MOANA SWIMMING POOL

GEOTHERMAL WELL

CONSTRUCTION AND TESTING

Project No. 81-195

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CITY OF RENO

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1.0 SUMMARY AND CONCLUSIONS

1. A 469.7-foot deep geothermal well was constructed in the northwest corner sun deck of the City of Reno Moana Pool located in southwest Reno, Nevada. The well was constructed so as to derive geothermal water for potential use as a source of heat for the swimming pool.

2. The well was test-pumped at the rates of 100, 150, 200 and 250 gpm for a period of 4 hours each, respectively, on June 9 and 10, 1981. A 24-hour constant-discharge pumping test at a pumping rate of 200 gpm was performed June 10 and 11, 1981. Temperature of the discharge water remained a constant 127.4°F throughout testing.

3. Bottom-hole (469.7 feet) temperature after the hole had stabilized was measured at 124.7°F. The hole is approximately isothermal below a depth of 400 feet.

4. Test data indicate that the well is capable of yielding up to 1200 gallons per minute of 127.4°F ground water.

5. Water chemistry data indicate that precipitation of silica or calcium carbonate in the well or heat exchanger does not appear to be a problem.

6. The chemical quality of the water does not meet state and federal drinking-water standards. However, water quality appears to be sufficiently good for direct use of the water for purposes of heating the swimming pool and space heating of the buildings. Direct use of the water would allow for a more efficient heating system.

2.0 INTRODUCTION

In summer of 1979 a test well was drilled at the Moana Pool Facility in southwest Reno to assess the potential of deriving an adequate supply of sub-surface, geothermal water for purposes of heating the pool facilities. Data collected during this program were evaluated and from these data the pool heating system appeared feasible (WEN, INC., 1979 and OIT, 1979). In January, 1981, WILLIAM E. NORK, INC., was contracted by the City of Reno to supervise drilling, construction, and testing of a production geothermal well at the same site. Aqua Drilling and Well Service, Sparks, Nevada, was contracted to construct and test the well.

The Moana Swimming Pool geothermal well is located in the NE$\frac{1}{4}$, NE$\frac{1}{4}$, NW$\frac{1}{4}$, Section 25, T. 19 N., R. 19 E., in southwest Reno (Figure 1). The well was completed to a depth of 469.7 feet on May 29, 1981. Ultimate construction design of the well was based on types of geologic materials penetrated, geophysical logs of the borehole, and data collected during drilling of the test and production holes.

Upon completion of well construction a test pump was installed and a series of aquifer/pumping tests were performed. This report describes in detail the construction of the well and the results of testing.

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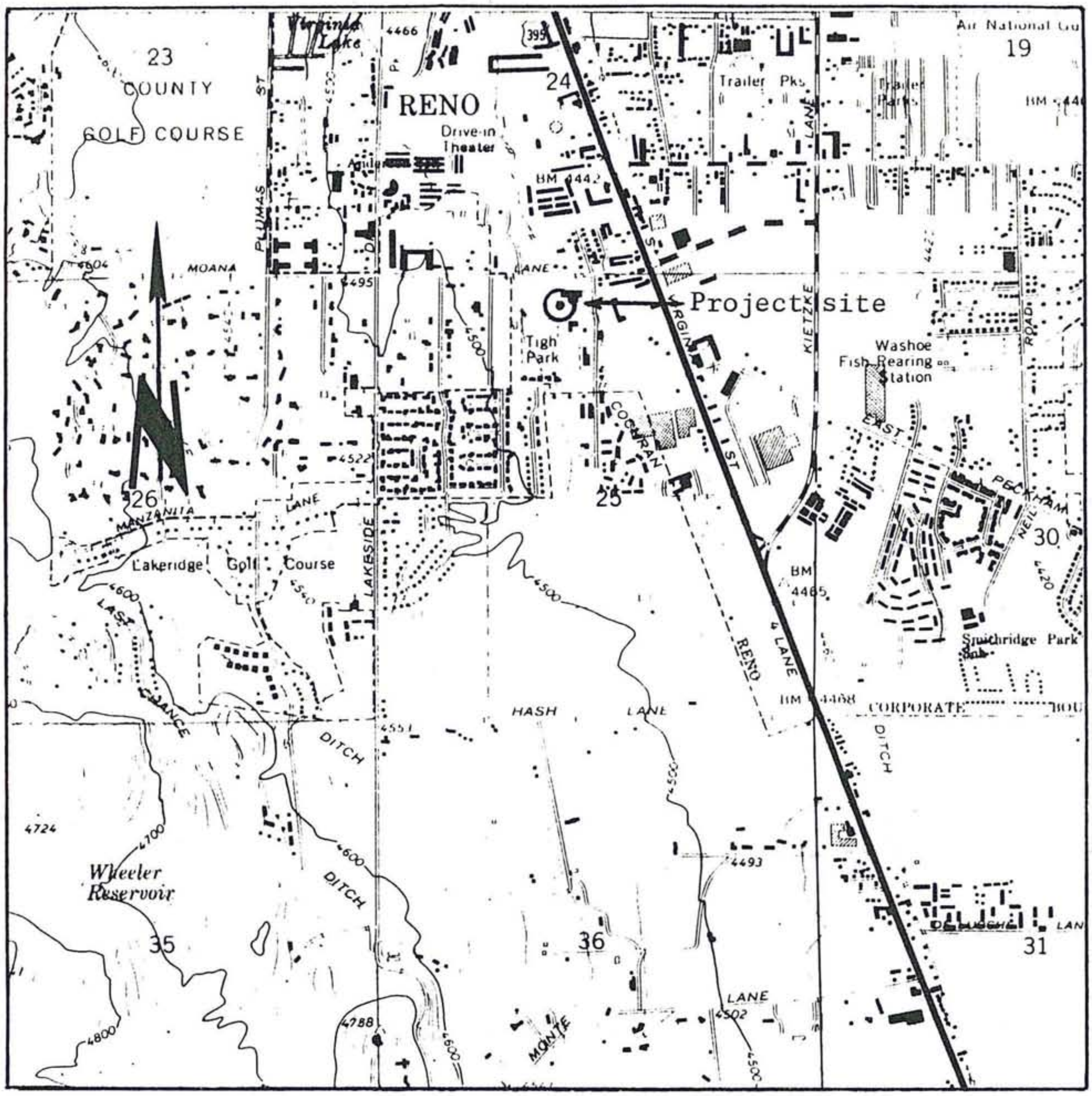


Map base : Mt. Rose NE, Nevada USGS 7.5 – minute topographic map

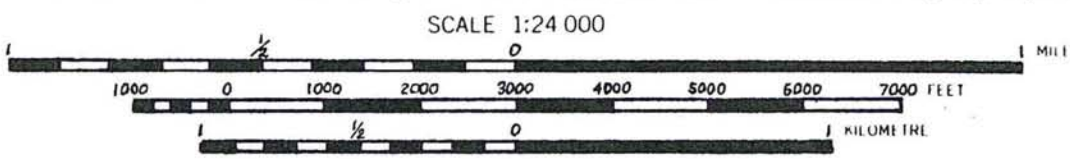


FIGURE . 1 Location map of the Moana Pool Geothermal Well.

3.0 CONSTRUCTION CHARACTERISTICS

3.1 WELL CONSTRUCTION

Drilling of the Moana Pool geothermal production well commenced on May 18, 1981. A $17\frac{1}{2}$-inch diameter hole, using the rotary-mud method, was drilled to a depth of 10 feet, and a temporary 16-inch conductor casing was installed from 2.26 feet above ground level to 7.74 feet below the surface. A nominal 14-inch diameter hole was then drilled to a depth of 120 feet, and $10\frac{1}{4}$-inch O.D. x 0.211-inch wall thickness steel casing was installed. A cement grout seal was emplaced in the annular space between the casing and borehole wall using a tremie pipe. The seal was placed from a depth of 115 feet to ground surface in order to prevent mixing of shallow and cooler ground water with the geothermal waters at depth.

A nominal 10-inch hole was drilled from 120 to 138 feet by the air-rotary method. Sloughing of the sands and gravels necessitated returning to the rotary-mud method. Drilling continued to a depth of 165 feet, but continual sloughing problems indicated that the hole had not stabilized and that erosion of the borehole may have occurred. To prevent possible collapse and ultimate loss of the hole, a cement drill plug was emplaced for the purpose of stabilizing the hole on May 26, 1981, to a depth of 165 feet. The cement was allowed to set up overnight, and was drilled through on the following day.

Drilling of a nominal 10-inch diameter borehole by the air-rotary method was resumed on May 27, 1981, but sloughing of the formation material resulted in discontinuing air-rotary drilling at 180 feet. The air-rotary method had been selected as the preferred method of drilling in the potential production zones because of the anticipated problems associated with removing of mud-based drilling fluids from a geothermal formation.

Using the rotary-mud method, drilling continued from a depth of 180 feet to the original target depth of 300 feet. The 300 feet depth was reached on May 28, 1981. The hole was geophysically logged (Appendix A) and lithologic samples of the materials penetrated during drilling were examined. Evaluation of data indicated that the probable yield of a well completed to this depth would not exceed 50 gpm because of the large percentage of clay in the formation. The composite water temperature recorded at this depth was 95.6°F. On the basis of this evaluation, WILLIAM E. NORK, INC., recommended additional drilling to a depth of about 500 feet.

The final 180 feet of the Moana well was drilled on May 29, 1981. Drilling was terminated in an impermeable clay bed at 480 feet. An abbreviated lithologic log of the Moana Pool geothermal well is as follows:

Depth Interval (feet)	Lithology
0-90	unconsolidated black volcanic sands and gravels, angular; minor quartz and green chert sands; per cent brown clay increasing with depth.
90-170	fine- to medium-grained volcanic sands, semi-angular; reduction in amount of clay.
170-320	fine- to medium-grained semi-angular black and green volcanic sands, interbedded with clay lenses, clayey sands and silts.
320-375	micas, quartz and volcanic sands, .05 inch average diameter; large reduction in amount of clays.
375-445	consolidated sands, one-inch average diameter; clay minor.
445-480	interbedded unconsolidated quartz and volcanic sands with clay lenses and clayey sands, clay increasing with depth.

Preliminary well design called for nominal 10-inch casing to 120 feet depth and nominal eight-inch casing from 120 to total depth. Primary purpose of the 10-inch casing in the upper 120 feet was simply to provide sufficient room to house an eight-inch pump. Smaller diameter casing and well screen below this depth would allow more than adequate flow of water into the well and provide for an overall cost savings. Johnson-UOP shaped wire wound well screen was selected because it contains more open area per linear foot than any other screen design. Large open area provides for low entrance velocity of water into the well through the well screen. Low entrance velocity results in high-well efficiency (lower pumping cost per gallon of water), and reduces the potential for chemical incrustation or corrosion of the well.

Final well design was based on lithologic samples of the formation materials penetrated, the driller's log, borehole geophysical logs, and temperature surveys of the borehole. The interval 355 to 455 feet depth was selected for installation of well screen. The well-sorted nature of the formation materials in this zone and their grain-size distribution permitted installation of 30 slot screen (0.030 inch slots) and development of a natural gravel pack. Because of approximately ten feet of fill at the base of the hole, the bottom of the 8-5/8-inch casing was set at a depth of 469.7 feet.

Final well construction is shown in Figure 2. Lithologic and geophysical logs are summarized in Appendix A, and copies of the Driller's Report to the State Engineer and WEN, Inc.'s Well Construction Summary are included in Appendix B.

