EG&G Idaho

FORM EG&G-954
(Rev. 9-76)

INTEROFFICE CORRESPONDENCE

date September 15, 1976

to J. F. Kunze
Office

from R. C. Stoker

subject RESERVOIR ENGINEERING SEMINAR SUMMARY - RCSt-25-76

A Raft River reservoir engineering seminar was held on May 21, 1976 at the Salt Lake City Airport Hawk's Nest Room. Those in attendance were as follows:

Steve Oriele, USGS, Denver
Harry Covington, USGS, Denver
Frank Trainer, USGS, Menlo Park
Manual Nathenson, USGS, Menlo Park
Dave Nichols, USGS, Sacramento
Jerry Crosthwaite, USGS, Boise
Ken Dunn, Idaho Dept. of Water Resources
Dale Ralston, Idaho Bureau of Mines and Geology
Roy Mink, Idaho Bureau of Mines and Geology
John Griffith, ERDA-Idaho
Jim Cotter, ERDA-Nevada
Gary Sandquist, University of Utah
Steve Swanson, University of Utah
Paul Witherspoon, LBL (Berkeley)
T. N. Narisimhan, LBL (Berkeley)
John Auten, REECo
Fred Huckabee, REECo
Arfon Jones, Terra Tek
Jay Kunze, INEL
Lowell Miller, INEL
Dennis Goldman, INEL
Bill Kettenacker, INEL
Jim Lofthouse, INEL
Susan Prestwich, INEL
Roger Stoker, INEL

Current work status and available data were presented by various people connected with the project and are summarized below. Open discussions were held in conjunction with the presentations and the resultant recommendations or observations concerning further work at Raft River are included under B. Summary and Future Plans on page 7.

A. Presentations

1. Well Status and Future Plans - Kunze

A short summary of the project and the experience acquired in drilling the three production wells was presented and discussed. Site locations were pointed out (Attachment 1) and a temperture profile of RRGE-2 (Attachment 2) was discussed in detail. This particular profile was taken after approximately eight million gallons of cool water had been pumped down the well and exhibits the temperature recovery after limited flow from the well.

The configuration and relationship of the three legs drilled in RRGE-3 were displayed (Attachment 3) and the temperature logs (Attachment 4) taken before production casing was installed were discussed. The flow tests and electric logs conducted prior to setting casing were shown to confirm the casing setting depth of 4,237 feet. Temperature logs (Attachment 5) and profiles (Attachment 6) from the leg "A" were presented and discussed. The poor flow ($\sim$ 80 gpm) and geysering action from RRGE-3A were pointed out. The geysering action operated on a 9 1/2 minute cycle; 3 1/2 minutes of flow at $\sim$ 220 gpm and 6 minutes of no flow. A summary of drilling and testing RRGE-3 A and B is shown in Attachment 7.

NOTE: After all three legs were completed in RRGE-3, flow rates of 800 gpm (cold) and a bottom hole temperature of 298°F were recorded.

The chemical water analysis of all three wells was presented (Attachment 8) and the near term testing plan (Attachment 9) was reviewed.

2. Production and Reinjection Performance Data - Miller

A summary of well production and reinjection characteristics were presented. This included the early time cool water high production rates followed by lower hot water flow rates characterized by choking due to flashing steam within the wellbore. It also included more detailed information about RRGE-2 temperature recovery following the injection of cold water (eight million gallons). See Attachment 2.

The transfer line between RRGE-1 and -2 was discussed and the one proposed between RRGE-1 and -3 was outlined (Attachment 10). The favorable experience gained from the downhole pump employed at Raft River was discussed. The relatively minor modification to the lower pump motor seal should solve the problem of water leakage that was experienced in the lower motor. The total pump assembly was satisfactory except for the water leakage and there was no evidence of corrosion or erosion. The pump operated for about two weeks running time and delivered flows up to 1800 gpm from RRGE-1.

3. Lithology, Cover and Permeability Data - Stoker

The structural controls around all three wells were explained, through cross sections, as determined from USGS data (Attachment 11, 12, and 13).

The lithology of all three wells (Attachment 14) was presented and discussed in detail. Actual core samples were examined and the presence of extensive fracturing was noted to be associated with the production zones. Specific core permeabilities were presented from each of the three wells. These permeabilities were measured under "in situ" simulated conditions by Terr Tek and represent values as much as 10 to 100 times lower than if measured under atmospheric conditions. See Attachment 15.

It was reiterated that the RRGE-3 (leg "A" hole) was a very poor producer (80 gpm free flow and geysering) drilled through limited fracture zones. Leg "B" was drilled through more permeable fracture zones and production increased to 250 gpm. Leg "C" encountered extensive fracturing and a total cold flow rate of 800 gpm. In all three wells, the production zones have been located in the highly permeable fracture zones.

The gneisic fabric of the quartz monzonite in the upper portion indicates that the rock underwent a crushing action probably due to differential flow during emplacement (protoclastic). The alteration of the biotite and plagioclase indicates a high degree of late stage hydrothermal activities.

The phyllitic schist of the metamorphased zone occurring directly above the quartz monzonite is indicative of regional (widespread) metamorphism (rock recrystallization). The parent rock was obviously an argillaceous (clay) sediment. The metamorphism is probably not a result of the quartz monzonite emplacement but rather a widespread regional feature that occurred after the quartz monzonite emplacement.

4. Down-Hole Pressure Response and Interpretation - Witherspoon

The testing and monitoring procedure employed during the interference testing of RRGE-1 and RRGE-2 was reviewed and explained. A series of three drawdown tests were conducted in RRGE-1 and RRGE-2 during September and October, 1975 and shown in Attachment 16.

The acquired data was presented as follows:

a. Computation of reservoir characteristics for RRGE-2, Attachment 17.
b. Pressure response at RRGE-2, Attachment 18.
c. Computation of reservoir characteristics between RRGE-1 and RRGE-2, Attachment 19.
d. Lunar attraction effects in Raft River reservoir, Attachment 20.
e. Pressure response at RRGE-1, Attachment 21.

The interpretation of the interference testing was summarized as follows:

a. The Raft River reservoir is apparently very large.
b. The reservoir shows boundaries that must be located and defined through further testing.
c. The reservoir shows high permeability and Kh factors. Compared Raft River (Kh = 228,000 md ft) with East Mesa reservoir (Kh = 30,000 md ft, at best).
d. Further extensive reservoir testing should be accomplished involving additional wells for more detailed, precise and extensive

information based on better data.

e. The reservoir appears to be adequate to support a 10 MW power plant or greater based on this limited data.

Similar interference tests were conducted in the East Mesa area of California involving three wells rather than just the two wells as in Raft River. The test results show a superior performance by the Raft River reservoir although the data is more limited and not as precise.

5. USGS Summaries

a. Raft River Groundwater - Nichols

The model depicting the groundwater situation in Raft River was review and explained. Two cases were presented based on two different values of transmissivity. The first case (high transmissivity) requires an average annual net recharge and discharge of about 61,500 acre-feet. A vailable data states two different total available recharge rates; 42,130 acre-feet estimated by Walker and others (1960) and 74,930 acre-feet of Nace and others (1961). The net flux is given as a solution with this model not the total recharge and discharge. However, the total recharge and discharge will be greater than the net flux.

The computer model had 350 grid points for finite differential modeling, on a one mile spacing grid. It has predicted a maximum decline of 82 feet in the water table over a five year period if pumped at an additional rate of 19,000 gpm. This assumes a consumptive use of the water with no recharge or reuse as a means of providing once through cooling for a 10 MW plant. Although non-recharge of cooling water is not contemplated, the information provides base line predictive data.

From available data, it was determined that the water table has declined as much as 20 feet from 1952 to 1965 due to irrigation water consumption.

b. Raft River Valley Temperature Profiles - Nathenson

Several wells and holes have been monitored for temperature profiles by Urban and Diment of the USGS, Sacramento. This data was reviewed and is shown in Attachments 22 through 32.

Indications are that, for the shallow depths, the temperature profiles increase with depth toward the Narrows (southwest portion of the valley). I.D. No. 4 and 5 both display a temperature reversal within the first 200 feet of depth.

c. Near-Surface Aquifer Measurements and Analysis - Crosthwaite

The new-surface aquifer investigations being conducted were reviewed. D/O^{18} is being pursued as a means of determining the Raft River recharge and the Goose Creek as the discharge areas.

d. Raft River Lithology - Covington

In general, the area consists of gravels down to about 2,000 feet. The fault zone was encountered at 4,050 feet and caprock (siltstone) at 4,500 feet in RRGE-1. The rock types were all encountered 50 to 200 feet deeper in RRGE-2 than RRGE-1. There is good correlation between the two wells.

6. Permeability Measurements - Jones

The core samples from RRGE-1 and -2 have been measured for permeabilities under "in situ" conditions (temperature and pressure). These results are a factor of 10 or more less than the results obtained under atmospheric conditions. Generally, the results obtained from the production zones of the wells have been above average. Moreover, the rocks exhibit high permeability values when fractures are included in the test sections.

7. Groundwater Measurement - Ralston

Data was presented which reflects on the groundwater system in Raft River. Transmissivity (T) factors are on the order of 100,000 - 200,000 gpd/ft. The storage coefficient (S) is about 0.001 and the leakage coefficient is 0.4 to 0.5. These factors apply to the valley proper while the area above the Narrows is a little lower in transmissivity values but about the same for storage and leakage coefficients.

8. INEL Raft River Reseroivr Computer Code - Kettenacker

This presentation was deferred due to time limitations and is presented here as Attachment 33 (Letter WCK-4-76).

B. Summary and Future Plans

Several consensus recommendations concerning future planning were made by the seminar participants and are summarized below:

1. Flow RRGE-3 for long period (∿ 30 days); monitor RRGE-1 amd -2 with the quartz crystal surface pressure instruments and RRGE-3 with the downhole pressure probe.

2. Repeat the three well test as above but flow RRGE-2.

3. Repeat the three well test as in 1. above but flow RRGE-1.

4. Conduct reinjection tests and monitor with the quartz crystal probe and surface instrumentation.

5. No reinjection well should be drilled at this time by REECo. REECo should demobilize and move out as soon as possible considering current budget restraints.

6. All three holes should be tested thoroughly and all plausible tests should be pursued for research reasons and to define the reservoir characteristics and boundaries.

7. The reservoir appears to be limited by fracturing and faulting. That is:

   a. Permeability is reduced away from the fractured zones.
   b. There are localized zones, even around known faults, that lack the fracturing to transmit the existing geothermal fluids into the wellbore. This fact is exemplified by the lack of production in RRGE-3A.
   c. Near verical fracturing occurs in the area and appears to be associated with the major faulting. This fracturing is responsible for good production rates where it has been penetrated.

8. Development of the geothermal resource should be pursued as rapidly as possible.

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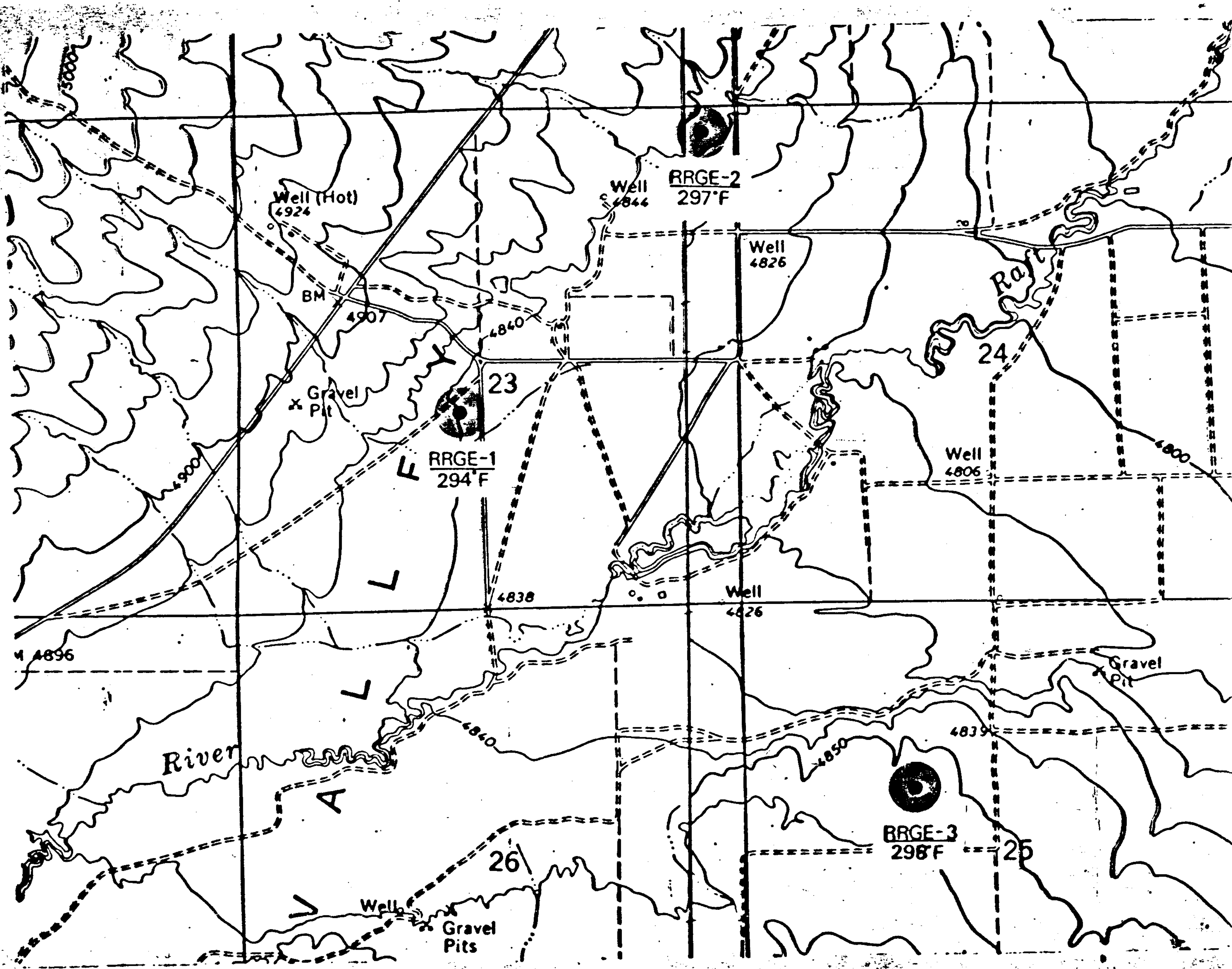
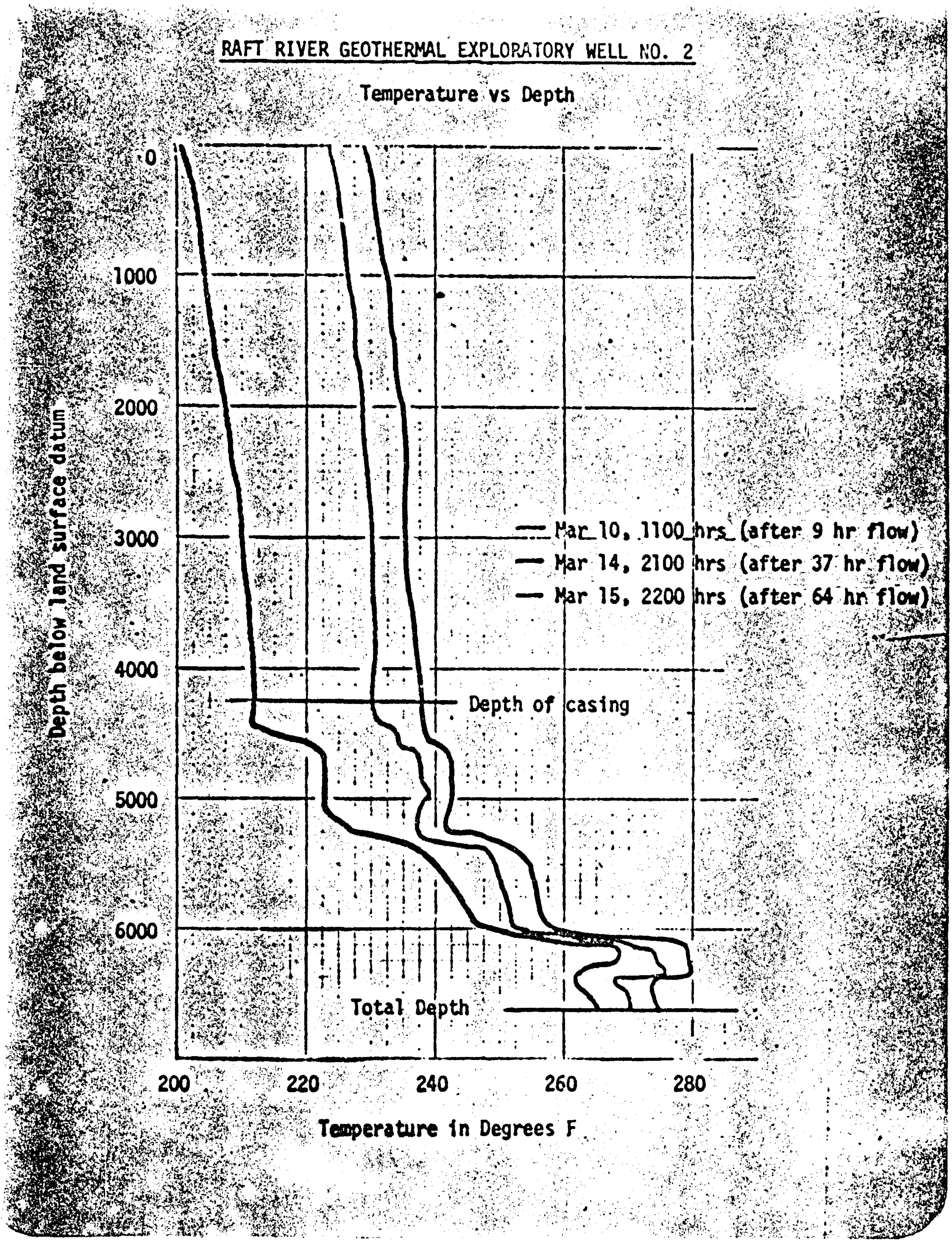
cc: SDGilliard
DGoldman
WWHickman
WCKettenacker
~~JH~~Lofthouse
LGMiller
SJPrestwich



