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REPORTS

DEEP PRODUCTION WELL FOR GEOTHERMAL DIRECT-USE HEATING OF A LARGE COMMERCIAL GREENHOUSE, RADIUM SPRINGS, RIO GRANDE RIFT, NEW MEXICO

FINAL REPORT
USDOE CONTRACT
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PREPARED BY
JAMES C. WITCHER
Las Cruces, NM

SUBMITTED BY
ALEX R. MASSON, INC.
Linwood, KS

SUBMITTED TO
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DISCLAIMER

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1.0 INTRODUCTION

1.1 Background

Expansion of a large commercial geothermally-heated greenhouse is underway and requires additional geothermal fluid production. This report discusses the results of a cost-shared U. S. Department of Energy (DOE) and A. R. Masson, Inc. drilling project designed to construct a highly productive geothermal production well for expansion of the large commercial greenhouse at Radium Springs. The well should eliminate the potential for future thermal breakthrough from existing injection wells and the inducement of inflow from shallow cold water aquifers by geothermal production drawdown in the shallow reservoir. An 800 feet deep production well, Masson 36, was drilled on a U. S. Bureau of Land Management (BLM) Geothermal Lease NM-3479 at Radium Springs adjacent to the A. R. Masson Radium Springs Farm commercial greenhouse 15 miles north of Las Cruces in Dona Ana County, New Mexico just west of Interstate 25 near the east bank of the Rio Grande. (Figure 1). The area is in the Rio Grande rift, a tectonically-active region with high heat flow, and is one of the major geothermal provinces in the western United States (Seager and Morgan, 1979; and White and Williams, 1975).

1.2 Objectives

The major objective of the Masson 36 well was to obtain 190 ^{o}F fluids at 1,500 gallons per minute (gpm) from a deep-confined reservoir. The objective of producing from the deep reservoir which is confined by a thick,

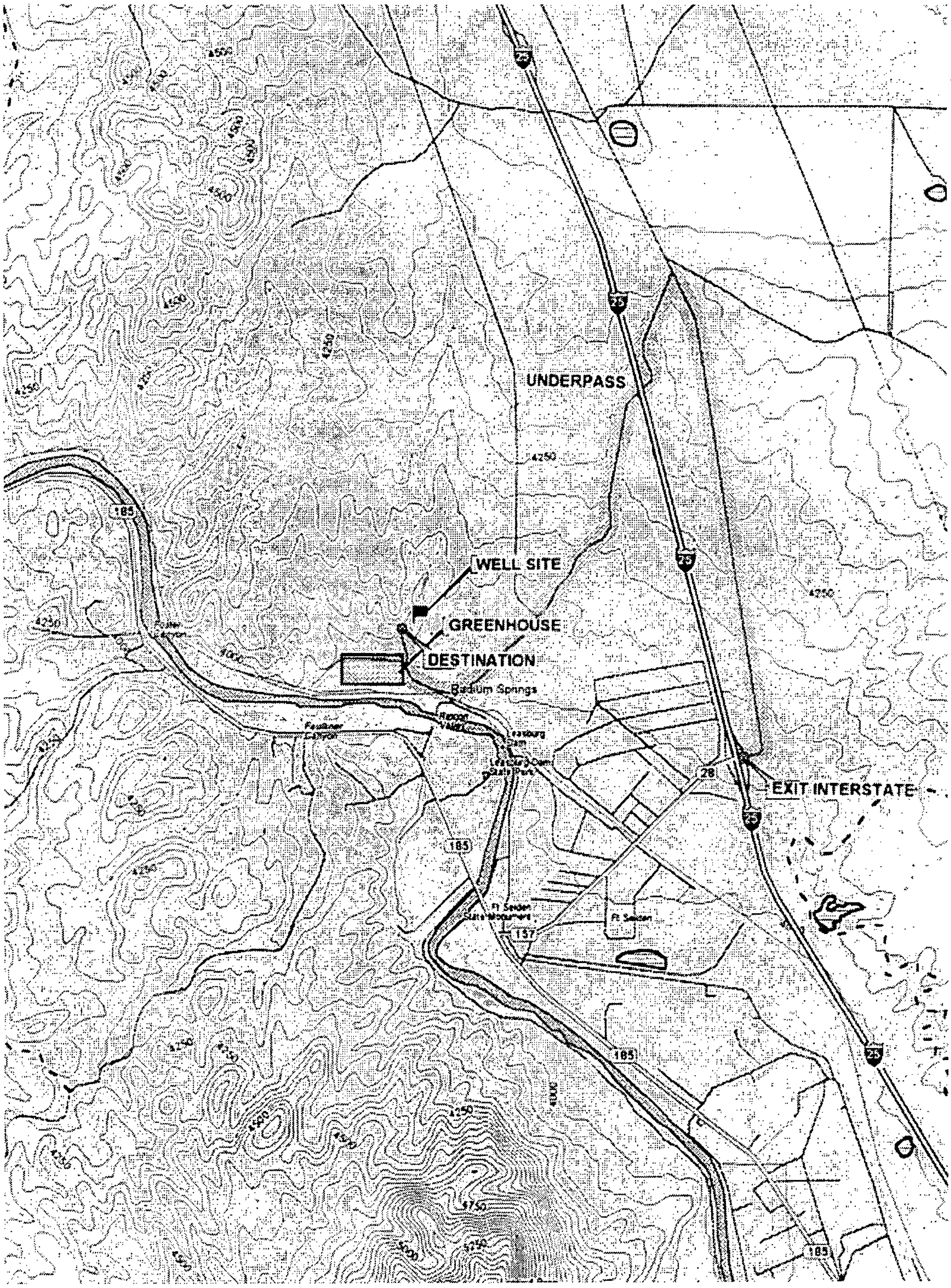

Figure 1. Location Map of the Masson 36 Well.

clay-rich aquitard, is to practically eliminate direct communication with the shallow cold water aquifers and the Rio Grande from geothermal production pumping in the future. Current geothermal production and injection forms a probable flow couplet that is contained in a shallow and fractured rhyolite intrusion. The couplet and intrusion are hydraulically-connected with nearby shallow cold water aquifers. Therefore, the third primary objective is to avoid drilling across the shallow rhyolite reservoir or seal it off during well construction, if it is encountered, so that only deeper water is produced. All of these objectives were apparently achieved with the Masson 36 well.

1.3 Site Selection and Well Design Considerations

The currently produced shallow reservoir at Radium Springs is contained in a fractured rhyolite intrusion with probable Oligocene age of limited areal extent and volume that intrudes across a thick Eocene aquitard, the Palm Park Formation (Seager, 1975). The fractured rhyolite is in hydraulic communication with nearby cold alluvial aquifers (Gross, 1987).

With the current shallow production-injection well couplet, decreases in temperature are experienced in late winter and early spring as the greenhouse facility has grown from 4 acres to about 17 acres since 1987. This decrease in temperature is probably from the combined affects of drawdown that encourages infiltration of cold water from the Rio Grande and sub adjacent aquifers and from cool injected fluids via the injection wells.

The shallow reservoir contains 150 to 162 °F sodium chloride water with a variable total dissolved solids (TDS) of around 3,300 milligrams per liter (mg/L) (Witcher, 1988). Current production is from two wells less than 300 feet depth, completed in fractured rhyolite. These wells were drilled by rotary air hammer. Two injection wells, approximately 1,000 feet distance from the production wells, accommodate about 400 gpm of 100 °F water.

The injection wells are located in the local outflow plume of the fractured rhyolite host, while the production wells are located over the local upflow plume. The upflow plume is a "geohydrologic window" of rhyolite that acts as a conduit across the Palm Park aquitard and allows upflow out of a deeper much larger reservoir (Witcher, 1988; and Ross and Witcher, 1998).

Two deep (8,000 and 9,000 feet depth) wells drilled by Hunt Energy north of the Masson greenhouses in the early 1980's, provide insight into the nature of the deep reservoir. A fractured, composite Precambrian and Paleozoic carbonate reservoir is capped or confined by the Eocene Palm Park Formation aquitard. Laramide Orogeny compressional (Late Cretaceous to early Eocene) and Rio Grande rift extensional (Oligocene to present day) fault zones and fractures host the deep-seated reservoir in Precambrian and Paleozoic rocks (Seager and others, 1984; and Seager and others, 1986).

Temperature gradient information in the area indicates a broad area of 12.6 to 14.3°F /100 feet temperature gradients over the area from Hunt well 53-27 and southward to the Masson greenhouse facility (Witcher, unpub. data). These temperature gradients are likely to continue into the Palm Park aquitard cap to the top of fractured and possible karst Paleozoic carbonate units. The carbonate rocks were first encountered at 675 to 960 feet depth in the Hunt wells 25-34 and 53-27, respectively (files, New Mexico Bureau of Mines and Mineral Resources). A temperature log of well 53-27 shows that the well becomes isothermal below 1,000 feet at a temperature of about 185 °F (Witcher, unpub data). If the top of the deep reservoir is about 175 to 190 °F over a broad area, then the temperature gradients also broadly define the depth to the top of the reservoir between 600 and 1,000 feet depth, provided the Palm Park aquitard has no large lateral variations in thermal conductivity.

A north-northwest trending Quaternary normal fault delimits the western surface extent of the shallow rhyolite reservoir host at Radium

Springs and the westward extent of the highest temperature gradients to the footwall side of the fault zone (Seager, 1975 and Witcher, unpub data). This fault crosses the eastern part of the Masson greenhouse complex.

The final site selected for drilling is on surface land owned by Masson that has an associated BLM geothermal lease that is held by Masson. This site is about 500 feet east of the northwest-striking fault zone on the foot wall and is situated in an area with no rhyolite outcrops. The selected site is closest to the fault zone, has the best access, and is just north of the greenhouse complex in an area with good security.

1.4 Participants

The Masson 36 production well project was administered by the Idaho Operations Office of the U. S. Department of Energy. The project was cost-shared by A. R. Masson, Inc. and the U. S. Department of Energy. The drilling contractor for the project, K. D. Huey Drilling of Capitan New Mexico, was selected on the basis of sealed competitive bid. Well site geotechnical services, permit coordination, and reporting was performed by Witcher and Associates of Las Cruces, New Mexico. The Resource Group, Palm Desert, California provided engineering assistance. Permitting and regulatory oversight was with the New Mexico State Engineer Office (NMSEO) and the BLM.

1.5 Permits

All operations conformed to the regulations, permitting and operational procedures administered by the BLM and the NMSEO. All access and surface issues were closely coordinated with the BLM. All drilling was in compliance with federal Geothermal Resources Operational Orders (GROO's), directives of the BLM and NMSEO and stipulations of the permits. Prior to drilling, specific details were submitted to the BLM through a formal Plan of Operations Report, Application for Permit to Drill (APD) and Sundry Notices. As operator, A. R. Masson, Inc. posted the required bonds with the BLM. Daily and weekly communications with Federal and State regulators was maintained throughout the project.

1.6 Scope

This report on the Masson 36 geothermal production well details the drilling operations and provides a brief analysis of the drilling operation. The subsurface geology in the Masson 36 well is briefly discussed and interpreted and supporting well history detail and logs are provided in the Appendices. Recommendations for testing and monitoring are also presented.

2.0 DRILLING AND SITE OPERATIONS

2.1 Drill Site Layout

The Masson 36 well is within the Radium Springs Known Geothermal Resource Area (KGRA) in the southeast quarter of the southwest quarter of section 3, Township 21 South, Range 1 West, approximately 2,380 feet from the west section line and 580 feet from the south section line at an approximate elevation of 3995 feet. The drill site is located on private surface, owned by Masson, adjacent a local arroyo flood control dike, trending east to west about 600 feet north of the Masson greenhouse complex. Access to the drill site is via a graded dirt road on the east side of the Masson greenhouse complex. A gate provides controlled entry to both the greenhouse operation and the well site. Gravel and caliche was laid down on the drill site road for all-weather egress to the drill site.

Dirt work included building a level and stable pad up to the grade of the top of the flood control dike. A couple of small dirt retention dams were placed along the backside of the flood control dike to act as temporary drilling fluid pits. The blowout prevention (BOPE) control or accumulater was installed east of the drill floor end of the rig. Overall layout provided for efficient water, mud, and equipment resupply, drilling operations, and well site geotechnical operations. An 8 by 8 by 8 feet reinforced cement cellar was constructed to allow clearance for BOPE equipment beneath the drill floor.

2.2 Water

Water for drilling operations was obtained from a Masson greenhouse fresh water supply well located about a quarter of a mile from the drill site. A 3,500 gallon capacity water truck was used to transport water to the drill site from the Masson supply well. Two 400 barrel (20,000 gallon) frac tanks were kept full during the drilling operations. One frac tank was kept in reserve as a contingency for well control operations.

2.3 Drill Rig Specifications

A truck-mounted Mobile Equipment Service SR35 rig was used for constructing the Masson 36 well. The SR35 is a top drive rig that is equipped with a 1,350 cfm/350 psi Sullair air compressor. An auxillary 1,150 cfm/350 psi Ingersol Rand air compressor was also used in tandom with the rig compressor as needed. The SR35 utilizes hydraulic drives for the drill motors, pumps, and hoist, allowing excellent variable controls. The rig has a 110,000 pound pullback with the hoist, a rotary torque of 12,000 pounds, and a 700 hp diesel engine on the deck.

2.4 Well Control

In the event that pressured fluids, gas, or rapidly boiling or flashing super-heated water entered the Masson 36 well while drilling, several steps were taken to insure that well discharges would be controlled. Well control consisted of blow out prevention (BOPE) equipment, valved flow and kill line ports, an auxiliary water tank with a minimum of 275 bbls (11,550 gallons) of water on site, and the monitoring of bottom-hole temperatures (BHT) and blooie line temperatures. The BOPE stack consisted of a Hydril GK 13 5/8 -

3M annular preventer installed on a 13 5/8 inch well head spacer spool with flow and kill line ports. A rotating head was installed over the annular BOPE. The kill line port was connected to the auxiliary water tank via a pump. The BOPE was activated by a pneumatic accumulator and was function tested to 2,700 psi. The BOPE and casing was tested to 500 psi for 15 minutes with only 10 psi bleed off. The pressure tests were witnessed by Masson and BLM representatives.

2.5 Hydrogen Sulfide Monitoring

Industry-standard, continuous-monitoring, hydrogen sulfide detectors, equipped with automatic visual and audio alarms, were installed at suitable locations to include the drill rig operators console, the cellar on top of the BOPE, and at the flow or blooie line discharge. Alarms were set to trigger visual alarms at 10 ppm hydrogen sulfide and audio alarms at 15 ppm. A wind sock was also installed at the location entry where it was visible to all site personnel. Self-contained breathing equipment were placed for emergency use at two different briefing area locations. The briefing areas were situated to provide one area that would be upwind of the hole at any given time. A warning and status sign was also placed at the entry to the drill site.

2.6 Well Site Geology and Operations Monitoring

Well site geotechnical operations included making field geologic logs of cuttings and archiving cuttings for future reference or study. Samples were taken at the blooie line over ten foot intervals. Cuttings will be sent for storage and archival at the New Mexico Bureau of Mines and Mineral Resources in Socorro, New Mexico.

Geophysical and temperature logs completed the geotechnical operations. Several temperature logs were taken after overnight breaks in drilling in order to gain information on the temperature gradient and bottom hole conditions. Because cement is exothermic as it cures, an additional temperature log was obtained several hours after the surface casing was cemented. Determination of the cement top in the annulus, facilitated calculation of how much cement to order to fill the backside of the casing to the surface. Geophysical logs were run prior to running surface casing and after reaching total depth (TD), but prior to running the production casing string.

Operations monitoring included daily report log, daily cost tabulation, and a well history log. A summary of the daily report and well history log is listed in Appendix 1. The daily report log was used to document footage per shift, blooie temperature measurements, all drilling activities, and materials used in drilling. A well history log complemented the daily report log. The well history log was used to record chronologically important events at the well site such as visitors, drilling milestones, or any other events not recorded by daily report log.

2.7 Drilling Summary and Analysis

Drilling and casing depths in this report are referenced to the drill table (DF) at 4 feet elevation above the ground surface. All drilling was done with air foam, using either an air hammer above 672 feet depth or rotary tri-cone bit below 672 feet depth.

On the basis of a competitive bid, the Masson 36 drilling contract was awarded to K. D Huey Drilling a water well driller from Capitan, New Mexico in May 2000. The Huey drill rig did not move on to the site until August 2000 (Table 1 and Appendix 1). On 7 August the borehole was spudded. The drilling assembly included 17 1/2 inch stabilizers for a straight and guage hole along with the air hammer and bit. Drilling progressed smoothly until 9 August when the air hammer bit was shanked or in other words broken at the splines inside the air hammer and left at the bottom of the hole when the drill string was tripped or brought out of the hole. On 22 August the "fish" or air hammer bit was recovered. Options were discussed and geophysical logging was performed. It was decided to run and cement surface casing. On 28 and 29 August 465 (DF) feet of 13 3/8 inch surface casing was run in the hole. On 31 August, Dowell/Schlumberger arrived on site from Artesia, New Mexico and ran 144 bbls of cement (Appendix 4). Cementing across the ryholite zone was done in stages to insure that fractures and washout zones were sealed (Appendix 1 and 4). A temperature log ran several hours after Schlumberger demobilized showed the cement at the top of the rhyolite interval. A backside cement job by a local contractor was performed on 1 September to complete the cementing of the surface casing annulus to the surface. This additional 17 bbls of cements filled the hole and more with overflow at the surface. Between 2 and 16 September the drilling rig top drive was overhauled and the BOPE was installed and tested. Pressure testing was witnessed by the BLM and Masson's consultants on site. On 16 September drilling operations resumed with a 12 1/4 drilling assembly. It took an additional ten days to drill a 12 1/4 inch hole to 800 feet and run and hang a 9 5/8 inch production casing string. A drilling assemblage change was necessary due to formation fluid production at 672 feet. The air hammer and bit was replaced with a tricone bit and rotary air operations resumed and the hole reached total depth (TD) of 800 feet on 22 September.

All operations from start to finish were daytime only and usually with only a two man crew. Analysis of drilling operations time indicates that only about 40 hours was actually spent drilling. A nearly equal amount of time or 37 hours was spent tripping in and out of the hole. Installing and uninstalling the BOPE took 47 hours. A much larger amount of time was spent repairing equipment or recovering a bit at the bottom of the hole. The bit splines broke in the air hammer while drilling the 17 1/2 inch hole. However, the bulk of time between the contract award and the completion of the well involved waiting on drilling personnel, equipment and supplies.

2.8 Well Completion

A total depth of 800 feet was reached on 22 September 2000 within the Permian Hueco Formation, a mostly limestone unit with some interbedded shale. The Hueco Formation was an important drilling target. However, the hole only encountered 12 feet of this unit. Much greater production and possibly 10 to 15 °F higher temperatures are likely within this unit and underlying carbonate units at a few hundred feet greater depth. However, the well construction and completion provides a contingency for re-entering the hole at a later time in order to drill at least to 2,300 ft depth if desired.

Table 1 Daily Footage and Activity Log of the Masson 36 Well.

date	footage feet/day	remarks
6/29	24	Auger conductor hole, run conductor casing and cement
6/30-8/6	0	Construct cellar and begin moving equipment on site
8/7	120	Finish rigging up, drill 17 1/2 in surface hole with air hammer
8/8	180	Continue 17 1/2 in surface hole with air hammer and foam
8/9	150	Ran temp log, continue 17 1/2 in surface hole with air foam
8/10	0	Ran temp log, trip out, shanked bit in air hammer, bit fish on bottom
8/11-8/21	0	Attempt to recover fish
8/22	0	Ran BHT (186 °F), successfully recovered fish, decide to run casing
8/23	0	Ran geophysical logs
8/24-8/27	0	Casing delivered
8/28	0	Begin to run surface casing with shoe and float collar
8/29	0	Finish run of 461 ft 13 3/8 in surface casing, haul water
8/30	0	Haul water, prepare for cementers, rig maintenance
8/31	0	Cement surface casing, ran temp log to evaluate cement job
9/1	0	Top job cement backside and WOC
9/2-9/5	0	Repair rig top drive
9/6	0	Clean cellar, cut top surface casing, prepare to install BOPE
9/7-9/11	0	Continue repair of rig top drive
9/12	0	Ran temp log, installed rig top drive, wait on BOPE
9/13	0	Unload BOPE, installed well head flange and set spool with side ports
9/14	0	Nipple up annular, rotating head, accumulator and test, install H_2S monitor
9/15	0	Install kill and choke lines, install blooie line, make up drill tools
9/16	51	Trip in, tag cement at 423 ft, drill out cement and float collar, drill ahead
9/17	0	Repair auxiliary air compressor
9/18	147	Drill ahead using 12 1/4 in air hammer with foam
9/19	0	Trip out, wait on 12 1/4 in tricone bit
9/20	0	Wait on 12 1/4 in tricone bit
9/21	68	Make up drill tools, trip in, drill air rotary foam
9/22	60	Drill ahead, TD 800 ft, producing 1175 gpm 196 °F water while drilling air
9/23	0	Trip out, break down BOPE
9/24	0	Unload casing, run geophysical logs
9/25	0	Finish removing BOPE, prepare to run 9 5/8 in production liner
9/26	0	Ran 9 5/8 in production liner to 793 ft, turn off hanger, trip and laydown rig

Table 2 Masson 36 Well Completion Specifications.

item	hole size inches	top ft	bottom ft	type grade	OD inches	weight lbs/ft	cement bbls
conductor casing	24	surf	28	H-40	20	78	3
surface casing	17 1/2	surf	465	N-80 btc	13 3/8	72	157
production liner	12 1/4	395	793	N-80 btc	9 5/8	47	(hung)
production perf	12 1/4	562	793	3/8 rnd	9 5/8	40 h/ft	(punch)

2.9 Geophysical and Temperature Logging

The Masson 36 was geophysically logged several times before the well was completed. A suite of temperature logs was performed with the New Mexico State University (NMSU) temperature logging system (Table 3). Southwest Geophysical Services of Farmington, New Mexico was contracted to perform additional temperature logs and various other geophysical logs to include caliper, gamma, neutron and electric logs. The NMSU and Southwest Geophysical Services temperature logs were performed with wireline tools that were outfitted with thermister probes which have an accuracy of between 0.005 and 0.05 ^{o}F. The geophysical and temperature logs are discussed in Chapter 3.

Table 3 Geophysical and Temperature Logs of the Masson 36 Well.

type log	date	interval ft	logged by
temperature	8/9/2000	0-265	NMSU
temperature	8/10/2000	0-425	NMSU
temperature	8/21/2000	BHT	NMSU
temperature	8/23/2000	0-425	Southwest Geophysical
gamma/neutron	8/23/2000	0-425	Southwest Geophysical
caliper	8/23/2000	0-425	Southwest Geophysical
temperature	8/31/2000	cement	NMSU
temperature	9/12/2000	0-430	NMSU
temperature	9/24/2000	0-789	Southwest Geophysical
gamma/neutron	9/24/2000	0-789	Southwest Geophysical
electric logs	9/24/2000	0-789	Southwest Geophysical

A caliper tool was run in the open hole prior to installing surface casing. The caliper log shows variation in borehole size which allows calculation of the amount of cement needed to insure a good surface casing seal. The gamma and neutron logs were also obtained. Maximum sampling radius for the gamma and neutron logs is about 1 to 2 feet into the formation. A logging rate of 20 feet per minute is used. As with temperature logs, the wireline signal is digitally converted into ASCII files for analysis and interpretation.

The gamma log measures gamma radiation from naturally occurring uranium, thorium, and potassium. Because different rock types have different radioactivity levels, the gamma log is a very useful lithology correlation tool. For instance, shales and clay may have higher natural radioactivity than sandstone and sand. The neutron tool contains an active radioactive source that emits neutrons and a detector that spaced on the tool about two feet from the neutron source. Neutrons emitted by the tool are principally slowed to low energies by hydrogen (ie. water and hydrocarbons) in the formation, resulting in less signal for the detector if porosity is high. Where hydrogen content is low (low porosity) the neutrons diffuse much greater distances (closer to the detector) before slowing to low energies. Because of hydrogen sensitivity, the neutron log has use as an indicator of relative formation porosity.

Electric logs can also measure the amount of porosity. Because salty water is a good conductor of electricity compared to rock or drilling mud, electric logs can have much value in well evaluation. The electric logs measure voltage potential and they are reported as a difference as in the SP log or resistance as in the single point "resistance" log or as resistance per unit length as in the normal (long 64 inch - short 16 inch) "resistivity" logs.

2.10 Site Cleanup

Site cleanup of the Masson 36 well pad at the end of well completion consisted of removing all trash and any oil contaminated soil to approved disposal sites. All equipment was removed from the site, except for the well head and locked well head housing. The cement cellar used for the BOPE was back filled to pad level to prevent animals and people from accidental injury.

3.0 GEOLOGY AND GEOTHERMAL RESOURCE

3.1 Geology of Masson 36 Well

A summary geologic log of the Masson 36 well is found in Appendix 2. Figures 2, 3 and 4 provide graphic logs of lithology and the geophysical logs for the well. Two productive geothermal reservoirs were encountered while drilling Masson 36. Each reservoir produced over 1,000 gpm while drilling with air.

The uppermost production zone, between 120 and 222 feet depth occurred in a fractured rhyolite with drilling discharge temperature around 151 °F. This upper reservoir was sealed off with the surface casing string and cement. Figure 1 shows this zone with a relative high gamma (125 to 150 API) and caliper log deviations much greater than the 17 1/2 inch nominal bit diameter. The 102 feet thick rhyolite intrusion is believed to be the same unit that provides current production at Radium Springs in the nearby shallow Masson wells. Rhyolite is exposed at the surface about 1,000 feet south and southeast of the Masson 36 well site. If this correlation is correct, then the rhyolite represents a dike that dips at low angle to the north or north-northeast and discordantly intrudes across the clay-rich "andesitic" Palm Park aquitard. The Palm Park forms a confining boundary on the shallow rhyolite geothermal reservoir except where it intersects the surface and shallow alluvial aquifer south of the drill site.

At the surface, the Palm Park Formation is a mostly andesitic lahar (hot volcanic mudflow deposit) breccia with an altered muddy and clay-rich matrix. Alteration is variably intense and ranges in color from purple to blue green. Clay, chlorite, and epidote are important alteration phases. Judging from cuttings and geophysical logs, the Palm Park in the Masson 36 well is

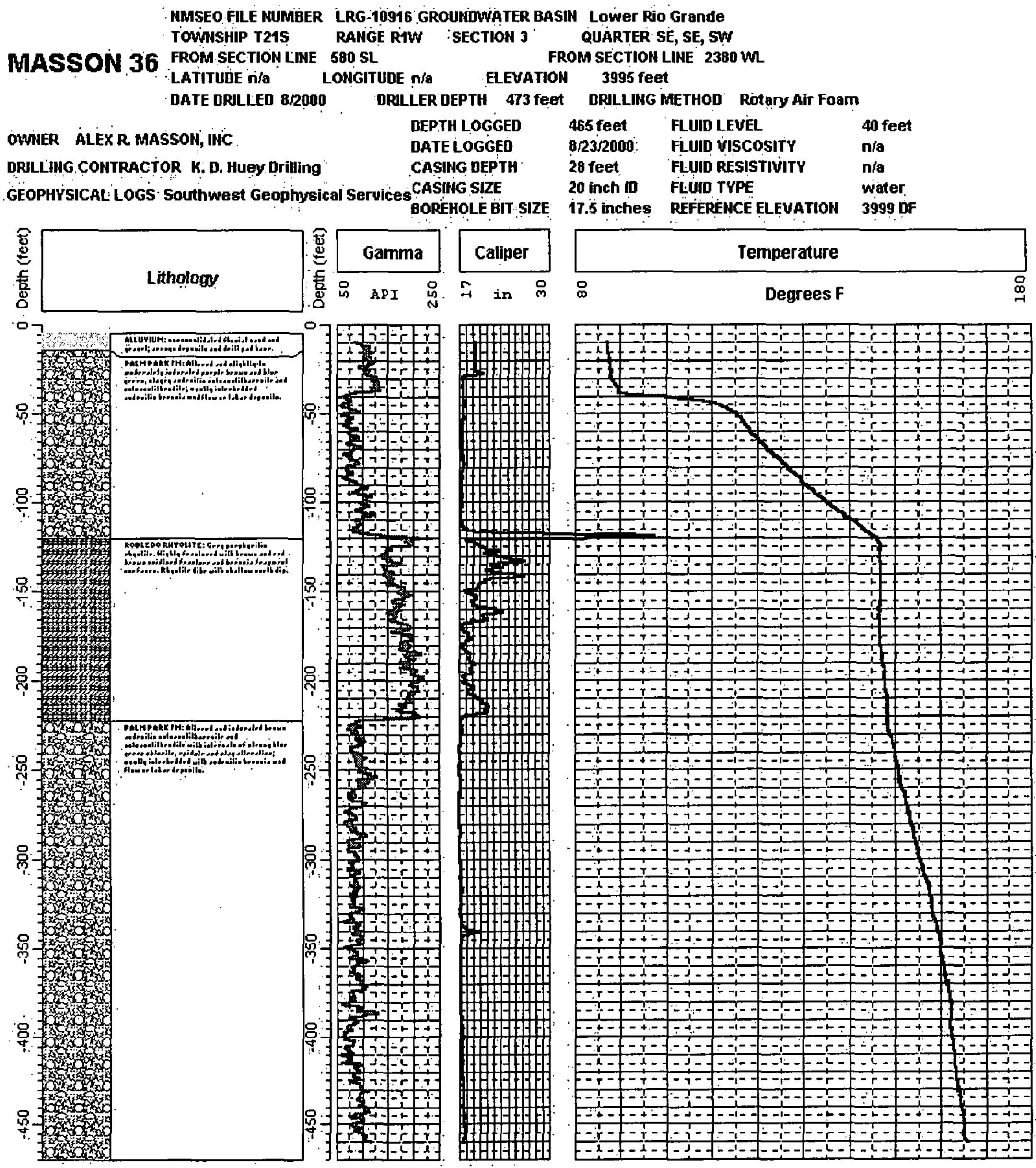

Figure 2. Pre-Surface Casing Temperature and Geophysical Logs.

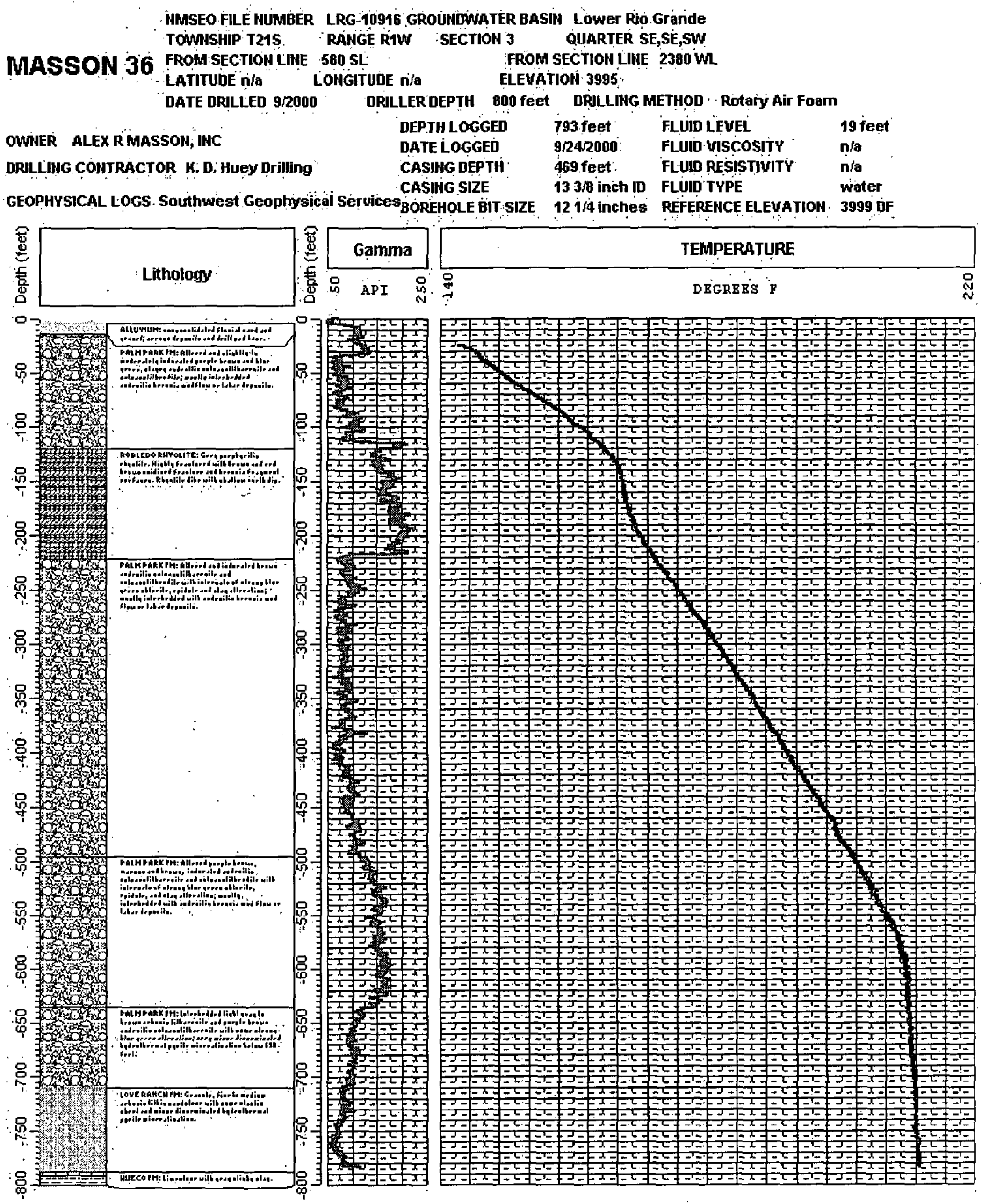

Figure 3. Post-Drilling Gamma and Temperature Logs.

MASSON 36

NMSEO FILE NUMBER LRG-10916 GROUNDWATER BASIN Lower Rio Grande
TOWNSHIP T21S RANGE R1W SECTION 3 QUARTER SE,SE,SW
FROM SECTION LINE 580 SL FROM SECTION LINE 2380 WL
LATITUDE n/a LONGITUDE n/a ELEVATION 3995
DATE DRILLED 9/2000 DRILLER DEPTH 800 feet DRILLING METHOD Rotary Air Foam

OWNER ALEX R MASSON INC
DRILLING CONTRACTOR K. D. Huey Drilling
GEOPHYSICAL LOGS Southwest Geophysical Services

DEPTH LOGGED	793 feet	FLUID LEVEL	19 feet
DATE LOGGED	9/24/2000	FLUID VISCOSITY	n/a
CASING DEPTH	461 feet	FLUID RESISTIVITY	n/a
CASING SIZE	13/3/8 inch ID	FLUID TYPE	water
BOREHOLE BIT SIZE	12 1/4 inches	REFERENCE ELEVATION	3999 DF

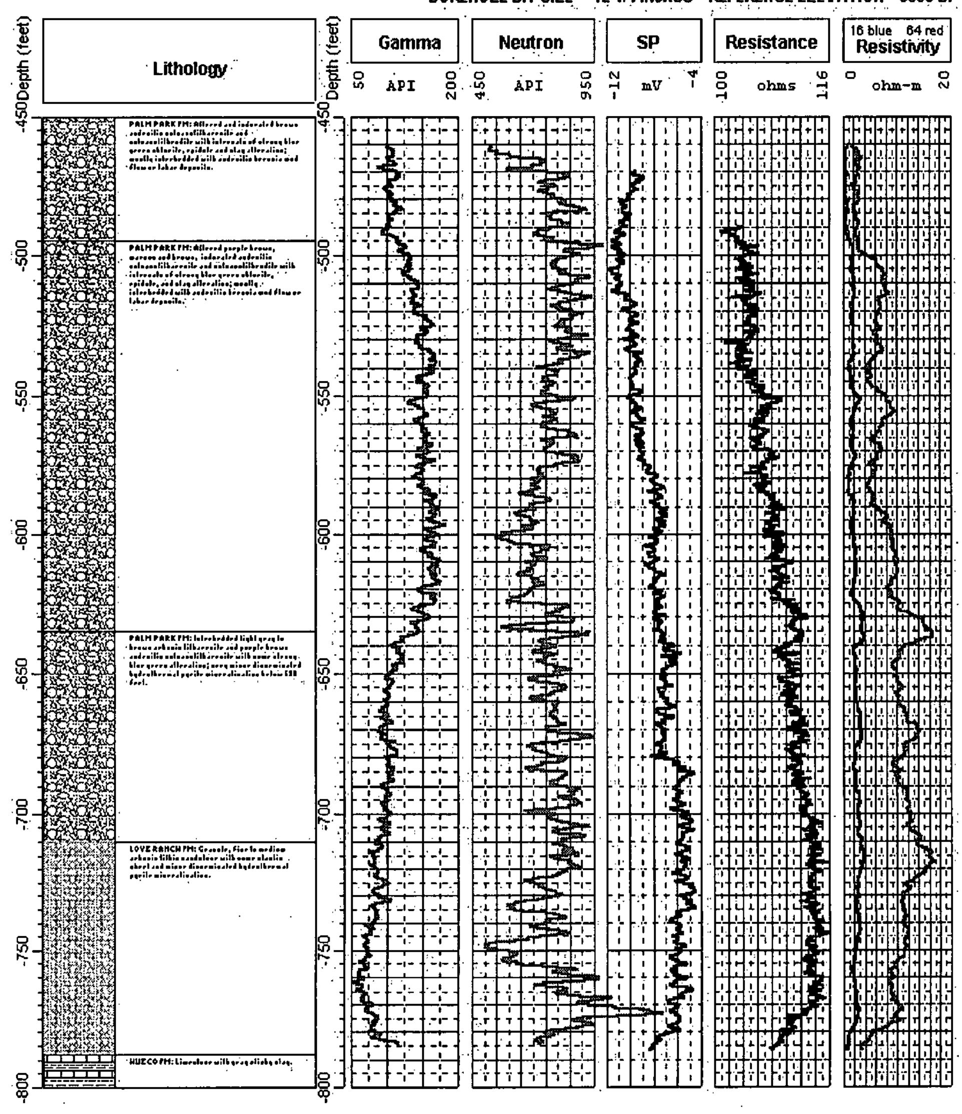

Figure 4. Electric Logs of the 460 to 793 Feet Interval

consistent with surface outcrops to at least a depth of 495 feet. Very little water production was noted in the Palm Park either prior to drilling into the rhyolite at 120 feet or after drilling out of the surface casing cement until at least 556 feet depth.

Between 495 and 635 feet depth the Palm Park is interbedded with abundant indurated lithic sandstone that is either purple brown and dark maroon or blue green color. Overall, this andesite volcanoarenite unit of the Palm Park is less clay-rich and may contain some fracture permeability. The first notable water production occurred at 556 feet depth and probably represents the top of the deep fracture-dominated reservoir. The first major production occurred at 600 to 615 feet depth at which point the blooie line discharge increased dramatically and the flow turned orange red and light reddish brown. It is believed that an important fracture was drilled in this interval. An additional fracture zone is inferred from reddish discharges at about 630 feet depth.

From 635 feet to 710 feet depth the Palm Park again changes character. This unit is an interbedded light gray to brown arkosic lithic sandstone and purple and blue green andesite volcanoarenite. Below 690 feet depth some disseminated pyrite was noted in cuttings. Again, several fractures were encountered in this zone, judging from periodic and temporary reddish orange discharges at the blooie line. The basal Palm Park unit appears to be a transitional unit with the underlying Love Ranch (?) Formation.

From 710 to 788 feet depth, cuttings are granule, fine to medium arkosic sand with some clastic chert and disseminated hydrothermal pyrite. This unit is tentatively correlated with the Eocene Love Ranch Formation (Mack and others, 1998). Several important fracture zones occur in this unit. The most important fractures occur between 730 and 765 feet depth. It may be notable that while temperature logging, the temperature probe temporarily hung at 752 feet depth. Turbulent flow in the bore around a fracture zone could have caused the probe to deviate from vertical and intersect the borehole wall as the probe was lowered. Also, the low neutron log response at this interval also gives support to a major fracture zone in this interval.

At 788 feet depth, limestone chips were discharged at the blooie line. At the end of temperature logging, the wire housing around the thermister was clogged with light gray, sticky clay. This clay probably come from 793 feet, total logging depth, and may represent a clay bed in the limestone unit that swelled across the hole so that the probe was unable to reach the TD of 800 feet. An X-ray diffraction analysis of the clay shows that it is montmorillonite, a swelling clay (Appendix 3). The clay and limestone are believed to represent the Permian Hueco limestone.