Using a drill-rig mounted air compressor, the well was developed for nine and one-half hours on June 8, 1981. Development of a well is undertaken in order to remove drilling fluid from the well bore and to break down the mud cake adhering to the borehole walls.When development of a well is effective, flow of water to the well is unrestricted. In addition, development often results in removal of fine sands and silt from the immediate vicinity of the borehole. Such action increases the effective radius of the well. In the case of the Moana Well discharge water at the completion of development had no odor or taste and was clear of sediment. The development work was, therefore, believed to be successful.

On June 16, 1981, (at the completion of test pumping of the well), 2 gallons of sodium hypochlorite were added to the well to produce a concentration of 200 gpm chlorine for purposes of disinfecting the well. After setting for 24 hours, the well was pumped free of all residual chlorine on June 17, 1981. Test pumping equipment was then removed and the bottom of the well was sounded. The well was open to 469.7 feet with only an insignificant amount of fill at the base of the 10-food sediment trap (blank casing) located below the screen. A steel plate was then welded to the top of the casing to prevent vandalism and contamination.

3.2 TEMPERATURES MONITORED DURING CONSTRUCTION

Temperature of the drilling fluid at various depths within the borehole was monitored during well construction. Cool drilling fluids and adjacent formation waters do not equilibrate thermally in short periods of time due to the rate of circulation of fluid within the hole. Therefore, drilling fluid temperatures which were measured were generally lower than the actual water temperatures of formation. Nevertheless, they are indicative in a qualitative sense of changes in formation water temperature (see Table 1).

Figure 2. Construction diagram of Moana Swimming Pool Geothermal Well.

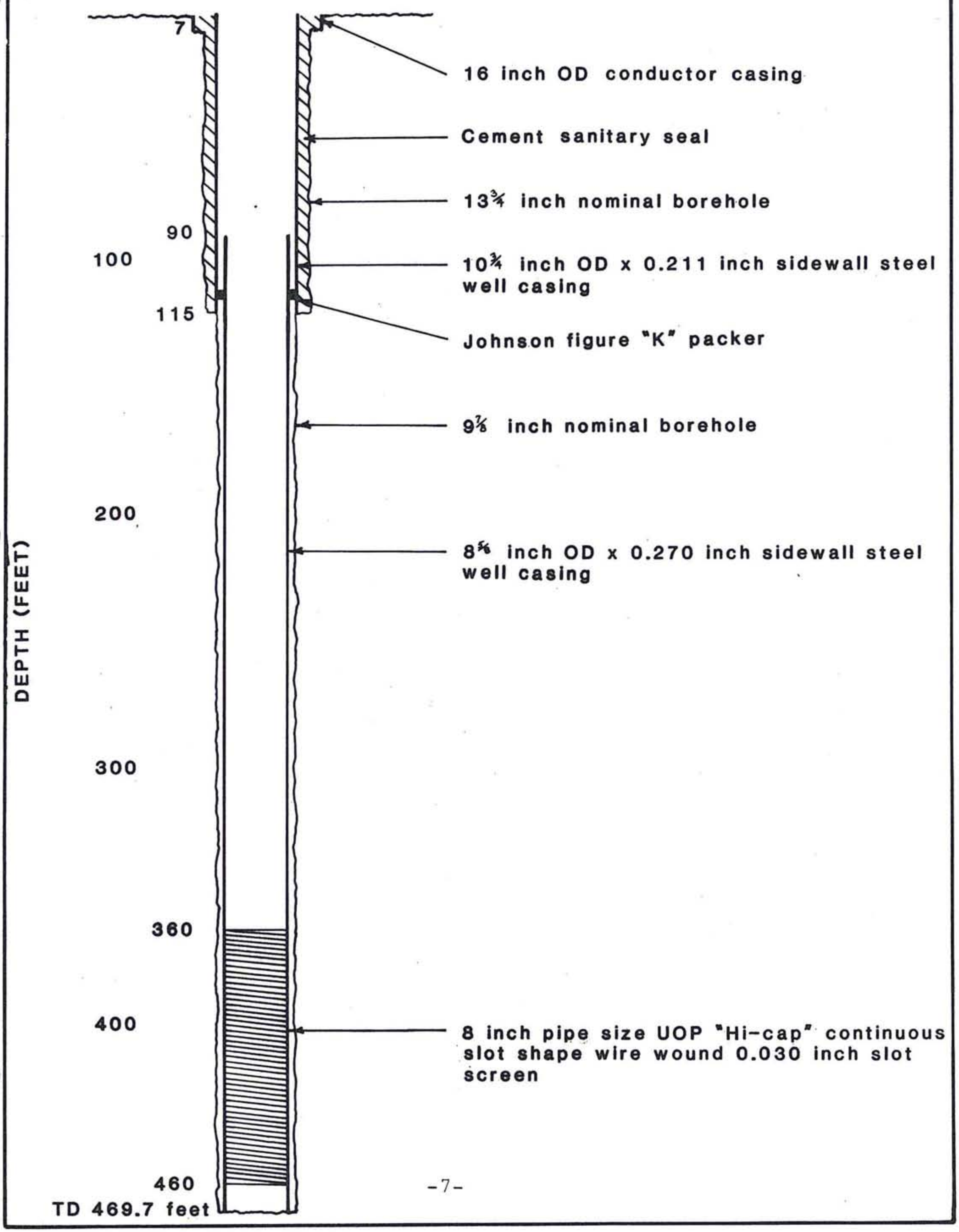


Table 1. Temperature of drilling fluid at various depths during rotary-mud drilling of the Moana Pool Geothermal Well.

Depth (feet)	Temperature (°F)
175	107.6*
190	82.4
245	89.6
265	93.2
290	94.1
375	95.0
445	96.8
465	97.7
475	98.6

*Temperature measured during air-rotary drilling.

On May 28, 1981, WILLIAM E. NORK, INC., conducted an initial temperature survey using a Keck DTM-75 Temperature Logging System. Bottom hole (290 feet) temperature was measured at 95.6°F (Figure 3). From results of this survey and data from the geophysical log of the borehole and formation cuttings, it was decided to drill to a depth of about 500 feet (3.1, above).

A second temperature log of the deepened hole was then run on May 30, 1981 (Figure 3). The temperature gradient in the upper 300 feet of the hole was approximately 7 °F per 100 feet, dropping to 5°F per 100 feet from 300 to 400 feet below L.S.D. At depths greater than 400 feet, the temperature became approximately isothermal. Bottom hole (469.7 feet) temperature prior to installation of well casing and development was measured at 120.1°F.

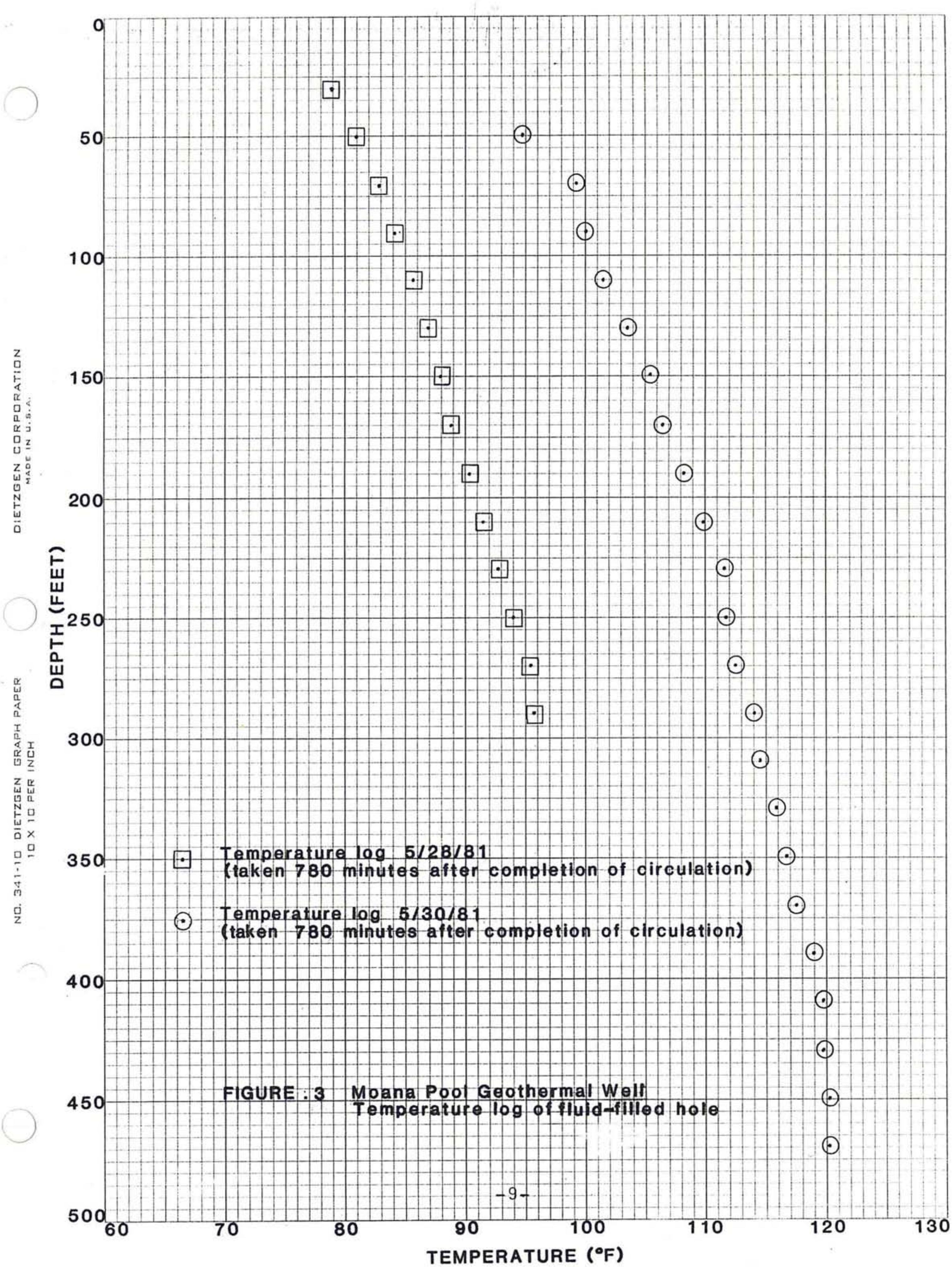


FIGURE : 3 Moana Pool Geothermal Well
Temperature log of fluid-filled hole

4.0 TESTING OF THE WELL

After completion of construction and development of the well, a 5-stage Red Jacket turbine pump equipped with a 25-horsepower Hitachi submersible motor was installed in the well by Aqua Drilling and Well Service on June 7, 1981. The pump intake was set at a depth of 194 feet below L.S.D. (land surface datum). Pump installation included a 3/4 inch diameter stilling well to assure accurate measurement of water levels in the well during testing. Development consisted of alternately surging and pumping of the well until water discharge was clear and sand-free.

Upon completion of developmental pumping, step-drawdown and constant-discharge pumping tests were performed.

4.1 STEP-DRAWDOWN TESTING

A 16.5-hour four-step-drawdown test was conducted June 9 and 10, 1981. Testing results are illustrated in Figures 4 and 5 and summarized in Table 2 and Appendix C.

> Static water level prior to testing was 20.06 feet below L.S.D. Testing commenced at 0830 hours June 9, 1981. Well was pumped at rates of 100, 150, 200, and 250 gpm. Testing terminated at 0030 hours June 10, 1981. Recovery of water levels in the well was rapid, approximately 91 per cent in 12 hours.