MAXIMUM DOWNHOLE TEMPERATURES OF WELLS

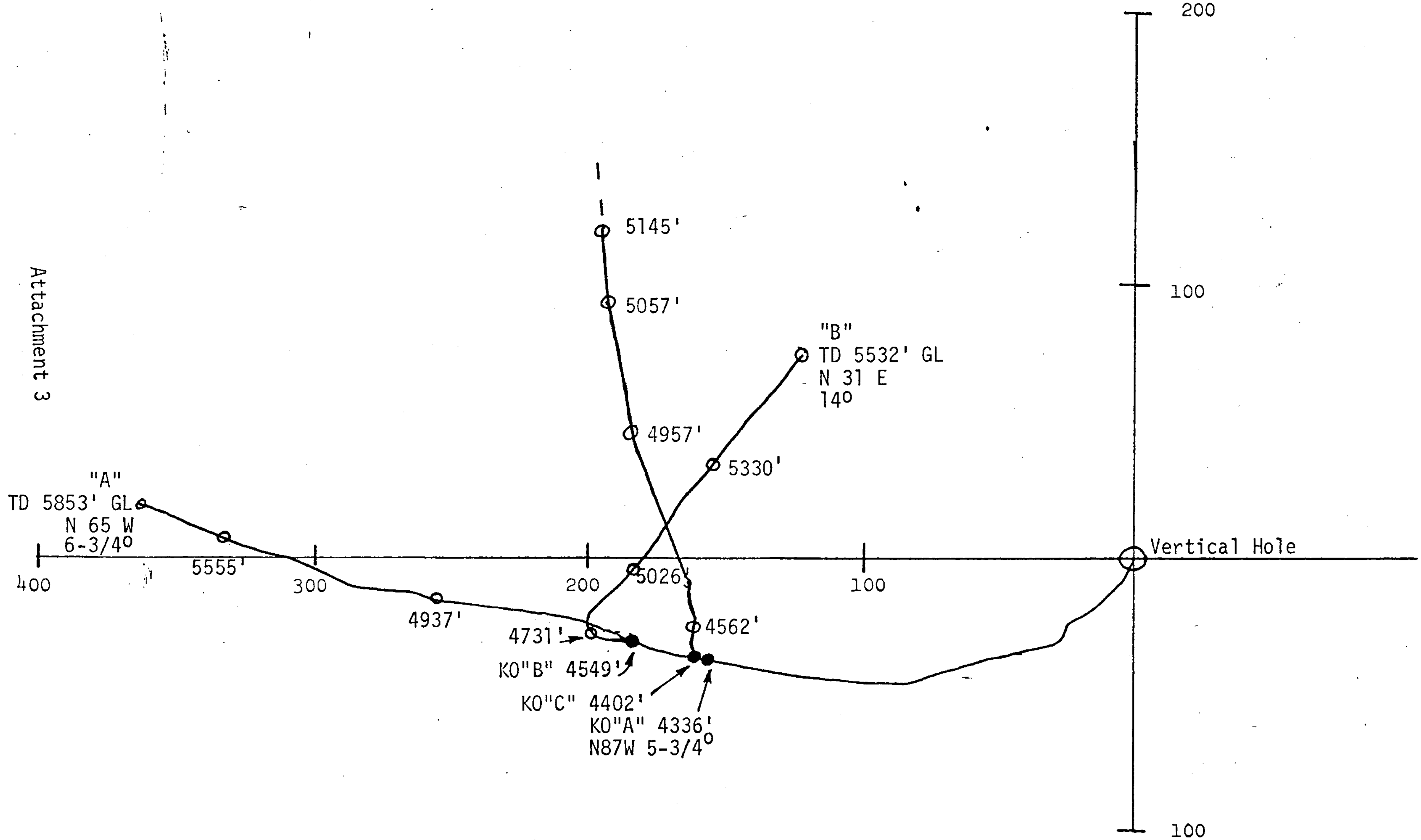
Attachment 1



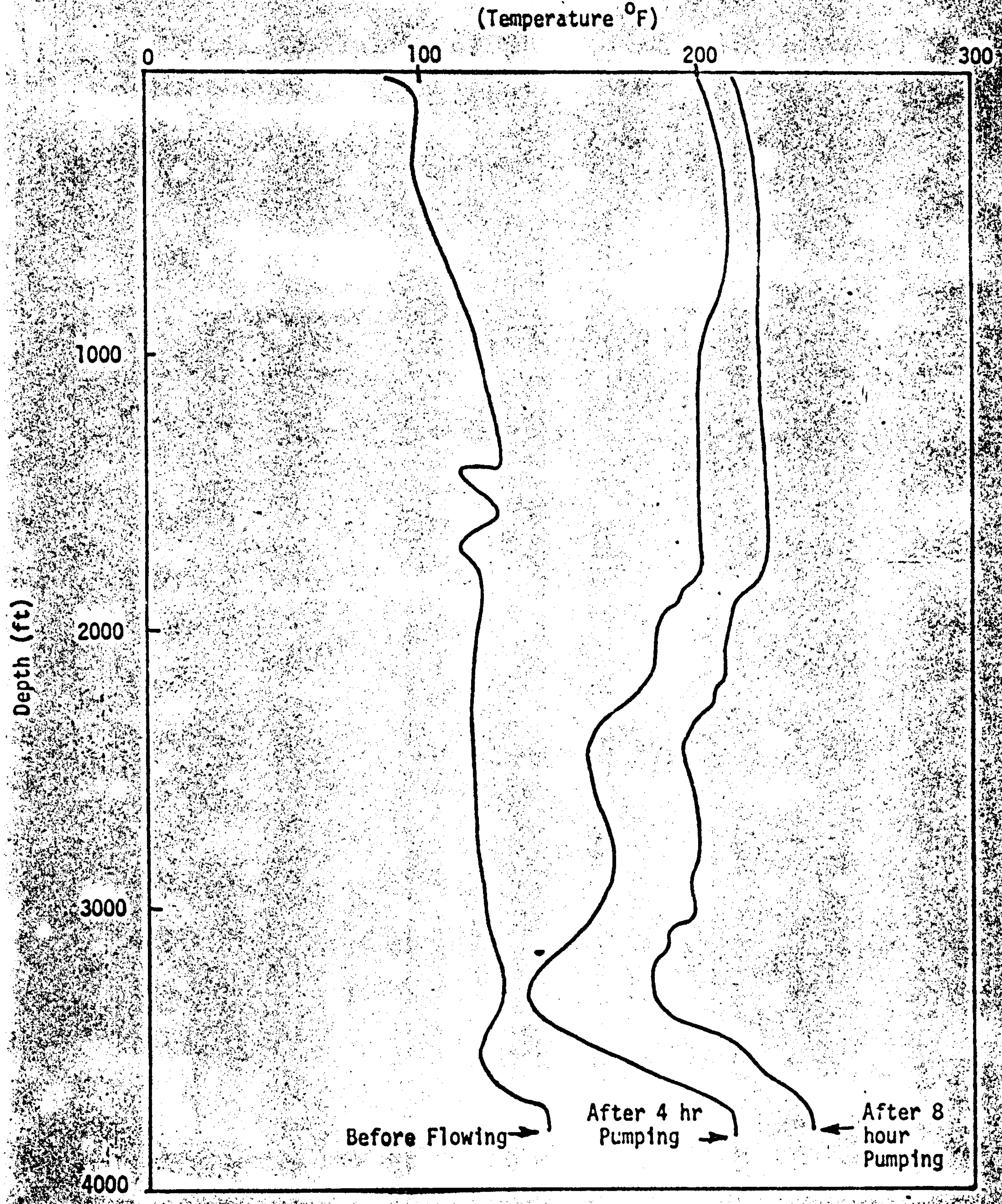
Attachment 2

Attachment 3

RRGE-3



RRGE-3 Temperature Logs Before Casing



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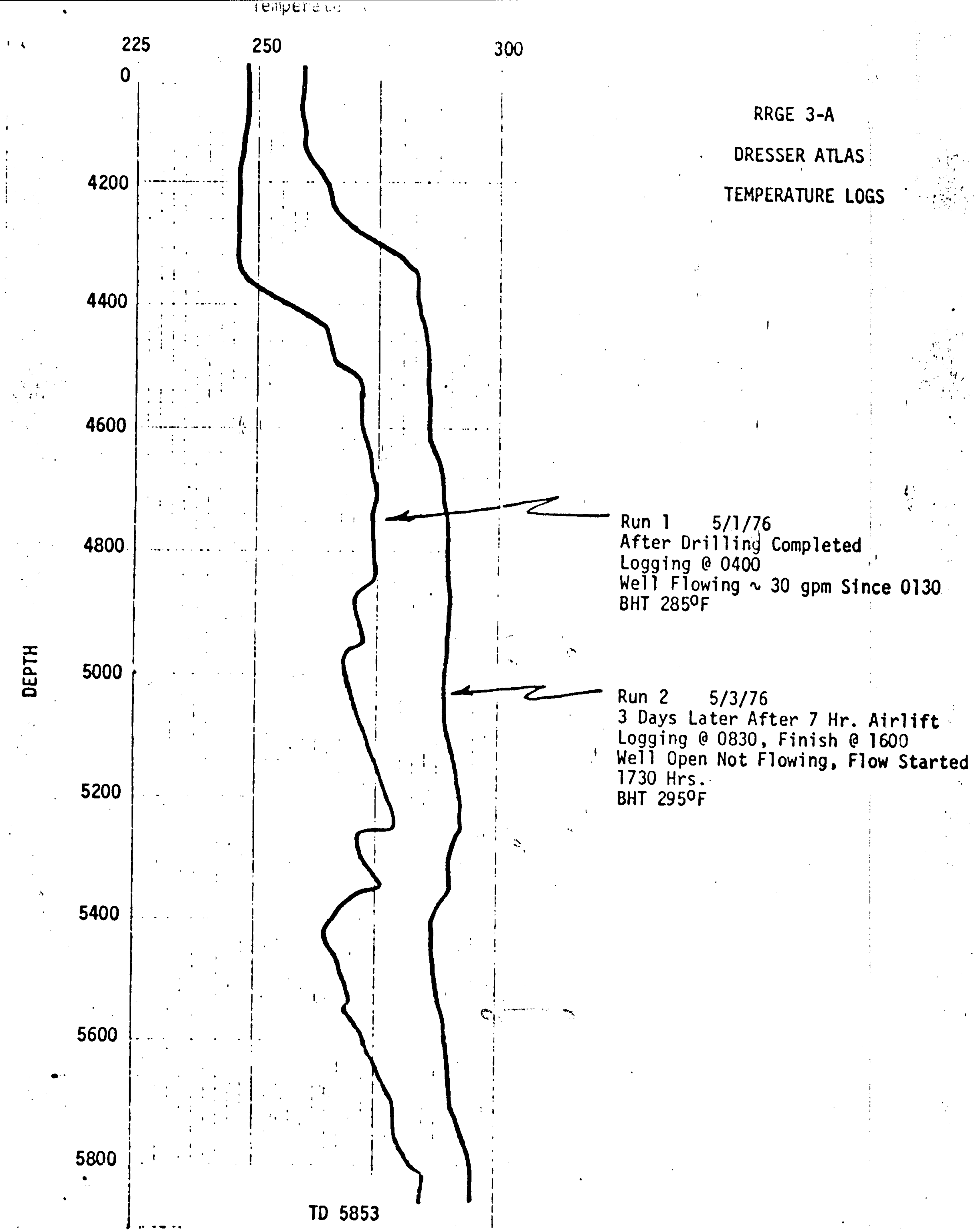

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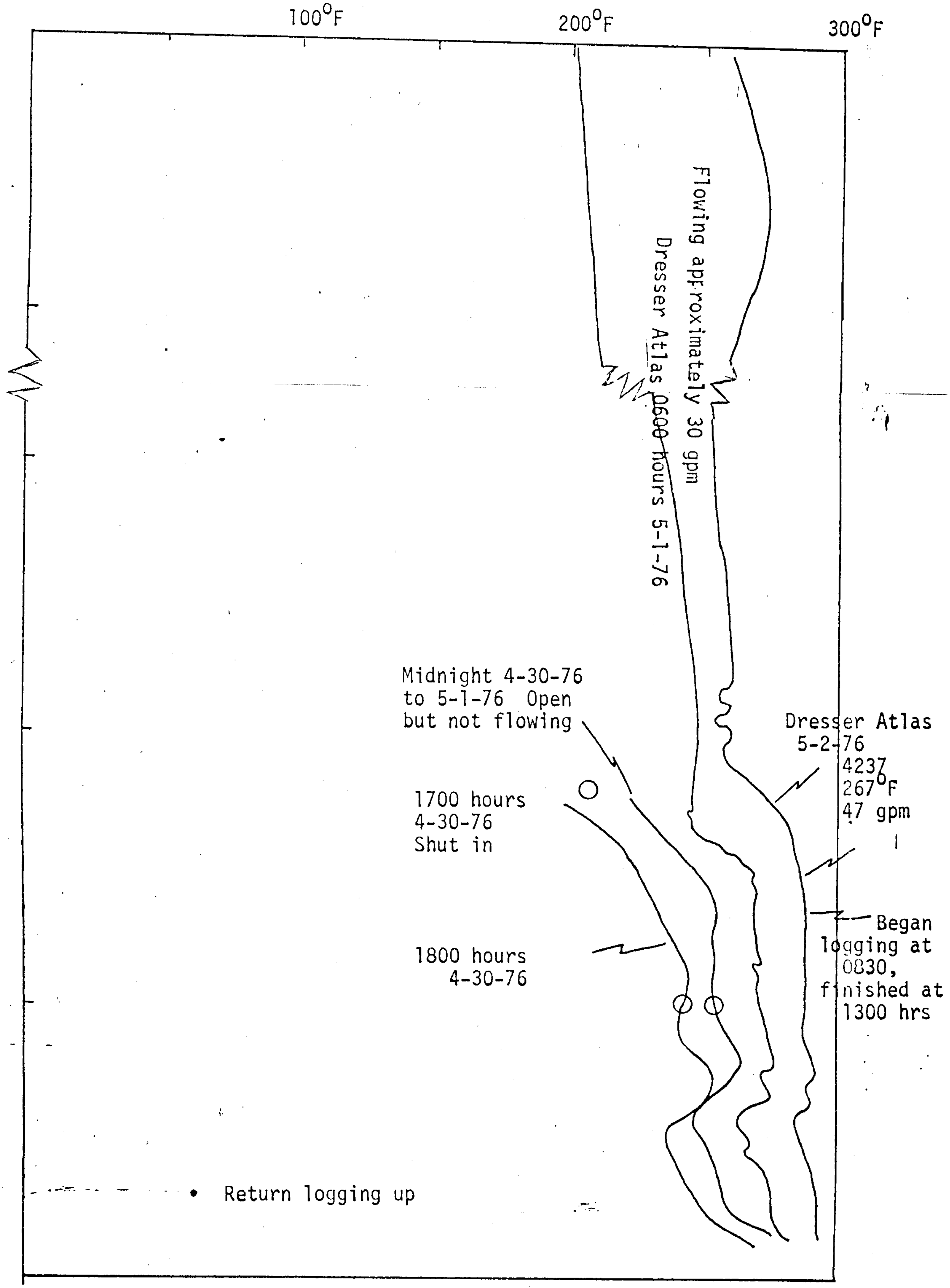


RRGE-3A - April 30 - May 1, 1976
Attachment 6

RRGE-3

SUMMARY OF DRILLING AND TESTING

SPUDDED IN ON MARCH 28

SURFACE CASING CEMENTED TO 1383 FT ON APRIL 1

DEPTH OF 4241 FT REACHED ON APRIL 16

3 DAYS OF FLOW TESTING AND LOGGING

CASING CEMENTING JOB COMPLETED, SECOND STAGE WORKING FROM TOP, ON APRIL 21

FIRST LEG COMPLETED TO 5853 FT DEPTH ON APRIL 30 IN WESTERLY DIRECTION
OFFSET 363 FT FROM WELLHEAD, WEST, 2° NORTH
OFFSET 212 FT FROM KICKOFF POINT AT 4318 FT

BEGAN DYNADRILLING SECOND LEG KICKOFF AT 4531 FT ON MAY 7

BOTTOM HOLE (5853 FT) TEMPERATURE ON MAY 3, 295°F

TEMPERATURE AT 4550 FT ON MAY 3 AND MAY 6, 286°F

TEMPERATURE AT 2000 FT ON MAY 6, 240°F

AS A RE-INJECTION HOLE, 1200 GPM REQUIRED 480 PSIG AT THE WELLHEAD (HOT WATER VISCOSITY)

AFTER DRILLING SECOND LEG TO 5530 FT IN NORTHEASTERLY DIRECTION

WELL HEAD PRESSURE COLD: 30 SPI

FLOW, WHEN COLD: APPROXIMATELY 250 GPM

Attachment 8

TABLE I

Well #	Depth (ft.)	Sample Temperature (°C)	Pressure (psi)	SiO_2 (ppm)	Na (ppm)	K (ppm)	Ca (ppm)	Cl^- (ppm)	†HCO_3^-	Geochemical Thermometers (°C)	
										SiO_2	Na-K-Ca
3	3313	73	8	58	805	23	116	1480	---	107	132
3	3806	106	25	90	1790	43	280	3310	40.6	130	129
3	3986	112	8	92	1940	45	293	4210	32.5	131	131
3	4214	99	23	99	1940	46	283	3540	32.5	129	131
3	5700	60	0	56	430	21	75	770	47	66	113
2*	--	108	30	150	484	40	49	829	29	160	182
1*	--	137	150	126	523	37	52	850	45	149	175
Crank	--	--	--	111	1065	35	135	--	--	142	142
BLM	--	--	--	107	550	19	55	1139	83	140	140
Irrigation water for	--	--	--	45	--	--	--	--	--	96	--

* Data from most recent sampling was used.

† As µg/ml $CaCO_3$.

