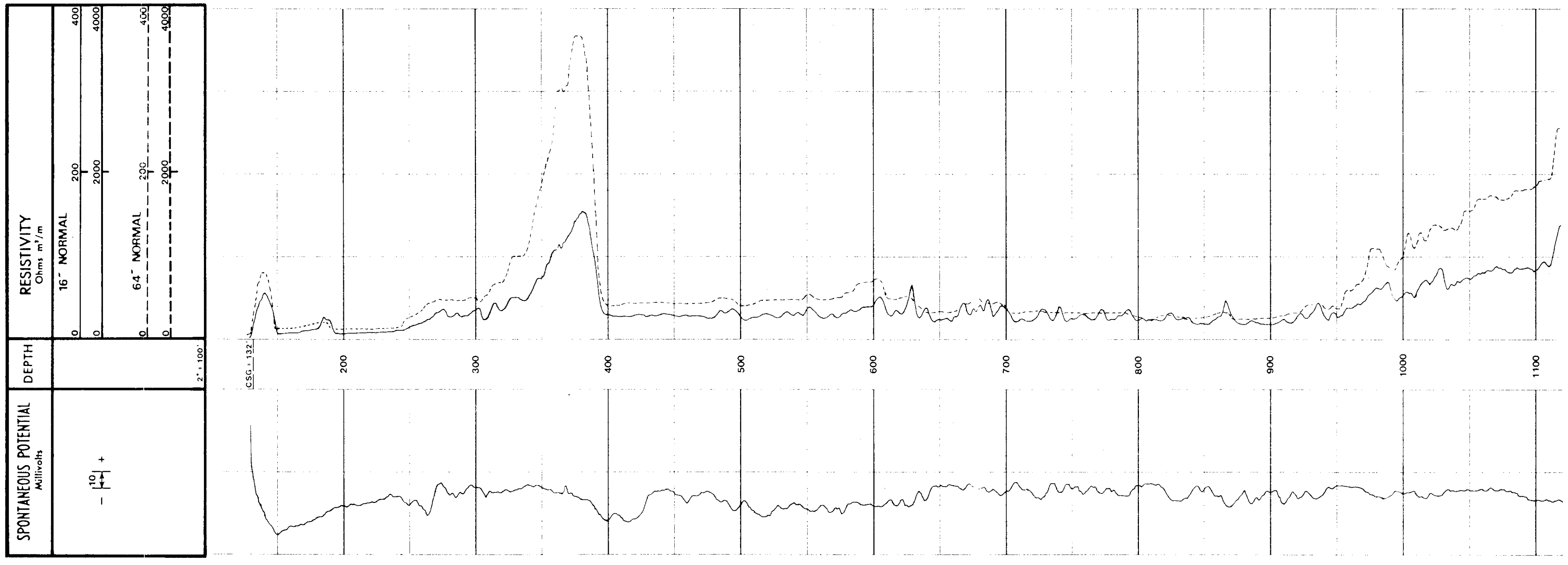
Date Sample No.	03/15/84 ONE	03/25/84 TWO
Depth-Driller	1855	2440
Type Fluid in Hole	CHEM. GEL	FORMATION WATER
Dens. Visc.	10.2 60	N/A N/A
pH Fluid Loss	N/A N/A cc	N/A N/A cc
Source of Sample	PIT	FLOWLINE
Rm @ Meas. Temp.	2.74 @ 70 °F	28.10 @ 65 °F
Rmf @ Meas. Temp.	2.45 @ 69 °F	N/A @ °F
Rmc @ Meas. Temp.	2.62 @ 73 °F	N/A @ °F
Source Rmf Rmc	MEAS. MEAS.	N/A N/A
Rm @ BHT	3.04 @ 63 °F	28.99 @ 63 °F
Rmf @ BHT	2.68 @ 63 °F	N/A @ °F
Rmc @ BHT	3.04 @ 63 °F	N/A @ °F

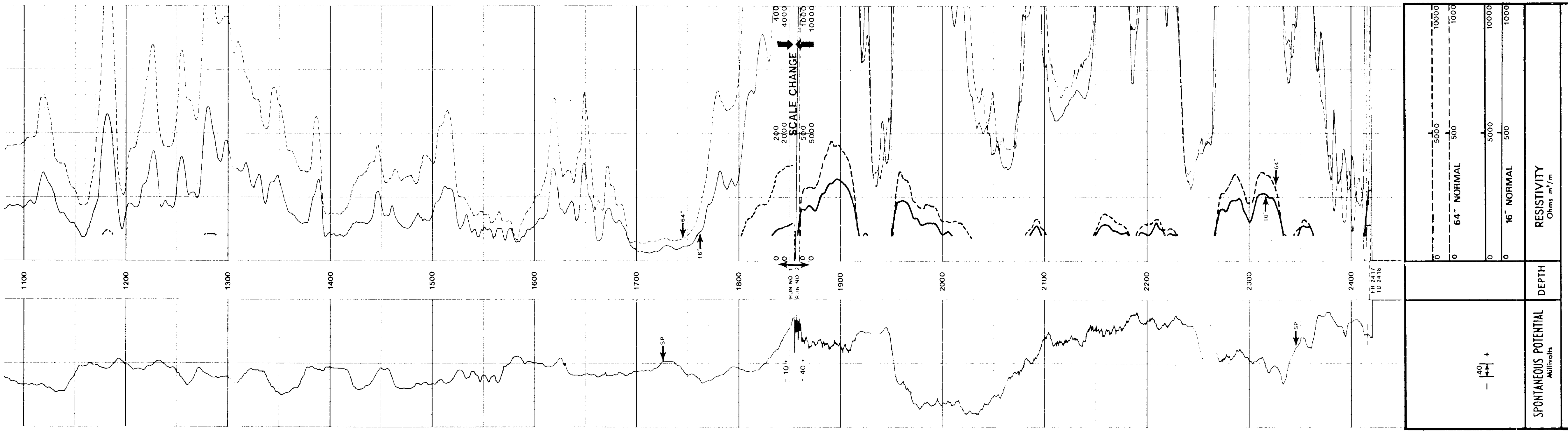
Scale Changes

Type Log	Depth	Scale Up Hole	Scale Down Hole

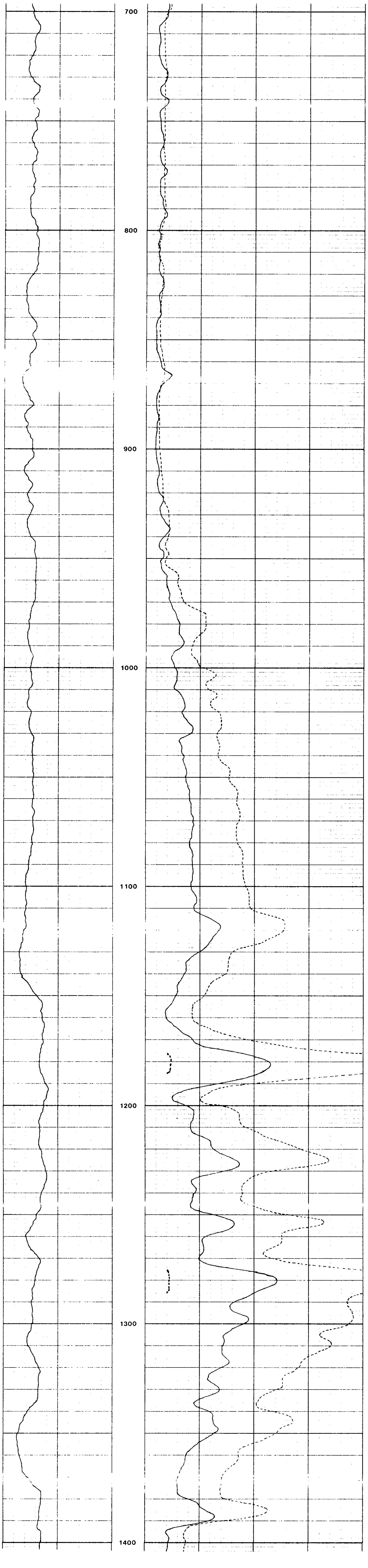
Equipment Data

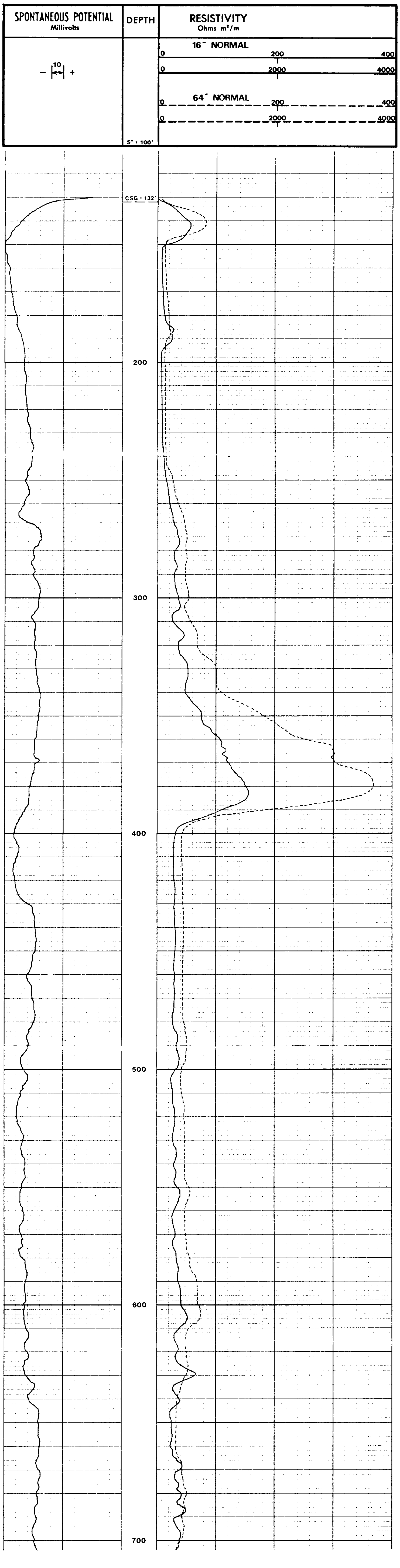
Run No.	Tool Type	Pad Type	Tool Position	Other
ONE	EL	N/A	FREE	MLS
TWO	EL	N/A	FREE	MLS

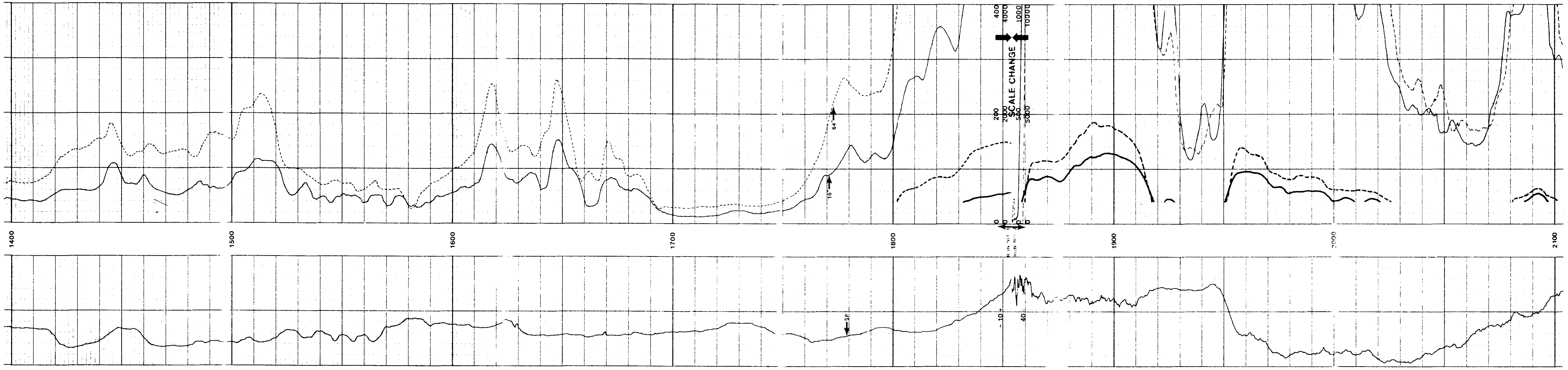


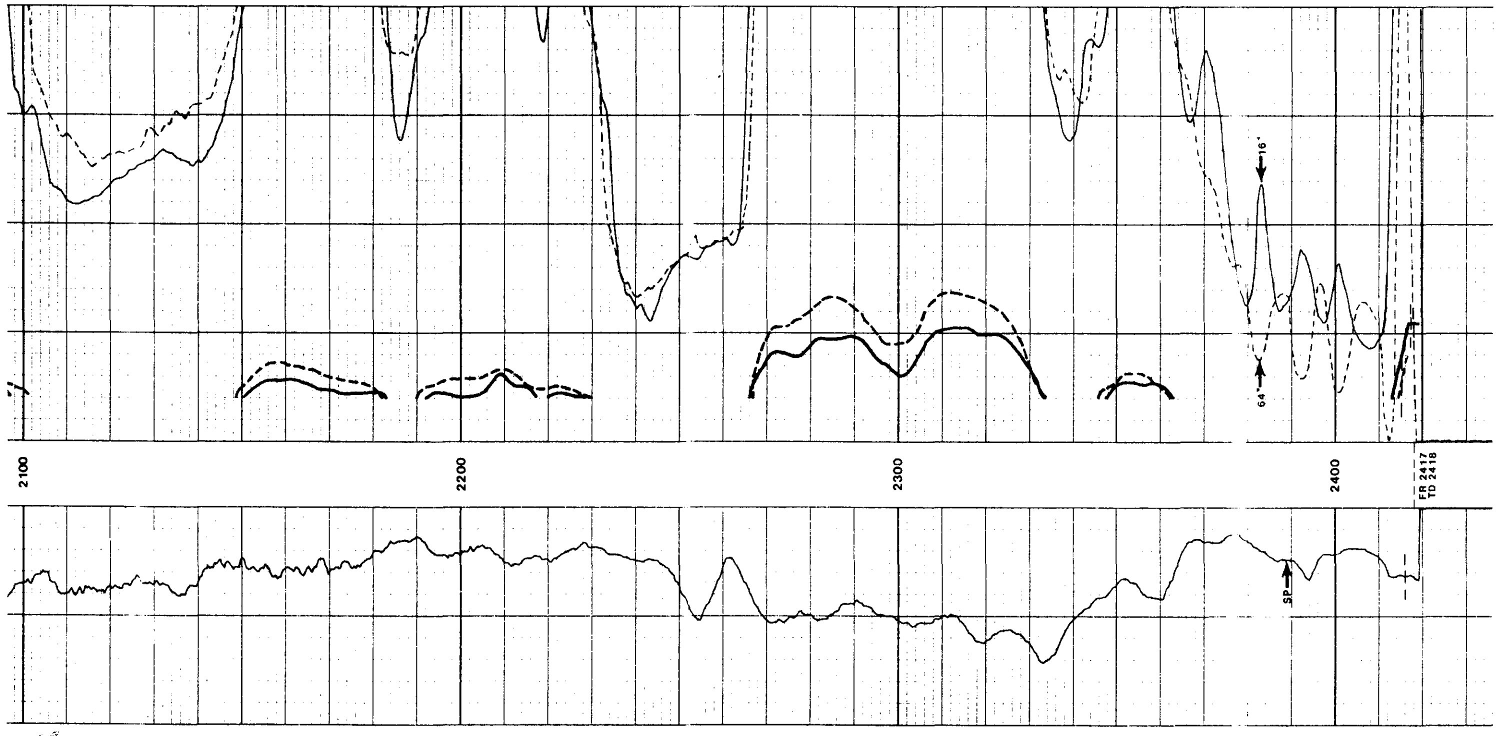


Company WYOMING WATER DEVELOPMENT COMMISSION Drillers T.D. 2440
Well SHELL VALLEY NO. 1 Log F.R. 2417
Field Log T.D. 2418
County BIG HORN Elevations:
State WYOMING K.B. 4405 D.F. G.L. 4400

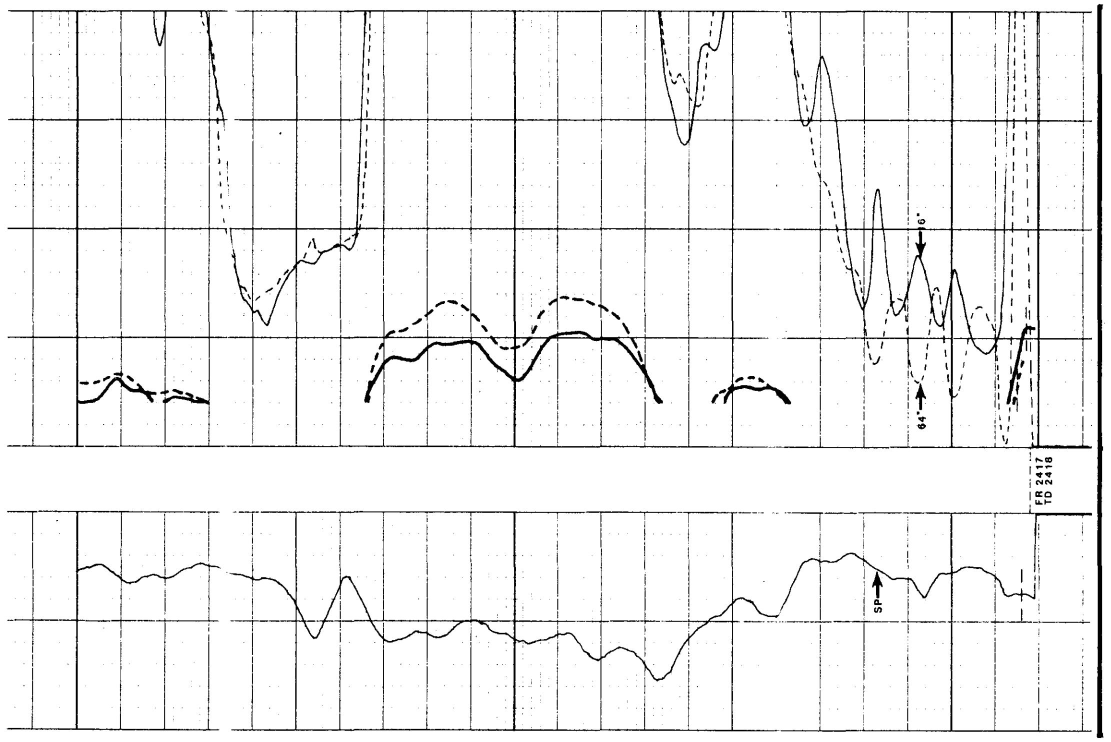

700
800
900
1000
1100
1200
1300
1400

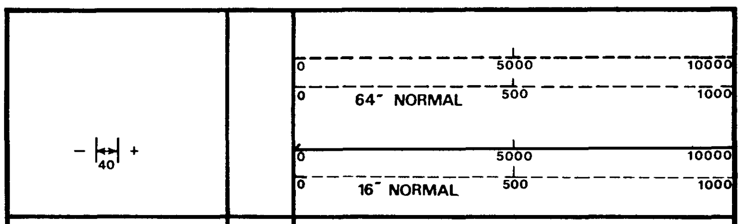

SPONTANEOUS POTENTIAL
Millivolts
– 10 +
DEPTH
5" = 100'
RESISTIVITY
Ohms m²/m
16" NORMAL
0
200
400
0
2000
4000
64" NORMAL
0
200
400
0
2000
4000
CSG - 132'
200
300
400
500
600
700





