

D Foley

UTAH STATE PRISON
GEOTHERMAL TEST

Prepared For:

UTAH STATE DIVISION OF
FACILITIES CONSTRUCTION AND MANAGEMENT

Prepared By:

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ABSTRACT
EXECUTIVE SUMMARY

Morrison-Knudsen Company, Inc. in association with the University of Utah Research Institute conducted a 30 day flow test of the Utah State Prison Geothermal well located near Riverton, Utah. The project consisted of pre-test monitoring, flow testing, chemical sampling and analysis, and well recovery monitoring. The test consisted of flowing at 300 gallons per minute for 20 days, increasing the flow to 600 gallons per minute for 14 days and monitoring recovery for 10 days. In addition to the test well seven surrounding wells and two thermal springs were monitored.

Data from the test show the water to be a sodium chloride type with a total dissolved solid content ranging from 1778 to 1898 ppm. The Utah Roses Well, the State Forestry Well, and Crystal Hot Springs all have similiar water chemistry as the Utah State Prison Well. A significant difference is seen in non-thermal ground water in the study area supporting the concept the source of the thermal water is the deeper quartzites with the source of the groundwater the overlying clay-rich sediments.

Reservoir data support the concept of a fractured, rather extensive reservoir. Transmissivities are high (for USP/TH-1) ranging up to 160,000 gpd/ft at the 600 gallon per minute flow rate. Test data indicate the Utah State Prison well will sustain flow at the desired 200 gallon per minute rate assuming no excessive withdrawals occur from other wells developed in the reservoir. Ample recharge should occur during the non-heating season to recharge the reservoir to within 80 to 100 percent of the original pre-production pressures.

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UTAH STATE PRISON
GEOTHERMAL TEST

1.0 INTRODUCTION

Morrison-Knudsen Company, Inc. (M-K) in association with the University of Utah Research Institute (URRI) contracted with the State of Utah, Department of Administrative Services for the Utah State Geothermal Well Test Program.

The testing program consisted of four (4) areas:

1. Test Set-Up and Pre-Test Monitoring
2. Pump Testing Well USP/TH-1
3. Chemical Sampling and Analysis
4. Well Recovery Monitoring

1.1 TEST SET-UP AND PRE-TEST MONITORING

M-K subcontracted the installation of the wellhead configuration and discharge piping, and initiated pre-test monitoring at the following sites:

- USP/TH-1
- SF-1
- Utah Roses Production Well
- Observation Wells B, C, D, E, and F
- Springs CF-1 and CF-2

1.2 PUMP TESTING WELL USP/TH-1

The initial test plan was to consist of 30 days of pumping well USP/TH-1 with subsequent monitoring of pressure, flow, temperature, and chemistry. Also, pressure was monitored at well SF-1 and Utah Roses production well with water level monitoring of Gradient Hole B and

discharge monitoring of springs CR-2 and CR-3. Four additional gradient holes were monitored during the test to gather interference data (Figure 1).

The initial test was executed 24 hours prior to full production. The first test sequence consisted of a Step-Drawdown test with discharges of 100 gpm, 200 gpm, and 300 gpm and then the well was allowed to recover overnight. A short duration 600 gpm test was conducted during the installation of the EG&G corrison coupon assembly. This test suggested modifying the test program to further stress the aquifer system. On July 6, 1982, the production test was increased to a 600 gpm discharge rate to provide additional stress to the reservoir. During the entire test period, geochemical samples were collected and analyzed by URRI.

1.3 CHEMICAL SAMPLING AND ANALYSIS

The sampling was conducted by URRI in accordance with the Utah State Prison Geothermal Production Test Plan and is described in more detail in Section 9.

1.4 WELL RECOVERY MONITORING

At the completion of the production test, pressure recovery monitoring was initiated. This involved pressure recovery monitoring of Production Well USP/TH-1, Well SF-1, and Utah Roses production well. Water level recovery monitoring was established at Gradient Hole B and flow monitoring of springs CR-2 and CR-3.

LEGEND

⊙ WELLS

⊕ TEMPERATURE GRADIENT HOLES

--- INFERRED FAULTS
(BALL SYMBOL ON DOWN THROWN SIDE OF FAULT)

⊙ LEE

⊙ ASARCO

UTAH ROSES
PRODUCTION WELL

USP/TH-1

UTAH STATE
PRISON

PRISON
FARM

SF-1

CR-2
MINIMUM
SECURITY
BLDG.

CANAL

CR-4

WESTERN
POND

⊕ E

CR-3

⊕ F

UTAH ROSES
COOLING WATER

⊙ HALL

500 Feet

Scale: approx. 1:6,000

FIGURE 1

MONITORING LOCATIONS-CRYSTAL HOT SPRINGS AREA
(From DOE/ET/27027-4, 1981)

2.0 PROJECT BACKGROUND

The project site is located at the Utah State Prison in an area known as Crystal Hot Springs. Development is focused on the Crystal Hot Springs geothermal resource, the surface expression of which is located on private property adjacent to Utah State Prison property.

The initial geophysical assessment of the geothermal resource at Crystal Hot Springs was initiated in October of 1979 and consisted of areo-magnetic and gravity surveys. The geophysical reconnaissance program provided the structural details needed to focus the test drilling program on the most promising production targets available to the State Prison. Subsequent drilling and well testing was conducted to provide additional data input in the siting and design of a production well and preliminary design activities. The results of this program provided preliminary baseline thermal, hydraulic, and chemical characteristics in the vicinity of Crystal Hot Springs.

3.0 GEOLOGY

The Crystal Hot Springs geothermal system is a deep convective system located at the eastern margin of the Basin and Range physiographic province. The thermal springs are located north of an east-northeast trending horst that is perpendicular to the structural trend of the Wasatch Front grabens. The horst, known as the Traverse Range, consists of highly fractured mid-Paleozoic quartzites and tertiary volcanics. Meteoric water enters the system in the adjacent ranges and circulates to depths of 3 KM, where it is heated. The thermal fluids return to the surface along steeply dipping range front faults that bound the northern flank of the range. The thermal springs issue between two range front faults that are buried beneath Tertiary and Quaternary age valley fill deposits. Highly fractured quartzite beneath the valley fill act as the reservoir for the thermal water that is being targeted for development.

The surface expression is defined by several hot thermal springs which discharge within a 70 acre area. At the center of the Crystal Hot Springs resource area, thermal springs at temperatures of 55-58°C issue to the surface through alluvium that is approximately 80 feet thick.

Subsurface geology, as interpreted from lithologic data collected from USP/TH-1 during drilling, indicate a layer of Bonneville Lake clays from the surface to approximately 85 feet with the last 20 feet containing some sand. A zone of quartzitic and andesitic sand and gravel was then encountered from 85 feet to approximately 261 feet. A 10 foot zone of clay was encountered between the clay and the top the quartzite. The quartzite is considered as the reservoir rock and was drilled from approximately 271 feet to a total well depth of 1,000 feet (Utah Energy Office, 1981).

From lithologic logs, drillers logs, and temperature logs collected on USP/TH-1 during and after drilling two zones appear to be permeable. The first occurs from 480 to 615 feet and the second from 615 to 1,000

feet. The deeper zone appears to have significantly greater permeability and was used in arriving at the 400 foot thickness for the production zone in Well USP/TH-1. Considering the fractured nature of the reservoir, this thickness can only be used as an approximation.

4.0 GEOHYDROLOGY

At the Utah State Prison site there are two separate aquifer systems: one a shallow, confined to semi-confined aquifer; the other a deep, artesian geothermal aquifer which contains waters apparently heated at depth in the fractures of the quartzites. There is some interaction between the two systems; however, each has its own distinct waterbearing characteristics.

4.1 SHALLOW AQUIFER (CONFINED/SEMI-CONFINED)

The shallow aquifer lies within the recent interbedded alluvium and lacustrine deposits and derives most of its recharge from surface sources such as rainfall, streams, canals, and irrigation.

Several wells have been drilled into the shallow aquifer for domestic and irrigation water supplies. Many of these wells have been reported to be discharging warm waters which indicates leakage of the deeper thermal aquifer into the shallow ground water system.

4.2 DEEP ARTESIAN GEOTHERMAL AQUIFER

The deep aquifer (geothermal reservoir) occurs at a depth of approximately 400 to over 1,000 feet and consists of a fractured system within Quartzitic rocks. Thermal water, upwelling along spur faults of the Wasatch Range, provides the shallow geothermal waters. Recharge is thought to occur through deep circulation within the range front faults with upwelling occurring within the spur faults associated with the major range front fault.

The results of the Crystal Hot Springs Resource Assessment (in 1979) yielded the following values for reservoir parameters:

1. Permeability = 1570-4340 millidarcy
2. Porosity/Compressibility Product = 1.59×10^{-5} psi⁻¹
3. Well Skin Factor = -1.51

4. Reservoir Area = $4.5 \times 10^6 \text{ ft}^2$
5. Impermeable Boundary Location = 730 ft
6. Well/Reservoir Shape Factor = 0.101
(DOE/ET/27027-4)

5.0 WELL TESTING

The objective of the reservoir test was to develop pressure response and drawdown data which would be analyzed to develop a prediction model of the geothermal system. The parameters identified would consist of the estimated life of the geothermal reservoir and water quality. The test essentially consisted of stressing the aquifer by producing fluid through artesian flow and observing changes, if any, in pressures or water levels at the production well and observation wells.

The production well (USP/TH-1) was allowed to flow artesian at constant discharges during the test period. The test program consisted of a step-drawdown test, a constant discharge test, and a recovery test. The discharge test was later modified to provide additional stress to the geothermal reservoir by doubling the discharge rate.

Drawdown pressures at the production well were measured at the surface by a pressure gauge and a Parascientific Digiquartz Pressure Transducer interfaced to a Hewlett Packard Thermal Printer via a Parascientific Digiquartz unit.

The Utah Roses observation well was similarly monitored while the SF-1 well was equipped with a Heise pressure gauge. Other observation wells were monitored using an electric sounding tape. The springs were monitored via a Parshall flume and staff gauge.

6.0 DATA PRESENTATION

6.1 STEP DRAWDOWN TESTING

The step drawdown test of USP/TH-1 was conducted at increments of 100 gpm, 200 gpm and 300 gpm. This data shows distinct pressure responses at each step. Wellhead pressure remained constant at 8.5 psi at the 100 gpm rate, 8.4 psi at the 200 gpm rate and 8.0 psi at the 300 gpm rate. A scattering of points is noted towards the latter part of the test as CO₂ gas lift conditions start to prevail. Also a sharp rise in well head pressure of 0.2 to 0.3 psi occurs immediately upon changing flow but stabilizes within 10 minutes into each flow increment (Figure 2).

6.2 300 GPM CONSTANT RATE TEST

The constant rate variable drawdown production test was initiated on June 16 at a constant artesian flow rate of 300 gpm in Well USP/TH-1. The well was flowed at a constant rate of 300 gallon/minute (gpm) for 20 days then increased to 600 gpm and flowed for 14 days.

At the 300 gpm rate the production well indicates a steady trend of pressure decline of approximately 0.4-0.5 psi per log cycle. A scattering of points occurred which was the result of CO₂ flashing within the well bore causing a gas lift with resultant surging (Figure 3).

Data from the Utah Roses production well which was used as an observation well indicates a stabilizing of pressure declines at 50 hours into the test. Two major boundaries can be seen from this data. The first boundary was one hour into the test and the second was 20 to 30 hours into the test (Figure 4).

The Utah State Forestry observation well also shows a pressure decline but with stabilization of drawdown occurring 200 hours into the test (Figure 5). Several boundaries can be detected in the curve such as at 19 hours and 200 hours into the test. The scattering of points in the last 100 hours of the test indicates a stabilization of the drawdown.

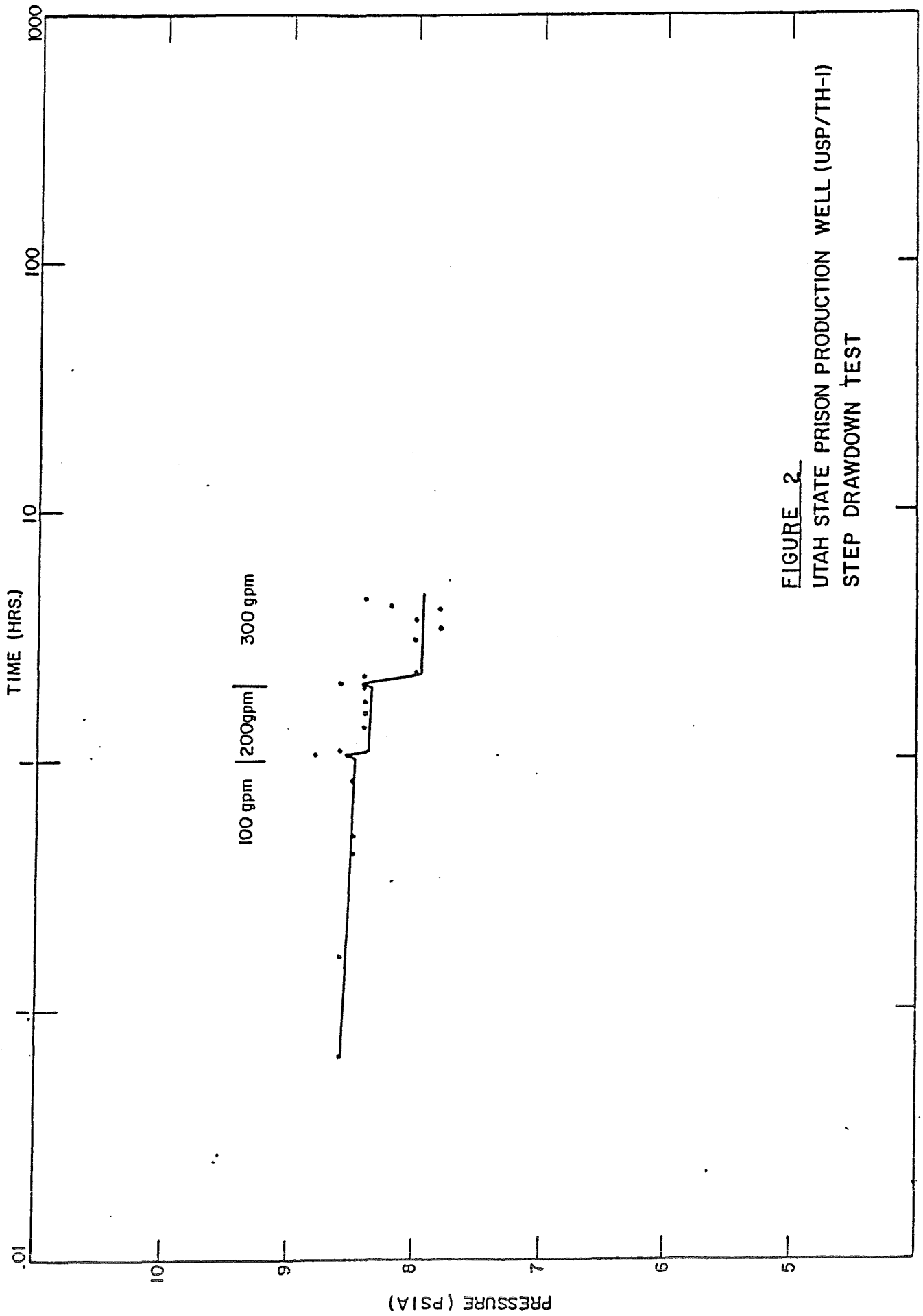


FIGURE 2
 UTAH STATE PRISON PRODUCTION WELL (USP/TH-1)
 STEP DRAWDOWN TEST

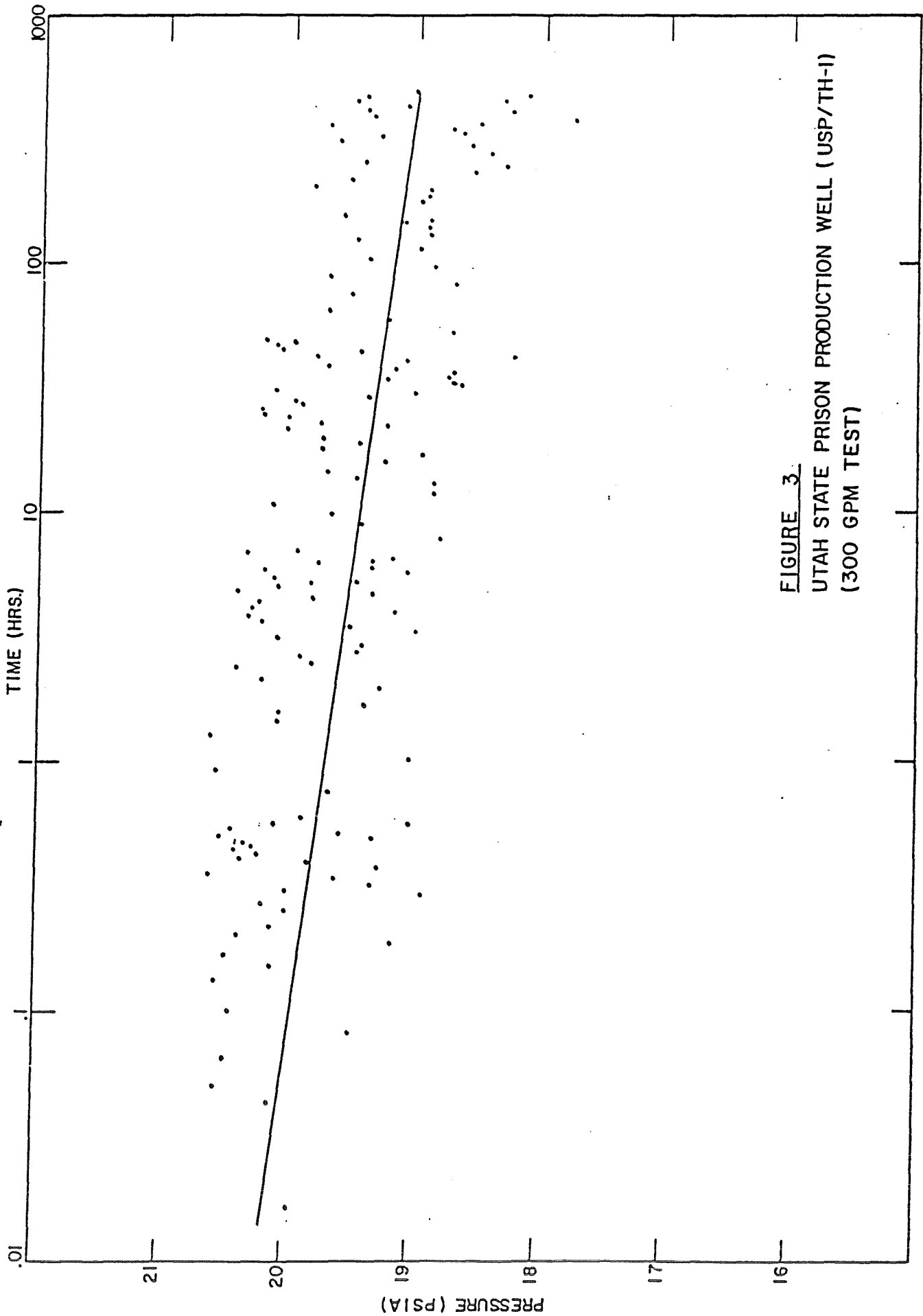


FIGURE 3.
UTAH STATE PRISON PRODUCTION WELL (USP/TH-1)
(300 GPM TEST)