NEAR TERM TESTING PLAN

JUNE 1 - 15

FLOW TEST NO. 3, WITH DOWNHOLE INSTRUMENTATION IN NO. 1 AND NO. 2, EACH OF THOSE SHUT-IN

JUNE 15 - JULY 8

FLOW TEST NO. 2 AND DISPOSE OF WATER IN AREA

JUNE 15 - DURATION

FLOW NO. 1 FOR ENGINEERING TESTING

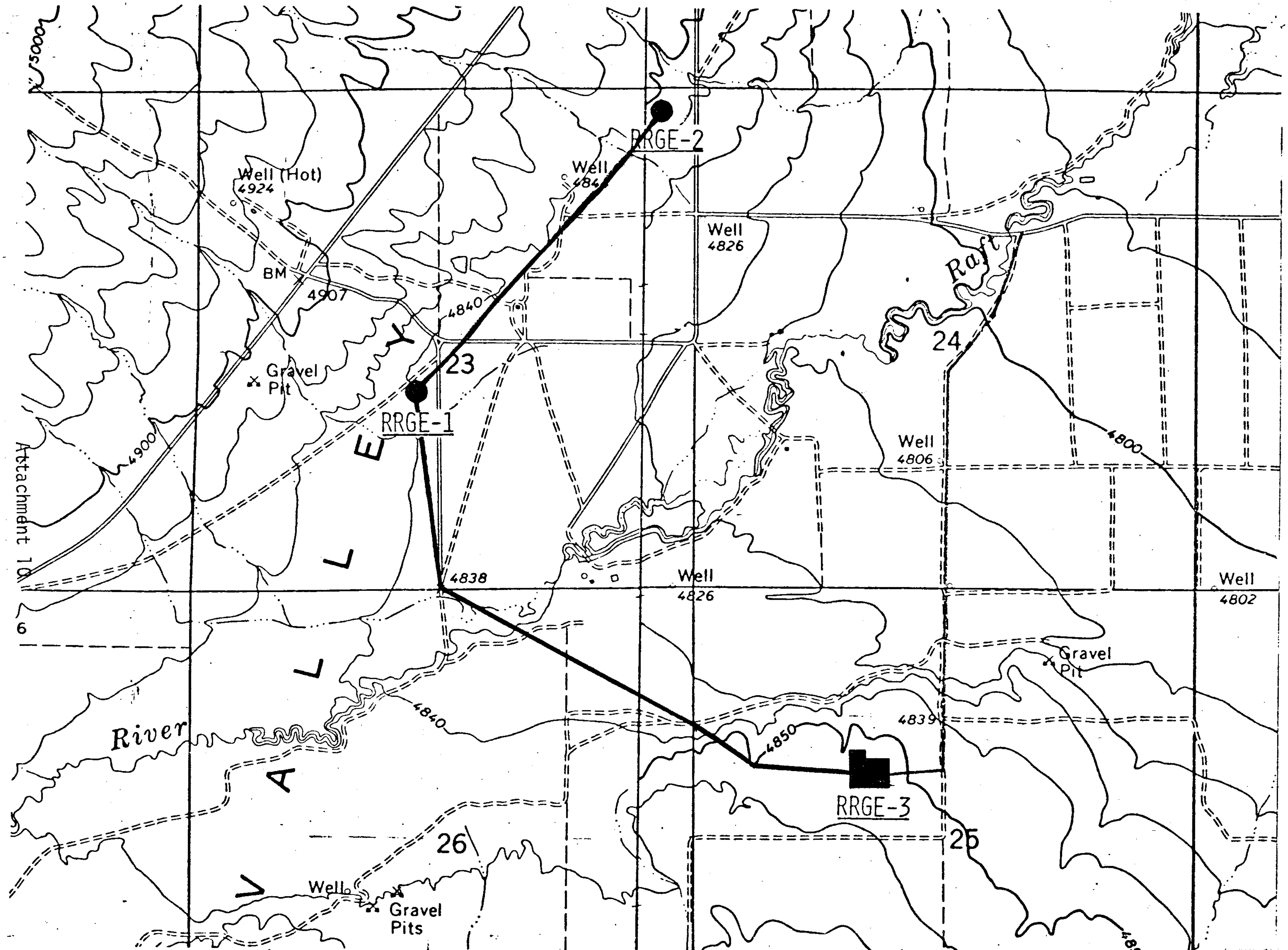
JUNE 20 - (IF POSSIBLE OR THEREABOUTS)

DOWNHOLE PUMP INSTALLATION IN NO. 3

JULY 6

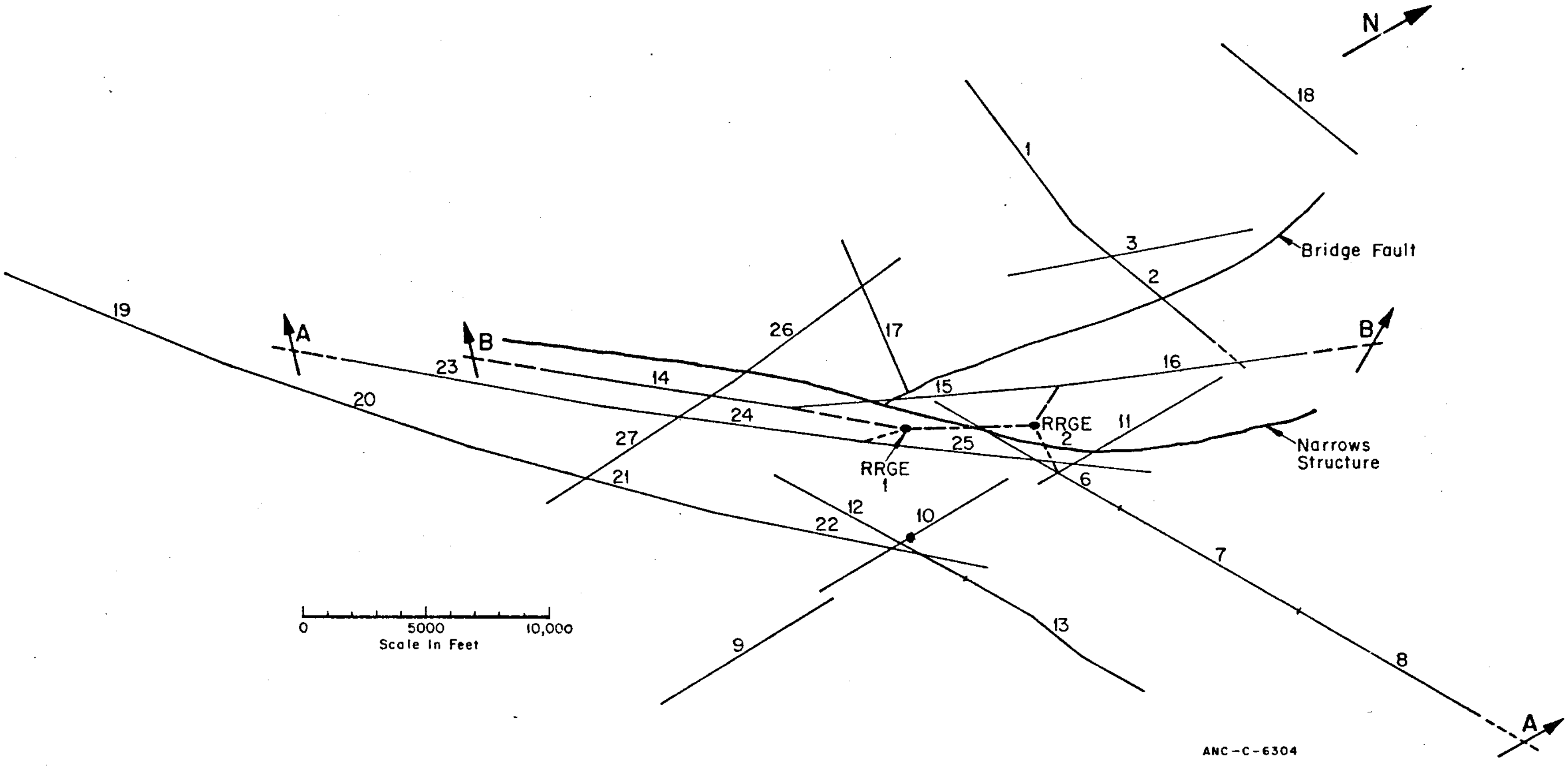
BEGIN REMOVING DRILL RIG IF NO FUNDS FOR REINJECTION HOLE

JFK:5-21-76



Attachment 10

Attachment 11



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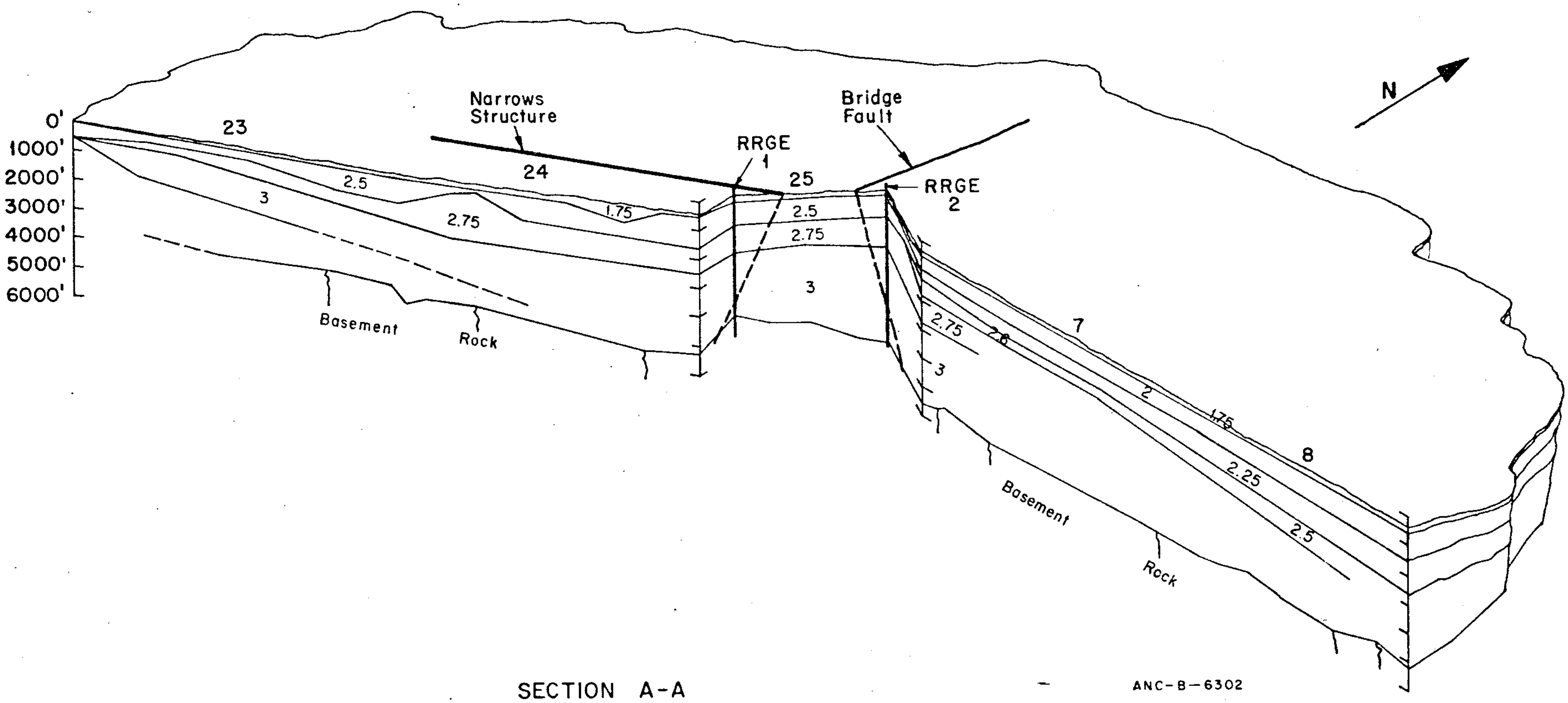
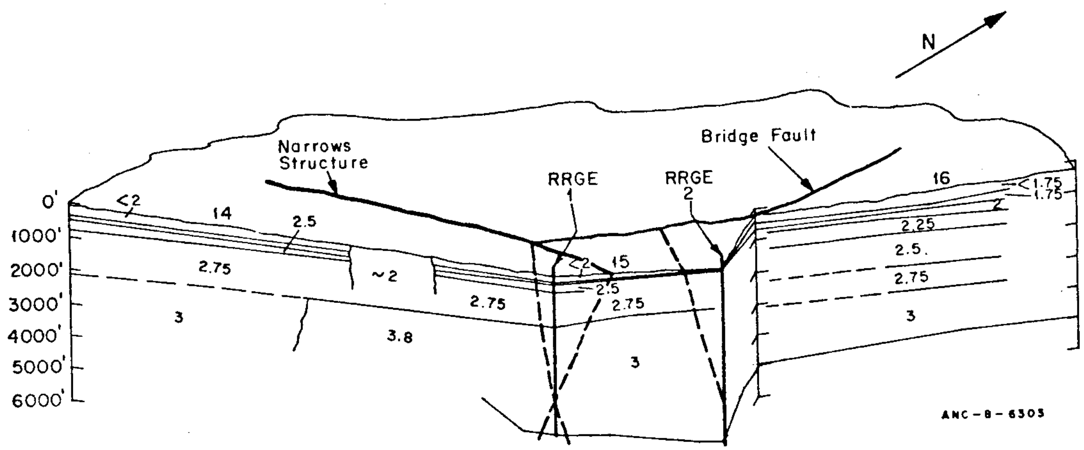


SECTION A-A

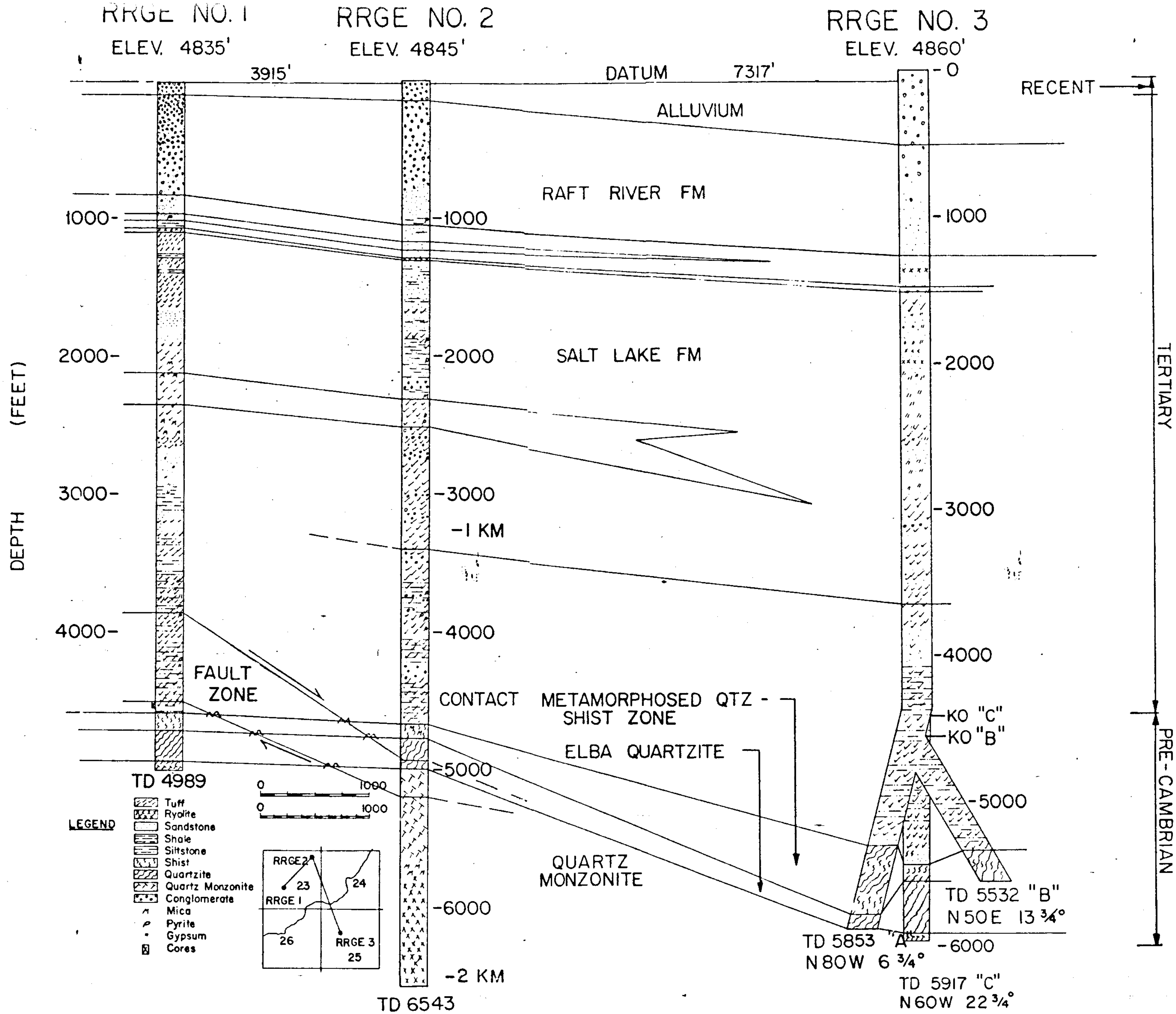
ANC-B-6302

Attachment 13



SECTION B-B

Attachment 14



RRGE WELL CORE PERMEABILITIES

Well	Depth, KB	Permeability (Millidarcies)	Rock Type
RRGE-1	4,227'	.003 - .04 (cap)	Siltstone
RRGE-1	4,506'	5.0	Tuffaceous Siltstone
RRGE-2	4,372'	0.0022 (cap)	Shale
RRGE-3	2,807'	.25	Sandstone
RRGE-3	3,365' lower	.04	Tuff
	3,365' upper	>35. (~100)	Tuff

Table I

Drawdown Tests

Test No.	Description	Duration Hours	Production Well No.	Production Flow Rate gpm	Pressure Gage in Well No.	Pressure Gage in Depth, feet	Maximum Pressure drop Well No.	Maximum Pressure drop Δp, psi
1	Short Term Test on RRGE #2	15	RRGE #2	210	RRGE #2	5200	RRGE #2	39
2	Long Term Test on RRGE #2	615-1/2	RRGE #2	400	RRGE #1	1000	RRGE #1	3.6
3	Short Term Test on RRGE #1	30	RRGE #1	26	RRGE #1	4700	RRGE #1	1.1