Water levels encountered at various stages of drilling of the Masson 36 well provide some insight into the hydrogeology of the site. While drilling in the Palm Park Formation above the rhyolite, the first notable indication of water was observed at 55 feet depth. After the shallow rhyolite reservoir was drilled, a water level of 40 feet was noted in temperature and geophysical logging. When the hole reached TD at 800 feet depth, with the upper rhyolite reservoir was sealed off by a cemented surface casing, the water level in Masson 36 was about 19 feet depth. A positive upward head difference at least of 21 to 36 feet exists between the shallow thermal and cold water and the top of the deep reservoir at Radium Springs.

3.2 Thermal Regime of the Masson 36 Well

Several temperature logs were run in the Masson 36 well during the drilling operations in order to gain subsurface information on hydrogeologic conditions, temperature gradients, and to evaluate the overall integrity and the top of the cement in the annulus between the casing and formation after the initial surface casing cement job by Dowell Schlumberger.

The last temperature log prior to running the production casing gives the best information on potential production temperatures and overall thermal regime (Figure 3). From 560 feet to 793 feet the borehole shows very low temperature gradients or almost isothermal conditions. This is expected in a fractured reservoir due to upflow in the formation. The temperature of this zone is about 209 to 212 ^{o}F and should closely reflect the production temperatures when the hole is pumped for production. Between 560 and 220 feet depth, the borehole shows a steep gradient that is largely the result of conductive processes in the country rock beyond the borehole. Conductive heat transfer processes are dominant only where no or extremely low natural flows of water occur. While the gradient in this interval shows a slight upward convex profile that could indicate some upward seepage across the Palm Park aquitard, the curvature may simply represent disturbance from convection in the large diameter borehole or slightly increasing thermal conductivity in the Palm Park unit with depth. Overall, the temperature gradient supports other data that indicate the deep reservoir is confined by a relatively impermeable Palm Park Formation. Of interest also is the interval from 120 to 220 feet. Here, the temperature gradient becomes isothermal once again. This interval coincides with the shallow rhyolite reservoir.

Figure 5 is a plot of all of the temperature measurements taken in the Masson 36 well, except for the cement temperature log. These logs plot to the left of the final log and show much cooling due to drilling disturbance. However, note that discrete bottom hole temperatures (BHT) for each log are

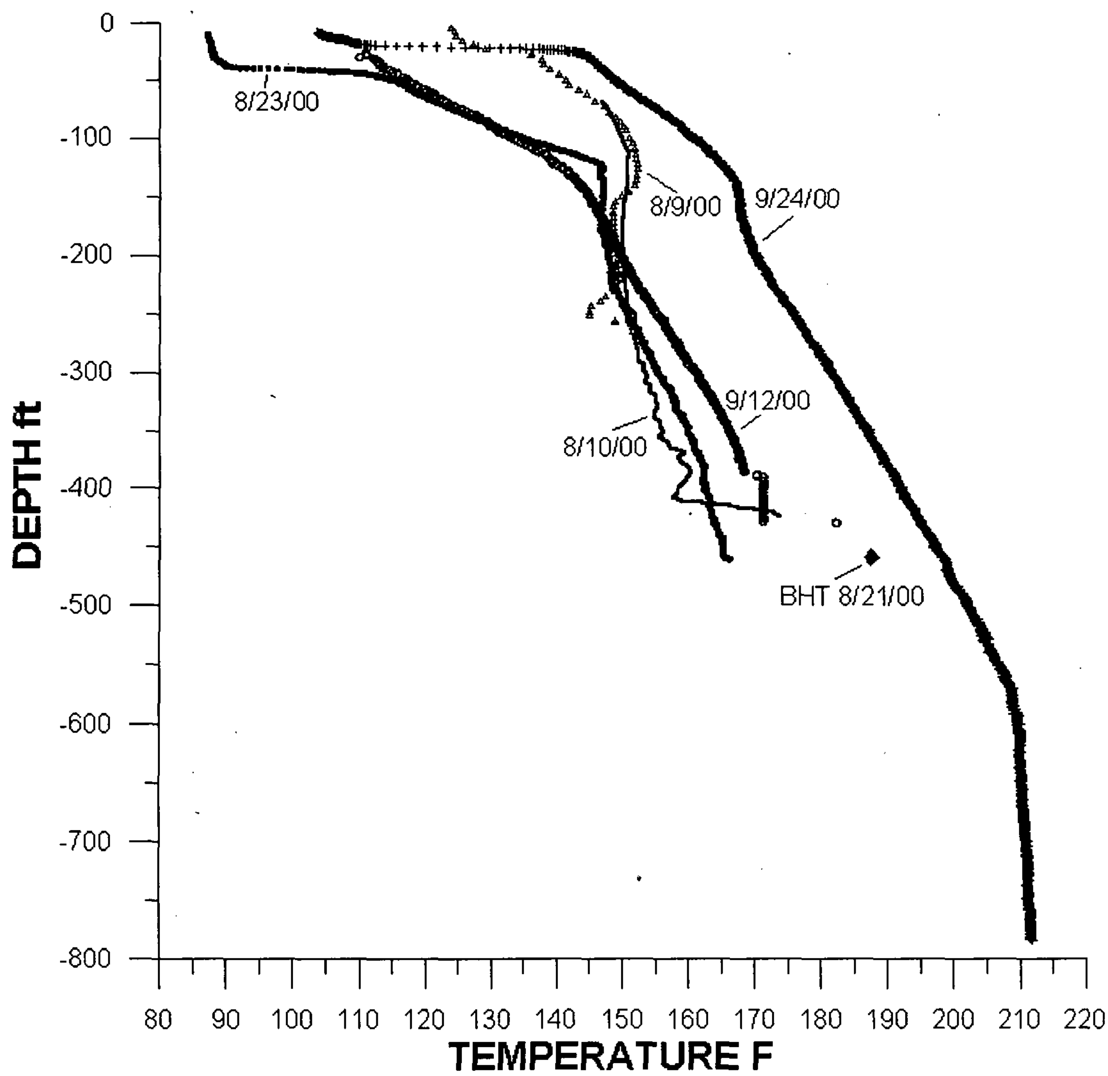

Figure 5. Composite Graph of Temperature Logs and BHT Measurements.

all much higher than measurements taken above them. The BHT measurements are the least disturbed by drilling because cooler drill water and air has only circulated past the newly drilled or uncovered rock for a comparatively short time. The BHT's were used during the drilling to qualitatively estimate reservoir tops and temperatures.

3.3 Reservoir Chemistry

After reaching total depth at 800 ft, the well was blown with air, but without foam additives, for two hours to clean the bore and also to obtain flow rate information and to acquire a good sample for water chemistry. An unfiltered sample with no acid preservatives was collected and delivered to the SWAT lab at NMSU for chemical analysis. A report of analysis is included in Appendix 3. The produced fluid is a sodium chloride water with a TDS of 3,800 mg/L. Silica (Si) concentration, if recalculated as (SiO_2), is 67 mg/L and gives a quartz geothermometer reservoir temperature of 240 ^{o}F (Fournier and Rowe, 1966) The chalcedony geothermometer is 189 ^{o}F. Temperature of the discharge at the time of collection was 196 ^{o}F as measured with a laboratory mercury thermometer. The maximum temperature of the deep reservoir at Radium Springs may not exceed 240 ^{o}F.

At the end of drilling and air stimulated flow testing, a powdery light pink scale was noted at the end of the blooie line. It is more than likely that most of this scale formed during the flow test at the end of drilling because cuttings would no doubt have eroded any soft scale formation. The scale only formed on the last few feet of the blooie line. An X-ray diffraction analysis of the scale powder reveals that it is a mixture of calcite and aragonite (see Appendix 3). The amount of scale is minor and probably resulted from loss of dissolved carbon dioxide at the blooie line discharge.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The Masson 36 well is completed in the top of a deep confined reservoir at Radium Springs. Production temperatures of 210 to 212 °F are likely. It is believed that the well will sustain long-term production in excess of 1,500 to 2,000 gpm.

A long term flow test should be performed to determine production and final pump design. The pump test should begin as a step test and end with a steady-state drawdown test for at least 48 hours. As important as measuring drawdown in Masson 36, drawdown should also be measured in several of the current shallow production wells. Drawdown should also be observed in at least one of the cold wells. Ideally, drawdown should also be monitored in the Hunt 25-37 well while the pump test is conducted. This will require BLM approval. If step tests indicate it is possible, Masson 36 should be pumped at 3,000 gpm for the steady-state drawdown test in order to stress the reservoir and determine any hydraulic connection with shallower reservoirs or with the deep reservoir to the north where the Hunt wells were drilled. The test should be planned and managed by a qualified engineer or geologist and not by a local southern New Mexico water well driller.

This well is configured in such a way that a very large pump can be installed. Also, the well could be deepened several thousand feet in the future if higher temperature or additional production is desired for either the greenhouse or for small-scale binary electrical power generation or both.

It is also recommended that Masson undertake a disciplined and regular monitoring of selected wells including the Masson 36 well. This would include chemistry, temperature, and water level measurements taken at regular and periodic times. As a part of such an effort, all of the wells to be monitored should be surveyed so that a <u>precise elevation</u> is known. If any shallow production or injection wells are to be abandoned, I would also recommend modifying the well constructions to create dedicated monitor wells or piezometers rather than plugging and abandoning the wells. This would require BLM and or NMSEO approval; but, I believe the agencies would be supportive of a proper monitor well design and use plan.

Without a monitoring program, the reservoir will probably not be understood. Monitoring also provides baseline data and procedure that can provide a measure of foresight into reservoir behavior and also "early warning" of impacts from possible overly aggressive development of electric power on the Radium Springs KGRA immediately north of the greenhouse.

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APPENDIX 1

SUMMARY WELL HISTORY OF THE MASSON 36 WELL

Well History
Compiler: Bill Rickard,Resource Group
Well Name: Masson 36

Operator: Alex R. Masson, Inc. **Field:** Radium Springs, NM

Spud Date: 07-Aug-00 **Completion date:** 26-Sep-00

Section:3 **Township:**21 South **Range:**1 West
Location:580' North and 2386.0' East of the Southwest corner of Section 3, Dona Ana County, New Mexico.

29-Jun-00 Depth: 24
Set 20" conductor at 24.2' below ground level.

30-Jun-00 to 06-Aug-00 Depth:24
No drilling activity. Moved in and rigged up rig and associated equipment.

07-Aug-00 Depth: 143
Made up bottom hole assembly. Installed pack off assembly on conductor and installed blooie line. Cleaned out cement in bottom of conductor and drilled 17-1/2" hole from 23' to 83' with air/mist, reamed each single down and circulated hole clean. Encountered first water at about 70'. Serviced rig. Drilled 17-1/2" hole from 83' to 143' with air/mist. Encountered rhyolite and hot water at 123'. Blooie line temperature increased to 150 F, with an initial water flow of about 200 gpm. rhyolite very fractured. Torque and drag increased significantly. Reamed and circulated hole every 1' to 2'. Reamed single down and circulated hole clean. Had 400-500 gpm flow at end of day. No fill. Shut down for night. Repaired hydraulic leak.

08-Aug-00 Depth: 323
Serviced rig. Had less than 1' of fill on bottom. Drilled 17-1/2" hole from 143' to 323' with air/mist, Reamed each single down and circulated hole clean. Had tight hole and very high torque 164' - 165'. Re-entered andesite at 220'. Water flow increased from about 400 gpm to 600 - 800 gpm at end of day. Circulated hole clean & shut down for night.

09-Aug-00 Depth: 473

Serviced Rig. Ran temperature log inside of drill pipe to top of bottom hole assembly at 268'. Temperature survey showed maximum temperature of 151 F at the top of the fractured rhyolite. (Had rhyolite from 123' to 220'.) Temperature dropped to 145 F at 250', in the andesite. Had no fill on bottom. Drilled 17-1/2" hole from 323' to 443' with air/foam, reamed each single down. Had about 600 gpm water flow to surface. Cuttings returns to surface decreased and had some minor fill on connections. Added polymer to injectate and circulated hole clean. Drilled some tuff with the andesite just above 400'. Drilled 17-1/2" hole from 443' to 473' with air/foam, had high torque and had to pick up frequently. Circulated hole clean with stiff foam and reamed single down. Shut down for night. Had up to 40% serpentine in andesite. Hammer not operating properly without lots
of soap.

10-Aug-00 Depth:473

Serviced rig. Ran temperature survey inside of drill pipe to 420', maximum temperature 174 F at 420'. Maximum temperature gradient 15F/100', Maximum expected temperature at casing point is 204 F. Rigged up to pull out of hole, worked on rig tongs. Circulated and singled out of hole, circulated each single out to 203. Singled out to top of tools. Pumped out cellar and removed pack off assembly. Pulled tools, left bit in hole. Shank broke off bit leaving part of the spline in the air hammer. Fish left in the hole consists of the bit and about 5" of shank up for a fishing neck. Broke out tools and removed 17-1/2" stabilizer from air hammer. Attempted to break out air hammer to recover remaining spline with out success. Shut down for night.

21-Aug-00 Depth: 473

Engaged fish with screw on sub on second attempt. (Previous attempts to engage the fish with screw on sub and taper tap the previous week had been unsuccessful in recovering the fish.) POH to tools and shut down for night.

22-Aug-00 Depth: 473

Serviced rig and removed pack off assembly. Pulled tools and recovered 17-1/2" hammer bit. Laid down fish and fishing tools. Ran 17-1/2" stabilizer in hole. Ran temperature survey in open hole. Maximum BHT was 186 F at 473'. Discussed options with BLM, geologist and driller. Decided to run casing at this depth.

Laid down 17-1/2" tools. Prepared for loggers. Shut down for night.

23-Aug-00 Depth: 473
Rigged up SouthWest Geophysical loggers. Ran temperature log from surface to 466'. BHT was 169 F at 466'. Ran 3 arm caliper. Tool failed. POH, replaced tool and reran 3 arm caliper. Logged from 465' to surface. Had washout, through rhyolite, of 19"avg. from 220' to 145' and of 23" avg., to 115', remainder of hole gage is okay. Ran Gamma Ray. Logged from 465' to surface. Rhyolite was well delineated from 220' to 120'. Rigged down loggers. Released loggers and shut down rig.

24-Aug-00 to 27-Aug-00 Depth:473
No drilling activity. Waited on casing delivery form Houston.

28-Aug-00 Depth: 473
Casing arrived on location over weekend. Serviced rig. Rigged up to run casing. Ran shoe joint with float shoe tacked and centralizer 10' up from shoe. Worked on rig tongs. Installed float collar and shut down for night.

29-Aug-00 Depth: 473
Ran 13-3/8", 72#, N-80, Butt. casing. Installed float between first and second joints. Tacked all connections on first three joints. Ran centralizers above float shoe and float collar and on collar of second joint. Ran centralizers on every other collar to 60' below table. Joints # 6 & 7 ran tight and joint #11 hit an obstruction and fell through. String consists of float shoe, 1 joint casing, float collar and 13 joints casing, total length equals 461.12', with casing shoe at 460.12'. Rigged down casing running tools. Hauled water for cement job. Shut down for night.

30-Aug-00 Depth: 473
Hauled water and prepared for cement job. Removed top drive to repair hydraulic oil leak. Waited on Dowell. Worked on top drive. Top drive will be completely gone through to replace all seals and broken parts. Dowell will be on location at 10 AM tomorrow.

31-Aug-00 Depth: 473
Waited for Dowell Schlumberger to arrive on location. Rigged up to cement. Rigged up Dowell to cement 13 3/8" casing shoe at 461.42 ft, and float collar at 429.72'. Pressure tested cementing lines to 1000 psi before cementing operations. Pumped 77 barrels of water ahead, followed by 78 barrels of

lead cement consisting of 225 sacks "H" cement with 40% D66, 3% D29 and 2% D20 mixed at 14.5 ppg and 62 barrels of tail slurry consisting of 250 sacks "H" cement with 40% D66, 2% D65 and 0.2% D46 mixed at 16.4 ppg. Dropped wiper plug, displaced with 64 barrels of displacement fluid (water) at 8.3 ppg. Pumped final displacement in three stages waiting 10 minutes between stages. Bumped plug with 700 psi. Bled off pressure to zero, floats held. CIP at 1358 Hrs. WOC. Ran temperature survey at one meter intervals from surface to top of float collar at 1800 Hrs. Temperature survey indicated top of cement in 17-1/2" hole at 120'. Top of cement correlates to electric log top of lost circulation zone.

01-Sep-00 Depth: 473

Met with Masson site supervisor and ordered 5 1/2 cubic yards of Redi-mix concrete, light slurry, suitable for filling of 13 3/8" X 20" annulus. Rigged up Redi-mix truck to well annulus. Poured two cubic yards of concrete into well annulus and had water returns to surface. Continued pouring slurry into annulus until approximately 3.5 cubic yards was placed in annulus, perfect fill in the annulus calculated at 3.6 cubic yards. Measured top of cement in 13 3/8" X 20" annulus using a 10 foot measuring stick. Had continuous returns to surface of water from two cubic yards placed until the total 3.5 cubic yards of concrete was placed. At conclusion of cement placement the fluid stood level at the flow nipple. WOC.

02-Sep-00 to 05-Sep-00 Depth:473

No drilling activity. Waited on repairs to top drive.

06-Sep-00 Depth: 473

Cleaned out mud from bottom of cellar, cleaned out timbers and all debris. Cut 20" casing in two pieces 18" up from cellar floor. Chipped away cement around 13 3/8" casing. Cut off 13 3/8" casing 18" up from cellar floor. Left 13 3/8" and 20" casing stub on wellhead until installation of BOP equipment.

07-Sep-00 to 11-Sep-00 Depth:473

No drilling activity. Waited on repairs to top drive.

12-Sep-00 Depth: 473

Installed top drive, tested same by rotating. Nippled down 13 3/8" and 20" casing stubs and removed same from cellar. Built up 12-1/4" stabilizers to gauge. Ran temperature survey from

429 ft to surface. Maximum temperature recorded at 429 feet was 181 degrees F.

13-Sep-00 Depth: 473
Unloaded BOP equipment from delivery truck. Set accumulator in front of rig. Cut off and beveled 13-3/8" casing to receive wellhead flange. Set 13-5/8"-3M wellhead flange in place and leveled same. Welded wellhead flange to 13 3/8" casing. Set 13-5/8"-3M spacer spool with side outlets on top of wellhead flange and nippled up spacer spool.

14-Sep-00 Depth: 473
Set Hydril (GK 13-5/8-3M) on top of spacer spool, nippled up Hydril to stack. Set "Williams" rotating head on top of Hydril, nippled up rotating head to stack. Installed hydraulic lines from Hydril to accumulator. Function tested Hydril with accumulator pressure at 2700 psi. Installed H2S safety equipment as per drilling program. Installed three H2S monitors, one at top of BOPE, one at drillers console, and one at exit of flow line. H2S monitors set to activate light at 10 ppm, alarm siren sounds at 15 ppm. Function tested H2S monitors OK. Set two each wind socks, one located at pipe trailer next to rig and one located at Baker tank next to rig. Set two briefing area signs on location. Set entry flag at bottom of hill leading to location. Set green flag at entry indicating no H2S. Continued to nipple up BOPE stack, tightened bolts on stack several times. Ran joint of drill pipe into Hydril, closed bag and pressure tested BOPE and casing to 500 psi for 15 minutes. Checked BOPE stack visually, had no leaks. Had only 10 psi bleed off during the 15 minute test. BOPE tested in compliance with contract, witnessed by BLM and A. R. Masson representative.

15-Sep-00 Depth: 473
Rigged up kill and choke lines to spacer spool. Rigged up blooie line to well site sump, welded supports to blooie line. Installed thermo-well in blooie line. Picked up drilling tools, found piston in air hammer jammed, laid down air hammer and attempted to free piston with lubricant.

16-Sep-00 Depth: 525
Rigged up drilling tools with 12-1/4" air hammer, ran in hole with drilling tools and made up drill string. Stood back drilling tool string. Picked up rotating head rubber stabbing tool on 5" drill pipe. Stabbed through rotating head rubber, stood back drill

pipe and rotating head assembly in derrick. Ran in hole with drilling tool string, made up 5" DP to tool string and set rotating head assembly into rotating head body. Made up locking nut on rotating head. Rigged up check valve on kill line. Ran in hole with 5" drill pipe and tools to top of cement at 423 '. Circulated water out of hole with air and foam. Drilled with one air compressor. Drilled cement, float collar, cement, and float shoe. Drilled 12-1/4" hole in new formation from 469' to 525'. Shut down for night, secured well.

17-Sep-00 Depth: 525

Auxiliary air compressor fuel controller broken. No drilling for 24 hr period. Drilling contractor obtaining replacement parts.

18-Sep-00 Depth: 672

Repaired auxiliary air compressor. Circulated hole clean with two air compressors at 525'. Drilled 12-1/4" hole to 555'. Flow line temperature 103 F. Drilled 12-1/4" hole from 555' to 615'. Flow line temperature 168 F. At 610' Had formation change, returns looked smokey brown. Began small flow of water at 610'. Connection at 615' took 3 minutes to unload water from wellbore. Drilled 12-1/4" hole from 615' to 645', flow line temperature increased steadily to 172 F. Drilled 12-1/4" hole from 645' to 660', had formation change, returns turned bright red and orange in color, water flow at blooie line increased steadily. Flow line temperature 185 F. Drilled 12-1/4" hole from 660' to 672', penetration rate decreased to near zero, Due to back pressure on drill string. Flow line temperature at 203 F. Decision made by drilling contractor to pull out of hole and make up tri-cone bit. Estimated water flow between 500-700 GPM. Shut down for night at 1815 Hrs.

19-Sep-00 Depth: 672

Pulled out of hole with drill string, recovered all tools. Wait on arrival of tri-cone bit.

21-Sep-00 Depth: 740

Broke out air hammer. Made up new bottom hole assembly, (assembly #2), identical to bottom hole assembly #1 with the addition of a float sub and a 12-1/4" bit instead of the air hammer. Ran in hole with new bottom hole assembly to 672'. Circulated hole, FLT = 203 F. Drilled 12-1/4" hole to 707', experienced increase in water flow at blooie line. Drilled kelly down at 710', had show of pyrite in cuttings. Drilled 12-1/4" hole from 710' to 740'.

22-Sep-00 Depth: 800

Rigged up 36" X 12" square weir to measure well flow. Tested well flow with the aid of air compressors with total depth at 740'. Well flow measured at weir, with weir depth of 4", is 845 GPM. Measured flow line temperature of 190 F with hand held temperature meter of KD Huey Drilling Co. Took water samples from flow line at 740' depth. Received orders to deepen well to 800'. Drilled 12-1/4" hole from 740' to 765', had drilling break at 765'. Water flow at weir increased after drilling break from 845 GPM to 1175 GPM. Measured flow line temperature after drilling break of 197 F. Drilled 12-1/4" hole from 765' to 800' total depth. Shut down air compressors and flow ceased, welded thermo-well into blooie line to measure flow line temperature. Flowed well with the aid of air compressors, flow line temperature of 91 C (196 F). Measured flow at weir of 1175 GPM. Shut down for night.

23-Sep-00 Depth: 800

Pull out of hole with drilling assembly. Recovered all of drilling assembly. Rigged down BOPE stack, removed rotating head. Unbolted Hydril and spacer spool.

24-Sep-00 Depth:800

Unloaded 15 joints of 9-5/8", 47 #/ft, N-80, buttress thread casing (8 joints of casing blank, 7 joints perforated). Unloaded 13-3/8" X 9-5/8" liner adapter, 9-5/8" casing shoe, and 9-5/8" liner setting tool. Rigged up to run electric logs, calibrated temperature tool. Ran in hole with temperature tool, hung up at 756 ft, spaded through obstruction, ran in to total depth of 793'. Logged out of hole with temperature tool, maximum recorded temperature was 212 F at bottom of logged interval. Temperature log indicates fluid level in wellbore at 20'. Rigged up Gamma Ray/Neutron logging tool. Ran in hole with GR/N tool to total depth of 791 ft, logged out of hole.

Gamma Ray tool indicates bottom of 13- 3/8" casing at 461'. Re-ran Gamma Ray/Neutron log, first run did not record Neutron log. Logged out of hole with GR/N log from 793'. Fluid level indicated at 20'. Ran in hole with Resistivity/SP tool to 793'. Logged out of hole with resistivity/SP tool to inside 13-3/8" casing. Rigged up 3 armed caliper tool, tool did not function, ran second 3 armed caliper tool to 793 ft, spooling motor slipped chain, hand pulled caliper tool from well. Decision made to not run caliper tool. Shut down for night.

25-Sep-00 Depth: 800
Removed BOPE stack from cellar. Cut off wellhead flange from 13-3/8" casing. Loaded rental equipment on transport for shipment to vendor. Rigged up to run 9-5/8" liner. Welded guide shoe on bottom of first joint of perforated 9 5/8" liner. Ran two (2) joints of 9-5/8" casing into wellbore. Shut down for night.

26-Sep-00 Depth: 800
Continued running 9 5/8" blank and perforated liner. Made up liner adapter and adapter setting tool. Ran liner in hole on drill pipe. Set liner on bottom with shoe at 793', top of liner adapter at 395'. Perforated 9-5/8" liner interval from 793' to 562'. Released liner adapter. Pulled out of hole with drill pipe and setting tool. Broke down running tools. Laid down derrick. Plan to weld plate on top of 13-3/8" casing.

APPENDIX 2

SUMMARY GEOLOGIC LOG OF THE MASSON 36 WELL

SUMMARY GEOLOGIC LOG OF MASSON 36 WELL

4 to 14 feet

ALLUVIUM unconsolidated fluvial sand and gravel; arroyo deposits and drill pad base.

14 to 120 feet

PALM PARK FM Altered and slightly-to moderately indurated purple brown and blue green, clayey andesitic volcanolitharenite and volcanolithrudite; mostly interbedded andesitic breccia mudflow or lahar deposits.

120 to 222 feet

ROBLEDO RHYOLITE Grey porphyritic rhyolite. Highly fractured with brown and red brown oxidized fracture and breccia fragment surfaces. Rhyolite dike with shallow north dip.

222 to 495 feet

PALM PARK FM Altered and indurated brown andesitic volcanolitharenite and volcanolithrudite with intervals of strong blue green chlorite, epidote and clay alteration; mostly interbedded with andesitic breccia mud flow or lahar deposits.

495 to 635 feet

PALM PARK FM Altered purple brown, maroon and brown, indurated andesitic volcanolitharenite and volcanolithrudite with intervals of strong blue green chlorite, epidote, and clay alteration; mostly interbedded with andesitic breccia mud flow or lahar deposits.

635 to 710 feet

PALM PARK FM Interbedded light gray to brown arkosic litharenite and purple brown andesitic volcanolitharenite with some strong blue green alteration; very minor disseminated hydrothermal pyrite mineralization below 690 feet.

710 to 788 feet

LOVE RANCH FM Granule, fine to medium arkosic lithic sandstone with some clastic chert and minor disseminated hydrothermal pyrite mineralization.

788 to 800 feet

HUECO FM Limestone with gray sticky clay.

APPENDIX 3
LABORATORY ANALYSIS OF WATER AND OTHER SAMPLES

SWAT Laboratory
New Mexico State University
Agronomy & Horticulture Department
Box 30003, Department 3Q
Las Cruces, NM 88003-8003

January 29, 2001

Jim Witcher
P.O. Box 3142
Las Cruces, NM 88003
646-3949

Dear Jim Witcher:

Below are the results of analysis of 1 sample received for examination on September 27, 2000.

Sample I.D. AB18378 Client Code: WITCHER
Sample Description: Geothermal Well
Sample collector: JAMES WITCHER Sample collection date: 09/23/00
Lab submittal date: 09/27/00 Time: 12:46

TEST PARAMETER	UNITS	TEST RESULT	DETECTION LIMIT
pH of water		7.46	
Total Dissolved Solids	mg/L	3800	1
Sodium by ICP-	mg/L	1221	10
Calcium by ICP-	mg/L	104	2
Magnesium by ICP-	mg/L	11.4	0.5
Bicarbonate	meq/L	5.73	0.01
Potassium by ICP-	mg/L	191	2
Chloride by Autoanalyzer	mg/L	2022	50
Sulfate	mg/L	276	50
Fluoride by electrode	mg/L	5.50	0.10
Bromide by Ion Chrom-	mg/L	Not detected	5
Arsenic by ICP-	mg/L	Not detected	0.05
Silica by ICP	mg/L	31.40	0.25
Strontium by ICP	mg/L	2.26	0.01
Lithium by ICP-	mg/L	1.11	0.05
Boron by ICP-	mg/L	0.85	0.01
Iron by ICP-	mg/L	0.16	0.05

Please advise should you have questions concerning these data.

Respectfully submitted,

Andrew Lee Bristol
Laboratory Manager
(505)646-4422

X-Ray Diffraction Lab				
Department of Earth Sciences			Operating conditions:	
New Mexico State University			kV	30
Dr. Nancy J. McMillan			mA	40
(505) 646-5000			scan rate	2deg/min
			full scale	800 cps
			chart speed	2mm/min
Name:	Jim Witcher		Analyst:	McMillan
Sample No.	clay		Interpreted by:	McMillan
Minerals present:	quartz, montmorillonite			
	note – the montmorillonite peak at 7.43 2θ is missing!			
2θ	d	Mineral	d or 2θ, matched peak	
20.1	4.413849944	montmorillonite	19.95	
21.1	4.206866805	quartz	20.85	
26.9	3.311525599	quartz	26.66	
29.7	3.005391876	montmorillonite	30.09	
35.2	2.547376652	montmorillonite	35.05	
36.8	2.440210201	quartz	36.56	
39.7	2.268384308	quartz	39.49	
40.5	2.225403182	quartz	2.237	
42.6	2.120433285	quartz	2.212	
43.4	2.08318257	??		
46	1.971304418	quartz	1.98	
50.4	1.809035844	quartz	50.21	
55.2	1.662543906	quartz	1.672	
60.2	1.53585944	quartz	1.541	
64.3	1.447463881	quartz	1.453	
68.5	1.368591429	quartz	68.2	

X-Ray Diffraction Lab			Operating conditions:		
Department of Earth Sciences			kV	30	
New Mexico State University			mA	40	
Dr. Nancy J. McMillan			scan rate	2deg/min	
(505) 646-5000			full scale	800 cps	
			chart speed	2mm/min	
			Analyst:	McMillan	
Name	Jim Witcher		Interpreted by:	McMillan	
Sample No	scaling				
Minerals present:	calcite, aragonite				
2θ	d	Mineral	d or 2θ, matched peak		
26.4	3.373098599	aragonite	26.24		
27.4	3.252221033	aragonite	27.25		
29.7	3.005391876	calcite	29.43		
33.4	2.680430841	aragonite	33.18		
36.4	2.466102745	calcite	36		
38.2	2.353936024	aragonite	37.93		
38.8	2.31890467	aragonite	2.34, 2.33		
39.7	2.268384308	calcite	39.43		
46.1	1.967260738	aragonite	45.6		
47.7	1.904939286	calcite	47.53		
48.7	1.868135234	calcite	48.55		
50.4	1.809035844	aragonite	1.814		
52.8	1.73231907	aragonite	1.742, 1.728		
57.9	1.591273771	calcite	1.604		
61.1	1.515374834	calcite	1.525		
43.4	2.08318257	calcite	43.18		

APPENDIX 4
DOWELL/SCHLUMBERGER SURFACE CASING CEMENT REPORT

Schlumberger

DESIGN – EXECUTE – EVALUATE – REPORT

CEMENTING
SURFACE 13 3/8

K D HUEY
MASSON 36
DONA ANNA COUNTY, NEW MEXICO

Prepared By: R KURT CROWE

SERVICE SUPERVISOR

ARTESIA DISTRICT

505-748-1392

AUGUST 31, 2000

Schlumberger
Dowell

Cementing Service Report

Customer	Job Number
K.D. HUEY	20175849

Well	Location (legal)	Dowell Location	Job Start
MASSON #36		Artesia, NM	8/31/00

Field	Formation Name/Type	Deviation	Bit Size	Well MD	Well TVD
		0 °	17.5 in	461 ft	461 ft

County	State/Province	BHP	BHST	BHCT	Pore Press. Gradient
DONA ANNA	NEW MEXICO	0 psi	0 °F	0 °F	0 psi/ft

Rig Name	Drilled For	Service Via
	Oil & Gas	Land

Offshore Zone	Well Class	Well Type
	New	Exploration

Drilling Fluid Type	Max. Density	Plastic Viscosity
	0 lb/gal	0 cp

Service Line	Job Type
Cementing	Cem Surface Casing

Max. Allowed Tubing Pressure	Max. Allowed Ann. Pressure	WellHead Connection
1000 psi	0 psi	13 3/8" CMT HEAD

Service Instructions
CEMENT 470' OF 13 3/8" CASING.

Casing/Liner

Depth, ft	Size, in	Weight, lb/ft	Grade	Thread
461.42	13.38	72	N80	BUTT
0	0	0		

Tubing/Drill Pipe

Depth,	Size, in	Weight, lb/ft	Grade	Thread
0	0	0		
0	0	0		

Perforations/Open Hole

Top, ft	Bottom, ft	spf	No. of Shots	Total Interval
0	0	0	0	0 ft
0	0	0	0	Diameter
0	0	0	0	0 in

Treat Down	Displacement	Packer Type	Packer Depth
Casing	63.6 bbl		0 ft

Tubing Vol.	Casing Vol.	Annular Vol.	OpenHole Vol
0 bbl	68.3 bbl	0 bbl	0 bbl

Casing/Tubing Secured ☐ 1 Hole Volume Circulated prior to Cementing ☐
Lift Pressure: 185 psi
Pipe Rotated ☐ Pipe Reciprocated ☐
No. Centralizers: 0 Top Plugs: 1 Bottom Plugs: 0
Cement Head Type: Single

Job Scheduled For:	Arrived on Location:	Leave Location:
8/31/00 11:00	8/31/00 11:00	8/31/00 14:00

Casing Tools

Shoe Type:	Guide
Shoe Depth:	461.42 ft
Stage Tool Type	
Stage Tool Depth:	0 ft
Collar Type:	Float
Collar Depth:	4429.72 ft

Squeeze Job

Squeeze Type	
Tool Type:	
Tool Depth:	0 ft
Tail Pipe Size:	0 in
Tail Pipe Depth:	0 ft
Sqz Total Vol:	0 bbl

Time 24 hr clock	CumVol bbl	Density ppg	TotFlowrate bpm	Treating Psi psi				Message
12:19	0	6.25	0	4071	0	0	0	
12:19	0	6.25	0	4071	0	0	0	Start Sensor Check
12:19	0	6.25	0	4071	0	0	0	Start Job
12:20	0	8.22	0	4.58	0	0	0	
12:20	0	8.22	0	4.58	0	0	0	Pressure Test Lines
12:21	0.082	8.22	0.019	1332	0	0	0	
12:21	0.082	8.22	0.019	1332	0	0	0	Start Pumping Spacer
12:22	0.082	8.2	0	22.69	0	0	0	
12:23	2.02	8.21	3.97	59.52	0	0	0	
12:24	6.01	8.21	3.97	27.47	0	0	0	
12:25	10	8.22	3.99	36.63	0	0	0	
12:26	13.99	8.22	3.97	36.63	0	0	0	
12:27	17.98	8.22	3.99	41.21	0	0	0	
12:28	21.98	8.22	3.97	41.21	0	0	0	
12:29	25.97	8.22	3.97	41.21	0	0	0	
12:30	29.97	8.22	3.97	41.21	0	0	0	
12:31	33.96	8.22	3.97	45.79	0	0	0	
12:32	36.88	8.22	0	32.05	0	0	0	
12:33	36.88	8.22	0	32.05	0	0	0	
12:34	36.88	8.22	0	32.05	0	0	0	
12:35	36.88	8.22	0	27.47	0	0	0	
12:36	36.89	8.22	0	27.47	0	0	0	

Well		Field			Service Date		Customer	Job Number
MASSON ##36							K.D. HUEY	20175840

Time (24 hr clock)	CumVol (bbl)	Density (ppg)	TotFlowrate (bpm)	Treating Psi (psi)				Message
12:37	36.89	8.22	0	27.47	0	0	0	
12:38	40.44	8.22	3.99	50.37	0	0	0	
12:39	44.44	8.22	3.99	54.95	0	0	0	
12:40	48.43	8.22	3.97	54.95	0	0	0	
12:41	52.42	8.23	3.97	59.52	0	0	0	
12:42	56.41	8.2	3.99	59.52	0	0	0	
12:43	60.4	8.2	3.97	59.52	0	0	0	
12:44	64.4	8.2	3.97	59.52	0	0	0	
12:45	68.39	8.2	3.97	59.52	0	0	0	
12:46	72.38	8.17	3.97	59.52	0	0	0	
12:47	72.38	8.17	3.97	59.52	0	0	0	End Spacer
12:47	72.38	8.17	3.97	59.52	0	0	0	Start Mixing Lead Slurry
12:47	76.38	11.12	3.97	59.52	0	0	0	
12:48	4.8	14.61	5.72	100.7	0	0	0	
12:49	10.32	14.84	5.48	100.7	0	0	0	
12:50	15.84	14.7	5.48	91.58	0	0	0	
12:51	21.36	14.54	5.48	91.58	0	0	0	
12:52	26.88	14.56	5.48	91.58	0	0	0	
12:53	32.4	14.67	5.58	87	0	0	0	
12:54	37.92	14.39	5.48	82.42	0	0	0	
12:55	43.44	14.26	5.5	77.84	0	0	0	
12:56	48.97	14.82	5.5	87	0	0	0	
12:57	54.48	14.44	5.48	82.42	0	0	0	
12:58	60	14.55	5.5	87	0	0	0	
12:59	65.52	14.8	5.46	87	0	0	0	
13:00	71.04	14.55	5.48	91.58	0	0	0	
13:00	71.04	14.55	5.48	91.58	0	0	0	End Lead Slurry
13:00	71.04	14.55	5.48	91.58	0	0	0	Start Mixing Tail Slurry
13:01	2.08	16.12	3.97	73.26	0	0	0	
13:02	7.28	16.45	5.46	146.5	0	0	0	
13:03	12.8	13.71	5.48	82.42	0	0	0	
13:04	18.32	16.04	5.48	123.6	0	0	0	
13:05	23.84	15.64	5.48	123.6	0	0	0	
13:06	29.38	15.77	5.48	137.4	0	0	0	
13:07	34.55	16.04	5.6	109.9	0	0	0	
13:08	40.05	15.35	4.3	109.9	0	0	0	
13:09	44.45	16.25	3.97	105.3	0	0	0	
13:10	49.12	16.24	5.48	155.7	0	0	0	
13:11	53.85	16.23	3.97	96.15	0	0	0	
13:12	58.13	16.17	3.97	96.15	0	0	0	
13:13	62.12	16.31	3.97	114.5	0	0	0	
13:13	62.12	16.31	3.97	114.5	0	0	0	End Tail Slurry
13:13	62.12	16.31	3.97	114.5	0	0	0	Shutdown
13:13	62.12	16.31	3.97	114.5	0	0	0	Drop Top Plug
13:14	62.12	16.31	3.97	114.5	0	0	0	Start Displacement
13:14	0.002	15.54	0	36.63	0	0	0	
13:15	0.002	12.72	0	54.95	0	0	0	
13:16	2.97	9.91	3.97	54.95	0	0	0	
13:17	6.98	8.51	3.97	50.37	0	0	0	
13:18	10.97	8.24	4.16	50.37	0	0	0	
13:19	14.97	8.2	3.97	59.52	0	0	0	
13:19	14.97	8.2	3.97	59.52	0	0	0	Pressure and Rate
13:20	18.97	8.18	3.97	82.42	0	0	0	
13:21	22.96	8.21	3.99	100.7	0	0	0	