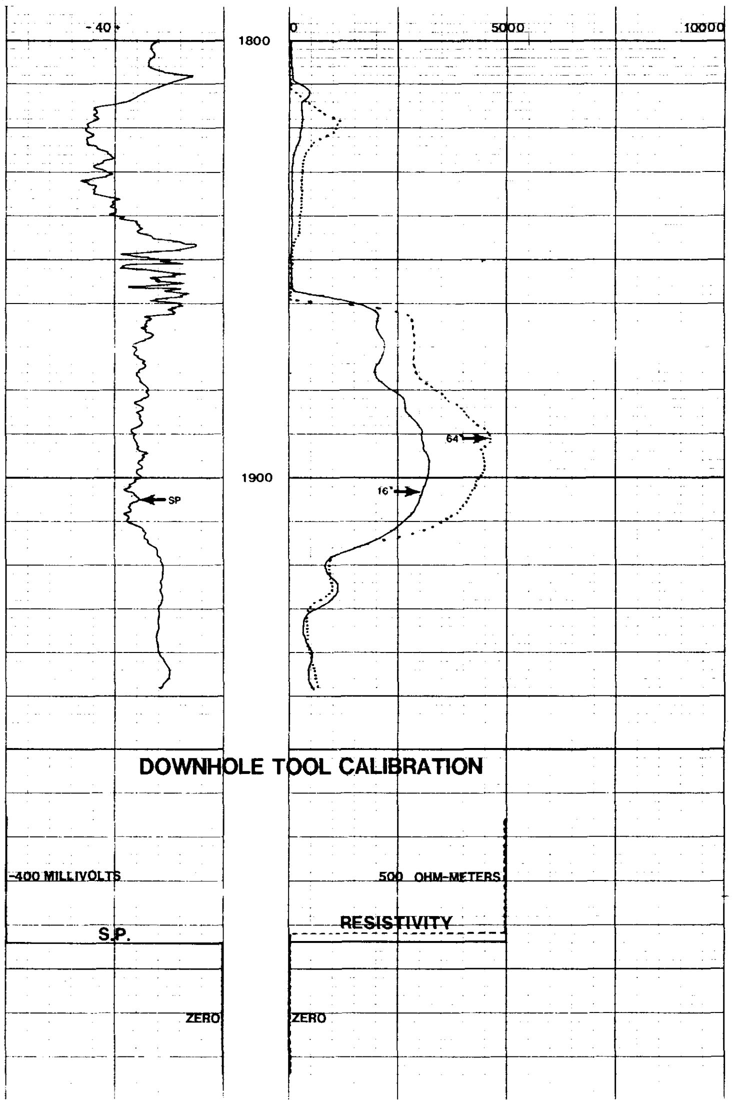
REPEAT SECTION





SPONTANEOUS POTENTIAL Millivolts	DEPTH	RESISTIVITY Ohms m²/m

Company WYOMING WATER DEVELOPMENT COMMISSION Drillers T.D. 2440
Well SHELL VALLEY NO. 1 Log F.R. 2417
Field Log T.D. 2418
County BIG HORN Elevations:
State WYOMING K.B. 4405 D.F. G.L. 4400



STRATA DATA INC

COMPENSATED DENSITY LOG
WITH CALIPER AND GAMMA RAY

FILE NO. 3032

COMPANY WYOMING WATER DEVELOPMENT COMMISSION
WELL SHELL VALLEY NO.1
FIELD
COUNTY BIG HORN STATE WYOMING
LOCATION: NE/NE
SEC 35 TWP 53N. RGE 91W.
Other Services: DNEL

Permanent Datum Ground Level Elev. 4400
Log Measured from K.B. 5 Ft. Above Permanent Datum
Drilling Measured from K.B.
Elevations: KB 4405 DF GL 4400

Date	03/15/84			
Run No.	ONE			
Depth—Driller	1855			
Depth—Logger	1855			
Bottom Logged Interval	1854			
Top Logged Interval	0			
Casing—Driller	18" @126	@	@	@
Casing—Logger	132			
Bit Size	16" - 12 1/4"			
Type Fluid in Hole	CHEM. GEL			
Density and Viscosity	10.2 | 60			
pH and Fluid Loss	N/A | N/A cc	cc	cc	cc
Source of Sample	PIT			
Rm @ Meas. Temp.	2.74 @ 70 F	@ F	@ F	@ F
Rmf @ Meas. Temp.	2.45 @ 69 F	@ °F	@ F	@ F
Rmc @ Meas. Temp.	2.62 @ 73 F	@ °F	@ F	@ F
Source of Rmf and Rmc	MEAS. | MEAS.			
Rm @ BHT	3.04 @ 63 F	@ F	@ F	@ F
Time Since Circ.	7 HRS.			
Max. Rec. Temp. Deg. F.	63 °F	F	°F	F
Equip. No. and Location	101 CASPER			
Recorded By	R. McDONALD			
Witnessed By	MR. DUNLAVY			

FOLD HERE

Equipment Data

	Density		Gamma Ray
Run No.	ONE	Run No.	ONE
Tool Model No.	2152	Tool Model No.	2148-A
Serial No.	2483	Serial No.	2254
Diam	2 1/8	Diam.	2 1/8
Computer Model No.	DPM-1	Detect. Model No.	S-14
Serial No.	2561	Type	SCINT.
Source Model No.	9381-000-S	Length	4 IN.
Serial No.	CSV-F69	Dist. to Source	8 FT.

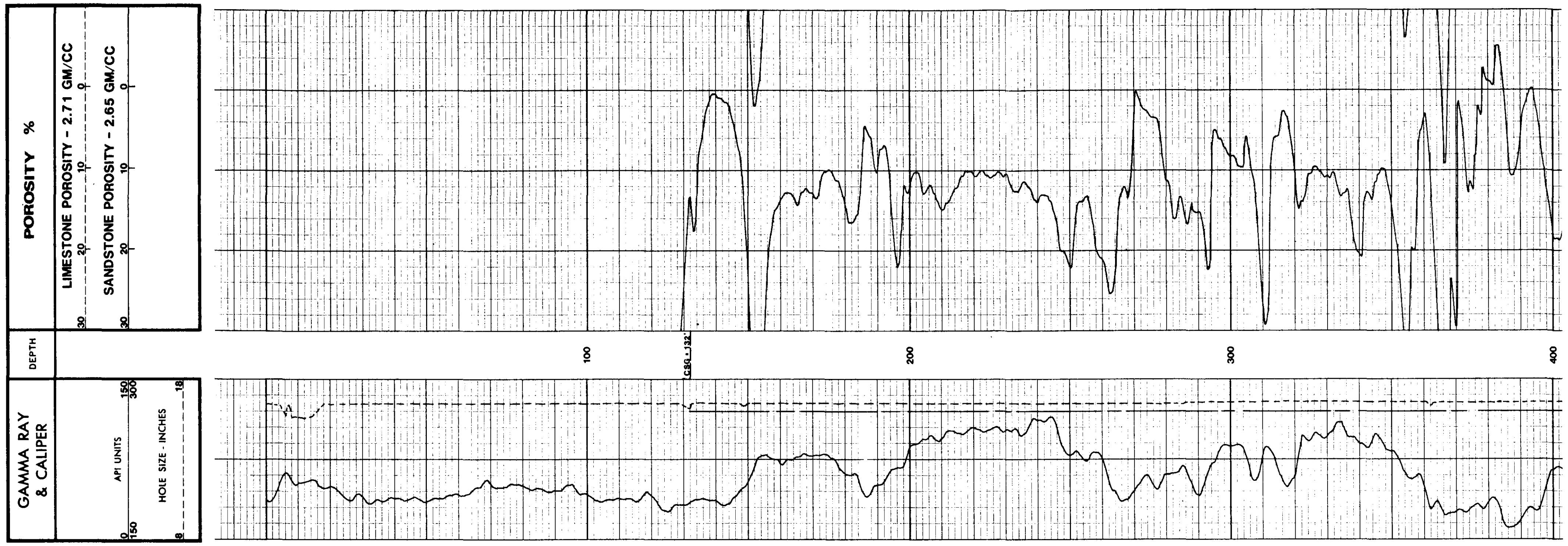
Computer Data		General	
DENSITY	85	Hoist Truck No.	101
POROSITY	100	Auxiliary Equipment	
CORRECTION	430		

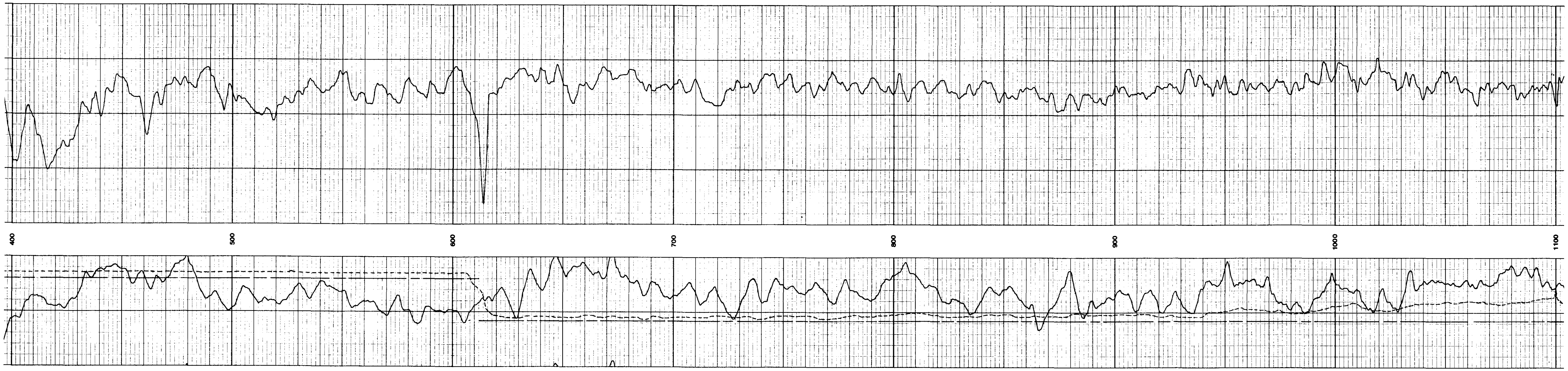
Logging Data

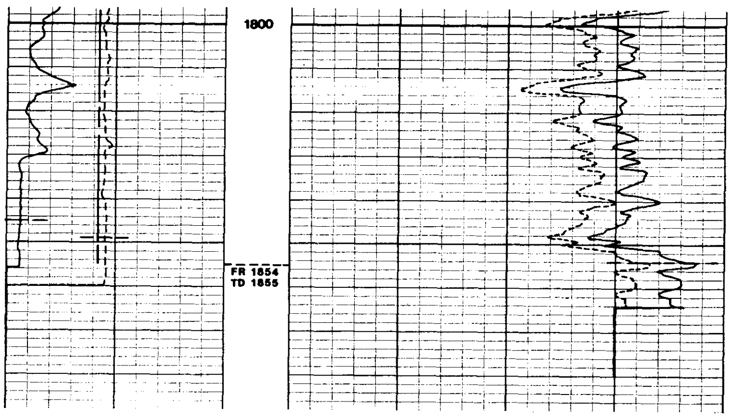
General				Gamma Ray				Density			
Run No.	Depths From	Depths To	Speed Ft./Min.	T.C. Sec.	Sens. Settings	Zero Div. L or R	API G.R. Units Per Log Div.	T.C. Sec.	Density Scale	Correction Scale	Porosity Scale Data
ONE	1854	0	20	3	97	ZERO	15	3	N/A	N/A	Dg=2.65
ONE	1854	1150	20	3	97	ZERO	15	3	N/A	N/A	Dg=2.71

Remarks: BIT SIZE 16" FROM SURF. CASING TO 612' AND 12 1/4" FROM 612' TO T.D.

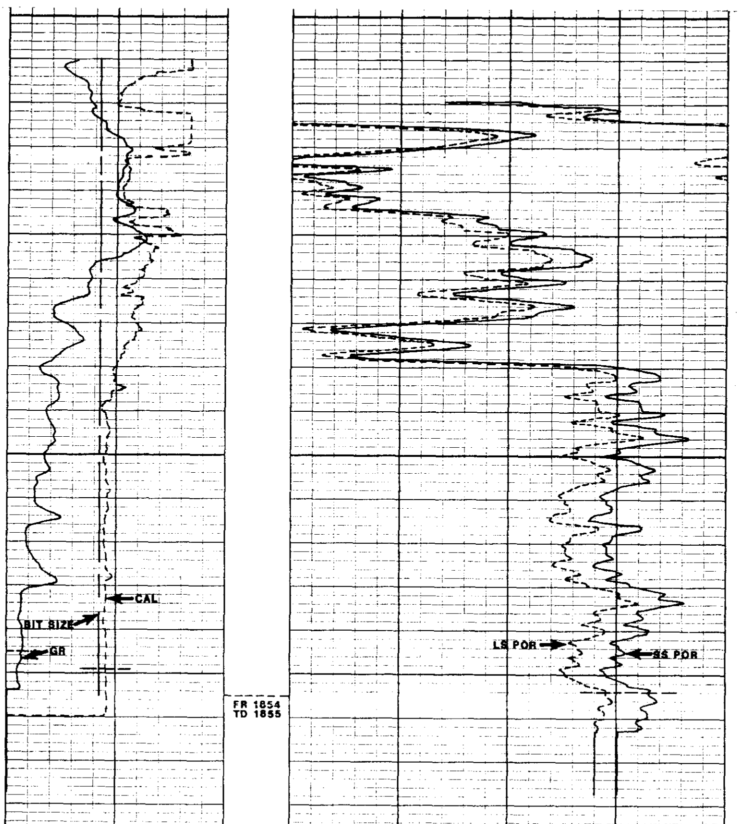
Reference Literature:







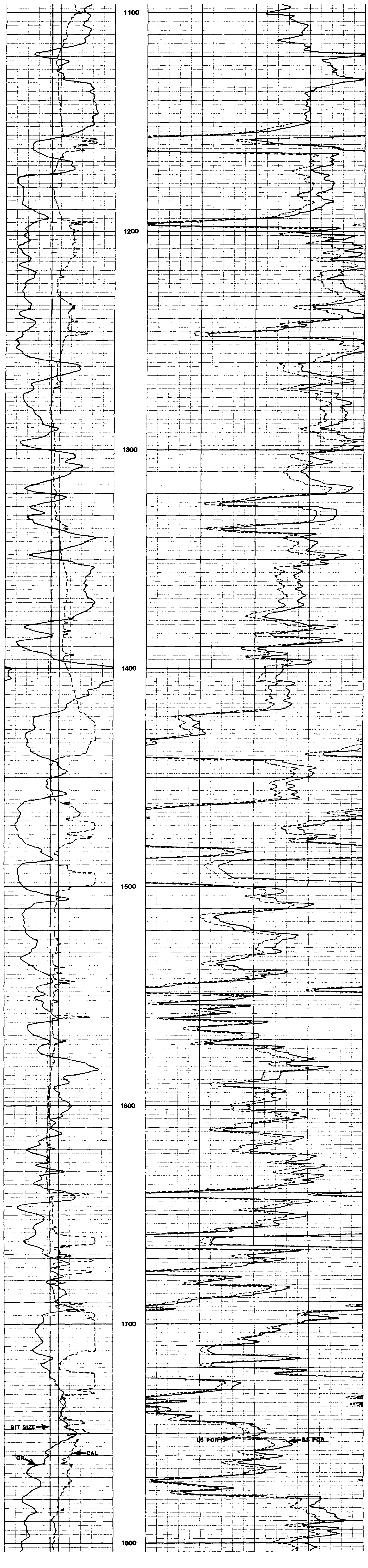
REPEAT SECTION



8 HOLE SIZE - INCHES 18 150 300 0 API UNITS 150		30 20 10 0 SANDSTONE POROSITY - 2.65 GM/CC 30 20 10 0 LIMESTONE POROSITY - 2.71 GM/CC
GAMMA RAY & CALIPER	DEPTH	POROSITY %

Company WYOMING WATER DEVELOPMENT COMMISSION
Well SHELL VALLEY NO. 1
Field
County BIG HORN
State WYOMING

Drillers T.D. 1855
Log F.R. 1854
Log T.D. 1855
Elevations:
K.B. 4405 D.F. G.L. 4400



8 HOLE SIZE - INCHES 18

150 API UNITS 300
0 150

30 20 10 0
SANDSTONE POROSITY - 2.65 GM/CC

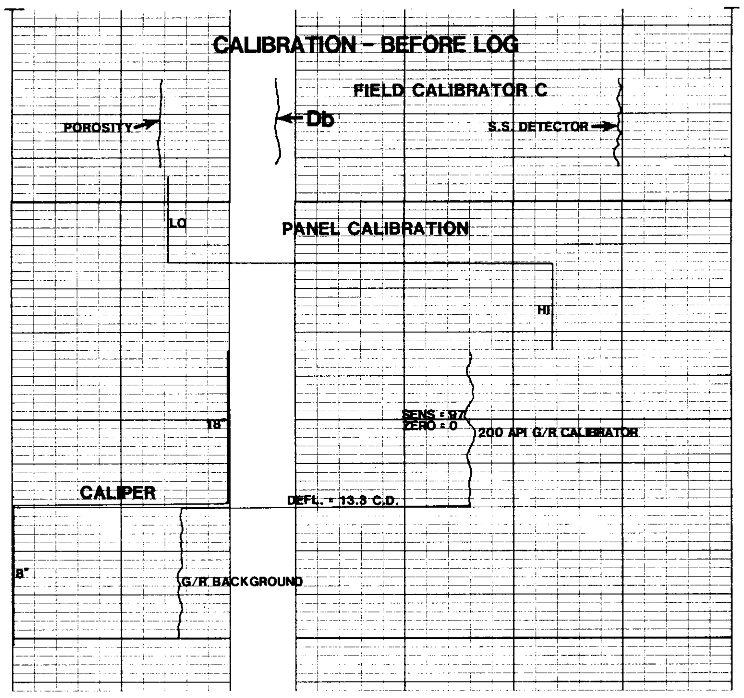
30 20 10 0
LIMESTONE POROSITY - 2.71 GM/CC

GAMMA RAY & CALIPER	DEPTH	POROSITY %

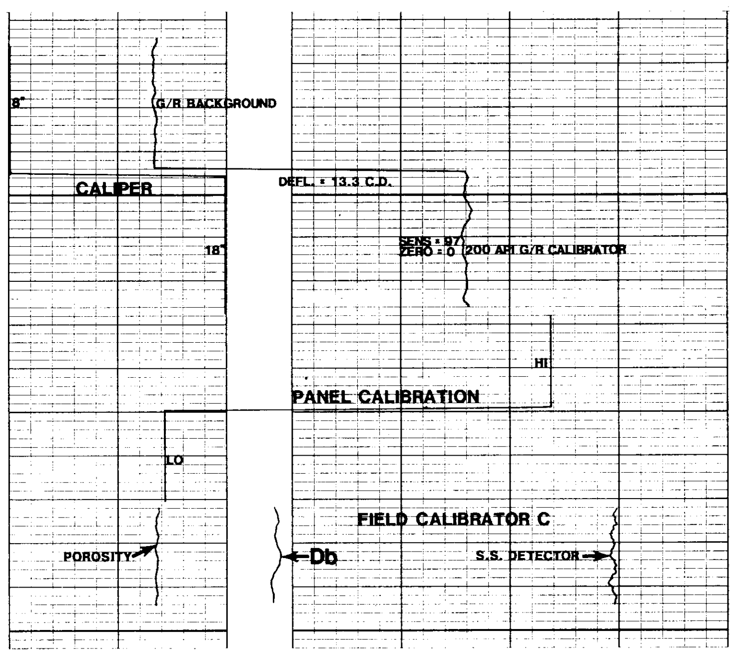
Company WYOMING WATER DEVELOPMENT COMMISSION
Well SHELL VALLEY NO. 1
Field
County BIG HORN
State WYOMING

