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PROCEEDINGS
FOURTH WORKSHOP
GEOTHERMAL RESERVOIR ENGINEERING

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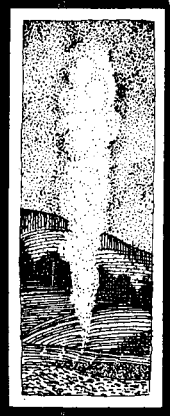

Stanford Geothermal Program
INTERDISCIPLINARY RESEARCH
IN ENGINEERING AND EARTH SCIENCES
Stanford University, Stanford, California

RECENT RESERVOIR ENGINEERING DEVELOPMENTS AT BRADY HOT SPRINGS, NEVADA

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Brady's Hot Springs is a hydrothermal area located approximately 28Km northeast of Fernley, Nevada. Surface manifestations of geothermal activity occur along a north - northeast trend fault zone (herein referred to as the Brady Thermal Fault) at the eastern margin of Hot Springs Flat, a small basin. Since September, 1959, Magma Power Company, its subsidiaries, and Union Oil Company (as Earth Energy Company) have drilled numerous wells in the area. In 1977 Magma's 160 acre lease in Section 12 was assigned to Geothermal Food Processors (GFP) for the purpose of providing heat from the wells on this acreage for the dehydration of food. GFP made application to the Geothermal Loan Guarantee Program (GLGP) for assistance in financing the effort, and consequently the GLGP office turned to the USGS for a resource evaluation. The USGS in turn recommended that a pumped flow test was necessary to truly determine the ability of the acreage's wells to provide the requisite water flow rate, temperature, and composition for the plant's operating lifetime of at least 15 years. Consequently, Thermal Power Company was contacted and procured to design, arrange, conduct, and evaluate a pumped flow program to satisfy these questions.

Brady's Geology

Brady's is easily accessed from Reno, Nevada by driving 88Km eastward on U.S. Interstate 80, taking the Nightingale-Hot Springs exit, and heading eastward toward the Hot Springs Mountains, on whose northwest flank lies the area. Small steam vents, areas of warm ground, and spring sinter deposits are present for 4Km (2.5m) along the zone of the N 19°E trending Brady Thermal Fault. The fault itself extends some 9.6Km (6m) through the area. It is a normal fault of small displacement (100') dipping 70 -80 NW with the downthrown side to the west. The fault is typical of the basin and range type faults in the western U.S.[2] Fluid emergence has been occurring for a minimum of 10,000 years as evidenced by the sinter deposits[3] sandwiched between Pleistocene Lake Lahontan sidements.

Four main rock types are exposed in the Brady Hot Springs area[3]:

1. Volcanic rocks of Tertiary/Quaternary age, chiefly basalt in the mountains east of the springs;

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2. Sedimentary rocks of Tertiary age consisting of sandstone, shale, tuff, diatomite, and minor limestone;

3. Lake deposits, of late Pleistocene Lake Lahontan;

4. Coarse alluvial fan and pediment deposits.

"Regional gravity and magnetic surveys do not suggest the presence of an upper crustal heat source."[2] Thus, a cooling magma or other intrusive body does not appear to be supplying heat to the Brady system. The geology suggests that the system is the result of deep circulating water, typical of basin and range hydrothermal systems.[2]

Production Test

A pumped flow test was designed to evaluate whether this complex reservoir could support GFP's dehydration plant with 700 gpm of 270°F (132°C) water for the plant's 15 year life. A shaft-driven turbine pump capable of pumping 600 gpm of water was purchased by GFP and installed in the designated producer, well Brady 8. The pump's bowls were set at 500 ft. to provide sufficient net positive suction head to prevent the entering water from flashing before entering the pump. The nearby artesian well Earth Energy 1 (EE-1) was instrumented with a Sperry-Sun Pressure Transmission System (PTS) with a ¼ of 1% accurate Bourdon tube gauge to measure interference effects. Three more distant wells (see Figure 1), Bradys 1, 3, and 4, were monitored for interference effects by measuring their changing water levels, with a Powers Portable Well Sounder. Some baseline data was gathered and the pump, driven by a portable diesel engine, was activated. A back pressure was maintained at the surface on the pump sufficient to both regulate the flow rate at 650 gpm and to allow the measurement of the water in a single liquid phase by means of an orifice.