Attachment 16

TABLE II

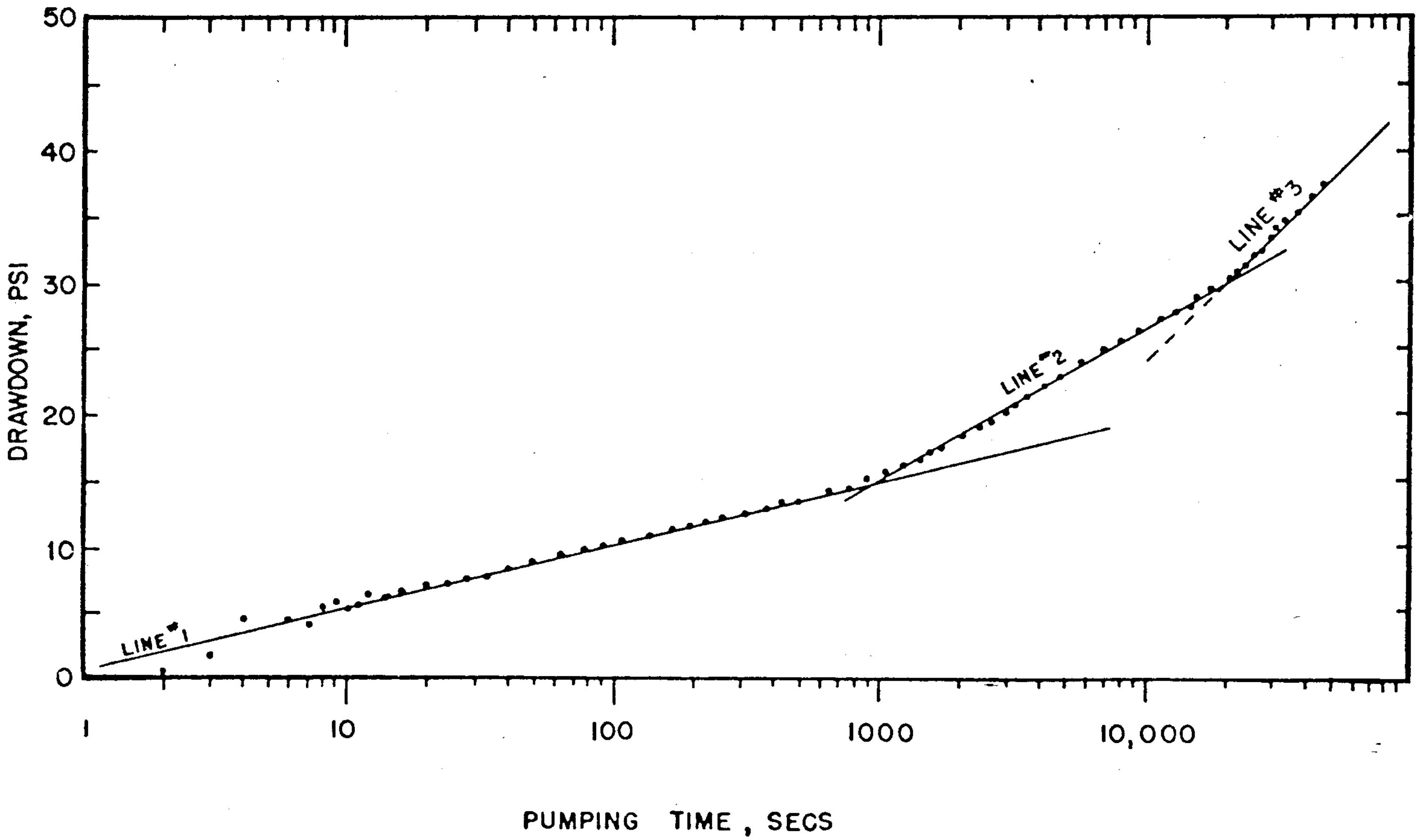
Characteristics of Reservoir as Deduced from Drawdown Measurements on RRGE-2 While Flowing RRGE-2

	Drawdown Data		Recovery Data
	Jacob's Method (Asymptote Solution)	Theis Method	Asymptote Solution
Transmissivity (gpd/ft^2 at 296°F)	4,667	4,696	4,718
kH md-feet	44,134	44,442	44,623
Storage Coefficient S	1.134×10^{-2}; r_w = 1 foot	1.09×10^{-2} r_w = 1 foot	-
ØCH (Porosity x Compressibility x Thickness)	2.82×10^{-2} ft/psi; r_w = 1 foot	2.71×10^{-2} ft/psi; r_w = 1 foot	-

Fig. 7

DRAWDOWN DATA FROM RAFT RIVER TEST AT RRGE NO 2

(9/12/75 TO 9/13/75)



Attachment 18

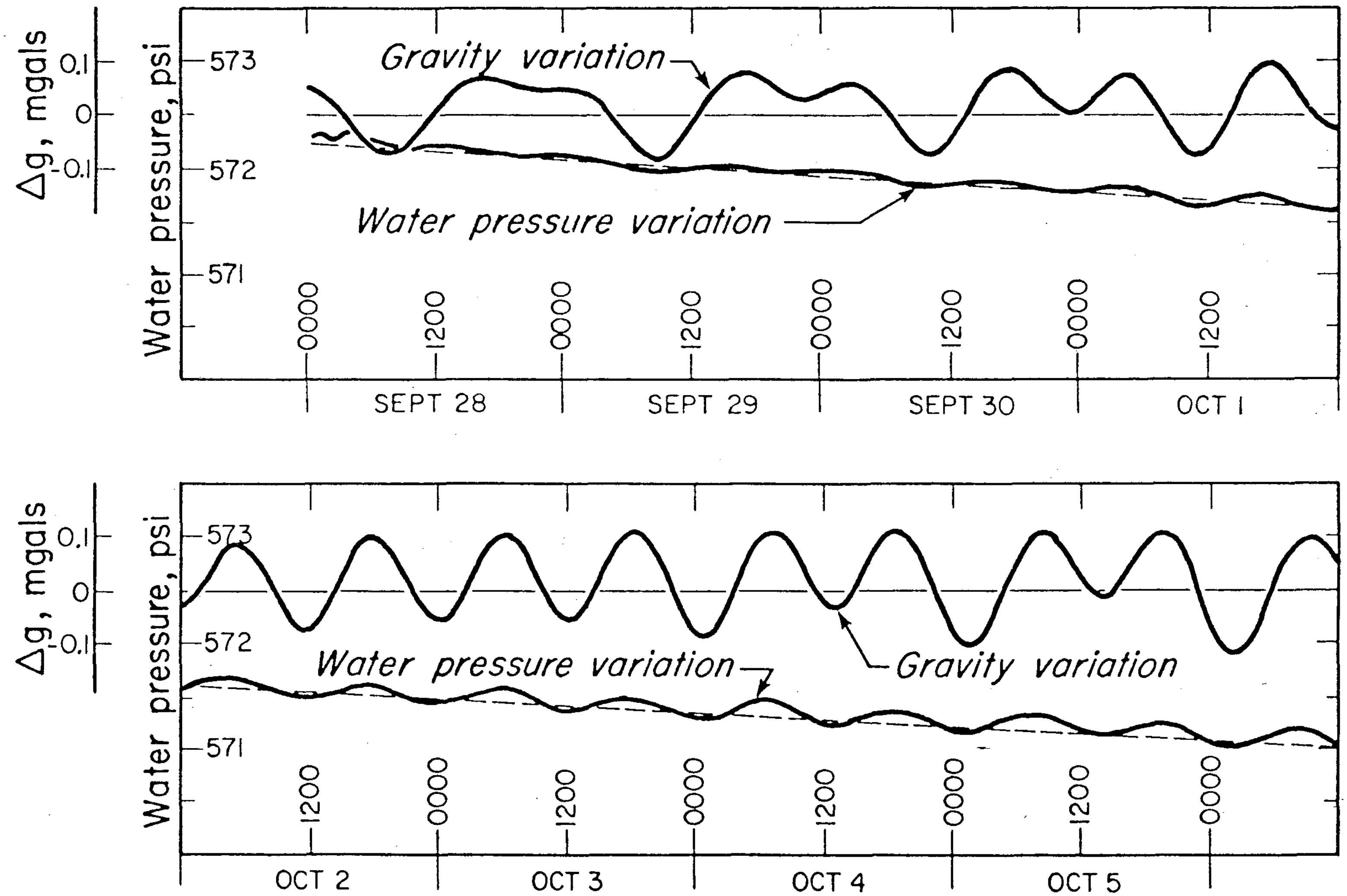
TABLE III

Results from Flowing RRGE-2 and Measuring Pressure in RRGE-1

	Preliminary Test Sept. 14 to Sept. 17, 1975		Long Duration Test Sept. 20 to Oct. 16, 1975	
	Theis Curve Matching Procedure	Asymptotic Solu. (Jacob's Method)	Theis Curve Matching Procedure	Asymptotic Solu. (Jacob's Method)
kH, md feet	2.25×10^5	2.22×10^5	2.28×10^5	2.28×10^5
ØCH, ft/psi (Porosity x Compressibility x Thickness)	5.74×10^{-4}	5.39×10^{-4}	1.19×10^{-3}	9.38×10^{-4}
Transmissibility gpd/ft at 296°F	2.37×10^4	2.34×10^4	2.41×10^4	2.37×10^4
Storage Coefficient S	2.31×10^{-4}	2.16×10^{-4}	4.78×10^{-4}	3.77×10^{-4}

Fig. 8

EFFECT OF LUNAR ATTRACTION ON WATER PRESSURE IN GEOTHERMAL RESERVOIR, RAFT RIVER VALLEY, IDAHO



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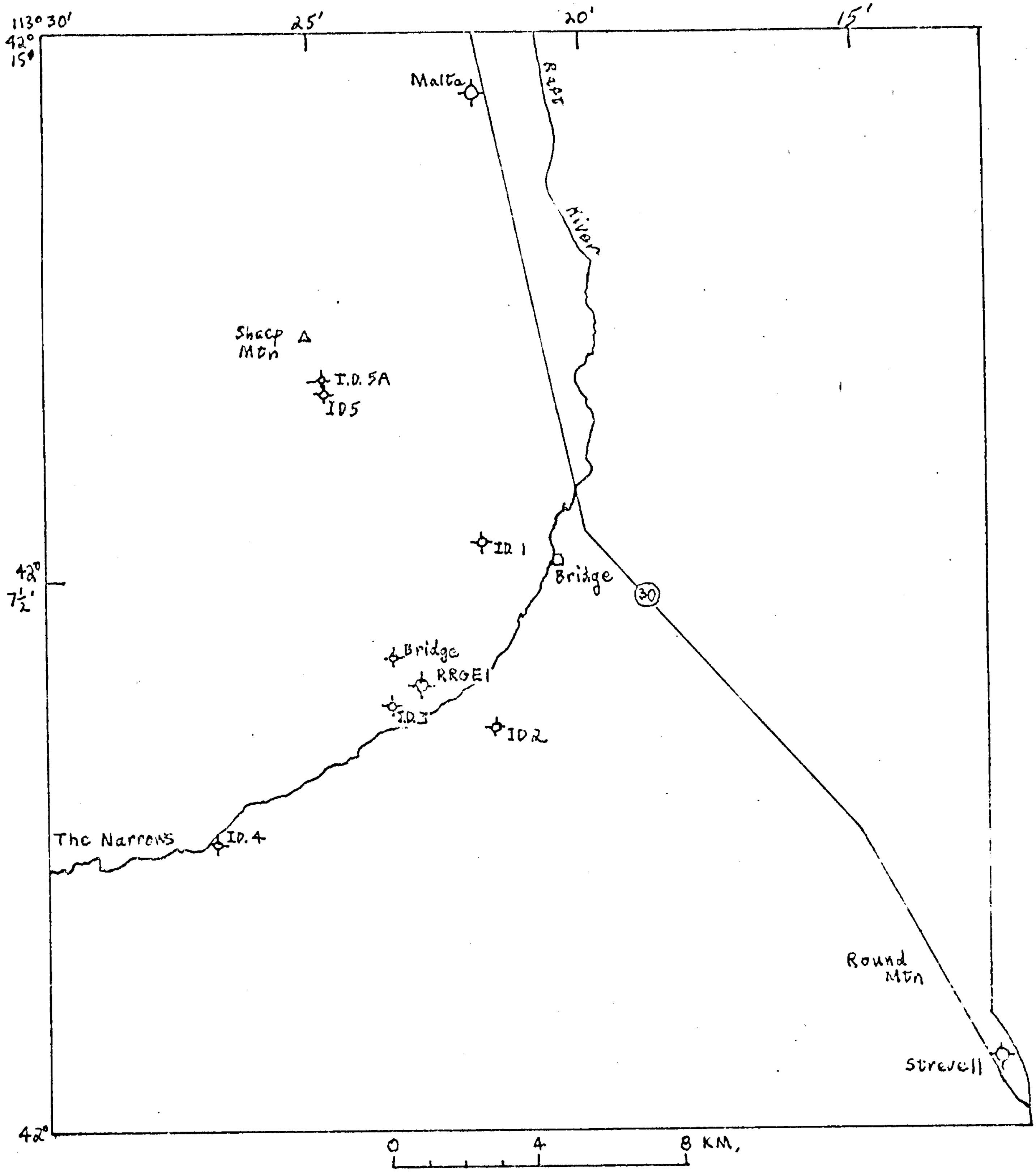
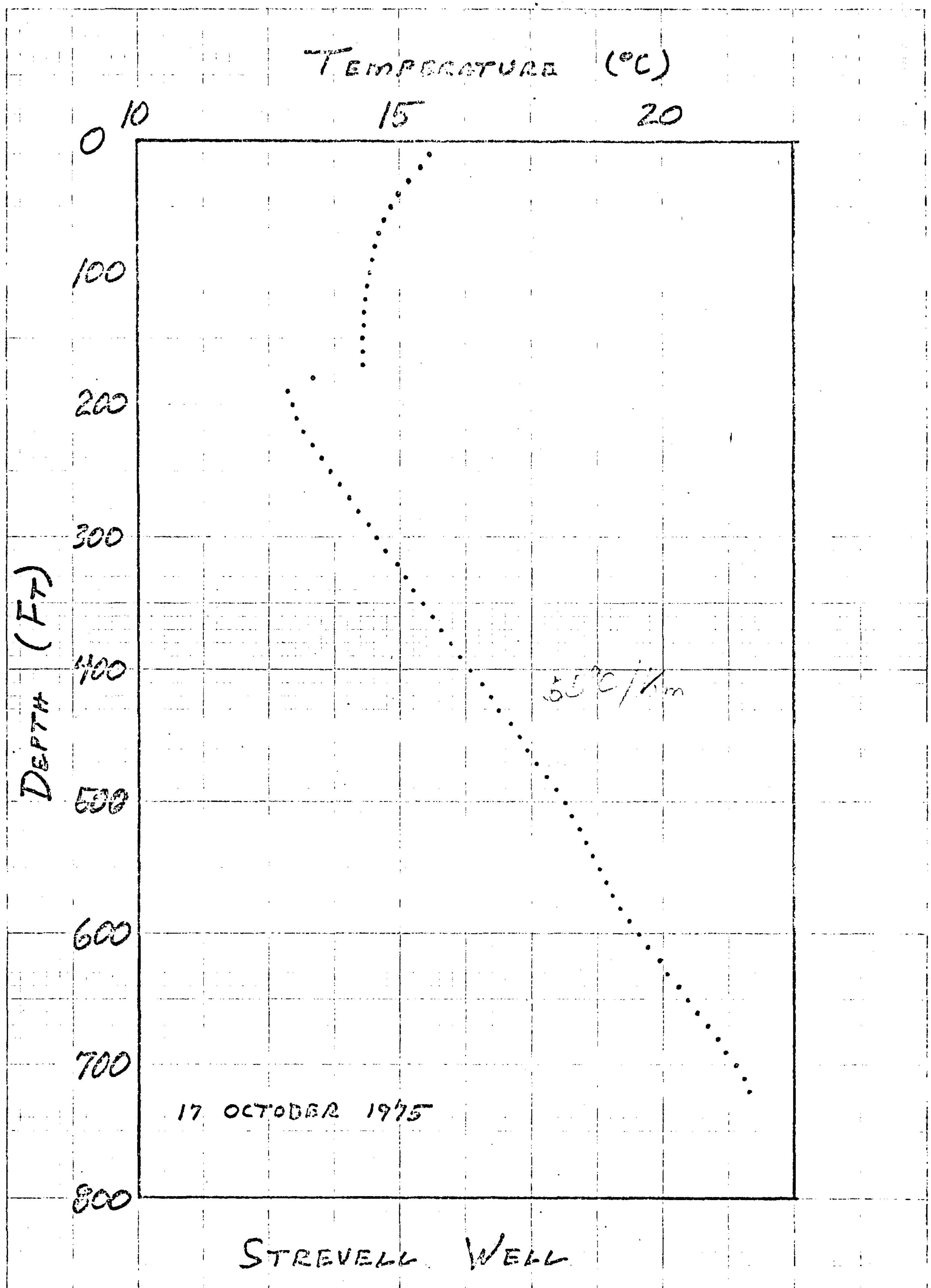


