MONITOR WELL DATA SUMMARY

THIRD QUARTER 1979

JUNE 30 TO SEPTEMBER 30

by

K. P. McCarthy

NOVEMBER 1979

Checked by:

Dennis Goldman, Supervisor
Geology/Hydrology

Approved by:

C. A. Allen, Manager
Biological and Earth Sciences Br.

ACKNOWLEDGEMENTS

Many individuals have provided much appreciated technical advice and support. The author owes a special thanks to the following individuals.

Technical Contributors

C. A. Allen
D. W. Allman
D. M. Callan
D. Goldman
K. S. Kennedy
J. A. Martinez
S. Petty
S. G. Spencer
N. E. Stanley

Raft River Field Support

C. G. Cooper
D. L. Fredrickson
R. S. Hope
C. B. Leek
G. M. Millar
R. D. Meininger

CONTENTS

LIST OF TABLES AND FIGURES

SUMMARY

The Raft River Geothermal Area is developed with five deep production wells and two intermediate depth injection wells. Seven shallow-wells monitor dynamic pressure response and water quality.

General trends in the first quarter of 1979 (1-1 to 3-30) showed steady water level increase. Water levels slowly decreased midway through the second quarter as irrigation began in the valley. Water levels continued to decrease through most of the third quarter, but began to level out as irrigation pumping decreased.

Monitor well water level response reflects three influences:

1. Seasonal trends
2. Irrigation pumping
3. Geothermal production/injection testing.

Slight water level increases in all the monitor wells during deep geothermal injection into RRGI-7 could be interpreted as response to the test. However, this response could be due to irrigation pump shut-off during this time. Anomalous water level changes are attributed to inhomogeniety and anisotropism of aquifers, and fracture controlled hydraulic connections.

Conductivity of monitor well water samples has increased since construction. Water quality changes can probably be attributed to increased irrigation pumping during the growing season, flushing salts into the shallow aquifer.

Monitoring of water levels and quality will continue. Proposed future evaluation includes calculating barometric efficiency, pump testing of monitor wells, and monitoring irrigation pumps.

INTRODUCTION

Seven geothermal wells in the Raft River Valley of southcentral Idaho have been drilled. Construction of a 5 MW binary Power Plant is about 60% complete. The power plant, which uses isobutane as the working fluid, is scheduled to go into operation in late 1980. Environmental, hydrogeologic, and engineering data collection programs currently underway are designed to mitigate impact, define the resource, and develop new analytical methods.

This report is first in a series of quarterly reports which summarize monitor well trends, response, and water quality. Monitor well data and analysis provide a working base for defining the relationship between the geothermal and shallow systems, and for avoiding detrimental environmental impact.

GENERAL GEOLOGY

Although the Raft River Basin is usually regarded as a northern extremity of the Basin and Range Physiographic Province, it is in fact at the junction between two dissimilar basins, the Snake River Plain to the north, and the Great Salt Lake Basin to the south. (Cunningham, 1971). There are indications of structural influence by the Idaho Batholith, and the Wyoming Overthrust Belt disguised in a morphology typical of Basin and Range (Cunningham, 1971, Anderson 1930). Associated faulting may locally serve as conduits for the geothermal fluid. The Basin structure is dissected by aggraded alluvial valleys with a floor that can be characterized as a bajada. Figure 1 shows the physiography and major faults of the area. The Raft River Valley is the largest valley in the basin and the site of the Raft River Geothermal Project.

Early Tertiary Laramide thrusting accounts for the lack of Paleozoic and Mesozoic sediments in the valley (Williams, 1976). The major faults in the basin trend along the basin of the tilted fault- block mounts. Faults with the greatest displacement are the Bridge fault, the east-west

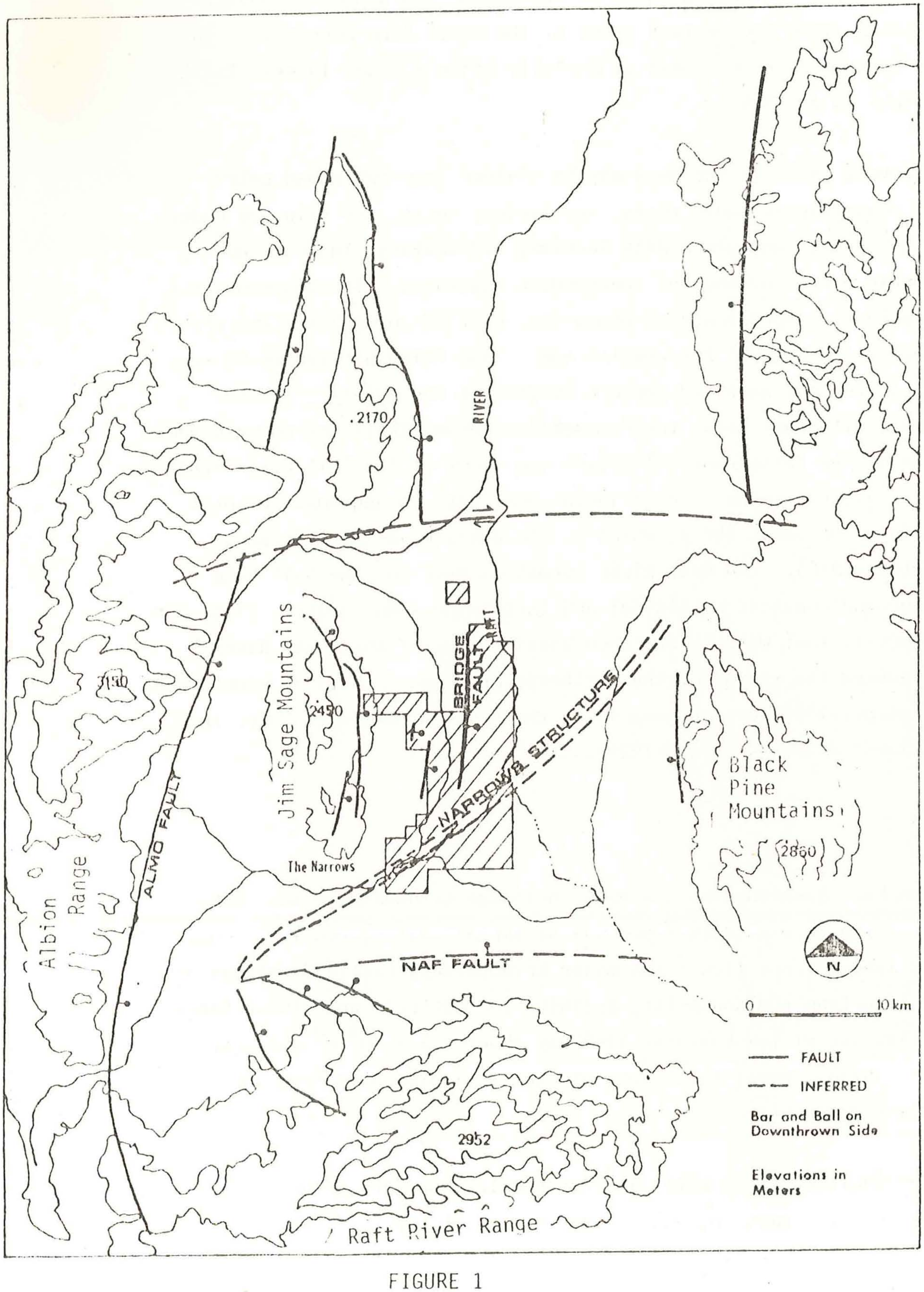


FIGURE 1

STRUCTURE AND TOPOGRAPHY RAFT RIVER KGRA

Naf fault in the southern portion of the basin, and a north-trending fault system along the western front of the Black Pine Mountains. The Narrows structure is described as probably being a right-lateral fault by Williams et al(1976).

The rock units in the area may be divided into two broad categories: Cenozoic volcanic rocks, sedimentary rocks, and alluvium underlying the valleys and pre-middle Tertiary sedimentary, igneous, and metamorphic rocks forming the surrounding mountains. The basement rock is intruded Precambrian quartz monzonite, overlain by schists and the Elba Quartzite, also of Precambrian age. Some Paleozoic sediments are present in the southern and eastern borders of the valley. In the geothermal withdrawl area, the Precambrian metamorphics are unconformably overlain by the tuffaceous siltstones and sands of the Salt Lake Formation. The Salt Lake Formation is of Pliocene age, with an aggregate exposed thickness of at least 762 m, which is the average valley thickness. (Covington, 1976). The Raft River Formation overlies the Salt Lake Formation and consists of fluvial and lacustrine sand, gravel, silt, and clay deposits that were formed when basalt flows of the Snake River Plain reduced the energy of the northerly drainage. Loess is widespread in the alluvial valleys and reaches a thickness of at least 30 m. in depressions (Williams et al, 1976).

HYDROLOGY

The Raft River Basin is a major drainage tributary to the Snake River. Historically, Raft River was perennial, but currently is characterized by intermittent flow. The major tributaries, Cassia Creek and Almo Creek, flow from the southwest, draining the Cottrell and Albion Ranges. Total flow out of the basin in 1968 was about 2.3×10^6 m^3 per year. (Walker, 1970). About two thirds of the total discharge from the basin moves as ground water.

The shallow ground water aquifer complex consists of basin alluvium, the Raft River Formation, and the upper unit of the Salt Lake Formation.

The main body of ground water is unconfined. The aquifer complex exhibits locally confined behavior, however regionally can be considered unconfined.

Depth to ground water in the basin ranges from 0 to 120 meters. Figure 2 shows groundwater countours for the basin. The slope of the water table at the geothermal site is about 4.8 m/km.

Water level declines of as much as 15 m. between 1952 and 1966 were reported north of Malta (Walker 1970). Increased pumping of irrigation wells caused ground water level declines in the valley. Consequently, a moratorium was declared on new irrigation wells in the valley in 1963.

Surface manifestations have indicated the presence of a geothermal resource in the KGRA. Data indicate that total dissolved solids and temperature both increase slightly in ground water at the KGRA. Geology, chemistry and hydraulic characteristics indicate an inhomogeneous geothermal reservior. The fault-controlled resource can best be thought of as an aquifer, with geothermal fluid (deep circulating meteoric water) migrating along fault swarms and associated fractures. The heat source is probably a combination of radiation from a shallow magma and residual heat from fault friction. The quartz monzonite (adamellite) basement rock acts as a "hot plate," conducting the heat from the source. (Allan, 1979).

Development of the resource has led to the requirement for monitor wells. Seven monitor wells have been completed in the KGRA, ranging in depth from 150 to 400 meters (Figure 3). Figure 4 shows well construction and general lithology. Monitor wells in the KGRA show seasonal water level trends, modified temporally by irrigation pumping. Water level changes, as response to dynamic hydrologic conditions, are monitored by digiquartz pressure transducers in artesian wells (MW-1, MW-2 and MW-4), and by Stevens Type F Water Level Recorders at non-flowing wells (MW-3, MW-4, MW-5, MW-6 and MW-7). Monitor well 4 (MW-4) is equipped with a dual system as the water level is near land surface.