Drillers T.D. 1855
Log F.R. 1854
Log T.D. 1855
Elevations:
K.B. 4405 D.F. G.L. 4400

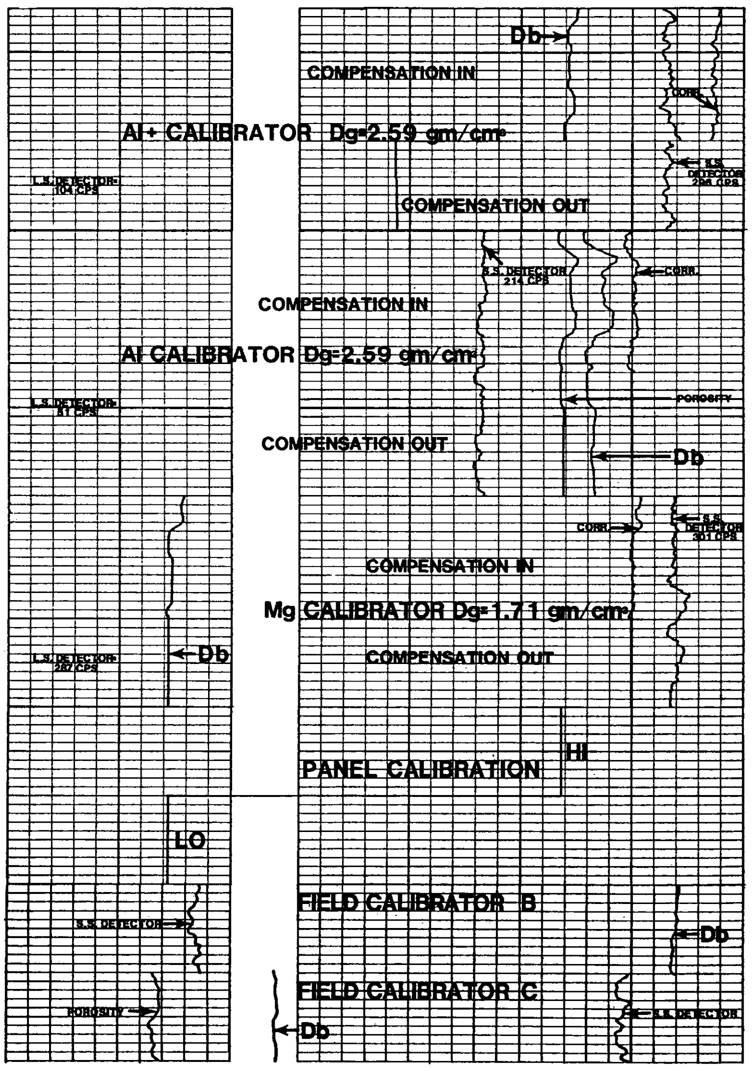
CALIBRATION - BEFORE LOG



CALIBRATION - AFTER LOG



SHOP CALIBRATION - DENSITY



APPENDIX D

STRATA DATA INC

DUAL NORMAL ELECTRIC LOG
WITH S. P.

FILE NO. 3085 3087

COMPANY WYOMING WATER DEVELOPMENT COMM.
WELL SHELL VALLEY NO. 2
FIELD
COUNTY BIG HORN STATE WYOMING
LOCATION: NE/NE
SEC 35 TWP 53N RGE 91W

Other Services
GR/CDL
GR/CAL
SPINNER
TEMP
DIFF TEMP

Permanent Datum GROUND LEVEL Elev. 4345
Log Measured from K.B. 5 Ft. Above Permanent Datum
Drilling Measured from K.B.

Elevations.
KB 4350
DF
GL 4345

Date	08/13/85	08/25/85		
Run No.	ONE	TWO		
Depth—Driller	3369	3369		
Depth—Logger	1680	3108		
Bottom Logged Interval	1679	3107		
Top Logged Interval	180	1820		
Casing—Driller	16 @ 180	9 5/8@ 1817	@	@
Casing—Logger	179	1817		
Bit Size	12 1/4	12 1/4		
Type Fluid in Hole	FORMATION WATER	FORMATION WATER		
Density and Viscosity	N/A N/A	N/A N/A		
pH and Fluid Loss	N/A N/A cc	N/A N/A cc	cc	cc
Source of Sample	NONE	FLOWLINE		
Rm @ Meas. Temp.	N/A @ F	27.00@ 82 F	@ F	@ F
Rmf @ Meas. Temp.	N/A @ F	N/A @ °F	@ F	@ °F
Rmc @ Meas. Temp.	N/A @ °F	N/A @ °F	@ F	@ °F
Source of Rmf and Rmc	N/A N/A	N/A N/A		
Rm @ BHT	N/A @ F	32.42@ 68.3 F	@ F	@ F
Time Since Circ.	*FLOWING	*FLOWING		
Max. Rec. Temp. Deg. F.	N/A F	68.3 F	°F	°F
Equip. No. and Location	101 CASPER	101 CASPER		
Recorded By	R. McDONALD	R. McDONALD		
Witnessed By	MR. KACZMAREK, MR. WIEGAND	, MR. WADE		

FOLD HERE

THIS HEADING AND LOG CONFORMS TO API RECOMMENDED STANDARD PRACTICE RP 3

REMARKS * WELL WAS FLOWING WATER AT APPROX. 900 G.P.M. WHILE LOGGING

*RUN NO.2 - WELL WAS FLOWING WATER AT APPROX. 1090 G.P.M. WHILE LOGGING.

Changes in Mud Type or Additional Samples

Date | Sample No.	08/13/85 ONE	08/25/85 TWO
Depth-Driller	3369	3369
Type Fluid in Hole	FORMATION WATER	FORMATION WATER
Dens. | Visc.	N/A N/A	N/A N/A
pH | Fluid Loss	N/A N/A cc	N/A N/A cc
Source of Sample	NONE	FLOWLINE
Rm @ Meas. Temp.	N/A @ °F	27.00@ 82 °F
Rmf @ Meas. Temp.	N/A @ °F	N/A @ °F
Rmc @ Meas. Temp.	N/A @ °F	N/A @ °F
Source Rmf | Rmc	N/A N/A	N/A N/A
Rm @ BHT	N/A @ °F	32.42@ 68.3 °F
Rmf @ BHT	N/A @ °F	N/A @ °F
Rmc @ BHT	N/A @ °F	N/A @ °F

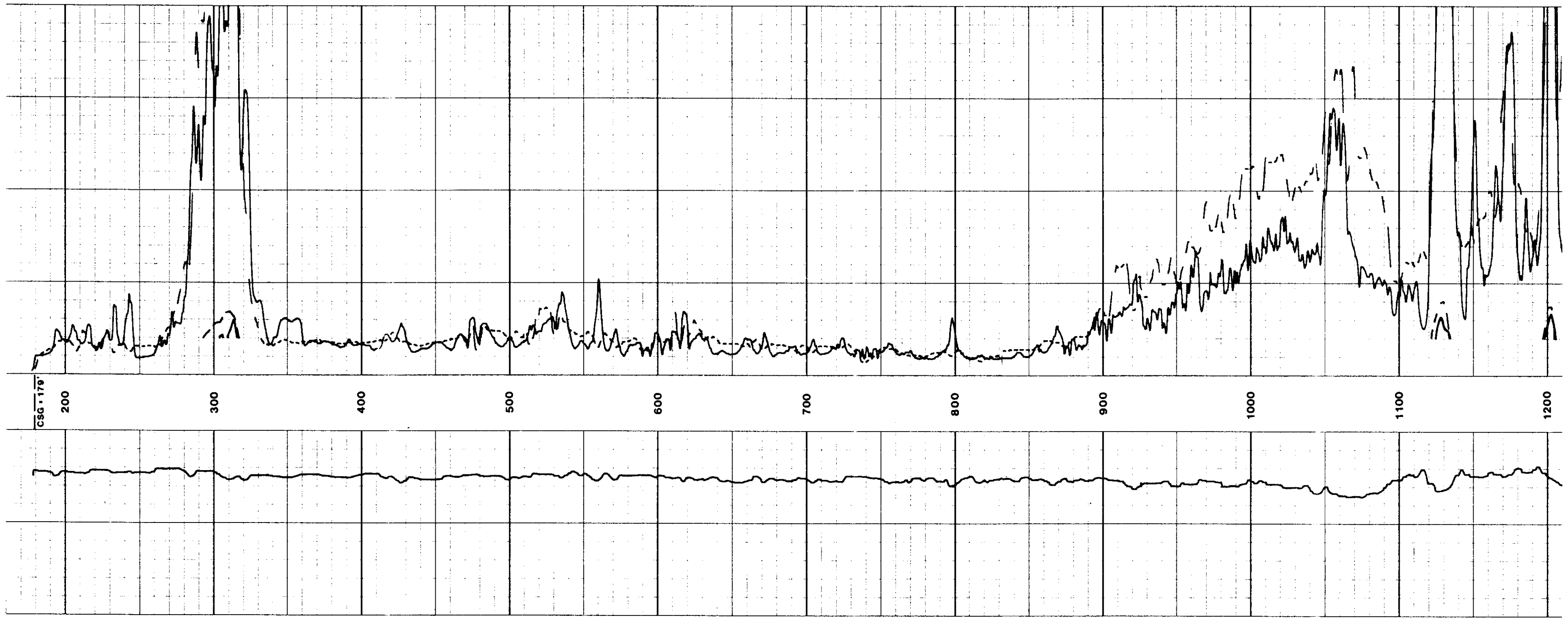
Scale Changes

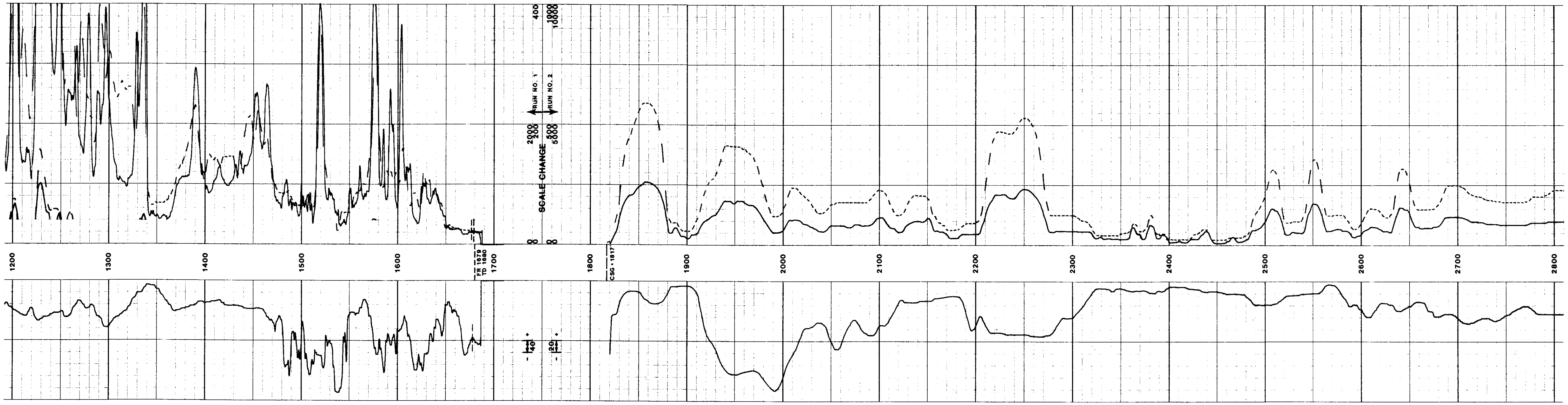
Type Log	Depth	Scale Up Hole	Scale Down Hole

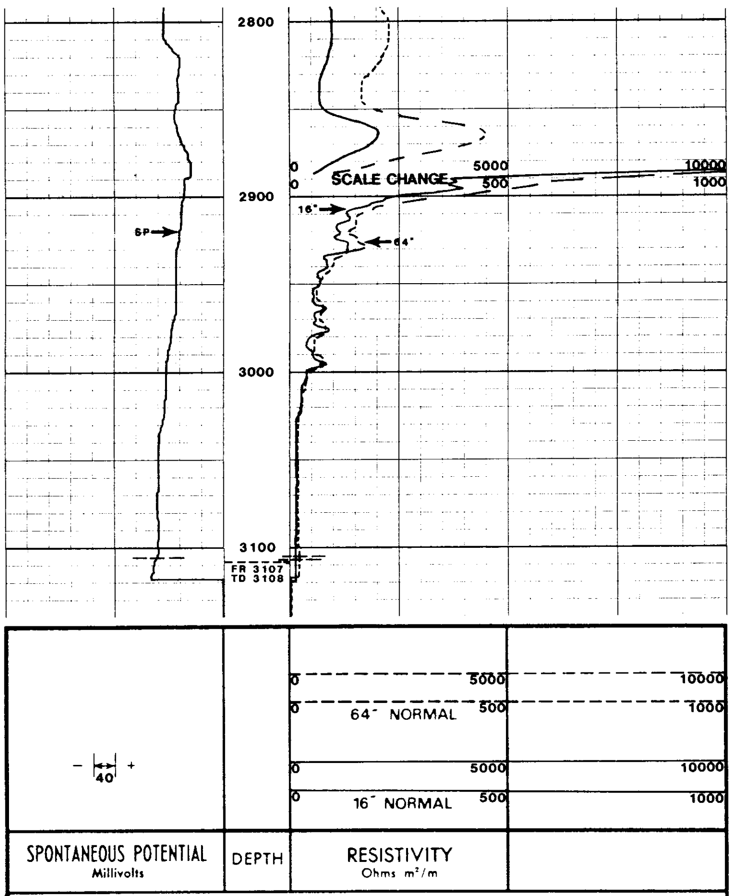
Equipment Data

Run No.	Tool Type	Pad Type	Tool Position	Other
ONE	EL	N/A	FREE	MLS
TWO	EL	N/A	FREE	MLS

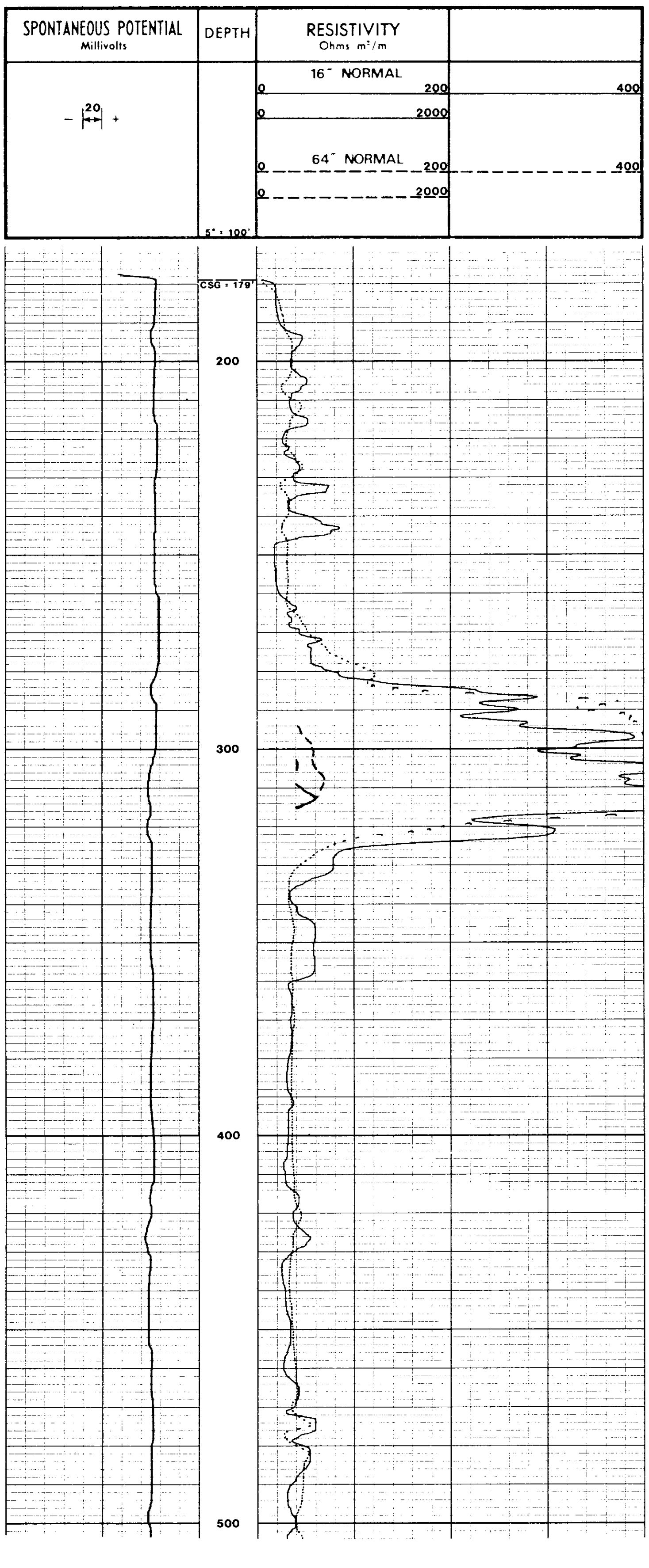
SPONTANEOUS POTENTIAL Millivolts	DEPTH	RESISTIVITY Ohms m²/m	
− 20 +	2" = 100'	16" NORMAL 0 200 0 2000 64" NORMAL 0 200 0 2000	400 400