Southern Raft River Valley

Attachment 22



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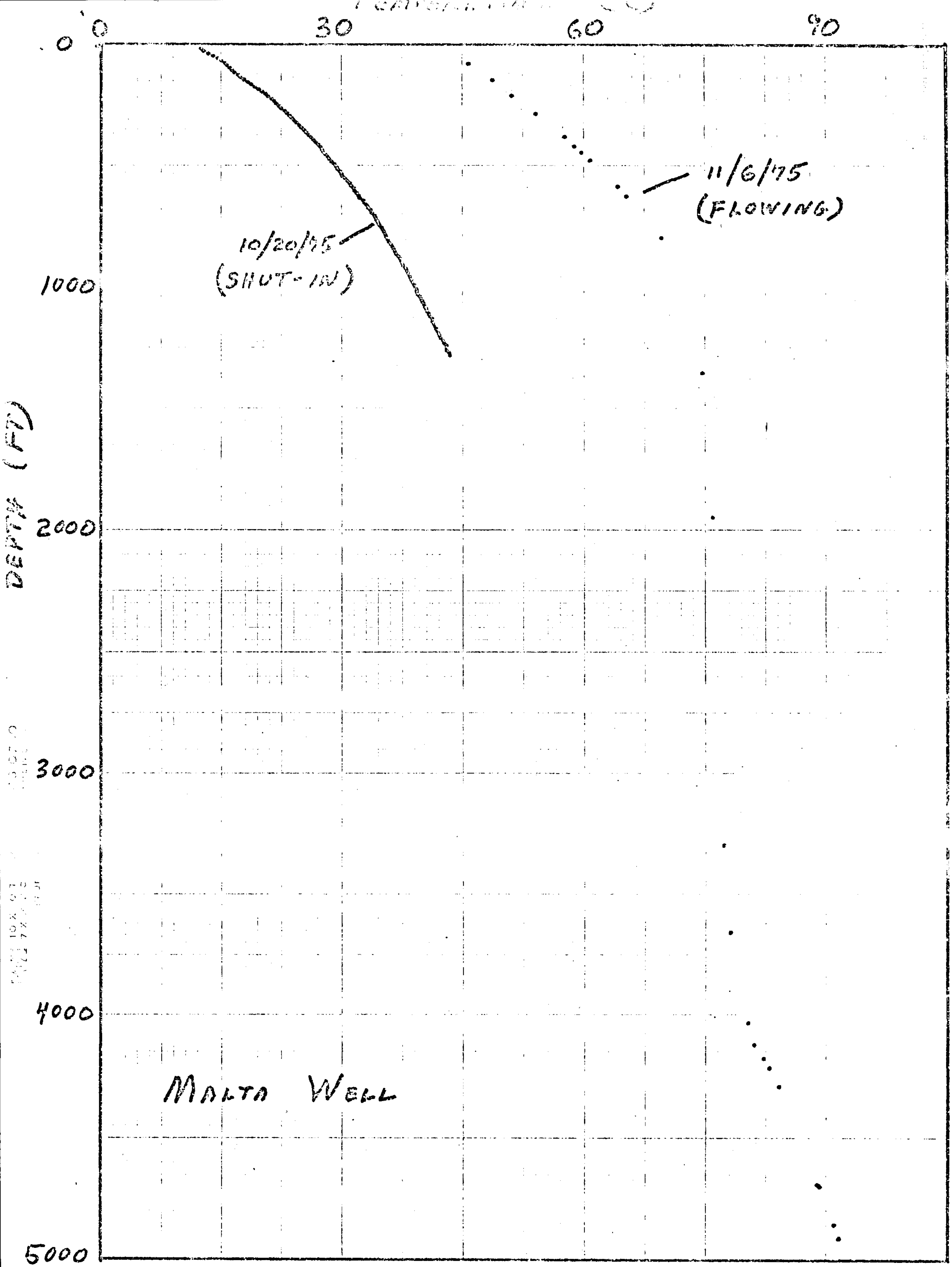

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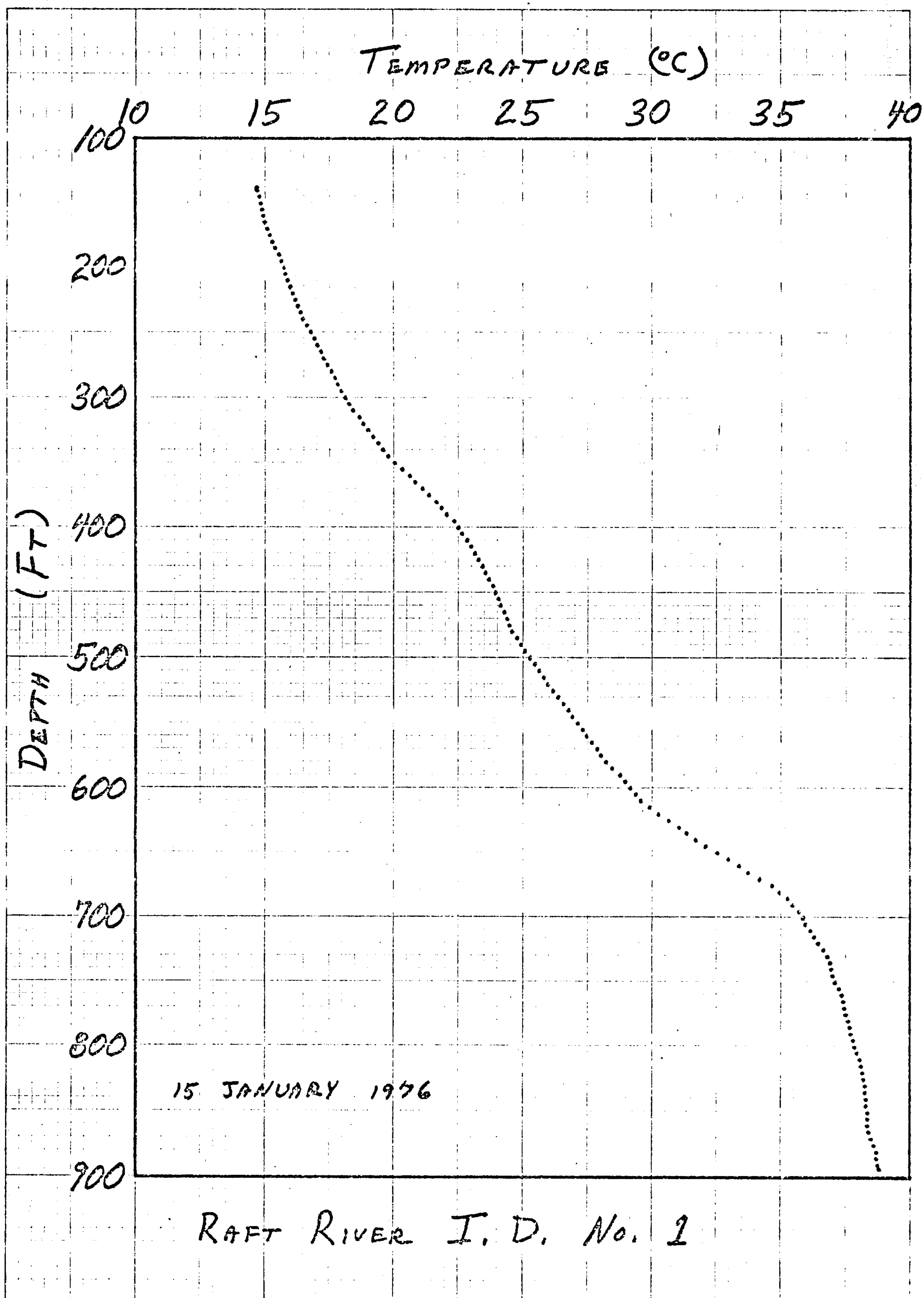

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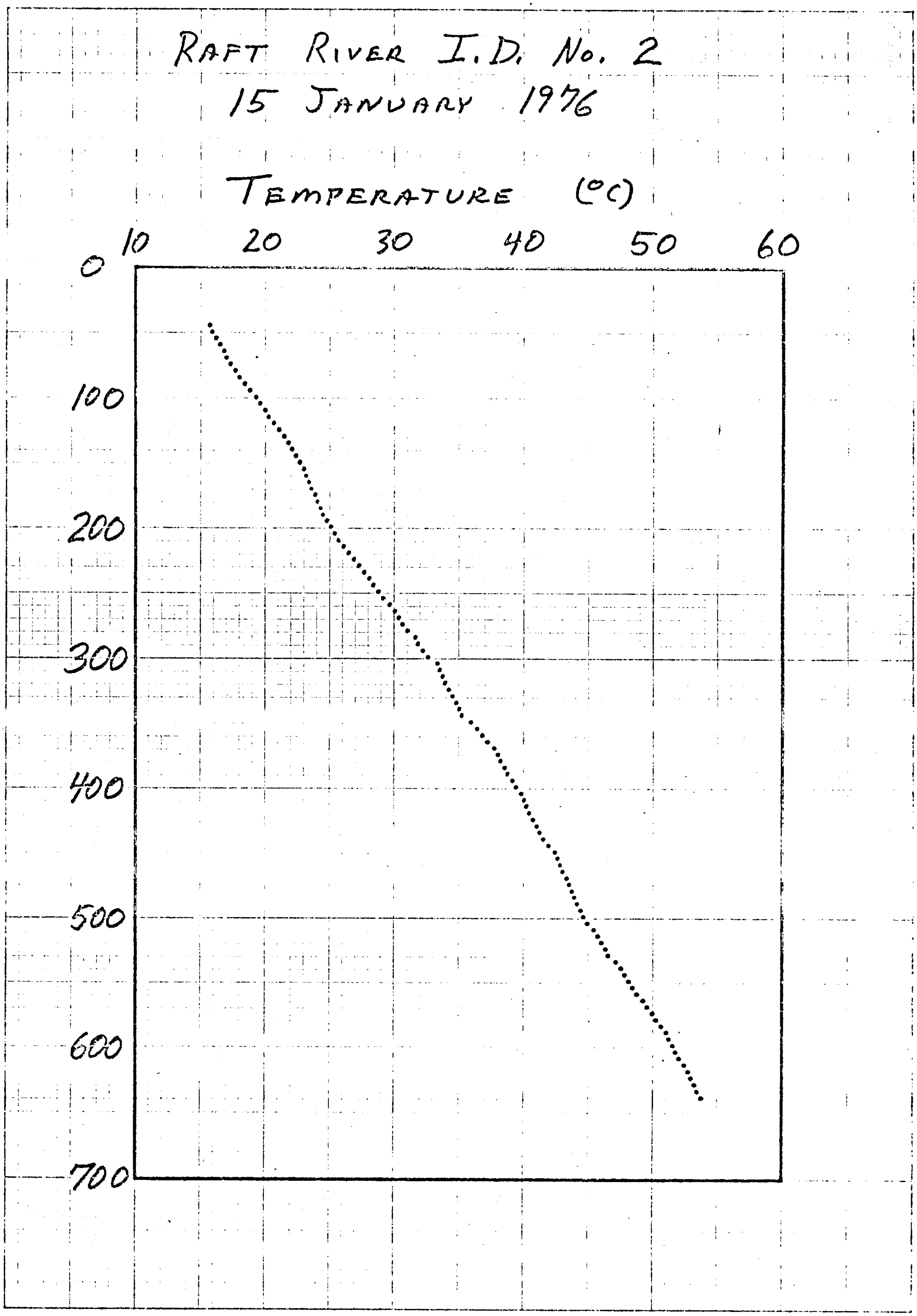
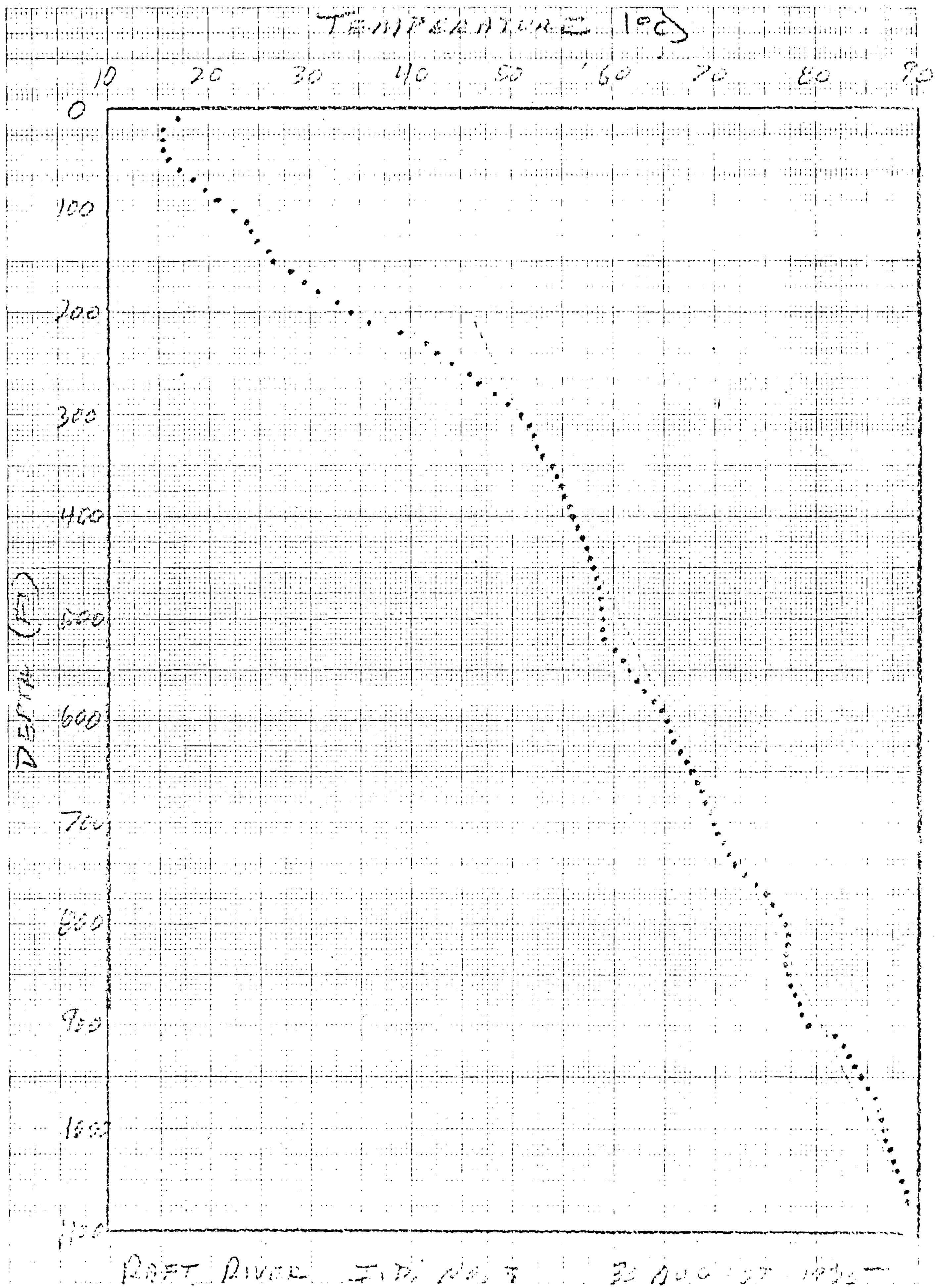