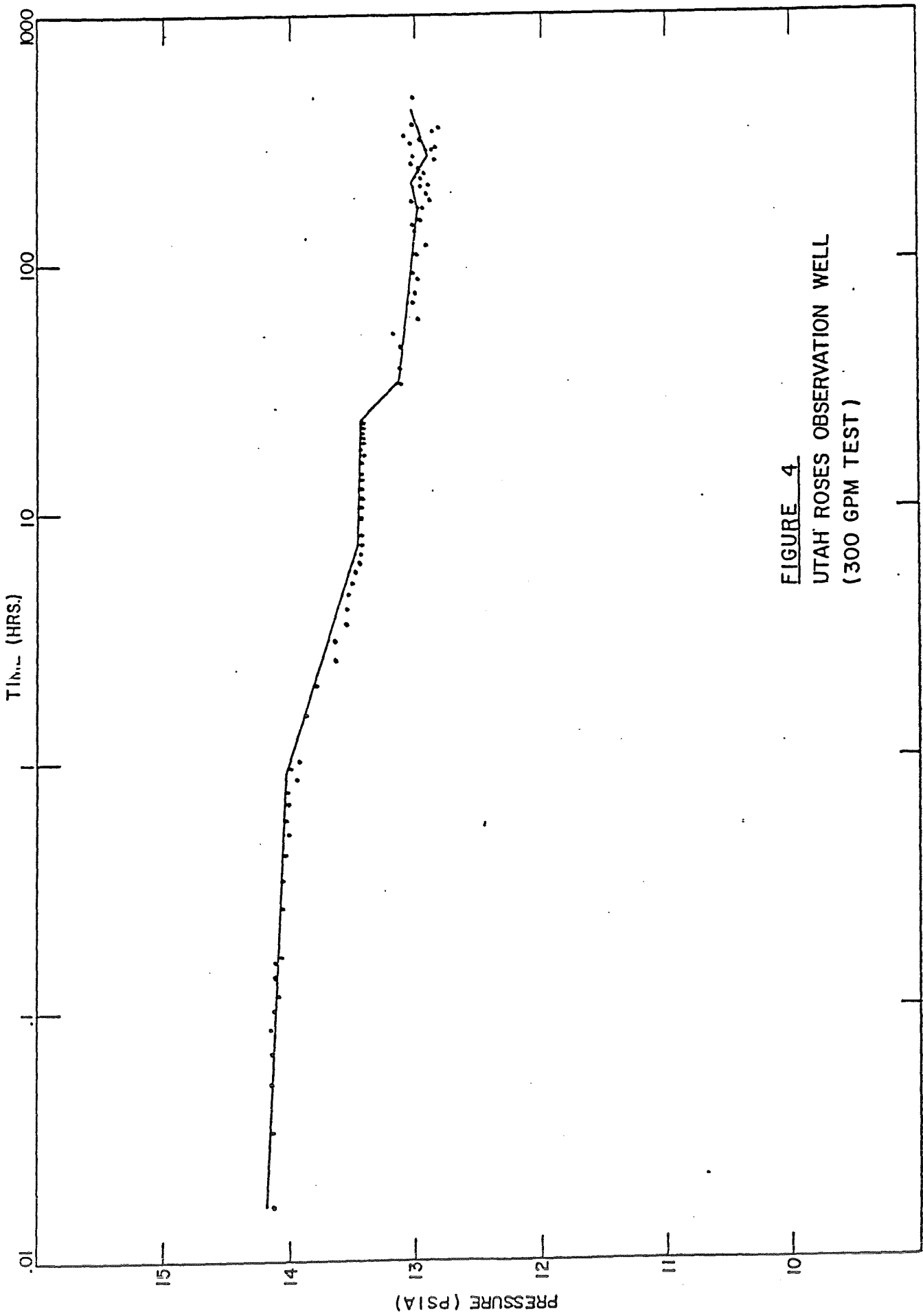


FIGURE 4
 UTAH ROSES OBSERVATION WELL
 (300 GPM TEST)

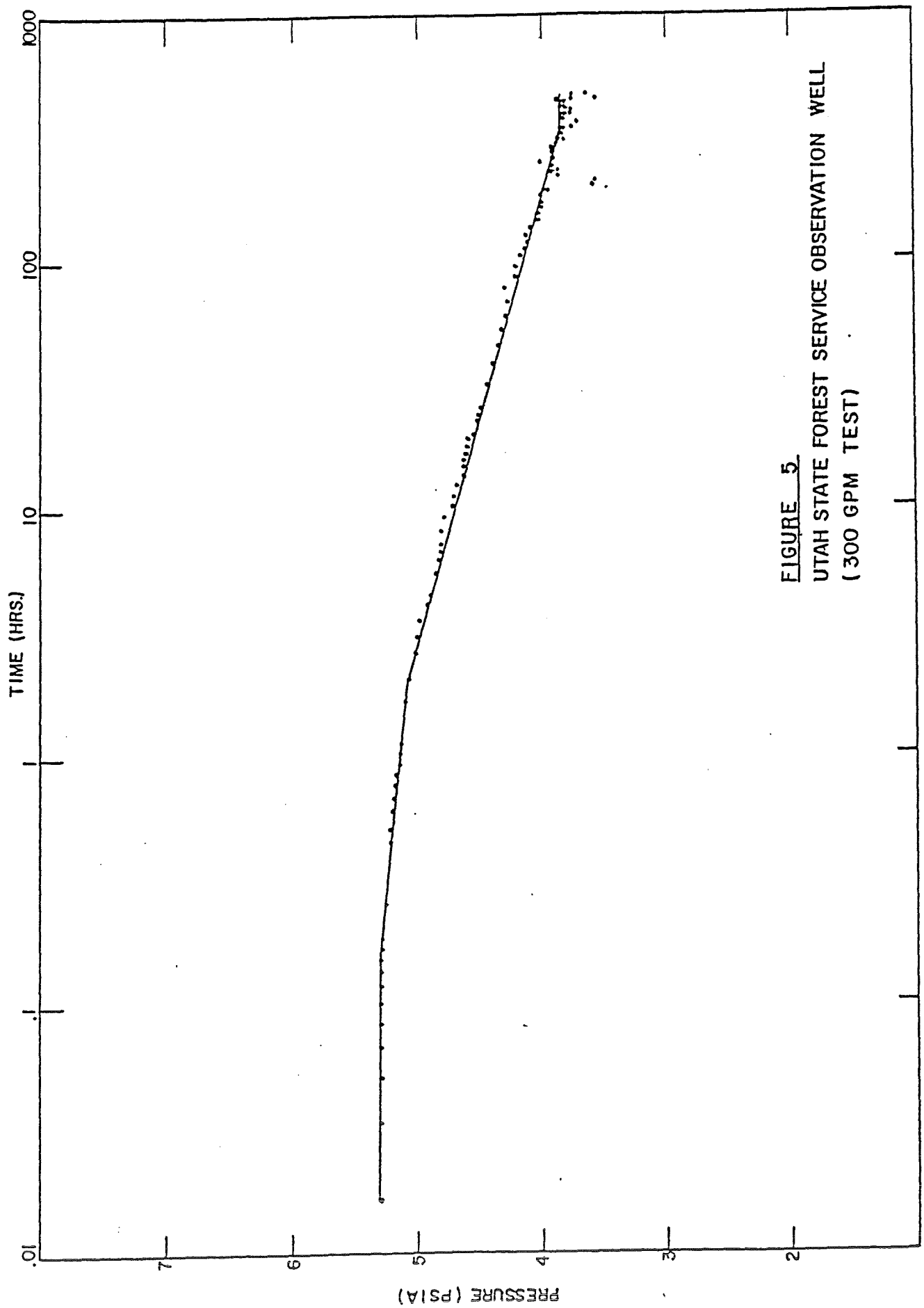


FIGURE 5.
UTAH STATE FOREST SERVICE OBSERVATION WELL
(300 GPM TEST)

6.3 600 GPM CONSTANT RATE TEST

Production at 600 gpm was initiated July 6 and was continued for 14 days. Surface pressure data was collected throughout the test. Problems with equipment prevented the collection of downhole pressure using the downhole pressure probe; so, a back-up system using a nitrogen charged bubbler tube was used until a leak in the air line developed. Attempts to fix the air line without terminating the test failed so the later data shows considerable spread (Figure 6).

The higher psi values obtained during the later stages of the test generally reflect the true downhole conditions as gas leakage somewhere in the line would cause lower pressures if the pressure was not recorded instantly after the line was charged. The surface pressure data continued to show a scatter of points because of CO₂ flooding and surging in the well bore (Figure 7).

The production well showed a steady trend of pressure decline of approximately 0.5 psi per log cycle for both the surface and downhole pressure. This is comparable to pressure declines noticed at the 300 gpm rate.

The data indicated the late time data may be undergoing a more rapid pressure drop.

Pressure declines in the Utah Roses well indicated a pressure response within 6 minutes after USP/TH-1 flow was increased to 600 gpm. The pressure declines at a 0.42 psi per log cycle rate during the early stages of the test. Data from the later portion of the test showed considerable scattering because of air in the transducer line causing atmospheric variation in the measurements (Figure 8).

The Utah State Forestry well showed a pressure response to the 600 gpm flow at approximately 8 minutes into the test. The decline is constant at 0.76 PSI/log cycle with an apparent stabilizing of drawdown occurring at 280 hours into the test (Figure 9).

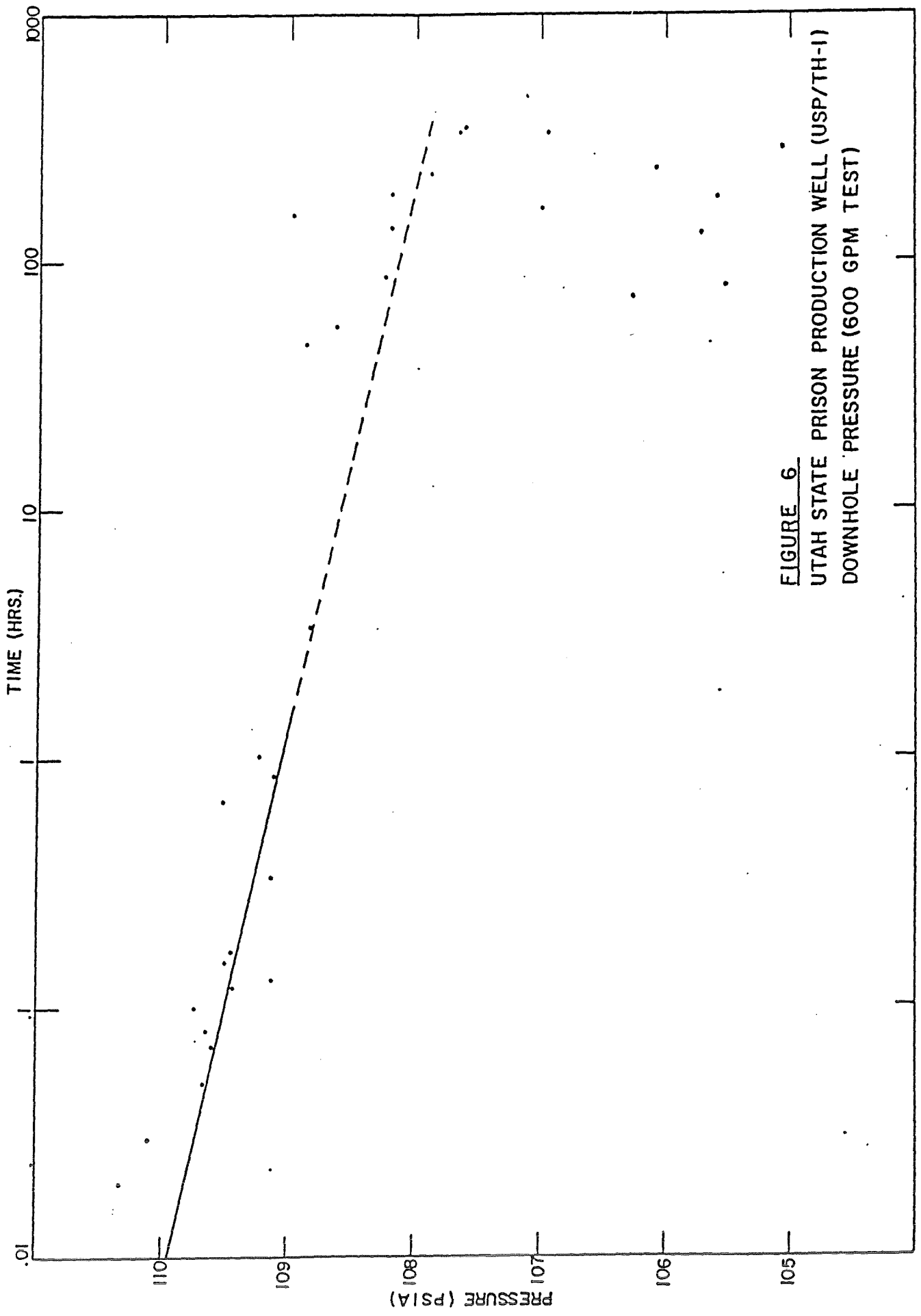


FIGURE 6
 UTAH STATE PRISON PRODUCTION WELL (USP/TH-1)
 DOWNHOLE PRESSURE (600 GPM TEST)

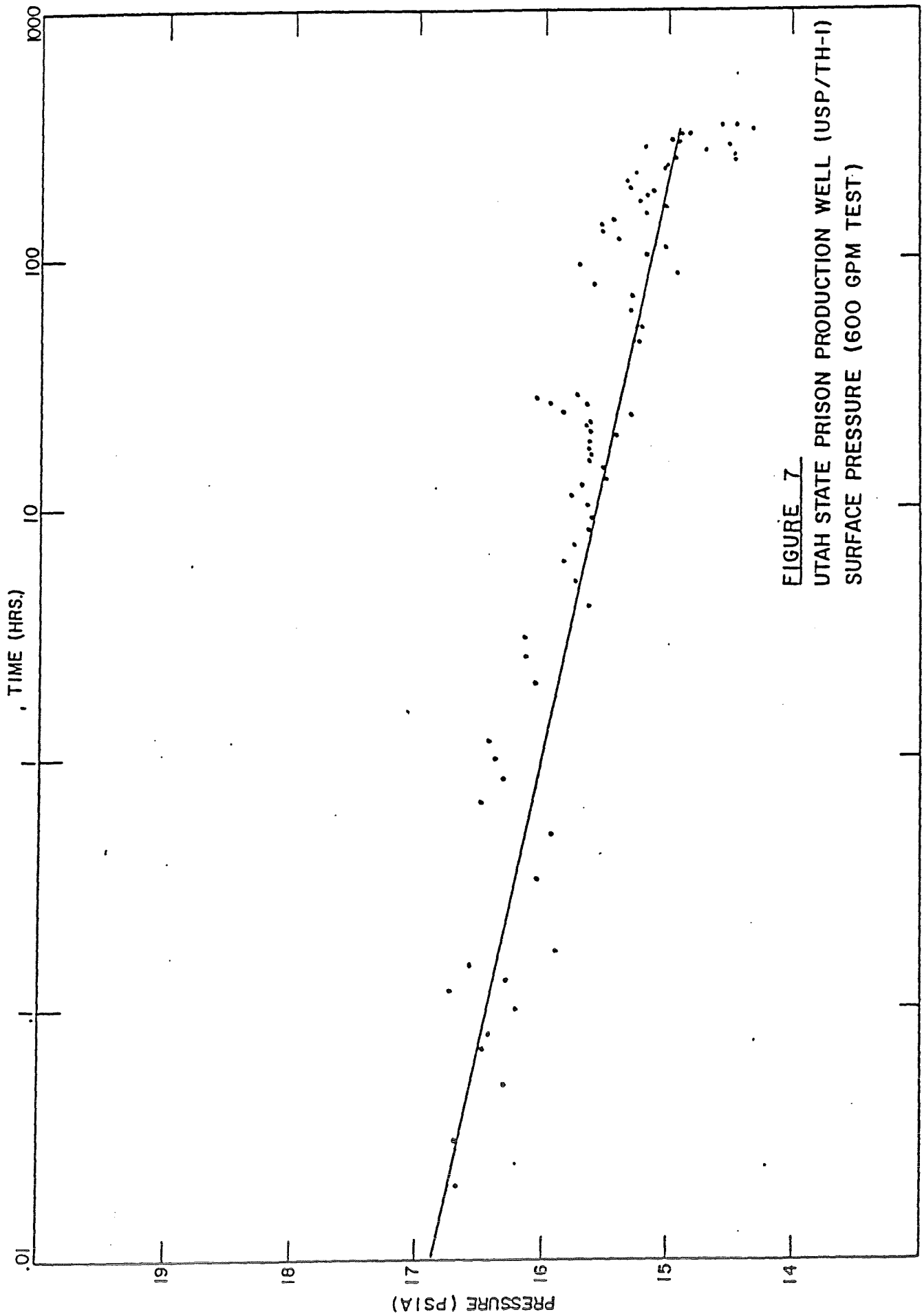


FIGURE 7
 UTAH STATE PRISON PRODUCTION WELL (USP/TH-1)
 SURFACE PRESSURE (600 GPM TEST)

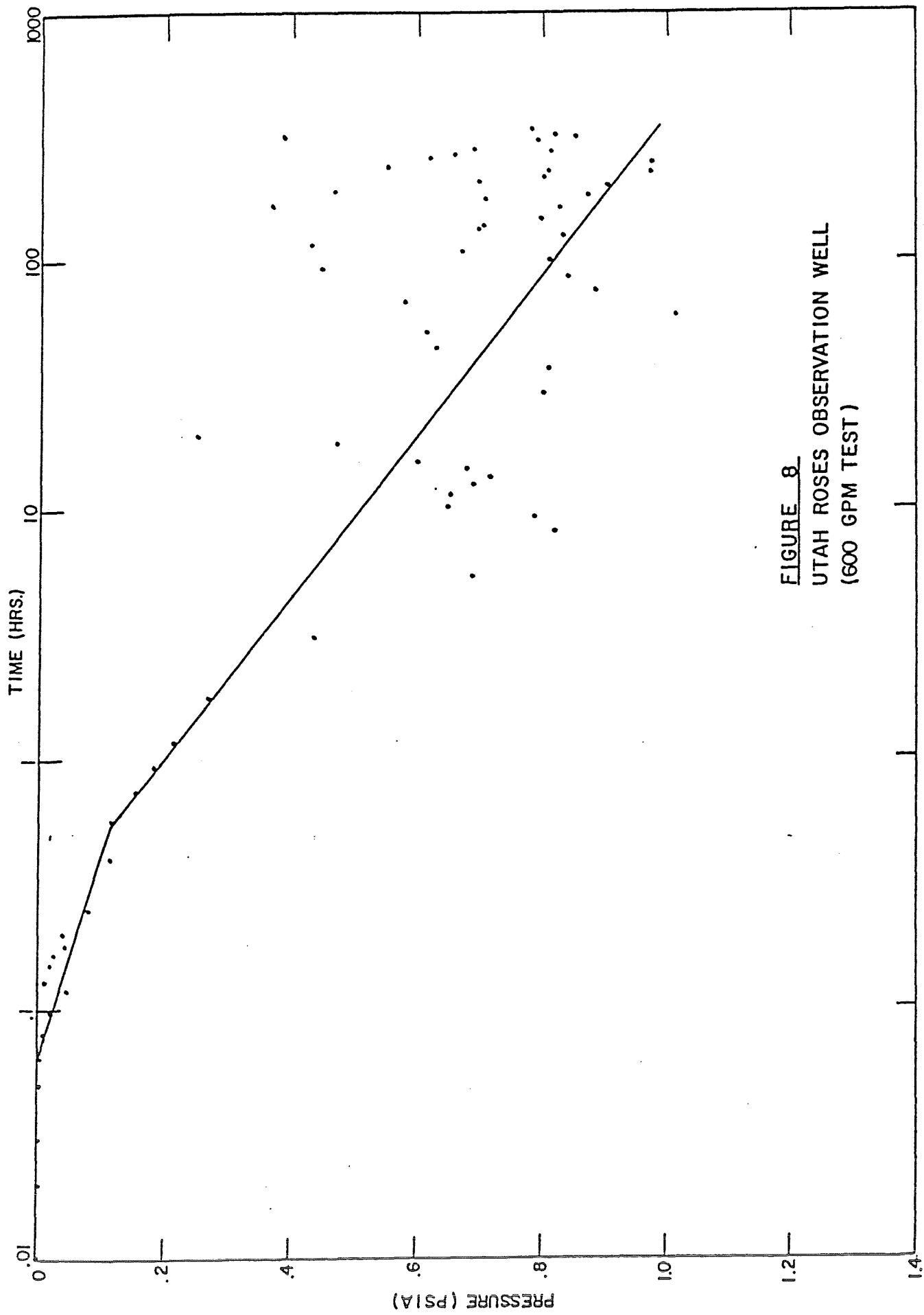


FIGURE 8
 UTAH ROSES OBSERVATION WELL
 (600 GPM TEST)