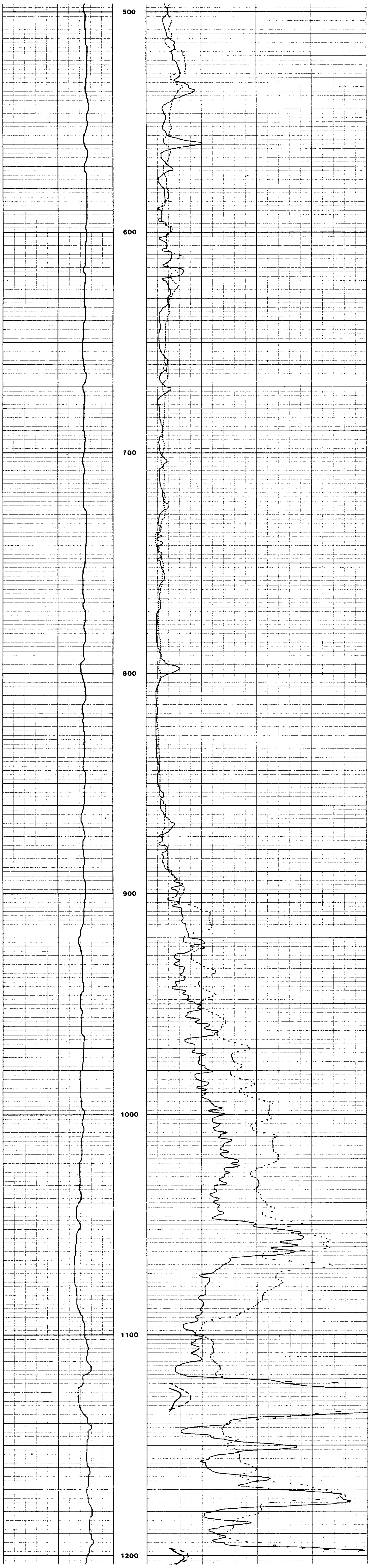


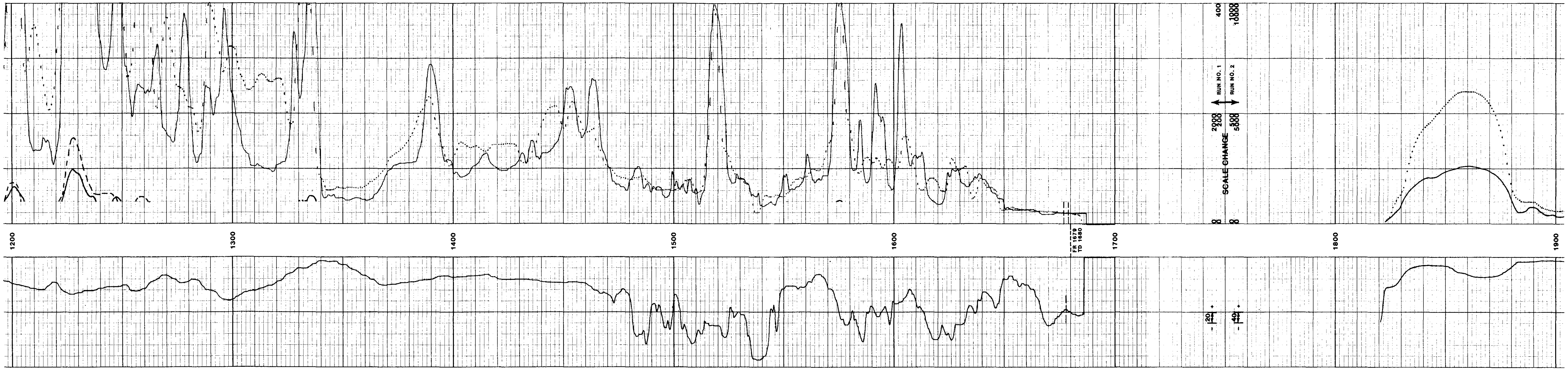


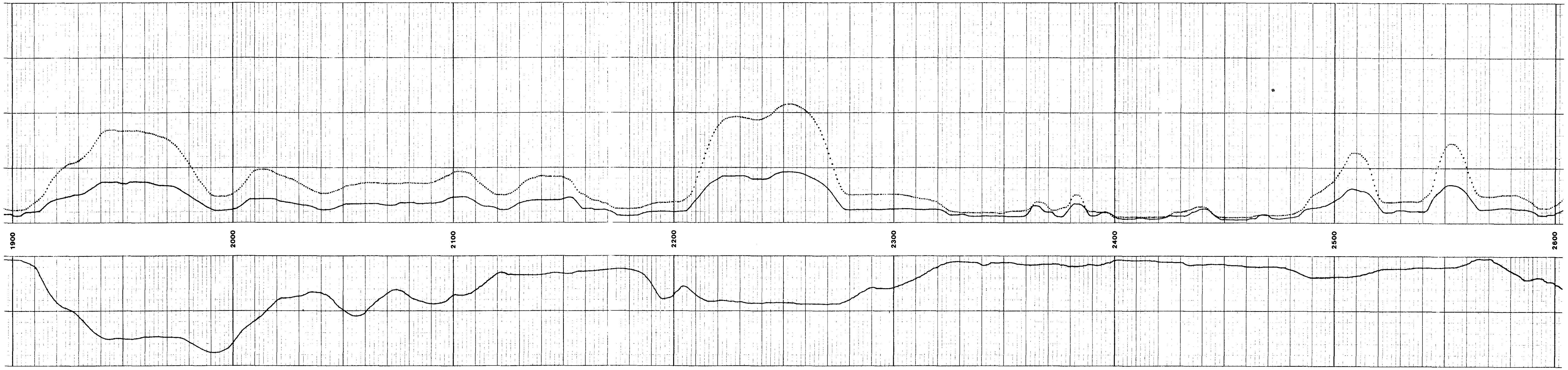


Company	WYOMING WATER DEVELOPMENT COMM.	Drillers T.D.	3369
Well	SHELL VALLEY NO. 2	Log F.R.	3107
Field		Log T.D.	3108
County	BIG HORN	Elevations:	
State	WYOMING	K.B. 4350 D.F.	G.L. 4345






1200
1300
1400
1500
1600
FR 1679
TD 1680
1700
1800
1900
0
0
0
0
SCALE CHANGE
2000
200
500
5000
RUN NO. 1
RUN NO. 2
400
1000
10000
- 20 +
- 40 +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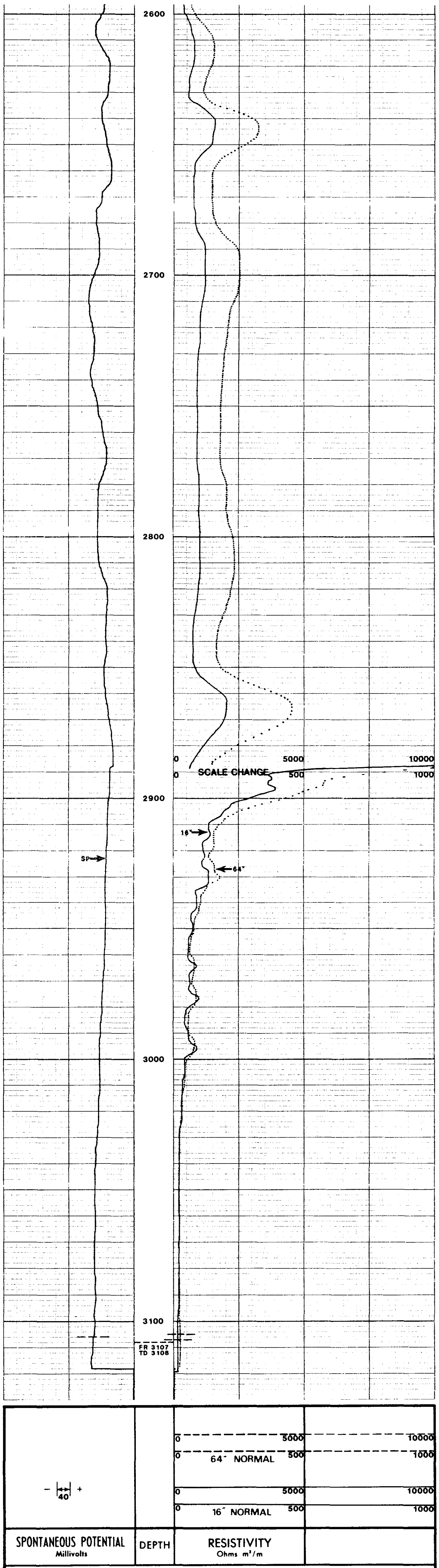
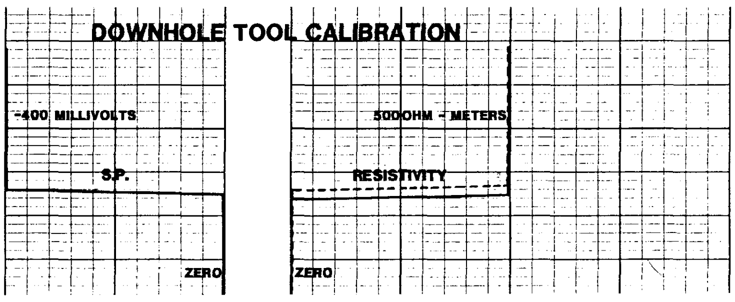


Company WYOMING WATER DEVELOPMENT COMM. Drillers T.D. 3369
Well SHELL VALLEY NO. 2 Log F.R. 3107
Field Log T.D. 3108
County BIG HORN Elevations:
State WYOMING K.B. 4350 D.F. G.L. 4345

DOWNHOLE TOOL CALIBRATION



STRATA DATA INC.

COMPENSATED DENSITY LOG
WITH CALIPER AND GAMMA RAY

FILE NO. 3087

COMPANY WYOMING WATER DEVELOPMENT COMM.
WELL SHELL VALLEY NO. 2
FIELD
COUNTY BIG HORN STATE WYOMING
LOCATION: NE/NE
SEC 35 TWP 53N RGE 91W

Other Services
DNEL
GR/ CAL
SPINNER
TEMP
DIFF TEMP

Permanent Datum GROUND LEVEL Elev. 4345
Log Measured from K.B. 5 Ft. Above Permanent Datum
Drilling Measured from K.B.

Elevations:
KB 4350
DF
GL 4345

Date	08/25/85			
Run No.	TWO			
Depth—Driller	3369			
Depth—Logger	3108			
Bottom Logged Interval	3107			
Top Logged Interval	1694			
Casing—Driller	9 5/8@ 1817	@	@	@
Casing—Logger	1817			
Bit Size	12 1/4			
Type Fluid in Hole	FORMATION WATER			
Density and Viscosity	N/A N/A			
pH and Fluid Loss	N/A N/A cc	cc	cc	cc
Source of Sample	FLOWLINE			
Rm @ Meas. Temp.	27.00@ 82 F	@ F	@ F	@ F
Rmf @ Meas. Temp.	N/A @ °F	@ °F	@ °F	@ °F
Rmc @ Meas. Temp.	N/A @ °F	@ °F	@ F	@ °F
Source of Rmf and Rmc	N/A N/A			
Rm @ BHT	32.42@ 68.3 F	@ F	@ F	@ F
Time Since Circ.	*FLOWING			
Max. Rec. Temp. Deg. F.	68.3 °F	°F	°F	°F
Equip. No. and Location	101 CASPER			
Recorded By	R. McDONALD			
Witnessed By	MR. KACZMAREK, MR. WADE			

THIS HEADING AND LOG CONFORMS TO API RECOMMENDED STANDARD PRACTICE RP 31

FOLD HERE

Equipment Data

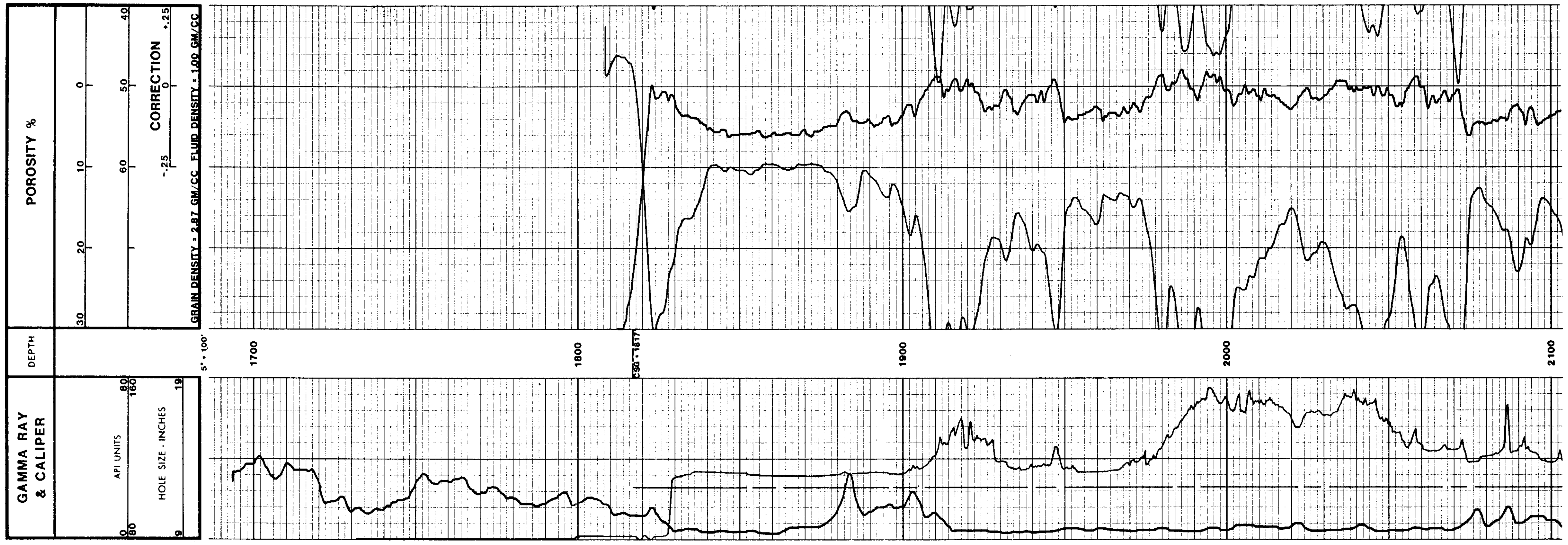
Gamma Ray		—		Density	
Run No.	TWO		Run No.	TWO	
Tool Model No.	2148-A		Tool Model No.	2152	
Serial No.	2254		Serial No.	2483	
Diam.	2 1/8		Diam.	2 1/8	
Detect. Model No.	S-14		Computer Model No.	DPM-1	
Type	SCINT.		Serial No.	2561	
Length	4 IN.		Source Model No.	9381-000-$	
Dist. to Source	8 FT.		Serial No.	CSV-F69	
General			Computer Data		
Hoist Truck No.	101		DENSITY	85	
Auxiliary Equipment			POROSITY	100	
			CORRECTION	520	

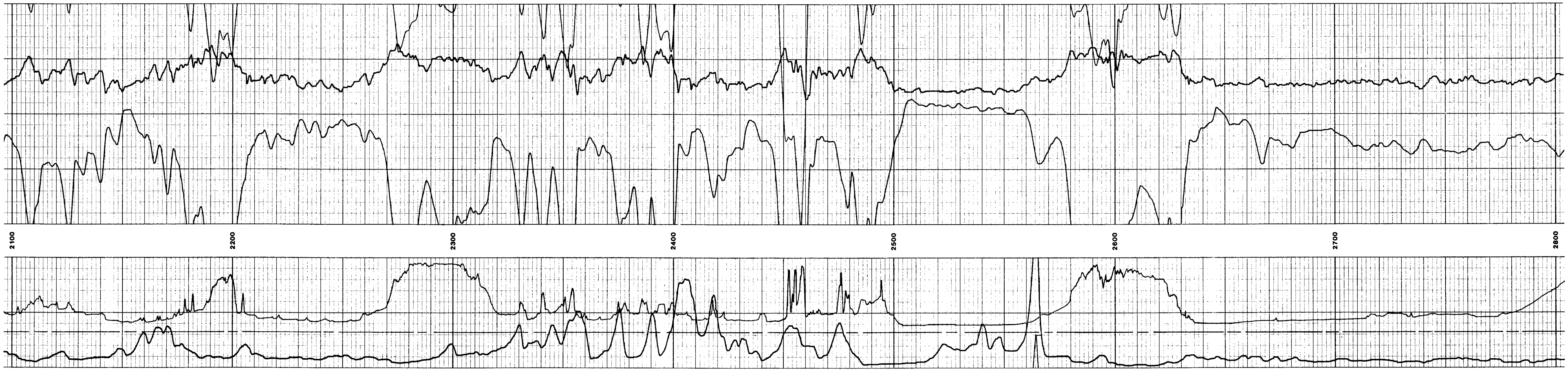
Logging Data

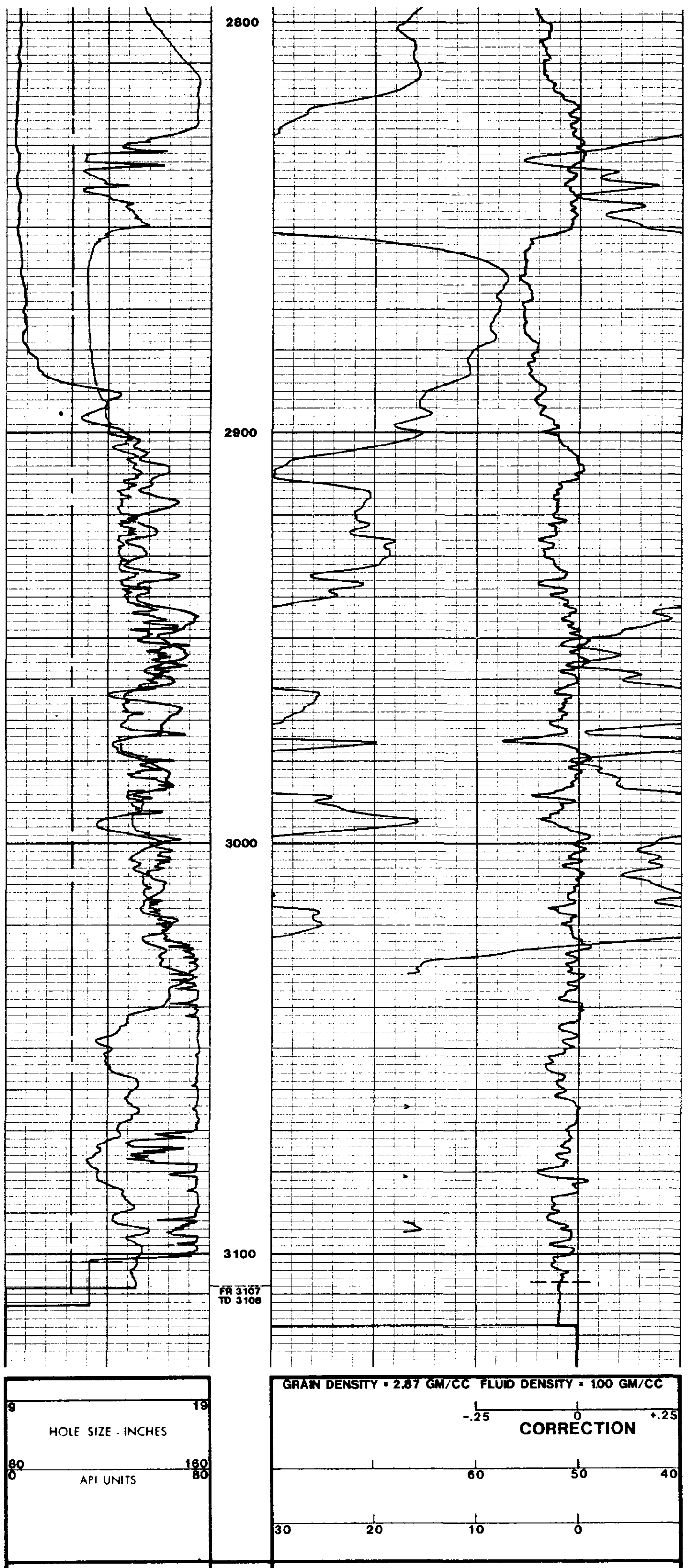
General					Gamma Ray				Density			
Run No.	Depths From	Depths To	Speed Ft./Min.	T.C. Sec.	Sens. Settings	Zero Div. L or R	API G.R. Units Per Log Div.	T.C. Sec.	Density Scale	Correction Scale	Porosity Scale Data	
TWO	1694	3107	20	3	96	0	8	3	N/A	-.25 +.25	Dg=2.87	

Remarks: * RUN NO.2 - WELL WAS FLOWING WATER AT APPROX. 1090 G.P.M. WHILE LOGGING.