RIGS.97 v2.1a SR

Well MASSON ##36			Field		Service Date	Customer K.D. HUEY		Job Number 20175849
Time	CemVol	Density	TotFlowrate	Treating Psi				Message
24 hr clock	bbl	ppg	bpm	psi				
13:22	26.95	8.21	3.97	123.6	0	0	0	
13:23	32.33	8.21	3.97	155.7	0	0	0	
13:24	36.32	8.21	3.97	169.4	0	0	0	
13:25	36.32	8.21	3.97	169.4	0	0	0	Lower Pump Rate
13:25	39.9	8.21	1.94	128.2	0	0	0	
13:26	41.93	8.21	2.02	123.6	0	0	0	
13:27	43.96	8.21	2	141.9	0	0	0	
13:28	45.3	8.21	0	109.9	0	0	0	
13:28	45.3	8.21	0	109.9	0	0	0	S/D WOC
13:29	45.3	8.21	0	91.58	0	0	0	
13:30	45.3	8.21	0	87	0	0	0	
13:31	45.3	8.21	0	82.42	0	0	0	
13:32	45.3	8.21	0	82.42	0	0	0	
13:33	45.3	8.21	0	77.84	0	0	0	
13:34	45.3	8.21	0	77.84	0	0	0	
13:35	45.3	8.21	0	77.84	0	0	0	
13:36	45.3	8.21	0	77.84	0	0	0	
13:37	45.3	8.21	0	77.84	0	0	0	
13:38	45.3	8.21	0	77.84	0	0	0	Resume Flush
13:38	45.3	8.21	0	77.84	0	0	0	
13:39	47.05	8.21	2.02	174	0	0	0	
13:40	49.08	8.21	2.02	192.3	0	0	0	
13:41	51.11	8.21	2.02	187.7	0	0	0	
13:42	53.14	8.21	2.02	196.9	0	0	0	
13:43	55.18	8.21	2.02	210.6	0	0	0	
13:43	55.18	8.21	2.02	210.6	0	0	0	S/D WOC
13:44	55.26	8.21	0	119	0	0	0	
13:45	55.26	8.21	0	105.3	0	0	0	
13:46	55.26	8.21	0	105.3	0	0	0	
13:47	55.26	8.21	0	105.3	0	0	0	
13:48	55.26	8.21	0	105.3	0	0	0	
13:49	55.26	8.21	0	105.3	0	0	0	
13:50	55.26	8.21	0	105.3	0	0	0	
13:51	55.26	8.21	0	105.3	0	0	0	
13:52	55.26	8.21	0	105.3	0	0	0	
13:53	55.26	8.21	0	105.3	0	0	0	Resume Flush
13:53	55.32	8.21	1.03	109.9	0	0	0	
13:54	57.16	8.21	1.94	283.9	0	0	0	
13:55	59.12	8.21	1.96	224.4	0	0	0	
13:56	61.08	8.21	1.94	224.4	0	0	0	
13:57	63.04	8.21	1.94	238.1	0	0	0	
13:58	65	8.21	1.94	274.7	0	0	0	
13:59	65	8.21	1.94	274.7	0	0	0	Bump Top Plug
13:59	65	8.21	1.94	274.7	0	0	0	Bleed Off Pressure
13:59	0	8.21	0	572.3	0	0	0	

Well	Field	Service Date	Customer	Job Number
MASSON ##36			K.D. HUEY	20175849

Time (24 hr clock)	CumVol (bbl)	Density (ppg)	TotFlowrate (bpm)	Treating Psi (psi)			Message

Post Job Summary

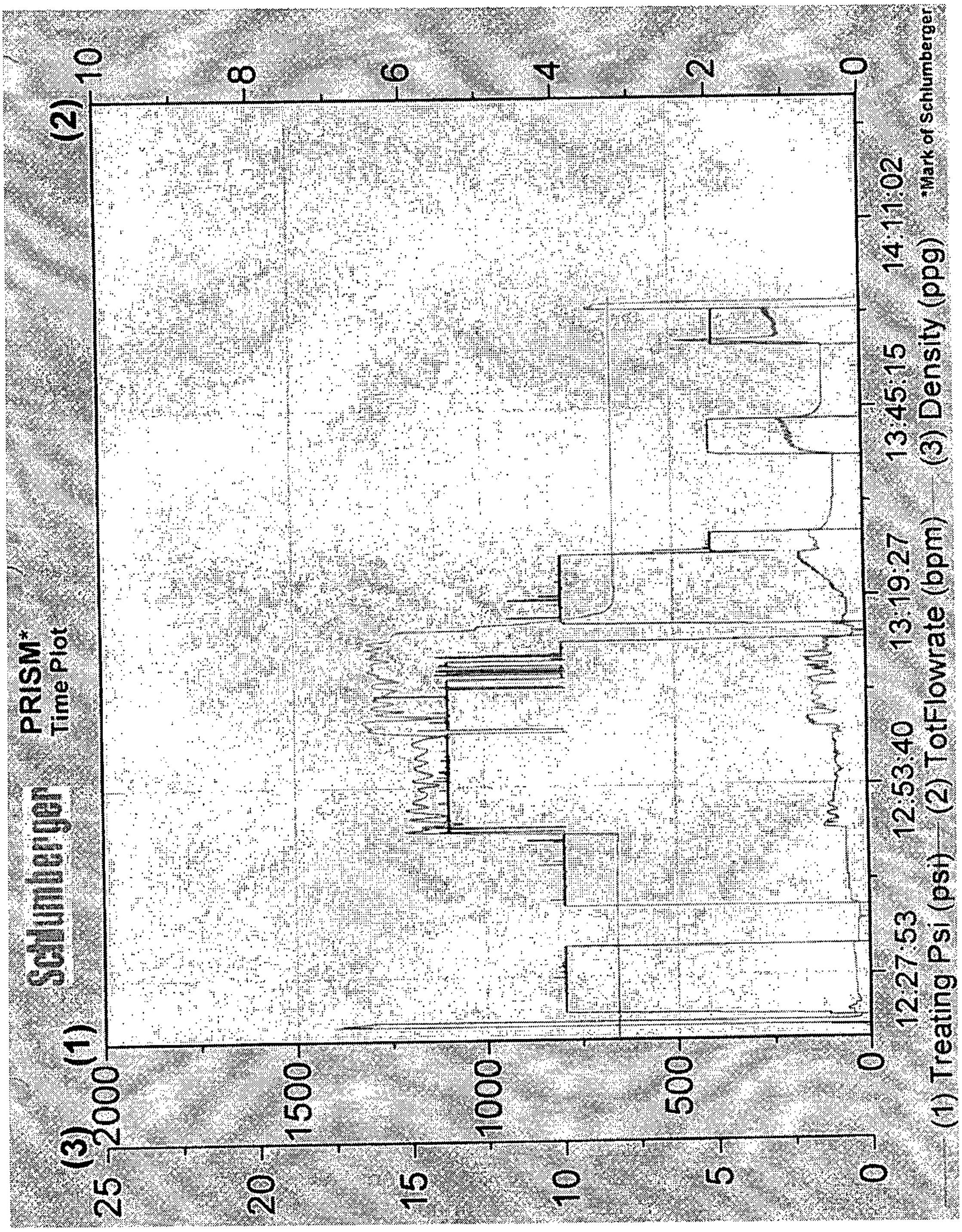
Average Pump Rates, bpm				Volume of Fluid Injected, bbl			
Slurry	N2	Mud	Maximum Rate	Total Slurry	Mud	Spacer	N2
4	0	0	4	144	0	75	0

Treating Pressure Summary, psi					Breakdown Fluid		
Maximum	Final	Average	Bump Plug to	Breakdown	Type	Volume	Density
0	0	0	700	0		0 bbl	0 lb/gal

Avg. N2 Percent	Designed Slurry Volume	Displacement	Mix Water Temp	Cement Circulated to Surface? Volume	Washed Thru Perfs To
0 %	144 bbl	63.6 bbl	80 °F	0 bbl.	0 ft.

Customer or Authorized Representative	Dowell Supervisor	Circulation Lost	Job Completed
K D Huey	Russell Crowe	☐	☑

RIGS 97 v2.1a-SR


Schlumberger
PRISM*
Time Plot
(3)
(1)
(2)
25
20
15
10
5
0
2000
1500
1000
500
0
10
8
6
4
2
0
12:27:53
12:53:40
13:19:27
13:45:15
14:11:02
(1) Treating Psi (psi)
(2) TotFlowrate (bpm)
(3) Density (ppg)
*Mark of Schlumberger

State Engineer Office Memorandum

Date: March 3, 1993

To: Paul Saavedra, Hearing Examiner

From: Peggy Barroll, Ph.D., Water Resource Engineering Specialist, Hydrology Section, NM SEO.

Subject: Evaluation of the Hydrologic Effects of LRG-4487-A-S-2

Introduction

The purpose of this memorandum is to address the hydrologic effects of a proposed supplemental irrigation well in the Radium Springs Geothermal area (Figure 1). Alex R. Masson Inc. applied for supplemental well LRG-4487-A-S-2 on April 6, 1992.

Alex R. Masson Inc. has possession of two permitted irrigation wells: LRG-4487-A and LRG-4487-A-S located in Section 10 (SE¼ NW¼ NW¼) of Township 21 South, Range 1 West. The locations of these and other nearby wells are shown in Figure 1. LRG-4487-A and LRG-4487-A-S are presently permitted 125 acre-feet of water per year combined diversion.

Water pumped under permit LRG-4487-A et al. is being used for irrigation in the applicant's greenhouses. SEO records indicate that greenhouse construction, and water use in the greenhouse began in 1987. Use of water in the greenhouse is unlikely to result in significant return flow, and it is assumed that no return flow will occur associated with the use of the presently permitted wells or the proposed supplemental well. It is also possible that the Masson greenhouse is located, at least in part, on top of the geothermal aquifer, instead of the alluvial aquifer, and if so, return flow could enter a different aquifer than that from which it was originally diverted.

Metering of the water pumped under this permit began in late 1990. SEO records indicate that 71.456 acre-feet of water was pumped in 1991. Records for 1992 are not complete because of meter malfunction.

Alex R Masson, Inc. filed application for supplemental well LRG-4487-A-S-2 located in Section 10 (SW¼ NW¼ NW¼), T21S, R1W. This well would supplement wells LRG-4487-A and LRG-4487-A-S, in diversion of 125 acre-feet/year of groundwater for use in greenhouse irrigation. This well is located 800 feet from the closest of the applicant's presently permitted irrigation wells. Emergency authorization for this well was requested (and granted) due to the failure of the existing irrigation wells to adequately supply applicant's greenhouse operation (Nixon, 1993). SEO records indicate that this well has already been drilled and is in use, and

LRG-4487-A is being used only on standby. The application states that the "current" presently permitted well (LRG-4487-A?) "has become inefficient due to silt and sand - old well will be maintained as a backup". This type of problem has been encountered previously in association with this permit. In September 1987, an application was filed by the previous owner of LRG-4487, H.N. Bailey to drill a replacement well; the reason given was "Old well produces sand . . .".

Application LRG-4487-A-S-2 was protested by D. Phelan, with declared rights LRG-8023 through LRG-8027. These declarations include wells and pits (sumps) ranging in depth from 8 feet, 2.5 inches to 30 feet in depth. In addition, Mr. Phelan has declared a surface water right to water from Radium Springs, File No. 03593. These points of diversion are all located in the northeast quarter of Section 10, T21S, R1W (Figure 1). Some of these declarations list geothermal uses, and some list irrigation use.

The nearest other permitted right, according to Nixon (1993), is LRG-6001, a declared right, located in SE¼NE¼NE¼ of Section 9, Township 21 South, Range 1 West. This is an irrigation well, 73 feet deep, located across the Rio Grande from Masson's and Phelan's wells (Figure 1).

Hydrogeology

LRG-4487-A and LRG-4487-A-S obtain water from a shallow alluvial aquifer associated with the Rio Grande. Well records indicate these wells are drilled to 80 feet in depth in alluvial material: sands and gravels. The well record submitted for LRG-4487-A-S-2 indicates that this well is completed at 63 feet in depth in coarse sand and gravel. All of these wells are within 250 feet of the Rio Grande. The depth to water in these alluvial aquifer wells is quite shallow. Gross (1986) uses data from a well he refers to as "Bailey Freshwater Well" which is located very close to the river. The depth to water in this well is given as 2 to 3 feet. Well records indicate the depths to water in LRG-4487-A and LRG-4487-A-S (located 230 feet from the river) are 12 and 11 feet. The depth to water for LRG-4487-A-S-2 is listed as 1 foot.

There is another shallow aquifer in this area. Geothermal water can be obtained from a fractured hard-rock aquifer composed of rhyolite and limestone. The water table in the geothermal aquifer is quite shallow; geothermal water is obtained from a number of relatively shallow wells and pits. This geothermal aquifer crops out within several hundred feet of the river, limiting the alluvial aquifer in areal extent.

In general, the alluvial aquifer produces fresh water suitable for irrigation, and the geothermal rhyolite-limestone aquifer produces saline water (TDS 1500 to 3300 ppm; Gross, 1986) suitable for geothermal uses.

Gross (1986) used water level and river stage data to study the connection between the river, the alluvial aquifer and the geothermal aquifer. He found that water levels in both the alluvial aquifer and the geothermal aquifer responded quickly to changes in river stage (although the alluvial aquifer may have responded more rapidly than the geothermal aquifer). This result indicates that both aquifers are in hydrologic connection with the river, and therefore with each other.

Hydrologic properties

Aquifer tests were performed in the geothermal aquifer (rhyolite and perhaps also limestone) in order to estimate the hydrologic properties of this aquifer (Gross, 1986). Rao (1986) reviewed this work and decided that a value of T = 4,000 ft^2/day is appropriate for the geothermal aquifer in this area. Rao's model of the southern Jornada del Muerto includes this area and a T of 5,000 ft^2/day was chosen in the zone around Radium Springs, which includes both the geothermal and alluvial aquifers.

Gross (1986) suggests a range of values of S values from 0.01 to 0.05 for the fractured rhyolite of the geothermal aquifer. Rao uses a value of S = 0.10 for his calculations involving a diversion from the geothermal aquifer, and in his model of the southern Jornada del Muerto.

There are no aquifer tests of the alluvial aquifer in the immediate vicinity of the proposed supplemental well. Therefore T and S values from similar aquifer units along the southern Rio Grande will be considered.

Wilson and others' (1981) Plate 11 provides a contour map of transmissivity estimated from specific capacity tests in the shallowest part of the alluvial aquifer of the Mesilla valley and adjacent areas. This map shows the Radium Springs area at the northernmost end of the Mesilla basin, north of and outside the T = 10,000 ft^2/day contour. Therefore it is reasonable to assume that transmissivity in this area is less than 10,000 ft^2/day.

Bill Fleming (1987) reviewed an application (LRG-5910), to divert water from a well or wells drilled in alluvial material located in T21S, R1W, Section 14. Fleming cites transmissivity values for the Mesilla Valley from Wilson et al. (1981) for "the shallow part of the alluvium" ranging from 6,280 to 18,000 ft^2/day that were calculated from specific capacity tests. He uses a value of T=10,000 ft^2/day and S = 0.20 for this area.

Hydraulic conductivity estimates for moderately deep alluvial materials (screened intervals within the range 145-680 feet deep) were made from aquifer tests in the Mesilla Valley, south of Las Cruces (Wilson and White, 1984). Hydraulic conductivity (k) was estimated at 50 - 80 ft/day. Thickness of the alluvial aquifer in the area of interest near the river is on the order of 100 feet. If we assume that the above values of hydraulic conductivity are reasonable for the similar alluvial material in the area of interest, we calculate a transmissivity (T = k multiplied by the saturated thickness of the aquifer) of 5000 to 8000 ft^2/day.

Use of Analytical Solutions

The analysis presented here uses analytical models to estimate stream depletion from the Rio Grande and drawdowns at neighboring wells. The analytical solutions we use assume a homogeneous two-dimensional aquifer. The Rio Grande is assumed to fully penetrate the alluvial aquifer and will be treated as a constant head boundary. Gross's results (discusses earlier) and the shallow depths to water near the river suggest that the river is well connected to the alluvial aquifer, and therefore the assumption that the river fully penetrates the aquifer is reasonable. The Rio Grande is perennial in this reach (although winter flow rates are often quite small), and therefore the assumption that it can be treated as a constant head boundary is reasonable.

The analytical solutions used require boundaries be straight lines (in areal view). The Rio Grande is relatively straight in the area of interest (Figure 1), and can be approximated as a linear boundary without significant error. Figure 2 shows a sketch of the system, generalized for use in the analytical solutions. The alluvial and geothermal aquifer are modeled together as a semi-infinite aquifer bounded by the Rio Grande on one side.

A transmissivity value of 5,000 ft^2/day will be used for the alluvial aquifer in accordance with Rao and to be consistent with Wilson, 1981, Plate 11. This value appears to be appropriate for both the alluvial aquifer and the geothermal aquifer.

A reasonable value of storage in the sand-and-gravel alluvial aquifer is 0.20, which is in agreement with Fleming. This value will be used in calculating stream depletions and drawdowns at wells drilled in the alluvium. Because some of the protestants wells are in the geothermal aquifer, which may have a considerably lower storage than the alluvial aquifer, a storage coefficient of 0.01 will also be used when calculating drawdowns at those sites.

Drawdowns

Drawdowns have been determined using a computer program that calculates the Theis equation with appropriate boundary conditions. Solutions were calculated for drawdowns assuming

1) the entire 125 acre-feet/year is pumped from LRG-4487-A (the permitted well farthest from the proposed supplemental well).

and

2) the entire 125 acre-feet/year is pumped from the proposed supplemental well: LRG-4487-A-S-2.

Drawdowns have been calculated at the sites of two of the applicants wells LRG-4487-A, LRG-4487-A-S. Drawdowns at the protestant's points of diversions have been calculated at the two following sites. Drawdowns were calculated at LRG-8026, an irrigation well that is assumed to take water from the alluvial aquifer, and 03593, a declared surface water right, located near declared geothermal well LRG-8023, assumed to obtain water from the geothermal aquifer. These are the sites of declared water rights belonging to the protestant that are nearest the applicant's existing and proposed irrigation wells. A sample computer output file is attached.

All calculations have been done for a 40 year time period. Drawdowns are not expected to increase significantly past 40 years. The presence of the river will cause drawdowns to approach constant values as the stream depletion rate approaches 100% of the diversion rate (within a few years, as will be shown in Table 1).

Drawdowns in applicant's wells:

Pumping of LRG-4487-A-S-2 is predicted to cause less than 0.1 feet of drawdown in the LRG-4487-A and LRG-4487-A-S. Drawdown in the aquifer at the applicant's pumped well was estimated using the Theis solution at a distance of 0.5 feet from the point of diversion. Pumping of 125 acre-feet/year is predicted to cause 3.2 feet of drawdown at the pumping well.

Drawdowns and geothermal effects at protestant's wells:

Drawdowns caused by pumpage of 125 acre-feet/year for 40 years, from either LRG-4487-A or LRG-4487-A-S-2, are predicted to be less than 0.1 feet. The protestant's points of diversion are located closer to LRG-4487-A than to the proposed supplemental well, therefore if pumping is relocated to the proposed supplemental well, the small drawdowns predicted in the protestant's wells would tend to become even smaller.

Another potential concern of the protestant is the potential for temperature reduction in the protestant's geothermal wells and spring. The applicant's irrigation wells pump from the alluvial aquifer, and thus do no deplete geothermal waters. Also, the very small drawdowns predicted indicate that the irrigation wells have very little influence on the groundwater flow regime at the protestant's geothermal wells. In addition, the proposed supplemental well is further from the protestant's wells than the presently permitted wells are and so the supplemental well would be expected to have less impact than the presently permitted wells.

Drawdowns at other nearby permitted rights:

LRG-6001 is predicted to experience no additional drawdowns due to use of the proposed supplemental well because it is located on the opposite side of the Rio Grande from the applicant's wells. The analytical model predicts no impacts at this site because the Rio Grande is assumed to be a fully penetrating stream, and a constant head boundary. This means that the effects of the applicant's pumping will not propagate beyond the river. This is a reasonable assumption for the Rio Grande's effects upon the alluvial aquifer and therefore no drawdowns at LRG-6001 are predicted.

Depletions from surface water

Depletions from Rio Grande:

Depletions from the Rio Grande were calculated using the Glover-Balmer equation, using T=5000 ft^2/day and S=0.20. The two presently approved points of diversion: LRG-4487-A and LRG-4487-A-S are both approximately the same distance from the river (230 feet), and therefore the stream depletions calculated for these wells are identical. The proposed supplemental well: LRG-4487-A-S-2 is located 190 feet from the river, and therefore we can anticipate that the effects of stresses from this well will reach the river more quickly then the effects of stresses from the presently permitted wells.

Two sets of calculations were performed. One calculation allowed 125 acre-feet/year to be pumped from LRG-4487-A and the second calculation allowed 125 acre-feet/year to be pumped from LRG-4487-S-2. The calculations were carried out for 100 years of pumping.

The results of the Glover-Balmer analysis are given in Table 1. Stresses from both wells (LRG-4487-A and LRG-4487-A-S-2) reach the river quickly, with the depletion rate reaching about 96% of the diversion rate in 1 year. The depletion rate for LRG-4487-A-S-2 is always slightly higher than that for LRG-4487-A. At one year, the depletion rate from LRG-4487-A-S-2 is about 1 acre-foot higher than the depletion rate from LRG-4487-A. The difference in the depletion rates decreases with time.

These calculations make the assumption that the presently permitted irrigation wells have pumped their fully permitted 125 acre-feet/year. Percentage effects for stream depletion are included, so that proportional depletions can be obtained for any pumping rate.

Depletions from Radium Springs

Depletions from Radium Springs (declared right from this source by the protestant, File No. 03593) were not explicitly calculated. The proposed supplemental well is located farther from the spring than the presently permitted wells are. Therefore depletions from the spring are predicted to be less if the proposed supplemental well is pumped than if the presently permitted wells are pumped by the same amount.

Availability of water

Drawdown calculations indicate that pumping any of the LRG-4487-A wells will cause negligible drawdowns at distances more than a few feet from the pumping well. Aquifer drawdowns at the pumping well are estimated to be 3.2 feet. The well record submitted for LRG-4487-A-S-2 indicates that this well has a column of water 62 feet in length, so if this well has a reasonable efficiency, drawdowns within the well should not significantly reduce the well's capacity. The well record lists an estimated yield of 250 gpm, equal to 402.5 acre-feet/year. Assuming the well is active 60% of the time, the maximum net production is estimated to be 241.5 acre-feet/year. These facts suggests that, in the short term, LRG-4887-A-S-2 should be able to produce 125 acre-feet/year. In the long term, siltation of the well is likely to occur (this has happened to other irrigation wells in this location) reducing production.

Summary

1) Drawdowns estimated at the protestant's wells due to pumping 125 acre-feet/year at LRG-4487-A or LRG-4487-A-S-2 are less than 0.1 feet. Pumping 125 acre-feet/year from LRG-4487-A-S-2 is predicted to produce smaller drawdowns at the protestant's well than pumping the same amount from LRG-4487-A. It is unlikely that significant temperature reduction effects at the protestant's geothermal wells would be caused by pumping LRG-4487-A or LRG-4487-A-S. Pumping the more distant proposed supplemental well would tend to reduce any such effects.

2) No drawdown is predicted to occur at LRG-6001 due to pumping at LRG-4487-A through LRG-4487-A-S-2. The presence of the Rio Grande would stop the effect of the applicant's wells from reaching LRG-6001.

3) Drawdowns caused by the pumping LRG-4487-A-S-2 are predicted to be negligible at distances more than a few feet from the well. At the site of the well itself, drawdown calculations predict 3.2 feet of drawdown at 0.5 feet radius. The well record submitted for LRG-4487-A-S-2 indicates a water column of 62 feet and lists an estimated yield of 250 gpm. It is expected that the proposed well will be able to produce 125 acre-feet/year.

4) The rate of depletion from the Rio Grande is predicted to increase if the new supplemental well is approved. If 125 acre-feet/year is pumped from LRG-4487-A-S-2 then the depletion rate from the Rio Grande will be higher than if that amount were pumped from LRG-4487-A or LRG-4487-A-S. Lower potential depletions from Radium Springs are predicted if pumping is moved to LRG-4487-A-S-2 from the presently permitted wells.

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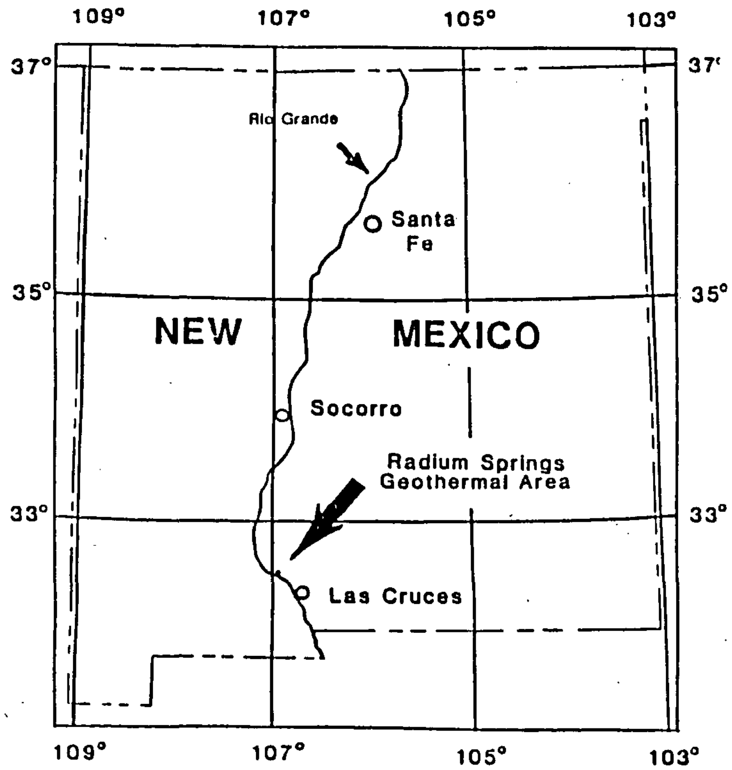

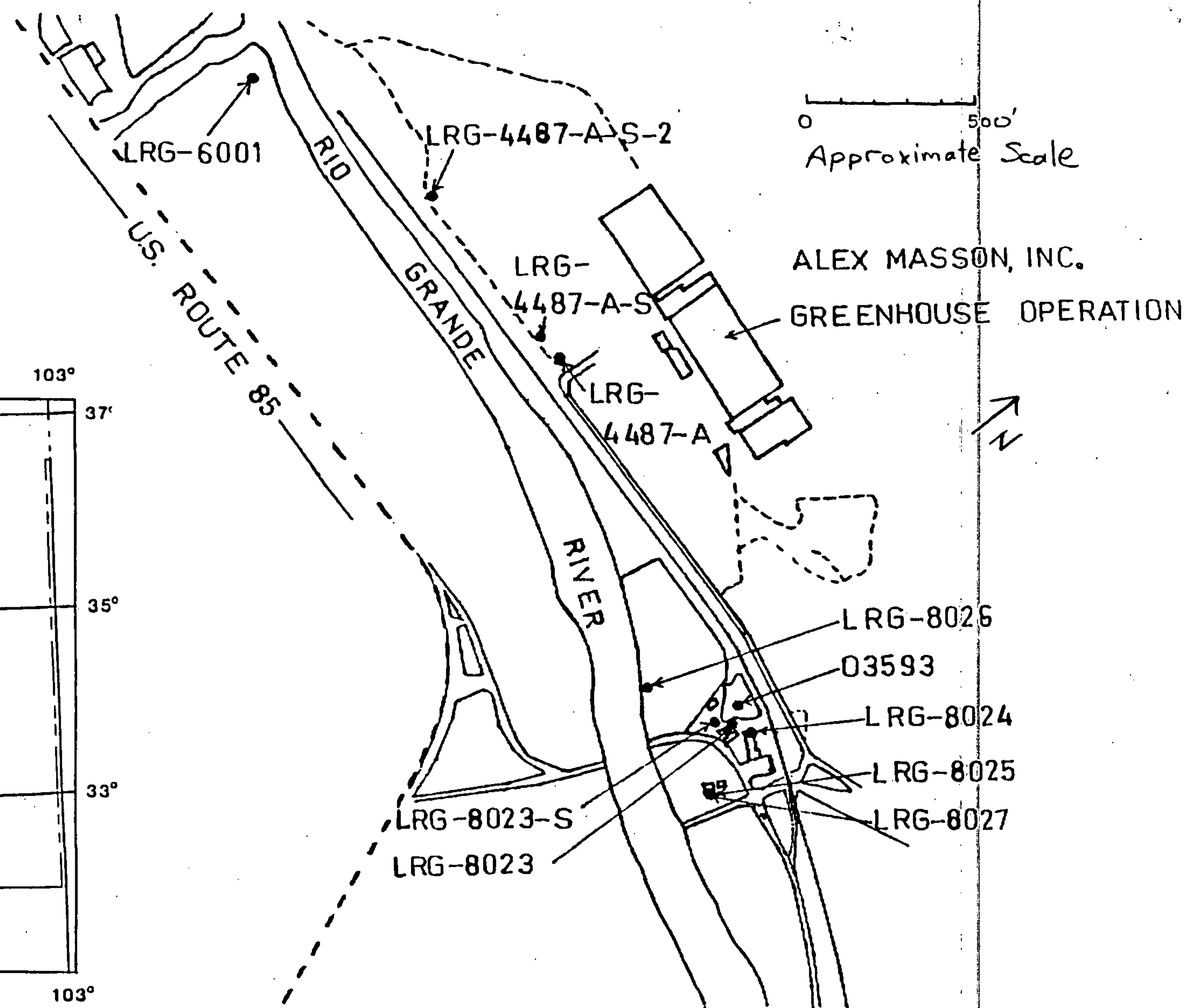

Figure 1

Location maps:
State of New Mexico
Locations of pertinent wells and Rio Grande, from Nixon, 1993.

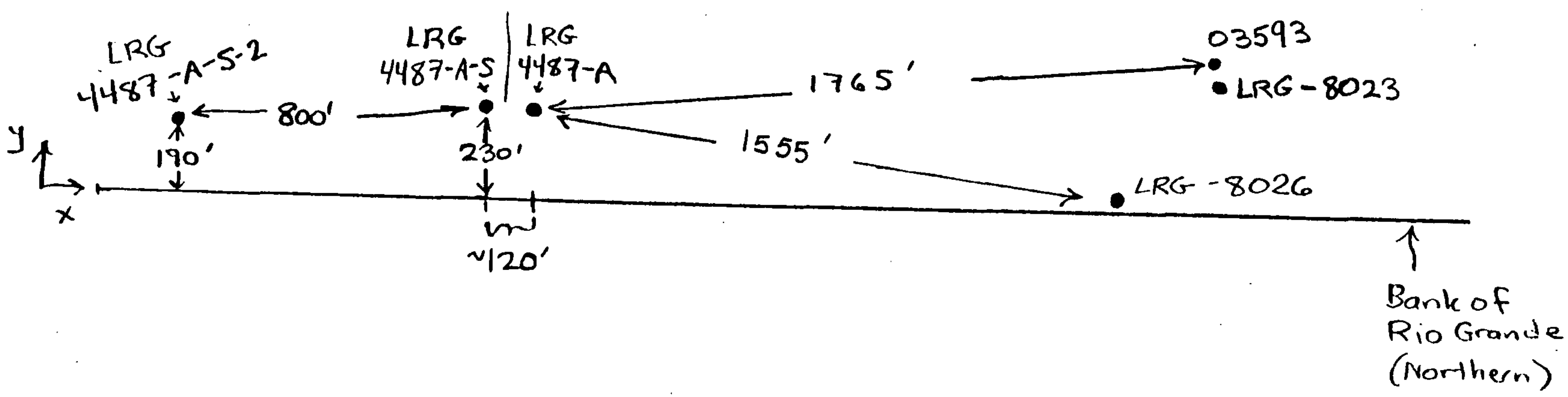

Figure 2

Generalized locations of pertinent points of diversion and the Rio Grande constant-head boundary condition, as defined for use in analytical models. Distances obtained from Nixon, 1993.

Table 1

Depletion to Rio Grande caused by pumping 125 acre-feet/year from LRG-4487-A and by switching to LRG-4487-A-S-2

Time (years)	LRG-4487-A Depletion rate (AF/Y)	% of 125 AF/Y	LRG-4487-A-S-2 Depletion rate (AF/Y)	% of 125 AF/Y	Change in Depletion rate (AF/Y)
1	119.6	95.71	120.6	96.45	0.93
2	121.2	96.96	121.9	97.49	0.66
3	121.9	97.52	122.4	97.95	0.54
4	122.3	97.85	122.8	98.23	0.47
5	122.6	98.08	123.0	98.41	0.42
6	122.8	98.25	123.2	98.55	0.38
7	123.0	98.38	123.3	98.66	0.35
8	123.1	98.48	123.4	98.75	0.33
9	123.2	98.57	123.5	98.82	0.31
10	123.3	98.64	123.6	98.88	0.30
11	123.4	98.71	123.7	98.93	0.28
12	123.5	98.76	123.7	98.98	0.27
13	123.5	98.81	123.8	99.02	0.26
14	123.6	98.85	123.8	99.05	0.25
15	123.6	98.89	123.9	99.08	0.24
16	123.7	98.93	123.9	99.11	0.23
17	123.7	98.96	123.9	99.14	0.23
18	123.7	98.99	124.0	99.16	0.22
19	123.8	99.01	124.0	99.19	0.21
20	123.8	99.04	124.0	99.21	0.21
25	123.9	99.14	124.1	99.29	0.19
30	124.0	99.22	124.2	99.35	0.17
35	124.1	99.27	124.3	99.40	0.16
40	124.2	99.32	124.3	99.44	0.15
45	124.2	99.36	124.3	99.47	0.14
50	124.2	99.39	124.4	99.50	0.13
60	124.3	99.45	124.4	99.54	0.12
70	124.4	99.49	124.5	99.58	0.11
80	124.4	99.52	124.5	99.60	0.10
90	124.4	99.55	124.5	99.63	0.10
100	124.5	99.57	124.6	99.65	0.09

Date (M/D/YR) = 03/02/93
Time (h:m:s:1/100) = 09:38:34.22

DRAWDOWN AT RANDOM COORDINATES IN AN INFINITE STRIP, NON - LEAKY AQUIFER USER SPECIFIED BOUNDARIES AT Y = 0 AND A Y SPECIFIED BY USER
PUMPING MULTIPLE WELLS LOCATED AT POINTS SPECIFIED BY USER. EACH WELL MAY HAVE A DIFFERENT PUMPING SCHEDULE. ALL COORDINATES IN THE X - Y PLANE.

(Theis equation)

At y = 0, there is a constant-head (river) boundary
There is no other boundary to system

T = 37400. gpd/ft S = 0.200000

Number of pumping wells = 1

Coordinates of pumping wells and the no. of pumping rates

Well #	X Coordinate	Y Coordinate	No. of Pumping Rates
1	0.0	190.0	1

PUMPING SCHEDULES FOR THE WELLS

Well Schedule for Pumping Well Number 1

Pumping Rate		Pumping Time
Q(1) = 77.5 gpm	for	14610.000 days

Coordinates of Computation Points

(Number of computation points = 5)

Point #	X Coordinates feet	Y Coordinates feet
1	0.0	190.0
2	800.0	230.0
3	920.0	230.0
4	2461.0	20.0
5	1885.0	400.0

Image Control = .1000000E-05

time variable (t)

t min = 730.500 days; t max = 21915.000 days;
delta t = 730.500 days

Pumping well 1 overlies comput. point 1
Therefore the computation point has been moved +.5 feet in the X direction

************* RESULTS **************

Drawdowns and Coordinates of computation points
Measured in feet

Time in days	X = 0.5, Y = 190.0	X = 800.0, Y = 230.0	X = 920.0, Y = 230.0
730.500	3.150	0.057	0.044
1461.000	3.150	0.057	0.044
2191.500	3.150	0.057	0.044
2922.000	3.150	0.057	0.044
3652.500	3.150	0.057	0.044
4383.000	3.150	0.057	0.044
5113.500	3.150	0.057	0.044
5844.000	3.150	0.057	0.044
6574.500	3.150	0.057	0.044
7305.000	3.150	0.057	0.044
8035.500	3.150	0.057	0.044
8766.000	3.150	0.057	0.044
9496.500	3.150	0.057	0.044
10227.000	3.150	0.057	0.044
10957.500	3.150	0.057	0.044
11688.000	3.150	0.057	0.044
12418.500	3.150	0.057	0.044
13149.000	3.150	0.057	0.044
13879.500	3.150	0.057	0.044
14610.000	3.150	0.057	0.044
15340.500	0.000	0.001	0.001
16071.000	0.000	0.000	0.000
16801.500	0.000	0.000	0.000
17532.000	0.000	0.000	0.000
18262.500	0.000	0.000	0.000
18993.000	0.000	0.000	0.000
19723.500	0.000	0.000	0.000
20454.000	0.000	0.000	0.000

21184.500	0.000	0.000	0.000
21915.000	0.000	0.000	0.000

************* RESULTS **************

Drawdowns and Coordinates of computation points
Measured in feet

	X = 2461.0	X = 1885.0
	Y = 20.0	Y = 400.0
Time in days		
730.500	0.001	0.018
1461.000	0.001	0.019
2191.500	0.001	0.019
2922.000	0.001	0.019
3652.500	0.001	0.019
4383.000	0.001	0.019
5113.500	0.001	0.019
5844.000	0.001	0.019
6574.500	0.001	0.019
7305.000	0.001	0.019
8035.500	0.001	0.019
8766.000	0.001	0.019
9496.500	0.001	0.019
10227.000	0.001	0.019
10957.500	0.001	0.019
11688.000	0.001	0.019
12418.500	0.001	0.019
13149.000	0.001	0.019
13879.500	0.001	0.019
14610.000	0.001	0.019
15340.500	0.000	0.001
16071.000	0.000	0.000
16801.500	0.000	0.000
17532.000	0.000	0.000
18262.500	0.000	0.000
18993.000	0.000	0.000
19723.500	0.000	0.000
20454.000	0.000	0.000
21184.500	0.000	0.000
21915.000	0.000	0.000

RESULTS OF GROUNDWATER MONITORING AND PUMP TESTING IN THE RADIUM SPRINGS GEOTHERMAL AREA, NEW MEXICO

Prepared by

James T. Gross

MALCOLM PIRNIE, INC.

2650 South 46th Street, Ste. 102
Phoenix, Arizona 85034-7416

August 21, 1986

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EXECUTIVE SUMMARY

Water-level data were collected from 4 geothermal wells and 2 fresh water wells during June and July of 1986 to investigate the geotechnical and institutional feasibility of using low-temperature geothermal water for space heating of commercial greenhouses at Radium Springs, New Mexico.

The largest water-level fluctuations are due to changes in stage of the Rio Grande. These fluctuations are generally less than or equal to 1 foot in amplitude. Smaller diurnal cycles having an amplitude of approximately 0.1 foot were detected in the 2 fresh water wells. These diurnal fluctuations may be due to barometric stresses.

Six pump test were carried out during the study period. The transmissivity of the geothermal field near well 21 is approximately 45,000 gpd/ft. Hydrologic impacts to wells 16 and 19 from the simultaneous pumping of well 21 and injection into well 15 at 350 gpm are negligible, or at the most only a few hundredths of a foot. There were no measurable impacts from any of the pump test on the 2 fresh water wells or the Rio Grande.

INTRODUCTION

Purpose and Scope

This project was undertaken to investigate the geotechnical and institutional feasibility of using low-temperature geothermal water for space heating of commercial greenhouses at Radium Springs, New Mexico. Geothermal development in New Mexico is subject to regulation by both the Oil Conservation Division (OCD) of the New Mexico Energy and Minerals Department, and the Office of the State Engineer. This project was designed to provide sufficient information for these state agencies to process the pending geothermal production applications of Alex. R. Masson, Inc.

The primary focus of OCD regulations is enunciated in Rule 1a of the New Mexico geothermal regulations:

> "...to conserve the natural geothermal resources of the State of New Mexico, to prevent waste, and to protect the correlative rights of all owners of geothermal resources."

Rule 503 of these regulations also provides protection for other natural resources, useable underground water supplies, and surface resources.

The principal interest of the New Mexico State Engineer in geothermal activity is to ensure that geothermal operations do not impair any preexisting surface or subsurface water rights. The State Engineer currently reserves the right to define impairment on a site-specific basis. This authority is intended to provide the necessary flexibilty for implementing regulations in the many and differing declared underground water basins of the state.

Low-temperature geothermal resource development is a relatively new phenomenon in New Mexico, and there is little evidence to illustrate hydrologic relationships between thermal and nonthermal groundwaters. Because of this lack of evidence and because the Radium Springs geothermal reservoir is close to fresh groundwater and surface water resources, OCD requested that a pump test be undertaken to simulate and measure the hydrologic stresses that would be encountered during geothermal production.

Groundwater levels in the Ryan and Bailey fresh wells adjacent to the Rio Grande, and in 4 geothemal wells north of the river were monitored during the entire project to determine the hydrologic relationships between:

1. the river and groundwater, and
2. between the thermal and nonthermal groundwaters

Acknowledgements

This project would not have been accomplished without the strong support of the New Mexico State University Energy Institute. We are especially grateful to Mr. Jack Whittier, who endured more than a few mosquito

bites and threats from rattlesnakes while logging data and checking field instruments. We also wish to extend thanks to Dr. William Fleming of the New Mexico State Engineer's Office for planning assistance and project definition. The El Paso office of the Bureau of Reclamation provided valuable data for river stage and flow rates at several measuring stations along the Rio Grande near the study area. Mr. Tim Tyler provided backup water-level equipment, and the Earth Science Department of NMSU provided barometric instruments for recording relative barometric fluctuations. And finally, Mr. Roy Johnson provided valuable insight for the timely completion of field activities.

