EG&G Idaho

GL07222

INTEROFFICE CORRESPONDENCE

date December 22, 1978

to J. W. Morfitt

from L. G. Miller

subject RAFT RIVER WELL DRILLING SUMMARY - Mlr-51-78

Attached is the Well Drilling Summary requested by you some time ago. The Summary was delayed until costs were complete on RRGP-4. Costs for well drilling support in some cases were best estimates. In Figure 2, well cost per kW(e) are very sensitive to projected flows.

Number 5 well seems to be getting somewhat better and therefore, its cost per kW(e) will drop. I hope this summary contains the answers to your questions.

cs

cc: L. F. Burdge
J. H. Ramsthaler

FORM EG&G-954
(Rev. 2-77)

EG&G Idaho

INTEROFFICE CORRESPONDENCE

date November 21, 1978

to J. W. Morfitt

from L. G. Miller

subject COMMENTS ON CEMENT PLUG AND FLOW TEST AT RRGP-5 - Mlr-49-78

John Griffith verbally requested a synopsis of the cement job on RRGP-5 well and further information on the flow test that was conducted before the salt incident. Several people have expressed that the measured flow was in error and nowhere near the reported 1100 gpm flow. John requested this information in order to give credence to his recommendation to multileg this well, expecially now that RRGP-4 has come up dry.

The initial plan was to kill No. 5 well during the running and cementing of the production casing. This was to be done by setting a 100 ft plug between the bottom of the casing and the producing zone, i.e. about 3700 ft. One hundred feet of cement can, in most cases, be drilled out. The formation is harder material than the cement and the bit will stay inside the old hole. If this did not hold, the well would then be backfilled with sand. A very effective method as was done in No. 1.

For an unknown reason, the plan was changed, 230 sacks (48 barrels of mixed cement) were pumped into the well through tubing set at 3720 ft. Which would have cemented 240 ft of hole. This did not shut off the well for unknown reasons. Instead of backfilling with sand to prevent any damage to the producing fracture system, 800 more sacks (165 barrels of mixed cement) were pumped into the well at the previous depth. This was a successful cement plug and the well was killed.

Since the bottom of the producing fracture zone is 4540 ft (from several spinner tests), the cement was pumped down the well and out into the producing fractures. Little cement would go below 4540 ft as it acts as a closed system. Therefore, with 213 barrels of cement, the well was cemented from 3735 ft to 4540 ft and 290 ft^3 of cement was forced out into the producing fractures cementing them closed out to some unknown radius.

When they came back to drill out the plug, the bit could not be kept within the old hole and drilled a new leg parallel to the old leg. The new leg was drilled to a depth of 4925 ft. Production from the new leg is considerably less than the original leg. The first test after drilling Leg B indicated only about 100 gpm but further testing has indicated the well is developing. Flows of 300 gpm can be sustained for a period of time.

No one can say for certain why the second leg does not produce similar to the first leg. But with that much cement in the producing fractures and the two legs being only 16 ft apart in the producing zone, I am confident the second leg was drilled through the region where most of the fractures were cemented closed (see attached figure).

If one was to consider further drilling on this hole, two factors should be strongly considered. The first would be the value of a 274°F supply well. The value of this well to the power plant could be considerable considering the results of No. 4 even though the temperature is low. Mixing this water with other wells will lessen the low temperature effect and will reduce the plant efficiency somewhat. It would provide sufficient flow to allow operation of the plant with over design flow rates and would provide a reserve fluid capacity in the event of a failure of a production well.

The second factor is directionally drilling a new leg to penetrate the producing formation away from the cemented fractures. It is impossible to predict the distance from the original leg in which cement has penetrated. Possibly some reservoir engineering or hydrology people could make this estimate from previous flow data. If there is a real need for 274°F water, additional legs could be drilled at a relatively low cost which should bring the production back to near the original flow of 1100 gpm.

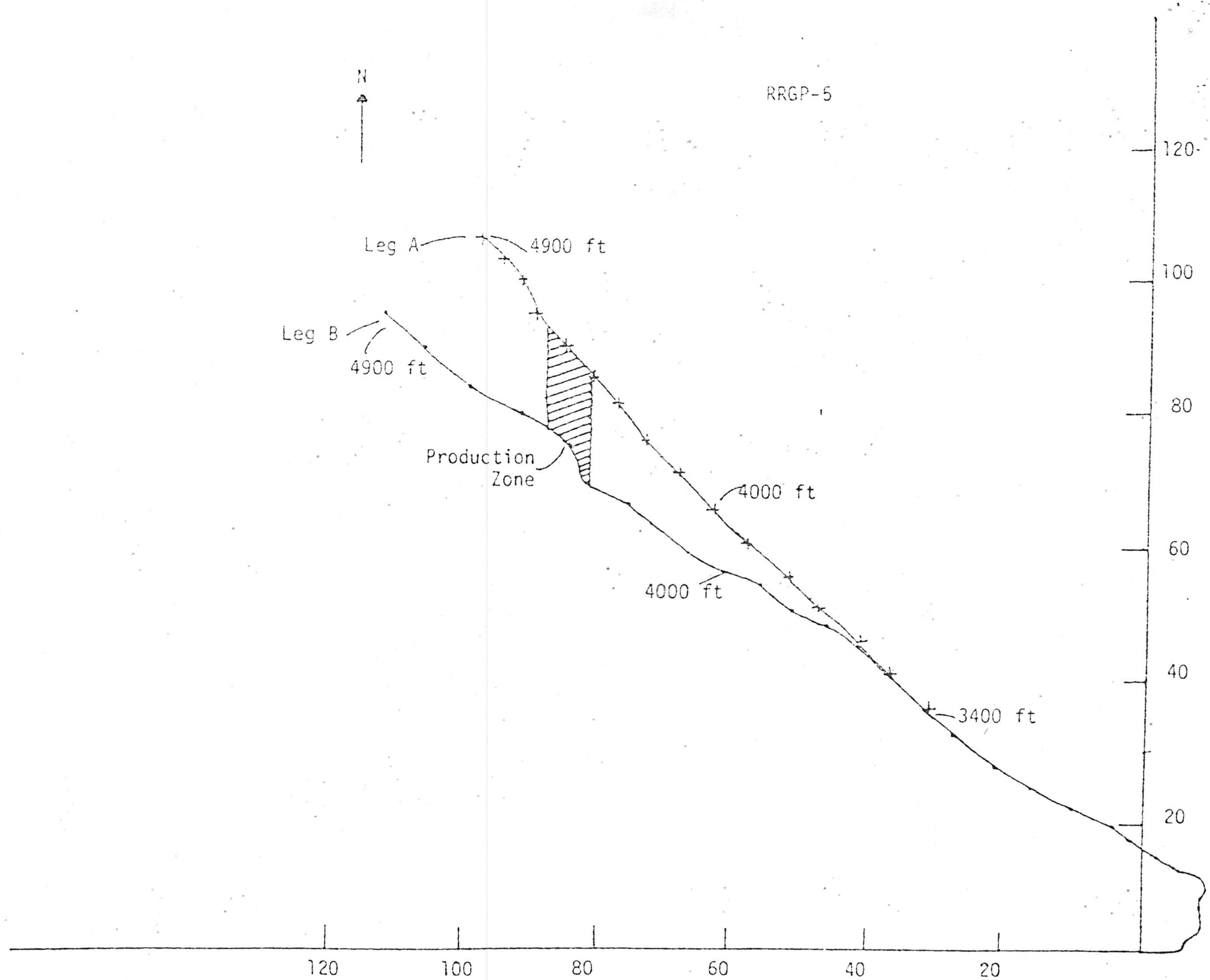
There seems to be a misunderstanding as to the flow capability of No. 5 well prior to the salt incident. Attached is a summary of the flow test along with substantiating information which supports the 1080 gpm flow measurement taken on June 10, 1978. The depth of the well at this time was 4505 ft. Using reserve pit fill up during the drilling from 4505 ft to 4911 ft or TD on Leg A indicated flow rates varied somewhat from 1000 to 2000 gpm.