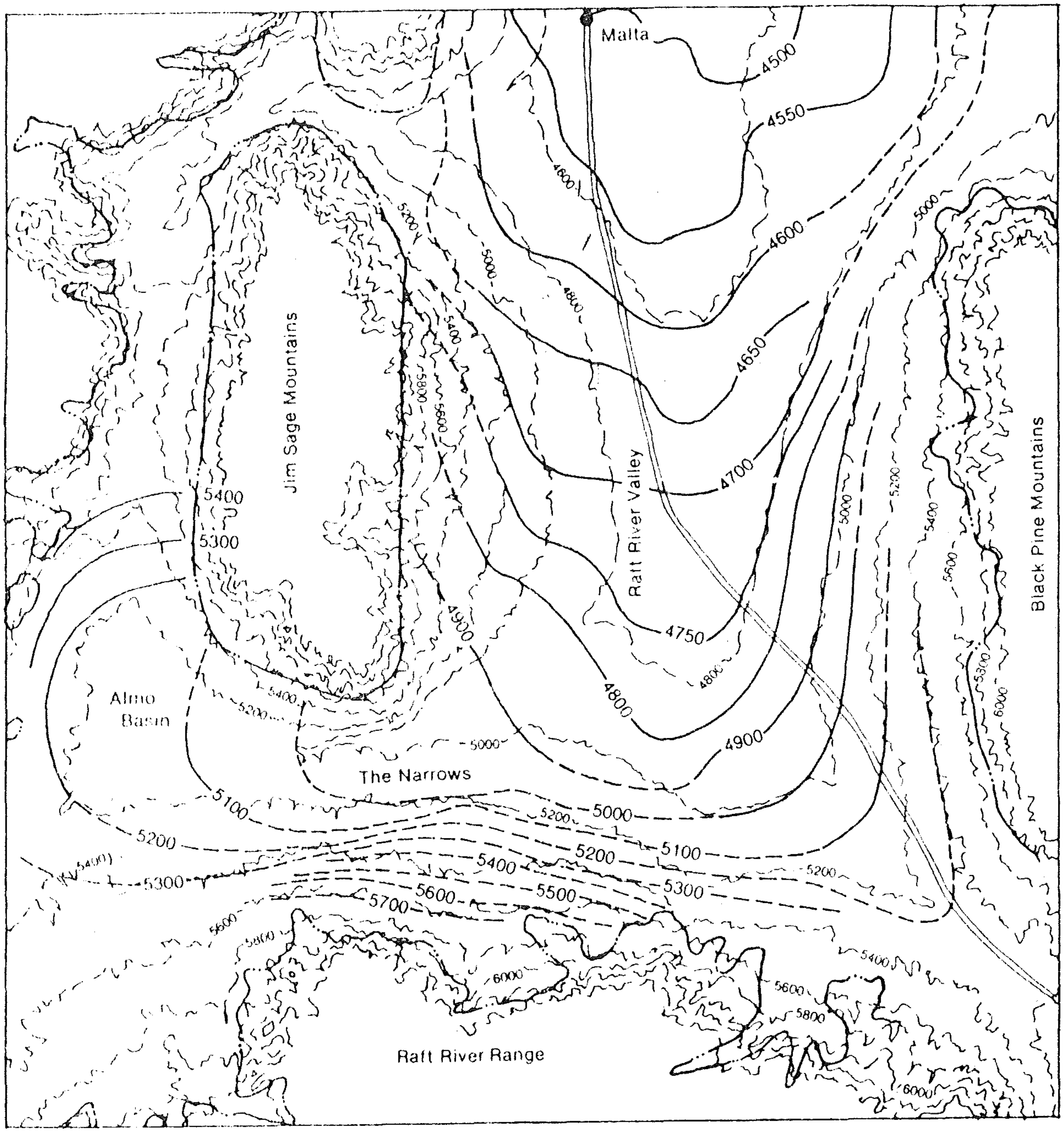


Figure 2

Water Level Contours, Raft River Valley

(from Walker et. al., 1970)

Boundary of water-bearing rocks and deposits considered in this report

4700 Water-level contour
Dashed where position uncertain
Contour intervals 50 and 100 feet

5600 Ground level contours

INEL-A-13 971

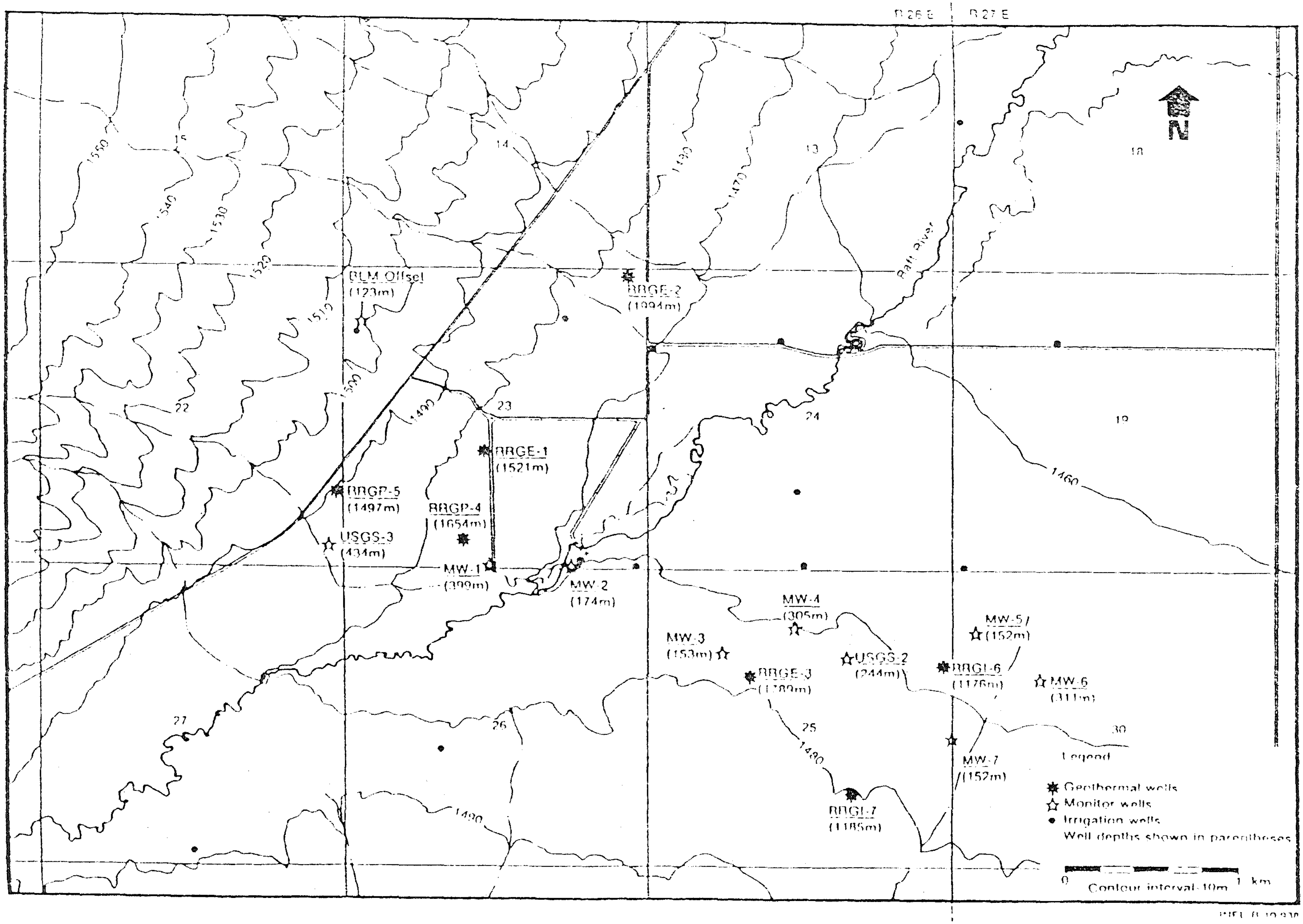


FIGURE 3

RAFT RIVER GEOTHERMAL AND MONITOR WELLS

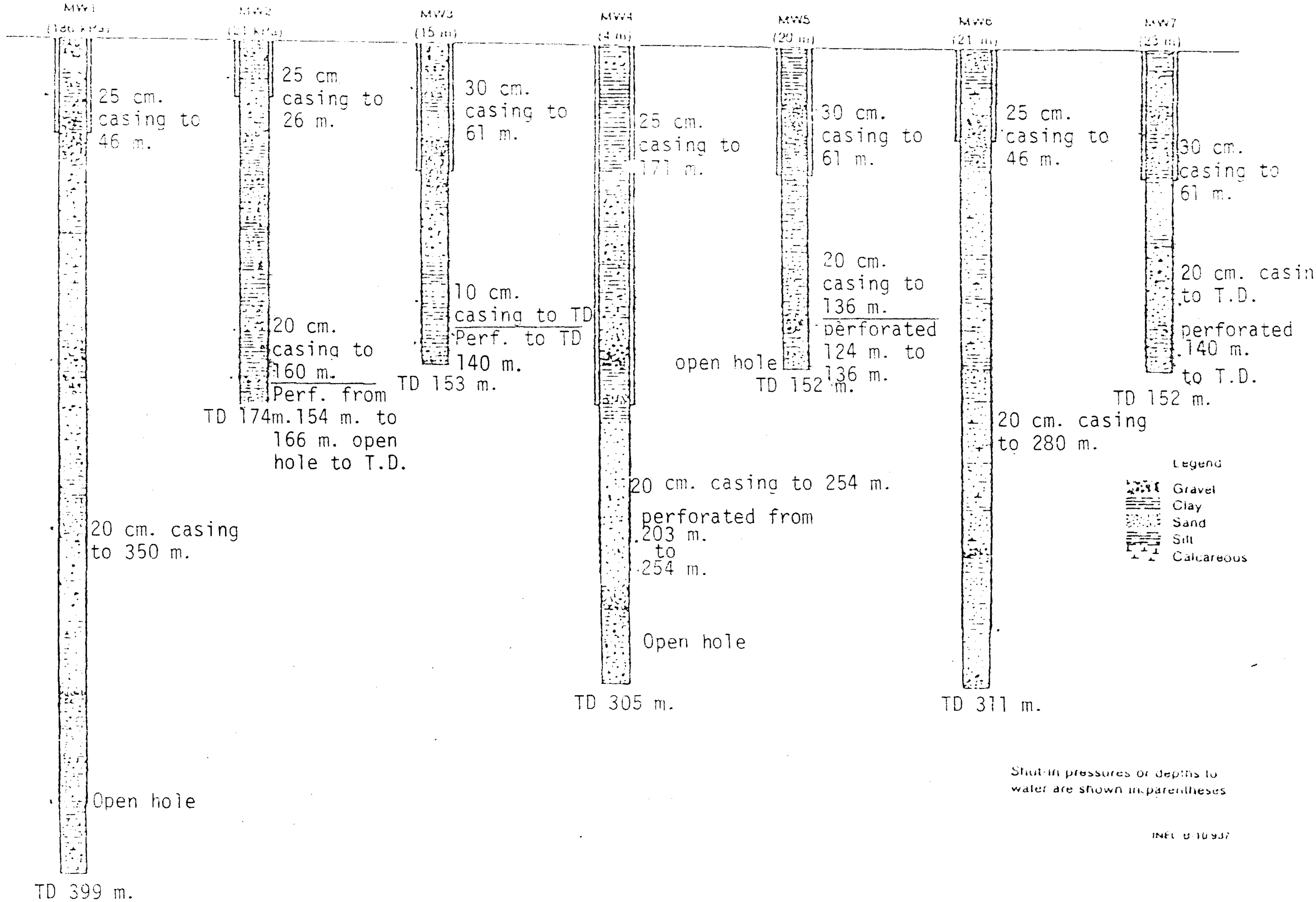


FIGURE 4
Raft River KGRA
MONITOR WELL CONSTRUCTION AND LITHOLOGY

Data for the U. S. Geological Survey wells (USGS-2 and USGS-3) may be available for future reports. Power problems at MW-1 and lack of available instrumentation at MW-2 render that intermittent data of very limited value.

This report will concern hydrologic conditions and water chemistry at MW-3, MW-4, MW-5, MW-6 and MW-7 from 6/30/79 to 9/30/79. All data for this time period were at wells in the vicinity of injection wells to the east of the Raft River.

INITIAL GROUNDWATER TRENDS

Regional Trends

An average Regional Trends water level rise of .01 m/day was seen in the first quarter of 1979 (1/1 to 3/30/79). All of the wells showed a water level decline during the second quarter of 1979. Table 1 shows trends for the first two quarters of 1979.

Specific Responses

MW-4 has shown a water level rise of .06 m/day (corrected for regional trend) following injection at RRGI-6 of 38 l/s (fet-2-79, 3-79 to 4-79). Flowmeter logs of RRGI-6 indicate a significant portion of the injected fluids leave the borehole immediately below the casing at a depth of 515 to 550 m. This "thief zone" has local hydraulic communication with the shallower aquifers (Spencer, 1979). The lack of response at a well of the same depth and a closer proximity to the injection well (MW-6), indicates that the system is inhomogeneous and anisotropic. MW-6 is cased deeper than monitor well MW-4, and is in an opposite direction than MW-4 from RRGI-6.

MW-5 has shown a rapid response to irrigation pumping, particularly of the Tracy well, about 360 m. to the north (KPM-3-79). An injection test at RRGI-6 (FET-22-79 January 1979) did not indicate response at

TABLE 1
RAFT RIVER
GROUNDWATER TRENDS QUARTERS 1 and 2, 1979

WELL	1ST QUARTER TREND(RISE) (m/day)	DATE OF/START OF WATER LEVEL DROP	2ND QUARTER TREND(DECLINE) (m/day)
MW-3	.011	4-22	.018
MW-4	.011	4-15	.012
MW-5	.010	4-22	.034
MW-6	.007	5-15	.024
MW-7	.006	4-19	.020

MW-5 during the non-pumping season. The response to irrigation pumping seen in this well would certainly mask an injection response during the growing season.