The test began shakily as a lack of constant supply of bearing flush water prevented continuous operation. Finally this logistical problem was overcome and a test of >300 hours of virtually continuous, 650 gpm pumping was accomplished. Unfortunately, drawdown levels in the producer, Brady 8, couldn't be measured because the proper instrumentation was not installed with the pump. However, build-up after shut-in of the producer was measured and plotted semi-logarithmicly in Figure 2. The response of wells Brady 1 and 4 was accurately measured during both drawdown and building and are presented in Figures 3 and 4. EE-s displayed no measurable response.

The conclusion of the test wells were 1) that Brady 8, although cased to 1048', appeared to be drawing production from a zone from 610 ft. to 800 ft. which is open to the shallow wells Brady 1 (1567 ft.) and Brady 4 (723 ft.). (See Figure 5). (2) EE-1 appeared to be isolated from this region by casing to 894'. (3) From the drawdown curves of Brady 4 and Brady 1, it appeared that the shallow reservoir being drawn upon is being fed by a deep, vast reservoir (probably

deep circulating up the Brady Thermal Fault) which would cause the pressure decline of the field to slow greatly over time. The build-up behavior of the wells confirmed the recharging ability of the system as wells B1, 4, and 8 logarithmicly approached their original water level. Finally, (4), water composition and temperature remained constant throughout the test, indicating a reliable, continuous reservoir composition. Thus, it was concluded that the Brady reservoir has a reasonable chance of providing the required flow rate for the 15 year plant life.

Injection Test

A short term injection test was then designed to answer the following questions:

1. Determine the injectivity of EE-1, the most prospective injection candidate due to its apparent isolation from Brady 8's production zone.
2. Determine the zones in the well which accept water during injection.
3. Determine as quantitatively as possible the relative ability of each of these zones to accept water.
4. Use the data gained above to ascertain the suitability of EE-1 for GFP on a production basis.

To accomplish these objectives in an expeditious manner it was decided to store fresh water on site, inject water in the well at initially varying rates, log the well while injecting at a constant rate, and then re-test the injection of injectivity of the well to determine whether any changes of the well's injectivity had occurred over time. Neighboring well's water levels were to be measured throughout the testing of EE-1.

Performance of the Injection Test

The performance of the injection test consisted of the following actions:

(a) Static temperature surveys.
(b) Wellhead selection and installation.
(c) Pre-injection surveys.
(d) Injectivity tests.
(e) Injection surveys.
(f) Survey at varied flow rates.
(g) Interference effects.

EE-1's Suitability as an Injector

From the field work, it was apparent that EE-1 in its present condition did not accept the design injection rate of 700 gpm without pressure interference at B-8, the producer. Water injected down EE-1 leaves the wellbore through 3 exit points:

1. the 9 5/8 in. - 7 in. lap at 371 ft.

2. the perforations at 1880 ft. - 1940 ft.

3. the perforations at 3200 ft. - 3300 ft.

It appears that the upper regions are causing interference with B-8. Accordingly, the injecting of water in zones above 2000 ft. must be avoided if EE-1 is to be used as an injector. Referring to the schematic of EE-1 in Figure 6, this could be accomplished by running smaller pipe into the 4½-in. liner below 2000 ft. and cementing back to surface. The tremendous pumping penalty imposed prevents this course of action from being a viable option. Alternatively, one could consider pulling the 4½-in. liner, reaming out a larger hole below the 7-in., and running a somewhat larger casing through the 7-in. down to the preferred depth. This operation poses a high drilling risk as well as a rather severe pumping penalty, and was thus also deemed a less-than-preferable action.