Previous Geological Work

The geology of the Radium Springs area has been described in a number of reports and maps (Seager, 1975; Seager, et al., 1976). The hydrogeology of this area has been discussed by several investigators, most notably King et al. (1971), and Wilson et al. (1981). Peterson et al. (1984) incorporated this area into a regional quasi 3-dimensional numerical model of the Mesilla Basin, and discussed components of basin recharge for this area. Lohse et al. (1985) have reported on the nature and extent of local geothermal activity.

Location

Radium Springs is situated approximately 20 miles north of Las Cruces in south central New Mexico. The area of investigation lies at the northernmost portion of the Mesilla Valley. Prominent nearby topographic features include the Robledo Mountains to the south, the Dona Ana Mountains to the east, and the Selden Hills to the northwest.

WATER-LEVEL DATA

Introduction

Field work and data collection for this study were undertaken during June and July of 1986. New data included continuous recording of water levels in 2 fresh water wells and interval measurements of water levels in four geothermal wells. The locations of all 6 wells are shown on figure 1. Drilling and completion data for these wells are shown in table 1. Groundwater is believed to be unconfined in both the Rio Grande stream gravels and in the geothermal reservoir.

Water-level measurements were taken before, during, after 6 pump tests of the geothermal reservoir. Table 2 summarizes the times and pumping rates for each of the pump tests. Masson well 21 was used as the production well and Bailey well 15 was used for injection during all 6 pump tests.

River discharge and stage data for the Leasburg cable station were provided by the Bureau of Reclamation. This station is located approximately 2 miles downstream from the project area. Daily measurements were available for the entire duration of the project. Since the time of day for each stream recording was not provided by the Bureau, all river data were assigned to 8:00 am of each day.

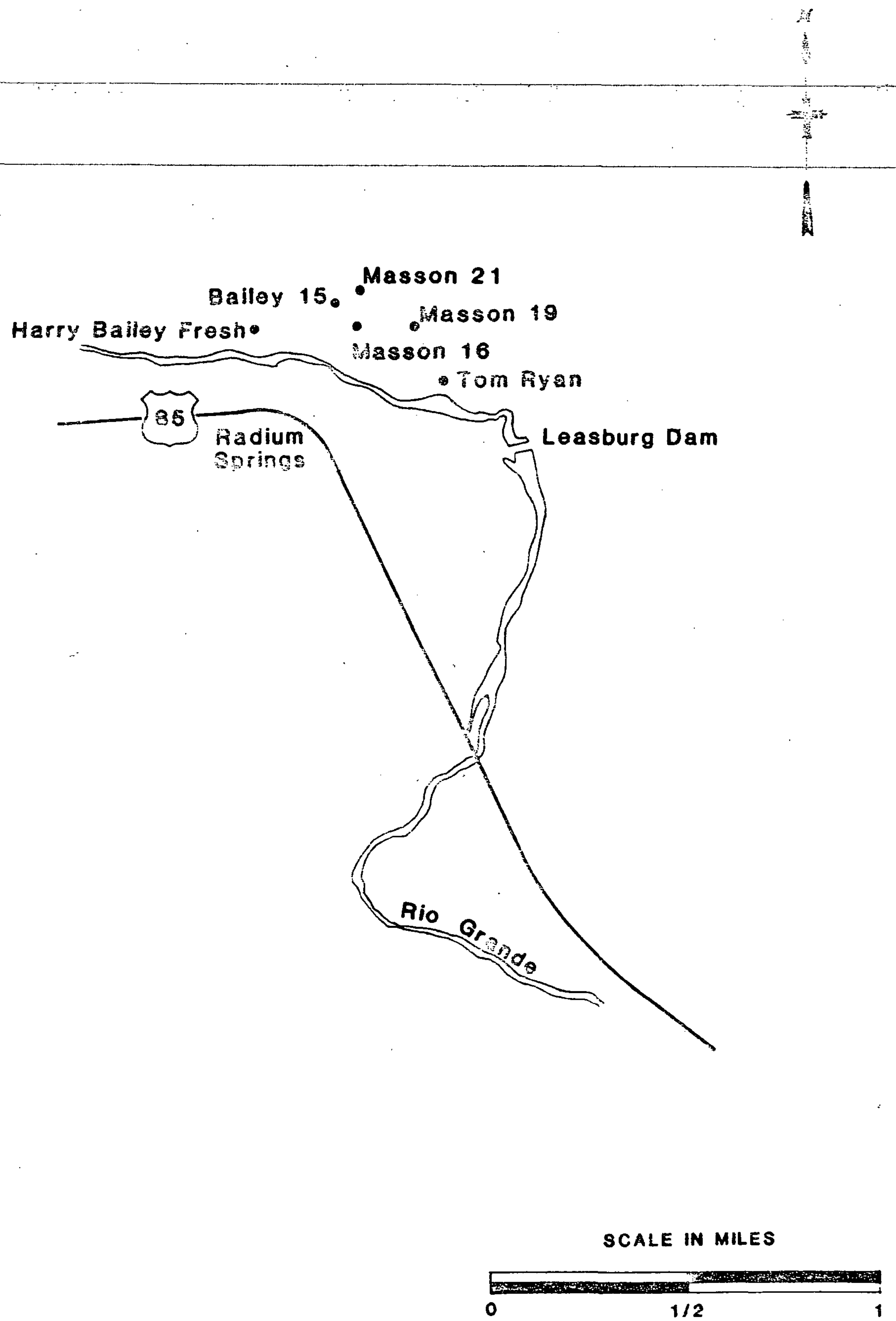
Relative barometric pressure was recorded at the New Mexico State Universty Energy Institute to determine whether any of the observed water-level cycles could be correlated to barometric stresses.

Field Equipment and Instrumentation

Water levels in the Ryan and Bailey fresh wells were recorded with "Stevens Type F" float recorders, installed in locked steel boxes mounted directly over each well. A 3-inch float and counterweight was installed in the Ryan well, and a 5-inch float and counterweight was used in the Bailey fresh well. Each instrument's recorder was connected to the float with a beaded line and slotted pulley to ensure no slip between the pulley and line.

Both instruments were equipped with 1:1-ratio English decimal gage scales and quartz "multispeed" timers. The timers were initially set at 2 days for the first several days of recording, but were later reset to 4 days for all but the last week of the project. Both timers were set to an 8-day cycle for the final week of July. The instrument clocks were tested for accuracy before field installation, and were accurate to within 0.1 percent using a digital watch as a standard. The clocks were checked at each change of chart records, approximately every 3 to 4 days. No systematic clock errors were noted during field operations.

The recorders were initially calibrated to water-level depth using an electronic water level meter with cable markings at 0.05-foot intervals. Calibration checks were done every 3 to 4 days with a steel tape which was marked at 0.01-foot intervals. Water-level data for both of the freshwater wells are referenced to the bottom of the instrument



MALCOLM PIRNIE

LOCATION MAP OF PROJECT AREA

Figure 1

Table 1 - Well Completion Data

WELL NAME	DRILLED DEPTH (ft)	COMPLETED DEPTH (ft)	TYPE OF CASING	CASING DEPTH (ft)	TYPE OF COMPLETION
Bailey 15	165	165	8-inch steel	24	Open Hole
Masson 16	255	240	7-inch steel	80	Open Hole
Masson 19	160	155	7-inch steel	40	Open Hole
Masson 21	280	280	7-inch steel	35	Open Hole
Bailey Fresh	120	120	17-inch steel	120	Perforated, ?
Ryan Fresh	67	67	5-inch pvc	67	Perforated, 57-67 ft

? - The perforated interval of the Bailey fresh well was not recorded.

MASSON 21 C-21-1-10 ABBBD
BAILEY 15 C-21-1-10 BAADD
MASSON 16 C-21-1-10 ABCBD
MASSON 19 C-21-1-10 ABDBA
MASSON 17 C-21-1-10 BAABA
MASSON 20 C-21-1-10 ABADB
BAILEY FRESH C-21-1-10 BACAD

Table 2 - Record of Pump Tests at Radium Springs

TEST NO.	START DATE	START TIME	END DATE	END TIME	HOURS	GPM	INJECTION
1	23-Jun-86	12:30 PM	23-Jun-86	01:00 PM	0.5	350	No
2	23-Jun-86	02:30 PM	24-Jun-86	09:00 AM	18.5	350	Yes
3	24-Jun-86	12:00 PM	25-Jun-86	07:00 AM	19.0	350	Yes
4	26-Jun-86	02:00 PM	29-Jun-86	10:35 AM	68.5	350	Yes
5	11-Jul-86	05:30 PM	16-Jul-86	08:00 AM	110.5	60	Yes
6	16-Jul-86	08:30 AM	21-Jul-86	04:05 PM	127.5	200	Yes

platforms. The complete analog field records for both the Harry Bailey fresh well and the Tom Ryan well are included in appendices 1 and 2, respectively.

Water levels in the 4 geothermal wells were measured with the electronic water-level meter or the steel tape, and logged with the date and time of the measurement. Water levels in the geothermal wells were generally taken at each change of record on the "Stevens" instruments. All water-level readings in the geothermal wells are referenced to the top of the well casing. Field records of water levels in the geothermal wells are in appendix 3.

There is currently no precise elevation control for any of the wells used in this study. Consequently, water-level data from the 6 wells have not been tied to a common base level. The best elevation data available for this study is by interpolation from the U.S.G.S. 7.5-minute maps. Since this interpolation is somewhat imprecise, all water levels are shown relative to the actual measuring points.

The discharge rate during pump tests was measured with a flow meter which included both a cumulative record of total volume pumped and a revolving needle for real-time checks of discharge. Each full revolution of the needle represented 100 gallons of flow. The meter was installed in the discharge line immediately adjacent to the pumping well. The pumping rate was not observed to fluctuate more than 5% during any of the tests.

Water temperature was also measured during pumping periods. A dial thermometer was installed in the discharge line approximately 10 feet downstream from the discharge meter. The water temperature ranged from 167 to 168 degrees Fahrenheit during the 6 pump tests.

A submersible pump was used for the first 4 pump tests; however, by the end of the 4th pump test it was clear that the water temperature was too hot for the submersible motor. Both tests 3 and 4 terminated because of pump-motor failures. The final 2 pump test were run with a line-shaft turbine pump. Test 5 was terminated because adjustments to the pump impellers were needed to achieve the desired pumping rate. Test 6 was terminated as a successful 5-day, 200 gpm test. Table 3 summarizes the pump equipment and termination comments for each of the 6 tests.

Data Reduction

Water-level data collected during this investigation were compiled onto a microcomputer database for direct graphical comparison and presentation. Analog records of water levels from the Stevens recorders were digitized at an evenly spaced interval of 4 hours. The times selected for conversion to digital data were as follows:

12:00 am	12:00 pm
4:00 am	4:00 pm
8:00 am	8:00 pm

Analog readings were converted to digital format by reading the analog-trace distance from a known base line with an engineering scale

Table 3 - Pumps Used for Pump Testing

TEST NO.	PUMP	TERMINATION COMMENTS
1	Submersible	test-run only
2	Submersible	generator failure
3	Submersible	pump-motor failure
4	Submersible	pump-motor failure
5	Line-Shaft	impeller adjustments needed
6	Line-Shaft	successful test @ 200 gpm

incremented at 50 lines per inch. The error introduced by this conversion is approximately plus-or-minus 0.01 foot. The units for water-levels used in this report are feet and decimal fractions of feet, unless otherwise noted. All measurements are reported to 0.01 foot.

The digital database record is comprised of 6 water levels per day for the 2 fresh wells, all of the water-level readings from the geothermal wells, and the daily river stage and discharge data. The complete database includes 1,118 entries for the period June 2nd through August 1st, 1986. Digital data for all 6 wells and the river are included in appendices 4 through 10.

There are 3 small gaps in the analog records for the 2 freshwater wells. Approximately 8.5 hours are missing from the Bailey fresh well on July 3rd, between 10:00 am and 6:30 pm. Another 65 hours of the Bailey fresh well record is missing between 6:00 pm on July 7th and 11:00 am on July 10th. The Tom Ryan well has a gap of approximately 47 hours between 6:00 pm, July 6th and 5:00 pm on July 8th.

The 4-hour spacing of data for the 2 fresh wells preserves nearly all of the water-level cycles evident from the analog record, although there is some filtering of very short pulses which last less than 4 hours. The random spikes seen on the analog record for the Bailey fresh well were produced by railroad traffic. This well is immediately adjacent to railroad tracks. These spikes have been eliminated from the digital record.

Monitoring Results

Figure 2 is a summary graph of water levels for the 2 freshwater wells (Bailey fresh and Ryan) during June and July, 1986. Water levels rise and fall simultaneously in the 2 wells throughout the study period, apparently from a common hydrologic stress.

Figures 3 through 11 present the same water-level data in a weekly format for both the 2 freshwater wells and also for the 4 geothermal wells. Each well is represented by the same symbol on all 9 figures. The weekly graphs begins and end at midnight on Sunday, so there is a no overlap between consecutive graphs. The weekly graphs allow a more detailed inspection of fluctuations, such as the diurnal cycle exhibited by the Bailey fresh well.

The 2-phase diurnal cycle exhibited by the analog records of the Bailey fresh well is also evident in the digital records shown in figures 3 to 11. This cycle is thought to be related to diurnal barometric cycles, since the barographs for this period show a similiar diurnal period. A diurnal cycle is also evident in the Ryan well, but it is much reduced in amplitude.