With No. 4 coming up dry in both legs, it is much more important that No. 5 be returned to full production by drilling one or two more legs at a maximum distance from the original legs. The bottom of the No. 5 casing was kept high enough to provide sufficient distance to kick off two more legs.

cs

Attachments
As Stated

cc: w/attachments
L. F. Burdge
J. H. Ramsthaler



N
RRGP-5
Leg A
4900 ft
Leg B
4900 ft
Production
Zone
4000 ft
4000 ft
3400 ft
120
100
80
60
40
20
120
100
80
60
40
20

RRGP-5 FLOW CAPABILITY
(Before Salt Incident)

Information is available which substantiates the accurately measured flows from RRGP-5. The rough estimates, impressions, and photographs all reinforce the measured flow. All of this is brought together in a synopsis starting June 1, 1978, when the rig twisted off a drill pipe while drilling at 4328 ft depth. On June 2, the wellhead was shut-in waiting for fishing tools.

At a depth of 4328 ft on June 5 and 6, after the fishing job was completed; flow tests were run using the mud pits. The two 15-minute tests measured 172 and 198 gpm. A temperature log measured a maximum downhole temperature of 275°F. Wellhead pressure had been previously recorded at 40 psi on the night of June 2, and 55 psi after being closed in all night.

From this information, we can conclude that the flow into the well bore from 1600 ft to 4328 ft was about 200 gpm and wellhead pressure of 55 psi. Some of this flow was probably from the 1600 to 2000 ft "thief zone." There were no water disposal problems during this portion of the drilling. Percolation out the bottom of the pit kept the reserve pit water level low. Makeup water was pumped from site 1 up to the rig using the 125 HP 1200 gpm transfer pump. Transfer pumping was done almost half time around the clock while drilling.

Considerable increase in flow was experienced and they tripped out of the hole to change bits. A bleed-off line was installed on the flow nipple to bypass the large flow of water past the shale shaker directly to the reserve pit. A temperature log again only measured 275°F at the bottom of the hole.

The Hydrill would not hold the pressure due to the deteriorating rubber liner and a new Hydrill was ordered. On June 10, a flow line was set up with an orifice plate and a back pressure valve. Recommended straight pipe sections were used upstream and downstream of the orifice plate. Orientation of the orifice plate was verified upon insertion. A flow test was conducted by two very competent people; Bill Munger, an experienced piping hardware man; and Virgil Egan, a highly experienced instrument engineer.

RRGP-5 FLOW CAPABILITY

All instruments and gauges used on this test had previously been calibrated onsite using a Wallace Tiernan precision pressure gauge and a dead weight tester. Calibration was done under Egan's direction and instruments tagged. A 3.0-inch diameter orifice plate was first used but flows were too high and rubber from Hydrill kept plugging the hole. A 5.443-inch diameter Daniels 304SS orifice plate was installed in the 8-inch flow line. A 50 psi back pressure was maintained to prevent any chance of two phase flow through the orifice. After flow had nearly stabilized, four readings were taken over a 20-minute period. The volume of water and steam discharging from the flow line was so great that it hit the opposite reserve pit bank about 125-150 ft away depositing pieces of the Hydrill rubber liner. Attached are photographs taken while drilling prior to the bleed-off line installation on June 8, 1978.

Lynn Nelson conducted a flow test on No. 5 soon after this test. Part of the 550 gpm test was to observe the distance the discharge traveled across the reserve pit. With this flow, the discharge did not get beyond the middle of the reserve pit. Surface temperatures were about the same for both tests.

Time	Water Temperature	Back Pressure	ΔP	Calculated Flow
1630	260°F	50 psi	3.2 psi	1116 gpm
1640	262°F	51 psi	3.0 psi	1080 gpm
1645	263°F	51 psi	3.0 psi	1080 gpm
1650	264°F	51 psi	3.0 psi	1080 gpm

The above flow rates are calculated using the Crane Flow of Fluids equation

$$Q = 236\, d_1^2\, C\sqrt{\frac{\Delta P}{\rho}}$$

C was calculated by two methods, one using the Crane equation for Reynolds Number and plots; and the second using the equation from Fisher and Porters "Flow Meter Orifice Sizing Handbook." The two equations gave values of C within 1%. The above equation is for a standard orifice plate with taps one diameter upstream and one half diameter downstream. Orifice flanges were used in this experiment which could introduce less than 2% error.