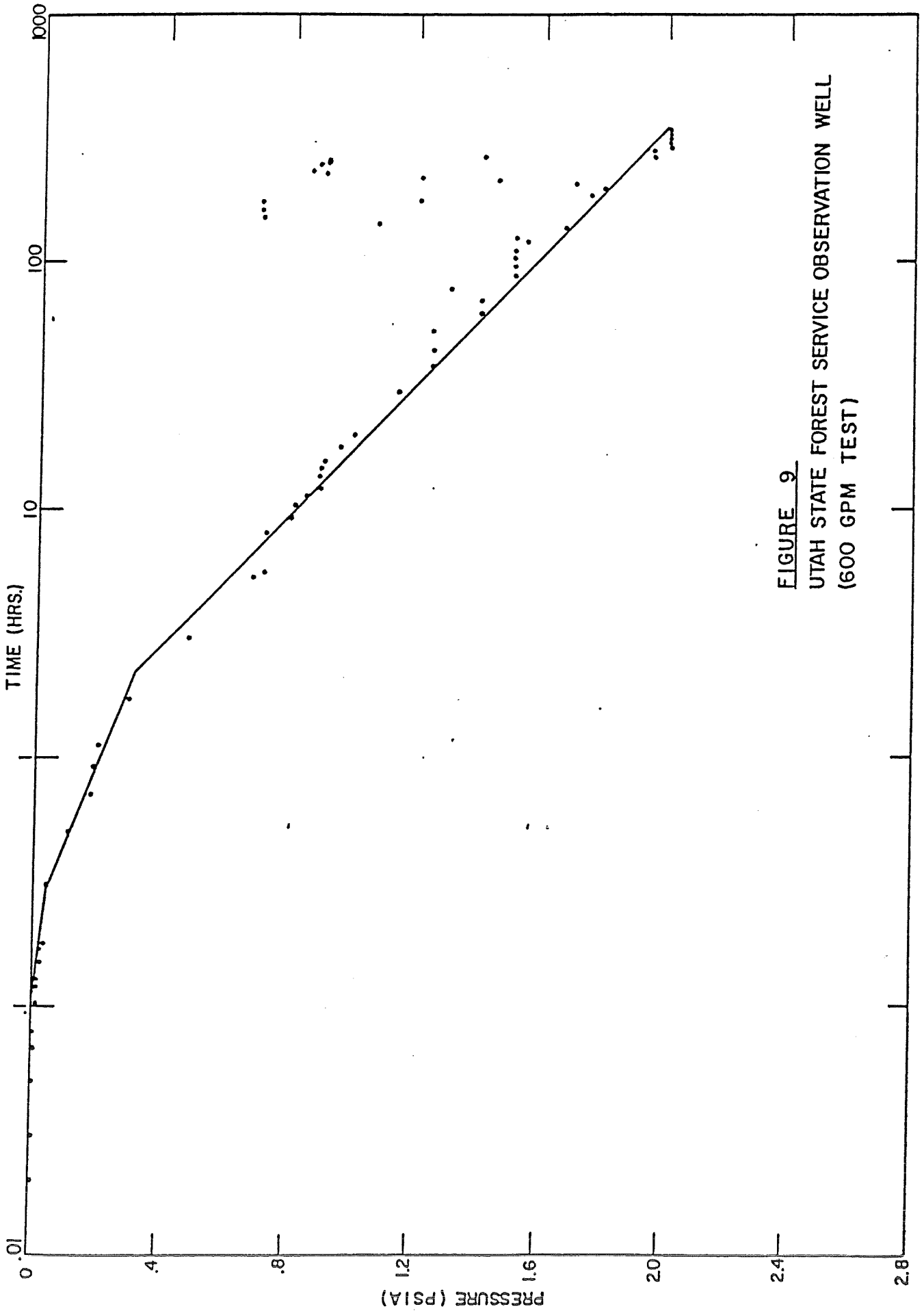


FIGURE 9
 UTAH STATE FOREST SERVICE OBSERVATION WELL
 (600 GPM TEST)

6.4 RECOVERY TEST

Recovery monitoring was conducted for 11 days after terminating the production test. Surface and downhole pressure was collected on USP/TH-1. Downhole pressure was collected via a bubbler tube system. Attempts were made to obtain down hole pressure data using a pressure probe but were not successful.

Production well USP/TH-1 showed a pressure response of 0.8 psi per log cycle for surface measurements and 2.0 psi per log cycle for downhole data (Figures 10 and 11). CO₂ gas escaping from the column of water and cooling effects of the well bore accounts for the difference. The erratic early time data and a drop in surface pressure at 24 minutes into the test was the result of entrapped CO₂ in the transducer. A continuous CO₂ bleed system was installed on the pressure port to gather the recovery data.

The Utah Roses well water level had declined to a level below the pressure port so a water level probe was used to gather water level data; however, restrictions in the well prevented it from going below 3.8 feet. As a result, data was not obtained for the first 700 minutes of the test. Also the transducer malfunctioned prior to the test due to a surge in power caused by an afternoon electrical storm. Late time data from the electric tape and the surface gauge indicated correlatable data with a 2.6 foot/log cycle recovery trend (Figure 13).

Recovery data from the USFS observation well showed a pressure buildup of 2.5 psi per log cycle. Data for the last 2,000 minutes indicates the well has essentially stabilized at 4.5 psi. This is 85% of the original well head pressure (Figure 13).

6.5 OBSERVATION WELLS B, C, D, E, F, AND SPRINGS CR-2 and CR-3

Other observation wells show distinct differences during the testing period. The F steel cased well did not show any changes which could be attributed to the testing at any time during the test period. Observation well C underwent a rapid water level rise at the beginning

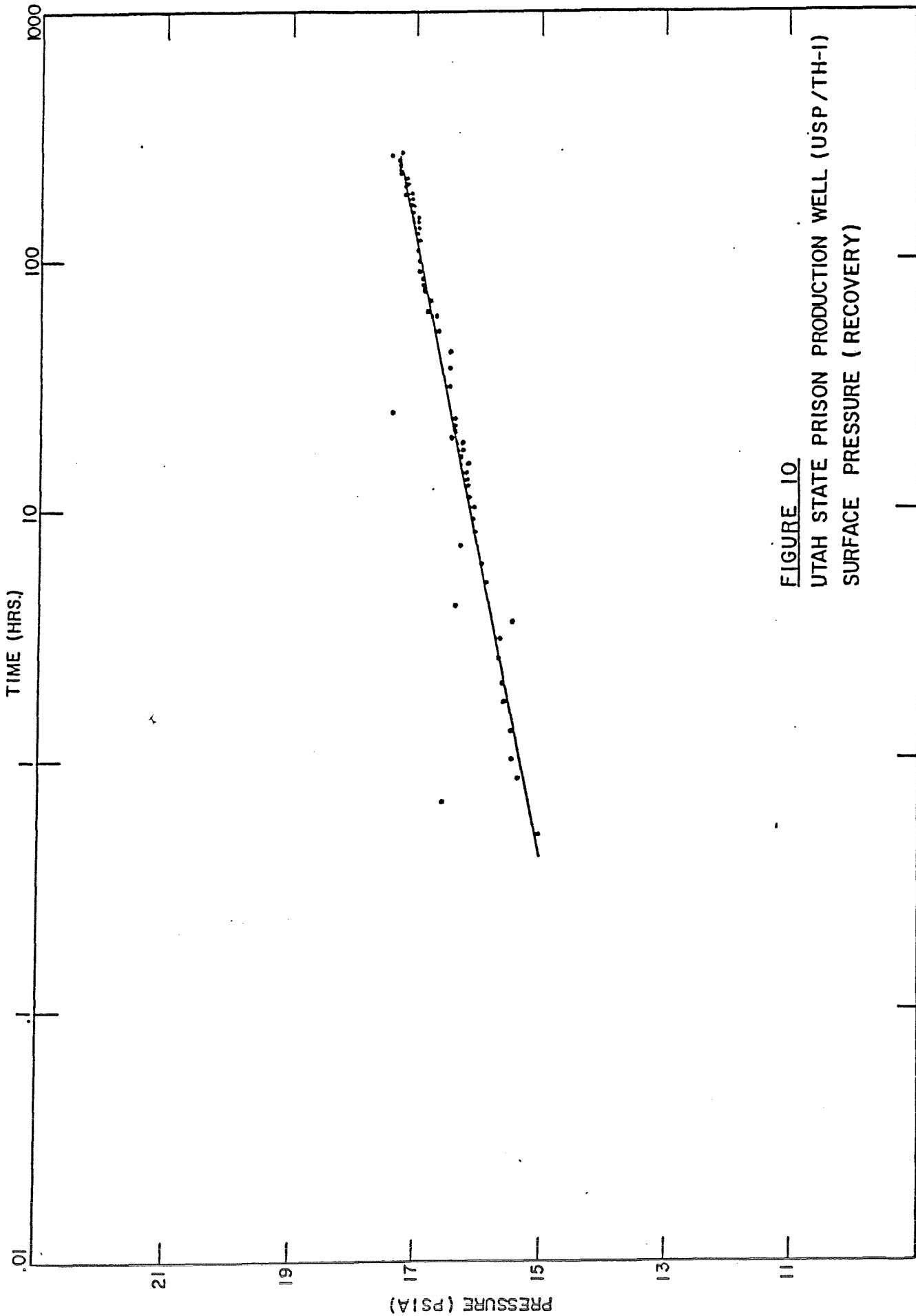
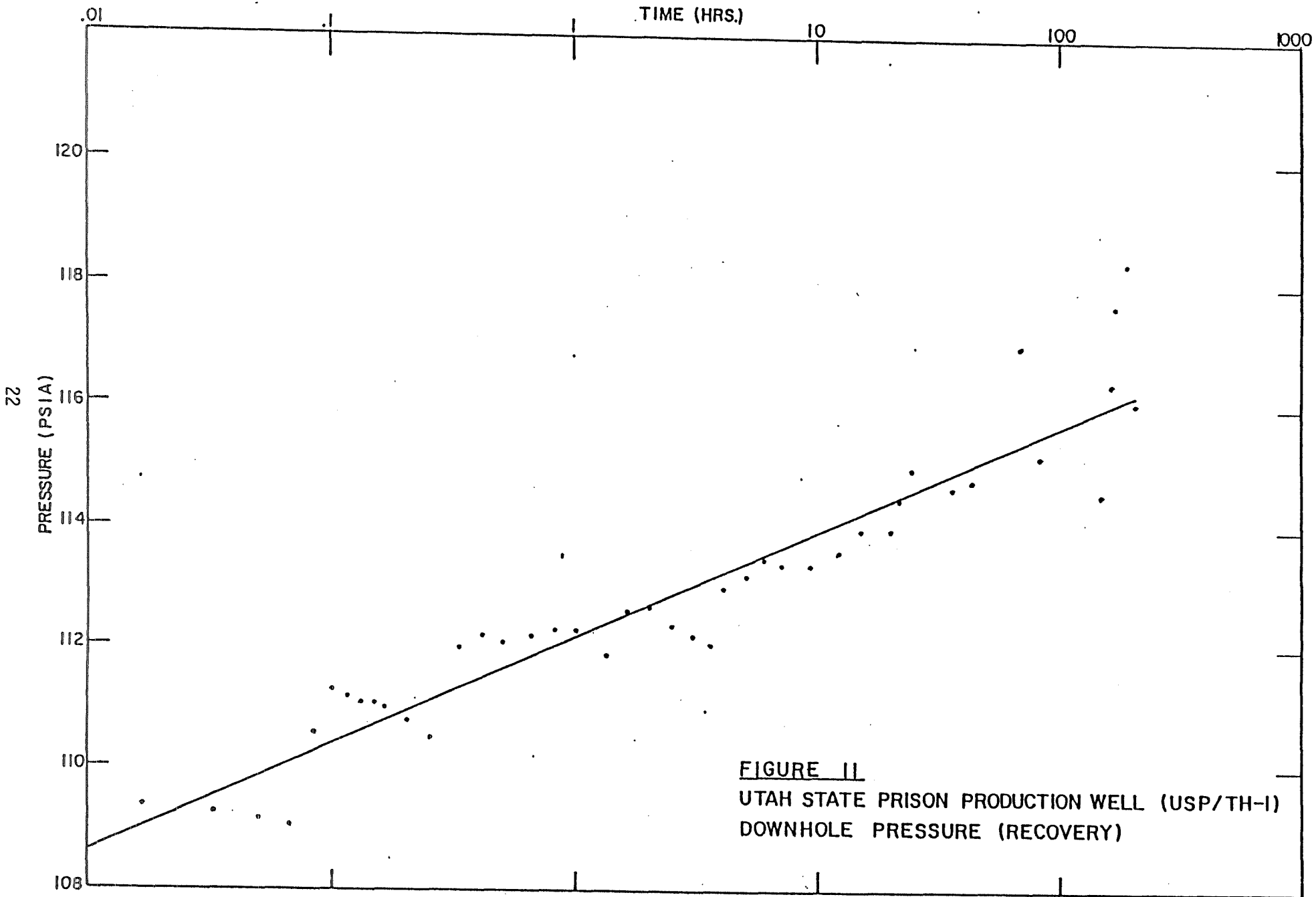


FIGURE 10
 UTAH STATE PRISON PRODUCTION WELL (USP/TH-1)
 SURFACE PRESSURE (RECOVERY)



23

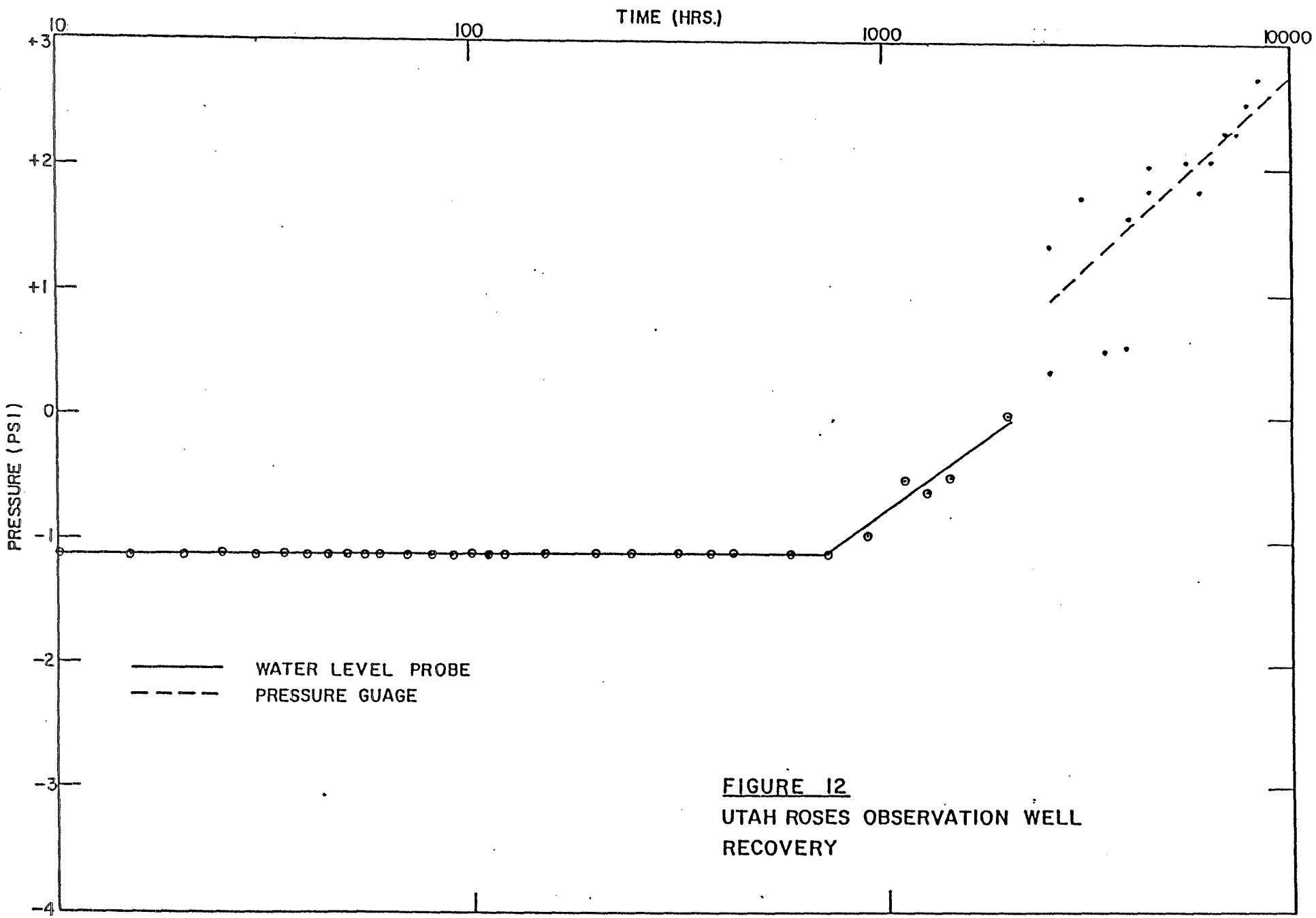


FIGURE 12
UTAH ROSES OBSERVATION WELL
RECOVERY

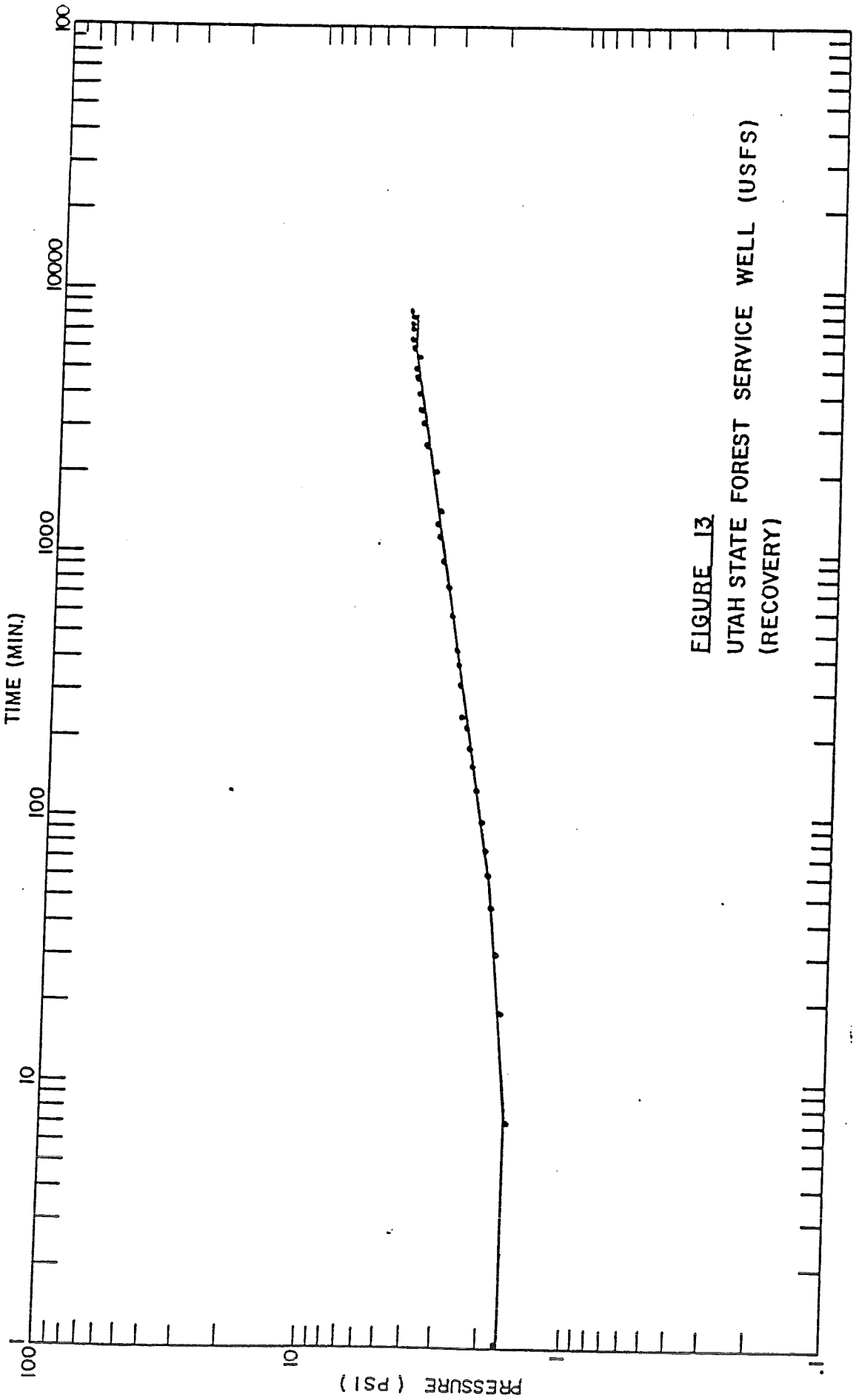


FIGURE 13
 UTAH STATE FOREST SERVICE WELL (USFS)
 (RECOVERY)

of the monitoring period which is attributed to release of CO₂ gas upon removal of the cap from the top of the 2 inch casing. The water level subsequently raised until it reached the top of the casing and began flowing.