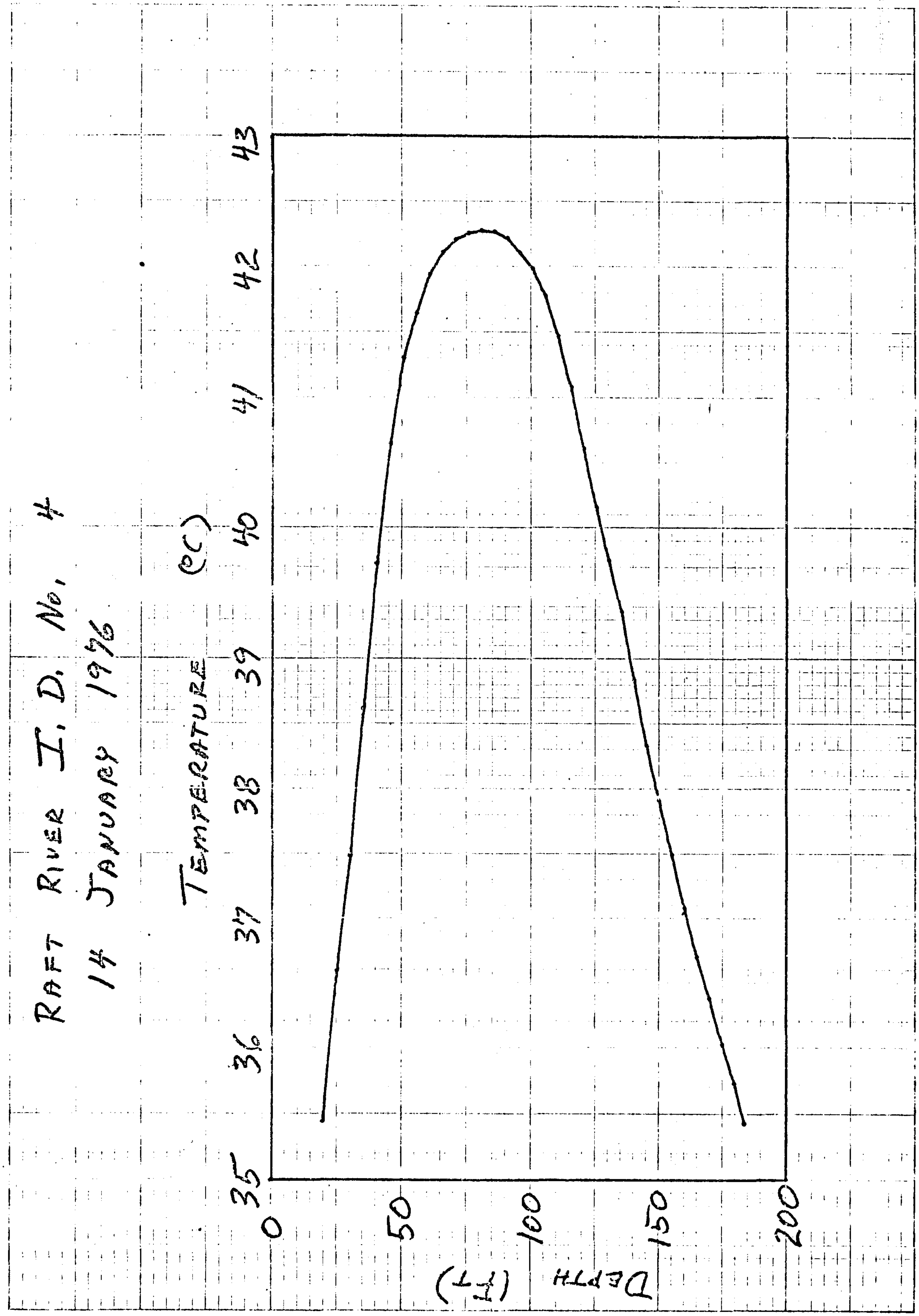
Attachment 26

6/2/76



10 X 10 TO THE CENTIMETER 46 1512
18 X 25 CM.
MADE IN U.S.A.
KEUFFEL & ESSER CO.

Attachment 27



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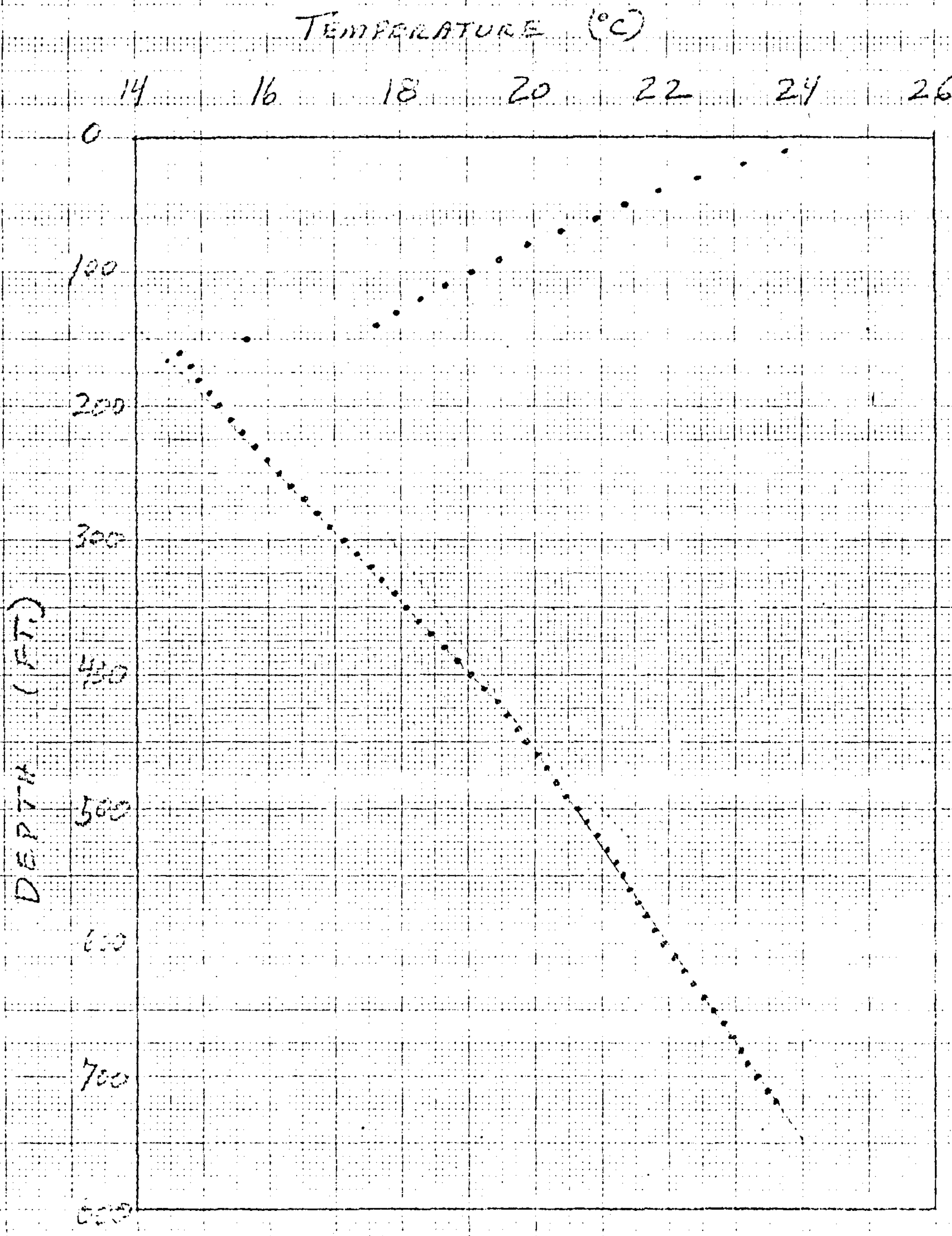
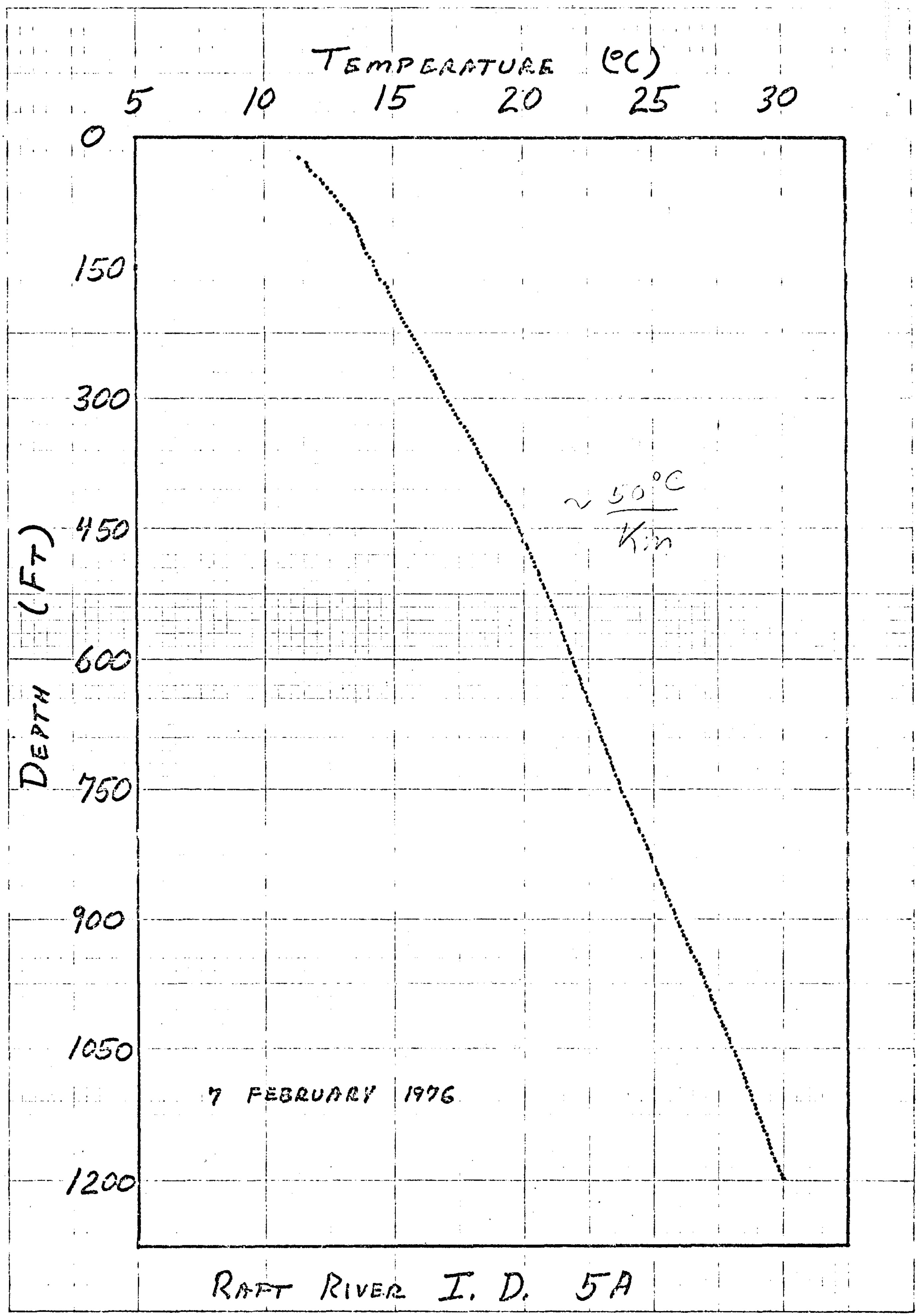
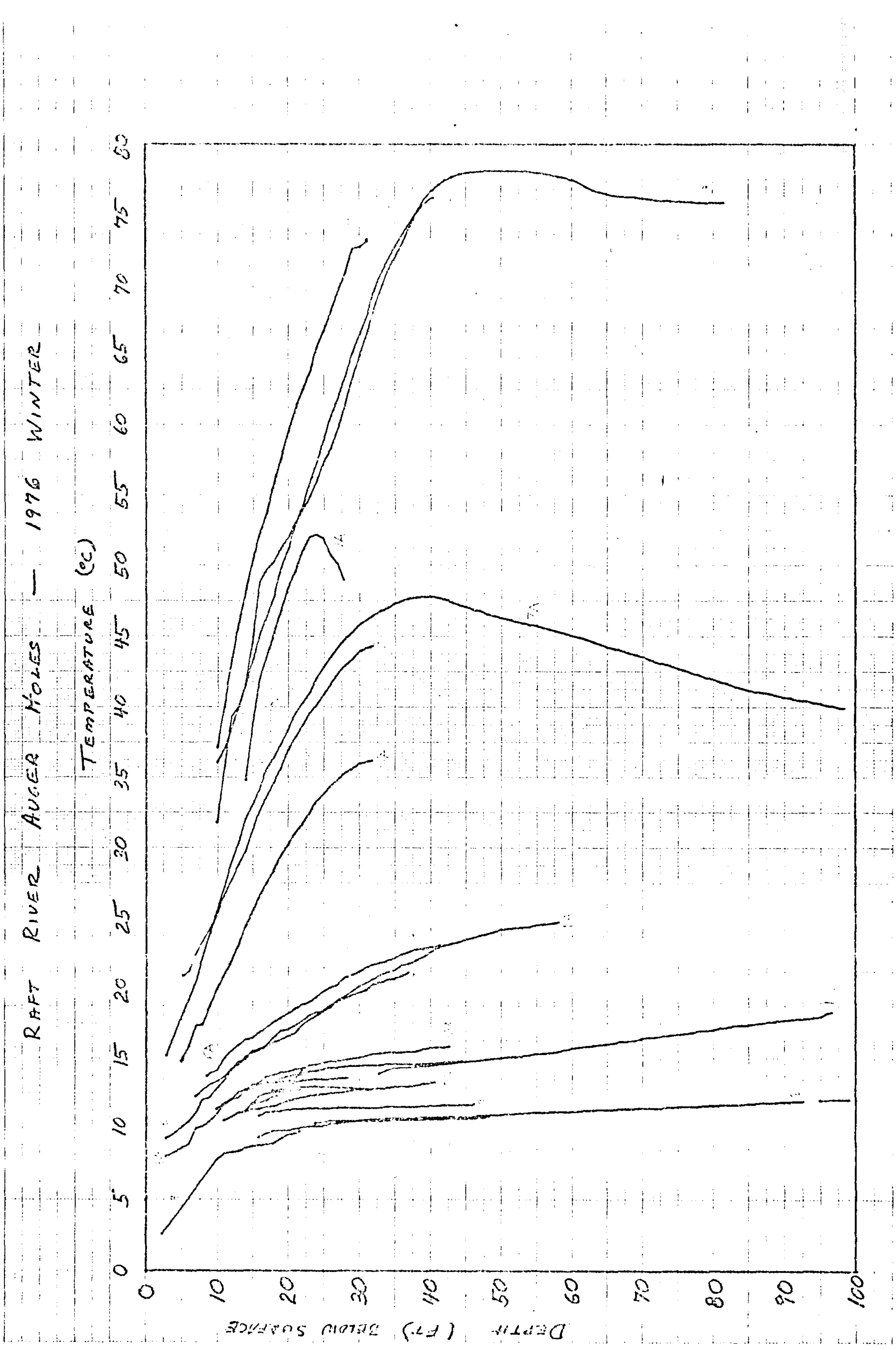


RAFT RIVER — I.D. NO. 5
19 OCTOBER 1975



Attachment 30



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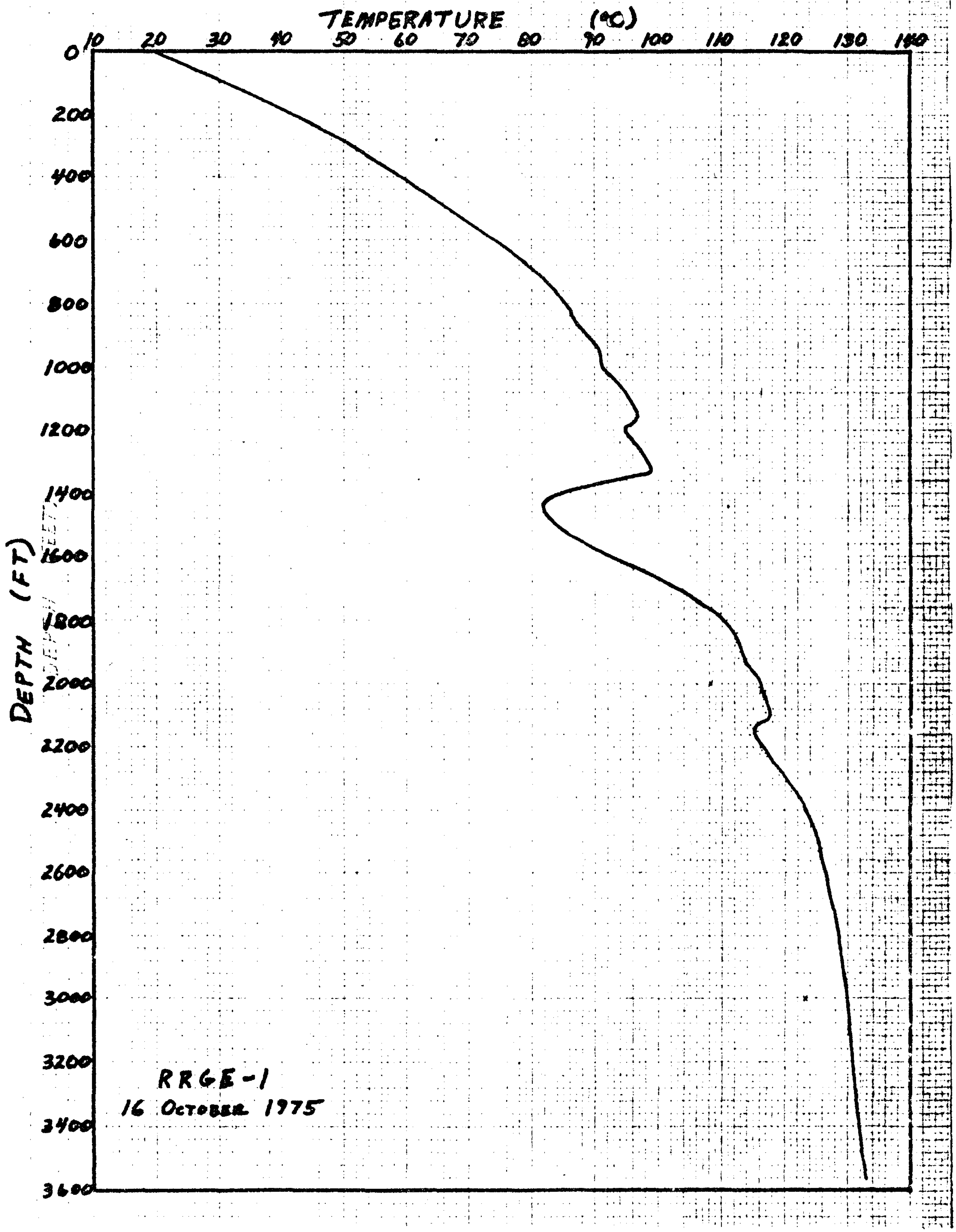

TEMPERATURE (°C)
10 20 30 40 50 60 70 80 90 100 110 120 130 140
DEPTH (FT)
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600
RRGE-1
16 October 1975

Aerojet Nuclear Company

Interoffice Correspondence

June 26, 1976

J. F. Kunze
UPD

RESERVOIR ENGINEERING SEMINAR - SALT LAKE CITY - 5/21/76 - WCK-4-76

Because of time limitations at the SLC Reservoir Engineering Seminar, the ANC Thermal Analysis Branch reservoir engineering effort was not discussed. This effort has resulted in the development of a computer code to predict the long term pressure response of the Raft River Geothermal Reservoir and the long term temperature response of each of the wells. This computer code uses a modified heat-transfer code (SINDA-3G) which employs a finite-difference solution scheme.

Currently the code is able to match, with reasonable success, the test data taken at Raft River wells 1 & 2 using aquifer properties that are virtually unchanged from those determined by Dr. Paul Witherspoon. However, aquifer size and boundary locations are not known at this time thus making input boundary conditions to the computer code somewhat of a guessing game. Since the computer code now uses a very large aquifer model (8 miles X 10 miles), the boundary conditions have not as yet caused problems in matching the test data since test data is not of long enough duration to show significant effects from boundaries. Computer code predictions for times greater than 2 months will need accurate definition of aquifer boundaries.

Figures 1A-1E show the test data taken during the long term flow test of 9/75 to 10/75 and the corresponding computer predictions. Figure 1A is the actual flow rate for the flow test while a constant 415 gpm flow rate (not shown) was used for the computer predictions. The test data shown in Figure 1D was corrected to remove the sinusoidal tidal effects by taking only those data points approximately mid-way between the peaks and troughs. Figures 2A-2C show the test data for the pump test conducted during the early part of 1976 along with the computer predictions of this test. For this test prediction a constant 900 gpm flow rate was used in the computer model. Instrumentation on this test was not accurate enough to detect noticeable tidal effects and therefore no alteration of the test data was needed. Figure 3 shows a typical computer predicted well head temperature response curve resulting from flow initiation in an initially undisturbed well. This type of curve has no real test data counterpart since undisturbed wells are hard to come by at Raft River. Continuous flow from the wells to supply the various ongoing experiments at Raft River keep the wells relatively hot all the time.