Table 2. Results of step-drawdown test.

Step	Pumping Rate (gpm)	Step Duration (minutes)	Water Level (feet)	Drawdown (feet)	Specific Capacity (gpm/ft)
I	100	240	42.44	22.38	4.47
II	150	240	57.86	37.80	3.97
III	200	240	74.36	54.30	3.68
IV	250	270	80.21	60.15	4.16

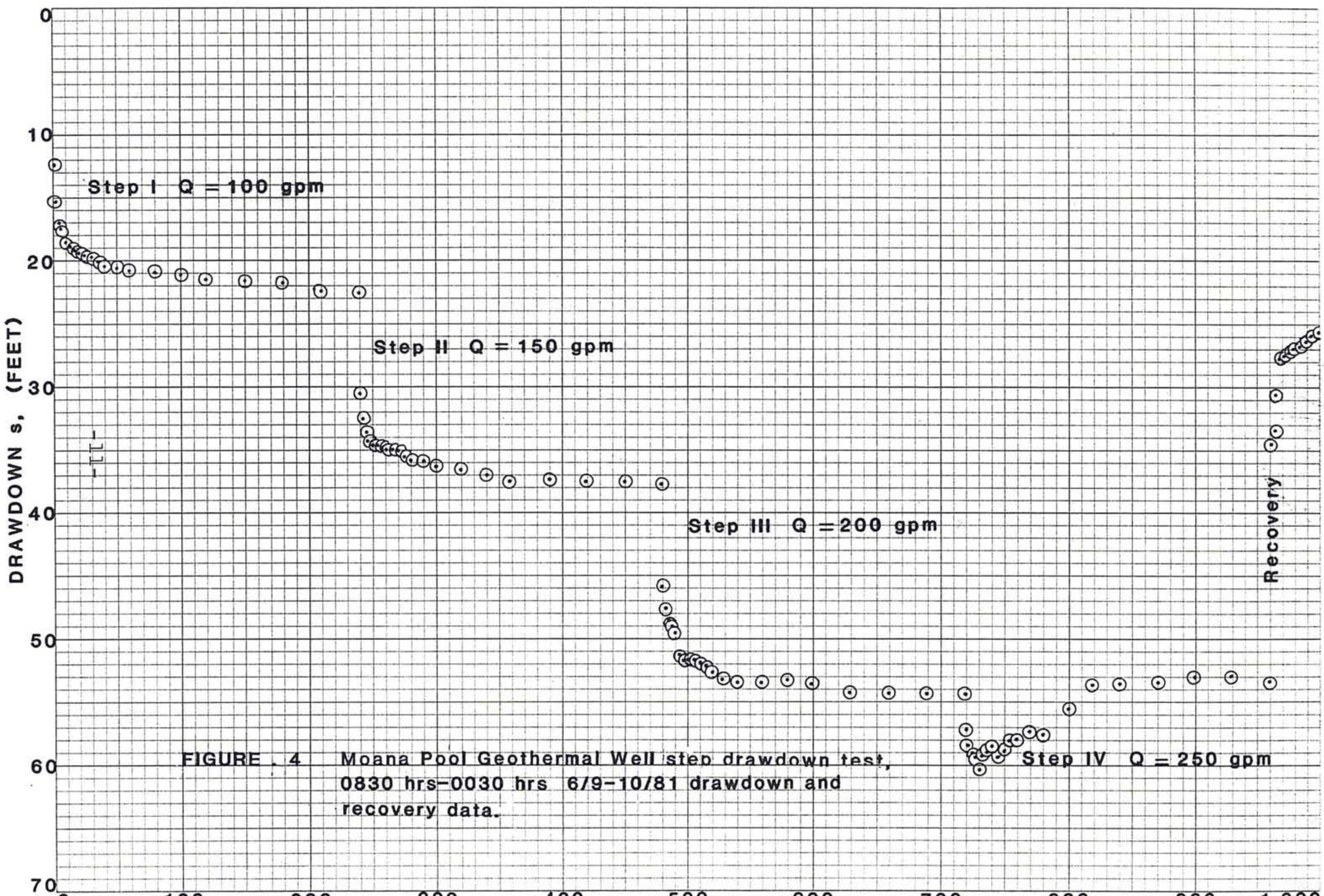


FIGURE . 4 Moana Pool Geothermal Well step drawdown test, 0830 hrs-0030 hrs 6/9-10/81 drawdown and recovery data.

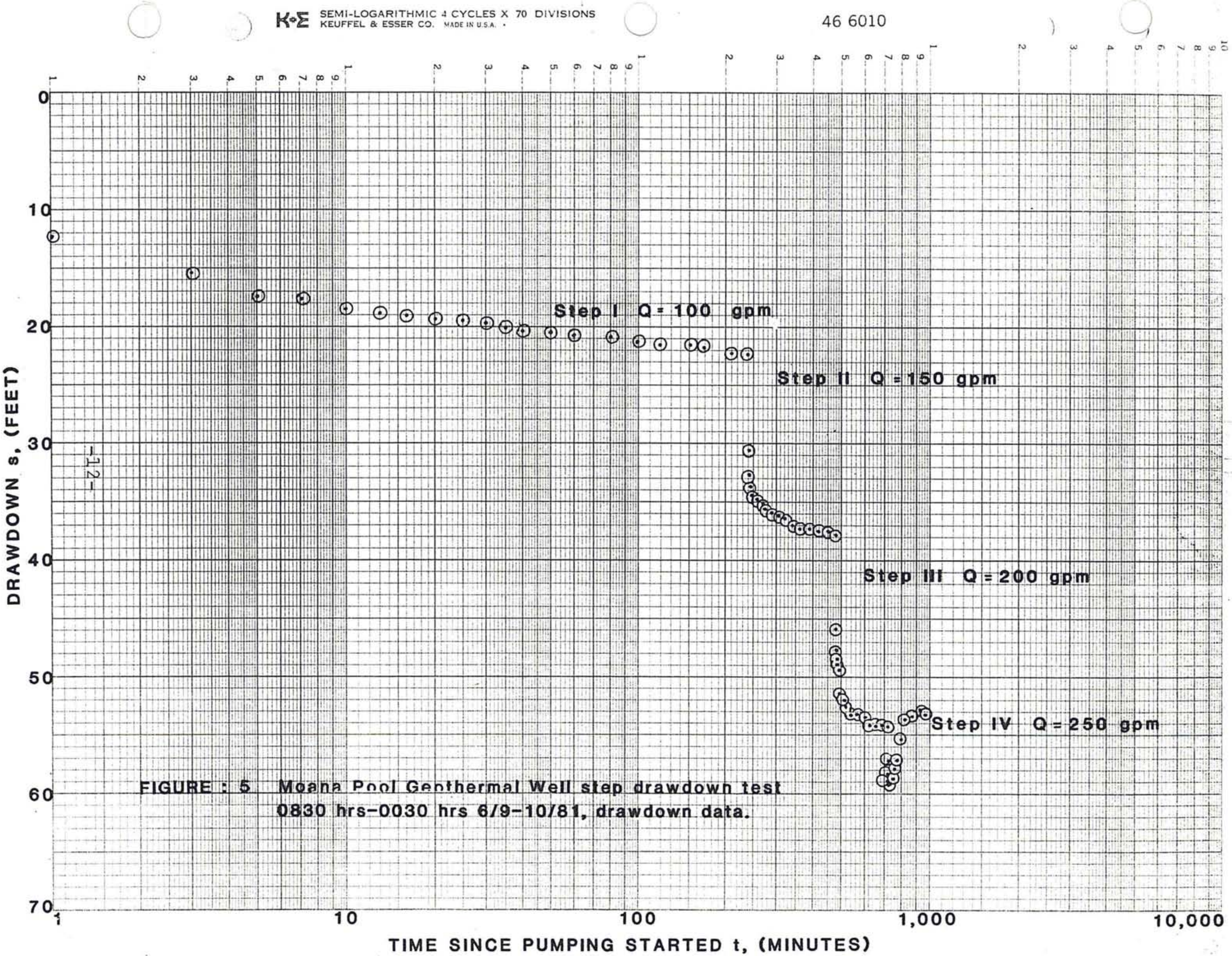


FIGURE : 5 Moana Pool Geothermal Well step drawdown test
0830 hrs-0030 hrs 6/9-10/81, drawdown data.

Temperature of discharge water during each step in the drawdown test remained a constant 51.5°C (124.7°F).

Step-drawdown test results indicate that additional well development occurred during the last step (250 gpm) of the test. During this step there was an abrupt rise in pumping water level, a decrease in drawdown, and an increase in the specific capacity (Figure 6). These effects suggest the collapse and removal of a "bridge" of formation fines which may have been plugging the formation. Step-drawdown test data were used to evaluate well efficiency prior to additional development of the well (Figures 7 and 8). The well loss analysis indicates that well efficiency improved near the end of step-drawdown testing. This is illustrated by the observed well efficiency of greater than 95 per cent compared to a theoretical well efficiency of about 80 per cent during the final step.

4.2 CONSTANT-DISCHARGE TESTING

A 24-hour (1440 minutes) constant-discharge test at a pumping rate of 200 gpm was conducted June 10 and 11, 1981, followed by 12 hours of recovery water level measurement. Test data are illustrated in Figures 9, 10 and 11 and summarized below:

> Static water level prior to testing was 21.74 feet below top of stilling well. Testing commenced at 2000 hours June 10, 1981. At the end of 24 hours drawdown was 46.76 feet, pumping water level was 68.50 feet, and specific capacity was calculated to be 4.28 gpm/ft. Testing terminated at 2000 hours June 11, 1981. Recovery of water levels in the well was rapid, approximately 96 per cent within 12 hours.

Appendix C contains constant-discharge pumping test drawdown and recovery data sheets.

Transmissivity, the overall ability of the aquifer to transmit ground water, was determined through analysis of the constant-discharge test data by the Theis non-steady state artesian aquifer equation, the Cooper-Jacob-straight-line approximation of the Theis equation, and Hantush-Jacob non-steady state leaky artesian aquifer equation (Lohman, 1972). The Theis equation describes the radial flow of ground water to a pumped well in an idealized artesian aquifer. When the artesian aquifer in which a well is completed is bounded above and/or below by a semi-permeable bed or aquitard, pumping of the well may induce vertical flow through such confining semi-permeable beds. This is referred to as "leakage". Calculated transmissivity values are summarized in Table 3.