The B wells and F plastic wells showed a steady water level rise throughout the entire test. No distinct differences can be detected between the 300 gpm, 600 gpm, or recovery portions of the test (Figures 14, 15, and 18).

Wells D and E show distinct water level declines during both the 300 and 600 gpm tests. Steady state conditions can be seen to occur in 8 days for Well E and in 13 days for Well D at the 300 gpm rate. A sharp decline occurred in both wells when the flow in USP/TH-1 was increased to 600 gpm. Recovery in the wells was also dramatic. Full recovery occurred in Well E within five days of terminating flow and Well D was showing a sharp rise in water level (Figures 16 and 17).

Springs CR-2 and CR-3 showed distinct differences. Spring CR-2 did not show any appreciable change in flow at the 300 gpm production rate but did show a slight decrease in flow at the 600 gpm rate. Spring CR-3 decreased flow slightly at 300 gpm but stopped flowing completely within one day of initiating the 600 gpm test. Flow was back to initial conditions in Spring CR-2 and Spring CR-3 initiated flow three days after the flow from USP/TH-1 was stopped (Figure 19).

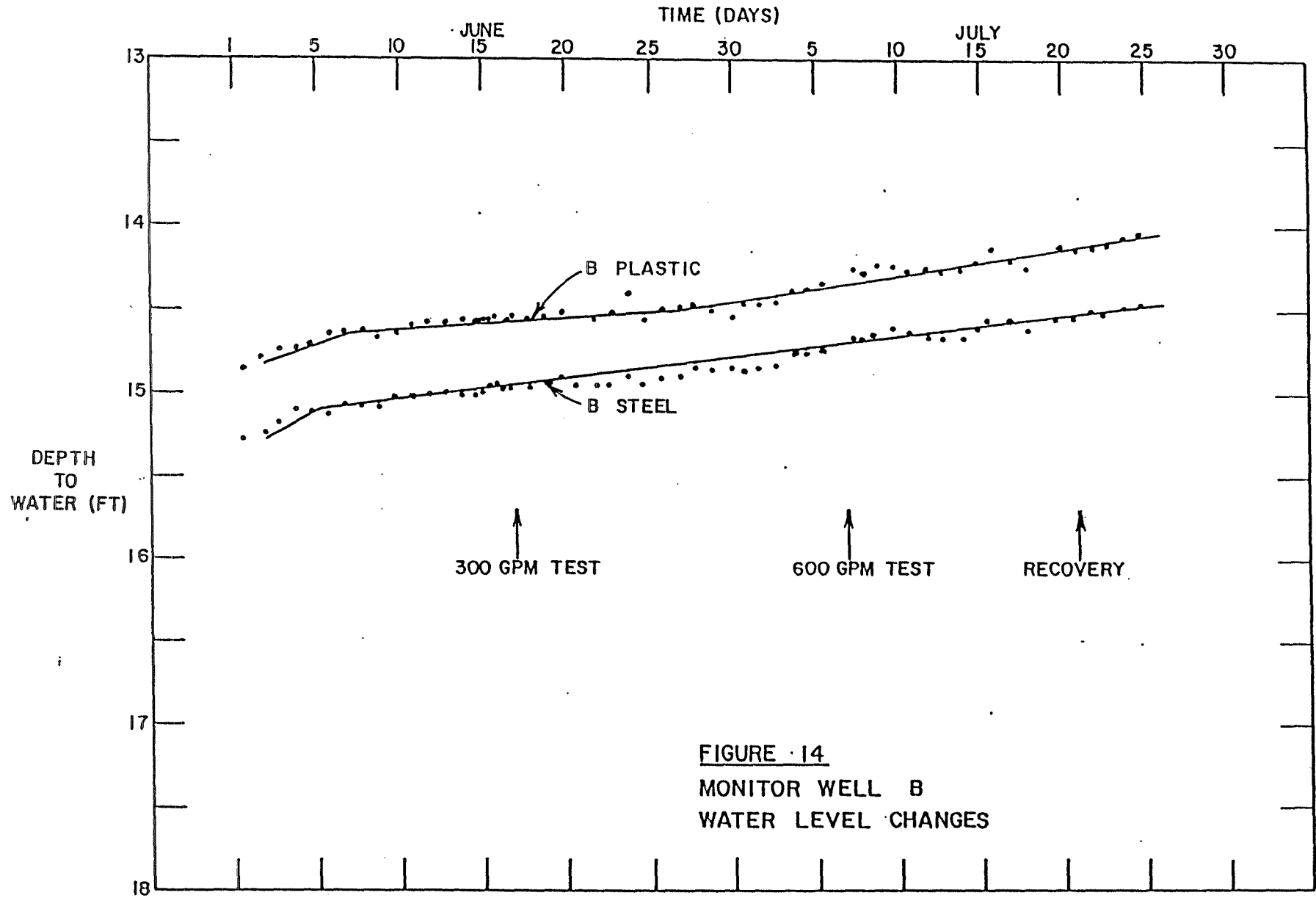


FIGURE 14
MONITOR WELL B
WATER LEVEL CHANGES

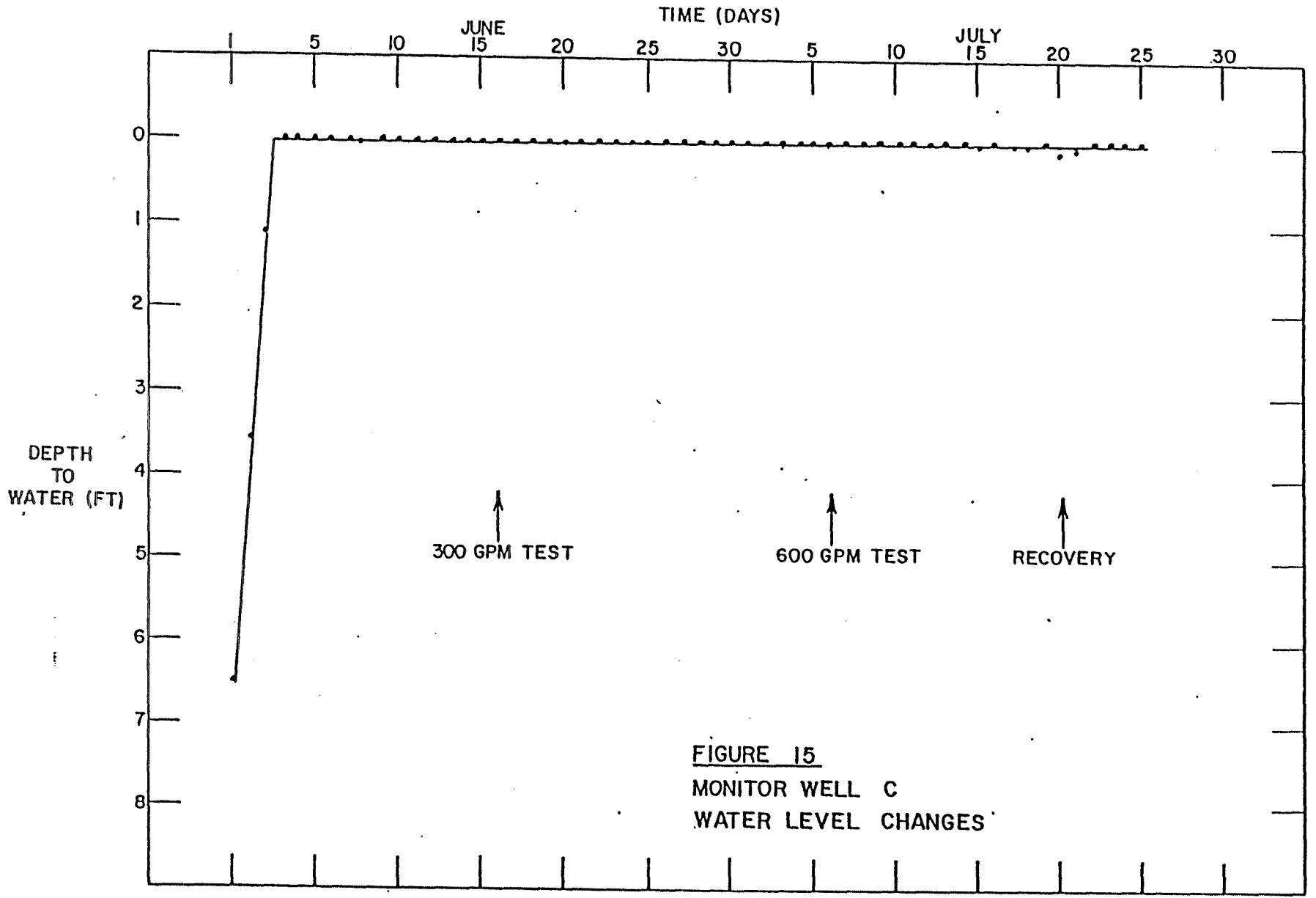


FIGURE 15
MONITOR WELL C
WATER LEVEL CHANGES

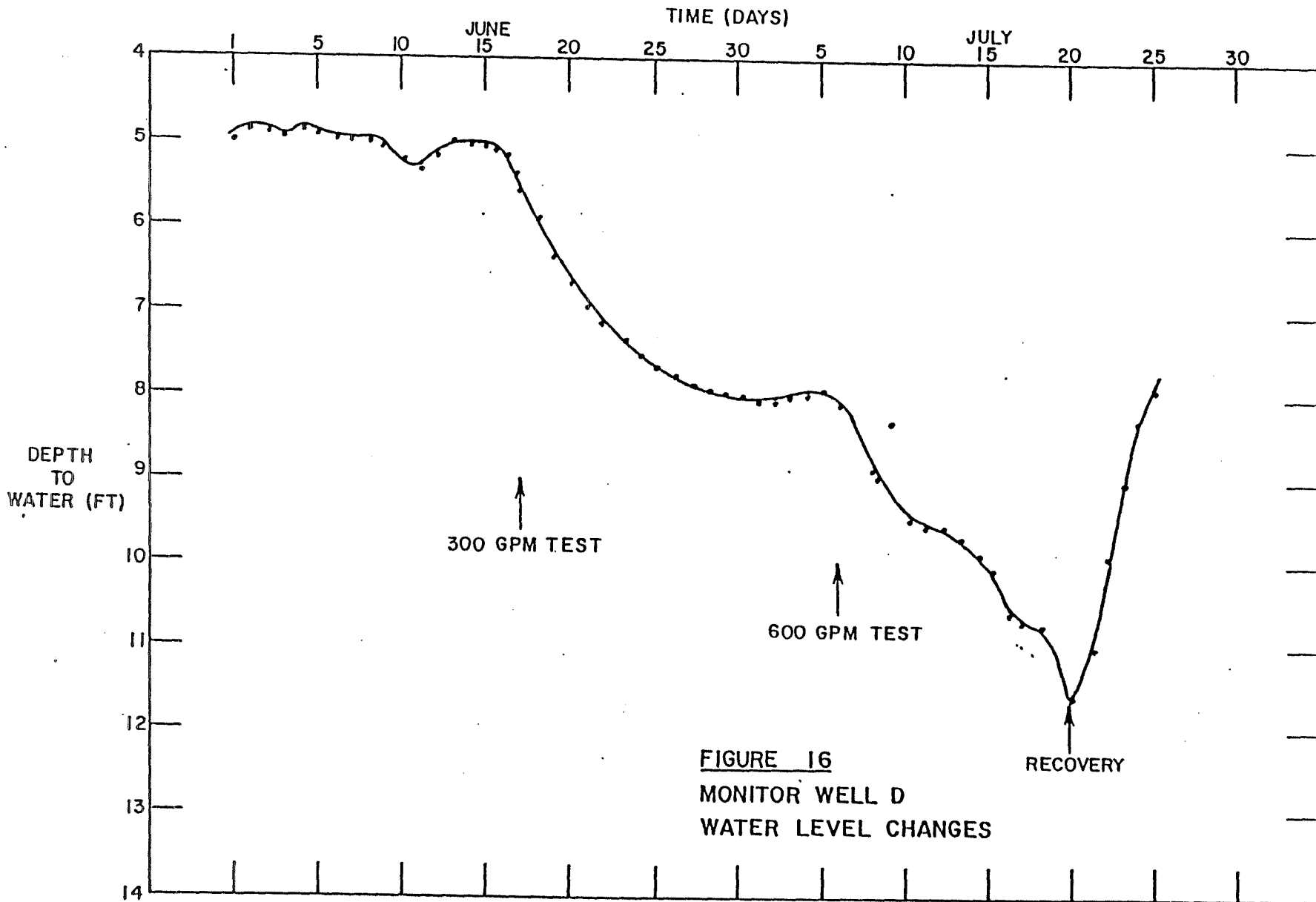


FIGURE 16
MONITOR WELL D
WATER LEVEL CHANGES

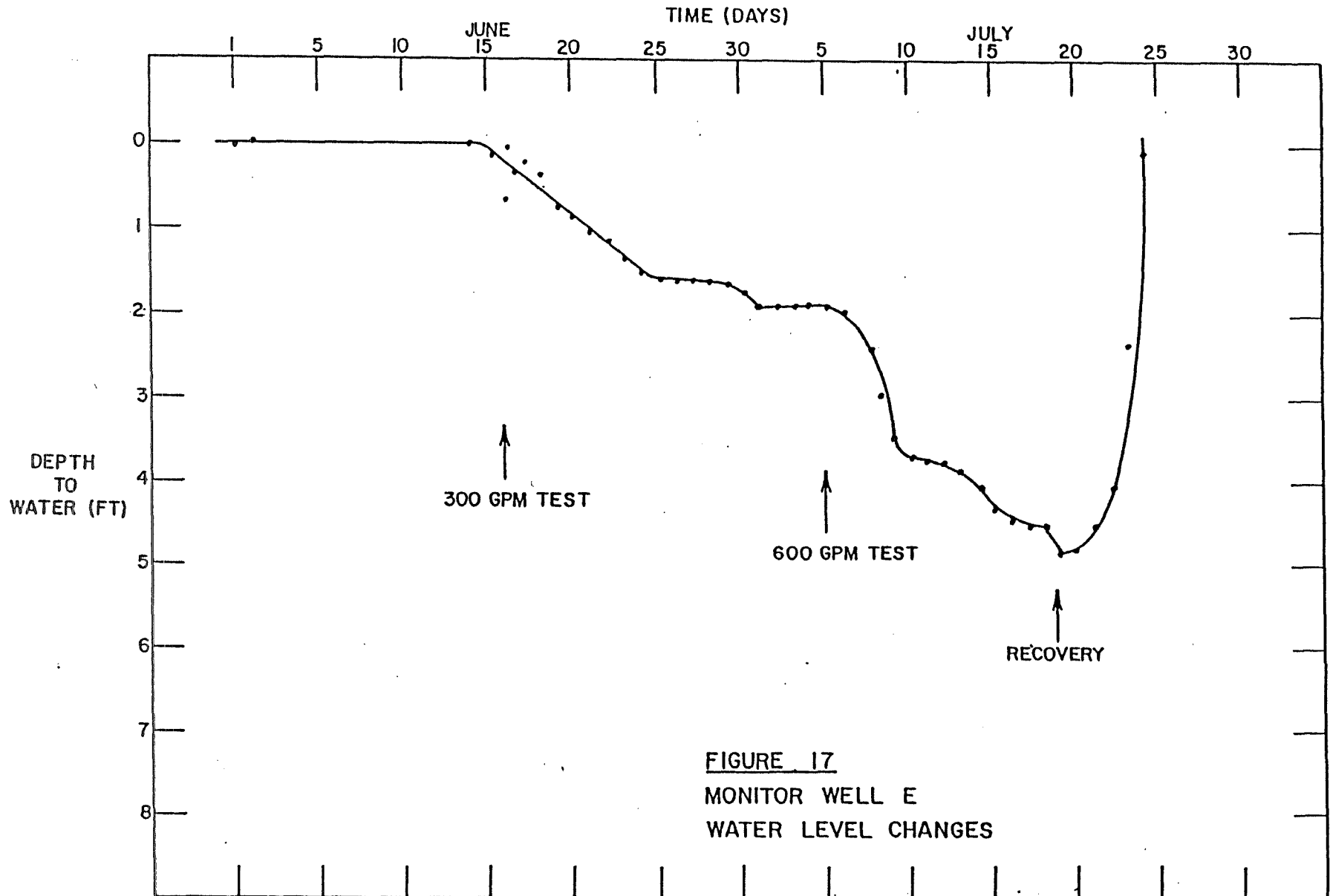


FIGURE 17
MONITOR WELL E
WATER LEVEL CHANGES

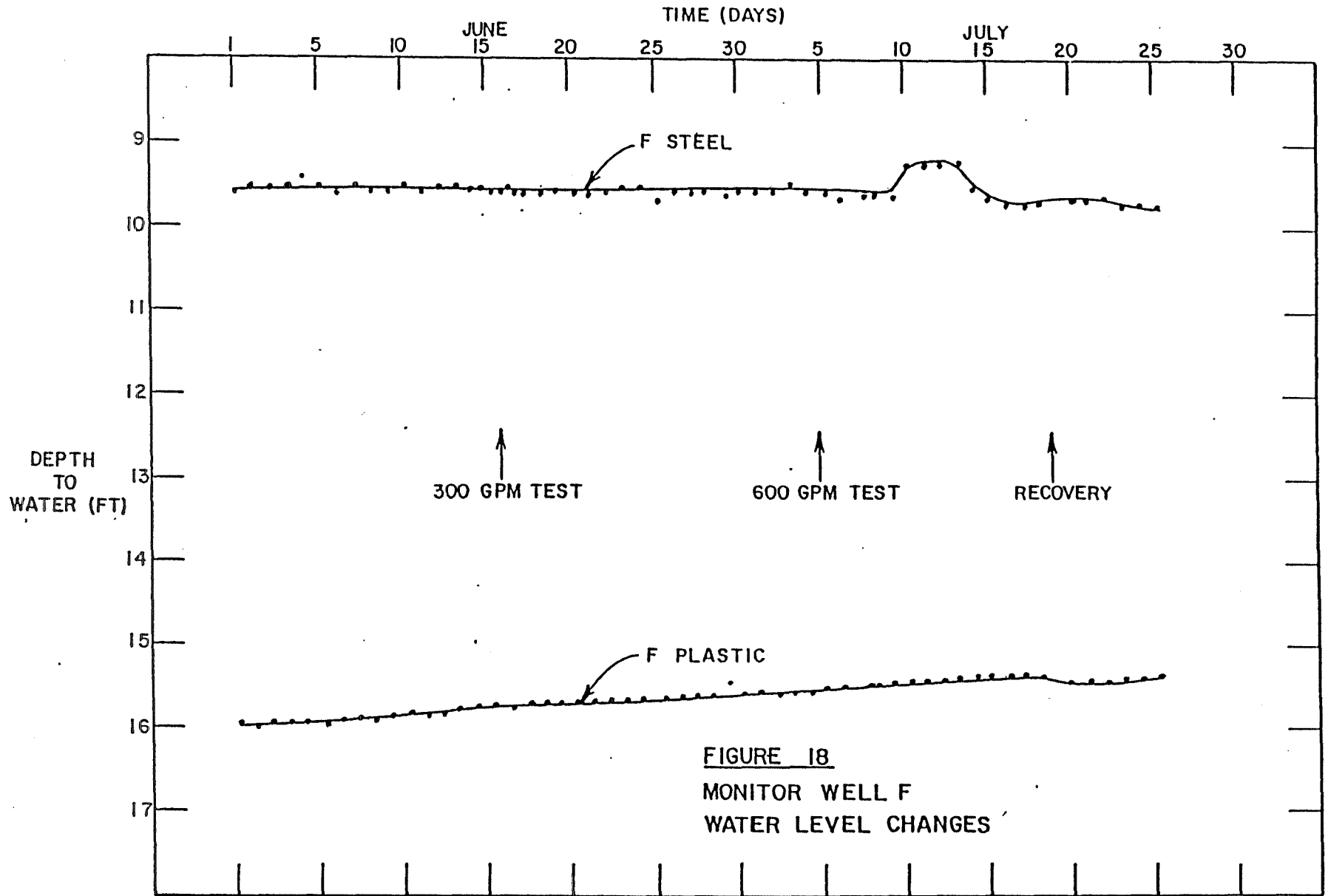


FIGURE 18
MONITOR WELL F
WATER LEVEL CHANGES

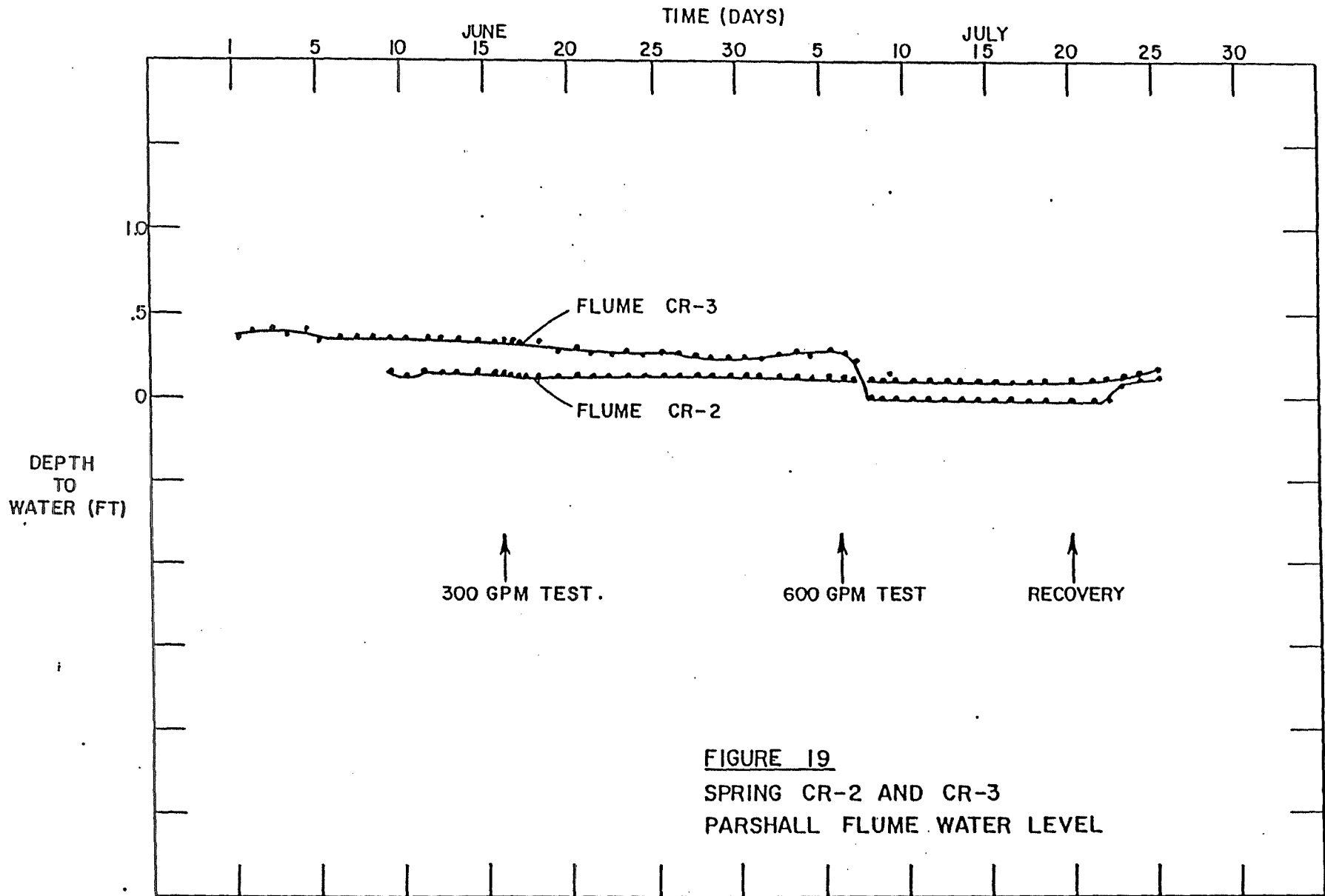


FIGURE 19
SPRING CR-2 AND CR-3
PARSHALL FLUME WATER LEVEL

7.0 RESERVOIR ANALYSIS

In evaluating the reservoir parameters both the techniques of the petroleum reservoir engineers and the groundwater hydrologists were used. This allows for a comparison of the techniques used by both disciplines and a evaluation of the interaction of the low temperature geothermal system and the groundwater system. Also the geothermal system is fracture controlled and utilizing a combination of the two techniques allows for a better evaluation of the system.

7.1 WELL LOSS FROM STEP DRAWDOWN TESTING

The initial evaluation of the production well requires a determination of well losses. Well loss may be calculated by the following equation (Jacob, 1946b):

$$S_w = CQ^2$$

where:

S_w = Well loss, in ft.

C = Well loss constant, in sec^2/ft^5

Q = Discharge, in cubic feet per second (cfs)

The value of C in this equation is computed from the data collected during a "step-drawdown" test, in which the well is operated during successive periods at constant fractions of full capacity. This value is computed from the following equation:

$$C = \frac{(\Delta s_i / \Delta Q_i) - (\Delta s^{i-1} / \Delta Q_{i-1})}{\Delta Q_{i-1} + \Delta Q_i}$$

For successive drawdown steps this equation may be rewritten as:

$$C = \frac{(\Delta s_2 / \Delta Q_2) - (\Delta s_1 / \Delta Q_1)}{\Delta Q_1 + \Delta Q_2}$$

On June 15th a step drawdown test was conducted on the Utah State Prison Geothermal Production well. The increments of discharge or step rates were 100 gpm, 200 gpm, and 300 gpm. The data produced from this test were substituted into the above step equations and produced the following values of C:

$$\begin{array}{ll} \text{Steps 1 \& 2} & C = 1.84 \text{ sec}^2/\text{ft}^5 \\ \text{Steps 2 \& 3} & C = 7.33 \text{ sec}^2/\text{ft}^5 \end{array}$$

Since the value of C for steps 2 and 3 is greater than the value of C for steps 1 and 2, this indicates that the well production is lower than the well is capable of yielding. the average value of C is about $4.59 \text{ sec}^2/\text{ft}^5$.

The well loss at the 300 gpm pumping rate was computed as shown:

$$S_w = 2.04'$$

The total evaluated drawdown in the well at 300 gpm was 8.03 feet. Thus, well loss amounted to about 27 percent of the total drawdown in the production well for a pumping rate of 300 gpm.

In conclusion, it appears two major factors may account for the well loss. The method of completion with a slotted liner has not allowed for enough openings compared to total surface area of the pipe. the second factor accounting for well loss is a result of the CO_2 flashing in the well bore, causing a gas lift condition to occur. The flashing appeared to have increased with time, probably as a result of well bore heating.

7.2 PERMEABILITY - FORMATION DATA

Two calculations are presented for formation permeability. The first uses a reservoir thickness of 600 feet which was obtained from well logs; the second calculation uses a reservoir thickness based on the thickness of the completed production zone. Both calculations use type curve matching techniques and data are given below.

Production Data: 300 gpm flow rate

<u>Elapsed Time (Hrs)</u>	<u>P (PSIA)</u>	<u>Δ P</u>
.042	20.12	- .019
.115	19.92	.010
.335	19.61	.32
.505	19.59	.34
1.72	19.39	.54
1.92	19.28	.65
3.91	19.16	.77
5.5	19.07	.86
11.70	18.86	1.07
12.65	18.86	1.07
30.28	18.72	1.21
35.65	18.71	1.22
52.17	18.71	1.22
240.10	18.32	1.61
391.00	18.28	1.65
462.00	18.13	1.80

$$K = -141.2 \frac{Bq}{h} \frac{(P_D)_m}{\Delta P_m} \quad (\text{Earlougher; 1977})$$

where:

- K = permeability (md)
- q = flow rate (bbl/day)
- B = formation volume factor
- u = viscosity (Cp)
- h = formation thickness (ft)
- $(P_D)_m$ = dimensionless pressure match point
- ΔP_m = pressure change match point

Permeability (q = 600 gpm):

$$\begin{aligned}
 q &= 600 \text{ gpm} \times \frac{1 \text{ bbl}}{5.615} \times \frac{60 \text{ min}}{1} \times \frac{24 \text{ hr}}{1} \\
 &= 20,571 \text{ bbl/day} \\
 B &= 1.027 \text{ (from Utah Energy Office, 1981)} \\
 u &= 0.34 \text{ cp (from Utah Energy Office, 1981)} \\
 h &= 600 \text{ ft. (from well logs)} \\
 K &= \frac{(141.2)(20,571)(1.027)(0.34)}{600} \left(\frac{0.097}{0.1} \right) - 1639 \text{ md}
 \end{aligned}$$

Permeability (Q = 400 gpm)

$$\begin{aligned}
 q &= 20,571 \text{ bbl/day} \\
 B &= 1.027 \\
 u &= 0.34 \text{ cp} \\
 h &= 400 \text{ ft (from production zone thickness)} \\
 K &= \frac{(141.2)(20,571)(1.027)(0.34)}{400} \left(\frac{0.097}{0.1} \right) \\
 &= \frac{1014237.027}{400} = (2535)(.97) = 2458 \text{ md}
 \end{aligned}$$

7.3 POROSITY - COMPRESSIBILITY

$$\emptyset C_t = \frac{0.0002637}{r^2} \frac{K}{u} \frac{tm}{(t_D/r_D^2)_m} \quad (\text{Earlougher; 1977})$$

where:

$$\begin{aligned}
 \emptyset &= \text{porosity (fraction)} \\
 C_t &= \text{compressibility (psi}^{-1}\text{)} \\
 r &= \text{distance between wells (ft)}
 \end{aligned}$$

$$\begin{aligned}
t_m &= \text{time value at the match point (hours)} \\
(t_D/r_D^2)_m &= \text{dimensionless time parameter at match point} \\
r &= \text{USP/TH-1 to Forestry well} = 400' \\
\emptyset Ct &= \frac{0.0002637}{(400)^2} \left(\frac{2458}{.34}\right) \left(\frac{10.0}{4.8}\right) \\
&= (.0000000016)(7729.41)(2.08) \\
&= 2.5 \times 10^{-5} \text{ psi}^{-1}
\end{aligned}$$

Using ground water units the above properties can be expressed as follows:

$$K = K_i \frac{(\text{pg})}{u}$$

where:

K = hydraulic conductivity

K_i = permeability

$$\begin{aligned}
K &= (2.5 \times 9.87 \times 10^{-9}) \times (.03281 \text{ ft})^2 \times 60.57 \text{ lb/ft}^3 \\
&\times \frac{32.2 \text{ ft/sec}^2}{.34 \text{ cp}} \times 1488.1 \times 86,400 = 19.39 \text{ ft/day}
\end{aligned}$$

7.4 COEFFICIENT OF STORAGE

$$S = \emptyset Cth \frac{(\text{pg})}{gc}$$

where:

S = Coefficient of Storage

S = $2.5 \times 10^{-5} \times 400 \times (60.57) \times 1/144$

S = .004

7.5 RESERVOIR LIMITS

Surface pressure data indicate a steady state pressure decline occurring in the production well over the duration of the test. This rate of decline is calculated at 0.004 psi/hr (Figure 2). One must keep in mind the calculated reservoir limits for this technique will be influenced by fracturing within the system which the equations do not account for.

$$\phi h A = \frac{-0.23395 q B}{C_t M^*}$$

$$A = \frac{-0.23395 q B}{\phi h C_t M^*}$$

where:

A = reservoir area (ft²)
M* = slope of linear pressure decline (psi/hr)

$$A = \frac{(-.23395)(20,571)(1.027)}{(2.5 \times 10^{-5})(400)(-.004)} \quad \begin{array}{l} 4942.53 \\ 0000004 \end{array}$$

$$A = 1.236 \times 10^{10} \text{ ft}^2$$

7.6 WELLBORE STORAGE