During a 21-day injection test at RRGI-6 (FET-2-79, 3-79 to 4-79), MW-5, MW-6 and MW-7 showed a sharp water level decline at the beginning of injection. Water levels then rose slowly during the test, at a rate consistent with previous trends. At the conclusion of the test, the water levels responded, rising to the trend line extrapolated from previous data (KPM-3-79). A theory for such response is aquifer dilation, a process of aquifer expansion due to increased interstitial fluid pressure during injection, causing altered monitor well elevations, and false water levels. Future surveys of the monitor wells may verify this theory.

THIRD QUARTER WATER LEVEL TRENDS

Figures 3A to 7C show detailed head changes for each well from mid-June to mid-September.

Table 2 shows pertinent data from FET-5-79, that was conducted during this quarter.

MW-3

The hydrographs for MW-3 show three recognizable sections. The response seen between June 13 and June 15 occurrs after pumping for a water quality sample. It is reported that a temperature increase occurred during sampling. The temperature/density effect could have caused the rapid rise and decline in water level. Beginning at the end of June, the water level showed a steady decline of .024 m/day, which is comparable to declines seen in MW-4, MW-6, and MW-7. The third section is the rise and decline seen between 8-20 and 9-8. A similar response is seen in MW-5 and MW-7 of the same depth, while a subdued response is seen in the deeper wells MW-4 and MW-6. This can be attributed to irrigation pump shut-down (see discussion MW-5). A leveling out of the water level decline begins at about 8-8-79 and coincides with test FET-5-79 (8-9 to 8-15-79).

TABLE 2
RAFT RIVER
PUMPING/INJECTION DATA - FET-5-79
Production Well RRGE-2 - Injection Well RRGI-7

Test	Date	Time	Duration (minutes)	Flow Rate (l/sec.)	Initial Wellhead Pressure RRGI-7 (kPa)	Final Wellhead Pressure RRGI-7 (kPa)
Pulse #1	8/9/79	09:22 to 10:14	51	47.33	441.26	1219.34
Pulse #2	8/9/79	13:32 to 19:09	337	47.33	446.09	1339.72
Pulse #3	8/10/79	11:43 to 19:43	480	39.12	401.62	1213.48
Long Term Test	8/11 to 8/15/79	09:07 to 09:13	5765	28.4	451.26	1043.73

MW-4

The water level decrease seen in the first portion of Figure 4A is probably recovery from test FET-1-79 (5-16 to 6-6-79).

The water level decline seen in Figure 4A is at a rate of .024 m/day, which is higher than the previous trend (Table 1), but consistent with the water level decline seen in Figure 4B. There is a slight water level rise or leveling off during the test period (8-9 to 8-15), but of less magnitude than the response at this well seen during injection at RRGI-6. The level trend seen in Figure 4-C corresponds to the water level rise and decrease seen in the other wells.

MW-5

The water level curves seen in figures 5b and 5c are text book examples of drawdown and recovery due to nearby pumping (Johnson 1972, p136).

The range of the vertical scale used in Figures 5A, 5B, and 5C, attests to the magnitude of response seen in MW-5. During test FET-5-79, (8-9 to 8-15) there was a slight water level rise. Response to irrigation pumping prevents interpretation.

MW-6

The response in this well is very similar to that at MW-4, a well open at the same depth. Monitor well MW-6 shows a fairly consistent water level decline of .037 m/day (figures 6A and 6B) which is greater than the average regional decline. The change of slope seen in Figure 6C corresponds to the change in slope in MW-4. An anomalous water level drop between 7-25 and 8-2 is most pronounced in this well. The drop seen from 9-3 to 9-8 has no obvious cause seen in other well data. This drop is similar to the 7-25 to 8-2 drop in magnitude, but of shorter duration.

MW-7

The hydrographs from this well reflect a similar shape as those at MW-3. A water level change seen at MW-7 and not at MW-3 is between 7-25 and 8-6 (Figure 7-B). This corresponds to build-up and fall-off seen at MW-5, and a water level drop at MW-6. The water level decline during July is at .037 m/day. The water level rise seen in Figure 7c is at .024 m/day, and the drop is at the same rate. This corresponds to the response to irrigation pumping seen in MW-5, and similar water level flux seen in the other wells. Minor response to injection at RRGI-7 could be a reason for the slight water level rise seen on August 8 (Figure 7b).

WATER QUALITY

Table 3 shows results of monitor well water analysis conducted in mid-September, compared to initial water quality (I.W.Q.), and water quality in geothermal wells. Most of the monitor wells were drilled in the spring and summer of 1978 and the I.W.Q. analysis is a composite of several analysis during that time. The water quality of the geothermal wells represented here is also a composite of several analysis between 1976 and 1979. Natural convection upwards has degraded water quality. Note the poorer water quality in RRGI-6 and RRGI-7 indicated by a higher conductivity. It is possible that injection in these wells will force a poorer quality of water upwards. The geothermal water from the production wells approaches the quality of the monitor wells in some cases. Flouride is a good indicator of known water quality types. Flouride levels in MW-5 and MW-7 probably indicate minimal mixing with poorer quality geothermal water. MW-1 has a similar conductivity value as RRGI-6 and RRGI-7, indicating possible aquifer communication.

The higher conductivity seen in the more recent analysis of the monitor wells reflects a poorer water quality. A possible reason for this could be that many farmers in the area employ intensive irrigation to flush salts out of the soil. This would degrade the water quality in

TABLE 3
CHEMICAL ANALYSIS OF RAFT RIVER GEOTHERMAL WATER
(Mean Value of Available Data - In mg/l Unless Otherwise Noted)

WELL	CONDUCTIVITY µmhos/cm		pH		CHLORIDE (PPM)		FLUORIDE (PPM)		TOTAL HARDNESS		TOTAL ALKALINITY	
	I.W.Q.	9/17/79	I.W.Q.	9/17/79	I.W.Q.	9/17/79	I.W.Q.	9/17/79	I.W.Q.	9/17/79	I.W.Q.	9/17/79
MW-1	11,200	N/A	8.1	N/A	3,590	N/A	2.7	N/A	483	N/A	25	N/A
MW-2	5,740	N/A	7.5	N/A	1,640	N/A	5.6	N/A	295	N/A	28	N/A
MW-3	6,100	9,250	7.6	N/A	2,410	2,360	5.1	6.16	433	470	50	N/A
MW-4	7,770	11,400	7.9	7.0	2,440	3,270	6.2	5.79	473	406	40	23.20
MW-5	2,000	2,720	7.8	7.0	610	560	.05	1.34	410	270	--	92.00
MW-6	7,020	9,400	9.8	7.7	2,380	2,690	3.7	4.60	483	540	--	38.4
MW-7	2,250	2,900	7.8	7.2	650	660	1.6	1.56	255	368	104	88.00
RRGE-1	3,370	N/A	8.4	N/A	776	N/A	6.3	N/A	N/A	N/A	N/A	N/A
RRGE-2	2,740	N/A	7.6	N/A	708	N/A	8.3	N/A	N/A	N/A	N/A	N/A
RRGE-3	9,530	N/A	7.3	N/A	2,170	N/A	4.6	N/A	N/A	N/A	N/A	N/A
RRGP-4	7,280	N/A	7.4	N/A	2,575	N/A	4.5	N/A	N/A	N/A	N/A	N/A
RRGP-5	2,150	N/A	8.1	N/A	900	N/A	8.4	N/A	N/A	N/A	N/A	N/A
RRGI-6	10,500	N/A	7.3	N/A	3,150	N/A	8.5	N/A	N/A	N/A	N/A	N/A
RRGI-7	12,000	N/A	---	N/A	4,085	N/A	5.0	N/A	N/A	N/A	N/A	N/A

the deeper groundwater system (N. E. Stanley, oral communication 1979). Other possibilities for the change include the influence of drilling water on I.W.Q, and systematic instrument error. Chlorides and fluorides present on 9-17-79 and I.W.Q. are similar, but generally more abundant in September. The decrease in pH between I.W.Q. and 9-17-79 cannot be interperted. The high I.W.Q. PH valve seen at MW-6 probably reflects analytical error.

DISCUSSION OF QUARTERLY WATER LEVEL RESPONSES

Possible influence on these water levels includes irrigation pumping, geothermal testing, barometric effects, earth tides, aquifer loading and other external influences.

Response to Geothermal Testing

Testing occurred just prior to this quarter (FET-1-79) 5-16 to 6-6-79 (KPM-3-79), and during this quarter (FET-5-79). Minor water level changes were seen in MW-3, MW-4, MW-5, MW-6 and MW-7 during the injection test (August 9 to August 15). In all cases, however, the change amounted to little more than water level stabilization. It is uncertain whether these changes are response to testing.

Other Response

There is no question that irrigation pumping is a major influence on the wells as evidenced in MW-5 (Figures 5-A, B, C). The largest anomaly of this period occurred between 7-26 and 8-2 (Figure 8). No testing of the geothermal wells occurred at this time. No anomalous response is seen at MW-3 and MW-4. Monitor wells MW-5 and MW-7 show a definite water level rise, while in MW-6 the water level declined for that period. Closer examination shows that MW-6 responded first, at 0900 on 7-26, followed by MW-5 at 1200 and MW-7 at 1400. The response of MW-5, MW-6 and MW-7 is believed to be a function of well depth. MW-6 is 1311 m. deep, and responded with a marked water level decline three hours before MW-5. Both MW-5 and MW-7 are 152 m. deep, responded at a similar time, and showed a marked water level rise. The head at MW-6 is normally higher than that at MW-5 and MW-7. The source of the change can be thought of as irrigation pump shutdown as illustrated by the characteristic response of MW-5 (Figure 8). The response at MW-6 is opposite to the response expected from deeper aquifer loading. A similar anomaly occurrs in early September. Niemi and Nelson (1978) site fracture - control of geothermal aquifers as the mechanism for selective monitor well response.

Erratic water level changes seen in early June in all the monitor wells may reflect irrigation pump fluctuations.

Conclusion

Conclusions about the ground water system derived from this data are:

1. Two types of response are seen: MW-3, MW-5 and MW-7 appear to penetrate one aquifer, 152 m. deep, and MW-4 and MW-6 penetrate a deeper groundwater aquifer and are about 310 m.

2. The connection between the geothermal system and the shallower aquifers is probably locally fracture controlled, and the aquifers are inhomogenious and anisotropic. This is evidenced by selective well response (KPM-3-79) and geochemistry.

3. Some degree of aquifer loading and/or dilation possibly occurs, as shown by MW-5, MW-6, and MW-7. This is illustrated in Figure 8.

Recommendations

Methods that would help understand athe aquifer relationships in the area include:

1. Calculating barometric efficiency for each well

2. Pump testing the monitor wells

3. Monitoring irrigation pumps

4. Recording field pH

5. Recording field temperature

6. Evaluating more wells in the monitoring network.

A program for adding tritium to the injection fluid during future tests has been initiated, and those results may refine concepts of the known aquifer connections in this complex hydrologic system.