Reference Literature:

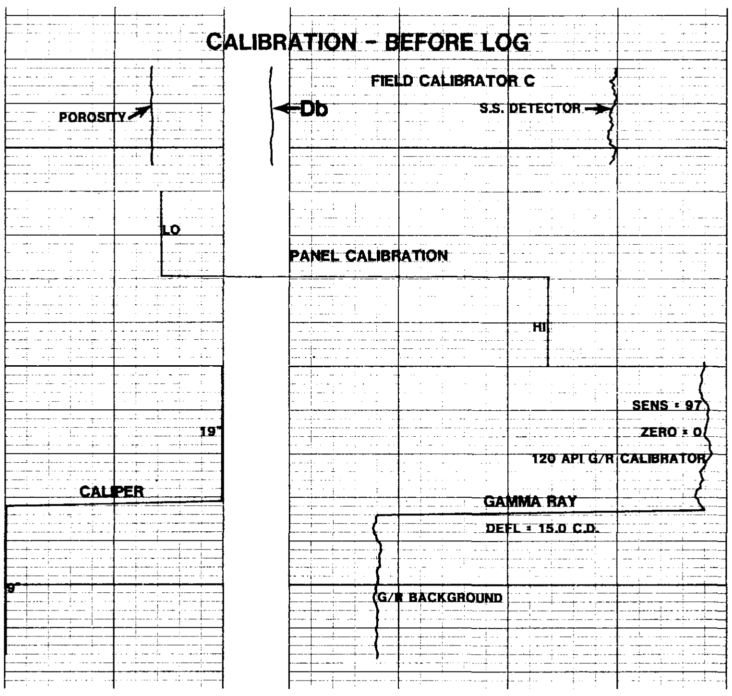




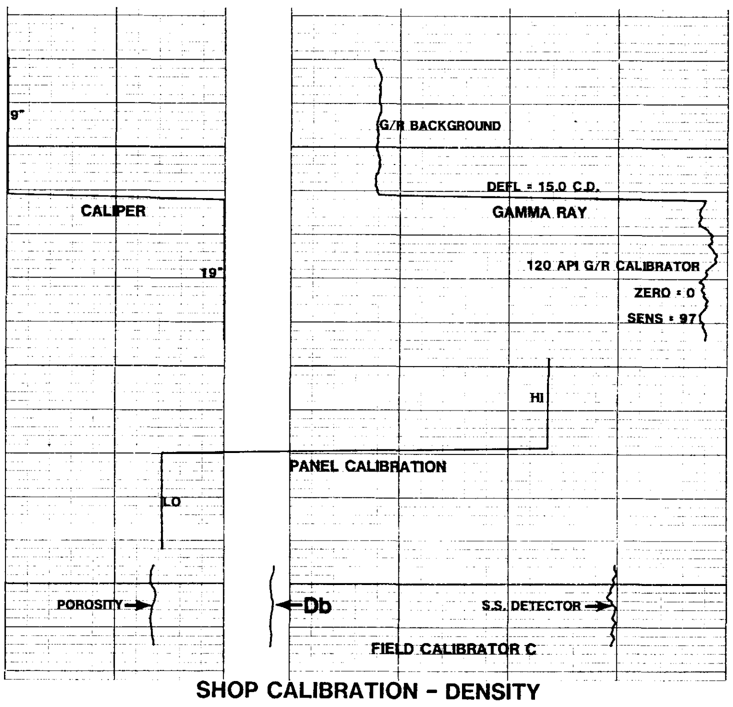


Company WYOMING WATER DEVELOPMENT COMM. Drillers T.D. 3369
Well SHELL VALLEY NO. 2 Log F.R. 3107
Field Log T.D. 3108
County BIG HORN Elevations:
State WYOMING K.B. 4350 D.F. G.L. 4345

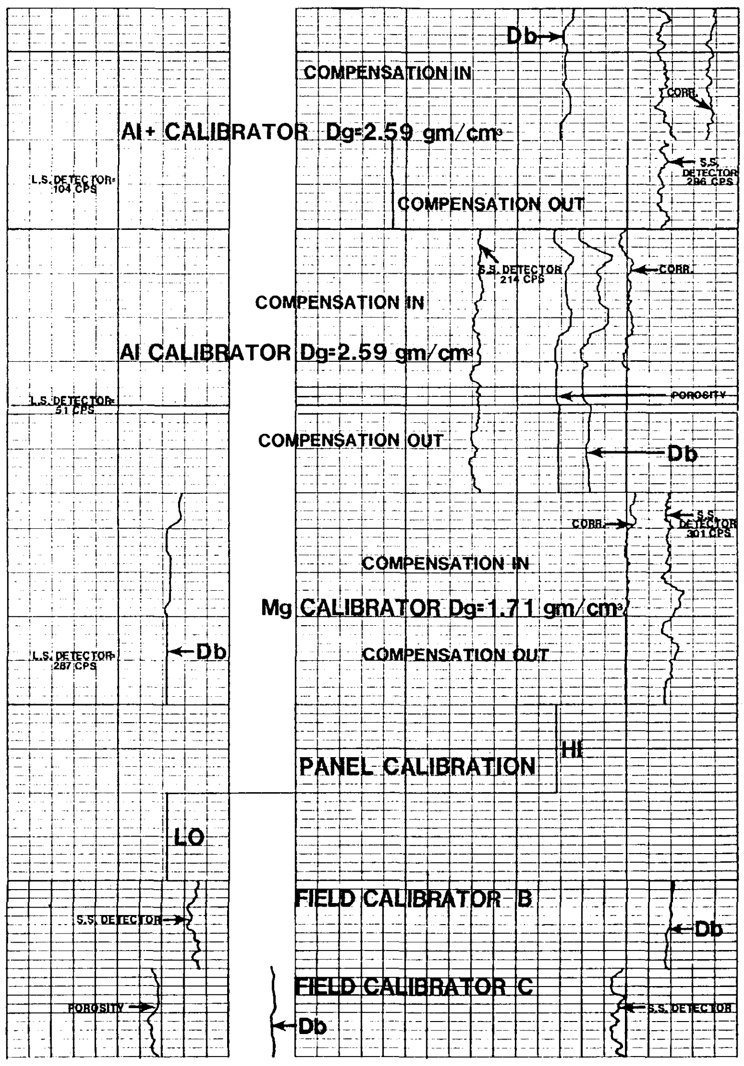
CALIBRATION - BEFORE LOG



CALIBRATION - AFTER LOG



SHOP CALIBRATION - DENSITY



STRATA DATA INC

THREE - ARM CALIPER LOG
WITH GAMMA RAY

FILE NO 3085 3087

COMPANY WYOMING WATER DEVELOPMENT COMM.
WELL SHELL VALLEY NO. 2
FIELD
COUNTY BIG HORN STATE WYOMING
LOCATION: NE/NE
SEC 35 TWP 53N RGE 91W

Other Services
GR/CDL
DNEL
SPINNER
TEMP
DIFF TEMP

Permanent Datum GROUND LEVEL Elev. 4345
Log Measured from K.B. 5 Ft. Above Permanent Datum
Drilling Measured from K.B.

Elevations
KB 4350
DF
GL 4345

Date	08/13/85		08/25/85			
Run No.	ONE		TWO			
Depth—Driller	3369		3369			
Depth—Logger	1680		3108			
Bottom Logged Interval	1676		3107			
Top Logged Interval	0		1755			
Casing—Driller	16 @ 180		9 5/8 @ 1817		@	@
Casing—Logger	179		1817			
Bit Size	12 1/4		12 1/4			
Type Fluid in Hole	FORMATION WATER		FORMATION WATER			
Density and Viscosity	N/A	N/A	N/A	N/A		
pH and Fluid Loss	N/A	N/A cc	N/A	N/A cc	cc	cc
Source of Sample	NONE		FLOWLINE			
Rm @ Meas. Temp.	N/A @ F		27.00 @ 82 F		@ F	@ F
Rmf @ Meas. Temp	N/A @ F		N/A @ F		@ F	@ F
Rmc @ Meas. Temp.	N/A @ F		N/A @ F		@ F	@ F
Source of Rmf and Rmc	N/A	N/A	N/A	N/A		
Rm @ BHT	N/A @ F		32.42 @ 68.3 F		@ F	@ F
Time Since Circ	*FLOWING		*FLOWING			
Max. Rec. Temp Deg. F	N/A F		68.3 F		F	F
Equip. No. and Location	101	CASPER	101	CASPER		
Recorded By	R. McDONALD		R. McDONALD			
Witnessed By	MR. KACZMAREK, MR. WIEGAND, MR. WADE					

FOLD HERE

Equipment Data

Gamma Ray			Density		
Run No.	ONE	TWO	Run No.	ONE	TWO
Tool Model No.	2148-A	2148-A	Tool Model No.	N/A	N/A
Serial No.	2254	2254	Serial No.	N/A	N/A
Diam.	2 1/8 IN.	2 1/8 IN.	Diam.	N/A	N/A
Detect. Model No.	S-14	S-14	Computer Model No.	N/A	N/A
Type	SCINT.	SCINT.	Serial No.	N/A	N/A
Length	4 IN.	4 IN.	Source Model No.	N/A	N/A
Dist. to Source	N/A	N/A	Serial No.	N/A	N/A

General			Computer Data
Hoist Truck No.	101	101	N/A
Auxiliary Equipment			N/A
			N/A

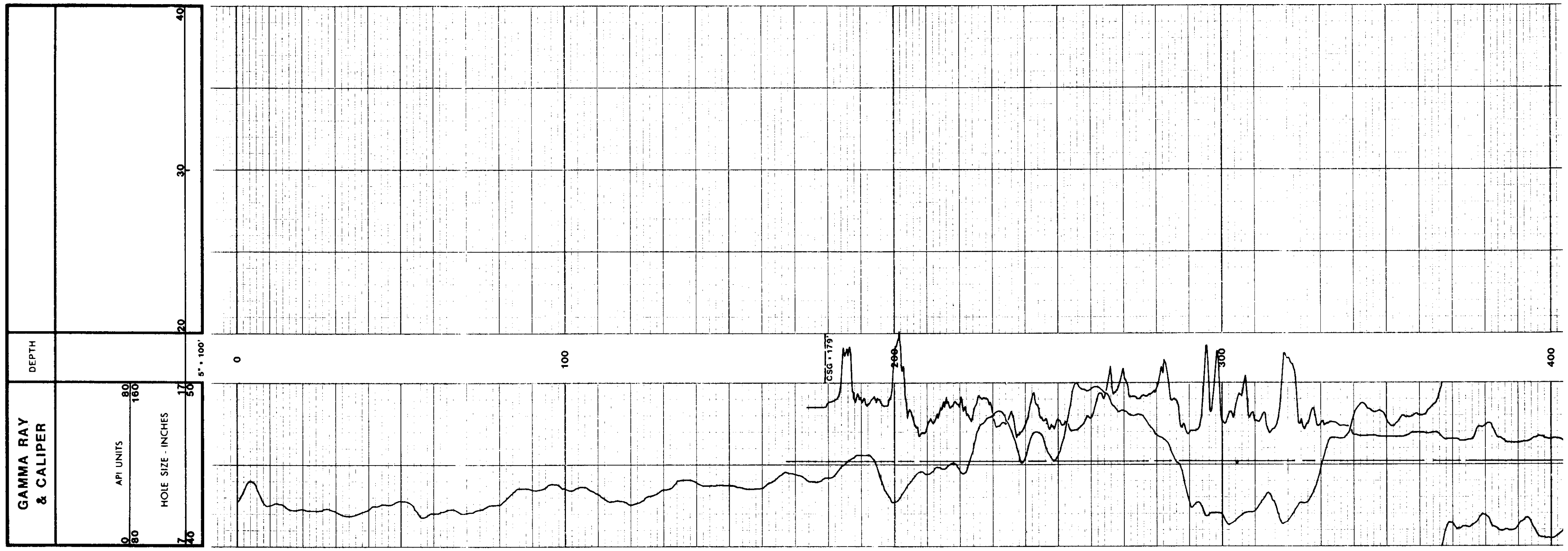
Logging Data

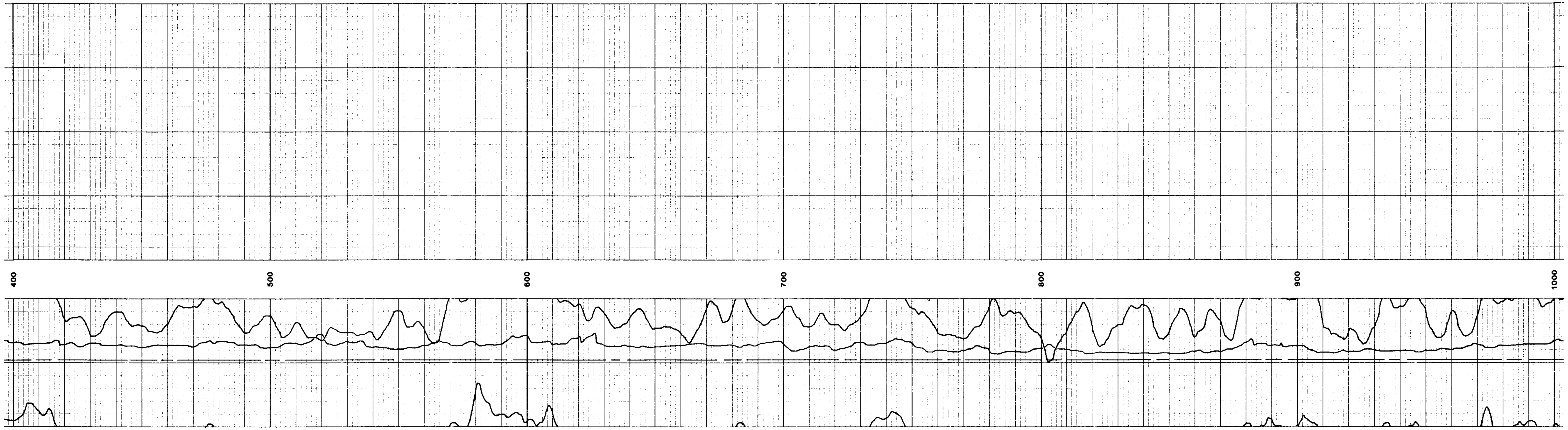
General					Gamma Ray				Density			
Run No.	Depths From	Depths To	Speed Ft./Min.	T.C. Sec.	Sens. Settings	Zero Div. L or R	API G.R. Units Per Log Div.	T.C. Sec.	Density Scale	Correction Scale	Porosity Scale Data
ONE	0	1750	30	3	96	0	8	0	0	0	0
TWO	1755	3107	30	3	96	0	8	0	0	0	0

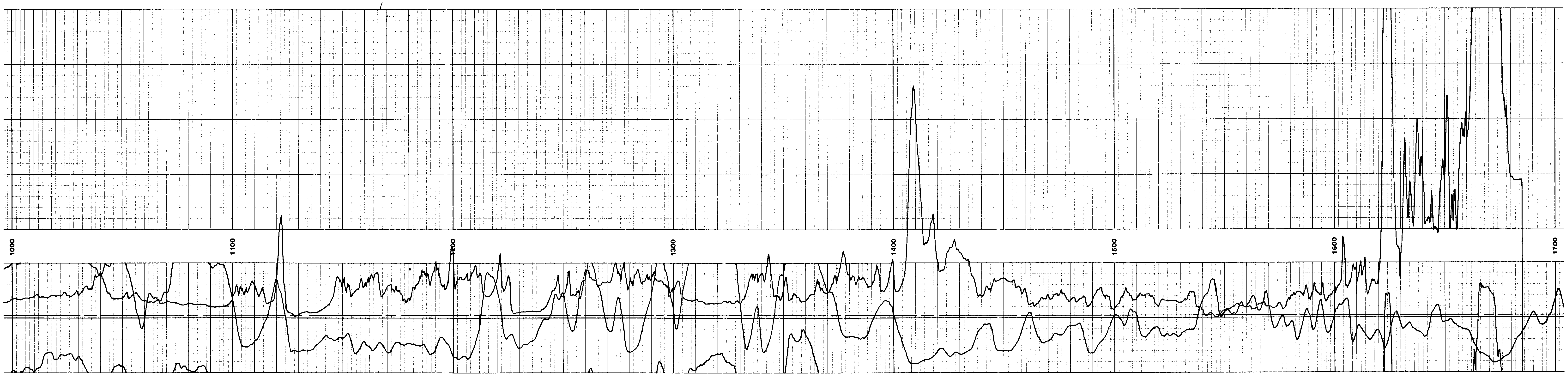
Remarks: *WELL WAS FLOWING WATER AT APPROX. 900 G.P.M. WHILE LOGGING.

* RUN NO.2 - WELL WAS FLOWING APPROX. 1090 G.P.M. WHILE LOGGING.

Reference Literature:



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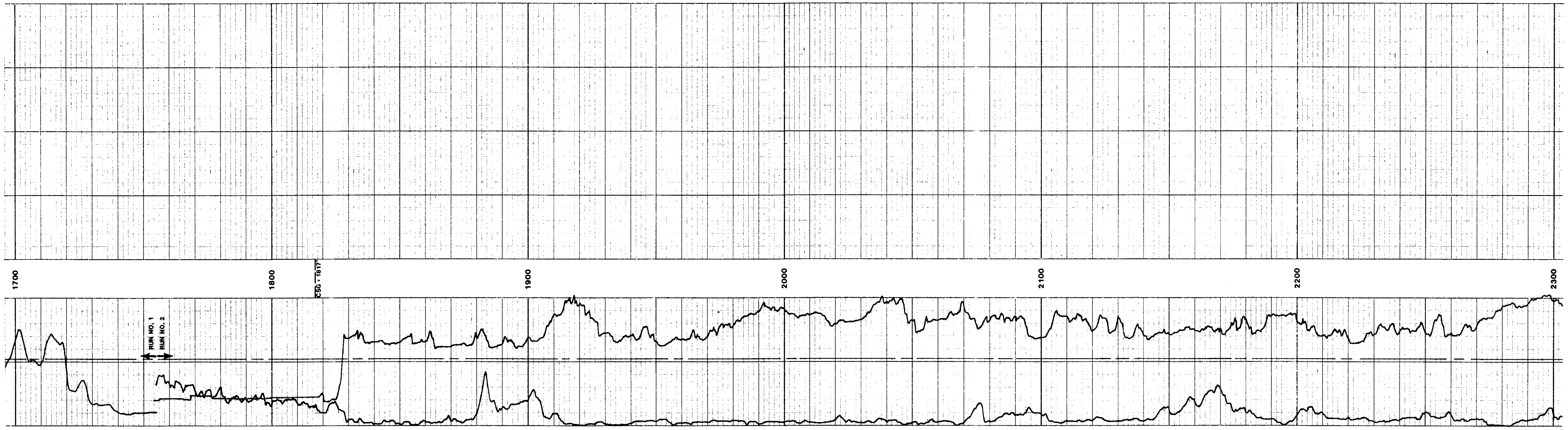
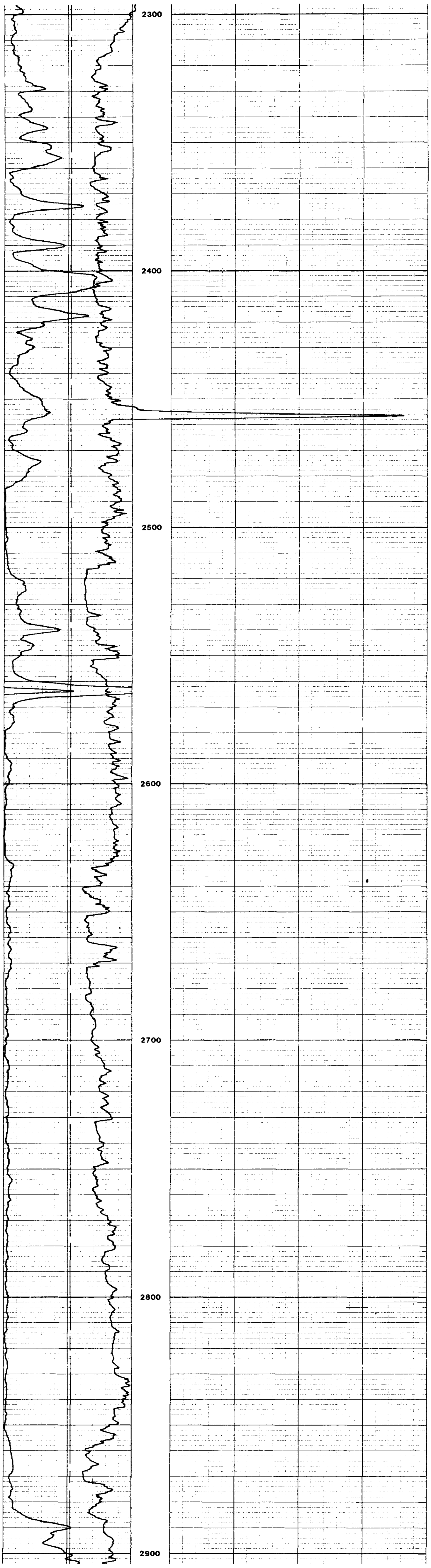
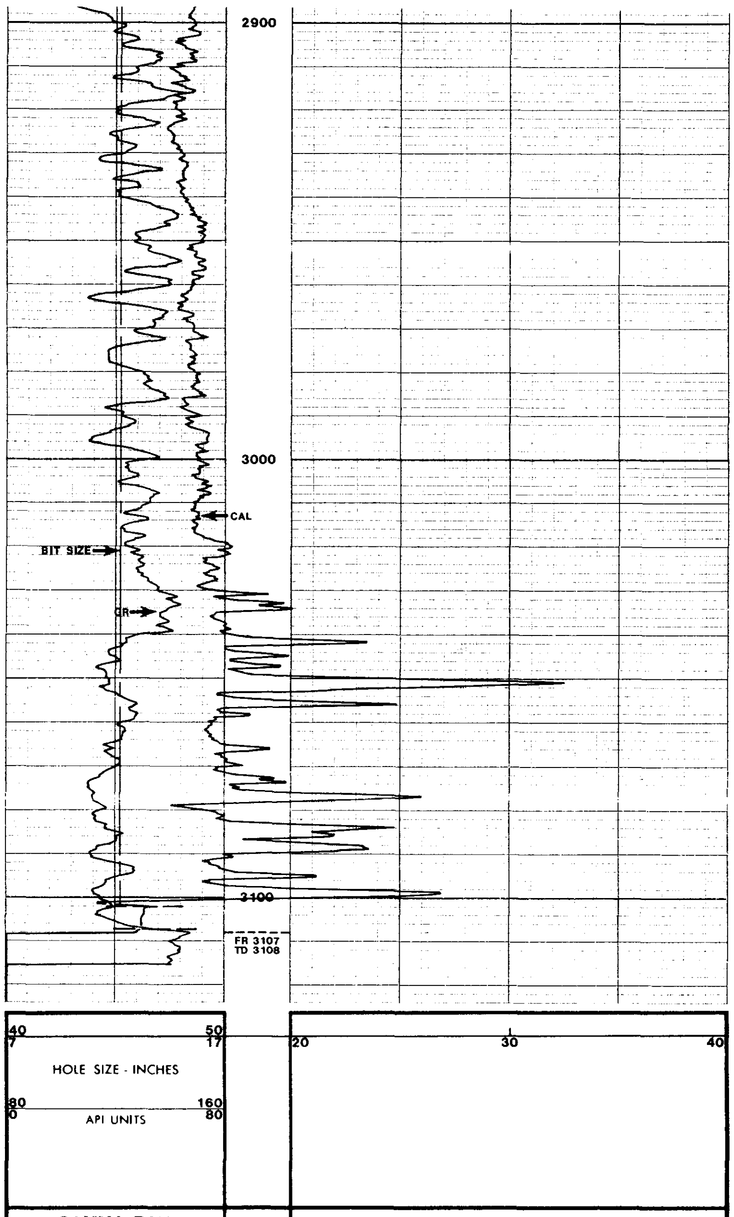
1100
1200
1300
1400
1500
1600
1700


1700
1800
CSG - 1817'
1900
2000
2100
2200
2300
RUN NO. 1
RUN NO. 2





GAMMA RAY & CALIPER	DEPTH	

Company **WYOMING WATER DEVELOPMENT COMM.** Drillers T.D. **3369**
Well **SHELL VALLEY NO. 2** Log F.R. **3107**
Field Log T.D. **3108**
County **BIG HORN** Elevations:
State **WYOMING** K.B. **4350** D.F. G.L. **4345**

STRATA DATA INC

SPINNER FLOWMETER LOG
WITH TEMPERATURE AND DIFFERENTIAL TEMPERATURE

FILE NO. 3087

COMPANY WYOMING WATER DEVELOPMENT COMM.
WELL SHELL VALLEY NO. 2
FIELD
COUNTY BIG HORN STATE WYOMING
LOCATION: NE/NE
SEC 35 TWP 53N RGE 91W

Other Services: GR/CDL, DNEL, GR/CAL

Permanent Datum GROUND LEVEL Elev. 4345
Log Measured from K.B. 5 Ft. Above Permanent Datum
Drilling Measured from K.B.

Elevations: KB 4350; DF; GL 4345

Date	08/25/85				
Run No.	TWO				
Depth—Driller	3369				
Depth—Logger	3108				
Bottom Logged Interval	3107				
Top Logged Interval	1600				
Casing—Driller	9 5/8 @ 1817		@	@	@
Casing—Logger	1817				
Bit Size	12 1/4				
Type Fluid in Hole	FORMATION WATER				
Density and Viscosity	N/A	N/A			
pH and Fluid Loss	N/A	N/A cc	cc	cc	cc
Source of Sample	FLOWLINE				
Rm @ Meas. Temp.	27.00 @ 82 F		@ F	@ F	@ F
Rmf @ Meas. Temp.	N/A @ F		@ F	@ F	@ F
Rmc @ Meas. Temp.	N/A @ F		@ F	@ F	@ F
Source of Rmf and Rmc	N/A	N/A			
Rm @ BHT	32.42 @ 68.3 F		@ F	@ F	@ F
Time Since Circ.	*FLOWING				
Max. Rec. Temp. Deg. F.	68.3 F		F	F	F
Equip. No. and Location	101	CASPER			
Recorded By	R. McDONALD				
Witnessed By	MR. KACZMAREK, MR. WADE				

THIS HEADING AND LOG CONFORMS TO API RECOMMENDED STANDARD PRACTICE RP 31

FOLD HERE ↓

REMARKS

*RUN NO.2 - WELL WAS FLOWING WATER AT APPROX. 1090 G.P.M. WHILE LOGGING.

Changes in Mud Type or Additional Samples

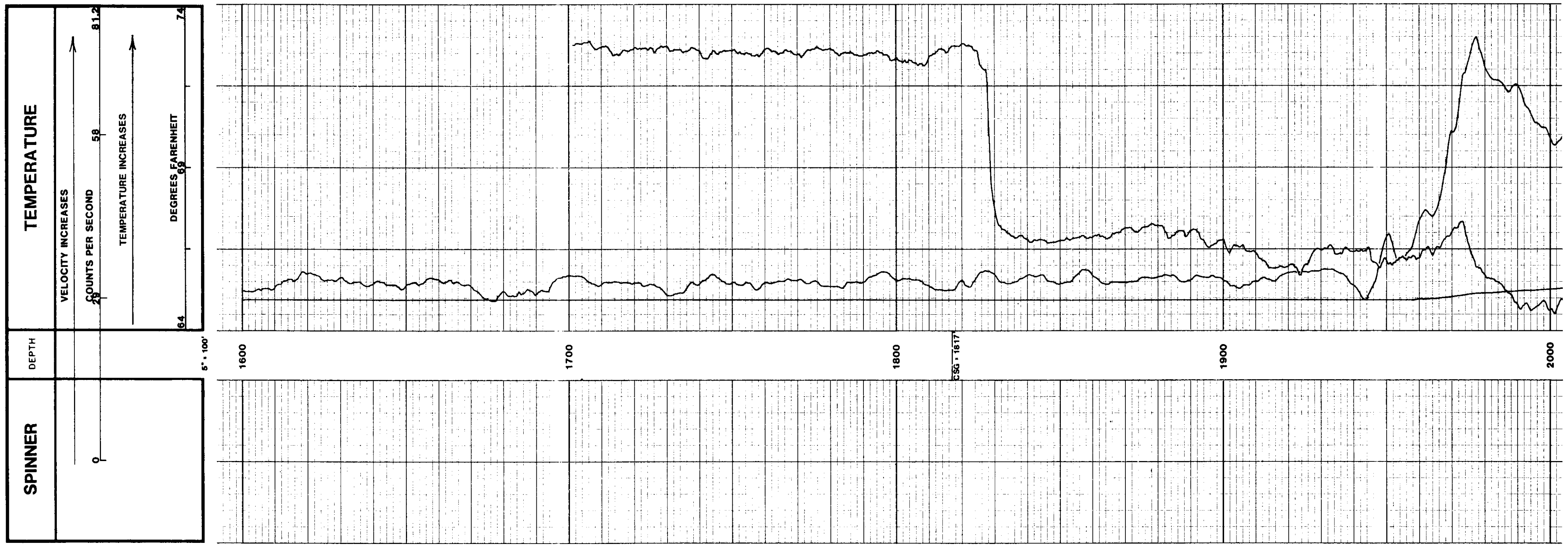
Date / Sample No.	08/25/85 TWO
Depth-Driller	3369
Type Fluid in Hole	FORMATION WATER
Dens / Visc	N/A / N/A
pH / Fluid Loss	N/A / N/A cc
Source of Sample	FLOWLINE
Rm @ Meas. Temp.	27.00 @ 82 °F
Rmf @ Meas. Temp.	N/A @ °F
Rmc @ Meas. Temp.	N/A @ °F
Source Rmf / Rmc	N/A / N/A
Rm @ BHT	32.42 @ 68.3 °F
Rmf @ BHT	N/A @ °F
Rmc @ BHT	N/A @ °F

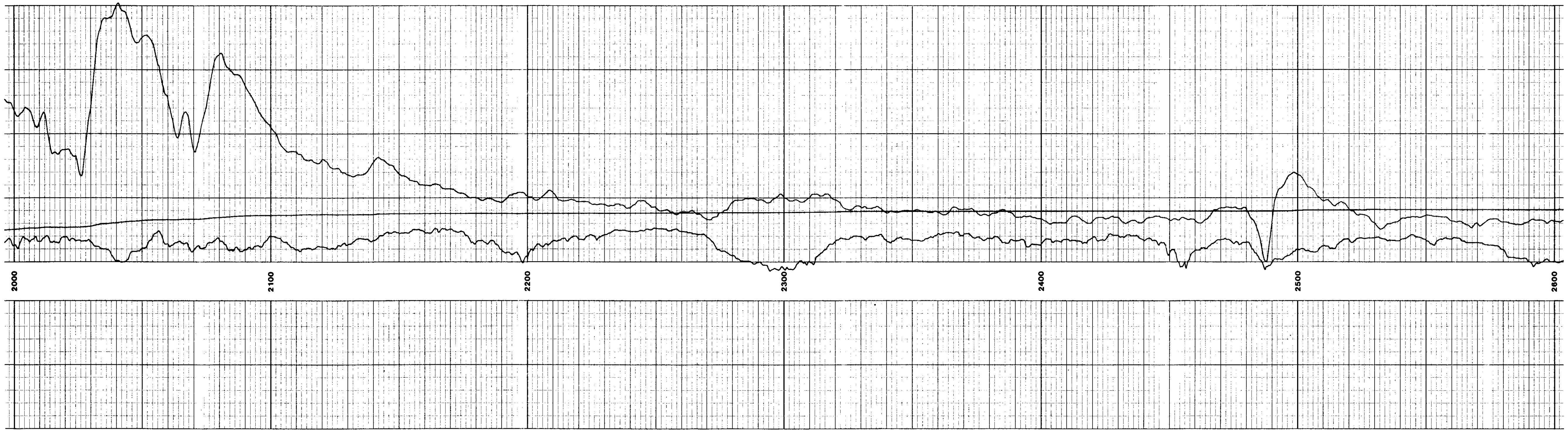
Scale Changes

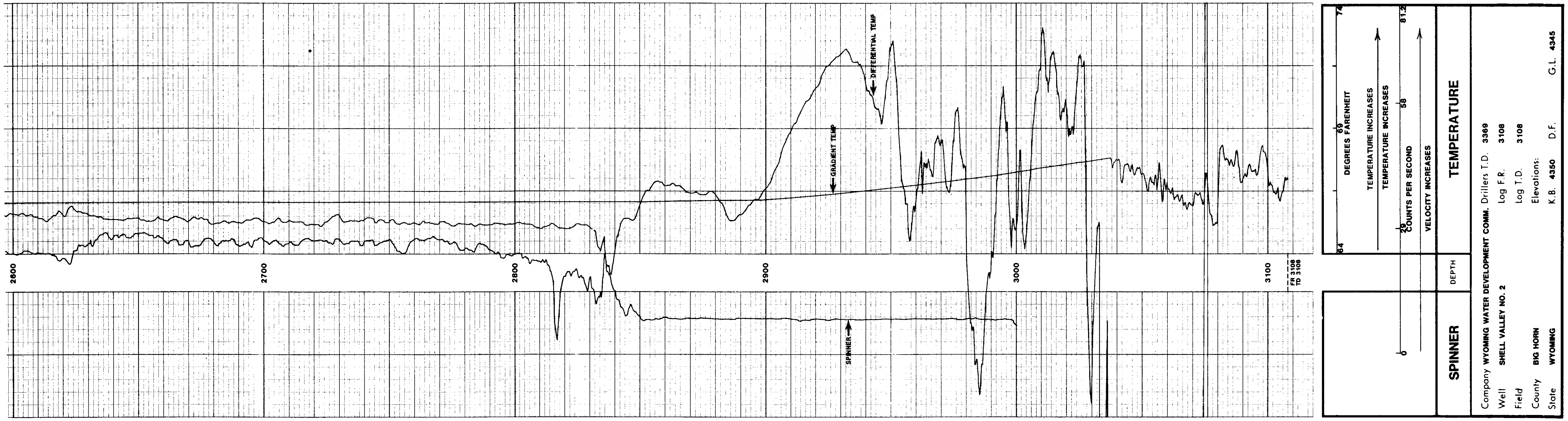
Type Log	Depth	Scale Up Hole	Scale Down Hole

Equipment Data

Run No.	Tool Type	Pad Type	Tool Position	Other







Company **WYOMING WATER DEVELOPMENT COMM.** Drillers T.D. **3369**
Well **SHELL VALLEY NO. 2** Log F.R. **3108**
Field Log T.D. **3108**
County **BIG HORN** Elevations:
State **WYOMING** K.B. **4350** D.F. G.L. **4345**

APPENDIX E

OBSERVATION WELL (WELL NO. 1) DRAWDOWN DATA FOR MADISON AQUIFER
WITH
WELL NO. 2 FLOWING

Well Name: Shell Well No. 1
Shut-in Pressure: 143 psi
Static Water Level: 330.00 feet above gage datum.
Distance to Flowing Well: 567 ft.
Flowing Well: Shell Well No. 2
Average Flow Rate: 1139 gpm
Test Starting Date: September 9, 1985
Test Termination Date: September 30, 1985
Test Starting Time: 22:25:00

Elapsed Time (min.)	Pressure Head (feet)	Drawdown (feet)	Elapsed Time (min.)	Pressure Head (feet)	Drawdown (feet)	Elapsed Time (min.)	Pressure Head (feet)	Drawdown (feet)
0	330	.00	.8333	329.94	-.06	18	328.04	-1.96
.0033	329.56	-.44	.9167	329.94	-.06	20	327.85	-2.15
.0066	329.56	-.44	1	329.94	-.06	22	327.6	-2.40
.0099	329.49	-.51	1.0833	330	.00	24	327.34	-2.66
.0133	329.43	-.57	1.1667	330	.00	26	327.15	-2.85
.0166	329.49	-.51	1.25	329.94	-.06	28	326.96	-3.04
.02	329.43	-.57	1.3333	329.94	-.06	30	326.77	-3.23
.0233	329.43	-.57	1.4166	329.94	-.06	32	326.58	-3.42
.0266	329.49	-.51	1.5	329.94	-.06	34	326.33	-3.67
.03	329.43	-.57	1.5833	329.94	-.06	36	326.14	-3.86
.0333	329.43	-.57	1.6667	329.88	-.12	38	325.95	-4.05
.05	329.94	-.06	1.75	329.88	-.12	40	325.76	-4.24
.0666	329.94	-.06	1.8333	329.94	-.06	42	325.57	-4.43
.0833	329.94	-.06	1.9167	329.94	-.06	44	325.44	-4.56
.1	329.94	-.06	2	329.88	-.12	46	325.25	-4.75
.1166	329.94	-.06	2.5	329.81	-.19	48	325.06	-4.94
.1333	329.94	-.06	3	329.81	-.19	50	324.94	-5.06
.15	329.94	-.06	3.5	329.75	-.25	52	324.75	-5.25
.1666	329.88	-.12	4	329.68	-.32	54	324.62	-5.38
.1833	329.88	-.12	4.5	329.62	-.38	56	324.43	-5.57
.2	329.88	-.12	5	329.62	-.38	58	324.3	-5.70
.2166	329.88	-.12	5.5	329.56	-.44	60	324.11	-5.89
.2333	329.88	-.12	6	329.49	-.51	62	323.99	-6.01
.25	329.88	-.12	6.5	329.43	-.57	64	323.8	-6.20
.2666	329.88	-.12	7	329.37	-.63	66	323.67	-6.33
.2833	329.88	-.12	7.5	329.31	-.69	68	323.54	-6.46
.3	329.94	-.06	8	329.24	-.76	70	323.42	-6.58
.3166	329.94	-.06	8.5	329.18	-.82	72	323.23	-6.77
.3333	329.94	-.06	9	329.12	-.88	74	323.16	-6.84
.4167	329.94	-.06	9.5	329.05	-.95	76	322.97	-7.03
.5	329.94	-.06	10	328.99	-1.01	78	322.85	-7.15
.5833	329.94	-.06	12	328.73	-1.27	80	322.72	-7.28
.6667	330	.00	14	328.48	-1.52	82	322.6	-7.40
.75	330	.00	16	328.29	-1.71	84	322.47	-7.53