The following data is derived from a log-log plot of surface pressure vs. time. Values for the equation are given in Section 7.2.

$$C = \frac{q B \Delta t}{24 \Delta P}$$

where:

C = well bore storage coefficient
 ΔP = pressure change (psi)
 Δt = testing time (hours)

$$= \frac{(20,571)(1.027)}{24} \left(\frac{1.60}{470} \right) = (880.27)(.0034) = 2.99$$

7.7 SKIN FACTOR

$$S = 1.1513 \left[\frac{P_{1hr} - P_i}{M} - \log \left(\frac{K}{\phi u C r_w^2} \right) + 3.2275 \right]$$

where:

P_{1hr} = pressure on straight line portion of semilog plot 1 hr after beginning a transient test (psi)

P_i = initial pressure (psi)

M = slope of linear portion of semilog plot of pressure transient data (psi/cycle)

r_w = wellbore radius (ft)

$$S = 1.1513 \left[\frac{18.20 - 19.45}{0.4 \text{ psi/cycle}} - \log \left(\frac{2458}{(2.5 \times 10^{-5})(.34)(.25)^2} \right) + 3.2275 \right]$$

$$S = -7.54$$

7.8 TRANSMISSIBILITY (T) AND COEFFICIENT OF STORAGE (S)

Standard ground water techniques were applied in evaluating the aquifer characteristics as a comparison to petroleum reservoir engineering methods and as a means of evaluating the effect of the geothermal system on the ground water aquifer in the area. These techniques are described in Walton (1970), Johnson Division (1980), and Kruseman and Riddes (1976). The first technique uses a semi-log plot of drawdown vs. time; the second uses a log-log plot and type curve matching technique.

The first technique uses a semi-log plot of time vs. drawdown and the modified non-equilibrium formula:

$$T = \frac{264 Q}{\Delta s}$$

where:

- T = Coefficient of Transmissibility in gallon per day per foot (gpd/ft)
- Q = Pumping rate in gallon per minute (gpm)
- Δs = Slope of the time drawdown graph

Calculations for the coefficient of storage used the formula.

$$S = \frac{0.3 T t_0}{r^2}$$

where:

- S = Coefficient of Storage
- T = Coefficient of Transmissibility (gpd)
- t_0 = Intercept of time drawdown curve at time 0 (days)
- r = Distance from pumped well to observation well

The second technique uses the non-equilibrium formula with a log-log plot of drawdown vs time and a type-curve match. In this method the transmissibility is calculated using the formula:

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

where:

- T = Coefficient of Transmissibility (gpd/ft)
- Q = Pumping rate (gpm)
- s = drawdown (ft)
- W(u) = Well function from type curve

The coefficient of storage calculation using the log-log plot uses the formula:

$$S = \frac{u T t}{1.87 r^2}$$

where:

- S = Coefficient of storage (gpd/ft)
- T = Coefficient of Transmissibility
- t = Time since pumping started (days)
- r = distance to observation well (ft)

7.9 TRANSMISSIBILITY VALUES FOR USP/TH-1

The transmissibility values for USP/TH-1 for the 300 gpm test and the 600 gpm test are 74,700 gpd/ft and 160,000 gpd/ft respectively. These values indicate the reservoir was not stressed at the 300 gpm flow rate and had greater capacity than initially indicated. The drawdown vs. time did not change significantly when the flow was increased from 300 gpm to 600 gpm. Using the higher transmissibility value gives a hydraulic conductivity of 160,000 gpd/ft² and a specific capacity of 111 gpm/ft.

The observation wells show similar effect. Transmissibility values for the Utah Roses observation well calculate to be 20,000 gpd/ft² for the 300 gpm test, 223,000 gpd/ft for the 600 gpm test, and 36,000 gpd/ft for the recovery phase of the test. A storage coefficient value of 0.001 was calculated for the 600 gpm test.

The Utah State Forestry observation well transmissibility values were 66,000 gpd/ft for the 300 gpd test, 90,500 gpd/ft for the 600 gpm test and 38,800 for the recovery test. A storage coefficient value of .006 was calculated for the 600 gpm test and .00007 for the recovery test.

8.0 WELL BORE TEST

A test, modified from EPA 570/9-75001, to determine the capability of the 8" portion of the well bore to receive a pump was conducted in conjunction with inserting the air-line into the well. The air line was fitted with de-centralizer rings made up of 7 5/8" 00 steel pipe prior to inserting it in the well. The rings were placed at 20 foot intervals throughout the full 253 foot length of the air. Murray Plumbing monitored the placement of the airline and noted there was no interference in the way of obstructions or excessive erection in lowering the airline into the well. It was concluded from this exercise that the well bore within the 8" section of casing to a depth of 260' would not pose any problem in placement of a pump in the well. The checking of the 6" section of pipe for compatibility to receive a pump was not conducted at the time of the airline placement because of the uncertainty of whether a pump was going to be used and if it was to be used at what depth the pump would be set.

It is the feeling of M-K that the possibility of having to place a pump in the 6" portion of the hole is remote. The well appears to meet the design criteria of 200 gpm through artesian flow. Also calcite deposition was not detected in the lower portion of the 8" casing. A factor which may be important is size limitations on pumps which can deliver the design flow and can work in the six inch portion of the well under thermal conditions.

9.0 GEOCHEMICAL RESERVOIR ASSESSMENT

9.1 INTRODUCTION

The evaluation of the chemical composition of thermal springs, wells and cold surface waters has proved for many geothermal systems to be a useful tool in the evaluation of the geothermal reservoir. Fluid geochemical surveys have provided information on the compositions and homogeneity of the fluids, subsurface temperatures, rock types, fluid origins, and fluid pathlines.

9.2 SAMPLING AND CHEMICAL ANALYSIS

Water samples were collected from Utah State Prison Well (TH1) and the nearby Utah Roses Production Well (UR1) during the June 16 to July 20, 1982 flow test. The dates of sampling and the analytic results are listed on Tables 9-1 and 9-2. Sample locations are shown on Figure 20a. Samples from TH1 were collected both at the well head and at depth using a "Kuster" down hole sampler.

All samples were filtered with a 0.45 μ membrane filter upon collection and stored in polyethylene containers. These containers were precleaned by soaking them in 20% nitric acid, rinsing in deionized water, and again with collection water prior to sampling. An untreated sample, a 20% nitric acid dilution sample and 10% hydrochloric acid dilution sample were collected at each site.

The pH and bicarbonate concentration were determined at the time of collection on filtered-untreated samples using an Orion Model 407 selective ion meter with Ag/AgCl combination pH electrode and sulfuric acid titration. Fluoride, chloride and total dissolved solids were determined on filtered-untreated samples by specific ion electrode, silver nitrate titration and gravimetric

Table 9-1
 Chemical Analyses of Utah State Prison Well Water (TH1)
 During Flow Test¹

Sample No.		TH1							
		Well Head						Down Hole	
		1	4	5	6	7	8	2 ²	3 ³
Collection Date		6-9-82	6-22-82	6-29-82	7-6-82	7-9-82	7-14-82	6-15-82	6-15-82
Flow Rate (Approx.)	gal/min	Pre-Flow	300	300	300	600	600	300	300
Collection Temperature	°C	82	81	82	82	82	82		
pH		6.7	6.4	6.7	6.4	6.9	6.7	6.1	5.65
Na	mg/l	407	415	411	405	405	408	423	406
K	mg/l	64	65	63	64	64	63	64	64
Ca	mg/l	142	148	155	144	145	144	148	146
Mg	mg/l	32	33	34	32	33	33	32	32
SiO ₂	mg/l	52	56	58	55	55	56	52	28 ⁴
HCO ₃	mg/l	428	457	430	423	433	417	475	514
SO ₄	mg/l	66	68	64	69	67	69	63	59
Cl ⁴	mg/l	752	774	760	757	742	756	773	774
F	mg/l	2.6	2.5	2.5	2.6	2.0	1.9	2.4	2.3
Total Dissolved Solids									
Measured	mg/l	1900	1780	1800	1830	1810	1830	1900	1810
Calculated	mg/l	1740	1790	1770	1740	1730	1740	1820	1820
Fe	mg/l	0.36	<0.025	0.40	0.38	<0.025	<0.025	<0.025	<0.025
Sr	mg/l	3.37	3.70	3.79	3.64	3.10	3.10	3.47	3.62
Mn	mg/l	0.5	0.5	0.5	0.5	0.5	0.5	0.9	1.3
Li	mg/l	1.45	1.53	1.53	1.46	1.26	1.26	1.45	1.49
B	mg/l	1.5	1.5	1.6	1.5	1.3	1.3	1.4	1.5

¹Samples collected at wellhead. Other elements analyzed for but below detection include: Al < 0.6, Ti < 0.1, P < 0.6, Ba < 0.6, V < 1, Cr < 0.05, Co < 0.03, Ni < 0.1, Cu < 0.06, Mo < 1, Pb < 0.3, Zn < 0.1, Cd < 0.06, Ag < 0.05, Au < 0.1, As < 0.6, Sb < 0.8, Bi < 2.5, Te < 1, Sn < 0.1, W < 0.1, Be < 0.005, Zr < 0.1, La < 0.1, Ce < 0.25, Th < 2.5

²Collected at 488 ft.