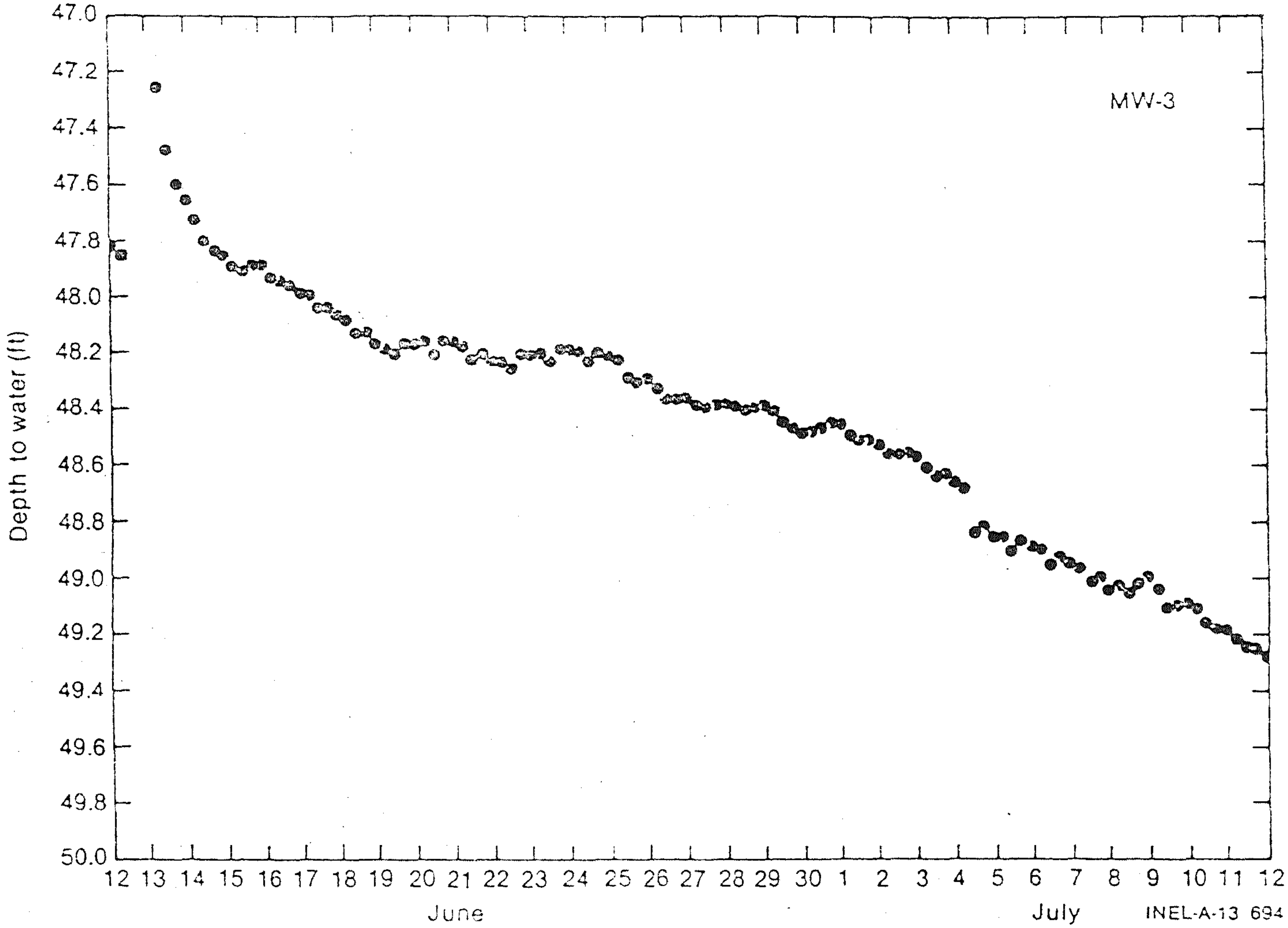


Figure 3-A
Raft River KGRA
HYDROGRAPH

MONITOR WELL 3 - THIRD QUARTER FY-79

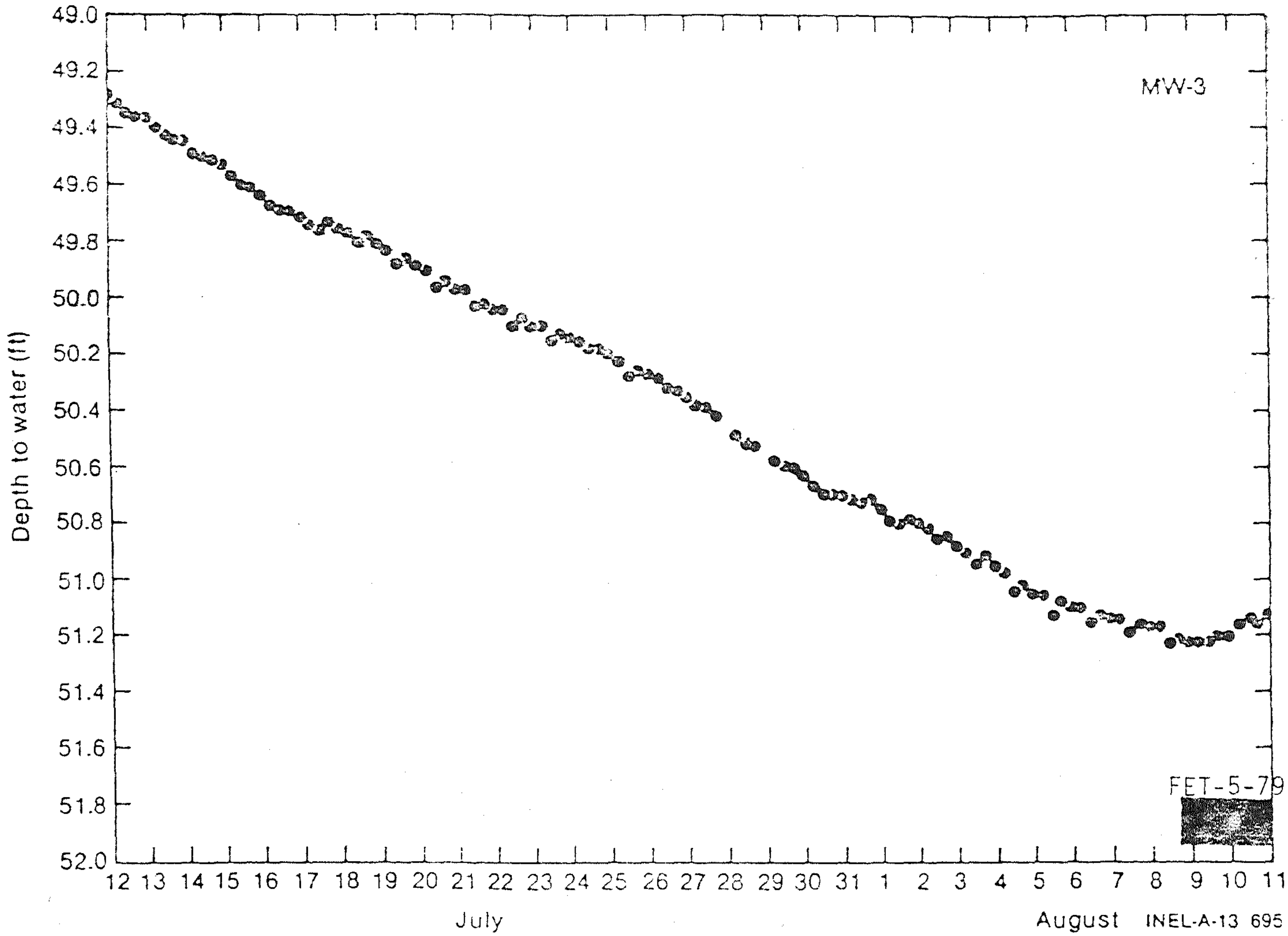


Figure 3-B
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 3 - THIRD QUARTER

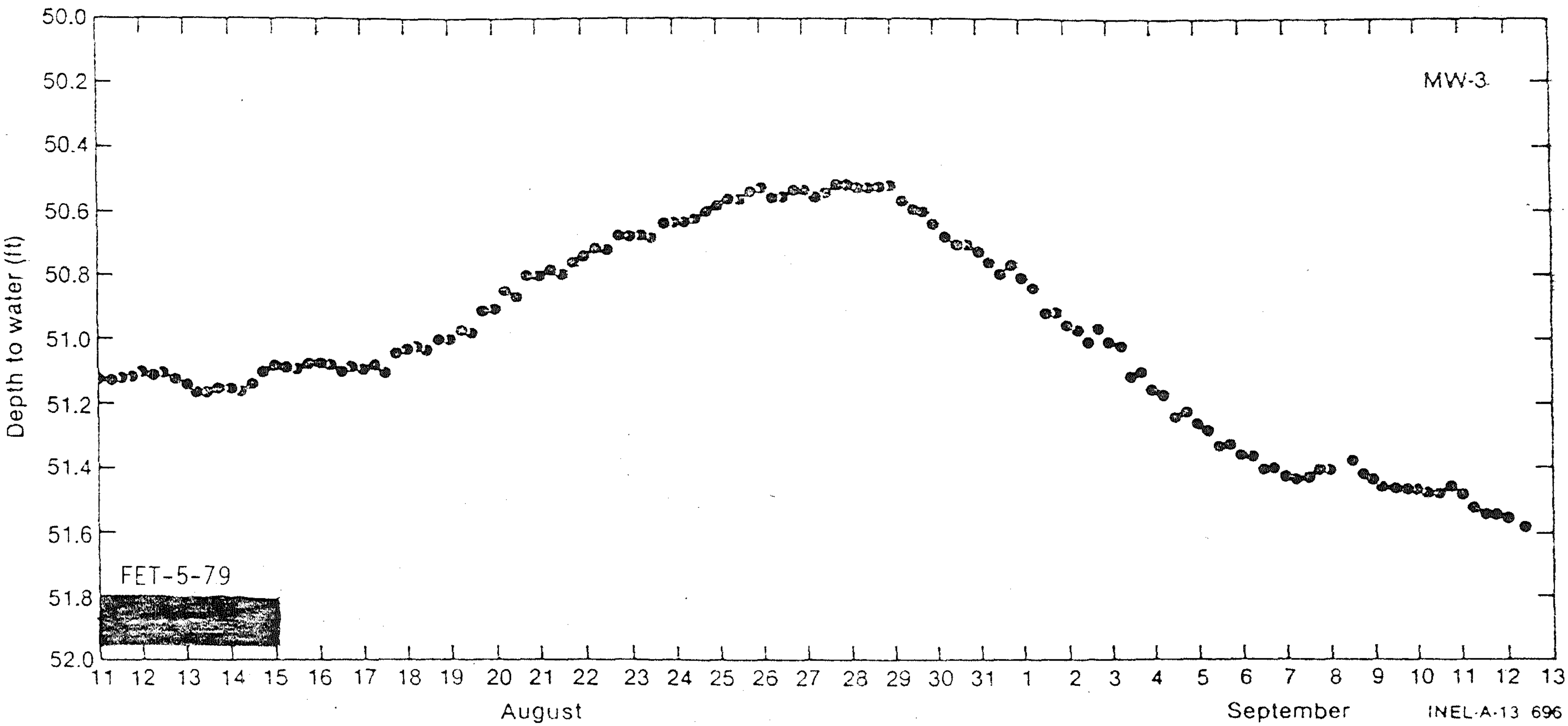


Figure 3-C
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 3 - THIRD QUARTER

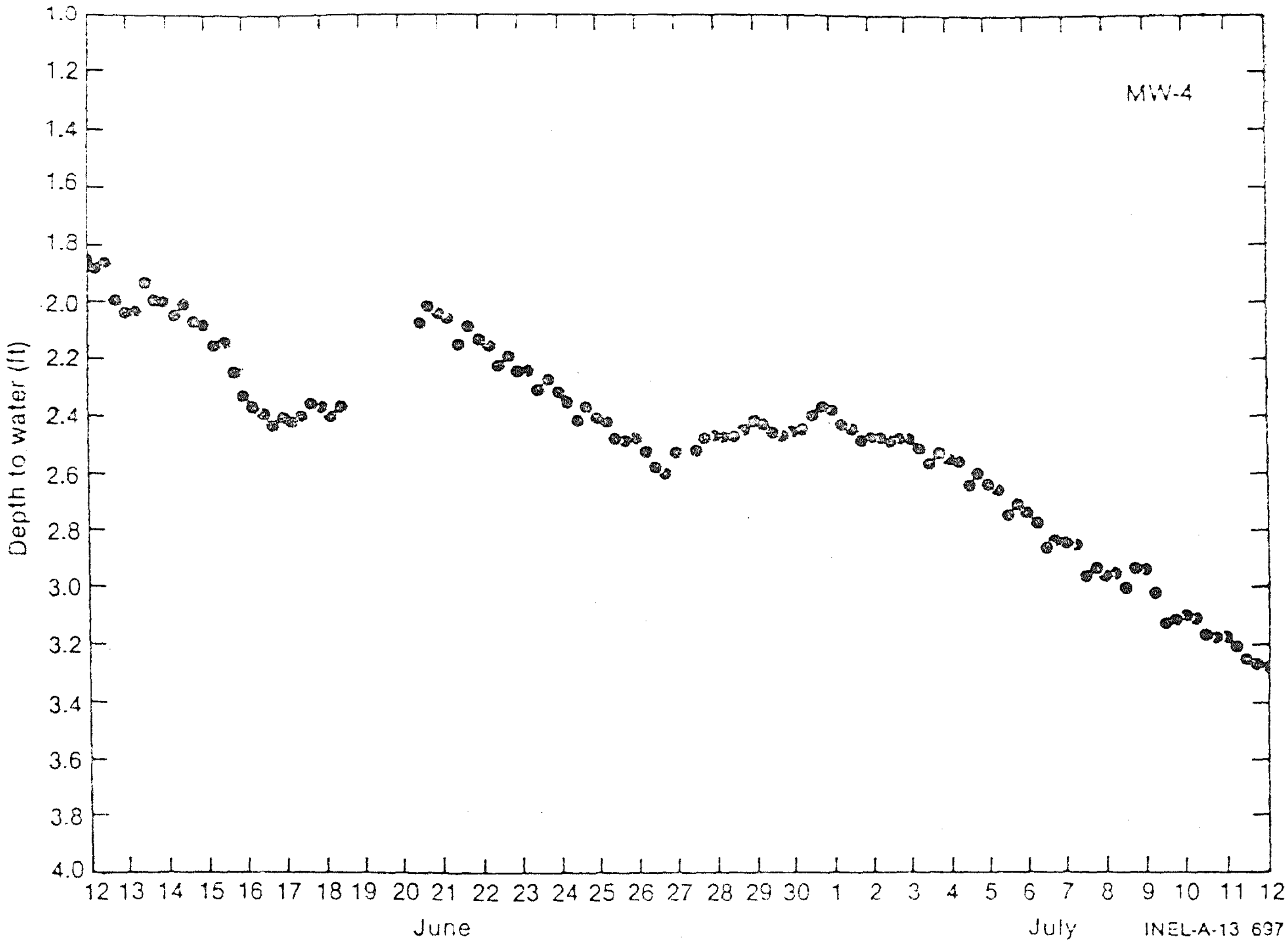


Figure 4-A
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 4 - THIRD QUARTER