Two other alternatives appeared available to GFP. A temporary surface disposal system could be cleared with the applicable Nevada State agencies. This system could be employed until GFP determined the ultimate course of action to take - whether to drill a new injection well, or attempt to rework EE-1 in the latter manner detailed above. It was recommended to GFP to pursue all alternatives with the ultimate objective of disposing the water underground.

The GFP plant has operated using surface disposal one month as of December 3, 1978 without problems from the geothermal reservoir. Unfortunately, preoccupation with operational problems concerning the food dehydration equipment has precluded the gathering of even rudimentary reservoir data. Hopefully, as the everyday plant operations smooth out more attention can be turned towards the reservoir.

References

1. Olmstead, et al., 1975 Preliminary hydrogeologic appraisal of selected hydrothermal systems in northern and central Nevada: USGS Survey Open-File Report 75-76, 267 p.

2. Evaluation - GFP, Inc. Loan Guarantee Application, USGS, July 15, 1977.

3. de Leon, Thermal Power Company Geotechnical Summary of Brady Hot Springs - unpublished report.

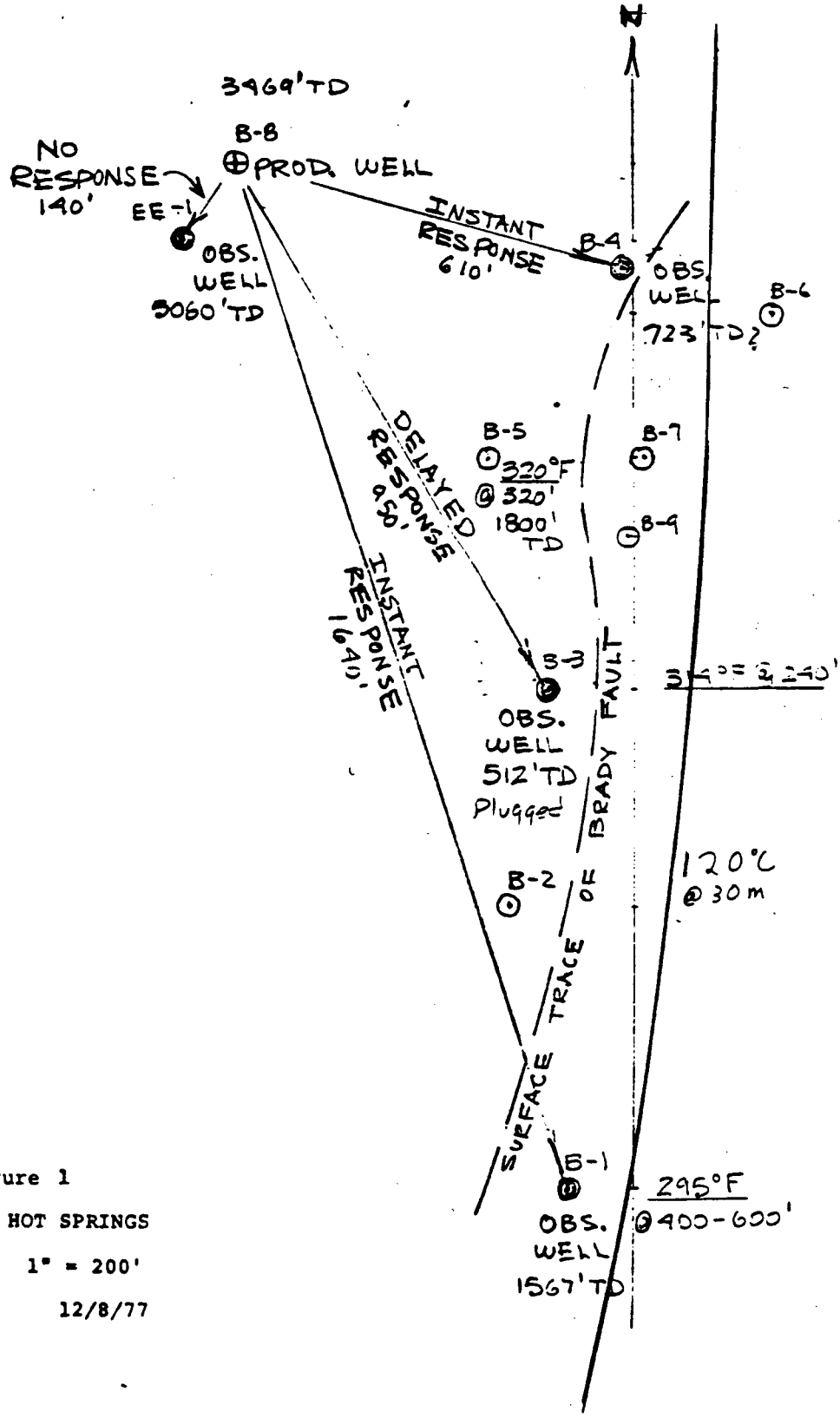

Figure 1

BRADY HOT SPRINGS

Scale 1" = 200'

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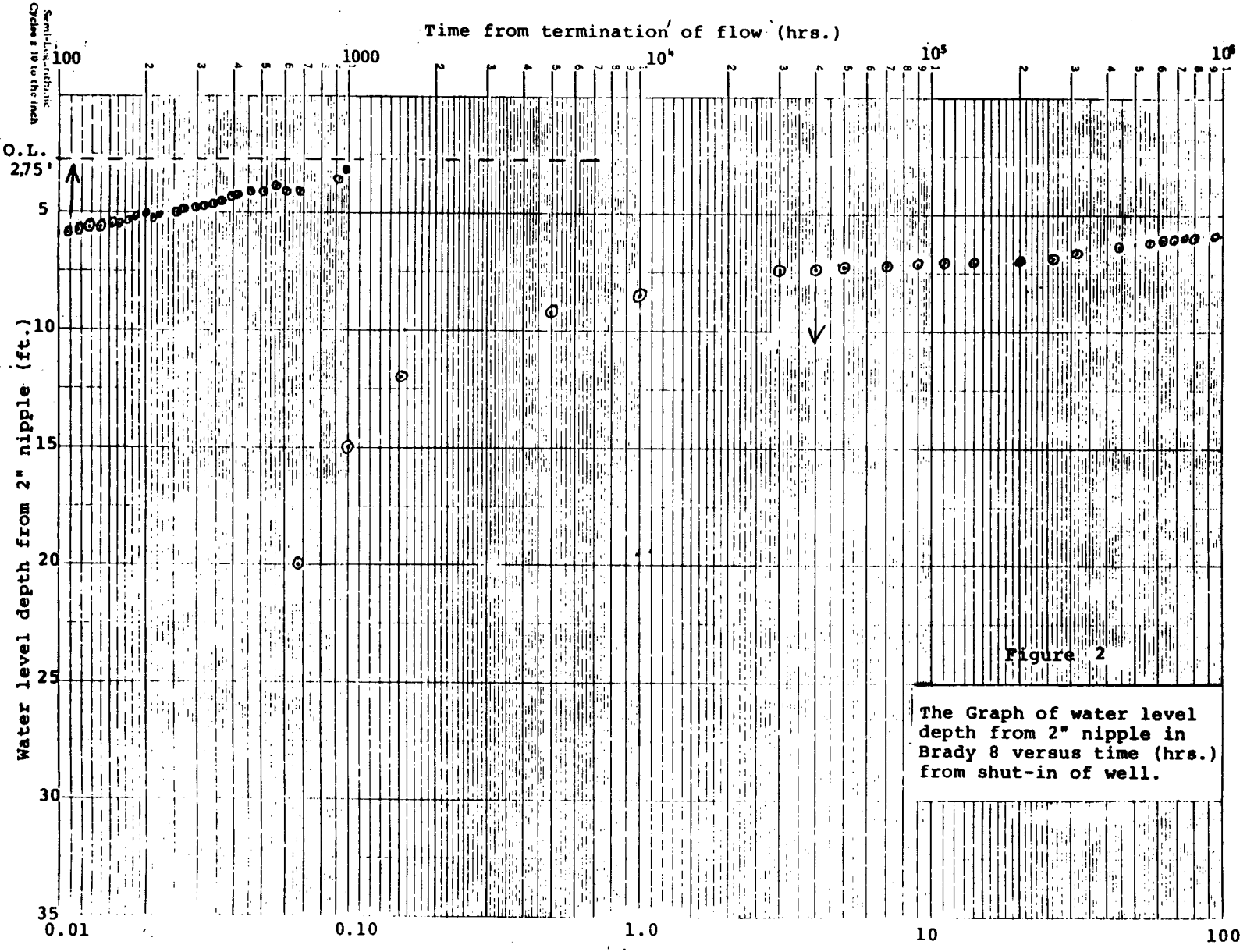