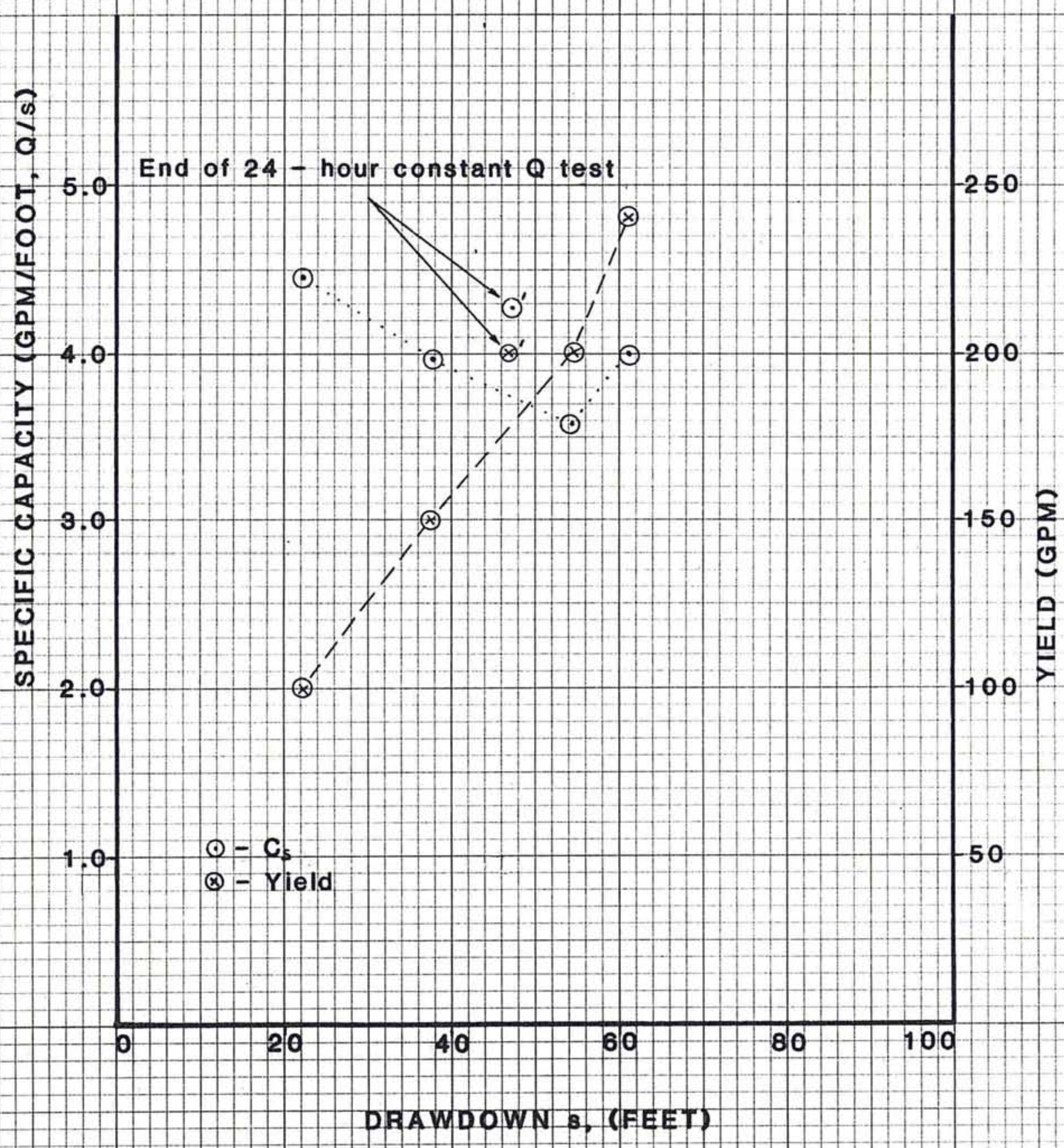


FIGURE . 6 Specific capacity and yield versus drawdown data, Moana Pool Geothermal Well.

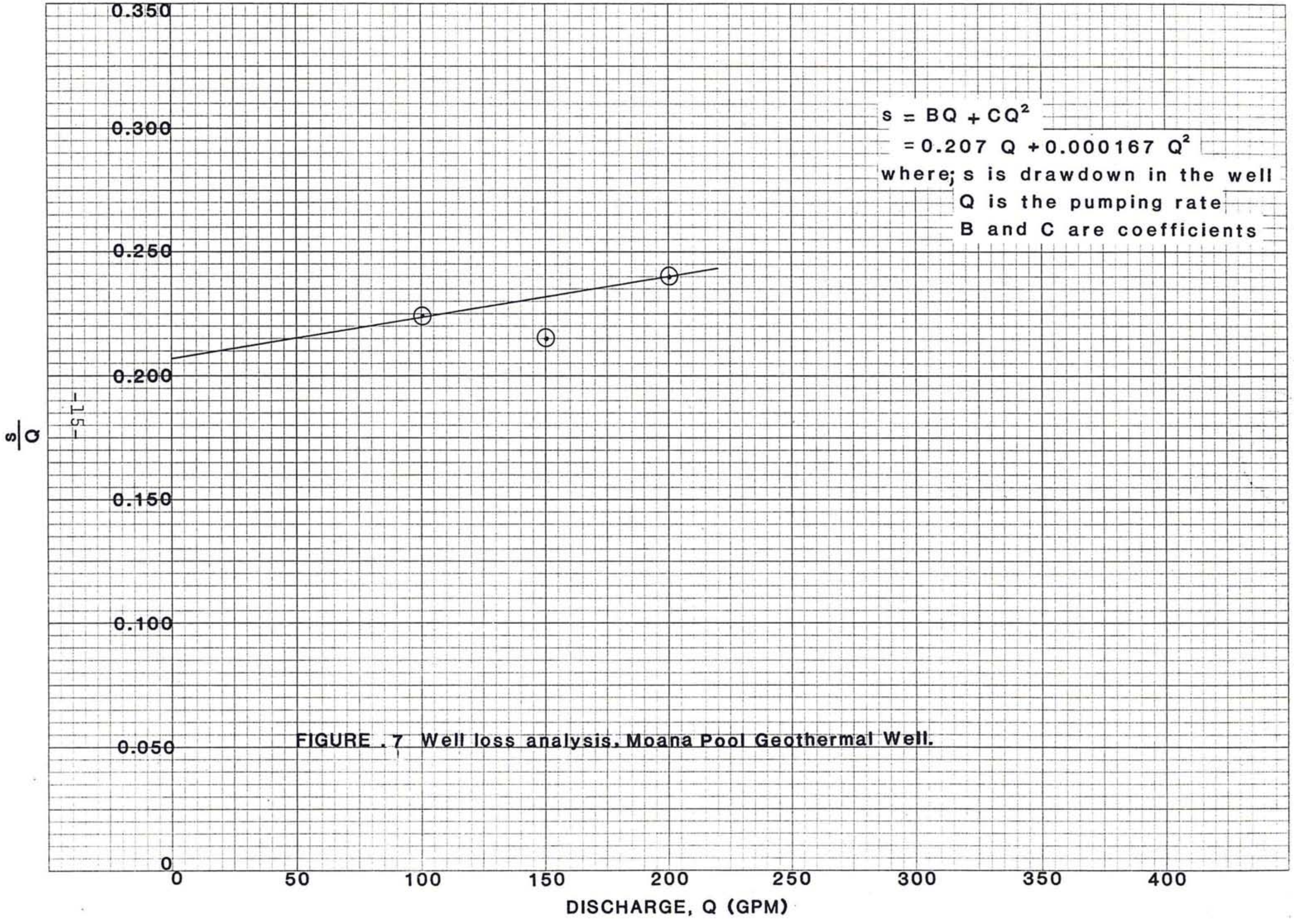


FIGURE . 7 Well loss analysis, Moana Pool Geothermal Well.

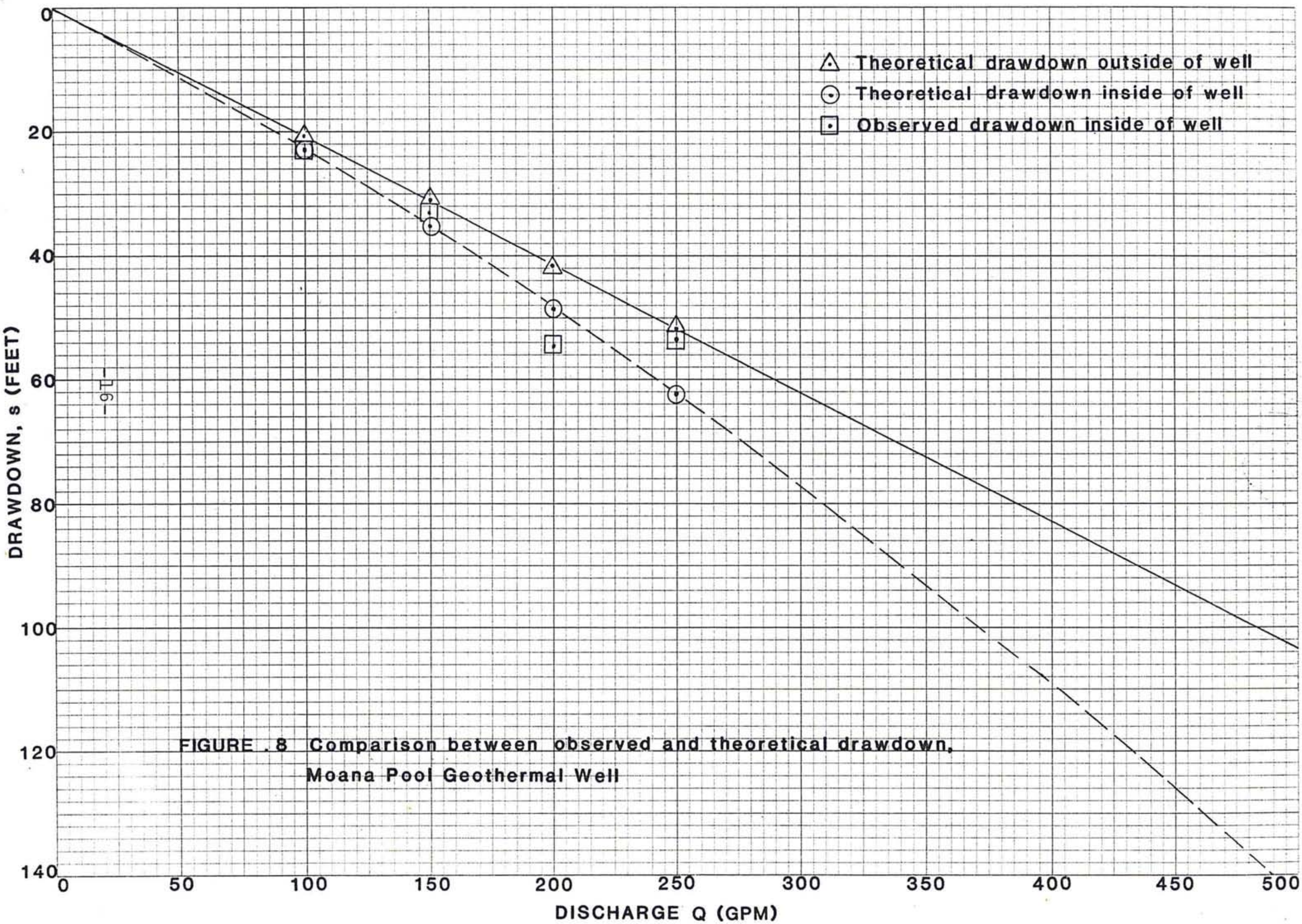


FIGURE . 8 Comparison between observed and theoretical drawdown, Moana Pool Geothermal Well