³Collected at 1000 ft.

⁴This value is low because the sample was not preserved immediately after collection.

Table 9-2

Chemical analyses of Utah Roses Well Water (UR1) during Utah State Prison Well (TH1) flow test.¹ Well head samples.

Sample No.		UR1			
		1	2	3	4
Collection Date		6-14-82	6-22-82	6-29-82	7-6-82
Collection Temperature	°C	82	73	79	81
pH		6.7	6.5	6.6	6.6
Na	mg/l	356	367	371	359
K	mg/l	55	57	58	56
Ca	mg/l	137	148	153	136
Mg	mg/l	30	31	33	33
SiO ₂	mg/l	56	60	62	58
HCO ₃	mg/l	412	461	413	391
SO ₄	mg/l	64	61	64	66
Cl	mg/l	696	676	692	697
F	mg/l	2.8	2.4	2.4	1.8
Total Dissolved Solids					
Measured	mg/l	1680	1680	1680	1690
Calculated	mg/l	1610	1660	1660	1600
Fe	mg/l	1.51	5.62	2.81	0.39
Sr	mg/l	3.41	3.72	3.77	3.62
Mn	mg/l	0.5	0.6	0.5	0.4
Li	mg/l	1.06	1.18	1.22	1.12
B	mg/l	1.1	1.3	1.3	1.2

methods, respectively. Other major and trace elements were determined using an ARL Inductively Coupled Plasma Quantometer.

Gas samples were collected at the well head using an evacuated steel cylinder and analyzed by mass spectrophotometry. The results of these analyses are not included because they were sporadic and the results questionable. One reason for the sporadic results is that the water fraction in the cylinders reabsorbed the gases upon cooling.

Water quality data for other thermal and nonthermal wells in the study area, including the State Forestry Well (SF1), and Crystal Hot Springs (CHS) were provided by R. H. Klauk (unpublished data, Utah Geologic and Mineral Survey, 1982).

9.3 DISCUSSION

The chemical composition of water from both TH1 and UR1 appears to be relatively constant throughout the flow test period. When flow of TH1 was stepped up to 600 gal/min, however, UR1 ceased to flow. Therefore samples were not collected from UR1 after July 6 and thus compositional changes in UR1 during the final stages of the flow test cannot be documented.

Utah State Prison (TH1) thermal water has a maximum measured temperature of 83°C. It is slightly acid with a sodium chloride character, and relatively dilute with dissolved solids ranging from 1780 to 1900 ppm. The chemical composition of down hole samples (Table 9-1) is consistent with that of surface samples collected at the pump head.

Utah Roses (UR1) thermal water is similar in chemical character to TH1, although, slightly more dilute with dissolved solids content ranging from 1680 to 1690. The more dilute character of UR1 as compared to TH1 is reflected in

lower sodium, potassium and chloride concentrations. This could indicate greater ground water dilution in UR1 samples relative to those from TH1. This is supported by the more dilute character of the local ground water in these elements relative to the thermal reservoir water (Table 2.1-3). Measured temperatures range from 73° to 82°C. The Utah Energy Office (1981) has measured a maximum temperature of 98°C for UR1.

Waters from Crystal Hot Springs (CHS) and the State Forestry well (SF1), which are in the immediate vicinity of TH1 and UR1 (Figure 20a), are similar in chemical character to the TH1 and UR1 water (Table 9-3, Figure 20b) and have maximum temperatures of 80°C (Utah Energy Office, 1981) and 86°C (Murphy and Gwynn, 1979a), respectively.

In addition, all other nearby thermal well waters sampled, wells 15, 56 and 121 (Figure 20a), also have a chemical character similar to that of TH1 and UR1 (Table 9-3, Figure 20b). Water from these peripheral wells, with temperatures ranging from 19° to 38°C and dissolved solids contents of less than 1310 ppm are, however, cooler and more dilute than thermal waters tapped by wells TH1, UR1, and SF1 which have temperatures over 54°C and dissolved solids contents ranging from 1680 to 1900 ppm.

Nonthermal ground water in the study area is distinctly different from that of the thermal water as shown on Figure 20b. The ground water is slightly basic with a sodium-calcium bicarbonate to sodium-calcium bicarbonate-sulfate-chloride character in contrast to the sodium chloride character of the thermal water (Table 9-3). In addition, the ground water is generally more dilute with dissolved solids contents ranging from 260 to 1600 ppm.

The different chemical characters suggests the thermal water has a different

Table 9-3
 Ranges In Composition of Thermal and Nonthermal Water from Study Area.

		CRYSTAL HOT SPRINGS AREA ³					Nonthermal Ground water ^{1,4}
		Thermal Water					
		TH1	UR1	SF1 ¹	CHS ¹	Other ¹	
Number of Samples		6	4	1	2	3 ²	16
Well Depth	m	306	125	85	Spring	82-88	37-257
Collection Temperature	°C	81-82	73-82	54	29-38 ⁵	19-38	13-17
pH		6.4-6.9	6.5-6.7	6.2	7.2-7.3	6.3-7.2	7.0-7.5
Na	mg/l	405-415	356-371	370	316-347	209-267	23-230
K	mg/l	63-65	55-58	55	47-53	18-39	<2.5-17
Ca	mg/l	142-155	136-153	139	124-146	59-143	40-200
Mg	mg/l	32-34	30-33	32	32-36	11-35	13-80
SiO ₂	mg/l	52-58	56-62	45	43-77	21-24	15-47
HCO ₃	mg/l	423-457	391-461	480	350-480	230-400	190-500
SO ₄	mg/l	64-69	61-66	62	74-94	45-129	33-440
Cl	mg/l	742-774	676-697	708	618-673	365-531	29-350
F	mg/l	1.9-2.6	1.8-2.8	2.4	2.3-2.5	0.8-1.8	0.2-1.1
Total Dissolved Solids	mg/l	1780-1900	1680-1690	1700	1560-1720	1000-1310	260-1600
	(Measured)						
B		1.3-1.5	1.1-1.3	1.4	0.8-1.1	0.3-0.5	2.2-2.7
Li		1.26-1.53	1.06-1.22	1.58	0.93-1.34	0.31-0.53	<0.05-0.07
<u>Geothermometers</u>							
Quartz (cond. cooled) ⁶	°C	104-107	107-112	97	95-123	65-70	
Chalcedony ⁶	°C	74-78	78-83	67	64-95	33-3	
Alpha Cristobalite ⁶	°C	53-57	57-62	47	45-72	16-21	
Na-K-Ca (Mg Corrected ⁷)	°C	80-82	74-83	77	61-79	66-81	

¹ Unpublished data from R. H. Klauk (Utah Geological and Mineral Survey, 1982).

² Samples 15, 56, and 121.

³ See Figure 2 for locations.

⁴ Nonthermal ground water in the Jordan Valley is designated by Klauk et al. (1981) as water having temperatures of less than 18°C.

⁵ Maximum measured temperature 80°C (Utah Energy Office, 1981).

⁶ Calculated using the methods of Fournier (1977).

⁷ Calculated using the methods of Fournier and Truesdell (1973, 1974) and Fournier and Potter (1979).

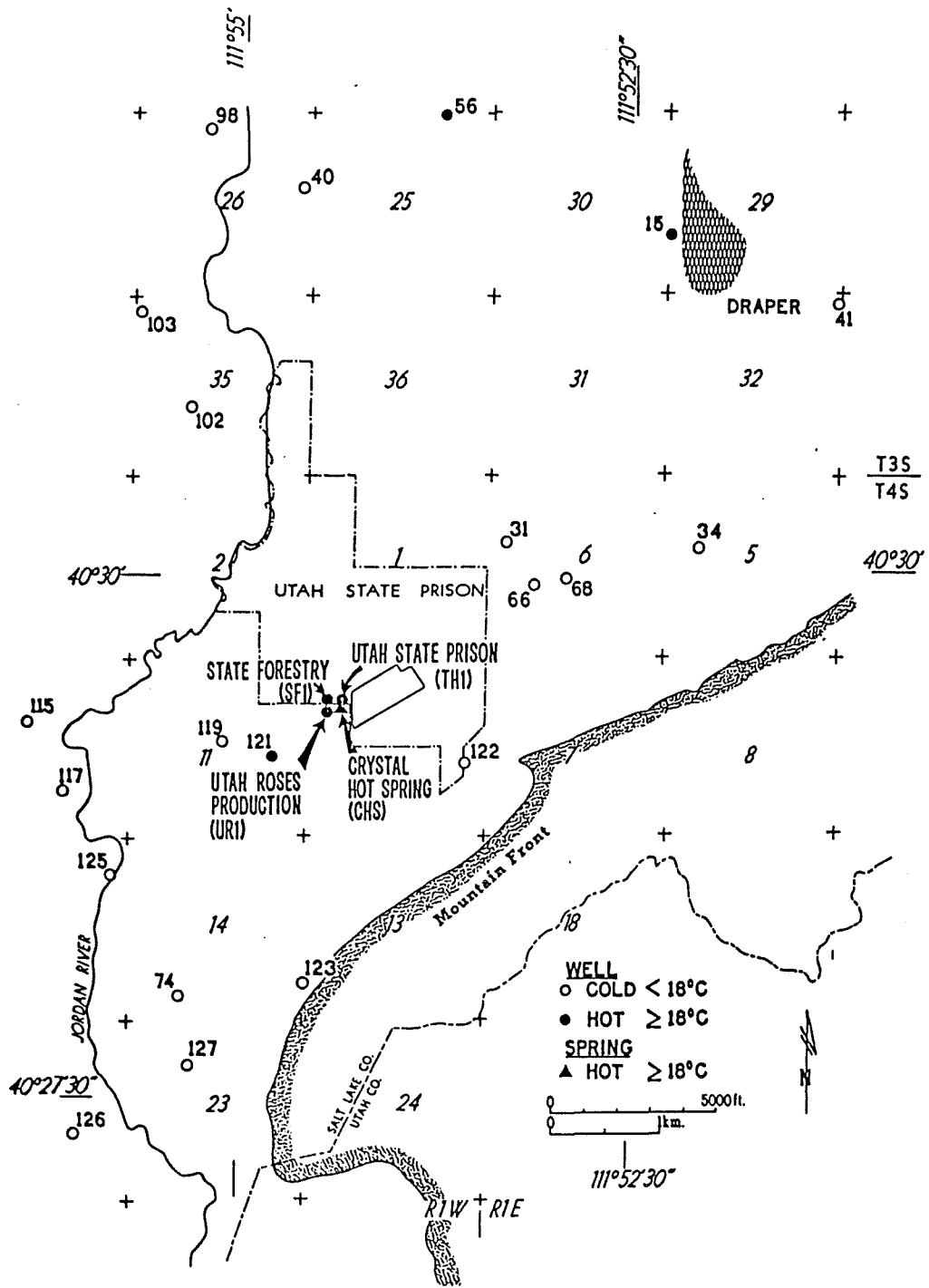


Figure 20a. Well and spring locations Utah State Prison study area.

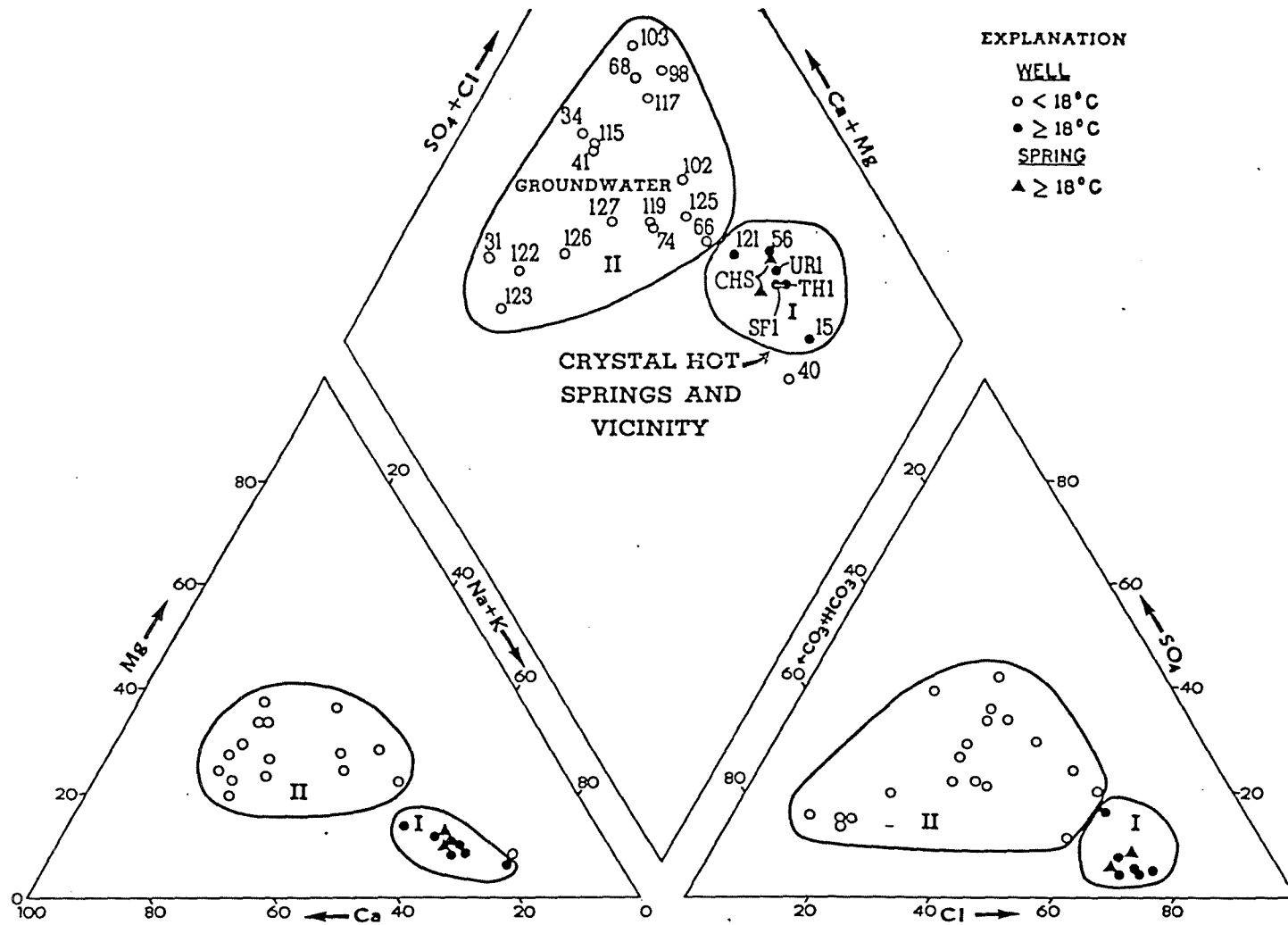


Figure 20b. Chemical character of well and spring water in the Utah State Prison study area. Representation in this trilinear diagram is in equivalent percents of anions and cations. For data sources see Table 9-3 and for sample locations see Figure 20a.

source than the local aquifer water. This supports the conclusion of the Utah Energy Office (1981) that the bedrock of Paleozoic Quartzite is the thermal reservoir source in this area rather than the overlying clay rich alluvium, the source of local ground water. All three of the deep geothermal wells (TH1, UR1 and SF1) penetrate the Paleozoic Quartzite (Utah Energy Office, 1981).

Calculated geothermometer temperatures suggest the maximum temperature of thermal water at depth in the study area is less than 95°C. This is based on the predicted chalcedony and Na-K-Ca with Mg correction temperatures, listed in Table 9-3, which are the most reliable chemical geothermometers for low to moderate temperature geothermal systems (Fournier, 1981). The maximum predicted temperature of 95°C is comparable to the maximum measured temperatures of 98°C in UR1, 83°C in TH1 and 86°C in SF1.

Hyland

9.0 GEOCHEMICAL RESERVOIR ASSESSMENT

9.1 INTRODUCTION

The evaluation of the chemical composition of thermal springs, wells and cold surface waters has proved, for many geothermal systems, to be a useful tool in the evaluation of the geothermal reservoir. fluid geochemical surveys have provided information on the compositions and homogeneity of the fluids, subsurface temperatures, rock types, and the origin of fluids, and fluid pathlines.

9.2 SAMPLING AND CHEMICAL ANALYSIS

Water samples were collected from Utah State Prison Well (USP/TH-1) and the nearby Utah Roses Production Well (UR1) during the June 16 to July 20, 1982 flow test. The dates of sampling and the analytic results are listed on Tables 9-1 and 9-2. Sample locations are shown on Figure 1. Samples from TH1 were collected both at the well head and at depth using a "Kuster" down hole sampler.

All samples were filtered with a 0.45 μ membrane filter upon collection and stored in polyethylene containers. These containers were precleaned by soaking them in 20% nitric acid, rinsing in deionized water and again with collection water prior to sampling. An untreated sample and a 20% nitric acid dilution sample were collected at each site.

The pH and bicarbonate concentration were determined at the time of collection on filtered-untreated samples using an Orion Model 407 selective ion meter with Ag/AgCl combination pH electrode and sulfuric acid titration. Fluoride, chloride and total dissolved solids were determined on filtered-untreated samples by a specific ion electrode, silver nitrate titration, and gravimetric methods, respectively. Other major and trace elements were determined using an ARL Inductively Coupled Plasma Quantometer.

Gas samples were collected at the well head using an evacuated steel cylinder and analyzed by mass spectrophometry. The results of these

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analyses are not included because they were sporadic and the results questionable. One reason for the sporadic results is that the water fraction in the cylinders reabsorbed the gases upon cooling.

Water quality data for other thermal and nonthermal wells in the study area, including the State Forestry Well (SF-1), and Crystal Hot Springs (CHS) were provided by R.H. Klauk (unpublished data, Utah Geologic and Mineral Survey, 1982).

9.3 DISCUSSION

The chemical composition of water from both USP/TH-1 and UR-1 appeared to be relatively constant throughout the flow test period (Tables 9-1 and 9-2). When flow of USP/TH-1 was stepped up to 600 gpm, however, UR-1 ceased to flow. Therefore no samples were collected from UR-1 for this time period and the chemical composition of the water cannot be documented.

Utah State Prison (USP/TH-1) thermal water has a maximum measured temperature of 83°C. It is slightly acid with a sodium chloride character, and relatively dilute with dissolved solids ranging from 1778 to 1898 ppm. The chemical composition of down hole samples is consistent with that of surface samples collected at the pump head.

Utah Roses (UR-1) thermal water is similar in chemical character to USP/TH-1, however, slightly more dilute with dissolved solids content ranging from 1676 to 1694. This more dilute character of UR-1 when compared to USP/TH-1 is reflected in lower sodium, potassium and chloride concentrations. This could possibly reflect a component of ground water in UR-1 samples, as the ground water is more dilute in these elements relative to the thermal reservoir water (Table 9-3). The maximum measured temperature of this water is 98°C (Utah Energy Office, 1981).