Figure 2 - Hydrograph for 2 Fresh Wells

June and July, 1986

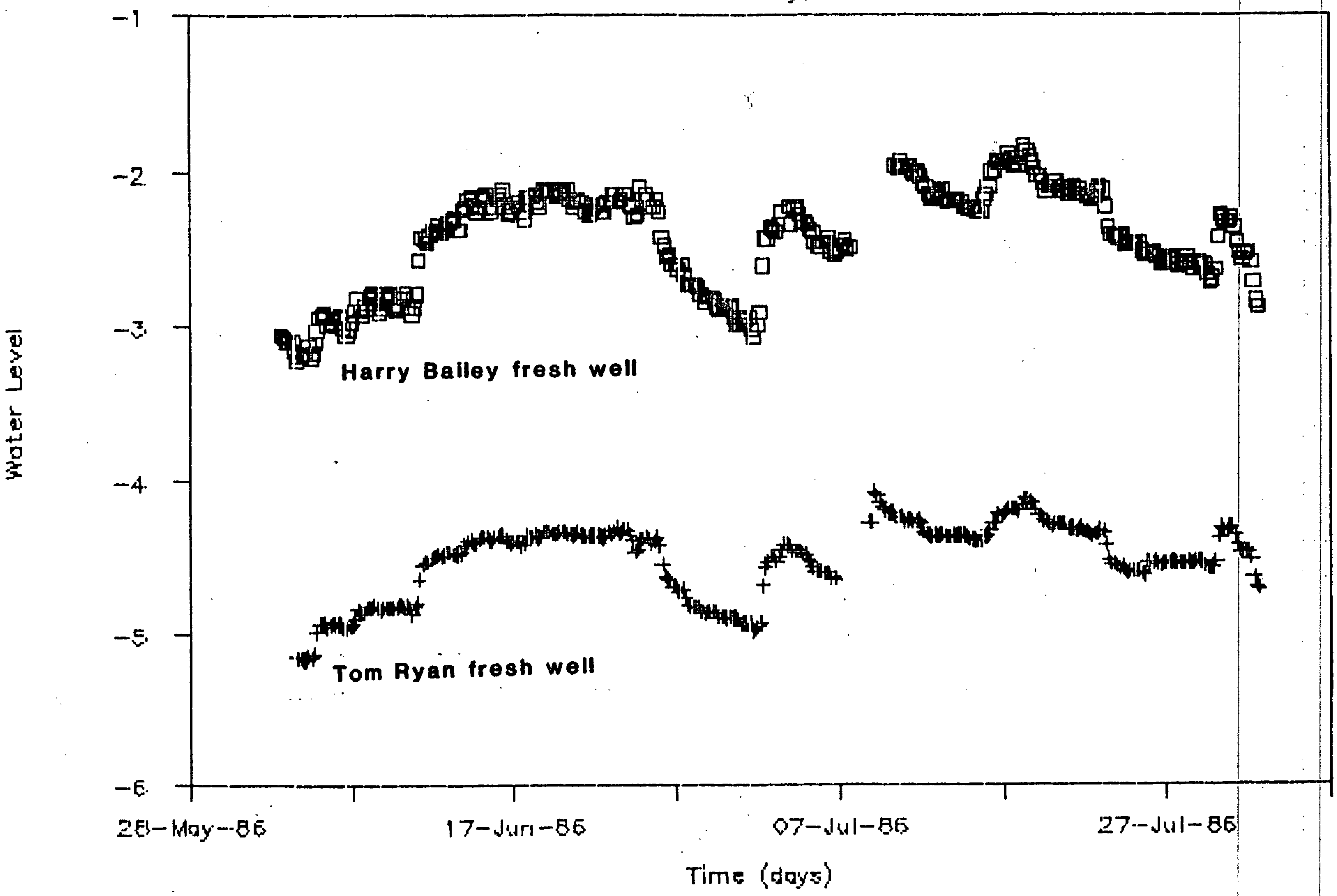


Figure 3 — Relative Water Levels

June 1–7, 1986

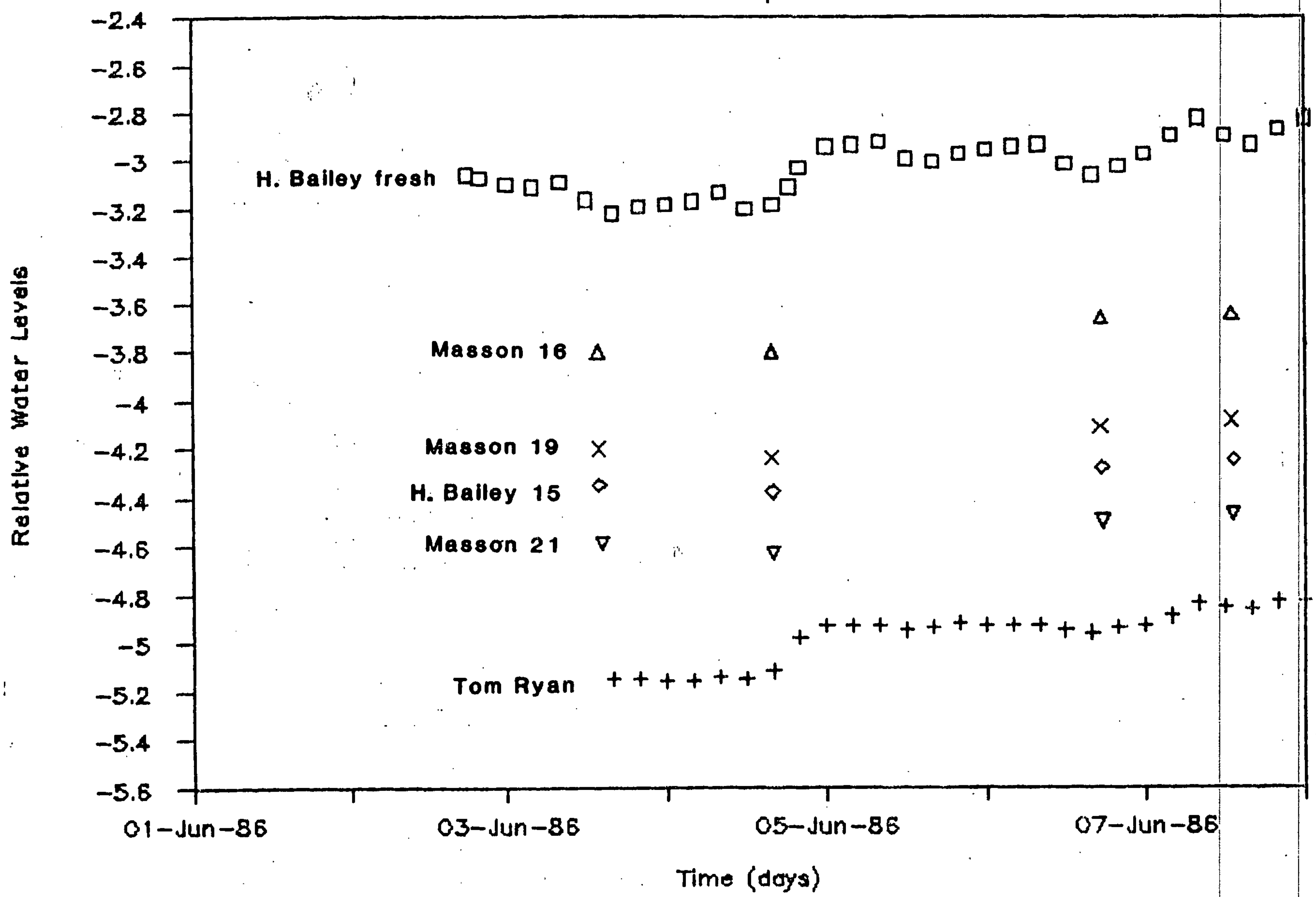


Figure 4 — Relative Water Levels

June 8–14, 1986

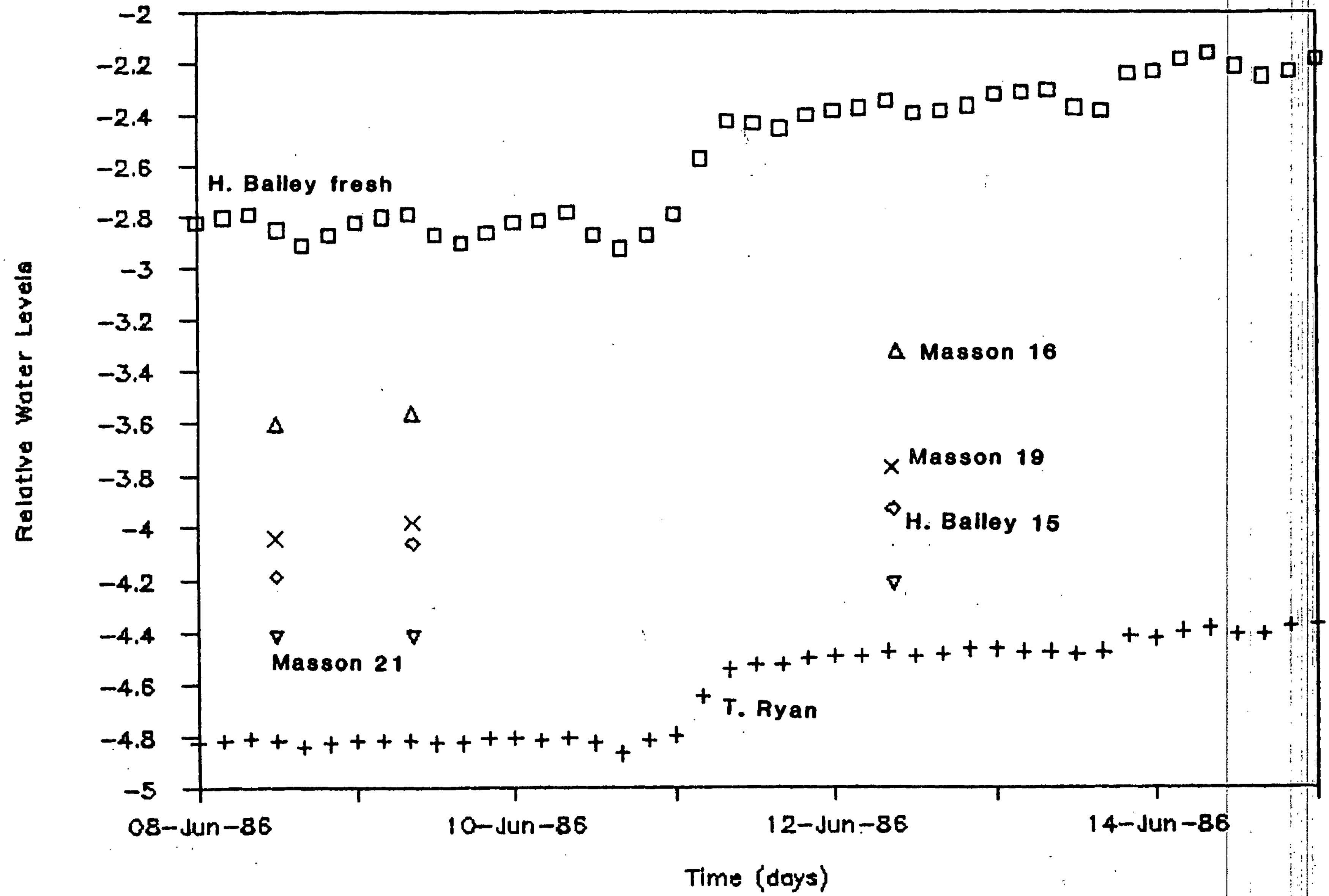


Figure 5 — Relative Water Levels

June 15–21, 1986

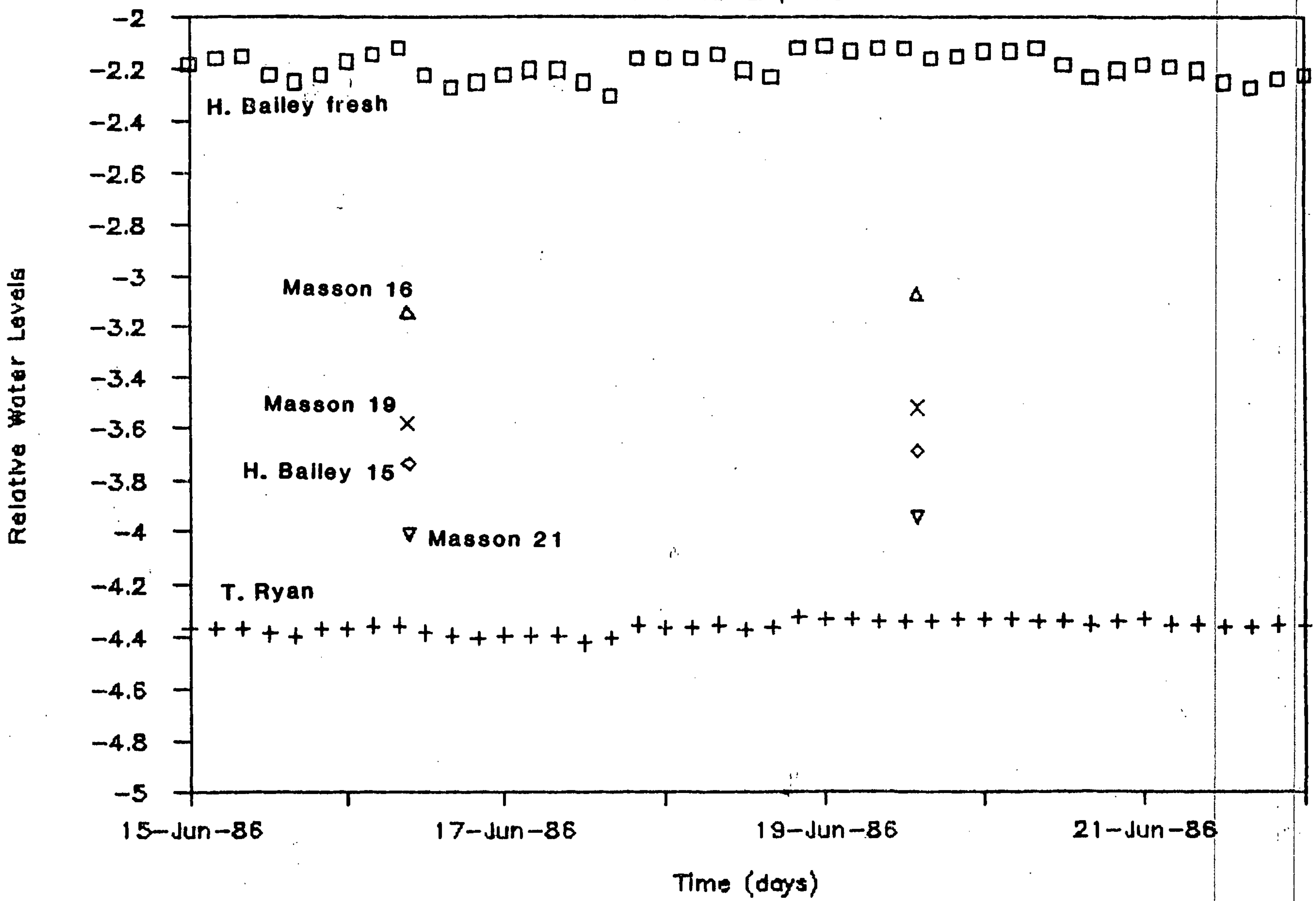


Figure 6 — Relative Water Levels

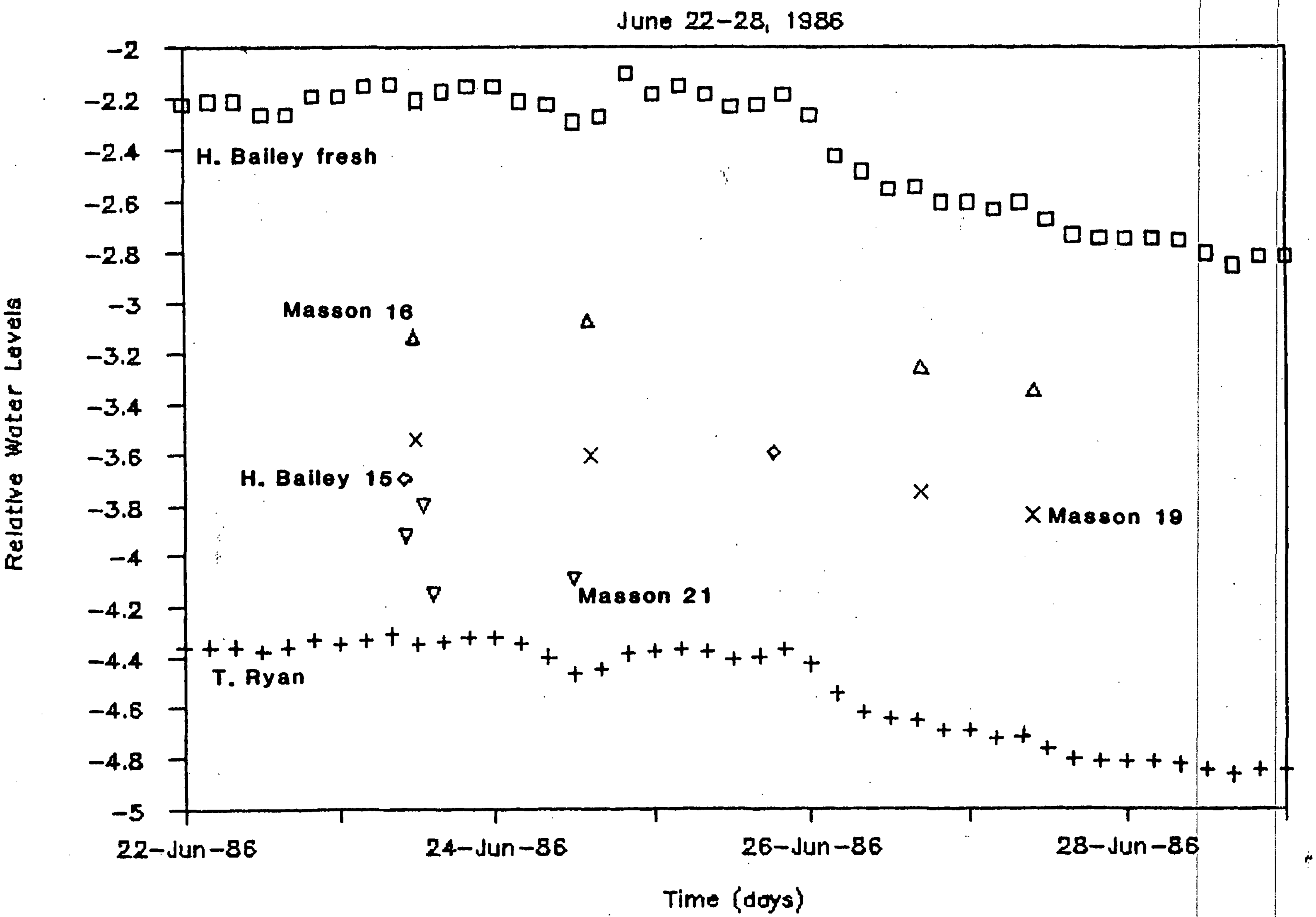


Figure 7 — Relative Water Levels

June 29 – July 5, 1986

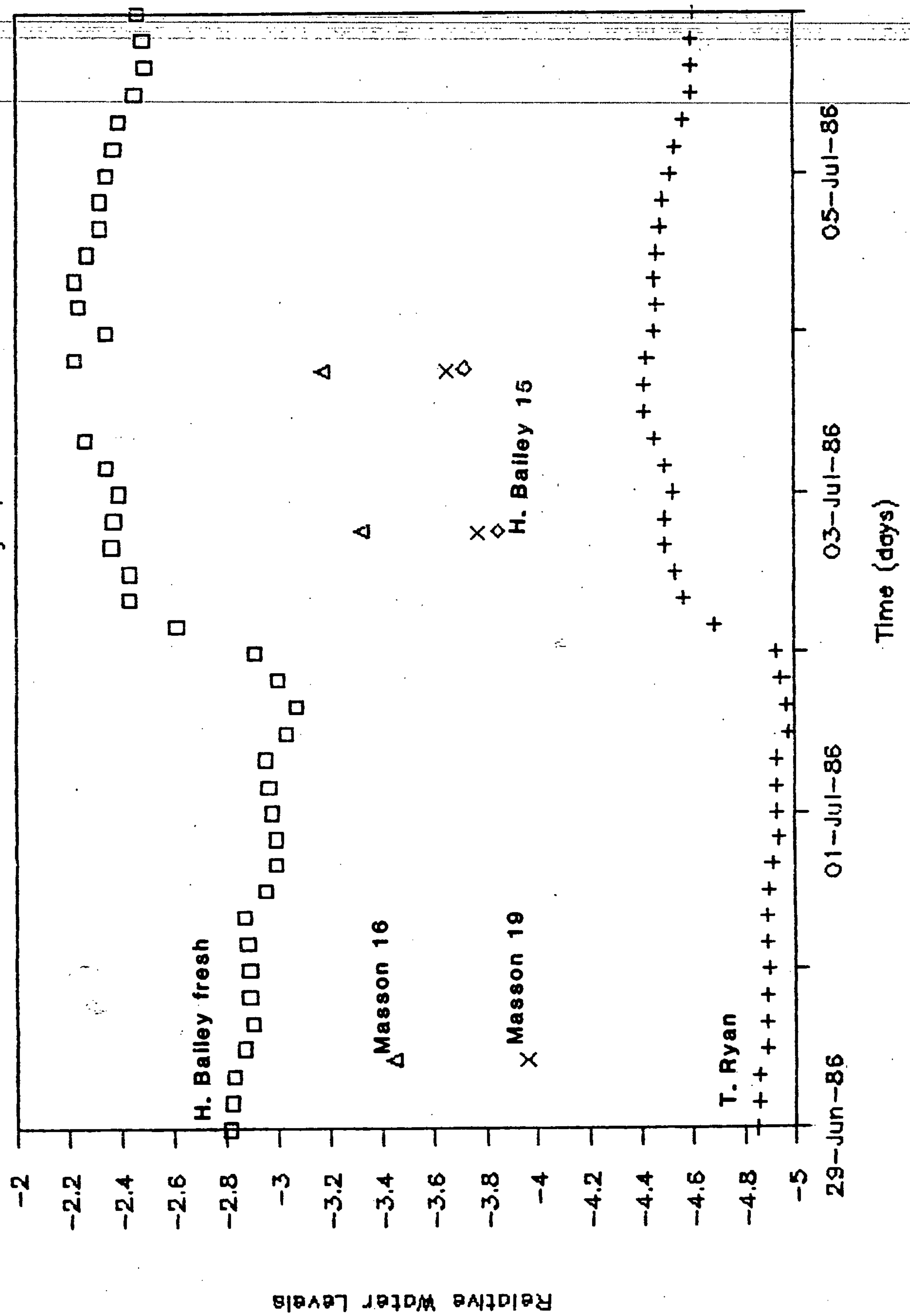


Figure 8 — Relative Water Levels

July 6-12, 1986

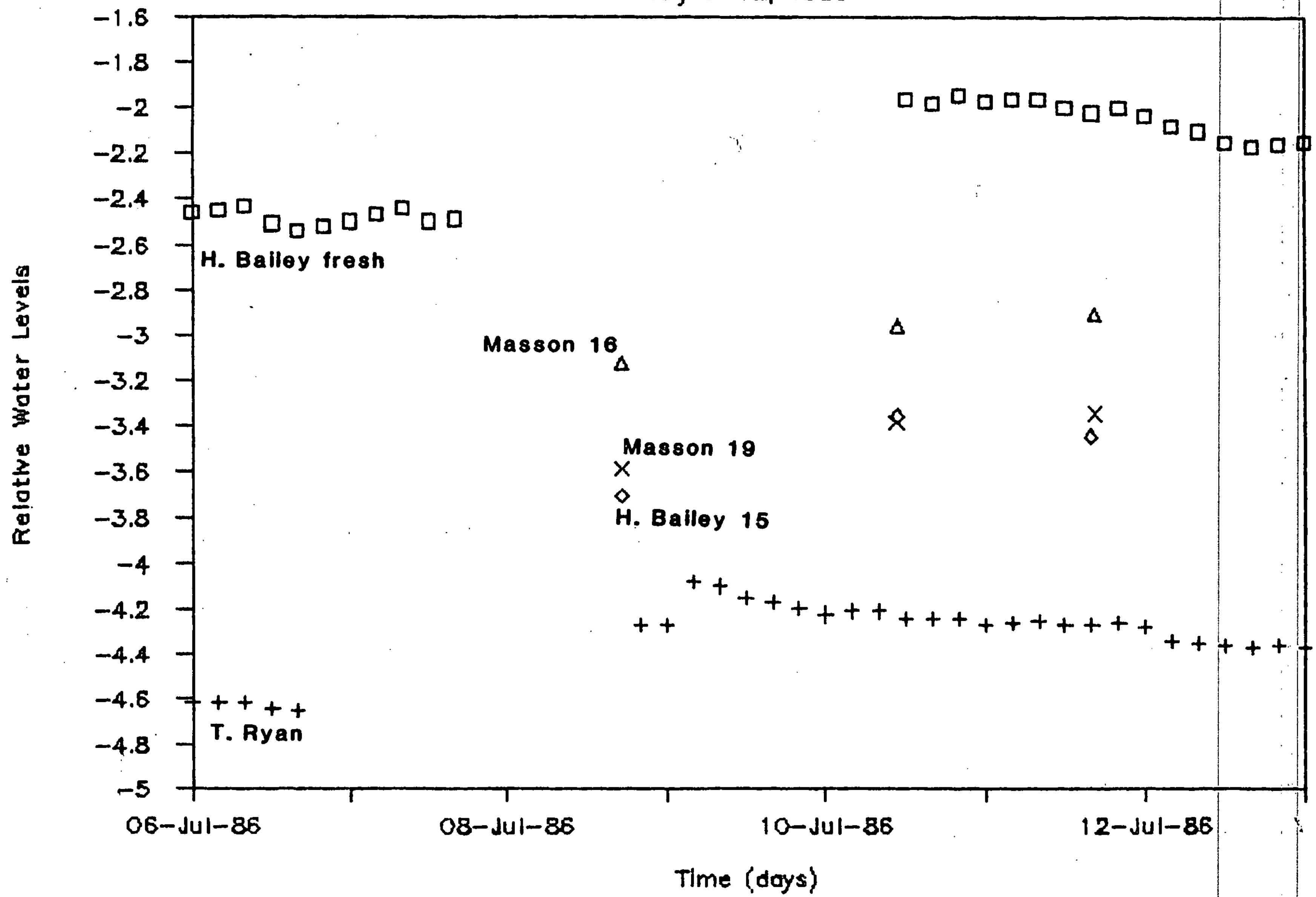


Figure 9 — Relative Water Levels

July 13–19, 1986

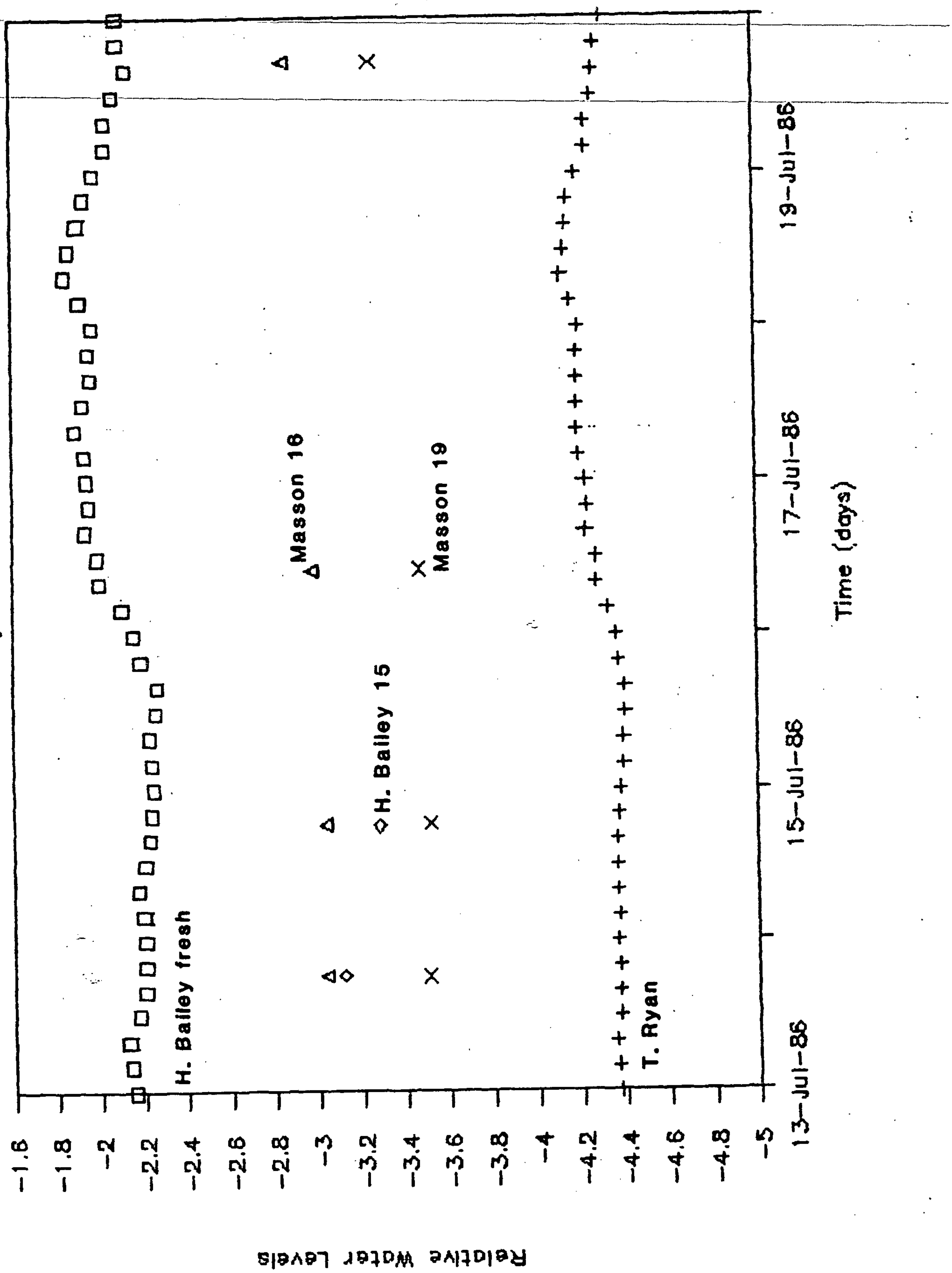


Figure 10 — Relative Water Levels

July 20-26, 1986

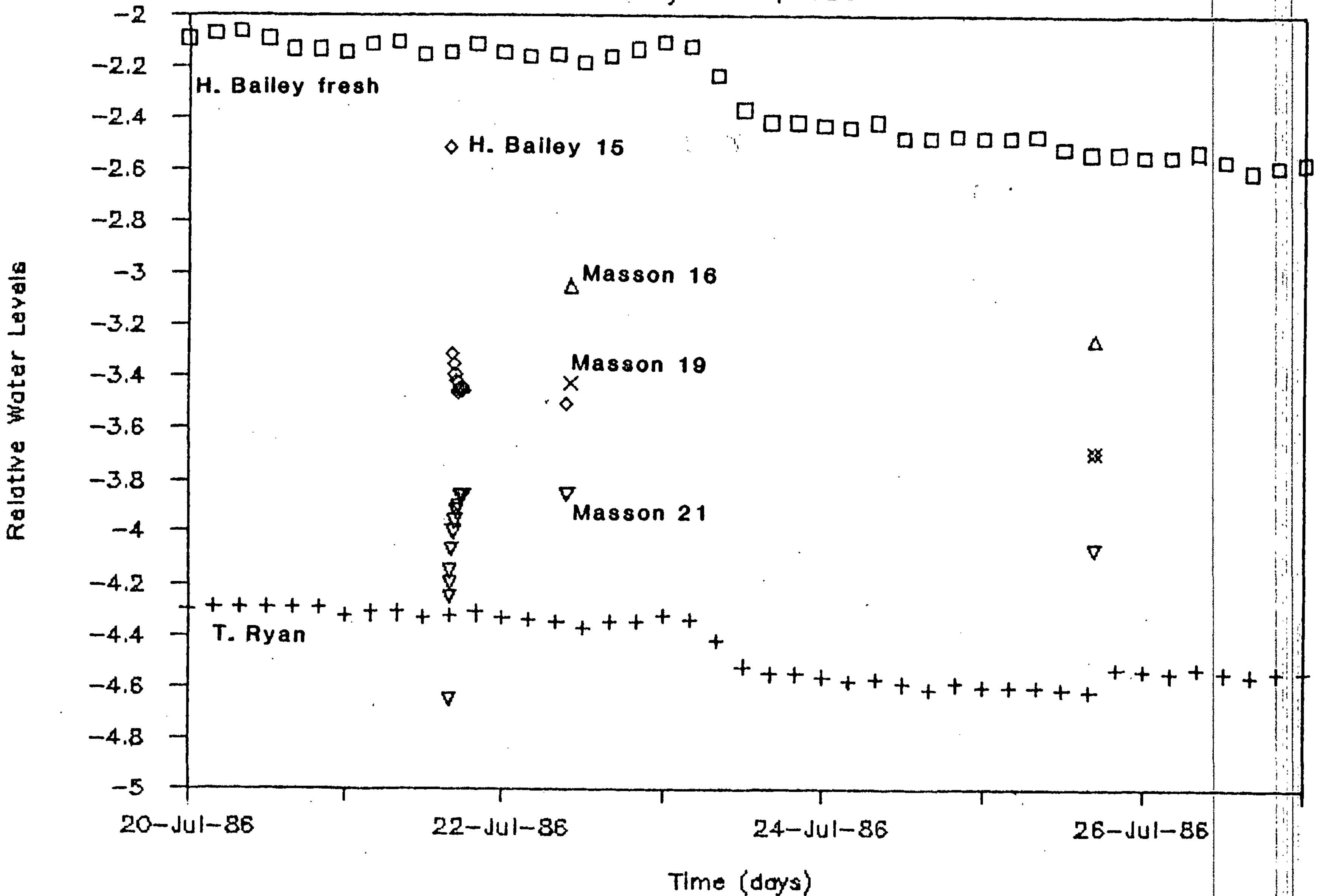
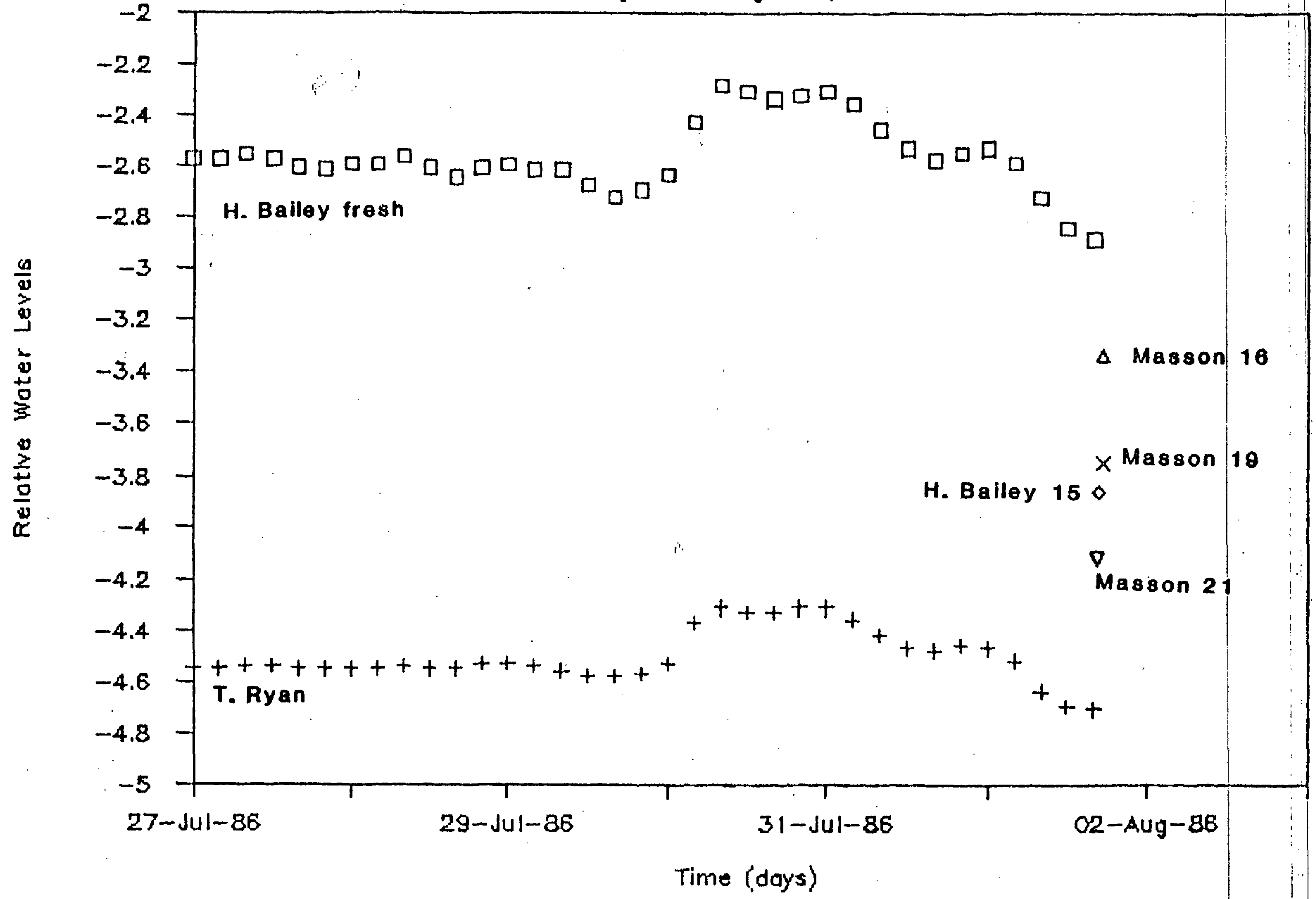


Figure 11 — Relative Water Levels

July 27 – August 2, 1986



The measured water-level depths of the geothermal wells have been shifted by constants in figures 3 through 11. This was done to show water-levels in all of the wells without compressing the vertical scale. The constants added to each water-level reading for the geothermal wells are as follows:

WELL	SHIFT-CONSTANT (ft)
15	6.00
16	6.25
19	6.50
21	32.25

Not all of the data collected from the geothermal wells is visible on figures 3 through 11 because of the limits chosen for the vertical scales on these graphs. The water-level drawdowns and rises recorded for Masson 16 and Bailey 15 during pump tests 2 and 3 are not shown. However, part of the recovery data from pump test 6 is shown on figure 10.

While figures 3 to 11 are useful to see all of the individual data points from the 2 fresh wells during the study period, figure 12 better illustrates the relationship between heads in the geothermal reservoir and those in the fresh water aquifer. This figure shows that water levels in the 2 fresh wells and in Masson geothermal wells 16 and 19 rose and fell nearly simultaneously during the study period, providing a compelling argument for hydrologic connection between the thermal and nonthermal groundwater systems. Both geothermal wells have been shifted up by the same constants noted above.

Figure 13 shows the relative water levels in the same 4 wells as in figure 12, and an additional set of data at the top of the graph. The topmost data set shows changes in river stage at the Leasburg measuring station. The river stage data are recorded in the field as positive numbers, and larger numbers reflect increased flows. However, the stage data have been changed by subtracting 6.5 feet from all of the measurements to show all 5 data sets together. The sense of direction has not been changed; higher river flows are seen as higher points on the graph.

Figure 13 suggests that heads in the thermal and nonthermal aquifers rise and fall together, because of river stage fluctuations. River stage is entirely controlled by three variables:

1. controlled releases from upstream dams
2. controlled diversions to irrigation
3. runoff from precipitation.

Figure 13 supports the argument that not only are the thermal and nonthermal groundwater systems hydrologically connected to each other, but they are also both connected to the the surface water system, the Rio Grande.

Head stresses imposed by the river are quickly propagated to both the cold water aquifer and to the geothermal reservoir. There is some evidence that equilibrium is achieved slightly faster in the nonthermal

Figure 12 — 2 Fresh Wells, 16, & 19

June and July, 1986

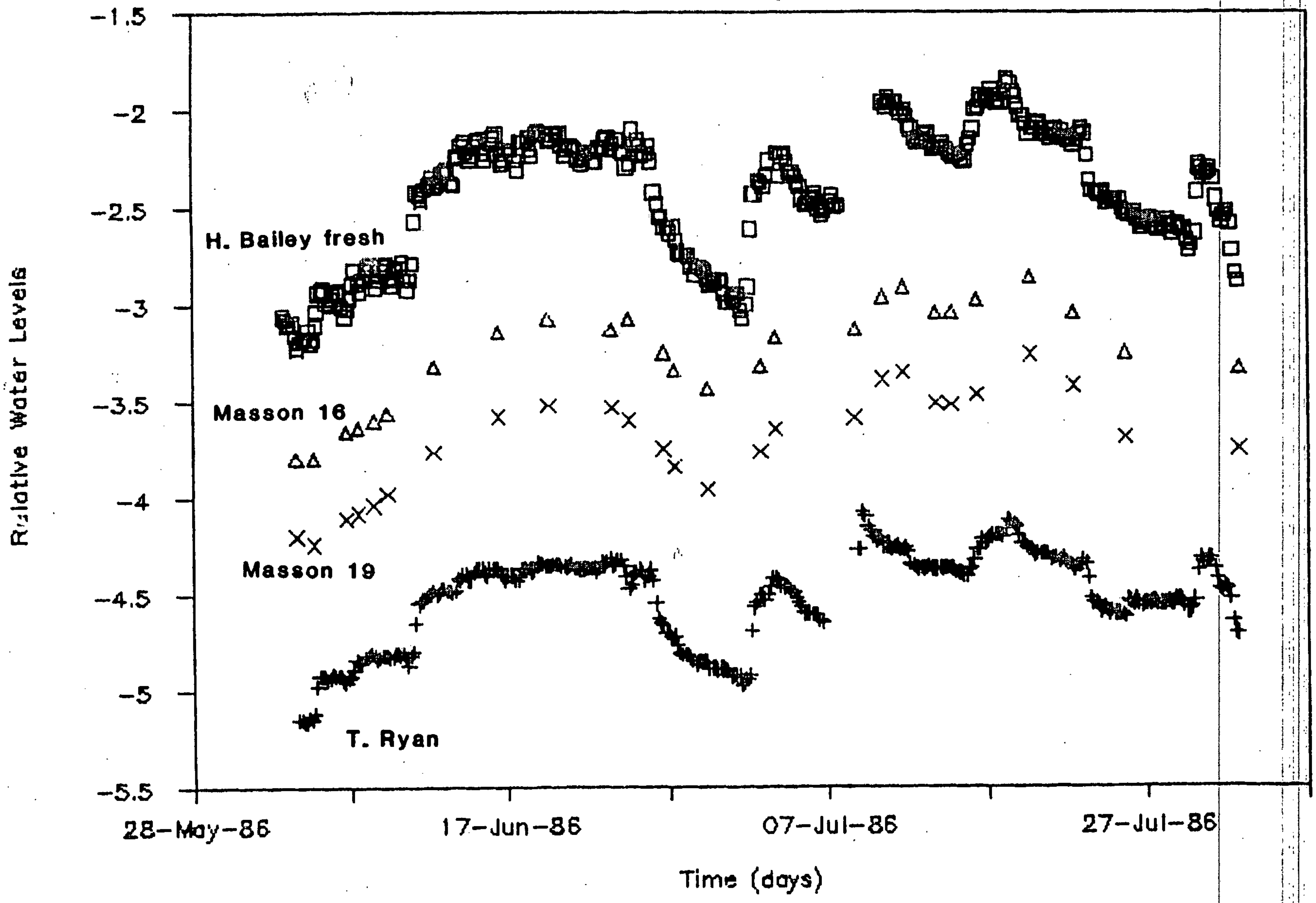
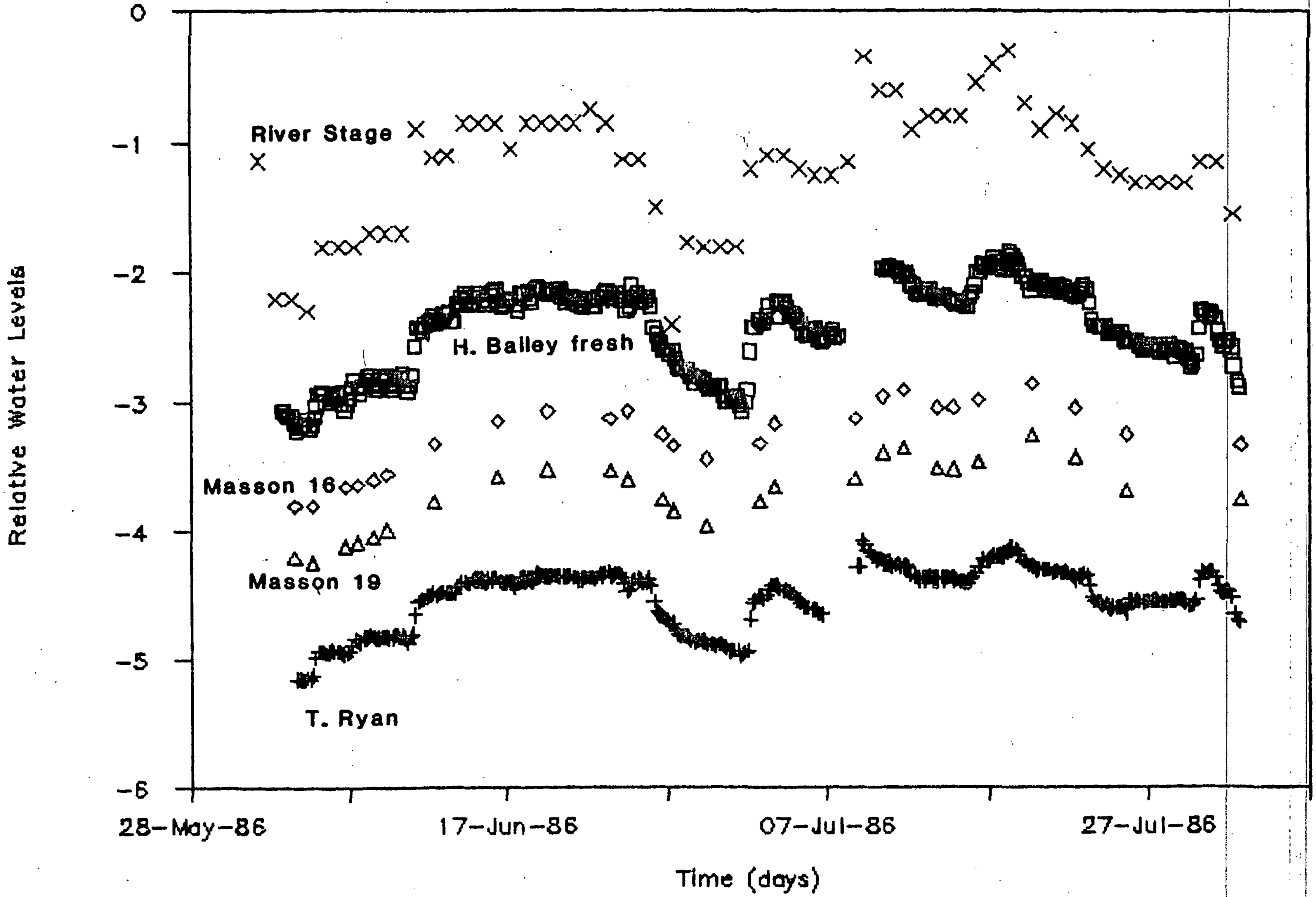


Figure 13 — 4 Wells and River Stage

June and July, 1986



aquifer, at least near the 2 fresh water wells that were monitored. This can be seen by considering data on figure 13 between June 3rd and 9th. The fresh wells exhibit a sharp rise and then level off in response to a similiar river change, whereas the 2 geothermal wells exhibit a slower and apparently more steady head gain. This may indicate that it takes approximately 1 day for the geothermal revervoir to reach a new head equilibrium from stresses imposed by the river. However, this interpretation might not be suppported by a more complete recording of heads in the geothermal reservoir. There is no evidence to suggest that river-imposed hydrologic stresses require more than 1 day to achieve equilibrium in the geothermal reservoir.

Pump-Test Results

Tansmissivities for the geothermal reservoir in the vicinity of Masson 16 were calculated using a numerical solution of the Theis equation (Czarnecki and Craig, 1985). The numerical solution was chosen to avoid the problems inherent to a graphical solution when non-ideal response is encountered. Although the application of the Theis equation to fractured media is not strictly correct, such media are often assumed to behave as equivalent porous continua (Gordon, 1986).

Table 4 summarizes the pump tests for which drawdown or recovery data were recorded. Total drawdown at the end of pump-test 1 was also measured. Table 5 shows the data from the first 3 pump tests which were used to calculate transmissivity. A pumping rate of 350 gallons per minute (gpm) was recorded for all 3 tests.

Table 6 presents the results of the calculations using a range of storage coefficients. Storage in the geothermal reservoir is not calculated, since only a very short test was done without injection. However, it is believed that the storage coefficent of the fractured rhyolite lies in the range of 0.01 to 0.05. The transmissivity of the geothermal reservoir is probably in the range of 40,000 to 50,000 gallons/day/foot (gpd/ft).

Figure 14 shows drawdown in the pumping well (Masson 21) during pump test 2, and the data are listed in table 7. Over 90 percent of the total drawdown at this pumping rate is accomplished in the first 5 minutes of pumping. Drawdown stabilizes at 11 feet after 2 hours of pumping.

Figure 15 and table 8 present similiar data from pump test 3. The pump was not running at a steady rate during the first few minutes, and the drawdown data reflect the erratic pumping. The total measured drawdown during this test appears to be approximately 13 feet. There is a 2-foot discrepancy between final drawdowns of pump tests 2 and 3. The cause of this discrepancy is uncertain, but may be related to an error in recording the pumping rate on June 23rd. The pumping rate on the 23rd may have been slightly less than 350 gpm.

Recovery in Masson well 21 after test 6 is presented in figure 16, and the data are listed in table 9. The pumping rate for this test was 200 gpm, and the total recovery appears to be 3.39 feet. Just as with the drawdown data from test 2, over 90 percent of the recovery occurs

Table 4 - Drawdown and Recovery Data Collected

TEST NO.	TYPE OF DATA COLLECTED	TIME INTERVAL OF DATA
1	Recovery	45 seconds
2	Drawdown	4.0 hours
3	Drawdown	6.3 hours
6	Recovery	2.0 hours

Table 5 - Data used to Calculate Transmissivity

Constants: $Q = 350$ gpm, $r = 0.25$ ft.

TEST NO.	TIME(days)	DRAWDOWN(ft)	SPEC. CAP. (gpm/ft)
1	0.021	9.8	35.7
2	0.167	11.1	31.5
3	0.264	13.5	25.9

Table 6 - Transmissivity near Well 21

	TRANSMISSIVITY (gal/day/ft)		
STOR. COEF.	TEST 1	TEST 2	TEST 3
0.01	53,978	55,282	46,297
0.05	46,873	49,004	41,339
0.10	43,754	46,356	38,904
0.20	40,742	43,704	36,781

Figure 14 – Drawdown in Masson Well 21

June 23, 1986

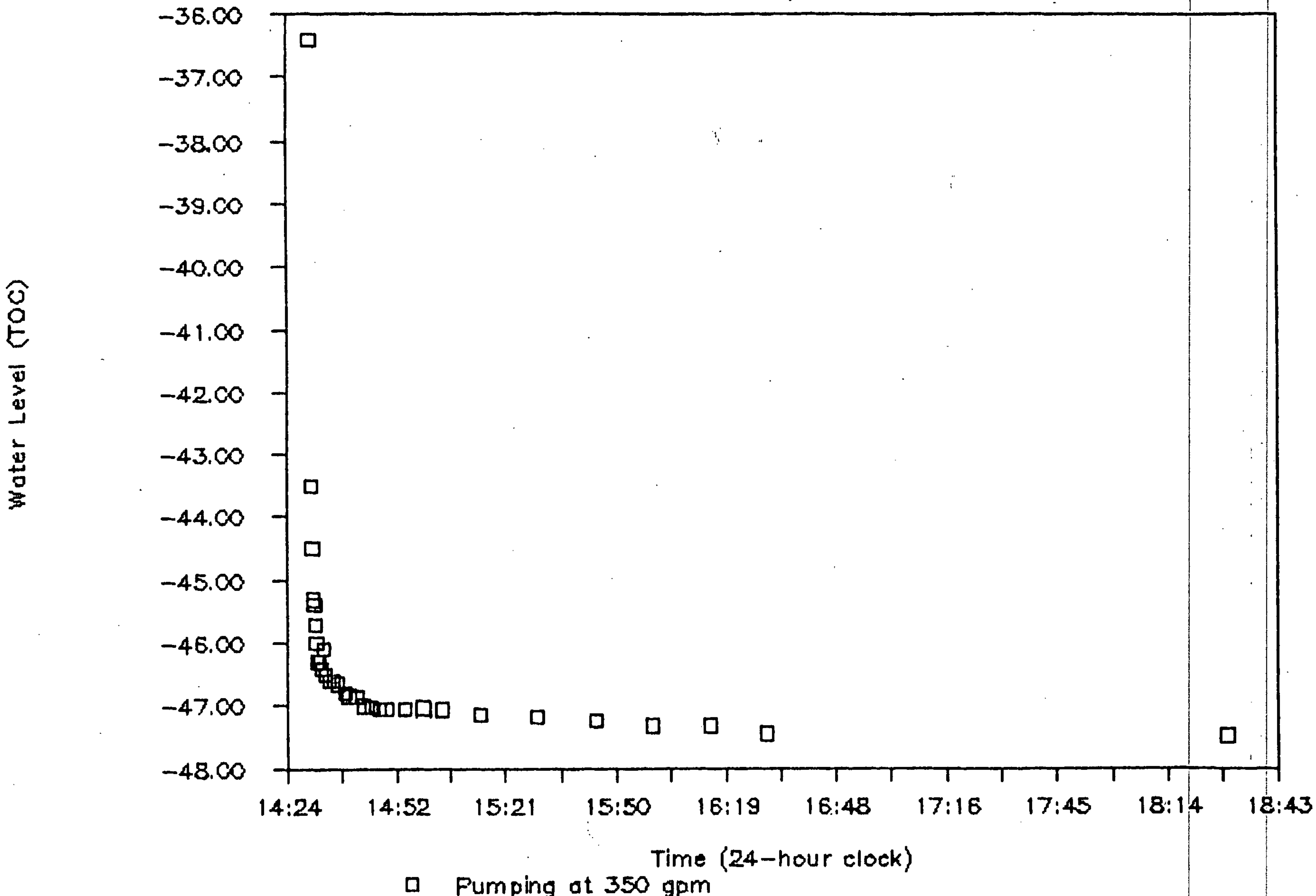


Table 7 - Pumping Well Drawdown Data from Pump Test 2

TIME	WATER LEVEL	DRAWDOWN (ft)
02:30:00 PM	-36.40	0.00
02:30:15 PM	-43.50	7.10
02:30:30 PM	-44.50	8.10
02:30:45 PM	-45.30	8.90
02:31:00 PM	-45.40	9.00
02:31:15 PM	-45.70	9.30
02:31:30 PM	-46.00	9.60
02:31:45 PM	-46.30	9.90
02:32:00 PM	-46.30	9.90
02:32:15 PM	-46.30	9.90
02:33:00 PM	-46.40	10.00
02:33:30 PM	-46.10	9.70
02:34:00 PM	-46.50	10.10
02:35:00 PM	-46.60	10.20
02:36:00 PM	-46.60	10.20
02:37:00 PM	-46.65	10.25
02:39:00 PM	-46.80	10.40
02:40:00 PM	-46.85	10.45
02:42:00 PM	-46.87	10.47
02:44:00 PM	-47.00	10.60
02:46:00 PM	-47.01	10.61
02:48:00 PM	-47.04	10.64
02:50:00 PM	-47.04	10.64
02:55:00 PM	-47.05	10.65
03:00:00 PM	-47.03	10.63
03:05:00 PM	-47.07	10.67
03:15:00 PM	-47.14	10.74
03:30:00 PM	-47.17	10.77
03:45:00 PM	-47.25	10.85
04:00:00 PM	-47.32	10.92
04:15:00 PM	-47.32	10.92
04:30:00 PM	-47.45	11.05
06:30:00 PM	-47.48	11.08

Figure 15 – Drawdown in Masson Well 21

June 24, 1986

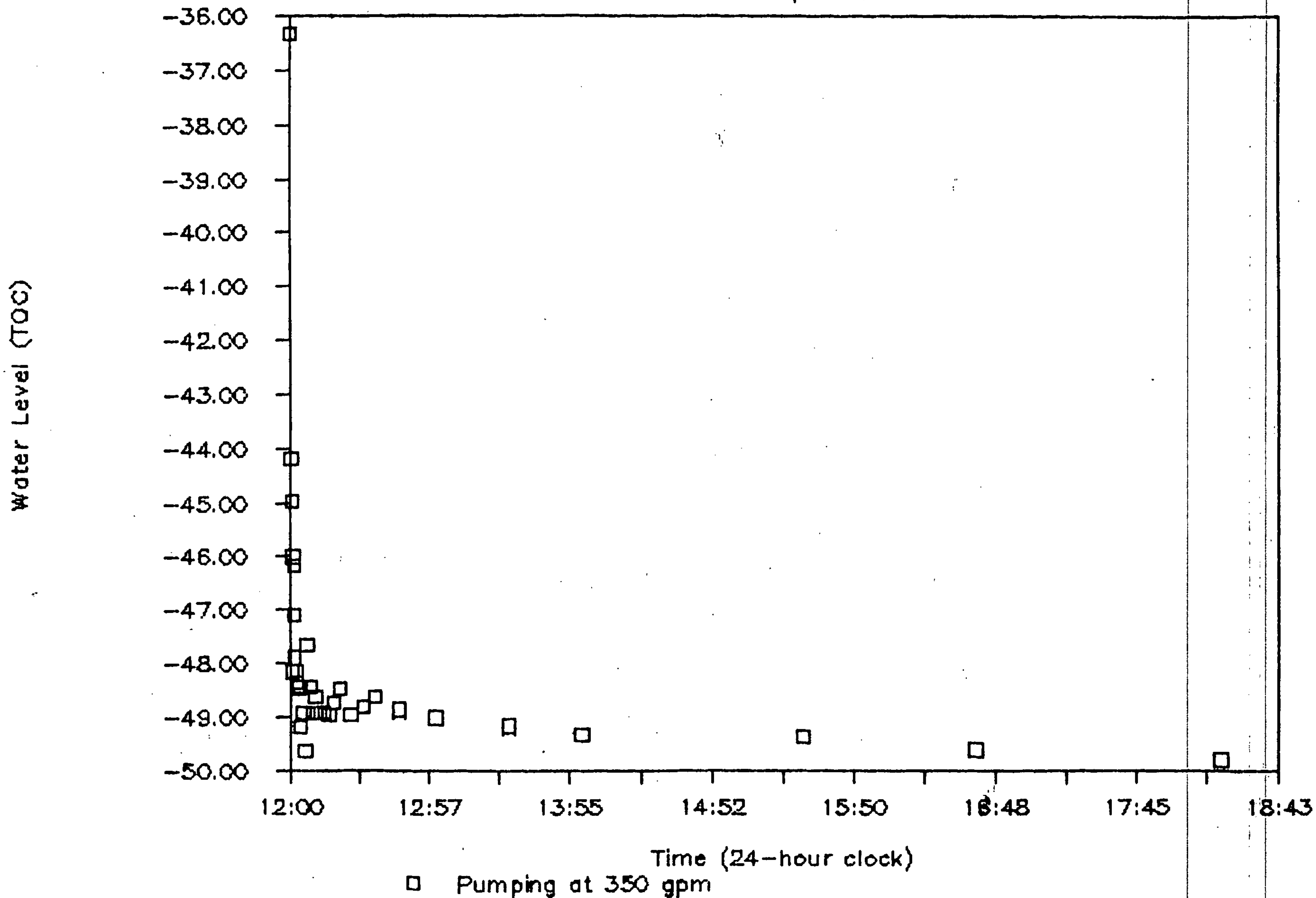


Table 8 - Pumping Well Drawdown Data from Pump Test 3

TIME	WATER LEVEL	DRAWDOWN (ft)
12:00:00 PM	-36.34	0.00
12:00:15 PM	-44.20	7.86
12:00:30 PM	-44.98	8.64
12:00:45 PM	-48.16	11.82
12:01:00 PM	-46.00	9.66
12:01:15 PM	-46.18	9.84
12:01:30 PM	-47.10	10.76
12:01:45 PM	-47.90	11.56
12:02:00 PM	-48.15	11.81
12:02:15 PM	-48.38	12.04
12:03:00 PM	-48.47	12.13
12:03:30 PM	-48.44	12.10
12:04:00 PM	-49.20	12.86
12:05:00 PM	-48.93	12.59
12:06:00 PM	-49.63	13.29
12:07:00 PM	-47.67	11.33
12:08:00 PM	-48.45	12.11
12:09:00 PM	-48.92	12.58
12:10:00 PM	-48.63	12.29
12:12:00 PM	-48.93	12.59
12:14:00 PM	-48.94	12.60
12:16:00 PM	-48.97	12.63
12:18:00 PM	-48.75	12.41
12:20:00 PM	-48.48	12.14
12:25:00 PM	-48.98	12.64
12:30:00 PM	-48.83	12.49
12:35:00 PM	-48.63	12.29
12:45:00 PM	-48.87	12.53
01:00:00 PM	-49.02	12.68
01:30:00 PM	-49.17	12.83
02:00:00 PM	-49.34	13.00
03:30:00 PM	-49.38	13.04
04:40:00 PM	-49.62	13.28
06:20:00 PM	-49.80	13.46

Figure 16 – Recovery in Masson 21

July 21, 1986

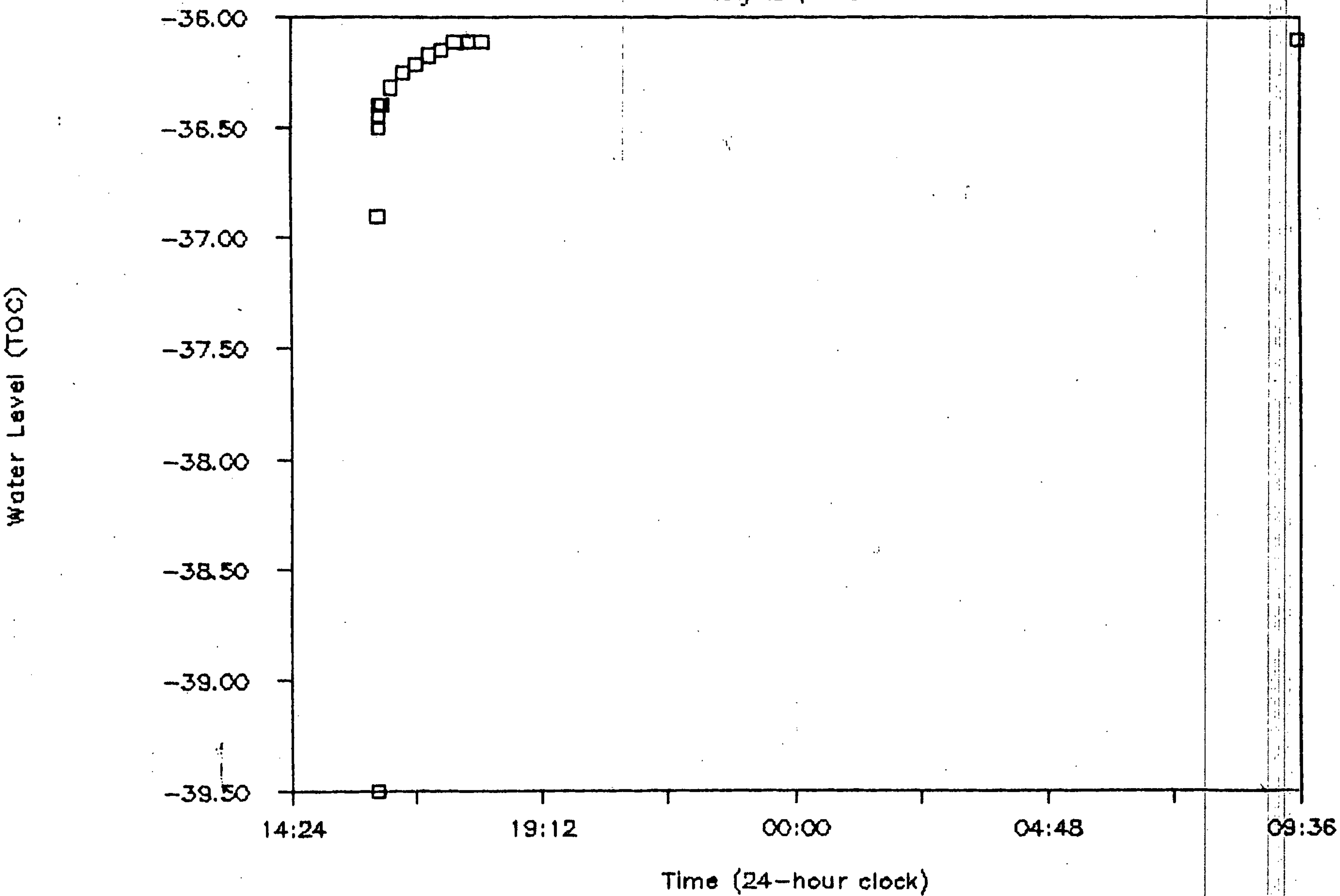


Table 9 - Pumping Well Recovery Data from Pump Test 6

TIME	WATER LEVEL	RECOVERY (ft)
04:05:00 PM	-39.50	0.00
04:05:30 PM	-36.90	2.60
04:05:45 PM	-36.50	3.00
04:06:00 PM	-36.45	3.05
04:06:15 PM	-36.40	3.10
04:06:30 PM	-36.40	3.10
04:06:45 PM	-36.40	3.10
04:07:00 PM	-36.40	3.10
04:07:30 PM	-36.40	3.10
04:08:00 PM	-36.40	3.10
04:08:30 PM	-36.40	3.10
04:09:00 PM	-36.40	3.10
04:10:00 PM	-36.40	3.10
04:20:00 PM	-36.32	3.18
04:35:00 PM	-36.25	3.25
04:50:00 PM	-36.21	3.29
05:05:00 PM	-36.17	3.33
05:20:00 PM	-36.15	3.35
05:35:00 PM	-36.11	3.39
05:50:00 PM	-36.11	3.39
06:05:00 PM	-36.11	3.39
09:35:00 AM	-36.10	3.40

during the first 5 minutes after pumping ceases. Complete recovery occurs within 30 minutes after pumping is stopped. The recovery of the injection well after test 6 is shown in figure 17 and table 10.

The Radium Springs geothermal reservoir appears to be significantly more productive than the New Mexico State University geothermal field. One of NMSU's principal production wells, PG-1, incurs approximately 10 times as much drawdown at only half the pumping rate of Masson well 21 (Mitchell, et al., 1981). Complete recovery in PG-1 takes about 5.5 hours compared to only 0.5 hour in Masson 21. The NMSU geothermal field has been in production for approximately 4 years with no adverse effects to either the geothermal field or to nonthermal groundwater.

Hydrologic impacts to Masson wells 16 and 19 during the Radium Springs pump tests appear to be very small or negligible. The best evidence is seen by examining data on figure 6 for the consecutive days of June 23 and 24. The data for wells 16 and 19 on June 23rd were taken before pump test 1, and the data for the same 2 wells on the next day were taken after test 3 had been underway for 2.25 hours. While the water level in well 16 increases by 0.06 foot between the two days, well 19 decreases by 0.07 foot. These results are in agreement with theoretical predictions for head changes around a doublet well system in an isotropic aquifer (Miller and Voss, 1986).

Figure 6 suggests that at the highest pumping rate of the study, 350 gpm, the maximum impact to the 2 closest wells (16 and 19) is only a few hundreths of a foot. This conclusion is supported by data in table 11. The last column of this table records the difference in water levels between wells 16 and 19 during the entire study period. The average difference in water levels between the 2 wells during the project was 0.70 foot, with a standard deviation of 0.04. The maximum difference during the study period was on June 24th, during pump test 3. However, this difference is only 2 standard deviations above the mean, and may not be statistically significant.