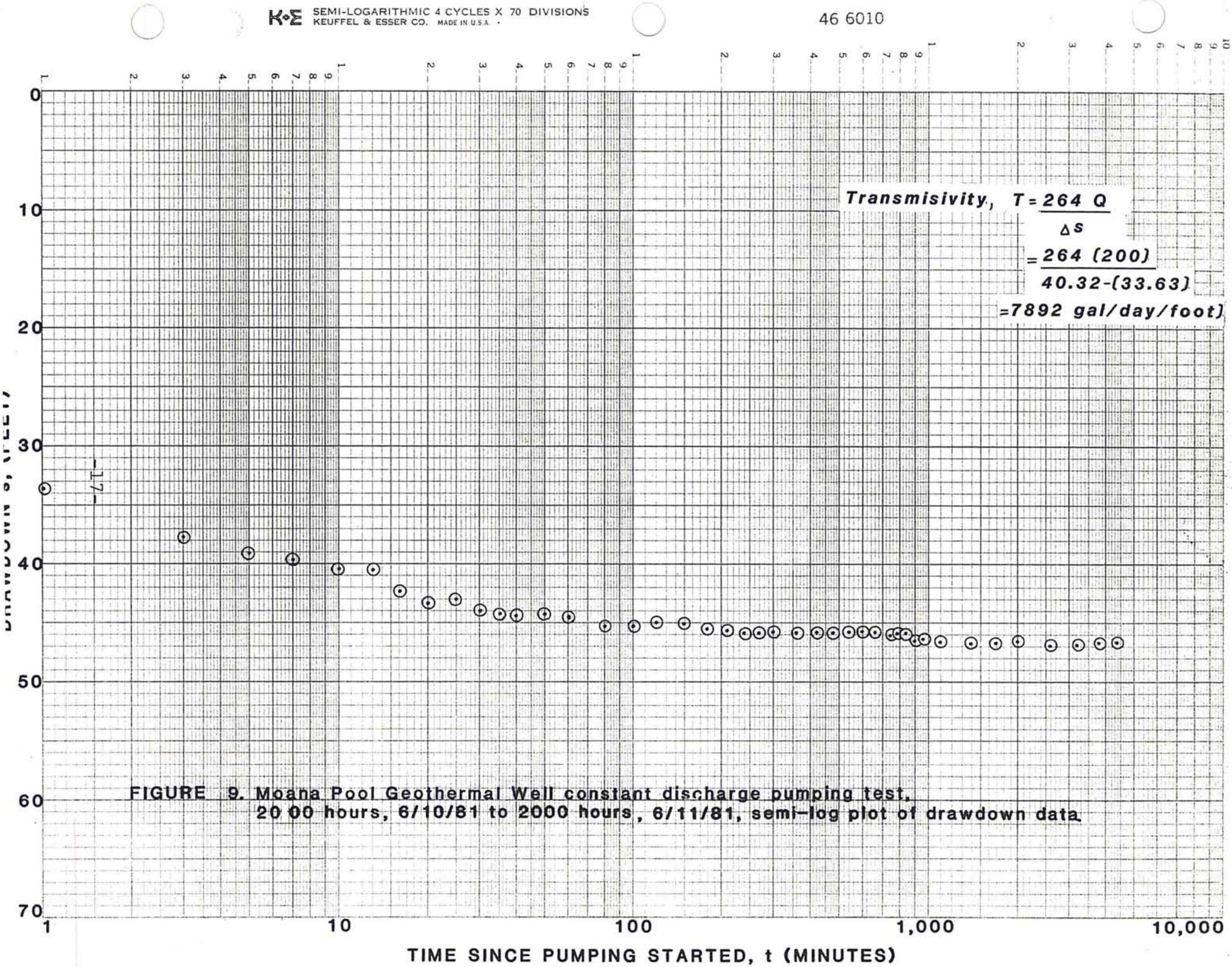


FIGURE 9. Moana Pool Geothermal Well constant discharge pumping test, 20 00 hours, 6/10/81 to 2000 hours, 6/11/81, semi-log plot of drawdown data.

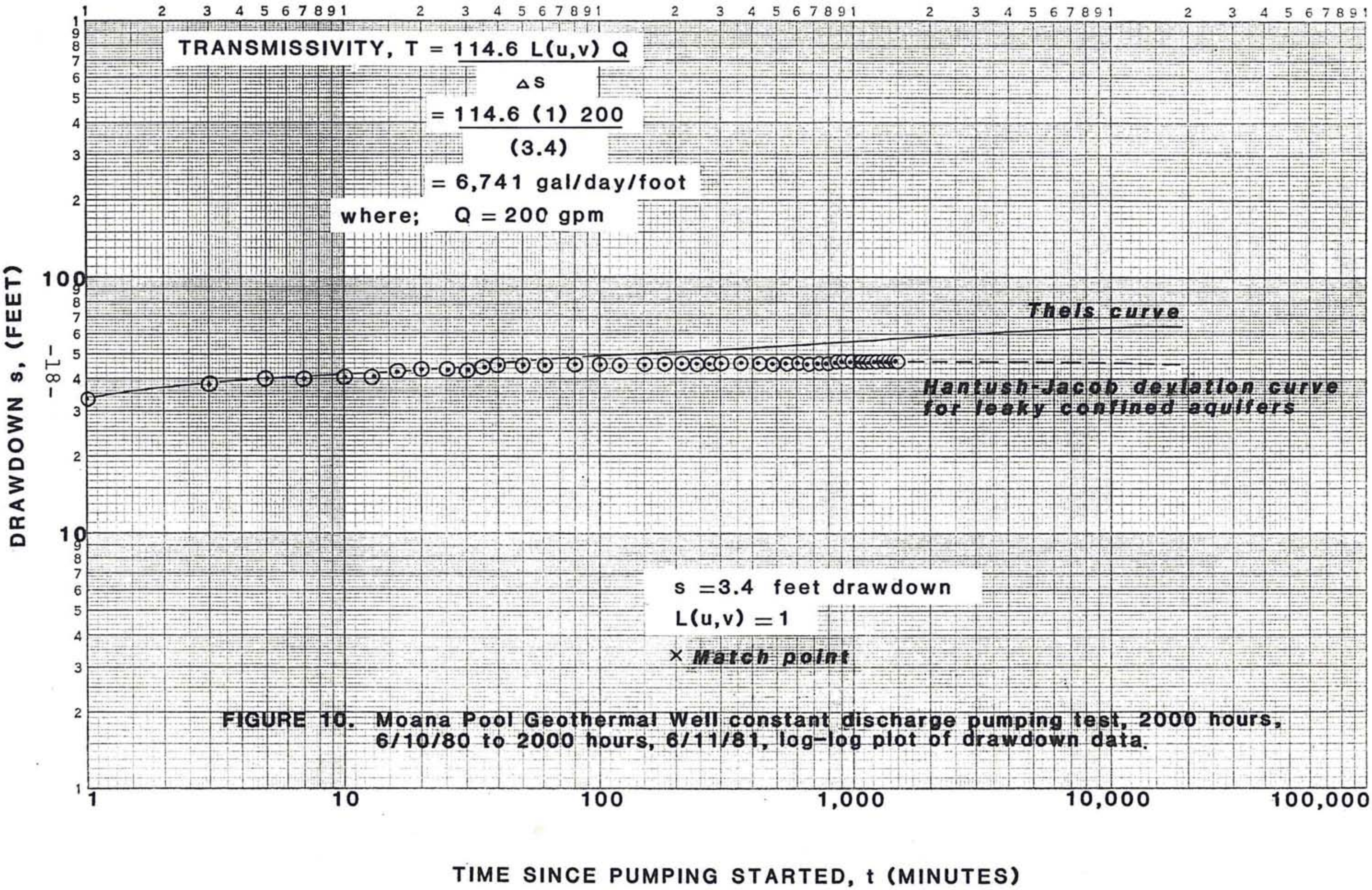


FIGURE 10. Moana Pool Geothermal Well constant discharge pumping test, 2000 hours, 6/10/80 to 2000 hours, 6/11/81, log-log plot of drawdown data.

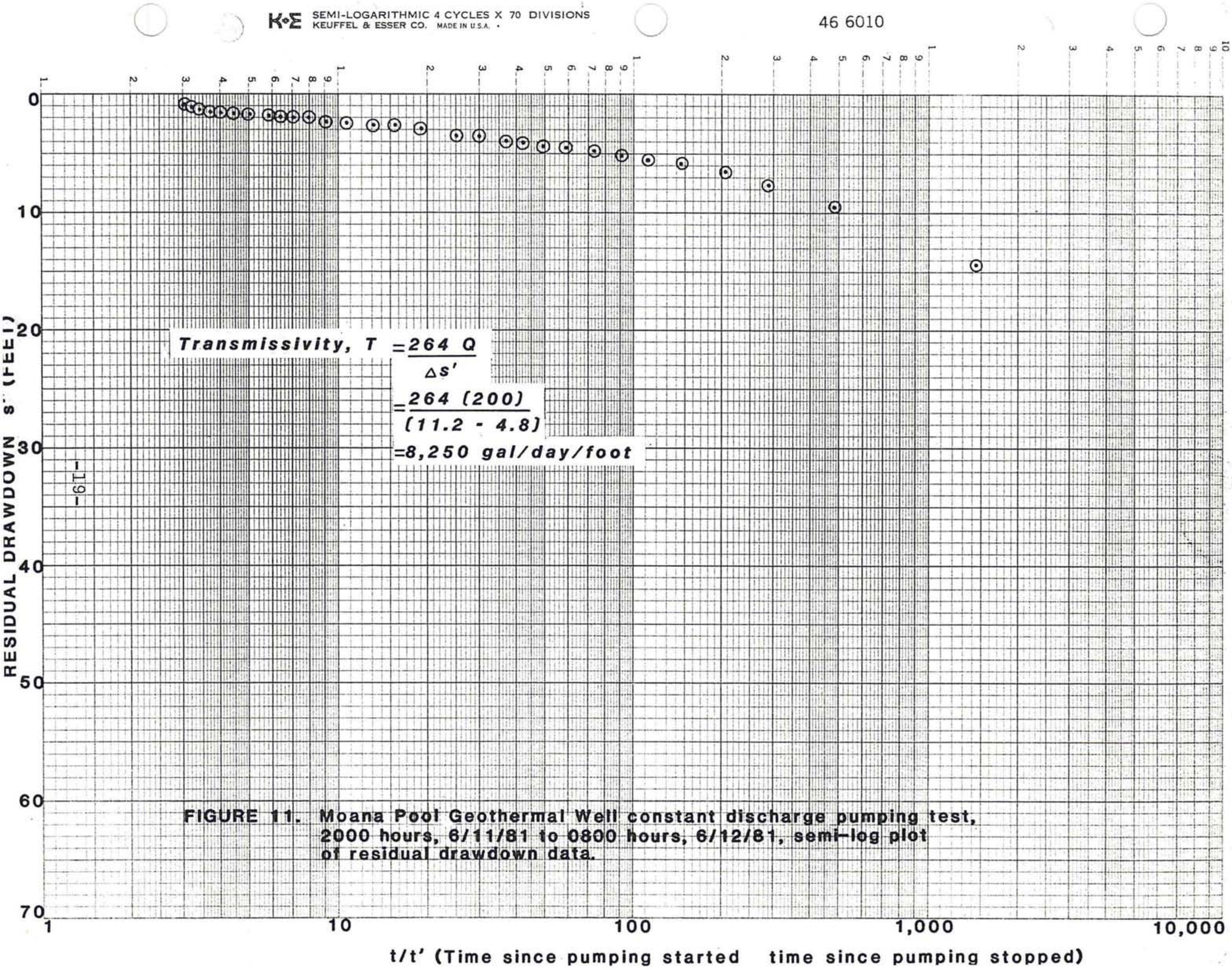


FIGURE 11. Moana Pool Geothermal Well constant discharge pumping test, 2000 hours, 6/11/81 to 0800 hours, 6/12/81, semi-log plot of residual drawdown data.

Table 3. Transmissivity values determined from pumping test data.

Method	Aquifer Type	Data	Transmissivity (gpd/ft/day)
Cooper-Jacob approximation	non-leaky artesian	drawdown	7892
Cooper-Jacob approximation	non-leaky artesian	residual drawdown	8250
Hantush-Jacob (and Theis)	Leaky artesian	drawdown	6741

Aquifer storage coefficient could not be calculated due to an absence of observation well data.