Water from Crystal Hot Springs (CHS) and the State Forestry well (SF-1), which are in the immediate vicinity of USP/TH-1 and UR-1 (Figure 1), is

Table 1

Chemical Analyses of Utah State Prison Well Water (TH1)
During Flow Test¹

Sample No.	TH1							
	Well Head						Down Hole	
	1	4	5	6	7	8	2 ²	3 ³
Collection Date	6-9-82	6-22-82	6-29-82	7-6-82	7-9-82	7-14-82	6-15-82	6-15-82
Flow Rate (Approx.) gal/min	Pre-Flow	300	300	300	600	600	300	300
Collection Temperature °C	82	81	82	82	82	82		
pH	6.7	6.4	6.7	6.4	6.9	6.7	6.1	5.65
Na mg/l	407	415	411	405	405	408	423	406
K mg/l	64	65	63	64	64	63	64	64
Ca mg/l	142	148	155	144	145	144	148	146
Mg mg/l	32	33	34	32	33	33	32	32
SiO ₂ mg/l	52	56	58	55	55	56	52	28 ⁴
HCO ₃ mg/l	428	457	430	423	433	417	475	514
SO ₄ mg/l	66	68	64	69	67	69	63	59
Cl mg/l	752	774	760	757	742	756	773	774
F mg/l	2.6	2.5	2.5	2.6	2.0	1.9	2.4	2.3
Total Dissolved Solids Measured mg/l	1898	1778	1798	1833	1812	1832	1896	1810
Calculated mg/l	1735	1793	1766	1744	1732	1742	1821	1816
Fe mg/l	0.36	<0.025	0.40	0.38	<0.025	<0.025	<0.025	<0.025
Sr mg/l	3.37	3.70	3.79	3.64	3.10	3.10	3.47	3.62
Mn mg/l	0.5	0.5	0.5	0.5	0.5	0.5	0.9	1.3
Li mg/l	1.45	1.53	1.53	1.46	1.26	1.26	1.45	1.49
B mg/l	1.5	1.5	1.6	1.5	1.3	1.3	1.4	1.5

¹Samples collected at wellhead. Other elements analyzed for but below detection include: Al < 0.6, Ti < 0.1, P < 0.6, Ba < 0.6, V < 1, Cr < 0.05, Co < 0.03, Ni < 0.1, Cu < 0.06, Mo < 1, Pb < 0.3, Zn < 0.1, Cd < 0.06, Ag < 0.05, Au < 0.1, As < 0.6, Sb < 0.8, Bi < 2.5, Te < 1, Sn < 0.1, W < 0.1, Be < 0.005, Zr < 0.1, La < 0.1, Ce < 0.25, Th < 2.5

²Collected at 488 ft.

³Collected at 1000 ft.

⁴This value is low because the sample was not preserved immediately after collection.

Revised

Replaced

Table 9-2

Chemical analyses of Utah Roses Well Water (URI) during Utah State Prison Well (TH1) flow test.¹ Well head samples.

Sample No.	URI			
	1	2	3	4
Collection Date	6-14-82	6-22-82	6-29-82	7-6-82
Collection Temperature °C	82	73	79	81
pH	6.7	6.5	6.6	6.6
Na mg/l	356	367	371	359
K mg/l	55	57	58	56
Ca mg/l	137	148	153	136
Mg mg/l	30	31	33	33
SiO ₂ mg/l	56	60	62	58
HCO ₃ mg/l	412	461	413	391
SO ₄ mg/l	64	61	64	66
Cl mg/l	696	676	692	697
F mg/l	2.8	2.4	2.4	1.8
Total Dissolved Solids Measured mg/l	1680	1684	1676	1694
Calculated mg/l	1606	1655	1656	1605
Fe mg/l	1.51	5.62	2.81	0.39
Sr mg/l	3.41	3.72	3.77	3.62
Mn mg/l	0.5	0.6	0.5	0.4
Li mg/l	1.06	1.18	1.22	1.12
B mg/l	1.1	1.3	1.3	1.2

¹Other elements analyzed for but below detection include: Al <0.6, Ti <0.1, P <0.6, Ba <0.6, V < 1, Cr < 0.05, Co < 0.03, Ni < 0.1, Cu < 0.06, Mo < 1, Pb < 0.3, Zn < 0.1, Col < 0.06, Ag < 0.05, Au < 0.1, As < 0.6, Sb < .8, Bi < 2.5, Te < 1, Sn < .1, W < .1, Be < .005, Zr < .1, La < .1, Ce < .25, Th < 2.5

explained

similar in chemical character to the USP/TH-1 and UR-1 water (Table 9-3) and has maximum temperatures of 80°C (Utah Energy Office, 1981) and 86° (Murphy and Gwynn, 1979a), respectively.

In addition thermal water tapped by wells 15, 56, and 121, which are outside the immediate Prison site (Figure 1), also has a chemical character similar to that of USP/TH-1 and UR-1 (Figure 20). Water from these peripheral wells, however, is a little more dilute with dissolved solids contents of less than 1310 ppm.

Nonthermal ground water in the study area is distinctly different from that of the thermal water as shown on Figure 20. The ground water is slightly basic with a sodium-calcium bicarbonate to sodium-calcium bicarbonate-sulfate-chloride character in contrast to the sodium chloride character of the thermal water. In addition, the ground water is relatively dilute with dissolved solids contents ranging from 1000 to 1300 ppm.

The different chemical characters suggests the thermal water has a different source than the local aquifer water. This supports the conclusion of the Utah Energy Office (1981) that the bedrock of Paleozoic Quartzite is the thermal reservoir source in this area rather than the overlying clay rich alluvium. All three of the deep geothermal wells (USP/TH-1, UR-1, and SF-1) penetrate the Paleozoic Quartzite (Utah Energy Office, 1981).

Calculated geothermometer temperatures suggest the maximum temperature of thermal water at depth in the study area is less than 95°C. This is based on the predicted chalcedony and Na-K-Ca with Mg correction temperatures, listed in Table 9-3, which are the most reliable geothermometers for low to moderate temperature geothermal systems (Fournier, 1981). This maximum temperature of 95°C is comparable to the maximum measured temperatures of 98°C in UR-1, 83°C in USP/TH-1, and 86°C in SF-1.

Table 9-3

Ranges in Composition of Thermal and Nonthermal Water from Study Area
and Thermal Water from Utah Roses north well.

		CRYSTAL HOT SPRINGS AREA ³					Nonthermal Ground water ^{1,5}	Utah Roses North Well ^{1,4}
		Thermal						
		TH1	UR1	SF1 ¹	CHS ¹	Other ¹		
Number of Samples		6	4	1	2	3 ²	16	3
Depth	m	306	125	85	Spring	82-88	37-257	1200
Collection Temperature	°C	81-82	73-82	54	29-38	19-38	13-17	38-48
pH		6.4-6.9	6.5-6.7	6.2	7.2-7.3	6.3-7.2	7.0-7.5	7.4-7.8
Na	mg/l	405-415	356-371	370	316-347	209-267	23-230	743-875
K	mg/l	63-65	55-58	55	47-53	18-39	<2.5-17	4-5
Ca	mg/l	142-155	136-153	139	124-146	59-143	40-200	48-58
Mg	mg/l	32-34	30-33	32	32-36	11-35	13-80	11-17
SiO ₂	mg/l	52-58	56-62	36	20-36	10-11	15-45	17-19
HCO ₃	mg/l	423-457	391-461	480	350-480	230-400	190-500	167
SO ₄	mg/l	64-69	61-66	62	74-94	45-129	33-440	919-934
Cl	mg/l	742-774	676-697	708	618-673	365-531	29-350	654-670
F	mg/l	1.9-2.6	1.8-2.8	2.4	2.3-2.5	0.8-1.8	0.2-1.1	0.8-0.9
Total Dissolved Solids Measured	mg/l	1778-1898	1676-1694	1700	1560-1720	1000-1310	260-1600	2600-2700
B		1.3-1.5	1.1-1.3	1.4	0.8-1.1	0.3-0.5	2.2-2.7	2.2-2.7
Li		1.26-1.53	1.06-1.22	1.58	0.93-1.34	0.31-0.53	<0.05-0.07	<0.05-0.07
Quartz (cond. cooled) ⁶		104-107	107-112	97	95-123	65-70		62-57
Chalcedony ⁶		74-78	78-83	67	64-95	33-39		25-29
Alpha Cristoballite ⁶		53-57	57-62	47	45-72	16-21		9-12
Na-K-Ca with Mg Correction ⁷		80-82	74-83	77	61-79	66-81		64

¹Unpublished data from R. H. Klauk (Utah Geological and Mineral Survey, 1982).

²Samples 15,56,121.

³See Figure 2 for locations.

⁴See Figure 1 for locations.

⁵Nonthermal ground water in the Jordan Valley is designated by Klauk et al. (1981) as water having temperatures of less than 18°C.

⁶Calculated using the methods of Fournier (1977).

⁷Calculated using the methods of Fournier and Truesdell (1973, 1974) and Fournier and Potter (1979).

Revised

10.0 CONCLUSIONS AND RECOMMENDATIONS

The tests indicate that the resource is a fracture controlled system. The variation in observation well data with some wells at considerable distance responding to fluid withdrawal in USP/TH-1 while other wells seeming to be unaffected is typical of the linear trend in fractured systems. The response of Utah Roses observation well, monitor wells D and E, and Spring CR-3 confirm the existence of a major trend in the SW direction which is hydraulically connected to the system. The effect on the Utah State Forestry well but lack of response at Observation Wells B and C indicate that trend is only hydraulically connected at depth. Also the capability of this trend to transmit water is much less when one compares the transmissibility values for the Utah Roses well to the values for the Utah State Forestry well. This data shows the aquifer is not a homogeneous system. Data from the Utah Roses and Utah State Forestry wells as well as data from the production well will show boundaries occurring within the system. As a result, caution should be exercised in using conventional transmissibility and storage coefficient values to assess the long term reservoir performance. These values are obtained from equations which do not take into full account the fractured in-homogeneous nature of the reservoir.

The transmissibility and storage coefficient values can be used to give information on well performance and, by using the trends obtained during the test, one can predict the reservoir performance.

The data indicate the well will flow at the design rate of 200 gallons per minute with a pressure decline of approximately 1.5 to 2.0 psi at the end of a 6 to 9 month heating season (Figure 21). This will result in a wellhead pressure of approximately 6.0 psi which will sustain the 200 gallon per minute rate. This predicted decline only accounts for Well USP/TH-1 flowing. Transmissibility values and pressure response between the Utah Roses well and the Utah State Prison production well indicate a highly transmissive zone between these two wells. Water chemistry data also indicate these wells produce from the same system.

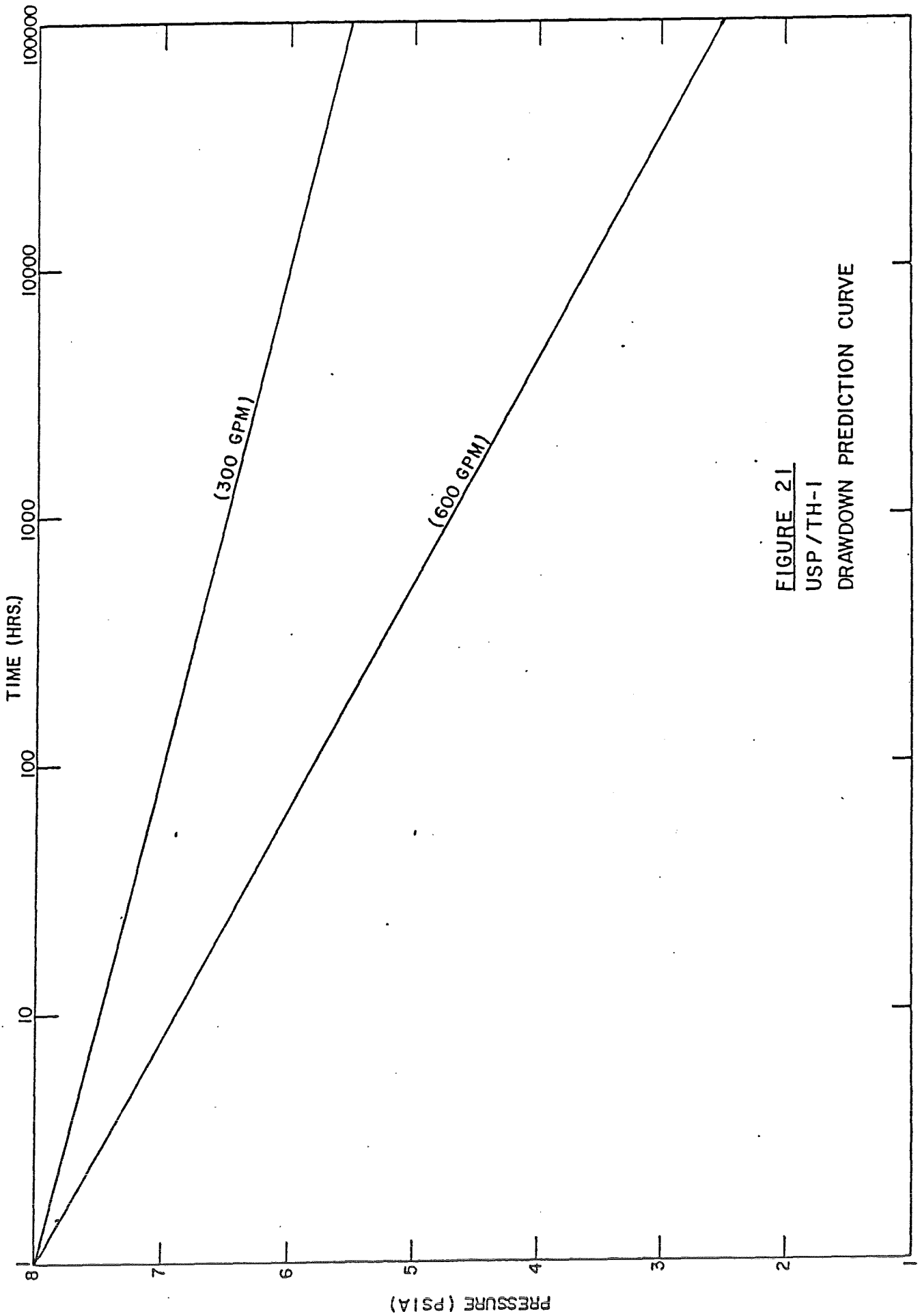


FIGURE 21
 USP / TH-1
 DRAWDOWN PREDICTION CURVE

Any pumping in one of these wells will directly affect the other well. Flow of USP/TH-1 at the 200 gallon per minute rate will cause a 3 psi pressure decline in the Utah Roses well which will result in the Utah Roses well dropping below flowing artesian conditions. At a flow rate of 400 gpm in USP/TH-1 there would be a pressure decline of approximately 2.5 psi in USP/TH-1 at the end of six months and the Utah Roses water level would drop to approximately 6 feet below ground surface.

Because of the interaction between the Utah Roses well and the Utah State Prison well, both wells producing at the same time would have a compounded impact. The two wells would interact with each other causing a greater stress on the system than if each were producing independently. The combined effect of the Utah Roses well, producing at design capacity of 260 gallons per minute, and the Utah State Prison, well producing at 200 gallons per minute, would cause an impact similar to either well flowing at a rate of 400 to 500 gallons per minute. Drawdown in the Utah State Prison well would be approximately 3.5 psi for a 6 to 9 month heating season. Artesian flow at the 200 gallon per minute rate should be maintained as predicted flowing well head pressure would be approximately 4.5 psi at the end of the heating season.

Drawdown in the Utah Roses well will be approximately 7 psi with both wells producing a total of 460 gallons per minute. This would result in a standing water level drawdown to 12 feet below ground surface. As a result the Utah Roses system would have to rely on pumping for a water source.

Production at higher rates for either USP/TH-1 or the Utah Roses well would correspondingly affect the other well. If Utah Roases Well was produced at a 400 gallon per minute rate and USP/TH-1 at 200 gallons per minute rate the system would result in approximately a 4.2 PSI drop in well head pressure during the heating season. This amount of pressure drawdown should not result in the flow of USP/TH-1 to decline below 200 gpm. One must keep in mind, however, the flow of USP/TH-1 is a direct result of CO₂ flashing in the wellbore causing a gas lift to occur.

If USP/TH-1 was shut in late in the season and the wellbore allowed to cool, a 4.2 psi drop in the reservoir pressure could result in the well not being able to self start flowing because of a higher density water column and lower reservoir pressure affecting the CO₂ flash point. As a result it may be necessary to stimulate the flow through air lift or pumping until the wellbore heats up sufficiently to self flow at the desired rate.

The predicted decline in the system will cause Spring CR-3 to dry up. This will cause an impact on water supply to the Western Pond and to a private beaver raising facility located adjacent to the pond. This facility would need to consider developing an alternative water supply or possibly using waste water from either the Utah Roses or Utah State Prison facility in the future.

Recharge to the system will occur during the summer non-heating season. With 3 to 6 months of non-geothermal use, the system will recharge to within 80 to 100 percent of the original pre-production pressures depending on length of the non-heating season. This assumes a production rate of up to 200 gpm for USP/TH-1 and up to 400 gallons per minute for Utah Roses production well during the heating season.

It is recommended a longer term flow test be conducted on USP/TH-1 at a flow rate of approximately 600 gpm. The test should be conducted for at least three months and monitoring be conducted in SF-1 and the Utah Roses Production well. If the system is developed prior to conducting additional testing a monitoring program should be initiated which includes flow and pressure monitoring from USP/TH-1 and the Utah Roses Production well and pressure monitoring of SF-1. With this information a better evaluation of the long term response to increased production in a fractured geothermal system can be made.

11.0 REFERENCES

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APPENDIX I

QUALITY OF GEOTHERMAL PRODUCTION WATER
UTAH STATE PRISON GEOTHERMAL WELL (TH1)
COLLECTED AS AN EPA MONITORING REQUIREMENT

QUALITY OF GEOTHERMAL PRODUCTION WATER
UTAH STATE PRISON GEOTHERMAL WELL (TH1)

Data Collected During 30 Day Flow Test
May 16, 1982 to June 20, 1982

As a Monitoring Requirement under
NPDES Discharge Permit Ut-0024082

Regina Capuano

Regina M. Capuano
Geochemist

8-18-82

Figure 1. Location Map for EPA monitor samples: 1 = Utah State Prison Well TH1; 2 = Jordan River sample location upstream from geothermal discharge; 3 = Jordan River sample location downstream from geothermal discharge; 4 = location of discharge sample just prior to entry of flow into the Jordan River. Map bas is U.S.G.S. 7½ minute topographic map.