There is no evidence that any measurable hydrologic impacts were propagated to either of the 2 fresh water wells or to the river. If any hydrologic stresses did propagate as far as the river, their magnitude is certainly beyond the detection of current state-of-the-art instruments, and probably on the order of thousandths of a foot or less.

Summary of Water-Level Data

Water-level data were collected from 6 wells between June 2nd and August 1, 1986. Two of the wells are completed in river gravels, and are adjacent to the Rio Grande. The other 4 wells are completed in fractured rhyolite of the geothermal reservoir, just north of the river.

The largest water-level fluctuations in both the thermal and nonthermal aquifers are the result of changes in stage in the Rio Grande. The total variation due to river stresses was generally less than 1 foot. Smaller diurnal cycles having an amplitude of approximately 0.1 foot or less were detected in the 2 fresh water wells.

The transmissivity of the geothermal reservoir near well 21 is

Figure 17 – Recovery in Bailey 15

July 21, 1986

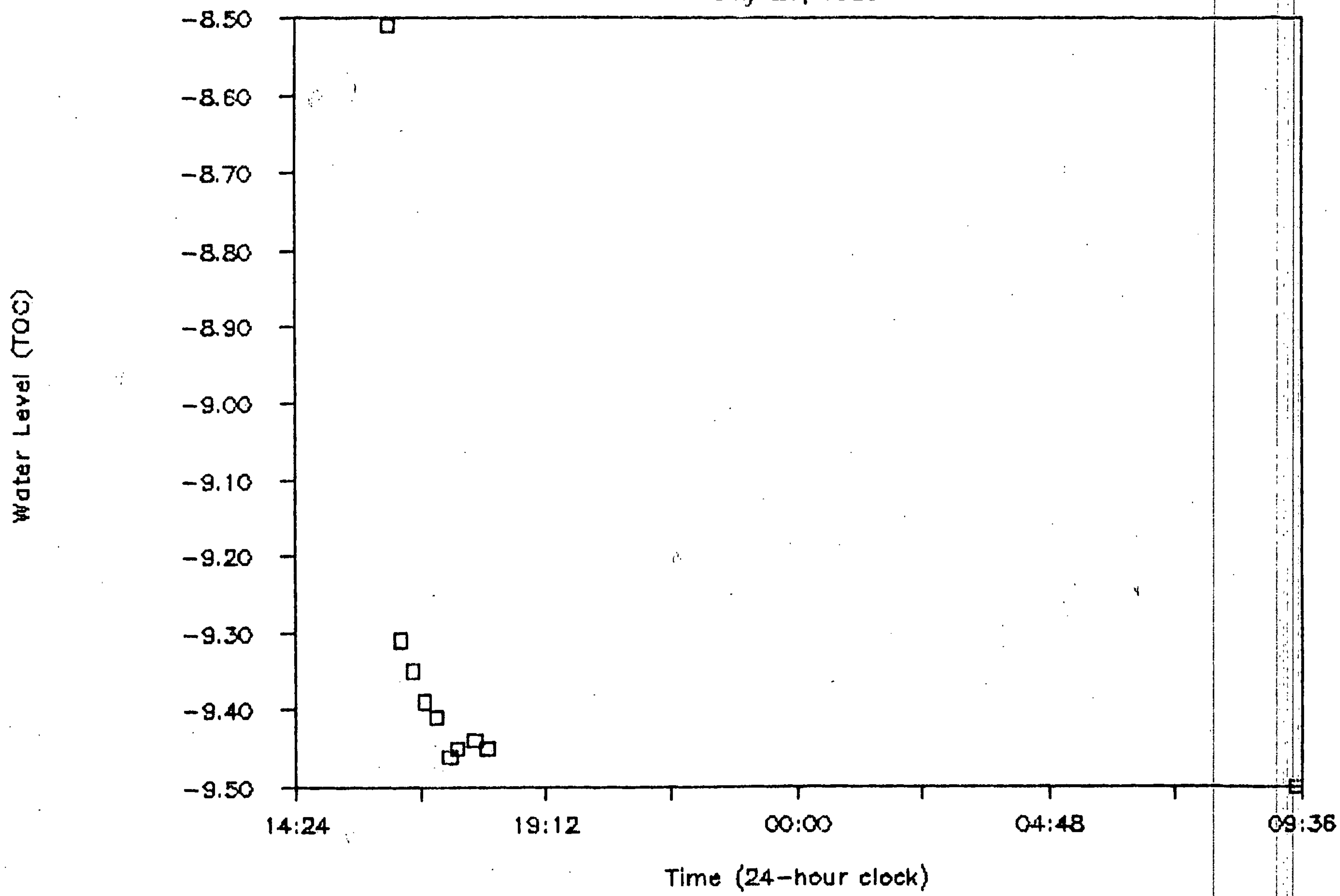


Table 10 - Injection Well Recovery Data from Pump Test 6

TIME	WATER LEVEL	RECOVERY (ft)
03:13 PM	-5.28	0.00
04:12 PM	-8.51	3.23
04:25 PM	-9.31	4.03
04:39 PM	-9.35	4.07
04:53 PM	-9.39	4.11
05:07 PM	-9.41	4.13
05:23 PM	-9.46	4.18
05:31 PM	-9.45	4.17
05:51 PM	-9.44	4.16
06:05 PM	-9.45	4.17
09:30 AM	-9.50	4.22

Table 11 - Simultaneous Head Differences between Wells 16 and 19

DATE	TIME	MASSON #16	DATE	TIME	MASSON #19	DIFFERENCE
06/03/86	01:40 PM	-10.05	06/03/86	01:50 PM	-10.70	0.65
06/04/86	03:55 PM	-10.05	06/04/86	03:50 PM	-10.74	0.69
06/06/86	05:19 PM	-9.91	06/06/86	05:15 PM	-10.61	0.70
06/07/86	01:05 PM	-9.89	06/07/86	01:00 PM	-10.58	0.69
06/08/86	11:47 AM	-9.85	06/08/86	11:45 AM	-10.54	0.69
06/09/86	08:30 AM	-9.81	06/09/86	08:30 AM	-10.48	0.67
06/12/86	09:20 AM	-9.57	06/12/86	08:35 AM	-10.27	0.70
06/16/86	09:25 AM	-9.39	06/16/86	09:20 AM	-10.08	0.69
06/19/86	01:45 PM	-9.32	06/19/86	01:45 PM	-10.02	0.70
06/23/86	11:30 AM	-9.38	06/23/86	11:50 AM	-10.03	0.65
06/24/86	02:10 PM	-9.32	06/24/86	02:20 PM	-10.10	0.78
06/26/86	04:45 PM	-9.50	06/26/86	04:40 PM	-10.25	0.75
06/27/86	09:50 AM	-9.59	06/27/86	09:45 AM	-10.34	0.75
06/29/86	10:20 AM	-9.69	06/29/86	10:15 AM	-10.46	0.77
07/02/86	06:15 PM	-9.57	07/02/86	06:05 PM	-10.27	0.70
07/03/86	06:05 PM	-9.42	07/03/86	06:05 PM	-10.15	0.73
07/08/86	05:10 PM	-9.38	07/08/86	05:05 PM	-10.09	0.71
07/10/86	10:40 AM	-9.21	07/10/86	10:35 AM	-9.89	0.68
07/11/86	04:30 PM	-9.16	07/11/86	04:35 PM	-9.85	0.69
07/13/86	06:25 PM	-9.29	07/13/86	06:20 PM	-10.01	0.72
07/14/86	06:25 PM	-9.29	07/14/86	06:30 PM	-10.02	0.73
07/16/86	10:00 AM	-9.23	07/16/86	10:05 AM	-9.97	0.74
07/19/86	05:20 PM	-9.11	07/19/86	05:15 PM	-9.76	0.65
07/22/86	10:00 AM	-9.29	07/22/86	10:05 AM	-9.92	0.63
07/25/86	04:45 PM	-9.50	07/25/86	04:40 PM	-10.19	0.69
08/01/86	05:20 PM	-9.58	08/01/86	05:25 PM	-10.25	0.67
Average Reading		-9.51			-10.21	0.70
1 Standard Deviation		0.27			0.27	0.04
Maximum Reading		-9.11			-9.76	0.78
Minimum Reading		-10.05			-10.74	0.63

approximately 45,000 gpd/ft. This high transmissivity results in very narrrow and steep drawdown cones around the pumping well, and almost no measurable impacts to wells 16 and 19. There are no measurable impacts from pumping the geothermal reservoir on the 2 fresh water wells or the Rio Grande.

GEOCHEMICAL DATA

Geothermal and Nonthermal Waters

Table 12 shows the results or lab analyses for major and minor dissolved constitutents, total dissolved solids, and pH for samples from the Bailey fresh well, and from the Bailey 15 and Masson 21 geothermal wells. The samples from both the Bailey fresh and Bailey 15 wells were taken before the pump test, and the sample from Masson 21 was taken after pump test 6 was completed. All 3 samples were collected by Jack Whittier of the NMSU Energy Institute, and analyzed by the Soil and Crop Science Lab at NMSU.

The fresh water sample is a calcium-sulfate water type, whereas the geothermal samples are sodium-chloride waters. Figure 18 is a graphical comparison of the 3 samples. The analyses are typical of both fresh and geothermal waters found along the Rio Grande Valley as far south as Vado. All of the geothermal waters that have been analyzed are sodium chloride waters with TDS ranging from 1,500 to 3,000 parts per million (ppm). Fresh waters from the same area typically are sodium or calcium bicarbonate waters, and usually have a TDS of 500 to 1,500 ppm.

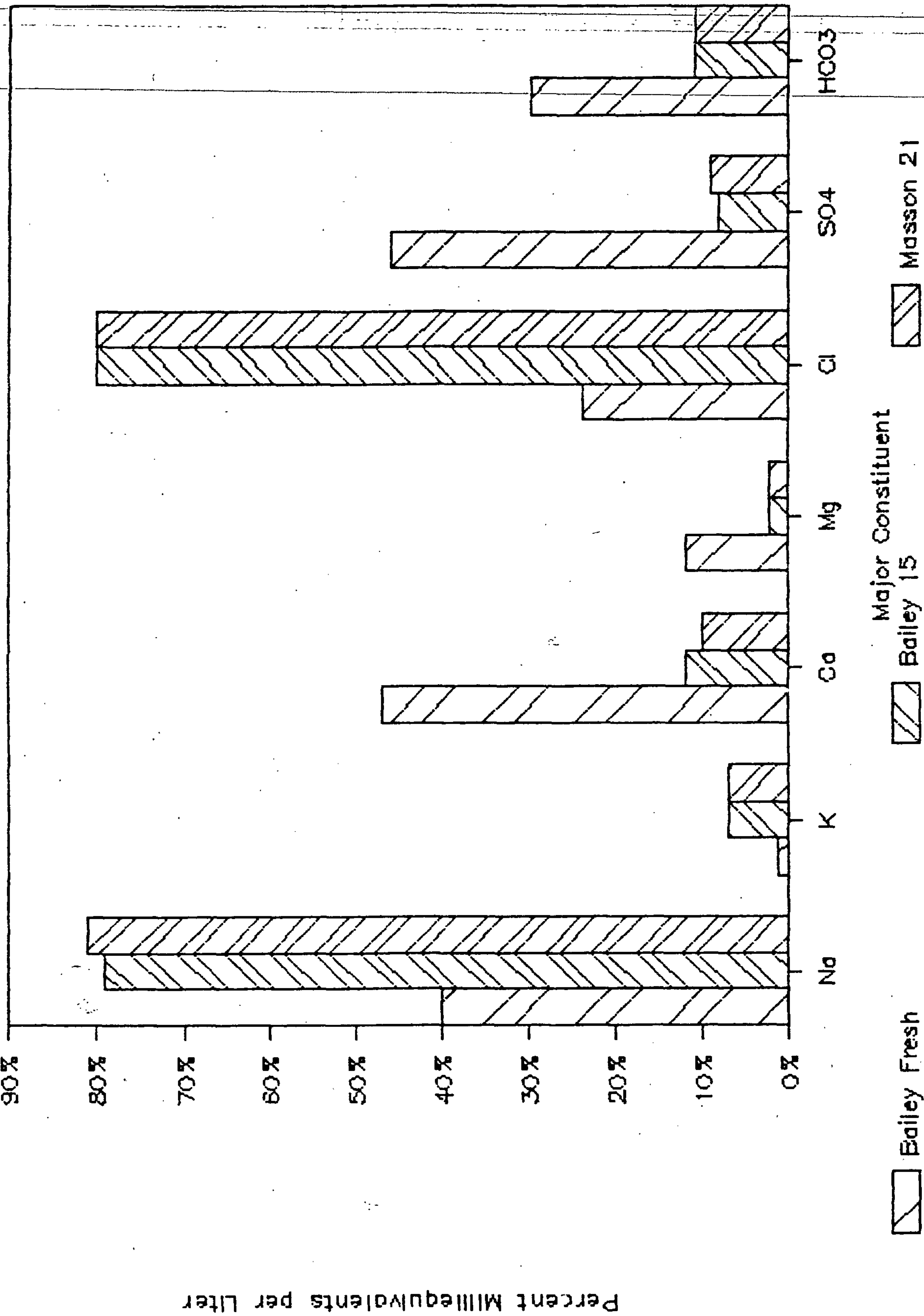
The very close similiarity of water types between the two geothermal samples collected before and after the testing suggests that little or no nonthermal water was drawn into the geothermal reservoir from pump testing. The pH values were measured in the lab, and probably do not reflect in-situ values for this parameter.

Table 12 - Geochemical Analyses for Bailey Fresh, Bailey 15 and Masson 21 Wells (dissolved constituents in mg/l).

PARAMETER	BAILEY FRESH	BAILEY 15	MASSON 21
Na	80.9	1,093	1,156
K	3.50	169	161
Ca	83.8	139	133
Mg	12.8	12.8	12.6
Cl	71.1	1,714	1,686
SO4	189	244	250
HCO3	156	420	399
CO3	0	0	14.4
SiO2	23.6	70.3	70.8
B	0.13	0.87	0.98
F	0.50	5.40	n/a
Fe	0	0	0.19
Mn	0.30	0.25	0.22
Li	0.06	0.94	0.88
TDS	540	3,680	3,682
pH	7.85	7.15	8.34

Figure 18 – Comparison of Water Types

Bailey Fresh, Bailey 15, & Masson 21



CONCLUSIONS AND RECOMMENDATIONS

Data developed during this study suggest that pumping and simultaneous injection of geothermal water at the Radium Springs geothermal area will have no adverse hydrologic impacts on nearby wells or the Rio Grande. There are no measurable effects at wells near the river, and the impacts at the closest wells are on the order of a few hundredths of a foot.

The data from this study can be projected to predict the hydrologic impacts of higher, sustained geothermal production. For example, the effects of pumping at 3,000 gpm from an array of production wells which form a hexagon with 500-foot sides can be readily calculated, using a reservoir transmissivity of 45,000 gpd/ft and the principle of superposition. After 1 year of continuous pumping at 500 gpm from each of the 6 wells, drawdown in each well is only 71 feet. This calculation assumes no injection, no recharge, and no interruptions to pumping. If one injection well is placed in the middle of the array, the drawdown in each pumping well after 1 year is only 13 feet. Peak pumping rates as high as these would never be sustanined as long as 1 year.

The results of this study are quite encouraging for the development of geothermal resources at the Radium Springs site, and it appears that the reservoir can sustain pumping rates probably as high as 10 times the highest pumping rate of this study or more without adverse hydrologic impacts either to the geothermal reservoir or to freshwater supplies.

It is recommended that permits be granted for production and injection from the geothermal reservoir, and that the permits allow production from or injection into any of the 4 wells that tap the common reservoir.

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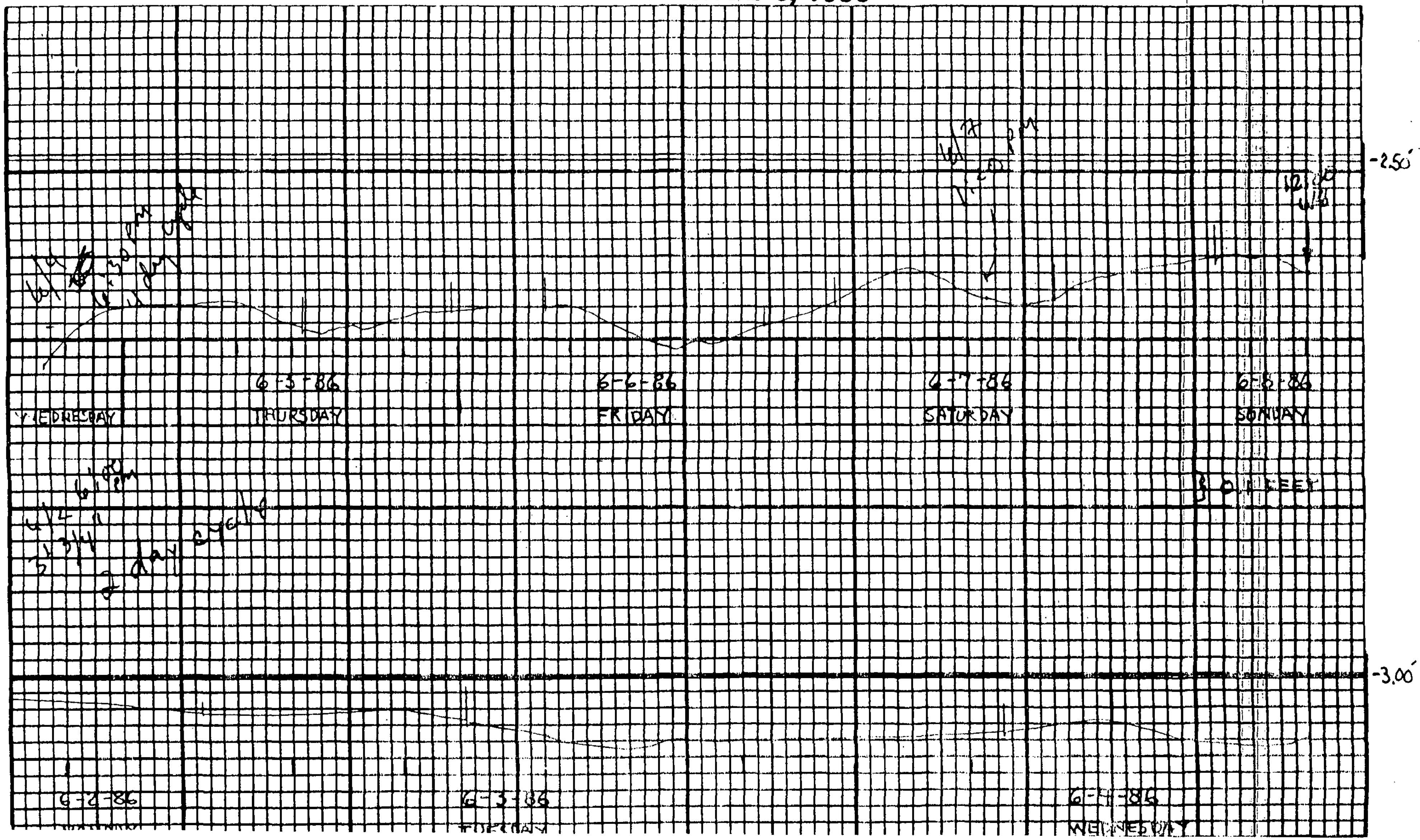
Appendix 1

Analog Records of Water Levels,

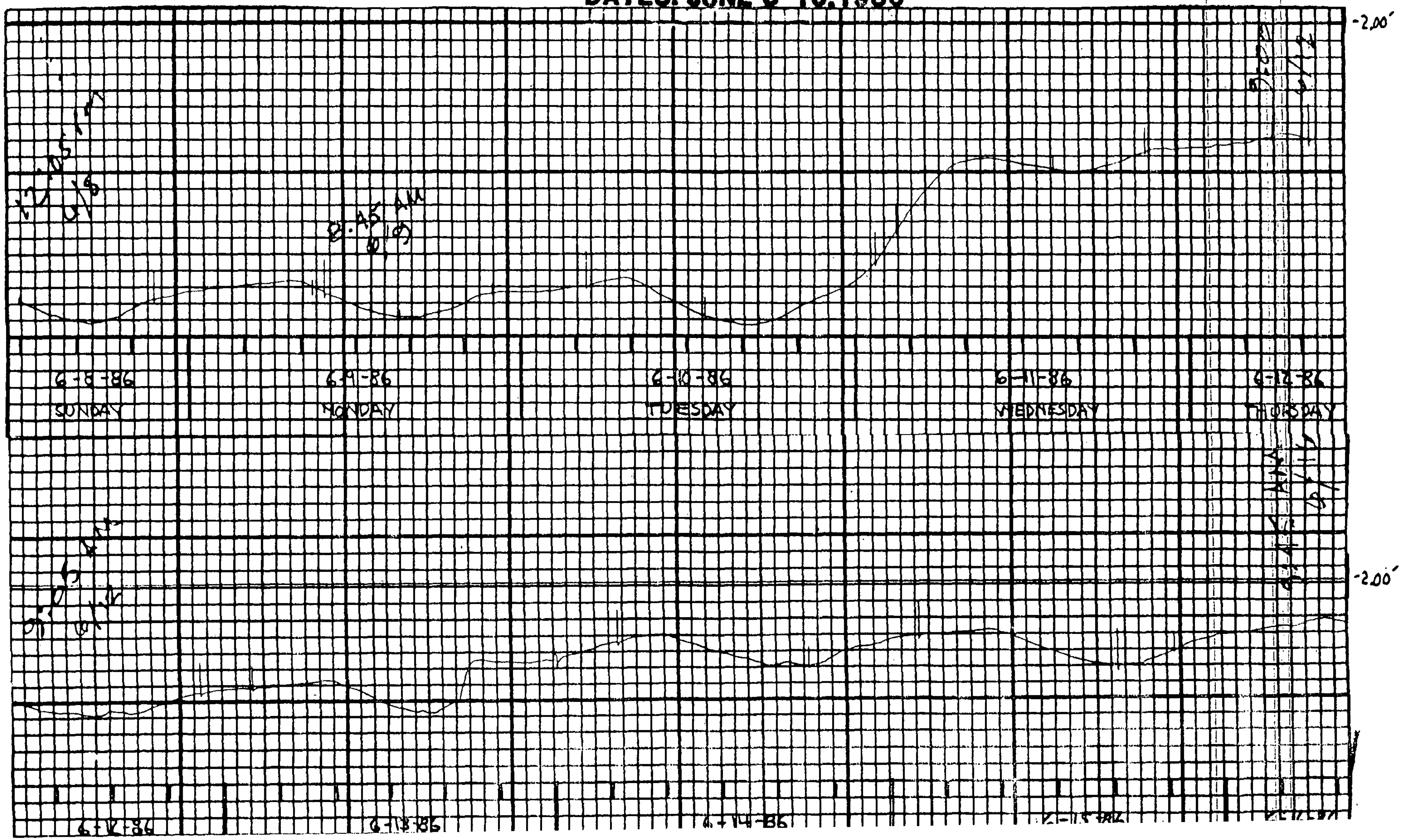
Harry Bailey fresh well

WELL NAME:HARRY BAILEY FRESH

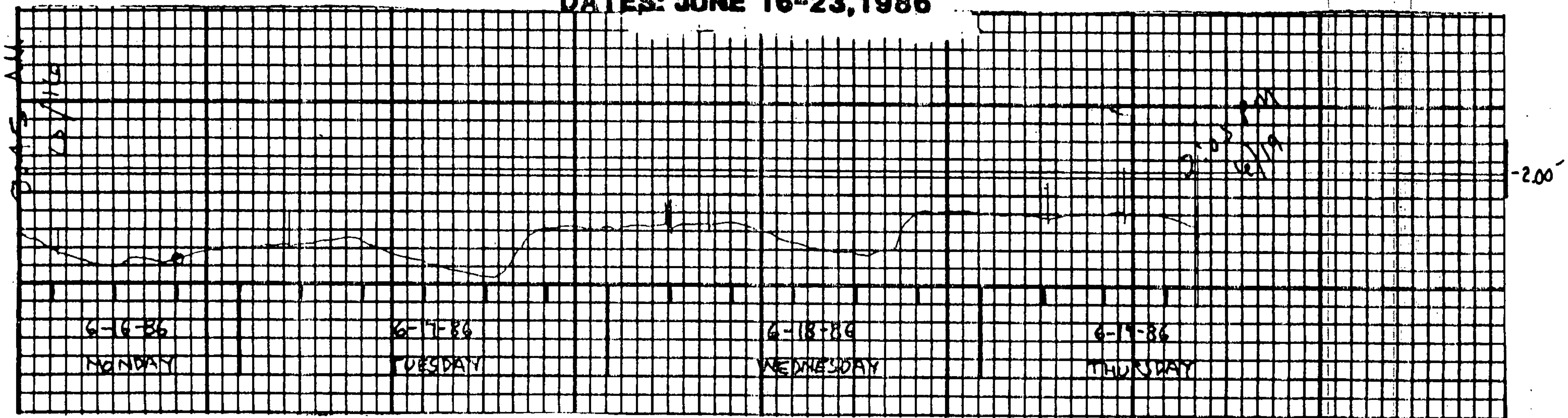
DATES: JUNE 2-8, 1986

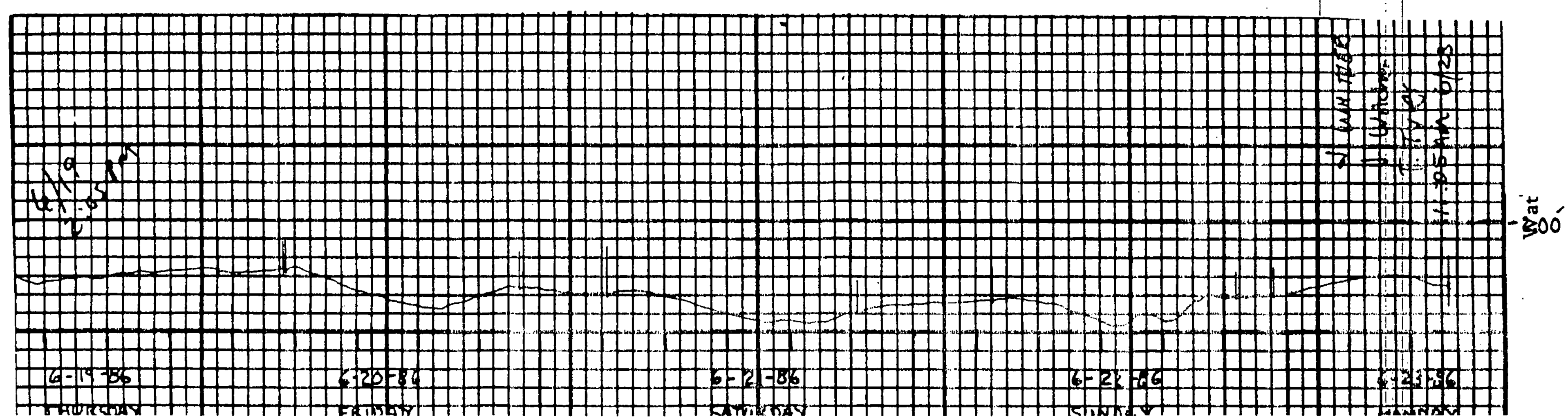


WELL NAME: HARRY BAILEY FRESH
DATES: JUNE 8-16,1986



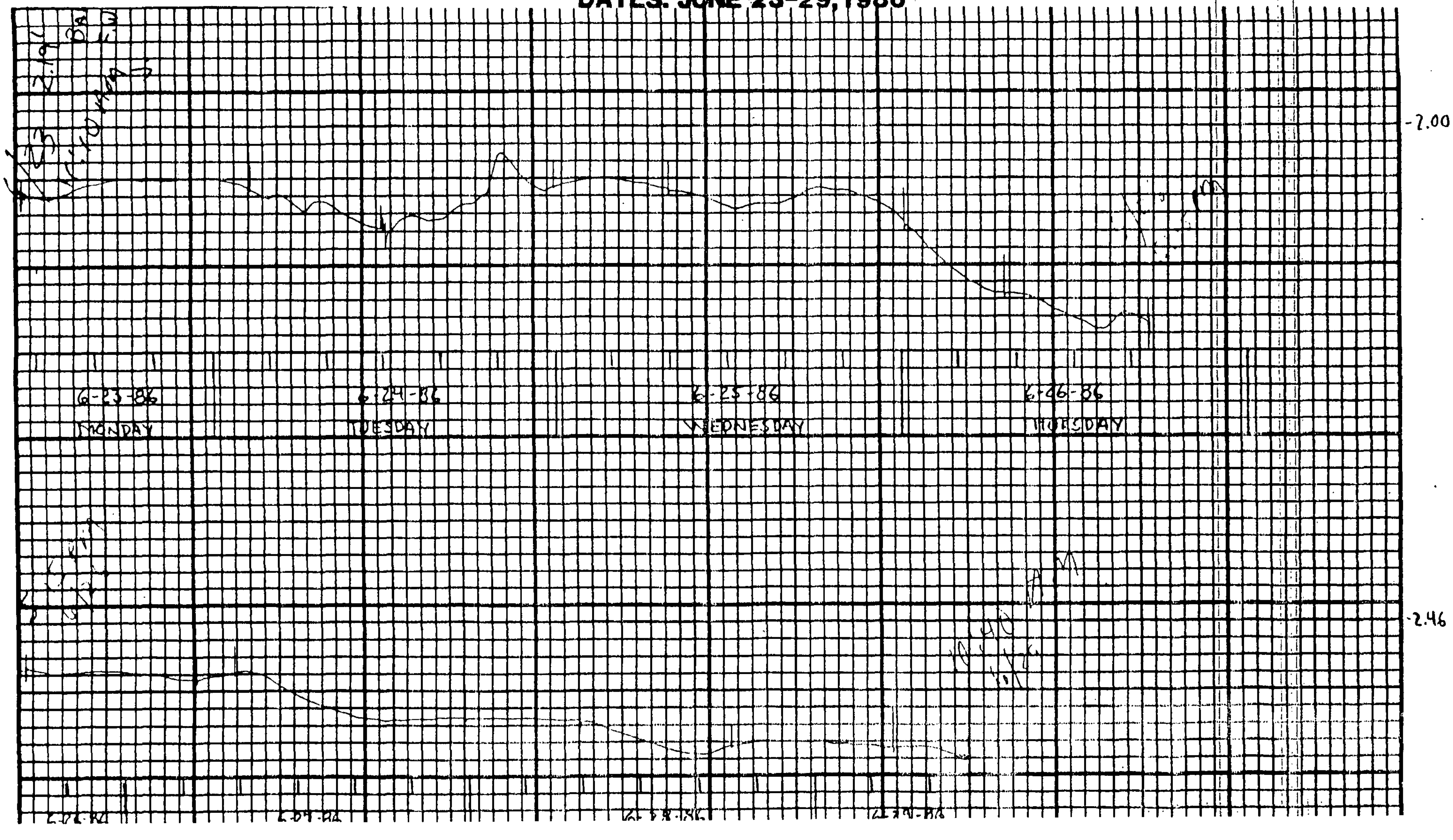
WELL NAME: HARRY BAILEY FRESH
DATES: JUNE 16-23,1986