5.0 HYDROGEOLOGY

In the southwest Reno area, geothermal ground water rising through faulted Tertiary bedrock units is confined below a widespread characteristically blue clay strata. The geothermal water, inhibited from upward movement, moves laterally through permeable deposits of sands and gravels. The base of this confining clay layer was reached at approximately 310.0 feet depth during drilling of the Moana Pool well. Penetration of the confining bed was accompanied by an increase in the composite water temperature above that measured during drilling of the initial 300 feet.

Analysis of test data suggests that the aquifer tapped by the Moana Pool well may be characterized as a leaky artesian aquifer. Transmissivity data indicates that the geothermal aquifer tapped by the well is sufficient to meet the long-term water-supply requirements of the project.

6.0 YIELD RATING OF WELL

Data collected during the pumping tests may be used to rate the performance of the well. The 24-hour specific capacity of the well calculated from the constant-discharge test data was 4.28 gpd/ft. Given a static water level of 20 feet below L.S.D. and a maximum potential drawdown of 290 feet (drawdown to top of the major hot water-bearing strata), the well could yield up to approximately 1,200 gallons per minute of ground water at temperatures of 53°C (127.4°F). Pumping water levels will be correspondingly higher in the well at lower pumping rates. They may be approximated by:

$$h = \frac{Q}{4.28 \text{ gpm/ft}} + 20 \text{ ft.}$$

where h = pumping water level below L.S.D. (feet)

Q = pumping rate (gpm)

Therefore, at a peak pumping rate of 125 gpm, the pumping water level in the well will be approximately 49.2 feet below L.S.D. Pumping water levels should remain relatively stable due to the nature of the aquifer.

7.0 CHEMICAL QUALITY OF WATER FROM WELL

A water sample for chemical analysis was collected (on June 11, 1981) at the conclusion of constant-discharge testing. Results of the analysis are given in Table 4.

Table 4. Chemical quality data, Moana Pool Geothermal Well

(all constituents reported as milligrams per liter, unless otherwise noted)

		Drinking Water Standard
Temperature (°C)	53.0	
Field pH (pH units)	7.76	
Lab pH (pH units)	8.1	
Field Conductivity (μMHO/cm)		
Hardness (as $CaCO_3$)	58	
Alkalinity	117	
Total Dissolved Solids	624	
Ca	21	
Mg	0.9	150[2]
Na	160	
K	8.2	
Fe	0.03	0.6[2]
Mn	0.03	0.1[2]
SO_4	218	500[2]
Cl	28	400[2]
F	< 2.7*	1.4-2.4[1]
NO_3	0.1	10[1]
PO_4	0.03	
As	0.10*	0.05[1]
Ba	<0.05	1.0[1]
B	1.2	
Cd	<0.01	0.01[1]
Cr	<0.02	0.05[1]
Bb	<0.05	0.05[1]
Hg	<0.0005	0.002[1]

Table 4. (continued)

		Drinking Water Standard
Se	<0.005	0.01[1]
Ag	<0.01	0.05[1]
Cu	<0.02	1.0[1]
Zn	0.01	5[1]
SiO_2	83	

* exceeds Drinking-Water Standards.
1. USEPA Primary Drinking-Water Standards.
2. State of Nevada Secondary Drinking-Water Standards.

Review of the results of the chemical analysis indicates that the water does not meet State of Nevada Drinking-Water Standards. However, direct use of the water in the swimming pool may be permissible.

Detailed analysis of the water chemistry results provide some salient findings. The water is under-saturated with silica at temperatures down to about 8°C (46.4°F). Therefore, precipitation of silica in the well or within the heat exchanger itself does not appear to be a problem. The ground water is only slightly saturated with respect to calcium carbonate at the ambient ground-water temperature. However, potential for precipitation of calcite within the well or heat exchanger is minimal.

SOURCES OF INFORMATION

Bugenig, D. C., 1979, "Geothermal Exploration Moana Pool Site, Reno, Nevada"; private report prepared for Oregon Institute of Technology, Klamath Falls, Oregon, prepared by WILLIAM E. NORK, INC.

Bruin, J. and Hudson, H. E., 1961, "Selected Methods for Pumping Test Analysis"; Illinois State Water Survey, pp. 30-37.

Lohman, S. W., 1972, "Ground-Water Hydraulics"; U.S.G.S. Professional Paper 708.

Driller's Report to the State Engineer's Office.

U.S.G.S. Mount Rose N.E., Nevada 7.5-minute Topographic Quadrangle.

APPENDIX A

LITHOLOGIC LOG OF THE BOREHOLE AND GEOPHYSICAL LOGS

LOG OF BOREHOLE

BOREHOLE 81-195
PAGE 1 OF 4

LOC. or COORDS. Moana Pool GROUND ELEV. TOTAL DEPTH 469.7' BOREHOLE DIAM 17½" 0-10'; 13¾" 10-118'; 9⅞" 120-469.7'	DRILLER Aqua Drilling and Well Service RIG Ingersoll-Rand Cyclone TL[illegible] BIT(S) 17.5" (ACL 422); 13¾" (422); 9⅞" (6325) FLUID Bentonite;	DATE START 5/18/81 FINISH 5/29/81 TIME 1810 GEOPHYS LOG ✓ YES — NO HOW LEFT See construction log

Scale: 1" = 20'

LOCATION Moana Municipal Pool
LOGGED BY T.J. Moggio
PROJECT 81-195

DEPTH	PENE. RATE	CIRC est. loss	AIRLIFT Q (gpm)	MATERIAL	SYMBOL	DESCRIPTION and COMMENTS
20'			N/A mud to 120			
25'						
35'						qTz, black-purple volcanic fragments, biotite frags, pyrite, assorted other rock frags; chert, chalcedony, greenstone, med-grained to cobble sized, mostly angular.
55'						Lithology similiar to that above but with some clay fragments. Grain size ranges from cobbles & coarse sands to clay sized particles
65'						Mainly quartz and volcanics with the addition of more clay fragments. Pyrite dissappeared. Clay is tan colored and crumbles in the fingers
75'						Lithology similiar to that of above but overall grain size becoming smaller (finer). Grains angular to sub-rounded. Assorted rock frags included.
90'						Drilling becomes slower in this zone. Formation harder. Lithology similiar to descriptions above but becoming more clayey. QTz, granite frags, cherts, black volcs, chalcedony?, clay frags.
100'						Lithology same as above but becoming less clayey. Drilling not as hard, smoothing out at a steady rate. Mostly black volcanic frags.
120'						Lithology same as above but w/ less clays. QTz, black volcs, granite/diorite frags, Assorted rock & mineral frags: greenstones, biotite, chalcedony. fine to med grained, sub-rounded to angular.
						Blow >100+ gpm @ 42°C — gravel + sand.

☐ ~.5"
☐ ~.1"
☐ >.1"
☐ clay

LOG OF BOREHOLE

BOREHOLE 81-195
PAGE 2 OF 4

LOC. or COORDS. ______
GROUND ELEV. ______
TOTAL DEPTH 470'
BOREHOLE DIAM. ______

DRILLER AQUA DRILLER
SPARKS
RIG ______
BIT(S) ______
FLUID BENTONITE

START FINISH
DATE ______
TIME ______
GEOPHYS LOG — YES — NO
HOW LEFT ______

LOCATION SW Reno
LOGGED BY DLC
PROJECT 81-195

DEPTH	PENE. RATE	CIRC. wt. loss	AIRLIFT Q (gpm)	MATERIAL	SYMBOL	DESCRIPTION and COMMENTS
140				Sand & sandy clay		clayey sand some yellow + "blue" clay sloughing badly from above. Much of the clay is washing out and cuttings are being circulated thru mud pump.
160						more of same. recirculated cuttings a real problem. Fouling jets on bit & interfering w/ pump operation.
170						Brown - grey clay matrix. Black, green & red volc sands. Minor green chert. .2" & .1" ave dia. Interbedded clays & clayey sands.
180						Clay matrix predom. Volc & qtz sands + chert grains. .05", .2", .8" ave dia - larger sand grains in sample because 170-180 air blown. Semi-Ang. .8" (gravels) probably sloughing from above. Frag. of concrete probably from partially (?) destroyed cement filling of possum belly T = 42°C
						Volc sands + minor qtz. Interbedded grey clay & clayey sands 90-95% grs. .05" ave dia (size decreased because switched from air to mud drilling). Semi-Ang. sands. $T_{190-200}$ = 28°C (mud) Additional bag of bentonite added at 200'.
205						Black & green Volc sands + qtz grs. Semi-ang. Extremely clayey - drill balling up. Added detergent at 215'. Grain size increased to .1" ave (due to increase in viscosity of mud ?).
230'						Clay decreased slightly - drilling faster
240'						90% grs. Chips of clay in sample vs clay mud. Drilling again slowing down - increase in clay. Semi-ang sand grs. of volc sands + minor qtz & chert. 2 sizes: .05" and .1" ave. $T_{245-250}$ = 32°C
265'						Clay lenses + clayey sands. .05" ave dia., larger population diminished. $T_{265-270}$ = 34°C $T_{290-295}$ = 35°C
280						

1" = 20'

LOG OF BOREHOLE

BOREHOLE Moana Pool 81-195
PAGE 3 OF 4

LOC. or COORDS. ______ DRILLER ______

GROUND ELEV. ______

TOTAL DEPTH ______ RIG ______

BOREHOLE DIAM. ______ BIT(S) ______

FLUID ______

START FINISH

DATE ______

TIME ______

GEOPHYS LOG — YES — NO

HOW LEFT ______

LOCATION SW Reno

LOGGED BY DLC

PROJECT 81-195

DEPTH	PENE. RATE	CIRC (est. loss)	AIRLIFT Q (gpm)	MATERIAL	SYMBOL	DESCRIPTION and COMMENTS
280'						Clay lenses + clayey sands. .05" ave dia, larger population (.1") diminished $T_{265-270} = 34°C$
						$T_{290-295} = 35°C$
300'						Ended 1 section of drilling
						Began drilling
310'						Grey clay + volc sands .05" & .1" ave dia.
315'						
320'						Large reduction in amt of clay. Cuttings are SS c̄ minor clays. 80-90% grs. Ang → Semi-Ang. Volcanics, qtz & micas. Extremely fine-grained sands (.01" ave dia) from 320-330'. .05" dia again at ~325', becoming predominant after 330'. Unconsolidated material (drilling slowed down) hit at 345'
						$T_{360-365'} = 34°C$
370'						75% Grs. Sub-Ang. Clays greatly diminished. Grs. slightly larger .1" ave. dia. Consolidated sands hit at 375'. $T_{375-380} = 35°C$
380'						90-95% Grs. Definite green chert sands. .05"-.1" ave. dia. from 380-390', losing predominance of .05" dia after 390'. $T_{415-420} = 35°C$
410'						

LOG OF BOREHOLE

BOREHOLE Moana Pool 81-195
PAGE 4 OF 4

LOC. or COORDS. ______
GROUND ELEV. ______
TOTAL DEPTH ______
BOREHOLE DIAM. ______

DRILLER ______
RIG ______
BIT(S) ______
FLUID ______

	START	FINISH
DATE		
TIME		

GEOPHYS LOG — YES — NO
HOW LEFT ______

DEPTH	PENE. RATE	CIRC	AIRLIFT Q (gpm)	MATERIAL	SYMBOL	DESCRIPTION and COMMENTS
410'						90-95 % Grs. Definite green chert sands. .05"-.1" ave. dia. from 380-390'. Losing predominance of .05" dia. after 390' $T_{415-420}$ = 35 °C
445'						after 445', again began hitting distinct clay beds. Qtz sands & monomineralic grains seen to be increasing. Clay again predominant. $T_{465-470}$ = 36.5 °C
480'						