RRGP-5 FLOW CAPABILITY

Since the flow had stabilized by 1650 hours, the test was terminated so that the well could be cooled and drilling resumed. This was the beginning of a series of serious water disposal problems.

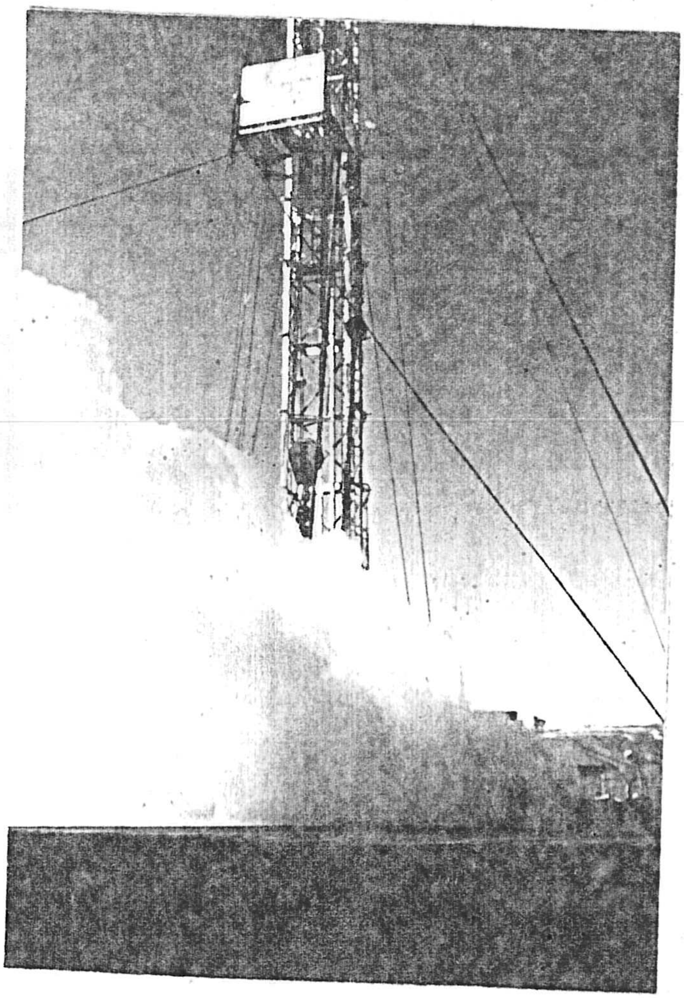
Cooler water from the reserve pit and site No. 1 was pumped into the mud pits and down the well. This lowered the return flow temperature below the flash point. The high water in the pond and the large volume of returning fluid caused the bank under the mud pits to erode. Rock was hauled for several days to build back the bank.

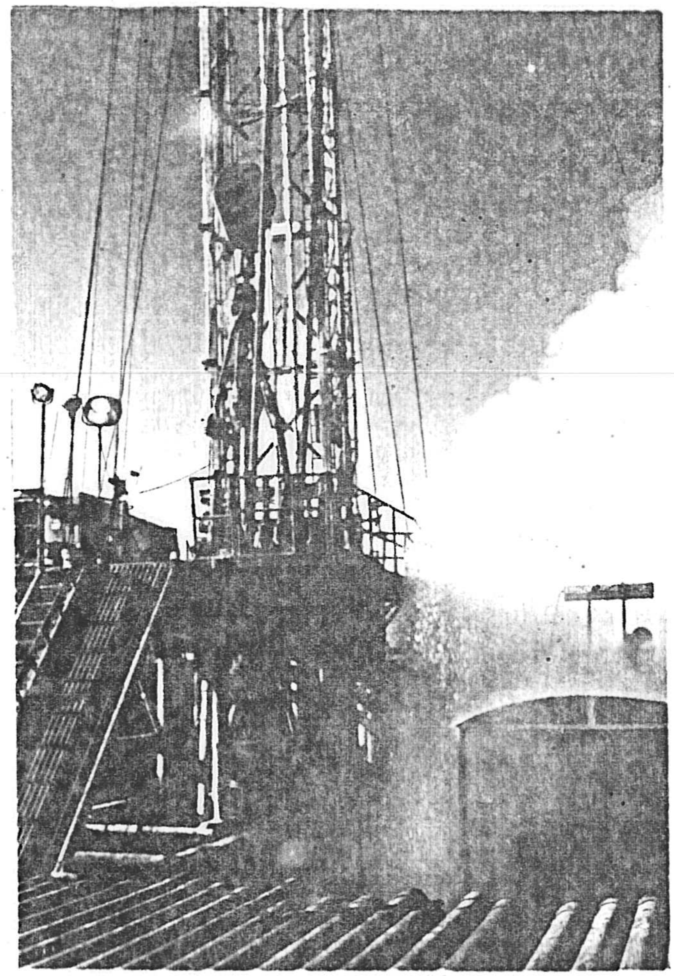
Two pumps were leased from Colorado Well Service, a pump was borrowed from the Raft River Highway District, a PTO pump and tractor was brought from site No. 1, and a 6-inch pump brought from the INEL site. One pump was used to pump water over to site No. 2 through a 6-inch aluminum line. (A second pump was added but the large flow caused the line to part.)

The water was checked for salinity and determined to be safe for surface disposal on the sagebrush. The additional pumps were then used to pump over the reserve pit berm into the sagebrush. The pumps were still not keeping up with the water. The drilling operation was halted periodically to allow the pumps to lower the reserve pit level.

A cut was made in the reserve pit berm and a large culvert installed to keep the water level about 3-ft below the top of the berm. This solved the drill site water problem. Even though the water spread out in the safebrush and percolated into the soil, water entered private land a quarter mile to the south. Trenches were dug in the sagebrush to slow the flow of water to the private land. Seven days after the flow test, the rig twisted off a drill pipe and drilling on this leg was terminated at 4911 ft.

Photographs were taken during the drilling of RRGP-5 prior to the installation of the bleed-off line on June 8, 1978. This line by-passed the flow across the shale shaker directly into the pond.