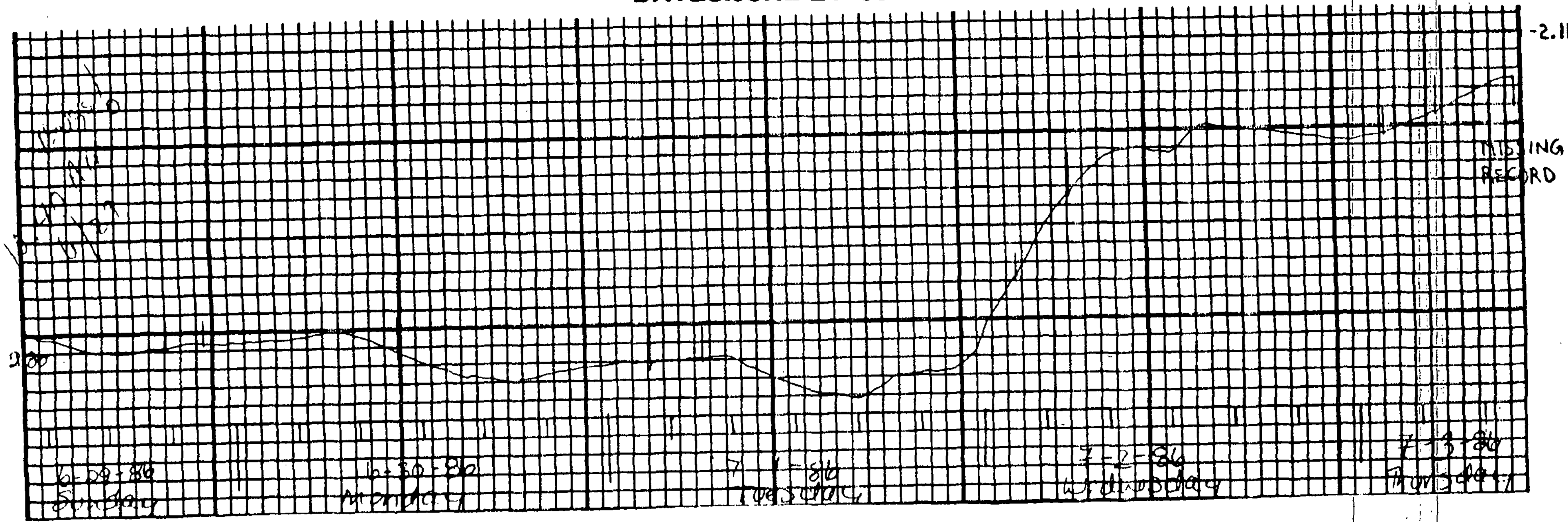
WELL NAME: HARRY BAILEY FRESH

DATES: JUNE 23-29,1986



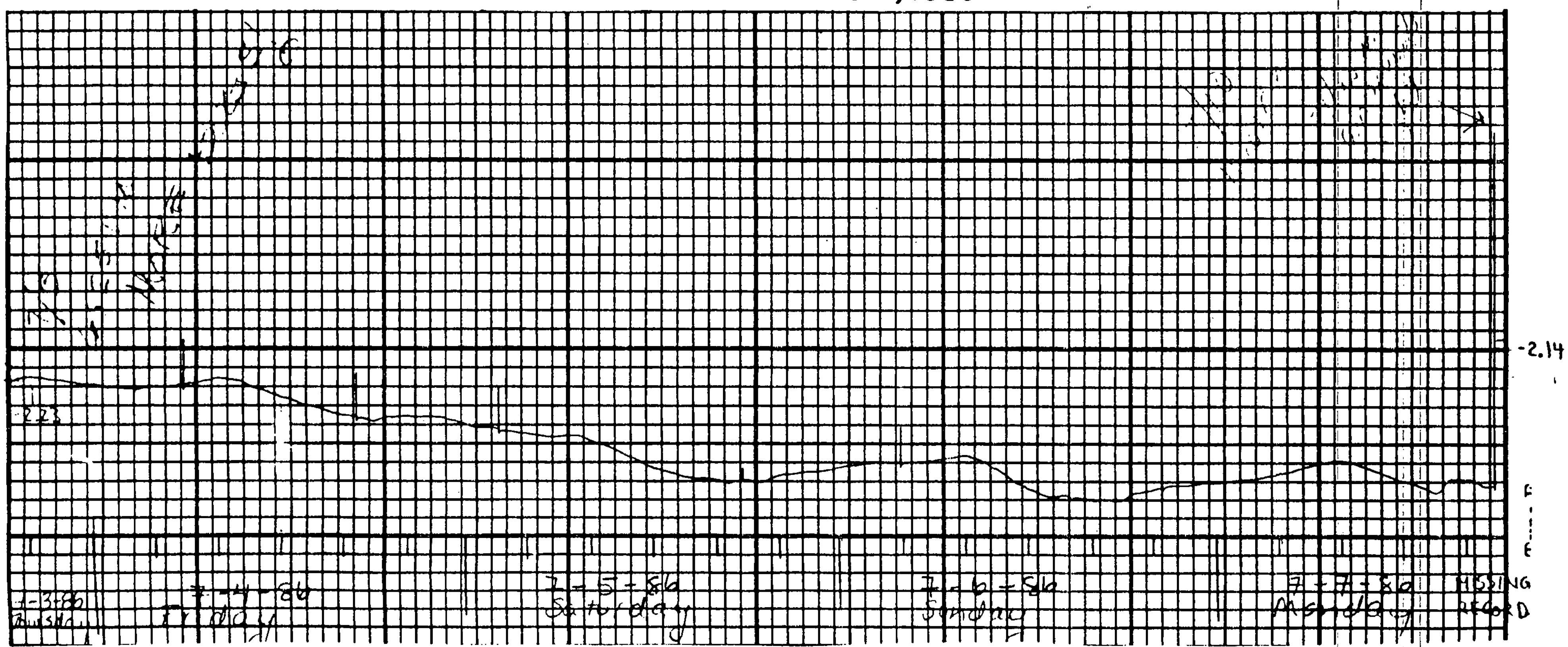
WELL NAME: HARRY BAILEY FRESH

DATES:JUNE 29–JULY 3



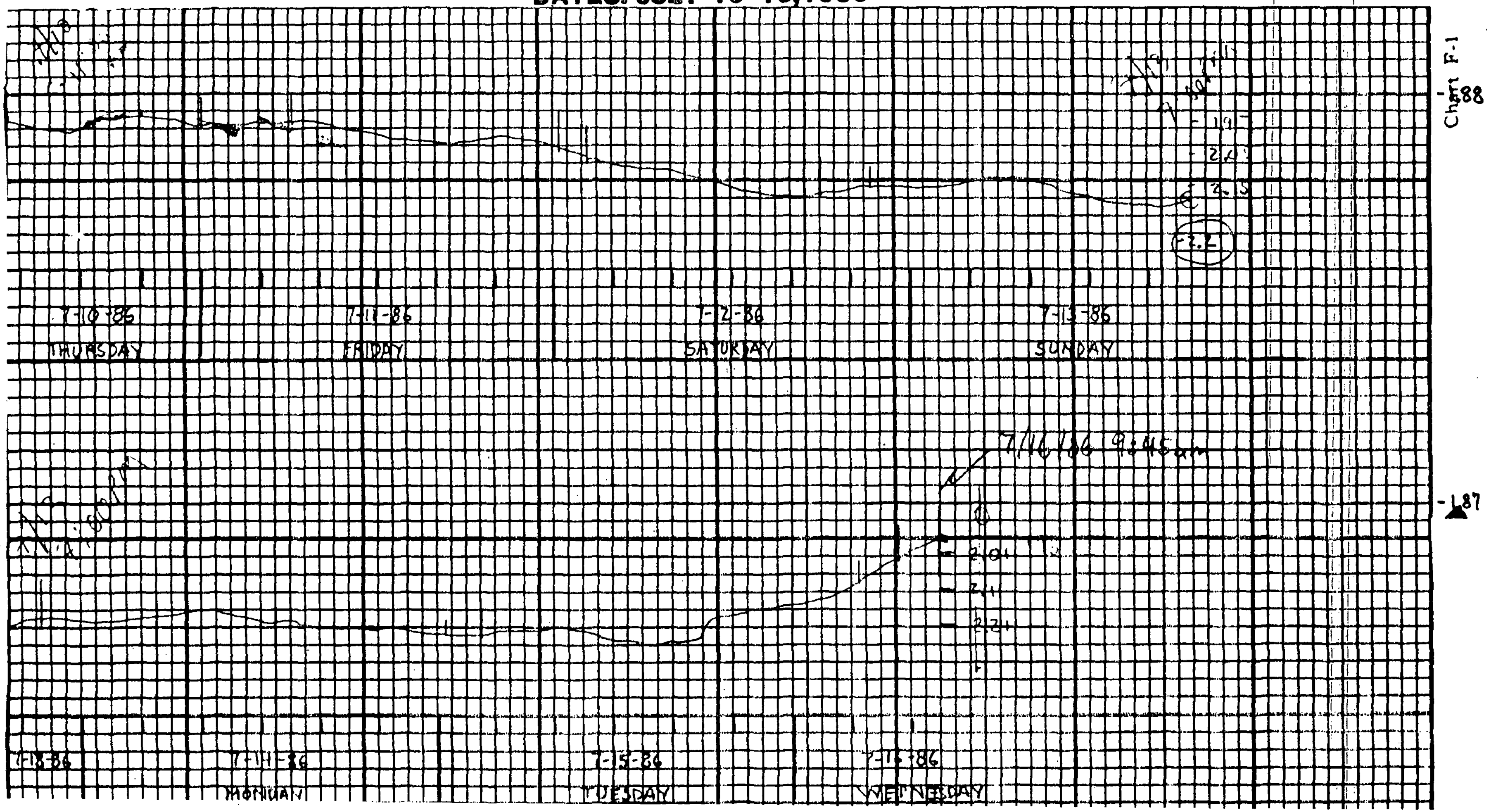
WELL NAME: HARRY BAILEY FRESH

JULY DATES: JULY 3-7,1986



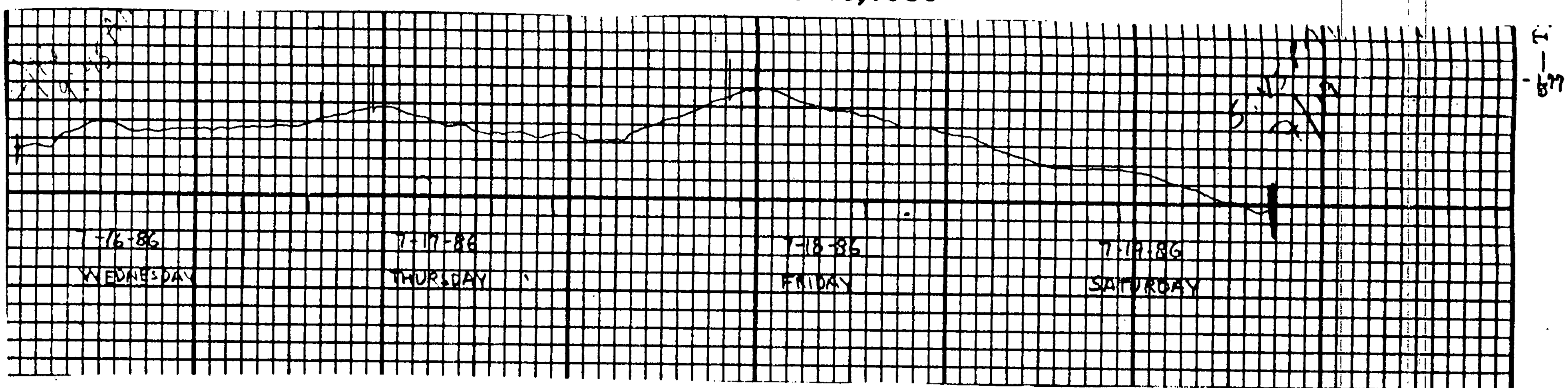
WELL NAME: HARRY BAILEY FRESH

DATES: JULY 10–16,1986



WELL NAME: HARRY BAILEY FRESH

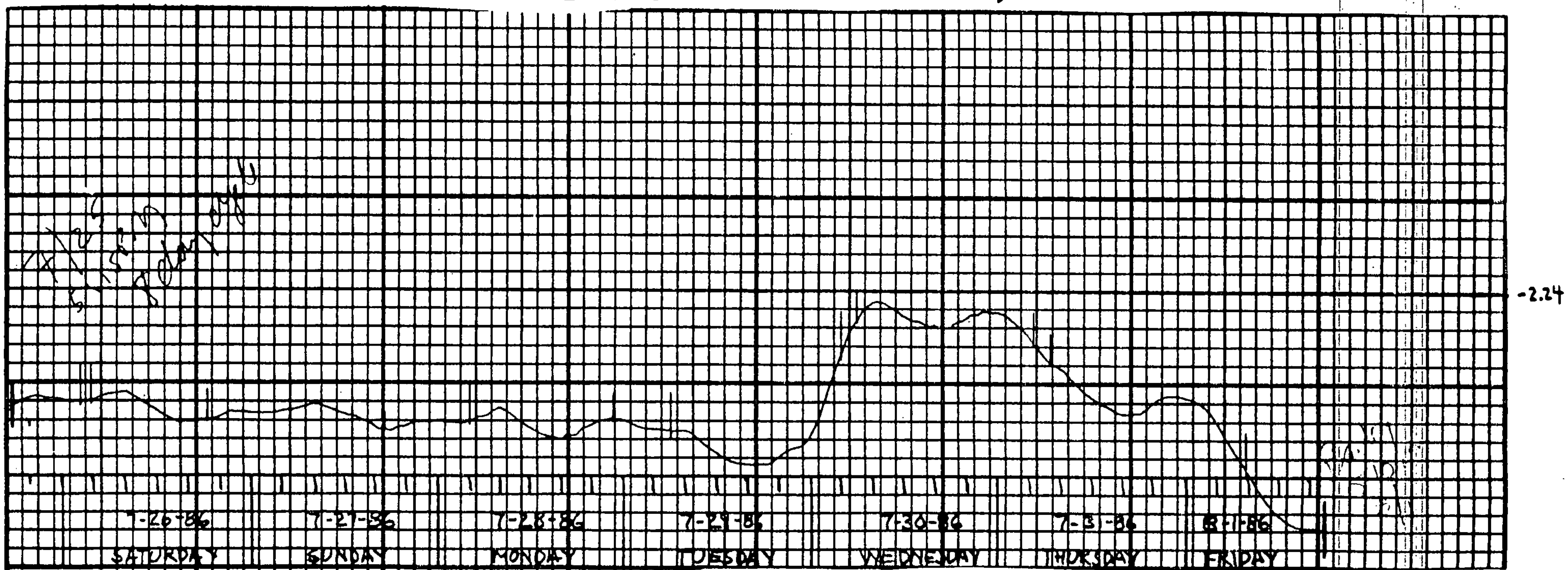
DATES : JULY 16-19,1986



WELL NAME: HARRY BAILEY FRESH

DATES: JULY 19-25,1986

WELL NAME: HARRY BAILEY
DATES: JULY 26-AUGUST 1,1986



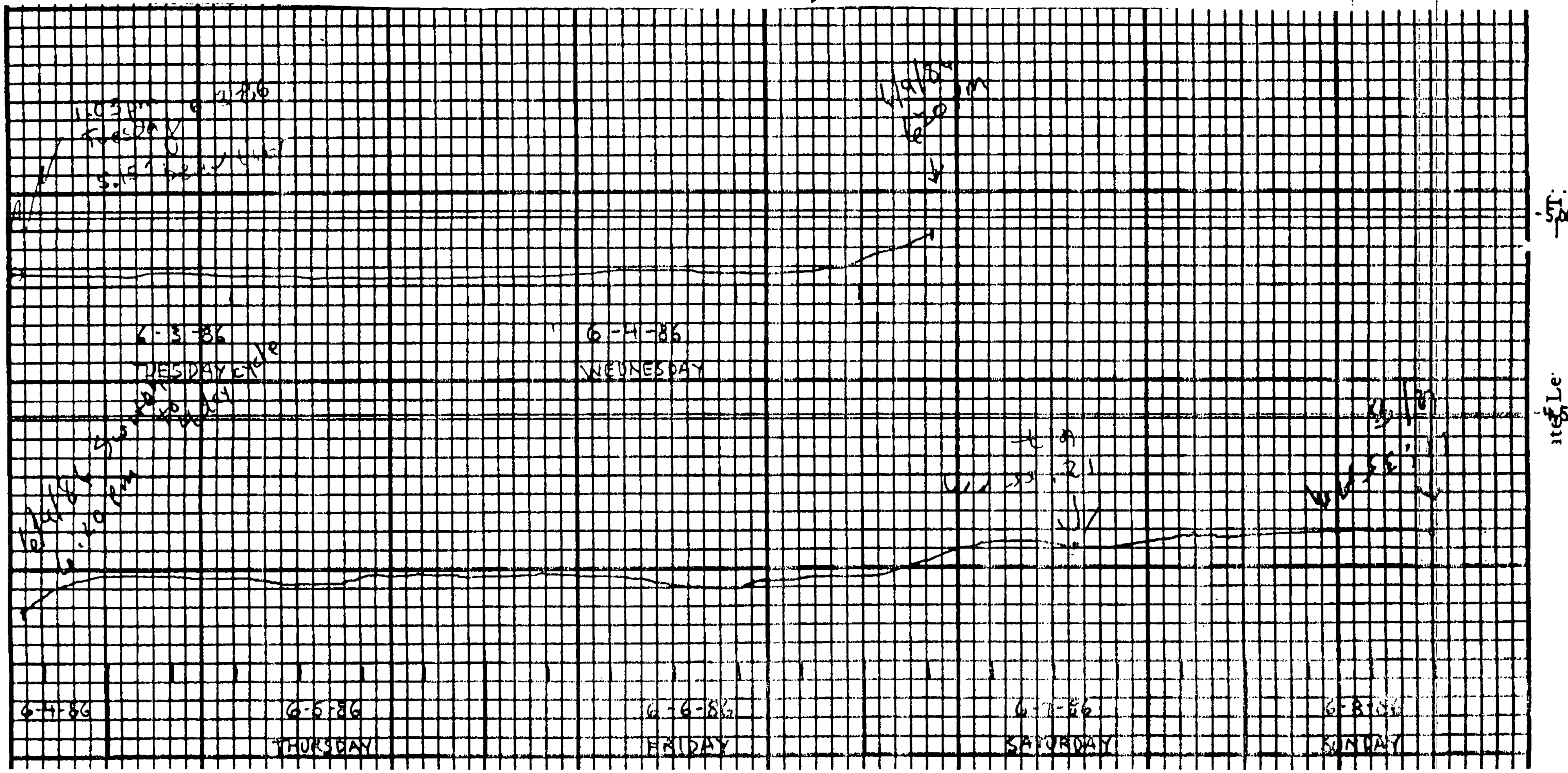
Appendix 2

Analog Record of Water Levels

Tom Ryan Well

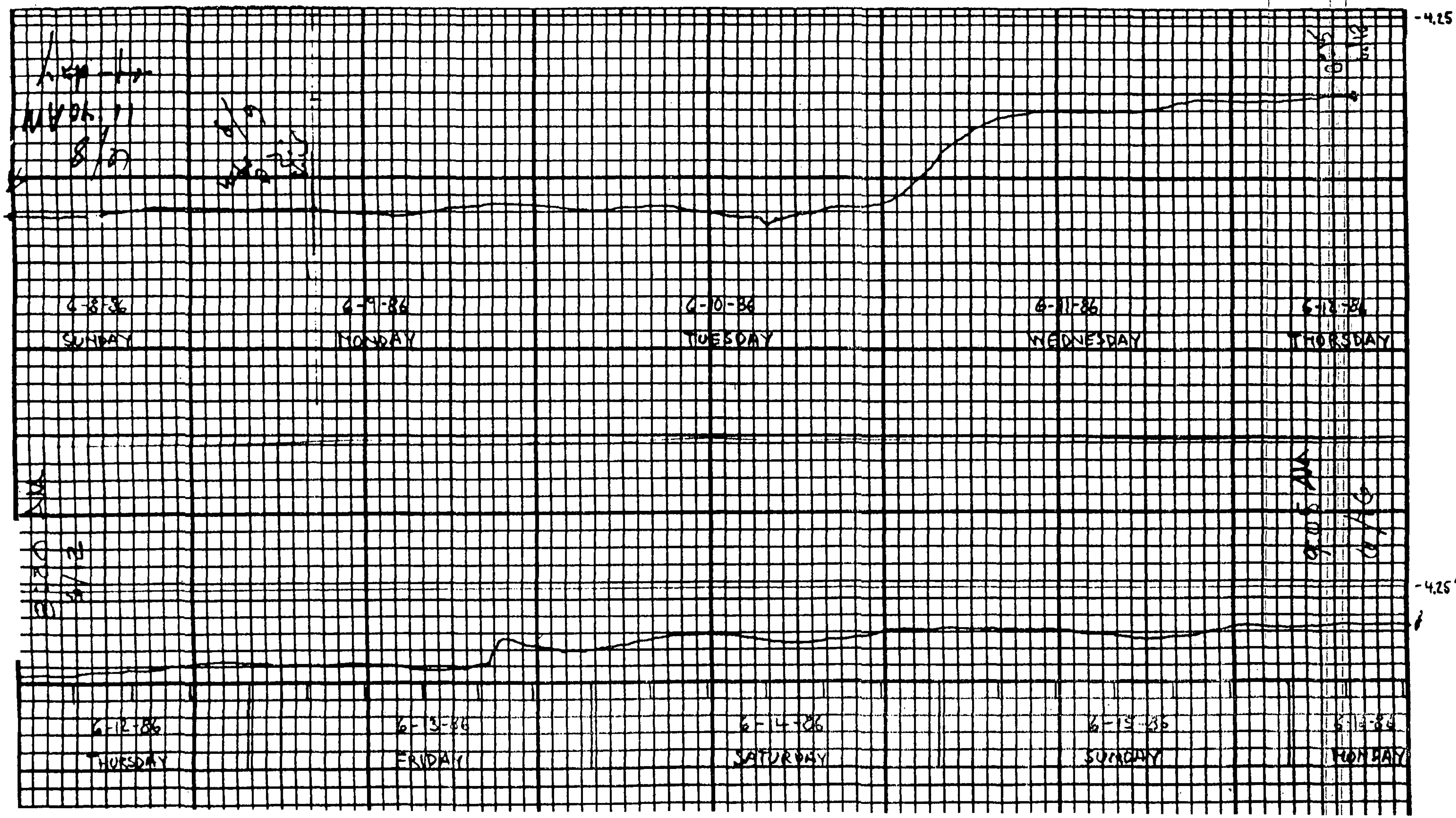
WELL NAME: TOM RYAN

DATES: JUNE 3-8,1986



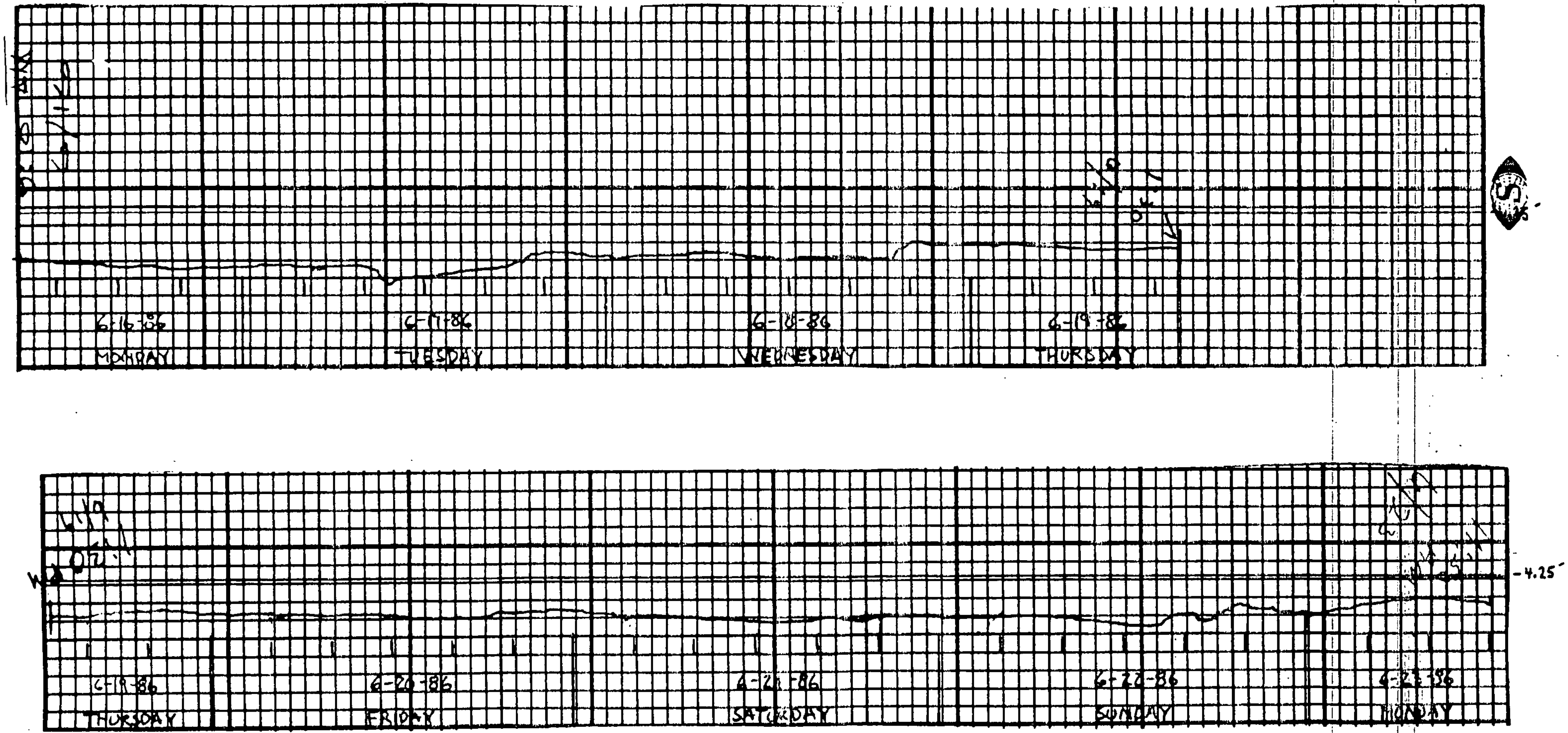
WELL NAME: TOM RYAN

DATES: JUNE 8-16,1986



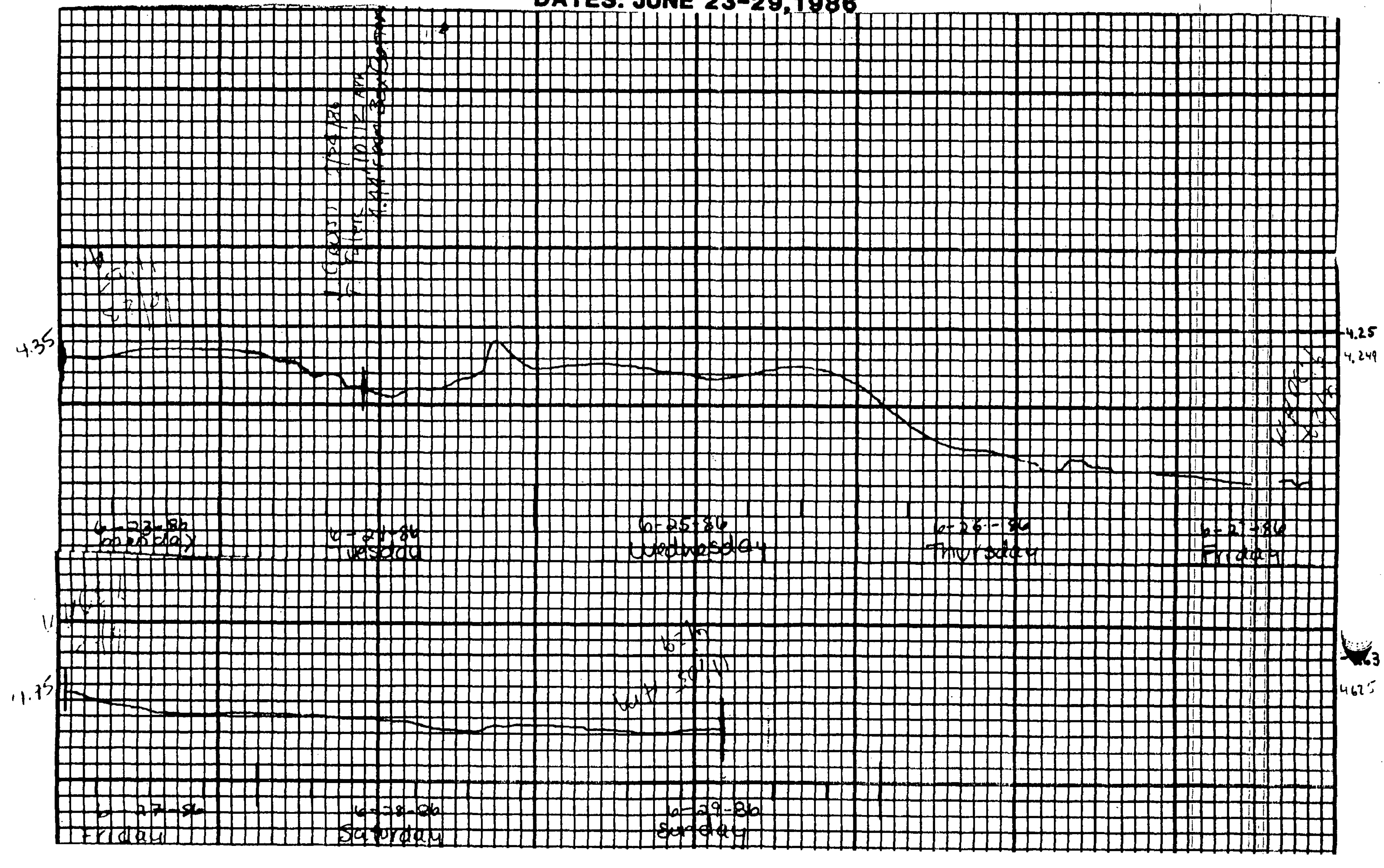
WELL NAME: TOM RYAN

DATES: JUNE 16-23,1986



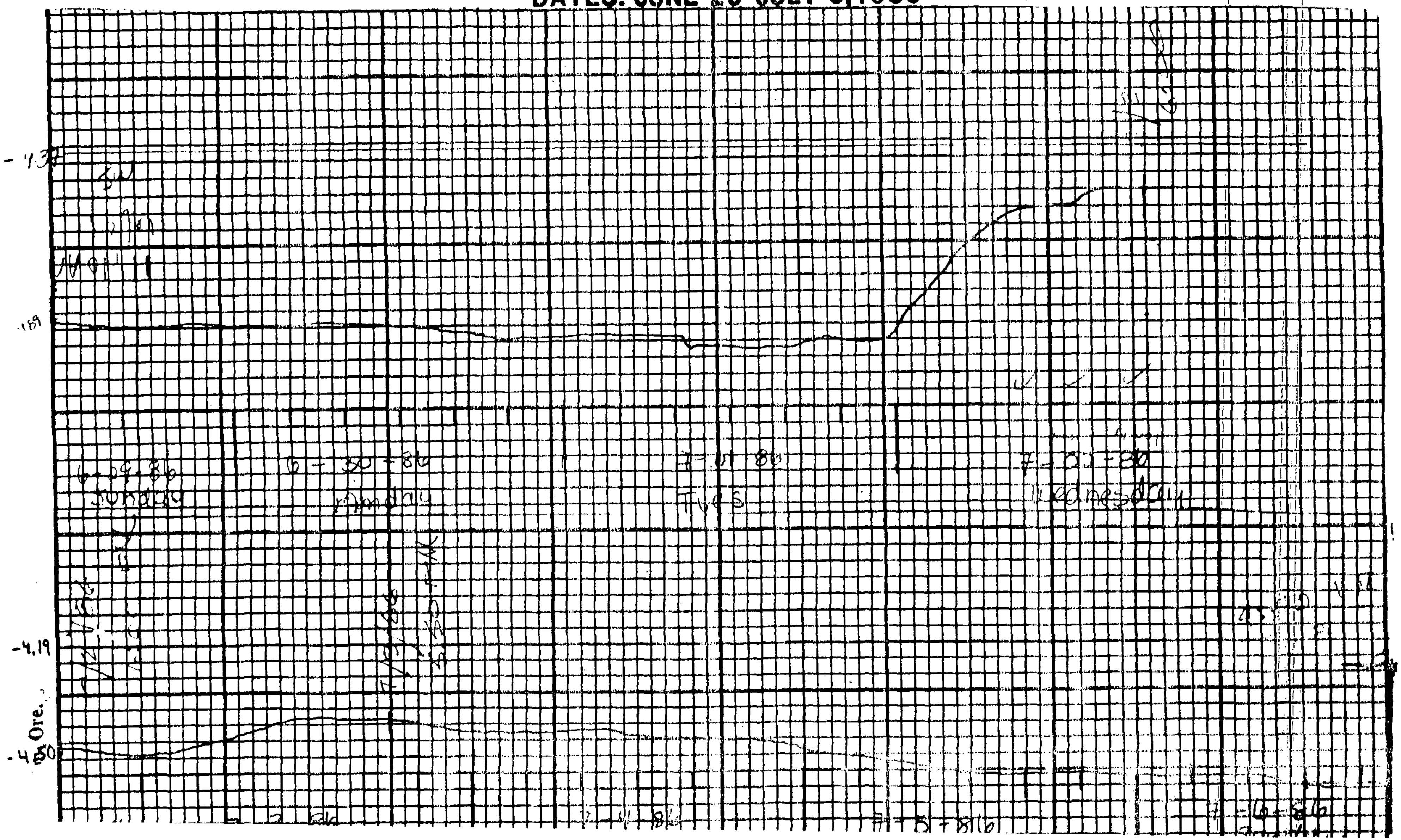
WELL NAME: TOM RYAN

DATES: JUNE 23-29, 1986



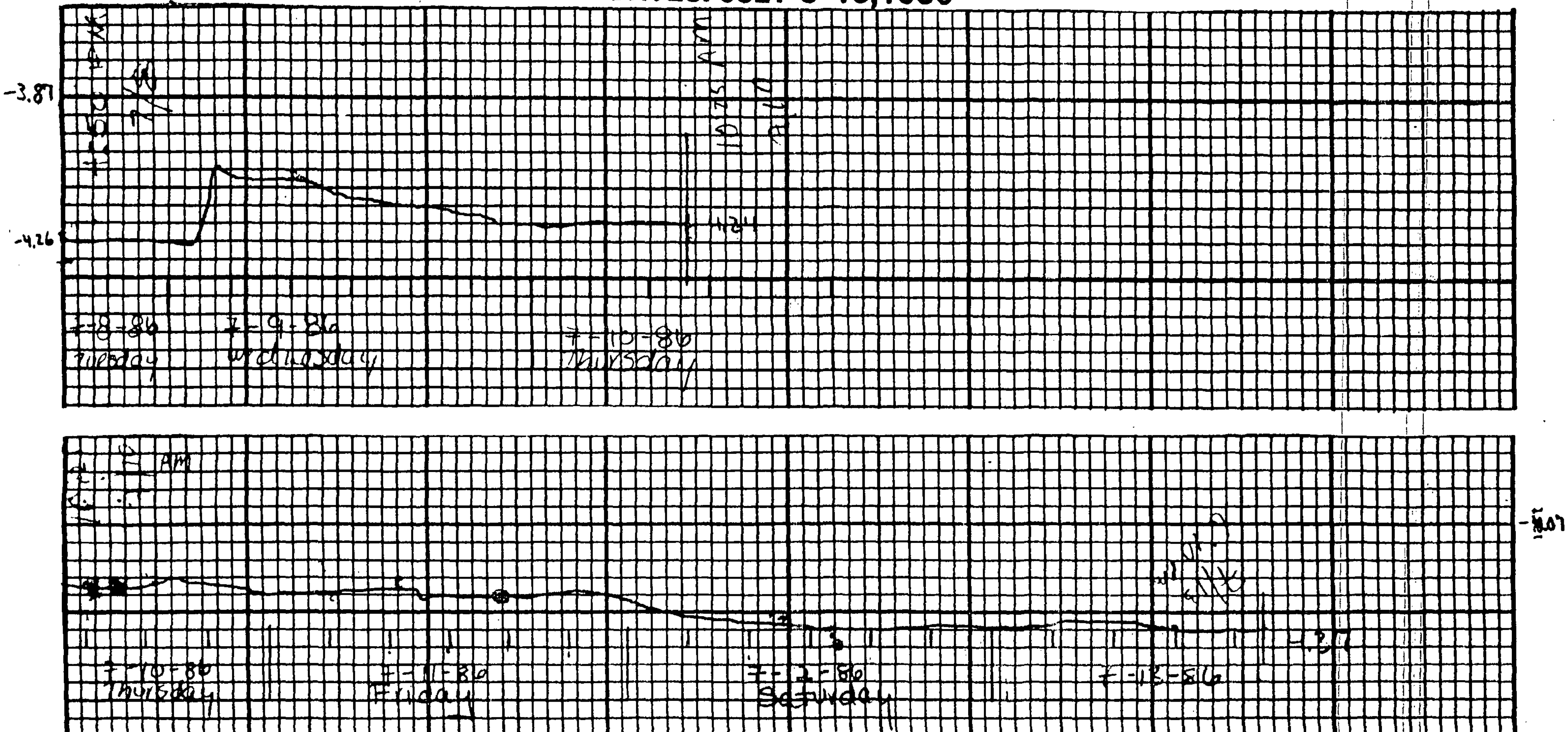
WELL NAME: TOM RYAN

DATES: JUNE 29-JULY 6,1986



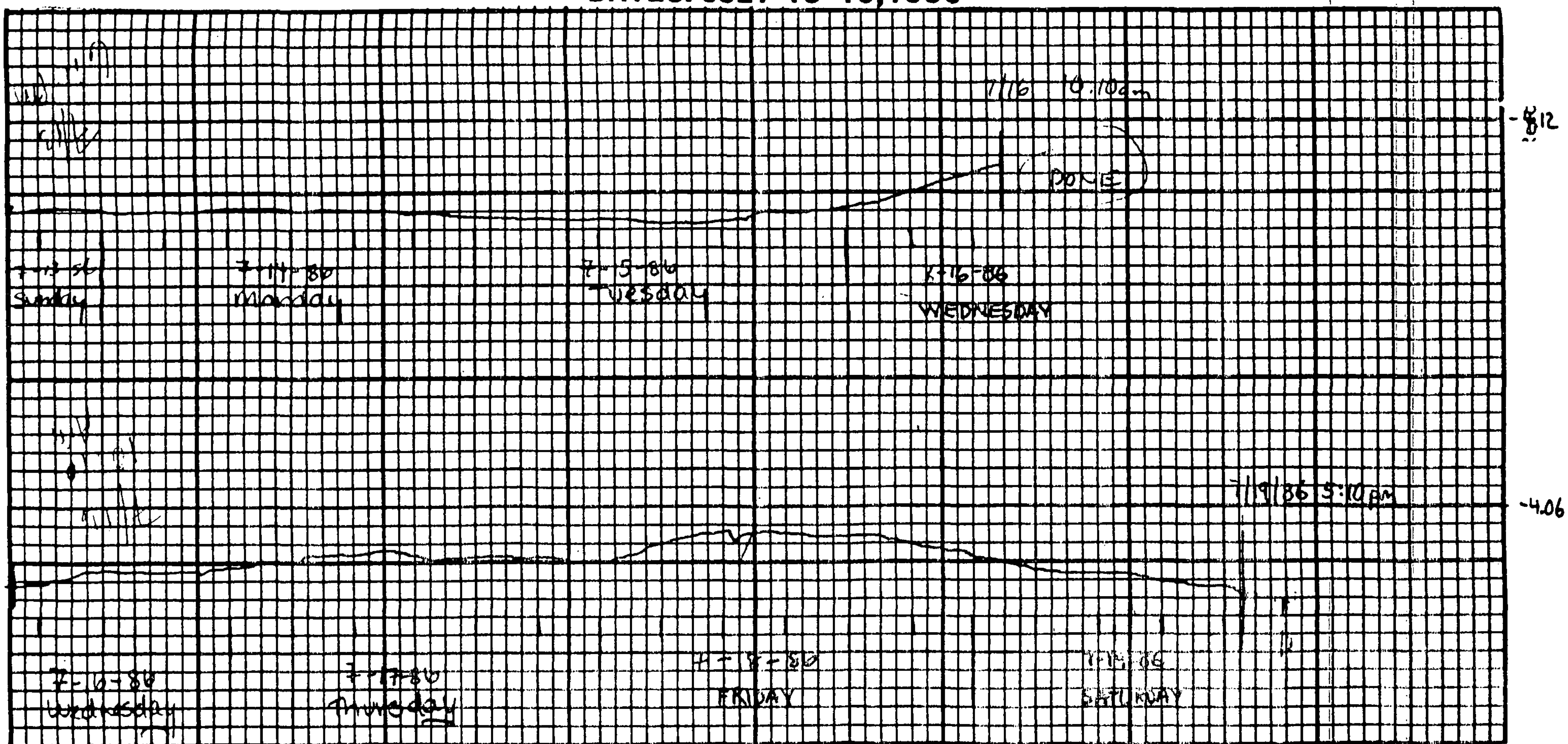
WELL NAME: TOM RYAN

DATES: JULY 8-13,1986



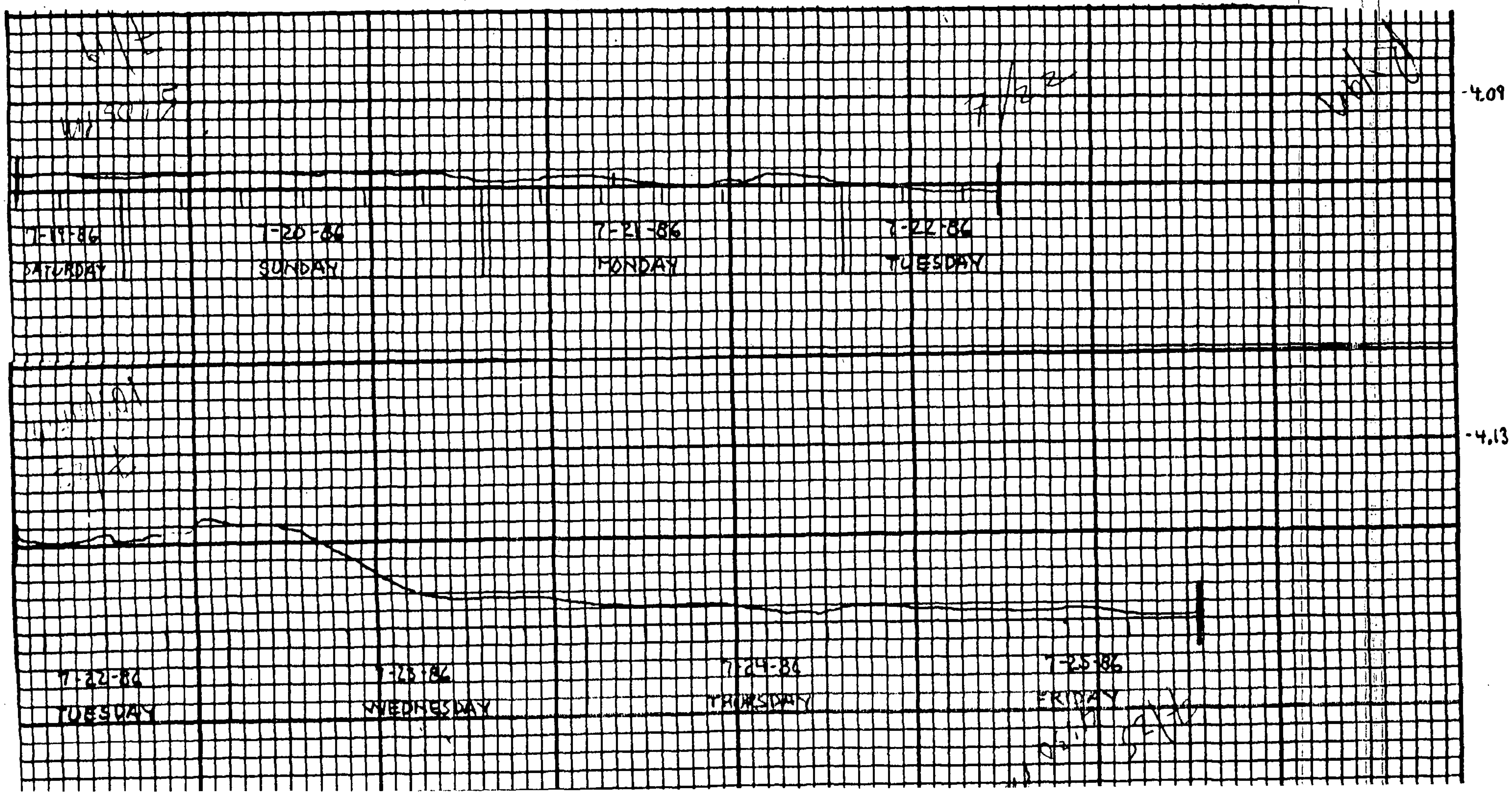
WELL NAME: TOM RYAN

DATES: JULY 13-19,1986



WELL NAME: TOM RYAN

DATES: JULY 19-25,1986



WELL NAME: TOM RYAN

DATES: JULY 26-AUGUST 1,1986

Appendix 4

Digital Record of Water Levels

Harry Bailey Fresh Well

DATE	TIME	BAILEY.FRESH	DATE	TIME	BAILEY.FRESH
06/02/86	06:00 PM	-3.06	06/10/86	08:00 PM	-2.87
06/02/86	08:00 PM	-3.07	06/11/86	12:00 AM	-2.79
06/03/86	12:00 AM	-3.10	06/11/86	04:00 AM	-2.57
06/03/86	04:00 AM	-3.11	06/11/86	08:00 AM	-2.42
06/03/86	08:00 AM	-3.09	06/11/86	12:00 PM	-2.43
06/03/86	12:00 PM	-3.16	06/11/86	04:00 PM	-2.45
06/03/86	04:00 PM	-3.22	06/11/86	08:00 PM	-2.40
06/03/86	08:00 PM	-3.19	06/12/86	12:00 AM	-2.38
06/04/86	12:00 AM	-3.18	06/12/86	04:00 AM	-2.37
06/04/86	04:00 AM	-3.17	06/12/86	08:00 AM	-2.34
06/04/86	08:00 AM	-3.13	06/12/86	12:00 PM	-2.39
06/04/86	12:00 PM	-3.20	06/12/86	04:00 PM	-2.38
06/04/86	04:00 PM	-3.18	06/12/86	08:00 PM	-2.36
06/04/86	06:30 PM	-3.11	06/13/86	12:00 AM	-2.32
06/04/86	08:00 PM	-3.03	06/13/86	04:00 AM	-2.31
06/05/86	12:00 AM	-2.94	06/13/86	08:00 AM	-2.30
06/05/86	04:00 AM	-2.93	06/13/86	12:00 PM	-2.37
06/05/86	08:00 AM	-2.92	06/13/86	04:00 PM	-2.38
06/05/86	12:00 PM	-2.99	06/13/86	08:00 PM	-2.24
06/05/86	04:00 PM	-3.00	06/14/86	12:00 AM	-2.23
06/05/86	08:00 PM	-2.97	06/14/86	04:00 AM	-2.18
06/06/86	12:00 AM	-2.95	06/14/86	08:00 AM	-2.16
06/06/86	04:00 AM	-2.94	06/14/86	12:00 PM	-2.21
06/06/86	08:00 AM	-2.93	06/14/86	04:00 PM	-2.25
06/06/86	12:00 PM	-3.01	06/14/86	08:00 PM	-2.23
06/06/86	04:00 PM	-3.06	06/15/86	12:00 AM	-2.18
06/06/86	08:00 PM	-3.02	06/15/86	04:00 AM	-2.16
06/07/86	12:00 AM	-2.97	06/15/86	08:00 AM	-2.15
06/07/86	04:00 AM	-2.89	06/15/86	12:00 PM	-2.22
06/07/86	08:00 AM	-2.82	06/15/86	04:00 PM	-2.25
06/07/86	12:00 PM	-2.89	06/15/86	08:00 PM	-2.22
06/07/86	04:00 PM	-2.93	06/16/86	12:00 AM	-2.17
06/07/86	08:00 PM	-2.87	06/16/86	04:00 AM	-2.14
06/08/86	12:00 AM	-2.82	06/16/86	08:00 AM	-2.12
06/08/86	04:00 AM	-2.80	06/16/86	12:00 PM	-2.22
06/08/86	08:00 AM	-2.79	06/16/86	04:00 PM	-2.27
06/08/86	12:00 PM	-2.85	06/16/86	08:00 PM	-2.25
06/08/86	04:00 PM	-2.91	06/17/86	12:00 AM	-2.22
06/08/86	08:00 PM	-2.87	06/17/86	04:00 AM	-2.20
06/09/86	12:00 AM	-2.82	06/17/86	08:00 AM	-2.20
06/09/86	04:00 AM	-2.80	06/17/86	12:00 PM	-2.25
06/09/86	08:00 AM	-2.79	06/17/86	04:00 PM	-2.30
06/09/86	12:00 PM	-2.87	06/17/86	08:00 PM	-2.16
06/09/86	04:00 PM	-2.90	06/18/86	12:00 AM	-2.16
06/09/86	08:00 PM	-2.86	06/18/86	04:00 AM	-2.16
06/10/86	12:00 AM	-2.82	06/18/86	08:00 AM	-2.14
06/10/86	04:00 AM	-2.81	06/18/86	12:00 PM	-2.20
06/10/86	08:00 AM	-2.78	06/18/86	04:00 PM	-2.23
06/10/86	12:00 PM	-2.87	06/18/86	08:00 PM	-2.12
06/10/86	04:00 PM	-2.92	06/19/86	12:00 AM	-2.11