LOCATION SW Reno
LOGGED BY DLC
PROJECT 81-195

APPENDIX B

CONSTRUCTION SUMMARY AND DRILLER'S REPORT

WELL *Moana Pool Geotherm*

WELL CONSTRUCTION SUMMARY

PROJECT *81-195 Moana Pool Geothermal Well*

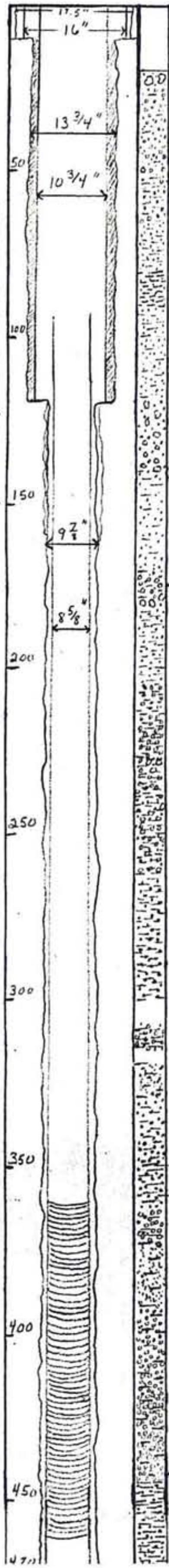
LOCATION *Moana Pool SW Reno*

PERSONNEL *TJ DCB DLC*

LOCATION or COORDS: *NE¼, NE¼ NW¼ Sec. 25, T.19 N., R.19E*

ELEVATION: GROUND LEVEL ______

TOP OF CASING ______



Scale: 1" = 50'

DRILLING SUMMARY:

TOTAL DEPTH *469.7 T.D.*

BOREHOLE DIAMETER *17 ½" 0-10'; 13 3/4" 10-118'; 9 7/8" 120-469.7'*

DRILLER *Aqua Drilling & Pump Service Sparks, NV*

RIG *Ingersoll-Rand Cyclone TH60*

BIT(S) *17 ½" (ACG 422); 13 3/4" (422); 9 7/8" (#6325)*

DRILLING FLUID *Bentonite*

SURFACE CASING *16" O.D.; +3.5' to -6.5'*

CONSTRUCTION TIME LOG.

TASK	START DATE	START TIME	FINISH DATE	FINISH TIME
DRILLING:				
17 ½"	5/18/81		5/18/81	
13 3/4"	5/19/81	1600	5/19/81	2000
9 7/8"	5/22		5/29/81	1810
GEOPHYS. LOGGING:	5/28	1330	5/28	1400
	5/30	730	5/30	900
CASING:				
10 3/4" (C1)	5/19/81	830	5/19/81	1145
8 5/8" (C2)	5/30/81	1145	6/2/81	0921
FILTER PLACEMENT	NONE			
CEMENTING:	5/21/81	1415	5/21/81	1445
DEVELOPMENT:	6/2/81	1000	6/11/81	2000
OTHER:				
drill plug	5/26/81	0945	5/26/81	1020

WELL DESIGN:

BASIS: GEOLOGIC LOG ✓ GEOPHYSICAL LOG ✓

CASING STRING(S): C=CASING S=SCREEN

+1	118'	C1
90	359.7	C2
359.7	459.7	S1
459.7	469.7	C2

CASING: C1 *10 3/4" OD. x 0.210" wall*

C2 *8 5/8" O.D. x 0.270" wall*

C3 ______

C4 ______

SCREEN: S1 *8" pipe size Johnson #30*

S2 ______

S3 ______

S4 ______

CENTRALIZERS *None*

FILTER MATERIAL *None (natural gravel pack)*

CEMENT *5170 lbs. cement in annular space from 118' to surface*

OTHER *drill plug 3 yd³ 165' to 90' (requested only 1.5 yd³ for 165' to 118')*

WELL DEVELOPMENT

Blow screened interval c̄ drill rig mounted compressor - no dispersant

COMMENTS:

cement installed via tremie pipe from 118' to surface to seal off cooler water.

Attempt to drill c̄ air below 118' foiled by loose formation & caving

Johnson Figure 'K' Packer

WHITE—DIVISION OF WATER RESOURCES
CANARY—CLIENT'S COPY
PINK—WELL DRILLER'S COPY

STATE OF NEVADA
DIVISION OF WATER RESOURCES

WELL DRILLERS REPORT

Please complete this form in its entirety

OFFICE USE ONLY
Log No.
Permit No.
Basin.

1. OWNER City of Reno ADDRESS Moana Pool - Moana Ln, Reno

2. LOCATION NE ¼ NW ¼ Sec. 25 T. 19 N/S R. 19 E. Washoe County
PERMIT NO.

3. TYPE OF WORK
New Well ☒ Reconditon ☐
Deepen ☐ Other ☐

4. PROPOSED USE
Domestic ☐ Irrigation ☐ Test ☐
Municipal ☒ Industrial ☐ Stock ☐
Geothermal Well

5. TYPE WELL
Cable ☐ Rotary ☒
Other ☐

6. LITHOLOGIC LOG

Material	Water Strata	From	To	Thickness
Concrete		0	1	1
Sand & cobbles		1	16	15
lightly cemented sands medium		16	58	42
Volcanic sand & gravel		58	90	32
Fine & Medium sands		90	170	80
Fine to Medium Sands w/ embedded clays blue & green		170	320	150
Medium sands - less clay than above				
Coarse sand & minor clay		375	445	70
Sand & minor clay		445	420	25
Compact clay		470	480	10
T.D. 480				

Date started 5-18, 19 81
Date completed 6-2, 19 81

7. WELL TEST DATA

Pump RPM	G.P.M.	Draw Down	After Hours Pump
Blew Well at 750 CFM - 175 # for 5½ hours to clean & develop			

BAILER TEST
G.P.M. Draw down feet hours
G.P.M. Draw down feet hours
G.P.M. Draw down feet hours

8. WELL CONSTRUCTION
17" - 10'
13¾' - 120
Diameter hole 9⅞ inches Total depth 480 feet
Casing record
Weight per foot 247 Thickness 277

Diameter	From	To
16" inches	0 feet	8 feet
10 ¾ inches	0 feet	115 feet
8 ⅝ inches	90 feet	470 feet
inches	feet	feet
inches	feet	feet
inches	feet	feet

Surface seal: Yes ☒ No ☐ Type Cement Slurry
Depth of seal 120' feet
Gravel packed: Yes ☐ No ☒
Gravel packed from — feet to — feet

Perforations:
Type perforation Johnson Screen
Size perforation .030
From 460 feet to 360 feet
From feet to feet
From feet to feet
From feet to feet
From feet to feet

9. WATER LEVEL
Static water level 18.35 Feet below land surface
Flow 50 + G.P.M.
Water temperature 133 °F. Quality Good

10. DRILLERS CERTIFICATION
This well was drilled under my supervision and the report is true to the best of my knowledge.

Name Agua Drilling
Address 2255 Glendale Av. Sparks
Nevada contractor's license number 15291
Nevada driller's license number 1132
Signed R M White
Date 6-4-81

RECEIVED
JUN 29 1981

USE ADDITIONAL SHEETS IF NECESSARY

APPENDIX C

TEST PUMPING DATA

Data for Well 81-195 Page 1 of 5

Distance, r, to pumping well _____ ft. Date 6/9-10/81 (830-0030)

Pumping well Moana Pool Geothermal Other observation wells ______

Location SW Reno Moana Pool Observers DLC

4 Step - Drawdown Test

DATE	time in hours	time, t, since pump started--mins.	time, t', since pump stopped--mins.	ratio t/t'	WATER depth -- ft.	WATER drawdown, s -- ft.	WATER residual DD, s' -- ft.	WATER distance to well $(r)^2$ -- ft^2	WATER r^2/t -- ft^2/min	PUMPING motor - RPM	PUMPING flow -- GPM	temp. -- °C	REMARKS
6-9-81	830	0			20.06						100		level of PVC pipe
	831	1			32.44	12.38						50.0	above
	833	3			35.39	15.33						50.5	ground =
	835	5			37.21	17.15							2.26'
	837	7			37.76	17.70							
	840	10			38.63	18.57							
	843	13			38.96	18.90							
	846	16			39.30	19.24						51.0	
	850	20			39.51	19.45							
	855	25			39.78	19.72						51.5	
	900	30			39.88	19.82							
	905	35			40.23	20.17							
	910	40			40.49	20.43						51.5	
	920	50			40.67	20.61							
	930	60			40.95	20.89						51.5	
	950	80			41.03	20.97							
	1010	100			41.29	21.23						51.5	
	1030	120			41.65	21.59						52.0	
	1100	150			41.65	21.59							
	1130	180			41.98	21.92						51.5	
	1200	210			42.33	22.27							
	1230	240			42.44	22.38						52.0	°C
													ave. T = 51.3
													C_s = 4.47

Data for Well 81-195 — Page 2 of 5

Distance, r, to pumping well ______ ft. — Date 6/9-10/81 (830-0030 HRS.)

Pumping well Moana Pool Geothermal — Other observation wells ______

Location SW Reno Moana Pool — Observers DLC

4 Step - Drawdown Test

DATE	time in hours	time, t, since pump started--mins.	time, t', since pump stopped--mins.	ratio t/t'	WATER: depth -- ft.	WATER: drawdown, s -- ft.	WATER: residual DD, s' -- ft.	WATER: distance to well $(r)^2$ -- ft^2	WATER: r^2/t -- ft^2/min	PUMPING: motor - RPM	PUMPING: flow -- GPM	temp. -- °C	REMARKS
6-9-81	1231	1 / 241			50.76	30.70					150		
	1233	3 / 243			52.83	32.77						51.5	
	1235	5 / 245			53.82	33.76						51.5	
	1237	7 / 247			54.28	34.22							
	1240	10 / 250			54.53	34.47						51.5	
	1243	13 / 253			54.77	34.71							
	1246	16 / 256			54.95	34.89							
	1250	20 / 260			55.00	34.94						51.5	
	1255	25 / 265			55.04	34.98							
	1300	30 / 270			55.16	35.10							
	1305	35 / 275			55.76	35.70						51.5	slightly
	1310	40 / 280			55.94	35.88							adjusted
	1320	50 / 290			56.10	36.04						51.5	pump up
	1330	60 / 300			56.30	36.24							
	1350	80 / 320			56.56	36.50						51.75	slightly
	1410	100 / 340			57.07	37.01							adjusted
	1430	120 / 360			57.31	37.25							pump
	1500	150 / 390			57.31	37.25						51.75	higher
	1530	180 / 420			57.53	37.47							°C
	1600	210 / 450			57.61	37.55						51.75	Ave T = 51.6
	1630	240 / 480			57.86	37.80						51.75	C_s = 3.97