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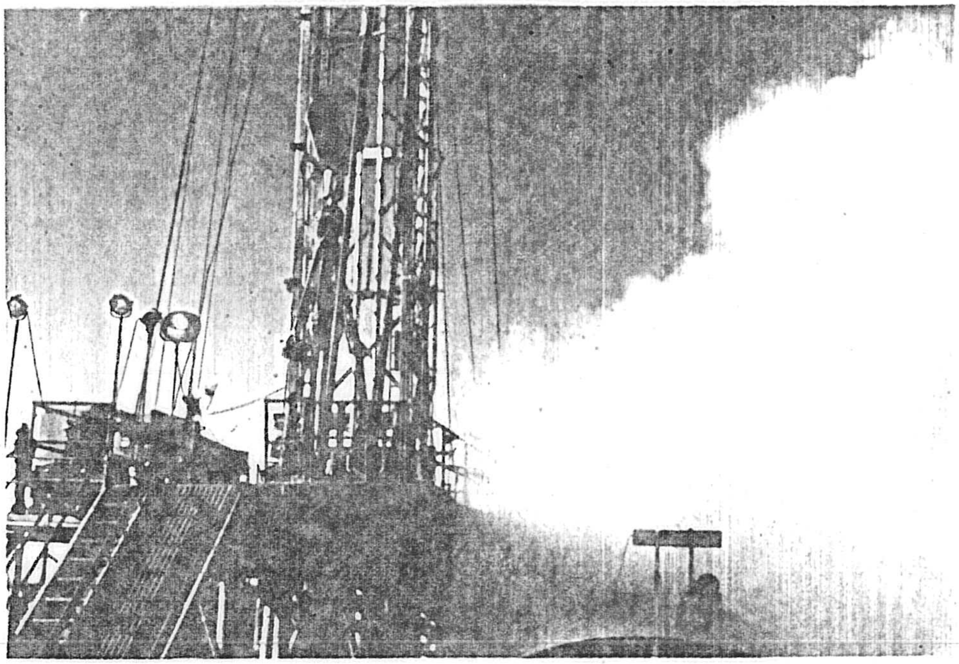

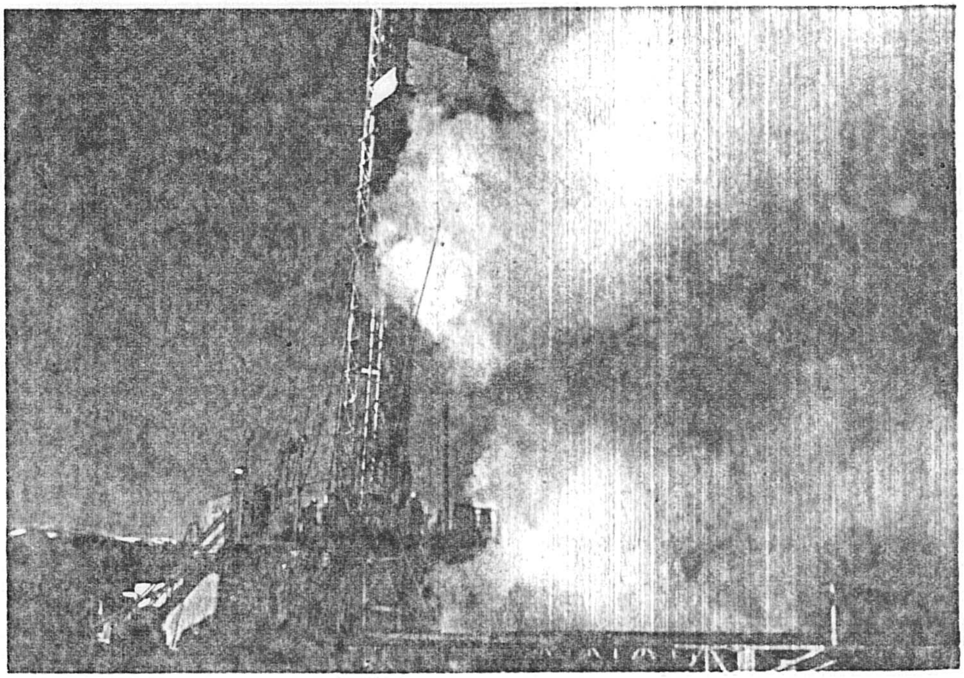

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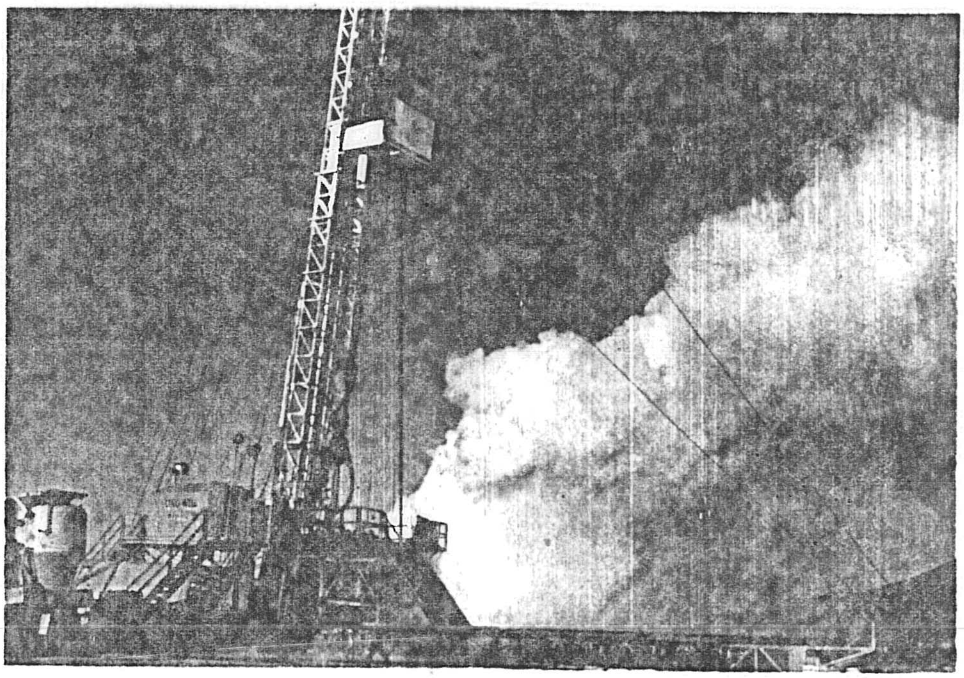