Elapsed Time (min.)	Pressure Head (feet)	Drawdown (feet)
86	322.34	-7.66
88	322.21	-7.79
90	322.09	-7.91
92	322.02	-7.98
94	321.83	-8.17
96	321.77	-8.23
98	321.64	-8.36
100	321.52	-8.48
110	321.01	-8.99
120	320.5	-9.50
130	320	-10.00
140	319.55	-10.45
150	319.05	-10.95
160	318.6	-11.40
170	318.29	-11.71
180	317.84	-12.16
190	317.47	-12.53
200	317.15	-12.85
210	316.77	-13.23
220	316.45	-13.55
230	316.13	-13.87
240	315.76	-14.24
250	315.5	-14.50
260	315.19	-14.81
270	314.93	-15.07
280	314.62	-15.38
290	314.36	-15.64
300	314.11	-15.89
310	313.86	-16.14
320	313.6	-16.40
330	313.35	-16.65
340	313.1	-16.90
350	312.84	-17.16
360	312.59	-17.41
370	312.4	-17.60
380	312.15	-17.85
390	311.96	-18.04
400	311.71	-18.29
410	311.52	-18.48
420	311.26	-18.74
430	311.07	-18.93
440	310.88	-19.12
450	310.69	-19.31
460	310.5	-19.50
470	310.31	-19.69
480	310.06	-19.94
490	309.93	-20.07
500	309.74	-20.26
510	309.55	-20.45
520	309.36	-20.64
530	309.17	-20.83
540	309.11	-20.89
550	308.92	-21.08
560	308.79	-21.21
570	308.67	-21.33
580	308.48	-21.52
590	308.35	-21.65
600	308.22	-21.78
610	308.1	-21.90
620	307.91	-22.09
630	307.84	-22.16
640	307.59	-22.41
650	307.4	-22.60
660	307.21	-22.79
670	307.09	-22.91
680	306.89	-23.11
690	306.77	-23.23
700	306.64	-23.36
710	306.52	-23.48
720	306.32	-23.68
730	306.2	-23.80
740	306.01	-23.99
750	305.82	-24.18
760	305.69	-24.31
770	305.5	-24.50
780	305.44	-24.56
790	305.31	-24.69
800	305.18	-24.82
810	305.06	-24.94
820	304.93	-25.07
830	304.87	-25.13
840	304.81	-25.19
850	304.68	-25.32
860	304.55	-25.45
870	304.49	-25.51
880	304.36	-25.64
890	304.24	-25.76
900	304.17	-25.83
910	304.04	-25.96
920	303.92	-26.08
930	303.86	-26.14
940	303.79	-26.21
950	303.67	-26.33
960	303.54	-26.46
970	303.48	-26.52
980	303.35	-26.65
990	303.29	-26.71
1000	303.16	-26.84
1100	302.21	-27.79
1200	301.2	-28.80
1300	300.25	-29.75
1400	299.3	-30.70
1500	298.47	-31.53
1600	297.72	-32.28
1700	296.89	-33.11
1800	296.13	-33.87
1900	295.44	-34.56
2000	294.8	-35.20
2100	294.23	-35.77
2200	293.66	-36.34
2300	293.09	-36.91
2400	292.59	-37.41
2500	292.02	-37.98
2600	291.45	-38.55
2700	290.94	-39.06
2800	290.43	-39.57
2900	289.93	-40.07
3000	289.42	-40.58
3100	288.92	-41.08
3200	288.53	-41.47
3300	288.09	-41.91
3400	287.58	-42.42
3500	287.08	-42.92
3600	286.57	-43.43
3700	286.13	-43.87
3800	285.75	-44.25
3900	285.43	-44.57
4000	285.05	-44.95
4100	284.61	-45.39
4200	284.04	-45.96
4300	283.6	-46.40
4400	283.22	-46.78
4500	282.84	-47.16
4600	282.52	-47.48
4700	282.27	-47.73
4800	281.89	-48.11
4900	281.57	-48.43
5000	281.26	-48.74
5100	280.94	-49.06
5200	280.69	-49.31
5300	280.37	-49.63
5400	280.18	-49.82
5500	279.99	-50.01
5600	279.61	-50.39

Elapsed Time (min.)	Pressure Head (feet)	Drawdown (feet)
5700	279.23	-50.77
5800	278.91	-51.09
5900	278.66	-51.34
6000	278.41	-51.59
6100	278.22	-51.78
6200	277.96	-52.04
6300	277.71	-52.29
6400	277.58	-52.42
6500	277.27	-52.73
6600	277.01	-52.99
6700	276.82	-53.18
6800	276.63	-53.37
6900	276.57	-53.43
7000	276.32	-53.68
7100	276	-54.00
7200	275.75	-54.25
7300	275.49	-54.51
7400	275.24	-54.76
7500	275.05	-54.95
7600	274.92	-55.08
7700	274.67	-55.33
7800	274.54	-55.46
7900	274.35	-55.65
8000	274.16	-55.84
8100	273.91	-56.09
8200	273.78	-56.22
8300	273.72	-56.28
8400	273.59	-56.41
8500	273.28	-56.72
8600	273.02	-56.98
8700	272.77	-57.23
8800	272.52	-57.48
8900	272.33	-57.67
9000	272.2	-57.80
9100	272.07	-57.93
9200	271.89	-58.11
9300	271.95	-58.05
9400	271.76	-58.24
9500	271.63	-58.37
9600	271.5	-58.50
9700	271.44	-58.56
9800	271.32	-58.68
9900	271.13	-58.87
10000	270.87	-59.13
10500	269.99	-60.01
11000	269.48	-60.52
11500	268.53	-61.47
12000	267.71	-62.29
12500	267.07	-62.93
13000	266.44	-63.56
13500	265.87	-64.13
14000	265.3	-64.70
14500	264.67	-65.33
15000	264.22	-65.78
15500	264.16	-65.84
16000	263.59	-66.41
16500	263.15	-66.85
17000	263.02	-66.98
17500	262.45	-67.55
18000	262.01	-67.99
18500	261.63	-68.37
19000	261	-69.00
19500	260.62	-69.38
20000	260.3	-69.70
20500	260.11	-69.89
21000	259.73	-70.27
21500	259.41	-70.59
22000	259.03	-70.97
22500	258.72	-71.28
23000	258.47	-71.53
23500	258.34	-71.66
24000	258.21	-71.79
24500	257.89	-72.11
25000	257.51	-72.49
25500	257.13	-72.87
26000	256.63	-73.37
26500	257.32	-72.68
27000	256.25	-73.75
27500	257.83	-72.17
28000	258.97	-71.03
28500	255.68	-74.32
29000	257.77	-72.23
29500	255.17	-74.83

APPENDIX F

DRAWDOWN DATA FROM WELL NO. 1 FOR INITIATION OF FLOW FROM WELL NO.1 AFTER 20 DAYS OF FLOW FROM WELL NO. 2. WELL NO. 2 REMAINS FLOWING DURING THIS TEST

Well Name: Shell Well No. 1
Shut-in Pressure: 143 psi
Static Water Level: 330.00 feet above gage datum.
Distance to Flowing Well: 567 ft.
Flowing Well: Shell Well Nos. 1 and 2
Average Flow Rate: Shell 1 = 229 gpm, Shell 2 = 1114 gpm
Test Starting Date: September 30, 1985
Test Termination Date: October 11, 1985
Test Starting Time: 16:05:00

Elapsed Time (min.)	Pressure Head (feet)	Drawdown (feet)	Elapsed Time (min.)	Pressure Head (feet)	Drawdown (feet)	Elapsed Time (min.)	Pressure Head (feet)	Drawdown (feet)
0	49.74	-280.26	.8333	19.73	-310.27	18	17.14	-312.86
.0033	48.47	-281.53	.9167	19.79	-310.21	20	17.14	-312.86
.0066	45.31	-284.69	1	19.6	-310.40	22	17.07	-312.93
.0099	41.76	-288.24	1.0833	19.48	-310.52	24	17.07	-312.93
.0133	40.24	-289.76	1.1667	19.29	-310.71	26	17.01	-312.99
.0166	38.47	-291.53	1.25	19.29	-310.71	28	17.01	-312.99
.02	36.63	-293.37	1.3333	19.1	-310.90	30	17.01	-312.99
.0233	34.74	-295.26	1.4166	19.1	-310.90	32	17.01	-312.99
.0266	33.47	-296.53	1.5	18.91	-311.09	34	16.95	-313.05
.03	32.71	-297.29	1.5833	18.84	-311.16	36	16.95	-313.05
.0333	31.89	-298.11	1.6667	18.78	-311.22	38	16.95	-313.05
.05	28.28	-301.72	1.75	18.72	-311.28	40	16.88	-313.12
.0666	27.33	-302.67	1.8333	18.66	-311.34	42	16.88	-313.12
.0833	27.01	-302.99	1.9167	18.59	-311.41	44	16.95	-313.05
.1	26.32	-303.68	2	18.53	-311.47	46	16.88	-313.12
.1166	25.62	-304.38	2.5	18.28	-311.72	48	16.88	-313.12
.1333	25.11	-304.89	3	18.09	-311.91	50	16.88	-313.12
.15	24.73	-305.27	3.5	17.96	-312.04	52	16.88	-313.12
.1666	24.23	-305.77	4	17.83	-312.17	54	16.88	-313.12
.1833	23.97	-306.03	4.5	17.77	-312.23	56	16.88	-313.12
.2	23.72	-306.28	5	17.71	-312.29	58	16.88	-313.12
.2166	23.47	-306.53	5.5	17.58	-312.42	60	16.88	-313.12
.2333	23.21	-306.79	6	17.52	-312.48	62	16.88	-313.12
.25	23.02	-306.98	6.5	17.45	-312.55	64	16.88	-313.12
.2666	22.33	-307.67	7	17.45	-312.55	66	16.82	-313.18
.2833	22.14	-307.86	7.5	17.39	-312.61	68	16.82	-313.18
.3	22.07	-307.93	8	17.33	-312.67	70	16.82	-313.18
.3166	21.95	-308.05	8.5	17.33	-312.67	72	16.82	-313.18
.3333	21.88	-308.12	9	17.26	-312.74	74	16.44	-313.56
.4167	21.38	-308.62	9.5	17.26	-312.74	76	16.82	-313.18
.5	20.93	-309.07	10	17.26	-312.74	78	16.76	-313.24
.5833	20.49	-309.51	12	17.26	-312.74	80	16.76	-313.24
.6667	20.24	-309.76	14	17.26	-312.74	82	16.76	-313.24
.75	19.98	-310.02	16	17.2	-312.80	84	16.76	-313.24

Elapsed Time (min.)	Pressure Head (feet)	Drawdown (feet)
86	16.76	-313.24
88	16.76	-313.24
90	16.76	-313.24
92	16.76	-313.24
94	16.76	-313.24
96	16.76	-313.24
98	16.76	-313.24
100	16.76	-313.24
110	16.76	-313.24
120	16.69	-313.31
130	16.76	-313.24
140	16.69	-313.31
150	16.69	-313.31
160	16.69	-313.31
170	16.69	-313.31
180	16.63	-313.37
190	16.69	-313.31
200	16.63	-313.37
210	16.63	-313.37
220	16.63	-313.37
230	16.57	-313.43
240	16.57	-313.43
250	16.57	-313.43
260	16.57	-313.43
270	16.57	-313.43
280	16.57	-313.43
290	16.5	-313.50
300	16.57	-313.43
310	16.57	-313.43
320	16.57	-313.43
330	16.5	-313.50
340	16.57	-313.43
350	16.5	-313.50
360	16.57	-313.43
370	16.5	-313.50
380	16.5	-313.50
390	16.5	-313.50
400	16.5	-313.50
410	16.5	-313.50
420	16.5	-313.50
430	16.5	-313.50
440	16.5	-313.50
450	16.5	-313.50
460	16.5	-313.50
470	16.5	-313.50
480	16.5	-313.50
490	16.5	-313.50
500	16.5	-313.50
510	16.5	-313.50
520	16.44	-313.56
530	16.5	-313.50
540	16.5	-313.50
550	16.5	-313.50
560	16.5	-313.50
570	16.44	-313.56
580	16.44	-313.56
590	16.44	-313.56
600	16.5	-313.50
610	16.44	-313.56
620	16.44	-313.56
630	16.44	-313.56
640	16.44	-313.56
650	16.44	-313.56
660	16.44	-313.56
670	16.44	-313.56
680	16.44	-313.56
690	16.44	-313.56
700	16.44	-313.56
710	16.44	-313.56
720	16.44	-313.56
730	16.44	-313.56
740	16.44	-313.56
750	16.44	-313.56
760	16.38	-313.62
770	16.38	-313.62
780	16.38	-313.62
790	16.44	-313.56
800	16.38	-313.62
810	16.38	-313.62
820	16.38	-313.62
830	16.38	-313.62
840	16.44	-313.56
850	16.44	-313.56
860	16.38	-313.62
870	16.38	-313.62
880	16.38	-313.62
890	16.38	-313.62
900	16.38	-313.62
910	16.38	-313.62
920	16.38	-313.62
930	16.38	-313.62
940	16.38	-313.62
950	16.38	-313.62
960	16.44	-313.56
970	16.44	-313.56
980	16.44	-313.56
990	16.5	-313.50
1000	16.5	-313.50
1100	16.5	-313.50
1200	16.57	-313.43
1300	16.5	-313.50
1400	16.5	-313.50
1500	16.44	-313.56
1600	16.44	-313.56
1700	16.44	-313.56
1800	16.44	-313.56
1900	16.44	-313.56
2000	16.5	-313.50
2100	16.5	-313.50
2200	16.63	-313.37
2300	16.57	-313.43
2400	16.69	-313.31
2500	16.76	-313.24
2600	16.82	-313.18
2700	16.82	-313.18
2800	16.82	-313.18
2900	16.88	-313.12
3000	16.88	-313.12
3100	16.88	-313.12
3200	16.88	-313.12
3300	16.88	-313.12
3400	16.88	-313.12
3500	16.88	-313.12
3600	16.88	-313.12
3700	16.88	-313.12
3800	16.88	-313.12
3900	16.88	-313.12
4000	16.95	-313.05
4100	16.95	-313.05
4200	16.95	-313.05
4300	16.88	-313.12
4400	16.88	-313.12
4500	16.88	-313.12
4600	16.95	-313.05
4700	16.95	-313.05
4800	16.88	-313.12
4900	16.88	-313.12
5000	16.95	-313.05
5100	16.95	-313.05
5200	16.95	-313.05
5300	17.01	-312.99
5400	17.14	-312.86
5500	17.14	-312.86
5600	17.2	-312.80

Elapsed Time (min.)	Pressure Head (feet)	Drawdown (feet)
5700	17.2	-312.80
5800	17.2	-312.80
5900	17.2	-312.80
6000	17.14	-312.86
6100	17.14	-312.86
6200	17.14	-312.86
6300	17.14	-312.86
6400	17.14	-312.86
6500	17.07	-312.93
6600	17.14	-312.86
6700	17.14	-312.86
6800	17.2	-312.80
6900	17.26	-312.74
7000	17.26	-312.74
7100	17.26	-312.74
7200	17.26	-312.74
7300	17.26	-312.74
7400	17.26	-312.74
7500	17.2	-312.80
7600	17.26	-312.74
7700	17.2	-312.80
7800	17.26	-312.74
7900	17.26	-312.74
8000	17.2	-312.80
8100	17.2	-312.80
8200	17.26	-312.74
8300	17.33	-312.67
8400	17.26	-312.74
8500	17.26	-312.74
8600	17.26	-312.74
8700	17.33	-312.67
8800	17.33	-312.67
8900	17.33	-312.67
9000	17.33	-312.67
9100	17.33	-312.67
9200	17.26	-312.74
9300	17.26	-312.74
9400	17.26	-312.74
9500	17.26	-312.74
9600	17.26	-312.74
9700	17.26	-312.74
9800	17.26	-312.74
9900	17.26	-312.74
10000	17.2	-312.80
10500	17.14	-312.86
11000	16.25	-313.75
11500	17.26	-312.74
12000	17.14	-312.86
12500	16.95	-313.05
13000	17.39	-312.61
13500	17.26	-312.74
14000	17.39	-312.61
14500	17.45	-312.55
15000	17.33	-312.67
15500	17.45	-312.55

APPENDIX G

LONG-TERM FLOW TEST RECOVERY DATA - SHELL WELL NO. 1

Well Name: Shell Well No. 1
Shut-in Pressure: 143 psi
Static Water Level: 330.00 feet above gage datum
Distance to Flowing Well: 567 ft.
Flowing Well: Shell Well Nos. 1 and 2
Average Flow Rate: N.A.
Test Starting Date: October 11, 1985
Test Termination Date: October 20, 1985
Test Starting Time: 15:40:00

Total Elapsed Time (min.)	Elapsed Time Since Well was Shut-in (min.)	Pressure Head (feet)	Residual Drawdown (feet)
45796	0	21.3	-308.7
45796.003	.0033	22.95	-307.05
45796.007	.0066	23.64	-306.36
45796.010	.0099	24.02	-305.98
45796.013	.0133	24.47	-305.53
45796.017	.0166	24.91	-305.09
45796.02	.02	25.8	-304.2
45796.023	.0233	26.87	-303.13
45796.027	.0266	28.83	-301.17
45796.03	.03	29.53	-300.47
45796.033	.0333	29.66	-300.34
45796.05	.05	30.16	-299.84
45796.067	.0666	32.13	-297.87
45796.083	.0833	36.94	-293.06
45796.1	.1	41.81	-288.19
45796.117	.1166	47.38	-282.62
45796.133	.1333	53.4	-276.6
45796.15	.15	53.59	-276.41
45796.167	.1666	59.54	-270.46
45796.183	.1833	66.82	-263.18
45796.2	.2	73.91	-256.09
45796.217	.2166	79.35	-250.65
45796.233	.2333	88.6	-241.4
45796.25	.25	88.47	-241.53
45796.267	.2666	95.31	-234.69
45796.283	.2833	99.04	-230.96
45796.3	.3	101.45	-228.55
45796.317	.3166	106.13	-223.87
45796.333	.3333	107.9	-222.1
45796.417	.4167	119.58	-210.42
45796.5	.5	126.96	-203.04
45796.583	.5833	133.16	-196.84
45796.667	.6667	138.23	-191.77
45796.75	.75	142.66	-187.34
45796.833	.8333	146.46	-183.54
45796.917	.9167	149.88	-180.12
45797	1	152.85	-177.15
45797.083	1.0833	155.58	-174.42
45797.167	1.1667	158.11	-171.89
45797.25	1.25	160.39	-169.61
45797.333	1.3333	162.41	-167.59
45797.417	1.4166	164.38	-165.62
45797.5	1.5	166.21	-163.79
45797.583	1.5833	167.86	-162.14
45797.667	1.6667	169.38	-160.62
45797.75	1.75	170.83	-159.17
45797.833	1.8333	172.23	-157.77
45797.917	1.9167	173.49	-156.51
45798	2	174.69	-155.31
45798.5	2.5	180.77	-149.23
45799	3	185.46	-144.54
45799.5	3.5	189.13	-140.87
45800	4	192.17	-137.83
45800.5	4.5	194.76	-135.24
45801	5	196.93	-133.07
45801.5	5.5	198.88	-131.12
45802	6	200.59	-129.41
45802.5	6.5	202.11	-127.89
45803	7	203.5	-126.5
45803.5	7.5	204.77	-125.23
45804	8	205.91	-124.09
45804.5	8.5	206.93	-123.07