Table 1. Quality of Geothermal Production Waters at Pump Head: Well TH-1

A. Daily Temperature and Visual Oil and Grease

SAMPLING		ANALYSIS ¹			
DATE (1982)	TIME	TEMPERATURE (°C)	OIL AND GREASE	DATE (1982)	ANALYST ²
6-16	17:30	82	None	6-16	MJ
6-17	17:35	82	None	6-17	MJ
6-18	17:22	82	None	6-18	MJ
6-19	17:18	82	None	6-19	MJ
6-20	17:06	82	None	6-20	MJ
6-21	17:00	82	None	6-21	MJ
6-22	17:04	82	None	6-22	MJ
6-23	17:25	82	None	6-23	MJ
6-24	9:47	82	None	6-24	MJ
6-25	6:26	82	None	6-25	MR
6-26	21:40	83	None	6-26	MR
6-27	21:37	82	None	6-27	MR
6-28	23:15	81	None	6-28	MJ
6-29	21:50	82	None	6-29	MJ
6-30	00:17	82	None	6-30	MR
7-1	21:73	82	None	7-1	MR
7-2	22:33	82	None	7-2	MR
7-3	21:70	82	None	7-3	MR
7-4	21:93	82	None	7-4	MR
7-5	21:00	82	None	7-5	MR
7-6	17:00	82	None	7-6	MR
7-7	21:07	82	None	7-7	MR
7-8	22:02	82	None	7-8	MR
7-9	21:48	82	None	7-9	MR
7-10	14:05	82	None	7-10	MR
7-11	14:13	83	None	7-11	MR
7-12	14:24	82	None	7-12	MR
7-13	15:17	82	None	7-13	MR
7-14	14:45	82	None	7-14	MR
7-15	15:30	82	None	7-15	MR
7-16	15:10	82	None	7-16	MR
7-17	14:28	82	None	7-17	MR
7-18	23:20	82	None	7-18	MR
7-19	14:06	82	None	7-19	MR
7-20	7:00	82	None	7-20	MR

¹See Table 5

²See Table 5

Collection Date/Time		6-22-82/12:10			6-29-82/9:00			7-6-82/9:55			7-9-82/9:30		
		ANALYSIS ¹			ANALYSIS ¹			ANALYSIS ¹			ANALYSIS ¹		
PARAMETER	UNITS	Concentration	Date (1982)	Analyst ²	Concentration	Date (1982)	Analyst ²	Concentration	Date (1982)	Analyst ²	Concentration	Date (1982)	Analyst ²
pH		6.4	6-22	MB	6.7	6-29	MB	6.4	7-6	MB	6.9	7-9	MB
Total Suspended Solids	mg/l	6	6-26	RM	1	7-5	RM	17	7-9	JM	6	7-13	JM
Total Dissolved Solids	mg/l	1750	6-27	RK	1750	7-1	RK	1824	7-8	RK	1824	7-12	RK
Dissolved Oxygen	mg/l	1.2	6-22	MB	1.0	6-29	MB	1.2	7-6	MB	1.6	7-9	MB
Chemical Oxygen Demand	mg/l	54.6	6-24	RM				37.4	7-9	JM			
Total Kjeldahl Nitrogen	mg/l	<0.05	6-24	RM				0.23	7-9	JM			
Oil and Grease	mg/l	1.55	6-24	RM	11	7-2	RM	1.3	7-9	JM	10.4	7-13	RM
Chlorides	mg/l	730	6-26	RM	746.8	7-5	RM	717.2	7-10	JM	747	7-13	RM
Sulfates	mg/l	70	6-27	RK	70	7-1	RK	68	7-8	RK	68	7-12	RK
Sulfides	mg/l	<0.01	6-26	RM	<0.1	7-2	RM	0.02	7-9	JM	<0.01	7-13	RM
Total Boron	ug/l	1500	6-24	RM	400	7-2	RM	1600	7-10	JM	1000	7-14	RM
Total Arsenic	ug/l	70	7-6	RM	196	7-14	RM	218	7-14	JM	212	7-14	RM
Total Copper	ug/l	110	7-6	RM	28	7-14	RM	25	7-14	JM	18	7-14	RM
Total Iron	ug/l	260	7-6	RM	262	7-14	RM	263	7-14	JM	264	7-14	RM
Total Lead	ug/l	30	7-6	RM	94	7-14	RM	79	7-14	JM	79	7-14	RM
Total Mercury	ug/l	0.79	7-6	RM	0.24	7-14	RM	0.36	7-14	JM	0.72	7-14	RM
Total Nickel	ug/l	10	7-6	RM	190	7-14	RM	30	7-14	JM	40	7-14	RM
Total Cadmium	ug/l	11	7-6	RM	7	7-14	RM	<1	7-14	JM	<1.0	7-14	RM
Total Uranium	ug/l	14	7-9	JM				<1	7-13	JM			
Gross Alpha Radiation	pCi/l	540 ± 60	7-6	JM	94 ± 30	7-5	JM	110 ± 30	7-13	JM	100 ± 30	7-15	JM
Gross Beta Radiation	pCi/l	160 ± 20	7-6	JM	91 ± 18	7-5	JM	83 ± 17	7-13	JM	95 ± 18	7-15	JM
Dissolved Radium 226,228 Combined	pCi/l	78 ± 5	7-6,7-14	JM	81 ± 5	7-5	JM	52 ± 3	7-13	JM	33.5 ± 4.2	7-15	JM
Total Radium 226,228 Combined	pCi/l	78.4 ± 5	7-6,7-14	JM	81.9 ± 5	7-5	JM	52 ± 3	7-13	JM	35.2 ± 4.2	7-15	JM

¹See Table 5

²See Table 5

Table 2. Quality at point just prior to entry
of flow into the Jordan River

Parameter	Sampling		Analysis ¹			
	Date (1982)	Time	Concentration	Units	Date (1982)	Analyst ²
Temperature	6-29	11:30	18	°C	6-29	MB
Temperature	7-14	9:30	18	°C	7-14	MB

¹See Table 5

²See Table 5

Collection Date/Time		6-29-82/11:30			7-9-82/AM		
		Analysis ¹			Analysis ¹		
Parameter	Units	Concentration	Date	Analyst ²	Concentration	Date	Analyst ²
Temperature	°C	22	6-29	MB	21	7-9	MB
Total Boron	µg/l	<100	7-2	RM	<100	7-13	RM
Alpha, gross	pCi/l	15 ± 9	7-5	JM	12 ± 8	7-15	JM
Beta, gross	pCi/l	23 ± 5	7-5	JM	19 ± 5	7-15	JM
Dissolved Radium 226,228 combined	pCi/l	1.4 ± 2.3	7-5	JM	1.5 ± 3.2	7-15	JM
Total Uranium	µg/l	4	7-5	JM	3	7-15	JM
Estimated Flow Rate of Jordan River	ft ³ /sec	315	6-29	DG	185	7-9	DG

¹See Table 5

²See Table 5

Table 4. Discharge quality of Jordan River at a point downstream of the point of entry on the geothermal production waters (after reasonable complete mixing occurs)

Collection Date/Time		6-29-82/11:30			7-9-82/AM		
		Analysis ¹			Analysis ¹		
Parameter	Units	Concentration	Date	Analyst ²	Concentration	Date	Analyst ²
Temperature	°C	20	6-29	MB	21	7-9	MB
Total Boron	µg/l	<100	7-2	RM	300	7-13	RM
Alpha, gross	pCi/l	10 ± 9	7-5	JM	93 ± 21	7-15	JM
Beta, gross	pCi/l	33 ± 5	7-5	JM	51 ± 9	7-15	JM
Dissolved Radium 226,228 combined	pCi/l	2.0 ± 2.5	7-5	JM	1.0 ± 3.0	7-15	JM
Total Uranium	µg/l	10	7-5	JM	11	7-15	JM

¹See Table 5

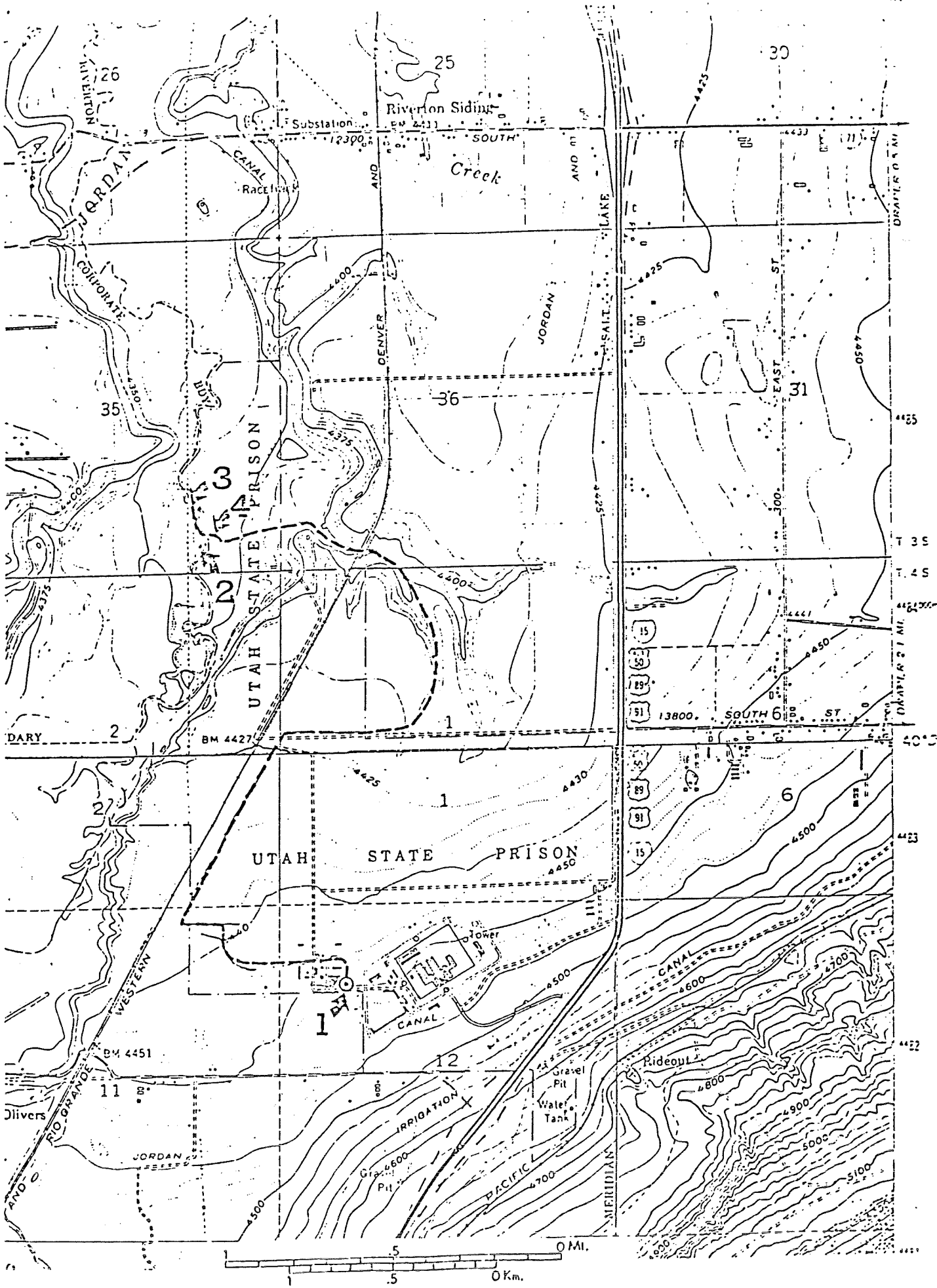
²See Table 5

Table 5. Footnotes for Tables 1 through 4

1) Analytic Techniques: For all samples approved EPA procedures for preservation, storage and analysis were used, as listed in the following references.

- 1) Methods for Chemical Analysis of Water and Wastes: U. S. Environmental Protection Agency, 1974.
- 2) Standard Methods for the Examination of Water and Wastewater, 14th ed., 1975.

- 2) MJ = M. Johnson, Morrison and Knudsen Company
MB = M. Bullett, Earth Science Lab/UURI
RK = R. Kroneman, Earth Science Lab/UURI
RM = R. McCallister, EDA Instruments Inc.
JM = J. McJunkin, EDA Instruments Inc.
MR = M. Retalick, Morrison and Knudsen Company
DG = D. Gardener, Commissioner of Utah Lake and Jordan River



APPENDIX II

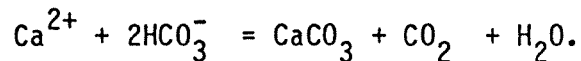
UTAH STATE PRISON GEOTHERMAL WELL (TH1)
SCALE POTENTIAL

Scale Potential

INTRODUCTION

When utilizing geothermal water detailed consideration must be given to the possibility of scale formation. Understanding the factors that control mineral deposition will allow design modifications such that mineral deposition occurs at noncritical parts in the geothermal plant.

Scale is actively depositing from the Utah State Prison Well (TH1) production fluid. X-ray analysis of this scale, precipitated at the surface, shows it to be composed of calcite (CaCO_3). Calcite cannot be deposited from a solution by simple cooling given a constant concentration of carbon dioxide (CO_2) and other constituents in the water. Loss of CO_2 from the solution, however, will induce calcite deposition according to the simplified reaction



Although the temperature of water from well TH1 is below its boiling point, CO_2 is lost from the solution in response to pressure release as the liquid flows to the surface. Analysis of gas released from TH1 water shows it to be composed predominantly of CO_2 with lesser amounts of methane (CH_4) and hydrogen sulfide (H_2S). Scale production will occur at the location where the CO_2 gas is released. Therefore, if the appropriate pressure is maintained to allow gas release only at a convenient location within the production assembly scale formation may be easily removed if necessary.

Scale Prediction

Calculation of changing mineral-fluid equilibria in the geothermal fluid will allow prediction of scale production. For this calculation the exact composition of the reservoir fluid at depth must be known. Without knowledge of this deep reservoir fluid composition within well TH1, it was only possible

to predict scale deposition taking place after the liquid had reached the surface. In addition, as this surface liquid cools calcite becomes more soluble. Thus, if the rate of calcite precipitation, which is unknown, is slow enough the total amount of calcite supersaturated in the surface outflow at the well head may not precipitate.

Calculations

Chemical equilibrium in TH1 surface water is calculated using WATEQ (Truesdell and Jones, 1978), a computer program that calculates the equilibrium distribution of inorganic aqueous species of major and important minor elements. Data needed for this calculation includes a complete chemical analysis, measured temperature, pH and redox potential of the water. From this program, the equilibrium states of the water with respect to minerals and gases are calculated. These equilibrium states include undersaturation, equilibrium and supersaturation. If a mineral is undersaturated with respect to a liquid it will dissolve, if it is in equilibrium it will coexist with the liquid, and if it is supersaturated it will precipitate from the liquid.

Results

The results of these equilibrium calculations indicates that several minerals are supersaturated in surface water collected from well TH1 and are thus potential scale products. These supersaturated minerals include: calcite (CaCO_3), magnesite (MgCO_3) and dolomite ($\text{CaMg}(\text{CO}_3)_2$). The potential masses of each mineral that could precipitate from TH1 water at the wellhead are 240, 110 and 500 grams of mineral per liter of water, respectively. As calcite is the only mineral phase present in the scale it is assumed that the other minerals, magnesite and dolomite, do not precipitate. Thus a maximum of approximately 240 grams of calcite would be expected to precipitate at the surface from each liter of water flowing from well TH1.

REFERENCES

- Truesdell, A. H., and Jones, B. F., 1973, WATEQ, A computer program for calculating chemical equilibria of natural waters: Jour. of Research, U.S. Geological Survey, v. 2, no. 2, p. 233-248.

UTAH STATE PRISON GEOTHERMAL WELL TEST

APPENDIX III

GEOCHEMICAL RESERVOIR ASSESSMENT:
ISOTOPE DATA AND EVALUATION

Prepared For:

State of Utah
Department of Facilities and Management

Prepared By:

The Earth Science Laboratory,
University of Utah Research Institute For:

Morrison-Knudsen Company, Inc.
As Per Subcontract No. 2937-1571-01

January, 1983

ISOTOPE DATA AND EVALUATION

INTRODUCTION

An understanding of the source of geothermal recharge water can prove useful in estimating thermal water recharge rates, the extent of nonthermal groundwater mixing, maximum reservoir temperatures and in siting future geothermal production and injection wells. Oxygen and hydrogen isotope analyses of Utah State Prison geothermal well water and other nearby thermal well and spring water allows prediction of geothermal recharge areas.

SAMPLING AND CHEMICAL ANALYSIS

Samples for oxygen and hydrogen isotope analyses were collected from Utah State Prison well (TH1) and the nearby Utah Roses well (UR1) during the June 16 to July 20, 1982 flow test. The dates of sampling and the analytical results are listed in Table 1. Chemical data on samples collected at the same time are presented in Tables 9-1 and 9-2 of the main report. An isotope analysis for Crystal Hot Springs (CHS) taken from Cole (1983) is also given in Table 1.

Isotope samples were collected untreated in air tight glass containers. The analyses were completed by the Laboratory of Isotope Geochemistry at the University of Arizona, Tucson, Arizona. Analytical error for oxygen-18/oxygen-16 ratios ($^{18}\text{O}/^{16}\text{O}$) is $\pm 0.2\text{‰}$ and $\pm 0.3\text{‰}$ for deuterium/hydrogen ratios (D/H). The isotope data for oxygen and hydrogen are reported relative to Standard Mean Ocean Water (SMOW) in δ notation, where

$$\delta X_{\text{sample}} = ((R_{\text{sample}} - R_{\text{SMOW}})/R_{\text{SMOW}})1000$$

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TABLE 1
Oxygen and Hydrogen Isotope Analyses of Select
Thermal Water Samples from Utah State Prison Study Area

SAMPLE LOCATION	SAMPLE NO. ¹	COLLECTION DATE ²	$\delta^{18}O$ (‰)	δD (‰)
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TH1	4	6-22-82	-16.7	-134
TH1	6	7-6-82	-16.7	-130
TH1	8	7-14-82	-16.4	-135
UR1	1	6-14-82	-17.0	-129
CHS ³	-	6-75	-15.9	-141

¹ See tables 9-1 and 9-2 for corresponding water analyses.

² Month-Day-Year or Month-Year.

³ Data source Cole (1983).

$\delta^{18}\text{O}$ or δD value of the sample in parts per thousand (‰).

DISCUSSION

Studies by Craig et al. (1956) and Craig (1963) indicate that geothermal waters are predominantly of local surface origin. In the Prison study area this would suggest local precipitation (meteoric water) as the thermal water source. The isotopic character of meteoric water for a given locality varies according to the elevation at which precipitation occurs. In general, both the $\delta^{18}\text{O}$ and δD decrease with increased elevation.

Changes in the isotopic composition of meteoric water can occur as a result of several processes. Typically, the meteoric water is heated to its geothermal temperature by deep circulation and then rises convectively to the surface. As this water circulates to depth, $\delta^{18}\text{O}$ values increase as a result of interaction with the reservoir rocks but δD remains nearly constant. The small δD change associated with water-rock reactions has been ascribed to the relative lack of hydrogen in the rocks compared to the amount present in water. Other processes that also affect the isotopic character of the water include: mixing with isotopically different water; evaporation and boiling. Evaporation and boiling will tend to increase the $\delta^{18}\text{O}$ and δD of the water, whereas the effect of mixing will be dependent on the isotopic characters of the waters involved.

A detailed isotopic study of thermal and nonthermal waters in the East Shore area was recently completed by Cole (1982) and provides some insight into the behavior of thermal waters along the Wasatch Front. The East Shore area is located approximately 25 km north of the Prison study area in a similar geologic setting. Cole (1982) suggested that East Shore area thermal

water, which is characterized by δD values ranging from -145 to -135 ‰, is meteoric water originating at high elevations within the Wasatch Range. In contrast, nonthermal ground water in the East Shore area, which is characterized by δD values ranging from -125 to -110 ‰, is meteoric water derived from lower elevations. This conclusion is supported by the relatively light δD value of -141‰ for a mountain cold spring located at an elevation of 3200 m, and 5 km east of the East Shore study area, within the Wasatch Range.

Thermal water from the Prison study area has $\delta^{18}O$ values ranging from -17.0 to -15.9 ‰ and δD values ranging from -141 to -129 ‰. Comparison of the isotopic analyses of geothermal water from the Prison study area with Cole's results suggests two possible sources: 1) a meteoric source that originated at moderate elevations within the Wasatch Range, or 2) a meteoric source that originated at higher elevations and was later diluted with isotopically heavier nonthermal ground water.

The isotopic data therefore suggests that the Prison area geothermal water has a meteoric source, originating from moderate to high elevations within the Wasatch Range. This meteoric water circulates to depths adequate to achieve the elevated temperatures reported, then rises to the surface by convection. A more detailed isotopic study of the Prison study area is recommended, however, to conclusively determine the origin of the Prison area thermal waters.

REFERENCES

- Cole, D. R., 1982, Tracing fluid sources in the East Shore Area, Utah: *Ground Water*, v. 20, p. 586-593.
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22-142 100 SHEETS
22-144 200 SHEETS



UNIVERSITY OF UTAH RESEARCH INSTITUTE

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TELEPHONE 801-581-5283

January 17, 1983

Mr. Craig Hibberd
Department of Administrative Services
Division of Facilities Construction and Management
4110 State Office Building
Salt Lake City, Utah 84114

Dear Craig:

Please find enclosed five copies of Appendix III to the report Utah State Prison Geothermal Test prepared by Morrison-Knudsen Company, Inc. for the Utah State Division of Facilities Construction and Management. Appendix III, titled Geochemical Reservoir Assessment: Isotope data and evaluation, includes the results of Oxygen and Hydrogen isotope analyses which were received after the final report was submitted. This is Earth Science Lab's (UURI) final contribution to the study at the Utah State Prison.

Sincerely,



Regina M. Capuano
Geochemist

RMC:jp

enclosures

UNIVERSITY OF UTAH RESEARCH INSTITUTE

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January 17, 1983

Dr. L. Roy Mink
Morrison-Knudsen
2 Morrison-Knudsen Plaza
422 Washington Street
P.O. Box 7808
Boise, Idaho 83729

Dear Roy:

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Sincerely,



Regina M. Capuano
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enclosure

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