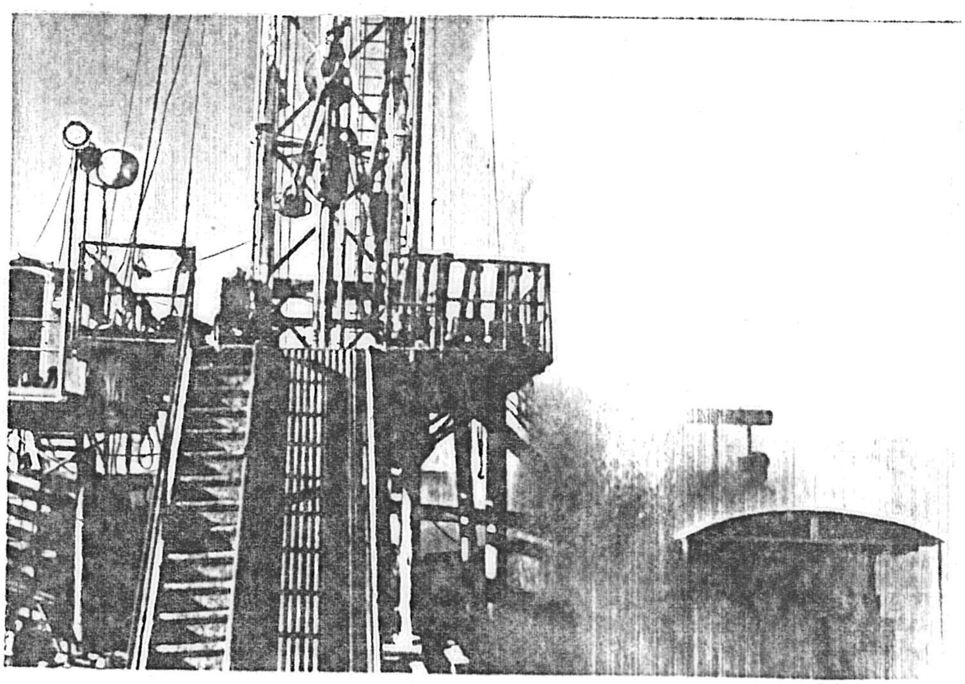

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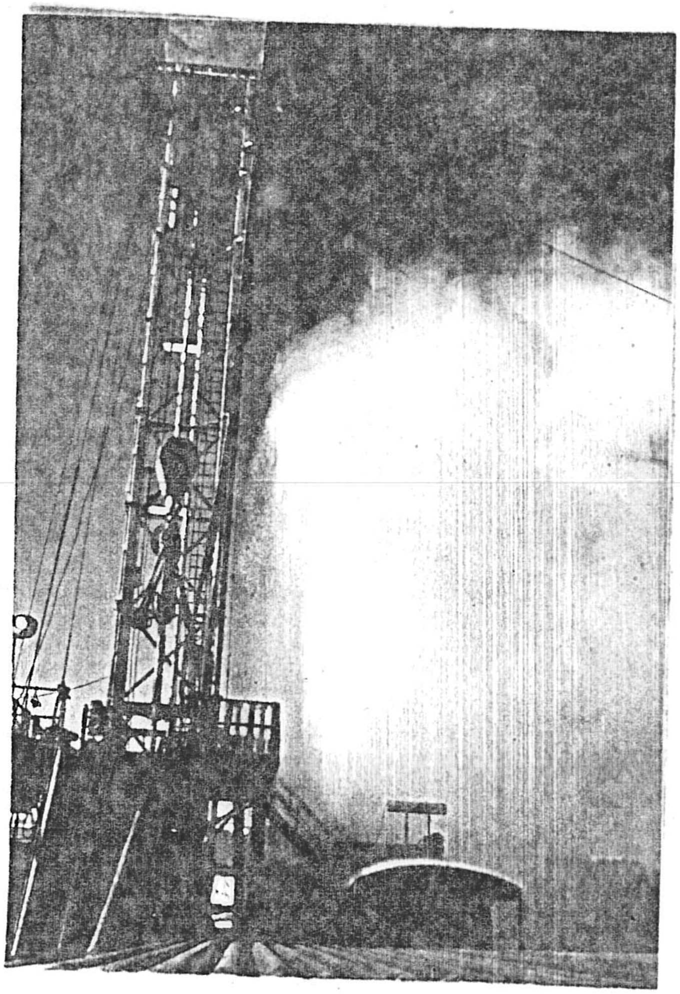