The nature and location of the Raft River Geothermal Reservoir boundaries must be determined if meaningful long term pressure response predictions of the reservoir are to be made with confidence. These boundaries, at least with respect to the first 3 wells, could be found with long term testing of the 3 wells as outlined by Drs. Witherspoon and Narasimhan at the seminar. This would involve flow testing each well at 200 gpm to 400 gpm for approximately one month and monitoring all wells during each test. This type of flow test is essential in defining the reservoir boundaries since geological data alone cannot accurately determine them. Accurate long term reservoir pressure response prediction using the computer code developed by Aerojet's Thermal Analysis Branch is dependent upon the ability to define the boundaries.

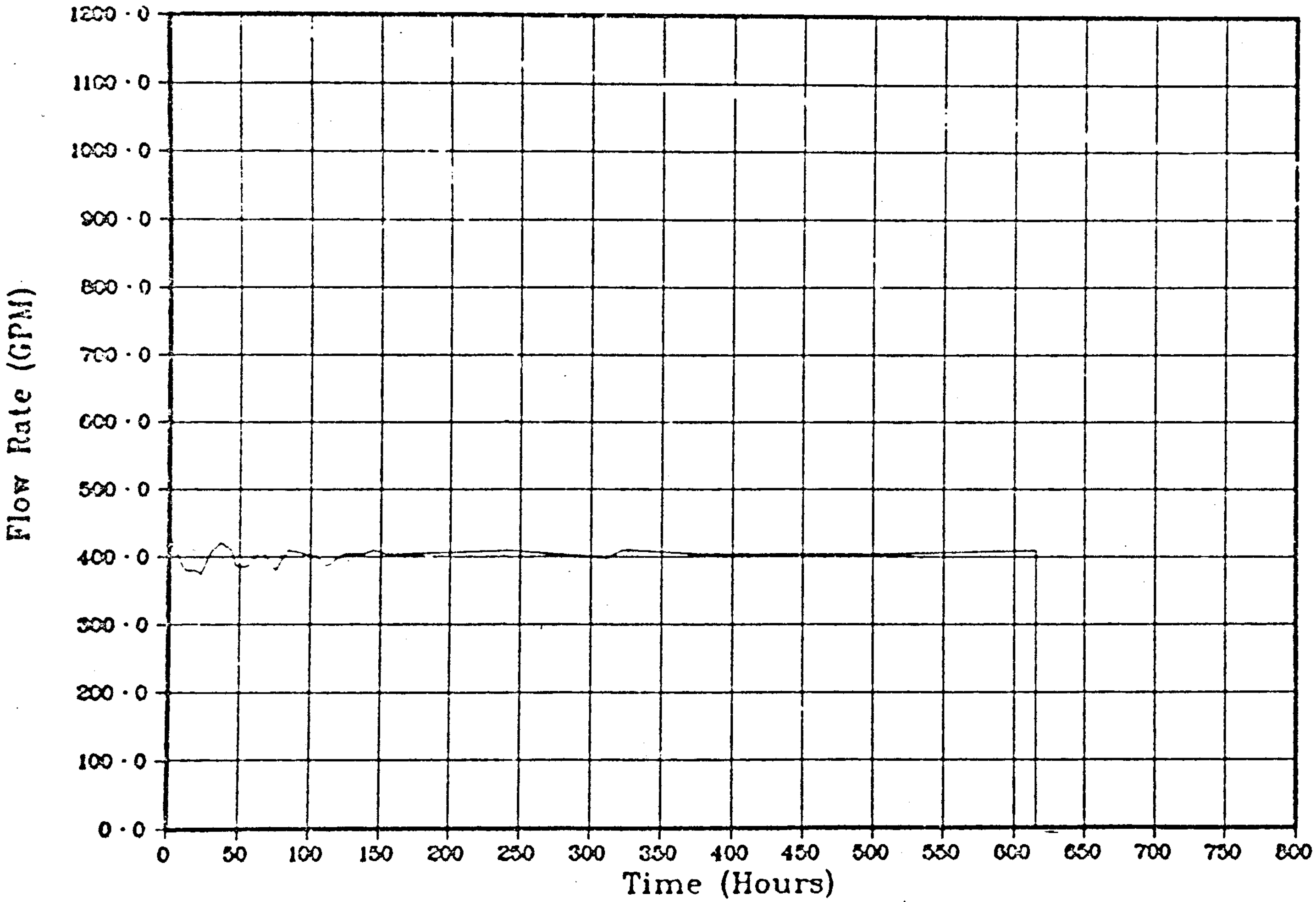
W. C. Kettenacker
Thermal Analysis

jr

Attachments: As stated

cc: w/attachments
DGoldman
WCKettenacker
ECLemmon
JLLiebenthal
LGMiller
NEPace
RCStoker
JFWhitbeck

RRGE #2 FLOW RATE



TEST DATA FROM 9/75 TO 10/75 - TIME 0 = 2230 HRS ON 9/20/75

Figure 1A - Test Data Flow Rate from RRGE #2 - Flow Test of 9/75 to 10/75.

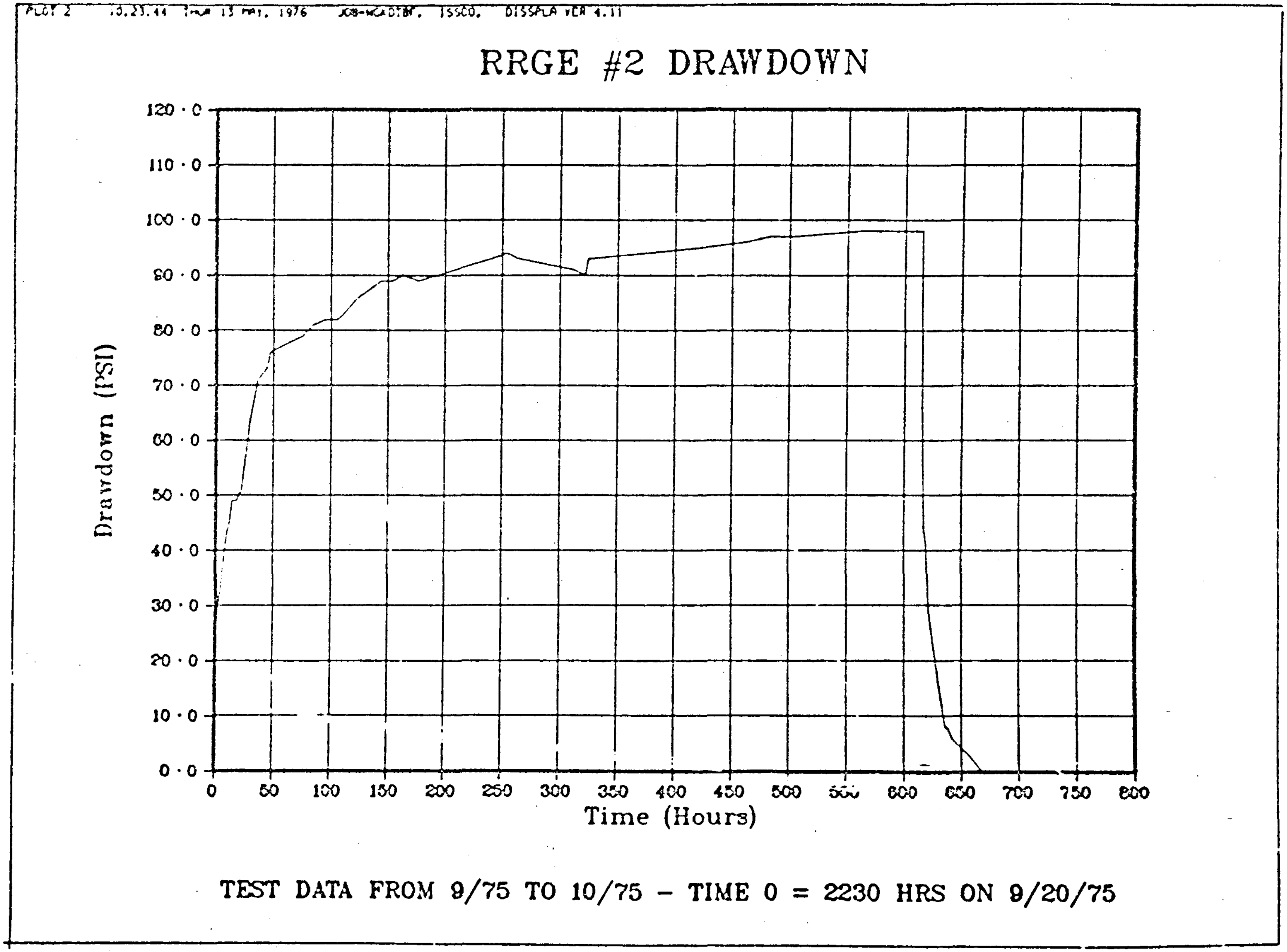


Figure 1B - Test Data Drawdown in RRGE#2 with Flow Rate of Figure 1A.

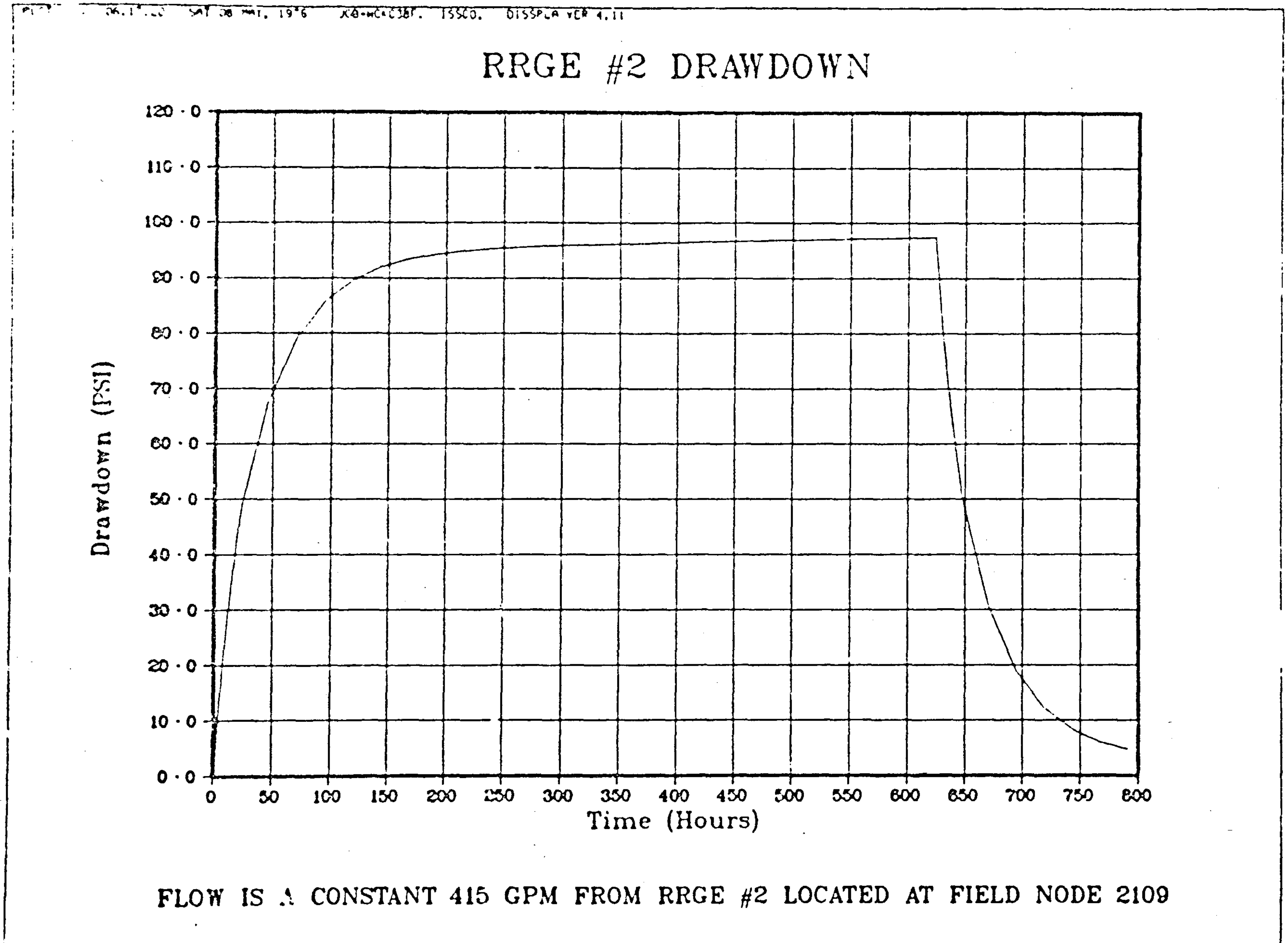


Figure 1C - Computer Predicted Drawdown in RRGE #2 with a 415 GPM Constant Flow Rate (This graph to match Figure 1B.).

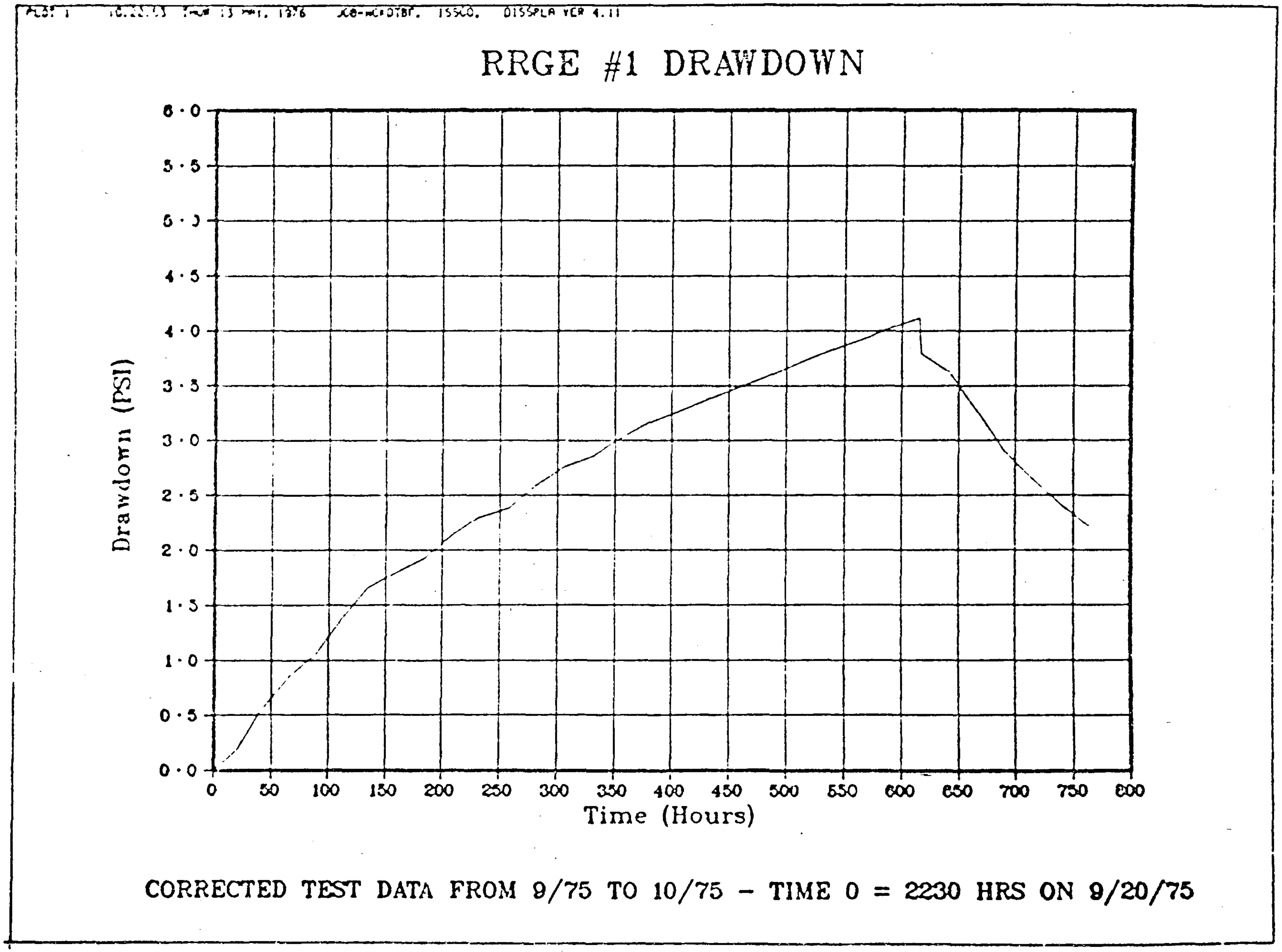


Figure 1D - Test Data Drawdown in RRGE #1 with Flow Rate of Figure 1A in RRGE #2 (Corrected to eliminate tidal effects).