Figure 2

The Graph of water level depth from 2" nipple in Brady 8 versus time (hrs.) from shut-in of well.

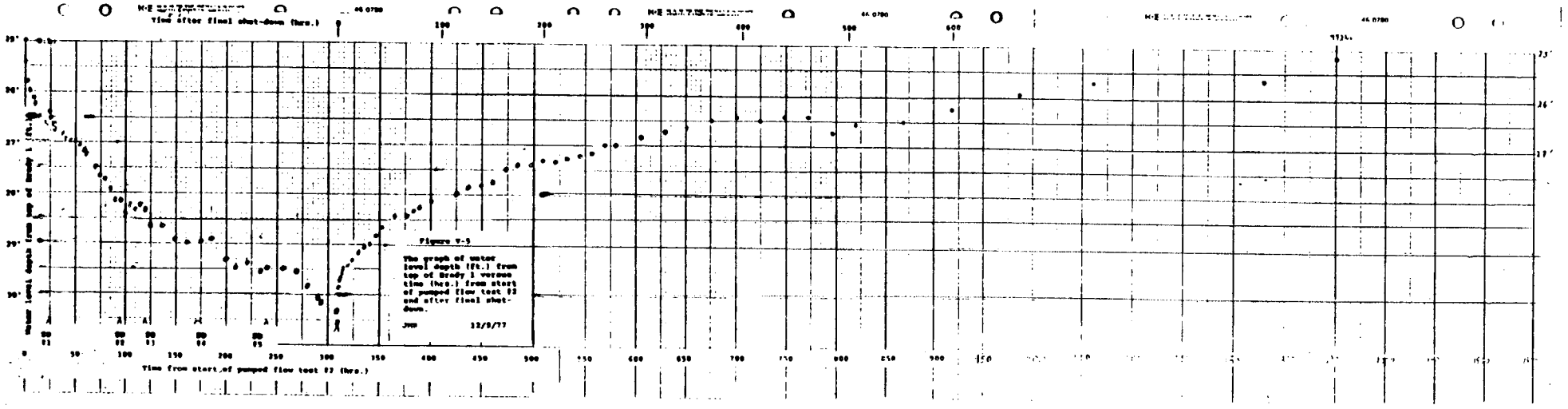
Time after final shut-down (hrs.)
Time from start of pumped flow test 02 (hrs.)
Figure V-5
The graph of water level depth (ft.) from top of Brady 1 versus time (hrs.) from start of pumped flow test 02 and after final shut-down.
JMH 12/9/77