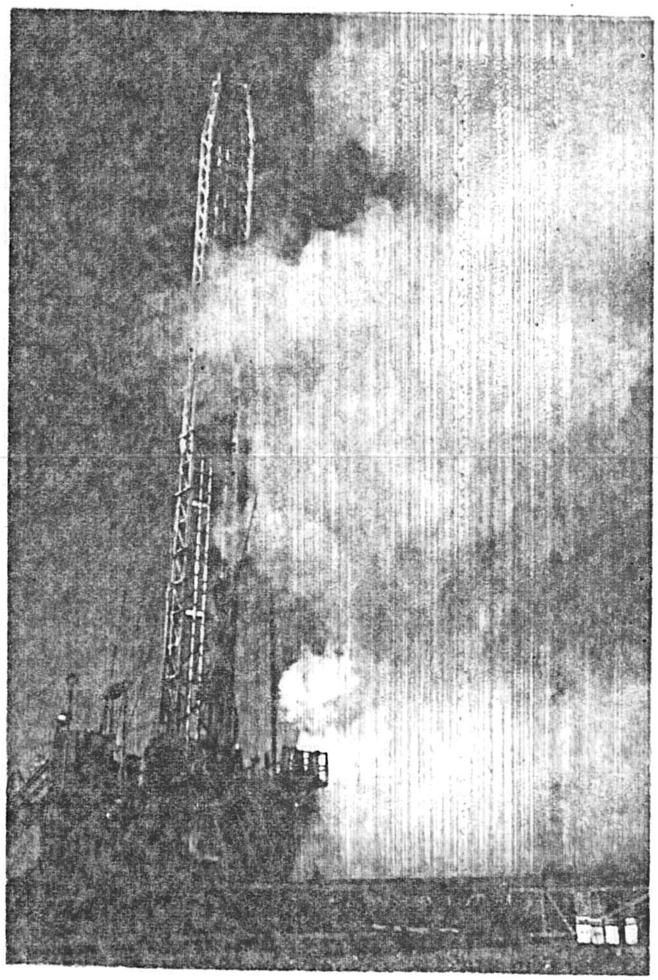

RAFT RIVER WELL DRILLING SUMMARY

L. G. Miller

INTRODUCTION

The drilling of the first well, early in 1975 in Raft River, verified the existence of a geothermal resource with a temperature of about 300°F. The pilot power plant was designed around this and the second well considering a few degrees temperature loss from resource to plant. Specifications were prepared for supply and injection system management plan, report GP-124, page 5. The system is to supply 2250 gpm of 290°F low salinity geothermal fluid to the pilot plant and inject 2125 gpm spent fluid into intermediate or deep injection wells, the depth of the injection zone to be determined by testing.

Initial estimates of flow from the first two wells indicated a need for three production wells and a standby well. Using initial injection tests on No. 2, two injection wells would be required with a standby well. As long term reservoir test data became available, it became apparent that after five years operation of the production and injection wells, their performance would be less than initially estimated. New five year production and injection estimates have been prepared and are shown in Table I. In the Table, No. 3 well is indicated as an injection well but the flow is shown in a production mode and may still be used for production.

SUMMARY OF WELLS DRILLED

RRGE-1

The first well was drilled by REECo (Reynolds Electric and Engineering Company, a subcontractor to the Nevada Operations Office), after Governor Andrus donated $200,000 in State funds to supplement the DOE (ERDA) funds. EG&G (ANC) had no drilling expertise at that time. The first two wells drilled by REECo were a learning experience for EG&G people. The third well drilled by REECo was then managed by EG&G people. All procurement actions and contracts were also set up and administered by EG&G people.

The first well was drilled in such a way that should no resource be encountered, minimal cost would be expended, i.e. production casing was not run and cemented until drilling was completed and well was found to be a success. This method worked exceedingly well. The bottom hole was backfilled with sand to shut off the resource during the casing and cementing operations.

Casing collapse during cementing was the only major problem encountered. Reaming was required to open the well bore. Production from this well is considered highest of any well drilled. Free flow from the well approaching 600 gpm.

RRGE-2

The second well was drilled in two parts and located along the same fault as No. 1 but further to the northeast. The well was to intercept the Bridge Fault at a greater depth than No. 1. The well was drilled with mud until a drill-stem-test (DST) measured temperatures exceeding 280°F. At this point, the casing was run and cemented. The well was drilled to basement rock at 6006 ft depth. During a major part of the next year, the drill rig set over the hole. Injection and flow tests were conducted during this period. Over 8-million gallons of cold aerated water were injected.

Drilling was resumed at USGS recommendation to determine if the quartz-monzonite basement rock was fractured and could produce fluids. No fractures were detected in the quartz-monzonite formation during the extremely hard drilling to 6561 ft.

RRGE-3

The third hole was drilled 9000 ft southeast across the river from the first two holes. This location was recommended by the USGS as this location would determine if the resource extended outside the fault zones. This well was planned to have three barefoot legs to increase the production by a calculated 50%. The first leg was drilled to basement rock. Formation temperature was above 294°F, but the first leg produced little fluid even after stimulation. The second leg was then drilled to the northeast and produced some increase in flow. The third leg was drilled to the north, toward the other production wells. Considerable flow was encountered in this leg. Maximum formation temperature was 301°F, but total production from the three legs is less than either of the first two wells. Major problem during the drilling of this well was the continued failure of the rubber components in the Dyna-drills during directional drilling.

RRGI-4

During the drilling of the first two wells, the intermediate zone from 1600 ft to 3000 ft appeared to have high permeability which could be utilized effectively for intermediate depth injection. A decision was made to drill an intermediate depth injection well for testing formation and interaction with the deep production zone. A location was selected by the USGS for this well with the plan to convert it to a production well after the injection test program. This well was located 2000 ft south of No. 1, a location considered to be a prime location for a production well. This location would be at the intersection of the Bridge Fault and the Narrows structure (possibly a fault structure).

A private rig was contracted and the well was drilled to 2900 ft. Cement failure at the casing shoe allowed the bottom two joints of casing to part from the main string causing a "trip in" problem. Maximum tempertaure at this depth was 252°F. Flow tests indicated formation permeability was less than predicted but temperature was considerably higher at this depth than any of the previous wells.

RRGI-6

No. 6 well was drilled as an intermediate injection well after completion of No. 4 initial injection tests. Location of the No. 6 and No. 7 injection wells was selected by DOE-ID, even though EG&G people recommended other areas. No. 3 had already proved that intermediate and deep formations were tight and would make a very poor injection well location. This well was drilled to 3888 ft at 30% less cost than estimated. Preliminary injection tests indicated somewhat tight formation. A recommendation was proposed to DOE-ID to drill the well deeper, i.e. opening up more formation which would reduce injection pump pressure. DOE-ID would not accept the recommendation and the drill rig was moved to No. 5.

RRGP-5

This well was located 3000 ft west of No. 1 well. Its location was selected by the USGS as being along the north edge of the Narrows structure. After drilling had commenced, Harry Covington, USGS Field Representative indicated that previous data had been analyzed which predicted a high basement in the region of No. 5. If this was true and No. 5 was cased to a depth indicated in the Management Plan, we would be casing a hole down to basement rock, a very costly mistake. A decision was made with ID concurrence to omit casing until the resource was verified.