Total Elapsed Time (min.)	Elapsed Time Since Well was Shut-in (min.)	Pressure Head (feet)	Residual Drawdown (feet)
45805	9	207.87	-122.13
45805.5	9.5	208.75	-121.25
45806	10	209.58	-120.42
45808	12	212.55	-117.45
45810	14	214.71	-115.29
45812	16	216.67	-113.33
45814	18	218.31	-111.69
45816	20	219.64	-110.36
45818	22	220.85	-109.15
45820	24	221.73	-108.27
45822	26	222.68	-107.32
45824	28	223.57	-106.43
45826	30	224.45	-105.55
45828	32	225.21	-104.79
45830	34	225.97	-104.03
45832	36	226.67	-103.33
45834	38	227.3	-102.7
45836	40	227.87	-102.13
45838	42	228.44	-101.56
45840	44	228.95	-101.05
45842	46	229.46	-100.54
45844	48	229.46	-100.54
45846	50	230.47	-99.53
45848	52	230.85	-99.15
45850	54	231.29	-98.71
45852	56	231.67	-98.33
45854	58	232.05	-97.95
45856	60	232.43	-97.57
45858	62	232.81	-97.19
45860	64	233.13	-96.87
45862	66	233.44	-96.56
45864	68	233.76	-96.24
45866	70	234.08	-95.92
45868	72	234.33	-95.67
45870	74	234.65	-95.35
45872	76	234.9	-95.1
45874	78	235.15	-94.85
45876	80	235.41	-94.59
45878	82	235.66	-94.34
45880	84	235.91	-94.09
45882	86	236.17	-93.83
45884	88	236.36	-93.64
45886	90	236.61	-93.39
45888	92	236.8	-93.2
45890	94	237.05	-92.95
45892	96	237.24	-92.76
45894	98	237.43	-92.57
45896	100	237.62	-92.38
45906	110	238.57	-91.43
45916	120	239.33	-90.67
45926	130	240.16	-89.84
45936	140	240.85	-89.15
45946	150	241.48	-88.52
45956	160	242.05	-87.95
45966	170	242.56	-87.44
45976	180	243.13	-86.87
45986	190	243.64	-86.36
45996	200	244.14	-85.86
46006	210	244.59	-85.41
46016	220	245.03	-84.97
46026	230	245.57	-84.43
46036	240	245.92	-84.08
46046	250	246.3	-83.7
46056	260	246.68	-83.32
46066	270	247.06	-82.94
46076	280	247.44	-82.56
46086	290	247.75	-82.25
46096	300	248.13	-81.87
46106	310	248.45	-81.55
46116	320	248.76	-81.24
46126	330	249.08	-80.92
46136	340	249.4	-80.6
46146	350	249.72	-80.28
46156	360	250.03	-79.97
46166	370	250.28	-79.72
46176	380	250.6	-79.4
46186	390	250.85	-79.15
46196	400	251.11	-78.89
46206	410	251.42	-78.58
46216	420	251.68	-78.32
46226	430	251.93	-78.07
46236	440	252.18	-77.82
46246	450	252.44	-77.56
46256	460	252.69	-77.31
46266	470	252.94	-77.06
46276	480	253.2	-76.8
46286	490	253.45	-76.55
46296	500	253.7	-76.3
46306	510	253.89	-76.11
46316	520	254.15	-75.85

Total Elapsed Time (min.)	Elapsed Time Since Well was Shut-in (min.)	Pressure Head (feet)	Residual Drawdown (feet)
46326	530	254.4	-75.6
46336	540	254.59	-75.41
46346	550	254.84	-75.16
46356	560	255.09	-74.91
46366	570	255.29	-74.71
46376	580	255.47	-74.53
46386	590	255.66	-74.34
46396	600	255.92	-74.08
46406	610	256.11	-73.89
46416	620	256.3	-73.7
46426	630	256.49	-73.51
46436	640	256.68	-73.32
46446	650	256.87	-73.13
46456	660	257.12	-72.88
46466	670	257.31	-72.69
46476	680	257.5	-72.5
46486	690	257.69	-72.31
46496	700	257.88	-72.12
46506	710	258.07	-71.93
46516	720	258.26	-71.74
46526	730	258.45	-71.55
46536	740	258.64	-71.36
46546	750	258.77	-71.23
46556	760	259.02	-70.98
46566	770	259.15	-70.85
46576	780	259.34	-70.66
46586	790	259.53	-70.47
46596	800	259.65	-70.35
46606	810	259.84	-70.16
46616	820	259.97	-70.03
46626	830	260.16	-69.84
46636	840	260.35	-69.65
46646	850	260.48	-69.52
46656	860	260.67	-69.33
46666	870	260.79	-69.21
46676	880	260.92	-69.08
46686	890	261.11	-68.89
46696	900	261.24	-68.76
46706	910	261.36	-68.64
46716	920	261.49	-68.51
46726	930	261.68	-68.32
46736	940	261.81	-68.19
46746	950	262	-68
46756	960	262.12	-67.88
46766	970	262.31	-67.69
46776	980	262.44	-67.56
46786	990	262.57	-67.43
46796	1000	262.69	-67.31
46896	1100	264.02	-65.98
46996	1200	265.29	-64.71
47096	1300	266.55	-63.45
47196	1400	267.69	-62.31
47296	1500	268.77	-61.23
47396	1600	269.78	-60.22
47496	1700	270.67	-59.33
47596	1800	271.55	-58.45
47696	1900	272.38	-57.62
47796	2000	273.26	-56.74
47896	2100	274.15	-55.85
47996	2200	275.04	-54.96
48096	2300	275.86	-54.14
48196	2400	276.56	-53.44
48296	2500	277.38	-52.62
48396	2600	278.14	-51.86
48496	2700	278.9	-51.1
48596	2800	279.72	-50.28
48696	2900	280.42	-49.58
48796	3000	281.18	-48.82
48896	3100	281.62	-48.38
48996	3200	282.13	-47.87
49096	3300	282.7	-47.3
49196	3400	283.2	-46.8
49296	3500	283.77	-46.23
49396	3600	284.41	-45.59
49496	3700	285.04	-44.96
49596	3800	285.55	-44.45
49696	3900	286.05	-43.95
49796	4000	286.62	-43.38
49896	4100	287.26	-42.74
49996	4200	287.83	-42.17
50096	4300	288.4	-41.6
50196	4400	288.9	-41.1
50296	4500	289.28	-40.72
50396	4600	289.72	-40.28
50496	4700	290.1	-39.9
50596	4800	290.42	-39.58
50696	4900	290.8	-39.2
50796	5000	291.24	-38.76
50896	5100	291.75	-38.25
50996	5200	292.19	-37.81

Total Elapsed Time (min.)	Elapsed Time Since Well was Shut-in (min.)	Pressure Head (feet)	Residual Drawdown (feet)
51096	5300	292.64	-37.36
51196	5400	293.14	-36.86
51296	5500	293.59	-36.41
51396	5600	294.03	-35.97
51496	5700	294.54	-35.46
51596	5800	294.85	-35.15
51696	5900	295.29	-34.71
51796	6000	295.42	-34.58
51896	6100	295.74	-34.26
51996	6200	295.99	-34.01
52096	6300	296.37	-33.63
52196	6400	296.63	-33.37
52296	6500	297	-33
52396	6600	297.45	-32.55
52496	6700	297.83	-32.17
52596	6800	298.21	-31.79
52696	6900	298.78	-31.22
52796	7000	299.22	-30.78
52896	7100	299.66	-30.34
52996	7200	299.98	-30.02
53096	7300	300.3	-29.7
53196	7400	300.49	-29.51
53296	7500	300.74	-29.26
53396	7600	300.93	-29.07
53496	7700	301.12	-28.88
53596	7800	301.31	-28.69
53696	7900	301.56	-28.44
53796	8000	301.72	-28.28
53896	8100	302.07	-27.93
53996	8200	302.39	-27.61
54096	8300	302.83	-27.17
54196	8400	303.21	-26.79
54296	8500	303.46	-26.54
54396	8600	303.84	-26.16
54496	8700	304.16	-25.84
54596	8800	304.35	-25.65
54696	8900	304.35	-25.65
54796	9000	304.54	-25.46
54896	9100	304.73	-25.27
54996	9200	304.92	-25.08
55096	9300	305.05	-24.95
55196	9400	305.5	-24.5
55296	9500	305.49	-24.51
55396	9600	305.74	-24.26
55496	9700	306.12	-23.88
55596	9800	306.44	-23.56
55696	9900	306.82	-23.18
55796	10000	307.07	-22.93
56296	10500	307.89	-22.11
56796	11000	308.84	-21.16
57296	11500	310.49	-19.51
57796	12000	311.12	-18.88
58296	12500	311.88	-18.12
58796	13000	313.34	-16.66

APPENDIX H

LONG-TERM FLOW TEST RECOVERY DATA - SHELL WELL NO. 2

Well Name: Shell Well No. 2
Shut-in Pressure: 161 psi
Static Water Level: 371.54 feet above gage datum.
Distance to Flowing Well: N.A.
Flowing Well: Shell Well Nos. 1 and 2
Average Flow Rate: N.A.
Recovery Test Starting Date: October 11, 1985
Test Termination Date: October 20, 1985
Test Starting Time: 15:40:00

Total Elapsed Time (min.)	Elapsed Time Since Well was Shut-in (min.)	Pressure Head (feet)	Residual Drawdown (feet)
45796	0	.7	-370.84
45796.003	.0033	1.33	-370.21
45796.007	.0066	1.41	-370.13
45796.010	.0099	1.51	-370.03
45796.013	.0133	1.57	-369.97
45796.017	.0166	1.57	-369.97
45796.02	.02	1.65	-369.89
45796.023	.0233	1.65	-369.89
45796.027	.0266	1.57	-369.97
45796.03	.03	1.57	-369.97
45796.033	.0333	1.57	-369.97
45796.05	.05	1.1	-370.44
45796.067	.0666	1.1	-370.44
45796.083	.0833	1.41	-370.13
45796.1	.1	1.65	-369.89
45796.117	.1166	2.12	-369.42
45796.133	.1333	2.51	-369.03
45796.15	.15	3.14	-368.4
45796.167	.1666	3.77	-367.77
45796.183	.1833	4.25	-367.29
45796.2	.2	4.88	-366.66
45796.217	.2166	5.58	-365.96
45796.233	.2333	7	-364.54
45796.25	.25	9.36	-362.18
45796.267	.2666	12.98	-358.56
45796.283	.2833	15.87	-355.67
45796.3	.3	17.78	-353.76
45796.317	.3166	20.46	-351.08
45796.333	.3333	22.9	-348.64
45796.417	.4167	35.02	-336.52
45796.5	.5	52.18	-319.36
45796.583	.5833	112.24	-259.3
45796.667	.6667	219.52	-152.02
45796.75	.75	256.51	-115.03
45796.833	.8333	263.52	-108.02
45796.917	.9167	266.12	-105.42
45797	1	267.77	-103.77
45797.083	1.0833	268.87	-102.67
45797.167	1.1667	269.58	-101.96
45797.25	1.25	270.29	-101.25
45797.333	1.3333	270.84	-100.7
45797.417	1.4166	271.31	-100.23
45797.5	1.5	271.78	-99.76
45797.583	1.5833	272.1	-99.44
45797.667	1.6667	272.49	-99.05
45797.75	1.75	272.81	-98.73
45797.833	1.8333	273.12	-98.42
45797.917	1.9167	273.36	-98.18
45798	2	273.67	-97.87
45798.5	2.5	275.01	-96.53
45799	3	275.96	-95.58
45799.5	3.5	276.82	-94.72
45800	4	277.61	-93.93
45800.5	4.5	278.39	-93.15
45801	5	278.95	-92.59
45801.5	5.5	279.42	-92.12
45802	6	279.73	-91.81
45802.5	6.5	280.2	-91.34
45803	7	280.6	-90.94
45803.5	7.5	280.91	-90.63
45804	8	281.31	-90.23
45804.5	8.5	281.54	-90

Total Elapsed Time (min.)	Elapsed Time Since Well was Shut-in (min.)	Pressure Head (feet)	Residual Drawdown (feet)
45805	9	281.78	-89.76
45805.5	9.5	282.02	-89.52
45806	10	282.25	-89.29
45808	12	283.12	-88.42
45810	14	283.83	-87.71
45812	16	284.53	-87.01
45814	18	285.01	-86.53
45816	20	285.48	-86.06
45818	22	285.95	-85.59
45820	24	286.42	-85.12
45822	26	286.9	-84.64
45824	28	287.21	-84.33
45826	30	287.68	-83.86
45828	32	288	-83.54
45830	34	288.39	-83.15
45832	36	288.7	-82.84
45834	38	289.1	-82.44
45836	40	289.34	-82.2
45838	42	289.54	-82
45840	44	289.89	-81.65
45842	46	290.2	-81.34
45844	48	290.6	-80.94
45846	50	290.91	-80.63
45848	52	291.23	-80.31
45850	54	291.54	-80
45852	56	291.54	-80
45854	58	291.7	-79.84
45856	60	291.85	-79.69
45858	62	292.01	-79.53
45860	64	292.25	-79.29
45862	66	292.4	-79.14
45864	68	292.64	-78.9
45866	70	292.88	-78.66
45868	72	293.03	-78.51
45870	74	293.19	-78.35
45872	76	293.35	-78.19
45874	78	293.59	-77.95
45876	80	293.74	-77.8
45878	82	293.9	-77.64
45880	84	294.06	-77.48
45882	86	294.37	-77.17
45884	88	294.61	-76.93
45886	90	294.61	-76.93
45888	92	294.69	-76.85
45890	94	294.85	-76.69
45892	96	295	-76.54
45894	98	295.24	-76.3
45896	100	295.32	-76.22
45906	110	296.1	-75.44
45916	120	296.81	-74.73
45926	130	297.44	-74.1
45936	140	297.99	-73.55
45946	150	298.54	-73
45956	160	299.02	-72.52
45966	170	299.49	-72.05
45976	180	299.96	-71.58
45986	190	300.43	-71.11
45996	200	300.91	-70.63
46006	210	301.3	-70.24
46016	220	301.69	-69.85
46026	230	302.17	-69.37
46036	240	302.48	-69.06
46046	250	302.87	-68.67
46056	260	303.27	-68.27
46066	270	303.58	-67.96
46076	280	303.97	-67.57
46086	290	304.29	-67.25
46096	300	304.6	-66.94
46106	310	305	-66.54
46116	320	305.23	-66.31
46126	330	305.63	-65.91
46136	340	305.86	-65.68
46146	350	306.18	-65.36
46156	360	306.49	-65.05
46166	370	306.73	-64.81
46176	380	307.05	-64.49
46186	390	307.36	-64.18
46196	400	307.6	-63.94
46206	410	307.83	-63.71
46216	420	308.15	-63.39
46226	430	308.38	-63.16
46236	440	308.62	-62.92
46246	450	308.86	-62.68
46256	460	309.17	-62.37
46266	470	307.41	-64.13
46276	480	309.64	-61.9
46286	490	309.88	-61.66
46296	500	310.12	-61.42
46306	510	310.35	-61.19
46316	520	310.59	-60.95

Total Elapsed Time (min.)	Elapsed Time Since Well was Shut-in (min.)	Pressure Head (feet)	Residual Drawdown (feet)
46326	530	310.82	-60.72
46336	540	311.06	-60.48
46346	550	311.3	-60.24
46356	560	311.53	-60.01
46366	570	311.69	-59.85
46376	580	311.93	-59.61
46386	590	312.16	-59.38
46396	600	312.4	-59.14
46406	610	312.63	-58.91
46416	620	312.79	-58.75
46426	630	312.95	-58.59
46436	640	313.19	-58.35
46446	650	313.34	-58.2
46456	660	313.58	-57.96
46466	670	313.82	-57.72
46476	680	313.97	-57.57
46486	690	314.21	-57.33
46496	700	314.37	-57.17
46506	710	314.52	-57.02
46516	720	314.68	-56.86
46526	730	315	-56.54
46536	740	315.15	-56.39
46546	750	315.31	-56.23
46556	760	315.47	-56.07
46566	770	315.7	-55.84
46576	780	315.78	-55.76
46586	790	316.02	-55.52
46596	800	316.18	-55.36
46606	810	316.33	-55.21
46616	820	316.49	-55.05
46626	830	316.73	-54.81
46636	840	316.81	-54.73
46646	850	316.96	-54.58
46656	860	317.2	-54.34
46666	870	317.28	-54.26
46676	880	317.43	-54.11
46686	890	317.59	-53.95
46696	900	317.75	-53.79
46706	910	317.91	-53.63
46716	920	317.99	-53.55
46726	930	318.22	-53.32
46736	940	318.3	-53.24
46746	950	318.46	-53.08
46756	960	318.62	-52.92
46766	970	318.77	-52.77
46776	980	318.93	-52.61
46786	990	319.09	-52.45
46796	1000	319.25	-52.29
46896	1100	320.43	-51.11
46996	1200	321.61	-49.93
47096	1300	322.87	-48.67
47196	1400	323.97	-47.57
47296	1500	325.07	-46.47
47396	1600	326.02	-45.52
47496	1700	326.88	-44.66
47596	1800	327.75	-43.79
47696	1900	328.61	-42.93
47796	2000	329.48	-42.06
47896	2100	330.27	-41.27
47996	2200	331.21	-40.33
48096	2300	331.92	-39.62
48196	2400	332.7	-38.84
48296	2500	333.33	-38.21
48396	2600	333.96	-37.58
48496	2700	334.52	-37.02
48596	2800	335.14	-36.4
48696	2900	335.92	-35.62
48796	3000	336.64	-34.9
48896	3100	337.11	-34.43
48996	3200	337.74	-33.8
49096	3300	338.22	-33.32
49196	3400	338.77	-32.77
49296	3500	339.32	-32.22
49396	3600	339.87	-31.67
49496	3700	340.42	-31.12
49596	3800	340.97	-30.57
49696	3900	341.36	-30.18
49796	4000	341.84	-29.7
49896	4100	341.23	-30.31
49996	4200	342.62	-28.92
50096	4300	343.1	-28.44
50196	4400	343.65	-27.89
50296	4500	344.04	-27.5
50396	4600	344.51	-27.03
50496	4700	344.83	-26.71
50596	4800	345.22	-26.32
50696	4900	345.53	-26.01
50796	5000	346.01	-25.53
50896	5100	346.4	-25.14
50996	5200	346.87	-24.67

Total Elapsed Time (min.)	Elapsed Time Since Well was Shut-in (min.)	Pressure Head (feet)	Residual Drawdown (feet)
51096	5300	347.27	-24.27
51196	5400	347.66	-23.88
51296	5500	347.9	-23.64
51396	5600	348.05	-23.49
51496	5700	348.45	-23.09
51596	5800	348.76	-22.78
51696	5900	349.16	-22.38
51796	6000	349.47	-22.07
51896	6100	349.86	-21.68
51996	6200	350.1	-21.44
52096	6300	350.49	-21.05
52196	6400	350.73	-20.81
52296	6500	351.12	-20.42
52396	6600	351.52	-20.02
52496	6700	351.91	-19.63
52596	6800	352.23	-19.31
52696	6900	352.54	-19
52796	7000	352.7	-18.84
52896	7100	352.93	-18.61
52996	7200	353.17	-18.37
53096	7300	353.49	-18.05
53196	7400	353.8	-17.74
53296	7500	354.11	-17.43
53396	7600	354.35	-17.19
53496	7700	354.51	-17.03
53596	7800	354.74	-16.8
53696	7900	354.98	-16.56
53796	8000	355.22	-16.32
53896	8100	355.45	-16.09
53996	8200	355.85	-15.69
54096	8300	356.08	-15.46
54196	8400	356.24	-15.3
54296	8500	356.4	-15.14
54396	8600	356.48	-15.06
54496	8700	356.79	-14.75
54596	8800	357.11	-14.43
54696	8900	357.26	-14.28
54796	9000	357.5	-14.04
54896	9100	357.75	-13.79
54996	9200	357.89	-13.65
55096	9300	358.05	-13.49
55196	9400	358.29	-13.25
55296	9500	358.52	-13.02
55396	9600	358.68	-12.86
55496	9700	358.99	-12.55
55596	9800	359.15	-12.39
55696	9900	359.23	-12.31
55796	10000	359.31	-12.23
56296	10500	360.41	-11.13
56796	11000	361.28	-10.26
57296	11500	362.14	-9.4
57796	12000	363.09	-8.45
58296	12500	363.95	-7.59
58796	13000	364.58	-6.96