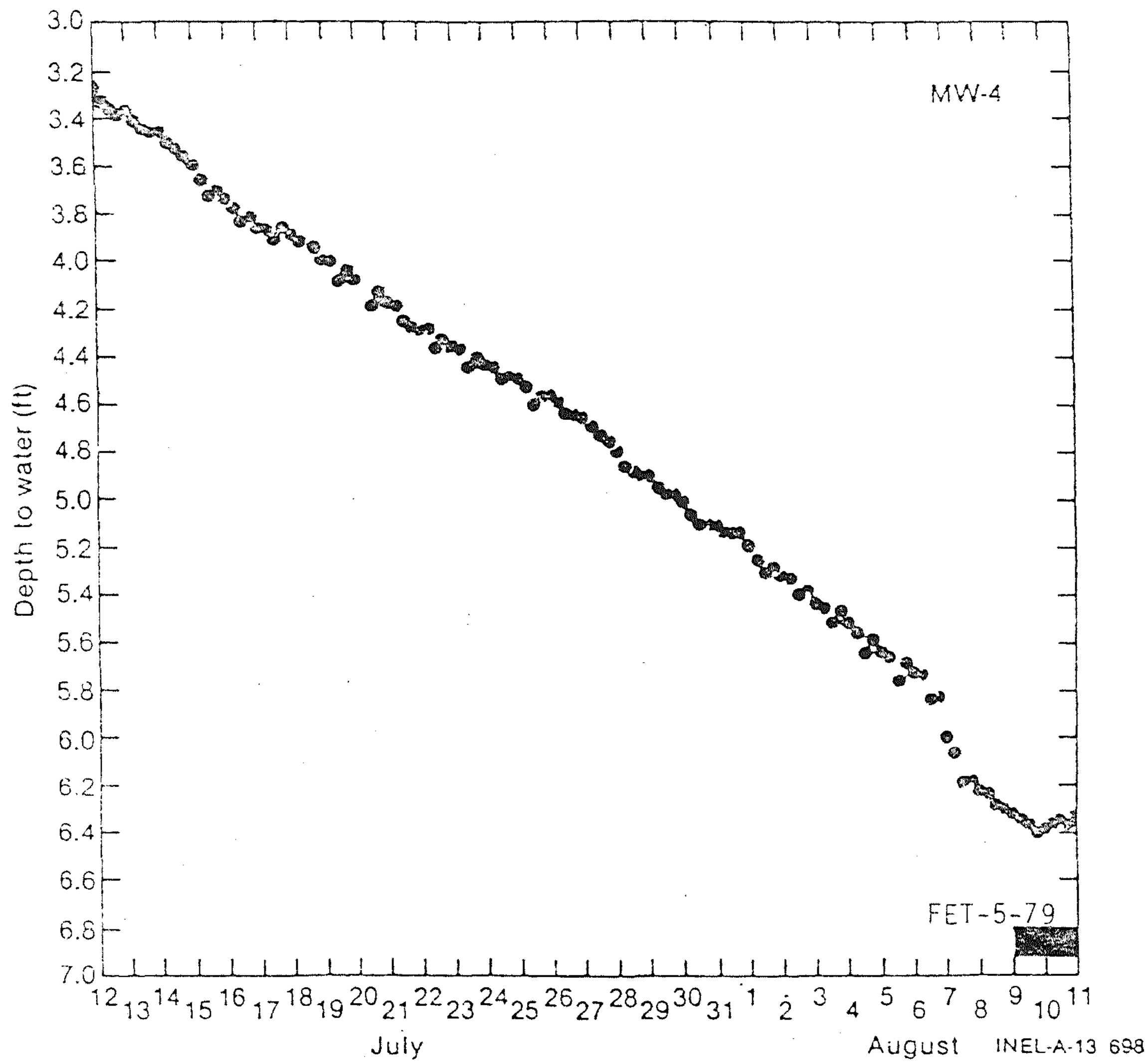


Figure 4-B
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 4 - THIRD QUARTER

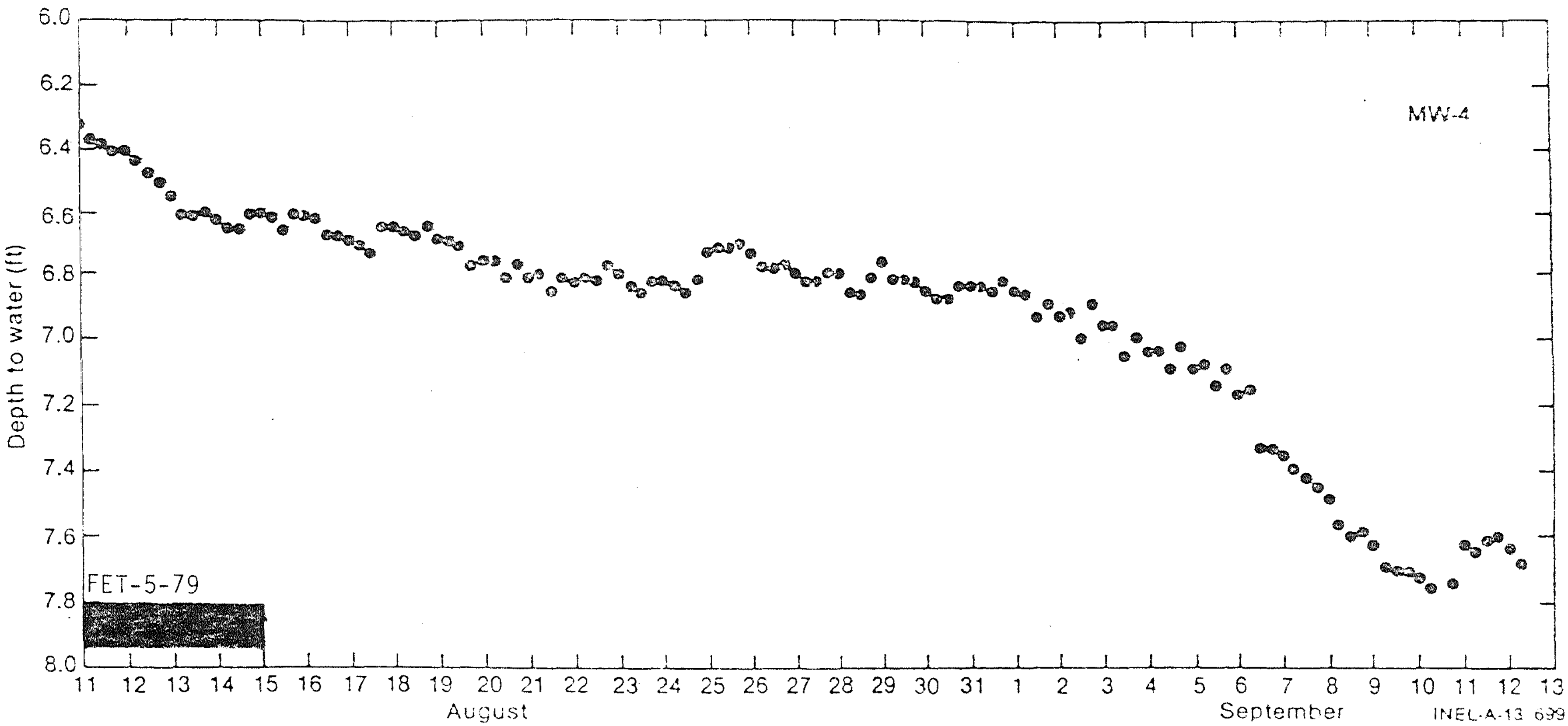


Figure 4-C
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 4 - THIRD QUARTER

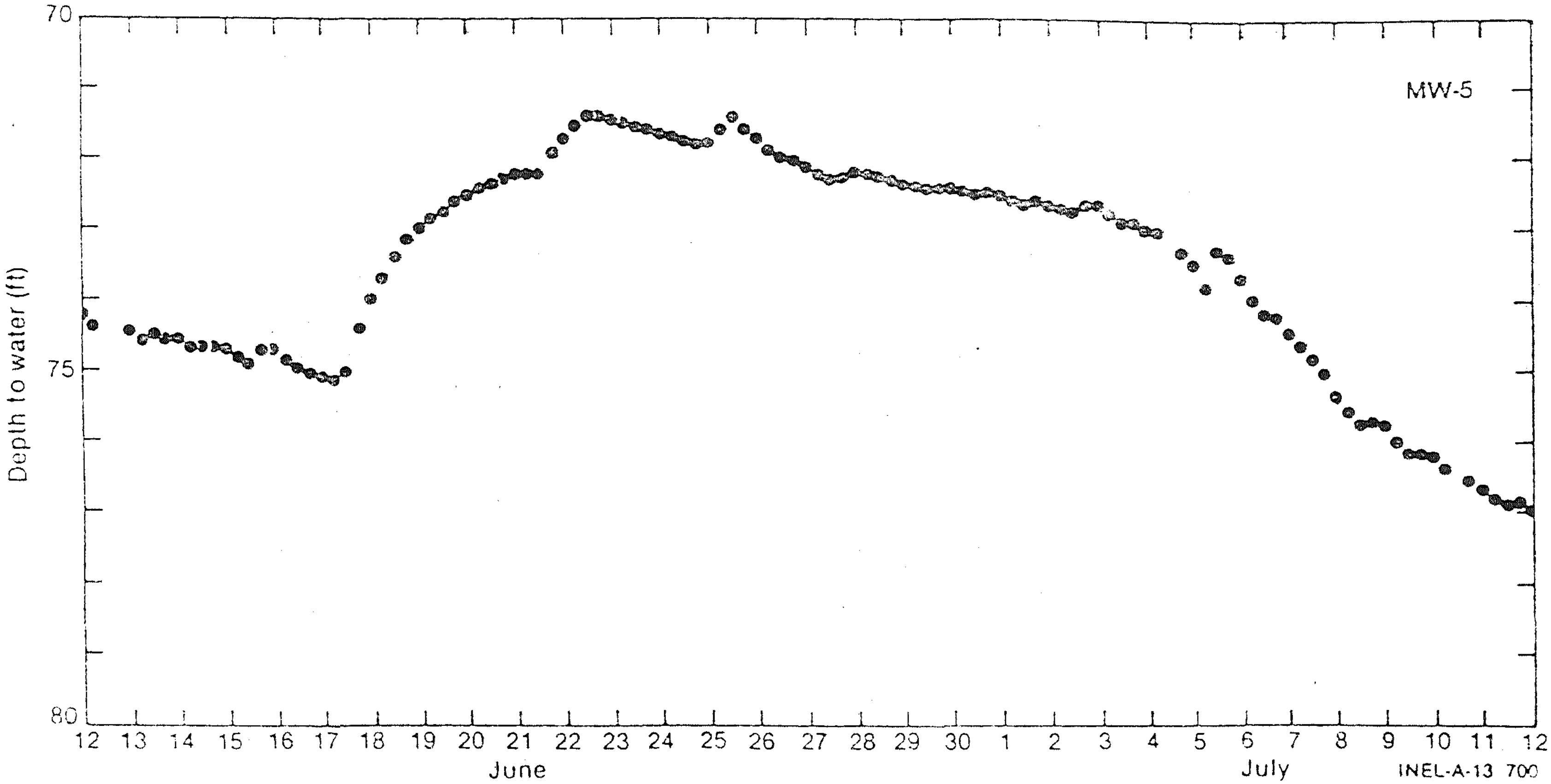


Figure 5-A
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 5 - THIRD QUARTER