A hot water resource of 274°F was encountered at about 4500 ft. Pilot plant use of this temperature water was considered marginal. The well could provide an important backup roll in the event of failure of a higher temperature well or be used to determine power plant characteristics with flow rates greater than the design. Drilling was resumed with DOE-ID concurrence to basement rock at 4911 ft. No additional hot water sources or higher temperatures were encountered.

At this depth, the hard quartz-monzonite was encountered and a drill pipe twisted off causing several weeks of fishing. Salt water was pumped into the hole intermittantly during the fishing job to keep the well "killed." During this period of fishing, DOE-ID was informed of the salt additions but they did not inform the Sate Water Resources until the salt injection was completed.

After the fishing job, the well was stimulated but initial characteristics did not return. DOE-ID agreed to allow the drill rig to move off No. 5 and drill No. 7 so that additional testing could be carried out on No. 5. The rig returned to complete the casing and cementing, but the two additional legs were not drilled as detailed in the test plant.

RRGI-7

This injection well was located 2300 ft southwest of No. 6 and drilled similar to No. 6. This well was drilled 40% below estimated cost. Initial injection tests indicated the permeability of No. 7 to be less than No. 6. EG&G recommended that this well be deepened while rig was over the hole,but the recommendation was not accepted.

During the completion of this well, DOE-ID assumed the management and direction of all drilling activities. Rig was moved back to No. 5 for well casing and completion.

RRGP-5 CASING AND COMPLETION

A cement plug was set below the proposed casing setting depth while the rig was drilling No. 7. Casing was then set and cemented to 3400 ft. Cementing failure required two remedial cement jobs. While drilling through the cement plug, hole was deviated out of original channel and a new hole was drilled to TD (4925 ft). Initial flow and temperature runs on the well indicate 100 gpm flow at 265°F maximum at the surface (274°F maximum temperature downhole). Flow measured prior to the salt incident and casing measured 1080 gpm. Most of this flow was attributed to the 4450 to 4500 ft producing zone.

RRGP-4 CASING AND COMPLETION

No. 4 was deepened to 3457 ft and 9-5/8 inch casing was run and cemented from TD up to casing hanger at 1512 ft depth. The Management Plan called for triple legs to this well, but after the first two legs produced nearly zero flow, the third leg was not attempted. The first leg was drilled to 5427 ft, 450 ft into the quartz-monzonite to determine if fractures and production could be located. Neither were intersected. A second leg was drilled to 5115 ft with similar results. Maximum downhole temperature was 288°F at 4900 ft, and bottom hole temperature was 273°F. Rig was removed from well and stacked in anticipation of drill rig use at INEL. Further drilling will be done after a thorough analysis of the present wells and further drilling funds are made available.

TABLE 1 WELL DRILLING SUMMARY

Well No.	Year Drill Com-plete	COST (Drilling Cas-ing & Logging) Drill and Mtls	Mgmt & Drill Support[3]	Total Well Costs[5]	Time (Drilling & Testing)	Name of Driller	Type of Well	Maximum DownHole Temperature	Wellhead Temperature	Projected FLOWRATE After 5 years gpm	DEPTH	Casing Size & Depth
1	1975	810	100	910	103 days	REECo	Prod	286°F	281-265°F	800	5007 ft	13-378" to 3624'
2	1976	800	70	870	82 days	REECo	Prod	291°F	282°F	400	6561 ft	13-3/8" to 4227'
3	1976	650	70	720	63 days	REECo	Inj	300°F	295°F	535	5853 ft[2]	13-38" to 1385'
											5532 ft 5917 ft	9-5/8" to 4255'
4A	1977	305	25	330	26 days	Colo Well	Inj	252°F	--	--	2840 ft	13-3/8"to 1820'
4B	1978	830[1]	30	885[1]	45 days	Colo Well	Prod	288°F	282°F	30 to 100[4]	5427 ft[2] 5115 ft	9-5/8" to 3457'
5	1978	1140	60	1200	88 days	Colo Well	Prod	276°F	265°F	400 to 600[4]	4925 ft	
6	1978	325	35	360	25 days	Colo Well	Inj	160"F	--	--	3888 ft	13-3/8" to 1698'
7	1978	275	35	310	21 days	Colo Well	Inj	172°F	--	--	3858 ft	13-3/8" to 2044'

1 - Includes cost of 4A.

2 - Multilegged wells.

3 - Estimated.

4 - Very preliminary data.

5 - Nationwide well costs have escalated 25 to 40% per year.