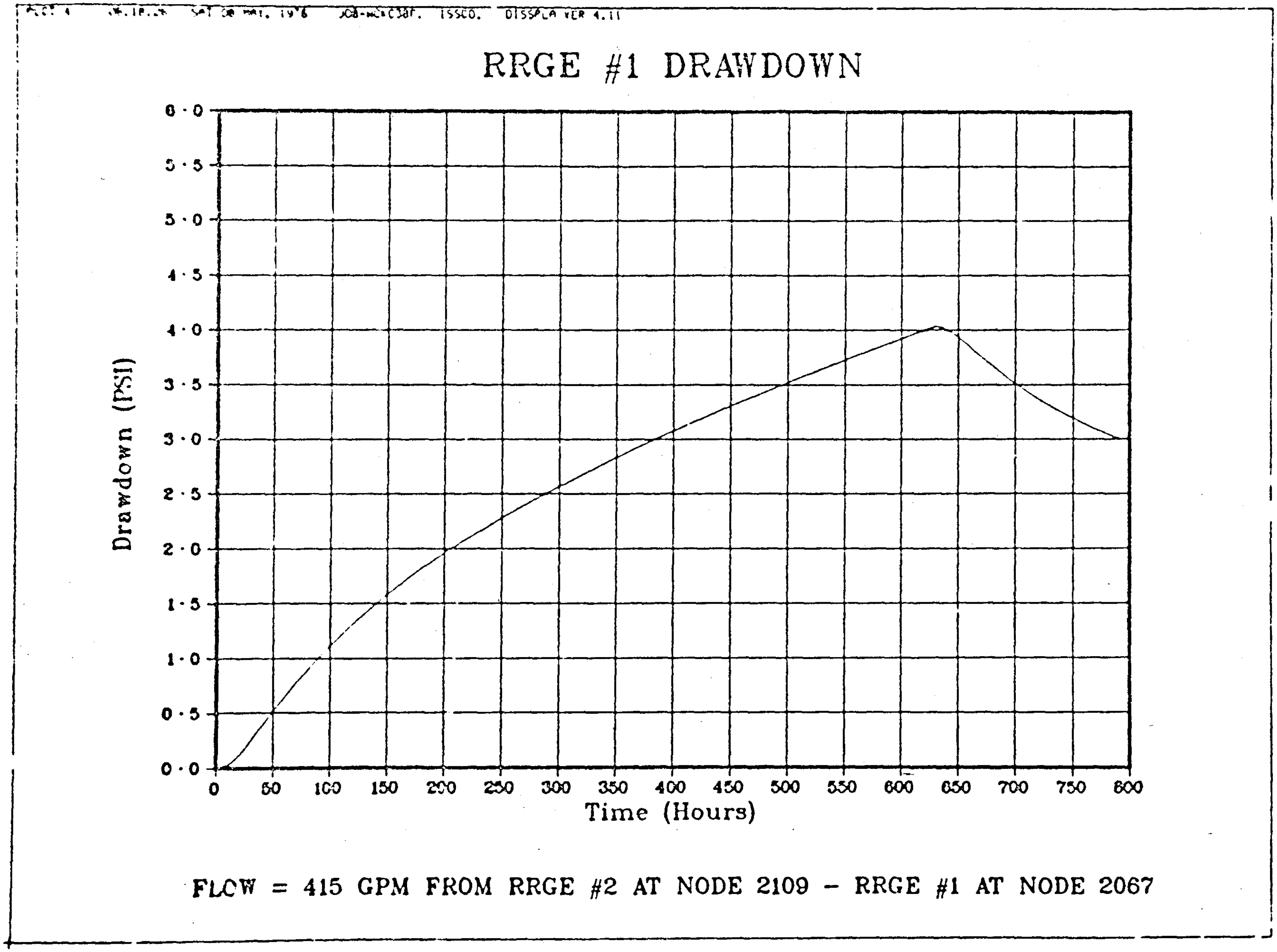
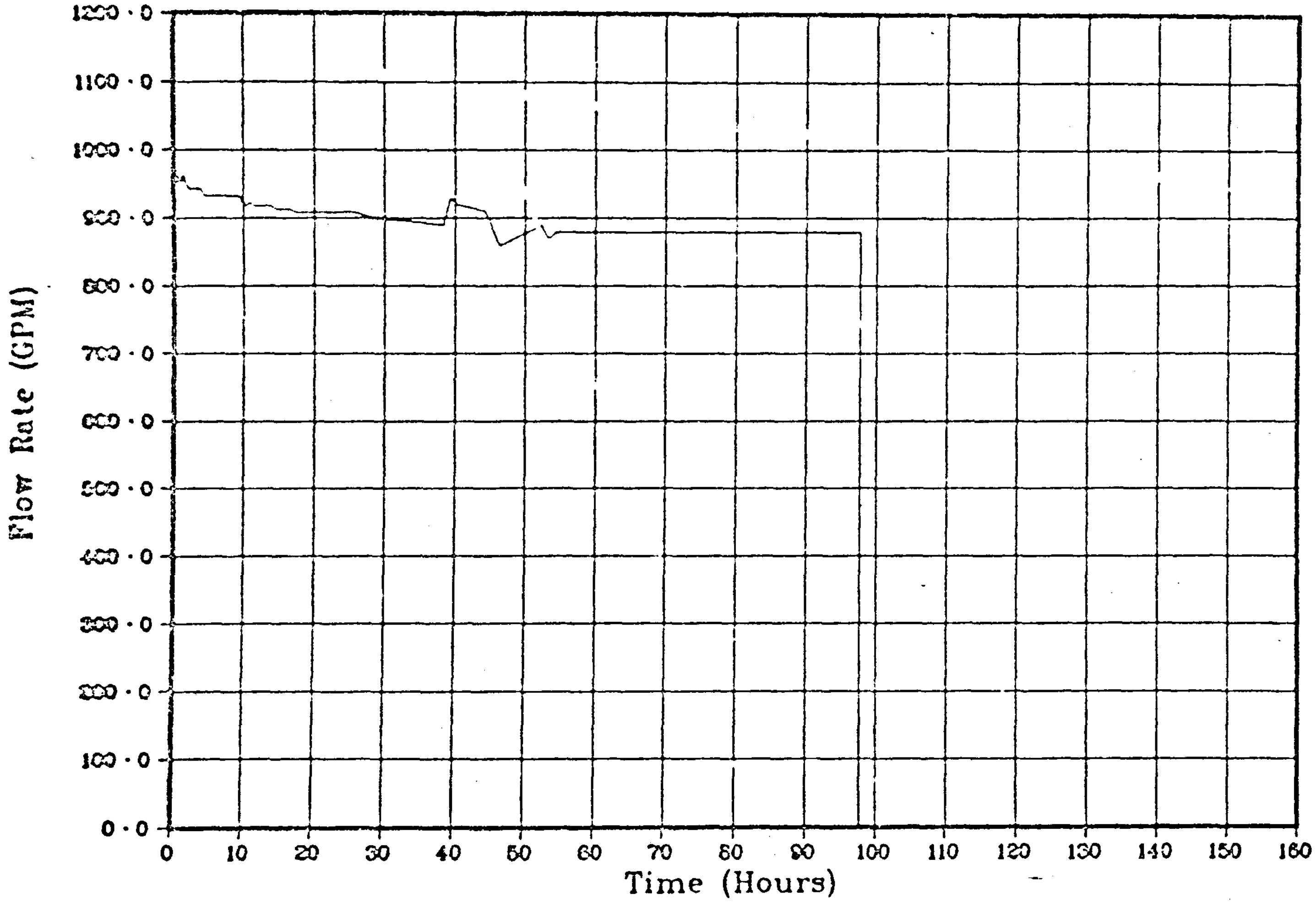


Figure 1E - Computer Predicted Drawdown in RRGE #1 with a 415 GPM Constant Flow Rate in RRGE #2 (This graph to match Figure 1D).

RRGE #1 FLOW RATE



TEST DATA FROM PUMP TEST OF 2/2/76 – TIME 0 = 1135 HRS ON 2/2/76

Figure 2A - Test Data Flow Rate in RRGE #1 - Pump Test of 2/76.

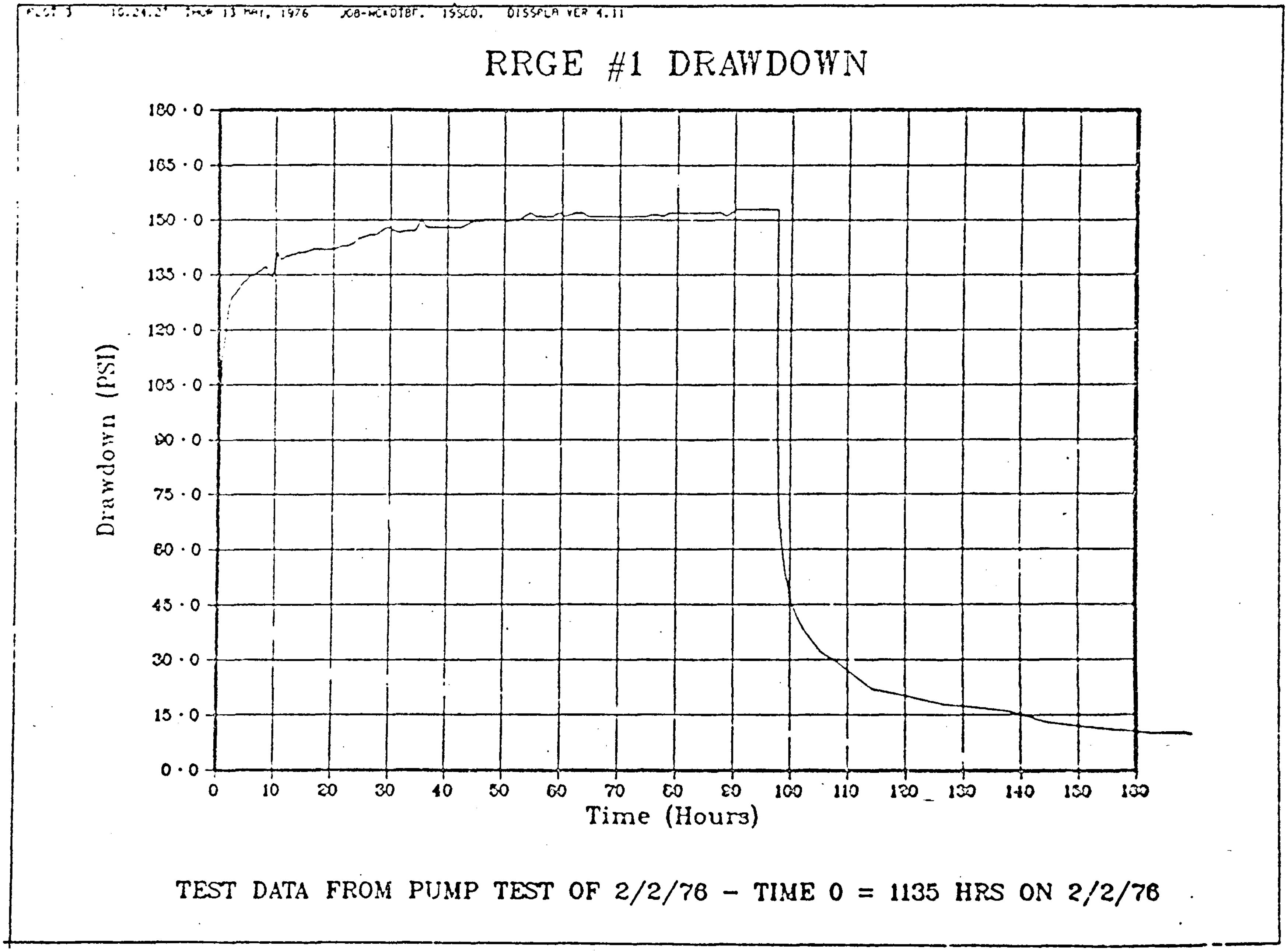


Figure 2B - Test Data Drawdown in RRGE #1 with Flow Rate of Figure 2A.

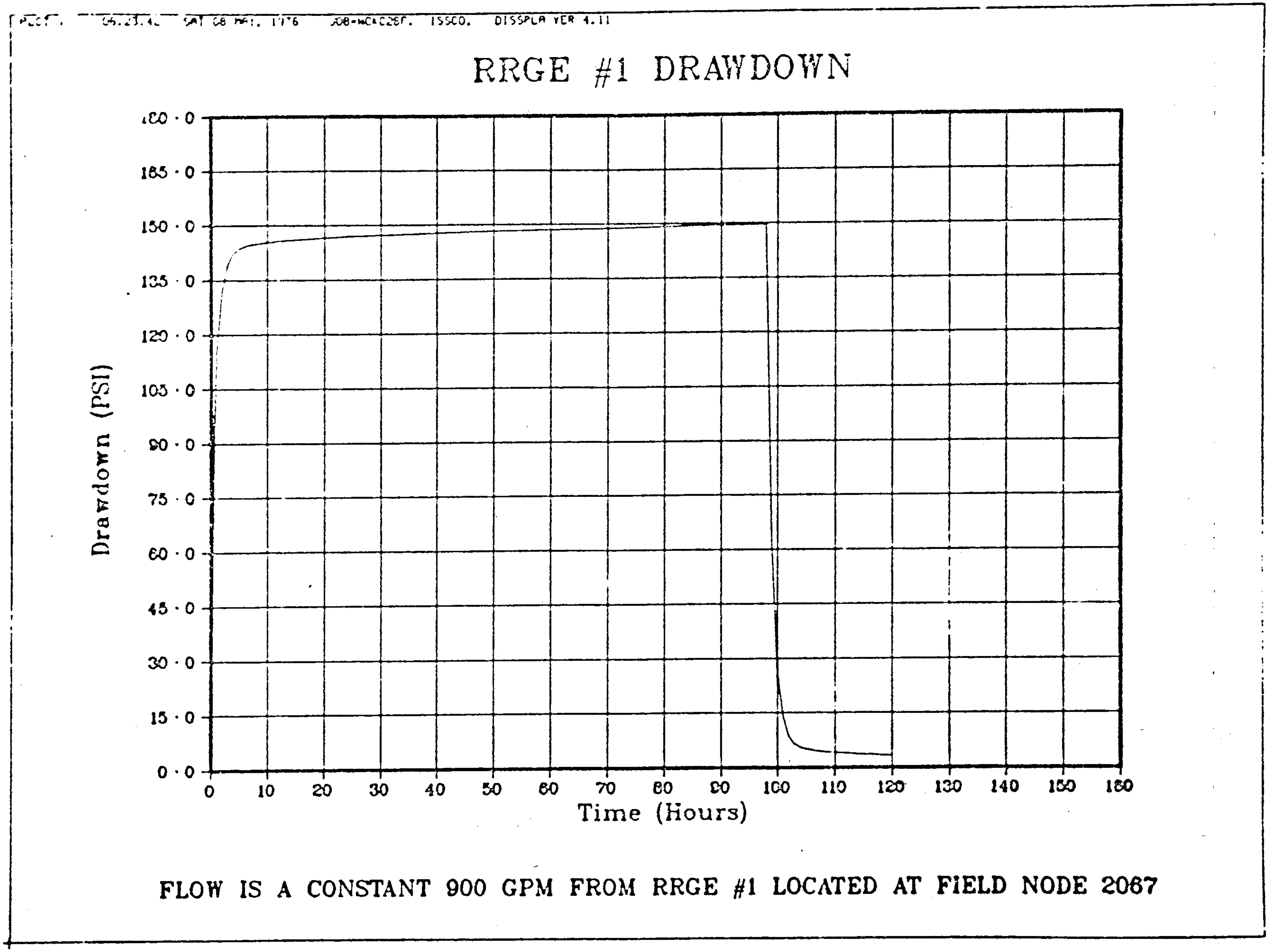


Figure 2C - Computer Predicted Drawdown in RRGE #1 with a 900 GPM Constant Flow Rate (This graph to match Figure 2B).

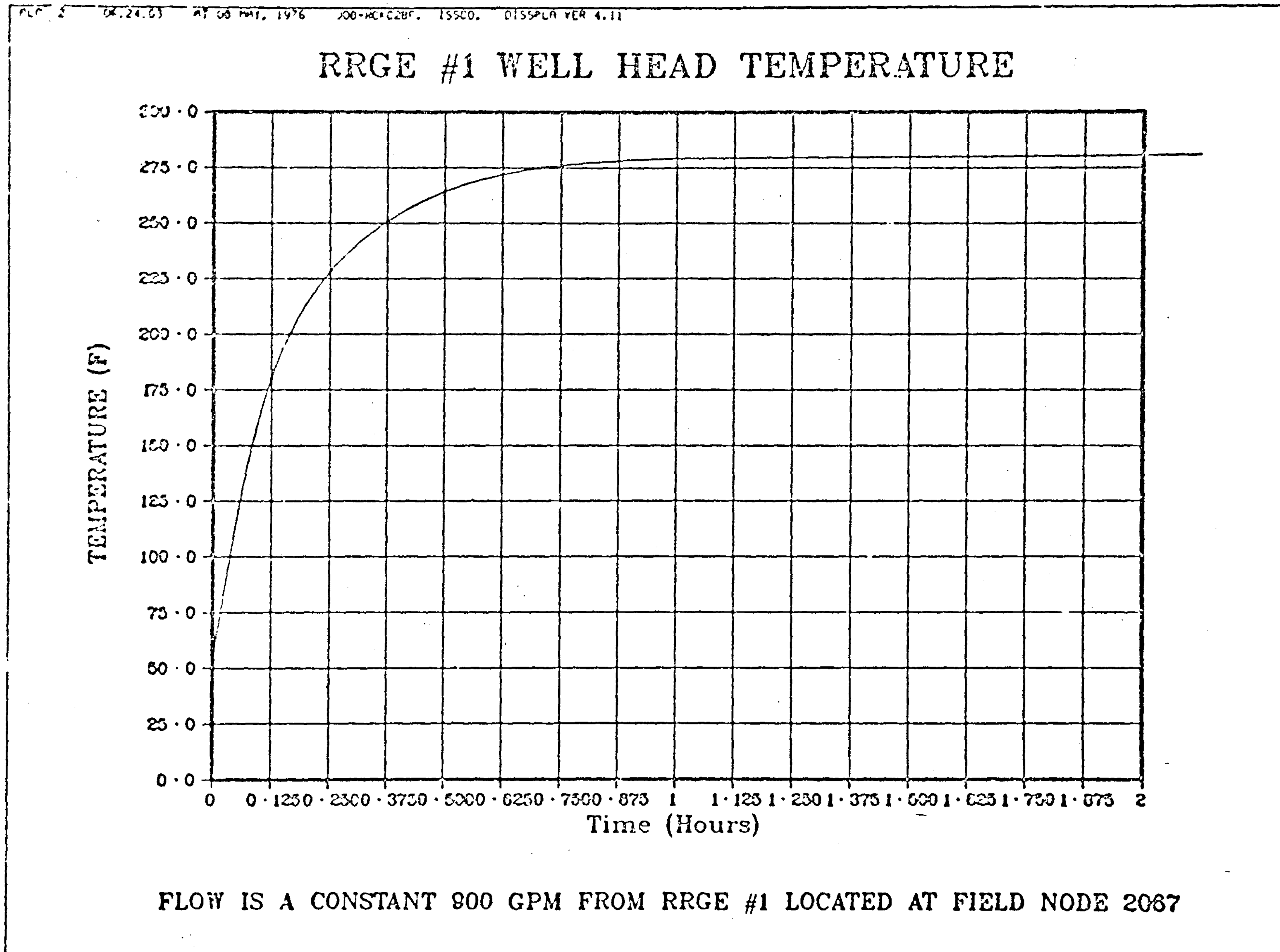


Figure 3 - Computer Predicted Well Head Temperature from Undisturbed Well
(Results taken from computer run to generate Figure 2C).