DATE	TIME	BAILEY.FRESH	DATE	TIME	BAILEY.FRESH
06/19/86	04:00 AM	-2.13	06/27/86	12:00 PM	-2.67
06/19/86	08:00 AM	-2.12	06/27/86	04:00 PM	-2.73
06/19/86	12:00 PM	-2.12	06/27/86	08:00 PM	-2.74
06/19/86	04:00 PM	-2.16	06/28/86	12:00 AM	-2.74
06/19/86	08:00 PM	-2.15	06/28/86	04:00 AM	-2.74
06/20/86	12:00 AM	-2.13	06/28/86	08:00 AM	-2.75
06/20/86	04:00 AM	-2.13	06/28/86	12:00 PM	-2.80
06/20/86	08:00 AM	-2.12	06/28/86	04:00 PM	-2.85
06/20/86	12:00 PM	-2.18	06/28/86	08:00 PM	-2.81
06/20/86	04:00 PM	-2.23	06/29/86	12:00 AM	-2.81
06/20/86	08:00 PM	-2.20	06/29/86	04:00 AM	-2.82
06/21/86	12:00 AM	-2.18	06/29/86	08:00 AM	-2.83
06/21/86	04:00 AM	-2.19	06/29/86	12:00 PM	-2.87
06/21/86	08:00 AM	-2.20	06/29/86	04:00 PM	-2.90
06/21/86	12:00 PM	-2.25	06/29/86	08:00 PM	-2.89
06/21/86	04:00 PM	-2.27	06/30/86	12:00 AM	-2.89
06/21/86	08:00 PM	-2.24	06/30/86	04:00 AM	-2.88
06/22/86	12:00 AM	-2.22	06/30/86	08:00 AM	-2.87
06/22/86	04:00 AM	-2.21	06/30/86	12:00 PM	-2.95
06/22/86	08:00 AM	-2.21	06/30/86	04:00 PM	-2.99
06/22/86	12:00 PM	-2.26	06/30/86	08:00 PM	-2.99
06/22/86	04:00 PM	-2.26	07/01/86	12:00 AM	-2.97
06/22/86	08:00 PM	-2.19	07/01/86	04:00 AM	-2.96
06/23/86	12:00 AM	-2.19	07/01/86	08:00 AM	-2.95
06/23/86	04:00 AM	-2.15	07/01/86	12:00 PM	-3.03
06/23/86	08:00 AM	-2.14	07/01/86	04:00 PM	-3.07
06/23/86	12:00 PM	-2.20	07/01/86	08:00 PM	-3.00
06/23/86	04:00 PM	-2.17	07/02/86	12:00 AM	-2.91
06/23/86	08:00 PM	-2.15	07/02/86	04:00 AM	-2.61
06/24/86	12:00 AM	-2.15	07/02/86	08:00 AM	-2.43
06/24/86	04:00 AM	-2.21	07/02/86	12:00 PM	-2.43
06/24/86	08:00 AM	-2.22	07/02/86	04:00 PM	-2.36
06/24/86	12:00 PM	-2.29	07/02/86	08:00 PM	-2.37
06/24/86	04:00 PM	-2.27	07/03/86	12:00 AM	-2.39
06/24/86	08:00 PM	-2.10	07/03/86	04:00 AM	-2.34
06/25/86	12:00 AM	-2.18	07/03/86	08:00 AM	-2.26
06/25/86	04:00 AM	-2.15	07/03/86	08:00 PM	-2.22
06/25/86	08:00 AM	-2.18	07/04/86	12:00 AM	-2.34
06/25/86	12:00 PM	-2.23	07/04/86	04:00 AM	-2.24
06/25/86	04:00 PM	-2.22	07/04/86	08:00 AM	-2.22
06/25/86	08:00 PM	-2.18	07/04/86	12:00 PM	-2.27
06/26/86	12:00 AM	-2.26	07/04/86	04:00 PM	-2.32
06/26/86	04:00 AM	-2.42	07/04/86	08:00 PM	-2.32
06/26/86	08:00 AM	-2.48	07/05/86	12:00 AM	-2.34
06/26/86	12:00 PM	-2.55	07/05/86	04:00 AM	-2.37
06/26/86	04:00 PM	-2.54	07/05/86	08:00 AM	-2.39
06/26/86	08:00 PM	-2.60	07/05/86	12:00 PM	-2.45
06/27/86	12:00 AM	-2.60	07/05/86	04:00 PM	-2.49
06/27/86	04:00 AM	-2.63	07/05/86	08:00 PM	-2.48
06/27/86	08:00 AM	-2.60	07/06/86	12:00 AM	-2.46

DATE	TIME	BAILEY.FRESH	DATE	TIME	BAILEY.FRESH
07/06/86	04:00 AM	-2.45	07/17/86	04:00 AM	-1.93
07/06/86	08:00 AM	-2.43	07/17/86	08:00 AM	-1.89
07/06/86	12:00 PM	-2.51	07/17/86	12:00 PM	-1.92
07/06/86	04:00 PM	-2.54	07/17/86	04:00 PM	-1.96
07/06/86	08:00 PM	-2.52	07/17/86	08:00 PM	-1.95
07/07/86	12:00 AM	-2.50	07/18/86	12:00 AM	-1.97
07/07/86	04:00 AM	-2.47	07/18/86	04:00 AM	-1.91
07/07/86	08:00 AM	-2.44	07/18/86	08:00 AM	-1.84
07/07/86	12:00 PM	-2.50	07/18/86	12:00 PM	-1.86
07/07/86	04:00 PM	-2.49	07/18/86	04:00 PM	-1.90
07/10/86	12:00 PM	-1.96	07/18/86	08:00 PM	-1.93
07/10/86	04:00 PM	-1.98	07/19/86	12:00 AM	-1.98
07/10/86	08:00 PM	-1.94	07/19/86	04:00 AM	-2.03
07/11/86	12:00 AM	-1.97	07/19/86	08:00 AM	-2.03
07/11/86	04:00 AM	-1.96	07/19/86	12:00 PM	-2.07
07/11/86	08:00 AM	-1.96	07/19/86	04:00 PM	-2.13
07/11/86	12:00 PM	-2.00	07/19/86	08:00 PM	-2.09
07/11/86	04:00 PM	-2.02	07/20/86	12:00 AM	-2.09
07/11/86	08:00 PM	-2.00	07/20/86	04:00 AM	-2.07
07/12/86	12:00 AM	-2.03	07/20/86	08:00 AM	-2.06
07/12/86	04:00 AM	-2.08	07/20/86	12:00 PM	-2.09
07/12/86	08:00 AM	-2.10	07/20/86	04:00 PM	-2.13
07/12/86	12:00 PM	-2.15	07/20/86	08:00 PM	-2.13
07/12/86	04:00 PM	-2.17	07/21/86	12:00 AM	-2.14
07/12/86	08:00 PM	-2.16	07/21/86	04:00 AM	-2.11
07/13/86	12:00 AM	-2.15	07/21/86	08:00 AM	-2.10
07/13/86	04:00 AM	-2.13	07/21/86	12:00 PM	-2.15
07/13/86	08:00 AM	-2.12	07/21/86	04:00 PM	-2.14
07/13/86	12:00 PM	-2.17	07/21/86	08:00 PM	-2.11
07/13/86	04:00 PM	-2.20	07/22/86	12:00 AM	-2.14
07/13/86	08:00 PM	-2.20	07/22/86	04:00 AM	-2.16
07/14/86	12:00 AM	-2.20	07/22/86	08:00 AM	-2.15
07/14/86	04:00 AM	-2.19	07/22/86	12:00 PM	-2.18
07/14/86	08:00 AM	-2.17	07/22/86	04:00 PM	-2.16
07/14/86	12:00 PM	-2.20	07/22/86	08:00 PM	-2.13
07/14/86	04:00 PM	-2.22	07/23/86	12:00 AM	-2.10
07/14/86	08:00 PM	-2.23	07/23/86	04:00 AM	-2.12
07/15/86	12:00 AM	-2.24	07/23/86	08:00 AM	-2.23
07/15/86	04:00 AM	-2.23	07/23/86	12:00 PM	-2.36
07/15/86	08:00 AM	-2.22	07/23/86	04:00 PM	-2.41
07/15/86	12:00 PM	-2.25	07/23/86	08:00 PM	-2.41
07/15/86	04:00 PM	-2.26	07/24/86	12:00 AM	-2.42
07/15/86	08:00 PM	-2.18	07/24/86	04:00 AM	-2.43
07/16/86	12:00 AM	-2.15	07/24/86	08:00 AM	-2.41
07/16/86	04:00 AM	-2.10	07/24/86	12:00 PM	-2.47
07/16/86	08:00 AM	-2.00	07/24/86	04:00 PM	-2.47
07/16/86	12:00 PM	-1.99	07/24/86	08:00 PM	-2.46
07/16/86	04:00 PM	-1.93	07/25/86	12:00 AM	-2.47
07/16/86	08:00 PM	-1.95	07/25/86	04:00 AM	-2.47
07/17/86	12:00 AM	-1.94	07/25/86	08:00 AM	-2.46

DATE	TIME	BAILEY.FRESH
07/25/86	12:00 PM	-2.51
07/25/86	04:00 PM	-2.53
07/25/86	08:00 PM	-2.53
07/26/86	12:00 AM	-2.54
07/26/86	04:00 AM	-2.54
07/26/86	08:00 AM	-2.52
07/26/86	12:00 PM	-2.56
07/26/86	04:00 PM	-2.60
07/26/86	08:00 PM	-2.58
07/27/86	12:00 AM	-2.57
07/27/86	04:00 AM	-2.57
07/27/86	08:00 AM	-2.55
07/27/86	12:00 PM	-2.57
07/27/86	04:00 PM	-2.60
07/27/86	08:00 PM	-2.61
07/28/86	12:00 AM	-2.59
07/28/86	04:00 AM	-2.59
07/28/86	08:00 AM	-2.56
07/28/86	12:00 PM	-2.60
07/28/86	04:00 PM	-2.64
07/28/86	08:00 PM	-2.60
07/29/86	12:00 AM	-2.59
07/29/86	04:00 AM	-2.61
07/29/86	08:00 AM	-2.61
07/29/86	12:00 PM	-2.67
07/29/86	04:00 PM	-2.72
07/29/86	08:00 PM	-2.69
07/30/86	12:00 AM	-2.63
07/30/86	04:00 AM	-2.42
07/30/86	08:00 AM	-2.28
07/30/86	12:00 PM	-2.30
07/30/86	04:00 PM	-2.33
07/30/86	08:00 PM	-2.32
07/31/86	12:00 AM	-2.30
07/31/86	04:00 AM	-2.35
07/31/86	08:00 AM	-2.45
07/31/86	12:00 PM	-2.52
07/31/86	04:00 PM	-2.57
07/31/86	08:00 PM	-2.54
08/01/86	12:00 AM	-2.52
08/01/86	04:00 AM	-2.58
08/01/86	08:00 AM	-2.72
08/01/86	12:00 PM	-2.84
08/01/86	04:00 PM	-2.88

Appendix 5

Digital Record of Water Levels

Tom Ryan Well

DATE	TIME	RYAN	DATE	TIME	RYAN
06/03/86	04:00 PM	-5.15	06/12/86	04:00 AM	-4.50
06/03/86	08:00 PM	-5.15	06/12/86	08:00 AM	-4.48
06/04/86	12:00 AM	-5.16	06/12/86	12:00 PM	-4.50
06/04/86	04:00 AM	-5.16	06/12/86	04:00 PM	-4.49
06/04/86	08:00 AM	-5.14	06/12/86	08:00 PM	-4.47
06/04/86	12:00 PM	-5.15	06/13/86	12:00 AM	-4.47
06/04/86	04:00 PM	-5.12	06/13/86	04:00 AM	-4.48
06/04/86	08:00 PM	-4.98	06/13/86	08:00 AM	-4.48
06/05/86	12:00 AM	-4.93	06/13/86	12:00 PM	-4.49
06/05/86	04:00 AM	-4.93	06/13/86	04:00 PM	-4.48
06/05/86	08:00 AM	-4.93	06/13/86	08:00 PM	-4.42
06/05/86	12:00 PM	-4.95	06/14/86	12:00 AM	-4.43
06/05/86	04:00 PM	-4.94	06/14/86	04:00 AM	-4.40
06/05/86	08:00 PM	-4.92	06/14/86	08:00 AM	-4.39
06/06/86	12:00 AM	-4.93	06/14/86	12:00 PM	-4.41
06/06/86	04:00 AM	-4.93	06/14/86	04:00 PM	-4.41
06/06/86	08:00 AM	-4.93	06/14/86	08:00 PM	-4.38
06/06/86	12:00 PM	-4.95	06/15/86	12:00 AM	-4.37
06/06/86	04:00 PM	-4.96	06/15/86	04:00 AM	-4.37
06/06/86	08:00 PM	-4.94	06/15/86	08:00 AM	-4.37
06/07/86	12:00 AM	-4.93	06/15/86	12:00 PM	-4.39
06/07/86	04:00 AM	-4.89	06/15/86	04:00 PM	-4.40
06/07/86	08:00 AM	-4.84	06/15/86	08:00 PM	-4.37
06/07/86	12:00 PM	-4.85	06/16/86	12:00 AM	-4.37
06/07/86	04:00 PM	-4.86	06/16/86	04:00 AM	-4.36
06/07/86	08:00 PM	-4.83	06/16/86	08:00 AM	-4.36
06/08/86	12:00 AM	-4.83	06/16/86	12:00 PM	-4.39
06/08/86	04:00 AM	-4.82	06/16/86	04:00 PM	-4.40
06/08/86	08:00 AM	-4.81	06/16/86	08:00 PM	-4.41
06/08/86	12:00 PM	-4.82	06/17/86	12:00 AM	-4.40
06/08/86	04:00 PM	-4.84	06/17/86	04:00 AM	-4.40
06/08/86	08:00 PM	-4.83	06/17/86	08:00 AM	-4.40
06/09/86	12:00 AM	-4.82	06/17/86	12:00 PM	-4.43
06/09/86	04:00 AM	-4.82	06/17/86	04:00 PM	-4.41
06/09/86	08:00 AM	-4.82	06/17/86	08:00 PM	-4.36
06/09/86	12:00 PM	-4.83	06/18/86	12:00 AM	-4.37
06/09/86	04:00 PM	-4.83	06/18/86	04:00 AM	-4.37
06/09/86	08:00 PM	-4.81	06/18/86	08:00 AM	-4.36
06/10/86	12:00 AM	-4.81	06/18/86	12:00 PM	-4.38
06/10/86	04:00 AM	-4.82	06/18/86	04:00 PM	-4.37
06/10/86	08:00 AM	-4.81	06/18/86	08:00 PM	-4.33
06/10/86	12:00 PM	-4.83	06/19/86	12:00 AM	-4.34
06/10/86	04:00 PM	-4.87	06/19/86	04:00 AM	-4.34
06/10/86	08:00 PM	-4.82	06/19/86	08:00 AM	-4.35
06/11/86	12:00 AM	-4.80	06/19/86	12:00 PM	-4.35
06/11/86	04:00 AM	-4.65	06/19/86	04:00 PM	-4.35
06/11/86	08:00 AM	-4.55	06/19/86	08:00 PM	-4.34
06/11/86	12:00 PM	-4.53	06/20/86	12:00 AM	-4.34
06/11/86	04:00 PM	-4.53	06/20/86	04:00 AM	-4.34
06/11/86	08:00 PM	-4.51	06/20/86	08:00 AM	-4.35
06/12/86	12:00 AM	-4.50	06/20/86	12:00 PM	-4.35

DATE	TIME	RYAN	DATE	TIME	RYAN
06/20/86	04:00 PM	-4.36	06/29/86	04:00 AM	-4.86
06/20/86	08:00 PM	-4.35	06/29/86	08:00 AM	-4.86
06/21/86	12:00 AM	-4.34	06/29/86	12:00 PM	-4.89
06/21/86	04:00 AM	-4.36	06/29/86	04:00 PM	-4.89
06/21/86	08:00 AM	-4.36	06/29/86	08:00 PM	-4.89
06/21/86	12:00 PM	-4.37	06/30/86	12:00 AM	-4.90
06/21/86	04:00 PM	-4.37	06/30/86	04:00 AM	-4.89
06/21/86	08:00 PM	-4.36	06/30/86	08:00 AM	-4.89
06/22/86	12:00 AM	-4.36	06/30/86	12:00 PM	-4.90
06/22/86	04:00 AM	-4.36	06/30/86	04:00 PM	-4.91
06/22/86	08:00 AM	-4.36	06/30/86	08:00 PM	-4.94
06/22/86	12:00 PM	-4.38	07/01/86	12:00 AM	-4.93
06/22/86	04:00 PM	-4.36	07/01/86	04:00 AM	-4.93
06/22/86	08:00 PM	-4.33	07/01/86	08:00 AM	-4.93
06/23/86	12:00 AM	-4.35	07/01/86	12:00 PM	-4.98
06/23/86	04:00 AM	-4.33	07/01/86	04:00 PM	-4.97
06/23/86	08:00 AM	-4.31	07/01/86	08:00 PM	-4.95
06/23/86	12:00 PM	-4.35	07/02/86	12:00 AM	-4.93
06/23/86	04:00 PM	-4.34	07/02/86	04:00 AM	-4.69
06/23/86	08:00 PM	-4.32	07/02/86	08:00 AM	-4.57
06/24/86	12:00 AM	-4.32	07/02/86	12:00 PM	-4.54
06/24/86	04:00 AM	-4.35	07/02/86	04:00 PM	-4.50
06/24/86	08:00 AM	-4.40	07/02/86	08:00 PM	-4.50
06/24/86	12:00 PM	-4.47	07/03/86	12:00 AM	-4.53
06/24/86	04:00 PM	-4.45	07/03/86	04:00 AM	-4.50
06/24/86	08:00 PM	-4.39	07/03/86	08:00 AM	-4.46
06/25/86	12:00 AM	-4.38	07/03/86	12:00 PM	-4.42
06/25/86	04:00 AM	-4.37	07/03/86	04:00 PM	-4.42
06/25/86	08:00 AM	-4.38	07/03/86	08:00 PM	-4.43
06/25/86	12:00 PM	-4.41	07/04/86	12:00 AM	-4.46
06/25/86	04:00 PM	-4.40	07/04/86	04:00 AM	-4.47
06/25/86	08:00 PM	-4.37	07/04/86	08:00 AM	-4.46
06/26/86	12:00 AM	-4.43	07/04/86	12:00 PM	-4.47
06/26/86	04:00 AM	-4.55	07/04/86	04:00 PM	-4.48
06/26/86	08:00 AM	-4.63	07/04/86	08:00 PM	-4.49
06/26/86	12:00 PM	-4.65	07/05/86	12:00 AM	-4.52
06/26/86	04:00 PM	-4.66	07/05/86	04:00 AM	-4.54
06/26/86	08:00 PM	-4.70	07/05/86	08:00 AM	-4.57
06/27/86	12:00 AM	-4.70	07/05/86	12:00 PM	-4.60
06/27/86	04:00 AM	-4.73	07/05/86	04:00 PM	-4.60
06/27/86	08:00 AM	-4.72	07/05/86	08:00 PM	-4.60
06/27/86	12:00 PM	-4.77	07/06/86	12:00 AM	-4.61
06/27/86	04:00 PM	-4.81	07/06/86	04:00 AM	-4.61
06/27/86	08:00 PM	-4.82	07/06/86	08:00 AM	-4.61
06/28/86	12:00 AM	-4.82	07/06/86	12:00 PM	-4.64
06/28/86	04:00 AM	-4.82	07/06/86	04:00 PM	-4.65
06/28/86	08:00 AM	-4.83	07/08/86	08:00 PM	-4.27
06/28/86	12:00 PM	-4.85	07/09/86	12:00 AM	-4.27
06/28/86	04:00 PM	-4.87	07/09/86	04:00 AM	-4.08
06/28/86	08:00 PM	-4.85	07/09/86	08:00 FM	-4.10
06/29/86	12:00 AM	-4.85	07/09/86	12:00 PM	-4.15

DATE	TIME	RYAN	DATE	TIME	RYAN
07/17/86	08:00 PM	-4.19	07/26/86	04:00 AM	-4.55
07/18/86	12:00 AM	-4.20	07/26/86	08:00 AM	-4.53
07/18/86	04:00 AM	-4.16	07/26/86	12:00 PM	-4.55
07/18/86	08:00 AM	-4.12	07/26/86	04:00 PM	-4.56
07/18/86	12:00 PM	-4.13	07/26/86	08:00 PM	-4.55
07/18/86	04:00 PM	-4.14	07/27/86	12:00 AM	-4.55
07/18/86	08:00 PM	-4.15	07/27/86	04:00 AM	-4.55
07/19/86	12:00 AM	-4.19	07/27/86	08:00 AM	-4.54
07/19/86	04:00 AM	-4.23	07/27/86	12:00 PM	-4.54
07/19/86	08:00 AM	-4.23	07/27/86	04:00 PM	-4.55
07/19/86	12:00 PM	-4.26	07/27/86	08:00 PM	-4.55
07/19/86	04:00 PM	-4.27	07/28/86	12:00 AM	-4.55
07/19/86	08:00 PM	-4.28	07/28/86	04:00 AM	-4.55
07/20/86	12:00 AM	-4.30	07/28/86	08:00 AM	-4.54
07/20/86	04:00 AM	-4.29	07/28/86	12:00 PM	-4.55
07/20/86	08:00 AM	-4.29	07/28/86	04:00 PM	-4.55
07/20/86	12:00 PM	-4.29	07/28/86	08:00 PM	-4.53
07/20/86	04:00 PM	-4.29	07/29/86	12:00 AM	-4.53
07/20/86	08:00 PM	-4.29	07/29/86	04:00 AM	-4.54
07/21/86	12:00 AM	-4.32	07/29/86	08:00 AM	-4.56
07/21/86	04:00 AM	-4.31	07/29/86	12:00 PM	-4.58
07/21/86	08:00 AM	-4.31	07/29/86	04:00 PM	-4.58
07/21/86	12:00 PM	-4.33	07/29/86	08:00 PM	-4.57
07/21/86	04:00 PM	-4.32	07/30/86	12:00 AM	-4.53
07/21/86	08:00 PM	-4.31	07/30/86	04:00 AM	-4.37
07/22/86	12:00 AM	-4.33	07/30/86	08:00 AM	-4.31
07/22/86	04:00 AM	-4.34	07/30/86	12:00 PM	-4.33
07/22/86	08:00 AM	-4.35	07/30/86	04:00 PM	-4.33
07/22/86	12:00 PM	-4.37	07/30/86	08:00 PM	-4.31
07/22/86	04:00 PM	-4.35	07/31/86	12:00 AM	-4.31
07/22/86	08:00 PM	-4.35	07/31/86	04:00 AM	-4.36
07/23/86	12:00 AM	-4.32	07/31/86	08:00 AM	-4.42
07/23/86	04:00 AM	-4.34	07/31/86	12:00 PM	-4.47
07/23/86	08:00 AM	-4.42	07/31/86	04:00 PM	-4.48
07/23/86	12:00 PM	-4.52	07/31/86	08:00 PM	-4.46
07/23/86	04:00 PM	-4.55	08/01/86	12:00 AM	-4.47
07/23/86	08:00 PM	-4.55	08/01/86	04:00 AM	-4.52
07/24/86	12:00 AM	-4.56	08/01/86	08:00 AM	-4.64
07/24/86	04:00 AM	-4.58	08/01/86	12:00 PM	-4.70
07/24/86	08:00 AM	-4.57	08/01/86	04:00 PM	-4.71
07/24/86	12:00 PM	-4.59			
07/24/86	04:00 PM	-4.61			
07/24/86	08:00 PM	-4.59			
07/25/86	12:00 AM	-4.60			
07/25/86	04:00 AM	-4.60			
07/25/86	08:00 AM	-4.60			
07/25/86	12:00 PM	-4.61			
07/25/86	04:00 PM	-4.62			
07/25/86	08:00 PM	-4.53			
07/26/86	12:00 AM	-4.54			

Appendix 6

Digital Record of Water Levels

Bailey 15

DATE	TIME	BAILEY #15
06/03/86	01:55 PM	-10.35
06/04/86	04:00 PM	-10.38
06/06/86	05:33 PM	-10.28
06/07/86	01:10 PM	-10.25
06/08/86	11:50 AM	-10.19
06/09/86	08:35 AM	-10.06
06/12/86	08:45 AM	-9.93
06/16/86	09:30 AM	-9.74
06/19/86	01:50 PM	-9.69
06/23/86	10:05 AM	-9.69
06/24/86	01:50 PM	-4.36
06/25/86	06:15 PM	-9.59
06/26/86	04:50 PM	-4.89
06/27/86	09:55 AM	-4.18
06/29/86	10:25 AM	-4.00
07/02/86	06:20 PM	-9.85
07/03/86	06:35 PM	-9.72
07/08/86	05:15 PM	-9.71
07/10/86	10:45 AM	-9.36
07/11/86	03:50 PM	-9.45
07/13/86	06:30 PM	-9.12
07/14/86	06:10 PM	-9.28
07/16/86	09:25 AM	-5.55
07/19/86	05:25 PM	-4.93
07/21/86	03:13 PM	-5.28
07/21/86	04:12 PM	-8.51
07/21/86	04:25 PM	-9.31
07/21/86	04:39 PM	-9.35
07/21/86	04:53 PM	-9.39
07/21/86	05:07 PM	-9.41
07/21/86	05:23 PM	-9.46
07/21/86	05:31 PM	-9.45
07/21/86	05:51 PM	-9.44
07/21/86	06:05 PM	-9.45
07/22/86	09:30 AM	-9.50
07/25/86	04:50 PM	-9.69
08/01/86	04:55 PM	-9.86

Appendix 7

Digital Record of Water Levels

Masson 16

DATE	TIME	MASSON #16
06/03/86	01:40 PM	-10.05
06/04/86	03:55 PM	-10.05
06/06/86	05:19 PM	-9.91
06/07/86	01:05 PM	-9.89
06/08/86	11:47 AM	-9.85
06/09/86	08:30 AM	-9.81
06/12/86	09:20 AM	-9.57
06/16/86	09:25 AM	-9.39
06/19/86	01:45 PM	-9.32
06/23/86	11:30 AM	-9.38
06/24/86	02:10 PM	-9.32
06/26/86	04:45 PM	-9.50
06/27/86	09:50 AM	-9.59
06/29/86	10:20 AM	-9.69
07/02/86	06:15 PM	-9.57
07/03/86	06:05 PM	-9.42
07/08/86	05:10 PM	-9.38
07/10/86	10:40 AM	-9.21
07/11/86	04:30 PM	-9.16
07/13/86	06:25 PM	-9.29
07/14/86	06:25 PM	-9.29
07/16/86	10:00 AM	-9.23
07/19/86	05:20 PM	-9.11
07/22/86	10:00 AM	-9.29
07/25/86	04:45 PM	-9.50
08/01/86	05:20 PM	-9.58

Appendix 8

Digital Record of Water Levels

Masson 19

DATE	TIME	MASSON #19
06/03/86	01:50 PM	-10.70
06/04/86	03:50 PM	-10.74
06/06/86	05:15 PM	-10.61
06/07/86	01:00 PM	-10.58
06/08/86	11:45 AM	-10.54
06/09/86	08:30 AM	-10.48
06/12/86	08:35 AM	-10.27
06/16/86	09:20 AM	-10.08
06/19/86	01:45 PM	-10.02
06/23/86	11:50 AM	-10.03
06/24/86	02:20 PM	-10.10
06/26/86	04:40 PM	-10.25
06/27/86	09:45 AM	-10.34
06/29/86	10:15 AM	-10.46
07/02/86	06:05 PM	-10.27
07/03/86	06:05 PM	-10.15
07/08/86	05:05 PM	-10.09
07/10/86	10:35 AM	-9.89
07/11/86	04:35 PM	-9.85
07/13/86	06:20 PM	-10.01
07/14/86	06:30 PM	-10.02
07/16/86	10:05 AM	-9.97
07/19/86	05:15 PM	-9.76
07/22/86	10:05 AM	-9.92
07/25/86	04:40 PM	-10.19
08/01/86	05:25 PM	-10.25

Appendix 9

Digital Record of Water Levels

Masson 21

DATE	TIME	MASSON #21	DATE	TIME	MASSON#21
06/03/86	02:25 PM	-36.84	06/24/86	12:01 PM	-46.18
06/04/86	04:05 PM	-36.88	06/24/86	12:01 PM	-47.10
06/06/86	05:38 PM	-36.75	06/24/86	12:01 PM	-47.90
06/07/86	01:15 PM	-36.72	06/24/86	12:02 PM	-48.15
06/08/86	11:55 AM	-36.67	06/24/86	12:02 PM	-48.38
06/09/86	08:40 AM	-36.67	06/24/86	12:03 PM	-48.47
06/12/86	08:50 AM	-36.47	06/24/86	12:03 PM	-48.44
06/16/86	09:35 AM	-36.26	06/24/86	12:04 PM	-49.20
06/19/86	01:53 PM	-36.20	06/24/86	12:05 PM	-48.93
06/23/86	10:10 AM	-36.17	06/24/86	12:06 PM	-49.63
06/23/86	01:00 PM	-46.04	06/24/86	12:07 PM	-47.67
06/23/86	01:00 PM	-44.65	06/24/86	12:08 PM	-48.45
06/23/86	01:00 PM	-38.84	06/24/86	12:09 PM	-48.92
06/23/86	01:00 PM	-36.05	06/24/86	12:10 PM	-48.63
06/23/86	02:30 PM	-36.40	06/24/86	12:12 PM	-48.93
06/23/86	02:30 PM	-43.50	06/24/86	12:14 PM	-48.94
06/23/86	02:30 PM	-44.50	06/24/86	12:16 PM	-48.97
06/23/86	02:30 PM	-45.30	06/24/86	12:18 PM	-48.75
06/23/86	02:31 PM	-45.40	06/24/86	12:20 PM	-48.48
06/23/86	02:31 PM	-45.70	06/24/86	12:25 PM	-48.98
06/23/86	02:31 PM	-46.00	06/24/86	12:30 PM	-48.83
06/23/86	02:31 PM	-46.30	06/24/86	12:35 PM	-48.63
06/23/86	02:32 PM	-46.30	06/24/86	12:45 PM	-48.87
06/23/86	02:32 PM	-46.30	06/24/86	01:00 PM	-49.02
06/23/86	02:33 PM	-46.40	06/24/86	01:30 PM	-49.17
06/23/86	02:33 PM	-46.10	06/24/86	02:00 PM	-49.34
06/23/86	02:34 PM	-46.50	06/24/86	03:30 PM	-49.38
06/23/86	02:35 PM	-46.60	06/24/86	04:40 PM	-49.62
06/23/86	02:36 PM	-46.60	06/24/86	06:20 PM	-49.80
06/23/86	02:37 PM	-46.65	07/21/86	04:05 PM	-39.50
06/23/86	02:39 PM	-46.80	07/21/86	04:05 PM	-36.90
06/23/86	02:40 PM	-46.85	07/21/86	04:05 PM	-36.50
06/23/86	02:42 PM	-46.87	07/21/86	04:06 PM	-36.45
06/23/86	02:44 PM	-47.00	07/21/86	04:06 PM	-36.40
06/23/86	02:46 PM	-47.01	07/21/86	04:06 PM	-36.40
06/23/86	02:48 PM	-47.04	07/21/86	04:06 PM	-36.40
06/23/86	02:50 PM	-47.04	07/21/86	04:07 PM	-36.40
06/23/86	02:55 PM	-47.05	07/21/86	04:07 PM	-36.40
06/23/86	03:00 PM	-47.03	07/21/86	04:08 PM	-36.40
06/23/86	03:05 PM	-47.07	07/21/86	04:08 PM	-36.40
06/23/86	03:15 PM	-47.14	07/21/86	04:09 PM	-36.40
06/23/86	03:30 PM	-47.17	07/21/86	04:10 PM	-36.40
06/23/86	03:45 PM	-47.25	07/21/86	04:20 PM	-36.32
06/23/86	04:00 PM	-47.32	07/21/86	04:35 PM	-36.25
06/23/86	04:15 PM	-47.32	07/21/86	04:50 PM	-36.21
06/23/86	04:30 PM	-47.45	07/21/86	05:05 PM	-36.17
06/23/86	06:30 PM	-47.48	07/21/86	05:20 PM	-36.15
06/24/86	12:00 PM	-36.34	07/21/86	05:35 PM	-36.11
06/24/86	12:00 PM	-44.20	07/21/86	05:50 PM	-36.11
06/24/86	12:00 PM	-44.98	07/21/86	06:05 PM	-36.11
06/24/86	12:00 PM	-48.16	07/22/86	09:35 AM	-36.10
06/24/86	12:01 PM	-46.00	07/25/86	04:55 PM	-36.32
			08/01/86	04:35 PM	-36.37

Appendix 10

Rio Grande Stage and Flow Data

Appendix 10 - Rio Grande Stage and Flow Data

	LEASBURG STATION		CABALLO STATION
DATE	STAGE (ft)	DISCHARGE (cfs)	DISCHARGE (cfs)
15-May-86	4.70	1600	2550
16-May-86	4.70	1625	2250
17-May-86	4.70	1625	2250
18-May-86	4.75	1650	2250
19-May-86	4.75	1650	2250
20-May-86	4.88	1775	2250
21-May-86	4.80	1750	2250
22-May-86	4.70	1650	2250
23-May-86	4.70	1650	2250
24-May-86	4.80	1700	2250
25-May-86	4.80	1700	2250
26-May-86	4.80	1700	2250
27-May-86	4.80	1700	2250
28-May-86	4.80	1700	2350
29-May-86	4.85	1750	2350
30-May-86	4.95	1825	2350
31-May-86	5.30	2200	2000
01-Jun-86	5.36	2280	1500
02-Jun-86	4.30	1200	1500
03-Jun-86	4.30	1200	1500
04-Jun-86	4.20	1200	2000
05-Jun-86	4.70	1700	2000
06-Jun-86	4.70	1700	2000
07-Jun-86	4.70	1700	2200
08-Jun-86	4.80	1800	2200
09-Jun-86	4.80	1800	2200
10-Jun-86	4.80	1800	2200
11-Jun-86	5.60	2500	3000
12-Jun-86	5.38	2250	3000
13-Jun-86	5.40	2275	3000
14-Jun-86	5.65	2665	3200
15-Jun-86	5.65	2665	3200
16-Jun-86	5.65	2665	3200
17-Jun-86	5.45	2350	3000
18-Jun-86	5.65	2500	3300
19-Jun-86	5.65	2500	3300
20-Jun-86	5.65	2500	3300
21-Jun-86	5.65	2500	3200
22-Jun-86	5.75	2800	3200
23-Jun-86	5.65	2500	3200
24-Jun-86	5.37	2324	2700
25-Jun-86	5.37	2324	2500
26-Jun-86	5.00	1918	2000
27-Jun-86	4.10	1650	2000
28-Jun-86	4.73	1700	2000
29-Jun-86	4.70	1620	2000
30-Jun-86	4.70	1620	2000

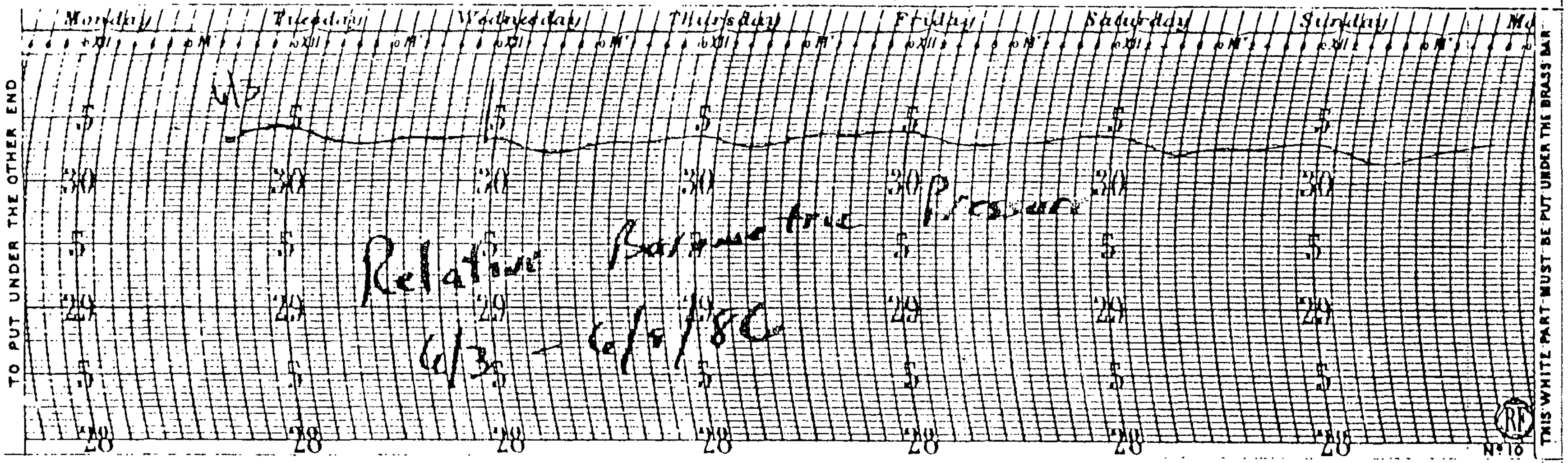
Appendix 10 - Rio Grande Stage and Flow Data

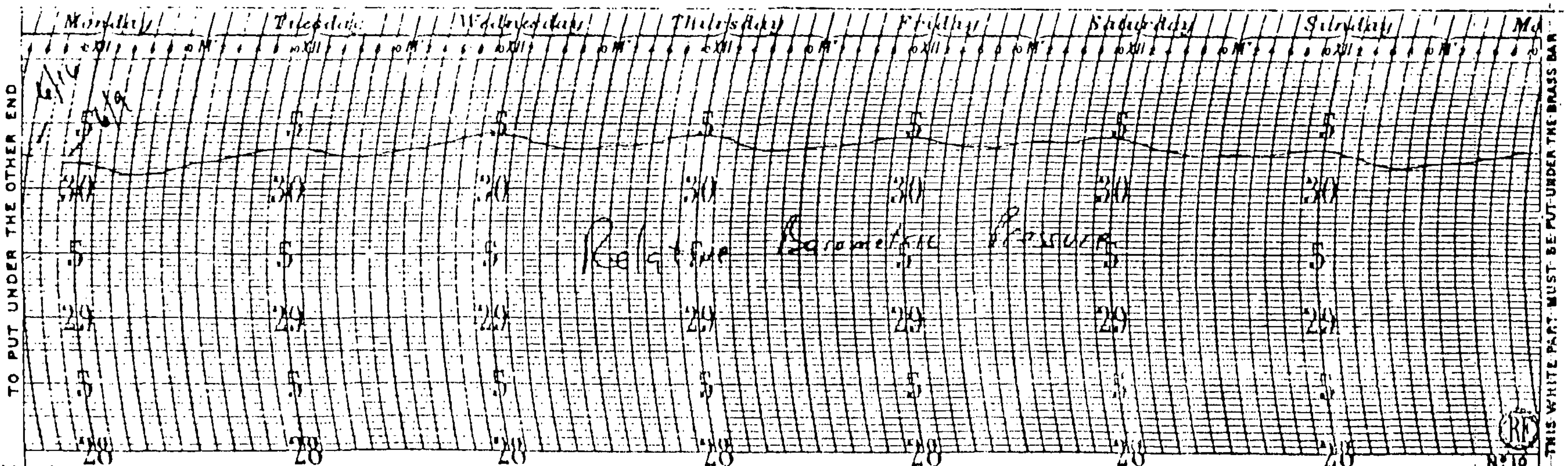
	LEASBURG STATION		CABALLO STATION
DATE	STAGE (ft)	DISCHARGE (cfs)	DISCHARGE (cfs)
01-Jul-86	4.70	1620	2000
02-Jul-86	5.30	2250	2800
03-Jul-86	5.40	2360	2800
04-Jul-86	5.40	2350	2800
05-Jul-86	5.30	2245	2650
06-Jul-86	5.25	2143	2650
07-Jul-86	5.25	2200	2650
08-Jul-86	5.35	2300	2650
09-Jul-86	6.15	3900	3300
10-Jul-86	5.90	3000	3300
11-Jul-86	5.90	3000	3300
12-Jul-86	5.60	2600	3050
13-Jul-86	5.70	2700	3050
14-Jul-86	5.70	2700	3050
15-Jul-86	5.70	2700	3050
16-Jul-86	5.95	3060	3700
17-Jul-86	6.10	3275	3700
18-Jul-86	6.20	3420	3700
19-Jul-86	5.80	2850	3100
20-Jul-86	5.60	2600	3100
21-Jul-86	5.72	2750	3100
22-Jul-86	5.65	2600	3100
23-Jul-86	5.45	2600	2700
24-Jul-86	5.30	2250	2700
25-Jul-86	5.25	2150	2700
26-Jul-86	5.20	2100	2700
27-Jul-86	5.20	2100	2700
28-Jul-86	5.20	2100	2700
29-Jul-86	5.20	2100	2700
30-Jul-86	5.35	2925	3500
31-Jul-86	5.35	2925	3000
01-Aug-86	4.95	1688	2500

Appendix 11

Barographs

RELATIVE BAROMETRIC PRESSURE
DATES: JUNE 3-16,1986





RELATIVE BAROMETRIC PRESSURE

DATES: JULY 14-28,1986