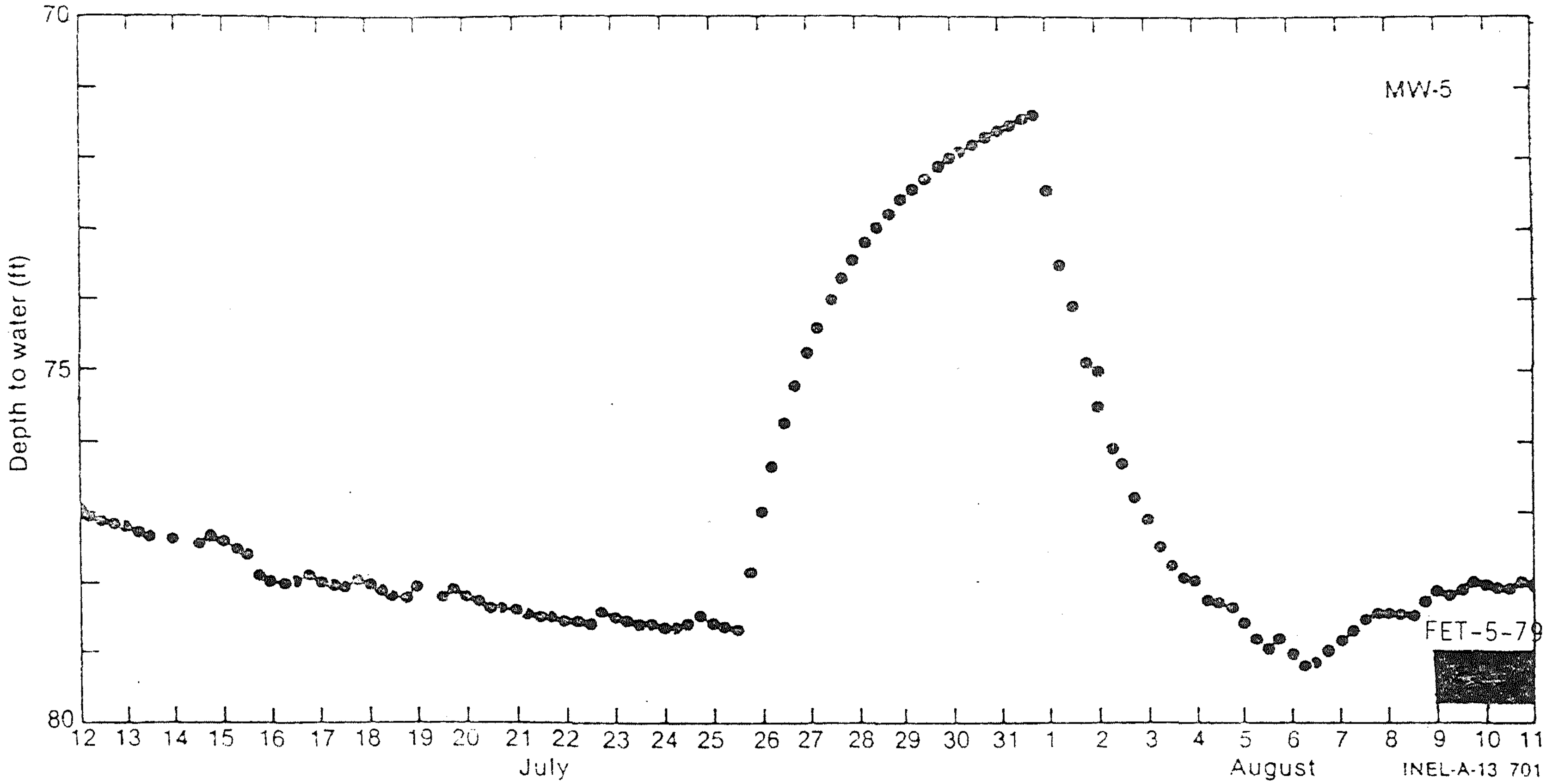


Figure 5-B
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 5 - THIRD QUARTER

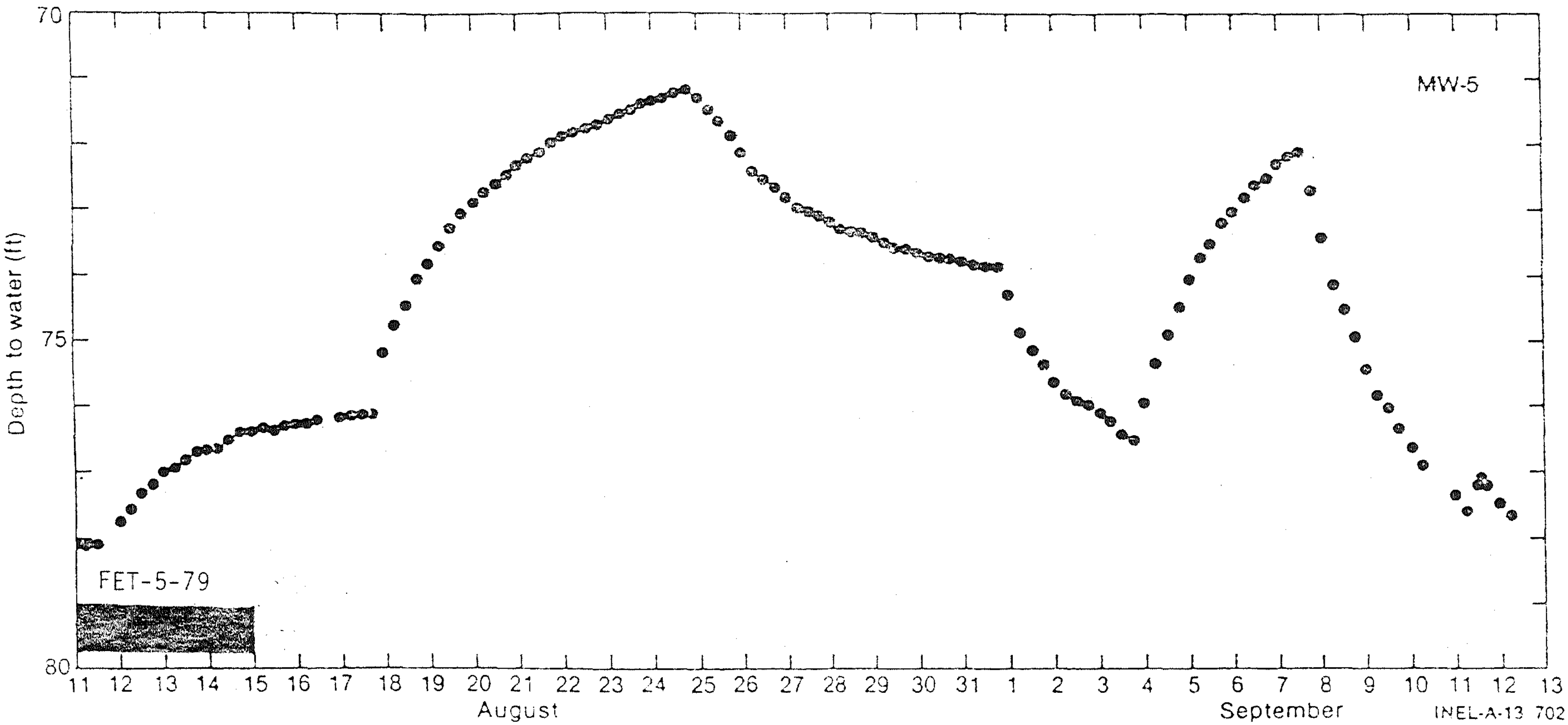


Figure 5-C
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 5 - THIRD QUARTER

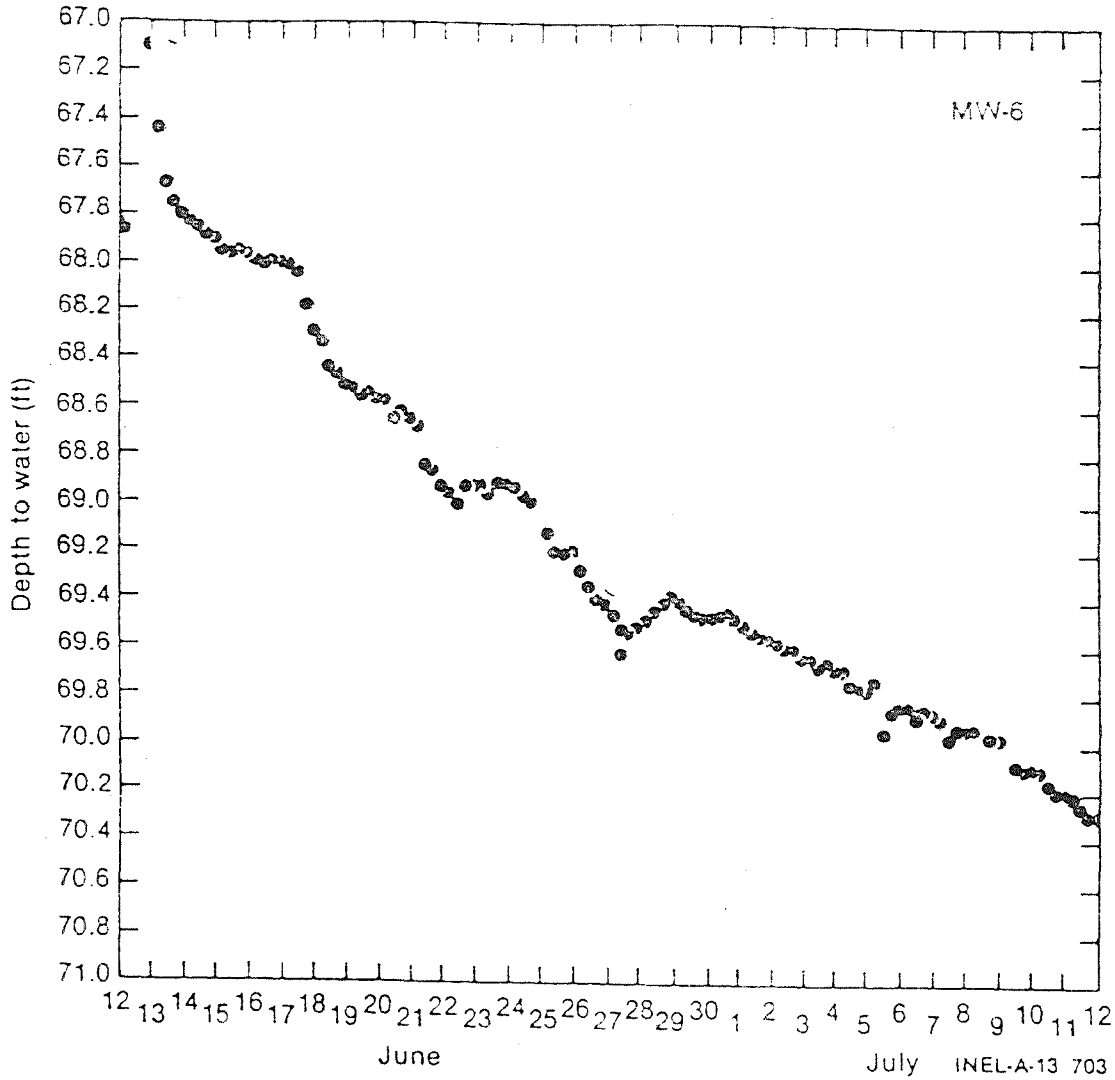


Figure 6-A
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 6 - THIRD QUARTER