11-30-78
LGM

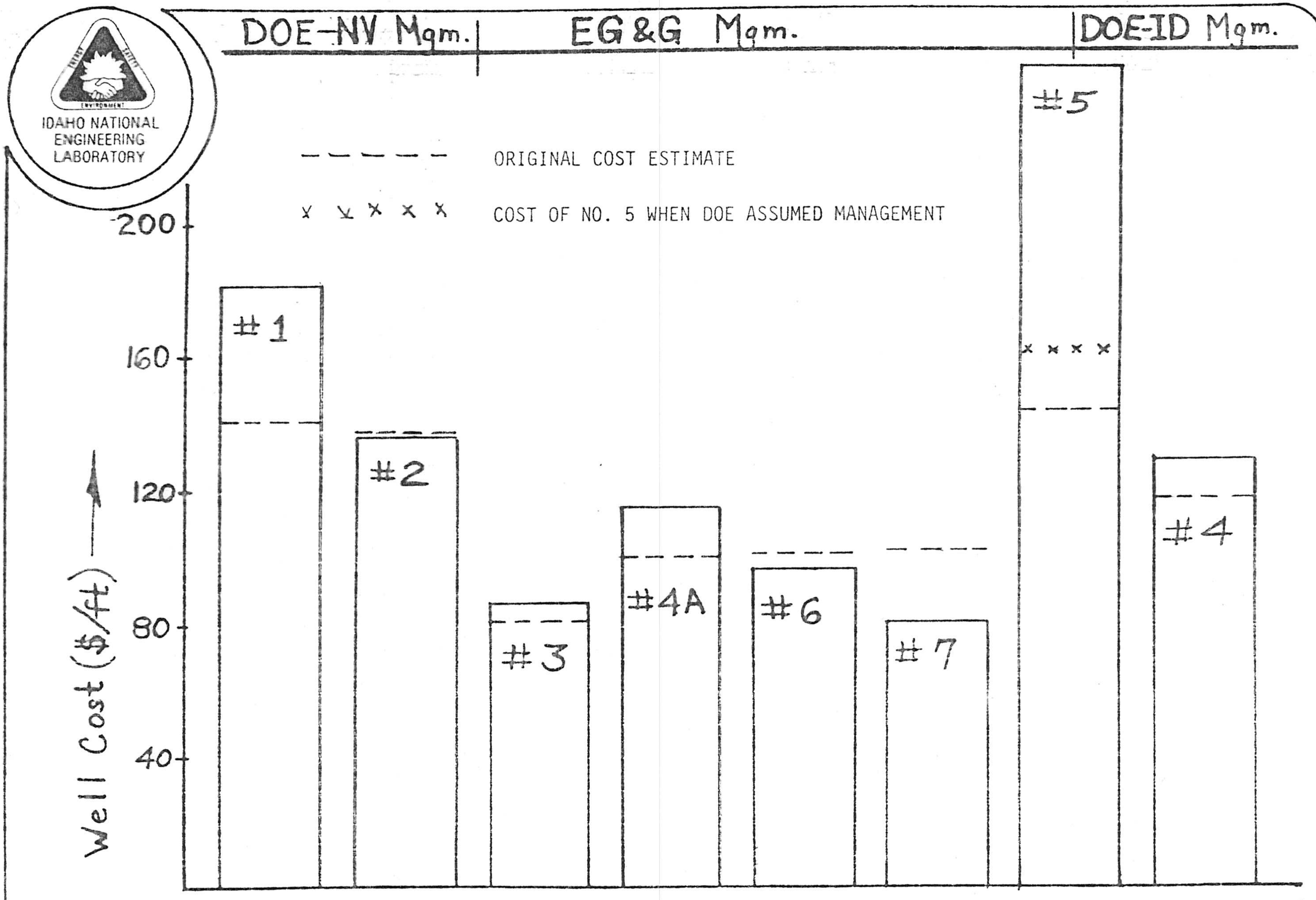

Figure 1. Raft River Well Cost

EG&G Idaho, Inc.

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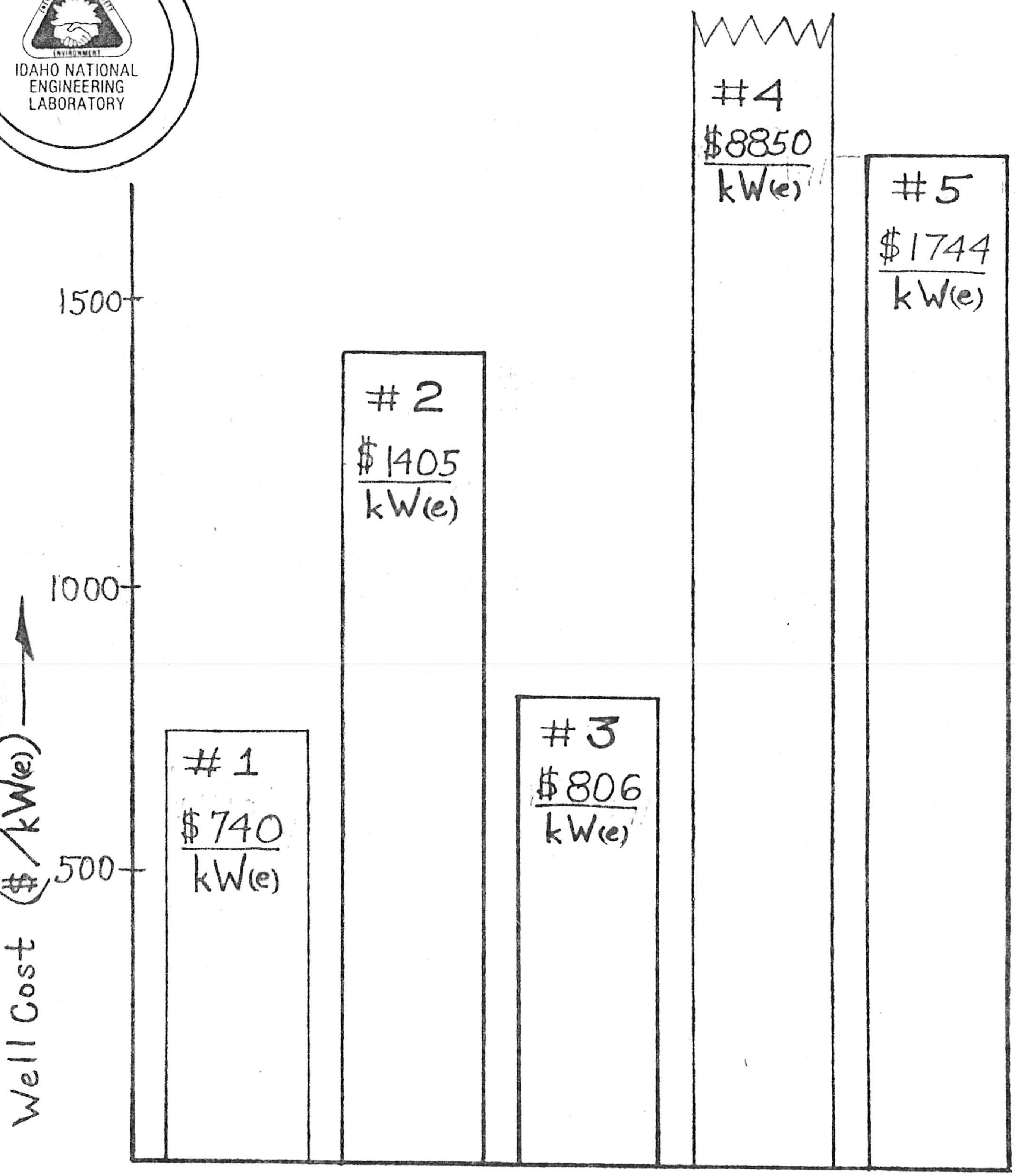

Figure 2. Raft River Well Cost.

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EG&G Idaho, Inc.