Figure 3

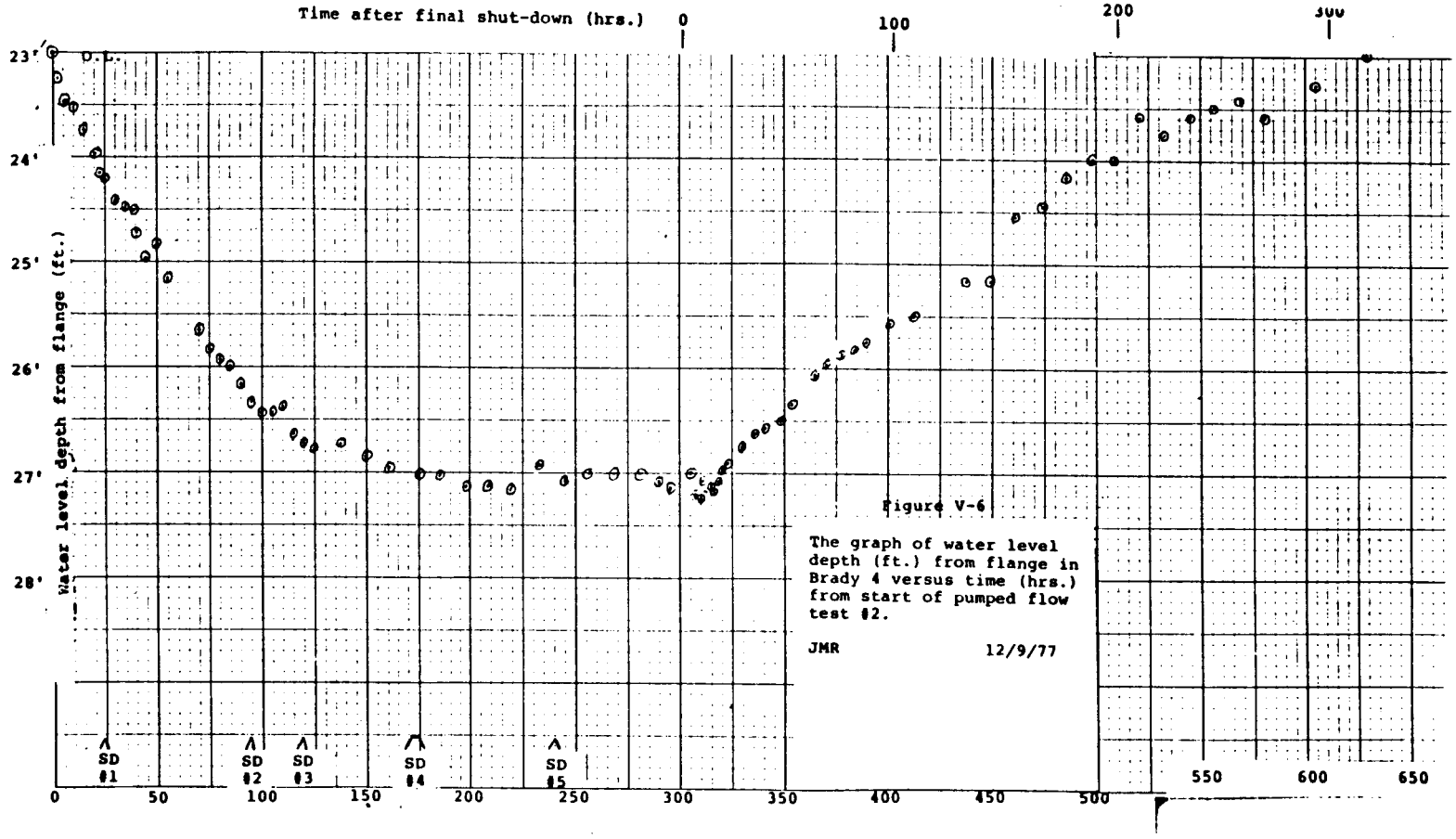
Time after final shut-down (hrs.)
0
100
200
300
D.L.
23'
24'
25'
26'
27'
28'
Water level depth from flange (ft.)
SD #1
SD #2
SD #3
SD #4
SD #5
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Figure V-6
The graph of water level depth (ft.) from flange in Brady 4 versus time (hrs.) from start of pumped flow test #2.
JMR
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Figure 4

FIGURE 5.