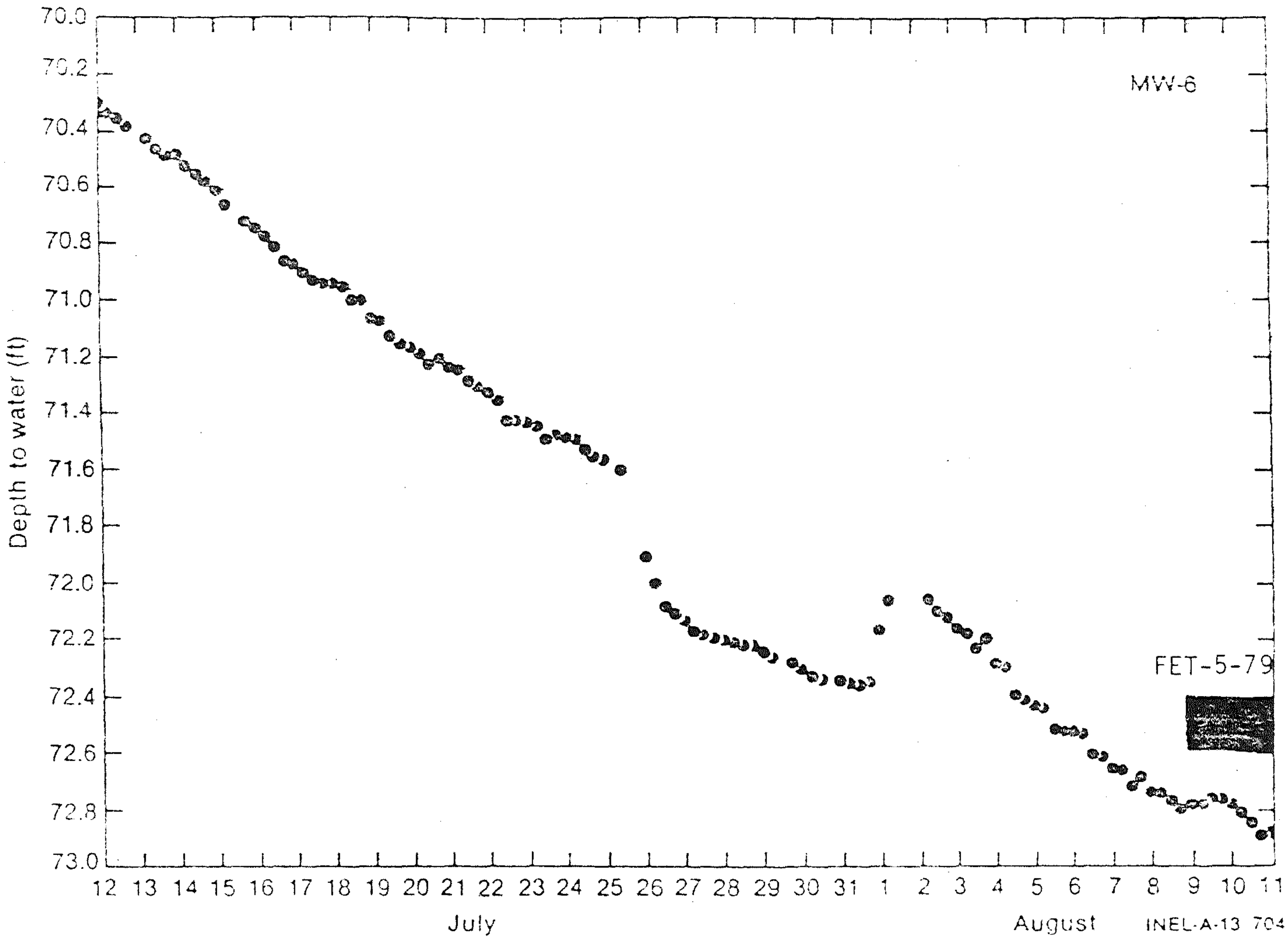


Figure 6-B
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 6 - THIRD QUARTER

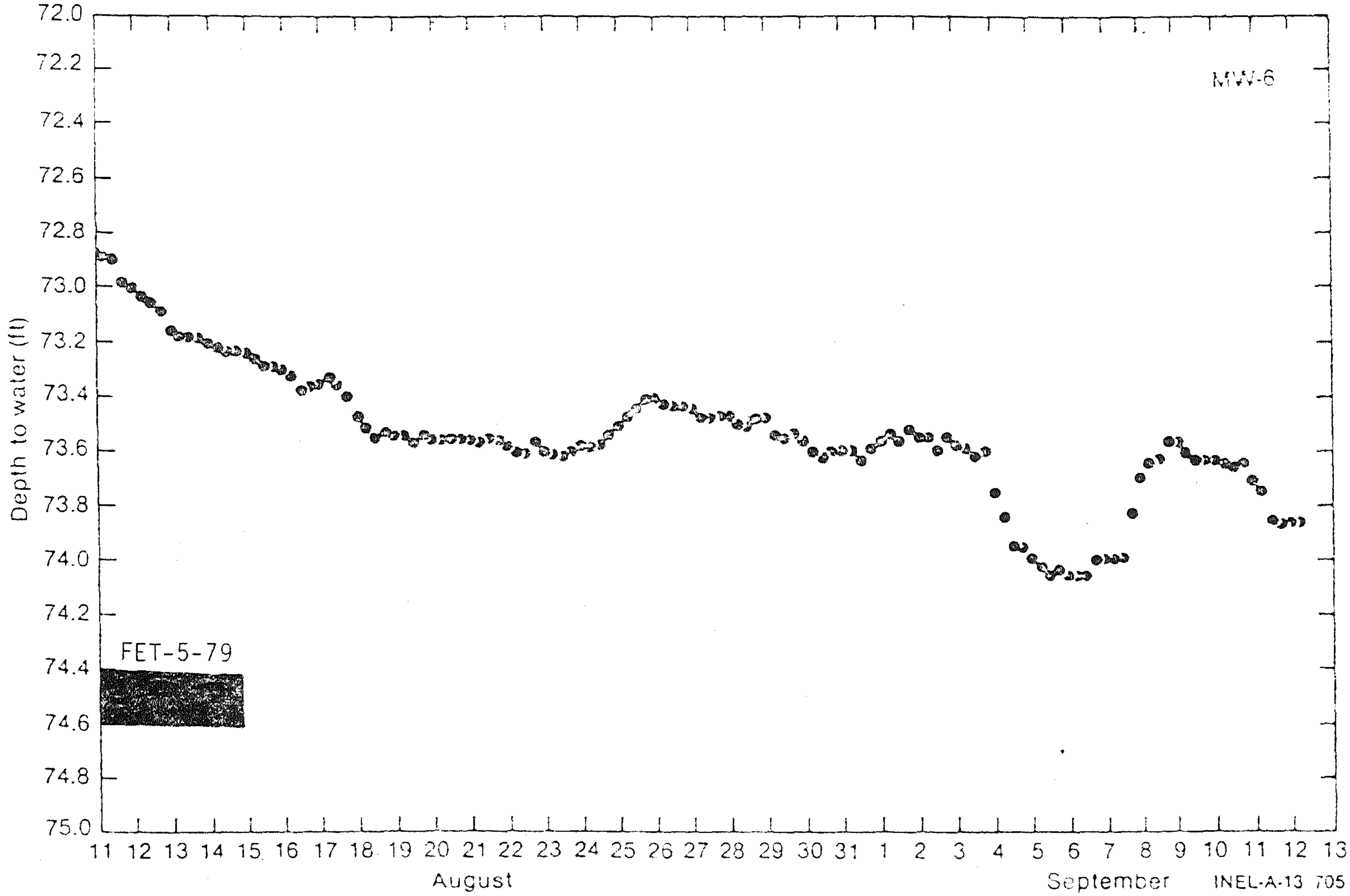


Figure 6-C
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 6 - THIRD QUARTER

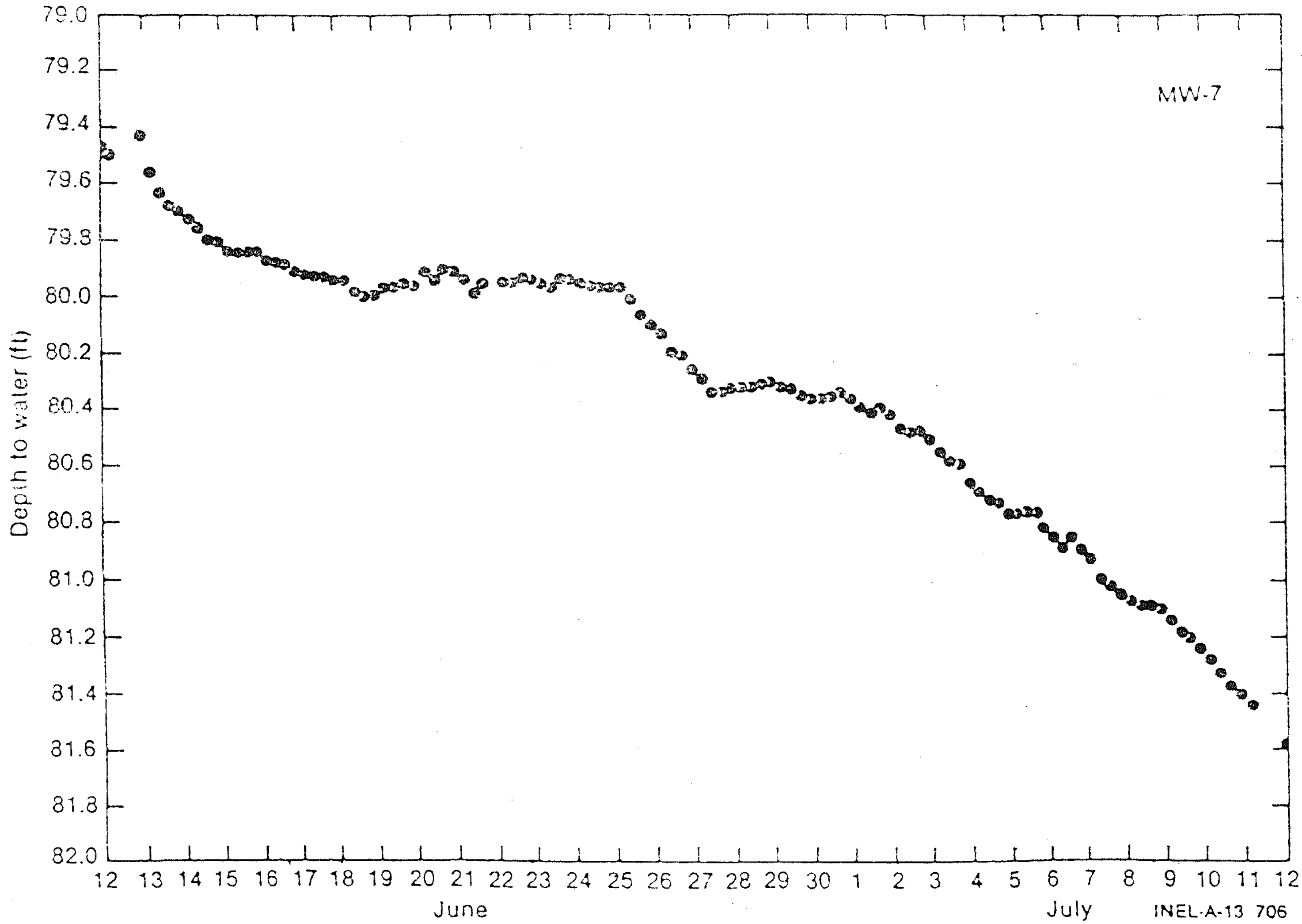


Figure 7-A
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 7 - THIRD QUARTER