Data for Well 81-195

Distance, r, to pumping well ______ ft. Date 6/9-10/81

Pumping well Moana Pool Geothermal Other observation wells ______

Location SW Reno Moana Pool Observers DLC / SP

Step drawdown

DATE	time in hours	time, t, since pump started--mins.	time, t', since pump stopped--mins.	ratio t/t'	WATER depth -- ft.	drawdown, s -- ft.	residual DD, s' -- ft.	distance to well (r)^2 -- ft^2	r^2/t -- ft^2/min	PUMPING motor - RPM	flow -- GPM	temp. -- °C	REMARKS
6-9-81	1631	1 / 481			66.05	45.99					200	51.5	
	1633	3 / 483			67.85	47.79							
	1635	5 / 485			68.61	48.55							
	1637	7 / 487			69.11	49.05						51.5	
	1640	10 / 490			69.44	49.38							adj back pressure up
	1643	13 / 493			71.43	51.37						51.5	slightly
	1646	16 / 496			71.88	51.82							readjusted down
	1650	20 / 500			71.71	51.65						51.75	
	1655	25 / 505			71.90	51.84							
	1700	30 / 510			72.06	52.00						51.75	
	1705	35 / 515			72.19	52.13							
	1710	40 / 520			72.80	52.74						51.5	increased back pres-
	1720	50 / 530			73.29	53.23							sure slightly
	1730	60 / 540			73.40	53.34						51.5	pressure
	1750	80 / 560			73.49	53.43							now ~
	1810	100 / 580			73.30	53.24							constant
	1830	120 / 600			73.79	53.73							
	1900	150 / 630			74.34	54.28							°C
	1930	180 / 660			74.32	54.26							Ave T = 51.6
	2000	210 / 690			74.34	54.28						51.5	C_s = 3.68
	2030	240 / 720			74.36	54.30							

William Nork

Data for Well 81-195 | Page 4 of 5

Distance, r, to pumping well ____ ft. | Date 6/9-10/81

Pumping well Moana Pool Geothermal | Other observation wells ____

Location SW Reno Moana Pool | Observers DLC / SP

Step - drawdown

DATE	time in hours	time, t, since pump started--mins.	time, t', since pump stopped--mins.	ratio t/t'	WATER: depth -- ft.	drawdown, s -- ft.	residual DD, s' -- ft.	distance to well (r)^2 -- ft^2	r^2/t -- ft^2/min	PUMPING: motor - RPM	flow -- GPM	temp. -- °C	REMARKS
	2031	1 / 721			77.31	57.25					250		
	2033	3 / 723			78.72	58.66							gate valve wide open -
	2035	5 / 725			79.15	59.09						51.5	pressure dropped to
	2037	7 / 727			79.47	59.41							240 gpm
	2040	10 / 730			80.21	60.15							at 2046 hrs
	2043	13 / 733			79.25	59.19							
	2046	16 / 736			79.06	59.00							well may
	2050	20 / 740			78.73	58.57							be developing
	2055	25 / 745			79.38	59.32							
	2100	30 / 750			79.01	58.95							
	2105	35 / 755			78.12	58.06							
	2110	40 / 760			78.01	57.95							
	2120	50 / 770			77.98	57.32							
	2130	60 / 780			77.64	57.58							
	2150	80 / 800			75.55	55.50							changed probe - same
	2210	100 / 820			73.81	53.75						51.5	reading
	2230	120 / 840			73.82	53.76							
	2300	150 / 870			73.64	53.58						51.5	
	2330	180 / 900			73.11	53.06							
	2400	210 / 930			73.05	52.99						51.5	pH = 7.61
6-10-81	0030	240 / 960			73.30	53.24							Sp. Cond =
													650 mgl
													°C
													Ave T = 51.5
													C_s = 3.99

Data for Well 81-195

Page 5 of 5

Distance, r, to pumping well ______ ft.

Date 6/10/81

Pumping well Moana Pool Geothermal Other observation wells

Location SW Reno Moana Pool

Observers DLC / SP

Step-drawdown Recovery

DATE	time in hours	time, t, since pump started--mins.	time, t', since pump stopped--mins.	ratio t/t'	WATER depth -- ft.	WATER drawdown, s -- ft.	WATER residual DD, s' -- ft.	WATER distance to well $(r)^2$ -- ft^2	WATER r^2/t -- ft^2/min	PUMPING motor - RPM	PUMPING flow -- GPM	temp. -- °C	REMARKS
6-10-81	0030	960	0		73.30		53.24						
	0031	961	1	961.0									
	0032	962	2	481.0	34.50		14.44						
	0035	965	5	193.0	33.41		13.35						
	0037	967	7	138.1	30.62		10.56						
	0040	970	10	97.0	27.90		7.84						
	0043	973	13	74.8	27.85		7.79						
	0046	976	16	61.0	27.44		7.38						
	0050	980	20	49.0	27.01		6.95						
	0055	985	25	39.4	26.98		6.92						
	0100	990	30	33.0	26.41		6.35						
	0105	995	35	28.4	26.00		5.94						
	0110	1000	40	25.0	25.85		5.79						
	0120	1010	50	20.2	25.00		4.94						
	0130	1020	60	17.0	24.61		4.55						
	0150	1040	80	13.0	24.04		3.98						
	0210	1060	100	10.6	23.98		3.92						
	0230	1080	120	9.0	23.46		3.40						
	0300	1110	150	7.4	23.00		2.94						
	0330	1140	180	6.3	22.99		2.93						
	0715	1185	225	5.3	22.44		2.38						
	1155	1645	685	2.4	22.07		2.01						
	1605	1925	965	2.0	21.88		1.82						92% recovery

Data for Well 81-195 Page 1 of 4

Distance, r, to pumping well ______ ft. Date 6/10-11/81 (2000 - 2000 HRS.)

Pumping well Moana Pool Geothermal Other observation wells ______

Location SW Reno Moana Pool Observers S.P.

Constant Discharge Test

DATE	time in hours	time, t, since pump started--mins.	time, t', since pump stopped--mins.	ratio t/t'	WATER: depth -- ft.	drawdown, s -- ft.	residual DD, s' -- ft.	distance to well (r)^2 -- ft^2	r^2/t -- ft^2/min	PUMPING: motor - RPM	flow -- GPM	temp. -- °C	REMARKS
6-10-81	2000	0			21.74						200		
	2001	1			55.37	33.63							
	2003	3			59.35	37.61						50.0	
	2005	5			60.97	39.23						50.0	adjust Q
	2007	7			61.51	39.77						51.0	
	2010	10			62.06	40.32							
	2013	13			62.07	40.33						51.0	
	2016	16			63.98	42.24							
	2020	20			64.93	43.19						51.0	
	2025	25			64.71	42.97							
	2030	30			65.65	43.91							
	2035	35			65.82	44.08							
	2040	40			65.95	44.21							
	2050	50			65.80	44.06						51.0	
	2100	60			66.36	44.62							
	2120	80			66.87	45.13							
	2140	100			66.86	45.12							
	2200	120			66.70	44.96							
	2230	150			66.83	45.09						51.5	
	2300	180			67.21	45.47							
	2330	210			67.53	45.79							
	2400	240			67.59	45.85						51.5	
-11-81	0030	270			67.59	45.85							
	0100	300			67.60	45.86							Cond = 750 µ/c
	0200	360			67.58	45.84							pH = 7.74
	0300	420			67.56	45.82						51.5	
	0400	480			67.57	45.83							

Williams Dixie

Data for Well 81-195

Distance, r, to pumping well ____ ft.

Date 6/10-11/81

Pumping well Moana Pool Geothermal Other observation wells ____

Location SW Reno Moana Pool

Observers S.P., DLC

Constant Discharge Test

DATE	time in hours	time, t, since pump started--mins.	time, t', since pump stopped--mins.	ratio t/t'	WATER depth -- ft.	drawdown, s -- ft.	residual DD, s' -- ft.	distance to well (r)^2 -- ft^2	r^2/t -- ft^2/min	PUMPING motor - RPM	flow -- GPM	temp. -- °C	REMARKS
6-11-81	0500	540			67.51	45.77					200	51.5	
	0600	600			67.46	45.72							
	0700	660			67.65	45.91							Ph=7.65
	0800	720			67.73	45.99						51.0	Cond=700ppm
	0900	780			67.60	45.86							
	1000	840			67.63	45.89							
	1100	900			68.03	46.29							
	1200	960			67.97	46.23							Ph meter
	1300	1020			68.24	46.50							touchy
	1400	1080			68.33	46.59						51.0	Ph=7.77
	1500	1140			68.28	46.54							cond=575ppm
	1600	1200			68.20	46.46							
	1700	1260			68.46	46.72							
	1800	1320			68.50	46.76							Ph=7.76
	1900	1380			68.50	46.76						51.0	Cond=625ppm
	2000	1440			68.48	46.74							
													Ph meter
													slow in
													calibrating
													$C_s = \frac{200}{46.76}$
													= 4.28

Data for Well 81-195

Distance, r, to pumping well ____ ft. Date 6/11-12/81 (2000 -

Pumping well Moana Pool Geothermal Other observation wells ____

Location SW Reno, Moana Pool Observers S.P., D&C

Constant Discharge Test Recovery

DATE	time in hours	time, t, since pump started--mins.	time, t', since pump stopped--mins.	ratio t/t'	WATER: depth -- ft.	WATER: drawdown, s -- ft.	WATER: residual DD, s' -- ft.	WATER: distance to well $(r)^2$ -- ft^2	WATER: r^2/t -- ft^2/min	PUMPING: motor - RPM	PUMPING: flow -- GPM	temp. -- °C	REMARKS
6-11-81	2000	1440	0		68.48		46.74						
	2001	1441	1	1441.0	36.05		14.31						
	2003	1443	3	481.0	31.27		9.53						
	2005	1445	5	289.0	29.29		7.55						
	2007	1447	7	206.7	28.23		6.49						
	2010	1450	10	145.0	27.66		5.92						
	2013	1453	13	111.8	27.11		5.37						
	2016	1456	16	91.0	26.85		5.11						
	2020	1460	20	73.0	26.52		4.78						
	2025	1465	25	58.6	26.25		4.51						
	2030	1470	30	49.0	26.07		4.33						
	2035	1475	35	42.1	25.81		4.07						
	2040	1480	40	37.0	25.67		3.93						
	2050	1490	50	29.8	25.36		3.62						
	2100	1500	60	25.0	25.12		3.38						
	2120	1520	80	19.0	24.66		2.92						
	2140	1540	100	15.4	24.42		2.68						
	2200	1560	120	13.0	24.27		2.53						
	2230	1590	150	10.6	24.00		2.26						
	2300	1620	180	9.0	23.85		2.11						
	2330	1650	210	7.9	23.70		1.96						
	2400	1680	240	7.0	23.65		1.91						
12-81	0030	1710	270	6.3	23.61		1.87						
	0100	1740	300	5.8	23.52		1.78						
	0200	1800	360	5.0	23.46		1.72						

Data for Well 81-195

Page 4 of 4

Distance, r, to pumping well ____ ft.

Date 6/11-12/81

Pumping well Moana Pool Geothermal Other observation wells ____

Location SW Reno Moana Pool

Observers SP, DLC

Constant Discharge Test Recovery

DATE	time in hours	time, t, since pump started--mins.	time, t', since pump stopped--mins.	ratio t/t'	WATER: depth -- ft.	WATER: drawdown, s -- ft.	WATER: residual DD, s' -- ft.	WATER: distance to well (r)^2 -- ft^2	WATER: r^2/t -- ft^2/min	PUMPING: motor - RPM	PUMPING: flow -- GPM	temp. -- °C	REMARKS
6-12-81	0300	1860	420	4.4	23.35		1.61						
	0400	1920	480	4.0	23.23		1.49						
	0500	1980	540	3.7	23.01		1.27						
	0600	2040	600	3.4	22.93		1.19						
	0700	2100	660	3.2	22.81		1.07						
	0800	2160	720	3.0	22.70		0.96						