A CARTOON DEPICTING
THE DYNAMICS OF THE
BRADY HOT SPRINGS RESERVOIR

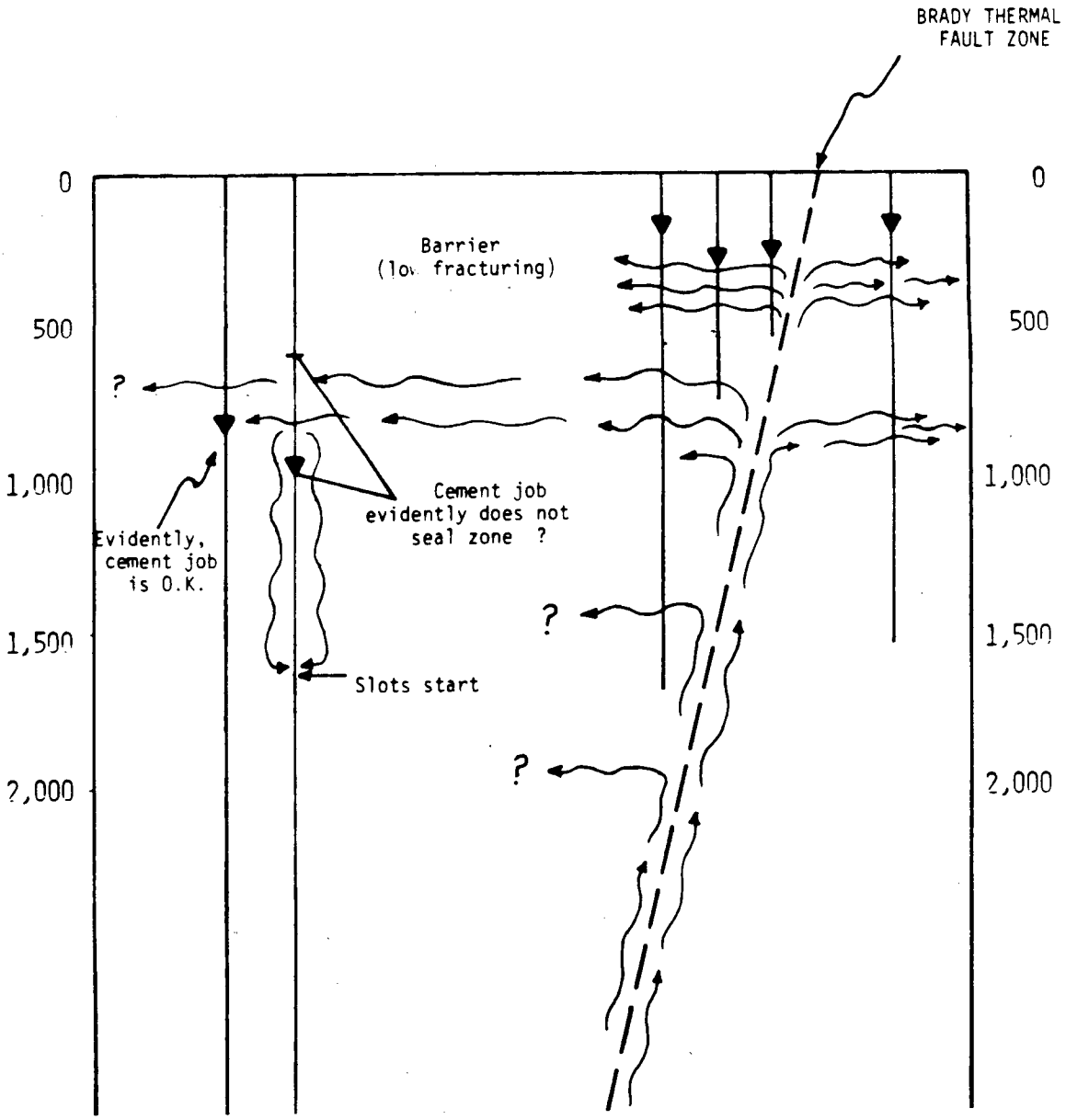

FIGURE 6

EE-1 Schematic
as of 2/78