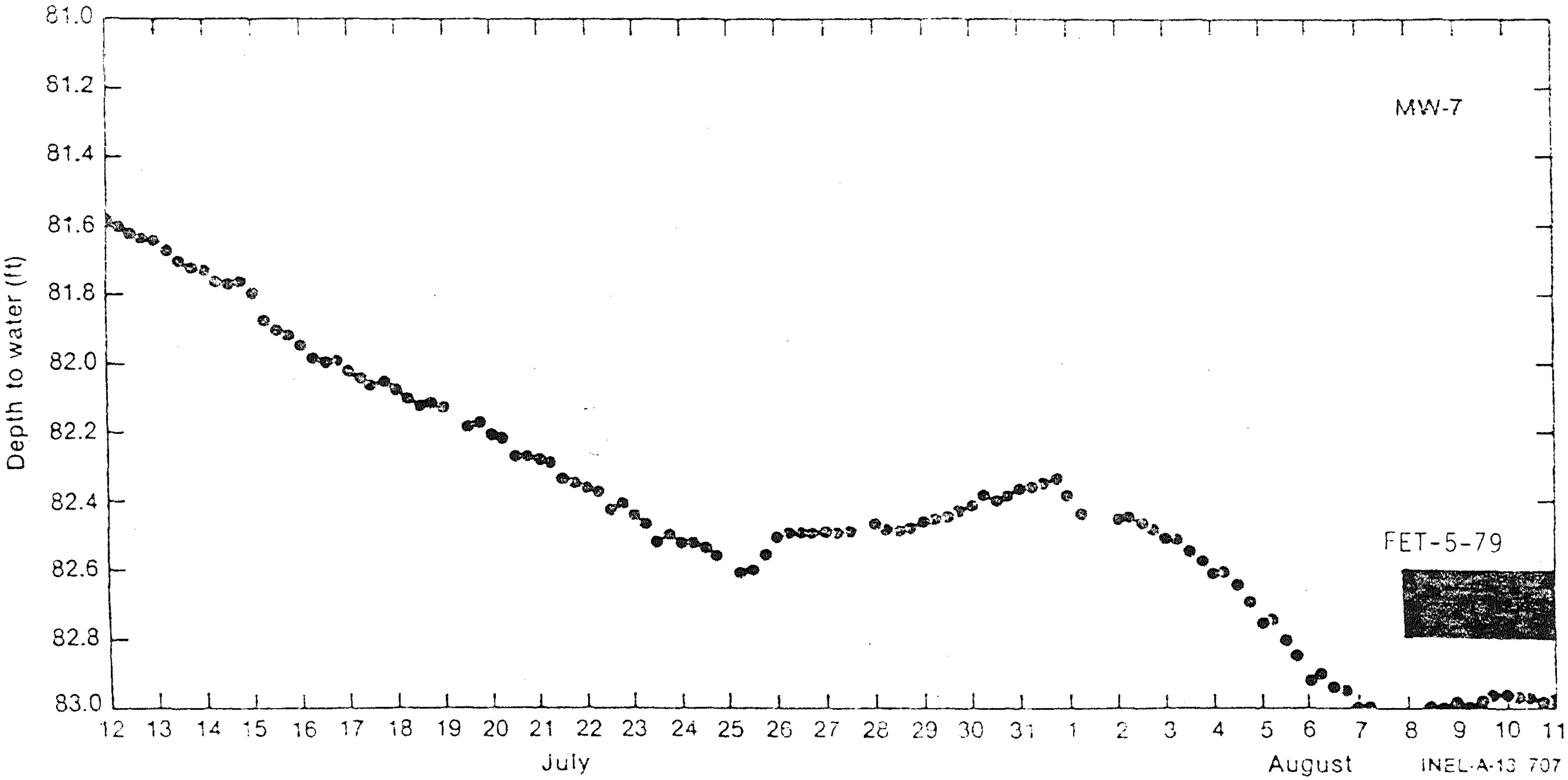


Figure 7-B
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 7 - THIRD QUARTER

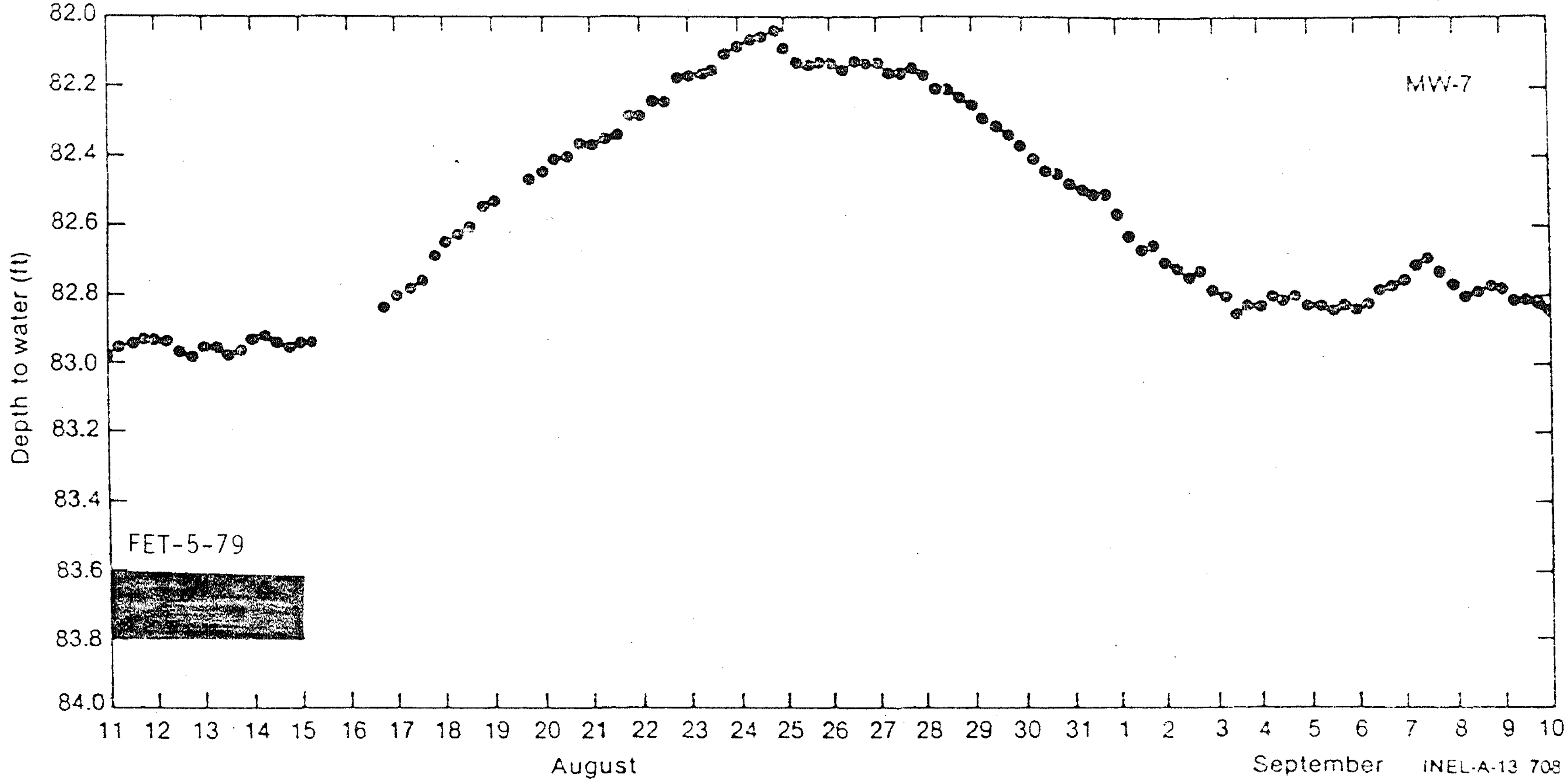
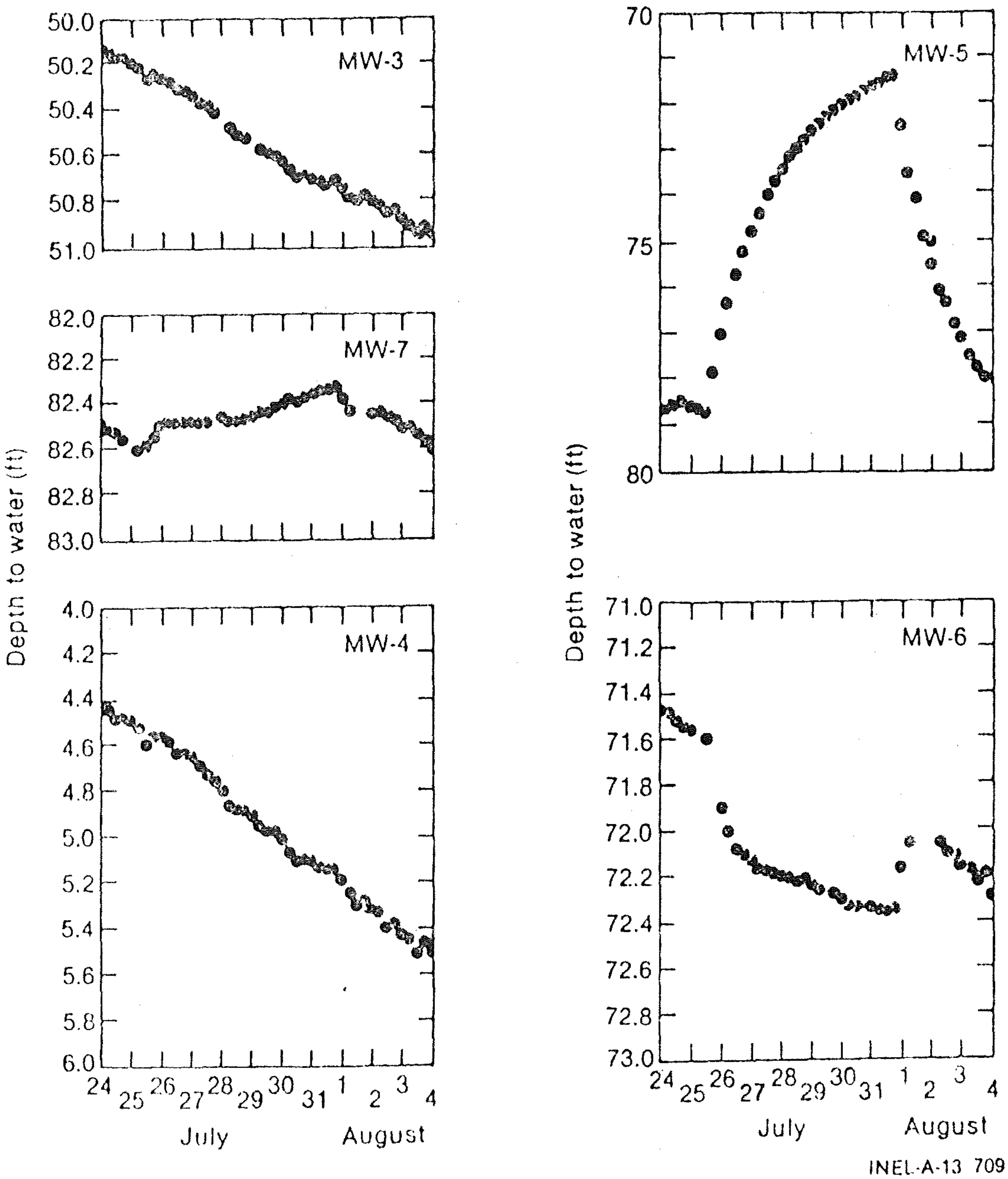


Figure 7-C
RAFT RIVER KGRA - HYDROGRAPH
MONITOR WELL 7 - THIRD QUARTER



RAFT RIVER KGRA
MONITOR WELL HYDROGRAPHS
7-24 to 8-4079

Figure 8

REFERENCES

1. C. A. Allen, R. E. Chaney and R. E. McAtee, Geochemical Modeling at Raft River from Transactions of Geothermal Resources Council Annual Meeting, Vol. 3, Reno, Nevada 1979, pp. 1-4.

2. A. L. Anderson, Geology and Mineral Resources of Eastern Cassia County, Idaho: Idaho Bureau of Mines and Geology Bulletin 14, 1931, 29 p.

3. H. R. Covington, Deep Drilling Data, Raft River Geothermal Area, U.S.G.S. open-file report 76-665, 1976.

4. F. F. Cunningham, The Silent City of Rocks, A bornhardt Landscape in the Cotterell Range, South Idaho, U.S.A., in Zeitschriff fuer Geomorphologie, Vol. 15, 1971, pp. 404-429.

5. E. E. Johnson, Ground Water and Wells, Johnson Division, Universal Oil Products, St. Paul, Minnesota, 1972.

6. W. L. Niemi and L. B. Nelson, Injection Testing at RRGI-4, Raft River, Idaho, from Second Annual Well Testing Symposium, Berkeley, California, 1978.

7. S. G. Spencer, et. al., 1978 Annual Report, INEL Geothermal Environmental Program, U.S. Department of Energy, TREE-1340, 1979.

8. S. G. Spencer, Injection at Raft River, an Environmental Concern?, from Transactions of Geothermal Resources Council Annual Meeting, Reno, Nevada, Vol. 3, 1979, pp. 675-679.

9. E. H. Walker, et. al., The Raft River Basin as of 1966: A Reappraisal of the Water Resources and Effects of Groundwater Development, U.S. Geological Survey and Idaho Department of Water Resources Water Information Bulletin No. 19, 1970.

10. P. C. Williams, et. al., Geology and Geophysics of the Southern Raft River Valley Geothermal Area, Idaho, U.S.A., Second U.N. Sypmpsium on the Developemtn and Use of Geothermal Resources, Proc., Vol. 2, 1976, pp. 1273-1282.